Quantification Methods and Management of Hydrogeochemistry in Decommissioned Collieries of the Mpumalanga Coalfields

---

Submitted as partial requirement for the degree

Ph.D. Hydrogeology

Submitted to:

Department of Geology

School of Physical Sciences

Faculty of Natural and Agricultural Sciences

University of Pretoria

Submitted by:

Altus Huisamen

04412141

February 2017

Declaration

I, the undersigned, declare that the thesis/ dissertation, which I hereby submit for the degree Ph.D. at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

Full names:	Altus Huisamen
Student number:	04412141
Date submitted:	February 2017
Degree:	Ph.D. Hydrogeology
Topic of work:	Quantification Methods and Management of Hydrogeochemistry in Decommissioned Collieries of the Mpumalanga Coalfields
Supervisor:	Dr. Matthys Dippenaar, Department of Geology, University of Pretoria
Supervisor:	Prof. Dr. rer. nat. habil. Christian Wolkersdorfer, Tshwane University of Technology/Lappeenranta University of Technology
Signature:	

Acknowledgements

I have received enormous support in my research from the highest calibre individuals and institutions. They are gratefully acknowledged for their contributions in the completion of this thesis. My gratitude to them cannot be expressed in words.

- First and foremost, mein Doktor Vader, Prof. Dr. rer. nat. habil. Christian Wolkersdorfer. Thank you Professor for countless hours spent in teaching me the ways of mine water hydrogeology and geochemistry. You have grown my knowledge to an extent I could never have imagined. You have been the best mentor a Ph.D. student and a young scientist could ask for and will always be the “pope” of mine water in my eyes.
- My supervisor, Dr. Matthys Dippenaar, for your support in managing affairs at the university and the review and assessment of my thesis.
- My parents Altus and Riana Huisamen, for your support and motivation in the completion of my thesis. The perseverance you have taught me is the reason I could complete this research.
- My sister and brother-in-law Lize and Dewan Lombard, for unending support and encouragement to carry on working through the late nights.
- Dr. Ahee Coetsee, for mentorship and additional funding of this research. You have truly been a father figure to me in the 8 years you have allowed me to be part of your company. Dankie Baas.
- Dr. Giep Du Toit, for always believing in my ideas and being one of the only people to understand the “language” I speak. You always have time for a discussion and to give a word of wisdom. Dankie Oom Giep.
- The senior staff of Geo Pollution Technologies for guidance and constructive criticism that have shaped my way of scientific thinking.
- The junior staff of Geo Pollution Technologies for reminding me why I love hydrogeochemistry so much. Your questions and hunger for knowledge have inspired me more than you know.
- The friends who have come and gone, but most importantly, who stayed through this journey, with many a word of motivation. It is a road I could not have walked alone.
- Ms. Leske van Dyk for her tireless assistance with the GIS and map drafting in this thesis. Without your artistic eye, these pages would only be mere words. Thank you for bringing the initial flush to life with me.
- Mr. Duheine Myburgh, the reason this thesis exists in the first place. Thank you, Duheine, for the time spent in the field with me and for providing most of the data that fills these pages. Without your assistance, I could not have completed my research.
- Ms. Ritva Mühlbauer and Mr. Henk Lodewijks, for guidance and discussions on the content of this thesis. You have afforded me all the opportunities a Ph.D. student could ask for and I am grateful for the time and wisdom you have granted me.
- The personnel at the anonymous mine sites for unhindered access to property and data. It is highly appreciated.
- The inputs from external reviewers are gratefully acknowledged.

"We can judge our progress by the courage of our questions and the depth of our answers, our willingness to embrace what is true rather than what feels good" – Carl Sagan

Abstract

Mine water chemistry and its evolution has been the focus of various studies. However, these studies were primarily based on data from underground mines, pit lakes and mining waste dumps. Backfilled opencast mines have received limited attention in this regard and were postulated to undergo an initial flush, in a similar fashion to underground mines. Previous work in the prediction of mine water quality focussed on the fitting of an idealised decay rate curve to existing mine water chemistry data, analytical calculations, simplified geochemical modelling approaches and numerical transport models. This study has taken components from these approaches to predict the evolution of mine water quality from backfilled opencast mines, during the initial flush, but with an additional component, defining it as a new approach. This component is calibration of geochemical modelling data and numerical flow and transport modelling data, with existing groundwater monitoring data over a short term, relative to the duration of the initial flush. Laboratory analyses were further used to augment the calibration process in various steps. Results obtained show that the initial flush in backfilled opencast mines is likely to last 20 to 100 years, depending on site specific conditions. To further understand this duration, speciation modelling and statistical analysis was undertaken to determine controlling mineral phases in solution at backfilled opencast coal mines. Pyrite, gypsum, calcite, kaolinite and possible smectite were identified as the major controlling mineral phases in mine water chemistry of backfilled opencast coal mines at the study sites used for this thesis. Based on the understanding of the controlling mineral phases in solution and the calibrated mine water quality predictions made, the study also proposed the maximisation of water addition to backfilled opencast coal mines as a means to accelerate the initial flush, potentially turning contaminated mine water into a resource.

Table of Contents

Declaration i

Acknowledgements ii

Abstract iv

Table of Contents v

List of Figures ix

List of Tables xiv

1 Introduction 1

1.1 Context of the study 1

1.2 Problem Statement 2

1.3 Investigation Objectives 3

2 Literature Review 4

2.1 Introduction 4

2.2 Geological Setting of the Study Area 4

2.2.1 Introduction 4

2.2.2 Coal Genesis in the Ecca Group 4

2.2.3 The Vryheid Formation 5

2.2.4 The Dwyka Group 6

2.2.5 Coalfields 6

2.2.6 The Witbank Coalfield 6

2.2.7 The Highveld Coalfield 7

2.2.8 The Ermelo (Eastern Transvaal) Coalfield 8

2.2.9 Mineralogy Associated with the Mpumalanga Coal Seams 8

2.3 Surface Coal Mining in South Africa 8

2.4 Rehabilitation of Opencast Coal Mines in South Africa 9

2.4.1 Introduction 9

2.4.2 Rehabilitation Methods 10

2.5 Mine Water 13

2.6 Mine Water Management 14

2.6.1 Introduction 14

2.6.2 Active treatment technologies 15

2.6.3 Passive treatment technologies 17

2.7 Common Backfill Mineralogy – Vryheid Formation 20
2.8 Quantification of Mineral Reactive Surface Areas 20
2.9 Hydraulic Properties of the Karoo Supergroup 21
2.9.1 Introduction 21
2.9.2 Hydraulic Properties of Fractures 21
2.9.3 Hydraulic Properties of Matrix Blocks 22
2.10 Influences on the Initial Flush of Rehabilitated Opencast Collieries 22
2.10.1 Introduction 22
2.10.2 Rehabilitation Status and Flooding Time 23
2.10.3 Pit Type 24
2.10.4 Groundwater Flow Rates 25
2.10.5 The Master Variables – pH and Redox 26
2.10.6 Pre- and Post-Backfill Contaminant Release Potential 27
2.11 Initial Flush Quantification 29
2.11.1 Mine Water Chemistry Prediction – Underground Mines 29
2.11.2 Mine Water Chemistry Prediction – Pit Lakes 32
3 Description of the Study Sites 34
3.1 Introduction 34
3.2 Mine Locations 34
3.3 Climatic Settings of the Mines 34
3.3.1 C-Mine 34
3.3.2 E-Mine 35
3.3.3 A-Mine 36
3.4 Hydrological Settings 37
3.4.1 C-Mine 37
3.4.2 E-Mine 38
3.4.3 A-Mine 38
3.5 Geological Settings of the Mines 38
3.5.1 C-Mine 38
3.5.2 E-Mine 38
3.5.3 A-Mine 39
3.6 Hydrogeological Setting 39
3.7 Mining Activities 42
3.7.1 C-Mine 42

3.7.2 E-Mine 42
3.7.3 A-Mine 42
4 Methodology 44
4.1 Introduction 44
4.2 Conceptual Hydrogeological Model 44
4.3 Numerical Flow Model Construction 45
4.3.1 Introduction 45
4.3.2 Flow Model Setup 46
4.3.3 Fixed Aquifer Parameters 46
4.3.4 Model Boundaries and Discretisation 47
4.3.5 Calibration 47
4.3.6 Modelling Scenario 47
4.4 Conceptual Geochemical Model 47
4.5 Mineralogical Analysis 48
4.6 Reactive Surface Area 49
4.7 Mineral Reaction Rates 49
4.8 Acid-Base Accounting 50
4.9 Leachate Chemistry 50
4.10 Interpretation of Available Groundwater Monitoring Data 50
4.11 Statistical Analysis of Geochemical Data 51
4.12 Geochemical System Calibration 51
4.12.1 Model Construction and Calibration 51
4.12.2 Simulation of the Natural Geochemical System 52
4.13 Chemical Calibration of the Numerical Flow Model 52
4.14 Geochemical Sensitivity Analyses and Implications for Rehabilitation Practices 53
4.15 Assumptions and Limitations 55
5 Results 58
5.1 C-Mine 58
5.1.1 Numerical Flow Model 58
5.1.2 Mineral Abundances 60
5.1.3 Distilled Water Leach Tests 62
5.1.4 Mineral Reaction Rates 63
5.1.5 Groundwater Monitoring Data 64
5.1.6 Geochemical Model Calibration 73

5.1.7 Simulated Natural Geochemical Conditions 74
5.1.8 Numerical Flow Model Chemical Calibration 75
5.1.9 Geochemical Parameter Sensitivity 77
5.2 E-Mine 77
5.2.1 Numerical Flow Model 77
5.2.2 Mineral Abundances 79
5.2.3 Distilled Water Leach Tests 82
5.2.4 Mineral Reaction Rates 83
5.2.5 Groundwater Monitoring Data 84
5.2.6 Geochemical Model Calibration 98
5.2.7 Simulated Natural Geochemical Conditions 98
5.2.8 Numerical Flow Model Chemical Calibration 99
5.2.9 Geochemical Parameter Sensitivity 101
5.3 A-Mine 101
5.3.1 Numerical Flow Model 101
5.3.2 Mineral Abundances 104
5.3.3 Distilled Water Leach Tests 107
5.3.4 Mineral Reaction Rates 108
5.3.5 Groundwater Monitoring Data 109
5.3.6 Geochemical Model Calibration 132
5.3.7 Simulated Natural Geochemical Conditions 132
5.3.8 Numerical Flow Model Chemical Calibration 133
5.3.9 Geochemical Parameter Sensitivity 135
6 Synthesis 136
6.1 Mineralogy and Geochemistry at the Study Sites 136
6.1.1 Comparison of Mineralogical Data between the Study Sites 136
6.1.2 Comparison of Acid-Base Accounting Data 139
6.1.3 Comparison of Leaching Test Data 141
6.2 Solution Speciation and Controlling Mineral Phases 144
6.3 Statistical Analysis of Geochemical Data 145
6.4 Statistical Analysis of Hydrochemical Data 151
6.5 Geochemical Modelling Calibration 163
6.6 Numerical Transport Modelling Calibration 164
6.7 Long Term Geochemical Behaviour and Contaminant Transport 165

6.8 Model Sensitivity Analyses and Implications for Rehabilitation 168
7 Discussion 172
7.1 Geochemistry of Mining Overburden in the Mpumalanga Coalfields 172
7.2 Geochemical and Numerical Transport Modelling 174
7.3 Model Sensitivity and Implications for Current Rehabilitation Practice in South Africa 174
8 Conclusions 176
References 180
APPENDIX A: Correlation Matrix 187
APPENDIX B: Geochemical Data for C-Mine 188
APPENDIX C: Geochemical Data for E-Mine 189
APPENDIX D: Geochemical Data for A-Mine 190
APPENDIX E: Groundwater Monitoring Data 191

List of Figures

Figure 1: Stratigraphic column of the typical lithologies of the Dwyka and Vryheid Formations modified after Johnson et al. (2006) 5
Figure 2: Extent of the Witbank, Highveld and Ermelo Coalfields including the locations of the investigated opencast coal mines in Mpumalanga, South Africa modified after Snyman (1998) 7
Figure 3: Opencast mine strip in Mpumalanga 9
Figure 4: Mixing of Acid Generating Overburden Material with Lime to Minimise Acid Generation Modified After Wisotzky (2003) 11
Figure 5: Potential rehabilitated Pit Types based on the model of Webster et al. (2006). Each of these types of opencast mines can also occur in relatively flat landscape 24
Figure 6: Climatic Data for the Carolina Area Nooitgedacht Dam 35
Figure 7: Climatic Data for the eMalahleni Area (Witbank Dam) 36
Figure 8: Climatic Data for the Middelburg Area (Middelburg Dam) 37
Figure 9: Stratigraphic Columns for the Study Sites (Pers. Comm. Myburgh, 2015) 40
Figure 10: Geological Map of the Lithologies Encountered at C-Mine 41
Figure 11: Geological Map of the Lithologies Encountered at E-Mine 41
Figure 12: Geological Map of the Lithologies Encountered at A-Mine 42
Figure 13: Conceptual Hydrogeological Model of the Initial Flush in Opencast Coal Mines. Details are outlined in the text. 45
Figure 14: Conceptual Model of Hydrogeochemical Source Characterisation of a Rehabilitated Opencast Mine 48
Figure 15: Example of a diffraction trace (sample KDC1 collected from E-Mine) 49
Figure 16: Flow-chart of steps in the modelling methodology 57
Figure 17: Groundwater flow directions at C-Mine Colliery 59
Figure 18: Transient head calibration graph for the numerical model constructed for C-Mine Colliery5

Figure 19: Sample collection areas at C-Mine 61
Figure 20: Groundwater monitoring data for MW2 at C-Mine (illustrating Fe, SO_4, pH and Alkalinity) 67
Figure 21: Groundwater monitoring data for MW3 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 67
Figure 22: Groundwater monitoring data for MW4 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 68
Figure 23: Groundwater monitoring data for MW5 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 68
Figure 24: Groundwater monitoring data for MW6 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 69
Figure 25: Groundwater monitoring data for MW8 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 69
Figure 26: Groundwater monitoring data for MW10 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 70
Figure 27: Groundwater monitoring data for MW11 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 70
Figure 28: Groundwater monitoring data for MW12 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 71
Figure 29: Groundwater monitoring data for MW13 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 71
Figure 30: Groundwater monitoring data for MW14 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 72
Figure 31: Groundwater monitoring data for MW15 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 72
Figure 32: Groundwater monitoring data for MW16 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 73
Figure 33: Groundwater monitoring data for MW17 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 73
Figure 34: Left: Calibration graph for the geochemical model of C-Mine; averaged analysis concentrations vs. calculated concentrations; standard errors are shown in the horizontal direction. Right: logarithmic ordinate for improved illustration of lower concentrations and standard error values 74
Figure 35: Simulated contaminant concentrations in the leachate of C-Mine generated from the backfill material on site over time; logarithmic ordinate 75
Figure 36: Chemical Calibration Graphs for the monitoring wells used in the C-Mine Numerical Flow and Transport Model, blue dots: simulated values; red diamonds: observed values. 76
Figure 37: Groundwater flow directions at E-Mine Colliery 79
Figure 38: Head calibration graph for the numerical model constructed for E-Mine Colliery 79
Figure 39: Sample collection areas at E-Mine 80
Figure 40: Groundwater monitoring data for KRW012 at E-Mine (illustrating Fe, SO_4, pH and Alkalinity) 88
Figure 41: Groundwater monitoring data for KRW014 at C-Mine (illustrating Fe, SO4, pH and Alkalinity) 88
Figure 42: Groundwater monitoring data for KRW024 at E-Mine (illustrating Fe, SO4, pH and Alkalinity) 89
Figure 43: Groundwater monitoring data for KRW026 at E-Mine (illustrating Fe, SO4, pH and Alkalinity) 89
Figure 44: Groundwater monitoring data for KRW027 at E-Mine (illustrating Fe, SO4, pH and Alkalinity) 90
Figure 45: Groundwater monitoring data for KRW028 at E-Mine (illustrating Fe, SO4, pH and

Alkalinity).....90
Figure 46: Groundwater monitoring data for KRW029 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....91
Figure 47: Groundwater monitoring data for KRW030 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....91
Figure 48: Groundwater monitoring data for KRW031 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....92
Figure 49: Groundwater monitoring data for MW34 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....92
Figure 50: Groundwater monitoring data for KRW035 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....93
Figure 51: Groundwater monitoring data for KRW036 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....93
Figure 52: Groundwater monitoring data for KRW038 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....94
Figure 53: Groundwater monitoring data for KRW039 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....94
Figure 54: Groundwater monitoring data for KRW040 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....95
Figure 55: Groundwater monitoring data for KRW041 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....95
Figure 56: Groundwater monitoring data for KRW043 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....96
Figure 57: Groundwater monitoring data for KRW047 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....96
Figure 58: Groundwater monitoring data for KRW049 at E-Mine (illustrating Fe, SO4, pH and Alkalinity).....97
Figure 59: Groundwater monitoring data for WP54 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)9
Figure 60: Left: Calibration graph for the geochemical model of E-Mine; averaged analysis concentrations vs. calculated concentrations; standard errors are shown in the horizontal direction. Right: Logarithmic ordinate for improved illustration of lower concentrations and standard error values. 98
Figure 61: Simulated contaminant concentrations in the leachate of E-Mine generated from the backfill material on site, over time; logarithmic ordinate.....99
Figure 62: Chemical Calibration Graphs for the monitoring wells used in the E-Mine Numerical Flow and Transport Model, blue dots: simulated values; red diamonds: observed values. 100
Figure 63: Groundwater flow directions at A-Mine Colliery 103
Figure 64: Head calibration graph for the numerical model constructed for A-Mine Colliery.....103
Figure 65: Sample collection areas at A-Mine.....105
Figure 66: Groundwater monitoring data for AW1 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)11
Figure 67: Groundwater monitoring data for AW10 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....115
Figure 68: Groundwater monitoring data for AW12 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....116
Figure 69: Groundwater monitoring data for AW13 at A-Mine (illustrating Fe, SO4, pH and

Alkalinity).....116
Figure 70: Groundwater monitoring data for AW14 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....117
Figure 71: Groundwater monitoring data for AW15 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....118
Figure 72: Groundwater monitoring data for AW18 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....119
Figure 73: Groundwater monitoring data for AW19 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....119
Figure 74: Groundwater monitoring data for AW2 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)12
Figure 75: Groundwater monitoring data for AW20 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....120
Figure 76: Groundwater monitoring data for AW21 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....121
Figure 77: Groundwater monitoring data for AW22 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....121
Figure 78: Groundwater monitoring data for AW23 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....122
Figure 79: Groundwater monitoring data for AW24 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....122
Figure 80: Groundwater monitoring data for AW25 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....123
Figure 81: Groundwater monitoring data for AW26 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....123
Figure 82: Groundwater monitoring data for AW27 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....124
Figure 83: Groundwater monitoring data for AW28 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....124
Figure 84: Groundwater monitoring data for AW3 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)12
Figure 85: Groundwater monitoring data for AW30 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....125
Figure 86: Groundwater monitoring data for AW31 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....126
Figure 87: Groundwater monitoring data for AW32 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....126
Figure 88: Groundwater monitoring data for AW33 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....127
Figure 89: Groundwater monitoring data for AW35 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....127
Figure 90: Groundwater monitoring data for AW37 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....128
Figure 91: Groundwater monitoring data for AW38 at A-Mine (illustrating Fe, SO4, pH and Alkalinity).....128
Figure 92: Groundwater monitoring data for AW4 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)12
Figure 93: Groundwater monitoring data for AW5 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)12

Figure 94: Groundwater monitoring data for AW6 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)13
Figure 95: Groundwater monitoring data for AW7 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)13
Figure 96: Groundwater monitoring data for AW8 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)13
Figure 97: Groundwater monitoring data for AW9 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)13
Figure 98: Left: Calibration graph for the geochemical model of A-Mine; averaged analysis concentrations vs. calculated concentrations; standard errors are shown in the horizontal direction. Right: Logarithmic ordinate for improved illustration of lower concentrations and standard error values 132
Figure 99: Simulated contaminant concentrations in the leachate generated from the backfill material on site over time; logarithmic ordinate 133
Figure 100: Chemical Calibration Graphs for the monitoring wells used in the A-Mine Numerical Flow and Transport Model, blue dots: simulated values; red diamonds: observed values. 134
Figure 101: Stability diagram constructed for a high [Si], low [Al] groundwater solution, indicating stability of quartz and kaolinite. Please see text with regards to kyanite stability. 137
Figure 102: Stability diagram constructed for Fe with HCO_3 present in the groundwater solution, indicating stability of hematite and siderite 138
Figure 103: Stability diagram constructed for a concentration of 0.01 mol SO_4 with Fe present in the groundwater solution, indicating stability of pyrite in reducing and low pH conditions.....138
Figure 104: Correlation Graph Illustrating the Correlation between Sulfide Sulfur Wt% and Acid Generation Potential in Collected Samples (red dots) with Potential Outliers KROM-2 and KROM-3 (blue dots) excluded from the Regression Calculation 141
Figure 105: Stability Diagram for a concentration of 0.01 mol Fe and 0.01 mol Mn in solution.....143
Figure 106: Stability Diagram for a 0.01 mol solution of Mn 143
Figure 107: Piper diagram of leachate chemistry and mine water discharge chemistry at the study sites 144
Figure 108: Dendrogram Relating All Analysis Data between the Collected Geochemical Samples at the Study Sites using Leaching Test Constituent Concentrations and XRD Identified Mineral Phases151
Figure 109: Cross-Correlation of SO_4 with pH in groundwater at C-Mine 154
Figure 110: Groundwater monitoring data at C-Mine illustrating SO_4 affected boreholes (SO_4 units = mg/L) 155
Figure 111: Cross-Correlation of SO_4 with pH in groundwater at E-Mine 158
Figure 112: Groundwater monitoring data at E-Mine illustrating SO_4 affected boreholes (SO_4 units = mg/L) 159
Figure 113: Cross-Correlation of SO_4 with pH in groundwater at E-Mine 162
Figure 114: Groundwater monitoring data at E-Mine illustrating SO_4 affected boreholes (SO_4 units = mg/L) 163
Figure 115: Sulfate concentration contours for the long term contaminant transport simulation for C-Mine 166
Figure 116: Sulfate concentration contours for the long term contaminant transport simulation for E-Mine 167
Figure 117: Sulfate concentration contours for the long term contaminant transport simulation for A-Mine 168
Figure 118: Sulfate concentration contours for the long term contaminant transport simulation for C-Mine with increased water flow and raised oxygen fugacity 170
Figure 119: Sulfate concentration contours for the long term contaminant transport simulation for

E-Mine with increased water flow and raised oxygen fugacity 170
Figure 120: Sulfate concentration contours for the long term contaminant transport simulation for A-Mine with increased water flow and raised oxygen fugacity 171
Figure 121: Low Intensity Rehabilitation Methods for Opencast Coal Mines 178
Figure 122: High Intensity Rehabilitation Methods for Opencast Coal Mines.....179

List of Tables

Table 1: Comparison of Treatment Systems; from International Network for Acid Prevention (INAP) (2009) 14
Table 2: Alkali Materials and Compounds applied to ARD Treatment (from International Network for Acid Prevention (INAP), 2009).....15
Table 3: Typical Hydraulic Properties of Karoo Aquifers (Botha et al., 1998), K_h = Horizontal hydraulic conductivity 22
Table 4: Factors Influencing the Flooding Rate of an Opencast Mine (Bredenkamp et al., 1995, Van Zyl, 2011) 23
Table 5: Potential Recharge Percentages in Mining Operations from Hodgson and Krantz (1998) 26
Table 6: Mineralogical Composition of Secondary Minerals with Contaminant Release Potential after Mine Backfilling; modified after Langmuir (1997) and Younger et al. (2002).....28
Table 7: Climatic Data for the Carolina Area (Nooitgedacht Dam) 35
Table 8: Climatic Data for the eMalahleni Area (Witbank Dam).....36
Table 9: Climatic Data for the Middelburg Area (Middelburg Dam).....37
Table 10: Parameters Selected for Sensitivity Analysis of the Model Inputs and Their Relation to Site Conditions 54
Table 11: Input parameters to the numerical flow model for C-Mine.....58
Table 12: Mineral Phases Identified During Analysis of Six Backfill Samples at C-Mine; Mineral Phase Abundances Reported as Weight Percentage.....60
Table 13: Acid-base accounting results for backfill samples collected at C-Mine (Huisamen and Naidoo, 2014) – Neutralisation potential and Net Neutralisation Potential (NNP) expressed as $CaCO_3$ equivalent kg per ton 61
Table 14: Analysis results of C-Mine mine water discharge (Huisamen and Naidoo, 2014); concentrations presented in mg/L.....62
Table 15: Leachate Analysis Results for C-Mine.....63
Table 16: Calculated statistics, rate constants and reactive surface areas from the XRD results of six backfill samples from C-Mine.....64
Table 17: Sensitivity Analysis of Parameters Influencing the Generation and Decay of Sulfate in Solution at C-Mine Based on Geochemical Modelling.....77
Table 18: Input parameters to the numerical flow model for E-Mine.....78
Table 19: Mineral Phases Identified During Analysis of Five Backfill Samples at E-Mine; Mineral Phase Abundances Reported as Weight Percentage (- not detected).....80
Table 20: Acid-base accounting results for backfill material collected at E-Mine (Williams, 2015) – Neutralisation potential and Net Neutralisation Potential (NNP) expressed as $CaCO_3$ equivalent kg per ton.....81
Table 21: Analysis results of field scale leach testing on backfill material sampled at E-Mine

(Williams, 2015); concentrations presented in mg/L.....81
Table 22: Analysis results of E-Mine mine water discharge (Pers. Comm. Myburgh, 2015); concentrations in mg/L 82
Table 23: Distilled Water Leach Test and Subsequent Leachate Analysis Results for E-Mine; b.d.l.: below detection limit 83
Table 24: Calculated statistics, rate constants and reactive surface areas from the XRD results of five backfill samples from E-Mine; b.d.l.: below detection limit 84
Table 25: Sensitivity Analysis of Parameters Influencing the Generation and Decay of Sulfate in Solution at E-Mine based on Geochemical Modelling 101
Table 26: Input parameters to the numerical flow model for A-Mine 102
Table 27: Mineral Phases Identified During Analysis of Three Backfill Samples at A-Mine; Mineral Phase Abundances Reported as Weight Percentage 104
Table 28: Acid-base accounting analysis results for backfill material collected at A-Mine (Fourie, 2013) – Base potential and Net Neutralisation Potential (NNP) expressed as $CaCO_3$ equivalent kg per ton 104
Table 29: Analysis results of leach testing on backfill material sampled at A-Mine, exactly reproduced from Fourie (2013); -: below detection limit.....106
Table 30: Analysis results of A-Mine mine water discharge (Pers. Comm. Myburgh, 2015); concentrations in mg/L; b.d.l.: below detection limit.....107
Table 31: Leachate Analysis Results for A-Mine 108
Table 32: Calculated statistics, rate constants and reactive surface areas from the XRD results of three backfill samples from A-Mine.....108
Table 33: Sensitivity Analysis of Parameters Influencing the Generation and Decay of Sulfate in Solution at A-Mine based on Geochemical Modelling.....135
Table 34: Comparison of Mineral Phases Encountered at the Study Sites (● shows major mineral phase present; ○ shows minor mineral phase present; - shows mineral phase not present).....137
Table 35: Compilation of Acid-Base Accounting Results from the Study Sites (Total S Values* are Extrapolated Based on the Acid Generation Potential of the Samples); description in text. 140
Table 36: Compilation of Distilled Water Leaching Test Leachate Analyses. Results are presented in mg/L, with the exception of pH, "-": Below detection limit; N/A – not analysed.....142
Table 37: Speciation Summary for Discharge Mine Water and Leach Test Analysis Results for C-Mine14
Table 38: Speciation Summary for Discharge Mine Water and Leach Test Analysis Results for E-Mine14
Table 39: Speciation Summary for Discharge Mine Water and Leach Test Analysis Results for A-Mine14
Table 40: Principal Component Analysis Results with Qualifying Sample Values Above 0.5 (Highlighted); $[H^+]$ used instead of pH 150
Table 41: Descriptive statistics for groundwater monitoring data at C-Mine 153
Table 42: Descriptive statistics for groundwater monitoring data at E-Mine.....157
Table 43: Descriptive statistics for groundwater monitoring data at A-Mine 161

1 Introduction

1.1 Context of the study

Post-opencast mining hydrogeological conditions in the Mpumalanga Coalfields are often associated with the release of contaminated mine water and transport of sulfate, acid and (semi-)metals (Bell et al., 2001). These contaminants can be sourced directly from backfill materials and pit walls that, even under the strictest rehabilitation criteria, continue to produce at least partial contamination of the surrounding Karoo aquifers (Pinetown and Boer, 2006). However, in many cases, only an indication of post-mining contamination potential can be provided, based on current geochemical analyses and applications in the South African context (Pinetown and Boer, 2006). With coal resources steadily becoming depleted in this area, increasing mine closures can be expected (Usher and Vermeulen, 2006). Therefore, advanced conceptualisation, quantification and management strategies will be required to ensure that the impact that collieries have on the groundwater environment, are kept to a minimum (Gomo and Vermeulen, 2013). Taking these factors into account, a novel method is presented in this study which combines various analytical and numerical approaches to the modelling of the initial flush in backfilled opencast coal mines. It has been compiled specifically from a consulting perspective by combining known methods/facts into a usable tool for situations where predictions are required with a restricted number of samples. This will ensure not only protection of water resources for future generations, but also water supplies for current groundwater users in the Mpumalanga Coalfields.

The premise of this study is that short term monitoring data can be used to determine the geochemical behaviour of a source term i.e. a backfilled opencast mine, even if detailed source characterisation has not been performed. Monitoring data provides insight into the behaviour of the source and with a basic understanding of the source composition, a representative simulation of its geochemical behaviour can be performed if it is calibrated against existing monitoring data. This is not to say that the simulation is perfect or completely representative of the conditions on site. There could be hundreds of different input sets for the simulation which produce the monitoring results. However, if the simulation does reproduce the monitoring data successfully, it is a possible way of determining future data at least reasonably reliably. Therefore, a large amount of input data and source characterisation is not required. The more input data available from source characterisation, the more precise the input into the simulation, reducing the allowable variance. However, if limited data is available a larger variance may be applied within statistically calculated boundaries for the input data to simulate the system. Therefore, with source characterisation data available such as that provided in this study (leach tests and mineralogical analyses/ABA) the variance of input data for the simulation is already reduced. Limited source characterisation data is the norm in the hydrogeological consulting environment in South Africa. Combined with short term monitoring data the model could be calibrated reliably as the monitoring data provides insight into the behaviour of the source term. Therefore, long term estimations could be made about the evolution of mine water flowing from the backfilled opencast mine. This is the novelty of the study and addresses a gap in the knowledge currently available for the modelling of the initial flush.

Further to this, the study addresses the modification of current backfill and rehabilitation methods for opencast coal mines. Current practice dictates that acid generating material is deposited at the base of the opencast mine and flooded as soon as possible while non-acid generating material is deposited at the top of the backfill spoil pile. While this proves effective in minimising contamination

and management of long term mine water evolution it does not address the accelerated depletion of a source which can lead to an exploitable resource. An additional novelty to this study is the exploration of a rehabilitation method to accelerate source depletion through the initial flush to return to a state of equilibrium as quickly as possible where the flooded mine can be exploited as a water resource.

1.2 Problem Statement

Quantification and understanding of contaminant release from rehabilitated opencast mines is extremely lacking in the South African context, even with advances in geochemical modelling techniques being made internationally such as the studies by Evans et al. (2003), Eriksson and Destouni (1997) or Banwart and Malmstrom (2001). The implementation and advancement of these techniques are imperative if accurate mine water quality calculations are to be made in the Mpumalanga Coalfields, ensuring proper aquifer management.

Further to the lack of modelling of contamination is the quantification of mineral assemblages common to the Karoo aquifers. These mineral assemblages and their associated field scale weathering rates are poorly documented in literature. Additionally, as noted in various studies, field scale weathering rates could differ considerably from laboratory derived rates (Gzyl and Banks, 2007). However, as a best estimate, laboratory derived weathering rates are still considered in geochemical modelling. This could potentially be improved by geochemical calibration, a currently emerging practice in geochemical modelling.

Currently, oxygen ingress rates are mostly assumed to be as low as possible for backfilled opencast mining environments, rather than being measured. Again, oxygen can play a key role in the contamination released, especially in terms of pyrite oxidation. Therefore, improved estimates could be made by calibrating geochemical models and by basing assumptions and geochemical models on sound conceptual models. Advanced ground vapour surveys, to depth, are additionally proposed for further certainty, but will not be addressed in this study.

One of the strongest controlling factors in contaminant release rates are the reactive mineral surface areas. Methods currently exist for quantification of this parameter such as the Brunauer, Emmett and Teller (BET) method (Brunauer et al., 1938). This parameter could also be estimated from grain size distribution using a shrinking core model as well as geochemical model calibration (Gautier et al., 2001).

An improved understanding and quantification of the above-mentioned specifications, along with sensitivity analyses, could provide methods for potential manipulation of contaminant breakthrough curves. This can be achieved by using adaptive rehabilitation methods. In turn, the improved rehabilitation methods are likely to lower expenditures in both an environmental as well as operational context, potentially turning rehabilitated opencast mines into groundwater reservoirs.

Selective placement of overburden material in decommissioned opencast mines could aid greatly in the management and prediction of the hydrogeochemistry from these mine sites (Deysel et al., 2014, Betrie et al., 2013). Understanding of the mineralogy and geochemistry of backfill materials will aid in placement of these materials as well as the development of groundwater sampling programmes for backfilled opencast coal mines. This understanding could imply changes to current rehabilitation practices with regards to selective placement (acid generating base, non-acid

generating top) to accelerate the initial flush to return to background conditions as quickly as possible. This may serve as an alternative to long term mine water management.

Further to this is the advancement of laboratory techniques to characterise waste materials. A simple example of this would be to determine oxidisable sulfur from backfill samples as opposed to a total sulfur analysis during ABA to give an indication of acid generation capacity as shown in the Modified Sobek method (Lawrence and Marchant, 1991). Simple modifications to current laboratory practices and methods may further advance the prediction of the initial flush in this way.

1.3 Investigation Objectives

In order to further explain the problem statement of the study, the following objectives are defined:

- Improve the understanding of overburden mineralogy and geochemistry associated with coal mining overburden with respect to the Vryheid Formation
- Assess the efficiency of a newly proposed methodology for modelling and prediction of the initial flush and transient release of contamination from a backfilled opencast coal mine with special focus on sulfate
- Conduct a sensitivity analysis of modifications to the current rehabilitation practice of selective placement of backfill material (acid forming base, non-acid forming top) in order to manipulate the geometry of sulfate breakthrough curves from rehabilitated opencast mines. This will be based on the interpretation of available and acquired data as well as geochemical and transport modelling.
- Develop a recommendation for the backfilling of opencast coal mines in South Africa.

2 Literature Review

2.1 Introduction

The following sections aim to provide a systematic description of opencast coal mining in the Mpumalanga Province in South Africa. They describe the geological setting, central coalfields, seams mined and the common mining methods of the area. Additionally, the hydrogeological and geochemical conditions likely to be associated with decommissioned opencast collieries are reviewed.

2.2 Geological Setting of the Study Area

2.2.1 Introduction

Coal mining in South Africa occurs predominantly in the Karoo Supergroup sedimentary rocks (Pinetown et al., 2007). The major coalfields of the country are situated within this Supergroup (Figure 2), with the Mpumalanga Coalfields, which are the focus of this study, situated within the Ecca Group in the Mpumalanga Province (Pinetown et al., 2007, Jeffrey, 2005). The five coal seams of the Mpumalanga Coalfields are contained within the Ecca Group's Vryheid Formation (Johnson et al., 2006) which consists mainly of sandstones and shales (Figure 1). A systematic description of this formation is given in the following paragraphs. The overlying Volksrust Formation is not discussed, as it is not developed or it is completely eroded in the Central Mpumalanga Coalfield. A brief description of the Underlying Dwyka Group is given, but the underlying Pietermaritzburg Formation is omitted from discussion as this formation is also undeveloped in the Central Mpumalanga Coalfield (Johnson et al., 2006).

2.2.2 Coal Genesis in the Ecca Group

Snyman (1998) ascribes the genesis of coal in the Ecca Group as a terrestrial deposition on a gently subsiding shelf platform, which is represented by fluviodeltaic sandstones. These sandstones eventually thin to mudstones and siltstone facies. The coal was formed in valleys in the Pre-Karoo basement, which were formed by glaciers and ice-sheets during the Dwyka Group deposition (Snyman, 1998). Upon the retreat of the glaciers and ice-sheets during the formation of the Ecca, these valleys were transformed into pro-glacial lakes and eventually swamps (Hancox and Götz, 2014). There, the lower-most coal seams of the Ecca were deposited and the pre-Karoo topography strongly influences the distribution of the coal seams (Snyman, 1998). Due to shallowing of the valleys, meandering and bifurcating streams as well as deltaic sedimentary deposits were formed along with further coal seams (Ruckwied et al., 2014, Holland et al., 1989).

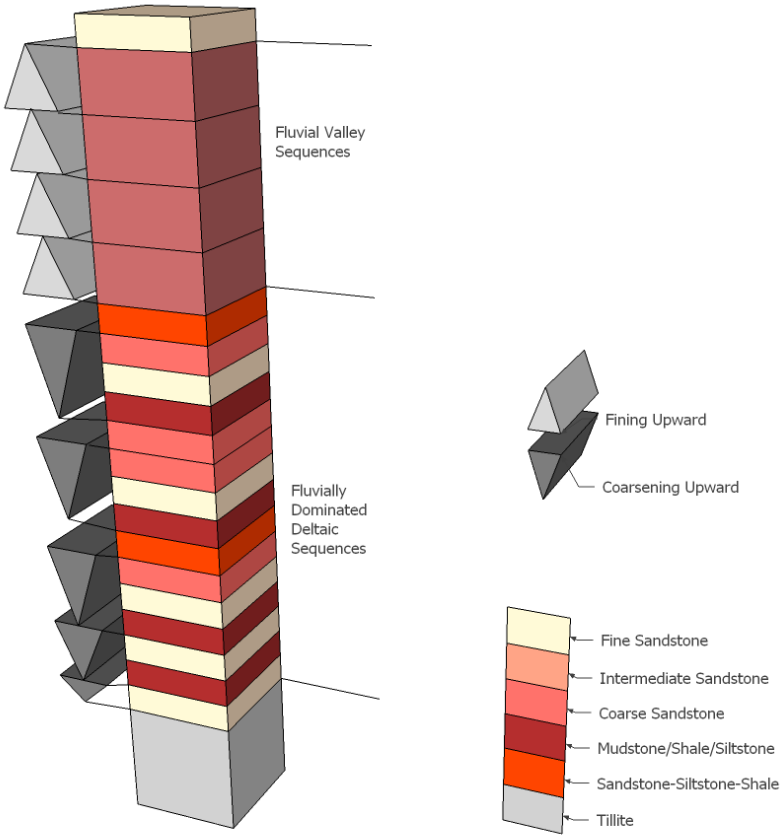


Figure 1: Stratigraphic column of the typical lithologies of the Dwyka and Vryheid Formations modified after Johnson et al. (2006)

2.2.3 The Vryheid Formation

The Vryheid Formation corresponds to the Mpumalanga Coalfields in the Karoo Supergroup and can be subdivided into two distinct intervals: a lower fluvial dominated deltaic interval and a middle fluvial interval (Johnson et al., 2006).

The base of the lower fluvial deltaic dominated interval is characterised by an upward coarsening sequence of muddy siltstones deposited in anoxic shelf suspension conditions. This is overlain by a facies of bioturbated immature sandstones, siltstones and mudstones on a centimetre to decimetre scale. Above this facies, is a facies of mouth-bar sediments. Distal mouth-bar sediments are found in the form of laminated, medium-grained sandstone, followed by ripple cross-laminated fine grained sandstone and siltstone. The proximal mouth-bar sediments are present as cross-stratified medium to coarse-grained sandstones. This mouth-bar facies is overlain by coarse to pebbly feldspathic sandstone (Johnson et al., 2006).

The middle fluvial interval includes up to six upward fining cycles which are typically sheet-like in geometry. Coarse-grained to pebbly immature sandstones can be found at the erosional base of this interval. These sandstones have an abrupt upward transition into fine-grained sediments and coal seams. Most of the economically important coal seams occur in this interval which grades into deltaic sediments in the southwest (Johnson et al., 2006).

2.2.4 The Dwyka Group

The sediments of the Dwyka Group are the glacial precursor to the Ecca Group. This group is estimated to be of late Carboniferous to early Permian age (Tankard et al., 2009). The Dwyka consists, from base to top, of three diamictite facies: the massive diamictite facies, the stratified diamictite facies and the massive carbonate-rich facies, all of which are considered to have been deposited in a marine basin (Johnson et al., 2006, Tankard et al., 2009). Therefore, the predominant lithologies of this group are diamictite, tillite and varved sediments formed due to glacial and paraglacial conditions (Glasspool, 2002). Diamictite, varved-siltstones, pebbly mudstones, fluvio-glacial gravel and conglomerates are common in this group (Zhao et al., 2010).

2.2.5 Coalfields

Coalfields in Mpumalanga are divided into three distinct areas, which also contain the mines investigated in this study (Figure 2): the Witbank Coalfield, the Highveld Coalfield and the Ermelo (Eastern Transvaal) Coalfield (Vermeulen and Usher, 2005, Snyman, 1998). Commonly, these coalfields contain five discernible coal seams within the Ecca Group, numbered No. 1 to No. 5 from deepest to shallowest (Cadle et al., 1993, Snyman, 1998). The environments forming the coal seams in this area from seam No. 1 to seam No. 2 are interpreted to have been of a paraglacial nature while the No. 3 to No. 5 seams were deposited in a deltaic environment. The distribution of the seams is controlled by the Pre-Karoo and Dwyka topographies, influencing continuity and depositional mode of the predominantly horizontally deposited coal seams (Glasspool, 2002, Snyman, 1998). The coal seams are disturbed by doleritic intrusions and faults (Johnson et al., 2006). These coalfields and their respective coal seams are described in the following paragraphs.

2.2.6 The Witbank Coalfield

The Witbank Coalfield stretches from Springs in the west, past Belfast and Carolina in the east of the Mpumalanga Province and contains approximately 16.2 Gt of coal. This coal is contained within the Vryheid Formation of the Karoo Supergroup (Glasspool, 2002). A description of the Witbank Coalfield coal seams after Jeffrey (2005) is given below:

- The No. 1 coal seam is commonly 0 to 3 m thick and is patchily developed. This can be attributed to the undulating pre-Karoo topography.
- The No. 2 coal seam is commonly 4.5 to 20 m thick. It contains up to 6 different coal quality zones and is the most economically important seam for steam coal export in the area.
- The No. 3 coal seam is commonly 0.5 m thick and of a high quality. However, it is generally considered to be uneconomic to mine.
- The No. 4 coal seam is generally split into three seams by mudstone partings. These seams are called the No. 4A, No. 4 Upper and No. 4 Lower Seams. The seams are of economic value but are generally of a lower quality than the No. 2 seam.
- The No. 5 coal seam is the shallowest and is generally an erosional remnant. It is commonly between 0 and 2 m thick.

The above-mentioned seams are generally flat lying to gently undulating and are intruded by dykes and sills of various thicknesses.

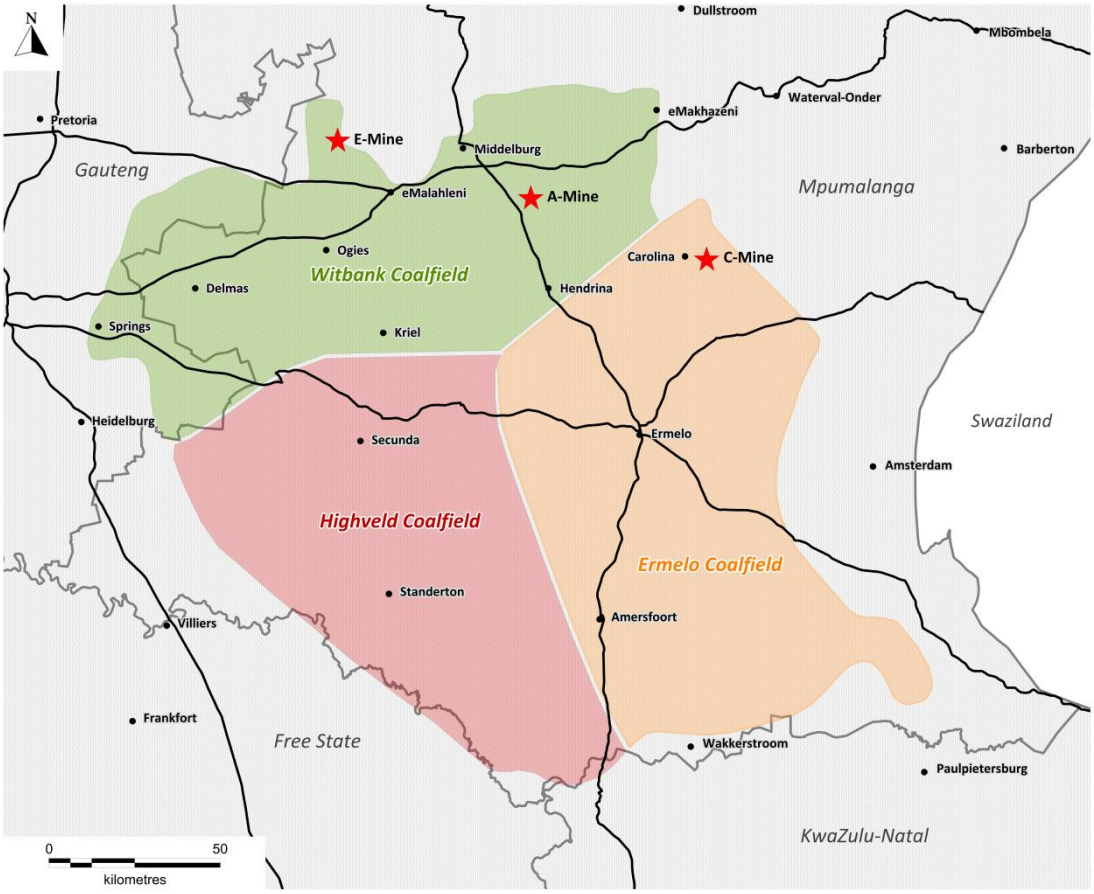


Figure 2: Extent of the Witbank, Highveld and Ermelo Coalfields including the locations of the investigated opencast coal mines in Mpumalanga, South Africa modified after Snyman (1998)

2.2.7 The Highveld Coalfield

The Highveld Coalfield of the Mpumalanga Province stretches from Springs in the west, past Bethal in the east (Glasspool, 2002). A description of the Highveld Coalfield coal seams after Jeffrey (2005) is given below:

- The No. 1 coal seam is generally thin and predominantly discontinuous.
- The No. 2 coal seam is generally 1.5 to 4 m thick and contains irregular shale partings of 0.1 to 1 m thickness. No quality zonation is present in the No. 2 coal seam in this coalfield, as opposed to the Witbank Coalfield.
- The No. 3 coal seam is commonly thin and discontinuous. It also commonly displays a poor quality.
- The No. 4 coal seam is generally split into three seams by sandstone partings. These seams are called the No. 4A, No. 4 Upper and No. 4 Lower Seams. The total combined thickness of the No. 4 Upper and No. 4 Lower coal seams varies between 1 and 12 m. The No. 4 Upper coal seam commonly has a thickness varying between 1 and 4 m. The No. 4 Lower coal seam commonly has a thickness varying between 4 and 12 m. These seams commonly have a sandstone parting with a thickness varying between 2 and 15 m. The No. 4A coal seam occurs above the No. 4 Upper seam in places, but is thin and

discontinuous. The seams are laterally continuous and of the highest economic value in the Highveld Coalfield.

- The No. 5 coal seam is commonly 1 to 2 m thick.
- Faults, dykes and sills commonly intruded the Highveld Coalfield.

2.2.8 The Ermelo (Eastern Transvaal) Coalfield

The Ermelo (Eastern Transvaal) Coalfield stretches from Hendrina in the west, past Ermelo and Carolina in the east of the Mpumalanga Province (Glasspool, 2002, Pinetown et al., 2007). Five coal seams are present in the Ermelo Coalfield, of which the nomenclature does not correspond to that of the Highveld and Witbank Coalfields. The Ermelo Coalfield coal seams are alphabetically numbered from A (top) to E (bottom) and the distribution of these coal seams are affected by the topography of the pre-Karoo basement and the present day erosional surface. A description of these coal seams after Jeffrey (2005) is given below:

- The E seam is the deepest coal seam in the Ermelo Coalfield and is commonly 0 to 3 m thick.
- The D seam is commonly 0.6 m thick.
- The C seam is commonly split into two seams. These seams are called the C Lower seam and the C Upper seam. The C Lower seam is commonly 1.5 m thick with sandstone partings in its upper section. The C Upper seam is commonly well developed and varies between 0.7 and 4 m in thickness. Sandstone, mudstone and siltstone partings commonly split the C Upper seam into two to three partings.
- The B seam is commonly split into two seams. These seams are called the B Lower seam and the B Upper seam. These seams may coalesce in the south of the Ermelo Coalfield and commonly have a combined thickness of 0 to 3 m.
- The A seam, which is generally removed by erosion, is commonly 0 to 1.5 m thick.
- The coal seams of the Ermelo Coalfield generally dip gently to the southwest and are intruded by dykes and sills.

2.2.9 Mineralogy Associated with the Mpumalanga Coal Seams

Based on studies by Zhao et al. (2010) coal in the Ecca Group most likely formed in fluvial conditions with the roof and floor sediments being delta-dominated deposits. This points to formation in a saline environment such as a sea shelf. Primary and secondary minerals in these strata as identified by Zhao et al. (2010), include calcite, dolomite, halite, gypsum, anhydrite, sylvite or sylvine, carnallite, hydrated chlorite and thenardite. They also found that sandstone and carbonaceous shales of the roof materials contain more leachable Na, especially to the southern parts of the Mpumalanga Coalfields. Effects of the above mentioned mineral phases on mine water chemistry is evident in the elevated total dissolved solids, alkalinity, SO_4, Ca and Cl concentrations identified in samples from the mining sites in Zhao et al. (2010) and Pinetown and Boer (2006).

2.3 Surface Coal Mining in South Africa

One of the most popular surface mining methods for coal is opencast or strip mining (Hartman and Mutmansky, 2002). Opencast mining entails the excavation of overburden material and casting of this material into adjacent mined-out panels. Therefore, the operation commonly consists of the

excavation of material and casting into a void by a single machine, which minimises material handling costs, maximises profit and also confines the mining operation to a much more localised space where rehabilitation can commence even during the life of mine. The typical dimensions of the opencast strip are: 30 to 60 m for the height of the highwall, 23 to 45 m for the width of the open cut, 60 to 70° for the slope of the highwall and 35 to 50° for the slope of the spoils. Overburden stripping and mining may be performed by using load and haulage equipment in smaller scale opencast mines, while larger scale opencast mines commonly use draglines for overburden stripping while load and haulage equipment is strictly used for mining of the seam. An additional method for overburden casting is cast blasting which, with proper blasting designs, can cast between 40 and 60% of overburden material into adjacent voids, which may save costs (Hartman and Mutmansky, 2002).

The sequence of opencast mining can be described as follows: initial drilling takes place using the drilling equipment suitable to the type of overburden. After drilling, blasting takes place, commonly using ammonium nitrate emulsions which can be loaded into blasting holes by hand or in bulk by machine. This is followed by excavation of overburden by dragline or any other suitable method, followed by haulage, if required, to the area of deposition (Hartman and Mutmansky, 2002).

Once this process is complete, the cleaning of the deposit commences using a rotary brush or dozer, after which drilling into the deposit takes place (Figure 3). This is followed by blasting or ripping, depending on the deposit. Excavation of the blasted deposit in South Africa then commonly takes place by load and haulage. Opencast mining of coal in South Africa is especially suited to the deposit due to most of the coal deposits being relatively flat, continuous and shallow (Hartman and Mutmansky, 2002).

Figure 3: Opencast mine strip in Mpumalanga

2.4 Rehabilitation of Opencast Coal Mines in South Africa

2.4.1 Introduction

The Minerals and Petroleum Resources Development Act of South Africa requires the holder of the prospecting permit or mining authorization to rehabilitate the surface of land concerned according to the following requirements (Department of Mineral Resources, 2002):

- In accordance with the environmental management plan approved in terms of section 39;
- As an integral part of the prospecting or mining operations;
- Simultaneously with those operations, unless the Director Mineral Development agrees otherwise and
- To the satisfaction of the Director Mineral Development.

Therefore, the common remediation method applied to opencast mines in South Africa is concurrent rehabilitation, which is followed by restoration of soils. However, additional factors also commonly influence rehabilitation practice in South Africa in terms of the regeneration priorities. These factors are summarised below after Limpitlaw et al. (2005):

- Restoration of the land surface should be performed to such a standard that the pre-mining land use can be supported
- Restoration of the ecological function of the mined area should be performed. In the case of a degraded area, the ecological function should be improved after mining
- Alternative use of mining infrastructure should be investigated if this is an economically justifiable option. If this option proves to be uneconomic, the mining infrastructure should be removed and the area should be rehabilitated to pre-mining conditions
- Current and future impacts on water quality and water supply should be kept to a minimum
- Stimulation of economic activity should be maximised in conjunction with education and subsequent job creation
- Development projects must be implemented to enable equitable community participation and upliftment post-mining.
- Skills and literacy training must be implemented to uplift communities.

2.4.2 Rehabilitation Methods

As described, South African law requires concurrent rehabilitation for opencast mines. Yet, as Tanner (2007) pointed out, very little technical information is available in South Africa, in terms of the methods used for rehabilitation to avoid or reduce acid rock drainage formation from overburden materials. However, international authors have published work in this regard.

Skousen et al. (1998) compiled a hand book of various methods that can be employed to reduce the ARD production from overburden materials during and after backfilling of opencast mines. They suggested options such as the addition of bactericides, which are anionic surfactants that can be applied to freshly excavated materials in liquid form to minimise bacteriological activity and subsequent disulfide oxidation. Another method proposed is the addition of alkaline materials to backfill in order to raise pH and potentially prevent disulfide oxidation (Skousen et al., 1998, Wisotzky, 2001). Alkaline material may be added by blending the materials (Figure 4) or as stratified layers within overburden backfill material (Skousen et al., 1998). This is sometimes referred to as blending of the material and can also form precipitates which limit water movement through the material.

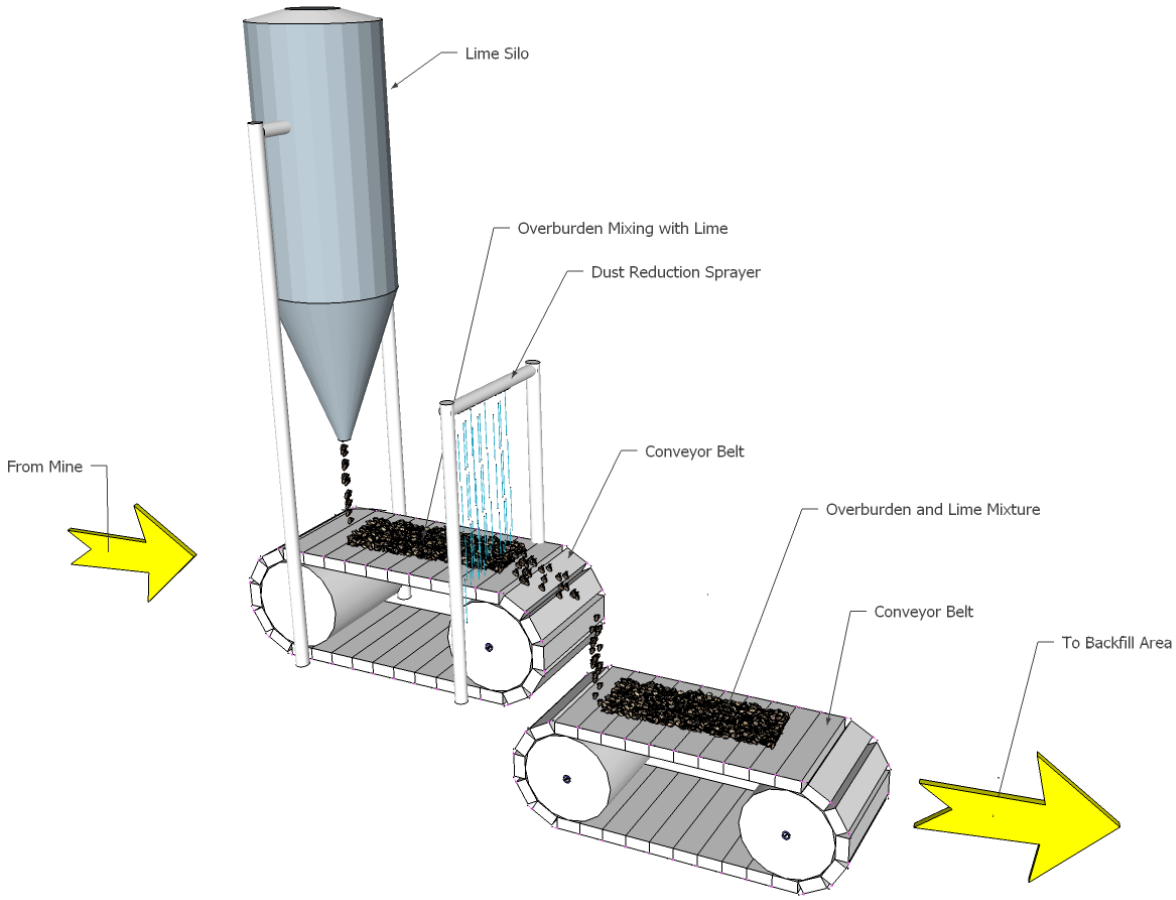


Figure 4: Mixing of Acid Generating Overburden Material with Lime to Minimise Acid Generation Modified After Wisotzky (2003)

In a post-mining scenario, alkaline recharge structures may be constructed within the backfill material to allow for elevated recharge focussed in certain areas of the opencast mine. These structures are filled with alkaline material which will dissolve and enter the groundwater with the increased recharge, subsequently raising pH and reducing disulfide oxidation (Skousen et al., 1998). Calcium and magnesium oxides, as well as coal combustion by-products such as fly-ash, have also been successfully used to mitigate acid rock drainage in opencast mines. These materials are commonly distributed on opencast mine floors and substantially raise the pH of inflowing water, while forming sealing precipitates on the opencast mine floor. This reduces the ingress of oxygen to also prevent further oxidation of disulfides while providing alkalinity to inflowing water. This is performed before backfilling the mined void with overburden material (Skousen et al., 1998). Organic wastes and sewage sludge have been suggested as an additive to acidity producing backfill materials. The bacteriological activity in these materials is likely to generate reducing conditions within the backfill material, while also adding alkalinity, minimising disulfide oxidation and raising the pH (Skousen et al., 1998).

Selective handling of overburden material is another method that can be considered (Betrie et al., 2013), where acid producing materials are disposed of in such a manner that the material is readily inundated after mine flooding. This requires the segregation of acid producing material and non-acid producing material during mining, with acid producing material placed at the base of an opencast mine. This method is dependent on the speed of mining to be effective, where continuous mining and backfilling, with no intermissions of mining activities show the best results for ARD prevention

(Skousen et al., 1998). This method is often prescribed by hydrogeologists working in the opencast coal mining industry but is more likely to be effective when combined with additional measures (Cravotta et al., 1994, Sahoo et al., 2013).

However, the most common method of minimising ARD formation is regrading and revegetation. This method promotes evapotranspiration by plants while reducing recharge and flows through pyritic spoils. Adding limestone to backfill material, along with this approach, may potentially improve mine water quality to the point of compliance with effluent limits (Skousen et al., 1998).

Additionally, Tanner (2007) compiled guidelines based on existing knowledge at the time. He drafted a technical document, outlining methods of accepted soil and overburden stockpiling and rehabilitation, during and after coal mining in South Africa.

As discussed, concurrent backfilling of the opencast mine should take place during mining. Spoil shaping usually takes place after mining, which is explained by Tanner (2007) as the reshaping and placement of the spoils to create the final desired topography. This topography should be free-draining with slopes designed to ensure the minimisation of erosion, where slopes range between gradients of 1:5 to 1:7 for grazing land and 1:10 to 1:14 for arable land. It is imperative that the final topography design is also updated accordingly, as hard materials may expand by as much as 25% while soft materials may compact by as much as 15%, commonly referred to as the bulking factor. This has substantial implications for the original landform design, when the variation in the deposit is encountered and the volume of material to be removed varies accordingly. Therefore, continuous monitoring should take place during mining to ensure that the original landform design is adapted according to the volumes of spoil encountered.

Another important factor of surface mine rehabilitation, as identified by Tanner (2007), is the replacement of the soil profile post-mining. This is performed after the establishment of the final post-mining topography and the soils should be replaced in the same sequence in which they were stripped. The current method for soil replacement in South Africa is by truck and shovel methods, replacing the soil in a single lift. Bowl scrapers can be used to assemble soil profiles in the correct sequence, but this is unfortunately not the current practice in South Africa. The following actions are considered to be best practice for soil rehabilitation in South Africa after Tanner (2007):

- A plan should be drafted prior to mining, according to which the soils must be replaced. The soils must also be stripped and stockpiled according to form, prior to mining
- A reserve of additional soils should be kept to repair areas of localised surface subsidence
- Compaction of soils must be kept to a minimum. This can be achieved by using the appropriate equipment. Additionally, soils should be replaced to the greatest possible thickness in single lifts
- Movement or transport of soils should be performed when the soil is in a dry state. This will aid in the minimisation of soil compaction. Wet soils should be moved strictly by truck and shovel methods
- In the event of restoration of multi-layered soil profiles, compaction of lower soil layers by heavy equipment must be kept to a minimum
- Compaction of soils during smoothing can be minimised by using dozers instead of graders

- Restored soils must be ripped to a sufficient depth for full root establishment of vegetation cover
- In the event that the natural re-vegetation of the area is not feasible, the restored soils must be tilled in order to create a seed-bed for the selected plant species utilised for artificial seeding.

Based on Tanner (2007), ponding of water on surface, increased groundwater make and surface cracking can be deduced in terms of rehabilitated land in South Africa and the associated challenges.

Ponding of Water on Surface

Ponding of water on the surface of a post-mining landscape is commonly dealt with using trenches and cut-off drains in the backfilled spoils and rehabilitated soils. The drains are inspected on a regular basis to ensure that residual subsidence is controlled and maximum efficiency is retained.

Increased Groundwater Make

Increases in groundwater make can be reduced by planting trees and additional vegetation to increase evapotranspiration. Additional to this is the drainage of surface water ponding as mentioned above.

Surface Cracking

Surface cracking is commonly associated with underground mining. This could also potentially be observed during subsidence of spoils in backfilled opencast mines. Cracking can be rehabilitated by infilling of these cracks with soil using an excavator. However, if the severity of cracking is low and deep cracks have not been developed, the surface could also be rehabilitated by deep agricultural ripping.

2.5 Mine Water

Wolkersdorfer (2008) describes mine water as water that enters mining sites and comes into contact with primary and secondary minerals under oxidising conditions. The water can then potentially dissolve certain elements from these minerals, given a suitable set of redox potential and proton activity conditions. In the presence of disulfide minerals such as pyrite, acidity may form in the water due to the oxidation of these minerals. The formed acidity may likely also dissolve other elements from mineral phases, liberating additional contaminants into solution. This type of solution, given a net-acidic character, is often referred to as acid rock drainage, acid mine drainage or acid mine water. Acid mine drainage commonly has a pH lower than, or equal to 6 (Wolkersdorfer, 2008, Nordstrom, 2011). When this water comes into contact with carbonate mineral phases, buffering reactions may occur, neutralising the formed acidity. This is commonly referred to as circumneutral mine water which may have a pH ranging between 6 and 8. Further buffering of the water may create possible alkaline mine drainage which commonly has a pH above 8. Wolkersdorfer (2008) also states that the importance of microbial activity in this system cannot be ignored. Although the first step in disulfide oxidation is inorganic, the subsequent processes are catalysed biologically by the metabolic processes of microorganisms.

2.6 Mine Water Management

2.6.1 Introduction

There are numerous systems available for mine water treatment and management (Table 1). These systems can be divided into two categories (Geller and Schultze, 2013, Wolkersdorfer, 2008, Younger et al., 2002): active systems and passive systems. They are described here to provide a compilation of potential treatment technologies, though the information is not explicitly used further in the thesis.

Table 1: Comparison of Treatment Systems; from International Network for Acid Prevention (INAP) (2009)

Criteria	Active	Passive
Period in mine's life cycle	Exploration and operational phase – a workforce is required on site for implementation, control and maintenance. Application in post-closure phase generally only feasible for large volume flows.	Decommissioning, closure or post-closure phases as processes are largely self-sustaining.
Financial consideration	High capital investment and operational cost.	Medium capital cost and low operation and maintenance costs.
Power supply	Mechanical or electrical energy required.	No external power supplies. Use of natural energy sources (solar energy and gravitational flow)
Supervision	High degree of operating supervision and on-going maintenance.	No operators or constant supervision although regular maintenance is required.
Flow rates	Can handle very high flow rates or water volumes depending on design.	Optimum performance at lower flow rates of 0.1 – 2 ML/d. Unlikely to be considered for flow rates > 5 ML/d.
Input material	Generally requires ongoing addition of chemicals, power supply and equipment maintenance.	Natural, prolonged and self-sustaining treatment materials, although certain process technologies will require ongoing addition of chemicals in passive mode.
Treatment range	Can treat any constituent of concern.	Not applicable to all constituents of concern (e.g. Total Dissolved Solids, Electrical Conductivity, Na, Cl). Mainly applicable for acidity, metals and sulfate removal.
Product	Produces very high quality water. Process is more reliable in terms of its output due to control. Product is certain.	Produces water of lower quality than active systems and of variable quality dependant on input water quality.

2.6.2 Active treatment technologies

Active treatment technologies treat contaminated water through physical and chemical processes which may require system operators, make use of generated energy resources, are commonly of high cost to construct and maintain and treat volumes of over 5 ML/d (International Network for Acid Prevention (INAP), 2009). The active treatment technologies discussed below were identified in International Network for Acid Prevention (INAP) (2009) and Younger et al. (2002).

Aeration units

The principal metal of concern in mine water is commonly ferrous iron (Fe^{2+}). Therefore, aeration is usually required to increase the oxidation of iron and manganese. This increases chemical treatment efficiency and lowers costs. Additionally, aeration of mine water releases dissolved carbon dioxide, which may increase the pH of the water and can reduce reagent usage (Younger et al., 2002). Aeration methods employed may include: cascade aeration, trickle filter aeration, in-line venturi aeration, mechanical aeration, biochemical oxidation and chemical oxidation (Younger et al., 2002).

Neutralisation/Hydrolysis

A variety of neutralisation materials are used for mine water treatment (Table 2) and are added to mine water as powders, slurries and liquids.

Table 2: Alkali Materials and Compounds applied to ARD Treatment (from International Network for Acid Prevention (INAP), 2009)

Alkali Compound/Material	Alkali Requirements (t/t of Acidity)	Neutralisation Efficiency (% of Applied Alkali Used)	Relative Cost ($/t)
Limestone, $CaCO_3$	1.00	30 – 50	10 – 15
Hydrated Lime, $Ca(OH)_2$	0.74	90	60 – 100
Unhydrated (Quick) Lime, CaO	0.56	90	80 – 240
Soda Ash, Na_2CO_3	1.06	60 – 80	200 – 350
Caustic Soda, NaOH	0.80	100	650 – 900
Magna lime, MgO	0.4	90	Project Specific
Fly Ash	Material Specific	–	Project Specific
Kiln Dust	Material Specific	–	Project Specific
Slag	Material Specific	–	Project Specific

Metal removal

The most widely used approach to metal removal from mine water is metal precipitation by chemical treatment. This forms metal precipitates which can then be separated from the mine water. Commonly observed insoluble metal precipitates formed with anions in solution include hydroxides, carbonates and sulfides. The process of metal precipitation commonly requires the addition of an alkali to reach a specific pH to selectively remove a metal of concern. Once the required alkali or chemical has been added to the mine water, it is commonly directed to sedimentation ponds to promote precipitation and settlement.

Chemical precipitation for sulfate removal

Desalinisation of mine water is commonly focused on the removal of sulfate, sodium and chloride. This is due to the predominance of those anions in mine water relative to other anionic species.

Commonly, limited sulfate precipitation takes place as gypsum during the addition of alkali materials such as lime, providing the required Ca. However, more effective processes such as the barium sulfate process or ettringite precipitation process, also referred to as the SAVMIN process (Younger et al., 2002), have been developed for the sulfate removal application. Barium sulfide treatment is based on the addition of a barium salt (Bosman et al., 1990). This is added to mine water to re-precipitate sulfate from solution. The resulting precipitated sludge is then removed from the main process stream and barium is recovered from the sludge and reused in the process. Younger et al. (2002) describes the SAVMIN or ettringite precipitation process in a similar way. The process is based on the addition of Ca, in order to super-saturate the mine water with regards to gypsum. Precipitated gypsum can then be used as a sellable by-product while also removing metals such as Fe, Mn and Zn. After the maximum volume of gypsum is removed, $Al(OH)_3$ is added under pH conditions between 11.6 and 12 to precipitate ettringite. This mineral is at equilibrium under very low sulfate concentration conditions in water, resulting in water that is potable. The ettringite sludge is then removed and decomposed using sulfuric acid, generating a fluid which is super-saturated with respect to gypsum and contains the released Al. Al is then reused in the ettringite precipitation process while the fluid that has been super-saturated with respect to gypsum, is added to the initial gypsum precipitation stream.

Membrane Treatment

Cartwright (2013) describes membrane treatment as the removal of solutes from water by forcing the water at high pressures through a membrane material. Crossflow is often employed in this process. These processes can be classified according to different pore sizes in filtration membrane materials used. Younger et al. (2002) classifies membrane treatments as follows:

- Microfiltration: bacteria are often removed from water with this process. Membranes used have pore sizes ranging between 0.1 and 0.45 µm.
- Ultrafiltration: colloids are removed from water using this process. Membranes used have pore sizes ranging between 0.01 and 0.1 µm.
- Nanofiltration: colour is removed from water using this process. Membranes used have pore sizes ranging between 0.001 and 0.01 µm.
- Reverse osmosis: solutes are removed from water using this process. Membranes used have pore sizes smaller than 0.001 µm.

The application of a reverse osmosis membrane treatment system to mine water is likely to be challenging due the scaling potential of mine water, which commonly contains metals, carbonate and sulfate. Additional to this are the high costs to maintain the pressures in the system at which water is forced through the membranes. The membrane treatment process, as applied to mine water, commonly leads to the formation of sludge and brine, requiring treatment and disposal. However, under specific circumstances, reverse osmosis can be an attractive technology for water treatment. It is possible that membrane treatment can produce sellable volumes of precipitated salts from which costs can be recovered when high volumes of highly polluted water are treated (Younger et al., 2002).

Commonly, the membrane treatment process advances according to the following steps:

- The mine water is treated with an alkali compound or material such as lime to precipitate metals and gypsum, which limits the scaling potential of the water.
- The mine water is then pre-treated to remove the residual suspended solids.
- After the removal of residual suspended solids, the pH of the mine water is adjusted and an anti-scaling agent is added.
- The membrane treatment of the water now takes place, commonly using spiral wound reverse osmosis membranes or nano-filtration.
- After the water is treated, a simple post-treatment of pH stabilisation is applied.

Biological sulfate removal

Biological sulfate removal is commonly performed in the following sequence (International Network for Acid Prevention (INAP), 2009):

- The mine water is pre-treated to remove metals by precipitation,
- An electron donor is then added to the water, commonly in the form of sugars, alcohols, hydrogen gas or even sewage sludge,
- Nutrients for the microbial sulfate reducers are then added to the mine water in forms of nitrogen, phosphate, potassium and trace minerals,
- Following all these steps, the mine water is then introduced into a biological reactor where sulfate is reduced to sulfide. This process is performed by sulfur reducing bacteria.

Sulfide precipitation

Sulfide precipitation is a process that converts soluble metals in solution into relatively insoluble metal sulfide precipitates. This is achieved by the addition of precipitating agents which include sodium sulfide, sodium hydrosulfide, ferrous sulfide and calcium sulfide. This process is effective over a wide pH range due to the high reactivity of sulfide with metals in solution. A resulting metal sulfide sludge must be removed from the treated water by flocculation, filtration or coagulation (Rao et al., 1993).

2.6.3 Passive treatment technologies

As noted by Younger et al. (2002), William Pulles defines passive treatment as follows: *"Passive treatment is the deliberate improvement of water quality using only naturally-available energy sources, in systems which require only infrequent maintenance in order to operate effectively over the entire system design life"*. Various passive mine water treatment technologies are available and are listed and described below (International Network for Acid Prevention (INAP), 2009, Younger et al., 2002, Watzlaf et al., 2004, Brown et al., 2002).

Aerobic wetlands

Aerobic iron removal commonly occurs in three steps: ferrous iron oxidation is followed by ferric iron hydrolysis where-after ferric oxyhydroxide solids are precipitated through sedimentation (Younger et al., 2002). Systems where this process can be achieved are aerobic wetlands. These systems are commonly constructed to remove selected metals and suspended solids from solution. The features associated with aerobic wetlands are:

- Shallow water to allow aeration of mine drainage
- Cascade structures to aerate mine water
- Wetland vegetation which promotes aeration of substrates and promotes favourable flow conditions
- Increased residence times to enhance treatment reactions
- Promotes settling and accumulation of metal precipitates
- Promotes the growth of algae and the subsequent increase in pH and manganese oxidation
- Hydraulic controls managing the water levels in the individual wetland cells.

Anaerobic wetlands

Anaerobic wetland systems rely on reduction reactions to precipitate metals from solution and neutralise acidic conditions. This is achieved by the incorporation of reactants and microbes upon construction. Mine water is infiltrated through permeable organic material with a high biological oxygen demand due to microbial activity, causing anaerobic conditions. This reduces contaminants such as sulfate to a lower redox state such as hydrogen sulfide gas, while generating alkalinity. Several other mediating mechanisms also act in this system including metal exchange reactions, metal sulfide precipitation, microbially generated alkalinity and continuous carbonate alkalinity generation due to limestone dissolution. Commonly, the formation of iron sulfide and iron carbonate species can be observed in such systems (Younger et al., 2002).

Anoxic limestone drains

Anoxic limestone drains (ALD) are buried drains into which anaerobic mine water is introduced for treatment. The ALD is buried to minimize the ingress of oxygen into the drain and to attempt to accumulate the maximum carbon dioxide concentration in the system. ALDs are constructed to add alkalinity and raise pH of mine water while minimizing armouring of limestone by iron hydroxides. This is achieved by the reducing conditions in the ALD, preventing iron hydroxide precipitation. Commonly, a pond is constructed downstream of the ALD to capture the discharge from the system. Upon exposure to the atmosphere, iron hydroxides precipitate from the treated mine water and can accumulate in the constructed pond. Typically, the pond is succeeded by constructed polishing wetlands downstream from the system to further enhance mine water treatment.

Reducing and alkalinity producing systems (RAPS)

In the event that mine water contains dissolved oxygen or ferric iron and aluminium, the use of a reducing and alkalinity producing system (RAPS) is preferred (Younger et al., 2002). These systems work on the principal of iron reduction in a relatively thin layer of organic material, to strip dissolved oxygen from the water and reducing ferric iron to ferrous iron. This step is followed by the addition of alkalinity and raising the pH of mine water. RAPS systems allow for the treatment of a wider range of mine water compositions in this way (Younger et al., 2002). Additionally, RAPS systems constrain the contact of all the treated water to the organic material and limestone drain, utilising a smaller area for treatment relative to compost wetlands (Younger et al., 2002). The system may also precipitate some metals as sulfides due to sulfate reduction, as well as possible hydroxides. A negative aspect to RAPS systems is that they require a driving head. However, clogging of the system is not frequently reported as metal hydroxides are suggested to be precipitated within the organic material layer (Watzlaf et al., 2002, Watzlaf et al., 2004).

Open limestone drains

Open limestone drain (OLD) systems are designed to introduce alkalinity into discharged mine water. OLDs are typically long channels of limestone used to discharge treated mine water to streams and other discharge points, after raising the pH and precipitating metals (Watzlaf et al., 2004).

Passive sulfate removal

Systems utilising passive sulfate removal technology (International Network for Acid Prevention (INAP), 2009) commonly work on the same principals as anaerobic wetland treatment systems. However, additional features to these systems include:

- Selected organic materials are incorporated into the system to hydrolyse ligno-cellulose materials to sustainably produce volatile fatty acids. These acids drive the sulfate reduction process.

- Following the sulfate reduction process, the mine water is passed through sulfide oxidizing reactors to partially oxidise hydrogen sulfide to sulfur.

Manganese oxidation beds

Manganese oxidation beds (MOB) can be used as the final step in mine water treatment in a successful passive treatment system treating circumneutral mine waters. These beds are typically filled with limestone which is not completely inundated by water to allow oxygen ingress and microbial oxidation of manganese. MOBs function as a polishing step in passive treatment systems as they are only effective if no ferrous iron is added to the system. Ferrous iron causes manganese to reduce and dissolve back into solution (Younger et al., 2002).

Vertical Flow Reactors

A vertical flow reactor (VFR) is similar in concept to an aeration cascade and settling lagoon combination, with the exception that vertical flow is induced in a much smaller surface area (Sapsford et al., 2006). To illustrate the design of these systems, an example is discussed from Sapsford et al. (2006). This study examined the efficiency of a vertical flow reactor at the pilot scale.

A galvanised steel tank was constructed, which was approximately 7 m long, 4 m wide and 2.5 m deep. The tank was sealed with bituminous paint and contained a gravel floor, which was supported by steel mesh and concrete support pillars. Therefore, a void space was present between the tank floor and the gravel bed. The mine water that fills the steel tank is then allowed to rise on the outside of a baffle wall and discharges through a weir which removes the treated mine water from the system. Fe^{2+} in the mine water is therefore oxidised upon discharge into the VFR. There ochre precipitation is promoted and subsequent Fe^{2+} oxidation and surface complexation takes place, resulting in further ochre and, eventually, goethite precipitation.

Dispersed Alkaline Substrates

Dispersed alkaline substrate (DAS) treatment systems are based on flow through a reactor filled with a non-reacting material, typically of a coarse grading, mixed with a reacting alkaline material (Caraballo et al., 2009, Rötting et al., 2008a, Rötting et al., 2008b). Studies such as Rötting et al. (2008a) and Rötting et al. (2008b) used reactor vessels filled with coarse wood chips as a non-reacting material, mixed with calcitic sand as the alkaline reacting material. These studies indicate metal removal can reach up to 100% if the reactor vessel is left open to the atmosphere and additional aeration and subsequent oxidation of metals take place. This is attributed to the accelerated dissolution of the alkaline substrate, before armouring of the material can take place. Additionally, the non-reactive material ensures that clogging of the reactor is kept to a minimum. Therefore, flow rates can be maintained in the long term with highly effective results.

2.7 Common Backfill Mineralogy – Vryheid Formation

Overburden and discard material is commonly used as backfill for opencast coal mines in South Africa (MacDonald, 2014). Therefore, understanding the mineralogy of this material is crucial in determining the possible effects on groundwater that may arise after mining. Based on studies by Bell et al. (2001), Deysel et al. (2014) as well as MacDonald (2014), the overburden material associated with coal mining in South Africa commonly has a mineralogy containing the following mineral phases: quartz, kaolinite, calcite, muscovite, possible siderite, possible rutile, pyrite, marcasite, hematite, possible apatite, pyrrhotite, feldspar and possibly jarosite. These minerals are commonly associated with the sandstones and shales, comprising the overburden material associated with coal mining in South Africa.

2.8 Quantification of Mineral Reactive Surface Areas

The general method for quantification of the specific surface area of a porous material is the Brunauer Emmett Teller (BET) method (Brantley, 1998, Gautier et al., 2001, White and Brantley, 2003, Brunauer et al., 1938). This method is based on Langmuir adsorption of gas molecules onto solid surfaces and is used to calculate the specific surface area of a porous material. However, although this method provides the total surface area within the material, it also provides an estimate of the reactive surface area of the material.

Gautier et al. (2001) found that the BET surface area of minerals increased by up to 5.6 times the original measured value during dissolution. However, within experimental uncertainty, reaction rates remained the same. This was explained by the deepening of etch pits in the mineral grain which may have unreactive faces, with no changes in etch pit density observed in the short term. Gautier et al. (2001) therefore proposed calculation of geometric surface areas based on grain size

distribution, to provide a more accurate estimation of dissolution rates, factoring reactive surface area into calculations.

Similar findings were made by Brantley (1998) who compared porosity and the degree of weathering to surface area and BET surface area of porous materials. The study also states that the calculation of the specific surface area based on grain size distribution is preferred to BET surface area due to potential unreactive etch pits and precipitates.

For the purpose of this study, BET surface areas are therefore not considered to be completely representative of the reactive surface area of the material. This is due to the reactivity of etch pits and precipitates which may alter the results of the BET method. Therefore, a roughness factor, as suggested by White and Brantley (2003) may provide a solution to a best estimate of initial reactive surface area based largely upon specific surface area calculated from grain size distribution. This may account for the dynamic reactive surface area forming on mineral surfaces during the weathering process. Current best estimation of reactive surface area is regarded as the calculation of specific surface area based on grain size distribution for fresh material such as overburden excavated from opencast mines.

2.9 Hydraulic Properties of the Karoo Supergroup

2.9.1 Introduction

According to Botha et al. (1998), the hydraulic properties of Karoo aquifers are variable and complex, with their flow controlled by fractures on a local scale and dolerite dykes and hydrochemical action on a regional scale. Botha et al. (1998) further states that the storage mechanism in Karoo aquifers is the matrix of Karoo lithologies, due to the poor water storage properties of fractures in these rocks, which are more suited to flow conditions. Therefore, this section focuses predominantly on the typical hydraulic properties of fracture zones and rock matrices of the Karoo lithologies and the effect on groundwater movement and storage.

2.9.2 Hydraulic Properties of Fractures

The flow in a saturated fractured medium is largely controlled by the fracture dimension, orientation and aperture (Botha et al., 1998). The bedding plane fractures in Karoo aquifers are commonly horizontal and sparsely distributed, with large-scale vertical fractures not commonly observed. Therefore, the volume of water being transmitted through Karoo aquifers will be controlled by the aperture of bedding plane fractures, as well as the piezometric head gradient within the fracture (Botha et al., 1998). The data in Table 3, which lists common hydraulic properties of Karoo lithologies, illustrates the higher hydraulic conductivity of a fracture, relative to that of matrix blocks. Similar results were reported by Kruseman and de Ridder (1994) for fractured rock aquifers, with fractured sedimentary rock hydraulic conductivities commonly in the order of 10^{-7} to 10^{-5} $m \cdot s^{-1}$.

Table 3: Typical Hydraulic Properties of Karoo Aquifers (Botha et al., 1998), K_h = Horizontal hydraulic conductivity

Layer	Depth, m	K_h, m · s^{-1}
Upper mudstone layers	8	9.910×10^{-7}
	10	6.538×10^{-6}
	12	3.601×10^{-6}
Carbonaceous shale layer	14	8.796×10^{-7}
	16	1.350×10^{-6}
Sandstone matrix of the main sandstone aquifer	18	4.055×10^{-5}
	20	1.345×10^{-4}
Average depth of Mode 1 fracture	22	2.754×10^{-4}
Sandstone matrix of the main sandstone aquifer	24	7.878×10^{-5}
	26	2.205×10^{-6}
Mudstone layers	28	2.309×10^{-7}
	30	7.970×10^{-8}
	32	4.440×10^{-8}
	34	1.234×10^{-7}
	36	1.564×10^{-7}
	37	2.497×10^{-8}
	38	1.740×10^{-8}
	40	4.652×10^{-8}
	42	1.745×10^{-8}

2.9.3 Hydraulic Properties of Matrix Blocks

Matrix blocks in fractured rock aquifers act as storage from which groundwater is released to bedding parallel fractures upon dewatering (Kruseman and de Ridder, 1994). The lithologies of the Karoo Supergroup commonly consist of mudstones, shales and sandstones, which have an initial high primary porosity. However, this porosity was reduced substantially during cementation and compaction over time, reducing the porosity to small pores and microfractures (Botha et al., 1998). Therefore, these rocks provide limited storage, although present, but considering a large enough aerial extent, could release and store notable volumes of water (Botha et al., 1998). The sedimentary rocks of the Ecca Group commonly have porosities ranging between 2% and 10%, which could potentially store and release groundwater depending on the connectivity of microfractures and pores (Botha et al., 1998).

2.10 Influences on the Initial Flush of Rehabilitated Opencast Collieries

2.10.1 Introduction

Wolkersdorfer (2008) noted that the initial flush was first named by Younger (1997). The initial flush phenomenon can be explained as the steep increase of contaminant concentrations in mine water, after flooding and possible discharge of a mine, followed by the gradual decrease in concentrations until a relatively stable concentration is reached (Wolkersdorfer, 2008, Banks et al., 1997).

The initial flush phenomenon in mine water (Glover, 1983, Whitehead and Jeffrey, 1995) has been quantified by different authors (Appelo and Postma, 2005, Banks, 1994, Gzyl and Banks, 2007, Younger, 2001, Younger and Sapsford, 2004b, Younger and Robins, 2002) using a variety of methods. The focus of these studies has been on deep underground mines. However, certain principles of

these studies are also applicable to rehabilitated opencast mines. Factors influencing initial flush quantification are discussed below as well as the additional factors to be accounted for in rehabilitated opencast scenarios.

2.10.2 Rehabilitation Status and Flooding Time

The flooding time of rehabilitated opencast mines depends strongly on the volume of the mine, the volume of annual precipitation, the mine's rehabilitation status and evapotranspiration. Common practice in South Africa, as mentioned in section 2.4.2, is concurrent rehabilitation during opencast mining. This works on the principal of mining a single boxcut at a time and using the following boxcut's material to backfill the initial void. These steps proceed until the final void is reached and backfilled or, in some instances, left open to form a terminal sink.

The effect of the backfill material and rehabilitation method on flooding cannot be overstated, as these are major determining factors of the amount of water that enters and exits the pit over time as concurrent rehabilitation is preferred (Table 4). Flooding is likely to be accelerated, relative to a pit lake approach. This is due to the decreased porosity to be filled by inflowing water, relative to the void, which existed prior to backfilling.

Table 4: Factors Influencing the Flooding Rate of an Opencast Mine (Bredenkamp et al., 1995, Van Zyl, 2011)

Factor Influencing Flooding Rate	Description
Thickness of unsaturated zone	Recharge will be higher in areas where the strata outcrops and precipitation can move freely into fractures
Composition of unsaturated zone	Determines rate at which precipitation moves through the unsaturated zone
Rainfall events	Heavy rainfall contributes more to surface runoff than to aquifer recharge
Topography	Steep topographies contribute more to surface runoff, while gentle slopes favour aquifer recharge
Land surface cover	A surface densely covered by vegetation will favour evapotranspiration, while poorly covered land surfaces will favour aquifer recharge (assuming a flat topography)
Evapotranspiration	Areas with high evapotranspiration rates will receive less recharge because of a loss of water due to evaporation and transpiration
Annual rainfall	Areas that receive high annual rainfall will receive high recharge (if above mentioned factors are favourable)
Permeability of the Rock Mass	Permeability controls inflows from pit walls along with hydraulic gradients and play a significant role in controlling lateral inflows to the pit
Fragmentation and Orientation of Structural Discontinuities	Faults, joints and fissures depending on their aperture and orientation often act as the largest contributors of lateral inflows from pit walls

In the Mpumalanga Coalfields, potential evaporation volumes commonly supersede rainfall volumes (Annandale et al., 2001). Therefore, reducing evaporation by backfilling of opencast pits ensures flooding, which is also controlled by the hydraulic conductivity of the surrounding aquifer as well as the volume of recharge entering the pit. As stated by Gzyl and Banks (2007), the flooding time of a mine is one of the factors that controls the duration of its initial flush. This could potentially be applied to rehabilitated opencast pits, as a volume to be flooded is also present. However, in the case of an opencast mine, the opposite of an underground mine's initial flush is anticipated in terms

of time scale of the initial flush. This is due to a much larger reactive surface area in the backfill material and a decreased flow rate to dissolve vestigial minerals. Therefore, contaminant concentrations are expected to remain elevated for a protracted period, resulting in an extended flush peak.

2.10.3 Pit Type

When an opencast mine is remediated, different methods are employed. In a South African context, concurrent rehabilitation by backfill is the norm. However, in some cases, a pit lake is created, depending on the mine's location in the topography, which is referred to as a final void in South Africa.

Based on studies by Webster et al. (2006), two types of pit lakes exist: drainage lakes and seepage lakes. Seepage lakes can be further subdivided into recharge lakes, flow-through lakes and discharge lakes. This can similarly be applied to opencast mines (Figure 5).

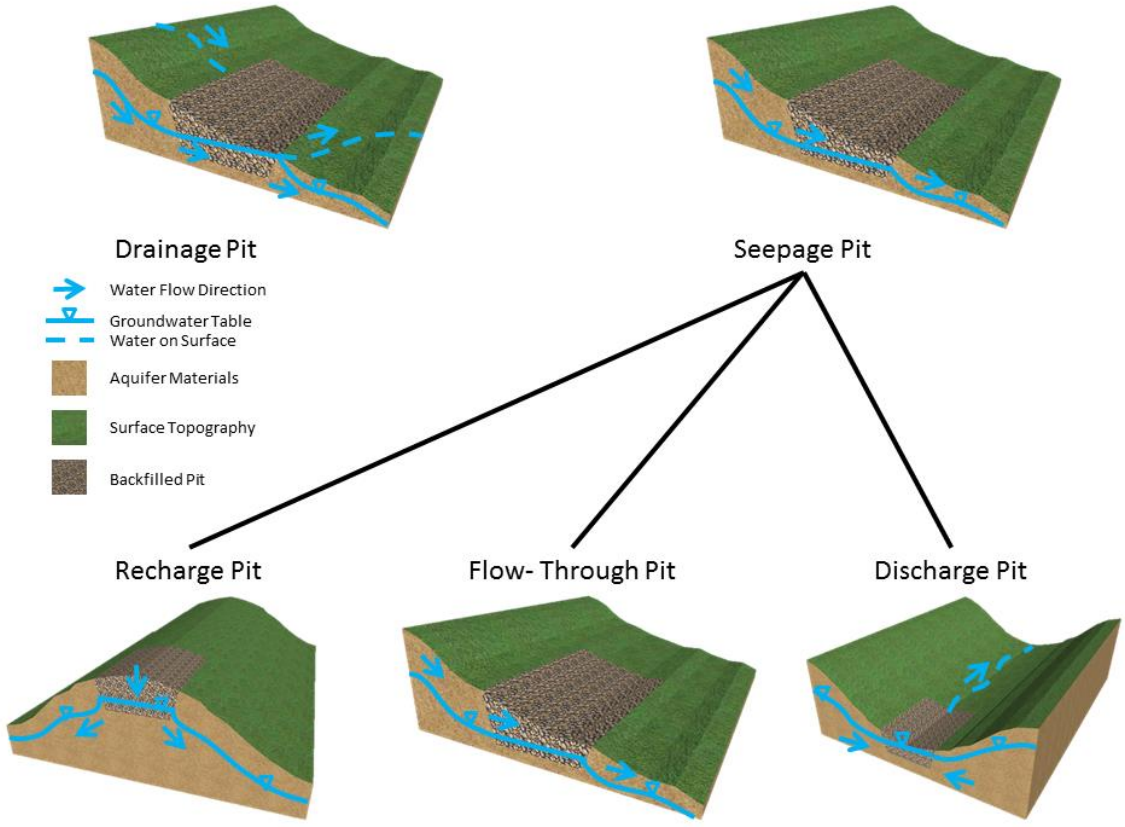


Figure 5: Potential rehabilitated Pit Types based on the model of Webster et al. (2006). Each of these types of opencast mines can also occur in relatively flat landscape.

The type of pit lake is determined by the position of the opencast mine in the landscape and how the groundwater behaves in the pit. This also determines the method of contaminant release (Geller and Schultze, 2013). However, the same principles can be applied to completely backfilled rehabilitated opencast mines for the following reasons:

- Elevated recharge volumes (Hodgson and Krantz, 1998) causing seepage and potential discharge: potential pit types, based on the model of Webster et al. (2006), could be a recharge pit, flow through pit, discharge pit and drainage pit.
- Seepage from the surrounding aquifer, filling and flushing backfill void space as well as discharge seepage from the rehabilitated pit to the aquifer: potential pit types, based on the model of Webster et al. (2006) could be a flow through pit or discharge pit if discharge and high levels of evaporation take place on surface.

The type of pit plays a substantial role in the release of contamination to the aquifer as contaminants can travel (or stagnate) through different pathways. Increased recharge and seepage dissolves vestigial minerals, dilutes and mobilises potential contaminants and generates a hydraulic head potential, inducing flow. Seepage and discharge from the pit releases the contaminants to the aquifer and, eventually, surface water. These processes could potentially occur in flow-through pits, drainage pits and recharge pits. However, contamination could stagnate and concentrate due to seepage into the pit and evaporative losses upon low volume discharge in discharge pits. A pit that was mined in a valley bottom (Figure 5) illustrates that groundwater flow is towards the pit where groundwater and contamination may stagnate until groundwater discharge takes place. This exposes water to evaporation and subsequent precipitation of secondary minerals may occur in a discharge pit scenario.

Increased seepage and recharge as well as discharge could result in lower levels of contamination released to the aquifer. Additionally, concentration and precipitation of contaminants and secondary minerals could result in stagnation and decreased release of contaminants to the aquifer, respectively.

2.10.4 Groundwater Flow Rates

Flow rate and residence time of groundwater in a rehabilitated pit controls the dissolution of minerals as well as the rate of release of contamination from the pit (Appelo and Postma, 2005). Flow, in turn, is controlled by the hydraulic gradient in and around the pit, recharge volumes, the porosity and hydraulic conductivity of the backfill material as well as the hydraulic conductivity of the surrounding aquifer systems (du Plessis, 2010).

Hydraulic gradients in rehabilitated opencast mines are commonly very small, if not zero. This is due to the higher porosity backfill material decreasing the hydraulic head potential, due to a lower pore fluid pressure, as determined by the Bernoulli theorem (Craig, 2004). Therefore, flow in the backfill material is principally driven by the head potential difference in the surrounding aquifer system. Additionally, head potential may be caused by increased recharge volumes which, in some cases, may be the only water flushing through the mine. Common recharge values in an opencast mining environment are summarised in Table 5 (Hodgson and Krantz, 1998). These values are illustrative of the volume of water added to the system, purely by recharge. This increased water volume causes an increase in groundwater level, which in turn, contributes to the head potential differences driving flow.

The hydraulic conductivity of the backfill material is highly heterogeneous, but in general, exceeds the hydraulic conductivity of secondary porosity aquifer systems (du Plessis, 2010). It can range between 1 $m \cdot d^{-1}$ and 100 $m \cdot d^{-1}$ which is typically 3 to 4 orders of magnitude higher than that of the surrounding bedrock (Younger and Sapsford, 2004b). A study at a rehabilitated colliery near Kriel,

Mpumalanga, suggested hydraulic conductivities ranging between 50 and 360 $m \cdot d^{-1}$ (Hodgson, 1984). Additionally, the higher porosity of the material suggests that storage coefficients in the material are likely to exceed 0.01 and could reach values of up to 0.25 (Younger and Sapsford, 2004b).

Another factor influencing the flow rate, which is comparable to the porosity and hydraulic conductivity, is the grain size distribution in the backfill material. Due to the heterogeneous nature of backfill material, preferential flow zones can occur causing increased and decreased flow in the backfill material, affecting residence times (du Plessis, 2010).

Table 5: Potential Recharge Percentages in Mining Operations from Hodgson and Krantz (1998)

Sources which contribute water	Water sources into opencast pits	Suggested average Values
Rain onto ramps and voids	20 – 100% of rainfall	70% of rainfall
Rain onto unrehabilitated spoils (runoff and seepage)	30 – 80% of rainfall	60% of rainfall
Rain onto levelled spoils (run-off)	3 – 7% of rainfall	5% of rainfall
Rain onto levelled spoils (seepage)	15 – 30% of rainfall	20% of rainfall
Rain onto rehabilitated spoils (run-off)	5 – 15% of rainfall	10% of rainfall
Rain onto rehabilitated spoils (seepage)	5 – 10% of rainfall	8% of rainfall
Surface run-off from pit surroundings into pits	5 – 15% of total pit water	6% of total pit water
Groundwater seepage	2 – 15% of total pit water	10% of total pit water

2.10.5 The Master Variables – pH and Redox

As stated by Younger and Sapsford (2004b) “In essence, all of the environmental problems associated with opencast coal mining (including the disposal of the lithic wastes to which it gives rise) can be attributed to a single cause: the incompatibility between naturally ‘reduced’ coal-bearing strata and the strongly oxidising surface / near-surface atmosphere”. This statement reflects the increase of the contamination potential from geological material prior to removal, to after backfilling of an opencast mine, with the main drivers being oxygen and water with a specific pH range and hydrochemistry.

Therefore, the “master variables” controlling contaminant release, as identified by Stumm and Morgan (1996), are:

- pH (proton activity), which will be determined by the balance between amounts and rates of proton generating reactions and proton consuming (alkalinity generating) reactions

- Eh (electron activity), determined by access to oxidizing species (e.g. oxygen) and access to reducing species (e.g. organic C)

An example of a proton generating reaction is pyrite oxidation and subsequent metal hydrolysis, denoted by the following equations (Stumm and Morgan, 1996).

$$2FeS_2 + 2H_2O + 7O_2 \leftrightarrow 2Fe^{2+} + 4SO_4^{2-} + 4H^+ \quad (1a)$$

$$FeS_2 + 14Fe^{3+} + 8H_2O \leftrightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \quad (1b)$$

$$Fe^{3+} + 3H_2O \leftrightarrow 3H^+ + Fe(OH)_3 \quad (1c)$$

Examples of proton consuming buffering reactions include the following (Stumm and Morgan, 1996):

$$CaCO_3 + H^+ \leftrightarrow Ca^{2+} + HCO_3^- \quad (2)$$

$$HCO_3^- + H^+ \leftrightarrow H_2CO_3 \leftrightarrow H_2O + CO_2 \quad (3)$$

$$2NaAlSi_3O_8 + 2H^+ + H_2O \leftrightarrow 2Na^+ + Al_2Si_2O_5(OH)_4 + 4SiO_2(aq) \quad (4)$$

$$Al_2Si_2O_5(OH)_4 + 6H^+ \leftrightarrow 2Al^{3+} + 2SiO_2 + 5H_2O \quad (5)$$

In a rehabilitated opencast mine, the redox potential is firstly influenced by the rate of diffusion of oxygen through the saturated backfill material, which is orders of magnitude lower than that in air (Cussler, 1997). Appelo and Postma (2005) noted that the diffusion of a gas through unconsolidated material into the saturated zone depends on the porosity of the material as well as the saturated fraction of the porosity. Therefore, this diffusion rate can be linked to the degree of saturation of the backfill material. This, in turn, is determined by the degree of flooding taking place in a backfilled opencast mine, commonly determined by the pit type as discussed in section 2.10.3.

The diffusion of a gas through unconsolidated geological material into the saturated zone depends on the porosity of the material as well as the saturated fraction of the porosity. This can be illustrated using one of the Millington-Quirk relations (Appelo and Postma, 2005):

$$D_{e,a} = D_a \varepsilon_g^2 / \varepsilon^{0.67} \quad (6)$$

Where D_o is the diffusion coefficient in air ($D_a = 10^{-5}\ m^2 \cdot s^{-1}$), ε_g and ε are the fractions of gas filled and total porosity respectively (Appelo and Postma, 2005). In the case of a higher degree of saturation, the gas filled porosity decreases (ε_g) yielding a lower diffusion coefficient. Therefore, the assumption can be made that a recharge pit will provide a higher contaminant load than a flow-through pit, which in turn, will provide a higher contaminant load than a drainage- or discharge pit, if di-sulfides are present in the material and oxygen is the main oxidant.

2.10.6 Pre- and Post-Backfill Contaminant Release Potential

The potential mineralogical composition of coal-associated strata is described in section 2.7. However, secondary minerals (Table 6) form due to mineral weathering during exposure to the atmosphere (section 2.10.5). These secondary minerals are the main contaminant release drivers in rehabilitated opencast mines (Younger and Sapsford, 2004b).

Table 6: Mineralogical Composition of Secondary Minerals with Contaminant Release Potential after Mine Backfilling; modified after Langmuir (1997) and Younger et al. (2002)

Mineral or Solid Phase	Formula
Allophane	$[Al(OH)_3]_{1-x}[SiO_2]_x$
Aluminocopiapite	$Fe(II)Fe(III)2Al_2(SO_4)_6(OH)_2{\cdot}20H_2O$
Amorphous $Al(OH)_3$	$Al(OH)_3(am)$
Alunite	$KAl_3(SO_4)_2(OH)_6$ (am) $KAl_3(SO_4)_2(OH)_6$ (c)
Alunogen	$Al_2(SO_4)_3{\cdot}17H_2O$
Anglesite	$PbSO_4$
Anhydrite	$CaSO_4$
Aphthitalite	$NaK_3(SO_4)_2$
Barite	$BaSO_4$
Basaluminite	$Al_4SO_4(OH)_{10}{\cdot}5H_2O$ (am) $Al_4SO_4(OH)_{10}{\cdot}5H_2O$ (c)
Celestite	$SrSO_4$
Copiapite	$Fe(II)Fe(III)_4(SO_4)_6(OH)_2{\cdot}20H_2O$
Coquimbite	$Fe_2(SO_4)_3{\cdot}9H_2O$
"ferrosic hydroxide" ("Interlayered Green Rust")	$Fe(II)_4Fe(III)_2(OH)_{12}(SO_4{\cdot}3H_2O)$
Gibbsite	$Al(OH)_3$
Gypsum	$CaSO_4{\cdot}2H_2O$
Halotrichite	$Fe(II)Al_2(SO_4)_4{\cdot}22H_2O$
Jarosites:	
Hydronium jarosite	$(H_3O^+)Fe_3(SO_4)_2(OH)_6$
Natrojarosite	$NaFe_3(SO4)_2(OH)_6$
"Jarosite"	$KFe_3(SO4)_2(OH)_6$
Jurbanite	$AlSO_4OH{\cdot}5H_2O$
Kieserite	$MgSO_4{\cdot}H_2O$
Kornelite	$Fe(III)_2(SO_4)_3{\cdot}7H_2O$
Melanterite	$FeSO_4{\cdot}7H_2O$
Pickeringite	$MgAl_2(SO_4)_4{\cdot}22H_2O$
Rhomboclase	$(H_3O^+)Fe(III)(SO_4)_2{\cdot}3H_2O$
Römerite	$Fe(II)Fe(III)_2(SO_4)_4{\cdot}14H_2O$
Rozenite	$Fe(II)SO_4{\cdot}4H_2O$
Schwertmannite	$Fe_8O_8(OH)_6SO_4$
Syngenite	$K_2Ca(SO_4)_2{\cdot}H_2O$
Szmolnokite	$FeSO_4{\cdot}H_2O$

A general increase in the contamination potential of waste material is observed from original excavation to mine backfill (Younger and Sapsford, 2004b), which is also illustrated by MacDonald (2014). The concentrations of contaminants released from the material are highly variable depending on the site-specific conditions. However, the release rate of contamination from backfill material is postulated to be always higher in the post-mining environment, relative to the release rate during mining. This is attributed to a higher secondary mineral abundance in the backfill material after prolonged exposure to atmospheric air and water. The contaminants generally associated with opencast coal mining include Fe, SO_4^{-2}, Ca, Na, K, Cl, Mn and Al (Geller and Schultze, 2013, Novhe et al., 2013).

2.11 Initial Flush Quantification

2.11.1 Mine Water Chemistry Prediction – Underground Mines

Different simplified approaches have been proposed for the quantification of the initial flush from abandoned underground mines. Initial flush quantification at opencast mines in this study can potentially build on some of these methods. Three of the approaches for the initial flush quantification from underground mines have been selected for discussion below. This will provide a background of the current methodology for the prediction of mine water quality evolution during the initial flush phenomenon.

The first of these approaches involves the estimation of contaminant concentrations during the initial flush using an idealised decay rate curve (Mack et al., 2010). This study was based upon samples collected from 40 underground mines between 1968 and 2005 to study the rate of decay in acidity in discharging mine water.

Results of the study showed a decrease in acidity in all studied mines. These results were also postulated to be applicable to sulfate concentrations, with acidity and sulfate concentrations both being linked to pyrite oxidation. Mack et al. (2010) showed that the underground mines followed acidity decrease rates of approximately 2% annually, similar to rates found by Demchak et al. (2001) and Ziemkiewicz (1994). However, some of the studied mines showed higher decreases in acidity, reaching up to 10% annually. Additionally, the study highlighted that due to changing hydrogeological conditions in the mines, the decay rates are likely to be dynamic with higher decay rates achieved in the initial stages of the initial flush, equilibrating at lower decay rates at later stages in the initial flush. This was attributed to fewer hydraulic and geochemical disturbances within the mining voids due to increased flushing. A basic methodology for the prediction of initial flush contaminant concentrations was highlighted by this study, based on measured values immediately after mine closure and could be used as a basic first estimation tool. Not only is it applicable in underground mines but could provide valuable estimates for rehabilitated opencast mines. However, it does not take factors such as varying flow rates, changing mineral reactive surface areas, mineralogical effects and oxygen ingress into account. Therefore, a more advanced method of estimation is required.

Similarly, in a study by Gzyl and Banks (2007), the temporal concentrations of sulfate and chloride in discharging mine water were fitted with exponential decay curves to confirm the initial flush phenomenon. In their study, comparisons were made to the study of Frost (1979) as well as studies by Younger (2000) and Younger et al. (2002). The decay of iron concentrations [Fe] in mine water occurred exponentially after the initial flush (Frost, 1979):

$$\log [Fe] = 1.684 + 0.102 \log (Q) - 8.58 \times 10^{-4} t \quad (7)$$

Where Q is the discharge rate in m^3/s and t is time in days.

Younger (2000) favoured a more complex dispersive transport equation but found the parameterisation of such an equation to be too complex. However, Younger (2000), along with Younger et al. (2002), still proposed a simplified equation for the estimation of the duration of the initial flush in the following form (Wolkersdorfer, 2008):

$$t_f = f(aci_{rem}, r_w, V, K, R_{GW}) \approx (3.95 \pm 1.2)t_r \quad (8)$$

Where t_f denotes the flushing time; aci_{rem} denotes acidity removal; r_w, denotes the weathering rate of acid containing minerals; V denotes the interconnected mine void volume being flushed; K denotes the hydraulic conductivities of the mine workings; R_{GW} denotes groundwater recharge and t_r denotes the flooding time of the mine.

Based on the study by Gzyl and Banks (2007), equation 8 is not universally applicable. However, the quantification of a initial flush was expanded by a degree of parameterisation and the subsequent proposal of equations to estimate this decay based on specific rate controlling factors. These factors include the following, which are also potentially applicable to rehabilitated opencast mines:

- Flooding rates which are applied as a "mixing tank model" – this factor was incorporated into a decay equation based on the assumption that a flooded mine has a finite volume, denoted by V, containing water with an initial solute concentration C_0, and if it is being flushed by pure water at rate Q assuming perfect mixing throughout the reservoir, then the concentration (C) at time t is given by the following equation:

$$C = C_0 \exp\left(\frac{-Q_t}{V}\right) \quad (9)$$

According to Gzyl and Banks (2007), equation 9 translates to 2.3 V/Q for the time to achieve a 90% reduction in the first-flush concentration. If the water through flow in the mine is constant, then V/Q is also the time the mine would have taken to flood, following abandonment. However, this study also states that flooding is a head dependent process and therefore, the time for the initial flush to take place may be extended. This is especially applicable in rehabilitated opencast mines where flooding is strongly head and porosity dependent as stated in section 2.10.4.

- Influence of different flushing regimes in a single mine: The study by Gzyl and Banks (2007) suggests that differing flow rates in a single mine, besides the effect of head dependent flow, can affect the rate of flushing in different depths. In an underground mining environment, this could be due to mine water stratification and lower inflow volumes at depth versus higher inflow volumes, shallower in the mine. Similarly, this factor could be applied to rehabilitated opencast mines where many preferential flow paths exist in the backfilled rock matrix. This means that the entire backfilled opencast mine will not necessarily be flushed as a single hydrogeological unit, but could be flushed through different preferential pathways at different flow rates. Similar to an underground mine, the initial flush from a backfilled opencast could be composed of several different decay curves superimposed on each other as suggested in Gzyl and Banks (2007).

- Influence of dewatered host rock: Dewatered host rock may have an influence on defining the volume which undergoes flushing. Frost (1979) proposed this factor as a control on contaminant release. In a mine where the wall rocks have partially been dewatered, a larger volume of water is required to flush the mine volume of vestigial- and juvenile acidity. This is due to blast fractures in wall rocks in the range of 2 m and sometimes reaching up to 8 m (Wolkersdorfer, 2008), increasing the volume of the mine and, subsequently, the volume of

water required for its initial flush. This is equally applicable to rehabilitated opencast mines where a volume of the surrounding host rock is dewatered during opencast mining, causing an increase of the volume to be flushed beyond the volume of the backfilled mine. This may also increase secondary mineral abundances in dewatered pore spaces, contributing partially to the contaminant load.

- Mineral dissolution rates: The rate of dissolution of minerals in abandoned underground mines is postulated by Gzyl and Banks (2007) to contribute to exponential decay. How the rate of dissolution determines the concentration of a solute in mine water can be quantified by the following equation (Gzyl and Banks, 2007):

$$c = c_0 \exp(-K_{diss} t) \quad (10)$$

Where $c_0 = k_{diss} M_{0/Q}$ and the initial mass of the secondary mineral phase in the mine is represented by M_0, which is assumed to dissolve in pure water flowing at a rate denoted by Q. The rate of dissolution of the secondary mineral phase is given by k_{diss} in s^{-1}. The solute concentration at a specific time t is denoted by c.

The release of contaminants such as sulfate and iron into mine water post-mining is linked to secondary minerals, often referred to as vestigial acidity (Younger, 1997). Additionally influencing the release of contaminants into mine water are the disulfide minerals and dissolved metals in mine water, collectively referred to as juvenile acidity. The rate of this release could be explained by this equation and subsequently, its contribution to the initial flush. However, more detail is required on the mineral assemblage producing solutes that are released into mine water and multiple rate constants may be involved. Still, this remains a tool for initial flush estimation and can potentially be applied to rehabilitated opencast mines, where factors such as reactive surface areas of minerals as well as flow rates may increase concentrations.

The study by Gzyl and Banks (2007), similar to that of Mack and Skousen (2008), offers simplified prediction tools in the form of curve fitting which is quantified into a set of equations, to predict mine water quality. However, what sets this study apart from previous studies is the accounting for rate controlling factors, which further parameterise the proposed equations and provide a more rigorous and precise calculation method. These factors and equations could equally be applied to opencast mines in some situations. However, advanced parameterisation is not performed and geochemical modelling of the system is also not considered. Also, additional factors applicable to rehabilitated opencast mines must be added to quantify the initial flush in these environments.

A more advanced approach is parameterisation by a simplified conceptual geochemical model, which is translated to a numerical model (Evans et al., 2003, Eriksson and Destouni, 1997, Banwart and Malmstrom, 2001). Numerical modelling has gained much attention as an improved method of mine water quality prediction. This can be attributed to the improved parameterisation through greater conceptual understanding and representation of mine water geochemical systems. Additional to this is the development of computer based models such as the PHREEQC (Parkhurst and Appelo, 2013) or Geochemist's Workbench codes (Bethke, 2008). PHREEQC (originally known as PHREEQE) was developed by Parkhurst, Thornesten and Plummer (Parkhurst et al., 1980). The code

is able to solve multi component chemical reactions using thermodynamic databases, developed through years of research.

The study by Evans et al. (2003), although not specifically focussed on the initial flush phenomenon from a mine itself, is an example of how water quality can be calculated within order of magnitude accuracy by parameterising a geochemical system using a conceptual model approach and translating this to a numerical model. The study focussed on the identification of processes and parameters governing the chemical evolution of discharges from Morrison Busty coal spoil heap, situated close to the village of Quaking Houses in County Durham, UK. The study also identified the effects of variation of input parameters, with respect to the calculated results corresponding with field observations, thereby identifying possible errors in initial assumptions with regards to discharge chemistry and elemental profiles. The study illustrates how the parameterisation of a chemical system, using a conceptual model and simplifying some parameters which cannot reasonably be determined directly, is an effective way to calculate results which are satisfactorily representative of the observations made in a field scenario. Even though the system is simplified using this approach, important parameters are taken into account. These parameters include chemical composition, mineralogy, reactive surface areas, dissolution rate constants, porosity, fluid flow velocity, oxygen availability and fluid to rock ratios. The mentioned parameters were not accounted for by idealised decay rate curve fitting, and are some of the most important factors controlling leachate chemistry. When applied to backfilled opencast mines or even defunct underground mines, mine water chemistry could likely be predicted using numerical models (Chen et al., 1999). The solutions calculated are likely to be of order of magnitude accuracy. This is under the assumption that the model is based on a well-defined and parameterised conceptual model and sensitivity analyses of input parameters within realistic boundaries.

2.11.2 Mine Water Chemistry Prediction – Pit Lakes

Prediction of pit lake geochemistry mostly follows laboratory approaches. This includes the estimation of wall-rock runoff from laboratory and field tests, mineral dissolution kinetics, estimation of wall rock leaching by oxidation modelling paired with laboratory leaching tests and batch tests with representative water compositions (Castendyk et al., 2015b).

According to Castendyk et al. (2015b), humidity cells are commonly used to approximate wall-rock leaching in pit lakes. Their results are up-scaled to represent field conditions in areas of the pit lake, which have not been flooded. However, the degree to which these tests are representative depends strongly on the degree of weathering of the samples. Samples collected during the operation of the mine which have been exposed to weathering processes are more likely to provide representative results, relative to fresh core samples. A limitation to this approach is the quantification of the sample surface area. Common methods used to determine this parameter are the BET method on a microscopic scale while mapping using technologies such as LiDAR can be used to estimate the macro-scale surface area of the pit. The humidity cell method provides a best estimate of the total amount of leachable constituents over time (Castendyk et al., 2015b).

A second approach to estimating runoff chemistry from wall-rocks is based on solute release rates based on mineral dissolution rates. According to Castendyk et al. (2015b), this approach utilises the quantification of wall-rock surface areas, mineral phase abundances and published mineral reaction

rates to determine the contaminant load being released by runoff into the pit lake. However, this approach is also limited by the quantification of the sample surface area, but also does not provide a complete estimation of the total concentration of potentially reactive elements in a sample.

An approach to the estimation of wall-rock leaching, described by Castendyk et al. (2015b), is oxidation modelling, which is used to model the rate of disulfide mineral oxidation, as well as the depth of the oxidation rim in the wall-rock of the flooding pit. This method is commonly paired with kinetic testing in the form of humidity cells to determine the release rates of specific elements. A limitation to this methodology is that weathered material is often not available prior to the commencement of mining. Therefore, drill cores are the only feasible material for use in kinetic testing, which is not as representative of expected conditions. However, various studies using this methodology have shown that the flushing of 3 to 20 pore volumes of the oxidised rim around the pit is required to reach the background groundwater composition, depending on flooding time and wall-rock reactivity (Castendyk et al., 2015b, Geller and Schultze, 2013).

Wall-rock leaching can also be simulated by batch tests, which are performed by mixing solutions with specific compositions which represent the various contaminant loads to the pit in a laboratory situation (Castendyk et al., 2015b). This is often referred to the “pit lake in a bucket” approach (Davis, 2003). After mixing, the precipitated secondary minerals and final solution composition are analysed and various scenarios can be simulated. This is an analogue test which incorporates the contributions of rainfall, stream-flow, wall-rock runoff and groundwater. This approach can also be used to confirm geochemical modelling simulations as a form of simplified calibration, as performed by Schafer et al. (2006).

According to studies by Castendyk et al. (2015a), Geller and Schultze (2013) and Castendyk et al. (2015b), an important part of pit lake modelling, as with the modelling of contaminant release from other mine types and mining wastes, is a sound conceptual model (Evans et al., 2003, Eriksson and Destouni, 1997, Banwart and Malmstrom, 2001). This is viewed as equally important in the modelling of the initial flush from backfilled opencast mines. Processes identified by Castendyk et al. (2015b), which are also applicable to conceptual geochemical models for backfilled opencast mines, include gas phase exchange between the atmosphere and water surface, mineral precipitation in the flooded pit, dissolution and oxidation of submerged wall-rock minerals and adsorption of elements onto mineral surfaces. These processes play a vital role in the quantification of pit lake chemistry and are likely to be useful in the quantification of mine water quality of backfilled opencast mines. Additionally, as stated by Castendyk et al. (2015a), estimation can further be improved by calibrating short-term models against existing monitoring data.

3 Description of the Study Sites

3.1 Introduction

Three decommissioned opencast collieries across Mpumalanga Province have been selected for the study. The opencast mines are located near Carolina, eMalahleni and Arnot. Due to data sharing constraints, these mines have been renamed as C-Mine, E-Mine and A-Mine, respectively, in this study (Figure 2). Each site was selected based on access and data availability. The site locations, climatic settings, hydrological, geological and hydrogeological situations are described in the following paragraphs.

3.2 Mine Locations

C-Mine colliery is located approximately 5 km east of Carolina, Mpumalanga. The farms on which this colliery was operated are situated 20 km north of Chrissiesmeer and 30 km northeast of Breyten (Figure 2).

E-Mine colliery is located approximately 20 km northwest of eMalahleni, Mpumalanga. The farms on which this colliery was operated are situated 30 km north of Ogies and 35 km east-northeast of Bronkhorstspruit (Figure 2).

A-Mine colliery is located approximately 10 km northwest of Arnot, Mpumalanga. The farms on which this colliery was operated are situated 15 km northeast of Pullen's Hope and 25 km southeast of Middelburg (Figure 2).

3.3 Climatic Settings of the Mines

3.3.1 C-Mine

Climatic data measured over 54 years was obtained from the Department of Water and Sanitation's weather station for the Nooitgedacht Dam area (Table 7). The rehabilitated mining site is located in the summer rainfall region of Southern Africa with precipitation usually occurring in the form of convectional thunderstorms. The average annual rainfall is in the order of 735 mm, with the high rainfall taking place in the months between October and March (Figure 6).

Table 7: Climatic Data for the Carolina Area (Nooitgedacht Dam)

Month	Average Monthly Rainfall, mm	Mean Monthly Evaporation, mm
January	122.9	195.3
February	91.5	171.9
March	78.2	161.9
April	42.0	126.0
May	12.8	108.0
June	7.9	86.7
July	4.3	95.8
August	10.0	127.2
September	25.0	169.2
October	90.0	185.6
November	129.9	178.9
December	125.2	193.0
Total Annual	735.8	1812.9

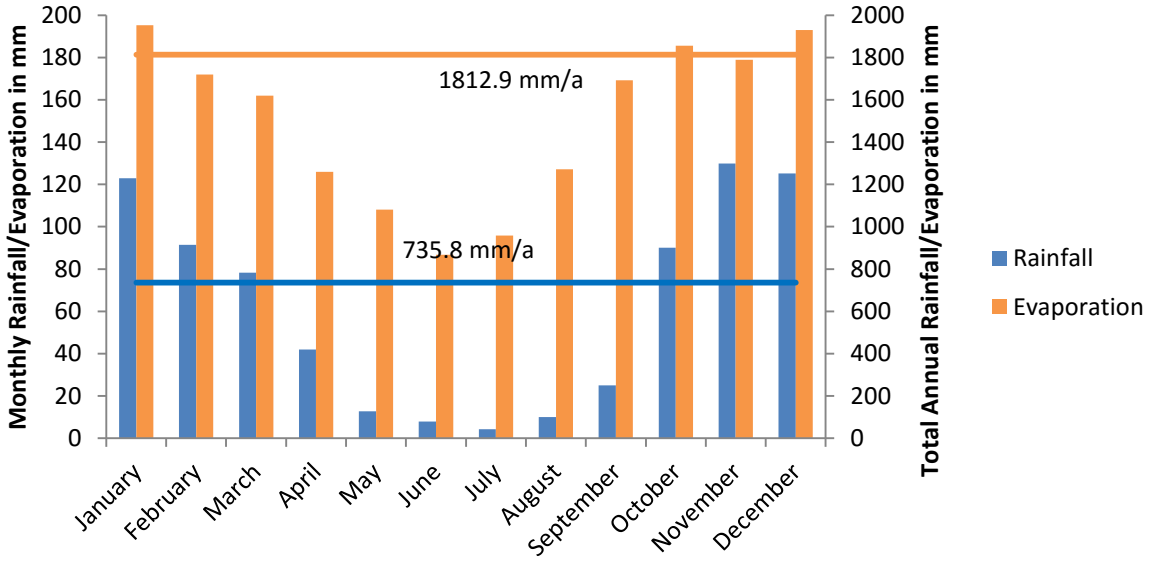


Figure 6: Climatic Data for the Carolina Area Nooitgedacht Dam

3.3.2 E-Mine

Climatic data measured over 45 years, was obtained from the Department of Water and Sanitation's weather station for the Witbank Dam (Table 8). The rehabilitated mining site is located in the summer rainfall region of Southern Africa with precipitation usually occurring in the form of convectional thunderstorms. The average annual rainfall is in the order of 703 mm, with the high rainfall taking place in the months between October and March (Figure 7).

Table 8: Climatic Data for the eMalahleni Area (Witbank Dam)

Month	Average Monthly Rainfall, mm	Mean Monthly Evaporation, mm
January	131.5	164.5
February	91.8	138.4
March	73.8	129.6
April	39.3	97.4
May	13.4	79.8
June	7.0	65.3
July	2.9	72.5
August	7.9	98.8
September	20.7	137.3
October	78.3	163.7
November	123.8	158.5
December	116.7	163.6
Total Annual	702.7	1476.2

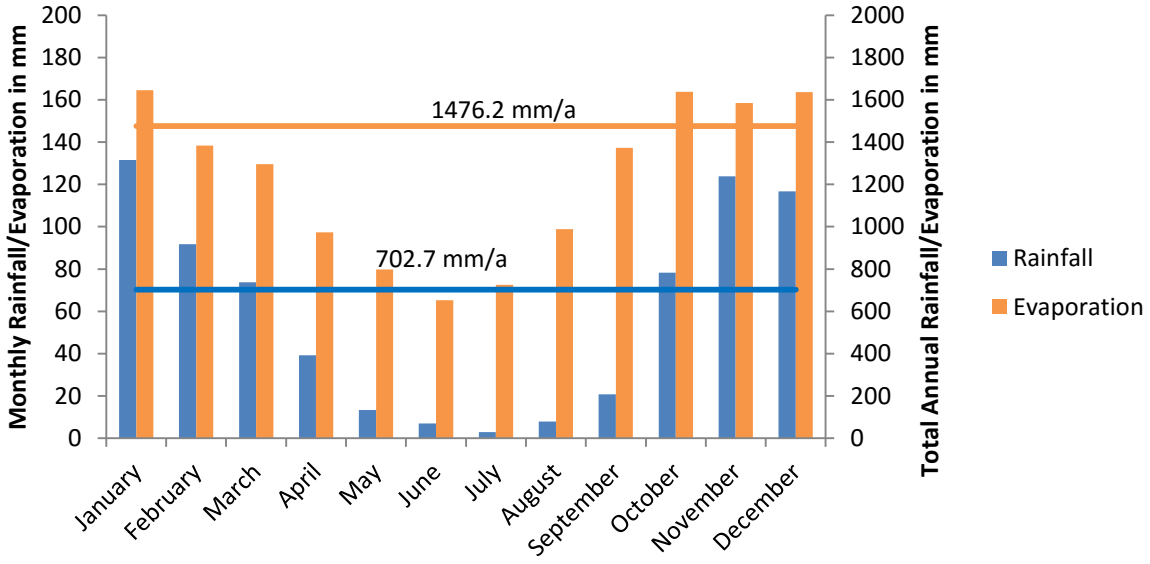


Figure 7: Climatic Data for the eMalahleni Area (Witbank Dam)

3.3.3 A-Mine

Climatic data measured over 35 years was obtained from the Department of Water and Sanitation's weather station for the Middelburg Dam (Table 9). The rehabilitated mining site is located in the summer rainfall region of Southern Africa with precipitation usually occurring in the form of convectional thunderstorms. The average annual rainfall is in the order of 657 mm, with the high rainfall taking place in the months between October and March (Figure 8).

Table 9: Climatic Data for the Middelburg Area (Middelburg Dam)

Month	Average Monthly Rainfall, mm	Mean Monthly Evaporation, mm
January	121.5	191.4
February	85.1	173.4
March	75.0	161.3
April	32.7	126.6
May	10.7	106.0
June	7.5	82.9
July	2.9	91.9
August	8.4	127.6
September	19.9	171.2
October	76.5	191.4
November	111.2	186.6
December	124.4	192.8
Total Annual	656.6	1794.6

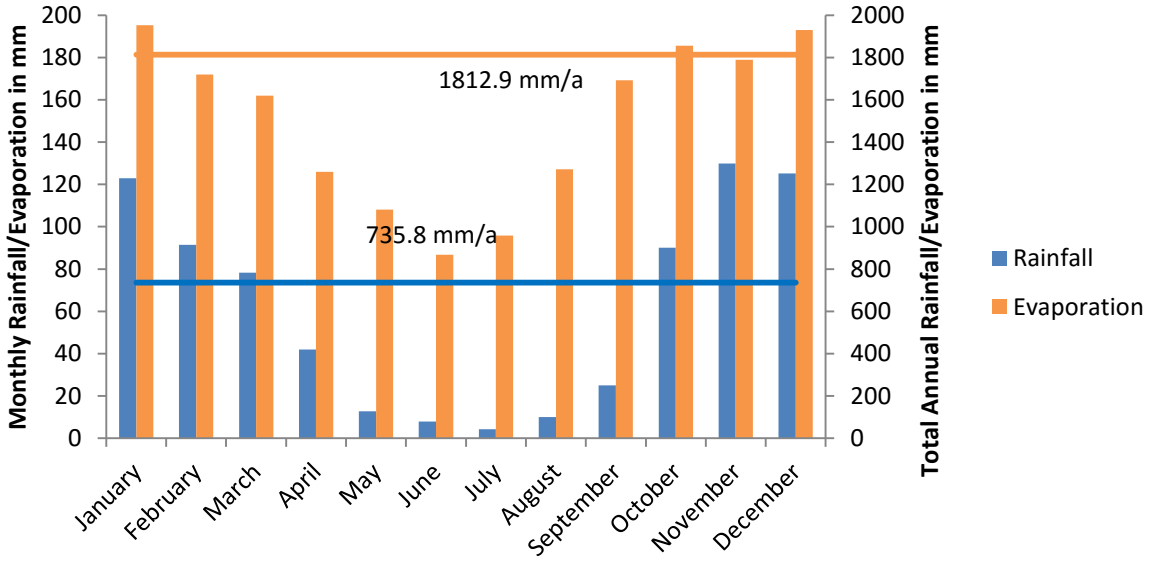


Figure 8: Climatic Data for the Middelburg Area (Middelburg Dam)

3.4 Hydrological Settings

3.4.1 C-Mine

Surface drainage at C-Mine is mainly directed to the east, draining into the stream on site, flowing from south to north. The opencast mine closest to the stream is currently discharging mine water at very low volumes and may contribute to the volume of runoff from the site into the stream (Figure 19).

3.4.2 E-Mine

Runoff at E-Mine drains to the southwest, northwest and to the east into various streams and rivers surrounding the site. The general flow direction of the streams surrounding this site is from the south to the north. Some backfilled areas are currently discharging mine water. However, the discharge is treated in a liming plant before reuse on site. Consequently, no mine water enters the surrounding streams (Figure 39).

3.4.3 A-Mine

Surface water runoff at A-Mine drains to the south, west and east into the surrounding streams. The stream to the north flows from east to west. The stream to the east flows from south to north. The stream to the south flows from east to west. All these streams join each other, surrounding the site almost completely. Mine water discharge is taking place at this site, but it is well managed using a pumped storage system. No discharge has been released to the surrounding streams (Figure 65).

3.5 Geological Settings of the Mines

3.5.1 C-Mine

Sedimentary lithologies of the Ecca Group were encountered at C-Mine during exploration drilling (Figure 9). A sandy clay layer of approximately 4 to 6 m thickness is present on site which is underlain by highly weathered sandstones and shales. The thickness of the highly weathered sandstone and shale layer is approximately 8.5 m on average. This layer is underlain by a competent, fractured hard rock layer comprised of sandstone and shale. This layer was penetrated by drilling to an average depth of 8 m from the top of competent rock. The seams that were mined at the site include the B Seam and the C Seam. The B Seam was encountered at an average depth of 11 m while the C Seam was encountered at an average depth of 17 m. Based on the available drilling data for the site, as well as the geological map for the area (Figure 10), no doleritic intrusions or major faults are present on site (Huisamen and Naidoo, 2014).

3.5.2 E-Mine

At the E-Mine site, sedimentary lithologies of the Ecca Group, as well as the Dwyka Group were encountered during exploration drilling (Figure 9). A sand layer of approximately 3 to 11 m thickness is present across the site. This sand layer is underlain by slightly to moderately weathered sandstones with siltstone, mudstone and shale present in places. The thickness of this layer varies between 9 and 23 m. Below the weathered sandstone layer lies a competent, fractured hard rock layer comprised of sandstone, siltstone and mudstone, which was penetrated by drilling to depths between 2 and 30 m from the top of the competent rock. The No. 2 Seam was encountered during drilling with a thickness of up to 7 m, while the No. 1 Seam was encountered with a thickness of up to 2 m. Based on geological mapping data (Figure 11), doleritic intrusions as well as faults intrude the site in north-south, southwest-northeast and southeast-northwest strikes (Williams et al., 2012).

3.5.3 A-Mine

Percussion drilling at the A-Mine site encountered sedimentary lithologies of the Ecca Group as well as igneous lithologies of the Pretoria Group (Figure 9). A sandy clay layer varying in thickness of approximately 1 to 4 m is present on site and is underlain by weathered sandstone and mudstone. The base of this weathered sandstone and mudstone layer varies between 15 and 18 m depth below surface. The weathered siltstone and mudstone layer is underlain by fractured, competent, hard rock comprised of sandstone and shale (Figure 12). During drilling, rhyolite and dolerite were also encountered. Drilling penetrated the fractured hard rock layers to depths between 20 and 30 m below the top of the hard rock layer. The No. 1 Seam and No. 2 Seam were mined at this colliery and were encountered at shallow depths and outcropped near the surrounding streams in places. Based on geophysical mapping data, minor doleritic intrusions and minor faults are present on site (Fourie, 2013, Mabedla, 2015).

3.6 Hydrogeological Setting

Three common aquifer systems are encountered at C-Mine, E-Mine and A-Mine, as Ecca Group lithologies are found at each site (Huisamen and Naidoo, 2014, Botha et al., 1998, Fourie, 2013). The aquifer types include a shallow perched aquifer system, a shallow weathered aquifer system as well as a deeper fractured rock aquifer system.

The shallow, perched aquifer systems are located in the regolith zone. These aquifers commonly contain water during high rainfall events but are generally unsaturated. Shallow, perched aquifers with thicknesses ranging between 2 and 10 m are associated with clay and ferricrete layers in the soil and feed local rivers and streams. These aquifers are recharged directly by rainfall.

Shallow weathered aquifers at the study sites are comprised of highly weathered sandstone and shale bedrock and develop between the regolith and fractured rock sedimentary layers. The local groundwater level is generally encountered within this layer. Shallow weathered aquifers in the Ecca Group are generally 10 to 20 m thick and develop along weathered zones, bedding planes and fractures. These aquifers are generally connected to deeper fractured rock aquifers by fractures, dykes and faults.

Deep fractured rock aquifers at the study sites are developed below shallow weathered aquifers and transmit groundwater through fractures and faults with limited flow taking place within matrix blocks. These aquifers are commonly thicker than 20 m and composed of sandstone and shale of the Ecca Group. They are connected to the overlying weathered aquifers by fractures, faults and dykes. Recharge of these aquifer systems occurs through the connecting fractures and faults from the shallow weathered aquifer systems.

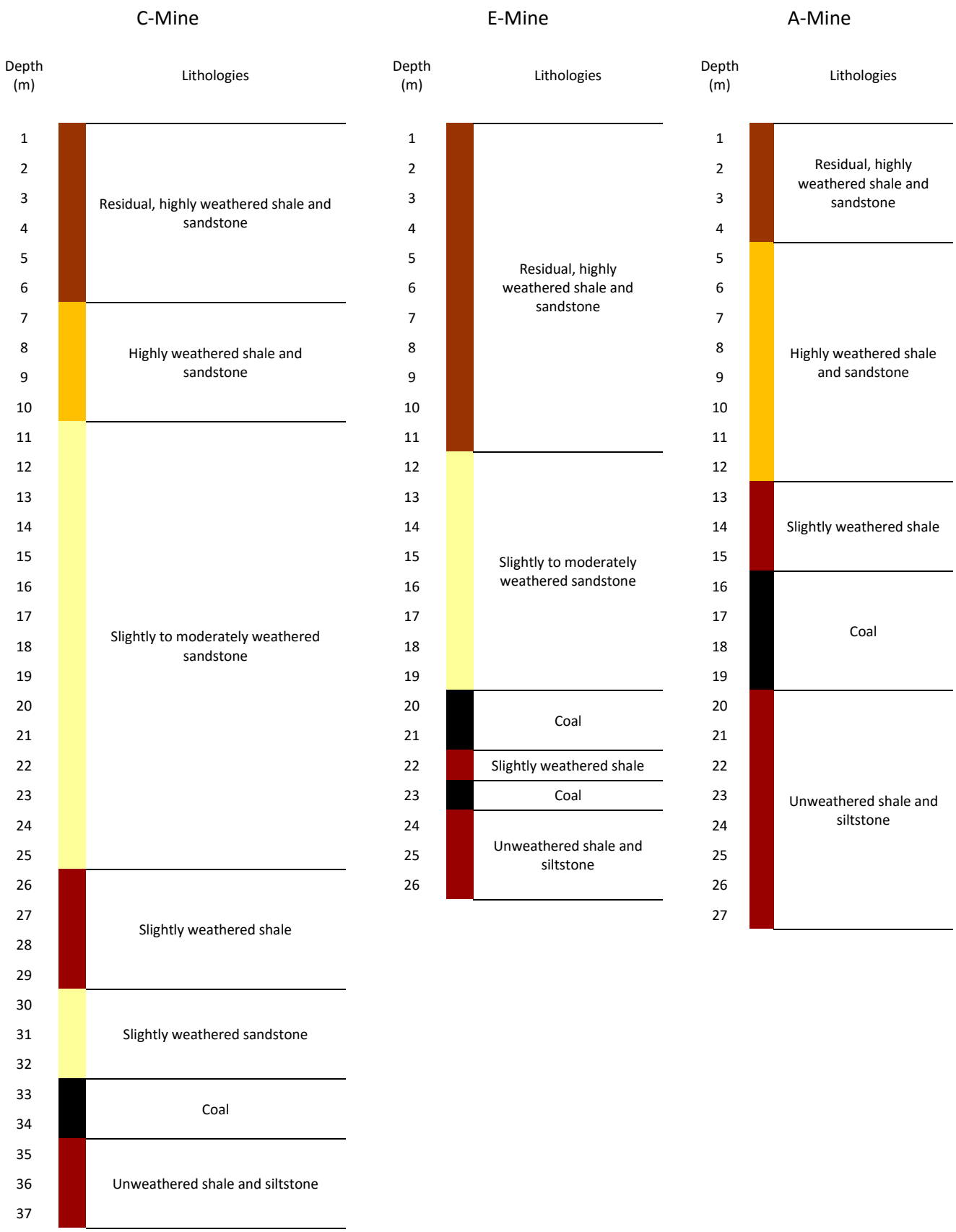


Figure 9: Stratigraphic Columns for the Study Sites (Pers. Comm. Myburgh, 2015)

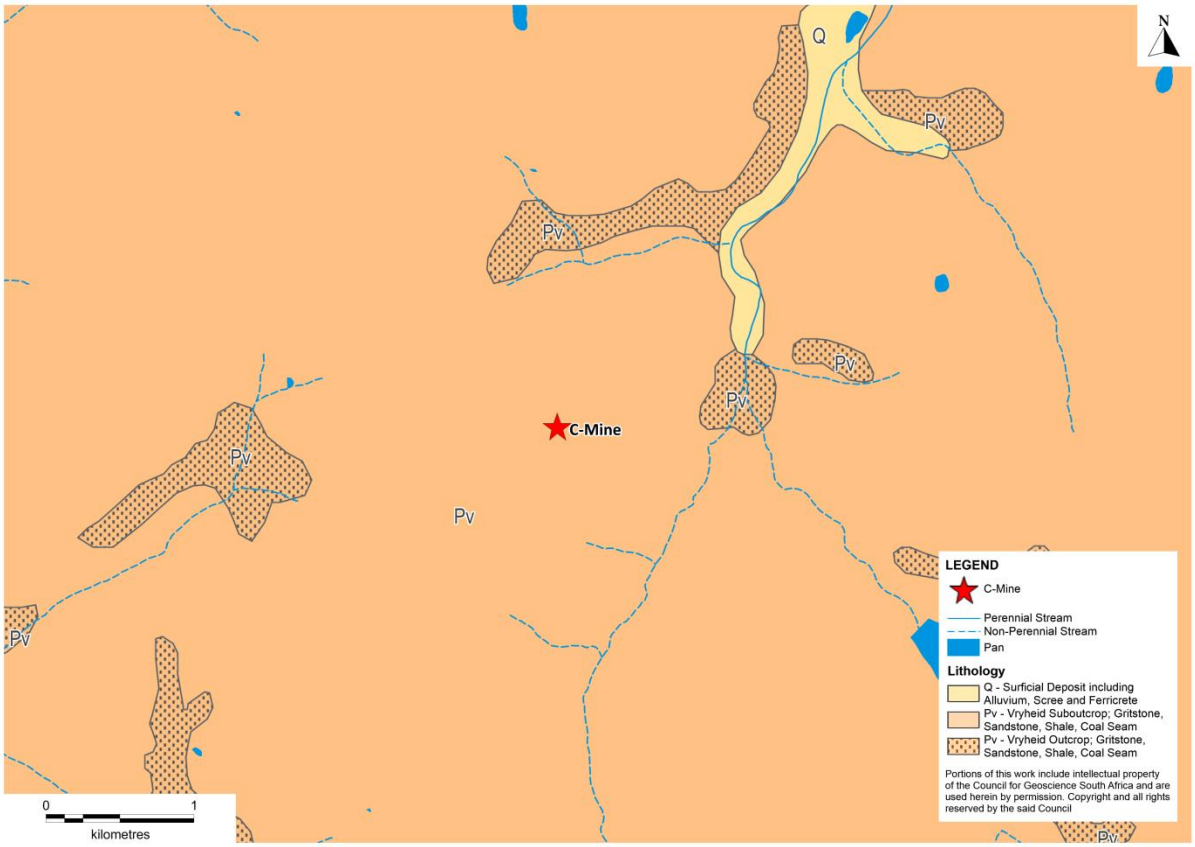


Figure 10: Geological Map of the Lithologies Encountered at C-Mine

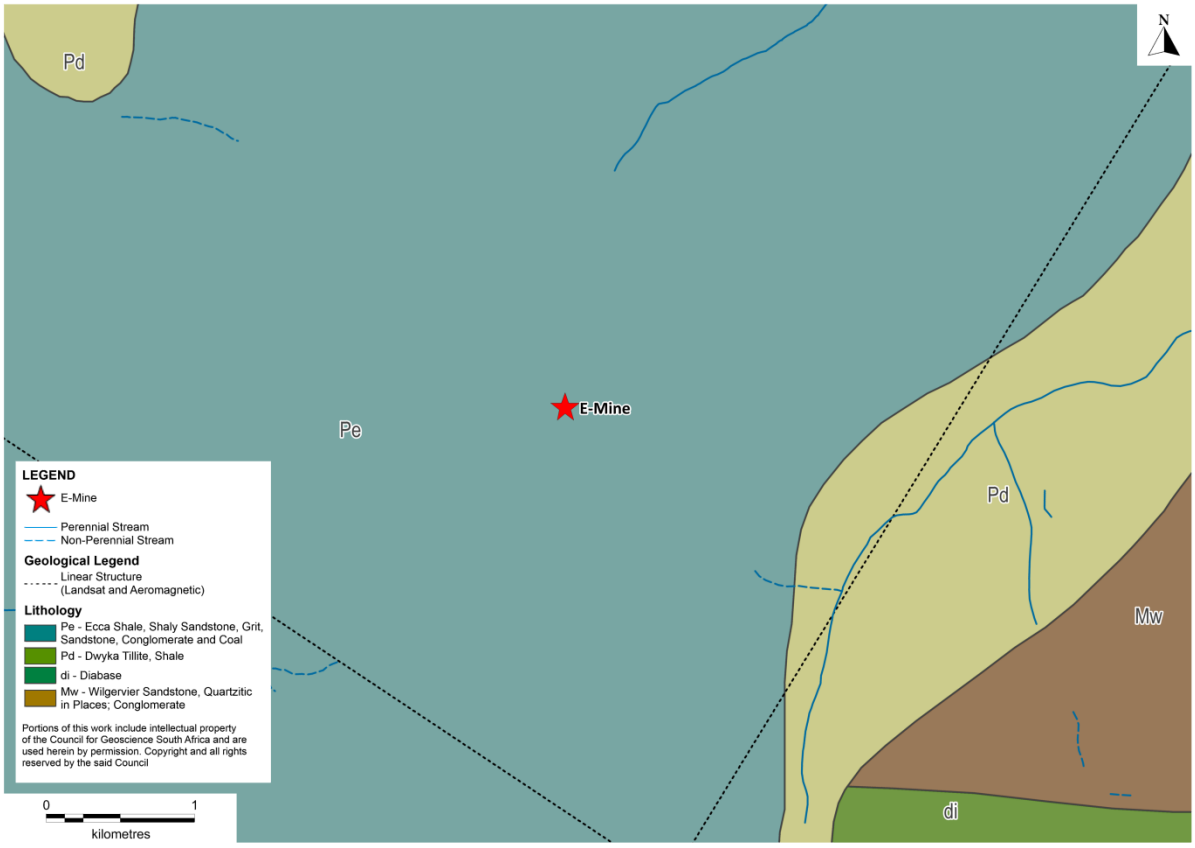


Figure 11: Geological Map of the Lithologies Encountered at E-Mine

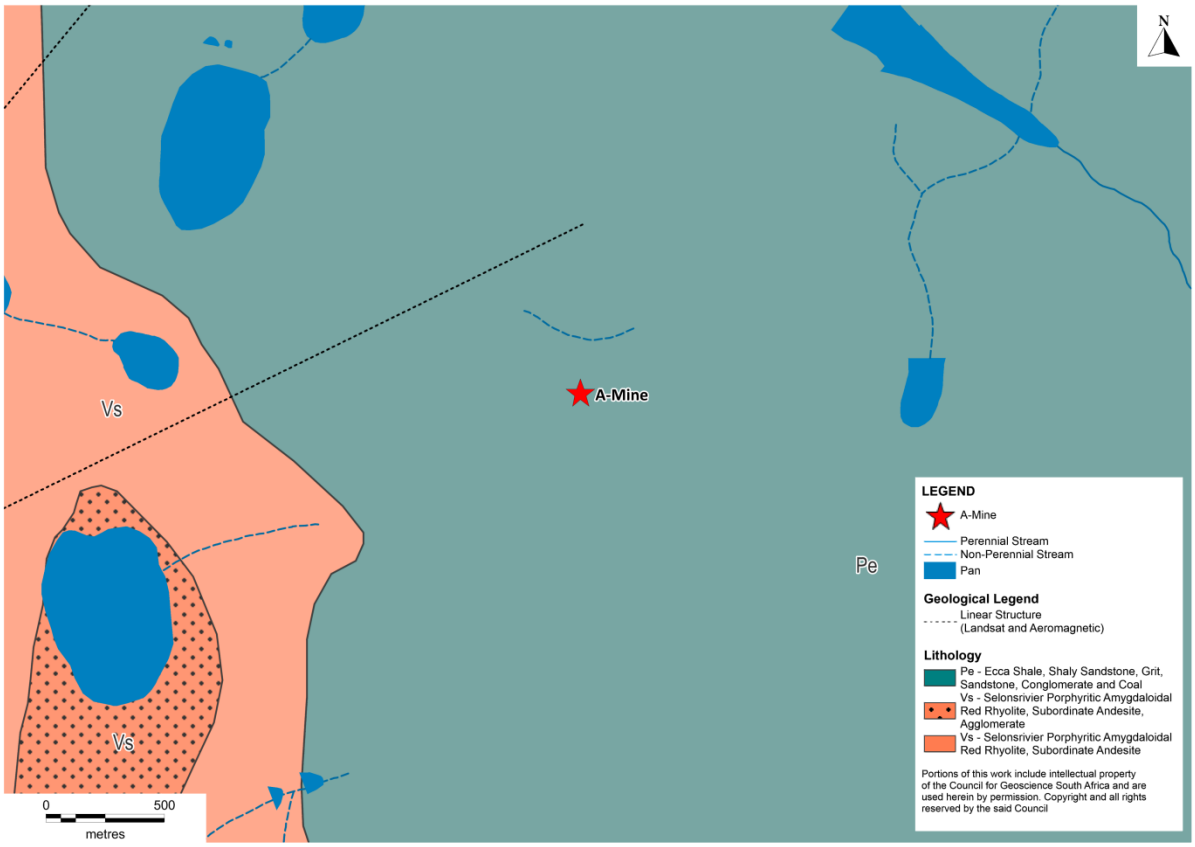


Figure 12: Geological Map of the Lithologies Encountered at A-Mine

3.7 Mining Activities

3.7.1 C-Mine

C-Mine Colliery was a small scale operation extracting coal by truck and shovel methods from four opencast mining sections. Rehabilitation commenced in the 1990's with full rehabilitation and groundwater level recovery taking place early in the 2000's. Opencast voids were backfilled with overburden material which was non-selectively placed and covered by topsoil and revegetated. Pit depths on site were approximately 20 m or less below surface level and no dewatering was required as groundwater inflows were purely evaporated.

3.7.2 E-Mine

Large scale mining operations are present at E-Mine Colliery with currently operational opencast mines as well as the rehabilitated pit to the north of the property. This pit was closed in the early 1990's and allowed to flood. Opencast mining in this area penetrated into a historic underground coal mine and mined out the pillars of the historic underground mine as well as the coal surrounding it. Backfill materials were not selectively placed and water in the backfilled pit investigated has a pH of 3.5 or less.

3.7.3 A-Mine

Large scale opencast coal mining commenced at A-Mine Colliery in the early 1970s. Two opencast pits were mined during the life of mine ending in the early 1990's after which the mines were

backfilled and flooded. During 2006 discharge from the western opencast mine commenced. However, due to large inflow volumes during mining various final voids were left in the western pit during rehabilitation in an attempt to reduce mine water discharge volumes by evaporation. Additionally, mine water is currently recirculated between these voids to manage discharge along with a sprayer system to evaporate water which irrigates backfilled areas.

4 Methodology

4.1 Introduction

The methodology used for the modelling of the hydrogeochemical evolution of rehabilitated opencast coal mines is discussed in the following chapter. This chapter aims to answer the objective of a methodology for modelling the initial flush from a backfilled opencast coal mine with special focus on sulfate. It outlines the initial steps of conceptual hydrogeological model and conceptual geochemical model development and discusses numerical modelling, geochemical modelling as well as geochemical sensitivity analysis of the constructed models.

4.2 Conceptual Hydrogeological Model

A conceptual model is constructed as a simplified representation of reality (Diersch, 2014). It outlines the understanding of the hydrogeological and hydrogeochemical processes active at a specific site at a specific time (Figure 13). However, the conceptual model is a transient system and must be updated regularly as more data becomes available and understanding improves.

For the study presented special focus was given to the post-mining hydrogeology of backfilled opencast coal mines. During mining groundwater flow is directed towards the opencast pit with groundwater inflows taking place from fractured and weathered Karoo aquifer systems. Pit dewatering is imperative for the continual safe operation of the mine during this stage with a single strip being mined and subsequently backfilled at any given time (Hartman and Mutmansky, 2002). After mining is completed at an opencast mine in South Africa the final strip is commonly backfilled with overburden material from the boxcut (Tanner, 2007). The material used to backfill the opencast mine will have undergone weathering and oxidation while exposed to surface conditions in overburden dumps (Marchand, 2002). This results in secondary mineral formation within the spoils.

Once the mine is completely backfilled, the groundwater level will rise in the backfilled mine and flood it along with recharge from rainfall. As mentioned in section 2.10.4, the percentage of rainfall that could infiltrate unrehabilitated spoils could reach up to 20%. Also, backfill porosity and hydraulic conductivity are highly variable, but in general exceeds that of the surrounding aquifer systems, causing faster flow velocities than in the surrounding aquifer which promotes faster flooding. At this stage the secondary minerals will begin to weather and dissolve along with further oxidation of disulphide minerals until the backfilled mine is completely flooded when the process is decelerated. However, the resulting contamination will remain within the confines of the pit until steady-state hydrogeological conditions are reached. Steady-state hydrogeological conditions could also include mine water discharge on surface as the post-mining water level will differ greatly from the pre-mining water level in the backfilled opencast mine.

Once these steady state conditions are reached, the initial flush can begin. This could include discharge of mine water on surface as well as into the surrounding aquifer. Dissolved and dissolving secondary minerals and oxidising disulfides at this stage have generated and will continue to generate a contaminant load in the water in the pit. Contaminated water will therefore continually move into the aquifer and onto surface. As more water is added into the system via recharge from rainfall and inflows from the aquifer, the secondary minerals and disulfides will further dissolve as well as oxidise and weather. Over time, the surface areas and abundances of these minerals will

decrease which will gradually deplete the source. Therefore, contaminant loads entering the aquifer are likely to decrease on a logarithmic scale over time which is what is called the initial flush. This process continues until the contaminant source is depleted or until a chemical equilibrium is reached in the backfilled opencast mine. Until the contaminant source is depleted, contaminants generated undergo dispersion and advection into the surrounding aquifer which generates a contaminant plume which may reach sensitive receptors.

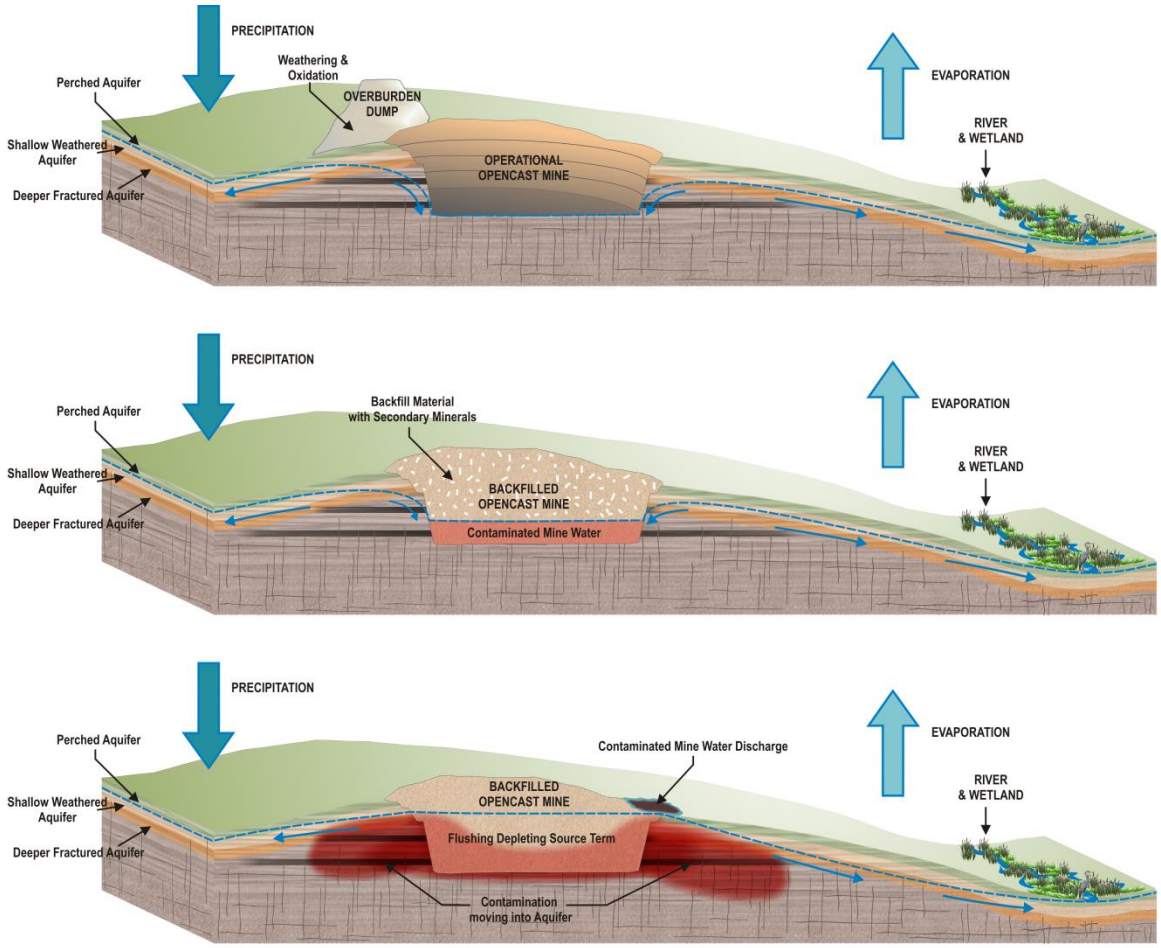


Figure 13: Conceptual Hydrogeological Model of the Initial Flush in Opencast Coal Mines. Details are outlined in the text.

4.3 Numerical Flow Model Construction

4.3.1 Introduction

Numerical groundwater flow models were constructed as a basis to understand the hydrogeology of the mining sites and to act as transport models using geochemical modelling results as input. Additionally, the purpose of the numerical models was to develop a tool than can be used to assess the various hydrogeological influences affecting the geochemistry of the source term as well as transport of contamination into the aquifer. Therefore, the constructed groundwater flow models were used to estimate flow volumes entering and exiting the rehabilitated opencast mines, groundwater flow directions and flow rates, potential future discharge volumes and plume migration.

4.3.2 Flow Model Setup

For the purpose of this study, the hydrogeological situation of the investigated mine sites was envisaged to consist of the following hydrogeological units:

- The upper few meters below surface consist of completely weathered material as shown in the various drilling logs and literature sources discussed. This layer is anticipated to have a reasonable high hydraulic conductivity and a seasonal water level is expected in this layer, especially after high rainfall events. Flow in this perched aquifer is expected to follow the surface contours closely and emerge as fountains or seepage at lower elevations.
- The next few tens of meters can be subdivided into two aquifer systems, which are composed of slightly weathered, highly fractured sedimentary rock such as shale or sandstone with a low hydraulic conductivity and backfill material which has a high hydraulic conductivity. The permanent groundwater level resides in this unit and could range between 5 to 20 meters below ground level depending on the site. The groundwater flow direction in this unit is influenced by the regional topography and is general from high lying areas to the surface drainage courses on site. This unit also contains the backfilled opencast mines which greatly influences the flow dynamics of the area. Backfilled opencast mines can be defined as artificial aquifer systems in this unit and terminate at average depths between 20 and 50 meters. Materials used to backfill these opencast mines have the hydraulic properties similar to that of coarse gravel mixed with clay and sand in different proportions, creating highly preferential flow paths in the system with a heterogeneous hydraulic conductivity, generally one to two orders of magnitude higher than the surrounding aquifer.
- Below a few tens of meters the fracturing of the aquifer is less frequent due to increased pressure. This results in an aquifer of lower hydraulic conductivity and very slow groundwater flow velocities.
- Hydraulic conductivity in the constructed models was decreased by an order of magnitude in each successive layer. This was performed based on the work by Wang et al. (2009), Jiang et al. (2009) and Cheema (2015) which shows that hydraulic conductivity often decreases exponentially with depth.

4.3.3 Fixed Aquifer Parameters

Although the most relevant aquifer parameters are optimised by the calibration of the model, many parameters were calculated and/or judged by conventional means. The following fixed assumptions and input parameters were used for the numerical model of this area:

- Recharge was calculated using the RECHARGE program created by van Tonder and Xu (2001).
- Horizontal hydraulic conductivity was estimated using existing data received from the mine sites as well as literature data.
- Hydraulic conductivity of the backfilled opencast mines was estimated from literature (du Plessis, 2010, Younger and Sapsford, 2004a, Hodgson, 1984).
- Vertical hydraulic anisotropy (KH/KV) of the bedrock was estimated by model calibration as suggested by Anderson et al. (2015) and was calculated as a value of 10, which is commonly used in layered sedimentary rock (Anderson et al., 2015).

- The effective porosity value of the bedrock was estimated as 0.05 declining gradually to 0.01 at a depth of 100-150 metres (Wang et al., 2009).
- Longitudinal dispersion was determine based on model scale and ranged between 50 and 100 m as recommended by Schulze-Makuch (2005).

4.3.4 Model Boundaries and Discretisation

Model boundaries were chosen to include the area where the groundwater pollution plume could reasonably be expected to spread. Wherever practical, natural topographical water divides were used as no-flow boundaries. Additionally, local perennial streams were also included as hydraulic boundaries if present. The modelling areas were discretised using structured grids which were refined at the mining areas.

4.3.5 Calibration

Water level and quality data as communicated in the monitoring data received from the mines was used to calibrate the numerical groundwater flow models and transport models. Results obtained from the water level calibration were used as initial conditions to simulate the transient post-mining water movement and contaminant transport. Head error ranges were defined based on 10% of the difference between the highest and lowest calculated groundwater head elevations.

4.3.6 Modelling Scenario

Numerical simulations were constructed for each mine to represent a period of 100 years after cessation of mining. This includes a time after flooding of the backfilled opencast, discharge as well as contaminant movement into the aquifer.

4.4 Conceptual Geochemical Model

A conceptual understanding of the active processes in a hydrogeochemical system is imperative to understand and model these processes. This is commonly conceptualised using a source-pathway-receptor approach (Figure 14). As this study focusses on the evolution of rehabilitated opencast collieries, which are generally sources of contamination, an integration of the controlling factors on the source term is required. To conceptualise this source term, an integration of the following data is proposed:

- Inflow volumes relative to backfill volumes in the form of groundwater and surface water inflow as well as recharge.
- Gas phase exchange where oxygen fugacity in the system is assumed sufficient to at least partially oxidise disulfide minerals.
- Mineral precipitation and dissolution. This is commonly observable near areas of discharge and within backfill material itself in the form of secondary minerals such as gypsum.
- Character of the source term which is commonly a mixture of overburden and discard materials containing weathering mineral phases with reactive surface areas. These minerals have rates of dissolution which can be quantified. Additionally, the material will have a certain acid generation capacity and leachability. Also, a certain degree of flushing and reactive transport takes place in the material.

- Solution outflow chemistry which can be quantified from mine water discharge, groundwater outflow and mine water in final voids or pit lakes. The evolution of chemistry in these waters in the short term is an indicator of the long term chemistry, which can be calculated if the correct parameterisation is performed.

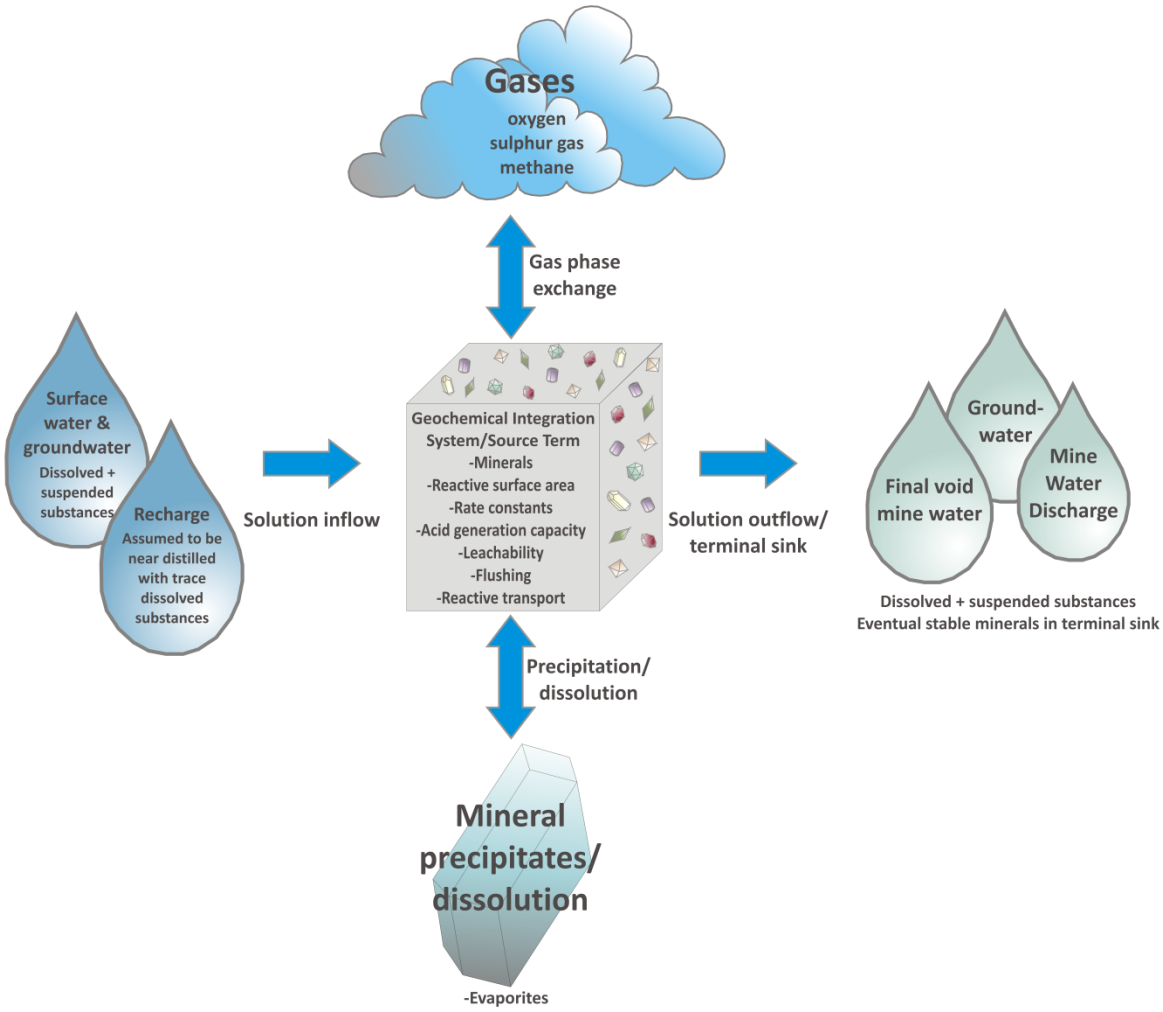


Figure 14: Conceptual Model of Hydrogeochemical Source Characterisation of a Rehabilitated Opencast Mine

4.5 Mineralogical Analysis

Mineral phase abundances in the backfill material were quantified using X-ray powder diffraction analysis (XRD). XRD is an analytical technique primarily used for phase identification of a crystalline material (Young, 1999, Klein et al., 2008). The analysed material is finely ground, homogenised and the average bulk composition is determined (Figure 15). However, it is important to note that XRD can only report the crystalline phases present above an abundance of 1 weight%. Using this method, the weight percentages of identified crystalline minerals in a sample are reported.

The XRD analysis method used in this study is as follows:

- Samples are dried in a drying oven.

- The dried sample matrix is ground to a fine powder in a tungsten carbide vessel using a swing mill.
- The samples are then prepared according to the standardised PANalytical back-loading system.
- A sample is analysed using a PANalytical X'Pert Pro powder diffractometer in ϑ-ϑ configuration.
- The powder diffractometer is equipped with an X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-Kα radiation.
- The subsequent diffraction traces are then analysed and mineral phase amounts are quantified using the Rietveld method (Young, 1999).

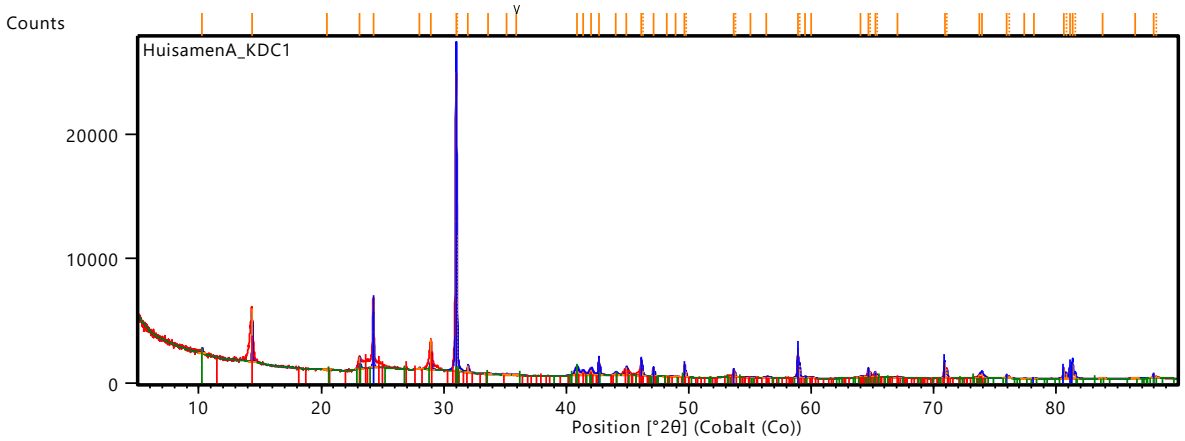


Figure 15: Example of a diffraction trace (sample KDC1 collected from E-Mine)

4.6 Reactive Surface Area

Mineral reactive surface areas were calculated using geometric surface areas based on grain size, as proposed by Gautier et al. (2001).

The average grain radius of an identified mineral is determined by an appropriate ruler in the field and, assuming spherical grains, such as in the assumptions used in Stoke's law, the idealized volume of the grain calculated. Using the mineral density (Klein et al., 2008), the mass of the identified mineral grain is calculated by multiplying the density with the grain volume. Following this, the number of grains in 1 g of such a mineral is calculated for the identified grain radius. The surface area for the specific grain radius is then calculated, also assuming a spherical grain. Finally, the total surface area of the mineral at the identified grain radius, in 1 g of that mineral material, is calculated. This is performed by multiplying the number of grains in 1 g of the mineral material, with the surface area of one grain of that mineral. It is then assumed that the entire calculated surface area is available for reaction upon commencement of a chemical reaction.

4.7 Mineral Reaction Rates

Mineral reaction rates were taken from literature sources as an estimate (Hersman et al., 1995, Huertas et al., 1999, Oelkers and Schott, 1998, Oelkers et al., 2008, Gudbrandsson et al., 2014, Gautier et al., 2001, Marty et al., 2015, Malmström et al., 2006, Jeschke et al., 2001, Pokrovsky and

Schott, 2002, Pokrovsky et al., 2005). Reaction rates were identified for each mineral phase that was identified in the XRD analysis.

4.8 Acid-Base Accounting

Acid-base accounting results used from literature sources in this thesis (Huisamen and Naidoo, 2014, Williams, 2015, Fourie, 2013) were all obtained using variations of the Modified Sobek Method (Lawrence and Marchant, 1991). In this procedure total sulfur content is measured as well as sulfate sulfur which is extracted from the analysis sample with dilute hydrochloric acid. The difference between these concentrations provides the sulphide sulfur content of the sample which is of special interest in terms of acid generation potential (Lawrence and Marchant, 1991). Neutralisation potential of the sample is determined by titrating the sample with standardised HCl and performing a fizz test. Excess acid is then titrated with a standardised base to a pH of 8.3 to calculate the $CaCO_3$ equivalent of the acid consumed by the sample (Lawrence and Marchant, 1991). The difference between the Acid Generation Potential and the Neutralisation Potential provides the Net Neutralisation Potential of the sample which indicates if the sample is acid producing or acid consuming. A positive value indicates acid consumption while a negative value indicates acid generation (Lawrence and Marchant, 1991).

Samples from C-Mine and E-Mine were both analysed using the methodology described in the preceding paragraph. Samples collected by Fourie (2013) were analysed using a variation of this methodology. Instead of only measuring acid generation potential and neutralisation potential, leachate generated during the test is also analysed for a range of elements using ICP methods. Additionally, the method used in the study by Fourie (2013) uses hydrogen peroxide instead of HCl in an attempt to only oxidise sulfide sulfur from a sample and measuring its concentration to calculate acid generation potential. This method assumes a closed system where little to no CO_2 can escape and the resulting H_2CO_3 contributes to the final measured pH of an analysed sample. This method is comparable to the Modified Sobek method in that it attempts to isolate sulphide sulfur for reaction, albeit using a different approach to this part of the analysis.

4.9 Leachate Chemistry

Samples collected at the various study sites were subjected to distilled water leaching tests. This type of leaching test is named “Shake Extraction of Solid Waste with Water”, or the “Neutral Leaching Procedure”. The test method was developed by the American Society for Testing and Materials (ASTM) and assesses the leaching potential of solid waste (ASTM D-3987-85). To perform this leaching test, a specified mass of material is mixed with leaching fluid, in this case distilled water. The liquid to solid ratio for the test is 20:1 and the mixture is then agitated for approximately 18 hours. Subsequently formed leachate is then separated from the solids and analysed. For this specific study, the inductively coupled plasma – optical emissions spectroscopy analysis (ICP-OES) method was used to identify the metal cations in solution. Ion chromatography was used to identify anions in solution.

4.10 Interpretation of Available Groundwater Monitoring Data

Groundwater monitoring data for the investigated sites was made available by the various mining companies responsible for the sites. Data received include major ion analysis data as well as

physical-chemical parameters. Identification of trends as well as statistical analyses were performed on the data to identify various evolutionary stages in the flushing of the backfilled mines. This included fitting the data with trend lines and also calculating the minimum, maximum and average concentrations of selected elements and parameters, comparing various parameter sets and relating trends in the monitoring data to specific rehabilitation practices for each site. This data proved useful in construction of the conceptual hydrogeological and geochemical models as well as in the calibration of numerical models. This data formed an important part of the basis for the characterisation of the source term and was critical in calculating long term trends and their sensitivity to various rehabilitation practices.

4.11 Statistical Analysis of Geochemical Data

Statistical analyses were performed on the data of this study to determine obvious and "hidden" relationships as well as controlling parameters in the geochemical system using IBM's SPSS 20. To identify these relationships, the data was correlated using a correlation matrix. All available XRD, leach testing and acid-base accounting results were used in the correlation matrix for bivariate regression analysis using the Pearson method with a two-tailed significance test. Significance levels used were 90 and 95%. This was performed to determine the relationships between parameters to establish potential cause-effect relationships between minerals and elements in solution. Relationships were also identified between elements in solution and the effect of this on mineral weathering and precipitation.

Principal component analysis (PCA) was also performed on the data for comparison of analysed parameters and to further investigate controlling parameters in the geochemical system. Eigenvalues greater than 0.5 were identified using the method of principal components with no rotation of the eigenvectors specified. Interpretation of the PCA results showed which processes control the mine water chemistry to the largest extent and also shows which parameters should be the main focus of geochemical model calibration.

Further to the principal component analysis was the construction of a dendrogram to identify hierarchical clusters of samples with similar parameters. Ward's method was used as the cluster method with the measure interval specified by squared Euclidian distance with no transformation of values. Results of the dendrogram interpretation aided in the explanation of why specific samples and sites showed a specific geochemical behaviour and why this may be different to other sites or samples.

4.12 Geochemical System Calibration

4.12.1 Model Construction and Calibration

The graphical user interface used to model and interpret geochemical data in this study is The Geochemist's Workbench® version 9.0 (Bethke, 2008). The model defines the geochemical system using mineral abundances, mineral reactive surface areas, mineral reaction rates and subsequent water qualities. As an input to the model, the identified minerals in the collected samples were averaged. However, as some variance in the averaged mineral assemblage may occur, the standard error for each mineral's average abundance was calculated and was then added as well as subtracted from the mean to define the upper and lower boundaries of the possible abundance of each mineral. These average mineral abundances were then defined in the model interface.

Following this step, the mineral reaction rates, as obtained from literature (section 4.7), were defined for each mineral. This was performed to create a kinetic geochemical model which may not necessarily reach equilibrium, as is the case in many geochemical systems. This is especially relevant in a laboratory analysis such as a leaching test, where minerals are unlikely to undergo complete reaction during leaching. Additionally, mineral reactive surface areas were calculated and defined as described in section 4.6.

To define a data set used for model calibration, the leaching test constituent concentrations were averaged. Again, some variance is expected and the standard error was calculated for each analysed constituent. The standard error was then added and subtracted from the mean concentration of the specific constituent to define the upper and lower boundaries for the possible concentrations of each constituent. Additionally, during this simulation, the oxygen fugacity was fixed at 0.21, as the system is open to atmospheric pressure during the leaching procedure.

The distilled water leaching test procedure (section 4.8) was simulated within the geochemical model. This entailed the reaction of the defined mineral assemblage with a distilled water leaching fluid. The final simulated concentrations were compared to the final leaching test concentrations. If the concentrations matched well with the average concentrations within the margins of the calculated standard error, the mineral assemblage was considered to be calibrated. However, if the results differed notably, the mineral assemblage, mineral weight percentages, reaction rates and reactive surface areas were revised. Each parameter, with regards to the defined mineral assemblage, was then varied within the acceptable boundaries to obtain a more representative simulated leachate. Parameters associated with the main controlling processes of the mine water chemistry, as identified during the statistical analyses, were favoured in this procedure.

4.12.2 Simulation of the Natural Geochemical System

Once the mineral assemblage was calibrated based on the leaching test data (section 4.12.1), it was simulated in the natural conditions expected to prevail in the opencast mine in a post-closure scenario. Therefore, an understanding of the recharge and groundwater volume in the backfilled opencast mine was required. These parameters were used to calculate the volume of fluid reacting with the calibrated mineral assemblage per time unit. For this study, these parameters were obtained from a pre-constructed numerical flow model as discussed in section 5.1.1, section 5.2.1 and section 5.3.1. The numerical flow model provided a constant daily rainfall volume and groundwater flow volume through the backfilled opencast mine.

Once these volumes were known, the ratio of the volume of water moving through the backfill material relative to the volume of the backfill material itself was calculated. This ratio was subsequently defined in the geochemical model with additional water being added to the geochemical simulation at the rate defined by the flow model. This scenario was then simulated in the geochemical model for the post-mining period in which groundwater monitoring data was available.

4.13 Chemical Calibration of the Numerical Flow Model

The data obtained from the simulation of the natural geochemical system (section 4.12.2) were integrated into a mass transport model, based on the solution of a numerical flow model. For this study, GMS® 10.0 was used as the graphical user interface for the MODFLOW® (McDonald and

Harbaugh, 2003) numerical code. Pre-constructed models were used to integrate the data using the MT3DMS® (Zheng and Wang, 1999) mass transport code.

To integrate the data from the geochemical model, the numerical flow model was first constructed and calibrated to the post-mining situation. This was performed using water level monitoring data available from the time after mine closure, to obtain a calibration. Once the flow model was calibrated based on water level data, the geochemical model's solution was integrated into the mass transport model.

The concentration of sulfate over time was specified in the mass transport model using a specified time dependent concentration in the backfilled opencast mine, populated with concentrations obtained from the geochemical model. Various sulfate concentrations were specified using time steps and stress periods. After these concentrations were specified, using the data from the geochemical model, the mass transport simulation was performed. Resulting concentrations at observation wells were then compared to the available monitoring data within the mass transport model. Calculated concentrations must fall within a specified error range. If this was not the case, the geochemical model, numerical flow model and mass transport model parameters were reviewed and a gap analysis was performed on the conceptual model. Parameters were then adjusted within the acceptable statistical boundaries until an improved calibration was obtained. These parameters included recharge rate, fluid to rock ratios and inflow volumes into the backfilled opencast pit from the surrounding aquifer. Therefore, a trial and error approach was used, similar to the calibration of a numerical model using transient water level data, to obtain a "chemical calibration" of the transport model. Once this "chemical calibration" was obtained within the specified criteria, the transport model was assumed to be calibrated.

This was followed by the simulation of the long term fluid-rock interaction in the backfilled opencast mine, using the geochemical model. The specified model term length was selected based on the project requirements. The solution obtained from the geochemical model was then integrated into the mass transport model as described for the "chemical calibration" procedure, and the long term contaminant transport was then simulated in terms of sulfate.

Unfortunately, no redox measurements were made available for the mine sites investigated as part of the monitoring data. Redox profiles would aid greatly to ensure the correct sampling depth and to provide a better understanding of the hydrochemistry of the aquifer system. This data would be useful to determine possible mineral precipitation and dissolution along the flow path and could provide an indication of preferential flow paths for mine water. Additionally, mineral stability and weathering rates could be determined with greater accuracy.

4.14 Geochemical Sensitivity Analyses and Implications for Rehabilitation Practices

After calibration of the geochemical model, a trial and error sensitivity analysis was performed to determine the most sensitive parameters influencing the calculated solution. This was performed by varying parameters such as mineral weight percentages, mineral reactive surface areas, mineral reaction rates, gas fugacities and fluid to rock ratios. The sensitivity analysis was performed to determine which parameters have the greatest effect on the simulated solution. Therefore, if the conceptual model must be revisited at a later time to update the various models, the most sensitive

parameters can be assessed first. The sensitivity analysis provided an indication of which parameters should be assessed and quantified to the highest accuracy (Table 10).

Table 10: Parameters Selected for Sensitivity Analysis of the Model Inputs and Their Relation to Site Conditions

Parameter Varied	Reason	Relation to Rehabilitation Practice
Oxygen Fugacity	Oxygen in the backfilled opencast mine plays a critical role in the rate of disulfide oxidation and weathering as well as the concentration of sulfate released	Oxygen ingress to the backfilled opencast mine can be related to the rate and degree of flooding of the backfilled opencast mine as well as the degree of covering and capping provided to the system by means of compaction and material placement. If the mine is not fully flooded and not well compacted, oxygen ingress rates are likely to be higher which will influence disulfide oxidation and weathering rates.
Gypsum Mass	The mass of gypsum in the backfill material of a backfilled opencast mine will contribute to the overall sulfate concentration in the mine water.	Gypsum mass in the system may not directly be influenced by rehabilitation practices but is certainly a product of the weathering of disulfides in the backfill material. However, postponing flooding and improper compaction and minimisation of oxygen ingress to the backfill material is likely to cause a larger mass of gypsum to form within the material.
Gypsum Surface Area	The reactive surface area of gypsum in the backfill material of a backfilled opencast mine plays a role in regulating the rate of sulfate release.	Gypsum reactive surface area in the system may not directly be influenced by rehabilitation practices but is certainly a product of the grading of the backfill material. If backfill material is not selectively placed taking grading into account fine grained material may be exposed to the most oxygen. This will cause the weathering of disulfides with larger reactive surface areas creating finer grained gypsum crystals with larger reactive surface areas.
Gypsum Reaction Constant	The reaction constant of gypsum in the backfill material of a backfilled opencast mine plays a role in regulating the rate of sulfate release.	The reaction constant of gypsum is an inherent property of the mineral phase unrelated to rehabilitation practice.
Pyrite Mass	The mass of pyrite in the backfill material of a backfilled opencast mine will contribute to the overall sulfate concentration in the mine water as well as changes in pH.	Pyrite mass in the system may not directly be influenced by rehabilitation practices but is an inherent property of the geology of the specific site. Postponing flooding and improper compaction and minimisation of oxygen ingress to the backfill material is likely to cause further weathering of these minerals. However, water plays an integral part in the oxidation of this mineral phase and it will therefore continue to weather at a specific rate depending on inflows to the pit as well as access to oxidising species.

Pyrite Surface Area	The reactive surface area of pyrite in the backfill material of a backfilled opencast mine plays a role in regulating the rate of sulfate release.	Pyrite reactive surface area in the system may not directly be influenced by rehabilitation practices but is certainly a product of the grading of the backfill material. If backfill material is not selectively placed taking grading into account fine grained material may be exposed to the most oxygen. This will cause the weathering of disulfides with larger reactive surface areas .
Pyrite Reaction Constant	The reaction constant of pyrite in the backfill material of a backfilled opencast mine plays a role in regulating the rate of sulfate release.	The reaction constant of pyrite is an inherent property of the mineral phase unrelated to rehabilitation practice.
Input Rate of Water	The input rate of water into a backfilled opencast mine from recharge and groundwater inflows plays a major role in the rate of mineral weathering and contaminant release as well as the dilution of this contamination and its transport into the aquifer. It is also a major contributor to the depletion of the contaminant source.	The input rate of water from recharge and inflows from groundwater are a function of the compaction of backfill material. Poorly compacted material is likely to allow higher volumes of water to enter the backfilled opencast mine. This will cause enhanced weathering and leaching of primary and secondary minerals potentially depleting the contaminant source at a faster rate but also causing higher levels of contamination.

Based on this sensitivity analysis and the identification of the most sensitive parameters, changes in current rehabilitation techniques could be proposed such as selective placement of acid-generating materials at the top of the deposition sequence to promote leaching and source depletion. An example would be to increase oxygen ingress and water flow through the system to increase the weathering of disulfides which would be the stoichiometric limiting factor in the oxidation reaction of these minerals. This could lead to faster flushing of contaminants and acidity from the backfilled opencast mine. Therefore, the sensitivity analysis is imperative not only in determining the highest priority parameters for calibration and quantification but also in the planning of management measures and rehabilitation techniques. The sensitivity analysis acts as a guide depending on the liabilities preferred to determine post-closure scenarios that best suit a mining company's finances and investment planning. It highlights parameters that can be influenced to determine a desired outcome in the resulting hydrochemistry after mine closure.

4.15 Assumptions and Limitations

Although all efforts have been made to base the research conducted on the most representative data and following a logical scientific approach (Figure 16), some limitations are recognised and certain assumptions were made:

- It is recognised that pit geometry and backfill porosity are highly variable parameters and best estimates were used in the calculation of these parameters using available data.

- Inflow and outflow of the investigated pits was estimated using numerical modelling. Although this may not be perfectly accurate and only estimates based on available data, defensible results were obtained based on measured monitoring data.
- It is recognised that some mineral phases are not detected by the chosen mineralogical analysis method. Abundances of some mineral phases were therefore estimated.
- Mineral reaction rates were sourced from literature and may not be representative of site specific reaction rates. However, variance of no more than one order of magnitude was assumed to ensure defensible inputs.
- It is recognised that the total surface area of each mineral is not necessarily available for reaction and that mineral grains are not spherical and in closest packing. However, based on the literature reviewed, calculation of reactive surface areas based on these assumptions still provide a defensible result when compared with the BET method.
- It is recognised that static leach testing provides only a single potential result and is not suitable for kinetic prediction by itself. However, kinetic parameters were incorporated into the simulation of leach tests and the calibration of the simulated mineral assemblage, showing that a kinetic component is therefore shown to be present in these leaching tests.
- Although limited sampling data is available for statistical analysis per site, the combined number of samples is deemed sufficient to perform at least indicative statistical analyses which are supported by an abundance of monitoring data.
- It is recognised that the sampling method for the monitoring data may have varied between sampling events and sample depths are unknown. These unknown parameters may contribute to the cause of simulation inaccuracies but the amount of data available is deemed sufficient to determine general trends. This was determined by fitting data with exponential trend lines.

Additional actions that could be further investigated to augment results include:

- Quantification of oxygen fugacity profiles with depth in flooded and backfilled opencast mines.
- Quantification of reactive surface areas and reaction rate constants in non-ideal conditions for minerals above and beyond best estimation and laboratory techniques, respectively.

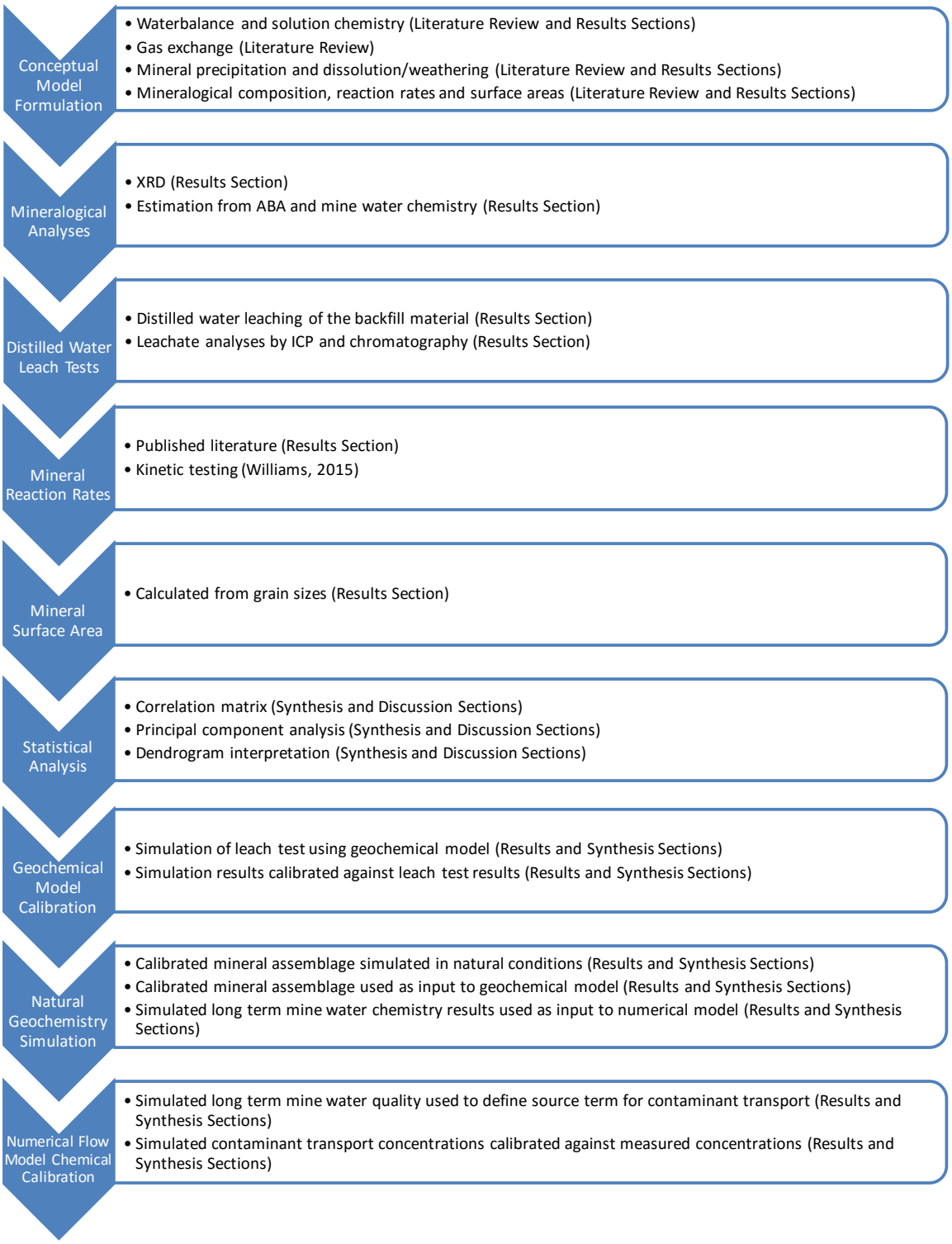


Figure 16: Flow-chart of steps in the modelling methodology

5 Results

5.1 C-Mine

5.1.1 Numerical Flow Model

The following parameters were specified within the numerical model (Table 11):

Table 11: Input parameters to the numerical flow model for C-Mine

Model Parameter	Value	Unit	Reason
Recharge to the aquifer	0.0001	m/d	Calculated
Recharge to the backfilled opencast mine	0.0004	m/d	Hodgson and Krantz (1998)
Evapotranspiration	0.005	m/d	Calculated
Boundaries	Topographic water divides	-	Existing boundary conditions present at the site that would potentially include modelled impacts
Refinement	20	m	Based on the scale of the mining area
Grid dimensions	427 x 484	Cell count	Product of the grid refinement
Hydraulic conductivity	0.01	m/d	Existing hydrogeological report (Du Toit, 2010)
Hydraulic anisotropy (vertical)	10	-	Anderson et al. (2015)
Effective porosity	5 declining to 3 with depth in each layer	%	Wang et al. (2009)
Layers	4	Count	Mining depth is 20m
Longitudinal dispersion	50	m	Schulze-Makuch (2005)
Mean residual head error	1.5	m	Head error statistics
Head error range	10	m	Calculated as 10 % of the difference between the maximum and minimum calculated head elevations

Flow directions interpreted from the numerical flow model showed that flow is directed away from the backfilled opencast mines. Groundwater flow is expected to follow the topography towards local drainage channels (Figure 17) as shown by monitoring data. This was confirmed by the calibration of the model to transient monitoring data (Figure 18).

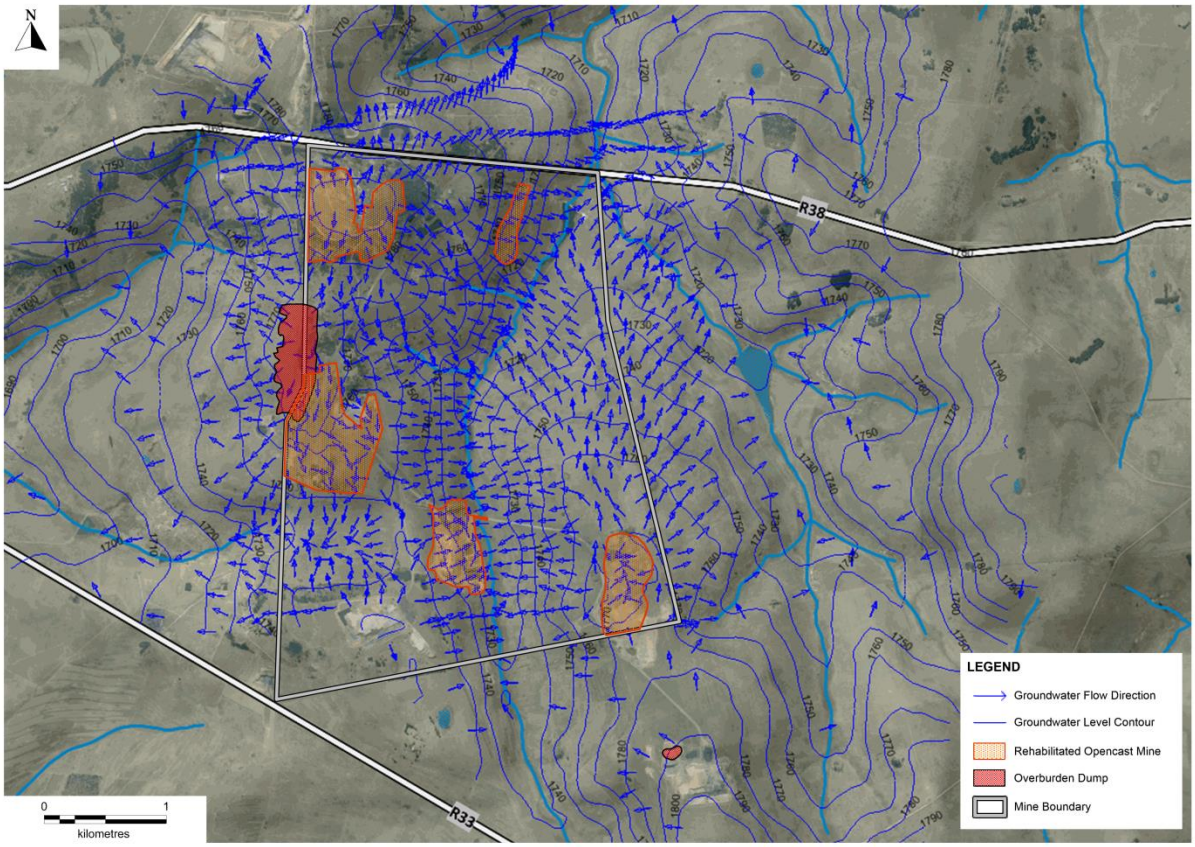


Figure 17: Groundwater flow directions at C-Mine Colliery

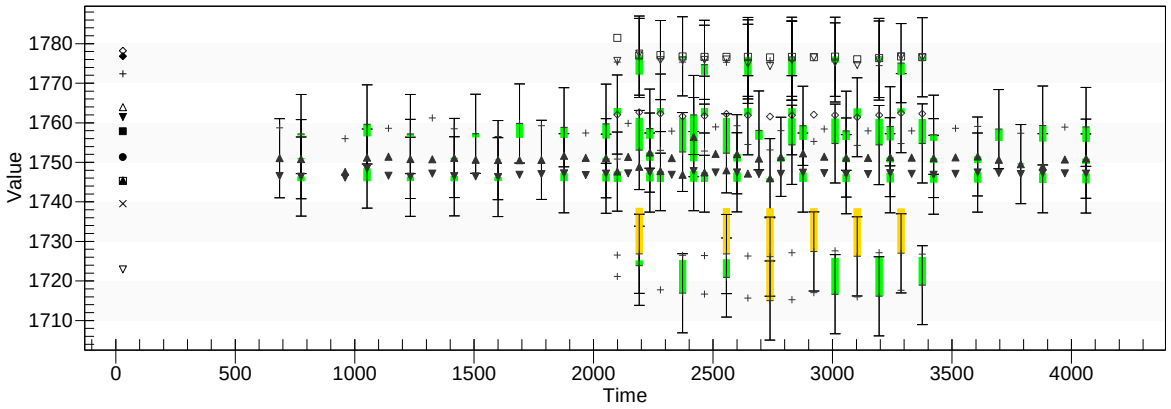


Figure 18: Transient head calibration graph for the numerical model constructed for C-Mine Colliery

Based on the calibrated model, the inflow rate into the backfilled opencast mines were estimated. Maximum inflow volumes calculated for the backfilled opencast mines on site ranged between 30 and 40 m^3/day. Assuming that the porosity of the backfill material in the backfilled opencast mines is 30% and multiplying this with the pit surface area and average depth a volume was calculated for the potentially fillable void space within the backfill material. This equated to an initial fluid to rock ratio of 2.5×10^{-4}:1 based on rainfall volumes with additional water being added to the system via inflows to the pit from the aquifer at a fluid to rock ratio of 2.5×10^{-5}:1.

5.1.2 Mineral Abundances

Samples collected from the backfilled opencast mines were composited to represent each backfilled mining area e.g ESG134 is a composite sample of ESG1, ESG3 and ESG4. The XRD analysis results for the backfill material samples collected from backfilled opencast mines at C-Mine (Figure 19) show that quartz, microcline k-feldspar, kaolinite and smectite are the predominant mineral phases present (Table 12). Minerals with a lesser abundance in the samples include hematite, plagioclase and muscovite.

Table 12: Mineral Phases Identified During Analysis of Six Backfill Samples at C-Mine; Mineral Phase Abundances Reported as Weight Percentage

Mineral Phase	ESG134	ESG678	ESG91011	ESG17	ESG2021	Pembali Mining 1
Hematite	1.33	0.37	1.17	0.36	1.04	0.36
Kaolinite	25.07	5.34	21.69	9.97	24.52	12.78
Microcline	13.44	9.15	14.50	8.66	10.91	8.57
Muscovite	6.7	3.97	7.28	5.17	8.11	4.85
Plagioclase	-	10.14	-	-	-	-
Quartz	53.47	28.61	55.40	38.85	55.41	39.78
Smectite1	-	37.98	-	37.0	-	33.67
Smectite2	-	4.43	-	-	-	-

In addition to the mineralogical analyses, sulfide mineral abundances were estimated. Mine water chemistry (Table 14) and acid-base accounting analyses (Table 13) were used to estimate the rock type according to the method of Price et al. (1997) as well as the abundance of sulfide minerals in the backfill material (Huisamen and Naidoo, 2014).

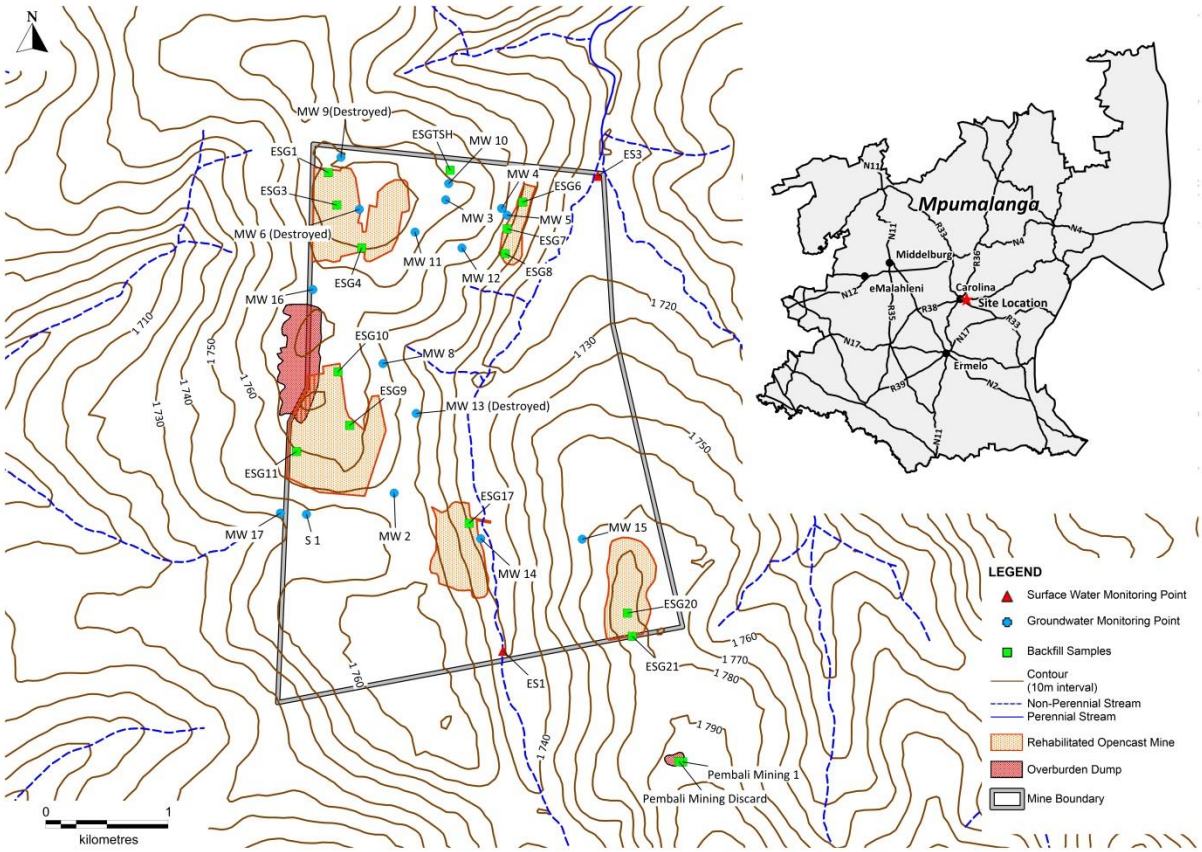


Figure 19: Sample collection areas at C-Mine

Table 13: Acid-base accounting results for backfill samples collected at C-Mine (Huisamen and Naidoo, 2014) – Neutralisation potential and Net Neutralisation Potential (NNP) expressed as $CaCO_3$ equivalent kg per ton

Sample Number	ESG134	ESG678	ESG91011	ESG17	ESG2021	Pembali Mining 1
Paste pH	5.8	7.0	6.6	6.0	6.1	6.1
Sulfur (%) (LECO)	0.30	0.02	0.04	0.05	0.02	0.07
Acid Potential (AP) (kg/t)	9.38	0.63	1.25	1.56	0.63	2.19
Neutralization Potential (NP)	0.50	1.50	2.00	0.25	1.75	-0.50
Net Neutralization Potential (NNP)	-8.88	0.87	0.75	-1.31	1.13	-2.69
Neutralising Potential Ratio (NPR) (NP : AP)	0.05	2.40	1.60	0.16	2.80	0.23
Rock Type	I	III	III	II	III	II

Table 14: Analysis results of C-Mine mine water discharge (Huisamen and Naidoo, 2014); concentrations presented in mg/L

Analysed Constituent	Concentration
pH	7.66
Temperature in °C	25
Measured Electrical Conductivity in mS/m	47.2
TDS Calculated (EC × 0.99:(Hubert and Wolkersdorfer, 2015))	46.7
Alkalinity as $CaCO_3$	48.9
Al	<0.05
Ca	31.5
Fe	0.13
K	6.15
Mg	34.9
Mn	<0.05
Na	16.8
Si	1.13
F	0.289
Cl	9.77
NO_2	<0.2
NO_3	<0.3
PO_4	<0.8
SO_4	189
Ion balance error (%)	2

5.1.3 Distilled Water Leach Tests

Six samples were collected from C-Mine Colliery and submitted for distilled water leach testing. The subsequent leachates were analysed using ICP-OES for major metal cations while anion concentrations were determined by ion-chromatography. Leachate pH is lowered by the material and the predominant leached constituent from the material is sulfate (Table 15).

Table 15: Leachate Analysis Results for C-Mine

Analysed Constituents (mg/L)	ESG134	ESG678	ESG91011	ESG17	ESG2021	Pembali Mining 1
Al	0.332	1.04	<0.100	<0.100	<0.100	<0.100
Ca	38	4	7	3	<2	3
Fe	0.045	0.751	<0.025	0.039	<0.025	0.028
K	6.1	<1.0	4.67	4.22	1.85	4.47
Mg	14	2	5	3	<2	4
Mn	7.66	0.039	0.419	0.038	0.087	0.050
Na	3	4	3	3	<2	3
Si	4.20	9.50	3.57	3.88	3.57	4.86
TDS Measured	322	61	52	51	51	59
Alkalinity as $CaCO_3$	<5	<5	<5	<5	<5	<5
Cl	<5	6	<5	<5	<5	<5
SO_4	203	42	38	36	9	42
NO_3	<0.2	<0.2	0.4	0.4	0.2	0.5
pH	4.4	6.4	4.7	4.5	4.9	4.6
EC	42.9	6.4	13.5	9.7	4.0	10.9

5.1.4 Mineral Reaction Rates

Estimated mineral abundances were averaged based on XRD analyses, acid-base accounting and mine water analyses. The standard error and standard deviation were calculated for each mineral phase and the reaction constant for each phase was obtained from literature (Table 16). With the applicable references and assumptions the initial reactive surface area was also calculated based on the described methodology (Table 16).

Table 16: Calculated statistics, rate constants and reactive surface areas from the XRD results of six backfill samples from C-Mine

Mineral Phase Based on Analysis Data	Mean, mass %	Standard Deviation, mass %	Standard Error of mean mass %	Initial Reaction Rate Constant, $mol \cdot cm^{-2} \cdot s^{-1}$	Initial Reactive Surface Area, $cm^2 \cdot g^{-1\#}$
Hematite	0.77	0.46	0.19	5×10^{-11} [a]	57
Kaolinite	16.56	8.32	3.39	1×10^{-17} [b]	58
K-Feldspar	10.87	2.57	1.05	1.7×10^{-17} [c]	58.5
Muscovite	6.01	1.59	0.65	2.9×10^{-15} [d]	53
Plagioclase	2.03	4.53	1.85	1.0×10^{-16} [e]	55
Quartz	45.25	11.15	4.55	5.0×10^{-14} [f]	22.5
Smectite	36.22	2.26	0.92	3.0×10^{-15} [g]	60
Pyrite	0.03 *	n.a.	n.a.	2.8×10^{-12} [h]	104
Gypsum	0.05 *	n.a.	n.a.	1.3×10^{-04} [i]	26

[a]Hersman et al. (1995); [b]Huertas et al. (1999); [c]Oelkers and Schott (1998); [d]Oelkers et al. (2008); [e]Gudbrandsson et al. (2014); [f]Gautier et al. (2001); [g]Marty et al. (2015); [h]Malmström et al. (2006); [I]Jeschke et al. (2001); [*]Estimated based on field observations, acid-base accounting, grain sizes and literature data; [#]Calculated from sample average grain size and mineral density, assuming entire surface is available for reaction (Brantley, 1998, Gautier et al., 2001, White and Brantley, 2003); n.a.: not applicable.

5.1.5 Groundwater Monitoring Data

A comparison of selected parameters was performed on the available groundwater monitoring data for C-Mine. Results of this comparison are described below for each monitoring well.

MW2 (Figure 20)

Low concentrations of SO_4 can be observed in the data collected from this well as well as a slightly alkaline pH indicating buffering reactions taking place. This is further supported by the high alkalinity concentrations observed in the data. Fe concentrations for this well are low and remain relatively stable due to the buffering effect of the high alkalinity concentration relative to that of sulfate.

MW3 (Figure 21)

Alkalinity concentrations in this well are elevated at the start of the monitoring period but are lowered by the end of 2011 which is also the case for the pH values observed. After this a fairly stable pH is observed with steadily increasing sulfate concentrations and decreasing alkalinity concentrations. Fe concentrations observed in this well vary by an order of magnitude or more per year of monitoring but do not exceed a concentration of 1 mg/L.

MW4 (Figure 22)

Sulfate concentrations below 20 mg/L are maintained in this monitoring well throughout the monitoring period with steadily decreasing and varying alkalinity concentrations. Also, a variable pH can be observed in the monitoring data corresponding to the alkalinity concentrations observed. Fe

concentrations in this monitoring well are highly erratic with a maximum concentration of 2.38 mg/L evident in 2006.

MW5 (Figure 23)

Elevated concentrations of SO_4 can be observed at the start of the monitoring period in 2001 up to 2004 where a lower concentration is maintained until the end of the monitoring period. Variable alkalinity concentrations are observed with a relatively stable and slightly alkaline pH value. Fe concentrations vary between 0.01 and 10 mg/L over the monitoring period and appear to vary seasonally.

MW6 (Figure 24)

Elevated sulfate concentrations can be observed in this monitoring well during 2002 and 2005 with Fe concentrations varying in a similar fashion. However, the slightly elevated concentrations of alkalinity remained fairly stable over the monitoring period never exceeding 140 mg/L $CaCO_3$ equivalents. A stable, slightly alkaline pH can also be observed throughout the monitoring period.

MW8 (Figure 25)

Variable sulfate concentrations can be observed in this monitoring well inversely corresponding to alkalinity concentrations indicating buffering of produced acidity. This is also reflected in the variations in pH and Fe concentrations.

MW10 (Figure 26)

A gradual decrease in sulfate concentrations over the monitoring period can be observed in this monitoring well with a starting concentration of around 600 mg/L. Low concentrations of alkalinity can be observed throughout the monitoring period but a gradual rise in pH can be observed from 2010 to 2014. A gradual decrease in Fe concentrations over the monitoring period can also be observed.

MW11 (Figure 27)

A variable but gradually increasing concentration of sulfate concentrations can be observed in this monitoring well over the monitoring period. However, inversely corresponding alkalinity values can also be observed as well as a relatively stable, neutral pH value. A variable Fe concentration can also be observed over the monitoring period, gradually increasing over time.

MW12 (Figure 28)

A variable sulfate concentration is evident in this monitoring well, although gradually increasing over the monitoring period. However, a relatively constant pH value and alkalinity concentration is also present with Fe concentrations largely mimicking sulfate concentrations.

MW13 (Figure 29)

A fairly constant sulfate concentration and pH value can be observed in this monitoring well with gradually decreasing alkalinity concentrations starting at around 60 mg/L $CaCO_3$ equivalents at the

start of the monitoring period. Variable Fe concentrations can also be observed displaying a decreasing trend.

MW14 (Figure 30)

Variable sulfate concentrations can be observed in this monitoring well showing a decreasing trend while alkalinity concentrations show an increasing trend. A variable, slightly acidic pH value can also be observed in this monitoring well with a steadily increasing Fe concentration over the monitoring period.

MW15 (Figure 31)

A decreasing alkalinity concentration can be observed in this monitoring well since early 2012 with a single concentration lowering observed in 2012. However, the sulfate concentration and pH value in this monitoring well remained relatively constant at low concentrations and slightly alkaline pH values. Fe concentrations in this monitoring well display an increasing trend since 2011.

MW16 (Figure 32)

Although a portion of the data for this monitoring well is missing, an increasing trend in sulfate and alkalinity concentrations can still be observed with a corresponding decrease in pH value. Fe concentrations show a similar increasing trend to sulfate concentrations over the monitoring period.

MW 17 (Figure 33)

A decreasing alkalinity concentration can be observed in this monitoring well since early 2012 with a single concentration lowering observed in 2012. However, the sulfate concentration and pH value in this monitoring well remained relatively constant at low concentrations and slightly alkaline pH values. Fe concentrations in this monitoring well display an increasing trend since 2011.

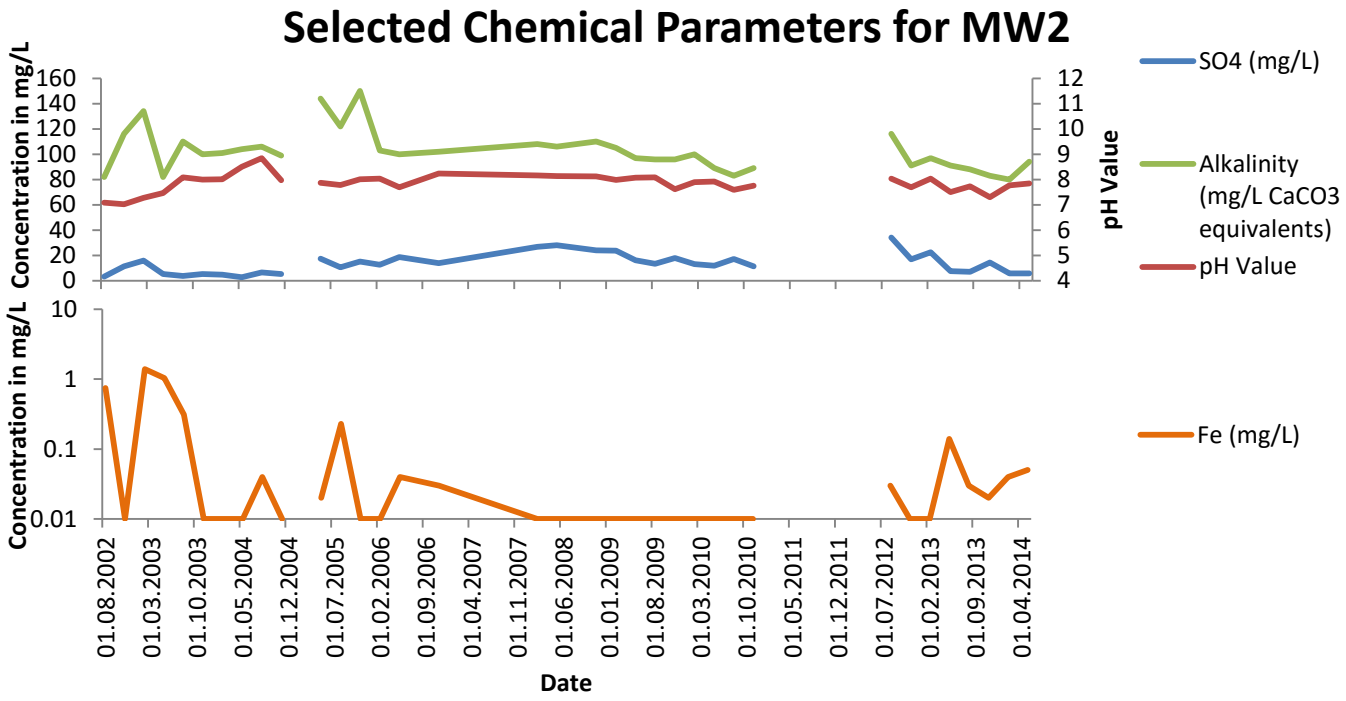


Figure 20: Groundwater monitoring data for MW2 at C-Mine (illustrating Fe, SO_4, pH and Alkalinity)

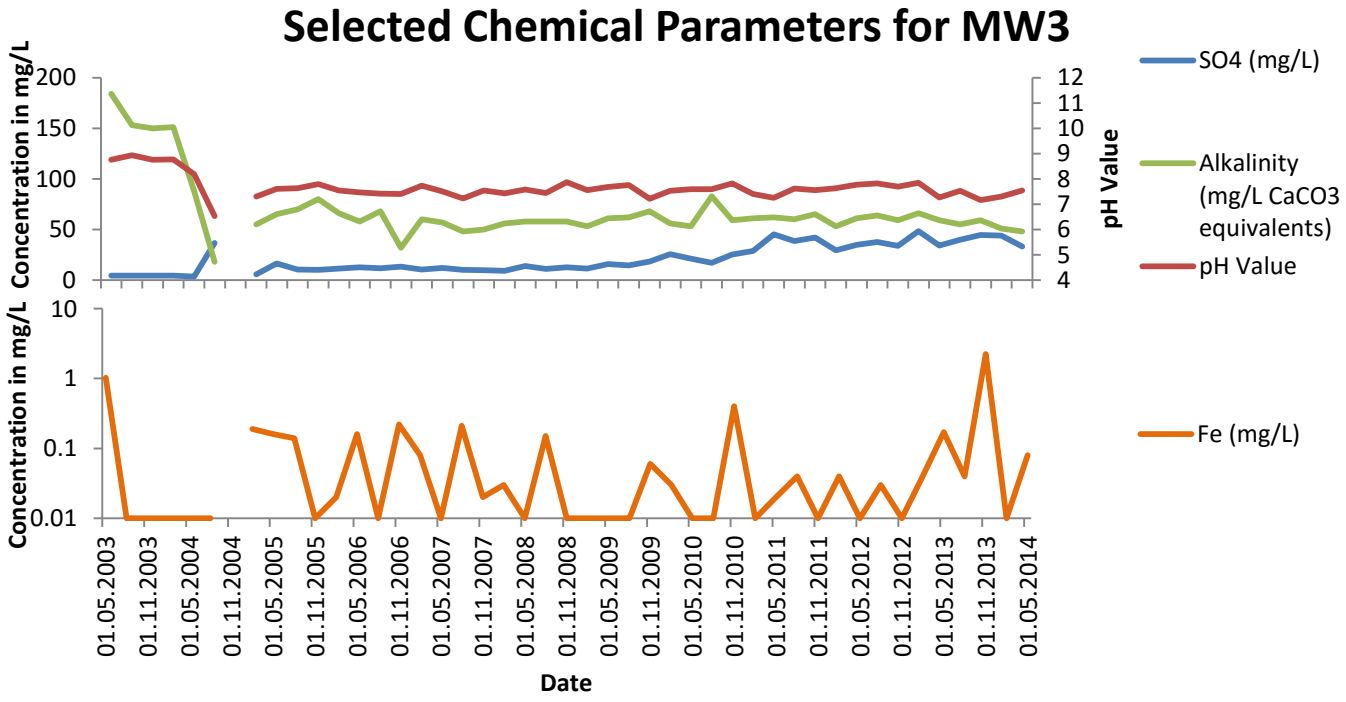


Figure 21: Groundwater monitoring data for MW3 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

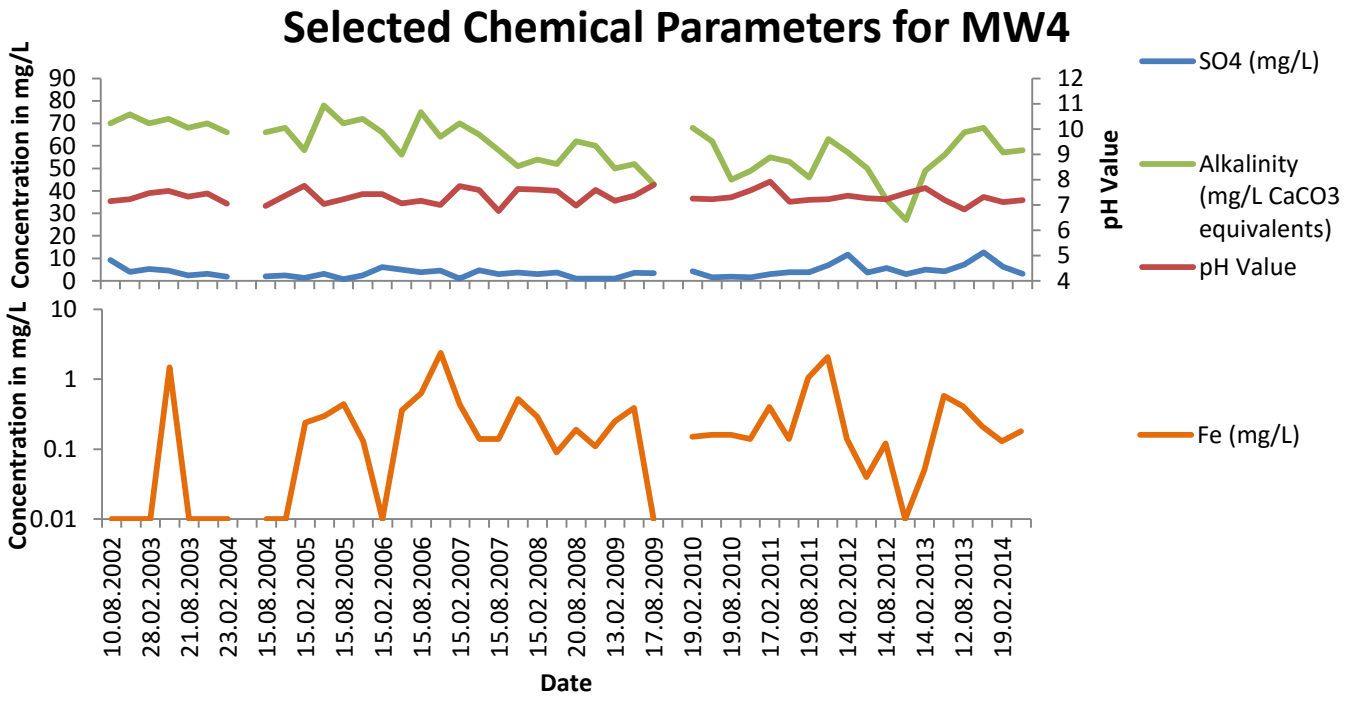


Figure 22: Groundwater monitoring data for MW4 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

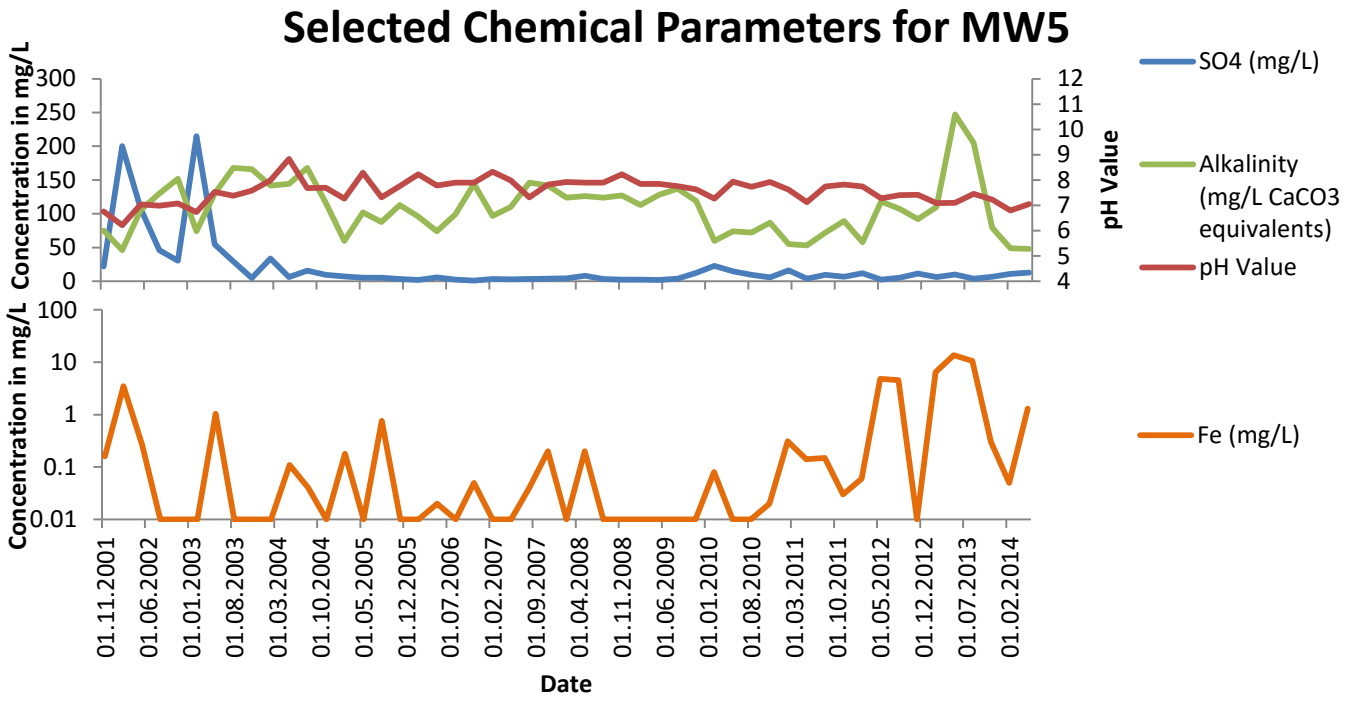


Figure 23: Groundwater monitoring data for MW5 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

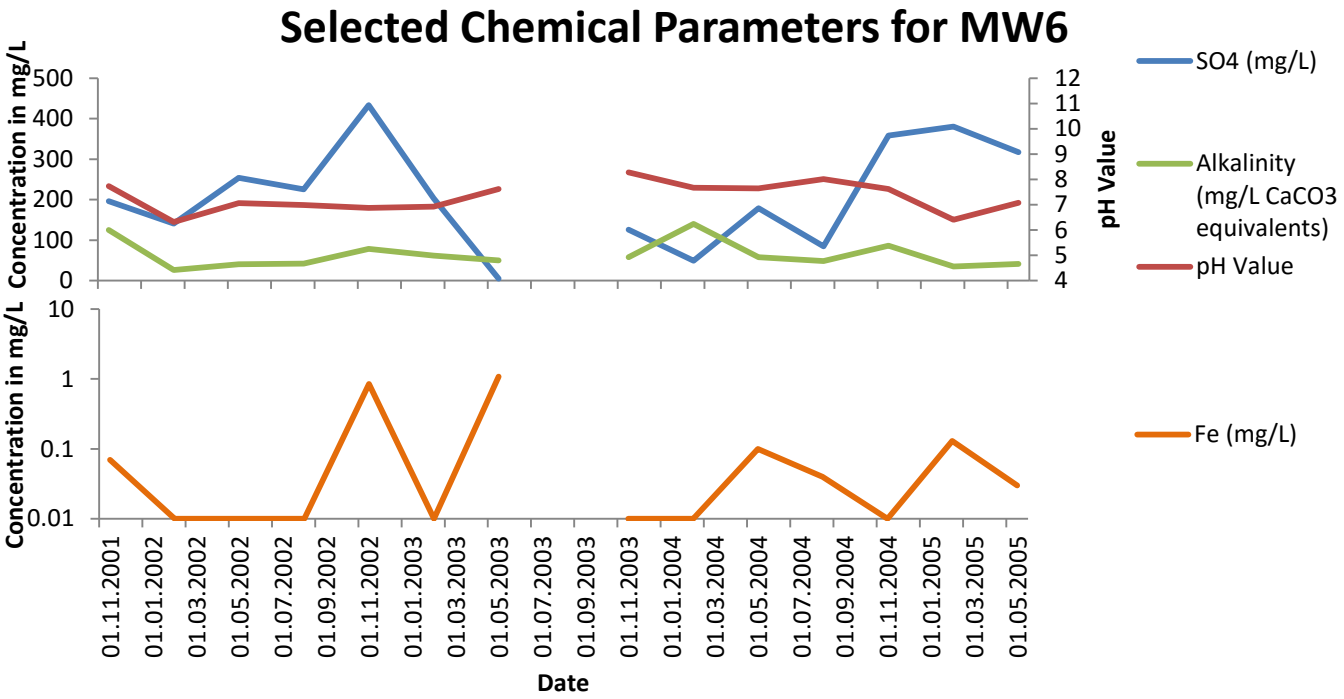


Figure 24: Groundwater monitoring data for MW6 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

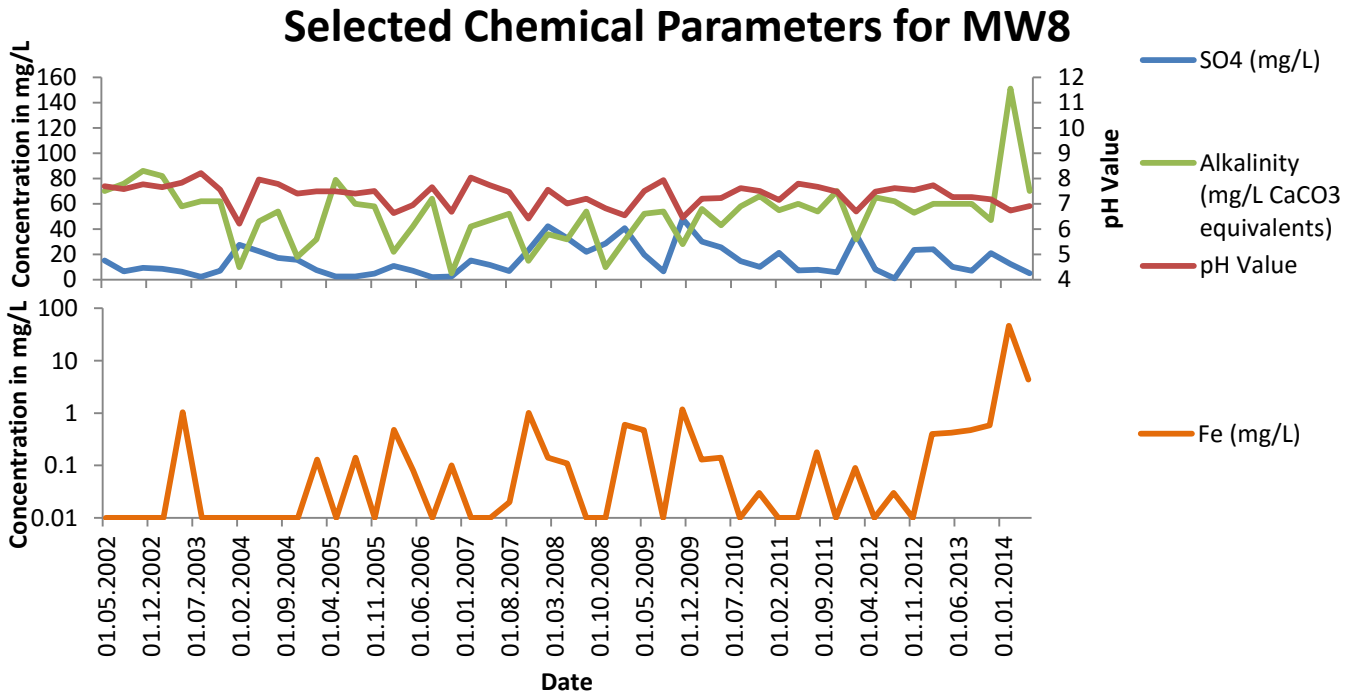


Figure 25: Groundwater monitoring data for MW8 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

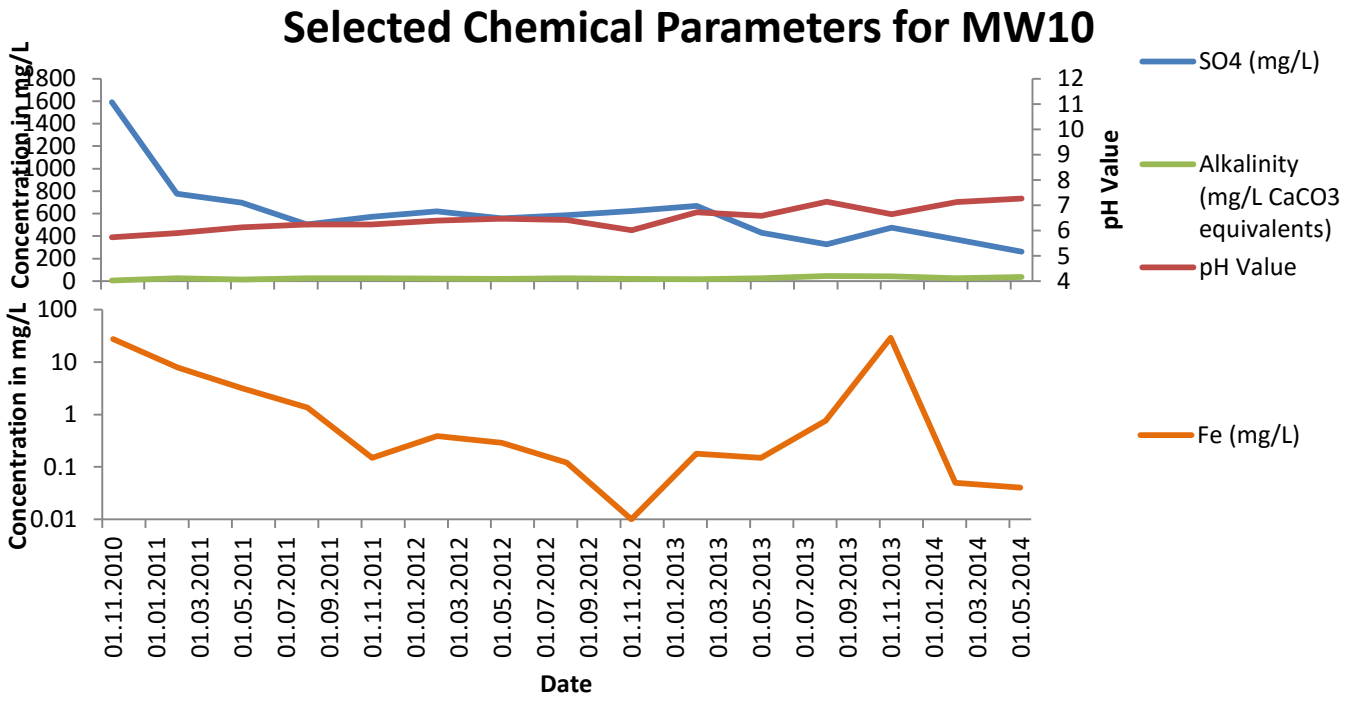


Figure 26: Groundwater monitoring data for MW10 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

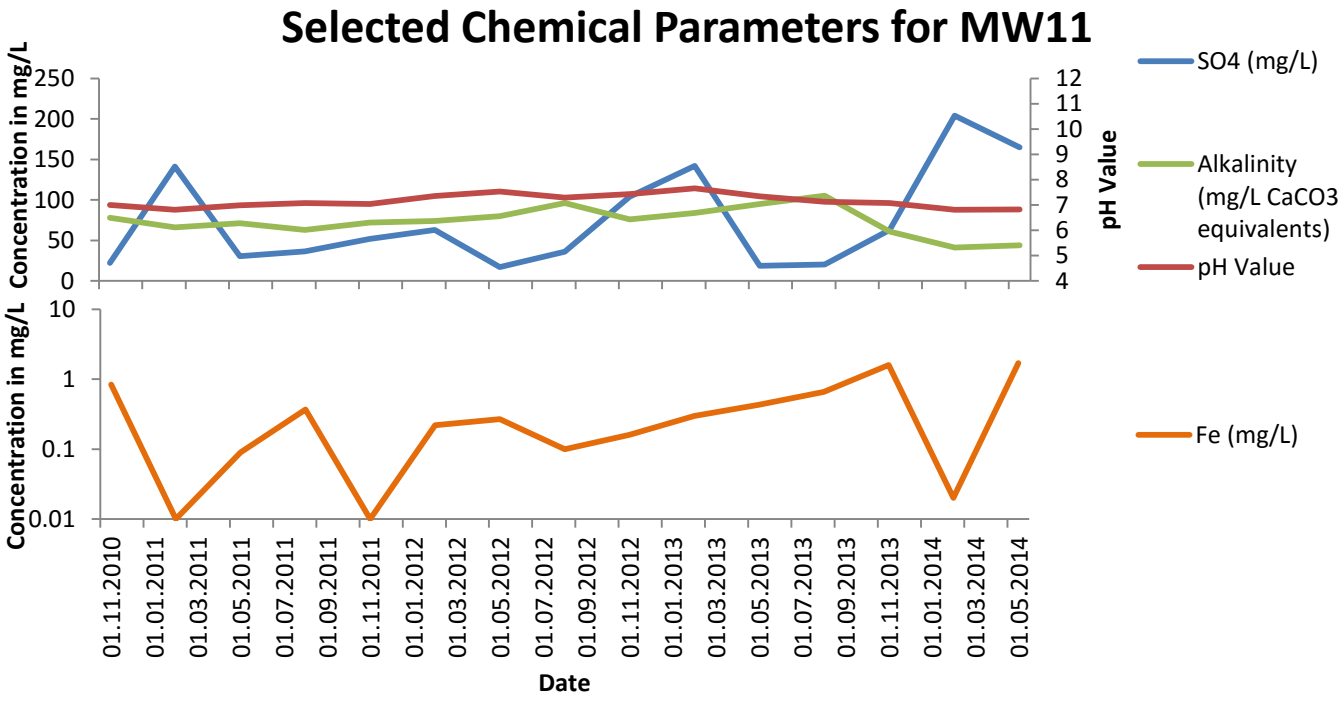


Figure 27: Groundwater monitoring data for MW11 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

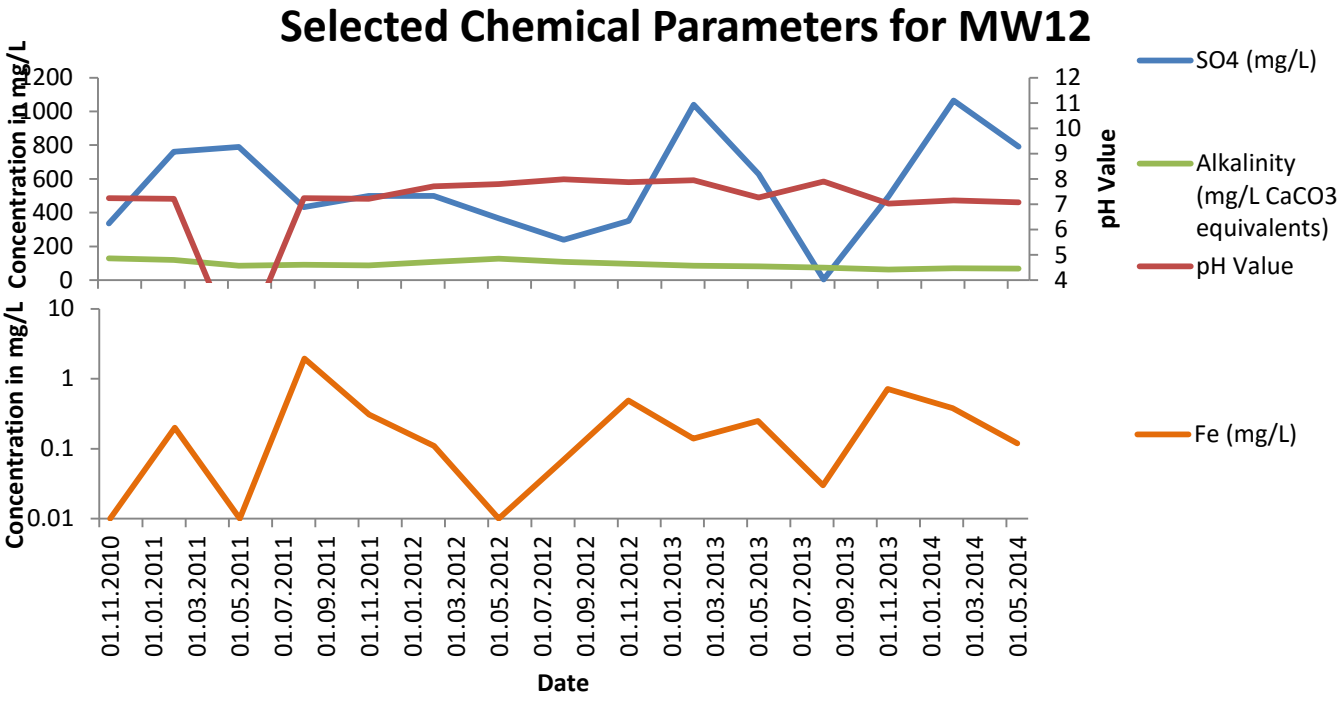


Figure 28: Groundwater monitoring data for MW12 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

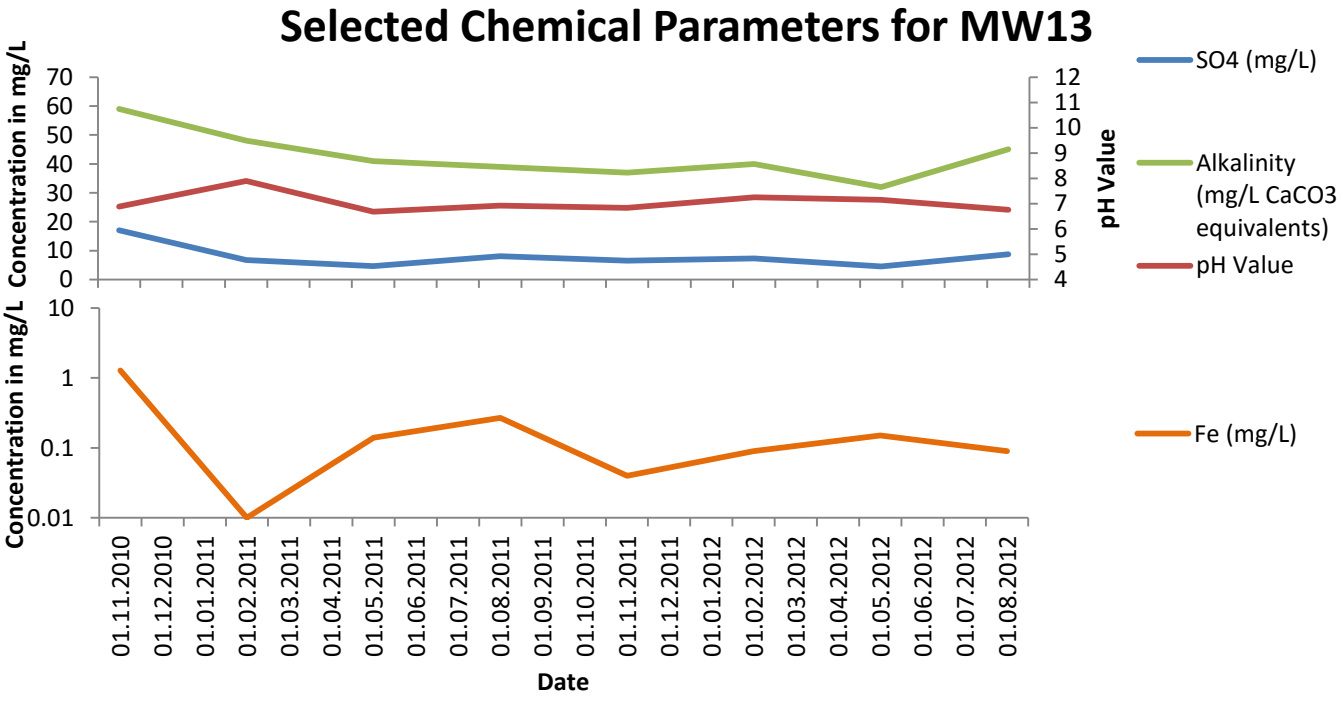


Figure 29: Groundwater monitoring data for MW13 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

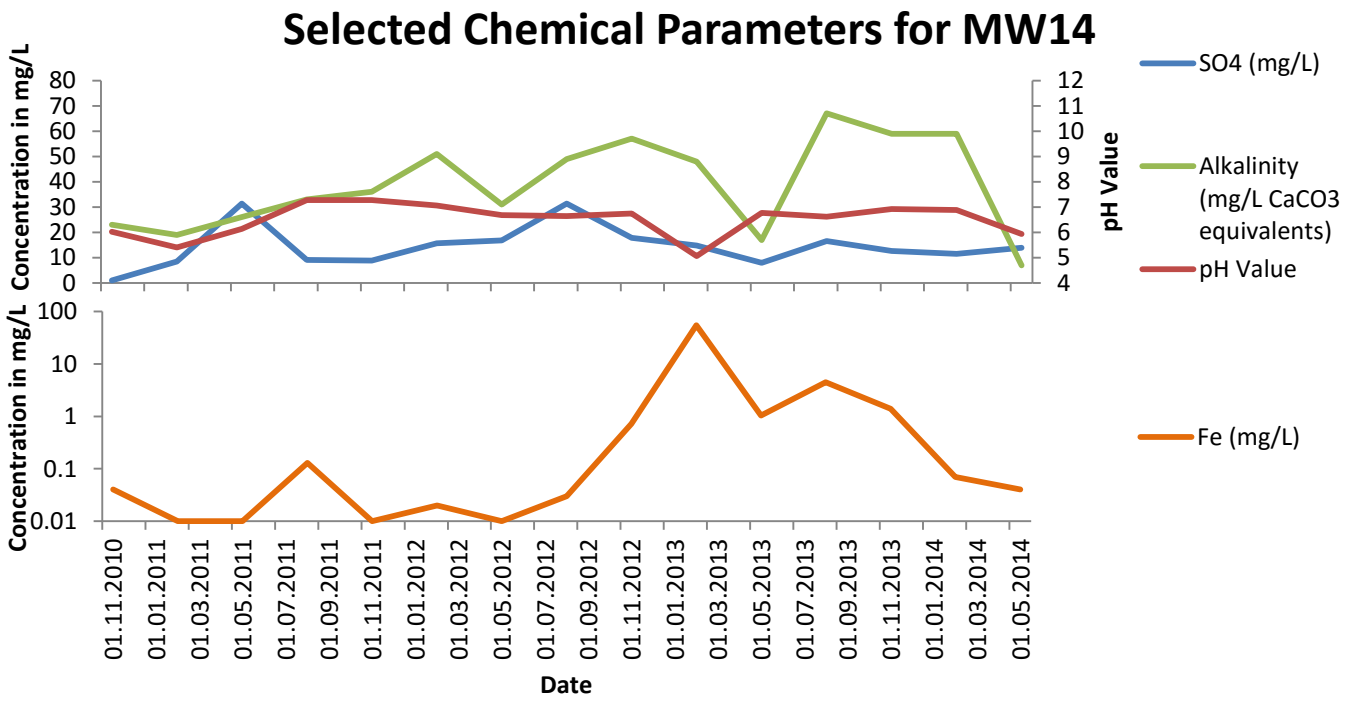


Figure 30: Groundwater monitoring data for MW14 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

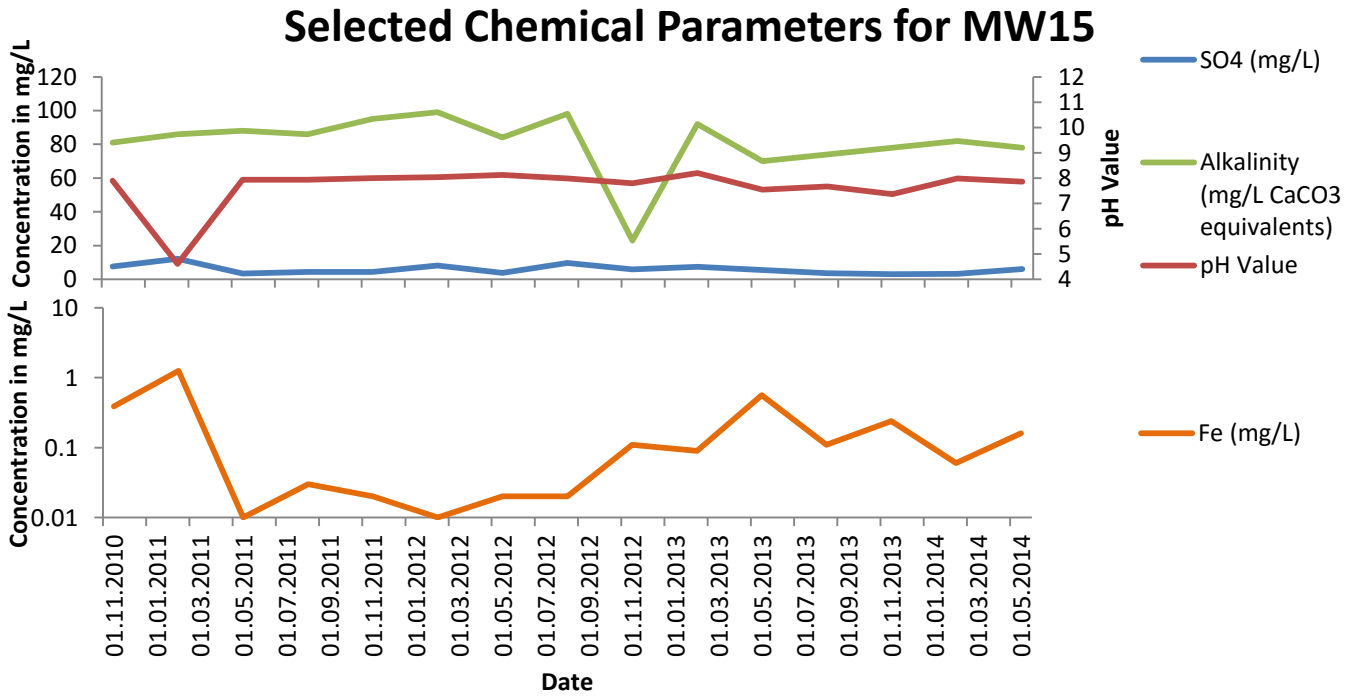


Figure 31: Groundwater monitoring data for MW15 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

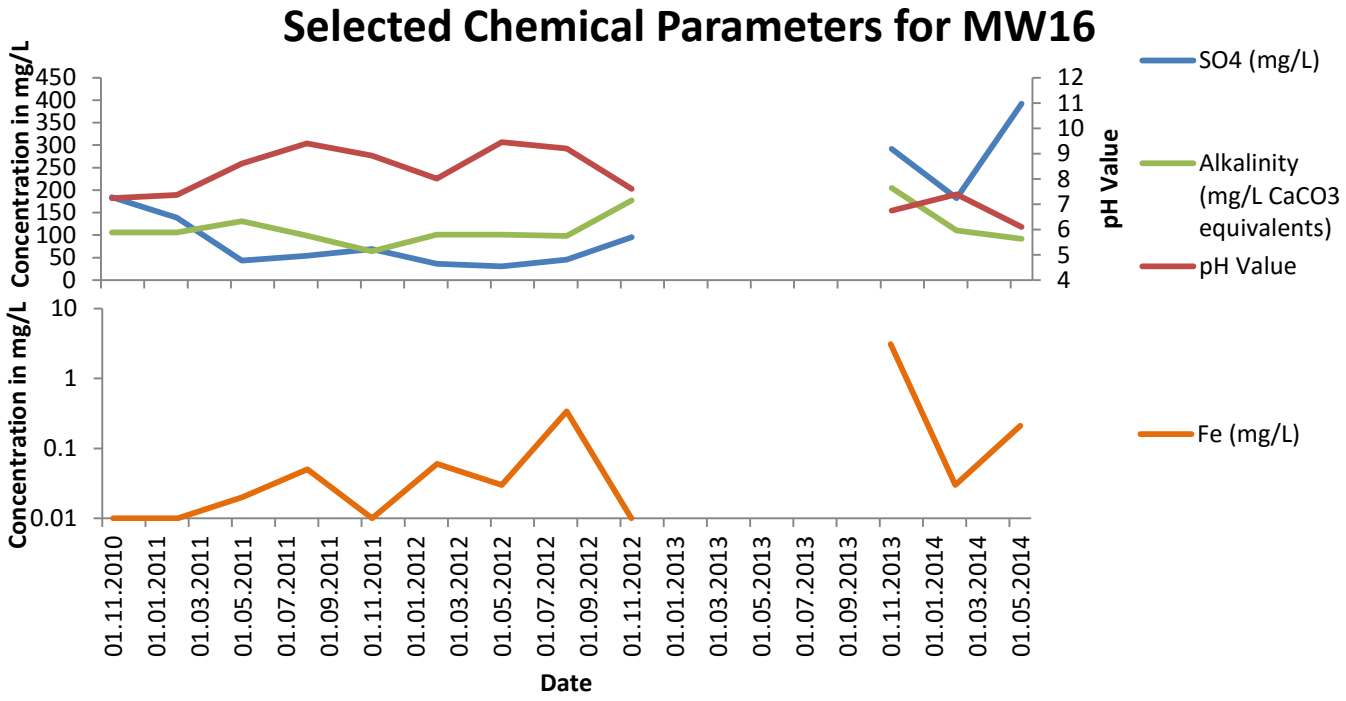


Figure 32: Groundwater monitoring data for MW16 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

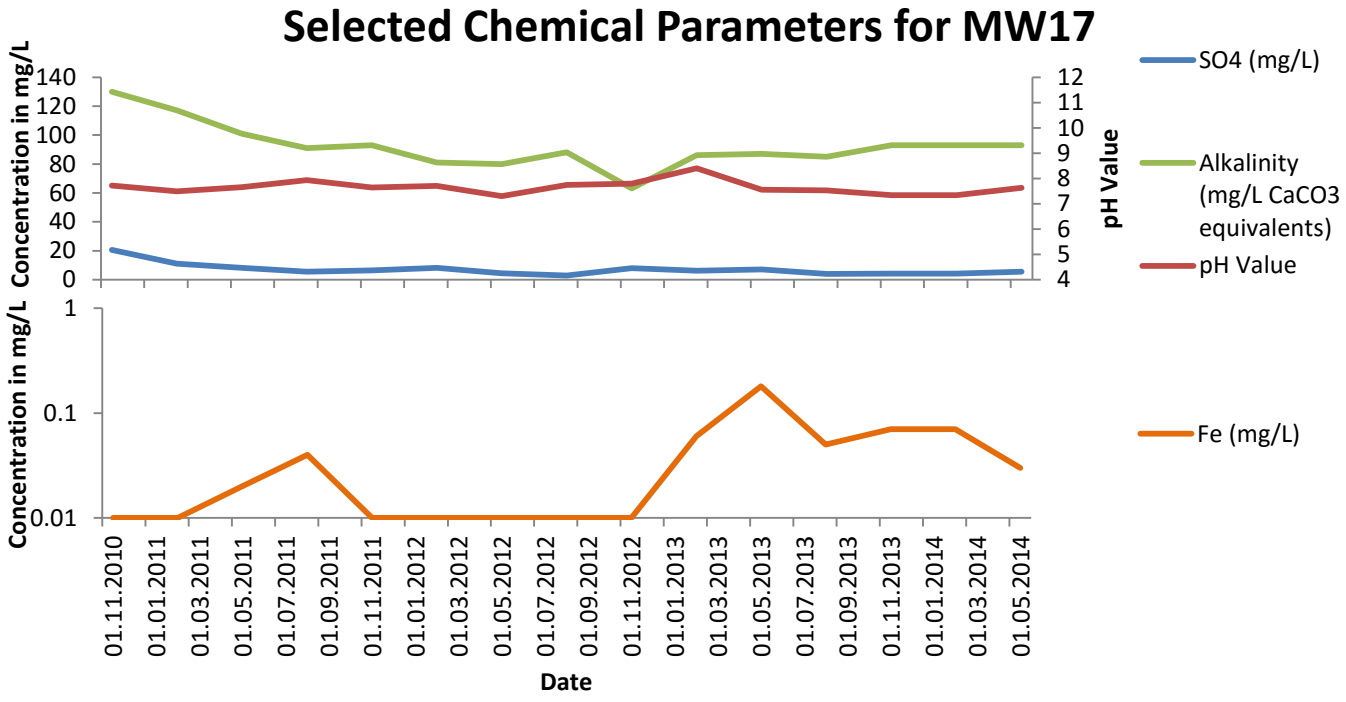


Figure 33: Groundwater monitoring data for MW17 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

5.1.6 Geochemical Model Calibration

The calibration of the geochemical model for C-Mine was performed as described (Figure 34). Constituent concentrations obtained from the leaching tests were averaged and plotted on the abscissa of the graph. The simulated concentrations of the constituents, obtained from the geochemical model, were plotted on the ordinate. Additionally, each data point has an error bar in the horizontal direction, which represents the standard error calculated for the average of each constituent concentration. The calibration graph shows a coefficient of determination (R^2-value) of 0.988. Most of the calculated values have a residual error within the calculated standard error for the average analysed concentrations as showed by the horizontal error bars.

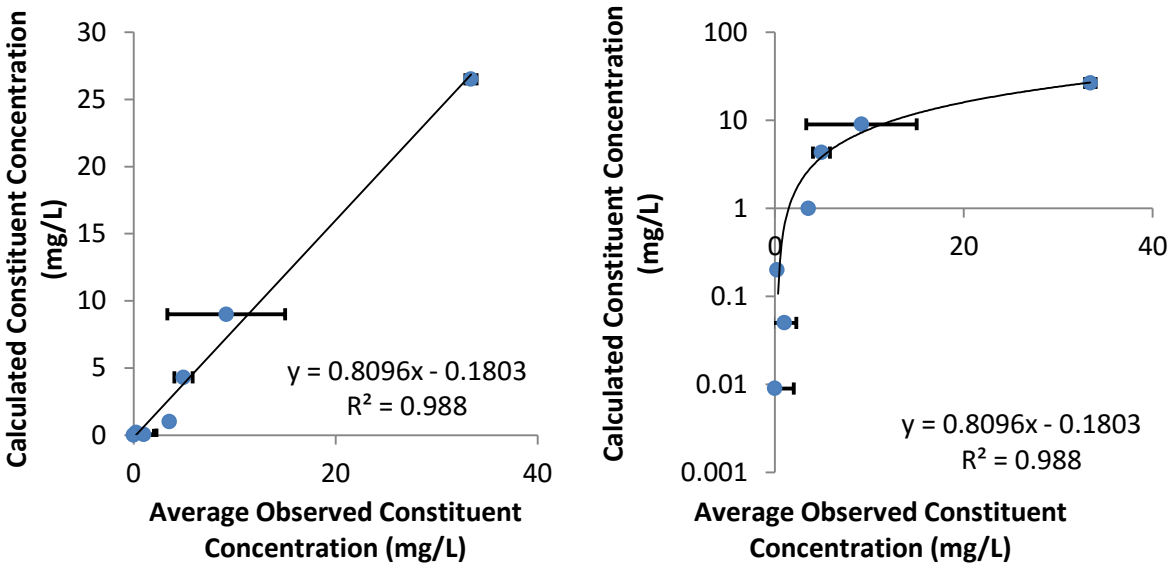


Figure 34: Left: Calibration graph for the geochemical model of C-Mine; averaged analysis concentrations vs. calculated concentrations; standard errors are shown in the horizontal direction. Right: logarithmic ordinate for improved illustration of lower concentrations and standard error values

5.1.7 Simulated Natural Geochemical Conditions

After calibration of the geochemical model, the natural geochemical conditions at C-Mine were simulated as described in the methodology section (Figure 35). Initial fluid to rock ratios used were approximately 2.5×10^{-4}:1, based on rainfall volumes and infiltration at the site. Additional water was added to the system at a fluid to rock ratio of 2.5×10^{-5}:1 every day of the simulation to simulate inflow of additional water into the system. A simulation lasted 40560 days (111 years), to account for long term changes in leachate chemistry, while also covering the period of available groundwater monitoring data. This simulation shows that a decrease in the release of SO_4^{2-} is likely to take place from a concentration of approximately 2500 mg/L to a concentration of approximately 44 mg/L.

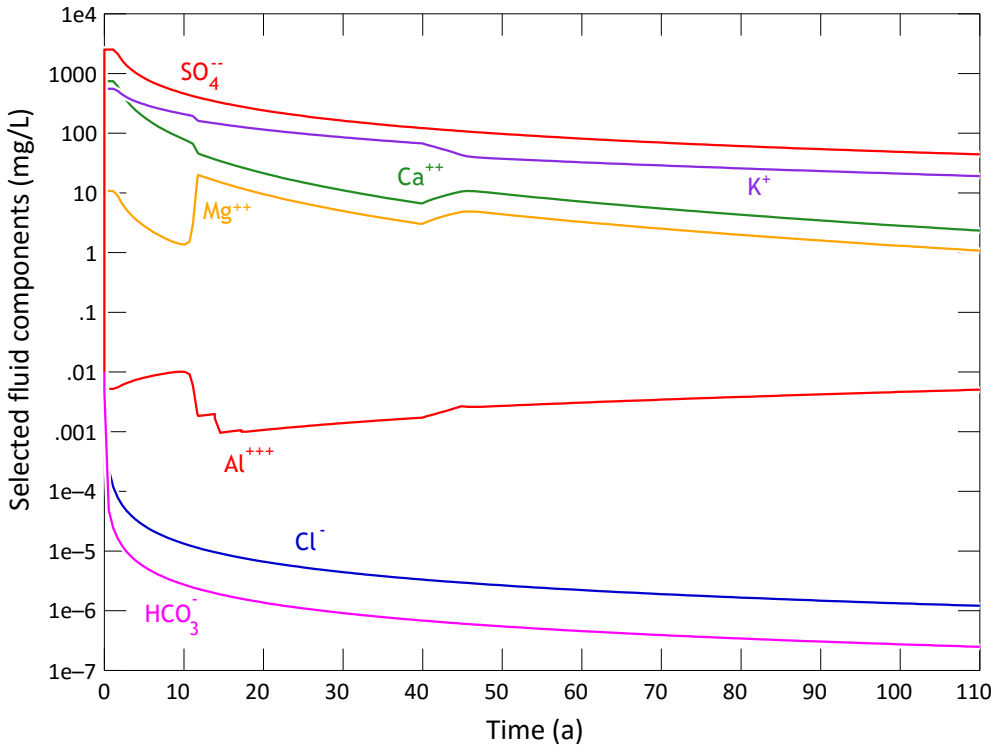


Figure 35: Simulated contaminant concentrations in the leachate of C-Mine generated from the backfill material on site over time; logarithmic ordinate

5.1.8 Numerical Flow Model Chemical Calibration

The simulated concentrations of sulfate in natural conditions of the backfilled opencast mine obtained from the geochemical model were used as input for the numerical flow and transport model. The concentrations in the opencast C-Mine were specified using various time steps and stress periods in the transport model. This was performed to determine if the specified concentrations in the transport model are chemically calibrated, using monitoring data at representative groundwater monitoring wells (Figure 36). The graphs show the simulated sulfate concentrations with an error bar of 20 mg/L, along with the observed sulfate concentrations at each selected monitoring point over time. An error range of 20 mg/L was used as concentrations of sulfate observed in the monitoring wells are all below 100 mg/L. Additional to this is the South African drinking water standard of 200 mg/L sulfate for the target water quality range. Therefore, a 10% error of the drinking water standard for sulfate was deemed applicable.

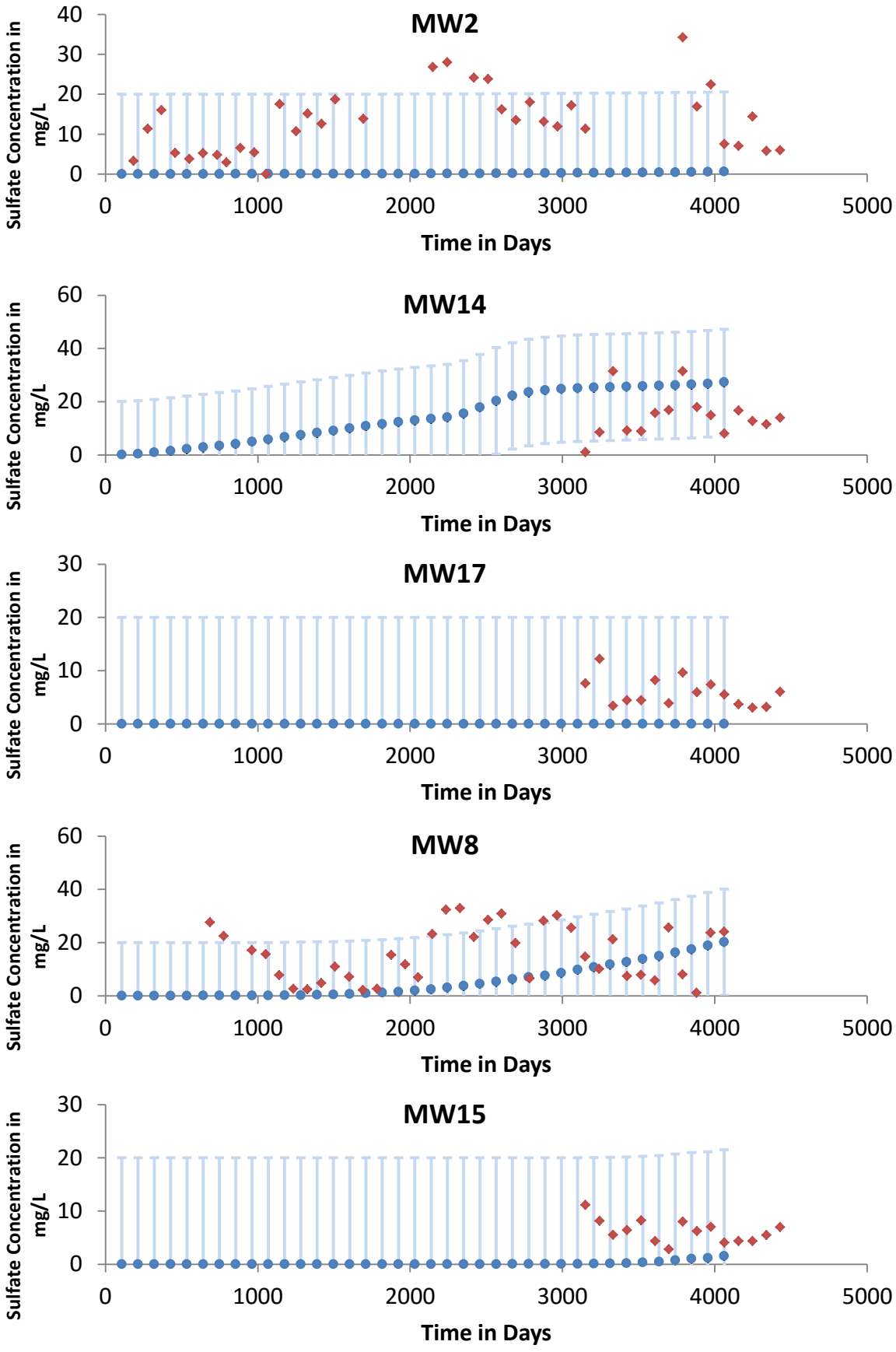


Figure 36: Chemical Calibration Graphs for the monitoring wells used in the C-Mine Numerical Flow and Transport Model, blue dots: simulated values; red diamonds: observed values.

5.1.9 Geochemical Parameter Sensitivity

The parameters influencing the generation and decay of sulfate in solution were varied in the geochemical model (Table 17). This was performed as a model sensitivity analysis to determine the sensitivity of each parameter with respect to its influence on rate limitation and concentration limitation of sulfate. Parameters providing a rate limitation were deemed to influence the rate of sulfate generation or decay in solution. Parameters providing a concentration limitation were deemed to influence the maximum and final concentrations of sulfate in solution.

Table 17: Sensitivity Analysis of Parameters Influencing the Generation and Decay of Sulfate in Solution at C-Mine Based on Geochemical Modelling

Parameter Varied	Orders of Magnitude	Rate Limitation	Change Observed in Sulfate Concentration	Contaminant Concentration Limitation	Change Observed in Sulfate Concentration, mg/L
Oxygen Fugacity	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	Yes	100
Gypsum Mass	1	No	None	Yes	30
Gypsum Surface Area	1	No	None	No	None
Gypsum Reaction Constant	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	Yes	5
Pyrite Mass	1	No	None	Yes	140
Pyrite Surface Area	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	No	None
Pyrite Reaction Constant	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	No	None
Input Rate of Water	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	Yes	30 to 400

5.2 E-Mine

5.2.1 Numerical Flow Model

The following parameters were specified within the numerical model (Table 18):

Table 18: Input parameters to the numerical flow model for E-Mine

Model Parameter	Value	Unit	Reason
Recharge to the aquifer	0.0001	m/d	Calculated
Recharge to the backfilled opencast mine	0.0004	m/d	Hodgson and Krantz (1998)
Evapotranspiration	0.005	m/d	Calculated
Boundaries	Topographic water divides north and south, Kromdraai spruit to the west, Brugspruit to the east.	-	Existing boundary conditions present at the site that would potentially include modelled impacts
Refinement	20	m	Based on the scale of the mining area
Grid dimensions	540 x 401	Cell count	Product of the grid refinement
Hydraulic conductivity	0.01 – 0.05	m/d	Pers. comm. Myburgh, 2015
Hydraulic anisotropy (vertical)	10	-	Anderson et al. (2015)
Effective porosity	5 declining to 3 with depth in each layer	%	Wang et al. (2009)
Layers	4	Count	Mining depth is 40m (Pers. comm. Myburgh, 2015)
Longitudinal dispersion	50	m	Schulze-Makuch (2005)
Mean residual head error	0.7	m	Head error statistics
Head error range	10	m	Calculated as 10 % of the difference between the maximum and minimum calculated head elevations

Flow directions interpreted from the numerical flow model showed that flow is directed away from the backfilled opencast mines. Groundwater flow is expected to follow the topography towards local drainage channels (Figure 37) as shown by monitoring data. This includes the Brugspruit to the east of the mine. This was confirmed by the calibration of the model to the latest available monitoring data (Figure 38).

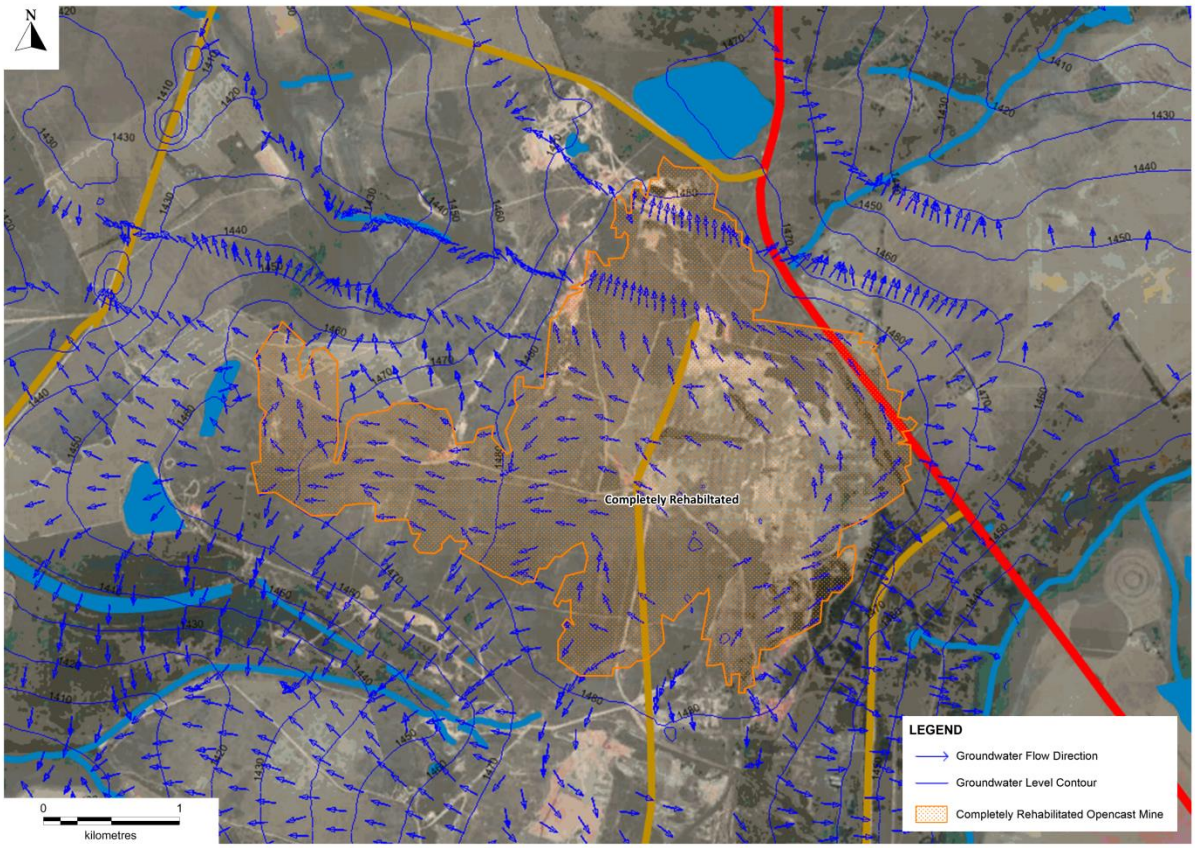


Figure 37: Groundwater flow directions at E-Mine Colliery

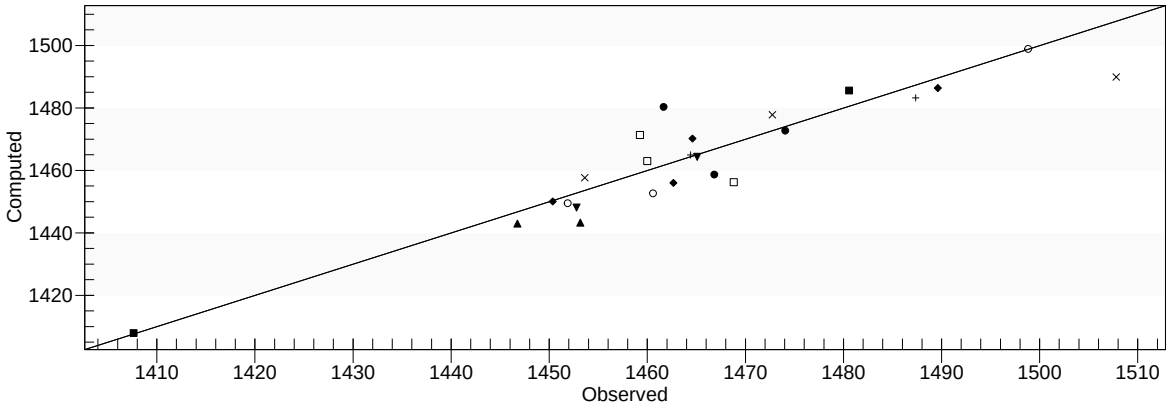


Figure 38: Head calibration graph for the numerical model constructed for E-Mine Colliery

Based on the calibrated model, the inflow rate into the backfilled opencast mine was estimated. A maximum inflow volume calculated for the backfilled opencast mine on site ranges between 5000 to 8000m^3/day (Hodgson, 2014). Assuming that the porosity of the backfill material in the backfilled opencast mines is 30% and multiplying this with the pit surface area and average depth a volume was calculated for the potentially fillable void space within the backfill material. This equated to an initial fluid to rock ratio of 0.3:1 based on rainfall volumes with additional water being added to the system via inflows to the pit from the aquifer at a fluid to rock ratio of 1×10^{-4}:1.

5.2.2 Mineral Abundances

XRD analysis results for the material samples collected from backfilled opencast mines from E-Mine (Figure 39) show that quartz, kaolinite and muscovite are predominant mineral phases present

(Table 19). Minerals with a lesser abundance in the samples include anatase and microcline k-feldspar.

Table 19: Mineral Phases Identified During Analysis of Five Backfill Samples at E-Mine; Mineral Phase Abundances Reported as Weight Percentage (- not detected)

Mineral Phase	KDC1	KDC2	KDC3	KDN1	KDN2
Anatase	-	1.75	1.41	0.78	0.69
Kaolinite	55.21	59.6	43.33	43.32	39.36
Microcline	-	-	1.12	7.27	7.02
Muscovite	4.61	4.81	3.81	4.33	4.13
Quartz	40.18	33.83	50.33	44.29	48.8

In addition to the mineralogical analyses performed on the samples, sulfide mineral abundances were estimated. Mine water chemistry (Table 22), acid-base accounting (Table 17) and field scale leach testing (Table 21) were used to classify the material according to the method of Price et al. (1997) as well as to estimate the abundance of sulfide minerals in the backfill material (Williams, 2015). It should be noted that large ion balance errors exist for the mine water samples which is caused by the highly elevated sulfate concentrations in these samples (Nordstrom, 2011).

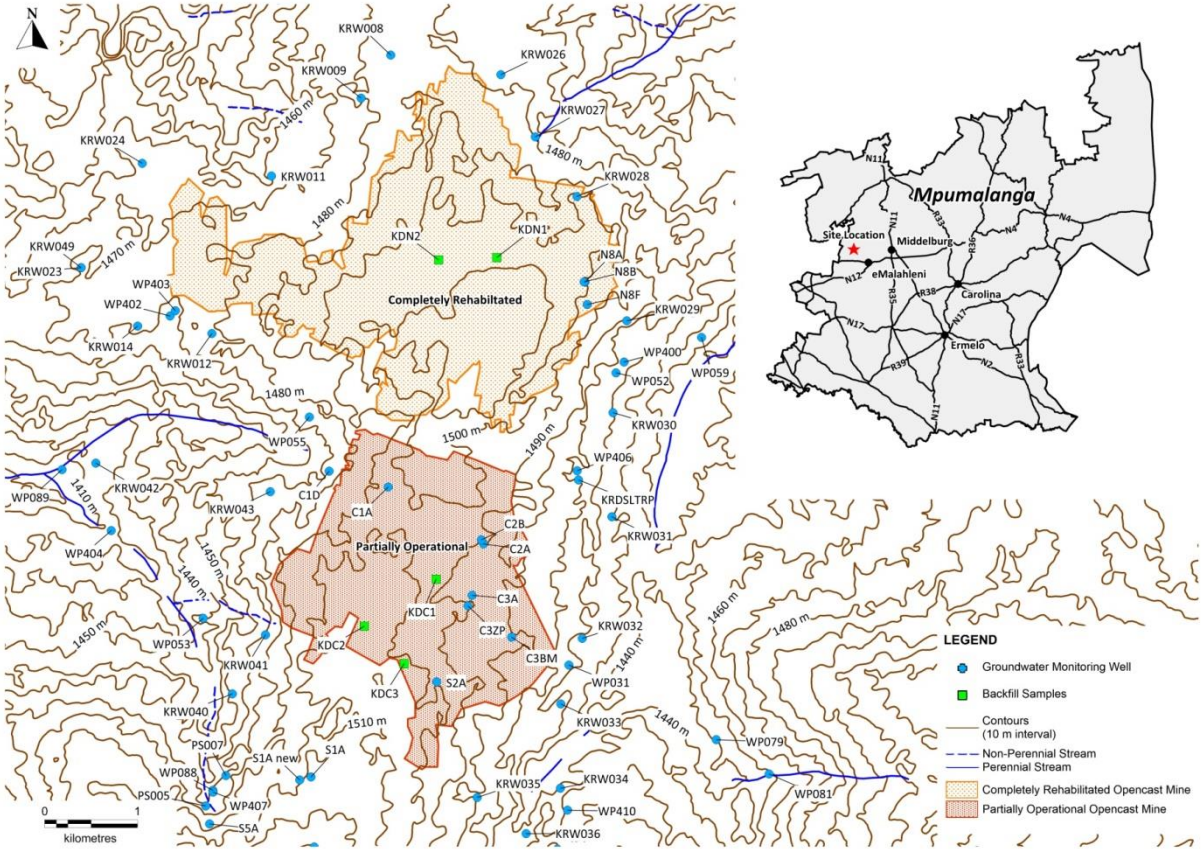


Figure 39: Sample collection areas at E-Mine

Table 20: Acid-base accounting results for backfill material collected at E-Mine (Williams, 2015) – Neutralisation potential and Net Neutralisation Potential (NNP) expressed as $CaCO_3$ equivalent kg per ton

Sample Number	E-Mine 2
Paste pH	2.26
Sulfur (%) (LECO)	1.25
Acid Potential (AP) (kg/t)	20.6
Neutralization Potential (NP)	-14.5
Net Neutralization Potential (NNP)	-35.1
Neutralising Potential Ratio (NPR) (NP : AP)	0

Table 21: Analysis results of field scale leach testing on backfill material sampled at E-Mine (Williams, 2015); concentrations presented in mg/L

Analysed Constituent	Concentration
pH	1.30
Temperature (°C)	19.1
Measured EC (mS/m)	2610
Alkalinity as $CaCO_3$	Below Detection
Al	857
Ca	283
Fe	22570
K	1.25
Mg	21.5
Mn	8.5
Na	6.1
Si	58
F	-
Cl	17.6
NO_3	4.3
PO_4	-
SO_4	44808

Table 22: Analysis results of E-Mine mine water discharge (Pers. Comm. Myburgh, 2015); concentrations in mg/L

Analysed Constituent	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
pH	2.64	2.42	2.39	2.55	2.46
Temperature (°C)	18.6	20.7	19.7	22.3	21.5
Measured EC (mS/m)	469.19	558.31	501.2	403.47	427.27
Measured TDS	7105	7033	6131	3565	4969
Alkalinity as $CaCO_3$	0.00	0.00	0.00	0.00	0.00
Al	260.63	245.71	235.96	175.30	90.97
Ca	268.48	320.44	327.09	206.08	196.11
Fe	552.25	447.45	367.19	196.71	60.50
K	11.51	11.42	12.72	12.25	10.19
Mg	166.07	188.12	181.34	137.76	125.44
Mn	64.09	86.20	92.56	74.32	1.39
Na	7.88	11.03	10.45	15.50	8.03
F	0.01	0.01	0.01	0.01	0.00
Cl	5.11	4.25	3.88	4.84	4.35
NO_3	0.09	0.00	0.00	0.39	0.22
PO_4	0.40	1.26	0.45	0.24	0.37
SO_4	5484	4988	4711	2521	3120
Ion Balance Error (%)	-71.85	-59.76	-56.62	-41.86	-53.9

5.2.3 Distilled Water Leach Tests

Five samples were collected from E-Mine colliery and submitted for distilled water leach testing. The subsequent leachates were analysed using ICP-OES for major metal cations and metals while anion concentrations were determined by ion-chromatography. The results show that the leachate pH is lowered by the material and the predominant leached constituent from the material is sulfate (Table 23).

Table 23: Distilled Water Leach Test and Subsequent Leachate Analysis Results for E-Mine; b.d.l.: below detection limit

Analysed Constituents, mg/L	KDC1	KDC2	KDC3	KDN1	KDN2
pH	3.64	3.71	6.23	4.16	5.33
EC (mS/m)	25.32	23.93	1.52	16.34	9.09
TDS Calculated	177.24	167.51	10.64	114.38	63.63
Alkalinity as $CaCO_3$	b.d.l.	b.d.l.	2.70	b.d.l.	1.20
Al	8.8	12.4	0.66	1.73	0.03
Ca	6.1	4.24	0.8	11.2	6.37
Fe	0.1	0.13	0.81	0.03	0.01
K	0.79	0.7	0.57	0.77	2.71
Mg	3.5	1.37	0.14	5.2	3.61
Mn	1.66	0.81	0.03	2.26	1.18
Na	1.18	0.88	1.98	0.63	0.76
Cl	0.74	0.57	0.41	0.34	0.33
NO_3	0.38	b.d.l.	0.69	b.d.l.	1.1
SO_4	144.3	149.5	24.1	95.2	52.1

5.2.4 Mineral Reaction Rates

Estimated mineral abundances were averaged based on XRD analyses, acid-base accounting and mine water analyses. The standard error and standard deviation were calculated for each mineral phase and the reaction constant for each phase was obtained from literature (Table 24). The initial reactive surface area was also calculated based on the described methodology.

Table 24: Calculated statistics, rate constants and reactive surface areas from the XRD results of five backfill samples from E-Mine; b.d.l.: below detection limit

Mineral Phase Based on Analysis Data	Mean, mass %	Standard Deviation, mass %	Standard Error of mean mass %	Initial Reaction Rate Constant, $mol \cdot cm^{-2} \cdot s^{-1}$	Initial Reactive Surface Area, $cm^2 \cdot g^{-1}$ #
Anatase	0.66	0.68	0.30	b.d.l.	b.d.l.
Kaolinite	34.40	8.73	3.90	1×10^{-17} a	250
K-Feldspar	2.20	3.74	1.67	1.7×10^{-17} b	170
Muscovite	3.10	0.39	0.18	2.9×10^{-15} c	200
Quartz	31.06	6.71	2.99	5.0×10^{-14} d	250
Calcite	0.04*	n.a.	n.a.	1.0×10^{-10} e	110
Pyrite	6.5*	n.a.	n.a.	2.8×10^{-12} f	400
Gypsum	0.04*	n.a.	n.a.	1.3×10^{-04} g	130

[a]Huertas et al. (1999); [b]Oelkers and Schott (1998); [c]Oelkers et al. (2008); [d]Gudbrandsson et al. (2014); [e]Cubillas et al. (2005); [f]Malmström et al. (2006); [g]Jeschke et al. (2001); [*]Estimated based on field observations, acid-base accounting and literature data; [#]Calculated from sample average grain size and mineral density, assuming entire surface is available for reaction (Brantley, 1998, Gautier et al., 2001, White and Brantley, 2003); n.a.: not applicable; n.d.: not defined – mineral phase abundance insufficient to affect geochemical modelling result.

5.2.5 Groundwater Monitoring Data

A comparison of selected parameters was performed on the available groundwater monitoring data for E-Mine. Results of this comparison are described below for each monitoring well.

KRW012 (Figure 20)

Sulfate concentrations in samples from this monitoring well are mostly below 50 mg/L and show a seasonal variability with a rise in concentration starting May of 2012 and increase until the end of the monitoring period. Alkalinity concentrations show a corresponding inverse behaviour with a variable pH throughout the monitoring period. Fe concentrations in this monitoring well are highly variable and range between 2 orders of magnitude.

KRW014 (Figure 21)

pH values in this monitoring well are variable and range between 4 and 7 with a decrease in alkalinity concentrations after mid-2011 and an inversely proportionate increase in sulfate concentrations around this time until the end of the monitoring period. Fe concentrations follow a similar trend to sulfate concentrations in this monitoring well.

KRW024 (Figure 42)

Concentrations of sulfate and alkalinity in this monitoring well are highly variable but generally do not exceed 50 mg/L. Additionally, pH values are variable but generally below 7 with Fe concentrations ranging between 0.01 and 1.

KRW026 (Figure 43)

Sulfate concentrations generally below 100 mg/L can be observed in the monitoring data for this monitoring well with a gradual increase during and after 2012. Alkalinity concentrations remain low for the entire monitoring period with a decrease in pH value during and after 2012. Fe concentrations are highly variable in this monitoring well ranging between 0.01 and 1 for the monitoring period.

KRW027 (Figure 24)

Alkalinity and sulfate concentrations in this monitoring well are generally below 50 mg/L and show a stable trend sulfate and alkalinity concentrations being inversely proportionate. pH values in this monitoring well are generally acidic with a raise in the pH value observed during 2004 and 2008. A similar trend to sulfate concentrations can be observed in the Fe concentrations in this monitoring well.

KRW028 (Figure 25)

Slightly acidic pH values are prevalent throughout the monitoring period of this monitoring well with low sulfate concentrations showing some variation and a potential increase after 2013. Alkalinity concentrations throughout the monitoring period are higher than that of sulfate but are much more variable with a decreasing trend in Fe concentration after 2007.

KRW029 (Figure 26)

Sulfate concentrations in samples from this monitoring well are mostly below 100 mg/L and show a seasonal variability with a rise in concentration starting in 2012 and increase until the end of the monitoring period. Alkalinity concentrations show a corresponding inverse behaviour with a variable pH throughout the monitoring period. Fe concentrations in this monitoring well are highly variable and range between 3 orders of magnitude.

KRW030 (Figure 27)

Slightly acidic pH values are prevalent throughout the monitoring period of this monitoring well showing a general decreasing trend with low sulfate concentrations showing some variation and a potential increase after 2013. Alkalinity concentrations throughout the monitoring period decrease from higher than that of sulfate to lower than that of sulfate after 2006 but are much more variable. A highly variable Fe concentration can be observed in this monitoring well.

KRW031 (Figure 28)

A variable sulfate concentration below 200 mg/L can be observed in this monitoring borehole with a stable pH which is close to neutral. Fe concentrations in this borehole are variable with no apparent trend in the monitoring period.

KRW034 (Figure 29)

Sulfate concentrations in samples from this monitoring well are mostly below 50 mg/L and show a seasonal variability with an increase in concentration starting 2010 and increasing until the end of

the monitoring period. Alkalinity concentrations show a corresponding inverse behaviour with a variable pH throughout the monitoring period which decreases after 2012 to the end of the monitoring period. Fe concentrations in this monitoring well are highly variable and range between 3 orders of magnitude and show similar trends in concentration to that of sulfate.

KRW035 (Figure 30)

Sulfate concentrations in this monitoring well can be observed to remain below 100 mg/L over the entire monitoring period and showing some seasonal variation while alkalinity concentrations show an inversely proportionate variation to sulfate. Periodic lowering of the pH value in response to the increase in sulfate concentration is also evident with no discernible trend in the erratic Fe concentrations measured.

KRW036 (Figure 51)

Variable sulfate concentrations can be observed in the monitoring data for this monitoring well with an inversely corresponding pH value decreasing with every increase in sulfate concentration. PH values in this monitoring well are generally below 7. Alkalinity concentrations in this monitoring well are generally lower than the sulfate concentration with a maximum concentration of 150 mg/L. Fe concentrations vary between 0.01 mg/L up to 10 mg/L and show a decreasing trend.

KRW038 (Figure 32)

pH values in this monitoring well are highly variable and can values lower than 4 at various times in the monitoring period. Sulfate concentrations show a decreasing trend after 2005 with consistent low alkalinity concentrations. Fe concentrations vary between 3 orders of magnitude but display a decreasing trend during the monitoring period, especially after 2005.

KRW039 (Figure 33)

An increasing trend in sulfate concentration is evident in the monitoring data for this monitoring well from 2005 to the end of the monitoring period. Inversely proportionate to this a decrease in the alkalinity concentrations and pH values. A variably increasing trend in Fe concentrations can also observable from 2005.

KRW040 (Figure 54)

Sulfate concentrations in this monitoring well are generally below 50 mg/L but show an increasing trend after 2010. A decreasing pH value trend is also evident from 2010. Alkalinity concentrations in this monitoring well are generally below20 mg/L. Fe concentrations show an increasing trend from 2010.

KRW041 (Figure 55)

Sulfate and alkalinity concentrations in this monitoring well are generally below 50 mg/L with a single spike observed in 2004. A relatively stable but slightly acidic pH value can be observed through most of the monitoring period with a variable Fe concentration.

KRW043 (Figure 56)

Sulfate and alkalinity concentrations in this monitoring well are generally below 60 mg/L with spikes observed in 2003 and 2008. Highly variable pH values are also evident throughtout the monitoring period with Fe concentrations inversely corresponding to pH trends.

KRW047 (Figure 57)

Sulfate concentrations in samples from this monitoring well are mostly below 50 mg/L and show a seasonal variability with a rise in concentration starting in early 2011 and increase until the end of the monitoring period. Alkalinity concentrations show a corresponding behaviour with a variable pH throughout the monitoring period. Fe concentrations in this monitoring well are highly variable and range between 3 orders of magnitude.

KRW049 (Figure 58)

Sulfate concentrations in samples from this monitoring well are mostly below 100 mg/L and show a seasonal variability with a rise in concentration starting in late 2011 and increase until the end of the monitoring period. Alkalinity concentrations show an inversely corresponding behaviour with a variable pH throughout the monitoring period which is also lowered after 2012. Fe concentrations in this monitoring well are highly variable and range between 3 orders of magnitude but show a general decreasing trend.

WP054 (Figure 59)

An increasing trend in sulfate concentrations from 2009 to the end of the monitoring period can be observed in the data for this discharge point with concentrations reaching up to 7100 mg/L. Alkalinity is fully depleted in the samples collected from this monitoring point with pH values almost exclusively below 4. Fe concentrations in samples from this monitoring point reach concentrations above 1500 mg/L.

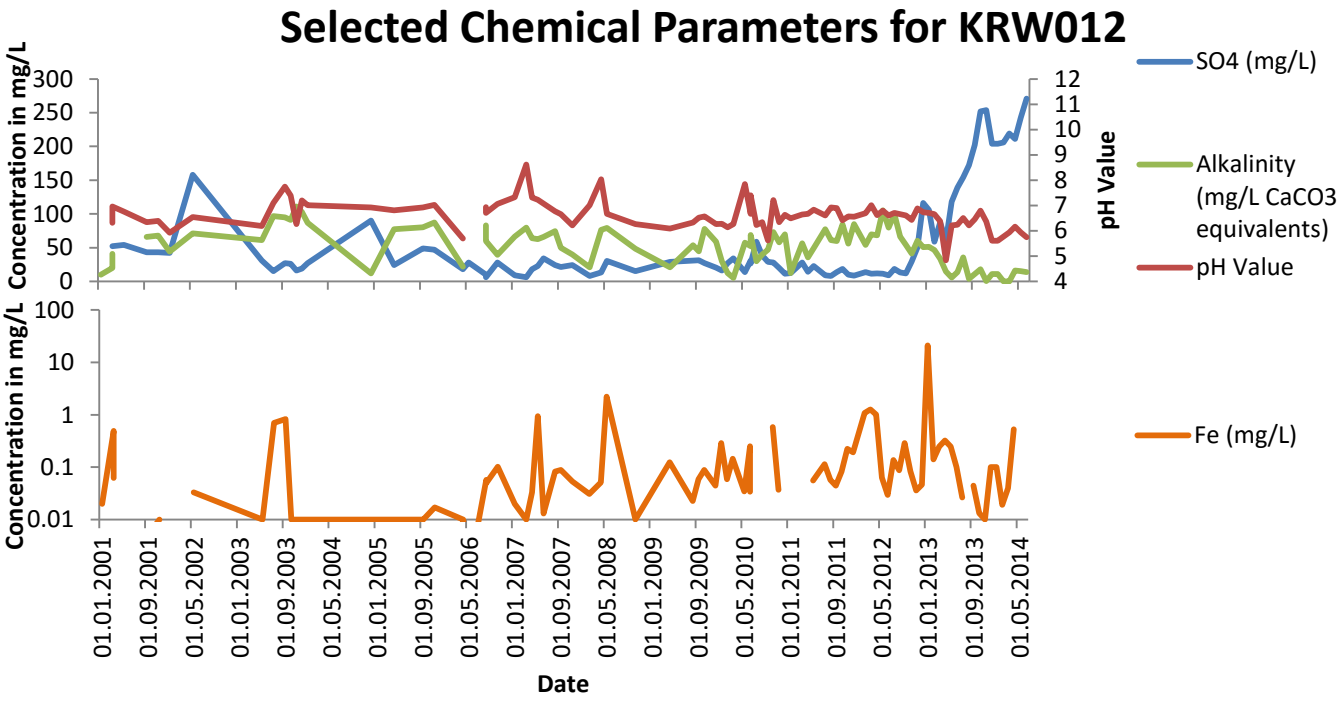


Figure 40: Groundwater monitoring data for KRW012 at E-Mine (illustrating Fe, SO_4, pH and Alkalinity)

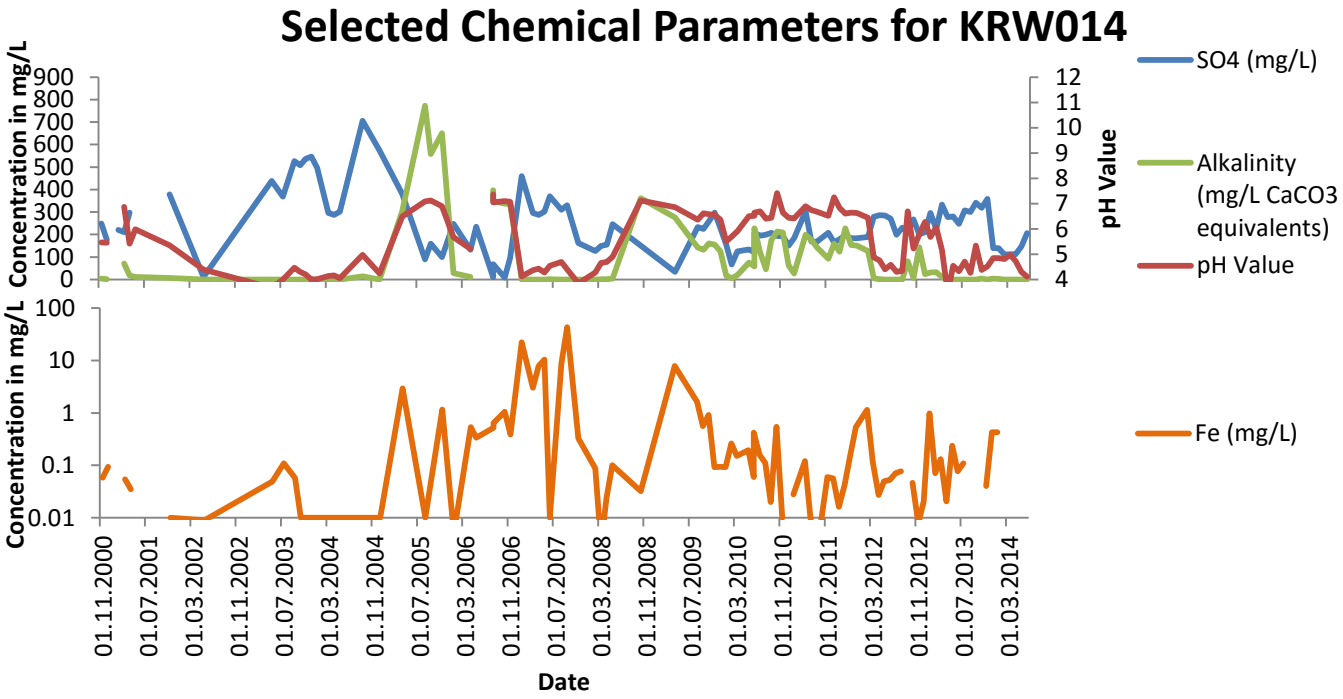


Figure 41: Groundwater monitoring data for KRW014 at C-Mine (illustrating Fe, SO4, pH and Alkalinity)

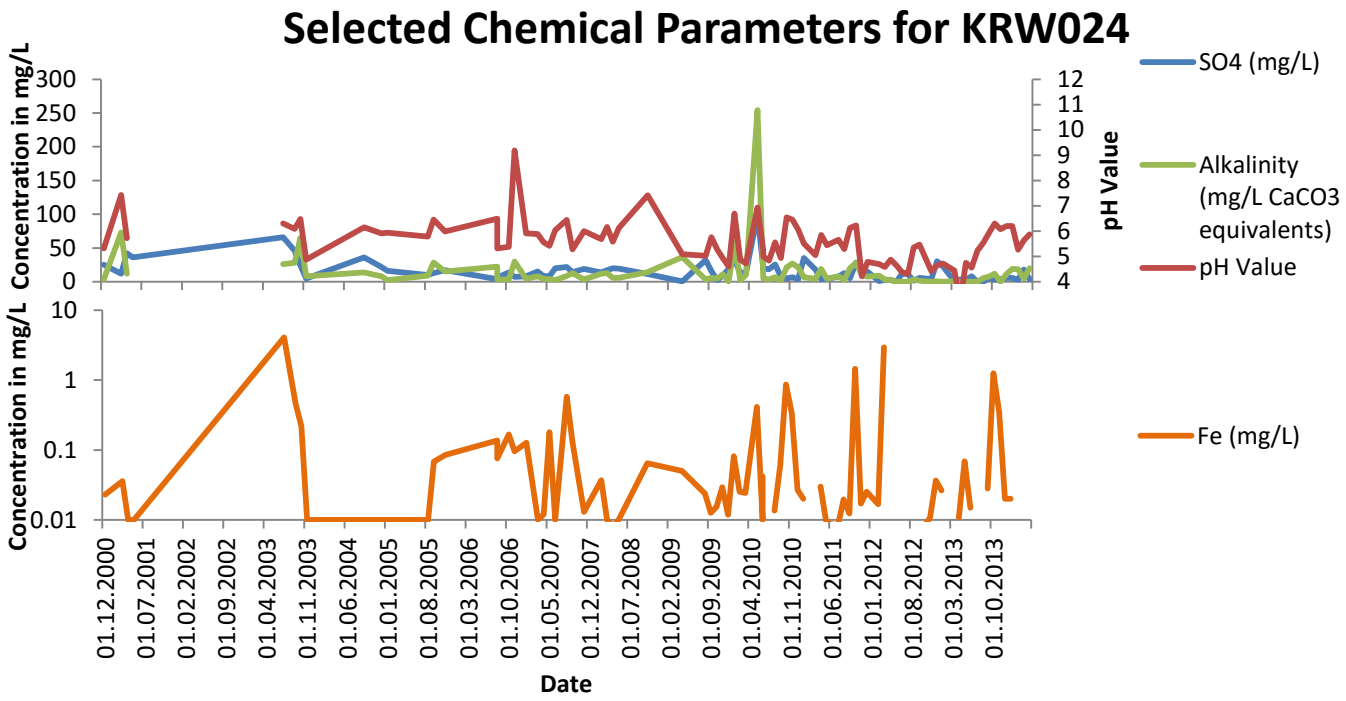


Figure 42: Groundwater monitoring data for KRW024 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

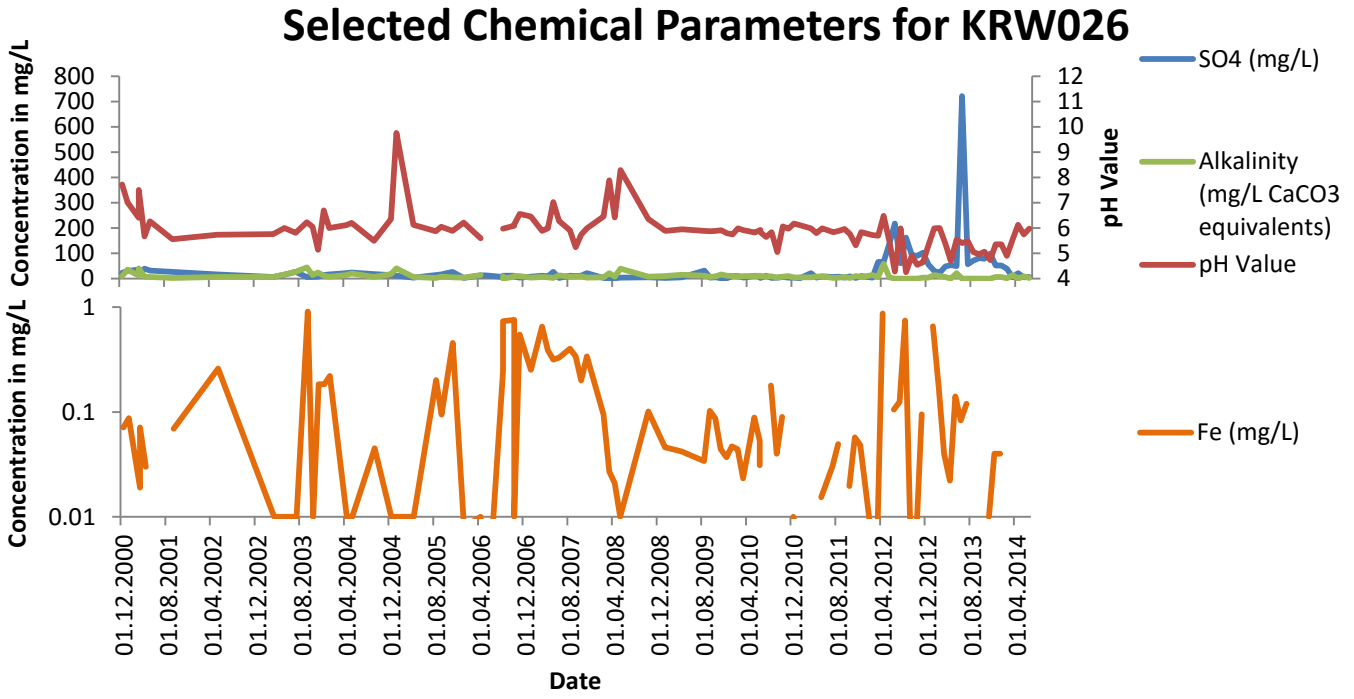


Figure 43: Groundwater monitoring data for KRW026 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

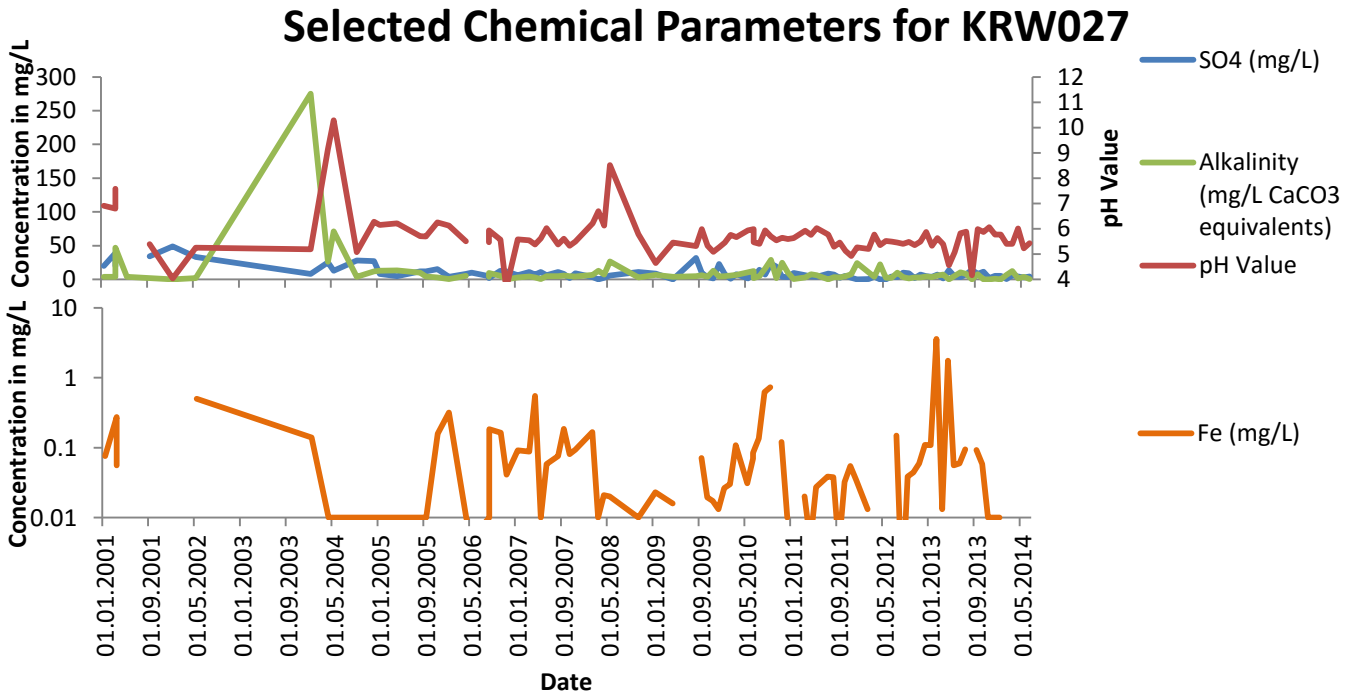


Figure 44: Groundwater monitoring data for KRW027 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

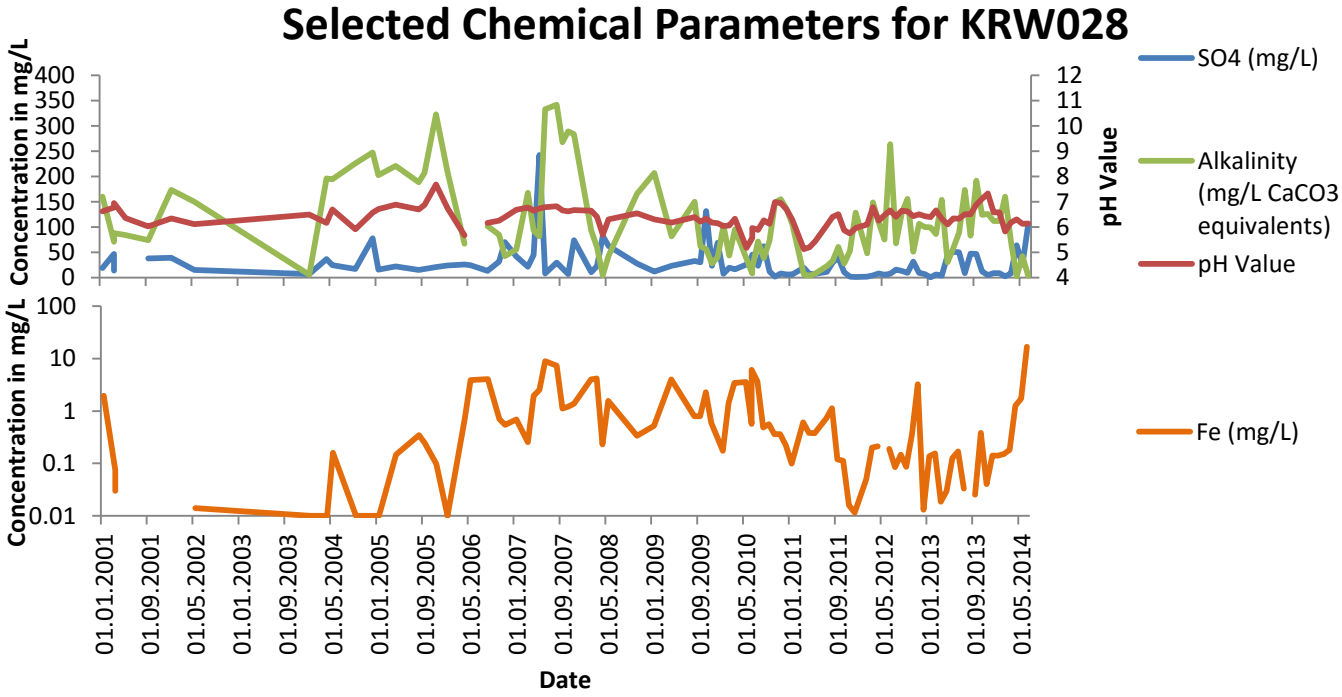


Figure 45: Groundwater monitoring data for KRW028 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

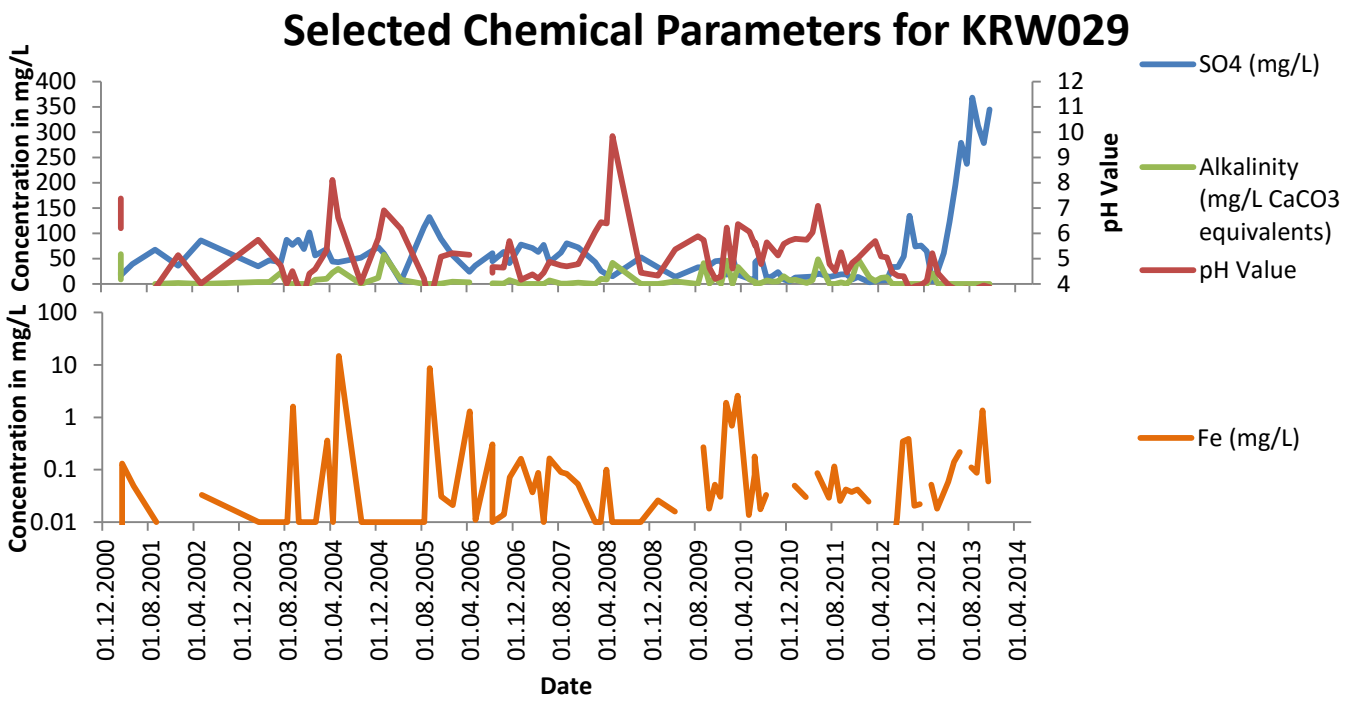


Figure 46: Groundwater monitoring data for KRW029 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

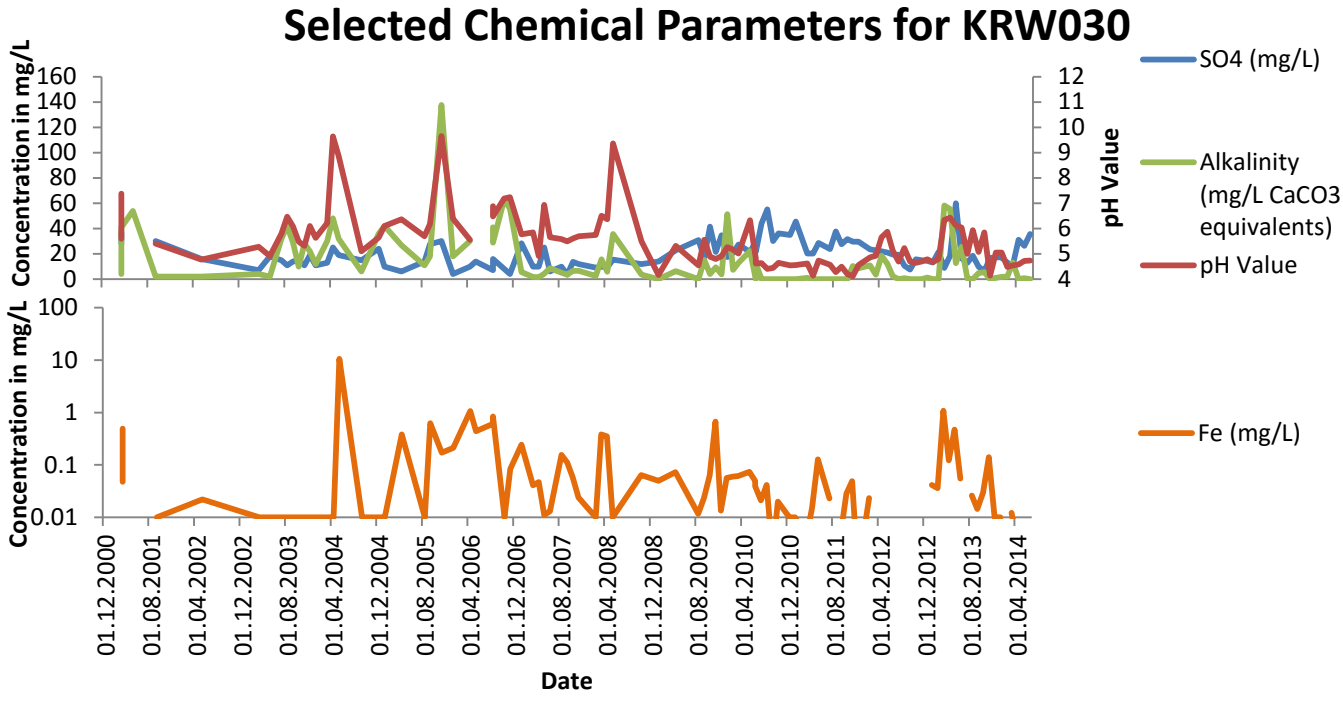


Figure 47: Groundwater monitoring data for KRW030 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

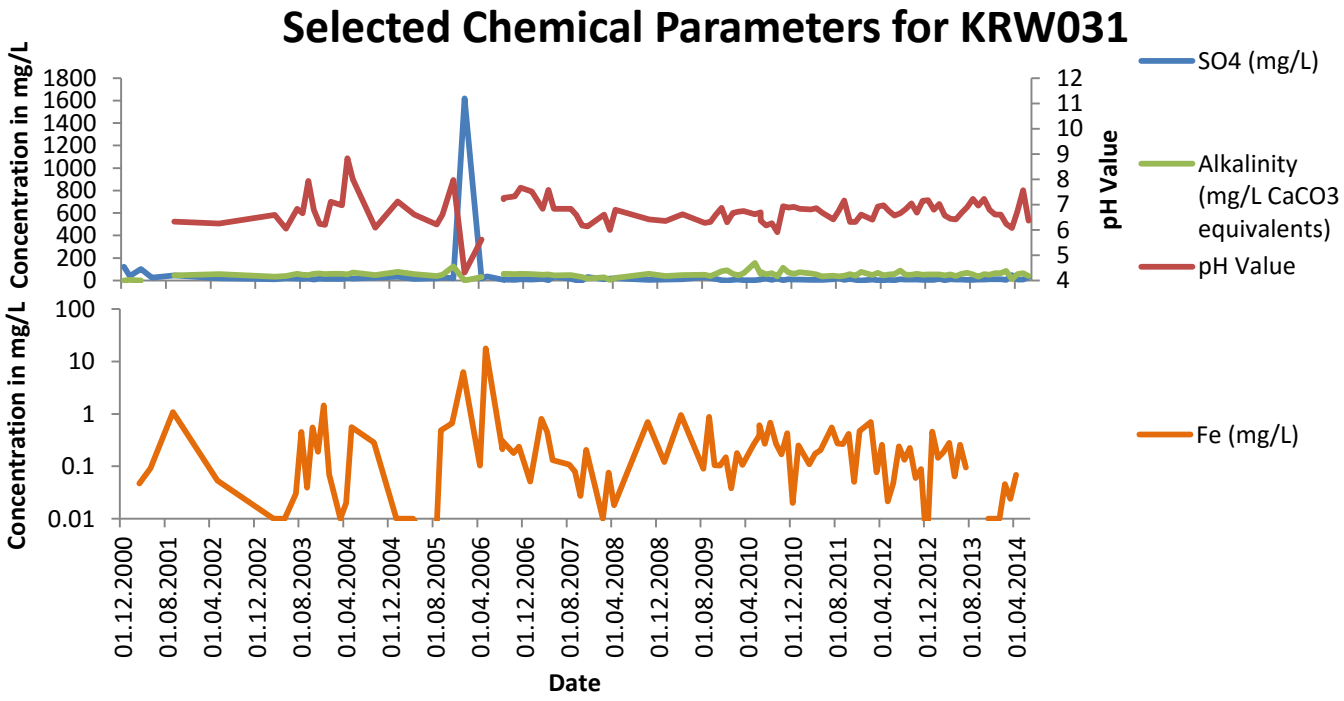


Figure 48: Groundwater monitoring data for KRW031 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

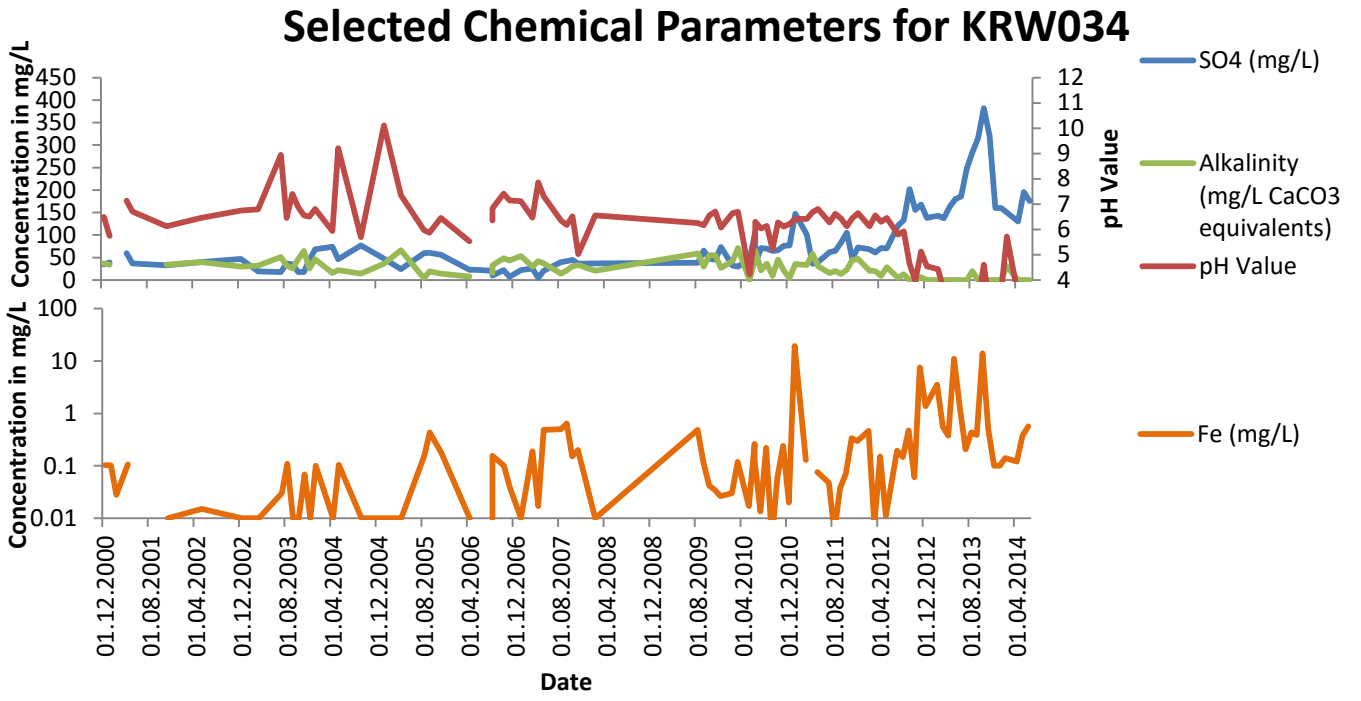


Figure 49: Groundwater monitoring data for MW34 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

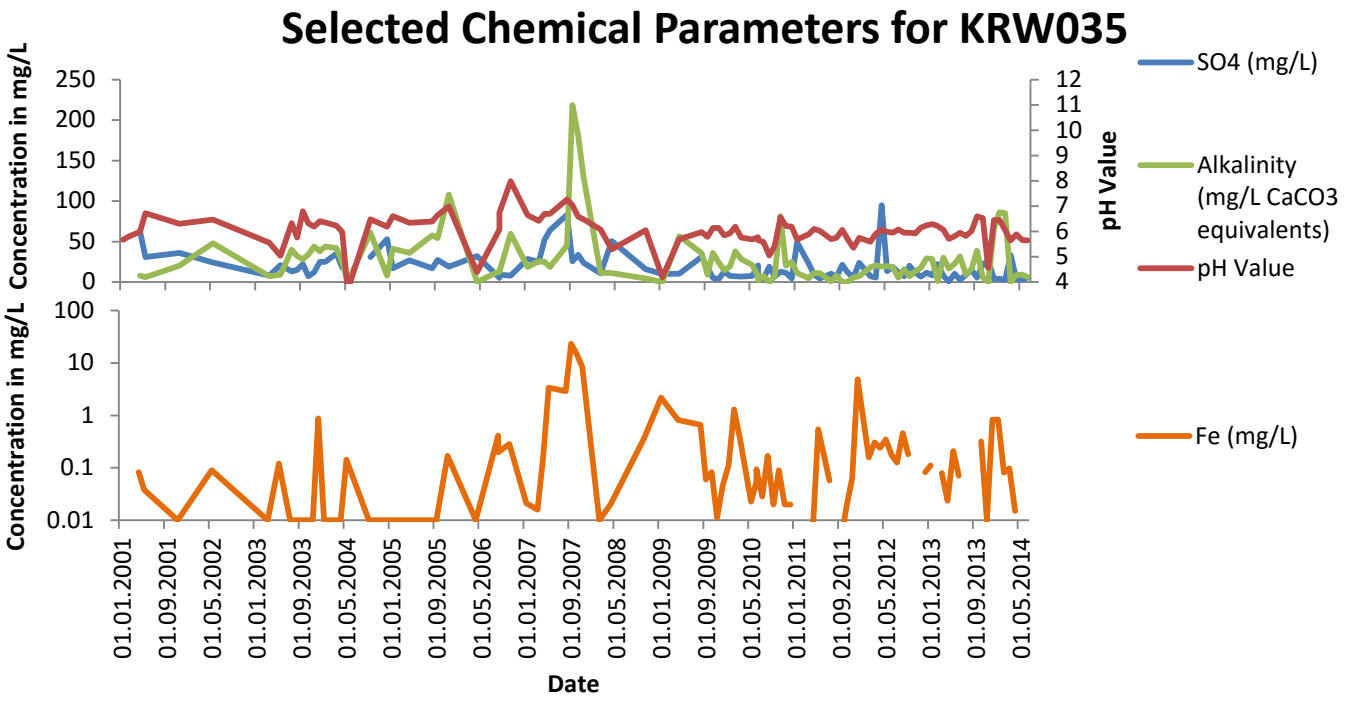


Figure 50: Groundwater monitoring data for KRW035 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

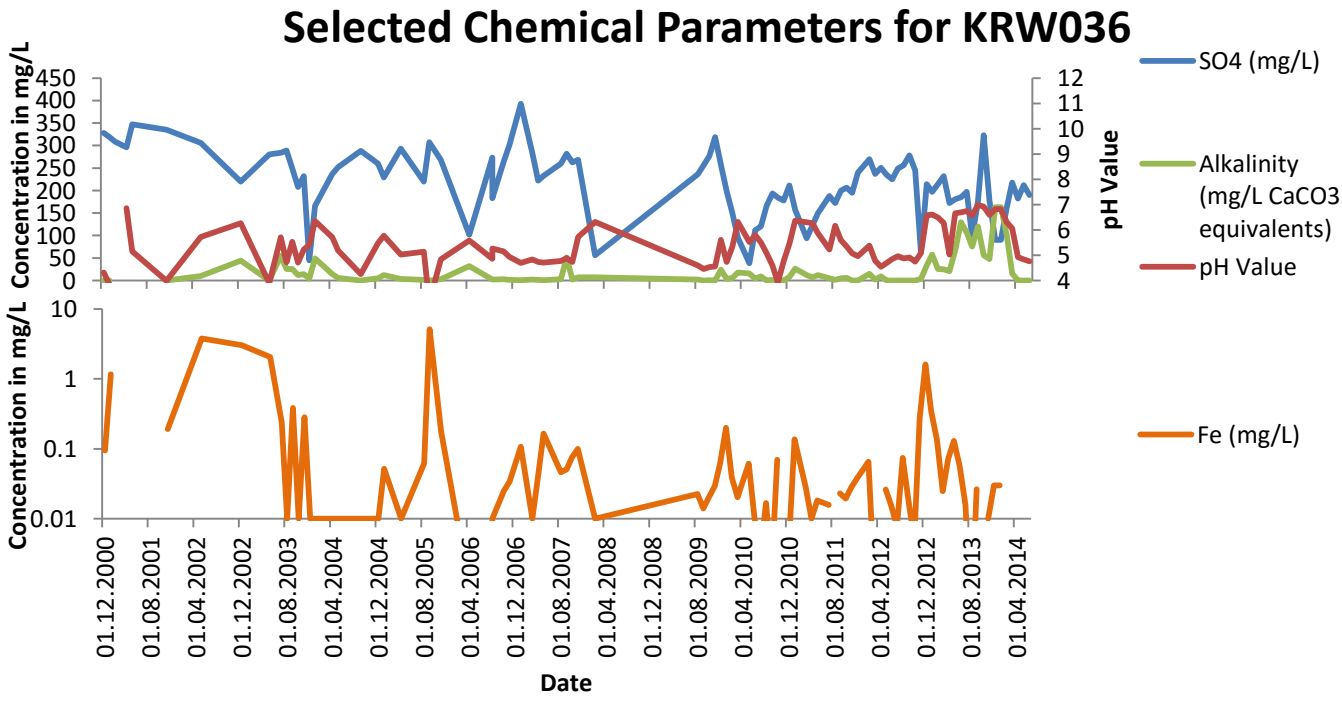


Figure 51: Groundwater monitoring data for KRW036 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

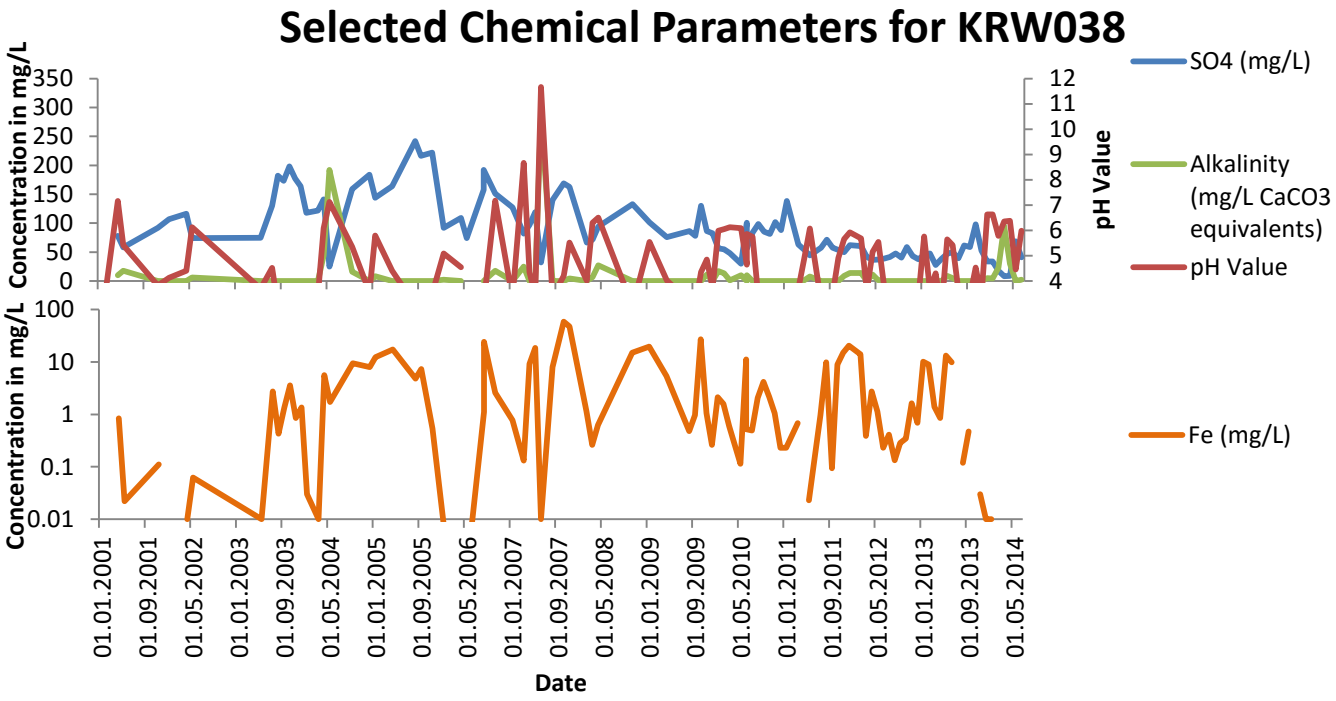


Figure 52: Groundwater monitoring data for KRW038 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

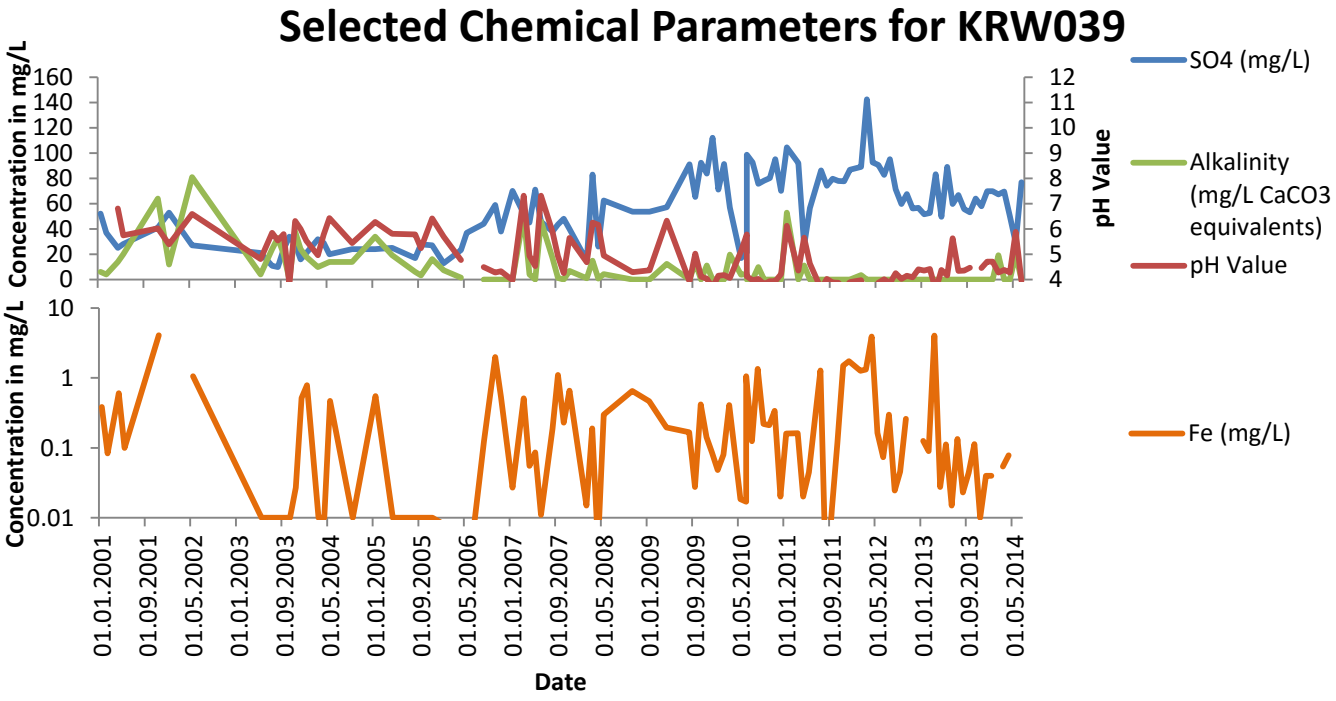


Figure 53: Groundwater monitoring data for KRW039 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

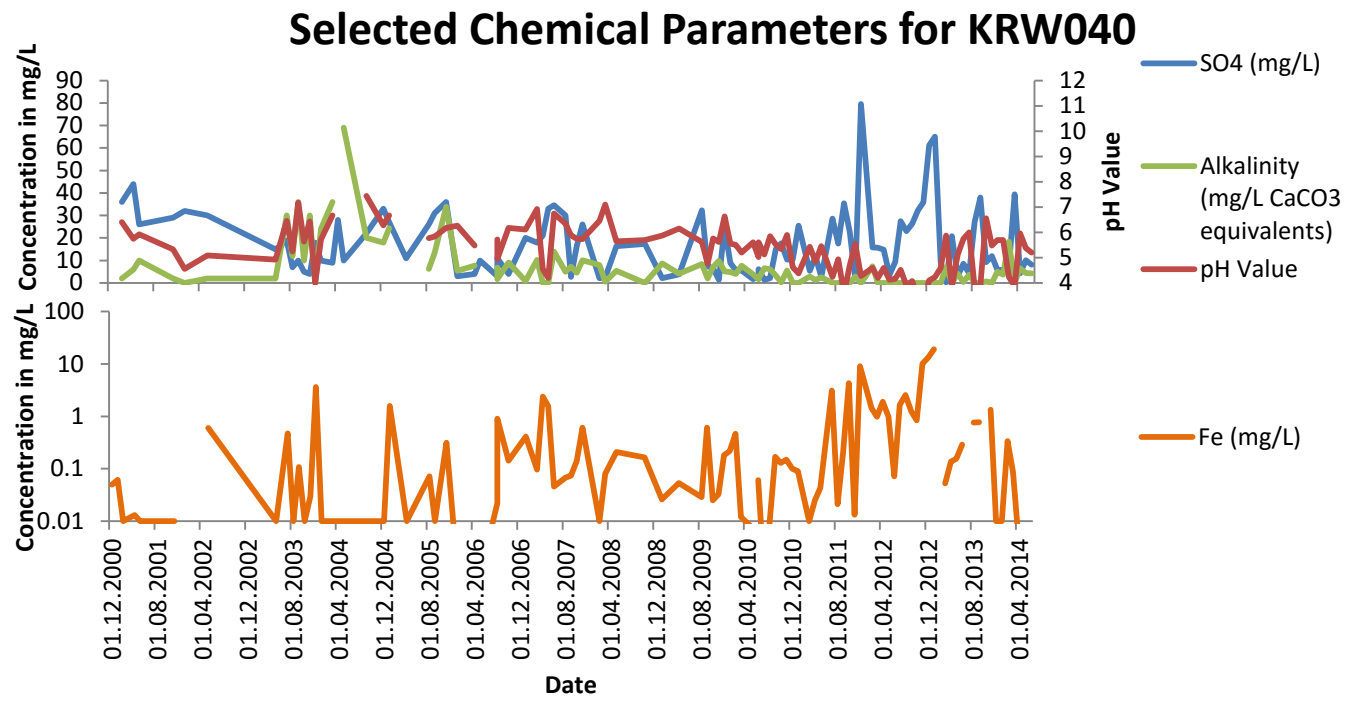


Figure 54: Groundwater monitoring data for KRW040 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

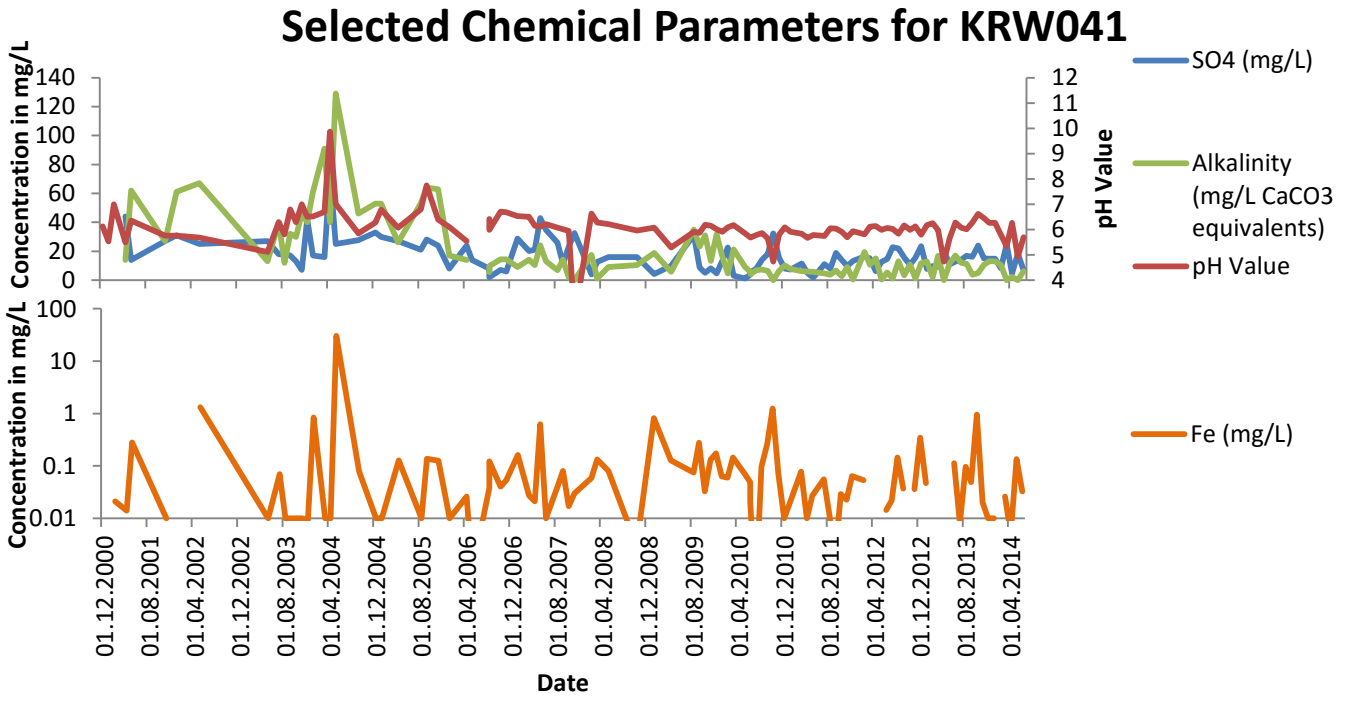


Figure 55: Groundwater monitoring data for KRW041 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

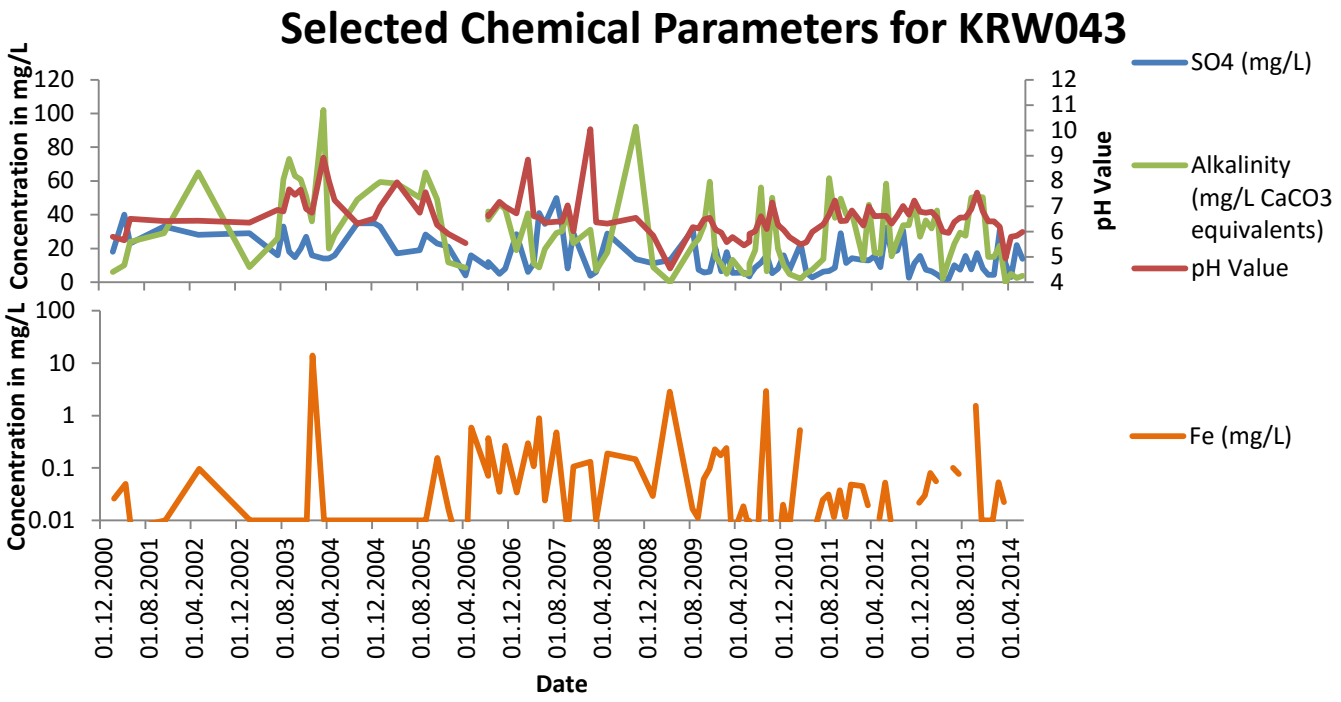


Figure 56: Groundwater monitoring data for KRW043 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

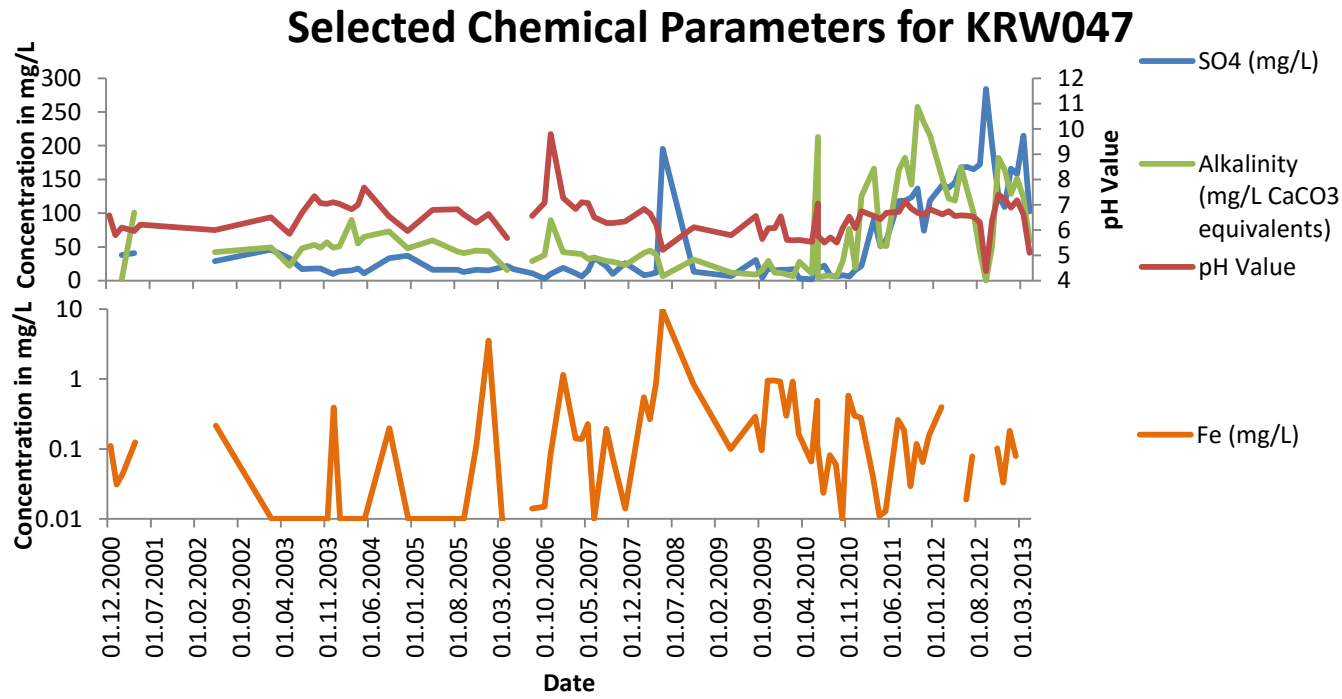


Figure 57: Groundwater monitoring data for KRW047 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

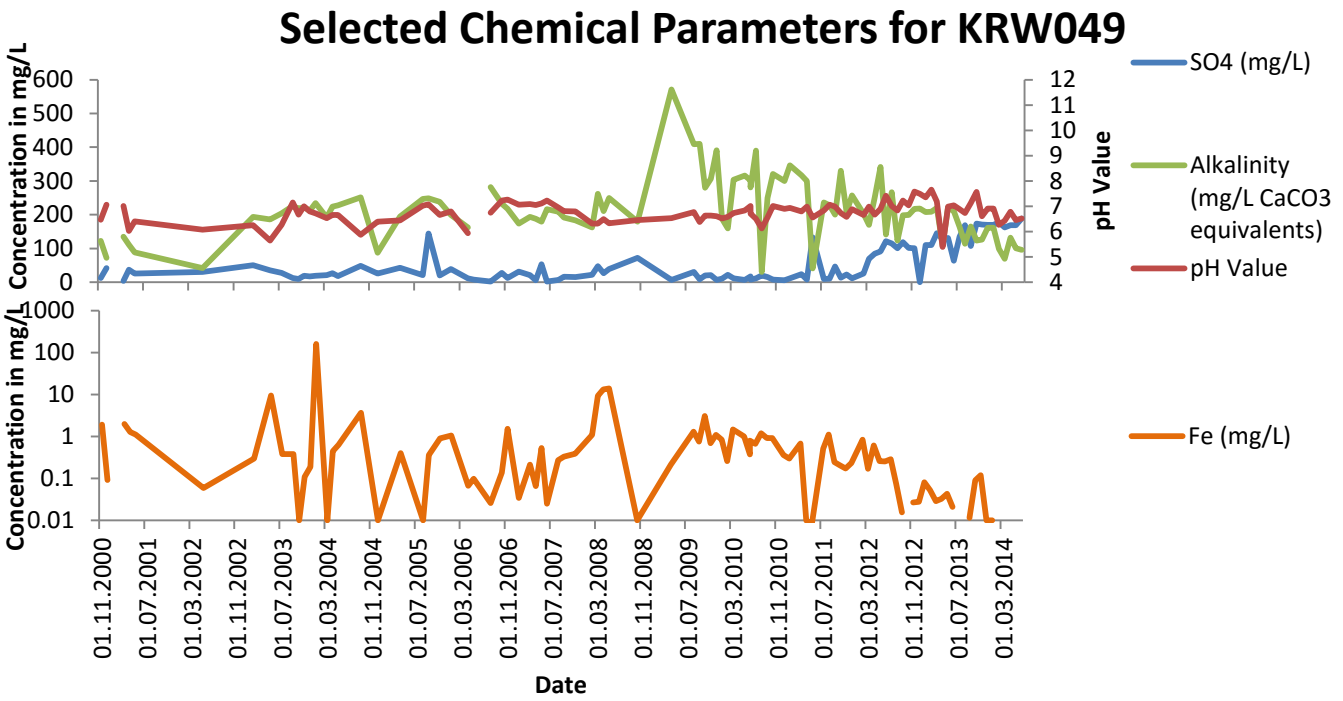


Figure 58: Groundwater monitoring data for KRW049 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

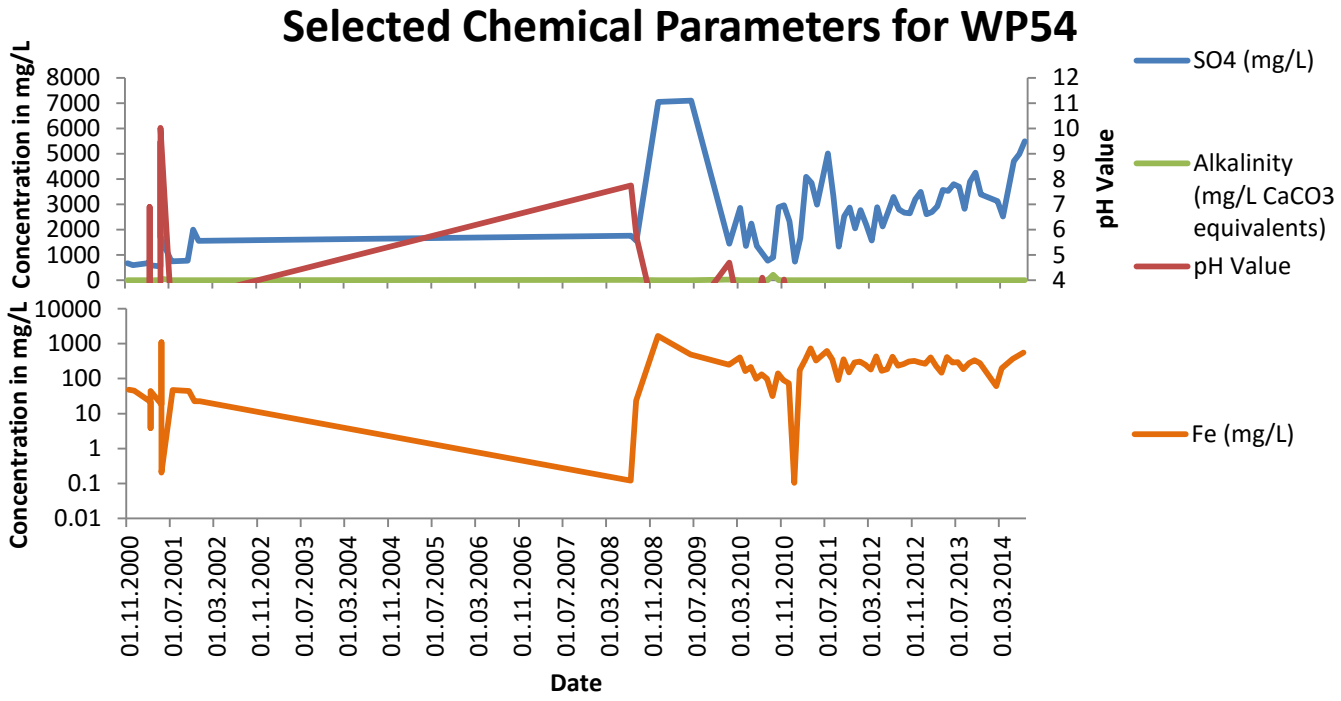


Figure 59: Groundwater monitoring data for WP54 at E-Mine (illustrating Fe, SO4, pH and Alkalinity)

5.2.6 Geochemical Model Calibration

The calibration of the geochemical model for E-Mine was performed as described in the methodology section (Figure 60). Constituent concentrations obtained from the leaching tests were averaged and plotted on the abscissa of the graph. The simulated concentrations of the constituents, obtained from the geochemical model, were plotted on the ordinate. Additionally, each data point has an error bar in the horizontal direction, which represents the standard error calculated for the average of each constituent concentration. The calibration graph shows a coefficient of determination (R^2-value) of 0.9993. Most of the calculated values have a residual error within the calculated standard error for the average analysed concentrations as showed by the horizontal error bars.

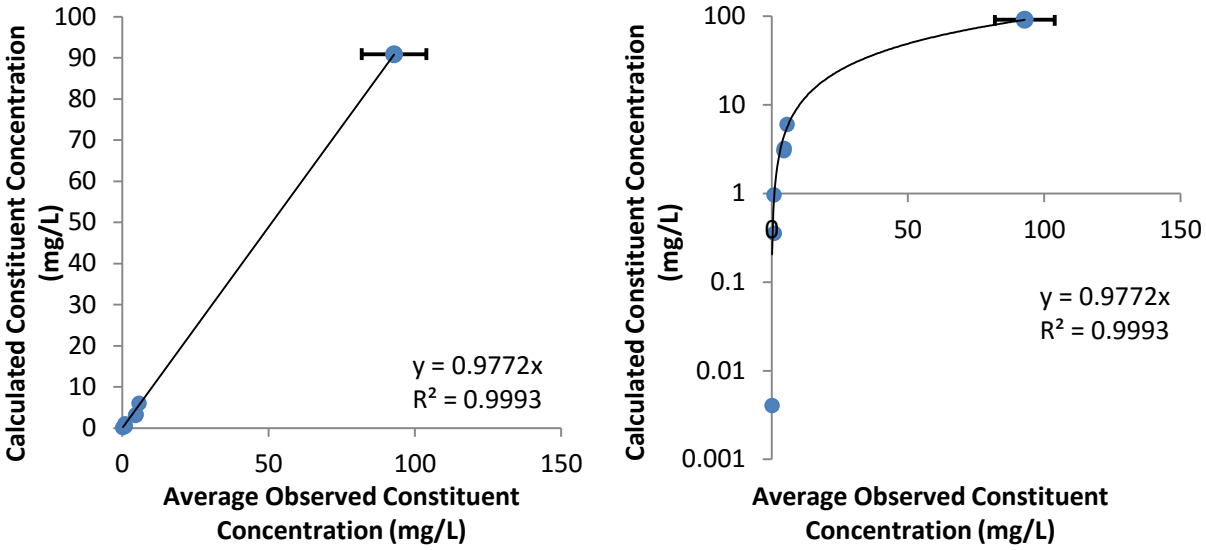


Figure 60: Left: Calibration graph for the geochemical model of E-Mine; averaged analysis concentrations vs. calculated concentrations; standard errors are shown in the horizontal direction. Right: Logarithmic ordinate for improved illustration of lower concentrations and standard error values.

5.2.7 Simulated Natural Geochemical Conditions

After calibration of the geochemical model, the natural geochemical conditions at E-Mine were simulated as described in the methodology section. An initial fluid to rock ratio of 0.3:1 was used, based on water levels and mine water discharge at the site. Additional water was added to the system at a fluid to rock ratio of 1×10^{-4}:1 every day of the simulation, to simulate inflow of additional water into the system, as groundwater and recharge from rainfall. The simulation time lasted 36500 days (100 years) (Figure 61), to account for long term changes in leachate chemistry, while also covering the period of available groundwater monitoring data. The simulation shows that a decrease in the release of SO_4^{2-} is likely to take place from a concentration of approximately 47500 mg/L to a concentration of approximately 300 mg/L.

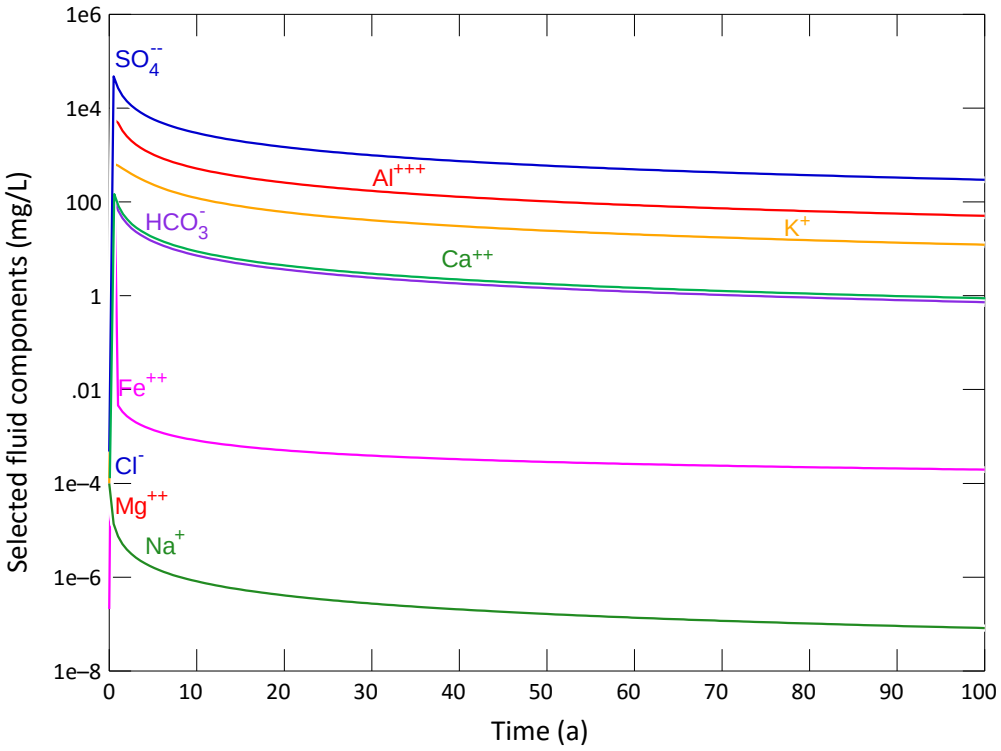


Figure 61: Simulated contaminant concentrations in the leachate of E-Mine generated from the backfill material on site, over time; logarithmic ordinate

5.2.8 Numerical Flow Model Chemical Calibration

The simulated concentrations of sulfate in natural conditions of the backfilled opencast mine obtained from the geochemical model were used as input for the numerical flow and transport model. The concentrations in the opencast E-Mine were specified using various time steps and stress periods in the transport model. This was performed to determine if the specified concentrations in the transport model are chemically calibrated, using monitoring data at representative groundwater monitoring wells (Figure 62). These graphs show the simulated sulfate concentrations with an error bar of 50 mg/L, along with the observed sulfate concentrations at each selected monitoring point over time. An error range of 50 mg/L was used as concentrations of sulfate observed in the monitoring wells reach levels of over 500 mg/L in some areas. Additional to this is the field scale leach tests performed at E-Mine indicating potential sulfate concentrations of over 40000 mg/L from overburden material. Therefore, a 10% error of the monitoring concentrations for sulfate was deemed applicable.

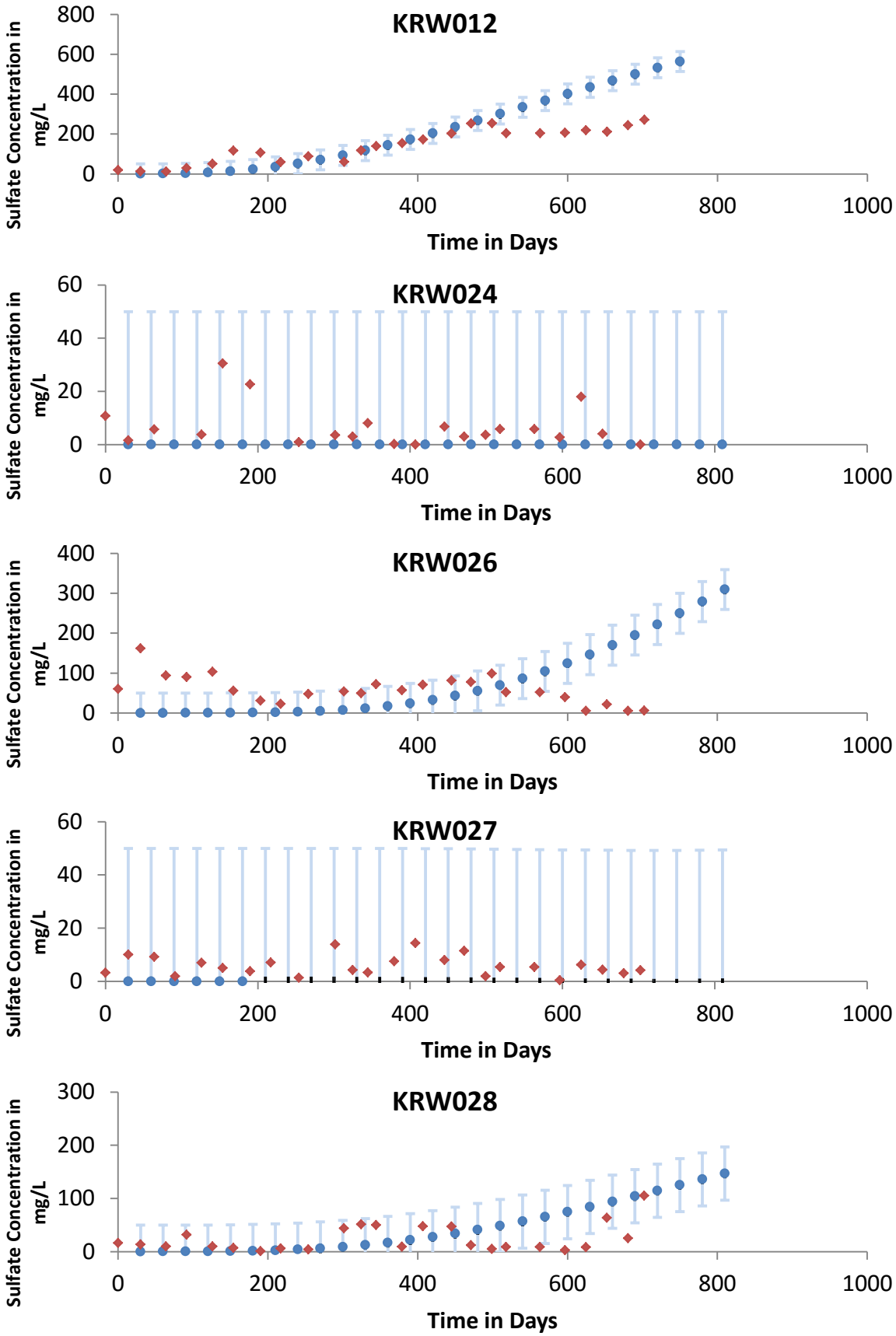


Figure 62: Chemical Calibration Graphs for the monitoring wells used in the E-Mine Numerical Flow and Transport Model, blue dots: simulated values; red diamonds: observed values.

5.2.9 Geochemical Parameter Sensitivity

The parameters influencing the generation and decay of sulfate in solution were varied in the geochemical model (Table 25). This was performed as a model sensitivity analysis to determine the sensitivity of each parameter with respect to its influence on rate limitation and concentration limitation of sulfate. Parameters providing a rate limitation were deemed to influence the rate of sulfate generation or decay in solution. Parameters providing a concentration limitation were deemed to influence the maximum and final concentrations of sulfate in solution.

Table 25: Sensitivity Analysis of Parameters Influencing the Generation and Decay of Sulfate in Solution at E-Mine based on Geochemical Modelling

Parameter Varied	Orders of Magnitude	Rate Limitation	Change Observed in Sulfate Concentration	Contaminant Concentration Limitation	Change Observed in Sulfate Concentration, mg/L
Oxygen Fugacity	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	Yes	100
Gypsum Mass	1	No	None	Yes	5
Gypsum Surface Area	1	No	None	No	None
Gypsum Reaction Constant	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	Yes	5
Pyrite Mass	1	No	None	Yes	100
Pyrite Surface Area	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	No	None
Pyrite Reaction Constant	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	No	None
Input Rate of Water	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	Yes	200 to 2000

5.3 A-Mine

5.3.1 Numerical Flow Model

The following parameters were specified within the numerical model (Table 26):

Table 26: Input parameters to the numerical flow model for A-Mine

Model Parameter	Value	Unit	Reason
Recharge to the aquifer	0.0001	m/d	Calculated
Recharge to the backfilled opencast mine	0.0004	m/d	(Hodgson and Krantz, 1998)
Evapotranspiration	0.005	m/d	Calculated
Boundaries	Topographic water divide east, Klein Olifants River to the west and south, Bosmanspruit to the north.	-	Existing boundary conditions present at the site that would potentially include modelled impacts
Refinement	20	m	Based on the scale of the mining area
Grid dimensions	294 x 604	Cell count	Product of the grid refinement
Hydraulic conductivity	0.01 – 0.05	m/d	(Fourie, 2013)
Hydraulic anisotropy (vertical)	10	-	(Anderson et al., 2015)
Effective porosity	5 declining to 3 with depth in each layer	%	(Wang et al., 2009)
Layers	4	Count	Mining depth approximately 20 to 40m (Pers. comm. Myburgh, 2015)
Longitudinal dispersion	100	m	Schulze-Makuch (2005)
Mean residual head error	1.6	m	Head error statistics
Head error range	10	m	Calculated as 10 % of the difference between the maximum and minimum calculated head elevations

Flow directions interpreted from the numerical flow model showed that flow is directed away from the backfilled opencast mines. Groundwater flow is expected to follow the topography towards local drainage channels (Figure 63) as shown by monitoring data. This includes the Klein Olifants River and Bosmanspruit to the west, south and north of the mine. This was confirmed by the calibration of the model to the latest available monitoring data (Figure 64).

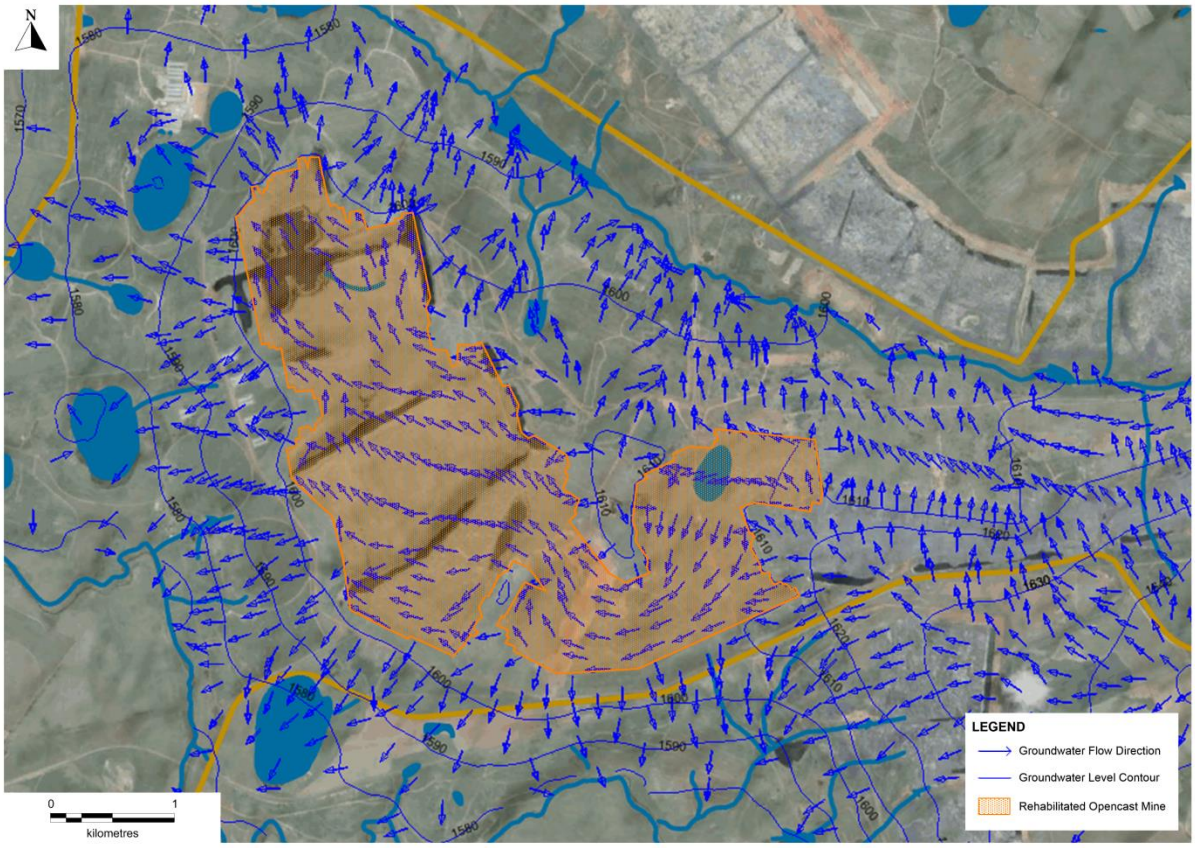


Figure 63: Groundwater flow directions at A-Mine Colliery

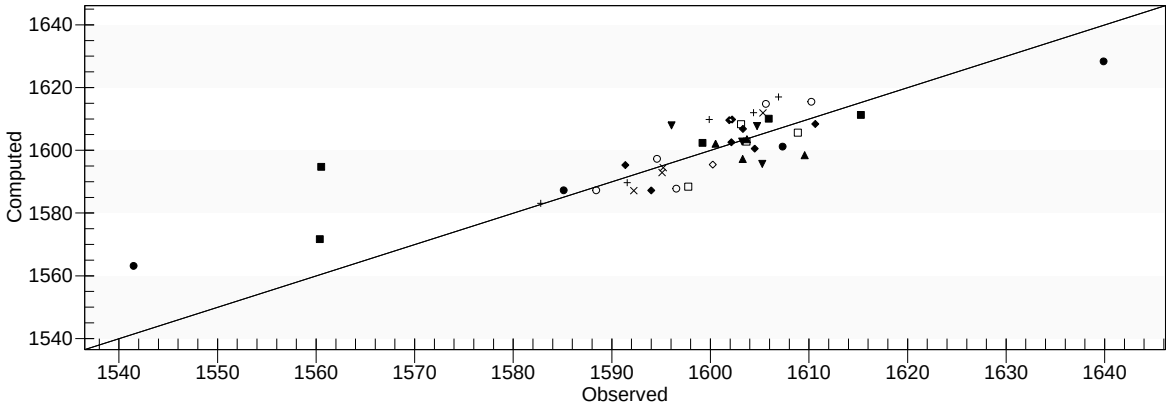


Figure 64: Head calibration graph for the numerical model constructed for A-Mine Colliery

Based on the calibrated model, the inflow rate into the backfilled opencast mine was estimated. A maximum inflow volume calculated for the modelled backfilled opencast mine on site is 3000 to 5000 m^3/day (Fourie, 2013). Assuming that the porosity of the backfill material in the backfilled opencast mines is 30% and multiplying this with the pit surface area and average depth a volume was calculated for the potentially fillable void space within the backfill material. This equated to an initial fluid to rock ratio of 0.3:1 based on rainfall volumes with additional water being added to the system via inflows to the pit from the aquifer at a fluid to rock ratio of 1×10^{-3}:1.

5.3.2 Mineral Abundances

The XRD analysis results for the material samples collected from the backfilled opencast mining areas at A-Mine (Figure 65) show that quartz and kaolinite are predominant mineral phases present (Table 27). However, the sample named ARN3 shows an anomalous abundance of carbonate mineral phases which were identified as dolomite and siderite. Further to this is an anomalous microcline abundance identified in the sample named ARN1. A mineral with a lesser abundance in the samples is muscovite.

Table 27: Mineral Phases Identified During Analysis of Three Backfill Samples at A-Mine; Mineral Phase Abundances Reported as Weight Percentage

Mineral Phase	ARN 1	ARN 2	ARN 3
Dolomite/Calcite	-	4.39	11.33
Kaolinite	24.68	9.19	13.19
Microcline	16.24	8.9	5.9
Muscovite	7.1	-	3.1
Quartz	47.25	77.53	15.14
Siderite	4.72	-	51.35

In addition to the mineralogical analyses performed on the samples, sulfide mineral abundances were estimated. Mine water chemistry (Table 30), acid-base accounting (Table 28) and leach testing (Table 29) were used to estimate the abundance of sulfide minerals in the backfill material (Fourie, 2013). No results are presented for sample ABA 04 as it was misplaced by the laboratory, according to Fourie (2013). Based on the results, the material collected is strongly acid generating which indicates an abundance of disulphide minerals.

Table 28: Acid-base accounting analysis results for backfill material collected at A-Mine (Fourie, 2013) – Base potential and Net Neutralisation Potential (NNP) expressed as $CaCO_3$ equivalent kg per ton

Sample Number	ABA 01	ABA 02	ABA 03	ABA 05	ABA 06	ABA 07	ABA 08	ABA 09	ABA 10	ABA 11	ABA 12
Initial pH	7.03	2.69	3.78	7.65	4.24	3.20	6.64	4.03	7.08	6.92	7.12
Final pH	2.08	1.13	1.24	1.51	1.48	1.07	3.21	1.28	2.21	3.91	3.77
Acid Potential (Closed)	2.249	51.498	38.56	57.739	1.607	51.798	1.266	47.292	3.084	3.079	2.482
Base Potential	4.103	-33.041	-25.71	32.206	-8.36	-24.872	2.393	-9.023	3.37	79.1	16.295
NNP (Closed)	1.854	-84.539	-64.27	-25.533	-9.967	-76.67	1.127	-56.314	0.287	76.021	13.813

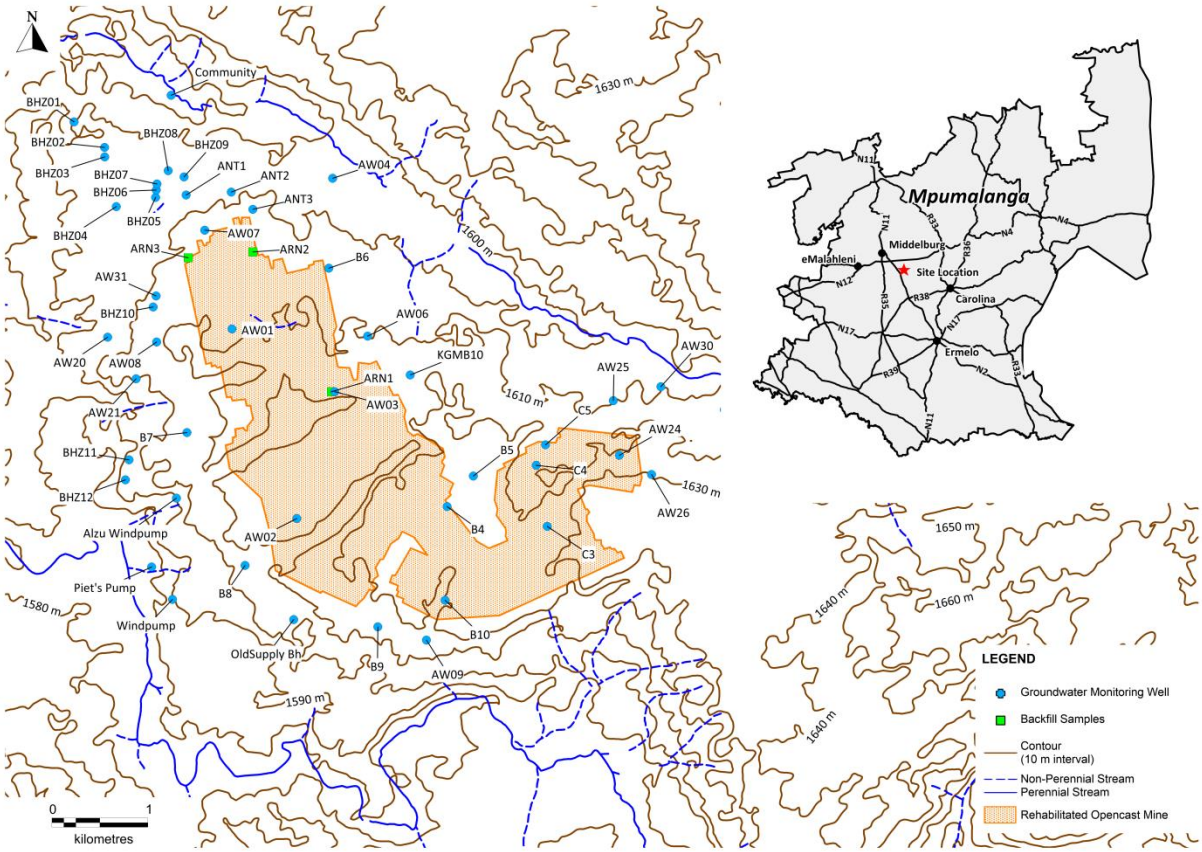


Figure 65: Sample collection areas at A-Mine

Table 29: Analysis results of leach testing on backfill material sampled at A-Mine, exactly reproduced from Fourie (2013); -: below detection limit

Condition	Sample Number	Initial pH	Al	Ba	Be	Ca	Cr	Co	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	Sr	Pb	V	Zn	SO_4^{2-}
Water soluble constituents	ABA01	7.03	0.001	0.001	-	0.922	-	-	-	-	0.090	-	0.282	0.010	-	0.112	-	0.007	-	-	-	3.225
	ABA02	2.69	1.570	-	-	3.598	0.001	0.001	-	3.876	0.033	0.002	0.169	0.007	-	0.053	0.002	0.034	-	0.001	0.004	21.85
	ABA03	3.78	1.363	-	-	5.400	-	0.001	-	0.241	0.039	0.004	0.259	0.011	-	0.036	0.001	0.026	-	-	0.008	19.12
	ABA05	7.65	0.001	0.002	-	0.489	-	-	-	0.001	0.044	-	0.096	0.001	-	0.084	-	0.013	-	-	-	1.095
	ABA06	4.24	0.008	-	-	0.199	-	-	-	0.017	0.086	0.001	0.145	0.013	-	0.065	-	0.002	-	-	0.001	1.569
	ABA07	3.2	0.772	-	-	6.638	-	0.001	-	0.952	0.031	0.001	0.203	0.031	-	0.049	0.001	0.082	-	-	0.003	20.8
	ABA08	6.64	0.001	-	-	0.220	-	-	-	0.001	0.098	-	0.132	0.003	-	0.035	-	0.002	-	-	0.001	1.278
	ABA09	4.03	0.133	-	-	4.482	-	0.004	-	0.113	0.091	0.001	1.019	0.146	-	0.034	0.005	0.024	-	-	0.009	14.84
	ABA10	7.08	0.003	0.001	-	0.080	-	-	-	0.001	0.127	-	0.034	0.001	-	0.058	-	-	-	-	-	0.205
	ABA11	6.92	0.002	-	-	0.458	-	-	-	0.001	0.489	-	0.135	0.002	-	0.087	-	0.001	-	-	-	0.148
	ABA12	7.12	-	-	-	0.001	-	-	-	-	0.001	-	0.010	-	-	0.020	-	-	-	-	-	0.001
Condition	**Sample Number**	**Initial pH**	**Al**	**Ba**	**Be**	**Ca**	**Cr**	**Co**	**Cu**	**Fe**	**K**	**Li**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Sr**	**Pb**	**V**	**Zn**	**SO_4^{2-}**
Constituents released during complete oxidation	ABA01	2.08	0.646	0.014	-	1.319	0.002	-	0.002	0.221	0.139	0.002	0.247	0.115	0.002	0.093	0.002	0.011	-	0.004	0.004	1.08
	ABA02	1.13	0.862	0.011	-	0.003	0.001	-	0.001	6.275	0.172	0.001	0.067	-	0.002	0.164	0.001	0.027	-	0.001	-	24.72
	ABA03	1.24	5.720	0.007	-	0.097	0.002	-	0.003	2.749	0.157	0.002	0.067	-	0.002	0.175	0.001	0.028	-	0.003	0.001	18.51
	ABA05	1.51	0.899	0.020	-	8.185	0.002	0.001	0.004	7.948	0.086	0.001	3.172	0.044	0.002	0.238	0.005	0.088	-	0.002	0.008	27.71
	ABA06	1.48	1.104	0.007	-	0.174	0.001	-	0.001	0.422	0.073	0.001	0.040	-	0.002	0.041	0.002	0.003	-	0.001	0.001	0.771
	ABA07	1.07	1.372	0.013	-	2.197	0.002	-	0.002	7.083	0.179	0.001	0.063	-	0.002	0.211	0.001	0.107	-	0.004	0.002	24.86
	ABA08	3.21	1.392	0.038	-	0.541	0.001	-	0.001	0.210	0.217	0.002	0.304	0.302	0.002	0.102	0.002	0.006	-	0.001	0.001	0.608
	ABA09	1.28	2.360	0.014	-	0.369	0.002	-	0.002	8.381	0.132	0.002	0.137	0.049	0.002	0.198	0.002	0.012	-	0.003	-	22.7
	ABA10	2.21	1.390	0.017	-	0.876	0.001	0.001	0.001	0.436	0.347	0.002	0.253	0.109	0.002	0.028	0.002	0.005	-	0.001	0.002	1.48
	ABA11	3.91	0.150	0.003	-	5.597	0.004	0.001	0.004	0.059	0.407	0.001	0.695	0.066	-	0.795	0.003	0.006	-	0.009	0.019	1.551
	ABA12	3.77	0.371	0.006	-	2.671	0.003	0.008	0.005	0.036	0.344	0.003	0.890	0.065	0.001	0.938	0.017	0.008	-	0.011	0.031	1.2
Condition	**Sample Number**	**Initial pH**	**Al**	**Ba**	**Be**	**Ca**	**Cr**	**Co**	**Cu**	**Fe**	**K**	**Li**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Sr**	**Pb**	**V**	**Zn**	**SO_4^{2-}**
Sulphuric acid soluble constituents	ABA01	1.77	2.560	0.001	-	4.080	0.003	0.205	0.030	3.847	0.293	0.004	0.756	0.220	-	0.281	0.151	0.066	0.001	0.004	0.006	No values - Sulphuric acid used to acidify samples
	ABA02	1.8	3.388	0.003	-	3.422	0.003	0.993	0.080	15.620	0.258	0.003	0.205	0.010	-	0.166	1.359	0.045	0.002	0.002	0.008	
	ABA03	1.89	8.043	0.001	-	5.603	0.004	0.001	0.002	2.857	0.177	0.007	0.343	0.011	-	0.123	0.002	0.037	0.001	0.002	0.014	
	ABA05	2.27	1.239	-	-	6.749	0.001	0.003	0.004	3.792	0.136	0.002	3.550	0.042	-	0.190	0.003	0.086	0.001	0.002	0.009	
	ABA06	1.66	2.856	0.001	-	0.279	0.008	0.328	0.045	5.062	0.232	0.003	0.283	0.026	-	0.197	0.344	0.008	0.001	0.003	0.006	
	ABA07	1.57	2.269	0.001	-	5.893	0.002	0.001	0.004	5.755	0.190	0.003	0.229	0.020	-	0.268	-	0.088	0.001	0.003	0.006	
	ABA08	1.9	5.618	-	-	1.512	0.004	0.006	0.006	3.689	0.464	0.004	0.851	0.680	-	0.116	0.003	0.013	0.001	0.004	0.009	
	ABA09	2.13	4.145	0.003	-	5.452	0.003	0.574	0.095	17.040	0.359	0.004	1.338	0.217	-	0.205	0.960	0.041	0.001	0.003	0.016	
	ABA10	1.86	4.069	0.001	0.001	1.954	0.004	0.010	0.010	4.647	0.769	0.005	0.752	0.272	-	0.165	0.008	0.010	0.001	0.004	0.024	
	ABA11	1.99	0.953	0.001	-	6.282	0.001	0.002	0.004	0.356	0.949	0.002	1.388	0.222	-	0.247	0.005	0.012	-	0.002	0.117	
	ABA12	2.56	2.377	0.001	-	4.731	0.001	0.043	0.032	5.398	0.433	0.003	1.931	0.443	-	0.201	0.105	0.021	-	0.004	0.023	

Ag, As, Cd, Sb, Se, Sn concentrations below detection limit for all samples

Table 30: Analysis results of A-Mine mine water discharge (Pers. Comm. Myburgh, 2015); concentrations in mg/L; b.d.l.: below detection limit

Analysed Constituent	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
pH	7.91	8.08	7.78	7.93	7.44
Temperature, °C	21.86	22.00	21.70	25.62	24.10
Measured TDS	5992	6078	5887	5996	5676
Alkalinity as $CaCO_3$	257.62	407.96	191.47	376.19	206.22
Al	0.00	0.14	0.00	0.01	0.00
Ca	488.93	670.18	565.93	488.49	540.91
Fe	0.02	0.07	0.00	0.01	0.00
K	29.85	114.32	38.66	41.07	40.29
Mg	519.64	833.32	650.38	497.38	614.05
Mn	1.47	0.34	0.25	0.22	0.22
Na	128.81	138.09	129.83	122.22	137.51
F	0.20	0.13	0.33	0.34	0.29
Cl	19.89	21.69	20.94	22.31	28.71
NO_3	b.d.l.	0.13	b.d.l.	0.17	b.d.l.
PO_4	0.26	0.29	0.34	b.d.l.	0.33
SO_4	2690	3315	2885	3270	3255
Ion Balance Error (%)	13.16	27.04	24.11	-4.98	11.73

5.3.3 Distilled Water Leach Tests

Three samples were collected from A-Mine colliery and submitted for distilled water leach testing. The subsequent leachates were analysed using ICP-OES for major metal cations and metals while anion concentrations were determined by ion-chromatography (Table 31). The results show that the leachate pH is raised by the material and the predominant leached constituent from the material is sulfate in two of the three samples.

Table 31: Leachate Analysis Results for A-Mine

Analysed Constituents, mg/L	ARN1	ARN2	ARN3
pH	7.81	7.57	8.46
Measured Total Dissolved Solids	83.2	163	90.6
Alkalinity	27.3	20	59.9
Ca	15	41.2	17.4
Fe	0.07	-	0.05
K	3.3	1.65	1.32
Mg	6.14	6.54	7.45
Mn	-	-	-
Na	5.2	2.01	1.81
Cl	0.49	0.9	1.19
NO_3	-	-	-
SO_4	27.5	88.8	3.92

5.3.4 Mineral Reaction Rates

Estimated mineral abundances were averaged based on XRD analyses, acid-base accounting and mine water analyses. The standard error and standard deviation were calculated for each mineral phase and the reaction constant for each phase was obtained from literature (Table 32). The initial reactive surface area was also calculated based on the described methodology, using the applicable references and assumptions.

Table 32: Calculated statistics, rate constants and reactive surface areas from the XRD results of three backfill samples from A-Mine

Mineral Phase Based on Analysis Data	Mean, mass %	Standard Deviation, mass %	Standard Error of mean mass %	Initial Reaction Rate Constant, $mol \cdot cm^{-2} \cdot s^{-1}$	Initial Reactive Surface Area, $cm^2 \cdot g^{-1}$ #
Dolomite	5.24	5.71	3.30	1×10^{-11} [a]	110
Kaolinite	15.69	8.04	4.64	1×10^{-17} [b]	250
K-Feldspar	10.35	5.32	3.07	1.7×10^{-17} [c]	250
Muscovite	3.40	3.56	2.06	2.9×10^{-15} [d]	212
Quartz	46.64	31.20	18.01	5.0×10^{-14} [e]	250
Siderite	18.69	28.38	16.39	1×10^{-12} [h]	200
Pyrite	2.00 *	n.a.	n.a.	2.8×10^{-12} [f]	400
Gypsum	0.05 *	n.a.	n.a.	1.3×10^{-04} [g]	130

[a]Pokrovsky and Schott (2002); [b]Huertas et al. (1999); [c]Oelkers and Schott (1998); [d]Oelkers et al. (2008); [e]Gudbrandsson et al. (2014);[f]Malmström et al. (2006); [g]Jeschke et al. (2001);[h](Pokrovsky and Schott, 2002); *Estimated based on field observations, acid-base accounting and literature data; #Calculated from sample average grain size and mineral density, assuming entire surface is available for reaction (Brantley, 1998, Gautier et al., 2001, White and Brantley, 2003); n.a.: not applicable.

5.3.5 Groundwater Monitoring Data

A comparison of selected parameters was performed on the available groundwater monitoring data for A-Mine. Results of this comparison are described below for each monitoring well.

AW1 (Figure 66)

Elevated concentrations of SO4 can be observed in the data collected from this well as well as a slightly alkaline pH indicating buffering reactions taking place. However alkalinity concentrations observed in the data are lower than sulfate concentrations but follow a similar trend. Fe concentrations for this well are highly variable and do not show an apparent trend of decrease or increase.

AW10 (Figure 67)

Alkalinity concentrations in this well are higher than that of sulfate in this monitoring well but do not show an increasing or decreasing trend. However, a spike is observed in both concentrations during 1998 with a corresponding lowering in pH value which is fairly stable and alkaline across the monitoring period. Fe concentrations are variable across atleast 2 orders of magnitude during the monitoring period and show no apparent trend.

AW12 (Figure 68)

Sulfate concentrations in this monitoring well show a decreasing trend over the monitoring period with a fairly stable pH which is slightly alkaline over the monitoring period. Fe concentrations in this monitoring well is highly variable and show no apparent trend.

AW13 (Figure 69)

Sulfate concentrations in this monitoring well show a decreasing trend over the monitoring period with a fairly stable pH which is slightly alkaline over the monitoring period. Fe concentrations in this monitoring well show a decreasing trend and vary over 2 orders of magnitude.

AW14 (Figure 70)

Highly variable alkalinity concentrations were measured during the monitoring period in this monitoring well and do not show an apparent trend. However, sulfate concentrations in this monitoring well have increased over the monitoring period but no concentration exceeded 140 mg/L. A variable pH is also observed in this monitoring well but remains fairly neutral. Fe concentrations in this monitoring well vary over 3 orders of magnitude and show a decreasing trend.

AW15 (Figure 71)

Although limited data exists for this monitoring well, a clear decreasing trend in sulfate concentrations can be observed with a corresponding rise in pH values as well as alkalinity concentrations. Fe concentrations decreased over the monitoring period.

AW18 (Figure 72)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with early concentrations of around 2500 mg/L showing some variation and 2 peaks during the early and late 1990's. Low concentrations of alkalinity can be observed throughout the monitoring period but a gradual rise in pH can be observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data and follow a similar to the variations in concentration observed for sulfate.

AW19 (Figure 73)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 1400 mg/L showing some variation and 3 peaks during 1993, 1996 and 2000. Low concentrations of alkalinity can be observed throughout the monitoring period but a gradual yet variable rise in pH can be observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data and follow a similar trend to the variations in concentration observed for sulfate.

AW2 (Figure 74)

An increasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 4500 mg/L showing some variation. Low concentrations of alkalinity can be observed throughout the monitoring period. Additionally, a stable and slightly alkaline pH can be observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data but no trend is apparent.

AW20 (Figure 75)

An increasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 1500 mg/L showing some seasonal variation. Elevated concentrations of alkalinity can be observed throughout the monitoring period with a decreasing trend in concentrations. Additionally, an increasing alkaline pH can be observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data with a decreasing trend.

AW21 (Figure 76)

A decreasing trend in alkalinity concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 450 mg/L showing some variation. Low concentrations of sulfate can be observed throughout the monitoring period and a gradual yet variable lowering in pH can be observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data and follow a similar trend to the variations in concentration observed for sulfate.

AW22 (Figure 77)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 350 mg/L showing some variation. Low concentrations of alkalinity can be observed throughout the monitoring period with a gradual yet variable rise in pH

can be observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data and follow a similar trend to the variations in concentration observed for sulfate.

AW23 (Figure 78)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 130 mg/L showing some variation. Low concentrations of alkalinity can be observed throughout the monitoring period with a variable pH observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data and follow a similar trend to the variations in concentration observed for sulfate.

AW24 (Figure 79)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 2500 mg/L. Decreasing concentrations of alkalinity can be observed throughout the monitoring period with a decreasing pH observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data and follow a similar trend to the variations in concentration observed for sulfate.

AW25 (Figure 80)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations reaching 1600 mg/L. Increasing concentrations of alkalinity can be observed throughout the monitoring period with an increasing pH observed throughout the monitoring period. Fe concentrations follow a similar trend to the variations in concentration observed for sulfate.

AW26 (Figure 81)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations reaching 1700 mg/L. Increasing concentrations of alkalinity can be observed throughout the monitoring period with a fairly stable pH observed throughout the monitoring period. Fe concentrations follow a similar trend to the variations in concentration observed for sulfate.

AW27 (Figure 82)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with low concentrations reaching only 80 mg/L. Decreasing concentrations of alkalinity can be observed throughout the monitoring period with a variable pH observed throughout the monitoring period following a similar trend to alkalinity concentrations. Fe concentrations follow a similar trend to the variations in concentration observed for sulfate.

AW28 (Figure 83)

A decreasing sulfate concentration can be observed between the start of the monitoring period up to 2000 where an increase in sulfate concentrations occurs to the end of the monitoring period. Very low concentrations of alkalinity are prevalent throughout the entire monitoring period. pH values

follow an inversely proportionate trend to that of sulfate while Fe concentrations follow a similar trend to that of sulfate concentrations.

AW3 (Figure 84)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 5000 mg/L. Decreasing concentrations of alkalinity can be observed throughout the monitoring period with an increasing pH observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data and follow a similar trend to the variations in concentration observed for sulfate.

AW30 (Figure 85)

An increasing sulfate concentration can be observed between the start of the monitoring period up to 2000 after which a gradually decreasing sulfate concentration is evident which decreases from 2100 mg/L to approximately 1500 mg/L. An inversely proportionate trend in alkalinity concentrations and pH values to sulfate can be observed throughout the monitoring period. Variable Fe concentrations inversely proportionate to pH values can be observed.

AW31 (Figure 86)

Variable decreasing concentrations of sulfate and alkalinity are evident in the monitoring data for this well with variable, slightly acidic pH values. Fe concentrations in this monitoring well do not show an apparent trend but vary across 2 orders of magnitude.

AW32 (Figure 87)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 2000 mg/L. Very low concentrations of alkalinity can be observed throughout the monitoring period with slightly decreasing pH values observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data but no trend is apparent.

AW33 (Figure 88)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations below 50 mg/L. Very low but increasing concentrations of alkalinity can be observed throughout the monitoring period with slightly decreasing pH values observed throughout the monitoring period. Variable Fe concentrations are observable in the monitoring data and follow a similar trend to the variations in concentration observed for sulfate.

AW35 (Figure 89)

A decreasing sulfate concentration can be observed between the start of the monitoring period up to 2000 where an increase in sulfate concentrations occurs to the end 2000 where after a decreasing trend can be observed. Alkalinity concentrations inversely proportionate to that of sulfate can be observed throughout the monitoring period with a decreasing trend in pH values observed. A decreasing trend in Fe concentrations is also apparent.

AW37 (Figure 90)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 850 mg/L. Increasing concentrations of alkalinity can be observed throughout the monitoring period with slightly increasing pH values observed throughout the monitoring period. Stable Fe concentrations are observable in the monitoring data.

AW38 (Figure 91)

Increasing trends in alkalinity and sulfate concentrations are evident in the monitoring data for this monitoring well with pH values ranging between 7 and 8. An increasing Fe concentration trend can also be observed.

AW4 (Figure 92)

A decreasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 1500 mg/L. Decreasing concentrations of alkalinity can be observed throughout the monitoring period with variable pH values observed throughout the monitoring period. Decreasing Fe concentrations are observable in the monitoring data and follow a similar trend to that of sulfate.

AW5 (Figure 93)

A variable concentration of sulfate can be observed in this monitoring well over the monitoring period with a decreasing trend after 1998 to the end of the monitoring period. Corresponding alkalinity values can also be observed as well as a variable pH value. A variable Fe concentration can also be observed over the monitoring period, gradually decreasing over time and partially corresponds to sulfate concentration trends.

AW6 (Figure 94)

A decreasing trend in sulfate and alkalinity concentrations over the monitoring period can be observed in this monitoring well. Increasing pH values are evident throughout the monitoring period. Decreasing Fe concentrations are observable in the monitoring data and follow a similar trend to that of sulfate.

AW7 (Figure 95)

An increasing sulfate concentration can be observed between the start of the monitoring period up to 2004 after which a gradually decreasing sulfate concentration is evident which decreases from 2600 mg/L to approximately 500 mg/L. An inversely proportionate trend in alkalinity concentrations and pH values to sulfate can be observed throughout the monitoring period. Variable Fe concentrations inversely proportionate to pH values can be observed.

AW8 (Figure 96)

An increasing sulfate concentration can be observed between 2000 and the end of the monitoring period. An inversely proportionate trend in pH values to sulfate can be observed throughout the

monitoring period with alkalinity concentrations below 210 mg/L throughout the monitoring period. Variable Fe concentrations proportionate to sulfate concentrations can be observed.

AW9 (Figure 97)

An increasing trend in sulfate concentrations over the monitoring period can be observed in this monitoring well with concentrations up to 2000 mg/L. An inversely proportionate trend in pH values to sulfate can be observed throughout the monitoring period with alkalinity concentrations below 210 mg/L throughout the monitoring period. Variable Fe concentrations proportionate to sulfate concentrations can be observed.

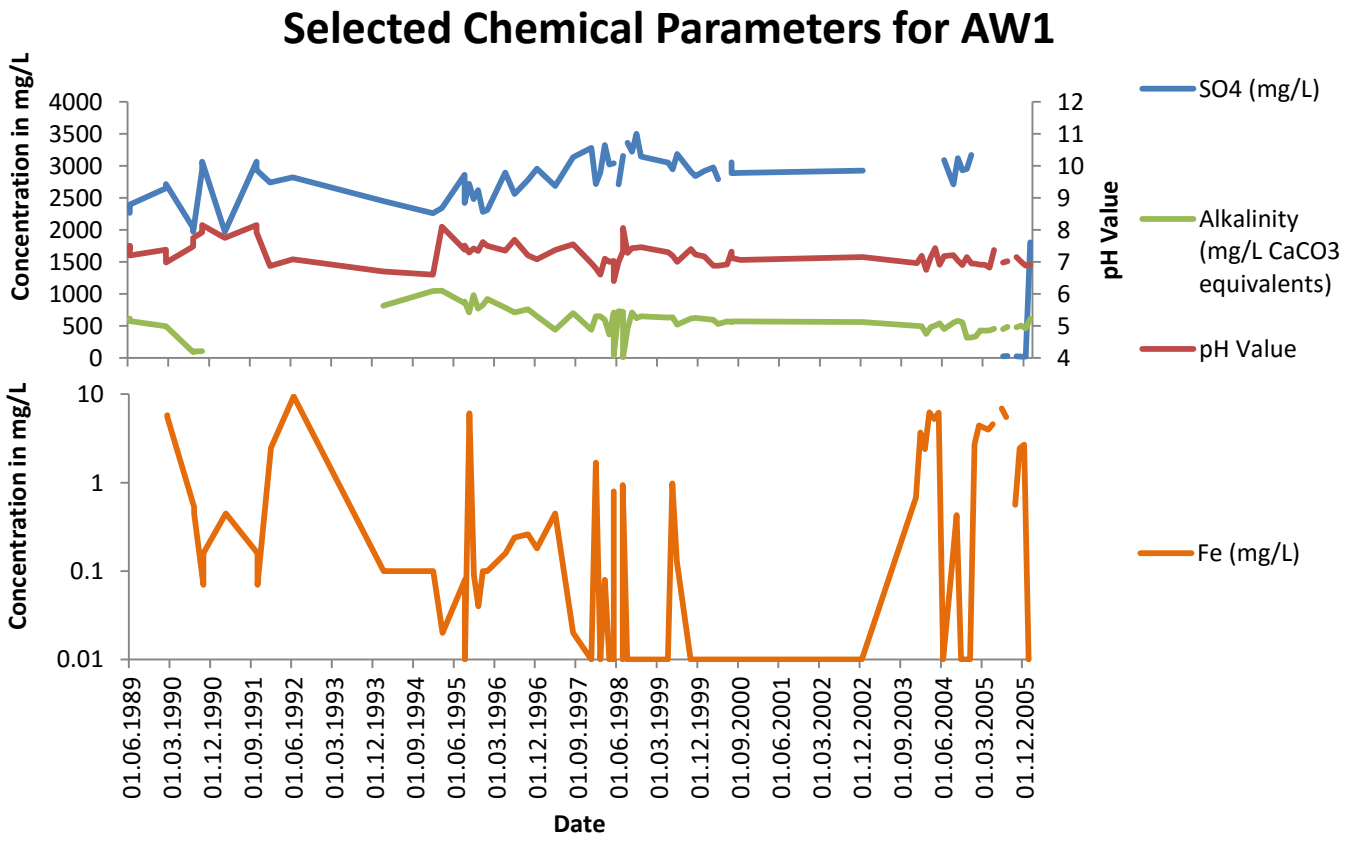


Figure 66: Groundwater monitoring data for AW1 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

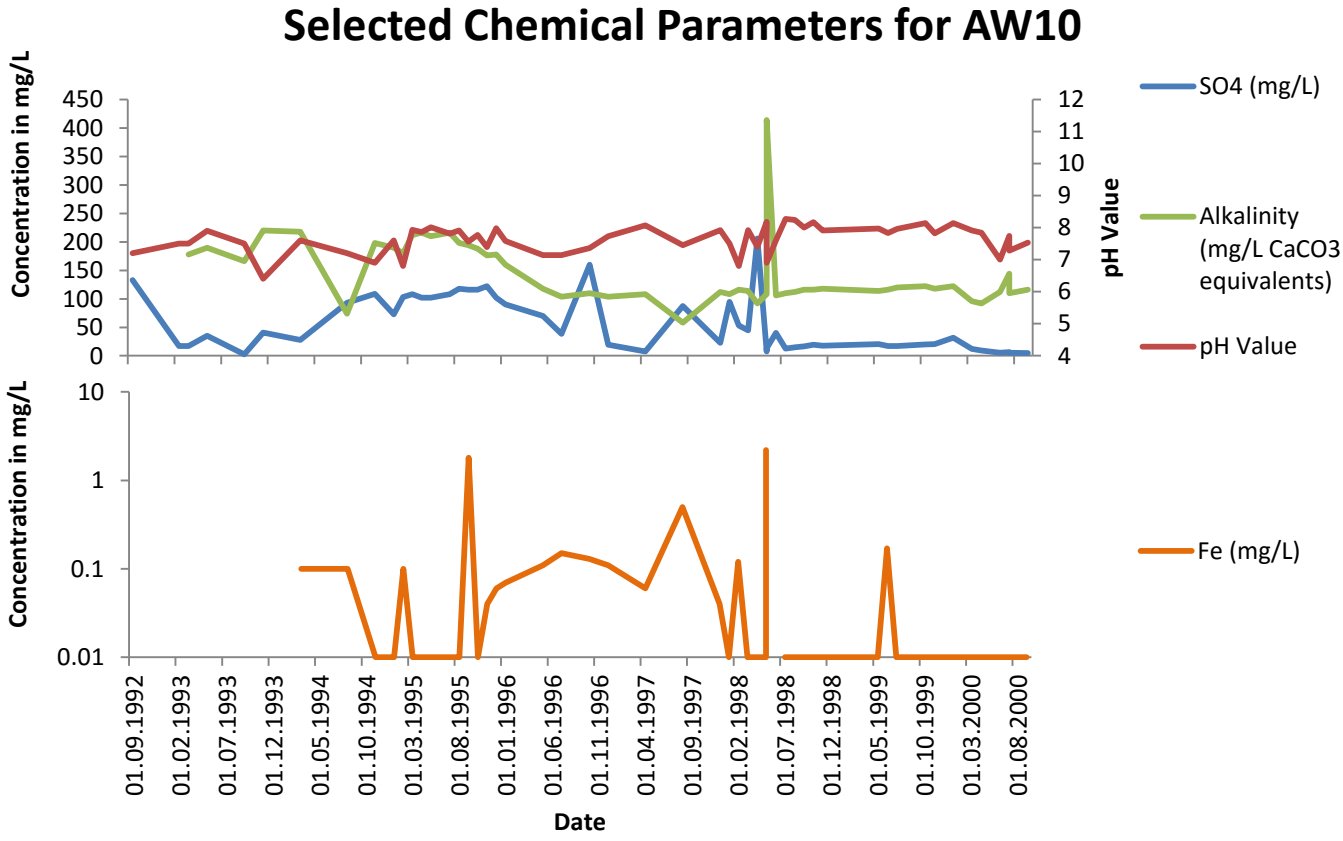


Figure 67: Groundwater monitoring data for AW10 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

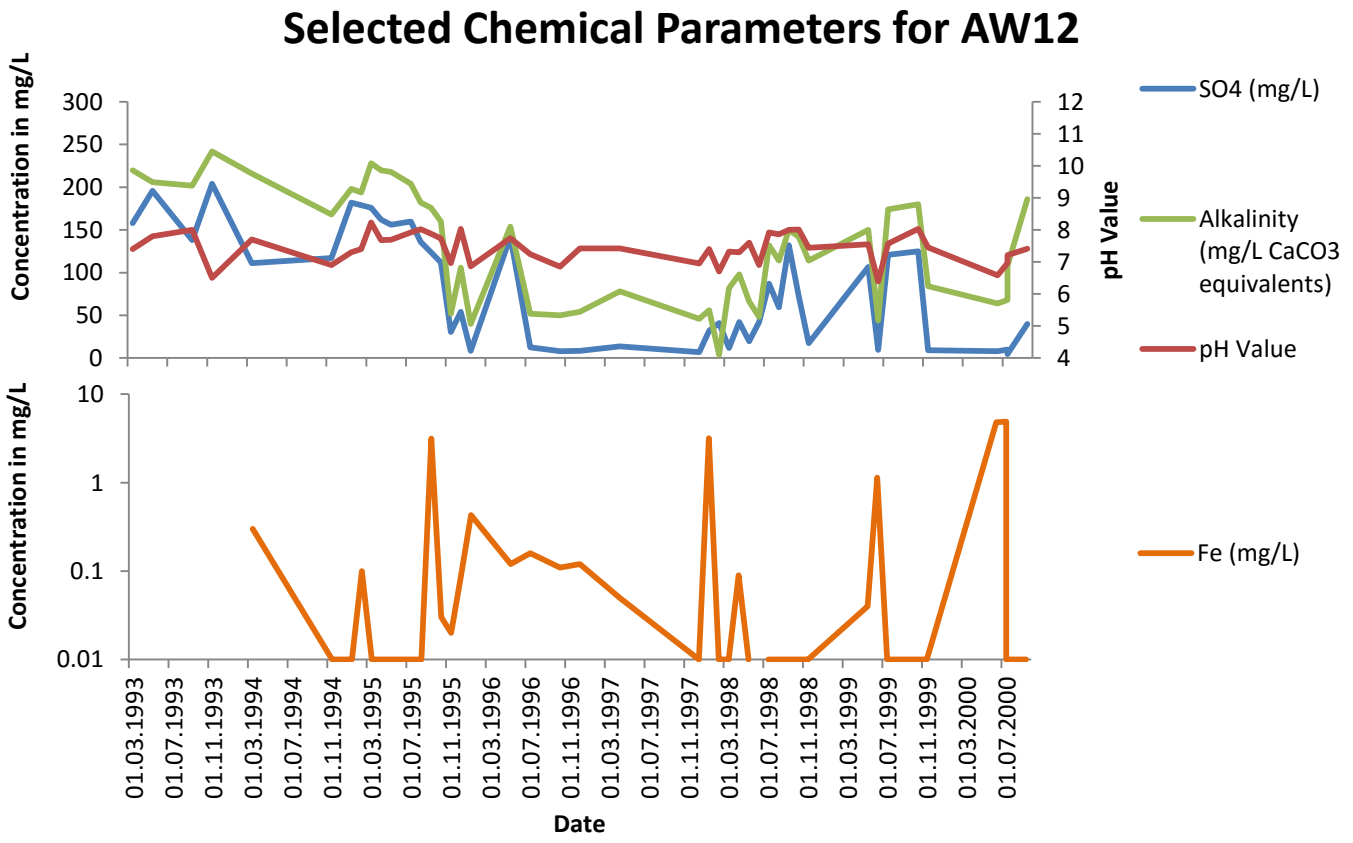


Figure 68: Groundwater monitoring data for AW12 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

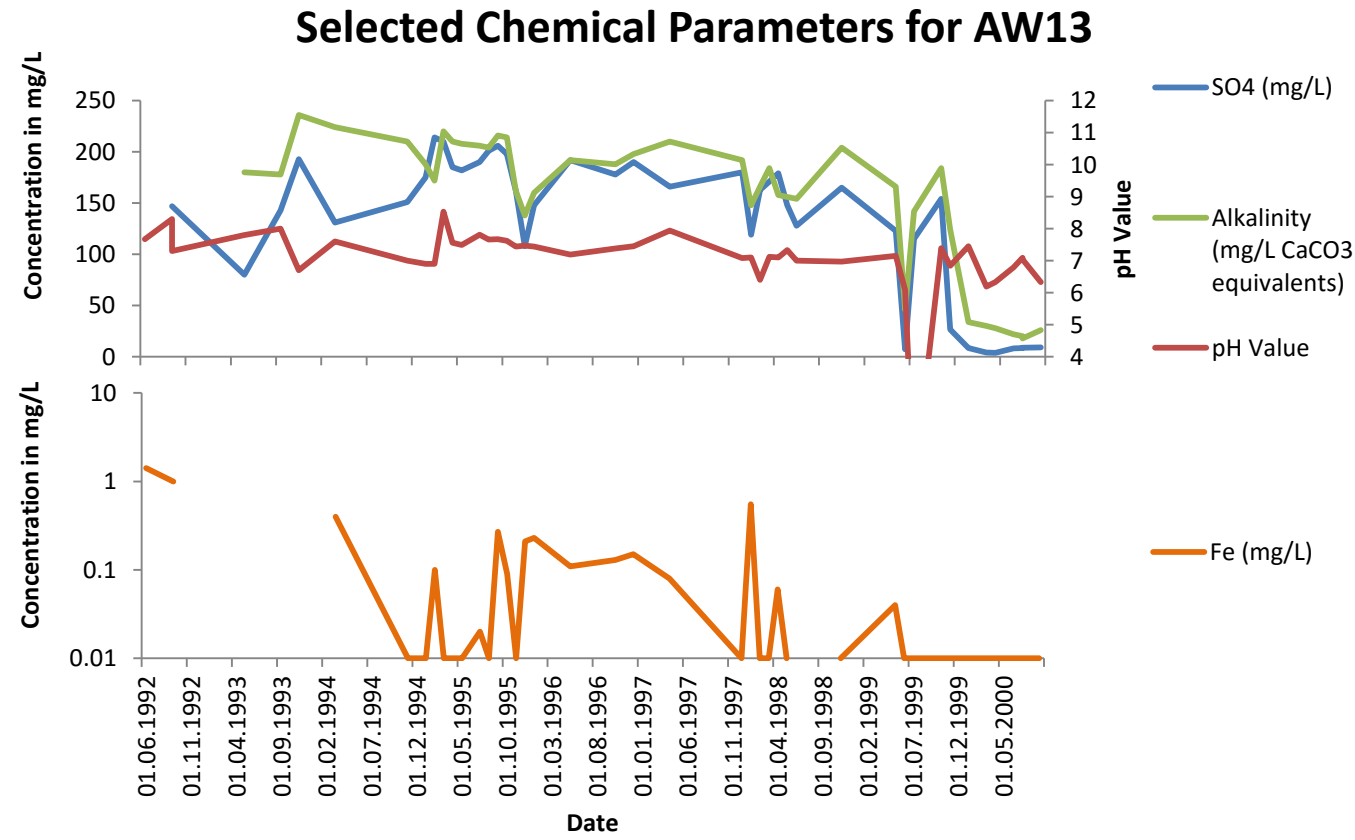


Figure 69: Groundwater monitoring data for AW13 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

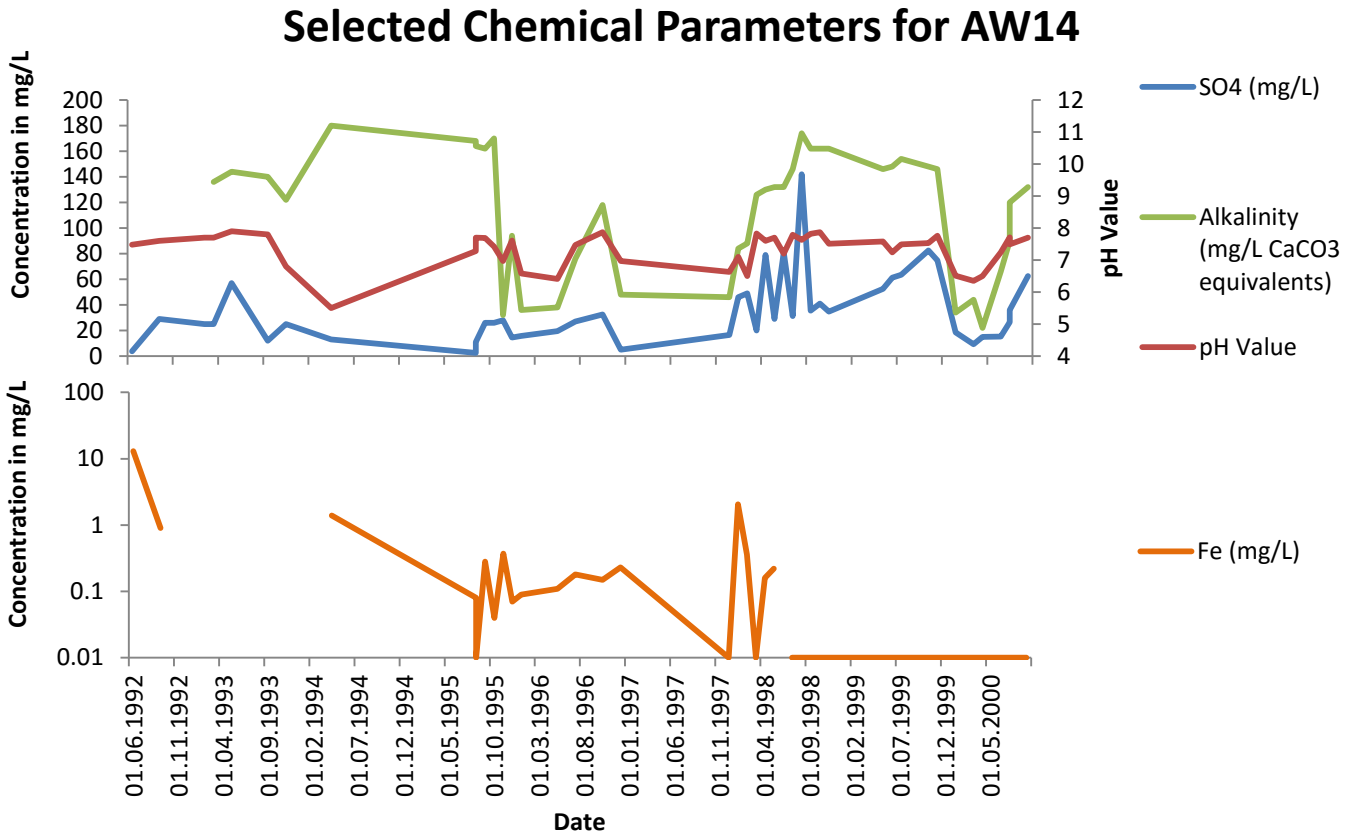


Figure 70: Groundwater monitoring data for AW14 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

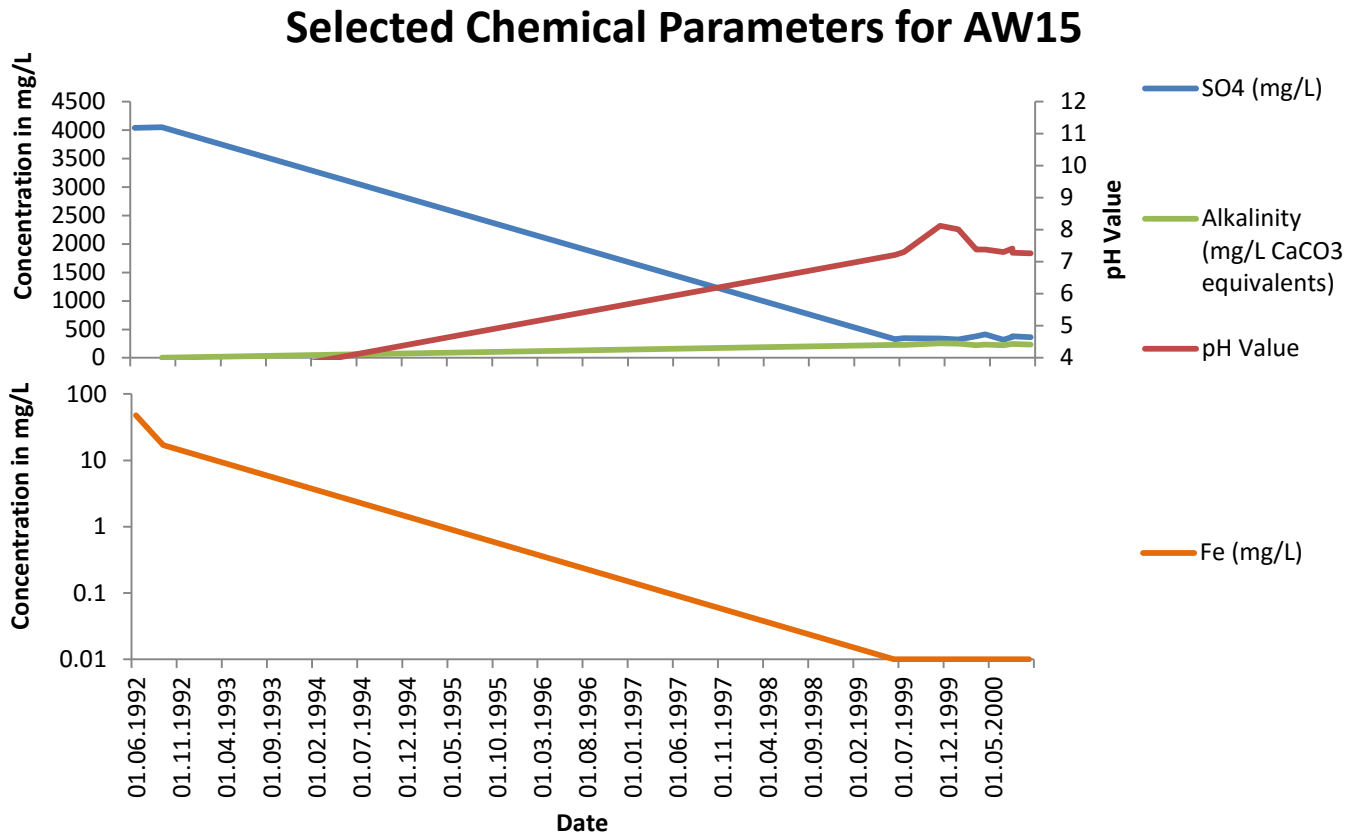


Figure 71: Groundwater monitoring data for AW15 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

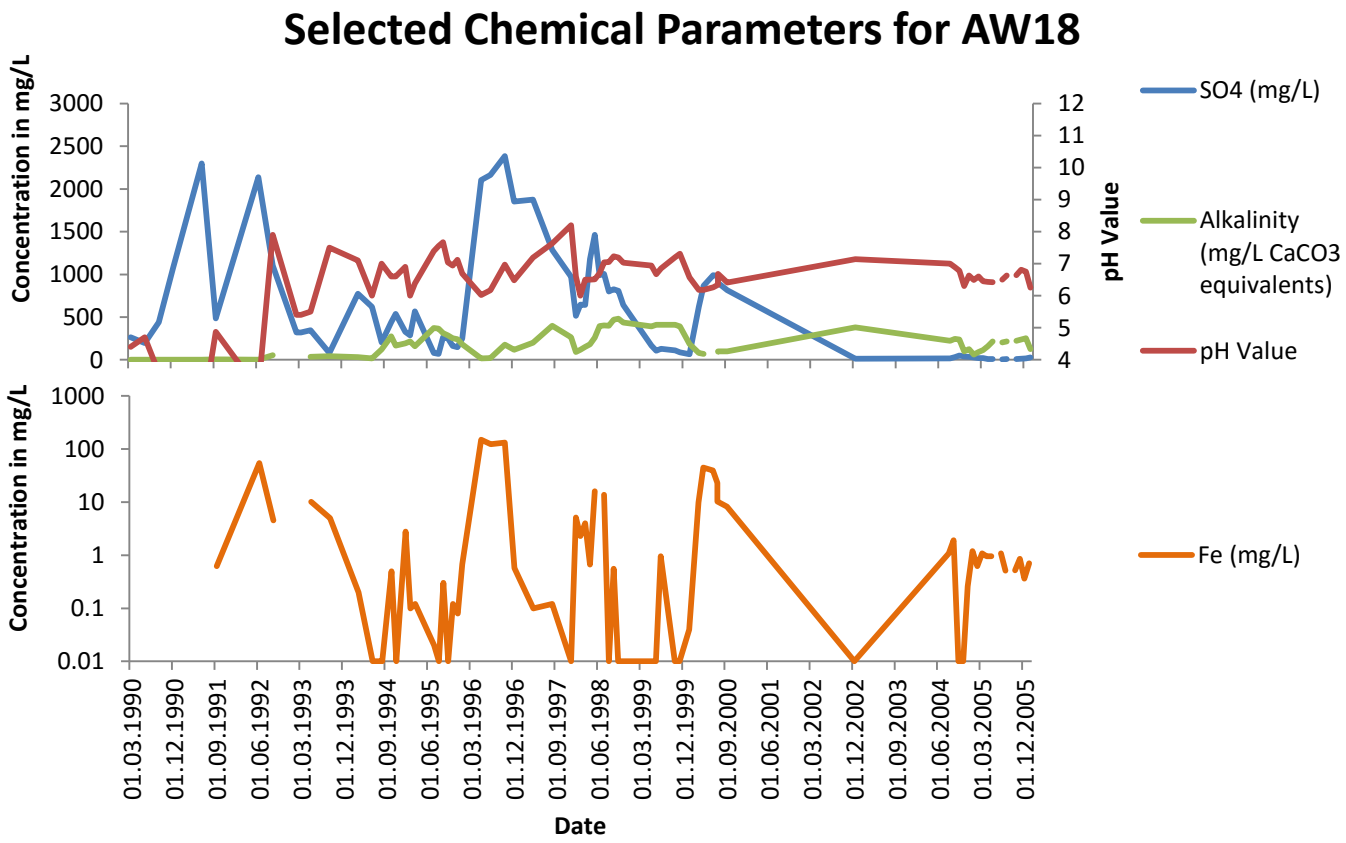


Figure 72: Groundwater monitoring data for AW18 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

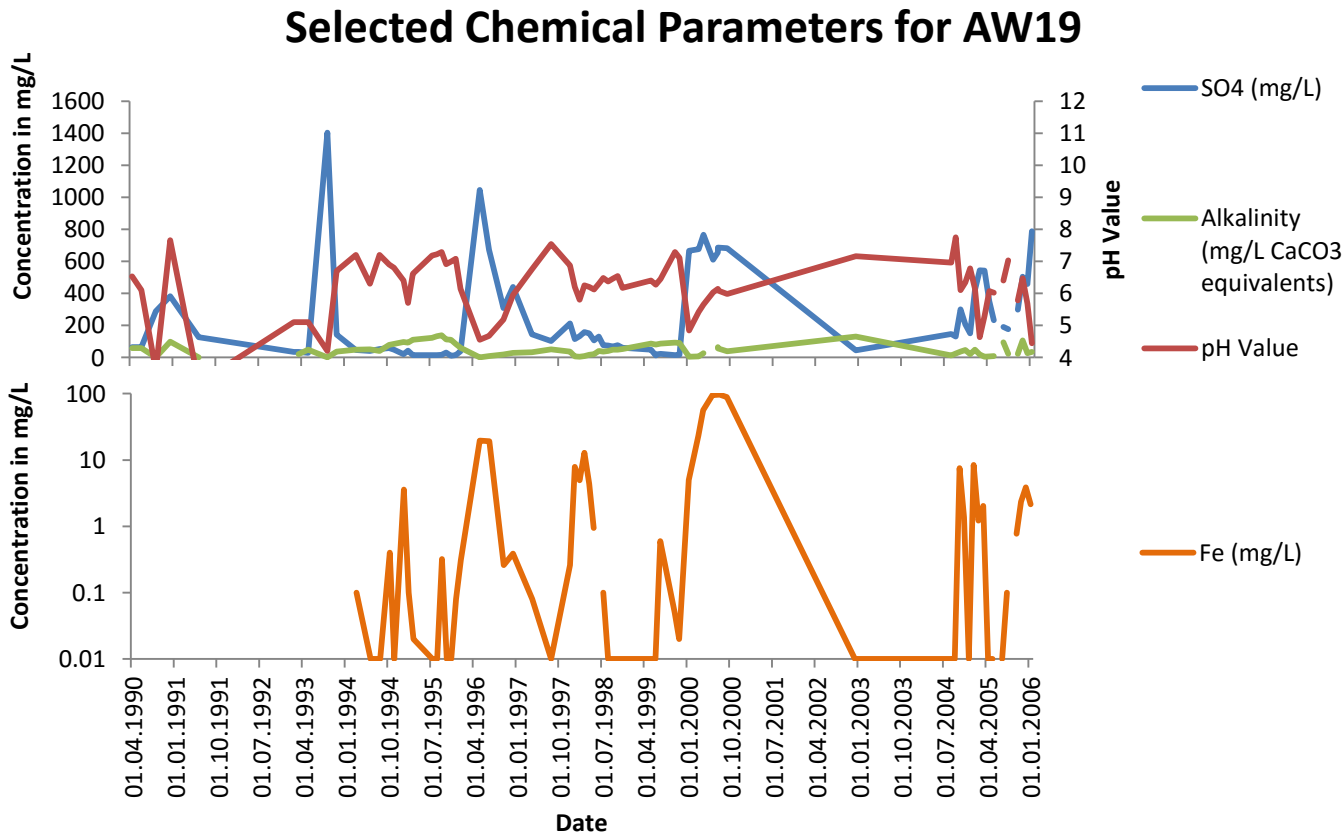


Figure 73: Groundwater monitoring data for AW19 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

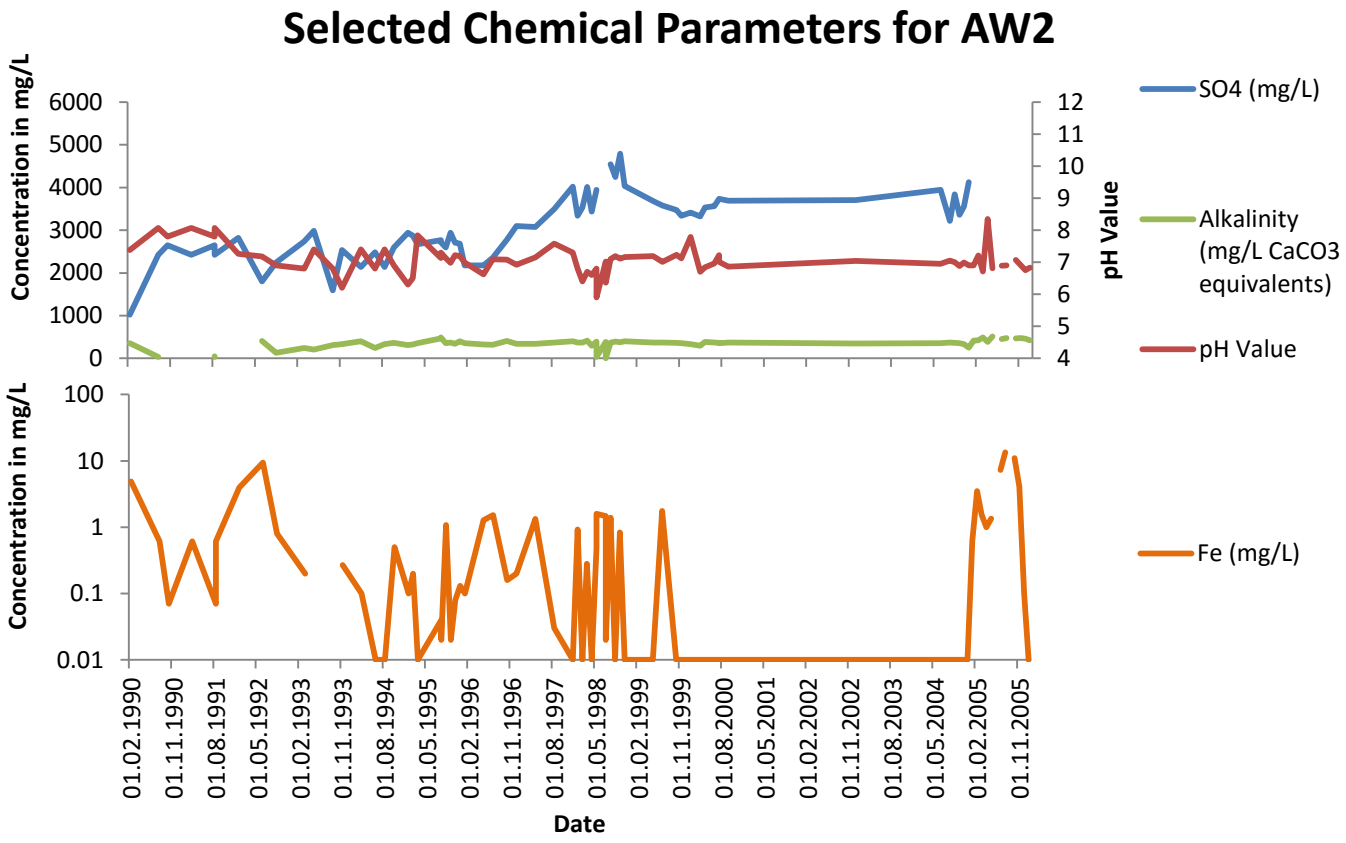


Figure 74: Groundwater monitoring data for AW2 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

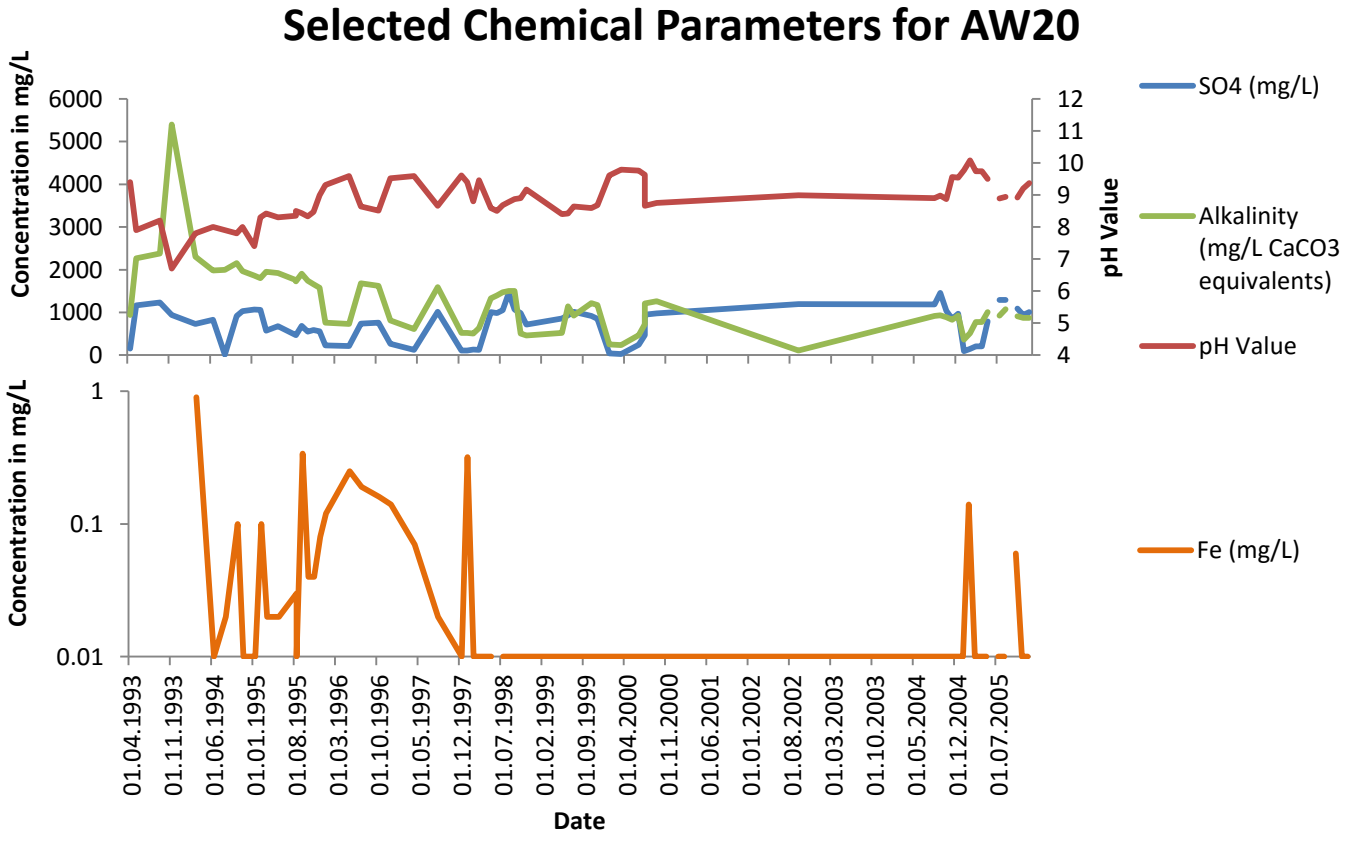


Figure 75: Groundwater monitoring data for AW20 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

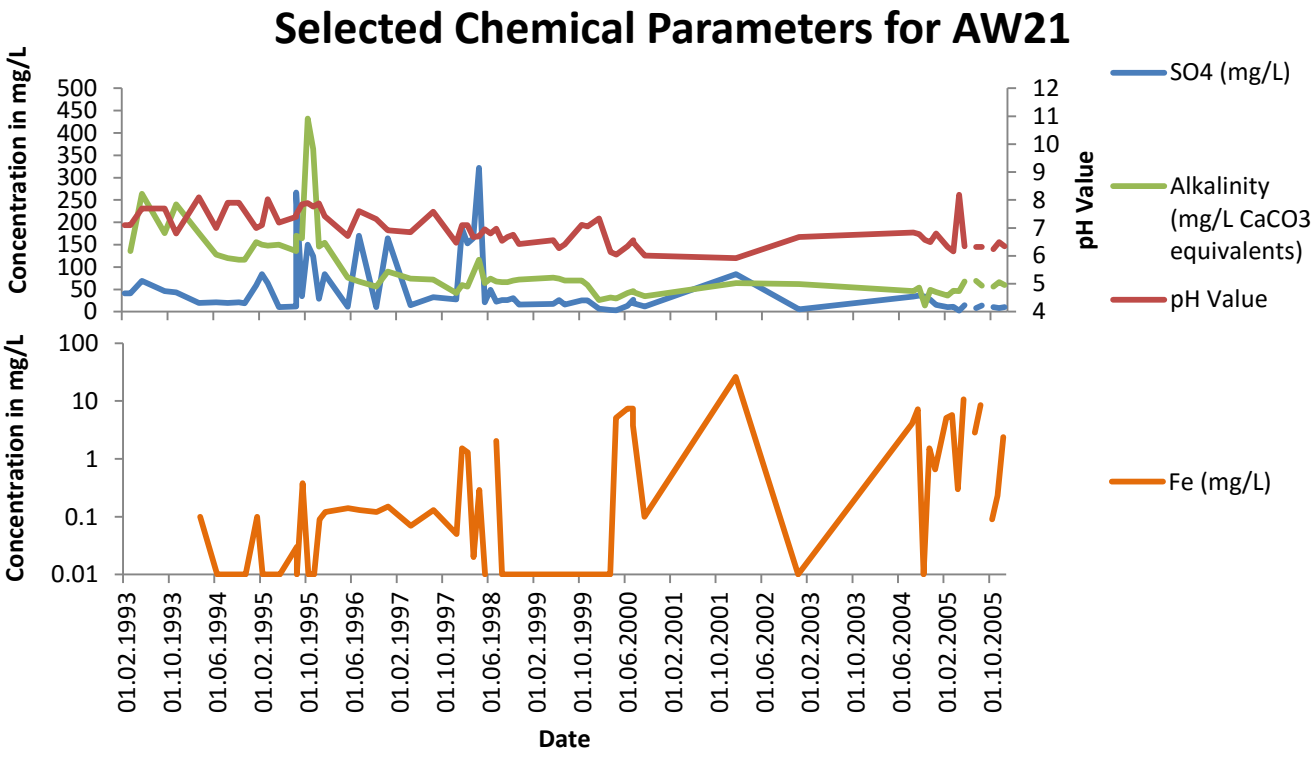


Figure 76: Groundwater monitoring data for AW21 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

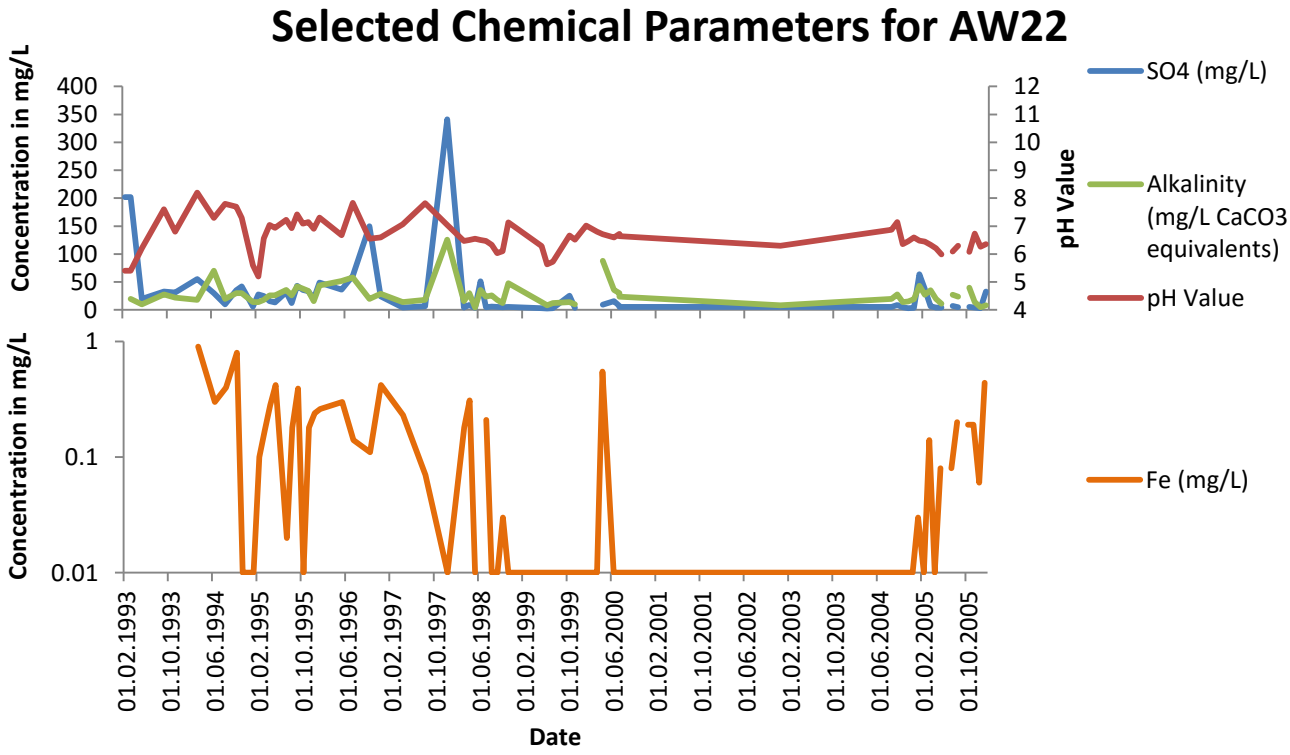


Figure 77: Groundwater monitoring data for AW22 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

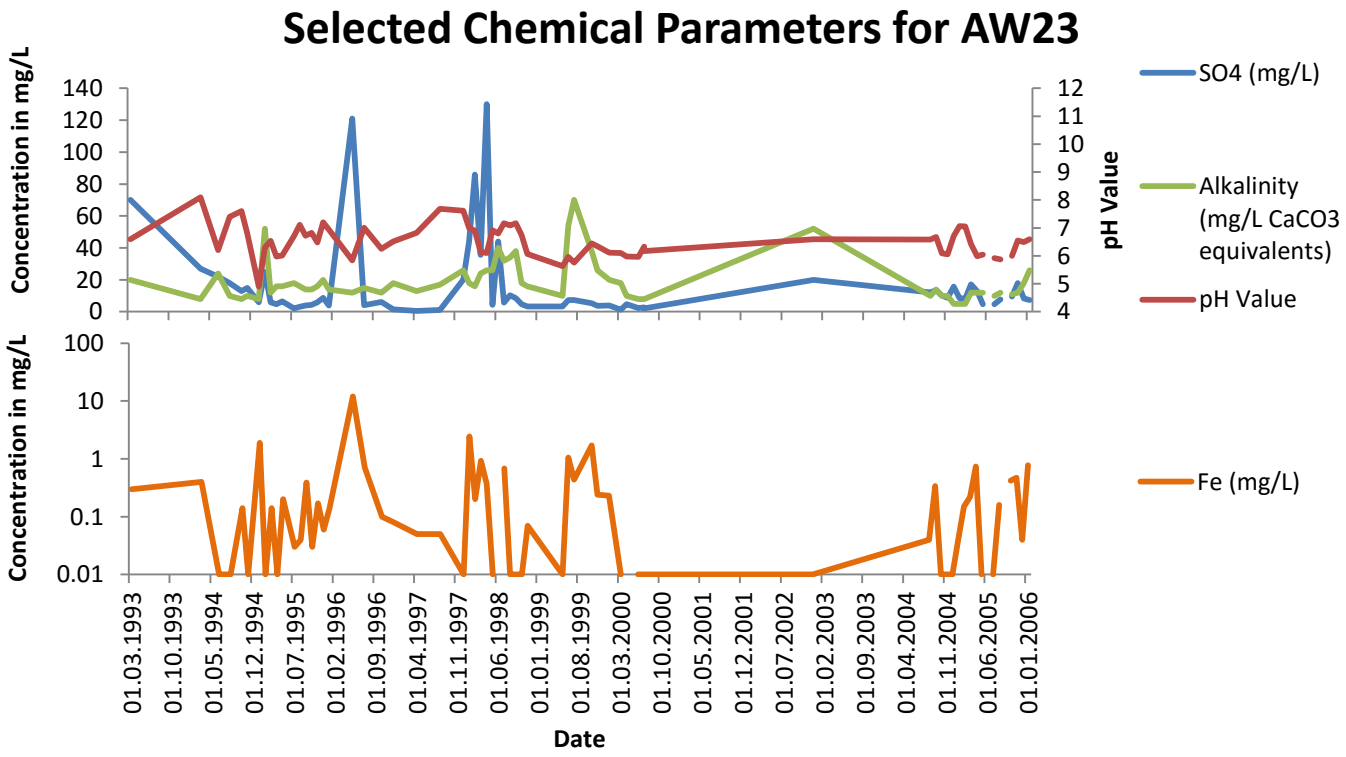


Figure 78: Groundwater monitoring data for AW23 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

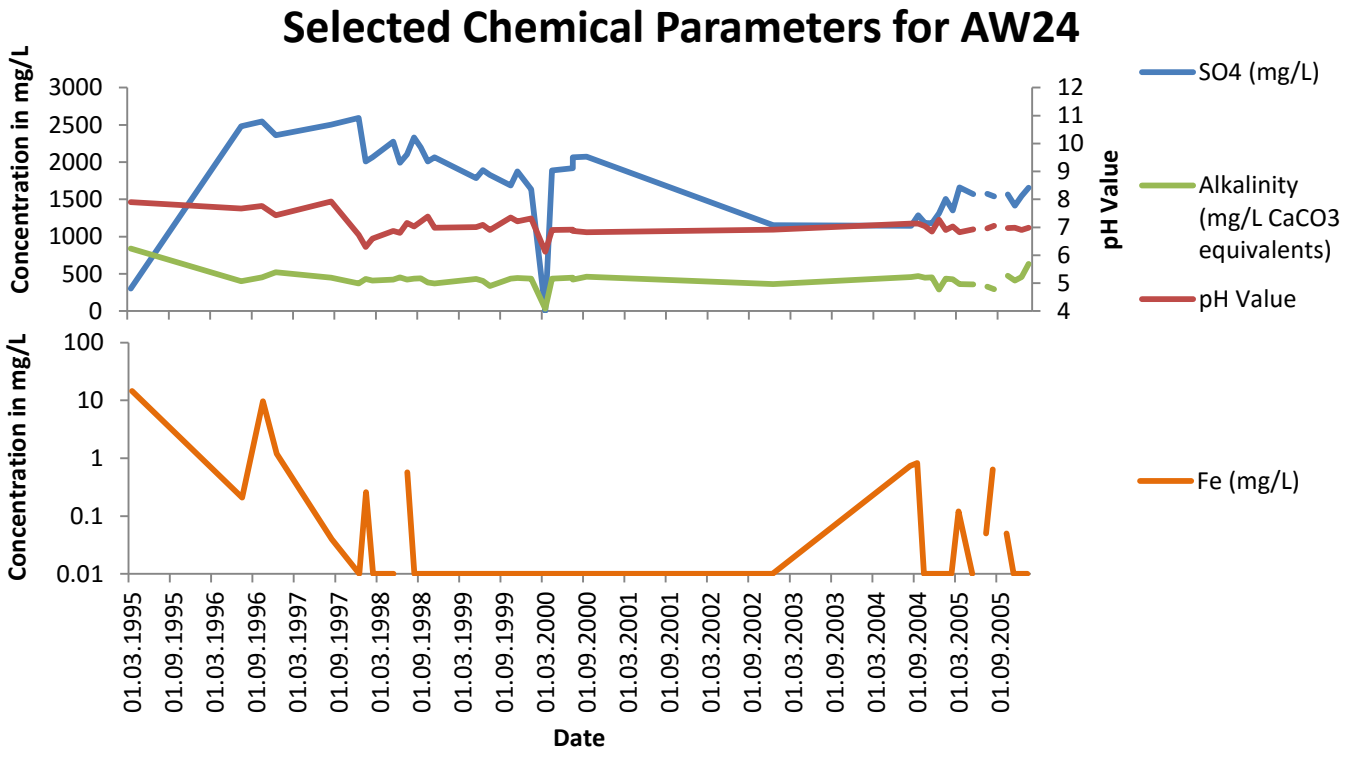


Figure 79: Groundwater monitoring data for AW24 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

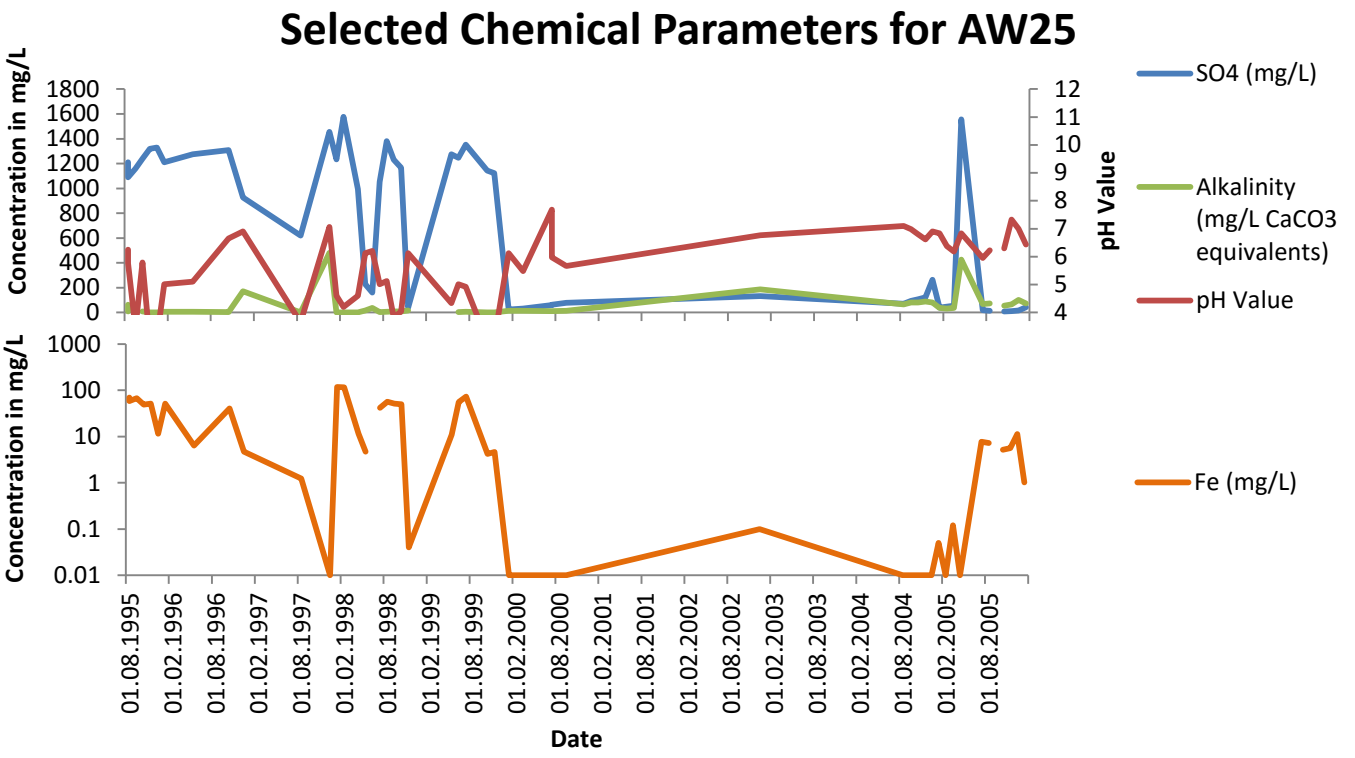


Figure 80: Groundwater monitoring data for AW25 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

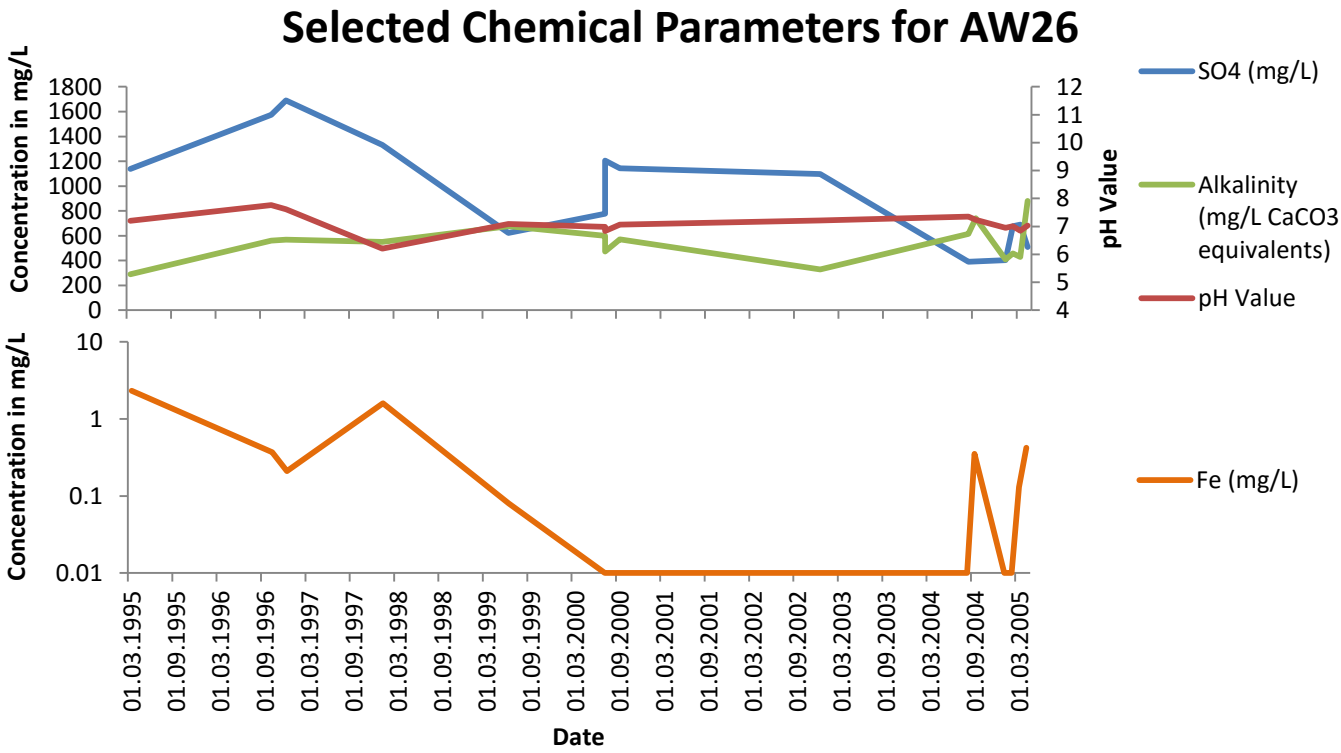


Figure 81: Groundwater monitoring data for AW26 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

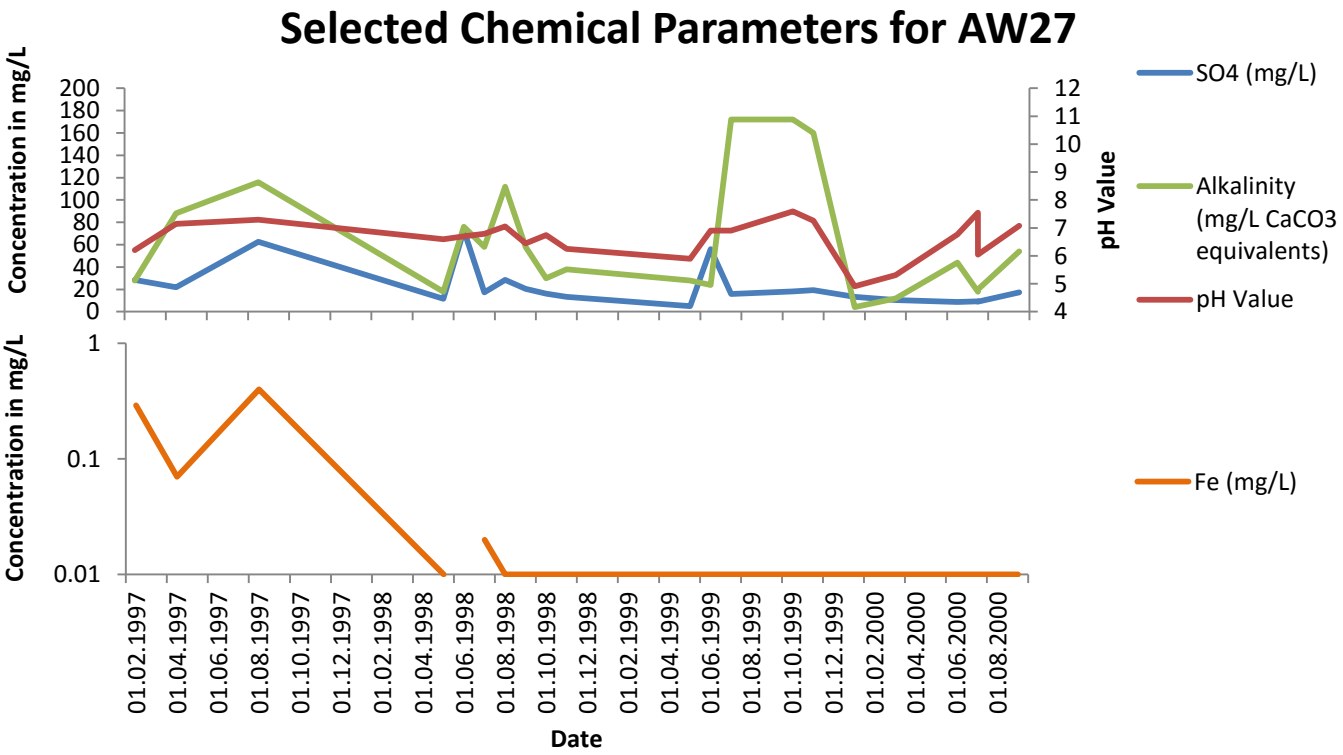


Figure 82: Groundwater monitoring data for AW27 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

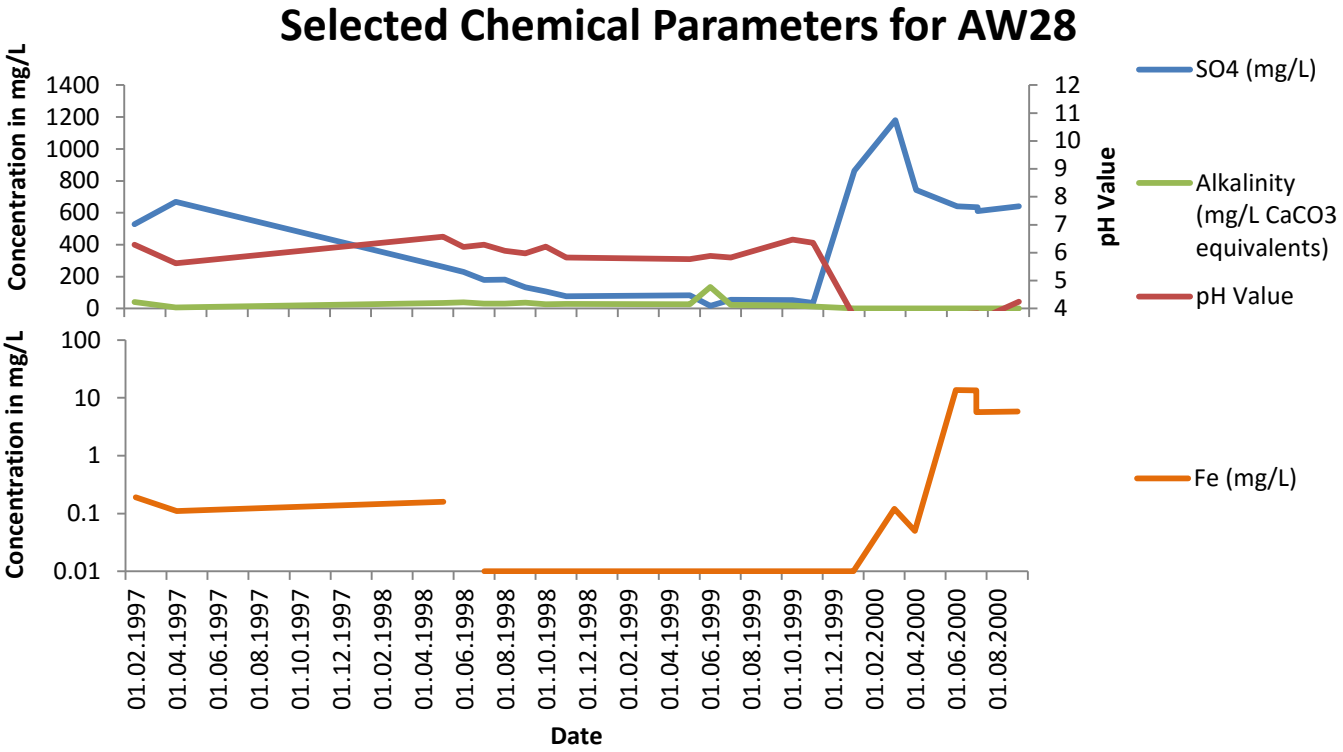


Figure 83: Groundwater monitoring data for AW28 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

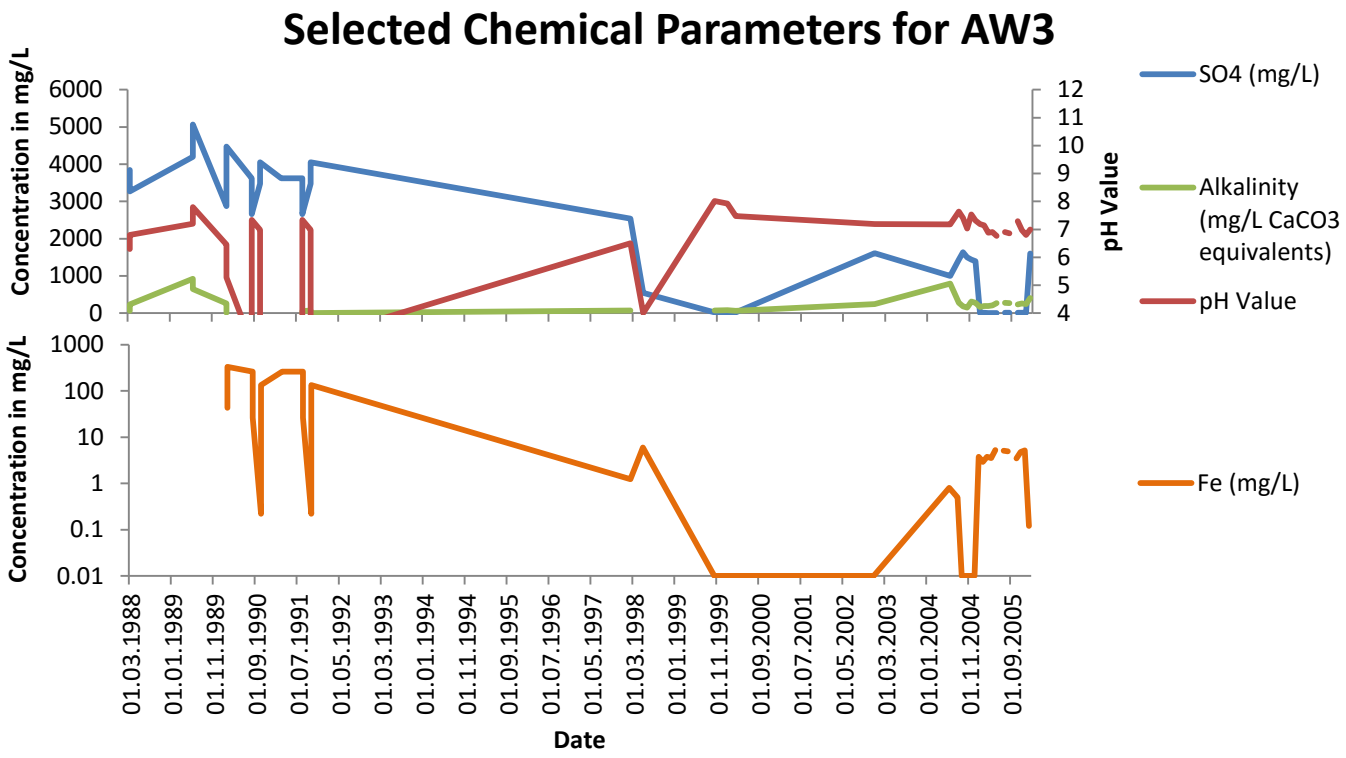


Figure 84: Groundwater monitoring data for AW3 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

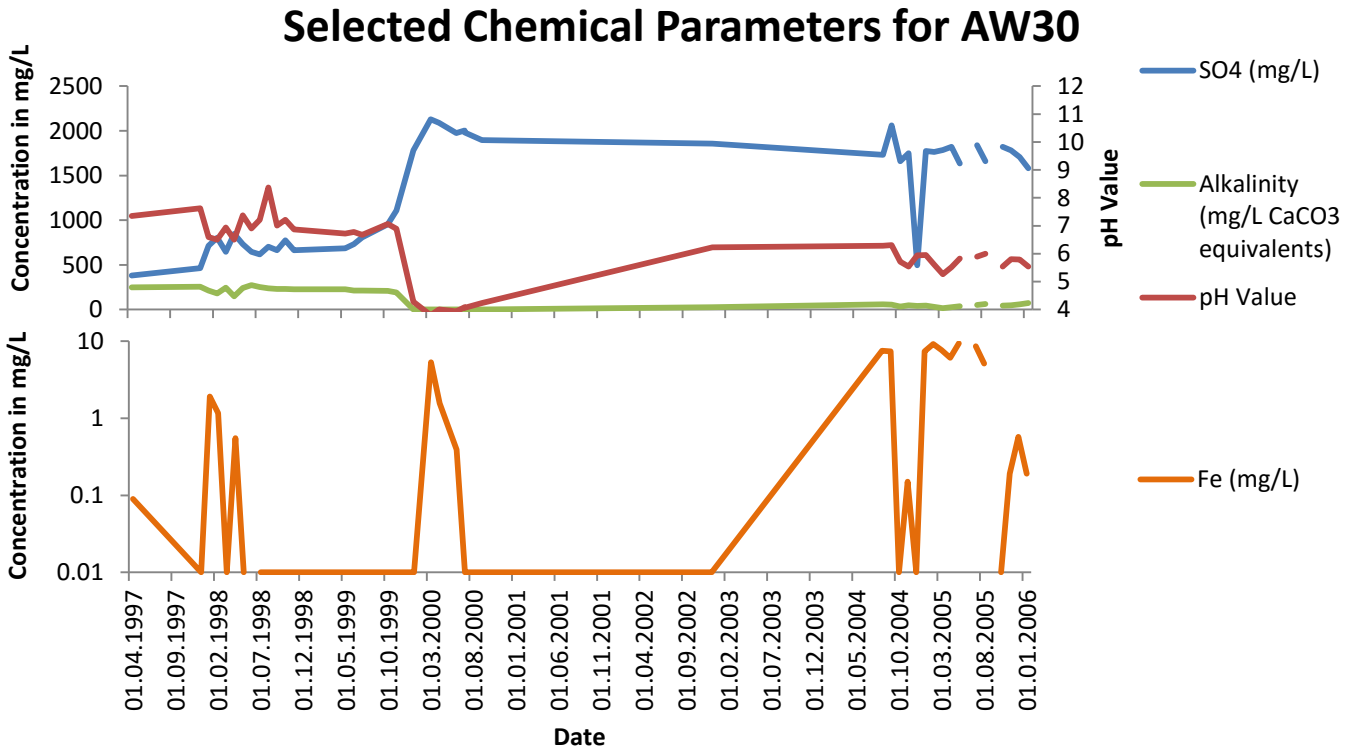


Figure 85: Groundwater monitoring data for AW30 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

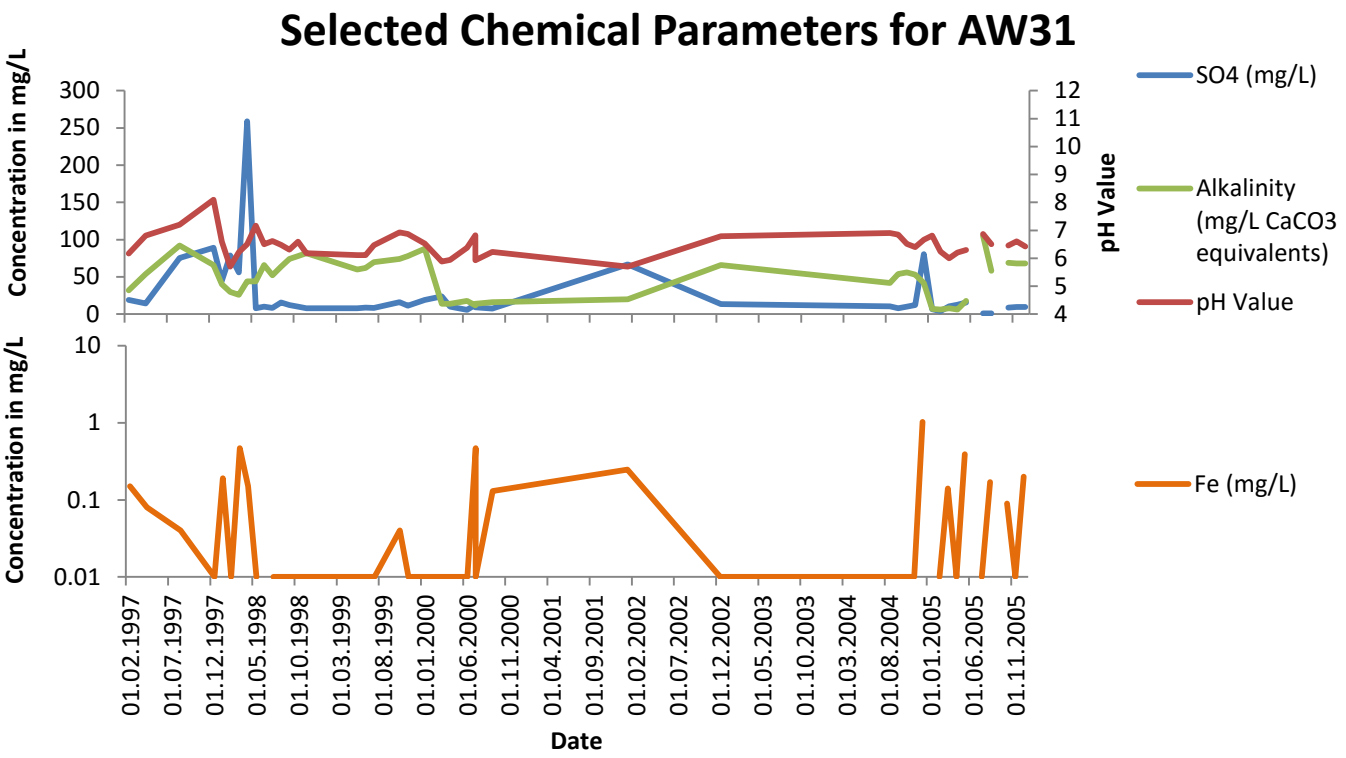


Figure 86: Groundwater monitoring data for AW31 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

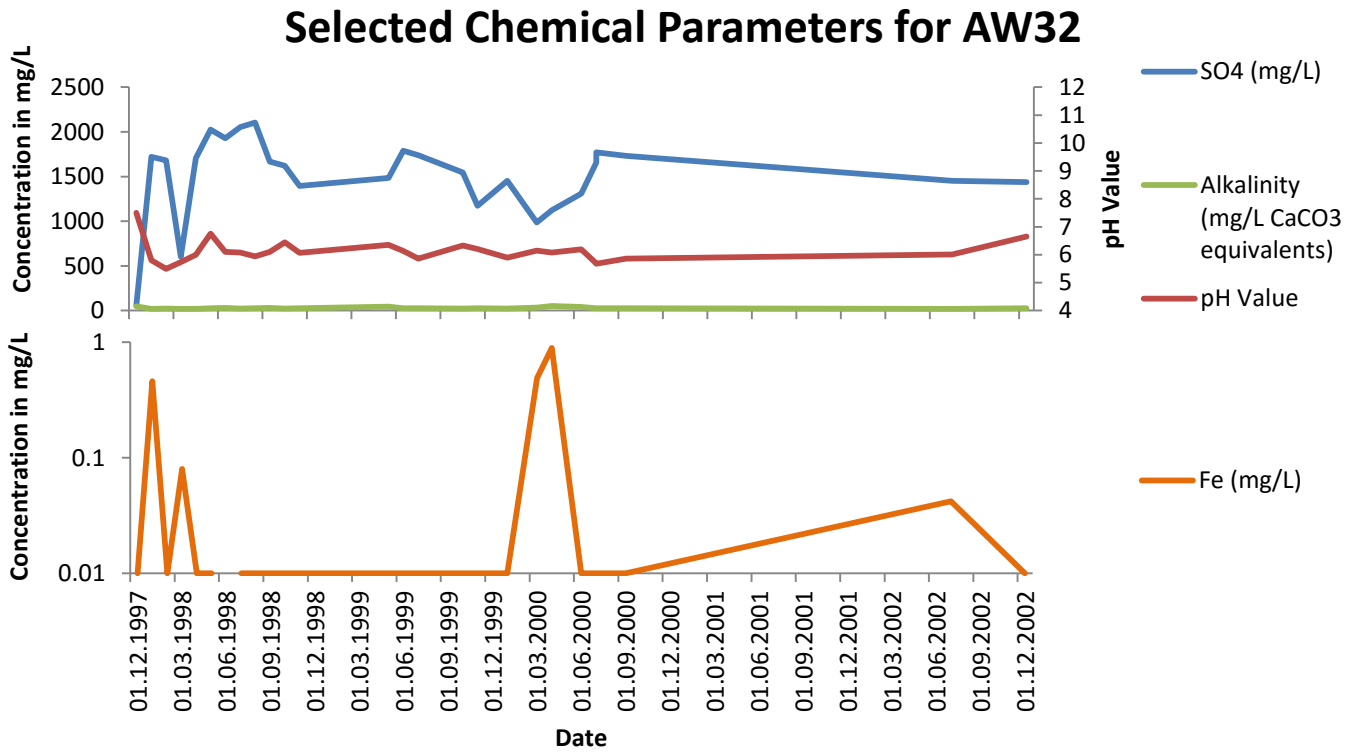


Figure 87: Groundwater monitoring data for AW32 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

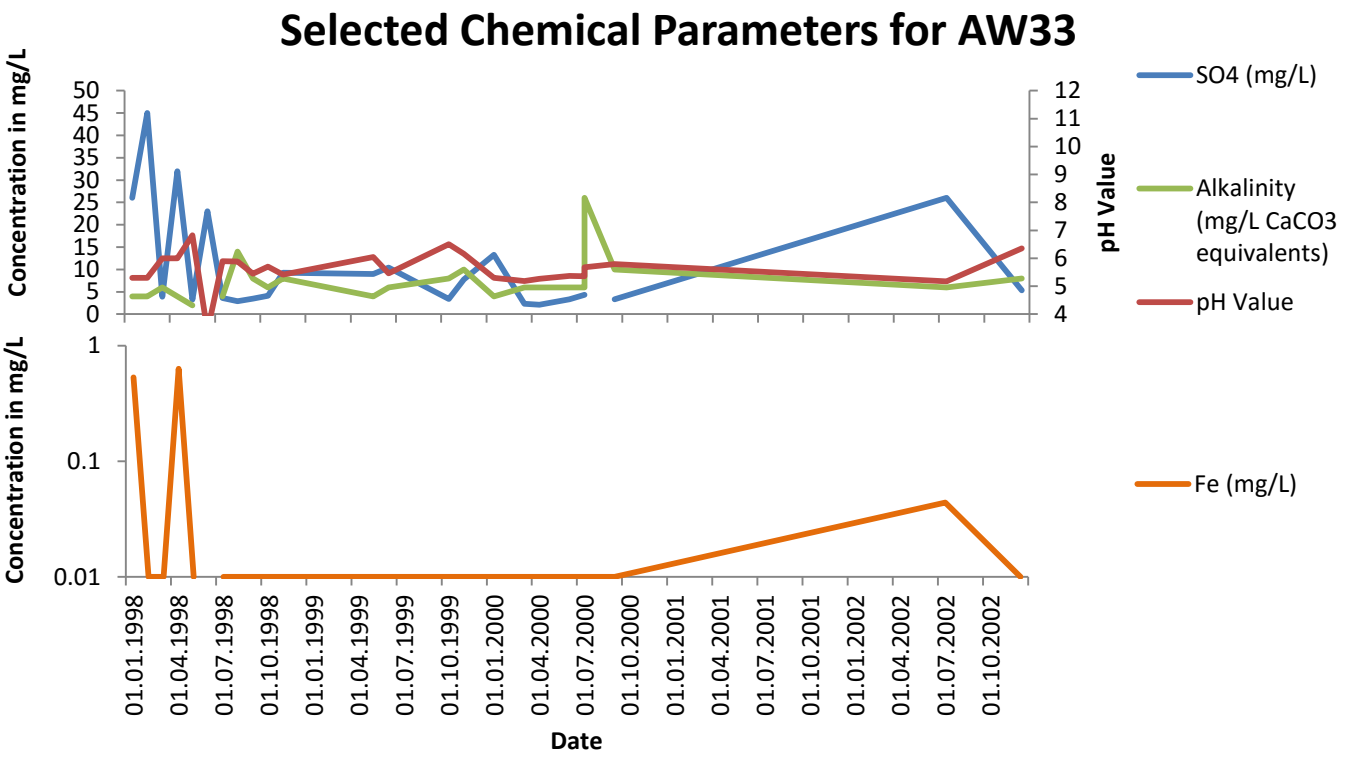


Figure 88: Groundwater monitoring data for AW33 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

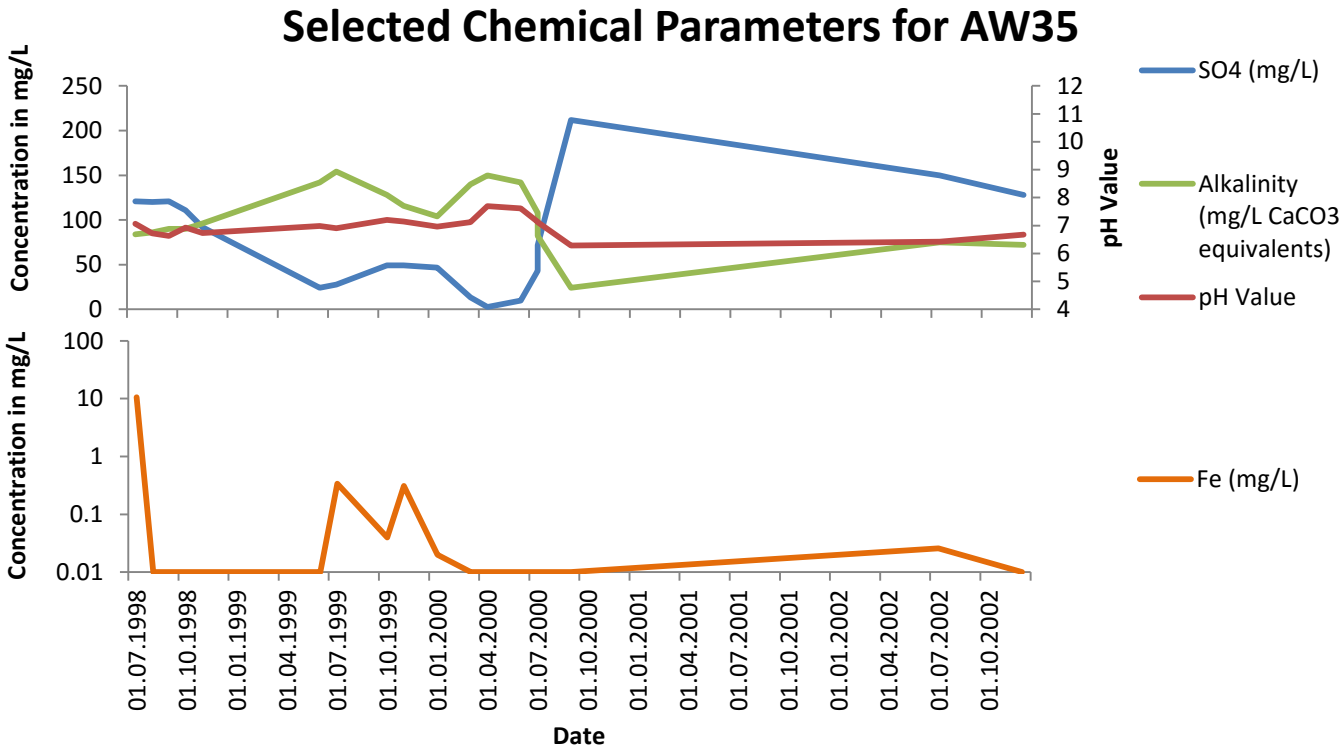


Figure 89: Groundwater monitoring data for AW35 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

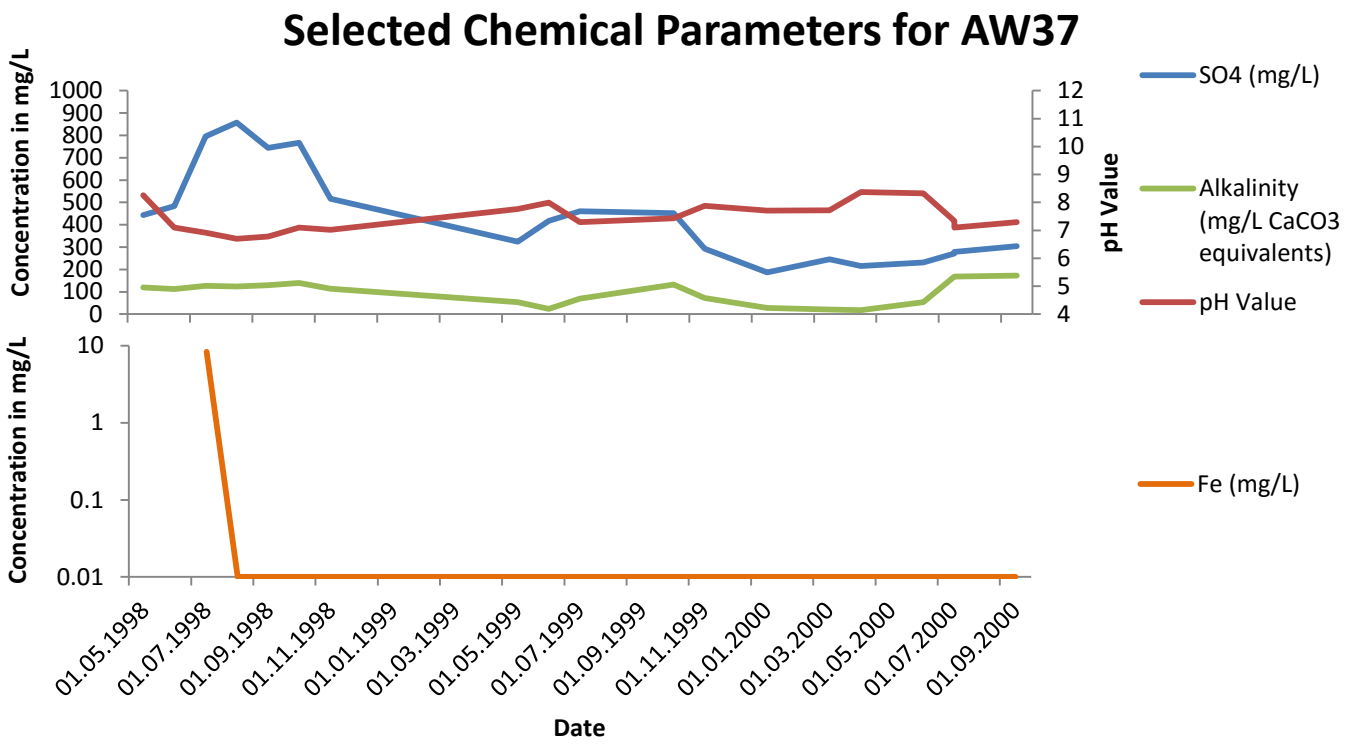


Figure 90: Groundwater monitoring data for AW37 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

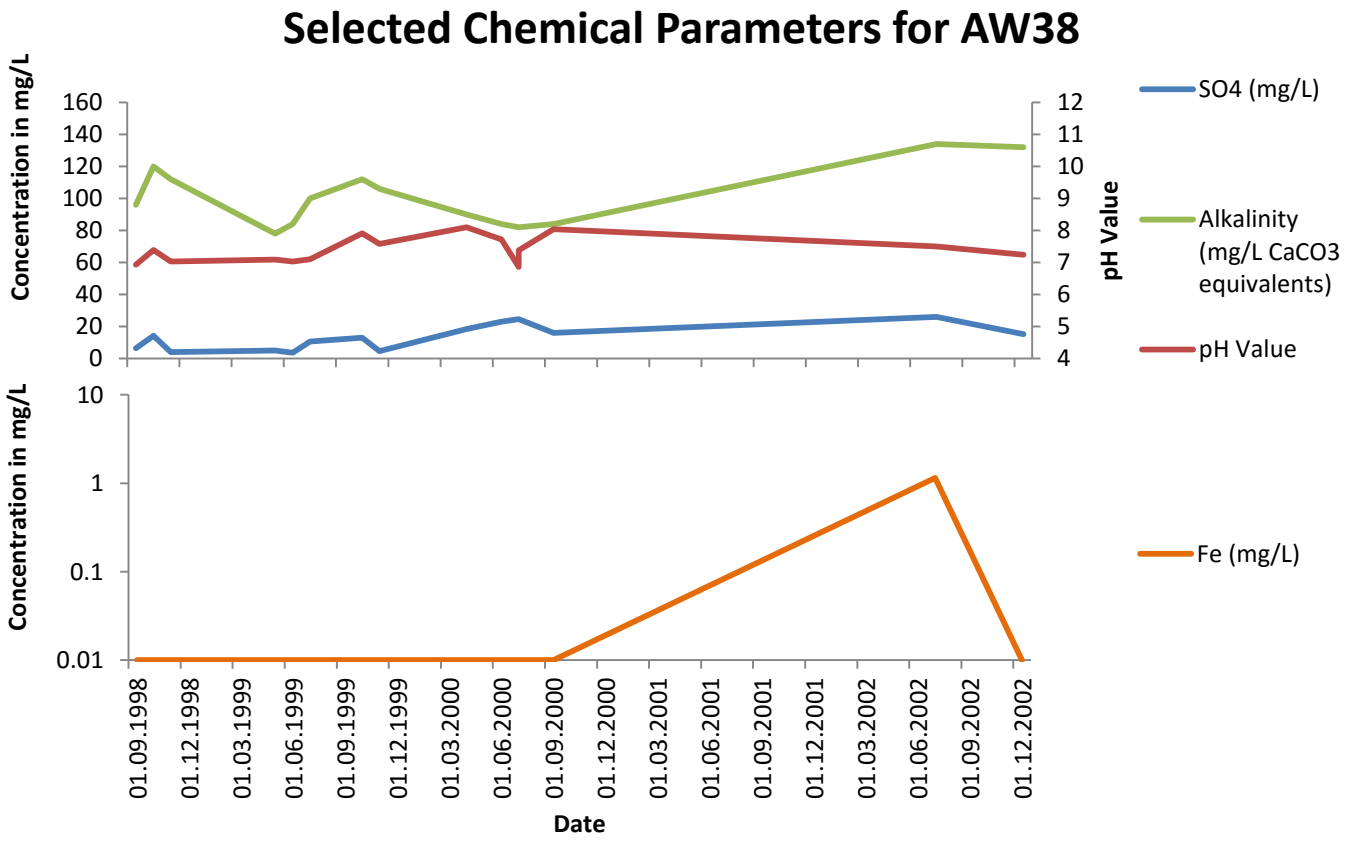


Figure 91: Groundwater monitoring data for AW38 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

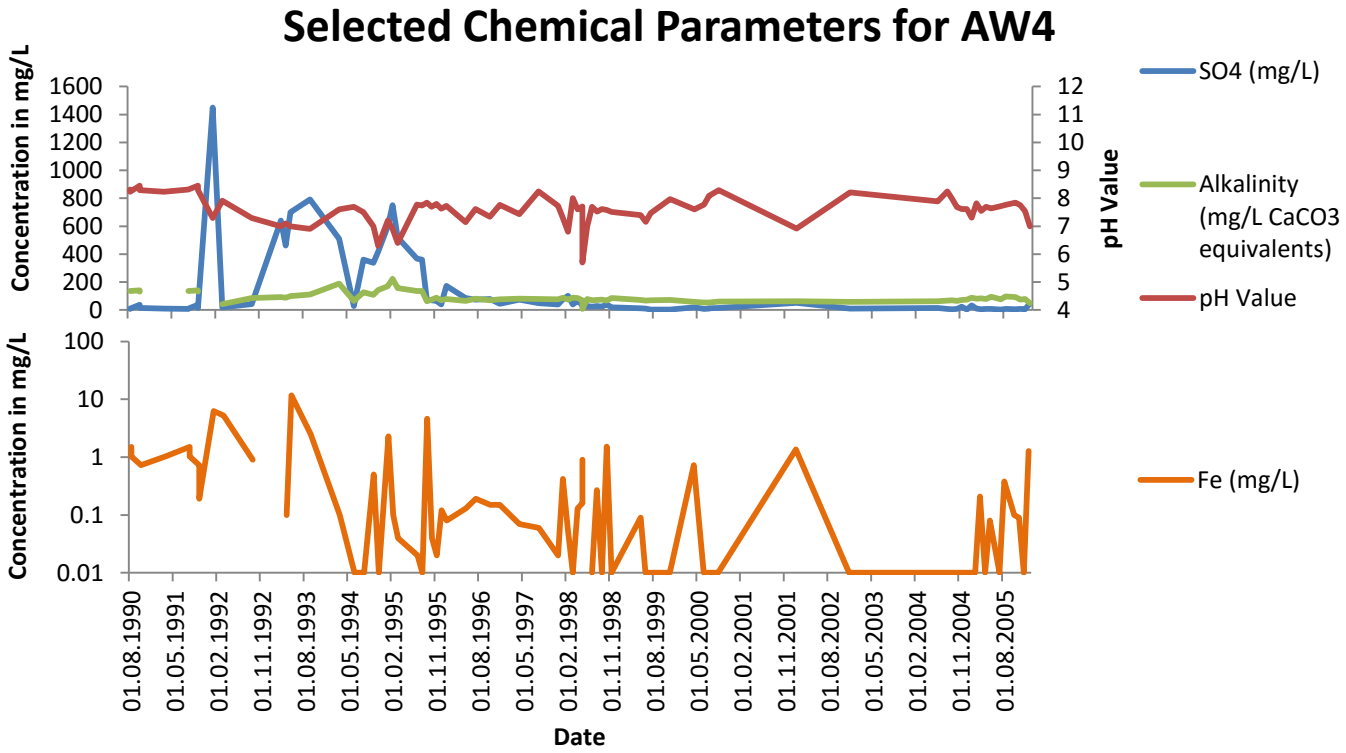


Figure 92: Groundwater monitoring data for AW4 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

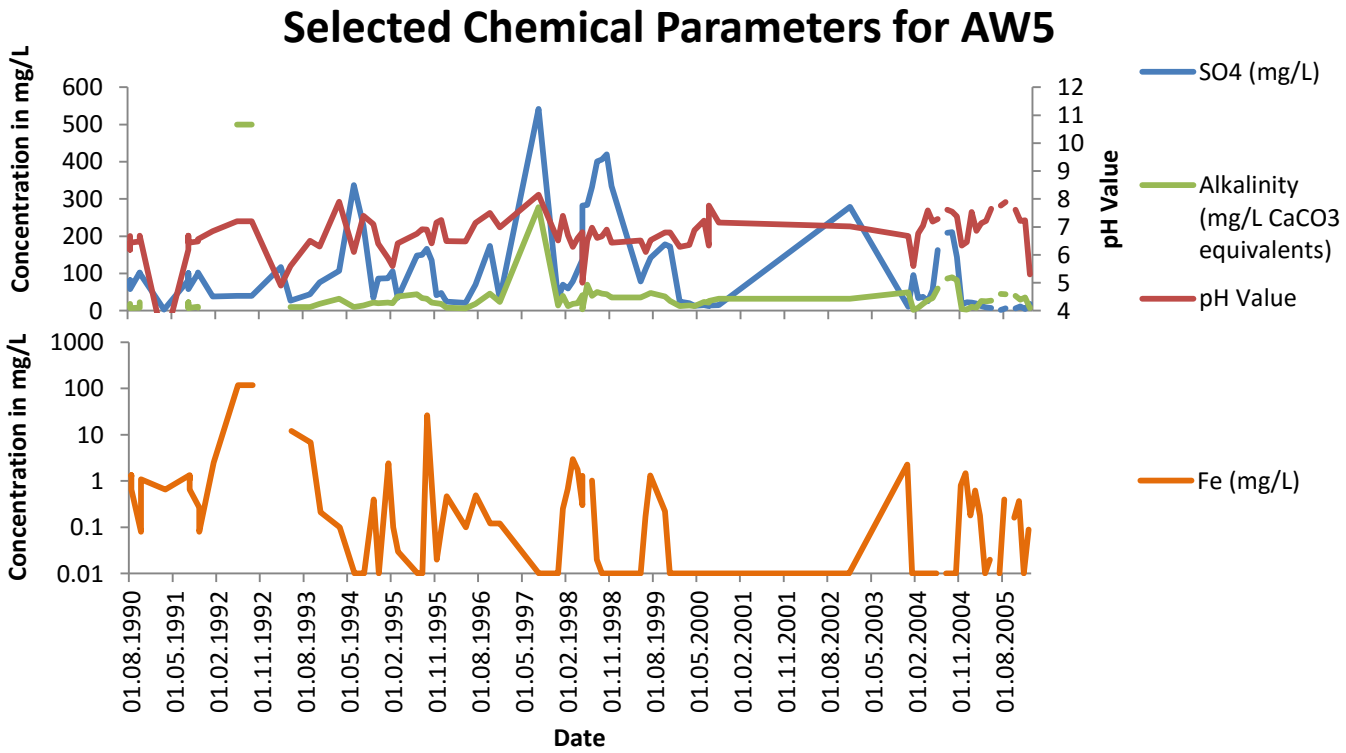


Figure 93: Groundwater monitoring data for AW5 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

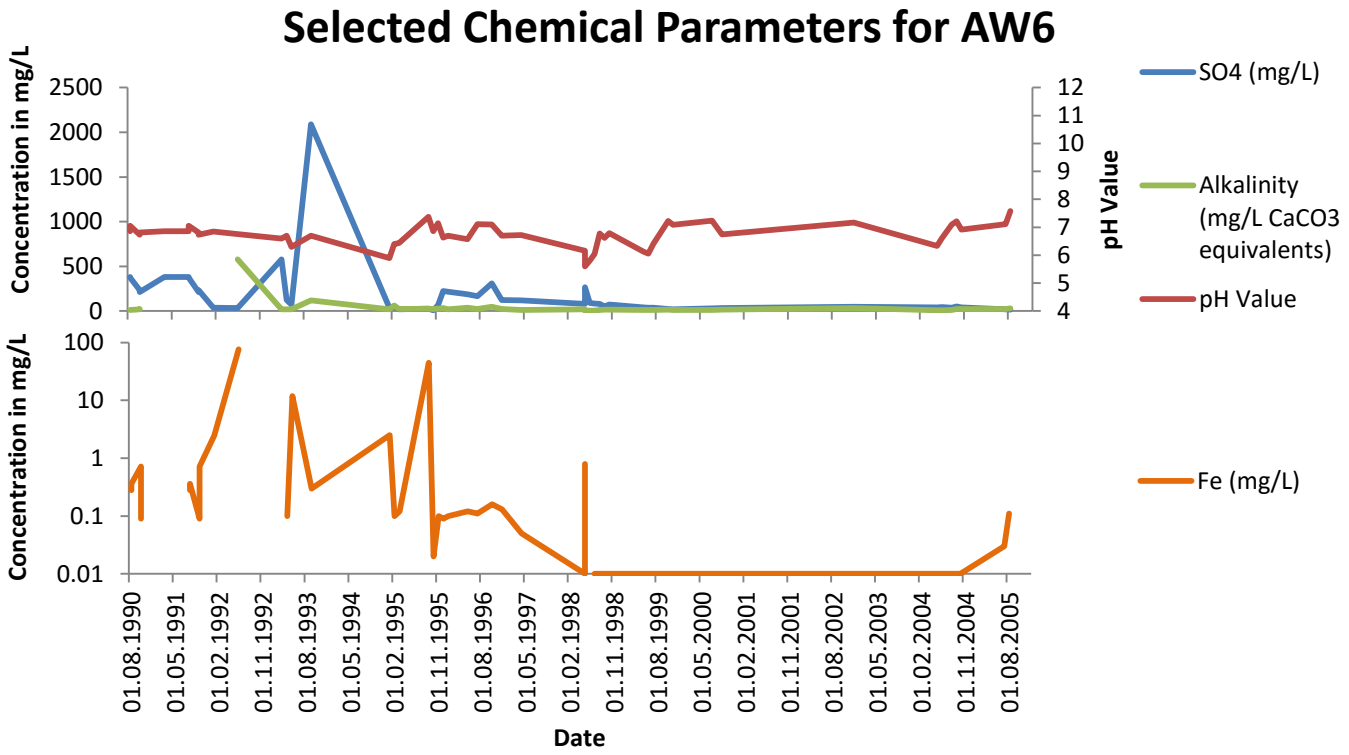


Figure 94: Groundwater monitoring data for AW6 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

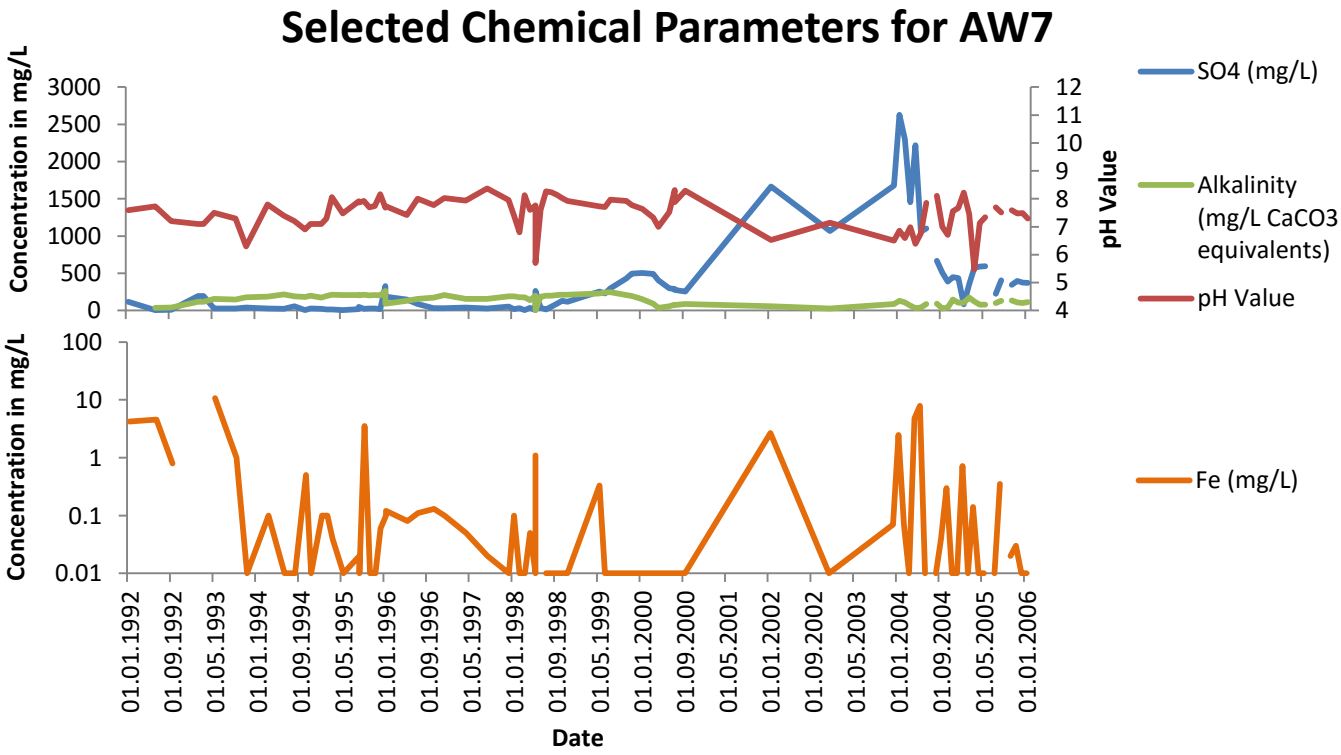


Figure 95: Groundwater monitoring data for AW7 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

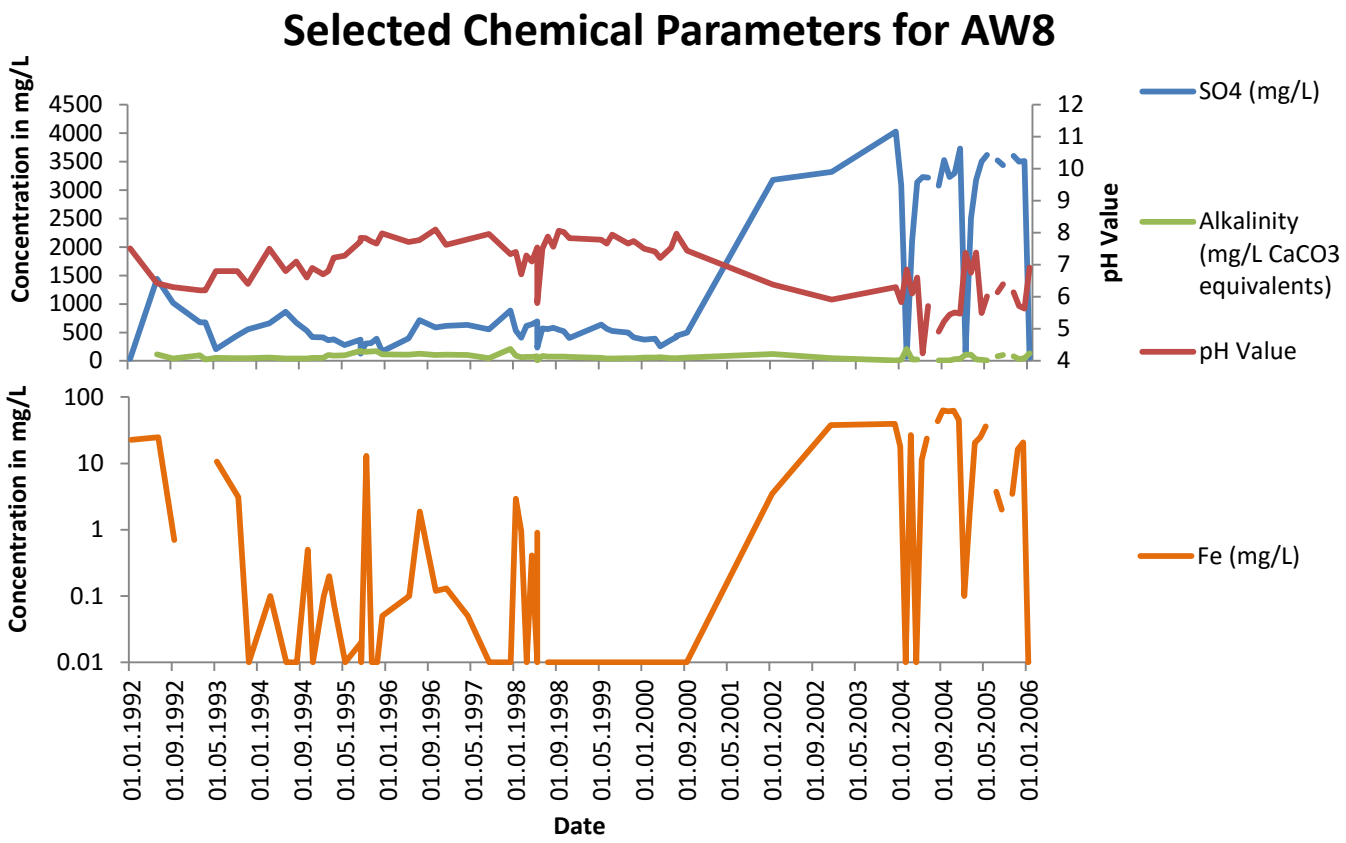


Figure 96: Groundwater monitoring data for AW8 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

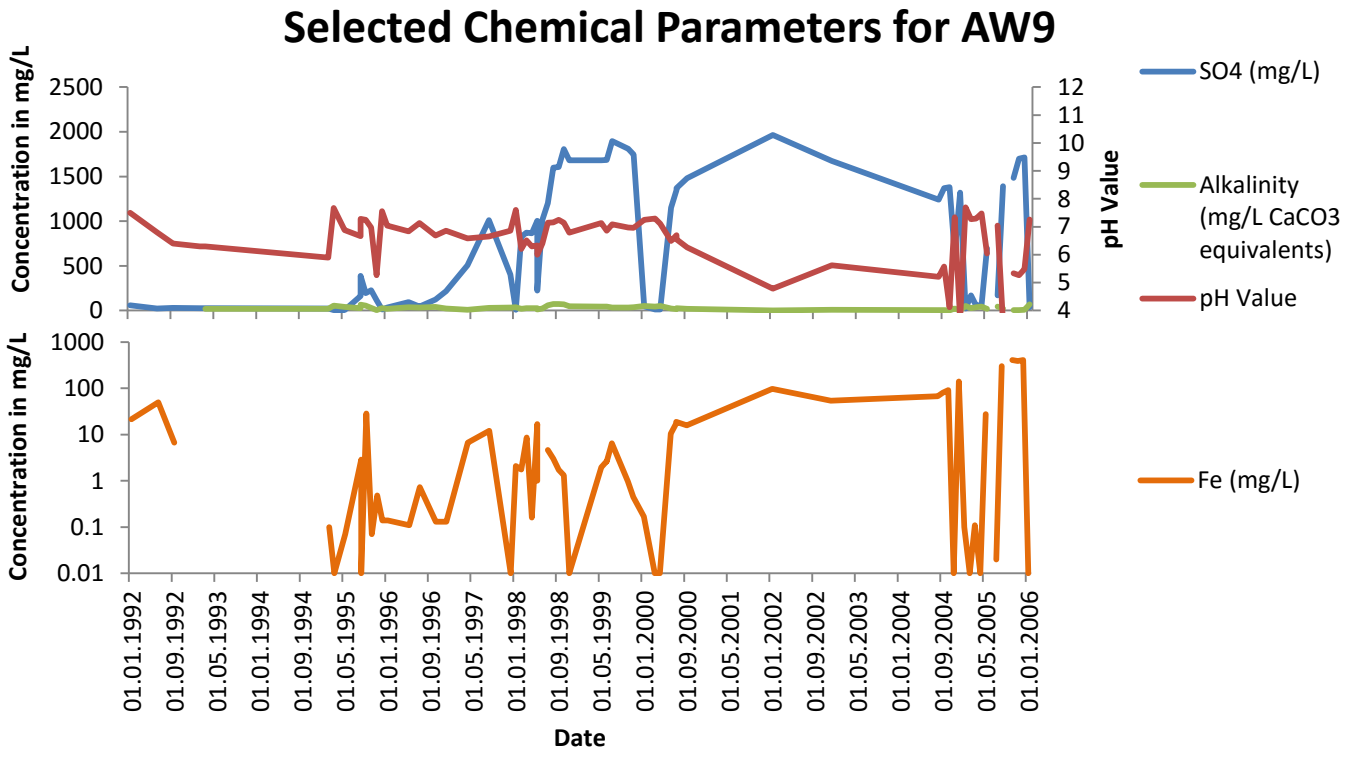


Figure 97: Groundwater monitoring data for AW9 at A-Mine (illustrating Fe, SO4, pH and Alkalinity)

5.3.6 Geochemical Model Calibration

The calibration of the geochemical model for A-Mine was performed as described in the methodology section (Figure 98). Constituent concentrations obtained from the leachate analyses of the leaching tests were averaged and plotted on the abscissa of the graph. The simulated concentrations of the constituents, obtained from the geochemical model, were plotted on the ordinate. Additionally, each data point has an error bar in the horizontal direction, which represents the standard error calculated for the average of each constituent concentration. The calibration graph shows a coefficient of determination (R^2-value) of 0.9886. Most of the calculated values have a residual error within the calculated standard error for the average analysed concentrations as showed by the horizontal error bars.

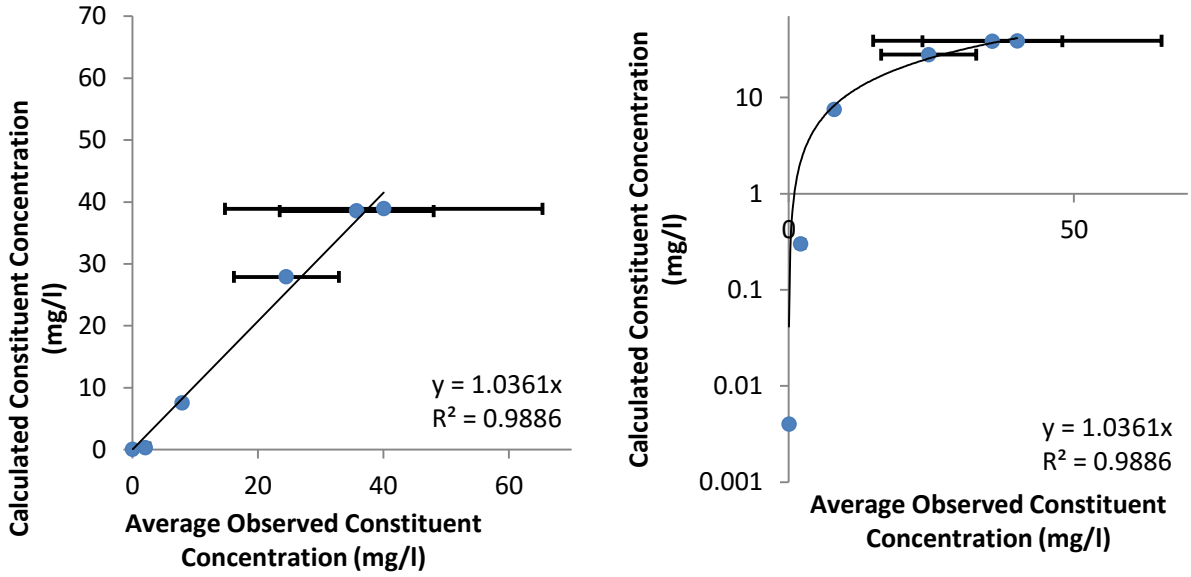


Figure 98: Left: Calibration graph for the geochemical model of A-Mine; averaged analysis concentrations vs. calculated concentrations; standard errors are shown in the horizontal direction. Right: Logarithmic ordinate for improved illustration of lower concentrations and standard error values

5.3.7 Simulated Natural Geochemical Conditions

After calibration of the geochemical model, the natural geochemical conditions at A-Mine were simulated as described in the methodology section 0. An initial fluid to rock ratio of 0.3:1 was used, based on water levels and mine water discharge at the site. Additional water was added to the system at a fluid to rock ratio of 1×10^{-3}:1 every day of the simulation to simulate inflow of additional water into the system, as groundwater and recharge from rainfall, as well as recirculated mine water that is pumped back into the system from discharge points around the mine. A simulation lasted 36500 days (100 years), to account for long term changes in leachate chemistry, while also covering the period of available groundwater monitoring data (Figure 99). The simulation shows that a decrease in the release of SO_4^{2-} is likely to take place from a concentration of approximately 17500 mg/L to a concentration of approximately 300 mg/L.

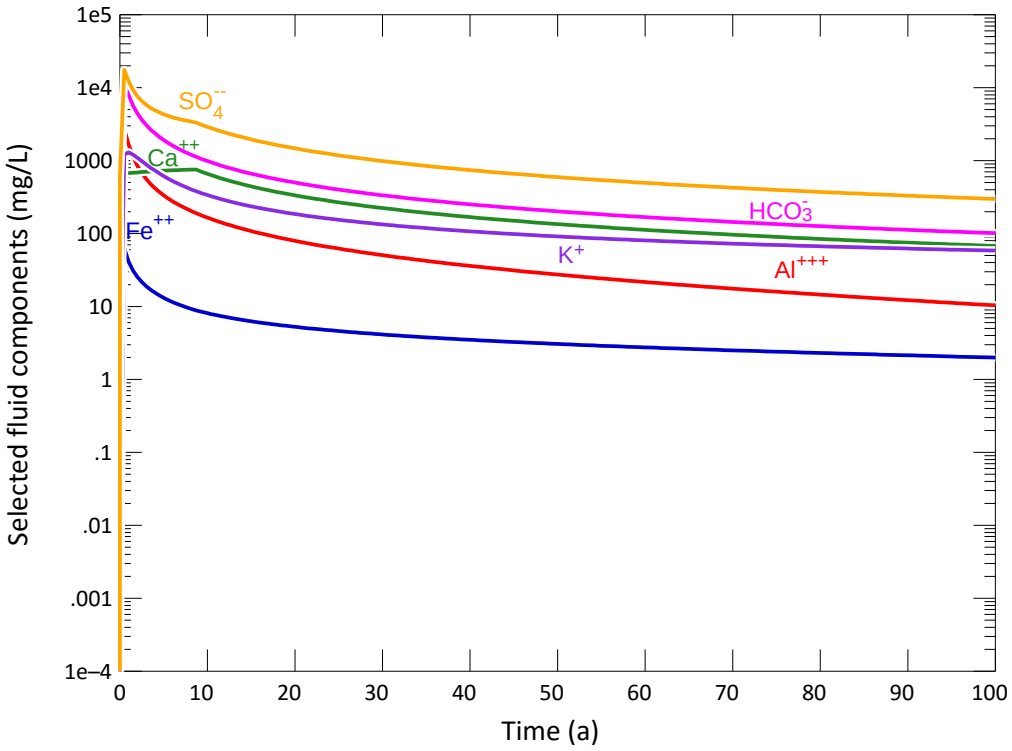


Figure 99: Simulated contaminant concentrations in the leachate generated from the backfill material on site over time; logarithmic ordinate

5.3.8 Numerical Flow Model Chemical Calibration

The simulated concentrations of sulfate in natural conditions of the backfilled opencast mine obtained from the geochemical model were used as input for the numerical flow and transport model. The concentrations in the opencast A-Mine were specified using various time steps and stress periods, in the transport model. This was performed to determine if the specified concentrations in the transport model are chemically calibrated, using monitoring data at representative groundwater monitoring wells (Figure 100). These graphs show the simulated sulfate concentrations with an error bar of 200 mg/L, along with the observed sulfate concentrations at each selected monitoring point over time. An error range of 200 mg/L was used as concentrations of sulfate observed in the monitoring wells reach levels of over 2000 mg/L in some areas. Therefore, a 10% error of the monitoring concentrations for sulfate was deemed applicable.

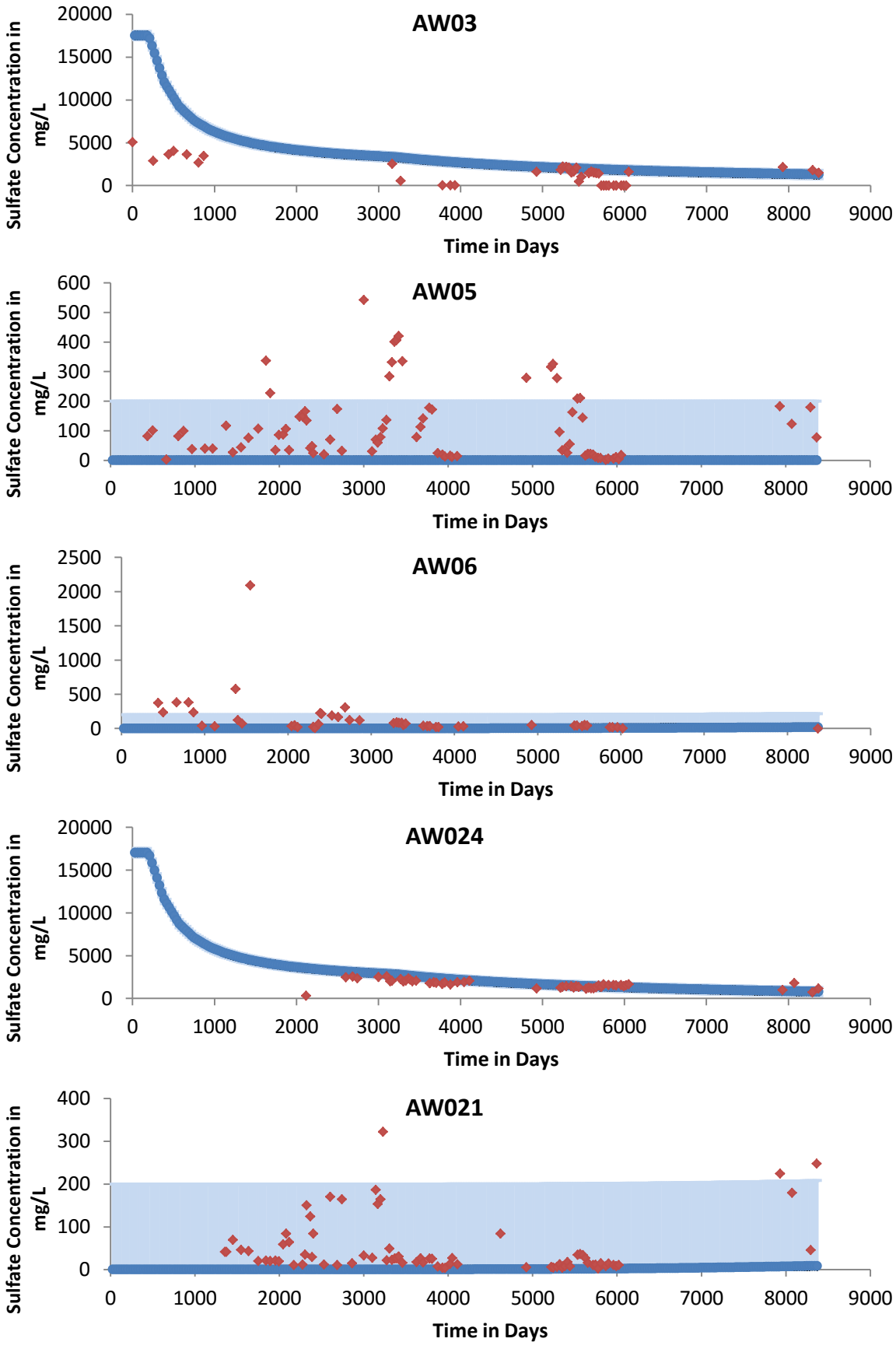


Figure 100: Chemical Calibration Graphs for the monitoring wells used in the A-Mine Numerical Flow and Transport Model, blue dots: simulated values; red diamonds: observed values.

5.3.9 Geochemical Parameter Sensitivity

The parameters influencing the generation and decay of sulfate in solution were varied in the geochemical model (Table 33). This was performed as a model sensitivity analysis to determine the sensitivity of each parameter with respect to its influence on rate limitation and concentration limitation of sulfate. Parameters providing a rate limitation were deemed to influence the rate of sulfate generation or decay in solution. Parameters providing a concentration limitation were deemed to influence the maximum and final concentrations of sulfate in solution.

Table 33: Sensitivity Analysis of Parameters Influencing the Generation and Decay of Sulfate in Solution at A-Mine based on Geochemical Modelling

Parameter Varied	Orders of Magnitude	Rate Limitation	Change Observed in Sulfate Concentration	Contaminant Concentration Limitation	Change Observed in Sulfate Concentration, mg/L
Oxygen Fugacity	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	Yes	1000
Gypsum Mass	1	No	None	Yes	5
Gypsum Surface Area	1	No	None	No	None
Gypsum Reaction Constant	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	Yes	5
Pyrite Mass	1	No	None	Yes	1000
Pyrite Surface Area	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	No	None
Pyrite Reaction Constant	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	No	None
Input Rate of Water	1	Yes	Faster/Slower Peak Concentration and Faster/Slower Concentration Decay	Yes	200 to 3000

6 Synthesis

6.1 Mineralogy and Geochemistry at the Study Sites

6.1.1 Comparison of Mineralogical Data between the Study Sites

The mineral phases encountered at each of the study sites show that quartz and kaolinite were found in all the collected overburden samples (Table 34). It can therefore be concluded that these mineral phases form an important part of the Ecca Group lithologies associated with opencast coal mining overburden. Based on this comparison, these mineral phases are likely to be found in the overburden material of similar mines in Mpumalanga. Additionally, as indicated by the stability diagram of the Si-Al-O-H system (disregarding the kinetics of the real system, as kyanite is unlikely to form in these conditions), these minerals are likely to be stable in a hydrogeological environment where low concentrations of metals are found in groundwater (Figure 101).

Microcline feldspar and muscovite were found in almost all samples and were interpreted as precursors to quartz and kaolinite as weathering products (Banfield and Eggleton, 1990). Based on the sample data, it is likely that these minerals will be encountered in Ecca Group lithologies associated with coal mining overburden.

Plagioclase and smectite were encountered in a single sample collected from C-Mine. Smectite-group clay in this sample was interpreted as a possible weathering product of plagioclase. However, both minerals may have been transported from a different source area to the specified sampling locality during deposition of the sedimentary rock.

Siderite and dolomite are present in two samples from A-Mine only as both minor and major mineral phases. These phases are anomalous when compared to the lithologies encountered during drilling on site as well as the samples from E-Mine and C-Mine. Hematite was only encountered in the samples collected from E-Mine as a minor mineral phase. However, the siderite and hematite phases may be interpreted as indicators of chemical conditions present during the diagenesis of these lithologies. When the stability diagram for iron is considered (Figure 102), a large stability field is present for hematite. When bicarbonate is present in the system, an additional stability field is present for siderite, which is also relatively large compared to that of hematite. These minerals could indicate the redox conditions during diagenesis of the lithology. Elevated Eh is required for the formation of hematite, while lowered Eh and dissolved bicarbonate is required for the formation of siderite. This can be linked to e.g. the presence or absence of pyrite.

Pyrite formation in the sediment is controlled by the availability of organic matter, dissolved sulfate in solution and the availability of detrital and reactive iron minerals (Berner, 1984), while the mineral itself is stable in lowered Eh values (Figure 103). When comparing Figure 102 and Figure 103, it can be observed that the stability fields of pyrite and siderite are likely to overlap, while that of hematite and pyrite are less likely to overlap. Therefore, siderite and hematite may act as indicator minerals with regards to pyrite content estimation in lithologies with appreciable abundances of carbonate minerals, which were deposited in reducing conditions.

Table 34: Comparison of Mineral Phases Encountered at the Study Sites (● shows major mineral phase present; ○ shows minor mineral phase present; - shows mineral phase not present)

Study Site	Sample	Anatase	Hematite	Dolomite	Kaolinite	Microcline	Muscovite	Plagioclase	Quartz	Smectite	Siderite
C-Mine	ESG134	-	○	-	●	●	○	-	●	-	-
	ESG678	-	○	-	○	●	○	●	●	●	-
	ESG91011	-	○	-	●	●	○	-	●	-	-
	ESG17	-	○	-	●	●	○	-	●	-	-
	ESG2021	-	○	-	●	●	○	-	●	-	-
	Pembali Mining 1	-	○	-	●	●	○	-	●	-	-
E-Mine	KDC1	-	-	-	●	-	○	-	●	-	-
	KDC2	○	-	-	●	-	○	-	●	-	-
	KDC3	○	-	-	●	○	○	-	●	-	-
	KDN1	○	-	-	●	○	○	-	●	-	-
	KDN2	○	-	-	●	○	○	-	●	-	-
A-Mine	ARN 1	-	-	-	●	●	○	-	●	-	○
	ARN 2	-	-	○	●	○	-	-	●	-	-
	ARN 3	-	-	●	●	○	○	-	●	-	●

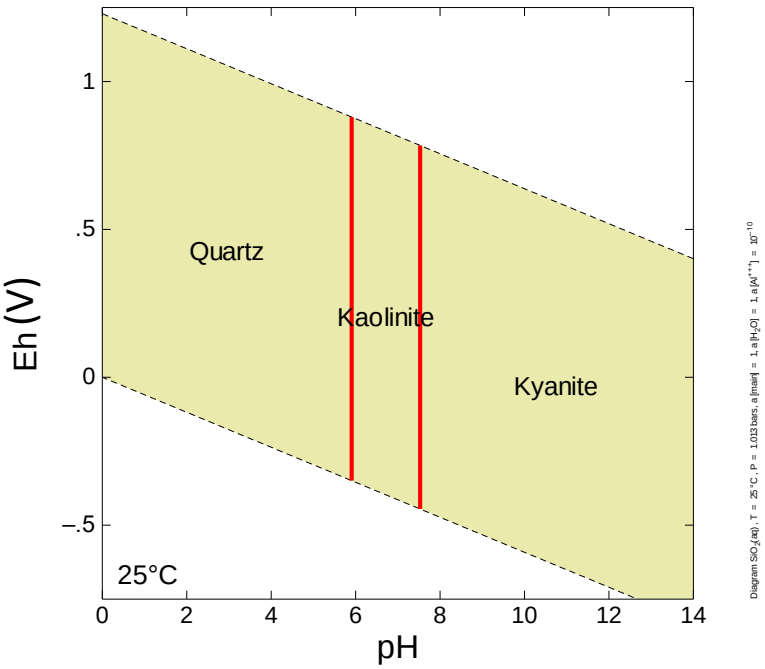


Figure 101: Stability diagram constructed for a high [Si], low [Al] groundwater solution, indicating stability of quartz and kaolinite. Please see text with regards to kyanite stability.

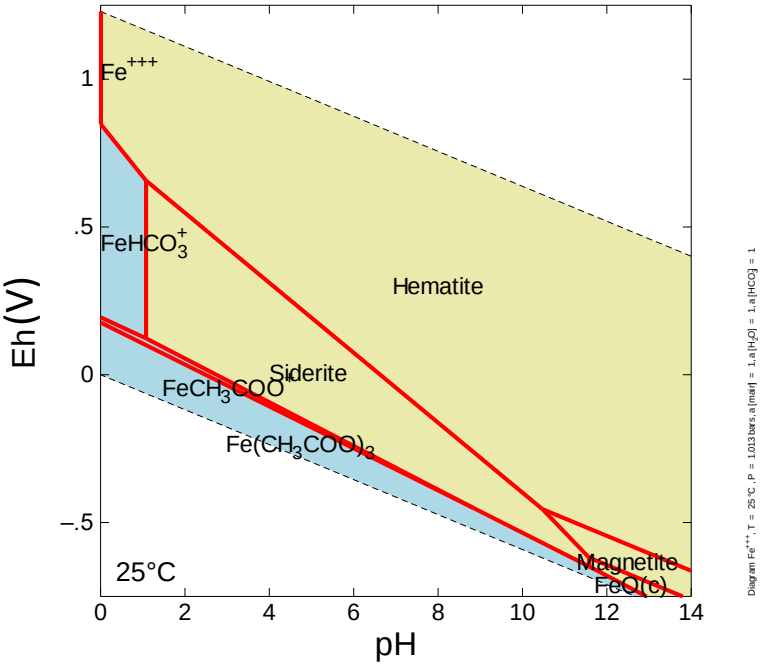


Figure 102: Stability diagram constructed for Fe with HCO_3 present in the groundwater solution, indicating stability of hematite and siderite

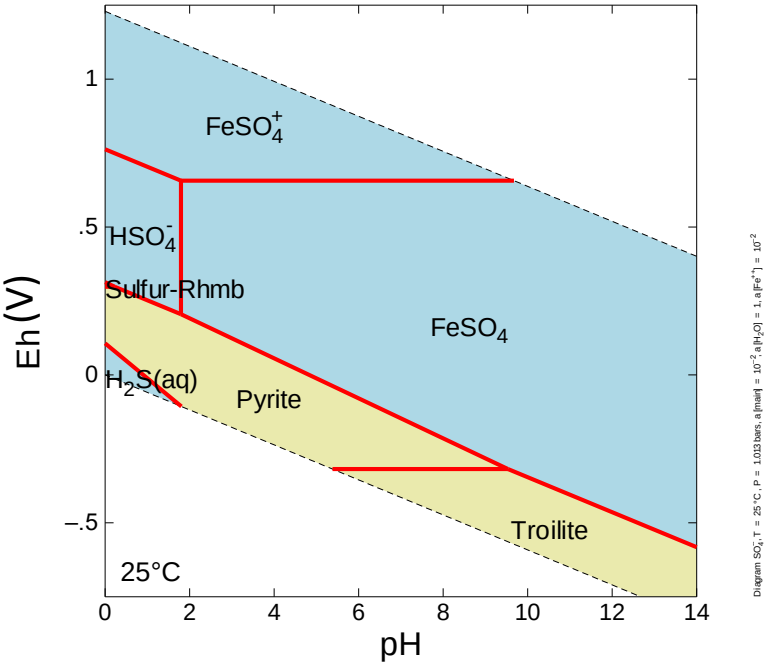


Figure 103: Stability diagram constructed for a concentration of 0.01 mol SO_4 with Fe present in the groundwater solution, indicating stability of pyrite in reducing and low pH conditions

6.1.2 Comparison of Acid-Base Accounting Data

Acid-Base Accounting analysis results show Sulfide-Sulfur Weight Percentages ranging between 0.02 and 1.25 wt% (Table 35), which is in agreement with the study by Pinetown and Boer (2006). However, for unknown reasons, methods used for acid-base accounting at A-Mine in previous studies by Fourie (2013), did not provide Sulfide-Sulfur Weight Percentages. Therefore, Sulfide Sulfur Weight Percentages were extrapolated based on the Acid Generation Potential (Figure 104). This figure illustrates the correlation between the Sulfide-Sulfur Weight Percentages and Acid Generation Potential, as well as the regression line of the data. Sulfide-Sulfur Weight Percentages for A-Mine were thus calculated by dividing the Acid Generation Potential values for these samples by the slope of the regression line as a coefficient of determination (R^2) of 0.99 was observed. This calculation changes the maximum Sulfide-Sulfur Weight Percentage observed to approximately 1.9 wt% (Figure 104).

When comparing the C-Mine data with that of E-Mine and A-Mine, it can be observed that higher weight percentages of Sulfide Sulfur are present in the E-Mine and A-Mine samples. Based on the samples collected, this shows a more sulfur rich character for the Witbank Coalfield compared to that of the Ermelo Coalfield. These results, therefore, show higher amounts of sulfide minerals present in the Witbank Coalfield, than in the Ermelo Coalfield which is further substantiated when comparing the paste pH values of the samples collected from C-Mine with that of A-Mine and E-Mine. However, based on alkalinity values observed, it is also possible that samples from C-Mine have already been leached of the majority of their carbonate minerals.

If the Sulfide Sulfur Weight Percentages in these samples are considered to represent only sulfur in the form of sulfide minerals, the disulfide mineral content can also be estimated from these analyses. Due to disulfides containing two moles of sulfur, the disulfide mineral weight percentage is roughly half of the Sulfide Sulfur Weight Percentage value in the sample.

Net Neutralisation Potentials of the samples collected show negative values for 13 samples. However, eight of the twenty one samples showed positive Net Neutralisation Potential values, indicating the presence of carbonate minerals such as calcite or dolomite. Therefore, the material has a variable acid generation potential. This variation is attributed to the variations in lithology at each site and the fact that the backfill material was not selectively placed. Therefore, it is likely that both acid generating and acid neutralising material was sampled as the distribution of both is random and unknown.

Table 35: Compilation of Acid-Base Accounting Results from the Study Sites (Total S Values* are Extrapolated Based on the Acid Generation Potential of the Samples); description in text.

	Sample ID	Paste pH	Total S wt%	Acid Generation Potential in kg $CaCO_3$/t	Neutralisation Potential in kg $CaCO_3$/t	Net Neutralisation Potential in kg $CaCO_3$/t
C-Mine	ESG134	5.8	0.3	9.38	0.5	-8.88
	ESG678	7.0	0.02	0.63	1.5	0.87
	ESG91011	6.6	0.04	1.25	2	0.75
	ESG17	6.0	0.05	1.56	0.25	-1.31
	ESG2021	6.1	0.02	0.63	1.75	1.13
	ESGTSH	6.4	0.09	2.81	-1.75	-4.56
	Pembali Mining 1	6.1	0.07	2.19	-0.5	-2.69
E-Mine	KROM-1	2.53	1.15	34.7	-8	-42.7
	KROM-2	2.26	1.25	20.6	-14.5	-35.1
	KROM-3	3.68	0.25	2.8	-2.3	-5.1
A-Mine	ABA01	2.08	0.07*	2.24	4.1	1.85
	ABA02	1.13	1.7*	51.5	-33.04	-84.53
	ABA03	1.24	1.28*	38.56	-25.71	-64.27
	ABA05	1.51	1.91*	57.74	32.21	-25.53
	ABA06	1.48	0.05*	1.61	-8.36	-9.97
	ABA07	1.07	1.71*	51.8	-24.87	-76.67
	ABA08	3.21	0.04*	1.27	2.39	1.13
	ABA09	1.28	1.56*	47.29	-9.02	-56.31
	ABA10	2.21	0.1*	3.08	3.37	0.29
	ABA11	3.91	0.1*	3.08	79.1	76.02
	ABA12	3.77	0.08*	2.48	16.3	13.81

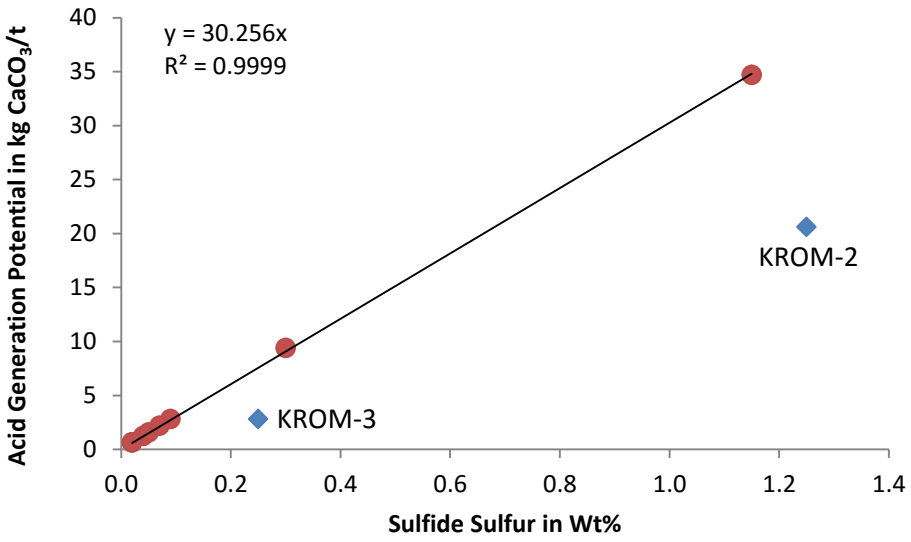


Figure 104: Correlation Graph Illustrating the Correlation between Sulfide Sulfur Wt% and Acid Generation Potential in Collected Samples (red dots) with Potential Outliers KROM-2 and KROM-3 (blue dots) excluded from the Regression Calculation

6.1.3 Comparison of Leaching Test Data

The leachable constituents encountered at each of the study sites show pH values varying between 3.64 and 8.46 with lower values encountered at C-Mine and E-Mine (Table 36). Alkalinity was not detected in most of the analysis results with values only available for the samples from A-Mine and two samples from E-Mine. When considering the Acid-Base Accounting results, these results may show either an acid generating character for the material or that the material has undergone extended leaching of the sulfide and carbonate minerals.

Al was detected in most of the samples from E-Mine and C-Mine. This is explicable based on the lowered pH values of the leachates, mobilising Al into solution, as well as lowering the stability of Al bearing mineral phases. Fe and Mn were detected in most samples where a lowered pH was observed, indicating mobilisation from minerals at lowered pH conditions and a range of Eh conditions (Figure 105 and Figure 106).

Elevated sulfate concentrations were detected in the samples with lower or depleted alkalinity concentrations (Figure 107). This shows that the acidity generated by sulfide oxidation reactions is likely to have depleted the buffering capacity of carbonates in the natural system, subsequently leading to further and faster oxidation of sulfide minerals. This is especially evident in the E-Mine and C-Mine samples, where alkalinity was only detectable in one sample, versus that in the A-Mine samples. Lower sulfate concentrations were therefore observed in the leachates generated by the A-Mine samples. This is in contrast to the results of the Acid-Base Accounting results of the study by Fourie (2013). However, some of the samples collected by Fourie (2013) for Acid-Base Accounting represent discard coal, rather than backfilled overburden material.

Table 36: Compilation of Distilled Water Leaching Test Leachate Analyses. Results are presented in mg/L, with the exception of pH, "-": Below detection limit; N/A – not analysed

		pH	Total Dissolved Solids (Measured)	Alkalinity ($CaCO_3$)	Al	Ca	Fe	K	Mg	Mn	Na	Cl	NO_3	SO_4
C-Mine	ESG134	4.4	322	-	0.33	38	0.05	6.1	14	7.66	3	-	-	203
	ESG678	6.4	61	-	1.04	4	0.75	-	2	0.04	4	6	-	42
	ESG91011	4.7	52	-	-	7	-	4.67	5	0.42	3	-	0.4	38
	ESG17	4.5	51	-	-	3	0.04	4.22	3	0.04	3	-	0.4	36
	ESG2021	4.9	51	-	-	-	-	1.85	-	0.09	-	-	0.2	9
	Pembali Mining 1	4.6	59	-	-	3	0.03	4.47	4	0.05	3	-	0.5	42
E-Mine	KDC1	3.64	177	-	8.8	6.1	0.1	0.79	3.5	1.66	1.18	0.739	0.378	144
	KDC2	3.71	168	-	12.4	4.24	0.13	0.7	1.37	0.81	0.88	0.567	-	149
	KDC3	6.23	10.6	2.7	0.66	0.8	0.81	0.57	0.14	-	1.98	0.414	0.685	24.1
	KDN1	4.16	114	-	1.73	11.2	-	0.77	5.2	2.26	0.63	0.342	-	95.2
	KDN2	5.33	63.6	1.2	-	6.37	-	2.71	3.61	1.18	0.76	0.33	1.1	52.1
A-Mine	ARN1	7.81	83.2	27.3	N/A	15	0.07	3.3	6.14	-	5.2	0.49	-	27.5
	ARN2	7.57	163	20	N/A	41.2	-	1.65	6.54	-	2.01	0.9	-	88.8
	ARN3	8.46	90.6	59.9	N/A	17.4	0.05	1.32	7.45	-	1.81	1.19	-	3.92

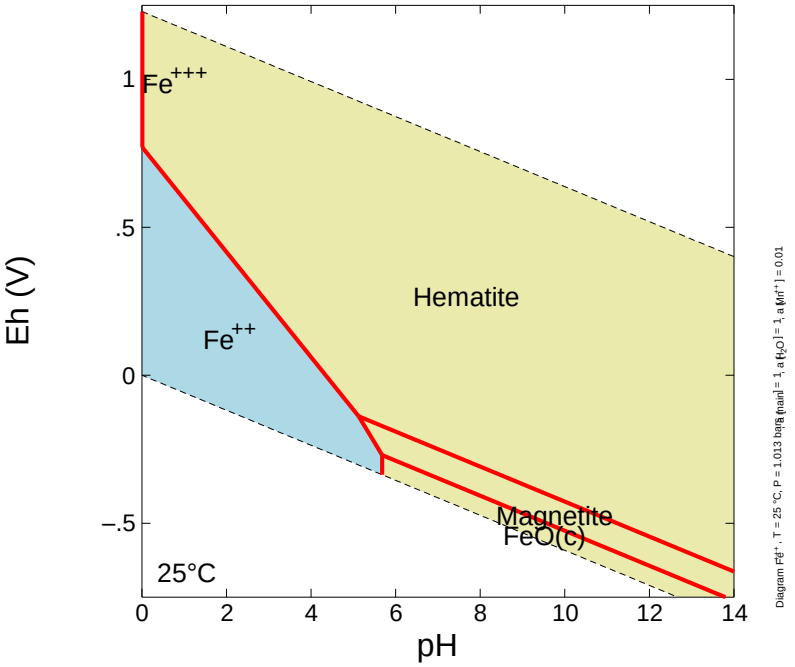


Figure 105: Stability Diagram for a concentration of 0.01 mol Fe and 0.01 mol Mn in solution

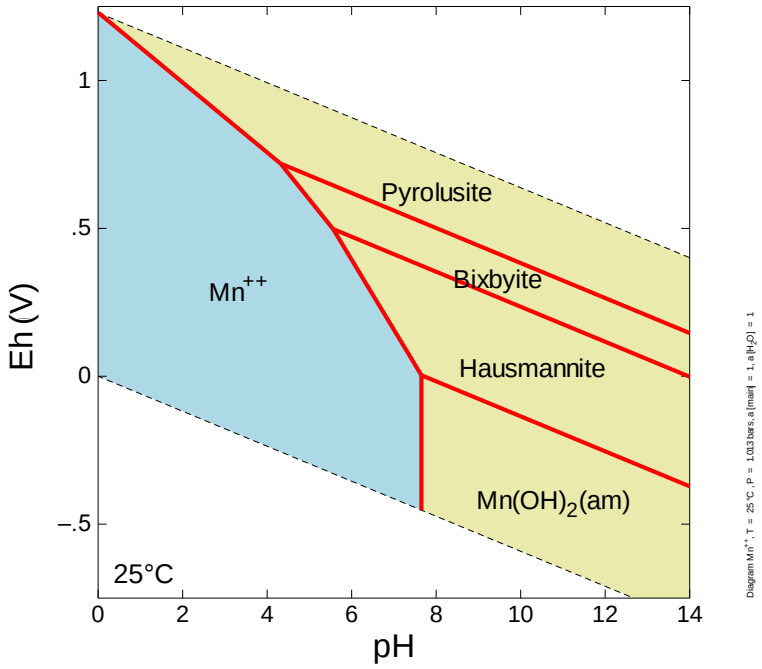


Figure 106: Stability Diagram for a 0.01 mol solution of Mn

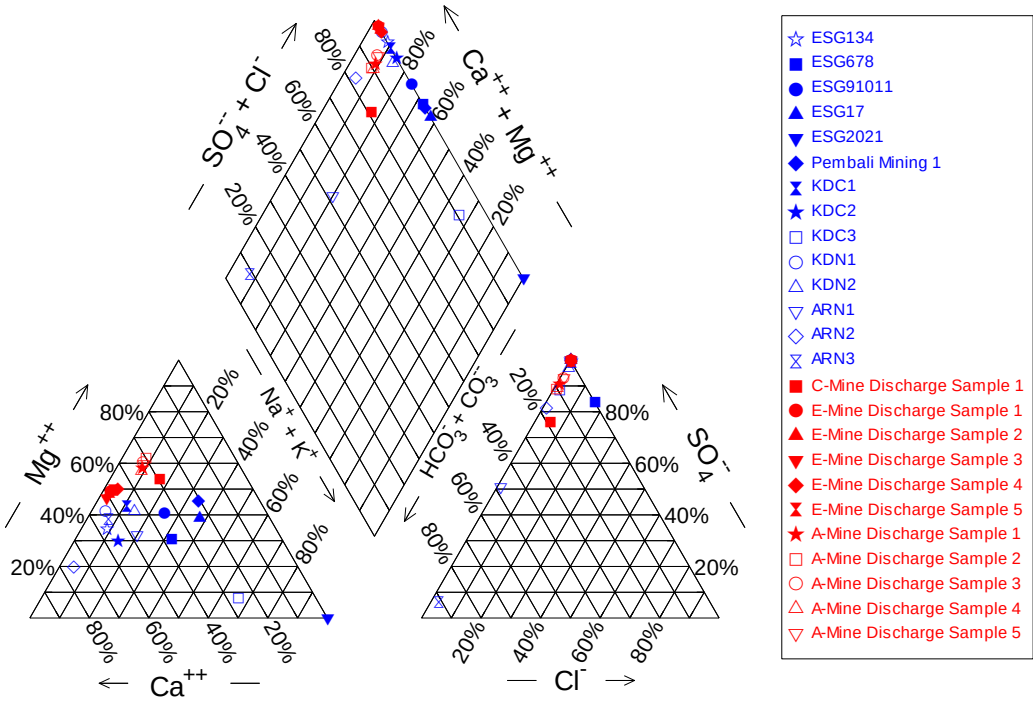


Figure 107: Piper diagram of leachate chemistry and mine water discharge chemistry at the study sites

6.2 Solution Speciation and Controlling Mineral Phases

Speciation calculations were performed using The Geochemist's Workbench v. 9.0 (Bethke, 2008) with the analysis data obtained from the mine sites and collected samples. These calculations aided in the understanding of the controlling mineral phases for each solution and how they could be traced to minerals identified during XRD analysis. Additionally, the calculations were used to verify laboratory analysis data and to determine the correspondence between mine water discharge chemistry and leach test chemistry. Speciation calculations show that the discharge water type for C-Mine is Mg-SO_4, which is in agreement with four of the six leaching test analyses. This shows water that has been influenced by mining related contamination. The calculations show that the predominant constituents in solution for the leach tests are SO_4, Mg, Ca and Na. Based on saturation calculations, the theoretical controlling mineral phases for these constituents are gypsum, anhydrite, epsomite and halite. However, these are secondary minerals and were not necessarily detected in the XRD analyses (section 5.1.1). Therefore, mineral phases that could weather and produce the calculated secondary minerals were identified from the XRD analyses. These minerals were then presumed to be the precursors to the potential calculated controlling phases in solution. Based on this comparison, pyrite, gypsum and anhydrite, which were observed on site, were concluded to be the controlling phases for Ca and SO_4 in solution. Furthermore, smectite was identified as another source of Ca as well as Mg. Halite was identified as a potential source of Na and Cl, as it is likely to precipitate in the mine spoils due to evaporative effects. K-feldspar and quartz were identified as potential sources of K and Si in solution, respectively (Table 37).

Speciation calculations show that the discharge water type for E-Mine is variable over time and includes Fe-SO_4, Ca-SO_4 and Mg-SO_4 which is in agreement with three of the five leaching test analyses. This shows water that has been influenced by mining related contamination. The calculations show that the predominant constituents in solution for the leach tests are SO_4, Mg, Ca, Fe and Al. Based on saturation calculations, the theoretical controlling mineral phases for these constituents are gypsum, anhydrite, epsomite, melanterite, siderite and calcite. However, these are secondary minerals and were not necessarily detected in the XRD analyses (section 5.2.1). Therefore, mineral phases that could weather and produce the calculated secondary minerals were identified from the XRD analyses. These minerals were then presumed to be the precursors to the potential calculated controlling phases in solution. Based on this comparison, pyrite, gypsum and anhydrite, which were observed on site, were concluded to be the controlling phases for Ca and SO_4 in solution. Furthermore, smectite was identified as a potential source of Ca, as well as Mg. However, no Mg bearing phases were identified during the XRD analyses, making the identification of the Mg controlling phase inconclusive for this site. Halite was identified as a potential source of Na and Cl, as it is likely to precipitate in the mine spoils due to evaporative effects. K-feldspar, muscovite and kaolinite were identified as potential sources of K, Al and Si in solution. The presence of Fe in solution was attributed to possible pyrite weathering and oxidation, but may also be attributed to goethite, as observed on site (Table 38).

Speciation calculations show that the discharge water type for A-Mine is Mg-SO_4 which is in disagreement with the leaching test analyses. However, one leach test sample shows a Ca-SO_4 water type, which is in partial agreement with the discharge water type. This shows water that has been influenced by mining related contamination. The calculations show that the predominant constituents in solution for the leach tests are SO_4, Mg, Ca and HCO_3. Based on saturation calculations, the theoretical controlling mineral phases for these constituents are gypsum, anhydrite, dolomite, magnesite, siderite, aragonite and calcite. However, these are secondary minerals and were not necessarily detected in the XRD analyses, with the exception of dolomite/calcite (section 5.2.1). Therefore, mineral phases that could weather and produce the calculated secondary minerals were identified from the XRD analyses. These minerals were then presumed to be the precursors to the potential calculated controlling phases in solution. Based on this comparison, pyrite, gypsum and anhydrite, which were observed on site, were concluded to be the controlling phases for Ca and SO_4 in solution. Furthermore, dolomite, siderite and calcite were identified as potential sources of Ca, as well as Mg (Table 39).

6.3 Statistical Analysis of Geochemical Data

Statistical analysis with IBM SPSS 20 was performed on the data to determine the main influences on the geochemistry of coal mining overburden in the Mpumalanga Province. Correlation matrix data (Appendix A) showed correlations between parameters and the 0.95 and 0.99 significance levels are indicated. Positive correlation coefficients on the 0.95 and 0.99 significance levels were observed between hematite, muscovite, microcline and K in solution, while a negative correlation was observed between hematite and proton activity. Kaolinite was further shown to correlate positively with proton activity, Fe and Al in solution. TDS showed a positive correlation with estimated pyrite content, Ca, Mg, Mn, SO_4, Total S and Acid Generation Potential.

Principal component analysis was also performed on the data (Table 40) to determine which parameters cause the most variance in the data, thereby illustrating a control on the mine water solution. Principal component analysis of the geochemical parameters analysed shows that SO_4, Total S, Acid Generation Potential, Ca, Mg, TDS, K, Paste Proton Activity and Fe cause the most variance within the data and constitute principal component 1 of the dataset. Principal component 2 of the dataset is shown to consist of muscovite, quartz, Neutralisation Potential, kaolinite, hematite and microcline. Only K and Na were found to constitute principal component 3 of the dataset. As illustrated by the correlation matrix, Na and K in solution are related to the microcline, hematite and kaolinite content of the material.

Table 37: Speciation Summary for Discharge Mine Water and Leach Test Analysis Results for C-Mine

C-Mine				Calculated Controlling Mineral Phases in Solution						Possible Controlling Mineral Phases in XRD					
Sample	Water Type	Predominant Species	Possible Precipitates	Controlling Phase	Element	Controlling Phase	Element	Controlling Phase	Element	Possible Controlling Phase	Element	Possible Controlling Phase	Element	Possible Controlling Phase	Element
ESG134	Ca-SO_4	SO_4, Ca, Mg	None	Gypsum, Anhydrite	SO_4, Ca	Epsomite	Mg			Pyrite, Gypsum, Anhydrite	SO_4, Ca	Smectite	Ca	Smectite	Mg
ESG678	Ca-SO_4	SO_4, Na, Cl, SiO_2	Quartz	Gypsum, Anhydrite	SO_4	Halite	Cl	Halite, Mirabilite	Na	Pyrite, Gypsum, Anhydrite	SO_4, Ca	Halite	Na, Cl		
ESG17	Mg-SO_4	SO_4, Na, Mg	None	Gypsum, Anhydrite	SO_4	Epsomite	Mg	Halite	Na	Pyrite, Gypsum, Anhydrite	SO_4, Ca	Smectite	Mg	Halite	Na
ESG2021	Mg-SO_4	SO_4, SiO_2, K	None	Gypsum, Anhydrite	SO_4	Quartz	Si	Kalicinite	K	Pyrite, Gypsum, Anhydrite	SO_4, Ca	Quartz	Si	K-feldspar	K
ESG91011	Mg-SO_4	SO_4, Mg, Ca	None	Gypsum, Anhydrite	SO_4, Ca	Epsomite	Mg			Pyrite, Gypsum, Anhydrite	SO_4, Ca	Smectite	Mg		
PembaliMining 1	Mg-SO_4	SO_4, Mg, Na	None	Gypsum, Anhydrite	SO_4	Epsomite	Mg	Halite	Na	Pyrite, Gypsum, Anhydrite	SO_4, Ca	Smectite	Mg	Halite	Na
C-Mine Discharge	Mg-SO_4	SO_4, Mg, Na	Dolomite/ Calcite	Gypsum, Anhydrite	SO_4, Ca	Epsomite	Mg	Halite	Na	Pyrite, Gypsum, Anhydrite	SO_4, Ca	Smectite	Mg	Halite	Na

Table 38: Speciation Summary for Discharge Mine Water and Leach Test Analysis Results for E-Mine

E-Mine				Calculated Controlling Mineral Phases in Solution								Possible Controlling Mineral Phases in XRD							
Sample	Water Type	Predominant Species	Possible Precipitates	Controlling Phase	Element	Controlling Phase	Element	Controlling Phase	Element	Controlling Phase	Element	Possible Controlling Phase	Element	Possible Controlling Phase	Element	Possible Controlling Phase	Element	Possible Controlling Phase	Element
KDC1	Ca-SO_4	SO_4, Ca, Mg	None	Gypsum, Anhydrite	SO_4, Ca	Epsomite	Mg					Pyrite, Gypsum, Anhydrite	SO_4, Ca	Possible Smectite	Mg				
KDC2	H-SO_4	SO_4, Ca, Mg	None	Gypsum, Anhydrite	SO_4, Ca	Epsomite	Mg					Pyrite, Gypsum, Anhydrite	SO_4, Ca	Possible Smectite	Mg				
KDC3	Na-SO_4	Na, HCO_3, SO_4	None	Gypsum, Anhydrite	SO_4	Siderite, Calcite	HCO_3	Halite	Na			Pyrite, Gypsum, Anhydrite	SO_4, Ca	Calcite	HCO_3	Halite	Na		
KDN1	Ca-SO_4	SO_4, Ca, Mg	None	Gypsum, Anhydrite	SO_4, Ca	Epsomite	Mg					Pyrite, Gypsum, Anhydrite	SO_4, Ca	Possible Smectite	Mg				
KDN2	Ca-SO_4	SO_4, Ca, Mg	None	Gypsum, Anhydrite	SO_4, Ca	Epsomite	Mg					Pyrite, Gypsum, Anhydrite	SO_4, Ca	Possible Smectite	Mg				
Sample1	Fe-SO_4	SO_4, Fe, $AlSO_4$, Mg	None	Gypsum, Anhydrite	SO_4	Melanterite	Fe, SO_4	Gypsum, Alunite	$AlSO_4$	Epsomite	Mg	Pyrite, Gypsum, Anhydrite	SO_4, Ca	Pyrite	Fe	K-feldspar, Muscovite, Kaolinite	Al	Possible Smectite	Mg
Sample2	Fe-SO_4	SO_4, Fe, Mg	None	Gypsum, Anhydrite	SO_4	Melanterite	Fe, SO_4	Epsomite	Mg			Pyrite, Gypsum, Anhydrite	SO_4, Ca	Pyrite	Fe	Possible Smectite	Mg		
Sample3	Ca-SO_4	SO_4, Ca, Mg	None	Gypsum, Anhydrite	SO_4, Ca	Epsomite	Mg					Pyrite, Gypsum, Anhydrite	SO_4, Ca	Possible Smectite	Mg				
Sample4	Mg-SO_4	SO_4, Mg, Ca	None	Gypsum, Anhydrite	SO_4, Ca	Epsomite	Mg					Pyrite, Gypsum, Anhydrite	SO_4, Ca	Possible Smectite	Mg				
Sample5	Mg-SO_4	SO_4, Mg, Ca	None	Gypsum, Anhydrite	SO_4, Ca	Epsomite	Mg					Pyrite, Gypsum, Anhydrite	SO_4, Ca	Possible Smectite	Mg				

Table 39: Speciation Summary for Discharge Mine Water and Leach Test Analysis Results for A-Mine

A-Mine				Calculated Controlling Mineral Phases in Solution				Possible Controlling Mineral Phases in XRD			
Sample	Water Type	Predominant Species	Possible Precipitates	Controlling Phase	Element	Controlling Phase	Element	Possible Controlling Phase	Element	Possible Controlling Phase	Element
ARN1	Ca-HCO_3	HCO_3, Ca, SO_4	None	Siderite, Dolomite, Aragonite, Magnesite.	HCO_3, Ca	Gypsum, Anhydrite	SO_4, Ca	Siderite, Dolomite, Calcite	HCO_3, Ca	Pyrite, Gypsum, Anhydrite	SO_4, Ca
ARN2	Ca-SO_4	Ca, SO_4, HCO_3	None	Calcite, Aragonite, Dolomite.	HCO_3, Ca	Gypsum, Anhydrite	SO_4, Ca	Siderite, Dolomite, Calcite	HCO_3, Ca	Pyrite, Gypsum, Anhydrite	SO_4, Ca
ARN3	Ca-HCO_3	HCO_3, Ca, Mg	Dolomite/ Calcite	Calcite, Aragonite, Dolomite.	HCO_3, Ca, Mg					Siderite, Dolomite, Calcite	HCO_3, Ca, Mg
Sample1	Mg-SO_4	SO_4, Mg, Ca	Dolomite/ Calcite	Calcite, Aragonite, Dolomite, Magnesite.	Ca, Mg	Gypsum, Anhydrite	SO_4, Ca	Dolomite, Calcite	Ca, Mg	Pyrite, Gypsum, Anhydrite	SO_4, Ca
Sample2	Mg-SO_4	Mg, SO_4, Ca	Dolomite/ Calcite/ Magnesite/ Gibbsite	Calcite, Aragonite, Dolomite, Magnesite.	Ca, Mg	Gypsum, Anhydrite	SO_4, Ca	Dolomite, Calcite	Ca, Mg	Pyrite, Gypsum, Anhydrite	SO_4, Ca
Sample3	Mg-SO_4	Mg, SO_4, Ca	Dolomite/ Calcite/ Magnesite	Calcite, Aragonite, Dolomite, Magnesite.	Ca, Mg	Gypsum, Anhydrite	SO_4, Ca	Dolomite, Calcite	Ca, Mg	Pyrite, Gypsum, Anhydrite	SO_4, Ca
Sample4	Mg-SO_4	SO_4, Mg, $MgSO_4$, Ca	Dolomite/ Calcite/ Magnesite	Calcite, Aragonite, Dolomite, Magnesite.	Ca, Mg	Gypsum, Anhydrite	SO_4, Ca	Dolomite, Calcite	Ca, Mg	Pyrite, Gypsum, Anhydrite	SO_4, Ca
Sample5	Mg-SO_4	SO_4, Mg, $MgSO_4$, Ca	Dolomite/ Calcite/ Magnesite	Calcite, Aragonite, Dolomite, Magnesite.	Ca, Mg	Gypsum, Anhydrite	SO_4, Ca	Dolomite, Calcite	Ca, Mg	Pyrite, Gypsum, Anhydrite	SO_4, Ca

Table 40: Principal Component Analysis Results with Qualifying Sample Values Above 0.5 (Highlighted); [H^+] used instead of pH

Principal Components	1 (58% of variance)		2 (33% of variance)		3 (8% of variance)
	Estimated Pyrite	1.000	Muscovite	0.984	Na	0.704
	SO_4	1.000	Quartz	0.978	K	0.523
	Total S	0.995	Neutralisation Potential	0.917	Microcline	0.448
	Acid Generation Potential	0.995	Kaolinite	0.905	Neutralisation Potential	0.158
	Ca	0.988	Hematite	0.870	Mg	0.141
	Mg	0.988	Microcline	0.782	NNP	0.118
	TDS	0.984	NNP	0.243	Hematite	0.072
	K	0.798	Ca	0.152	Quartz	0.022
	H^+	0.783	TDS	0.114	Ca	-0.005
	Fe	0.712	Mg	0.059	SO_4	-0.017
	Hematite	0.487	Estimated Pyrite	0.021	Estimated Pyrite	-0.017
	Na	0.430	SO_4	0.021	Total S	-0.087
	Microcline	0.430	Acid Generation Potential	-0.005	Acid Generation Potential	-0.087
	Kaolinite	0.374	Total S	-0.005	TDS	-0.140
	Quartz	0.203	Paste [H^+]	-0.261	Kaolinite	-0.146
	Muscovite	-0.039	K	-0.298	Fe	-0.156
	Neutralisation Potential	-0.264	Na	-0.562	Muscovite	-0.161
	NNP	-0.957	Fe	-0.637	Paste H^+	-0.547

Further to the principal component analysis, a dendrogram was constructed for the analysis data to determine which samples are likely to be related and to determine the reason for this relation or difference (Figure 108). Groupings can be observed between ESG17, Pembali Mining 1 and ESG91011. Similarly, a grouping can be observed between KDN2, ESG2021 and KDC3. All these samples fall under one grouping when compared to ARN3 which subsequently forms part of another grouping with the previous samples when compared to ARN2. The above-mentioned samples were interpreted to generate less acidity upon weathering and leaching as compared to a grouping of KDC1, KDC2, KDN1 and ESG134, which were interpreted to be more acid-generating. This acid-generating group can be further split into a grouping of KDC1 and KDC2 when compared to KDN1 while all the mentioned acid-generating samples can be grouped together when compared to ESG134. A 25% variance was observed between the more acid-generating and less-acid generating samples.

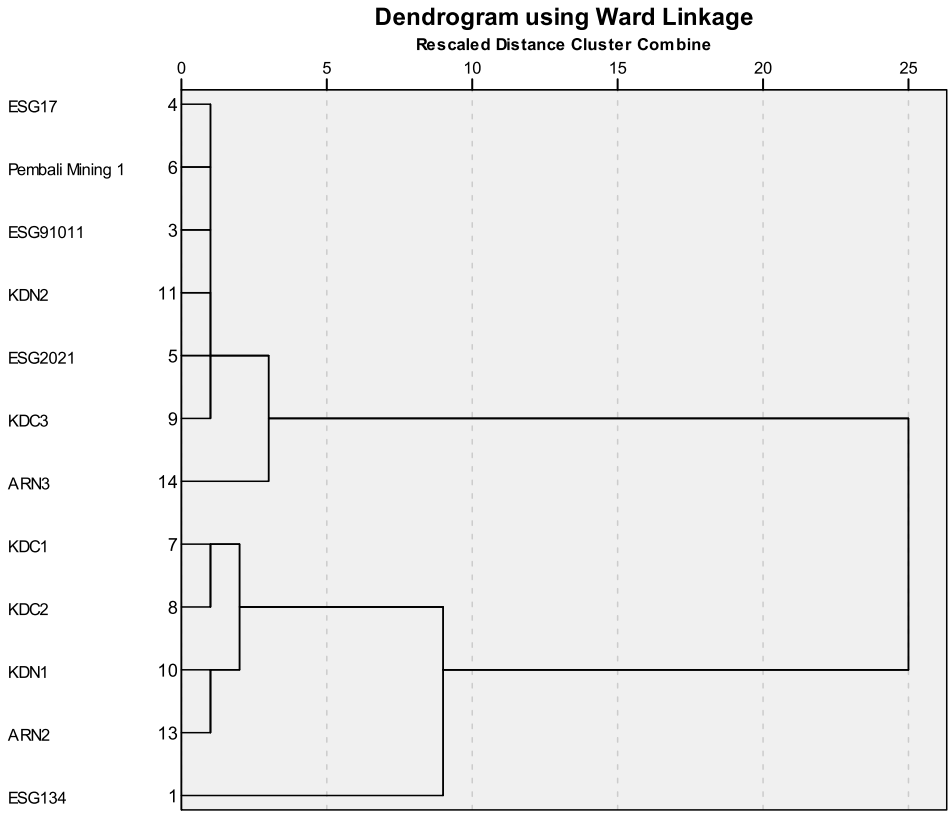


Figure 108: Dendrogram Relating All Analysis Data between the Collected Geochemical Samples at the Study Sites using Leaching Test Constituent Concentrations and XRD Identified Mineral Phases

6.4 Statistical Analysis of Hydrochemical Data

Statistical analyses were performed on the monitoring data for C-Mine to determine the maximum, minimum and average element concentrations in the data. Additional to this is the cross-correlation of sulfate with pH to determine if sulfide oxidation is the controlling mechanism on sulfate generation which would indicate early stages of the initial flush. A 3D graphical representation of the temporal data was also performed to determine which monitoring wells have been affected by the initial flush.

Descriptive statistics (Table 41) show that the minimum sulfate concentration measured during the monitoring period is 0.8 mg/L while the maximum is 1590 mg/L. An average sulfate concentration of approximately 77 mg/L can also be observed.

Cross-correlation of the sulfate concentrations measured with the pH values measured (Figure 109) show that sulfate concentration is inversely correlated with the pH values measured across the site. This shows that the initial flush from the backfilled opencast mines on site is still in an early stage and active sulfide oxidation is taking place. The associated minimum and maximum pH values are 1.1 and 9.5 respectively.

From the groundwater monitoring data graphically illustrated in Figure 110 it is evident that MW10, MW11, MW12, MW16, MW3, MW5, MW6 and MW8 have been affected by sulfate contamination. MW 10 shows a decline in sulfate concentration over time which suggests that it has been affected quite early in the initial flush process while MW11, MW12 and MW16 show increasing trends. This

shows that the afore-mentioned monitoring wells are in an earlier stage of contaminant transport through this portion of the aquifer and a decline in sulfate concentrations in these monitoring wells can only be expected at a later stage. However, this does show that contaminant plume movement is actively taking place away from the backfilled opencast mines which indicates source depletion along with MW10. MW3 and MW8 show much lower concentrations of sulfate which show possible contamination during the mining process with MW3 showing very early stage initial flush contamination by its increasing trend. MW5 and MW6 show very early stage contamination which is more likely due to contamination during mining and coal processing.

Table 41: Descriptive statistics for groundwater monitoring data at C-Mine

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
TDS	349	.0	2086.0	208.058	260.2957
NO_3	349	.0	15.3	.441	1.1892
Cl	349	1.0	118.0	6.771	8.8403
Alkalinity	349	5.0	247.0	74.716	35.6802
F	349	.0	7.8	.392	.7174
SO_4	349	.8	1590.0	76.778	185.8159
Hardness	349	2.0	1492.0	124.745	184.7083
Ca	349	.0	296.0	24.815	31.0099
Mg	349	.0	221.0	15.177	28.0516
Na	349	1.3	97.7	14.579	13.2097
K	349	.2	22.3	4.061	2.9438
Fe	349	.0	54.4	.831	4.4927
Mn	349	.0	51.6	.890	3.9391
EC	349	2.9	233.0	29.849	30.3208
pH	349	1.1	9.5	7.411	.6900
Al	349	.0	3.9	.062	.2191
Valid N (listwise)	349				

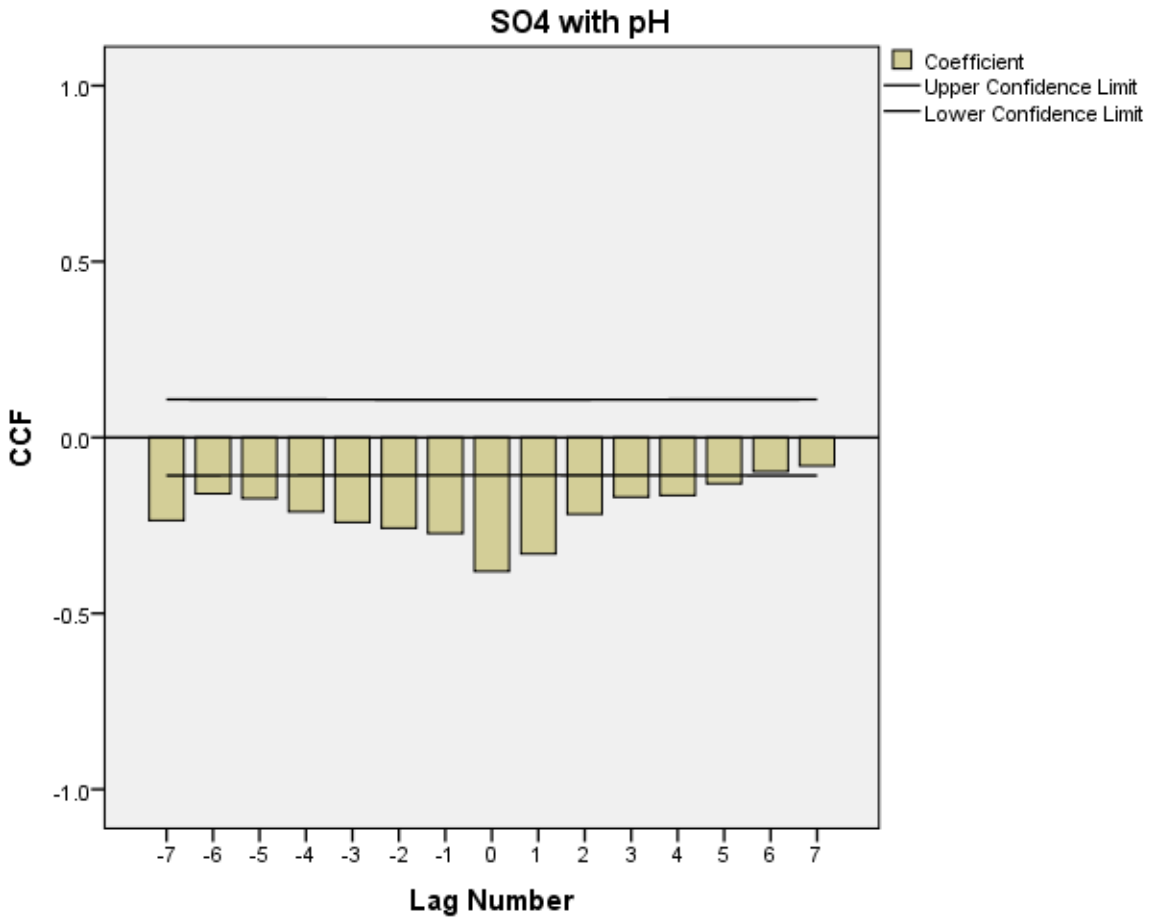


Figure 109: Cross-Correlation of SO_4 with pH in groundwater at C-Mine

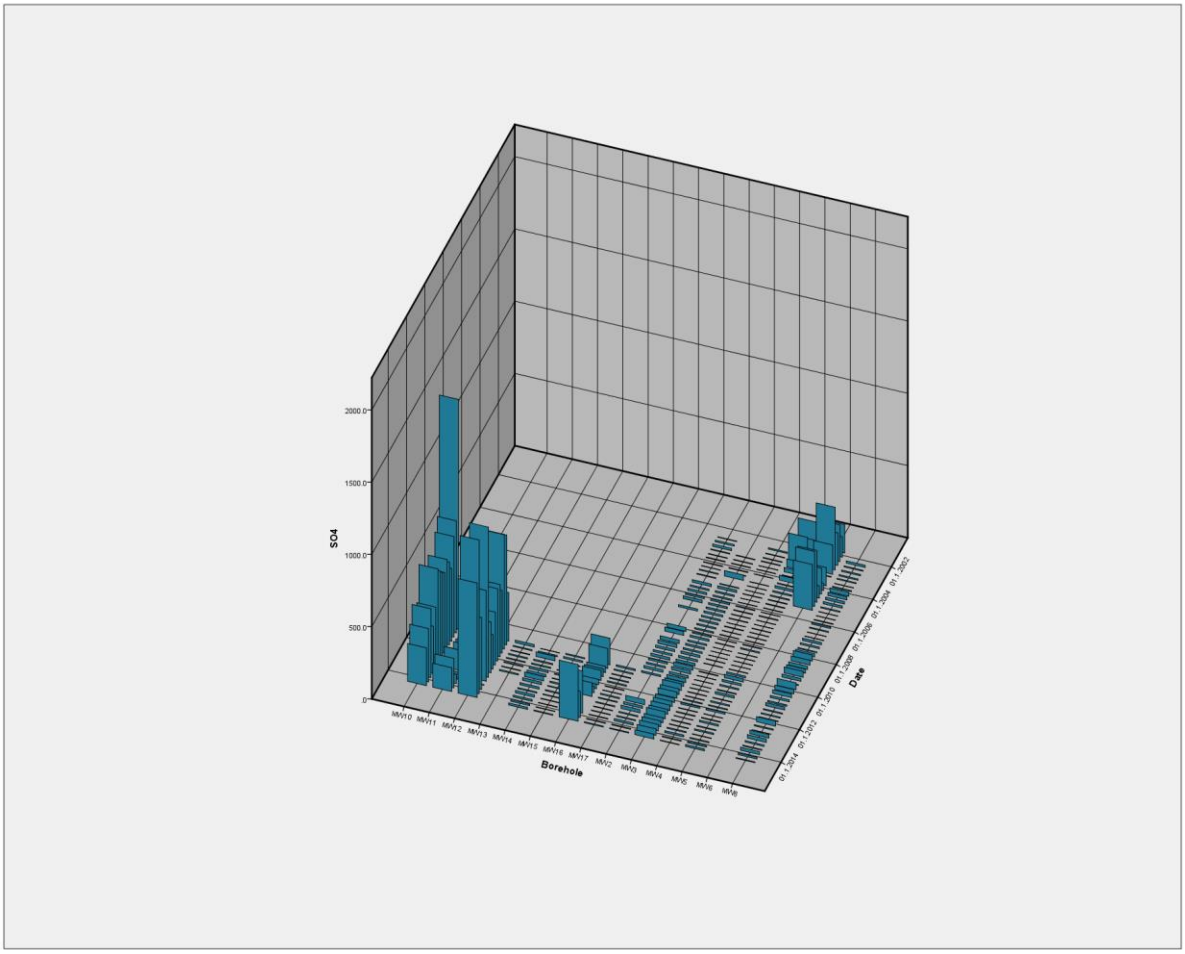


Figure 110: Groundwater monitoring data at C-Mine illustrating SO_4 affected boreholes (SO_4 units = mg/L)

Statistical analyses were performed on the monitoring data for E-Mine to determine the maximum, minimum and average element concentrations in the data. Additional to this is the cross-correlation of sulfate with pH to determine if sulfide oxidation is the controlling mechanism on sulfate generation which would indicate early stages of the initial flush. A 3D graphical representation of the temporal data was also performed to determine which monitoring wells have been affected by the initial flush.

Descriptive statistics (Table 42) show that the minimum sulfate concentration measured during the monitoring period is 0.7 mg/L while the maximum is 7100 mg/L. An average sulfate concentration of approximately 153.23 mg/L can also be observed.

Cross-correlation of the sulfate concentrations measured with the pH values measured (Figure 111) show that sulfate concentration is inversely correlated with the pH values measured across the site. This shows that the initial flush from the backfilled opencast mine on site is still in an early stage and active sulfide oxidation is taking place. The associated minimum and maximum pH values are 2.1 and 11.7 respectively.

From the groundwater monitoring data graphically illustrated in Figure 110 it is evident that KRW012, KRW014, KRW026, KRW029, KRW034, KRW036, KRW038, KRW039, KRW047, KRW049 and the discharge point WP054 have been affected by sulfate contamination. WP054 shows an increase in sulfate concentration over time, especially after 2010, which shows that the initial flush is in its early tages and may have started during 2010 after discharge of contaminated mine water in this area. Elevated sulfate concentrations at this discharge point which are inversely correlated to the pH values as discussed show that active and continuous disulfide weathering is taking place in the backfilled opencast. An increasing sulfate trend in KRW012, KRW014, KRW026 and KRW029 after 2012 show that the initial flush has reached these monitoring wells after flooding of the backfilled opencast but is still in a progressive stage and peak contaminant concentrations are likely to be reached later in the initial flush process. KRW034, KRW036, KRW038 and KRW039 show variable sulfate concentrations which were caused by contaminant release during mining and do not appear to be affected by the initial flush yet, with the exception of KRW034. This is due to the distance of these monitoring wells from the backfilled opencast mine. These monitoring wells are likely to show the effects of the initial flush only at a later stage. KRW047 and KRW049 show increases in sulfate concentrations after 2011 which shows that these monitoring wells have been affected by the initial flush but are still in the early stages of the initial flush and are likely to reach peak concentrations at a later stage. These wells are also located close to the backfilled opencast mines and are likely to be affected by contamination early in the initial flush development.

Table 42: Descriptive statistics for groundwater monitoring data at E-Mine

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
EC	1906	.1	929.0	32.430	71.4803
Alkalinity	1896	.0	772.0	39.876	71.2839
Fe	1905	.0	1657.8	9.837	67.7028
Mn	1910	.0	162.6	2.643	12.1442
pH	1898	2.1	11.7	5.723	1.2326
Cl	1909	.1	540.0	5.572	14.1240
Mg	1909	.0	344.9	9.774	24.5341
Na	1904	.0	235.9	9.635	10.6134
Al	1883	.0	415.4	5.624	29.8015
Ca	1908	.0	979.2	24.332	57.2861
SO4	1915	.7	7100.0	153.229	563.4019
NH4	550	.0	30.7	2.033	4.1828
K	1908	.0	55.0	3.490	4.1836
NO3	522	0.7	41.9	1.292	3.4823
PO4	549	0.9	10.2	.352	.5409
Temp	1771	13.2	37.1	22.623	2.8284
F	577	.0	20.2	.440	1.2153
Valid N (listwise)	470				

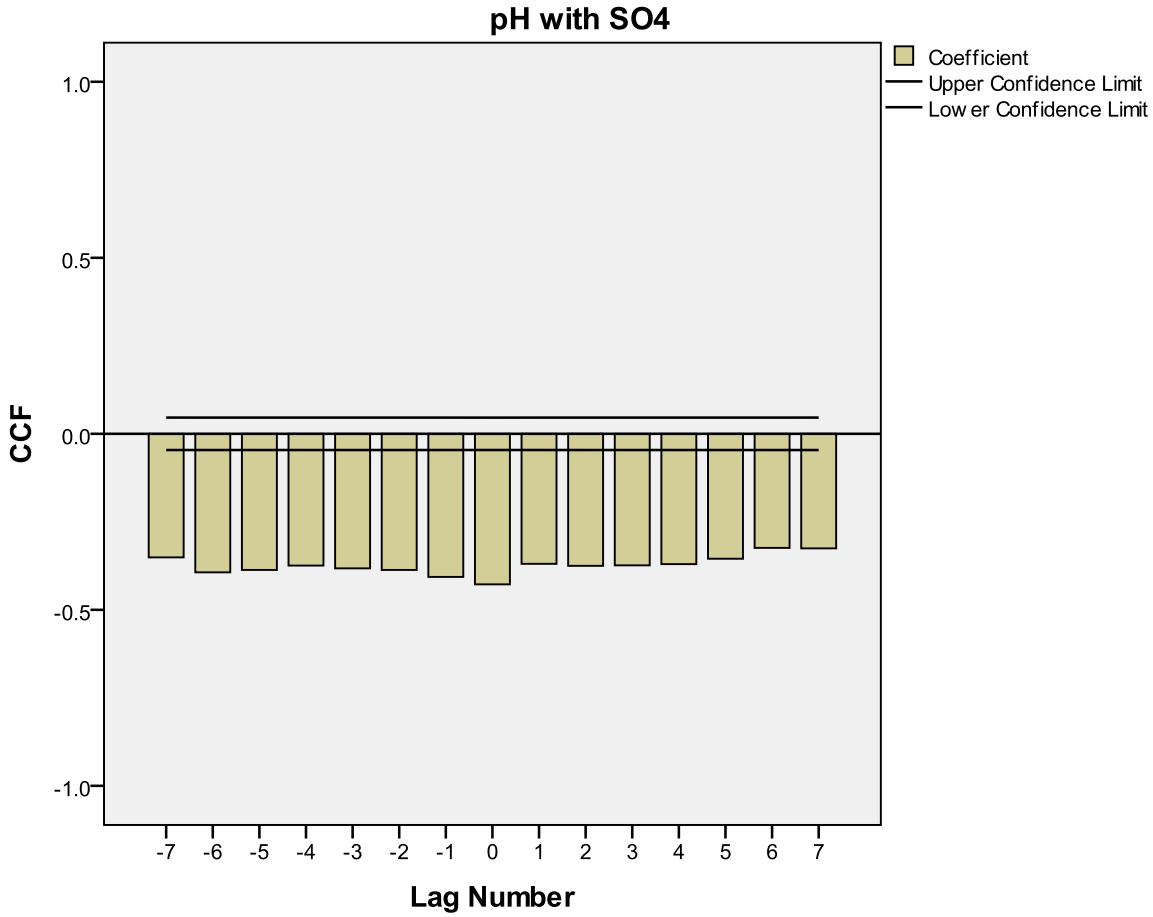


Figure 111: Cross-Correlation of SO_4 with pH in groundwater at E-Mine

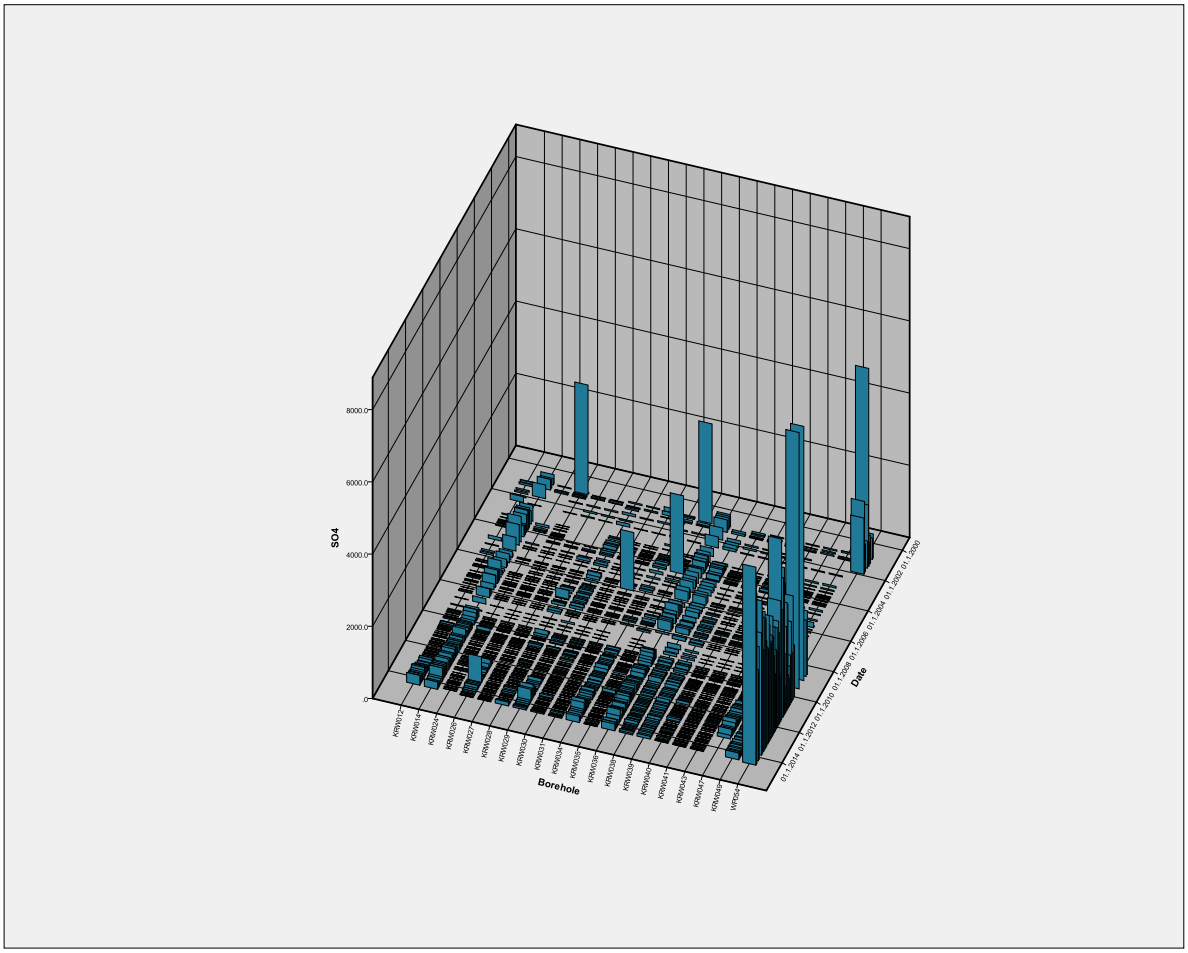


Figure 112: Groundwater monitoring data at E-Mine illustrating SO_4 affected boreholes (SO_4 units = mg/L)

Statistical analyses were performed on the monitoring data for A-Mine to determine the maximum, minimum and average element concentrations in the data. Additional to this is the cross-correlation of sulfate with pH to determine if sulfide oxidation is the controlling mechanism on sulfate generation which would indicate early stages of the initial flush. A 3D graphical representation of the temporal data was also performed to determine which monitoring wells have been affected by the initial flush.

Descriptive statistics (Table 43) show that the minimum sulfate concentration measured during the monitoring period is 0.5 mg/L while the maximum is 5070 mg/L. An average sulfate concentration of approximately 647.72 mg/L can also be observed.

Cross-correlation of the sulfate concentrations measured with the pH values measured (Figure 113) show that sulfate concentration is inversely correlated with the pH values measured across the site. This shows that the initial flush from the backfilled opencast mines on site is in a developed stage although active sulfide oxidation is taking place. The associated minimum and maximum pH values are 3 and 10.7 respectively.

From the groundwater monitoring data graphically illustrated in Figure 110 it is evident that AW1, AW19, AW2, AW20, AW24, AW25, AW26, AW3, AW30, AW32, AW36, AW37, AW6, AW7, AW8 and AW9 have been strongly affected by sulfate contamination. However, most of the affected monitoring wells show a decreasing trend in sulfate concentrations. This shows that peak concentrations have been reached in these monitoring wells which is interpreted as the intermediate to advanced development of the initial flush from the backfilled opencast mine on site. Further increases in sulfate concentrations are not expected and the recirculation of mine water through the backfilled opencast mine is likely to aid in the concentration decreases observed in these monitoring wells. Although the wells are at greatly varying distances from the backfilled opencast mine, the effect of the initial flush is readily observable as the closure of the mine took place in the 1980's. This is a large enough timeframe for the mine to flood and notable contaminant transport to take place away from the backfilled opencast mine.

Table 43: Descriptive statistics for groundwater monitoring data at A-Mine

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
pH	1629	3.0	10.7	6.891	1.0051
EC	1628	3.0	1832.0	152.564	194.6242
TDS	1367	.0	7775.0	1267.311	1637.4471
Alkalinity	1579	.0	5400.0	184.960	315.6692
Ca	1602	.0	960.0	119.311	162.2853
Mg	1602	.0	894.0	100.139	157.9347
Na	1602	.4	2475.0	88.541	274.2191
K	1601	.0	3930.0	69.772	407.1463
SO4	1627	.5	5070.0	647.716	999.5780
Cl	1614	.0	2072.0	51.430	204.3702
F	1615	.0	53.0	.625	1.5610
Fe	1549	.0	410.0	5.197	27.7324
Mn	1558	.0	99.4	2.610	7.5833
Al	1474	.0	136.4	1.078	7.4620
Valid N (listwise)	1233				

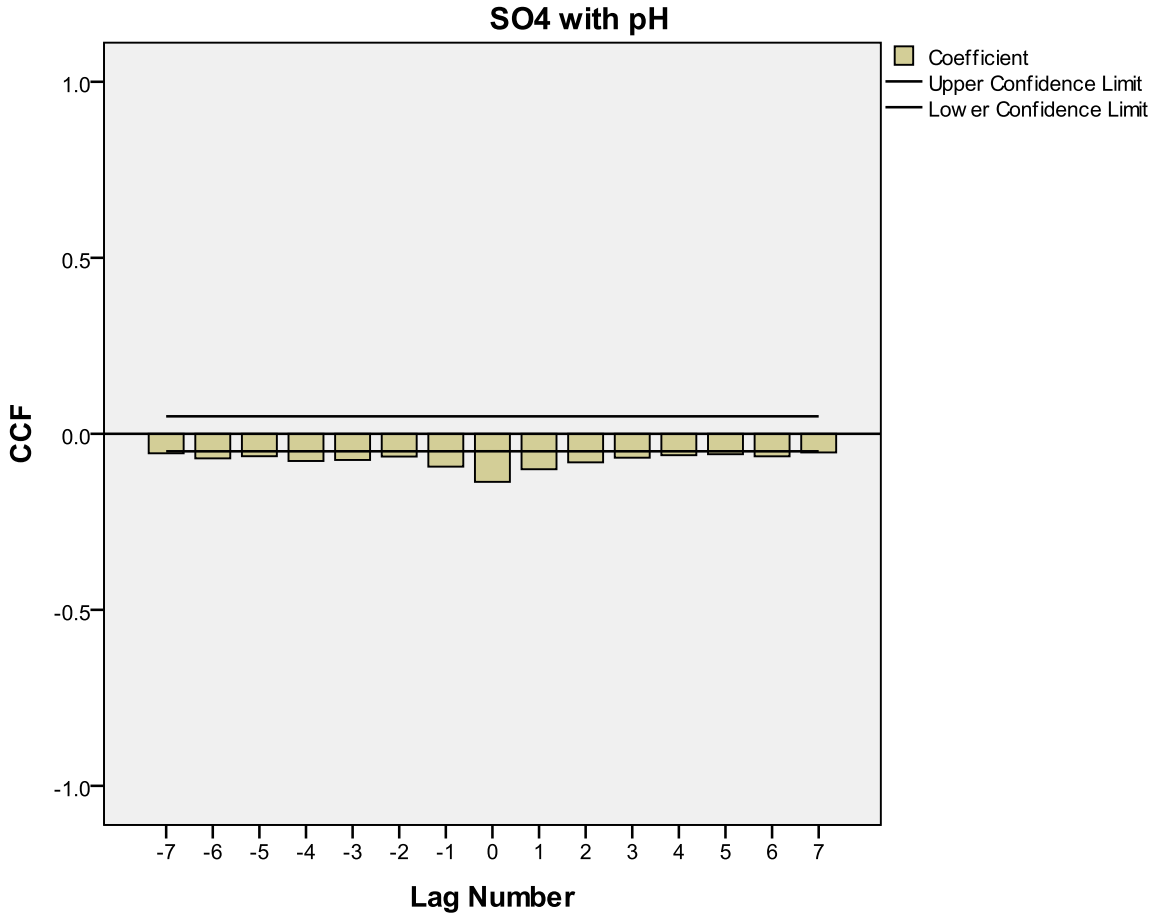


Figure 113: Cross-Correlation of SO_4 with pH in groundwater at E-Mine

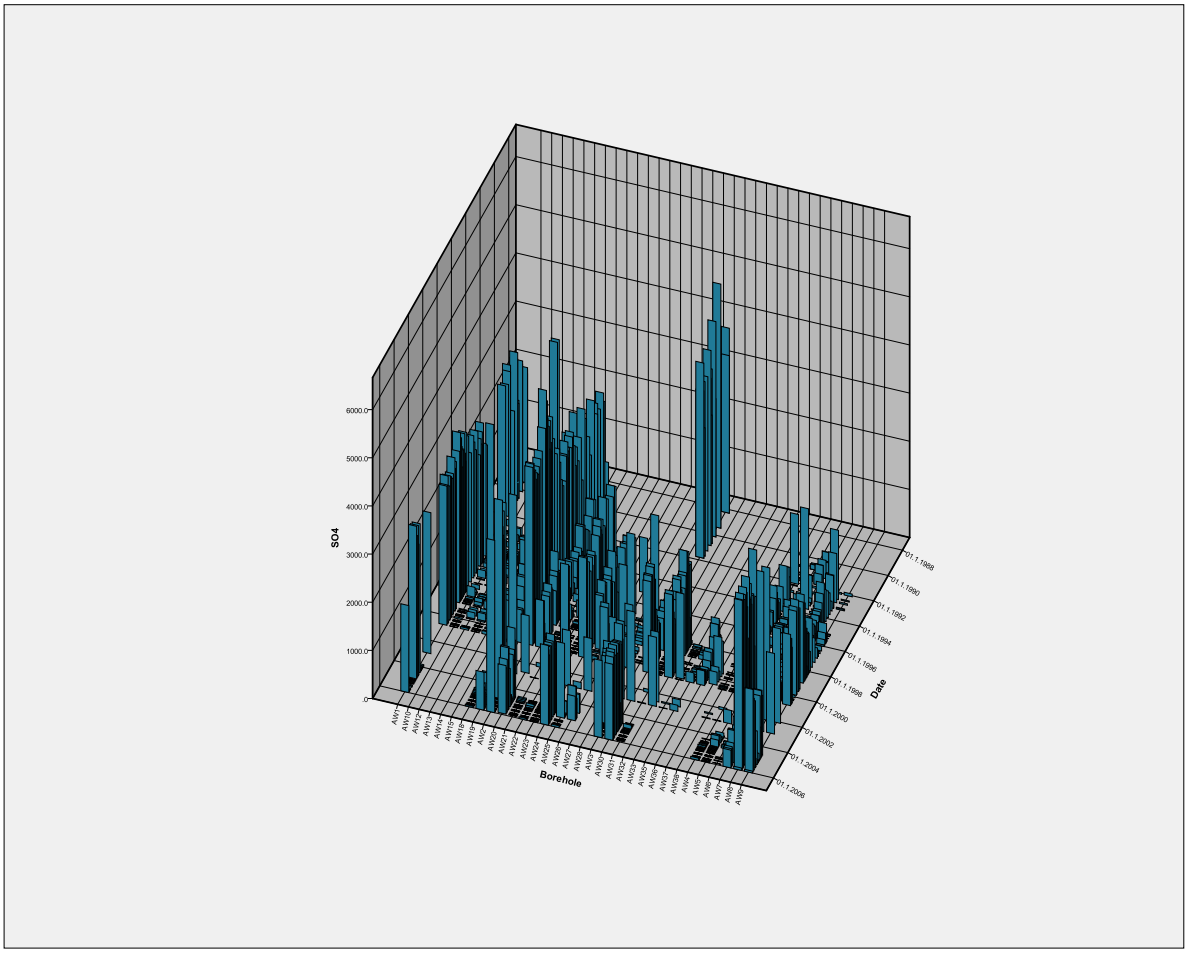


Figure 114: Groundwater monitoring data at E-Mine illustrating SO_4 affected boreholes (SO_4 units = mg/L)

6.5 Geochemical Modelling Calibration

Calibration results for the geochemical models show correspondence of modelled values with leach test concentrations. The coefficients of determination for the calibration graphs of C-Mine, E-Mine and A-Mine are all above 0.98, which shows a good correlation between simulated and analysed values. Calibration results for C-Mine show that calculated concentrations generally correspond to analysis concentrations within 10%. The average difference between calculated and analysed concentrations is less than 0.5 mg/L. The largest discrepancies between calculated and analysed concentrations are with regards to Si (difference of 3.3 mg/L – 12% error) and Ca (difference of 3.2 mg/L – 1% error).

Results obtained for the calibration of the E-Mine model show that calculated concentrations generally correspond to analysis concentrations within 17%. The average difference between calculated and analysed concentrations is less than 0.85 mg/L. The largest discrepancies between calculated and analysed concentrations are with regards to Al (difference of 1.5 mg/L – 20% error), Fe (difference of 0.2 mg/L – 23% error) and K (difference of 0.8 mg/L – 60% error).

Calibration results for A-Mine show that calculated concentrations generally correspond to analysis concentrations within 15%. The average difference between calculated and analysed concentrations

is less than 0.46 mg/L. The largest discrepancies between calculated and analysed concentrations are with regards to Fe (difference of 0.04 mg/L – 90% error) and K (difference of 1.8 mg/L – 66% error).

These results show that discrepancies between analysed concentrations and calculated values are likely to be model- and site specific. However, K and Fe seem to be problematic elements in total model calibration. This is due to the likely precipitation of Fe as iron(oxy)hydroxides from solution. Fe calibration is of interest as this is one of the more common contaminants in mine water (Geller and Schultze, 2013). K, on the other hand, is of lesser concern in terms of mine water contamination. However, with enough dissolved Fe, Al and SO_4 in mine water the concentration of K is likely to influence the saturation index of minerals such as K-jarosite and alunite. This may directly affect the concentration of Fe, Al and SO_4 in mine water. Additionally, the precipitation of Fe-sulfate minerals such as jarosite, rozenite and melanterite are unlikely to affect sulfate concentrations considerably, due to the low concentrations of Fe in solution, relative to SO_4. This is due to K, Fe and Al concentrations limiting the precipitation of these minerals due to their concentrations generally being lower than that of sulfate, in mine water (Gzyl and Banks, 2007, Geller and Schultze, 2013, Annandale et al., 2001, Banks, 1994, Bullock and Bell, 1997). Precipitation of minerals such as goethite and iron(oxy)hydroxides are, however, likely to affect iron concentrations in solution as illustrated in section 6.1, by the poor correlations between Fe and SO_4.

Calibration of Ca concentrations, however, is postulated to have a larger effect on the calibration of sulfate values calculated, which is also supported by the calculations in section 6.1. This is due to the higher concentrations of Ca commonly encountered in mine water, relative to that of Fe, Al and K. Ca concentrations may differ from SO_4 concentrations by only one order of magnitude (Gzyl and Banks, 2007, Geller and Schultze, 2013, Annandale et al., 2001, Banks, 1994, Bullock and Bell, 1997). This is postulated to generate up to a 10% error in the calculation of SO_4 concentrations, as minerals such as anhydrite and gypsum may be precipitated from and dissolved into solution in notable quantities.

6.6 Numerical Transport Modelling Calibration

Simulated sulfate concentrations in the numerical transport model were compared to analysed sulfate concentrations obtained from monitoring data (Figure 36, Figure 62 and Figure 98), as described in sections 5.1.8, 5.2.8 and 5.3.8. Results obtained for C-Mine show a fit obtained within an error range of 20 mg/L. Although calibration was obtained from this transport model within the specified error, a clear trend in the data, in terms of concentrations, is not easily discernible. This may show results that are not fully conclusive and further groundwater monitoring data may be required to fully observe the effect of the initial flush. Additional to this is the role of the low concentrations of sulfate observed in the monitoring results, which add to the lack of discernibility of clear concentration trends. This shows that the proposed modelling method is less applicable to sites where low sulfate concentrations are observed in monitoring data.

Although a slightly larger error range was used in the model results of E-Mine, calibration was obtained in terms of the modelled data, fitting observation data. Clearly discernible trends can be observed in the data and the calculated concentrations were within 50 mg/L of analysed sulfate concentrations. However, some discrepancies were still observed between modelled and analysed data. Due to imperfect conditions on site as well as possible sampling discrepancies and unknown temporal events, variations in data trends can be observed. However, the general trend of sulfate

concentrations can be identified. Therefore, the modelling method is interpreted as more applicable to sites with higher sulfate concentrations which show concentration peak trends.

This finding is further supported by the results obtained for A-Mine. Due to the elevated concentrations of sulfate observed at A-Mine, an error range of 200 mg/L was used for the transient calibration. However, due to the extended time after closure of the opencast mine, clearly discernible concentration trends can be observed in the monitoring data. A good fit was obtained for the simulated values and most of the simulated concentrations are within 200 mg/L of the monitoring data concentrations. This is supported especially by monitoring data from the monitoring well AW24, which was drilled in the backfilled opencast mine, representing the decrease of sulfate input over time. However, discrepancies were again observed between monitoring data and simulated concentrations at A-Mine. Sources besides the backfill material are present at the mine, which are likely to influence the concentrations observed in groundwater, causing deviations from idealised concentration peaks. Additional to this are discrepancies caused by groundwater sampling and representativeness of backfill samples. Fewer backfill samples were collected at A-Mine due to access constraints, which could lead to errors in modelling results.

6.7 Long Term Geochemical Behaviour and Contaminant Transport

After chemical calibration of the various transport models constructed for the study sites, long-term simulations were performed to understand contaminant transport from the backfilled opencast mines. Based on the calibration of the models, as discussed in sections 5.1.8, 5.2.8 and 5.3.8, the results were considered to be representative within the specified error range for each transport model. The long-term modelling results for C-Mine show that completion of the initial flush is likely to take place within 25 years from the present situation (Figure 115), which is a relatively short period when compared to the other mine sites. This is attributed to the low contamination potential of these mines (section 5.1.3), as well as lowered recharge due to final rehabilitation being completed.

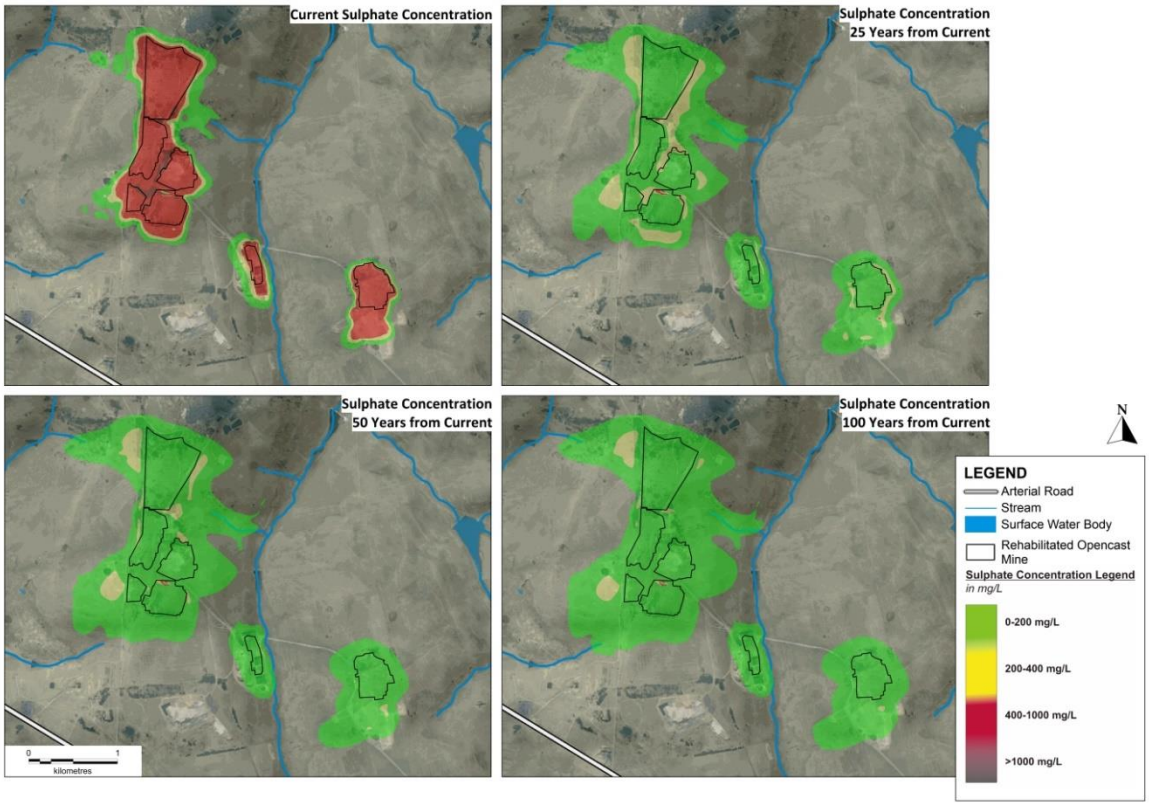


Figure 115: Sulfate concentration contours for the long term contaminant transport simulation for C-Mine

Results for the long term contaminant transport simulation for E-Mine show a timeframe of approximately 75 years for the initial flush to decrease to potable sulfate concentrations (Figure 116). However, the higher rate of water addition by inflow and recharge lowers concentrations due to dilution, dissolution and transport. Adding to this is the fact that E-Mine is currently discharging a notable volume of mine water, thereby removing contamination from the aquifer at a faster rate. Therefore, even though the contamination potential of the backfill material at E-Mine is higher than that of C-Mine (section 5.2) dilution, discharge and transport still favour the decrease of contaminant concentrations in the mine water.

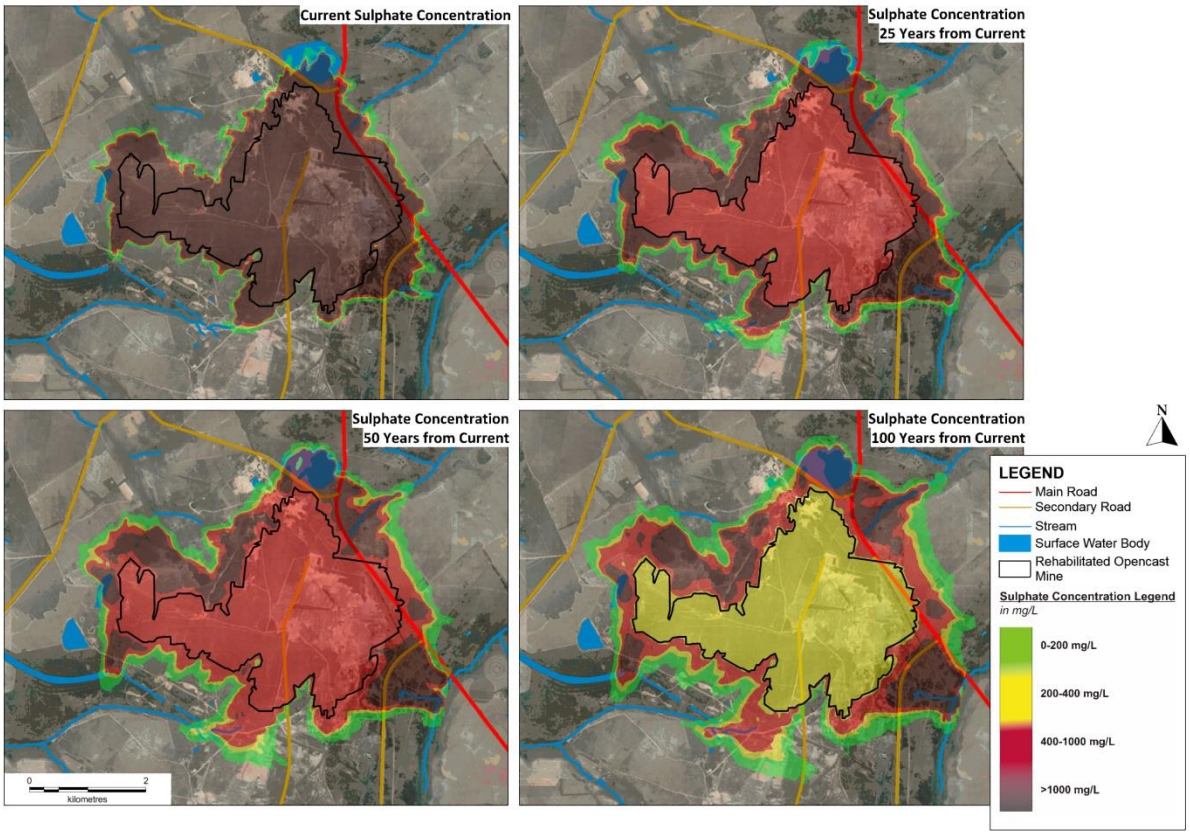


Figure 116: Sulfate concentration contours for the long term contaminant transport simulation for E-Mine

Transport modelling for A-Mine shows a longer time frame. Based on the modelling results, the initial flush does not fully complete to potable sulfate concentrations in the A-Mine backfilled opencast mine within 100 years from the current situation (Figure 117). Even though groundwater is recirculated in the backfilled opencast mine, increasing the rate of sulfide mineral breakdown, mine water is not allowed to discharge at a constant rate. Additionally, the contamination potential of the backfill material is also higher than that of C-Mine. These may be reasons for the estimated prolonging of the initial flush. However, it should be noted that the water quality at A-Mine is calculated to reach lower sulfate concentrations (between 200 and 400 mg/L) within 50 years, which is a shorter timeframe than calculated for E-Mine. This shows the positive side of mine water recirculation through the backfilled opencast mine.

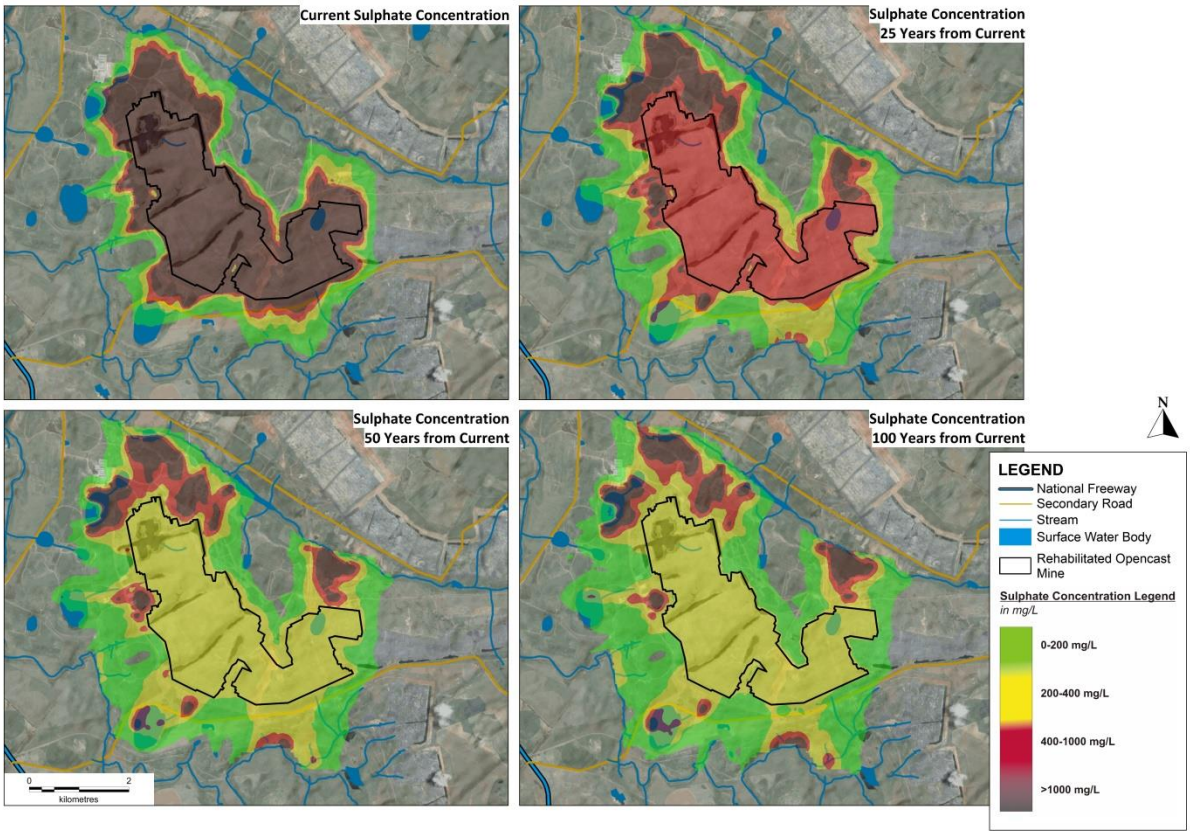


Figure 117: Sulfate concentration contours for the long term contaminant transport simulation for A-Mine

6.8 Model Sensitivity Analyses and Implications for Rehabilitation

Sensitivity analyses were conducted on the geochemical models for each of the sites to determine the variation of modelled sulfate concentrations on account of specific parameters. The parameters included and varied in the sensitivity analyses were selected based on a potential influence on sulfate generation rates and/or concentrations. With each parameter variation, observations were noted with regards to the rate of sulfate generation and contaminant concentrations calculated.

Oxygen fugacity variation by one order of magnitude in all the models showed an influence on the rate of sulfate generation. A higher oxygen fugacity showed that concentration peaks are reached faster, with concentrations lowering faster. A lower oxygen fugacity showed that concentration peaks are reached slower, with concentrations lowering more gradually. Subsequently, the final sulfate concentration at the end of each simulation was either higher or lower by 100 to 1000 mg/L depending on the decrease or increase of the oxygen fugacity in the system. This shows a strong influence on the model results and the subsequent correspondence of simulated values with observed values.

Gypsum mass in the simulation was not observed to have an effect on the rate of sulfate generation in any of the models. However, it did act as a limiting factor on the concentrations of sulfate generated, with a small influence of 5 to 30 mg/L variance beyond calculated values. Variation of gypsum surface area in each of the models did not show any notable changes in the rate of sulfate generation or the final concentration of sulfate in solution. However, the small variations can be linked to the dissolution rate constant of gypsum, which is a higher value than e.g. that of silicate

minerals. The variation of the rate constant for gypsum showed effects on the rate of sulfate release and the decrease of sulfate concentrations in solution, as well as the final simulated concentrations. Higher rate constants caused a slightly faster peak in sulfate concentrations as well as faster decrease in sulfate concentrations while lower rate constants did the opposite. Changes of approximately 5 mg/L were observed in the final simulated sulfate concentrations.

Pyrite mass variations showed no influence on the rate of sulfate generation in solution. However, pyrite mass variation did show variations in the final concentrations of sulfate, ranging between 5 and 1000 mg/L, depending on the pyrite content observed in the backfill material on site. However, changes were observed with regards to the decrease of sulfate concentrations in solution, as well as the peak concentration observed. No changes in the final concentrations of sulfate released were observed in any of the models for the investigated sites, upon variation of pyrite surface area and dissolution rate constant. These results show a notable influence of pyrite content, dissolution rate constant and surface area, on sulfate concentrations in solution.

Variation of the inflow rate of water into the system showed a distinct influence on the peak concentration and the rate of decrease of the sulfate concentration in solution. An input rate of water, raised by one order of magnitude, showed a faster peak of sulfate at a lower concentration, as well as a faster decrease in concentration of sulfate in solution, over time, in all investigated sites. A slower input rate showed the opposite. Additionally variation of the input rate of water into the simulated system changed the final sulfate concentration in solution. Changes observed ranged between 30 mg/L and 3000 mg/L. Smaller changes were attributed to accelerated flow rates, while larger changes were attributed to slower flow rates. This is interpreted to be a function of the water volume entering and exiting the system, as well as the pyrite content in the backfill material at a site.

To demonstrate the effect of parameter variation by adaptive rehabilitation methods on expected sulfate concentrations the geochemical modelling results were incorporated into the numerical flow model for each site after parameter variation (Figure 118, Figure 119 and Figure 120). Modelled concentrations calculated for variation of water flow and oxygen fugacity in the system were used for the simulation. An order of magnitude increase in flow volume and oxygen fugacity was applied for illustrative purposes which can be achieved through mine water re-circulation and selective placement of material (acid generating top, non-acid generating base). The simulations showed that an increase in water and air flow through the backfill spoil pile through selective placement and water re-circulation can achieve lower sulfate concentrations in a faster time in mine water. However, initial conditions of the initial flush showed higher sulfate concentrations as compared to current practice. A comparison of Figure 115 to Figure 117 with Figure 118 to Figure 120 shows that selective placement (acid generating top, non-acid generating base) and increased water flow to backfilled opencast mines accelerates source depletion and a return to background conditions.

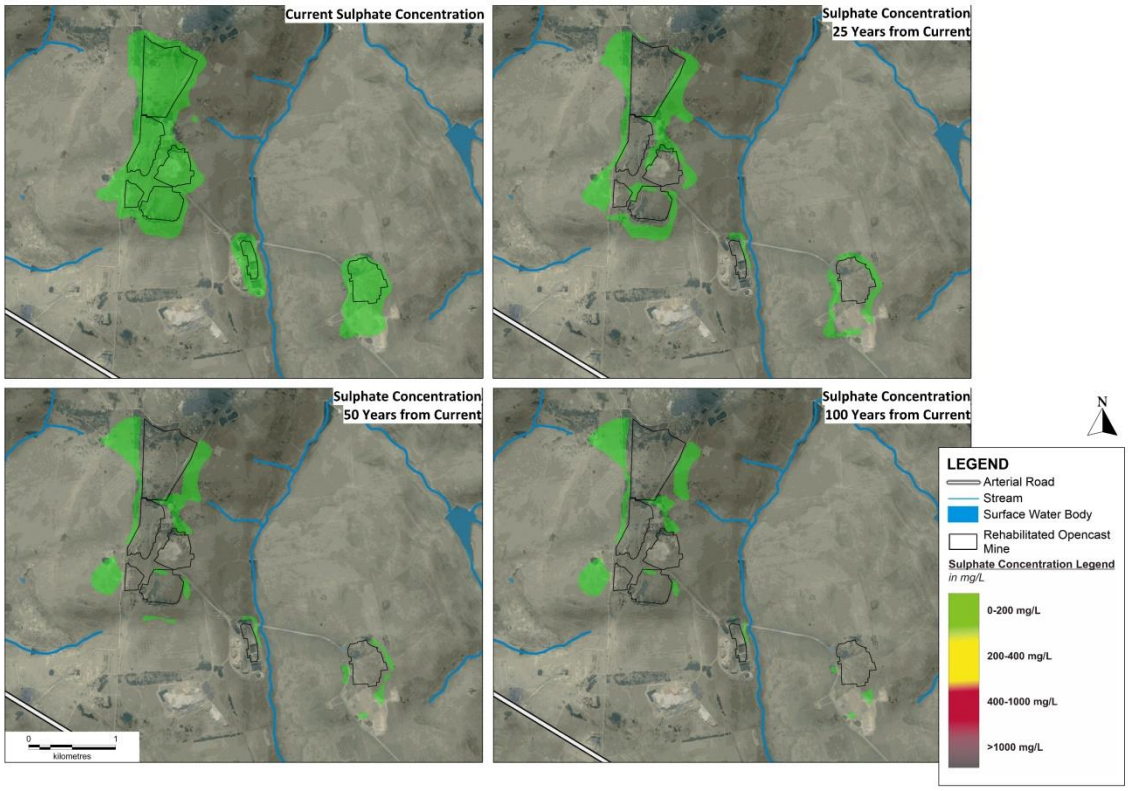


Figure 118: Sulfate concentration contours for the long term contaminant transport simulation for C-Mine with increased water flow and raised oxygen fugacity

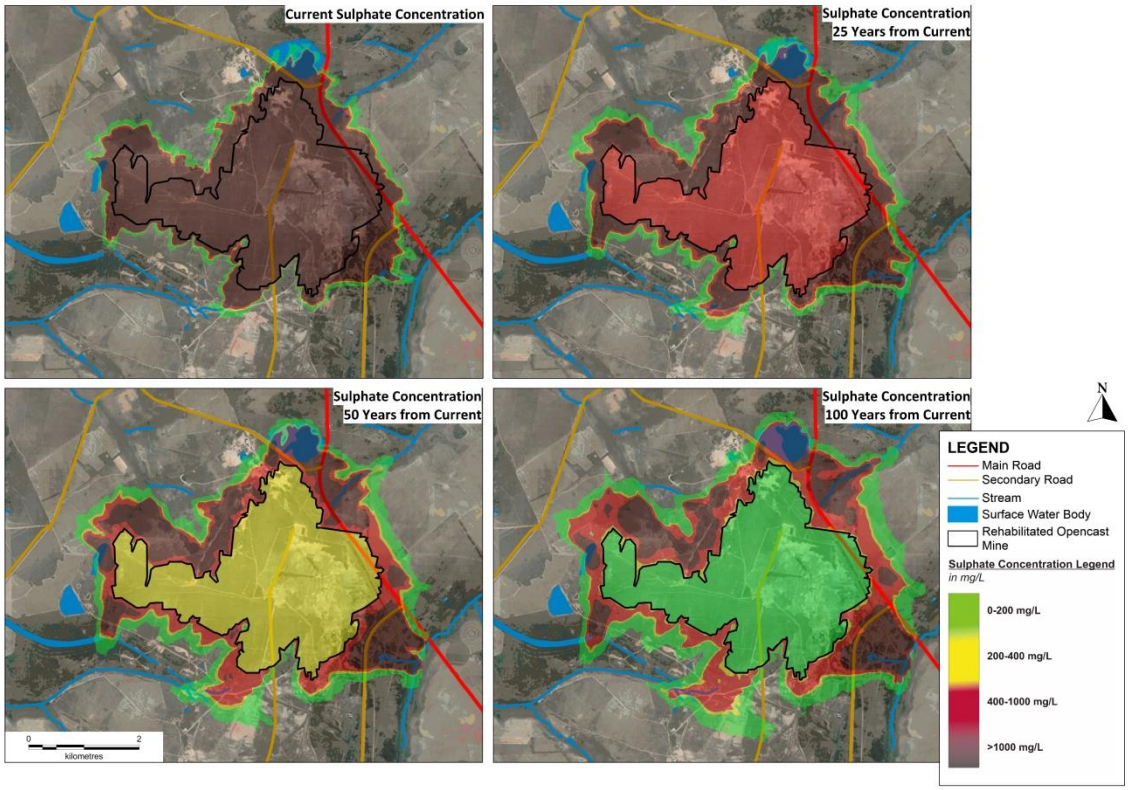


Figure 119: Sulfate concentration contours for the long term contaminant transport simulation for E-Mine with increased water flow and raised oxygen fugacity

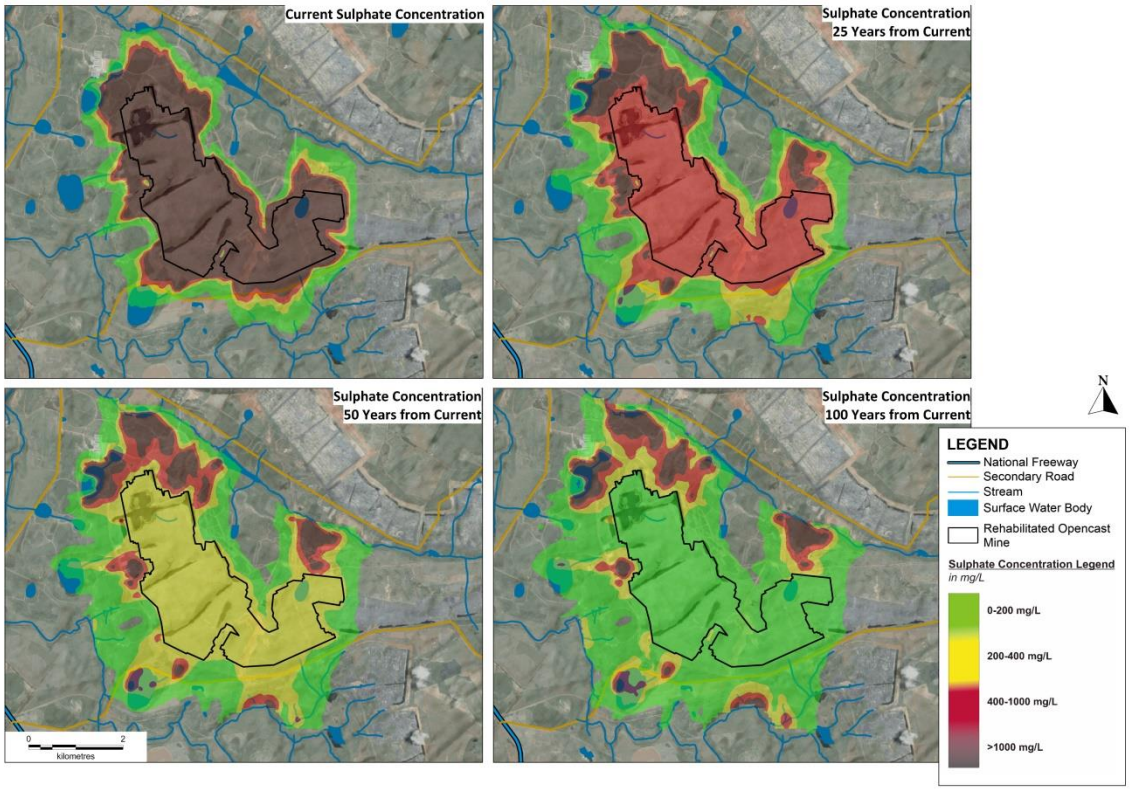


Figure 120: Sulfate concentration contours for the long term contaminant transport simulation for A-Mine with increased water flow and raised oxygen fugacity

7 Discussion

7.1 Geochemistry of Mining Overburden in the Mpumalanga Coalfields

Based on the interpretation of the correlation matrix constructed for the geochemical parameters, the following observations can be made with regards to the geochemical behaviour of overburden material associated with coal mining.

Anatase is positively correlated with kaolinite and Fe in solution which shows that it is likely to occur in the same formation as kaolinite and is also likely to be associated with Fe-poor and Al-rich strata. This is further supported by its negative correlation with hematite. Additionally, anatase shows a negative correlation with microcline (α = 0.95) which shows that it is likely to be a weathering product of microcline. Anatase is a secondary Ti-bearing mineral which is stable in a wide range of pH-values (Bowles et al., 2011, Klein et al., 2008).

Hematite is interpreted to from part of the same strata as muscovite and microcline or at least precipitate more readily in these strata due to the weathering processes of muscovite and microcline based on correlations (α = 0.95). This interpretation is supported by the correlation of hematite with K in solution which illustrates a buffering effect on the solution from these minerals, subsequently precipitating hematite. Further support for this interpretation is shown by the negative correlation between microcline and proton activity. Muscovite and microcline are associated with shale in opencast coal mines in South Africa, which commonly show a red to black colour, indicating the presence of iron.

Dolomite is positively correlated with siderite and solution alkalinity (α = 0.99), which can be based purely on carbonate content within the minerals and solution. The more abundant these carbonate minerals are, the higher the alkalinity of the solution will be.

Kaolinite is shown to correlate positively with anatase, proton activity and Al (α = 0.95), while it correlates with Fe (α = 0.99). This is expected as anatase is associated with Al-rich strata, the composition of which shows high levels of kaolinite present. This mineral is stable at lower proton activity and weathers readily in conditions of high proton activity.

However, kaolinite shows a negative correlation with microcline which shows that it is a weathering product of microcline which is positively correlated with hematite. Therefore, increased kaolinite would mean decreased microcline weight percentages which would lower the buffering capacity of the strata as discussed earlier, increasing proton activity in solution. Fe would subsequently be mobilised into solution from minerals such as hematite. This interpretation is further supported by the negative correlation between kaolinite and hematite. A negative correlation between kaolinite and Na can also be observed which is attributed to the negative correlation between kaolinite and microcline. Increased kaolinite weight percentages are likely to cause lower Na concentrations in solution as microcline as a source is depleted.

Quartz content shows a negative correlation with siderite (α = 0.95) which shows that these minerals are present in different formations.

As proton activity is positively correlated with the presence of kaolinite (α = 0.95) and negatively correlated with microcline (α = 0.99), further support is provided to the hypothesis that kaolinite is a

weathering product of microcline which acts as a buffer in solution. As pyrite weathering contributes strongly to proton activity, estimated pyrite abundances support the negative correlation between microcline and kaolinite due to a positive correlation with proton activity (α = 0.99) and a positive correlation with kaolinite. Further correlation of proton activity with Fe and Al concentrations (α = 0.95) is interpreted as the weathering of microcline and kaolinite, as well as hematite, releasing these metals into solution. As proton activity is also correlated with SO_4 in solution (α = 0.99), it is deduced that disulfide minerals are the primary control on this parameter which was also supported by the speciation calculations performed, with microcline and dolomite weathering decreasing proton activity in solution. This idea is further illustrated by the positive correlation of proton activity with paste proton activity, as well as its negative correlation with the Net Neutralisation Potential, both on the 0.99 level and associated with the S and CO_3 content in the geological material, respectively.

As TDS concentrations correlate positively with estimated pyrite content, Ca, Mg, Mn, SO_4, Total S and Acid Generation Potential, it can be concluded that disulfide and carbonate mineral weathering are the main controls on TDS. This conclusion is supported by the correlations between pyrite content, SO_4, Mn, Total S and Acid Generation Potential which are all associated with pyrite oxidation and weathering. This releases metals and SO_4 into solution, thereby increasing TDS concentrations. Similarly, the weathering of dolomite is associated with the Ca and Mg in solution, as well as the negative correlation between TDS and Net Neutralisation Potential. This is interpreted as the depletion of carbonate minerals due to dissolution, subsequently releasing Ca, Mg and HCO_3 into solution, further increasing the TDS concentration. A further interpretation from this is that pyrite content and subsequent SO_4 in solution is the main control on TDS.

Mn concentrations can be observed to be positively correlated with estimated pyrite content, TDS, Mg, SO_4 and Total S (α = 0.95). Therefore, it can be concluded that this element is released into solution by pyrite weathering as well as dolomite dissolution, based on the interpretation provided for TDS. This is further supported by its negative correlation (α = 0.99) with Net Neutralisation Potential.

Based on the PCA (principal component analysis) which compared geochemical parameters, the following can be deduced:

Component 1 shows that the main control on the mine water quality is pyrite oxidation and weathering. This controls SO_4 concentrations, proton activity, metal concentrations and TDS. Carbonate mineral phase weathering and dissolution also forms part of component 1, which acts as a buffer to acidity in solution. Ca and Mg concentrations in solution, which form part of component 1, is evidence for this and are derived from dolomite weathering. Component 1 accounts for 58% of the variance observed in the geochemical data.

Component 2 shows that the mineral assemblage present in the system is the secondary control on mine water chemistry. Major mineral phases which form component 2 are evidence of this secondary control. Component 2 accounts for 33% of the variance observed in the geochemical data.

Component 3, represented by Na and K in solution, shows that weathering of the major mineral phases is the tertiary control on mine water chemistry. Component 3 accounts for 8% of the variance observed in the geochemical data.

Dendrogram interpretation of the geochemical data, which compares samples with each other, yielded the following observations:

Two distinct groups of samples can be identified from the dendrogram. Group 1 (KDC1, KDC2, KDN1, ARN2 and ESG134) forms a distinct group as these samples are more acid generating while Group 2 (ESG17, Pembali Mining 1, ESG91011, KDN2, ESG2021, KDC3 and ARN3) is less acid generating. Al and SO_4 concentrations released during leach testing of these samples as well as the differences in proton activity illustrate this difference well.

7.2 Geochemical and Numerical Transport Modelling

Modelled constituent concentrations in the geochemical and numerical models corresponded well with measured concentrations within the identified error ranges at the sites with higher sulfate concentrations. This shows that the focus of this modelling method depends on the controlling parameters of the site geochemistry (Box, 1979). As demonstrated in section 7.1, pyrite oxidation and weathering, as well as carbonate mineral weathering are the main controls (Younger and Sapsford, 2004a) on solution pH and chemistry, with major the mineralogy playing a secondary role. Therefore, the calibration of pH and SO_4 is essential for modelling representative values and was the main focus of the geochemical model calibration. As pyrite and carbonate mineral weathering are the primary controls on mine water chemistry in the Mpumalanga coalfields, the correspondence of the modelled and measured constituent concentrations is explicable. Further to the identification of the primary controls on the mine water chemistry is the enhancement of calibration accuracy with abundant measured data. As sites with larger monitoring data sets were available, it was deduced that monitoring data plays an essential role in the prediction of long term mine water chemistry. This observation is based on clearer concentration trends observed over longer periods, which gives a better indication of how calculated concentration trends should behave if they are based on defensible model inputs.

As SO_4 concentration forms a major part of component 1 (section 6.3), a larger standard error exists for this parameter, which makes its calibration, and the calibration of parameters associated with it (section 6.3), simpler. However, other geochemical parameters with less varied concentrations require more time and effort to calibrate, such as Fe and K. Upon further investigation (section 7.1) it can be observed that these parameters are strongly dependent on the mineral assemblage present and the level of data resolution and accuracy required for their calibration must be high. However, they play a lesser role in overall model calibration as can be observed in the third component of the PCA (section 6.3).

7.3 Model Sensitivity and Implications for Current Rehabilitation Practice in South Africa

Model sensitivity analyses indicated that the most sensitive parameters for model calibration include pyrite reaction rate constant, oxygen fugacity in the system and inflow rate of water. This is the case due to pyrite oxidation and weathering being the primary control on mine water chemistry, with pyrite oxidising and weathering more effectively in higher oxygen fugacities and in more water. This observation can be related to the stoichiometric balance of pyrite oxidation in water and air. Therefore, model calibration relies strongly on the quantification of these parameters which could have a notable effect on long-term predictions. It is essential that these parameters are measured in

the highest possible detail for a specific site if long-term mine water quality predictions are to be undertaken. However, model sensitivity analyses could also prove useful in terms of pit rehabilitation. If the optimum achievable water and oxygen addition rates are calculated, an accelerated initial flush can be engineered which could shorten the timeframe of reaching a sustainable groundwater supply, extractable from the backfilled opencast.

Water addition to the backfilled opencast mine can be achieved by refraining from backfill compaction and re-establishment of soils in the early stages of the initial flush to maximise infiltration. This could even be achieved by constructing infiltration trenches within the backfill material. Also, re-circulation of mine water within the spoils could be considered using irrigation methods such as those used at A-Mine which would control mine water discharge volumes while accelerating weathering of disulphide minerals.

Due to the loose, uncompacted nature of the backfill material in this setting airflow is likely to increase which could potentially boost oxygen ingress. However, this is unlikely to increase oxygen diffusion deep into the mine water in the backfill material. Therefore, higher levels of dissolved oxygen in infiltrating water will prove to be a better alternative. This can be achieved by channelling and cascading surface water flow towards the backfilled opencast mine to maximise the concentration of oxygen in the infiltrating water. A similar approach can be followed with recirculated water obtained from mine water discharge utilising infiltration trenches.

Finally, selective placement of materials is likely to aid in the oxidation of disulfides. This is not meant as selective placement in the traditional sense of the word but rather as the complete reversal of current practice which is a backfill spoil pile with an acid-generating base and a non-acid generating top. If uncompacted acid-producing material is placed at the top of the backfill pile, the maximum amount of oxygen and water could reach disulphide minerals and maximise the weathering and oxidation rates of these minerals. Therefore, accelerated source depletion could take place in this manner as shown in the synthesis chapter (Morin and Hutt, 2001). Infiltrating acidic leachate would then be neutralised by a non-acid generating base which could incorporate lime upon initial backfilling. Although a very high environmental impact can be expected initially, treatment systems can be implemented to lower environmental risks. In this way, source depletion rates would increase dramatically which could leave backfilled opencast mines as groundwater reservoirs and areas of elevated recharge which would be an asset in arid regions where a strong agricultural sector is present, such as Mpumalanga. This method can be seen as a “high intensity” rehabilitation method which is likely to become a water supply in the future.

8 Conclusions

Geochemical uncertainty and lack of data is commonly observed in hydrogeological and hydrogeochemical investigations associated with the overburden material used as backfill in decommissioned opencast mines. However, findings of the study presented here show that disulfide and carbonate mineral content are the major controls on pH which was shown to be the most important factor controlling mine water chemistry. Quantification of disulfide and carbonate mineral phases to determine possible future mine water chemistry is essential and should be the major focus of mineralogical analysis for environmental purposes. Mineral assemblages and their weathering play a lesser role in determining mine water quality and larger error ranges for mineral abundances may therefore be acceptable in analysis data. However, the study showed that specific minerals influence the precipitation and/or dissolution of others such as the relationship illustrated between microcline-feldspar, muscovite and hematite, which form a stoichiometric balance regulating Fe in solution, as well as buffering pH to an extent. Further support to disulfide content as a controlling factor was shown by statistical analyses where the parameter causing the highest percentage of difference between samples was shown to be pH, which was found to be controlled by the disulfide content. These findings have implications for fieldwork as well as modelling applications. They reiterate the importance of the measurement of field pH and redox conditions during groundwater sampling, the importance of the accurate quantification of pH during leaching tests and the accurate quantification of disulfide and carbonate mineral phases during mineralogical analyses. This is further supported by the presence of model deviations from measured values due to uncertain sampling and analysis conditions.

However, even in light of these uncertainties, the proposed modelling method was shown to prove efficient in estimating long term mine water geochemical behaviour to acceptable accuracies in comparison to measured data in terms of sulfate. This is an improvement upon constant source/worst-case scenario simulations as the simulated values represent a scenario much closer to reality. Therefore, the implication of this finding is the prediction of mine water quality within acceptable error ranges using less geochemical data and reducing investigation costs while improving long-term water management cost estimations. Using this methodology, an estimate can also be provided of when a backfilled opencast mine may reach chemical equilibrium at lower concentrations. This might point towards backfilled opencast mines as future water resources instead of liabilities. It should be noted that the method was demonstrated to work well for sites that are highly contaminated and produces data that corresponds well with long term measurements. Unfortunately, the method is less effective in terms of estimating short term changes as compared to short term measurements. However, it should also be noted that the focus of the study was the estimation of long term trends rather than short term variations. Prediction of long term hydrogeochemical behaviour will aid in the determination of long term management costs which are far greater than short term damage control costs.

With any scientific finding, however, comes a level of uncertainty, the quantification of which is essential. This study shows that mine water quality is highly sensitive to variations in oxygen fugacity, water volumes moving through the geochemical system and disulfide content of the material under investigation. Although variations of these parameters may cause variation in the predicted mine water quality and illustrate the importance of their accurate quantification, they also provide a view to manipulation of the initial flush by adapting backfill and rehabilitation practices.

Because the most sensitive parameters in the geochemical system are known, it is proposed that backfilling and rehabilitation methods are changed to suit specific needs. If a mining company chooses to accept a liability over a short period which is likely to change to an asset in the short term, a high intensity rehabilitation method can be considered (Figure 122), entailing the crushing or blasting of overburden material to the smallest economically viable grain size to increase disulfide reactive surface areas, increase recharge to the backfilled opencast mine by not compacting or replacing soils immediately and maximising airflow to the spoils. Also, acid generating material should be placed as high as possible in the backfill spoil pile to maximise its exposure to oxygen and water to accelerate disulphide depletion through weathering and oxidation. Subsequently, a rapid increase in sulfate concentrations can be expected as well as the lowering of pH conditions. However, the initial flush process will be accelerated in this way and depletion of disulfide minerals will occur at a much faster rate, implying that a shorter period of mine water management will be required until the mine water reaches acceptable qualities. From here the water can either be utilised for possible sale for farming or industrial purposes by the mining company or released to surface drainage if authorised to do so based on quality. An alternative to this rehabilitation approach is low intensity rehabilitation (Figure 121) which entails the blasting of overburden material to a maximum grain size which is economically viable, thereby decreasing the reactive surface area of disulfides and the reduction of recharge and airflow to the spoils. Accelerated induced flooding will also assist in this rehabilitation method as well as the placement of acid-generating spoils at the base of the opencast mine prior to flooding. By implication a slower release of sulfate to groundwater can be expected and pH conditions which can be buffered sufficiently by the carbonate mineral phases present so as to maintain an acceptable water quality over the long term. This will also entail long-term management of the system to ensure that the required geochemical conditions are maintained. To improve the mine water quality at these sites in the future, opencast mine operations can also consider mixing alkaline materials such as lime with excavated overburden (Wisotzky, 2001, Wisotzky, 2003). These findings show that realistic estimates of mine water quality are achievable in the long term. In addition, rehabilitation practices can be modified to influence the initial flush to accelerate source depletion if current practices are reviewed. This implies that the reversal of current selective placement of backfill material in a backfilled opencast mine (acid generating base and non-acid generating top) can accelerate depletion of the contamination source and turn backfilled opencast mines into utilisable water reservoirs.

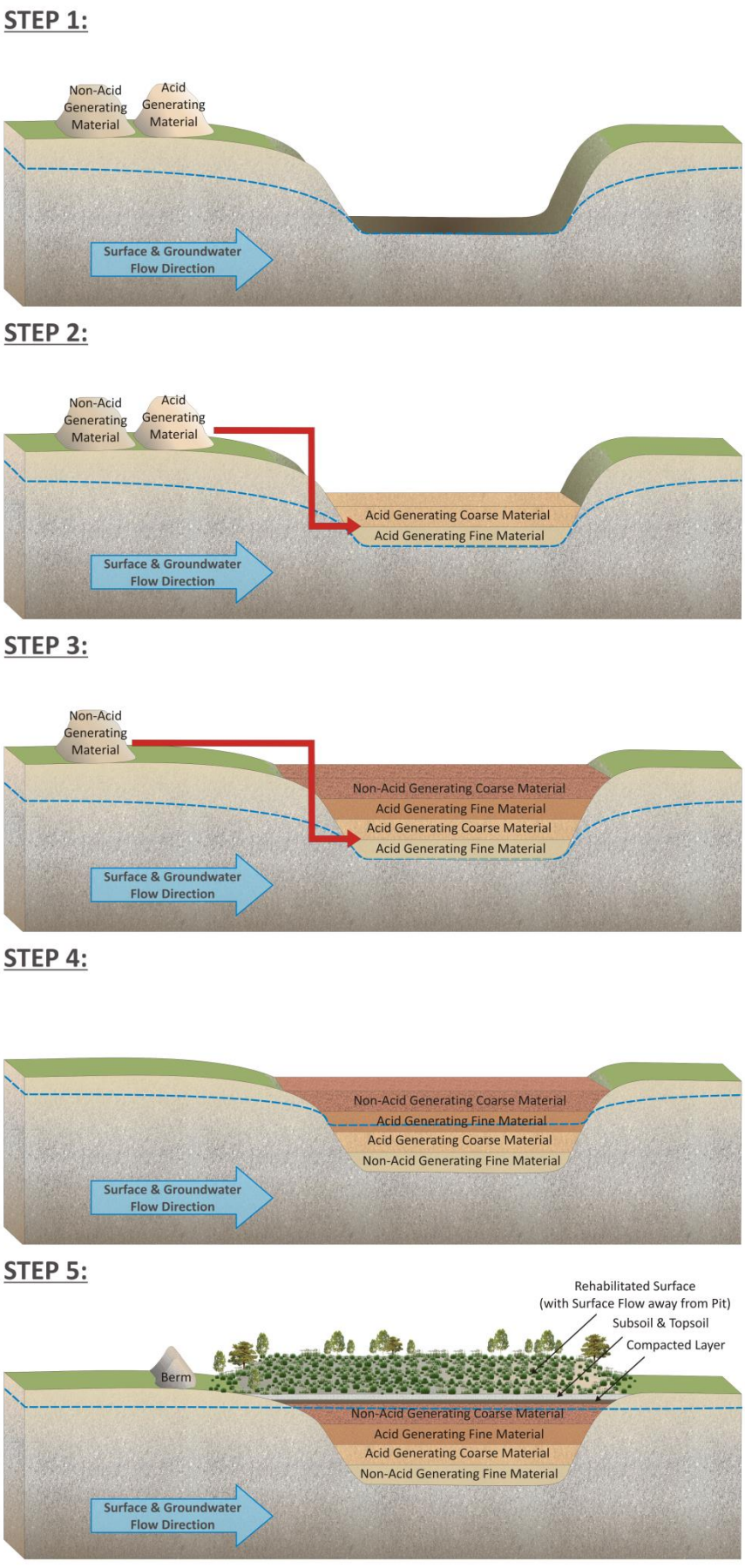


Figure 121: Low Intensity Rehabilitation Methods for Opencast Coal Mines

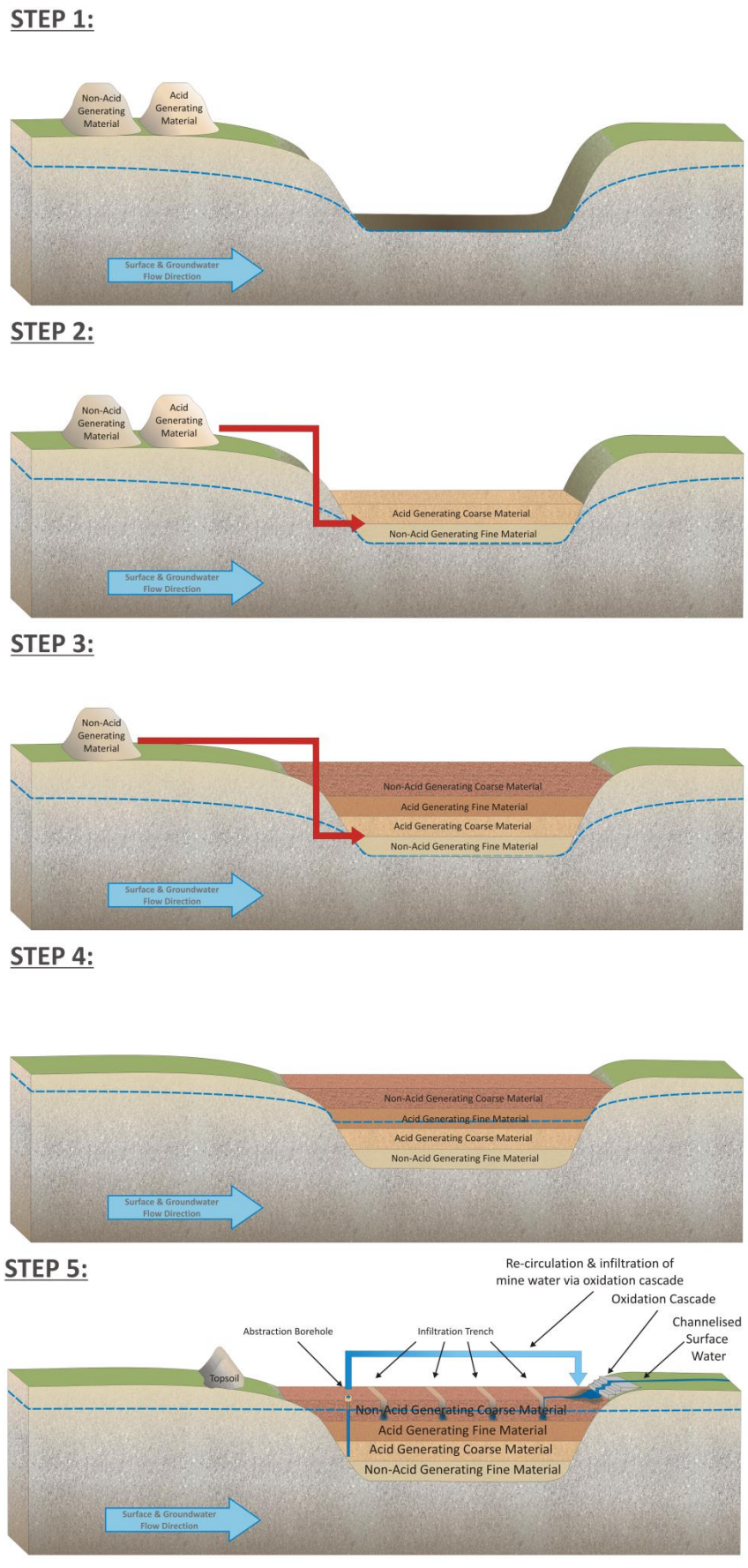


Figure 122: High Intensity Rehabilitation Methods for Opencast Coal Mines

References

ANDERSON, M. P., WOESSNER, W. W. & HUNT, R. J. 2015. Applied groundwater modeling : simulation of flow and advective transport. Second edition. ed. London, UK :: Academic Press.

ANNANDALE, J. G., JOVANOVIC, N. Z., RETHMAN, N. F. G., PRETORIUS, J. J. B. & TANNER, P. D. 2001. Gypsiferous mine water use in irrigation on rehabilitated open-cast mine land: Crop Production, soil water and salt balance. *Ecol. Eng.,* 17**,** 153-164.

APPELO, C. A. J. & POSTMA, D. 2005. *Geochemistry, groundwater & pollution,* Leiden, Balkema.

BANFIELD, J. F. & EGGLETON, R. A. 1990. Analytical transmission electron microscope studies of plagioclase, muscovite, and K-feldspar weathering. *Clay Clay Miner,* 38**,** 77-89.

BANKS, D. 1994. The Abandonment of the Killingdal Sulphide Mine, Norway: a Saga of Acid Mine Drainage and Radioactive Waste Disposal. *Mine Water Environ.,* 13**,** 35-48.

BANKS, D., YOUNGER, P. L., ARNESEN, R.-T., IVERSEN, E. R. & BANKS, S. B. 1997. Mine-water chemistry: the good, the bad and the ugly. *Environ Geol,* 32**,** 157-174.

BANWART, S. A. & MALMSTROM, M. E. 2001. Hydrochemical modelling for preliminary assessment of mine water pollution. *J. Geochem. Explor.,* 74**,** 73-79.

BELL, F. G., BULLOCK, S. E. T., HALBICH, T. F. J. & LINDSAY, P. 2001. Environmental impacts associated with an abandoned mine in the Witbank Coalfield, South Africa. *Int. J. Coal Geol.,* 45**,** 195-216.

BERNER, R. A. 1984. Sedimentary pyrite formation: An update. *Geochim. Cosmochim. Acta,* 48**,** 605-615.

BETHKE, C. M. 2008. *Geochemical and Biogeochemical Reaction Modeling,* New York, Cambridge University Press.

BETRIE, G. D., SADIQ, R., MORIN, K. A. & TESFAMARIAM, S. 2013. Selection of remedial alternatives for mine sites: A multicriteria decision analysis approach. *Journal of environmental management,* 119**,** 36-46.

BOSMAN, D., CLAYTON, J., MAREE, J. & ADLEM, C. 1990. Removal of sulphate from mine water with barium sulphide. *Int. J. Mine Water,* 9**,** 149-163.

BOTHA, J. F., VERWEY, J. P., VAN DER VOORT, I., VIVIER, J. J. P., BUYS, J., COLLISTON, W. P. & LOOCK, J. C. 1998. Karoo Aquifers – Their Geology, Geometry and Physical Properties. *Water Research Commission.* South Africa: Water Research Commission.

BOWLES, J. F. W., DEER, W. A., HOWIE, R. A., VAUGHAN, D. J. & ZUSSMAN, J. 2011. *Rock-forming Minerals: Non-silicates: oxides, hydroxides and sulphides. Volume 5A*, Geological Society of London.

BOX, G. E. 1979. Robustness in the strategy of scientific model building. *Robustness in statistics,* 1**,** 201-236.

BRANTLEY, S. L. 1998. Surface area and porosity of primary silicate minerals. *Goldschmidt Conference* Toulouse.

BREDENKAMP, D. B., BOTHA, L. J., VAN TONDER, G. J. & VAN RENSBURG, H. J. 1995. Manual on quantitative estimation of groundwater recharge and aquifer storativity: based on practical hydrological methods. *Water Research Commission.* Pretoria.

BROWN, M., BARLEY, B. & WOOD, H. 2002. *Minewater treatment: technology, application and policy*, IWA Publishing.

BRUNAUER, S., EMMETT, P. H. & TELLER, E. 1938. Adsorption of gases in multimolecular layers. *J. Am. Chem. Soc.,* 60**,** 309-319.

BULLOCK, S. E. T. & BELL, F. G. 1997. Some problems associated with past mining at a mine in the Witbank coalfield, South Africa. *Environ. Geol.,* 33**,** 61-71.

CADLE, A. B., CAIRNCROSS, B., CHRISTIE, A. D. M. & ROBERTS, D. L. 1993. The Karoo Basin of South Africa: type basin for the coal-bearing deposits of southern Africa. *Int. J. Coal Geol.,* 23**,** 117-157.

CARABALLO, M. A., RÖTTING, T. S., MACÍAS, F., NIETO, J. M. & AYORA, C. 2009. Field multi-step limestone and MgO passive system to treat acid mine drainage with high metal concentrations. *Appl. Geochem.,* 24**,** 2301-2311.

CARTWRIGHT, P. S. 2013. The role of membrane technologies in water reuse applications. *Desalination,* 51**,** 4806-4816.

CASTENDYK, D. N., BALISTRIERI, L. S., GAMMONS, C. & TUCCI, N. 2015a. Modeling and management of pit lake water chemistry 2: Case studies. *Appl Geochem,* 57**,** 289-307.

CASTENDYK, D. N., EARY, L. E. & BALISTRIERI, L. S. 2015b. Modeling and management of pit lake water chemistry 1: Theory. *Appl Geochem,* 57**,** 267-288.

CHEEMA, T. 2015. Depth dependent hydraulic conductivity in fractured sedimentary rocks-a geomechanical approach. *Arabian Journal of Geosciences,* 8**,** 6267-6278.

CHEN, M., SOULSBY, C. & YOUNGER, P. L. 1999. Modelling the evolution of minewater pollution at Polkemmet Colliery, Almond catchment, Scotland. *Q. J. Eng. Geol.,* 32**,** 351-362.

CRAIG, R. F. 2004. *Craig's soil mechanics,* Abingdon, Spon Press.

CRAVOTTA, C. A., DUGAS, D. L., BRADY, K. B. & KOVALCHUK, T. 1994. Effects of selective handling of pyritic, acid-forming materials on the chemistry of pore gas and ground water at a reclaimed surface coal mine, Clarion County, PA, USA. *US Bureau of Mines Spec. Publ. SP A,* 6**,** 365-374.

CUBILLAS, P., KÖHLER, S., PRIETO, M., CHAÏRAT, C. & OELKERS, E. H. 2005. Experimental determination of the dissolution rates of calcite, aragonite, and bivalves. *Chem. Geol.,* 216**,** 59-77.

CUSSLER, E. L. 1997. *Diffusion: Mass Transfer in Fluid Systems,* New York, Cambridge University Press.

DAVIS, A. 2003. A screening-level laboratory method to estimate pit lake chemistry. *Mine Water Environ.,* 22**,** 194-205.

DEMCHAK, J., SKOUSEN, J. & MCDONALD, L. 2001. Water quality improvements over time and longevity of acid mine discharges from underground mines in northern West Virginia. *18th Annual National Meeting of the American Society of Mining and Reclamation.* Albuquerque.

DEPARTMENT OF MINERAL RESOURCES, S. A. 2002. Mineral and Petroleum Resources Development Act of South Africa. *In:* DEPARTMENT OF MINERAL RESOURCES, S. A. (ed.). South Africa: Department of Mineral Resources, South Africa.

DEYSEL, L., MACDONALD, N., APHANE, V. & VERMEULEN, P. D. 2014. A Detailed Acid Base Accounting Study of the Coal-Bearing Karoo Formations in the Waterberg Coalfield. Pretoria: Water Research Commission.

DIERSCH, H. J. G. 2014. *FEFLOW Finite Element Modeling of Flow, Mass and Heat Transport in Porous and Fractured Media,* Berlin, Springer.

DU PLESSIS, J. L. 2010. *Decant Calculations and Groundwater – Surface Water Interaction in an Opencast Coal Mining Environment.* M. Sc. Unpublished, University of the Free State.

DU TOIT, G. J. 2010. Groundwater Modelling Report For The C-Mine Colliery. Pretoria, South Africa: Geo Pollution Technologies.

ERIKSSON, N. & DESTOUNI, G. 1997. Combined effects of dissolution kinetics, secondary mineral precipitation, and preferential flow on copper leaching from mining waste rock. *Water Resour. Res.,* 33**,** 471-483.

EVANS, K. A., GANDY, C. J. & BANWART, S. A. 2003. Mineralogical, numerical and analytical studies of the coupled oxidation of pyrite and coal. *Mineral. Mag.,* 67**,** 381-398.

FOURIE, F. D. 2013. Water Management Plan for A-Mine Closed Colliery. Bloemfontein, South Africa: Institute for Groundwater Studies.

FROST, R. C. 1979. Evaluation of the rate of decrease in the iron content of water pumped from a flooded shaft mine in County Durham, England. *J. Hydrol.,* 40**,** 101-111.

GAUTIER, J. M., OELKERS, E. H. & SCHOTT, J. 2001. Are quartz dissolution rates proportional to B.E.T. surface areas? *Geochim. Cosmochim. Acta,* 65**,** 1059-1070.

GELLER, W. & SCHULTZE, M. 2013. Remediation and management of acidified pit lakes and outflowing waters. *In:* GELLER, W., SCHULTZE, M., KLEINMANN, R. & WOLKERSDORFER, C. (eds.) *Acidic Pit Lakes: The Legacy of Coal and Metal Surface Mines.* Berlin, Heidelberg: Springer.

GLASSPOOL, I. J. 2002. Hypautochthonous–allochthonous coal deposition in the Permian, South African, Witbank Basin No. 2 seam; a combined approach using sedimentology, coal petrology and palaeontology. *Int. J. Coal Geol.,* 53**,** 81-135.

GLOVER, H. G. 1983. Mine water pollution - an overview of problems and control strategies in the United Kingdom *Water Sci. Technol.,* 15**,** 59-70.

GOMO, M. & VERMEULEN, D. 2013. Investigation of hydrogeochemical processes in groundwater resources located in the vicinity of a mine process water dam. *J. Afr. Earth. Sci.,* 86**,** 119-128.

GUDBRANDSSON, S., WOLFF-BOENISCH, D., GISLASON, S. R. & OELKERS, E. H. 2014. Experimental determination of plagioclase dissolution rates as a function of its composition and pH at 22°C. *Geochim. Cosmochim. Acta,* 139**,** 154-172.

GZYL, G. & BANKS, D. 2007. Verification of the "first flush" phenomenon in mine water from coal mines in the Upper Silesian Coal Basin, Poland. *J. Contam. Hydrol.,* 92**,** 66-86.

HANCOX, P. J. & GÖTZ, A. E. 2014. South Africa's coalfields — A 2014 perspective. *Int. J. Coal Geol.,* 132**,** 170-254.

HARTMAN, H. L. & MUTMANSKY, J. M. 2002. *Introductory Mining Engineering,* Hoboken, Wiley & Sons.

HERSMAN, L., LLOYD, T. & SPOSITO, G. 1995. Siderophore-promoted dissolution of hematite. *Geochim. Cosmochim. Acta,* 59**,** 3327-3330.

HODGSON, F. D. I. 1984. Installation and evaluation of a groundwater monitoring system in the strip mining area at Kriel colliery. South Africa: Institute for Groundwater Studies.

HODGSON, F. D. I. 2014. SACE Mine Water Balance Revision 1 March 2014.pdf. Bloemfontein: University of the Free State.

HODGSON, F. D. I. & KRANTZ, R. M. 1998. Groundwater Quality Deterioration in the Olifants River Catchment above the Loskop Dam with Specialized Investigation in the Witbank Dam Sub-Catchment. *Water Research Commission Report.* South Africa: Water Research Commission.

HOLLAND, M. J., CADLE, A. B., PINHEIRO, R. & FALCON, R. M. S. 1989. Depositional environments and coal petrography of the Permian Karoo Sequence: Witbank Coalfield, South Africa. *Int. J. Coal Geol.,* 11**,** 143-169.

HUBERT, E. & WOLKERSDORFER, C. 2015. Establishing a conversion factor between electrical conductivity and total dissolved solids in South African mine waters. *Water SA,* 41**,** 490-500.

HUERTAS, F. J., CHOU, L. & WOLLAST, R. 1999. Mechanism of kaolinite dissolution at room temperature and pressure Part II: kinetic study. *Geochim. Cosmochim. Acta,* 63**,** 3261-3275.

HUISAMEN, A. & NAIDOO, V. 2014. Groundwater Report For Long Term Groundwater Management At C-Mine Colliery, Carolina, Mpumalanga. Pretoria, South Africa: Geo Pollution Technologies.

INTERNATIONAL NETWORK FOR ACID PREVENTION (INAP) 2009. Global Acid Rock Drainage Guide (GARD Guide). http://www.gardguide.com.

JEFFREY, L. S. 2005. Characterization of the coal resources of South Africa. *J. S. Afr. Inst. Min. Metall.***,** 95-102.

JESCHKE, A. A., VOSBECK, K. & DREYBRODT, W. 2001. Surface controlled dissolution rates of gypsum in aqueous solutions exhibit nonlinear dissolution kinetics. *Geochim. Cosmochim. Acta,* 65**,** 27-34.

JIANG, X.-W., WAN, L., WANG, X.-S., GE, S. & LIU, J. 2009. Effect of exponential decay in hydraulic conductivity with depth on regional groundwater flow. *Geophysical Research Letters,* 36**,** n/a-n/a.

JOHNSON, M. R., VAN VUUREN, C. J., VISSER, J. N. J., COLE, D. J., WICKENS, H. D. V., CHRISTIE, A. D. M., ROBERTS, D. L. & BRANDL, G. L. 2006. Sedimentary Rocks of the Karoo Supergroup. *In:* JOHNSON, M. R., ANNHAEUSSER, C. R. & THOMAS, R. J. (eds.) *The Geology of South Africa.* South Africa: The Geological Society of South Africa.

KLEIN, C., DUTROW, B. & DANA, J. D. 2008. *The 23rd edition of the manual of mineral science: (after James D. Dana),* Hoboken, J. Wiley.

KRUSEMAN, G. P. & DE RIDDER, N. A. 1994. *Analysis and Evaluation of Pumping Test Data,* Wageningen, The Netherlands, International Institute for Land Reclamation and Improvement.

LANGMUIR, D. 1997. *Aqueous Environmental Geochemistry,* New Jersey, Prentice-Hall.

LAWRENCE, R. & MARCHANT, P. 1991. Acid rock drainage prediction manual. *MEND/NEDEM Report*.

LIMPITLAW, D., AKEN, M., LODEWIJKS, H. & VILJOEN, J. 2005. Post-mining rehabilitation, land-use and pollution at collieries in South Africa. *Sustainable Development in the Life of Coal Mining.* Boksburg, South Africa.

MABEDLA, B. 2015. A-Mine Closed Colliery Aeromagnetic Data Interpretation. *In:* PETTIT, W. (ed.). Johannesburg: Geosciences Solutions.

MACDONALD, N. 2014. *The management of spoils in the Waterberg Coalfield.* M.Sc., University of the Free State.

MACK, B., MCDONALD, L. M. & SKOUSEN, J. 2010. Acidity decay of above-drainage underground mines in West Virginia. *J. Environ. Qual.,* 39**,** 1043-1050.

MACK, B. & SKOUSEN, J. 2008. Acidity Decay Curves of 40 Above Drainage Mines in West Virginia. *2008 National Ground Water Association Remediation of Abandoned Mines Conference.* Denver.

MALMSTRÖM, M. E., GLEISNER, M. & HERBERT, R. B. 2006. Element discharge from pyritic mine tailings at limited oxygen availability in column experiments. *Appl. Geochem.,* 21**,** 184-202.

MARCHAND, E. A. 2002. Minerals and Mine Drainage. *Water Environment Research,* 74**,** 746-772.

MARTY, N. C. M., CLARET, F., LASSIN, A., TREMOSA, J., BLANC, P., MADÉ, B., GIFFAUT, E., COCHEPIN, B. & TOURNASSAT, C. 2015. A database of dissolution and precipitation rates for clay-rocks minerals. *Appl. Geochem.,* 55**,** 108-118.

MCDONALD, M. G. & HARBAUGH, A. W. 2003. The history of MODFLOW. *Groundwater,* 41**,** 280-283.

MORIN, K. A. & HUTT, N. M. 2001. Prediction of minesite-drainage chemistry through closure using operational monitoring data. *Journal of Geochemical Exploration,* 73**,** 123-130.

NORDSTROM, D. K. 2011. Mine Waters: Acidic to Circumneutral. *Elements,* 7**,** 393-398.

NOVHE, N. O., NETSHITUNGULWANA, R., YIBAS, B., MOTLAKENG, T. & SAKALA, E. 2013. Metal pollution sources and transport in mined watershed: an insight from Ermelo Coalfield, South Africa. *In:* WOLKERSDORFER, B. F. (ed.) *IMWA 2013: Reliable Mine Water Technology.* Golden, Colorado: IMWA.

OELKERS, E. H. & SCHOTT, J. 1998. Does organic acid adsorption affect alkali-feldspar dissolution rates? *Chem. Geol.,* 151**,** 235-245.

OELKERS, E. H., SCHOTT, J., GAUTHIER, J.-M. & HERRERO-RONCAL, T. 2008. An experimental study of the dissolution mechanism and rates of muscovite. *Geochim. Cosmochim. Acta,* 72**,** 4948-4961.

PARKHURST, D. L. & APPELO, C. A. J. 2013. Description of Input and Examples for PHREEQC Version 3 - A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. Denver, Colorado: United States Geological Survey.

PARKHURST, D. L., THORSTENSON, D. C. & PLUMMER, L. N. 1980. *PHREEQE: a computer program for geochemical calculations*, US Geological Survey, Water Resources Division.

PINETOWN, K. L. & BOER, R. H. 2006. A quantitative evaluation of the modal distribution of minerals in coal deposits in the Highveld area and the associated impact on the generation of acid and neutral mine drainage. *WRC Report.* Pretoria: Water Research Commission.

PINETOWN, K. L., WARD, C. R. & VAN DER WESTHUIZEN, W. A. 2007. Quantitative evaluation of minerals in coal deposits in the Witbank and Highveld Coalfields, and the potential impact on acid mine drainage. *Int. J. Coal Geol.,* 70**,** 166-183.

POKROVSKY, O. & SCHOTT, J. 2002. Surface chemistry and dissolution kinetics of divalent metal carbonates. *Env. Sci. Tech.,* 36**,** 426-432.

POKROVSKY, O. S., GOLUBEV, S. V. & SCHOTT, J. 2005. Dissolution kinetics of calcite, dolomite and magnesite at 25 C and 0 to 50 atm pCO_2. *Chem. Geol.,* 217**,** 239-255.

PRICE, W. A., MORIN, K. & HUTT, N. Guidelines for the prediction of Acid Rock Drainage and Metal leaching for mines in British Columbia. Proceedings of the Fourth International Conference on Acid Rock Drainage, 1997 Vancouver, BC. 15 – 30.

RAO, S. R., LEROUX, M., FINCH, J., SHEREMETA, T. & KUYUCAK, N. 1993. Metals Removal from Acidic Drainage-Chemical Methods. Canada: Noranda Technology Centre, Environmental Program, Mineral Sciences Laboratory.

RÖTTING, T. S., CARABALLO, M. A., SERRANO, J. A., AYORA, C. & CARRERA, J. 2008a. Field application of calcite Dispersed Alkaline Substrate (calcite-DAS) for passive treatment of acid mine drainage with high Al and metal concentrations. *Appl. Geochem.,* 23**,** 1660-1674.

RÖTTING, T. S., THOMAS, R. C., AYORA, C. & CARRERA, J. 2008b. Passive treatment of acid mine drainage with high metal concentrations using dispersed alkaline substrate. *J. Environ. Qual.,* 37**,** 1741-51.

RUCKWIED, K., GÖTZ, A. E. & JONES, P. 2014. Palynological records of the Permian Ecca Group (South Africa): Utilizing climatic icehouse–greenhouse signals for cross basin correlations. *Palaeogeography, Palaeoclimatology, Palaeoecology,* 413**,** 167-172.

SAHOO, P. K., KIM, K., EQUEENUDDIN, S. M. & POWELL, M. A. 2013. Current approaches for mitigating acid mine drainage. *Reviews of Environmental Contamination and Toxicology Volume 226.* Springer.

SAPSFORD, D. J., BARNES, A., DEY, M., WILLIAMS, K. P., JARVIS, A., YOUNGER, P. L. & LIANG, L. 2006. Iron and manganese removal in a vertical flow reactor for passive treatment of mine water. *In:* BARNHISEL, R. I. (ed.) *7th International Conference on Acid Rock Drainage (ICARD).* St. Louis: American Society of Mining and Reclamation (ASMR).

SCHAFER, W. M., LOGSDON, M., ZHAN, G. & ESPELL, R. Post-Betze pit lake water quality prediction, Nevada. Proceedings of the 7th International Conference on Acid Rock Drainage. Society for Mining, Metallurgy, and Exploration, Littleton, 2006. 1863-1886.

SCHULZE-MAKUCH, D. 2005. Longitudinal dispersivity data and implications for scaling behavior. *Ground Water,* 43**,** 443-456.

SKOUSEN, J., ROSE, A., GEIDEL, G., FOREMAN, J., EVANS, R. & HELLIER, W. 1998. *Handbook of technologies for avoidance and remediation of acid mine drainage*, National Mine Land Reclamation Center Morgantown.

SNYMAN, C. P. 1998. Coal. *In:* WILSON, M. G. C. & ANHAEUSSER, C. R. (eds.) *The Mineral Resources of South Africa.* 6th ed. Pretoria: Council for Geoscience.

STUMM, W. & MORGAN, J. J. 1996. *Aquatic Chemistry – Chemical Equilibria and Rates in Natural Waters,* New York, Wiley & Sons.

TANKARD, A., WELSINK, H., AUKES, P., NEWTON, R. & STETTLER, E. 2009. Tectonic evolution of the Cape and Karoo basins of South Africa. *Mar. Petrol. Geol.,* 26**,** 1379-1412.

TANNER, P. 2007. Guidelines for the rehabilitation of mined land. South Africa: Chamber of Mines of South Africa/Coaltech.

USHER, B. H. & VERMEULEN, P. D. 2006. The impacts of coal and gold mining on the associated water resources in South Africa. *In:* XU, Y. & USHER, B. (eds.) *Groundwater Pollution in Africa.* South Africa: CRC Press.

VAN TONDER, G. & XU, Y. A guide for the estimation of groundwater recharge in South Africa. 2001.

VAN ZYL, N. L. 2011. *The Influence of Flooding on Underground Coal Mines.* M.Sc. Master, University of the Free State.

VERMEULEN, P. D. & USHER, B. H. 2005. Sulphate generation in South African underground and opencast collieries. *Env. Geol.,* 49**,** 552-569.

WANG, X.-S., JIANG, X.-W., WAN, L., SONG, G. & XIA, Q. 2009. Evaluation of depth-dependent porosity and bulk modulus of a shear using permeability–depth trends. *International Journal of Rock Mechanics and Mining Sciences,* 46**,** 1175-1181.

WATZLAF, G. R., KAIRIES, C. L., SCHROEDER, K. T., DANEHY, T. & BEAM, R. 2002. Quantitative results from the flushing of four reducing and alkalinity-producing systems. *West Virginia Surface Mine Drainage Task Force Symposium.* Morgantown.

WATZLAF, G. R., SCHROEDER, K. T., KLEINMANN, R., KAIRIES, C. L. & NAIRN, R. W. 2004. The Passive Treatment of Coal Mine Drainage USA: U.S. Department of Energy, National Energy Technology Laboratory, University of Oklahoma, School of Civil Engineering and Environmental Science.

WEBSTER, K. E., BOWSER, C. J., ANDERSON, M. P. & LENTERS, D. J. 2006. Understanding the lake-groundwater system: just follow the water. *In:* MAGNUSON, J. J., KRATZ, T. K. & BENSON, B. J. (eds.) *Long- term dynamics of lakes in the landscape.* Oxford: Oxford University Press.

WHITE, A. F. & BRANTLEY, S. L. 2003. The effect of time on the weathering of silicate minerals: why do weathering rates differ in the laboratory and field? *Chem. Geol.,* 202**,** 479-506.

WHITEHEAD, P. & JEFFREY, H. 1995. Heavy metals from acid mine drainage – impacts and modelling strategies. *In:* PETTS, G. E. (ed.) *Man's Influence on Freshwater Ecosystems and Water Use.* Wallingford: International Association of Hydrological Sciences.

WILLIAMS, M. 2015. Update – Field-Scale Kinetic Testing Of E-Mine Colliery Coal Waste. Johannesburg: Schlumberger Water Services.

WILLIAMS, M., MARAIS, H. & TAIT, D. 2012. E-Mine Colliery: evaluation of post-closure rebound and surface water discharge: REVISION 2. Johannesburg: Schlumberger Water Services.

WISOTZKY, F. 2001. Prevention of Acidic Groundwater in Lignite Overburden Dumps by the Addition of Alkaline Substances: Pilot-scale Field Experiments. *Mine Water Environ.,* 20**,** 122-128.

WISOTZKY, F. 2003. *Saure Bergbauwässer (acid mine drainage) und deren Qualitätsverbesserung durch Zugabe von alkalisch wirkenden Zuschlagstoffen zum Abraum: Untersuchungen im Rheinischen Braunkohlenrevier*, Landesumweltamt Nordrhein-Westfalen.

WOLKERSDORFER, C. 2008. *Water Management at Abandoned Flooded Underground Mines – Fundamentals, Tracer Tests, Modelling, Water Treatment*, Springer.

YOUNG, R. A. 1999. *The Rietveld Method,* Oxford, Oxford University Press.

YOUNGER, P. & SAPSFORD, D. 2004a. Evaluating the potential impact of opencast coal mining on water quality (Groundwater Regulations 1998) – An assessment framework for Scotland. Scottish Environment Protection Agency (SEPA).

YOUNGER, P. L. 1997. The longevity of minewater pollution: a basis for decision-making. *Sci. Total Environ.***,** 194-195.

YOUNGER, P. L. 2000. Predicting temporal changes in total iron concentrations in groundwaters flowing from abandoned deep mines: a first approximation. *J. Contam. Hydrol.,* 44**,** 47-69.

YOUNGER, P. L. 2001. Mine water pollution in Scotland: nature, extent and preventative strategies. *Sci. Total Environ.,* 265**,** 309-326.

YOUNGER, P. L., BANWART, S. A. & HEDIN, R. S. 2002. *Mine Water: Hydrology, Pollution Remediation,* Dordrecht, Kluwer.

YOUNGER, P. L. & ROBINS, N. S. 2002. Challenges in the characterization and prediction of the hydrogeology and geochemistry of mined ground. *Spec. Publ. – Geol. Soc. London,* 198**,** 1-16.

YOUNGER, P. L. & SAPSFORD, D. J. 2004b. Evaluating the potential impact of opencast coal mining on water quality (Groundwater Regulations 1998) An assessment framework for Scotland. Scotland: Scottish Environmental Protection Agency.

ZHAO, B., USHER, B. H., YIBAS, B. & PULLES, W. 2010. Evaluation and Validation of Geochemical Prediction Techniques for Underground Coal Mines in the Witbank/Vryheid Regions: Report to the Water Research Commission.[Gezina]. *Water Research Commission*.

ZHENG, C. & WANG, P. P. 1999. MT3DMS: A modular three-dimensional multispecies transport model for simulation of advection, dispersion, and chemical reactions of contaminants in groundwater systems; documentation and user's guide. Alabama: DTIC Document.

ZIEMKIEWICZ, P. 1994. AMD/time: a simple spreadsheet for predicting acid mine drainage. *International Land Reclamation and Mine Drainage Conference, USDI, Bureau of Mines.* Pittsburgh.

APPENDIX C: Geochemical Data for E-Mine

APPENDIX D: Geochemical Data for A-Mine

APPENDIX A: Correlation Matrix

		Anatase	Hematite	Dolomite	Kaolinite	Microcline	Muscovite	Plagioclase	Quartz	Smectite	Siderite	EstPyrite	Proton Activity	TotalDissolvedSolids	Alkalinity	Al	Ca	Fe	K	Mg	Mn	Na	Cl	NO3	SO4	PasteProtonActivity	TotalS	AcidGenerationPotential	NeutralisationPotential	NNP
Anatase	Pearson Correlation	1,000	-0,406	-0,213	0,720	-0,635	-0,156	-0,160	-0,085	-0,160	-0,175	0,193	0,335	-0,069	-0,243	0,529	-0,306	0,595	-0,463	-0,433	-0,045	-0,453	-0,194	0,233	0,193	,c	,c	,c	,c	,c
	Sig. (2-tailed)		0,149	0,466	0,004	0,015	0,595	0,585	0,773	0,585	0,549	0,509	0,241	0,814	0,402	0,052	0,288	0,041	0,096	0,122	0,880	0,103	0,507	0,422	0,509	0,000	0,000	0,000	0,000	0,000
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Hematite	Pearson Correlation	-0,406	1,000	-0,260	-0,301	0,588	0,653	0,023	0,265	0,023	-0,214	0,137	-0,209	0,235	-0,334	-0,306	0,135	-0,385	0,657	0,360	0,471	0,161	-0,039	-0,145	0,137	0,343	0,534	0,534	0,466	-0,350
	Sig. (2-tailed)	0,149		0,370	0,295	0,027	0,011	0,937	0,360	0,937	0,463	0,641	0,474	0,418	0,243	0,287	0,646	0,216	0,011	0,206	0,089	0,581	0,895	0,620	0,641	0,506	0,276	0,275	0,352	0,497
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Dolomite	Pearson Correlation	-0,213	-0,260	1,000	-0,338	-0,094	-0,490	-0,102	-0,324	-0,102	0,922	-0,260	-0,231	0,029	0,907	-0,177	0,376	-0,068	-0,205	0,296	-0,187	-0,095	0,047	-0,273	-0,260	,c	,c	,c	,c	,c
	Sig. (2-tailed)	0,466	0,370		0,238	0,750	0,075	0,728	0,259	0,728	0,000	0,370	0,426	0,921	0,000	0,545	0,185	0,834	0,483	0,304	0,522	0,748	0,873	0,345	0,370	0,000	0,000	0,000	0,000	0,000
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Kaolinite	Pearson Correlation	0,720	-0,301	-0,338	1,000	-0,625	0,111	-0,364	-0,034	-0,364	-0,241	0,470	0,737	0,213	-0,320	0,740	-0,276	0,700	-0,387	-0,259	0,203	-0,571	-0,391	0,223	0,470	0,466	0,468	0,468	0,290	-0,337
	Sig. (2-tailed)	0,004	0,295	0,238		0,017	0,707	0,201	0,909	0,201	0,406	0,090	0,003	0,465	0,265	0,002	0,339	0,011	0,171	0,371	0,485	0,033	0,167	0,444	0,090	0,352	0,349	0,349	0,577	0,513
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Microcline	Pearson Correlation	-0,635	0,588	-0,094	-0,625	1,000	0,468	0,067	0,330	0,067	-0,075	-0,213	-0,622	0,014	0,089	-0,681	0,339	-0,817	0,678	0,494	0,168	0,609	0,022	-0,231	-0,213	0,116	0,441	0,441	0,525	-0,253
	Sig. (2-tailed)	0,015	0,027	0,750	0,017		0,092	0,821	0,249	0,821	0,798	0,465	0,018	0,963	0,762	0,007	0,236	0,001	0,008	0,073	0,566	0,021	0,941	0,428	0,465	0,826	0,381	0,381	0,285	0,628
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Muscovite	Pearson Correlation	-0,156	0,653	-0,490	0,111	0,468	1,000	-0,125	-0,050	-0,125	-0,218	-0,039	0,033	-0,039	-0,313	-0,045	-0,354	-0,066	0,475	0,031	0,236	0,197	-0,218	-0,033	-0,039	0,257	0,156	0,156	0,491	-0,011
	Sig. (2-tailed)	0,595	0,011	0,075	0,707	0,092		0,671	0,865	0,671	0,453	0,896	0,910	0,894	0,275	0,878	0,214	0,838	0,086	0,915	0,417	0,501	0,454	0,911	0,896	0,622	0,768	0,768	0,322	0,984
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Plagioclase	Pearson Correlation	-0,160	0,023	-0,102	-0,364	0,067	-0,125	1,000	-0,322	1,000	-0,084	-0,126	-0,173	-0,157	-0,131	-0,057	-0,162	,c	-0,296	-0,206	-0,139	0,370	0,986	-0,205	-0,126	-0,598	-0,288	-0,287	0,291	0,327
	Sig. (2-tailed)	0,585	0,937	0,728	0,201	0,821	0,671		0,262	0,000	0,775	0,667	0,555	0,592	0,654	0,847	0,579	0,000	0,304	0,480	0,637	0,193	0,000	0,481	0,667	0,210	0,580	0,581	0,576	0,527
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Quartz	Pearson Correlation	-0,085	0,265	-0,324	-0,034	0,330	-0,050	-0,322	1,000	-0,322	-0,585	0,167	-0,208	0,169	-0,324	-0,262	0,454	-0,469	0,250	0,146	0,145	-0,056	-0,363	0,108	0,167	0,376	0,339	0,339	0,335	-0,212
	Sig. (2-tailed)	0,773	0,360	0,259	0,909	0,249	0,865	0,262		0,262	0,028	0,569	0,476	0,564	0,259	0,365	0,103	0,124	0,389	0,618	0,620	0,849	0,202	0,715	0,569	0,463	0,511	0,511	0,517	0,687
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Smectite	Pearson Correlation	-0,160	0,023	-0,102	-0,364	0,067	-0,125	1,000	-0,322	1,000	-0,084	-0,126	-0,173	-0,157	-0,131	-0,057	-0,162	,c	-0,296	-0,206	-0,139	0,370	0,986	-0,205	-0,126	-0,598	-0,288	-0,287	0,291	0,327
	Sig. (2-tailed)	0,585	0,937	0,728	0,201	0,821	0,671	0,000	0,262		0,775	0,667	0,555	0,592	0,654	0,847	0,579	0,000	0,304	0,480	0,637	0,193	0,000	0,481	0,667	0,210	0,580	0,581	0,576	0,527
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Siderite	Pearson Correlation	-0,175	-0,214	0,922	-0,241	-0,075	-0,218	-0,084	-0,585	-0,084	1,000	-0,329	-0,191	-0,058	0,902	-0,146	0,143	0,039	-0,156	0,257	-0,154	-0,026	0,044	-0,225	-0,329	,c	,c	,c	,c	,c
	Sig. (2-tailed)	0,549	0,463	0,000	0,406	0,798	0,453	0,775	0,028	0,775		0,251	0,514	0,844	0,000	0,619	0,625	0,905	0,595	0,375	0,599	0,929	0,883	0,439	0,251	0,000	0,000	0,000	0,000	0,000
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
EstPyrite	Pearson Correlation	0,193	0,137	-0,260	0,470	-0,213	-0,039	-0,126	0,167	-0,126	-0,329	1,000	0,651	0,911	-0,349	0,571	0,463	0,454	0,132	0,473	0,783	-0,188	-0,133	-0,243	1,000	0,706	0,985	0,985	-0,274	-0,938
	Sig. (2-tailed)	0,509	0,641	0,370	0,090	0,465	0,896	0,667	0,569	0,667	0,251		0,012	0,000	0,222	0,033	0,095	0,138	0,653	0,087	0,001	0,519	0,651	0,403	0,000	0,117	0,000	0,000	0,599	0,006
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
ProtonActivity	Pearson Correlation	0,335	-0,209	-0,231	0,737	-0,622	0,033	-0,173	-0,208	-0,173	-0,191	0,651	1,000	0,436	-0,297	0,936	-0,177	0,781	-0,292	-0,150	0,194	-0,403	-0,156	-0,132	0,651	0,862	0,758	0,757	-0,589	-0,818
	Sig. (2-tailed)	0,241	0,474	0,426	0,003	0,018	0,910	0,555	0,476	0,555	0,514	0,012		0,119	0,302	0,000	0,546	0,003	0,311	0,609	0,506	0,153	0,595	0,652	0,012	0,027	0,081	0,081	0,219	0,047
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
TotalDissolvedSolids	Pearson Correlation	-0,069	0,235	0,029	0,213	0,014	-0,039	-0,157	0,169	-0,157	-0,058	0,911	0,436	1,000	-0,030	0,349	0,715	0,272	0,247	0,732	0,833	-0,067	-0,125	-0,426	0,911	0,747	0,984	0,984	-0,219	-0,923
	Sig. (2-tailed)	0,814	0,418	0,921	0,465	0,963	0,894	0,592	0,564	0,592	0,844	0,000	0,119		0,919	0,221	0,004	0,393	0,394	0,003	0,000	0,820	0,671	0,129	0,000	0,088	0,000	0,000	0,677	0,009
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Alkalinity	Pearson Correlation	-0,243	-0,334	0,907	-0,320	0,089	-0,313	-0,131	-0,324	-0,131	0,902	-0,349	-0,297	-0,030	1,000	-0,226	0,354	-0,047	-0,143	0,321	-0,238	0,164	0,005	-0,316	-0,349	,c	,c	,c	,c	,c
	Sig. (2-tailed)	0,402	0,243	0,000	0,265	0,762	0,275	0,654	0,259	0,654	0,000	0,222	0,302	0,919		0,437	0,215	0,886	0,625	0,263	0,412	0,575	0,987	0,271	0,222	0,000	0,000	0,000	0,000	0,000
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Al	Pearson Correlation	0,529	-0,306	-0,177	0,740	-0,681	-0,045	-0,057	-0,262	-0,057	-0,146	0,571	0,936	0,349	-0,226	1,000	-0,216	0,859	-0,434	-0,280	0,054	-0,379	-0,033	-0,165	0,571	-0,376	0,008	0,009	0,232	0,052
	Sig. (2-tailed)	0,052	0,287	0,545	0,002	0,007	0,878	0,847	0,365	0,847	0,619	0,033	0,000	0,221	0,437		0,459	0,000	0,121	0,332	0,855	0,181	0,911	0,572	0,033	0,463	0,988	0,987	0,659	0,923
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Ca	Pearson Correlation	-0,306	0,135	0,376	-0,276	0,339	-0,354	-0,162	0,454	-0,162	0,143	0,463	-0,177	0,715	0,354	-0,216	1,000	-0,233	0,285	0,825	0,526	0,154	-0,094	-0,414	0,463	0,693	0,978	0,978	-0,163	-0,903
	Sig. (2-tailed)	0,288	0,646	0,185	0,339	0,236	0,214	0,579	0,103	0,579	0,625	0,095	0,546	0,004	0,215	0,459		0,467	0,323	0,000	0,053	0,598	0,748	0,141	0,095	0,127	0,001	0,001	0,758	0,014
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Fe	Pearson Correlation	0,595	-0,385	-0,068	0,700	-0,817	-0,066	,c	-0,469	,c	0,039	0,454	0,781	0,272	-0,047	0,859	-0,233	1,000	-0,448	-0,244	0,068	-0,192	0,197	-0,168	0,454	0,845	0,715	0,715	-0,733	-0,829
	Sig. (2-tailed)	0,041	0,216	0,834	0,011	0,001	0,838	0,000	0,124	0,000	0,905	0,138	0,003	0,393	0,886	0,000	0,467		0,144	0,446	0,834	0,551	0,539	0,601	0,138	0,072	0,175	0,175	0,159	0,083
	N	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	5	5	5	5	5
K	Pearson Correlation	-0,463	0,657	-0,205	-0,387	0,678	0,475	-0,296	0,250	-0,296	-0,156	0,132	-0,292	0,247	-0,143	-0,434	0,285	-0,448	1,000	0,590	0,446	0,450	-0,353	0,110	0,132	0,668	0,694	0,693	-0,474	-0,732
	Sig. (2-tailed)	0,096	0,011	0,483	0,171	0,008	0,086	0,304	0,389	0,304	0,595	0,653	0,311	0,394	0,625	0,121	0,323	0,144		0,026	0,110	0,107	0,215	0,707	0,653	0,147	0,126	0,127	0,343	0,098
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Mg	Pearson Correlation	-0,433	0,360	0,296	-0,259	0,494	0,031	-0,206	0,146	-0,206	0,257	0,473	-0,150	0,732	0,321	-0,280	0,825	-0,244	0,590	1,000	0,745	0,277	-0,169	-0,339	0,473	0,693	0,974	0,974	-0,263	-0,926
	Sig. (2-tailed)	0,122	0,206	0,304	0,371	0,073	0,915	0,480	0,618	0,480	0,375	0,087	0,609	0,003	0,263	0,332	0,000	0,446	0,026		0,002	0,337	0,563	0,236	0,087	0,127	0,001	0,001	0,615	0,008
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Mn	Pearson Correlation	-0,045	0,471	-0,187	0,203	0,168	0,236	-0,139	0,145	-0,139	-0,154	0,783	0,194	0,833	-0,238	0,054	0,526	0,068	0,446	0,745	1,000	-0,045	-0,173	-0,153	0,783	0,745	0,983	0,983	-0,181	-0,912
	Sig. (2-tailed)	0,880	0,089	0,522	0,485	0,566	0,417	0,637	0,620	0,637	0,599	0,001	0,506	0,000	0,412	0,855	0,053	0,834	0,110	0,002		0,879	0,555	0,601	0,001	0,089	0,000	0,000	0,732	0,011
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Na	Pearson Correlation	-0,453	0,161	-0,095	-0,571	0,609	0,197	0,370	-0,056	0,370	-0,026	-0,188	-0,403	-0,067	0,164	-0,379	0,154	-0,192	0,450	0,277	-0,045	1,000	0,354	-0,234	-0,188	-0,240	0,150	0,150	-0,260	-0,200
	Sig. (2-tailed)	0,103	0,581	0,748	0,033	0,021	0,501	0,193	0,849	0,193	0,929	0,519	0,153	0,820	0,575	0,181	0,598	0,551	0,107	0,337	0,879		0,215	0,422	0,519	0,647	0,776	0,777	0,618	0,704
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
Cl	Pearson Correlation	-0,194	-0,039	0,047	-0,391	0,022	-0,218	0,986	-0,363	0,986	0,044	-0,133	-0,156	-0,125	0,005	-0,033	-0,094	0,197	-0,353	-0,169	-0,173	0,354	1,000	-0,268	-0,133	-0,598	-0,288	-0,287	0,291	0,327
	Sig. (2-tailed)	0,507	0,895	0,873	0,167	0,941	0,454	0,000	0,202	0,000	0,883	0,651	0,595	0,671	0,987	0,911	0,748	0,539	0,215	0,563	0,555	0,215		0,355	0,651	0,210	0,580	0,581	0,576	0,527
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
NO3	Pearson Correlation	0,233	-0,145	-0,273	0,223	-0,231	-0,033	-0,205	0,108	-0,205	-0,225	-0,243	-0,132	-0,426	-0,316	-0,165	-0,414	-0,168	0,110	-0,339	-0,153	-0,234	-0,268	1,000	-0,243	-0,123	-0,373	-0,374	-0,423	0,220
	Sig. (2-tailed)	0,422	0,620	0,345	0,444	0,428	0,911	0,481	0,715	0,481	0,439	0,403	0,652	0,129	0,271	0,572	0,141	0,601	0,707	0,236	0,601	0,422	0,355		0,403	0,816	0,466	0,465	0,403	0,675
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
SO4	Pearson Correlation	0,193	0,137	-0,260	0,470	-0,213	-0,039	-0,126	0,167	-0,126	-0,329	1,000	0,651	0,911	-0,349	0,571	0,463	0,454	0,132	0,473	0,783	-0,188	-0,133	-0,243	1,000	0,706	0,985	0,985	-0,274	-0,938
	Sig. (2-tailed)	0,509	0,641	0,370	0,090	0,465	0,896	0,667	0,569	0,667	0,251	0,000	0,012	0,000	0,222	0,033	0,095	0,138	0,653	0,087	0,001	0,519	0,651	0,403		0,117	0,000	0,000	0,599	0,006
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12	14	14	14	14	14	14	14	6	6	6	6	6
PasteProtonActivity	Pearson Correlation	,c		0,343	,c		0,466	0,116	0,257	-0,598	0,376	-0,598	,c	0,706	0,862	0,747	,c		-0,376	0,693	0,845	0,668	0,693	0,745	-0,240	-0,598	-0,123	0,706	1,000	0,766	0,806	-0,500	-0,791
	Sig. (2-tailed)		0,000	0,506		0,000	0,352	0,826	0,622	0,210	0,463	0,210	0,000	0,117	0,027	0,088	0,000	0,463	0,127	0,072	0,147	0,127	0,089	0,647	0,210	0,816	0,117		0,000	0,000	0,025	0,000
	N	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6	6	6	6	20	20	20	20	20
TotalS	Pearson Correlation	,c		0,534	,c		0,468	0,441	0,156	-0,288	0,339	-0,288	,c	0,985	0,758	0,984	,c		0,008	0,978	0,715	0,694	0,974	0,983	0,150	-0,288	-0,373	0,985	0,766	1,000	0,983	-0,354	-0,800
	Sig. (2-tailed)		0,000	0,276		0,000	0,349	0,381	0,768	0,580	0,511	0,580		0,000	0,000	0,081		0,000	0,988	0,001	0,175	0,126	0,001	0,000	0,776	0,580	0,466	0,000	0,000		0,000	0,126	0,000
	N	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6	6	6	6	20	20	20	20	20
AcidGenerationPotential	Pearson Correlation	,c		0,534	,c		0,468	0,441	0,156	-0,287	0,339	-0,287	,c	0,985	0,757	0,984	,c		0,009	0,978	0,715	0,693	0,974	0,983	0,150	-0,287	-0,374	0,985	0,806	0,983	1,000	-0,330	-0,795
	Sig. (2-tailed)		0,000	0,275		0,000	0,349	0,381	0,768	0,581	0,511	0,581		0,000	0,000	0,081		0,000	0,000	0,987	0,001	0,175	0,127	0,001	0,000	0,777	0,581	0,465	0,000	0,000	0,000		0,155	0,000
	N	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6	6	6	6	20	20	20	20	20
NeutralisationPotential	Pearson Correlation	,c		0,466	,c		0,290	0,525	0,491	0,291	0,335	0,291	,c	-0,274	-0,589	-0,219	,c		0,232	-0,163	-0,733	-0,474	-0,263	-0,181	-0,260	0,291	-0,423	-0,274	-0,500	-0,354	-0,330	1,000	0,835
	Sig. (2-tailed)		0,000	0,352		0,000	0,577	0,285	0,322	0,576	0,517	0,576		0,599	0,219	0,677		0,000	0,659	0,758	0,159	0,343	0,615	0,732	0,618	0,576	0,403	0,599	0,025	0,126	0,155		0,000
	N	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6	6	6	6	20	20	20	20	20
NNP	Pearson Correlation	,c		-0,350	,c		-0,337	-0,253	-0,011	0,327	-0,212	0,327	,c	-0,938	-0,818	-0,923	,c		0,052	-0,903	-0,829	-0,732	-0,926	-0,912	-0,200	0,327	0,220	-0,938	-0,791	-0,800	-0,795	0,835	1,000
	Sig. (2-tailed)		0,000	0,497		0,000	0,513	0,628	0,984	0,527	0,687	0,527		0,006	0,047	0,009		0,000	0,923	0,014	0,083	0,098	0,008	0,011	0,704	0,527	0,675	0,006	0,000	0,000	0,000	0,000	
	N	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6	6	6	6	20	20	20	20	20

**: Correlation is significant at the 0.01 level (2-tailed).
*: Correlation is significant at the 0.05 level (2-tailed).

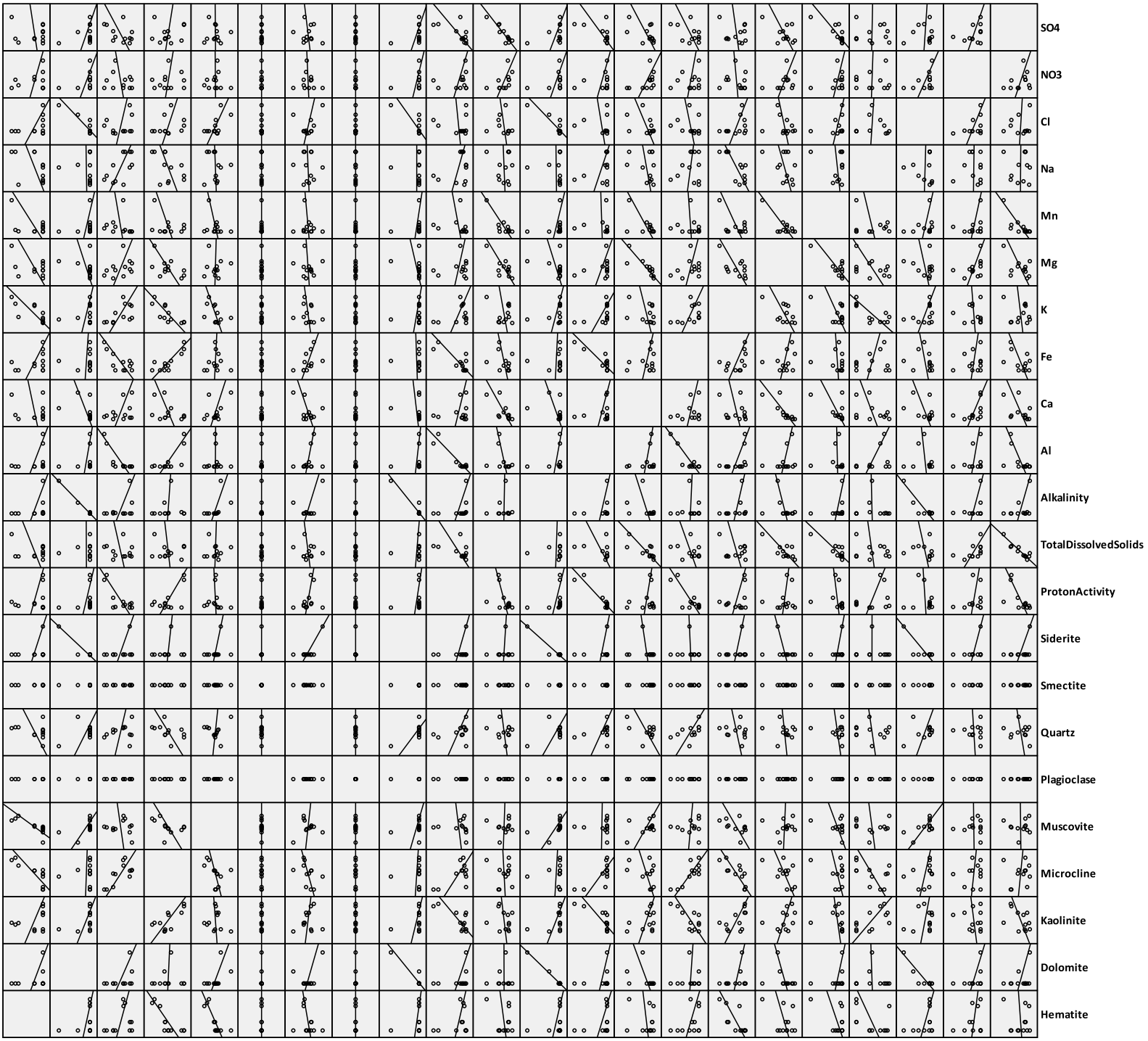
c: Cannot be computed because at least one of the variables is constant.

	1		2
EstPyrite	1,000	Muscovite	,984
SO4	1,000	Quartz	,978
TotalS	,995	NeutralisationPotential	,917
AcidGenerationPotential	,995	Kaolinite	,905
Ca	,988	Hematite	,870
Mg	,988	Microcline	,782
TotalDissolvedSolids	,984	NNP	,243
K	,798	Ca	,152
PastePA	,783	TotalDissolvedSolids	,114
Fe	,712	Mg	,059
Hematite	,487	EstPyrite	,021
Na	,430	SO4	,021
Microcline	,430	AcidGenerationPotential	-,005
Kaolinite	,374	TotalS	-,005
Quartz	,203	PastePA	-,261
Muscovite	-,039	K	-,298
NeutralisationPotential	-,264	Na	-,562
NNP	-,957	Fe	-,637

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

	3
Na	,704
K	,523
Microcline	,448
NeutralisationPotential	,158
Mg	,141
NNP	,118
Hematite	,072
Quartz	,022
Ca	-,005
SO4	-,017
EstPyrite	-,017
TotalS	-,087
AcidGenerationPotential	-,087
TotalDissolvedSolids	-,140
Kaolinite	-,146
Fe	-,156
Muscovite	-,161
PastePA	-,547


SO4
NO3
Cl
Na
Mn
Mg
K
Fe
Ca
Al
Alkalinity
TotalDissolvedSolids
ProtonActivity
Siderite
Smectite
Quartz
Plagioclase
Muscovite
Microcline
Kaolinite
Dolomite
Hematite
NO3
Na
Mg
Fe
Al
TotalDissolvedSolids
Siderite
Quartz
Muscovite
Kaolinite
Hematite

APPENDIX B: Geochemical Data for C-Mine

UIS Analytical Services (Pty) Ltd • Reg. No. 2000/027788/07 • VAT No. 4920202969
13 Esdoring Nook, Highveld Technopark, Centurion • PO Box 8286, Centurion, 0046
Tel. +27 12 665 4291 • Fax. +27 12 665 4294 • info@uis-as.co.za • www.uis-as.co.za

Geo Pollution Technologies - Gauteng
81 Rauch Avenue, Georgeville, Meyerspark
Pretoria
0184
South Africa
Altus Huisamen
Tel: +27 12 804 8120
Fax: +27 12 804 8140
E-Mail: altus@gptglobal.com

FINAL CERTIFICATE OF ANALYSIS

Contract No	
Date Required	2015-02-19
Order/Ref No	MenCof-15-050
Page	1/4
Request ID	11418
Report Date	2015-02-25
Report Revision	0

T0184

Reference: Carolina Mine Extension

Sample ID: 421998 Received: 2015-02-09 Matrix: Water
Sample Number: Carolina/Mine/Extension/Decant

1-pH	7.66	5-Fe	0.13 mg/l	6-NO3	<0.3 mg/l
1-pH Temp.	25 Deg C	5-K	6.15 mg/l	6-PO4	<0.8 mg/l
2-Tot Cond @25C	47.2 mSm	5-Mg	34.9 mg/l	6-SO4	189 mg/l
3-TDS by EC*6.5	307 mg/l	5-Mn	<0.05 mg/l	7-Sum of Cat	5.34 me/l
3-TDS by EC*7	330 mg/l	5-Na	16.8 mg/l	7-Sum of Ani	5.13 me/l
4-P Alk.	<0.6 mg/l CaCO3	5-Si	1.13 mg/l	7-Ion Balanc	2 %
4-M Alk.	48.9 mg/l CaCO3	6-F	0.289 mg/l		
5-Al	<0.05 mg/l	6-Cl	9.77 mg/l		
5-Ca	31.5 mg/l	6-NO2	<0.2 mg/l		

Sample ID: 421999 Received: 2015-02-09 Matrix: Water
Sample Number: Carolina/Mine/Extension/DG1

1-pH	6.98	5-Fe	<0.05 mg/l	6-NO3	0.325 mg/l
1-pH Temp.	25 Deg C	5-K	3.92 mg/l	6-NO3 as N	<0.3 mg/l
2-Tot Cond @25C	13.4 mSm	5-Mg	4.86 mg/l	6-PO4	<0.8 mg/l
3-TDS by EC*6.5	87.3 mg/l	5-Mn	0.27 mg/l	6-SO4	3.68 mg/l
3-TDS by EC*7	94 mg/l	5-Na	18.2 mg/l	7-Sum of Cat	1.39 me/l
4-P Alk.	<0.6 mg/l CaCO3	5-Si	1.29 mg/l	7-Sum of Ani	1.33 me/l
4-M Alk.	45.6 mg/l CaCO3	6-F	0.115 mg/l	7-Ion Balanc	2.19 %
5-Al	<0.05 mg/l	6-Cl	13.9 mg/l		
5-Ca	1.81 mg/l	6-NO2	<0.2 mg/l		

Sample ID: 422000 Received: 2015-02-09 Matrix: Water
Sample Number: Carolina/Mine/Extension/DG2

1-pH	6.93	5-Fe	<0.05 mg/l	6-NO3	2.39 mg/l
1-pH Temp.	25 Deg C	5-K	4.43 mg/l	6-NO3 as N	0.54 mg/l
2-Tot Cond @25C	15.8 mSm	5-Mg	6.28 mg/l	6-PO4	<0.8 mg/l
3-TDS by EC*6.5	103 mg/l	5-Mn	<0.05 mg/l	6-SO4	11.6 mg/l
3-TDS by EC*7	111 mg/l	5-Na	14.3 mg/l	7-Sum of Cat	1.7 me/l
4-P Alk.	<0.6 mg/l CaCO3	5-Si	5.8 mg/l	7-Sum of Ani	1.88 me/l
4-M Alk.	53.5 mg/l CaCO3	6-F	0.179 mg/l	7-Ion Balanc	-4.92 %
5-Al	<0.05 mg/l	6-Cl	10.2 mg/l		
5-Ca	9.04 mg/l	6-NO2	<0.2 mg/l		

Geo Pollution Technologies - Gauteng
81 Rauch Avenue, Georgeville, Meyerspark
Pretoria
0184
South Africa
Altus Huisamen
Tel: +27 12 804 8120
Fax: +27 12 804 8140
E-Mail: altus@gptglobal.com

FINAL CERTIFICATE OF ANALYSIS

Contract No	
Date Required	2015-02-19
Order/Ref No	MenCof-15-050
Page	2/4
Request ID	11418
Report Date	2015-02-25
Report Revision	0

sanas Testing Laboratory T0184

Reference: Carolina Mine Extension

Sample ID: 422001 Received: 2015-02-09 Matrix: Water
Sample Number: Carolina/Mine/Extension/DG7

1-pH	6.53	5-Fe	<0.05 mg/l	6-NO3	<0.3 mg/l
1-pH Temp.	25 Deg C	5-K	3.09 mg/l	6-PO4	<0.8 mg/l
2-Tot Cond @25C	8.17 mSm	5-Mg	3.68 mg/l	6-SO4	19 mg/l
3-TDS by EC*6.5	53.1 mg/l	5-Mn	0.08 mg/l	7-Sum of Cat	0.97 me/l
3-TDS by EC*7	57.2 mg/l	5-Na	7.63 mg/l	7-Sum of Ani	1.12 me/l
4-P Alk.	<0.6 mg/l CaCO3	5-Si	4.61 mg/l	7-Ion Balanc	-7.25 %
4-M Alk.	16.7 mg/l CaCO3	6-F	0.12 mg/l		
5-Al	<0.05 mg/l	6-Cl	3.89 mg/l		
5-Ca	5.01 mg/l	6-NO2	<0.2 mg/l		

Sample ID: 422002 Received: 2015-02-09 Matrix: Water
Sample Number: Carolina/Mine/Extension/DG8

1-pH	7.04	5-Fe	<0.05 mg/l	6-NO3	<0.3 mg/l
1-pH Temp.	25 Deg C	5-K	1.65 mg/l	6-PO4	<0.8 mg/l
2-Tot Cond @25C	6.75 mSm	5-Mg	2.48 mg/l	6-SO4	3.47 mg/l
3-TDS by EC*6.5	43.9 mg/l	5-Mn	0.33 mg/l	7-Sum of Cat	0.84 me/l
3-TDS by EC*7	47.3 mg/l	5-Na	11.7 mg/l	7-Sum of Ani	0.91 me/l
4-P Alk.	<0.6 mg/l CaCO3	5-Si	3.5 mg/l	7-Ion Balanc	-3.83 %
4-M Alk.	29.1 mg/l CaCO3	6-F	<0.1 mg/l		
5-Al	<0.05 mg/l	6-Cl	3.45 mg/l		
5-Ca	1.5 mg/l	6-NO2	<0.2 mg/l		

Sample ID: 422003 Received: 2015-02-09 Matrix: Water
Sample Number: Carolina/Mine/Extension/DG5

1-pH	7.68	5-Fe	<0.05 mg/l	6-NO3	<0.3 mg/l
1-pH Temp.	25 Deg C	5-K	4.91 mg/l	6-PO4	<0.8 mg/l
2-Tot Cond @25C	43.4 mSm	5-Mg	28.6 mg/l	6-SO4	95 mg/l
3-TDS by EC*6.5	282 mg/l	5-Mn	0.47 mg/l	7-Sum of Cat	4.7 me/l
3-TDS by EC*7	304 mg/l	5-Na	23.6 mg/l	7-Sum of Ani	4.29 me/l
4-P Alk.	<0.6 mg/l CaCO3	5-Si	0.67 mg/l	7-Ion Balanc	4.59 %
4-M Alk.	102 mg/l CaCO3	6-F	0.118 mg/l		
5-Al	<0.05 mg/l	6-Cl	19.6 mg/l		
5-Ca	23.6 mg/l	6-NO2	<0.2 mg/l		

Sample ID: 422004 Received: 2015-02-09 Matrix: Water
Sample Number: Carolina/Mine/Extension/P5

1-pH	6.19	5-Fe	0.5 mg/l	6-NO3	<0.3 mg/l
1-pH Temp.	25 Deg C	5-K	4.57 mg/l	6-PO4	<0.8 mg/l
2-Tot Cond @25C	11 mSm	5-Mg	7.45 mg/l	6-SO4	21.6 mg/l
3-TDS by EC*6.5	71.7 mg/l	5-Mn	0.13 mg/l	7-Sum of Cat	1.15 me/l
3-TDS by EC*7	77.2 mg/l	5-Na	5.66 mg/l	7-Sum of Ani	1.35 me/l
4-P Alk.	<0.6 mg/l CaCO3	5-Si	5.32 mg/l	7-Ion Balanc	-7.79 %
4-M Alk.	18 mg/l CaCO3	6-F	0.139 mg/l		
5-Al	<0.05 mg/l	6-Cl	7.51 mg/l		
5-Ca	3.07 mg/l	6-NO2	<0.2 mg/l		

Geo Pollution Technologies - Gauteng
81 Rauch Avenue, Georgeville, Meyerspark
Pretoria
0184
South Africa
Altus Huisamen
Tel: +27 12 804 8120
Fax: +27 12 804 8140
E-Mail: altus@gptglobal.com

FINAL CERTIFICATE OF ANALYSIS

Contract No	
Date Required	2015-02-19
Order/Ref No	MenCof-15-050
Page	3/4
Request ID	11418
Report Date	2015-02-25
Report Revision	0

sanas Testing Laboratory T0184

Reference: Carolina Mine Extension

Sample ID: 422005 Received: 2015-02-09 Matrix: Water
Sample Number: Carolina/Mine/Extension/VB1

1-pH	5.82	5-Fe	<0.05 mg/l	6-NO3	6.55 mg/l
1-pH Temp.	25 Deg C	5-K	12.1 mg/l	6-NO3 as N	1.48 mg/l
2-Tot Cond @25C	24.8 mSm	5-Mg	5.34 mg/l	6-PO4	<0.8 mg/l
3-TDS by EC*6.5	161 mg/l	5-Mn	0.21 mg/l	6-SO4	14.8 mg/l
3-TDS by EC*7	173 mg/l	5-Na	26.1 mg/l	7-Sum of Cat	2.11 me/l
4-P Alk.	<0.6 mg/l CaCO3	5-Si	5.53 mg/l	7-Sum of Ani	2.56 me/l
4-M Alk.	4.1 mg/l CaCO3	6-F	<0.1 mg/l	7-Ion Balanc	-9.67 %
5-Al	<0.05 mg/l	6-Cl	59.6 mg/l		
5-Ca	4.31 mg/l	6-NO2	<0.2 mg/l		

Sample ID: 422006 Received: 2015-02-09 Matrix: Water
Sample Number: Carolina/Mine/Extension/DS1

1-pH	6.34	5-Fe	0.62 mg/l	6-NO3	<0.3 mg/l
1-pH Temp.	25 Deg C	5-K	4.21 mg/l	6-NO3 as N	<0.3 mg/l
2-Tot Cond @25C	29.3 mSm	5-Mg	17 mg/l	6-PO4	<0.8 mg/l
3-TDS by EC*6.5	190 mg/l	5-Mn	1.02 mg/l	6-SO4	117 mg/l
3-TDS by EC*7	205 mg/l	5-Na	10.3 mg/l	7-Sum of Cat	3.09 me/l
4-P Alk.	<0.6 mg/l CaCO3	5-Si	4.18 mg/l	7-Sum of Ani	3.21 me/l
4-M Alk.	6.7 mg/l CaCO3	6-F	0.311 mg/l	7-Ion Balanc	-1.89 %
5-Al	<0.05 mg/l	6-Cl	11.9 mg/l		
5-Ca	21.5 mg/l	6-NO2	<0.2 mg/l		

Sample ID: 422007 Received: 2015-02-09 Matrix: Water
Sample Number: Carolina/Mine/Extension/DS5

1-pH	6.33	5-Fe	<0.05 mg/l	6-NO3	<0.3 mg/l
1-pH Temp.	25 Deg C	5-K	3.25 mg/l	6-PO4	<0.8 mg/l
2-Tot Cond @25C	28.9 mSm	5-Mg	10.2 mg/l	6-SO4	30.7 mg/l
3-TDS by EC*6.5	188 mg/l	5-Mn	0.83 mg/l	7-Sum of Cat	2.74 me/l
3-TDS by EC*7	202 mg/l	5-Na	27 mg/l	7-Sum of Ani	2.92 me/l
4-P Alk.	<0.6 mg/l CaCO3	5-Si	3.68 mg/l	7-Ion Balanc	-3.1 %
4-M Alk.	16.8 mg/l CaCO3	6-F	0.148 mg/l		
5-Al	<0.05 mg/l	6-Cl	61.2 mg/l		
5-Ca	12.3 mg/l	6-NO2	<0.2 mg/l		

Notes

#1 pH
#2 Electrical Conductivity
*3 Calculated Total Dissolved Solids from EC
#4 P and Total (M) Alkalinity
*5 Disolved Cations in Water by ICP-OES
#6 Anions by Ion Chromatography
*7 Ion Balance Error
SANAS accredited analysis included in the SANAS Schedule of Accredition for this laboratory.
* Not SANAS accredited analysis and not included in the SANAS schedule of accreditation for this laboratory.
$ Outsourced not performed by this laboratory.

The results relate specifically to the items tested.
The report shall not be reproduced except in full, without the written approval of the laboratory.

Geo Pollution Technologies - Gauteng
81 Rauch Avenue, Georgeville, Meyerspark
Pretoria
0184
South Africa
Altus Huisamen
Tel: +27 12 804 8120
Fax: +27 12 804 8140
E-Mail: altus@gptglobal.com

FINAL CERTIFICATE OF ANALYSIS

Contract No	
Date Required	2015-02-19
Order/Ref No	MenCof-15-050
Page	4/4
Request ID	11418
Report Date	2015-02-25
Report Revision	0

sanas Testing Laboratory T0184

Reference: Carolina Mine Extension

Ferdie van Niekerk
TECHNICAL SIGNATORY

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2014-07-21 **Date completed: 2014-08-06**
Project number: 123 **Report number: 47078** **Order number:**

Client name: GEO POLLUTION TECHNOLOGIES **Contact person: Altus Huisamen**
Address: P O Box 38384, Garsfontein East, 0060 **Email: altus@gptglobal.com**
Telephone: 012 804 8120 **Fax: 012 804 8140** **Cell: 083 352 0223**

Analyses	Sample Identification: GeoEast - 14-438			
	ESG134		ESG678	
Sample number	11468		11469	
TCLP / Acid Rain / Distilled Water / H_2O_2	Distilled Water		Distilled Water	
Dry Mass Used (g)	250		250	
Volume Used (mℓ)	1000		1000	
pH Value at 25˚C	4.4		6.4	
Electrical Conductivity in mS/m at 25˚C	42.9		6.4	
Units	mg/ℓ	mg/kg	mg/ℓ	mg/kg
Total Dissolved Solids at 180 ˚C	322	1 288	*61	244
Total Alkalinity as $CaCO_3$	<5	<20	<5	<20
Chloride as Cl	<5	<20	6	24
Sulphate as SO_4	203	812	42	168
Nitrate as N	<0.2	<0.8	<0.2	<0.8
ICP–OES Scan	See attached report 47078 ICP DW		See attached report 47078 ICP DW	
Acid Base Accounting	See attached report 47078 ABA		See attached report 47078 ABA	
X-Ray Diffraction [s]	See attached report 47078 XRD		See attached report 47078 XRD	

Please note:

- The blank was subtracted from all leach results, except pH and Electrical Conductivity.
- [s] = Subcontracted
- * TDS taken from balancing.

E. Botha
Geochemistry Project Manager

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2014-07-21 **Date completed: 2014-08-06**
Project number: 123 **Report number: 47078** **Order number:**

Client name: GEO POLLUTION TECHNOLOGIES **Contact person: Altus Huisamen**
Address: P O Box 38384, Garsfontein East, 0060 **Email: altus@gptglobal.com**
Telephone: 012 804 8120 **Fax: 012 804 8140** **Cell: 083 352 0223**

Analyses	Sample Identification: GeoEast - 14-438			
	ESG91011		ESG17	
Sample number	11470		11471	
TCLP / Acid Rain / Distilled Water / H_2O_2	Distilled Water		Distilled Water	
Dry Mass Used (g)	250		250	
Volume Used (mℓ)	1000		1000	
pH Value at 25˚C	4.7		4.5	
Electrical Conductivity in mS/m at 25˚C	13.5		9.7	
Units	mg/ℓ	mg/kg	mg/ℓ	mg/kg
Total Dissolved Solids at 180 ˚C	52	208	*51	204
Total Alkalinity as $CaCO_3$	<5	<20	<5	<20
Chloride as Cl	<5	<20	<5	<20
Sulphate as SO_4	38	152	36	144
Nitrate as N	0.4	1.6	0.4	1.6
ICP–OES Scan	See attached report 47078 ICP DW		See attached report 47078 ICP DW	
Acid Base Accounting	See attached report 47078 ABA		See attached report 47078 ABA	
X-Ray Diffraction [s]	See attached report 47078 XRD		See attached report 47078 XRD	

E. Botha
Geochemistry Project Manager

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2014-07-21 **Date completed: 2014-08-06**
Project number: 123 **Report number: 47078** **Order number:**

Client name: GEO POLLUTION TECHNOLOGIES **Contact person: Altus Huisamen**
Address: P O Box 38384, Garsfontein East, 0060 **Email: altus@gptglobal.com**
Telephone: 012 804 8120 **Fax: 012 804 8140** **Cell: 083 352 0223**

Analyses	Sample Identification: GeoEast - 14-438			
	ESG2021		ESGTSH	
Sample number	11472		11473	
TCLP / Acid Rain / Distilled Water / H_2O_2	Distilled Water		Distilled Water	
Dry Mass Used (g)	250		250	
Volume Used (mℓ)	1000		1000	
pH Value at 25˚C	4.9		5.0	
Electrical Conductivity in mS/m at 25˚C	4.0		79.2	
Units	mg/ℓ	mg/kg	mg/ℓ	mg/kg
Total Dissolved Solids at 180 ˚C	<10	<40	592	2 368
Total Alkalinity as $CaCO_3$	<5	<20	<5	<20
Chloride as Cl	<5	<20	<5	<20
Sulphate as SO_4	9	36	441	1 764
Nitrate as N	0.2	0.8	<0.2	<0.8
ICP–OES Scan	See attached report 47078 ICP DW		See attached report 47078 ICP DW	
Acid Base Accounting	See attached report 47078 ABA		See attached report 47078 ABA	
X-Ray Diffraction [s]	See attached report 47078 XRD		See attached report 47078 XRD	

E. Botha
Geochemistry Project Manager

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2014-07-21 **Date completed: 2014-08-06**
Project number: 123 **Report number: 47078** **Order number:**

Client name: GEO POLLUTION TECHNOLOGIES **Contact person: Altus Huisamen**
Address: P O Box 38384, Garsfontein East, 0060 **Email: altus@gptglobal.com**
Telephone: 012 804 8120 **Fax: 012 804 8140** **Cell: 083 352 0223**

Analyses	Sample Identification: GeoEast - 14-438			
	Pembali Mining 1		Pembali Mining Discard	
Sample number	11474		11475	
TCLP / Acid Rain / Distilled Water / H_2O_2	Distilled Water		Distilled Water	
Dry Mass Used (g)	250		250	
Volume Used (mℓ)	1000		1000	
pH Value at 25˚C	4.6		3.2	
Electrical Conductivity in mS/m at 25˚C	10.9		118	
Units	mg/ℓ	mg/kg	mg/ℓ	mg/kg
Total Dissolved Solids at 180 ˚C	*59	236	784	3 136
Total Alkalinity as $CaCO_3$	<5	<20	<5	<20
Chloride as Cl	<5	<20	<5	<20
Sulphate as SO_4	42	168	605	2 420
Nitrate as N	0.5	2.0	<0.2	<0.8
ICP–OES Scan	See attached report 47078 ICP DW		See attached report 47078 ICP DW	
Acid Base Accounting	See attached report 47078 ABA		See attached report 47078 ABA	
X-Ray Diffraction [s]	See attached report 47078 XRD		See attached report 47078 XRD	

E. Botha
Geochemistry Project Manager

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received: 2014-07-21 **Date completed:** 2014-08-06

Project number: 123 **Report number:** 47078 **Order number:**

Client name: GEO POLLUTION TECHNOLOGIES **Contact person:** Altus Huisamen

Address: P O Box 38384, Garsfontein East, 0060 **Email:** altus@gptglobal.com

Telephone: 012 804 8120 **Fax:** 012 804 8140 **Cell:** 083 352 0223

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification				
	ESG134	ESG678	ESG91011	ESG17	ESG2021
Sample Number	11468	11469	11470	11471	11472
Paste pH	5.8	7.0	6.6	6.0	6.1
Total Sulphur (%) (LECO)	0.30	0.02	0.04	0.05	0.02
Acid Potential (AP) (kg/t)	9.38	0.63	1.25	1.56	0.63
Neutralization Potential (NP)	0.50	1.50	2.00	0.25	1.75
Nett Neutralization Potential (NNP)	-8.88	0.87	0.75	-1.31	1.13
Neutralising Potential Ratio (NPR) (NP : AP)	0.05	2.40	1.60	0.16	2.80
Rock Type	I	III	III	II	III

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification			
	ESGTSH	Pembali Mining 1	Pembali Mining Discard	Pembali Mining Discard
Sample Number	11473	11474	11475	11475 D
Paste pH	6.4	6.1	4.2	4.2
Total Sulphur (%) (LECO)	0.09	0.07	0.20	0.20
Acid Potential (AP) (kg/t)	2.81	2.19	6.25	6.25
Neutralization Potential (NP)	-1.75	-0.50	-3.75	-3.00
Nett Neutralization Potential (NNP)	-4.56	-2.69	-10.00	-9.25
Neutralising Potential Ratio (NPR) (NP : AP)	0.62	0.23	0.60	0.48
Rock Type	II	II	II	II

*** Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH: 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.**

Please refer to Appendix (p.2) for a Terminology of terms and guidelines for rock classification

E. Botha
Geochemistry Project Manager

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received: 2014-07-21		**Date completed:** 2014-08-06
Project number: 123	**Report number:** 47078	**Order number:**
Client name: GEO POLLUTION TECHNOLOGIES		**Contact person:** Altus Huisamen
Address: P O Box 38384, Garsfontein East, 0060		**Email:** altus@gptglobal.com
Telephone: 012 804 8120	**Fax:** 012 804 8140	**Cell:** 083 352 0223

APPENDIX : TERMINOLOGY AND ROCK CLASSIFICATION

TERMINOLOGY (SYNONYMS)

- Acid Potential (AP) ; *Synonyms*: Maximum Potential Acidity (MPA)
  Method: Total S(%) (Leco Analyzer) x 31.25
- Neutralization Potential (NP) ; *Synonyms:* Gross Neutralization Potential (GNP) ; *Syn*: Acid Neutralization Capacity (ANC) (The capacity of a sample to consume acid)
  Method: Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)
- Nett Neutralization Potential (NNP) ; *Synonyms:* Nett Acid Production Potential (NAPP)
  Calculation: NNP = NP – AP ; NAPP = ANC – MPA
- Neutralising Potential Ratio (NPR)
  Calculation: NPR = NP : AP

CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)

If NNP (NP – AP) < 0, the sample has the potential to generate acid
If NNP (NP – AP) > 0, the sample has the potential to neutralise acid produced

Any sample with NNP < 20 is potentiall acid-generating, and any sample with NNP > -20 might not generate acid (Usher *et al*., 2003)

ROCK CLASSIFICATION

TYPE I	Potentially Acid Forming	Total S(%) > 0.25% and NP:AP ratio 1:1 or less
TYPE II	Intermediate	Total S(%) > 0.25% and NP:AP ratio 1:3 or less
TYPE III	Non-Acid Forming	Total S(%) < 0.25% and NP:AP ratio 1:3 or greater

E. Botha
Geochemistry Project Manager

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received: 2014-07-21		**Date completed:** 2014-08-06
Project number: 123	**Report number:** 47078	**Order number:**
Client name: GEO POLLUTION TECHNOLOGIES		**Contact person:** Altus Huisamen
Address: P O Box 38384, Garsfontein East, 0060		**Email:** altus@gptglobal.com
Telephone: 012 804 8120	**Fax:** 012 804 8140	**Cell:** 083 352 0223

CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)

Guidelines for screening criteria based on ABA (Price *et al*., 1997 ; Usher *et al*., 2003)

Potential for ARD	Initial NPR Screening Criteria	Comments
Likely	**< 1:1**	Likely AMD generating
Possibly	**1:1 – 2:1**	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides
Low	**2:1 – 4:1**	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
None	**>4:1**	No further AMD testing required unless materials are to be used as a source of alkalinity

CLASSIFICATION ACCORDING TO SULPHUR CONTENT (%S) AND NEUTRALISING POTENTIAL RATIO (NPR)

For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity but it is likely to be only of short-term significance. From these facts, and using the NPR values, a number of rules can be derived:

1) Samples with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation.
2) NPR ratios of >4:1 are considered to have enough neutralising capacity.
3) NPR ratios of 3:1 to 1:1 are consider inconclusive.
4) NPR ratios below 1:1 with Sulphide-S above 3% are potentially acid-generating. (Soregaroli & Lawrence, 1998 ; Usher *et al*., 2003)

E. Botha
Geochemistry Project Manager

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received: 2014-07-21		**Date completed:** 2014-08-06
Project number: 123	**Report number:** 47078	**Order number:**
Client name: GEO POLLUTION TECHNOLOGIES		**Contact person:** Altus Huisamen
Address: P O Box 38384, Garsfontein East, 0060		**Email:** altus@gptglobal.com
Telephone: 012 804 8120	**Fax:** 012 804 8140	**Cell:** 083 352 0223

REFERENCES

LAWRENCE, R.W. & WANG, Y. 1997**. Determination of Neutralization Potential in the Prediction of Acid Rock Drainage**. Proc. 4th International Conference on Acid Rock Drainage. Vancouver. BC. pp. 449 – 464.

PRICE, W.A., MORIN, K. & HUTT, N. 1997. **Guidelines for the prediction of Acid Rock Drainage and Metal leaching for mines in British Columbia** : Part 11. Recommended procedures for static and kinetic testing. In: Proceedings of the Fourth International Conference on Acid Rock Drainage. Vol 1. May 31 – June 6. Vancouver, BC., pp. 15 – 30.

SOBEK, A.A., SCHULLER, W.A., FREEMAN, J.R. & SMITH, R.M. 1978. **Field and laboratory methods applicable to overburdens and minesoils**. EPA-600/2-78-054. USEPA. Cincinnati. Ohio.

SOREGAROLI, B.A. & LAWRENCE, R.W. 1998. Update on waste Characterisation Studies. Proc. Mine Design, Operations and Closure Conference. Polson, Montana.

USHER, B.H., CRUYWAGEN, L-M., DE NECKER, E. & HODGSON, F.D.I. 2003. **Acid-Base : Accounting, Techniques and Evaluation (ABATE): Recommended Methods for Conducting and Interpreting Analytical Geochemical Assessments at Opencast Collieries in South Africa.** Water Research Commission Report No 1055/2/03. Pretoria.

ENVIRONMENT AUSTRALIA. 1997. **Managing Sulphidic Mine Wastes and Acid Drainage**.

E. Botha
Geochemistry Project Manager

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2014-07-21
Project number: 123
Report number: 47078
Date completed: 2014-08-06
Order number:

Client name: GEO POLLUTION TECHNOLOGIES
Address: P O Box 38384, Garsfontein East, 0060
Telephone: 012 804 8120
Fax: 012 804 8140
Contact person: Altus Huisamen
Email: altus@gptglobal.com
Cell: 083 352 0223

Composition (%) [s]

ESG134		ESG678		ESG91011	
11468		11469		11470	
Mineral	Amount (weight %)	**Mineral**	Amount (weight %)	**Mineral**	Amount (weight %)
Hematite	1.33	Hematite	0.37	Hematite	1.17
Kaolinite	25.07	Kaolinite	5.34	Kaolinite	21.69
Microcline	13.44	Microcline	9.15	Microcline	14.5
Muscovite	6.7	Muscovite	3.97	Muscovite	7.28
Quartz	53.47	Plagioclase	10.14	Quartz	55.4
		Quartz	28.61		
		Smectite1	37.98		
		Smectite2	4.43		

Composition (%) [s]

ESG17		ESG2021		ESGTSH	
11471		11472		11473	
Mineral	Amount (weight %)	**Mineral**	Amount (weight %)	**Mineral**	Amount (weight %)
Hematite	0.36	Hematite	1.04	Hematite	0.07
Kaolinite	9.97	Kaolinite	24.52	Kaolinite	2.34
Microcline	8.66	Microcline	10.91	Microcline	0.98
Muscovite	5.17	Muscovite	8.11	Muscovite	0.86
Quartz	38.85	Quartz	55.41	Quartz	95.75
Smectite	37				

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2014-07-21 **Date completed: 2014-08-06**
Project number: 123 **Report number: 47078** **Order number:**

Client name: GEO POLLUTION TECHNOLOGIES **Contact person: Altus Huisamen**
Address: P O Box 38384, Garsfontein East, 0060 **Email: altus@gptglobal.com**
Telephone: 012 804 8120 **Fax: 012 804 8140** **Cell: 083 352 0223**

Composition (%) [s]			
Pembali Mining 1		**Pembali Mining Discard**	
11474		**11475**	
Mineral	Amount (weight %)	**Mineral**	Amount (weight %)
Hematite	0.36	Hematite	0
Kaolinite	12.78	Kaolinite	32.45
Microcline	8.57	Microcline	10.88
Muscovite	4.85	Muscovite	8.56
Quartz	39.78	Quartz	48.12
Smectite	33.67		

[s] Results obtained from sub-contracted laboratory

Note:

Thematerial was prepared for XRD analysis using a backloading preparation method.
It was analysed with a PANalytical Empyrean diffractometer with PIXcel detector and fixed slits with Fe filtered Co-Kα radiation. The phases were identified using X'Pert Highscore plus software.

The relative phase amounts (weight%) were estimated using the Rietveld method.

Comment:

- Due to crystallite size effects results errors may be larger than shown.
- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.
- Sample 11469 seems to contain 2 smectite polytypes
- Smectite may be overestimated

Amorphous phases, if present, were not taken into account in the quantification

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2014-07-21 | **Date completed: 2014-08-06**
Project number: 123 | **Report number: 47078** | **Order number:**

Client name: GEO POLLUTION TECHNOLOGIES | **Contact person: Altus Huisamen**
Address: P O Box 38384, Garsfontein East, 0060 | **Email: altus@gptglobal.com**
Telephone: 012 804 8120 | **Fax: 012 804 8140** | **Cell: 083 352 0223**

Ideal Mineral Composition	
Hematite	Fe2O3
Kaolinite	Al2 Si2 O5 (OH)4
Microcline	K Al Si3 O8
Muscovite	K Al2 ((OH)2 Al Si3 O10)
Plagioclase	(Na,Ca)(Si,Al)4O8
Quartz	SiO2
Smectite (Montmorillonite)	(Na,Ca)0,3(Al,Mg)2Si4O10(OH)2•n(H2O)

The information contained in this report is relevant only to the sample/samples supplied to **WATERLAB (Pty) Ltd**. Any further use of the above information is not the responsibility or liability of **WATERLAB (Pty) Ltd.** Except for the full report, parts of this report may not be reproduced without written approval of **WATERLAB (Pty) Ltd**.

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-OES - SCAN

Date received:	2014-07-21	**Date Completed:**	2014-08-06
Project number:	123	**Report number:**	47078

Client name:	GEO POLLUTION TECHNOLOGIES	**Contact person:**	Altus Huisamen
Adress:	P O Box 38384, Garsfontein East, 0060	**Email:**	altus@gptglobal.com
Telephone:	012 804 8120	**Facsimile:**	012 804 8140

Extract	Sample Dry Mass	Volume	Mass (g/l)	Factor
	250	1000	250	4

Sample Id	Sample number	Ag	Ag	Al	Al	As	As
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.100	<0.400	<0.010	<0.040
ESG134	11468	<0.025	<0.100	0,332	1,33	<0.010	<0.040
ESG678	11469	<0.025	<0.100	1,04	4,15	<0.010	<0.040
ESG91011	11470	<0.025	<0.100	<0.100	<0.400	<0.010	<0.040
ESG17	11471	<0.025	<0.100	<0.100	<0.400	<0.010	<0.040
ESG2021	11472	<0.025	<0.100	<0.100	<0.400	<0.010	<0.040
ESGTSH	11473	<0.025	<0.100	0,475	1,90	<0.010	<0.040
Pembali Mining 1	11474	<0.025	<0.100	<0.100	<0.400	<0.010	<0.040
Pembali Mining Discard	11475	<0.025	<0.100	16	64	<0.010	<0.040

Sample Id	Sample number	B	B	Ba	Ba	Be	Be
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESG134	11468	1,35	5,38	0,063	0,252	<0.025	<0.100
ESG678	11469	0,030	0,120	0,045	0,180	<0.025	<0.100
ESG91011	11470	<0.025	<0.100	0,062	0,248	<0.025	<0.100
ESG17	11471	<0.025	<0.100	0,048	0,192	<0.025	<0.100
ESG2021	11472	<0.025	<0.100	0,054	0,216	<0.025	<0.100
ESGTSH	11473	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
Pembali Mining 1	11474	0,066	0,264	0,053	0,212	<0.025	<0.100
Pembali Mining Discard	11475	<0.025	<0.100	<0.025	<0.100	0,030	0,120

Sample Id	Sample number	Bi	Bi	Ca	Ca	Cd	Cd
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<2	<8	<0.005	<0.020
ESG134	11468	<0.025	<0.100	38	152	<0.005	<0.020
ESG678	11469	<0.025	<0.100	4	16	<0.005	<0.020
ESG91011	11470	<0.025	<0.100	7	28	<0.005	<0.020
ESG17	11471	<0.025	<0.100	3	12	<0.005	<0.020
ESG2021	11472	<0.025	<0.100	<2	<8	<0.005	<0.020
ESGTSH	11473	<0.025	<0.100	89	356	<0.005	<0.020
Pembali Mining 1	11474	<0.025	<0.100	3	12	<0.005	<0.020
Pembali Mining Discard	11475	<0.025	<0.100	38	152	<0.005	<0.020

Sample Id	Sample number	Co	Co	Cr	Cr	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESG134	11468	0,199	0,796	<0.025	<0.100	<0.025	<0.100
ESG678	11469	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESG91011	11470	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESG17	11471	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESG2021	11472	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESGTSH	11473	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
Pembali Mining 1	11474	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
Pembali Mining Discard	11475	0,749	3,00	<0.025	<0.100	<0.025	<0.100

Sample Id	Sample number	Fe	Fe	K	K	Li	Li
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<1.0	<4.00	<0.025	<0.100
ESG134	11468	0,045	0,180	6,1	24	<0.025	<0.100
ESG678	11469	0,751	3,00	<1.0	<4.00	<0.025	<0.100
ESG91011	11470	<0.025	<0.100	4,7	18,7	<0.025	<0.100
ESG17	11471	0,039	0,156	4,2	16,9	<0.025	<0.100
ESG2021	11472	<0.025	<0.100	1,8	7,4	<0.025	<0.100
ESGTSH	11473	0,089	0,356	6,8	27	<0.025	<0.100
Pembali Mining 1	11474	0,028	0,112	4,5	17,9	<0.025	<0.100
Pembali Mining Discard	11475	0,325	1,30	7,9	32	<0.025	<0.100

Sample Id	Sample number	Mg	Mg	Mn	Mn	Mo	Mo
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<2	<8	<0.025	<0.100	<0.025	<0.100
ESG134	11468	14	56	7,66	31	<0.025	<0.100
ESG678	11469	2	8	0,039	0,156	<0.025	<0.100
ESG91011	11470	5	20	0,419	1,68	<0.025	<0.100
ESG17	11471	3	12	0,038	0,152	<0.025	<0.100
ESG2021	11472	<2	<8	0,087	0,348	<0.025	<0.100
ESGTSH	11473	37	148	3,51	14	<0.025	<0.100
Pembali Mining 1	11474	4	16	0,050	0,200	<0.025	<0.100
Pembali Mining Discard	11475	73	292	1,93	7,72	<0.025	<0.100

Sample Id	Sample number	Na	Na	Ni	Ni	P	P
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<2	<8	<0.025	<0.100	<0.025	<0.100
ESG134	11468	3	12	0,088	0,352	<0.025	<0.100
ESG678	11469	4	16	<0.025	<0.100	<0.025	<0.100
ESG91011	11470	3	12	<0.025	<0.100	<0.025	<0.100
ESG17	11471	3	12	<0.025	<0.100	<0.025	<0.100
ESG2021	11472	<2	<8	<0.025	<0.100	<0.025	<0.100
ESGTSH	11473	4	16	<0.025	<0.100	<0.025	<0.100
Pembali Mining 1	11474	3	12	<0.025	<0.100	0,107	0,428
Pembali Mining Discard	11475	2	8	2,04	8,16	<0.025	<0.100

Sample Id	Sample number	Pb	Pb	Sb	Sb
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.020	<0.080	<0.010	<0.040
ESG134	11468	<0.020	<0.080	<0.010	<0.040
ESG678	11469	<0.020	<0.080	<0.010	<0.040
ESG91011	11470	<0.020	<0.080	<0.010	<0.040
ESG17	11471	<0.020	<0.080	<0.010	<0.040
ESG2021	11472	<0.020	<0.080	<0.010	<0.040
ESGTSH	11473	<0.020	<0.080	<0.010	<0.040
Pembali Mining 1	11474	<0.020	<0.080	<0.010	<0.040
Pembali Mining Discard	11475	<0.020	<0.080	<0.010	<0.040

Sample Id	Sample number	Se	Se	Si	Si	Sn	Sn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.020	<0.080	<0.200	<0.800	<0.025	<0.100
ESG134	11468	<0.020	<0.080	4,2	16,8	<0.025	<0.100
ESG678	11469	<0.020	<0.080	9,5	38	<0.025	<0.100
ESG91011	11470	<0.020	<0.080	3,6	14,3	<0.025	<0.100
ESG17	11471	<0.020	<0.080	3,9	15,5	<0.025	<0.100
ESG2021	11472	<0.020	<0.080	3,6	14,3	<0.025	<0.100
ESGTSH	11473	<0.020	<0.080	2,3	9,4	<0.025	<0.100
Pembali Mining 1	11474	<0.020	<0.080	4,9	19,4	<0.025	<0.100
Pembali Mining Discard	11475	<0.020	<0.080	6,1	24	<0.025	<0.100

Sample Id	Sample number	Sr	Sr	Ti	Ti	V	V
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESG134	11468	0,237	0,948	<0.025	<0.100	<0.025	<0.100
ESG678	11469	<0.025	<0.100	0,030	0,120	<0.025	<0.100
ESG91011	11470	0,043	0,172	<0.025	<0.100	<0.025	<0.100
ESG17	11471	0,030	0,120	<0.025	<0.100	<0.025	<0.100
ESG2021	11472	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESGTSH	11473	0,663	2,65	<0.025	<0.100	<0.025	<0.100
Pembali Mining 1	11474	0,038	0,152	<0.025	<0.100	<0.025	<0.100
Pembali Mining Discard	11475	0,468	1,87	<0.025	<0.100	<0.025	<0.100

Sample Id	Sample number	W	W	Zn	Zn	Zr	Zr
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESG134	11468	<0.025	<0.100	0,099	0,396	<0.025	<0.100
ESG678	11469	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESG91011	11470	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESG17	11471	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESG2021	11472	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
ESGTSH	11473	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
Pembali Mining 1	11474	<0.025	<0.100	<0.025	<0.100	<0.025	<0.100
Pembali Mining Discard	11475	<0.025	<0.100	2,45	9,80	<0.025	<0.100

Schlumberger
Water Services

Office 0004, Building H3
Ground Floor
10 Melrose Blvd
Melrose Arch
Melrose North
2196 – Johannesburg
South Africa

TEL: +27 11 684 1122
FAX: +27 86 579 6034

MEMORANDUM

To: Ms. Annelie Rossouw
Environmental Coordinator
Landau Colliery
Clewer
Witbank/Mpumalanga
South-Africa
CC:
Project No.: 53393.R TM01v2
From: Hugo Marais
Date: 13 January 2015
Pages: 10 not including Appendices & Figures

SUBJECT: UPDATE - FIELD-SCALE KINETIC TESTING OF LANDAU COLLIERY COAL WASTE

1 Introduction

Schlumberger Water Services (SWS) has been retained by Anglo American Thermal Coal (AATC) to design and construct of a set of on-site column tests for assessment of the acid rock drainage (ARD) and metal leaching (ML) characteristics of coal and production waste rock at the company's Landau Colliery, located near Witbank in Mpumulanga Province, South Africa. Such kinetic tests are anticipated to be of direct value for refinement of predictions long-term mine decant water quality at Landau. The field columns were established on site during December 2013 and augmented in November 2014, with initial leachate sampling undertaken following the onset of sufficient rainfall to irrigate the columns in April 2014. A site locality map is included in Figure 1-1.

Previous ARD/ML hazard assessment of waste or spoil materials from Landau has been undertaken only using static tests such as acid base accounting (ABA). Kinetic tests differ from static' test procedures by elucidating not only the net balance of acid forming and acid consuming mineral phases in rock material, but also the relative rates of reaction of these phases during weathering. As such, they assist in determining the time period over which acid contact water may evolve (often associated with the exhaustion of matrix buffering minerals such as carbonates, or an increase of sulphide oxidation rate to a level which overwhelms buffering capacity at some critical threshold point during the rock weathering process). They may also determine the duration over which acid production may be anticipated to continue (as determined by the progression of the sulphide oxidation process to complete sulphide mass exhaustion).

This technical memorandum documents the set-up details of nine tests established at Landau in December 2013 along with results of initial sampling and analysis performed to April 2014 and subsequently in December 2014.

1.1 Objectives

The central objective of the column tests is to assess under field conditions the effects of concurrent acid generation (principally sulphide oxidation) and buffering in a manner which replicates to the greatest possible extent the reaction kinetics which can be anticipated during the infiltration of rainwater through waste/spoil and stockpiled coal, or during ingress to open pit and/or underground workings.

Results from kinetic tests are commonly used in isolation for closure planning to provide 'high level' estimation of the following key factors:

- Anticipated post-closure trends of water quality deterioration or improvement (in terms of mine water pH, TDS, sulphate, metals).
- The potential for onset of ARD following prolonged weathering of mine rock or spoil.
- The time frame over which ARD generation may persist, as dictated by the rate of oxidation to exhaustion of the reactive sulphide mass in mine rock or waste.

The analytical interpretation of these results is applicable to support ARD risk management including:

1. Optimization of LOM waste management, and
2. Definition of closure and rehabilitation measures for the waste commensurate with long-term ARD risks.

2 Project description

The Landau Colliery encompasses two essentially independent operations, Kromdraai to the northwest of Witbank and Navigation to the south. Mining at Landau dates back to the late 19th century, however, the current Landau operation commenced production in 1990. In conjunction, the Kromdraai and Navigation operations produce in excess of 4 MT of coal annually, approximately 75% of which serves the export market.

The Witbank district hosts extensive coal deposits within the Karoo System. At Landau, the local stratigraphy is dominated by sandstone and interbedded coal/carbonaceous sediments of the Vryheid Formation. This forms a component of the Ecca Group. The sequence is invaded by dolerite dykes, as is characteristic of much of the Karoo of Mpumalanga Province.

Coal at the two operations has historically been exploited by both opencast and underground mining. The current mine plan contemplates the extension of opencast workings into formerly mined underground compartments. The final pit configuration will comprise:

- Kromdraai: four opencast pits plus historic underground workings (until 2017)
  - North Block opencast and underground workings (completed and largely rehabilitated)
  - Central Block opencast with historic underground workings
  - South Block underground workings
  - Excelsior/Turnbull opencast and with underground workings
- Navigation: five opencast pits plus historic underground workings (until 2025)
  - Schoongezicht East (including Mini Pit) opencast
  - Schoongezicht West opencast
  - Navigation East 1 opencast
  - Navigation East 2 opencast
  - Navigation East 3 opencast
  - Underground workings (historic).

A recent addition is the Umlalazi North and South opencast of the number 4 coal seam, totaling almost 265 ha.

3 Sample details

3.1 Sample collection

A total of six barrel tests were constructed at Landau Colliery in December 2013. Two barrels were set up at each of three sites, containing rock samples from each one:

- Umlalazi Pit - Collected from the dove stockpile and backfill material form the Minipit.
- Kromdraai Pit - Collected from the Kromdraai crusher spills at the conveyor and backfill material from the North Block.
- Schoongezicht Pit (Navigation) - Collected from the Schoongezicht crusher (first crusher at bottom of conveyor) and backfill material from the Minipit. The sample material collected was send to be crushed finer (no leach sample collected to date).

Table 3-1 provides the collection details of each barrel sample. Sub-samples of approximately 2 kg each were collected from each of the 6 barrel samples for laboratory analysis.

Table 3-1 Barrel sample details

Barrel ID	Location	Sample collected from	Rock mass (kg)
UML-1	Umlalazi pit	Dove stockpile	Approx. 300
UML-2	Umlalazi Minipit	Backfill material	Approx. 300
KROM-1	Kromdraai pit	Crusher spills at conveyor	Approx. 300
KROM-2	Kromdraai North Block	Backfill material	Approx. 300
NAV-1	Schoongezicht pit (Navigation)	1st crusher at bottom of conveyor	Approx. 300
NAV-2	Schoongezich Minipit	Backfill material	Approx. 300

3.2 Static test geochemical characterization

3.2.1 Static test suite

Sub-samples of each column test sample (approximately 2 kg) were collected for use in static test characterization and particle size analyses. The following tests were conducted at Maxxam Analytics laboratory in Burnaby, Canada:

- Acid-base accounting (ABA) package (includes paste pH, fizz rating, modified Neutralization Potential (NP) & total S by Leco)
- Sulphur speciation (sulphate sulphur and sulphide sulphur)
- Single Addition Net Acid Generation (NAG)
- Trace metals using aqua regia digestion & ICP-MS finish
- Whole rock analysis
- Particle size analysis

3.2.2 Static test results

Acid-base accounting

ABA test results are shown in Table 3-2. The three samples from Kromdraai are classifiable as net acid generating. The samples from Schoongezicht (Navigation) and Umlalazi are slightly net acid neutralizing with the exception of UML-3 (backfill) which is classed as net acid generating. Note that the 3rd sample of each location is representative of the backfill material at each individual site.

The UML samples contain an average of 0.34% S (wt.) which is present almost exclusively as sulphide S. Acid generating potential (AP) values are thus around 10 kg CaCO3/t. Neutralization potential (NP) is 24-25 kg CaCO3/t in samples UML-1 and UML-2, resulting in a positive Net Neutralization Potential (NNP) of around 15 kg CaCO3/t for these samples; however sample UML-3 (backfill) contains no neutralization capacity

The NAV samples contain average 1.05% S (wt.), half of which is present as sulphate in sample NAV-1. The NAV samples exhibit the highest NP values of the three locations, at average 44 kg CaCO3/t, and AP varies from 7.8 kg CaCO3/t in NAV-3 to 49 kg/t in NAV-2, resulting in variable NNPs (4 – 27 kg/t CaCO3).

The KROM samples exhibit net potentially acid generating characteristics with an average total S value of 0.88% (wt.) of which almost half is sulphate S in sample KROM-2. The KROM samples yielded negative NPs of -2 to -15 kg/t CaCO3 (consistent with stored sulphate acidity), with negative NNPs of -5 to -43kg/t.

Table 3-2 ABA test results

Sample ID	Paste pH	Total Carbon	Total S	HCl Extractable Sulphur	Sulphide Sulphur (by diff.)	Acid Generation Potential	Mod. ABA Neutralization Potential	Fizz Rating	Net Neutralization Potential	Neutralization Potential Ratio
Units	**pH Units**	**wt%**	**wt%**	**wt%**	**wt%**	**Kg CaCO3/T**	**Kg CaCO3/T**	**N/A**	**Kg CaCO3/T**	**N/A**
UML-1	7.79	72.30	0.32	<0.01	0.32	10.0	25.0	NONE	15.0	2.5
UML-2	7.72	76.20	0.35	0.04	0.31	9.7	24.0	NONE	14.3	2.5
UML-3	4.99	9.68	0.35	0.06	0.29	9.1	-0.300	NONE	-9.40	N/A
KROM-1	2.53	52.80	1.15	0.04	1.11	34.7	-8.00	NONE	-42.7	N/A
KROM-2	2.26	53.30	1.25	0.59	0.66	20.6	-14.5	NONE	-35.1	N/A
KROM-3	3.68	6.10	0.25	0.16	0.09	2.8	-2.30	NONE	-5.10	N/A
NAV-1	7.73	56.80	1.23	0.41	0.82	25.6	52.5	SLIGHT	26.9	2.1
NAV-2	7.49	56.20	1.63	0.05	1.58	49.4	53.8	SLIGHT	4.40	1.1
NAV-3	7.42	23.16	0.29	0.04	0.25	7.8	24.5	SLIGHT	16.7	3.1

Net acid generation (NAG) tests

NAG tests are designed to measure the acidity generated upon oxidation of all sulphide material in the sample. NAG test results are shown in Table 3-3.

NAG pH values of 2.3 to 3.6 were observed from the UML and KROM samples. The NAV samples NAG pH ranged from 3.6 to 8.8.

Samples UML-1 and UML-2 yield the highest NAG acidity values of around 140-145 kg/t H_2SO_4 at pH 4.5 and 220 kg/t H_2SO_4 at pH 7, contrasted by UML-3 with a low NAG acidity of 12 kg/t H_2SO_4 at pH 7.

KROM-1 and KROM-2 show NAG acidity values of around 30-35 kg/t at pH 4.5 and 50 kg/t at pH 7; while KROM-3, with a similar NAG pH of 2.5, shows negligible levels of acidity (2.4 kg/t H_2SO_4 at pH 4.5 and 8.2 kg/t at pH 7.

All three NAV samples yielded relatively low or negligible NAG acidities.

Table 3-3 NAG test results

Sample ID	NAG pH	NAG Volume to pH 4.5	NAG Volume to pH 7.0	NAG NaOH Conc.	NAG Acidity pH 4.5	NAG Acidity pH 7.0
Units	**pH Units**	**mL**	**mL**	**N**	**Kg H2SO4/T**	**Kg H2SO4/T**
UML-1	2.41	73.90	112.50	0.1	145	221
UML-2	2.30	72.50	110.80	0.1	142	217
UML-3	3.54	1.80	6.00	0.1	3.53	11.8
KROM-1	2.41	15.50	24.80	0.1	30.4	48.6
KROM-2	2.36	17.90	25.90	0.1	35.1	50.8
KROM-3	3.55	1.20	4.20	0.1	2.35	8.23
NAV-1	8.22	0.00	0.00	0.1	0.00	0.00
NAV-2	3.56	1.70	10.90	0.1	3.33	21.4
NAV-3	8.75	0.00	0.00	0.1	0.00	0.00

Trace metals and whole rock analysis

Trace metals (Table 3-4) and major oxides (Table 3-5) were analyzed by ICP-MS on all samples following aqua regia digestion. Manganese is significantly higher (201 - 338 ppm) in the NAV samples than the others which range 78-93 ppm in UML and 16-71 ppm in KROM. No other significant correlations by location are apparent.

Table 3-4 Trace metals

Sample ID	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th	Sr	Cd	Sb	Bi	V	Ca	P	La	Cr	Mg	Ba	Ti	B	Al	Na	K	W	Hg	Sc	Tl	S	Ga	Se	Te
Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	%	ppm	%	%	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
UML-1	0.2	11.7	4.8	3	<0.1	4.9	1.8	80	0.08	<0.5	1.3	<0.5	3.7	218	<0.1	<0.1	0.7	17	0.98	0.112	16	7	0.05	100	0.007	<20	0.20	0.004	0.02	<0.1	0.02	3.6	<0.1	0.17	1	<0.5	<0.2
UML-2	0.2	10.8	3.5	2	0	4.9	1.9	93	0.08	<0.5	1.3	<0.5	4.0	253	<0.1	<0.1	0.7	18	1.03	0.133	20	7	0.05	102	0.007	<20	0.19	0.004	0.02	<0.1	0.02	3.3	<0.1	0.17	1	<0.5	<0.2
UML-3	2.3	24.3	14.3	17	<0.1	13.7	7.9	78	2.29	16.1	2.0	0.6	8.3	33	<0.1	0.2	0.8	30	0.08	0.010	16	70	0.04	135	0.004	<20	0.36	0.004	0.07	<0.1	0.21	5.3	<0.1	0.24	3	<0.5	<0.2
KROM-1	1.5	12.8	21.9	16	<0.1	8.4	4.9	17	0.91	1.9	1.4	<0.5	4.8	171	<0.1	0.2	0.7	17	0.05	0.034	11	33	<0.01	248	0.006	<20	0.36	0.003	0.03	<0.1	0.20	2.8	<0.1	0.97	2	0.6	<0.2
KROM-2	1.2	18.4	22.5	19	<0.1	8.3	4.5	16	0.93	2.4	1.5	<0.5	6.7	228	0.1	0.1	0.8	16	0.06	0.045	14	34	<0.01	232	0.005	<20	0.39	0.001	0.02	<0.1	0.16	3.8	<0.1	1.14	2	0.5	<0.2
KROM-3	1.0	24.6	15.5	55	<0.1	18.2	9.0	71	0.99	3.6	1.1	1.0	4.5	20	0.1	<0.1	0.4	24	0.02	0.007	7	83	0.02	235	0.005	<20	0.41	0.004	0.07	<0.1	0.14	4.0	0.1	0.22	2	<0.5	<0.2
NAV-1	0.9	15.6	24.2	16	<0.1	5.0	3.6	388	2.55	8.7	1.6	0.8	8.0	288	<0.1	0.1	0.8	16	1.88	0.170	23	15	0.37	229	0.005	<20	0.38	0.006	0.03	<0.1	0.19	4.4	<0.1	1.15	2	0.6	<0.2
NAV-2	1.3	15.5	20.0	15	<0.1	5.4	3.1	201	1.63	4.9	1.5	<0.5	8.3	273	0.1	<0.1	0.8	14	1.81	0.135	22	13	0.34	144	0.005	<20	0.34	0.004	0.03	<0.1	0.32	3.6	<0.1	1.59	2	<0.5	<0.2
NAV-3	0.8	24.8	19.3	53	<0.1	16.9	9.5	229	1.55	3.4	2.0	<0.5	9.7	140	0.1	0.1	0.7	33	0.95	0.030	25	69	0.23	273	0.015	<20	0.54	0.006	0.10	<0.1	0.08	5.9	<0.1	0.20	3	0.6	<0.2

Table 3-5 Whole rock analysis

Sample ID	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	Cr2O3	Ba	Ni	Sr	Zr	Y	Nb	Sc	LOI	Total
Units	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%
UML-1	6.19	3.99	0.26	0.10	1.48	0.01	0.12	0.25	0.30	<0.01	0.005	158	<20	477	85	17	<5	5	87.2	100
UML-2	5.89	3.71	0.16	0.09	1.52	<0.01	0.09	0.26	0.34	<0.01	0.007	162	<20	502	85	19	<5	5	87.8	100
UML-3	61.4	14.7	3.59	0.17	0.12	0.02	0.75	0.73	0.08	<0.01	0.025	317	<20	259	295	33	19	11	18.3	100
KROM-1	20.1	8.25	1.76	0.04	0.08	0.01	0.19	0.52	0.14	<0.01	0.012	408	<20	297	190	20	14	7	68.7	99.9
KROM-2	18.8	8.81	1.66	0.03	0.08	0.01	0.16	0.47	0.15	<0.01	0.011	655	<20	314	161	19	13	7	69.6	99.9
KROM-3	67.7	14.1	1.64	0.09	0.03	0.02	0.96	0.91	0.07	<0.01	0.031	419	22	135	540	37	22	11	14.3	100
NAV-1	13.3	7.67	4.44	0.68	2.77	0.02	0.22	0.48	0.43	0.05	0.007	339	<20	338	127	23	12	8	69.8	99.9
NAV-2	14.4	8.27	3.15	0.65	2.72	0.02	0.24	0.51	0.37	0.03	0.007	363	<20	355	143	23	11	8	69.4	99.9
NAV-3	44.8	14.4	2.64	0.46	1.28	0.03	0.82	0.78	0.12	0.03	0.024	490	25	260	283	34	19	13	34.4	100

4 Barrearrel test setup

The three pairs of column or barrel tests set up at the Umlalazi, Kromdraai and Navigation were constructed in accordance with guidelines produced by SWS as detailed in previous technical memoranda to Landau Colliery, as included in Appendix A:

- Sampling procedure for barrel leachates (Appendix A).

The selected field column format has been used widely by ARD assessment at a wide range of coal, base metals and gold mining operations worldwide and conforms to industry standards for field-based kinetic testing. The columns comprise HDPE barrels filled with a mass of crushed rock of a composition representative of the major coal and inter-bed units mined or stored as waste. The barrels are left open to natural irrigation by rainwater. Infiltrating water drains through the rock sample in the barrels and through a hole at the base and into collection containers. The leachate is then sampled periodically for on-site pH and EC analysis, plus laboratory analysis for major/trace cations and anions.

The selection of HDPE barrels for the Landau kinetic tests was in part based on their tendency to impede excessive oxygen ingress from the sides and base of the rock mass, thus better representing conditions in the interior of large waste rock facilities. Barrels, as opposed to narrower diameter columns, also minimize the by-passing of infiltration down the inner walls of the column.

The Landau barrel tests, viewed in Figures 4-1 to 4-3, were constructed using the following material specifications:

- 6 x HDPE rigid plastic barrels, with an approximate volume of 200 litres.
- 6 x sealable, graduated tanks for solution collection, of approximately 30 litres.
- Tubing, mesh (preclude blocking of the drainage system by rock fragments) and sealant to ensure watertight seals between the barrels and collection tanks.

Locations for the three sets of barrel pairs were selected by Landau Colliery staff at each of the Umlalazi, Kromdraai and Navigation sites. The following considerations were made regarding barrel test locations:

- Open areas away from buildings or trees that may offer shadow or shade.
- Away from roads and tracks to minimise dust deposition on the rock surfaces within the barrels.
- Elevation/aspect such that precipitation levels are analogous to those comparable with on-site weather stations.

The barrels were mounted onto benches to permit access to the base of the barrels and to provide space for the positioning of collection tanks and tubing beneath each barrel, as seen in Figures 4-1 to 4-3. SWS provided the basic plans to Landau Colliery for the construction of plinths or benches onto which the barrels were positioned. Each barrel was then filled with the relevant crushed rock sample to within approximately 15 cm of the rim.

Since construction of the barrel tests, each rock matrix has been allowed to be irrigated naturally by rainfall. This percolates through the rock mass and reports to the collection buckets beneath each barrel. The transparent leachate buckets require monitoring on a monthly basis. The volume of leachate collected must be recorded and sampling is to be completed following the sampling procedure provided (Appendix A) including dispatch for laboratory analysis. If insufficient leachate for sampling is collected, this must also be recorded. Following each monthly monitoring/sampling event, the leachate collection buckets must be emptied ready for the ensuing cycle.

5 Barrel test leachate results

The initial flush of leachate from the test columns was sampled on 11th April, 2014. Precipitation from January through March 2014 did not produce leachate sufficient for monitoring purposes. During the 11th April monitoring event, leachate was sampled from all UML and KROM barrels; however no sample was available from the NAV barrels (re-crushing).

The two UML barrel leachate samples had neutral-alkaline pH values of 7.5 - 8.0 with alkalinities of 30 - 79 mg/L. Sulphate concentrations were elevated at 830 – 1,300 mg/L for these samples. Ca, Mg, Na and K are all elevated in these leachates with average concentrations of 313, 141, 58 and 33 mg/L, respectively. Other metal concentrations are generally low or below detection limits including Fe, Mn, Al, Cd, Cr, Cu, Ni and Zn. An exception was lead which measured 0.02 mg/L in both samples.

The leachates from both KROM barrels were highly acidic with pH values 1.30 - 1.39 and acidity in the range of 47,000 – 56,000 mg/L $CaCO_3$. Most solute concentrations were observed at high elevations, including sulphate in excess of 40,000 mg/L, Fe around 20,000 mg/L, Mn up to 27 mg/L, Al 1,400 mg/L, Cd 0.8 mg/L, Cu 10 mg/L, Ni 6 mg/L and Zn at 21 mg/L. Pb and Se read at sub-detection limits, though Si was elevated in both samples to almost 60 mg/L.

Table 5-1 Initial leachate results (April 2014)

Parameter	Unit	UML-1	UML-2	KROM-1	KROM-2
pH	pH U	8.02	7.50	1.39	1.30
Nitrate & Nitrite as N	mg/L	1.10	0.70	2.80	4.30
Cl	mg/L	8.23	6.50	15.3	17.6
Alkalinity	mg/L	79	30	Nil	Nil
F	mg/L	0.54	0.41	<0.20	<0.20
Sulphate	mg/L	1291	837	39125	44808
Total Hardness as $CaCO_3$	mg/L	1682	1309	1070	795
Calcium Hardness as $CaCO_3$	mg/L	982	582	787	707
Magnesium Hardness as $CaCO_3$	mg/L	700	457	283	88
Ca	mg/L	393	233	315	283
Mg	mg/L	170	111	68.7	21.5
Na	mg/L	73.0	42.5	4.6	6.10
K	mg/L	39.1	26.5	0.28	1.25
Fe	mg/L	0.23	0.15	18240	22570
Mn	mg/L	<0.01	<0.01	27.2	8.50
EC	mS/m	229	158	2270	2610
Al	mg/L	0.17	0.11	1437	857
Cd	mg/L	<0.003	<0.003	0.53	0.851
Cr	mg/L	<0.01	<0.01	1.2	0.67
Cu	mg/L	<0.01	<0.01	9.33	10.9
Ni	mg/L	<0.01	<0.01	5.91	4.74
Pb	mg/L	0.02	0.02	<0.01	<0.01
Se	mg/L	<0.01	<0.01	<0.01	<0.01
B	mg/L	0.05	0.04	<0.01	<0.01
Si	mg/L	2.74	1.89	59.10	58.0
V	mg/L	<0.01	<0.01	1.04	1.50
Zn	mg/L	0.02	<0.01	25.1	21.4

Ba	mg/L	0.08	0.07	<0.01	<0.01
Co	mg/L	<0.01	<0.01	4.80	3.36
Free and Saline Ammonia NH_3 as N	mg/L	1.52	<0.20	4.9	8.6
Ortho Phosphate PO_4 as P	mg/L	<0.1	<0.1	<0.1	<0.1
Total Acidity as $CaCO_3$ to pH 8.3	mg/L	<2.0	8.13	47476	55726

6 Summary

Six on-site kinetic ARD tests have been set up adjacent to three different operational areas at AATC's Landau Colliery, near Whitbank, South Africa. The three barrel pairs contain rock samples from the Umlalazi pit stockpile and backfill from the Minipit, Kromdraai pit crusher and backfill from the North Block and from the Schoongezicht pit (Navigation) crusher and backfill from the Minipit, which are open to site climatic conditions and are irrigated by natural rainfall.

A 2 kg sub-sample from each of the barrels was sent to Maxxam Analytics laboratory in Canada, where a suite of industry standard ARD static tests were conducted, including ABA, NAG, whole rock and trace metals analyses, to define the sample compositions and theoretical potential for ARD generation. Results show that the samples from Kromdraai are classifiable as net acid generating, while the samples from Schoongezicht (Navigation) and Umlalazi are slightly net acid neutralizing with the exception of UML-3 (backfill) which is also classed as net acid generating.

A monthly monitoring/sampling program for the barrels is in place, and since the barrels' construction in December 2013, leachate has been generated from the Umlalazi and Kromdraai barrels in April 2014. This was sampled on 11th April and analyzed at the onsite laboratory. The UML leachates were pH neutral-alkaline with elevated sulphate, Ca, Mg, Na and K concentrations but generally negligible concentrations of other metals. The KROM leachates, however were strongly acidic showing pH suppression to 1.3 and extremely elevated concentrations of sulphate (>40,000 mg/L) and many metals (including Fe around 20,000 mg/L, Mn <27 mg/L, Al 1,400 mg/L and Cu 10 mg/L).

Since these results were provided, the contents of one of the barrels at each location has been replaced with its representative backfill material, and will potentially provide first flush results following the rainy season.

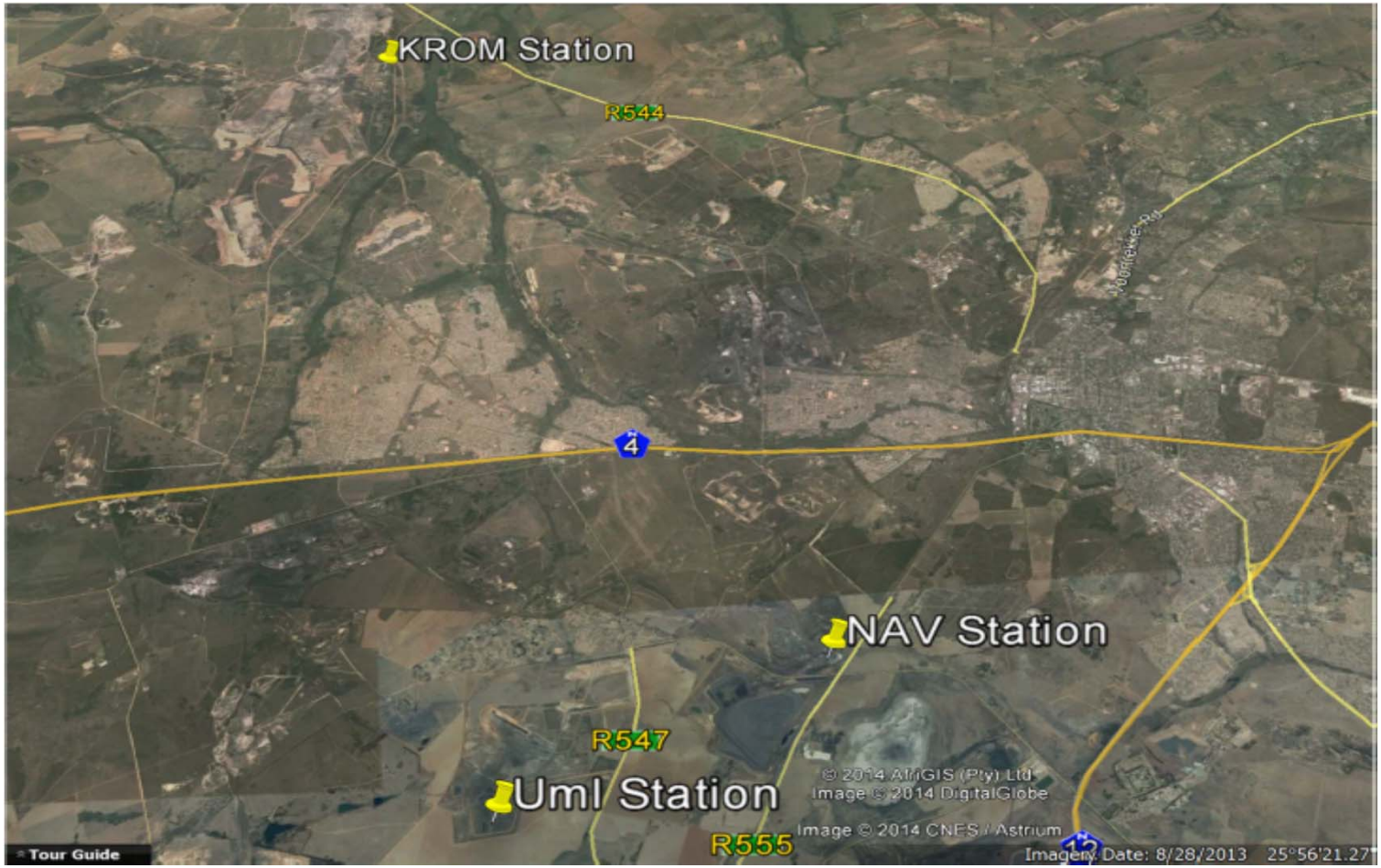
With our best regards,

Schlumberger

Martin Williams
Project Manager

LIST OF ATTACHMENTS

- Figure 1-1 Barrel test site locations
- Figure 4-1 Umlalazi barrels photograph
- Figure 4-2 Kromdraai barrels photograph
- Figure 4-3 Navigation barrels photograph
- Appendix A Sampling procedure for barrel leachates
- Appendix B Laboratory certificates
- Appendix C Memorandum limitations



Schlumberger Water Services		Barrel test site locations			
DRAWN:	HM	DATE:	July 2014	PROJECT:	Field scale kinetic testing
CHECKED:	MW	JOB:	53393	CLIENT:	AATC
		TASK:	2	FIGURE	1-1

Schlumberger Private

Schlumberger Water Services		Umlalazi barrels photograph			
DRAWN:	HM	DATE:	July 2014	PROJECT:	Field scale kinetic testing
CHECKED:	MW	JOB:	53393	CLIENT:	AATC
		TASK:	2	FIGURE	4-1

Schlumberger Private

Schlumberger Water Services

Kromdraai barrels photograph

DRAWN:	HM	DATE:	July 2014	PROJECT: Field scale kinetic testing
CHECKED:	MW	JOB:	53393	CLIENT: AATC
		TASK:	2	FIGURE 4-2

Schlumberger Private

Schlumberger Water Services

Navigation barrels photograph

DRAWN:	HM	DATE:	July 2014	PROJECT:	Field scale kinetic testing
CHECKED:	MW	JOB:	53393	CLIENT:	AATC
		TASK:	2	FIGURE	4-3

Schlumberger Private

APPENDIX A: SAMPLING PROCEDURE FOR BARREL LEACHATES

TECHNICAL MEMORANDUM

Schlumberger Water Services

SCHLUMBERGER WATER SERVICES
OFFICE 004, BUILDING H3
GROUND FLOOR, 10 MELROSE BLVD
MELROSE ARCH
2196 – JOHANNESBURG
SOUTH AFRICA

TEL:+27 11 684 1122
WWW.WATER.SLB.COM

To: Annelie Rossouw

Company: Anglo Thermal Coal

Copy to: Martin Williams

Project No: 53393.R

From: Hugo Marais

Date: 24/03/2014

Pages: Five (including this page)

Document status			
Date	**Document ID**	**Version**	**SWS Approval**
24/03/2014	53393TM01v1	Final	Martin Williams

Landau Field Kinetics: Sampling Procedure

1 Sampling and analysis requirements

1.1 Field testing

The barrels/cribs and seepage collection drums should be monitored on a weekly basis. On each occasion, the volume of water which has reported to the collection vessels should be recorded using a record sheet as attached (Annex A). This should include the following details:

- Date
- Barrel ID
- Volume of water reporting to collection drum
- Water colour/appearance

Physicochemical properties of the water in each vessel should be measured, including:

- pH
- Temperature
- Electrical conductivity

It is also recommended that field test kits be used to measure the following key parameters on a weekly basis:

- Acidity – to be measured when the solution pH is <pH 7. This will provide information on the concentration of acid released, and therefore how easy it will be to neutralise/mitigate.

- Alkalinity – to provide an accurate measurement of alkalinity released by weathering. Dissolved alkalinity is susceptible to change with time, and should be measured regularly.

If measurements of alkalinity and acidity are not undertaken in the field, unfiltered, unpreserved samples of 200 ml should be collected to permit determination of these parameters in the laboratory.

Samples of the water reporting to the vessels in all weeks of operation should be collected during each weekly inspection of the barrels in which water is recorded to have reported to the collection vessels. These should be preserved as appropriate and stored in the event of subsequent requirement for laboratory analysis. Sampling and preservation should follow the protocol outlined in Section 1.2, below.

Following the measurement of physicochemical parameters and collection of water samples, the collection vessels for each column should be emptied.

1.2 Laboratory samples

Water quality samples for laboratory analysis should be dispatched at four weekly intervals. Where possible, these should ideally be freshly collected samples, recovered in the fourth week of each monthly cycle. Water collected during earlier monitoring events during the month may be dispatched for analysis in the event that no water has reported to the collection vessels during week 4.

Samples subject to laboratory analysis should be analysed for major ions and dissolved metals. There should be two sample bottles per barrel:

- Filtered unacidified (FUA). The sample should be filtered through a 0.45 µm Millipore (or similar) cellulose acetate membrane using a 50 mL syringe. This sample should be analysed for: pH, EC, alkalinity, acidity and major anions (to be sent partially filled if insufficient water collected during the month). The preferred method of anion analysis would be ICP-MS.

- Filtered and acidified (FA). This sample should be filtered through a 0.45 µm filter, and should then be acidified to <pH 2 using nitric acid (ARISTAR grade). This bottle should be sent for major cations and trace metal analysis. The preferred mode of cation analysis would be ICP-MS.

All water samples for laboratory analysis should be kept refrigerated once collected until dispatched, and should be packed with freezer packs to maintain low temperatures during transit.

1.3 Laboratory analysis

Water samples should be dispatched to an accredited laboratory for analysis. The recommended list of analytical parameters analysed is:

- pH;
- EC;
- Alkalinity (if not measured in the field);
- Major anions (alkalinity, sulphate, chloride, nitrate); and
- Major cations and trace metals.

Yours sincerely,

Schlumberger Water Services

Hugo Marais
Principal Hydrogeologist: SWS Johannesburg

Annex A
Record Form

Landau AMDML Field Tests: Weekly Measurement Record Sheet

Schlumberger Water Services

Barrel ID	Date	Time	Volume Collected (L)	Water Colour	pH	Temperature (°C)	EC (uS/cm)	DO (mg/L)	ORP (mV)	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulphate (mg/L)	Initials	Comments
Nav1	11/04/2014	09:45	>25	Clear	-	-	-	-	-	-	-	-	SWS	Barrel material to crush
Nav2	11/04/2014	09:45	>25	Clear	-	-	-	-	-	-	-	-	SWS	Barrel material to crush
Krom1	11/04/2014	10:15	>25	Coffee	2	20	>200	0.04	549	-	-	-	SWS	Salty
Krom2	11/04/2014	10:15	14	Coffee	2.6	25	>200	-	616	-	-	-	SWS	Salty
Uml1	11/04/2014	11:45	6.5	Clear	7.9	20	TDS = 7.22 g/L	5.8	493	-	-	-	SWS	
Uml2	11/04/2014	11:45	>25	Clear	6.5	20	TDS = 6.76 g/L	4.9	474	-	-	-	SWS	

LANDAU COLLIERY

P.O. BOX 78
KWA MTHUNZI
VILAKAZI
1036

CERTIFICATE OF CHEMICAL ANALYSIS	Our Ref : LKT/ 602 - 607 / F / 04 /14
Date Received : 11 April 2014 **Date Reported : 2 May 2014** **Quantity Analyzed: 6**	**Att : Annelie Rossouw**

Analysis Results mg/l	LPM METHOD	F 602 UML - 1 (Unfiltered)	F 603 UML - 2 (Unfiltered)
Total Alkalinity as $CaCO_3$	LPM 11	81	34
Conductivity at 25° C in mS/m	LPM 4	229	156
pH-Value at 25 ° C	LPM 51	8.00	7.40
Total Acidity as $CaCO_3$ to pH 8.3	LPM 35	8.30	8.06
Langelier Saturation Index	Calculation	19.1	19.3

P.L.G. UYS (M.D.)
Technical Signatory

LANDAU COLLIERY

P.O. BOX 78
KWA MTHUNZI
VILAKAZI
1036

CERTIFICATE OF CHEMICAL ANALYSIS	Our Ref : LKT/ 602 - 607 / F / 04 /14
Date Received : 11 April 2014	Att : Annelie Rossouw
Date Reported : 2 May 2014	
Quantity Analyzed: 6	

		F 604	F 605
Analysis Results mg/l	LPM METHOD	UML 1	UML 2
Nitrate & Nitrite as N	LPM 32	1.10	0.70
Chlorides as Cl	LPM 10	8.23	6.50
Total Alkalinity as $CaCO_3$	LPM 11	79	30
Fluoride as F	LPM 27	0.54	0.41
Sulphate as SO_4	LPM 28	1291	837
Total Hardness as $CaCO_3$	Calculation	1682	1309
Calcium Hardness as $CaCO_3$	Calculation	982	582
Magnesium Hardness as $CaCO_3$	Calculation	700	457
Calcium as Ca	LPM 15	393	233
Magnesium as Mg	LPM 15	170	111
Sodium as Na	LPM 15	73.0	42.5
Potassium as K	LPM 15	39.1	26.5
Iron as Fe	LPM 15	0.23	0.15
Manganese as Mn	LPM 15	<0.01	<0.01
Conductivity at 25° C in mS/m	LPM 4	229	158
pH-Value at 25 ° C	LPM 51	8.02	7.50
Aluminium as Al	LPM 15	0.17	0.11
Cadmium as Cd	LPM 15 / 67	<0.003	<0.003
Chromium as Cr	LPM 15 / 67	<0.01	<0.01
Copper as Cu	LPM 15 / 67	<0.01	<0.01
Nickel as Ni	LPM 15 / 67	<0.01	<0.01
Lead as Pb	LPM 15 / 67	0.02	0.02
Selenium as Se	LPM 15 / 67	<0.01	<0.01
Boron as B	LPM 15 / 67	0.05	0.04
Silicon as Si	LPM 15 / 67	2.74	1.89
Vanadium as V	LPM 15 / 67	<0.01	<0.01
Zinc as Zn	LPM 15 / 67	0.02	<0.01
Barium as Ba	LPM 15 / 67	0.08	0.07
Cobalt as Co	LPM 15 / 67	<0.01	<0.01
Free and Saline Ammonia NH_3 as N	LPM 32/76	1.52	<0.20
Ortho Phosphate PO_4 as P	LPM 35	<0.1	<0.1
Total Acidity as $CaCO_3$ to pH 8.3	LPM 35	<2.0	8.13
Temperature °C	-	19.6	19.3

All heavy metal analyses have been performed on filtered samples.
Tests marked with an asterisk * are not SANAS accredited
These results are related only to the items tested

P.L.G. UYS (M.D.)
Technical Signatory

LANDAU COLLIERY

P.O. BOX 78
KWA MTHUNZI
VILAKAZI
1036

CERTIFICATE OF CHEMICAL ANALYSIS	Our Ref : LKT/ 602 - 607 / F / 04 /14
Date Received : 11 April 2014	Att : Annelie Rossouw
Date Reported : 2 May 2014	
Quantity Analyzed: 6	

Analysis Results mg/l	LPM METHOD	F 606 Krom 1	F 607 KROM 2
Nitrate & Nitrite as N	LPM 32	2.80	4.30
Chlorides as Cl	LPM 10	15.3	17.6
Total Alkalinity as $CaCO_3$	LPM 11	Nil	Nil
Fluoride as F	LPM 27	<0.20	<0.20
Sulphate as SO_4	LPM 28	39125	44808
Total Hardness as $CaCO_3$	Calculation	1070	795
Calcium Hardness as $CaCO_3$	Calculation	787	707
Magnesium Hardness as $CaCO_3$	Calculation	283	88
Calcium as Ca	LPM 15	315	283
Magnesium as Mg	LPM 15	68.7	21.5
Sodium as Na	LPM 15	4.6	6.10
Potassium as K	LPM 15	0.28	1.25
Iron as Fe	LPM 15	18240	22570
Manganese as Mn	LPM 15	27.2	8.50
Conductivity at 25° C in mS/m	LPM 4	2270	2610
pH-Value at 25 ° C	LPM 51	1.39	1.30
Aluminium as Al	LPM 15	1437	857
Cadmium as Cd	LPM 15 / 67	0.53	0.851
Chromium as Cr	LPM 15 / 67	1.2	0.67
Copper as Cu	LPM 15 / 67	9.33	10.9
Nickel as Ni	LPM 15 / 67	5.91	4.74
Lead as Pb	LPM 15 / 67	<0.01	<0.01
Selenium as Se	LPM 15 / 67	<0.01	<0.01
Boron as B	LPM 15 / 67	<0.01	<0.01
Silicon as Si	LPM 15 / 67	59.10	58.0
Vanadium as V	LPM 15 / 67	1.04	1.50
Zinc as Zn	LPM 15 / 67	25.1	21.4
Barium as Ba	LPM 15 / 67	<0.01	<0.01
Cobalt as Co	LPM 15 / 67	4.80	3.36
Free and Saline Ammonia NH_3 as N	LPM 32/76	4.9	8.6
Ortho Phosphate PO_4 as P	LPM 35	<0.1	<0.1
Total Acidity as $CaCO_3$ to pH 8.3	LPM 35	47476	55726
Temperature °C	-	19.3	19.1

All heavy metal analyses have been performed on filtered samples.
Tests marked with an asterisk * are not SANAS accredited
These results are related only to the items tested

P.L.G. UYS (M.D.)
Technical Signatory

Maxxam

ARD SAMPLE REQUISITION and CHAIN OF CUSTODY FORM

Maxxam Analytics, 3456 Gardner Court, Burnaby, BC V5G 3K4
Phone: (604) 734-7276 Fax: (604) 731-2386
Attn: Ashley Leow, Kevin Bunten & Said Zeinab
E-mail: aleow@maxxam.ca , kbunten@maxxam.ca and szeinab@maxxam.ca

Maxxam Project No:

Company: Schlumberger Water Services

Project Name: Landau

Project No: 53393

Address: Office 004, Building H3, Ground Floor, 10 Melrose Blvd, Melrose Arch, Melrose North, 2196, Johannesburg, South Africa

Telephone: +27 11 6841122

Fax:

Email: lmarais@slb.com

Contact Person: Hugo Marais

Analysis Requested

	Sample ID	Sample Wt. (Kg)	Sample Type & Condition	Modified ABA package (paste pH, total S by LECO and NP)	Sulphate Sulphur (sulphide sulphur by difference)	Total alkalinity	Single Addition NAG	NAG Extract Analysis	Trace Metals on solids by Aqua Regia Digestion (Group 1DX)	Metals on solids: 4 acid (Group 1EX)	Ultra Trace Metals on solids by Aqua Regia Digestion (Group 1F-MS)	Whole Rock - Majors by ICP (Group 4A)	Whole Rock - Majors by XRF	Water Extraction: MEND-SFE	Water Extraction: SPLP	Water Extraction: MWMP	Water Extraction: TCLP	Mineralogy: Optical Microscopy on polished thin sections	Mineralogy: Rietveld XRD	Humidity Cell - MEND method	Humidity Cell - ASTM Method								Comments
1	KROM-1	0.5	Coal spoil	x	x			x	x			x																	
2	UML-1	0.5	Coal spoil	x	x			x	x			x																	
3	NAV-1	0.5	Coal spoil	x	x			x	x			x																	
4	KROM-2	0.5	Coal spoil	x	x			x	x			x																	
5	UML-2	0.5	Coal spoil	x	x			x	x			x																	
6	NAV-2	0.5	Coal spoil	x	x			x	x			x																	
7																													
8																													
9																													
10																													
11																													

Relinquished by:	Hugo Marais	Date:	16/05/2014	Time:	12:00	**Contact info to whom the Invoice for the requested work should go to:**	**Maxxam Storage Policy:**
Received by:		Date:		Time:		Contact person: Hugo Marais	Samples will be store for 3 months after analysis for no fee. Beyond 3 months a storage fee will apply.
Relinquished by:		Date:		Time:		Email: lmarais@slb.com	
Received by:		Date:		Time:		Mailing Address: Office 004, Building H3, Ground Floor, 10 Melrose Blvd, Melrose Arch, Melrose North, 2196, Johannesburg, South Africa	

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Client: Schlumberger Water Services

Table 1: ABA Test Results for project LANDAU

Maxxam Sample No	Sample ID	Paste pH	Total Carbon	Total S	HCl Extractable Sulphur	Sulphide Sulphur (by diff.)	Acid Generation Potential	Mod. ABA Neutralization Potential	Fizz Rating	Net Neutralization Potential	Neutralization Potential Ratio
	Units	pH Units	wt%	wt%	wt%	wt%	Kg CaCO3/T	Kg CaCO3/T	N/A	Kg CaCO3/T	N/A
JQ5594	KROM-1	2.53	52.80	1.15	0.04	1.11	34.7	-8.00	NONE	-42.7	#N/A
JQ5595	UML-1	7.79	72.30	0.32	<0.01	0.32	10.0	25.0	NONE	15.0	2.5
JQ5596	NAV-1	7.73	56.80	1.23	0.41	0.82	25.6	52.5	SLIGHT	26.9	2.1
JQ5597	KROM-2	2.26	53.30	1.25	0.59	0.66	20.6	-14.5	NONE	-35.1	#N/A
JQ5598	UML-2	7.72	76.20	0.35	0.04	0.31	9.7	24.0	NONE	14.3	2.5
JQ5599	NAV-2	7.49	56.20	1.63	0.05	1.58	49.4	53.8	SLIGHT	4.40	1.1
Detection Limits		*N/A*	*0.02*	*0.02*	*0.01*	*0.02*	*0.6*	*0.1*	*N/A*	*0.1*	*N/A*
Maxxam SOP #		*BBY0-000*	*LECO*	*LECO*	*BBY0-00010*	*Calculation*	*Calculation*	*BBY0SOP-00020*	*BBY0SOP-00*	*Calculation*	*Calculation*

Notes:

Lawrence, R.W. 1991. Acid Rock Drainage Prediction Manual

References:

Acid Generation Potential = Sulphide Sulphur (by diff.)*31.25

Fizz Rating - Reference method used is based on NP method.

Net Neutralization Potential = (Modified ABA Neutralization Potential)-(Acid Generation Potential (S-S by diff))

Mod. ABA Neutralization Potential - MEND Acid Rock Drainage Prediction Manual, MEND Project 1.16.1b (pages 6.2-11 to 17), March 1991.

Neutralization Potential Ratio = (Neutralization Potential)/(Acid Generation Potential)

Paste pH - Field and Laboratory Methods Applicable to Overburdens and Minesoils, (EPA 600 / 2-78-054, March 1978).

HCl Extractable Sulphur is based on a modified version of ASTM Method D 2492-02

Sulphide Sulphur = (Total Sulphur)-(Sulphate Sulphur)

Total sulphur, total carbon & carbonate carbon (CO2; HCl direct method) by Leco done at Acme Labs.

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Table 2: ABA QAQC Test Results for project LANDAU

	Duplicate QC										
Maxxam Sample No	**Sample ID**	Paste pH Reported	**Paste pH Dup**			HCl Extractable Sulphur Reported	**HCl Extractable Sulphur Dup**	Mod. ABA Neutralization Potential Reported	**Mod. ABA Neutralization Potential Dup**	Fizz Rating Reported	**Fizz Rating Dup**
	Units	pH Units	pH Units			wt%	wt%	Kg CaCO3/T	Kg CaCO3/T	N/A	N/A
JQ5594 Dup	KROM-1	2.53	2.54			0.04	0.04	-8.00	-8.30	NONE	NONE

Reference Material QC						
	Paste pH		Total Carbon	Total S	HCl Extractable Sulphur	Mod. ABA Neutralization Potential Reported
Units	pH Units		wt%	wt%	wt%	Kg CaCO3/T
Reference Material						
KZK-1ModS moderate (7508564) (61.6 Kg CaCO3/T)						56.5
PPHARD 2012-1 (7508566) (8.34 pH Units)	8.65					
ARD REF MAT GS311-1 (7513207) (1.01 wt%)			1.05			
ARD REF MAT GS311-1 (7513207) (2.32 wt%)				2.29		
ARD SPIKE GS910-4 CS (7513207) (2.65 wt%)			2.75			
ARD SPIKE GS910-4 CS (7513207) (8.27 wt%)				8.68		
ARD Ref Mat RS10 (0.06 wt%)					0.06	
Blank QC						
Method Blank			<0.02		<0.01	
Method Blank				<0.02		

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Table 3: NAG Test Results for project LANDAU

Maxxam Sample No	Sample ID	Pulp Sample Weight	NAG Vol. of 15% H2O2 Used	NAG pH	NAG Volume to pH 4.5	NAG Volume to pH 7.0	NAG NaOH Conc.	NAG Acidity pH 4.5	NAG Acidity pH 7.0
	Units	g	mL	pH Units	mL	mL	N	Kg H2SO4/T	Kg H2SO4/T
JQ5594	KROM-1	2.50	250.00	2.41	15.50	24.80	0.1	30.4	48.6
JQ5595	UML-1	2.50	250.00	2.41	73.90	112.50	0.1	145	221
JQ5596	NAV-1	2.50	250.00	8.22	0.00	0.00	0.1	0.00	0.00
JQ5597	KROM-2	2.50	250.00	2.36	17.90	25.90	0.1	35.1	50.8
JQ5598	UML-2	2.50	250.00	2.30	72.50	110.80	0.1	142	217
JQ5599	NAV-2	2.50	250.00	3.56	1.70	10.90	0.1	3.33	21.4
QAQC									
Duplicates									
JQ5594 Dup	KROM-1	2.50	250.00	2.38	15.70	24.90	0.1	30.8	48.8
Detection Limits		0	N/A	N/A	N/A	N/A	N/A		
Maxxam SOP #		BBY0-00007	BBY0-00007	BBY0SOP-00007	BBY0-00007	BBY0-00007	neration (NAG) T	Calculation	Calculation
Method Blank		0.00	250.00	5.45	0.00	2.80	0.1		

Notes:

EGi Environmental Geochemistry International. 2006. Single Addition Net Acid Generation (NAG) Test Procedure. Page 1 to 4.

References:

NAG Acidity pH 4.5 = (NAG Volume to pH 4.5) * 49 * (NaOH Conc.) / Pulp Sample Weight

NAG Acidity pH 7.0 = (NAG Volume to pH 7.0) * 49 * (NaOH Conc.) / Pulp Sample Weight

Solid:Liquid ratio used = 1:100; 2.5g Pulp Sample:250mL 15% H2O2.

Single Addition NAG - S. Miller, EGI Pty. Ltd., Net Acid Generation (NAG) Test Procedures, March 2001.

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Table 4: WRA-ICP Test Results for project LANDAU

Maxxam Sample No	Sample ID	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	Cr2O3	Ba	Ni	Sr	Zr	Y	Nb	Sc	LOI	Total
	Units	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**ppm**	**%**	**%**
JQ5594	KROM-1	20.1	8.25	1.76	0.04	0.08	0.01	0.19	0.52	0.14	<0.01	0.012	408	<20	297	190	20	14	7	68.7	99.9
JQ5595	UML-1	6.19	3.99	0.26	0.10	1.48	0.01	0.12	0.25	0.30	<0.01	0.005	158	<20	477	85	17	<5	5	87.2	100
JQ5596	NAV-1	13.3	7.67	4.44	0.68	2.77	0.02	0.22	0.48	0.43	0.05	0.007	339	<20	338	127	23	12	8	69.8	99.9
JQ5597	KROM-2	18.8	8.81	1.66	0.03	0.08	0.01	0.16	0.47	0.15	<0.01	0.011	655	<20	314	161	19	13	7	69.6	99.9
JQ5598	UML-2	5.89	3.71	0.16	0.09	1.52	<0.01	0.09	0.26	0.34	<0.01	0.007	162	<20	502	85	19	<5	5	87.8	100
JQ5599	NAV-2	14.4	8.27	3.15	0.65	2.72	0.02	0.24	0.51	0.37	0.03	0.007	363	<20	355	143	23	11	8	69.4	99.9
QAQC																					
Duplicates																					
JQ5599 Dup	NAV-2	14.5	8.31	3.07	0.64	2.73	0.02	0.24	0.52	0.35	0.03	0.007	379	<20	356	144	23	14	8	69.4	99.9
Blanks																					
Method Blank		<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.002								<0.01	0.02
Method Blank													<5	<20	<2	<5	<3	<5	<1		
Reference Material																					
ARD SPK SO-18 % (7513211)		58.26	14.1	7.58	3.33	6.33	3.66	2.12	0.69	0.82	0.4	0.545								1.9	99.88
True Values ARD SPK SO-18 %		**58.47**	**14.23**	**7.67**	**3.35**	**6.42**	**3.71**	**2.17**	**0.69**	**0.83**	**0.39**	**0.55**									
Percent Difference (7513211)		-0.4	-0.9	-1.2	-0.6	-1.4	-1.3	-2.3	0.0	-1.2	2.6	-0.9									
Reference Material																					
ARD SPIKE SO18 ppm (7513215)													483	39	385	300	30	23	24		
True Values ARD SPIKE SO18 ppm													**515**	**44**	**402**	**280**	**31**	**21.3**	**25**		
Percent Difference (7513215)													-6.2	-11.4	-4.2	7.1	-3.2	8.0	-4.0		
Reference Material																					
ARD SPK SO-18 % (7513211)		58.16	14.14	7.56	3.34	6.31	3.69	2.16	0.69	0.82	0.4	0.549								1.9	99.86
True Values ARD SPK SO-18 %		**58.47**	**14.23**	**7.67**	**3.35**	**6.42**	**3.71**	**2.17**	**0.69**	**0.83**	**0.39**	**0.55**									
Percent Difference (7513211)		-0.5	-0.6	-1.4	-0.3	-1.7	-0.5	-0.5	0.0	-1.2	2.6	-0.2									
Reference Material																					
ARD SPIKE SO18 ppm (7513215)													486	48	390	302	30	21	24		
True Values ARD SPIKE SO18 ppm													**515**	**44**	**402**	**280**	**31**	**21.3**	**25**		
Percent Difference (7513215)													-5.6	9.1	-3.0	7.9	-3.2	-1.4	-4.0		
Detection Limits		0.01	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.002	5	20	2	5	3	5	1	0.01	N/A
Acme Method		*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Client: Schlumberger Water Services

Table 5: Aqua Regia Metals Test Results for project LANDAU

Maxxam Sample No	Sample ID	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th	Sr	Cd	Sb	Bi	V	Ca	P	La	Cr	Mg	Ba	Ti	B	Al	Na	K	W	Hg	Sc	Tl	S	Ga	Se	Te
	Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	%	ppm	%	%	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
JQ5594	KROM-1	1.5	12.8	21.9	16	<0.1	8.4	4.9	17	0.91	1.9	1.4	<0.5	4.8	171	<0.1	0.2	0.7	17	0.05	0.034	11	33	<0.01	248	0.006	<20	0.36	0.003	0.03	<0.1	0.20	2.8	<0.1	0.97	2	0.6	<0.2
JQ5595	UML-1	0.2	11.7	4.8	3	<0.1	4.9	1.8	80	0.08	<0.5	1.3	<0.5	3.7	218	<0.1	<0.1	0.7	17	0.98	0.112	16	7	0.05	100	0.007	<20	0.20	0.004	0.02	<0.1	0.02	3.6	<0.1	0.17	1	<0.5	<0.2
JQ5596	NAV-1	0.9	15.6	24.2	16	<0.1	5.0	3.6	388	2.55	8.7	1.6	0.8	8.0	288	<0.1	0.1	0.8	16	1.88	0.170	23	15	0.37	229	0.005	<20	0.38	0.006	0.03	<0.1	0.19	4.4	<0.1	1.15	2	0.6	<0.2
JQ5597	KROM-2	1.2	18.4	22.5	19	<0.1	8.3	4.5	16	0.93	2.4	1.5	<0.5	6.7	228	0.1	0.1	0.8	16	0.06	0.045	14	34	<0.01	232	0.005	<20	0.39	0.001	0.02	<0.1	0.16	3.8	<0.1	1.14	2	0.5	<0.2
JQ5598	UML-2	0.2	10.8	3.5	2	0	4.9	1.9	93	0.08	<0.5	1.3	<0.5	4.0	253	<0.1	<0.1	0.7	18	1.03	0.133	20	7	0.05	102	0.007	<20	0.19	0.004	0.02	<0.1	0.02	3.3	<0.1	0.17	1	<0.5	<0.2
JQ5599	NAV-2	1.3	15.5	20.0	15	<0.1	5.4	3.1	201	1.63	4.9	1.5	<0.5	8.3	273	0.1	<0.1	0.8	14	1.81	0.135	22	13	0.34	144	0.005	<20	0.34	0.004	0.03	<0.1	0.32	3.6	<0.1	1.59	2	<0.5	<0.2
QAQC																																						
Duplicates																																						
JQ5599 Dup	NAV-2	1.5	15.5	21.7	15	<0.1	5.6	3.4	206	1.65	4.7	1.6	<0.5	8.4	290	<0.1	0.1	0.9	14	1.86	0.139	23	13	0.35	137	0.005	<20	0.35	0.004	0.03	<0.1	0.31	3.6	<0.1	1.62	2	<0.5	<0.2
Blanks																																						
Method Blank										<0.01										<0.01	<0.001			<0.01		<0.001		<0.01	<0.001	<0.01					<0.05			
Method Blank													<0.5																									
Method Blank		<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<1		<0.5	<0.1		<0.1	<1	<0.1	<0.1	<0.1	<2			<1	<1		<1		<20				<0.1	<0.01	<0.1	<0.1		<1	<0.5	<0.2
Reference Material																																						
REF OREAS45EA (%) (7513216)										22.06										0.04	0.028			0.1		0.11		3.11	0.008	0.05					<0.05			
True Values REF OREAS45EA										**23.51**										**0.036**	**0.029**			**0.095**		**0.106**		**3.32**	**0.02**	**0.053**					**0.036**			
Percent Difference (7513216)										-6.2										11.1	-3.4			5.3		3.8		-6.3	-60.0	-5.7								
Reference Material																																						
REF OREAS45EA PPB (7513217)													47																									
True Values REF OREAS45EA PPB													**53**																									
Percent Difference (7513217)													-11.3																									
Reference Material																																						
REF OREAS45EA PPM (7513218)	1.6	683.9	15.5	30	0.2	381.7	51.6	405		9.7	1.9		11.6	4	<0.1	0.3	0.2	310			7	799		138		<20				<0.1	<0.01	75.9	<0.1		12	0.6	<0.2
True Values REF OREAS45EA PPM	**1.39**	**709**	**14.3**	**28.9**	**0.26**	**381**	**52**	**400**		**9.1**	**1.73**		**10.7**	**3.5**	**0.02**	**0.2**	**0.26**	**303**			**6.57**	**849**		**148**							**0.34**	**78**	**0.072**		**11.7**	**0.63**	**0.07**
Percent Difference (7513218)	15.1	-3.5	8.4	3.8	-23.1	0.2	-0.8	1.3		6.6	9.8		8.4	14.3		50.0	-23.1	2.3			6.5	-5.9		-6.8								-2.7			2.6	-4.8	
Reference Material																																						
DS10 % (7513216)									2.67											1.03	0.072			0.75		0.085		1	0.054	0.32					0.27			
True Values DS10 %									**2.719**											**1.09**	**0.079**			**0.81**		**0.077**		**1.06**	**0.066**	**0.35**					**0.3**			
Percent Difference (7513216)									-1.8											-5.5	-8.9			-7.4		10.4		-5.7	-18.2	-8.6					-10.0			
Reference Material																																						
DS10 ppb (7513217)													71.6																									
True Values DS10 ppb													**91.9**																									
Percent Difference (7513217)													-22.1																									
Reference Material																																						
DS10 ppm (7513218)	13	151.9	142.2	355	1.6	71.8	12.6	839		46	2.6		7.6	68	2.6	8.5	12.9	41			17	54		397		<20				3.1	0.27	3.1	4.9		4	1.9	5
True Values DS10 ppm	**14.69**	**154.61**	**150.55**	**370**	**2.02**	**74.6**	**12.9**	**875**		**43.7**	**2.59**		**7.5**	**67.1**	**2.49**	**8.23**	**11.65**	**43**			**17.5**	**54.6**		**359**						**3.32**	**0.3**	**2.8**	**5.1**		**4.3**	**2.3**	**5.01**
Percent Difference (7513218)	-11.5	-1.8	-5.5	-4.1	-20.8	-3.8	-2.3	-4.1		5.3	0.4		1.3	1.3	4.4	3.3	10.7	-4.7			-2.9	-1.1		10.6						-6.6	-10.0	10.7	-3.9		-7.0	-17.4	-0.2
Detection Limits	0.1	0.1	0.1	1	0.1	0.1	0.1	1	0.01	0.5	0.1	0.5	0.1	1	0.1	0.1	0.1	2	0.01	0.001	1	1	0.01	1	0.001	20	0.01	0.001	0.01	0.1	0.01	0.1	0.1	0.05	1	0.5	0.2
Acme Method	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Table 6: Sample List for project LANDAU

Maxxam Sample ID	Client Sample ID	Sample Form	Dry Weight Received (kg)
JQ5594	KROM-1	Coal Spoil	2.708
JQ5595	UML-1	Coal Spoil	1.946
JQ5596	NAV-1	Coal Spoil	1.837
JQ5597	KROM-2	Coal Spoil	2.529
JQ5598	UML-2	Coal Spoil	2.083
JQ5599	NAV-2	Coal Spoil	2.032
		Total Weight	13.14
		Total Samples Received	6

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Table 7: Sample Summary for project LANDAU

Date Samples Rec'd by Maxxam:	6 sample were rec'd on 21-May-2014.
Sample Prep Conducted by Maxxam:	YES
Date of Analysis:	May 2014

Client:	SCHLUMBERGER WATER SERVICES
Client Project Name:	LANDAU
Client Project No:	53393
Maxxam Job No:	B440491
Contact Person:	Hugo Marais
E-mail Address:	LMarais@slb.com

Data Validated by:	Ashley Leow
Position:	Burnaby ARD Laboratory Supervisor

Sample Storage

Sample rejects (and selected test residues where applicable) have been archived
Standard archive protocol is archiving for samples for 3 months after testing is complete.
If archiving is required past 3 months a fee will be required.

Maxxam

ARD SAMPLE REQUISITION and CHAIN OF CUSTODY FORM

Maxxam Analytics, 3456 Gardner Court, Burnaby, BC V5G 3K4
Attn: Ashley Leow, Kevin Bunten & Said Zeinab
Phone: (604) 734-7276 Fax: (604) 731-2386
E-mail: aleow@maxxam.ca , kbunten@maxxam.ca and szeinab@maxxam.ca

Page: 1 of 1
Maxxam Project No:

Company: Schlumberger Water Services
Project Name: Landau
Project No: 53393

Address: Office 004, Building H3, Ground Floor, 10 Melrose Blvd, Melrose Arch, Melrose North, 2196, Johannesburg, South Africa
Telephone: +27 11 6841122
Fax:
Email: lmarais@slb.com
Contact Person: Hugo Marais

Analysis Requested

	Sample ID	Sample Wt. (Kg)	Sample Type & Condition	Modified ABA package (paste pH, total S by LECO and NP)	Sulphate Sulphur (sulphide sulphur by difference)	Total alkalinity	Single Addition NAG	NAG Extract Analysis	Trace Metals on solids by Aqua Regia Digestion (Group 1DX)	Metals on solids: 4 acid (Group 1EX)	Ultra Trace Metals on solids by Aqua Regia Digestion (Group 1F-MS)	Whole Rock - Majors by ICP (Group 4A)	Whole Rock - Majors by XRF	Water Extraction: MEND-SFE	Water Extraction: SPLP	Water Extraction: MWMP	Water Extraction: TCLP	Mineralogy: Optical Microscopy on polished thin sections	Mineralogy: Rietveld XRD	Humidity Cell - MEND method	Humidity Cell - ASTM Method								Comments
1	KROM-3	0.5	Coal backfill	x	x			x	x			x																	
2	UML-3	0.5	Coal backfill	x	x			x	x			x																	
3	NAV-3	0.5	Coal backfill	x	x			x	x			x																	

Relinquished by:	Hugo Marais	Date:	10/11/2014		Time:	12:00	**Contact info to whom the Invoice for the requested work should go to:**		**Maxxam Storage Policy:**
Received by:		Date:			Time:		Contact person:	Hugo Marais	Samples will be store for 3 months after analysis for no fee. Beyond 3 months a storage fee will apply.
Relinquished by:		Date:			Time:		Email:	lmarais@slb.com	
Received by:		Date:			Time:		Mailing Address:	Office 004, Building H3, Ground Floor, 10 Melrose Blvd, Melrose Arch, Melrose North, 2196, Johannesburg, South Africa	

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Client: Schlumberger Water Services

Table 1: ABA Test Results for project SWS-LANDAU

Maxxam Sample No	Sample ID	Paste pH	Total Carbon	Total S	HCl Extractable Sulphur	Sulphide Sulphur (by diff.)	Acid Generation Potential	Mod. ABA Neutralization Potential	Fizz Rating	Net Neutralization Potential	Neutralization Potential Ratio
	Units	pH Units	wt%	wt%	wt%	wt%	Kg CaCO3/T	Kg CaCO3/T	N/A	Kg CaCO3/T	N/A
LD3949	KROM-3	3.68	6.10	0.25	0.16	0.09	2.8	-2.30	NONE	-5.10	#N/A
LD3950	UML-3	4.99	9.68	0.35	0.06	0.29	9.1	-0.300	NONE	-9.40	#N/A
LD3951	NAV-3	7.42	23.16	0.29	0.04	0.25	7.8	24.5	SLIGHT	16.7	3.1
Detection Limits		*N/A*	*0.02*	*0.02*	*0.01*	*0.02*	*0.6*	*0.1*	*N/A*	*0.1*	*N/A*
Maxxam SOP #		*BBY0SOP-00016*	*LECO*	*LECO*	*BBY0SOP-00010*	*BBY WI-00033*	*BBY WI-00033*	*BBY0SOP-00020*	*BBY0SOP-00*	*BBY WI-00033*	*BBY WI-00033*

Notes:

Lawrence, R.W. 1991. Acid Rock Drainage Prediction Manual

References:

Acid Generation Potential = Sulphide Sulphur (by diff.)*31.25

Fizz Rating - Reference method used is based on NP method.

Net Neutralization Potential = (Modified ABA Neutralization Potential)-(Acid Generation Potential (S-S by diff))

Mod. ABA Neutralization Potential - MEND Acid Rock Drainage Prediction Manual, MEND Project 1.16.1b (pages 6.2-11 to 17), March 1991.

Neutralization Potential Ratio = (Neutralization Potential)/(Acid Generation Potential)

Paste pH - Field and Laboratory Methods Applicable to Overburdens and Minesoils, (EPA 600 / 2-78-054, March 1978).

HCl Extractable Sulphur is based on a modified version of ASTM Method D 2492-02

Sulphide Sulphur = (Total Sulphur)-(Sulphate Sulphur)

Total sulphur, total carbon & carbonate carbon (CO2; HCl direct method) by Leco done at Acme Labs.

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Client: Schlumberger Water Services

Table 2: ABA QAQC Test Results for project SWS-LANDAU

	Duplicate QC										
Maxxam Sample No	**Sample ID**	Paste pH Reported	**Paste pH Dup**			HCl Extractable Sulphur Reported	**HCl Extractable Sulphur Dup**	Mod. ABA Neutralization Potential Reported	**Mod. ABA Neutralization Potential Reported Dup**	Fizz Rating Reported	**Fizz Rating Dup**
	Units	pH Units	pH Units			wt%	wt%	Kg CaCO3/T	Kg CaCO3/T	N/A	N/A
LD3949 Dup	KROM-3	3.68	3.71			0.16	0.15	-2.30	-2.80	NONE	NONE

Reference Material QC						
	Paste pH		Total Carbon	Total S		Mod. ABA Neutralization
Units	pH Units		wt%	wt%		Kg CaCO3/T
Reference Material						
ARD-Paste pH 8.29 (7748103) (8.29 pH Units)	8.27					
KZK-1ModS Slight (7748104) (58.9 Kg CaCO3/T)						54.5
ARD REF MAT GS311-1 (7759622) (1.01 wt%)			1.02			
ARD REF MAT GS311-1 (7759622) (2.32 wt%)				2.25		
ARD SPIKE GS910-4 CS (7759622) (2.65 wt%)			2.70			
ARD SPIKE GS910-4 CS (7759622) (8.27 wt%)				8.33		
ARD Ref Mat RS10 (0.08 wt%)					0.07	
ARD Ref Mat DBOHC (0.27 wt%)					0.28	
Blank QC						
Method Blank					<0.01	
Method Blank			<0.02			
Method Blank				<0.02		

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Table 3: NAG Test Results for project SWS-LANDAU

Maxxam Sample No	Sample ID	Pulp Sample Weight	NAG Vol. of 15% H2O2 Used	NAG pH	NAG Volume to pH 4.5	NAG Volume to pH 7.0	NAG NaOH Conc.	NAG Acidity pH 4.5	NAG Acidity pH 7.0
	Units	g	mL	pH Units	mL	mL	N	Kg H2SO4/T	Kg H2SO4/T
LD3949	KROM-3	2.50	250.00	3.55	1.20	4.20	0.1	2.35	8.23
LD3950	UML-3	2.50	250.00	3.54	1.80	6.00	0.1	3.53	11.8
LD3951	NAV-3	2.50	250.00	8.75	0.00	0.00	0.1	0.00	0.00
QAQC									
Duplicates									
LD3949 Dup	KROM-3	2.50	250.00	3.53	1.30	4.40	0.1	2.55	8.62
Detection Limits		0	N/A	N/A	N/A	N/A	N/A		
Maxxam SOP #		BBY0-00007	BBY0SOP-00007	BBY0SOP-00007	BBY0SOP-00007	BBY0SOP-00007	BBY0SOP-00007	BBY WI-00033	BBY WI-00033
Method Blank		0.00	250.00000	6.88	0.00	0.1	0.1		

Notes:

EGi Environmental Geochemistry International. 2006. Single Addition Net Acid Generation (NAG) Test Procedure. Page 1 to 4.

References:

NAG Acidity pH 4.5 = (NAG Volume to pH 4.5) * 49 * (NaOH Conc.) / Pulp Sample Weight
NAG Acidity pH 7.0 = (NAG Volume to pH 7.0) * 49 * (NaOH Conc.) / Pulp Sample Weight
Solid:Liquid ratio used = 1:100; 2.5g Pulp Sample:250mL 15% H2O2.
Single Addition NAG - S. Miller, EGI Pty. Ltd., Net Acid Generation (NAG) Test Procedures, March 2001.

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Client: Schlumberger Water Services

Table 4: WRA-ICP Test Results for project SWS-LANDAU

Maxxam Sample No	Sample ID	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	Cr2O3	Ba	Ni	Sr	Zr	Y	Nb	Sc	LOI	Total
	Units	%	%	%	%	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	%
LD3949	KROM-3	67.7	14.1	1.64	0.09	0.03	0.02	0.96	0.91	0.07	<0.01	0.031	419	22	135	540	37	22	11	14.3	100
LD3950	UML-3	61.4	14.7	3.59	0.17	0.12	0.02	0.75	0.73	0.08	<0.01	0.025	317	<20	259	295	33	19	11	18.3	100
LD3951	NAV-3	44.8	14.4	2.64	0.46	1.28	0.03	0.82	0.78	0.12	0.03	0.024	490	25	260	283	34	19	13	34.4	100
QAQC																					
Duplicates																					
LD3951 Dup	NAV-3	44.7	14.5	2.68	0.47	1.33	0.03	0.78	0.78	0.11	0.03	0.023	485	21	260	269	34	17	13	34.4	100
Blanks																					
Method Blank		<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.002								<0.01	<N/A
Method Blank													<5	<20	<2	<5	<3	<5	<1		
Reference Material																					
ARD SPK SO-18 % (7759627)		58.24	13.99	7.64	3.41	6.26	3.70	2.16	0.70	0.79	0.39	0.549								1.9	99.89
True Values ARD SPK SO-18 %		**58.47**	**14.23**	**7.67**	**3.35**	**6.42**	**3.71**	**2.17**	**0.69**	**0.83**	**0.39**	**0.55**									
Percent Difference (7759627)		-0.4	-1.7	-0.4	1.8	-2.5	-0.3	-0.5	1.4	-4.8	0.0	-0.2									
Reference Material																					
ARD SPIKE SO18 ppm (7759628)													488	44	382	300	29	21	25		
True Values ARD SPIKE SO18 ppm													**515**	**44**	**402**	**280**	**31**	**21.3**	**25**		
Percent Difference (7759628)													-5.2	0.0	-5.0	7.1	-6.5	-1.4	0.0		
Reference Material																					
ARD SPK SO-18 % (7759627)		58.12	14.14	7.63	3.38	6.36	3.66	2.14	0.69	0.79	0.39	0.547								1.9	99.90
True Values ARD SPK SO-18 %		**58.47**	**14.23**	**7.67**	**3.35**	**6.42**	**3.71**	**2.17**	**0.69**	**0.83**	**0.39**	**0.55**									
Percent Difference (7759627)		-0.6	-0.6	-0.5	0.9	-0.9	-1.3	-1.4	0.0	-4.8	0.0	-0.5									
Reference Material																					
ARD SPIKE SO18 ppm (7759628)													4887	45	381	298	29	21	24		
True Values ARD SPIKE SO18 ppm													**515**	**44**	**402**	**280**	**31**	**21.3**	**25**		
Percent Difference (7759628)													848.9	2.3	-5.2	6.4	-6.5	-1.4	-4.0		
Detection Limits		0.01	0.01	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.002	5	20	2	5	3	5	1	0.01	N/A
Maxxam SOP #		*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*	*4A*

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Client: Schlumberger Water Services

Table 5: Aqua Regia Metals Test Results for project SWS-LANDAU

Maxxam Sample No	Sample ID	Mo	Cu	Pb	Zn	Ag	Ni	Co	Mn	Fe	As	U	Au	Th	Sr	Cd	Sb	Bi	V	Ca	P	La	Cr	Mg	Ba	Ti	B	Al	Na	K	W	Hg	Sc	Tl	S	Ga	Se	Te
	Units	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	ppm	%	%	ppm	ppm	%	ppm	%	ppm	%	%	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
LD3949	KROM-3	1.0	24.6	15.5	55	<0.1	18.2	9.0	71	0.99	3.6	1.1	1.0	4.5	20	0.1	<0.1	0.4	24	0.02	0.007	7	83	0.02	235	0.005	<20	0.41	0.004	0.07	<0.1	0.14	4.0	0.1	0.22	2	<0.5	<0.2
LD3950	UML-3	2.3	24.3	14.3	17	<0.1	13.7	7.9	78	2.29	16.1	2.0	0.6	8.3	33	<0.1	0.2	0.8	30	0.08	0.010	16	70	0.04	135	0.004	<20	0.36	0.004	0.07	<0.1	0.21	5.3	<0.1	0.24	3	<0.5	<0.2
LD3951	NAV-3	0.8	24.8	19.3	53	<0.1	16.9	9.5	229	1.55	3.4	2.0	<0.5	9.7	140	0.1	0.1	0.7	33	0.95	0.030	25	69	0.23	273	0.015	<20	0.54	0.006	0.10	<0.1	0.08	5.9	<0.1	0.20	3	0.6	<0.2
QAQC																																						
Duplicates																																						
LD3951 Dup	NAV-3	0.8	26.3	20.8	55	<0.1	18.9	10.5	246	1.63	4.0	2.1	<0.5	9.9	144	0.2	0.1	0.7	35	0.99	0.030	26	73	0.24	280	0.016	<20	0.56	0.007	0.10	<0.1	0.09	5.9	<0.1	0.21	3	0.6	<0.2
Blanks																																						
Method Blank										<0.01										<0.01	<0.001			<0.01		<0.001		<0.01	<0.001	<0.01					<0.05			
Method Blank		<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<1		<0.5	<0.1		<0.1	<1	<0.1	<0.1	<0.1	<2			<1	<1		<1		<20				<0.1	<0.01	<0.1	<0.1		<1	<0.5	<0.2
Method Blank													<0.5																									
Reference Material																																						
REF OREAS45EA (%) (7759629)										19.78										0.04	0.028			0.11		0.102		2.89	0.012	0.05					<0.05			
True Values REF OREAS45EA										**23.51**										**0.036**	**0.029**			**0.095**		**0.106**		**3.32**	**0.02**	**0.053**					**0.036**			
Percent Difference (7759629)										-15.9										11.1	-3.4			15.8		-3.8		-13.0	-40.0	-5.7								
Reference Material																																						
REF OREAS45EA PPM (7759631)		1.6	655	12.7	29	0.3	359.8	48.8	391		9.7	1.6		8.5	4	<0.1	0.3	0.2	290			7	722		143		<20				<0.1	0.01	74.1	<0.1		12	0.5	<0.2
True Values REF OREAS45EA PPM		**1.39**	**709**	**14.3**	**28.9**	**0.26**	**381**	**52**	**400**		**9.1**	**1.73**		**10.7**	**3.5**	**0.02**	**0.2**	**0.26**	**303**			**6.57**	**849**		**148**							**0.34**	**78**	**0.072**		**11.7**	**0.63**	**0.07**
Percent Difference (7759631)		15.1	-7.6	-11.2	0.3	15.4	-5.6	-6.2	-2.3		6.6	-7.5		-20.6	14.3	-100.0	50.0	-23.1	-4.3			6.5	-15.0		-3.4							-97.1	-5.0			2.6	-20.8	
Reference Material																																						
REF OREAS45EA_PPB (7759632)													54.7																									
True Values REF OREAS45EA_PPB													**53**																									
Percent Difference (7759632)													3.2																									
Reference Material																																						
DS10 % (7759629)										2.68										1.05	0.077			0.77		0.085		1.00	0.061	0.33					0.29			
True Values DS10 %										**2.719**										**1.09**	**0.079**			**0.81**		**0.077**		**1.06**	**0.066**	**0.35**					**0.3**			
Percent Difference (7759629)										-1.4										-3.7	-2.5			-4.9		10.4		-5.7	-7.6	-5.7					-3.3			
Reference Material																																						
DS10 ppm (7759631)		13.6	156.3	170.8	372	2	78.7	13.6	876		46.7	2.4		6.8	65	2.7	7.8	11.3	42			18	55		422		<20				3.1	0.27	2.9	5.2		4	2.5	5
True Values DS10 ppm		**14.69**	**154.61**	**150.55**	**370**	**2.02**	**74.6**	**12.9**	**875**		**43.7**	**2.59**		**7.5**	**67.1**	**2.49**	**8.23**	**11.65**	**43**			**17.5**	**54.6**		**359**						**3.32**	**0.3**	**2.8**	**5.1**		**4.3**	**2.3**	**5.01**
Percent Difference (7759631)		-7.4	1.1	13.5	0.5	-1.0	5.5	5.4	0.1		6.9	-7.3		-9.3	-3.1	8.4	-5.2	-3.0	-2.3			2.9	0.7		17.5						-6.6	-10.0	3.6	2.0		-7.0	8.7	-0.2
Reference Material																																						
DS10 ppb (7759632)													70.6																									
True Values DS10 ppb													**91.9**																									
Percent Difference (7759632)													-23.2																									
Detection Limits		0.1	0.1	0.1	1	0.1	0.1	0.1	1	0.01	0.5	0.1	0.5	0.1	1	0.1	0.1	0.1	2	0.01	0.001	1	1	0.01	1	0.001	20	0.01	0.001	0.01	0.1	0.01	0.1	0.1	0.05	1	0.5	*0.2*
Maxxam SOP #		*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*	*1DX*

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Table 6: Sample List for project SWS-LANDAU

Maxxam Sample ID	Client Sample ID	Sample Form	Dry Weight Received (kg)
LD3949	KROM-3	Coal backfill	0.5000
LD3950	UML-3	Coal backfill	0.5000
LD3951	NAV-3	Coal backfill	0.5000

Total Weight	1.50
Total Samples Received	3

Maxxam Analytics 4606 Canada Way, Burnaby, BC Canada V5G 1K5 Tel: 604 734 7276 Fax: 604 731 2386 www.maxxam.ca

Table 7: Sample Summary for project SWS-LANDAU

Date Samples Rec'd by Maxxam:	3 sample were rec'd on 10-Nov-2014.
Sample Prep Conducted by Maxxam:	YES
Date of Analysis:	December 2014

Client:	Schlumberger Water Services
Client Project Name:	SWS-LANDAU
Client Project No:	53393.00
ARD Project #:	
Maxxam Job No:	B4A3862
Contact Person:	Hugo Marais
E-mail Address:	LMarais@slb.com

Data Validated by:	Ashley Leow
Position:	Burnaby ARD Laboratory Supervisor

Sample Storage

Sample rejects (and selected test residues where applicable) have been archived
Standard archive protocol is archiving for samples for 3 months after testing is complete.
If archiving is required past 3 months a fee will be required.

APPENDIX C: MEMORANDUM LIMITATIONS

MEMORANDUM LIMITATIONS

This memorandum has been prepared for the specific purpose identified herein at the request of and for the use of the Client. Observations, conclusions, and recommendations contained herein are opinions based upon the scope of services, information obtained through observations and measurements taken by Schlumberger Water Services at certain points and certain times, and interpretation and extrapolation of secondary information from published and unpublished material. The memorandum may infer the configuration of strata, ground and groundwater conditions both between data points and below the maximum depth of investigation. The memorandum also may deduce temporal trends and averages for climatic, hydrological, and water quality parameters. Such interpretations and extrapolations are only indicative and no liability is accepted for variations between the opinions expressed herein and conditions which may be identified at a later date through direct measurement and observation.

Unless otherwise agreed in writing by Schlumberger Water Services, Schlumberger Water Services accepts no responsibility for any use of, or reliance on any contents of this memorandum by any person other than Client and shall not be liable to any person other than Client, on any ground, for any loss, damage or expense arising from such use or reliance.

Should any information contained in this memorandum be used by any unauthorized third party, it is done so at their own risk.

UIS Analytical Services (Pty) Ltd • Reg. No. 2000/027788/07 • VAT No. 4920202969
13 Esdoring Nook, Highveld Technopark, Centurion • PO Box 8286, Centurion, 0046
Tel. +27 12 665 4291 • Fax. +27 12 665 4294 • info@uis-as.co.za • www.uis-as.co.za

Geo Pollution Technologies - Gauteng
81 Rauch Avenue, Georgeville, Meyerspark
Pretoria
0184
South Africa
Altus Huisamen
Tel : +27 12 804 8120
Fax : +27 12 804 8140
E-Mail : altus@gptglobal.com

FINAL CERTIFICATE OF ANALYSIS	
Report Date	2015-05-23
Date Required	2015-04-18
Contract No	
Order/Ref No	QUOTE: 11682

T0184

QUOTE: 11682

Notes
The results relate specifically to the items tested.
The report shall not be reproduced except in full, without the written approval of the laboratory.
[1] SANAS accredited analysis included in the SANAS Schedule of Accredition for this laboratory.
[2] Not SANAS accredited analysis and not included in the SANAS schedule of accreditation for this laboratory.
[3] Outsourced not performed by this laboratory.

Request ID: 11809 **Sample ID:** 428486 **Received:** 2015-04-08 **Matrix:** Soil **Page:** 1 / 4
Sample Number: KDC1/29/3/2015 **Revision Number:** 2

Method: [1]UIS-EA-T001(pH) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	3.64		[1]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	25.3	mSm	[1]Total Conductivity	25.3	mS/m	[1]TC Temperature	21.8	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	165	mg/l	[2]TDS by EC*7	177	mg/l

Method: [3]UIS-EA-T010(Acidity) **Completed:** 2015-05-23

Parameter	Value	Unit
[3]Acidity to pH 8.3	14.00	mg/l CaCO3

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	<3.5	mg/l CaCO3

Method: [2]UIS-TEA-T001(Disolved Cations in Water by ICP-OES) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	8.8	mg/l	[2]Ca	6.1	mg/l	[2]Fe	0.1	mg/l
[2]K	0.79	mg/l	[2]Mg	3.5	mg/l	[2]Mn	1.66	mg/l
[2]Na	1.18	mg/l						

Method: [1]UIS-EA-T008(Anions by Ion Chromatography) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Cl	0.739	mg/l	[1]NO3	0.378	mg/l	[1]NO3 as N	<0.3	mg/l
[1]SO4	144	mg/l						

Method: [2]UIS-CP-T002(Ion Balance Error) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	1.71	me/l	[2]Sum of Anions	3.03	me/l	[2]Ion Balance Error	-28	%

Request ID: 11809 **Sample ID:** 428487 **Received:** 2015-04-08 **Matrix:** Soil **Page:** 1 / 4
Sample Number: KDC2/29/3/2015 **Revision Number:** 2

Method: [1]UIS-EA-T001(pH) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	3.71		[1]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	23.9	mSm	[1]Total Conductivity	23.9	mS/m	[1]TC Temperature	21.9	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	156	mg/l	[2]TDS by EC*7	168	mg/l

Method: [3]UIS-EA-T010(Acidity) **Completed:** 2015-05-23

Parameter	Value	Unit
[3]Acidity to pH 8.3	12.00	mg/l CaCO3

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	<3.5	mg/l CaCO3

Method: [2]UIS-TEA-T001(Disolved Cations in Water by ICP-OES) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	12.4	mg/l	[2]Ca	4.24	mg/l	[2]Fe	0.13	mg/l
[2]K	0.7	mg/l	[2]Mg	1.37	mg/l	[2]Mn	0.81	mg/l
[2]Na	0.88	mg/l						

Method: [1]UIS-EA-T008(Anions by Ion Chromatography) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Cl	0.567	mg/l	[1]NO3	<0.3	mg/l	[1]SO4	149	mg/l

Method: [2]UIS-CP-T002(Ion Balance Error) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	1.79	me/l	[2]Sum of Anions	3.13	me/l	[2]Ion Balance Error	-27.1	%

Method: [1]UIS-EA-T001(pH) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	6.23		[1]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	1.52	mSm	[1]Total Conductivity	1.52	mS/m	[1]TC Temperature	22	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	9.88	mg/l	[2]TDS by EC*7	10.6	mg/l

Method: [3]UIS-EA-T010(Acidity) **Completed:** 2015-05-23

Parameter	Value	Unit
[3]Acidity to pH 8.3	<5.00	mg/l CaCO3

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	<3.5	mg/l CaCO3

Method: [2]UIS-TEA-T001(Disolved Cations in Water by ICP-OES) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	0.66	mg/l	[2]Ca	0.8	mg/l	[2]Fe	0.81	mg/l
[2]K	0.57	mg/l	[2]Mg	0.14	mg/l	[2]Mn	<0.05	mg/l
[2]Na	1.98	mg/l						

Method: [1]UIS-EA-T008(Anions by Ion Chromatography) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Cl	0.414	mg/l	[1]NO3	0.685	mg/l	[1]NO3 as N	<0.3	mg/l
[1]SO4	24.1	mg/l						

Method: [2]UIS-CP-T002(Ion Balance Error) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	0.26	me/l	[2]Sum of Anions	0.57	me/l	[2]Ion Balance Error	-38	%

Method: [1]UIS-EA-T001(pH) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	4.16		[1]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	16.3	mSm	[1]Total Conductivity	16.3	mS/m	[1]TC Temperature	22	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	106	mg/l	[2]TDS by EC*7	114	mg/l

Method: [3]UIS-EA-T010(Acidity) **Completed:** 2015-05-23

Parameter	Value	Unit
[3]Acidity to pH 8.3	<5.00	mg/l CaCO3

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	<3.5	mg/l CaCO3

Method: [2]UIS-TEA-T001(Disolved Cations in Water by ICP-OES) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	1.73	mg/l	[2]Ca	11.2	mg/l	[2]Fe	<0.05	mg/l
[2]K	0.77	mg/l	[2]Mg	5.2	mg/l	[2]Mn	2.26	mg/l
[2]Na	0.63	mg/l						

Method: [1]UIS-EA-T008(Anions by Ion Chromatography) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Cl	0.342	mg/l	[1]NO3	<0.3	mg/l	[1]SO4	95.2	mg/l

Method: [2]UIS-CP-T002(Ion Balance Error) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	1.31	me/l	[2]Sum of Anions	1.99	me/l	[2]Ion Balance Error	-20.6	%

Method: [1]UIS-EA-T001(pH) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	5.33		[1]pH Temperature	25	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	9.09	mSm	[1]Total Conductivity	9.09	mS/m	[1]TC Temperature	21.8	Deg C

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	59.1	mg/l	[2]TDS by EC*7	63.6	mg/l

Method: [3]UIS-EA-T010(Acidity) **Completed:** 2015-05-23

Parameter	Value	Unit
[3]Acidity to pH 8.3	<5.00	mg/l CaCO3

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	<3.5	mg/l CaCO3

Method: [2]UIS-TEA-T001(Disolved Cations in Water by ICP-OES) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Al	<0.05	mg/l	[2]Ca	6.37	mg/l	[2]Fe	<0.05	mg/l
[2]K	2.71	mg/l	[2]Mg	3.61	mg/l	[2]Mn	1.18	mg/l
[2]Na	0.76	mg/l						

Method: [1]UIS-EA-T008(Anions by Ion Chromatography) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]Cl	0.33	mg/l	[1]NO3	1.1	mg/l	[1]NO3 as N	<0.3	mg/l
[1]SO4	52.1	mg/l						

Method: [2]UIS-CP-T002(Ion Balance Error) **Completed:** 2015-05-23

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	0.76	me/l	[2]Sum of Anions	1.13	me/l	[2]Ion Balance Error	-19.4	%

Japie Oberholzer
AUTHORISED SIGNATORY

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Faculty of Natural & Agricultural Sciences
XRD & XRF Facility
Department of Geology
Pretoria 0002, South Africa

Direct Telephone: (012) 420-2722
Direct Telefax: (012) 362 5219
E-Mail: wiebke.grote@up.ac.za
http://www.up.ac.za/academic/science

CLIENT: Altus Huisamen

DATE: 14 April 2015

SAMPLES: 5 Samples

ANALYSIS: Qualitative and Quantitative XRD (mineralogy)

After drying the samples in a drying oven, they were ground to a fine powder in a tungsten carbide vessel using a swing mill and prepared according to the standardized Panalytical back-loading system, to avoid preferred orientation.

They were analyzed using a PANalytical X'Pert Pro powder diffractometer in θ–θ configuration with an X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-Kα radiation (λ=1.789Å). The phases were identified using X'Pert Highscore plus software. The diffraction traces with the identified phases follow below.

The relative phase amounts (weight%) were estimated using the Rietveld method (Autoquan Program). Errors are on the 3 sigma level in the column to the right of the amount. The quantitative results (weight%) are tabled below.

> **Comment:** Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group (i.e "Biotite" and "Muscovite" would represent the mineral group "Mica").

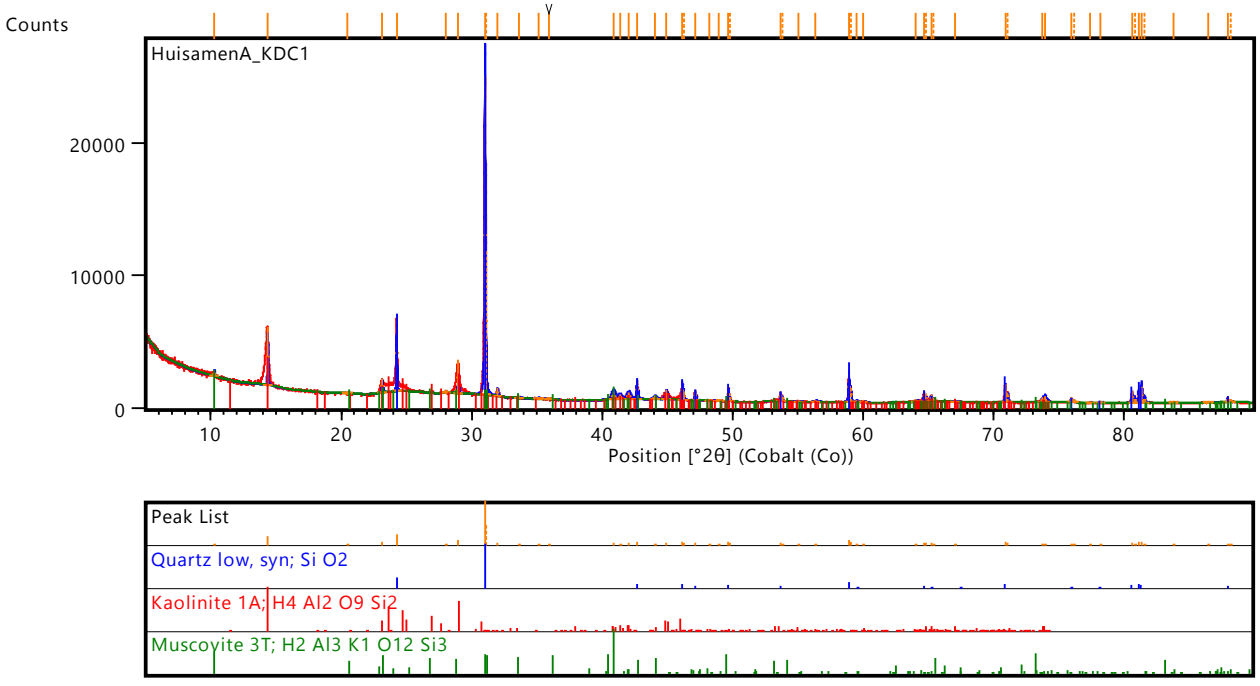
If you have any questions, kindly contact the laboratory.

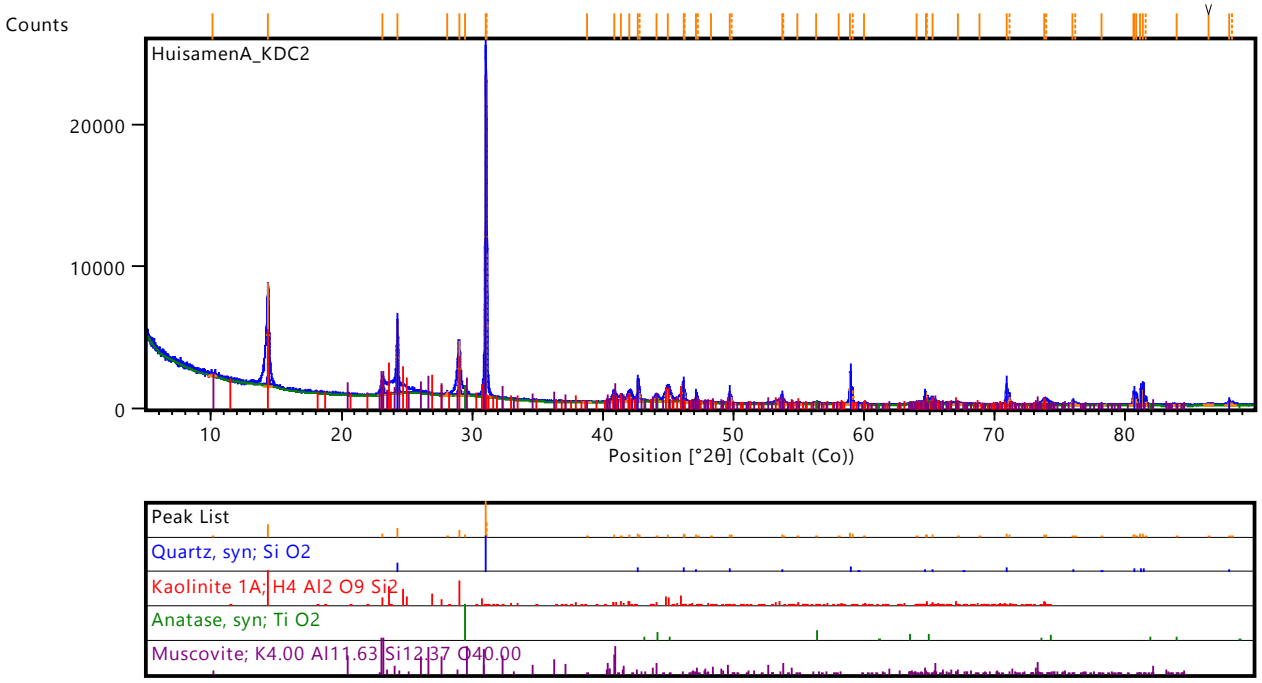
Analyst:

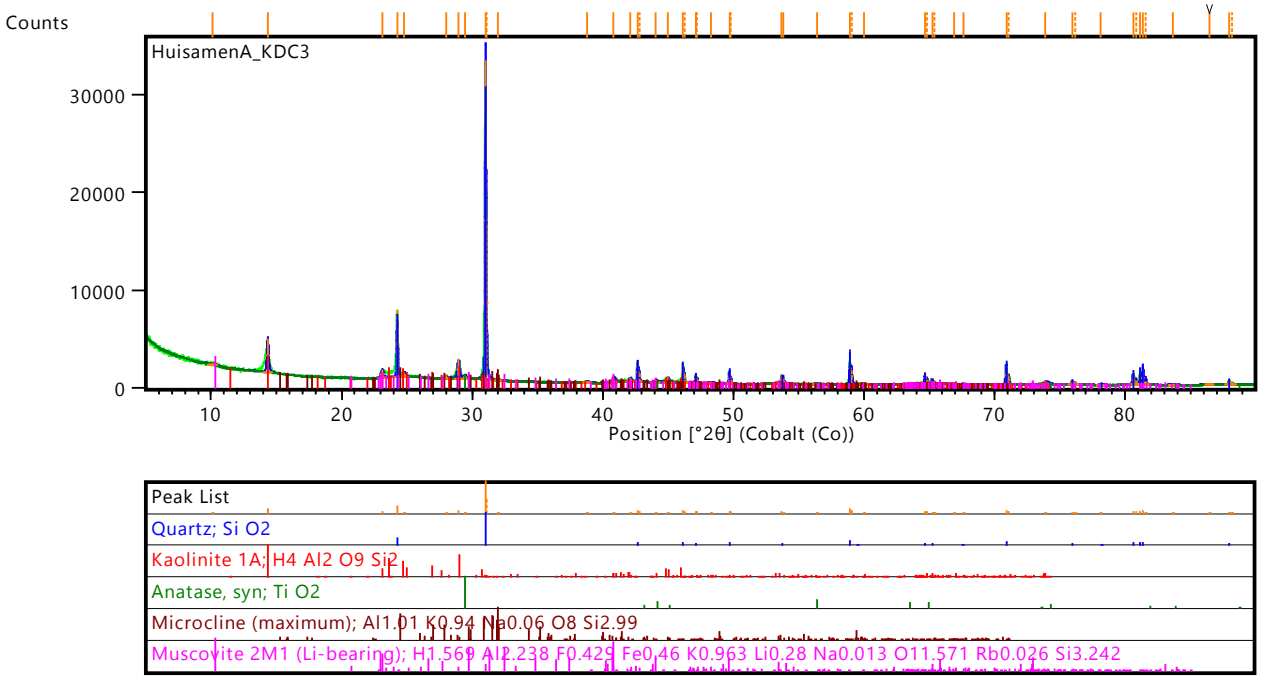
Wiebke Grote

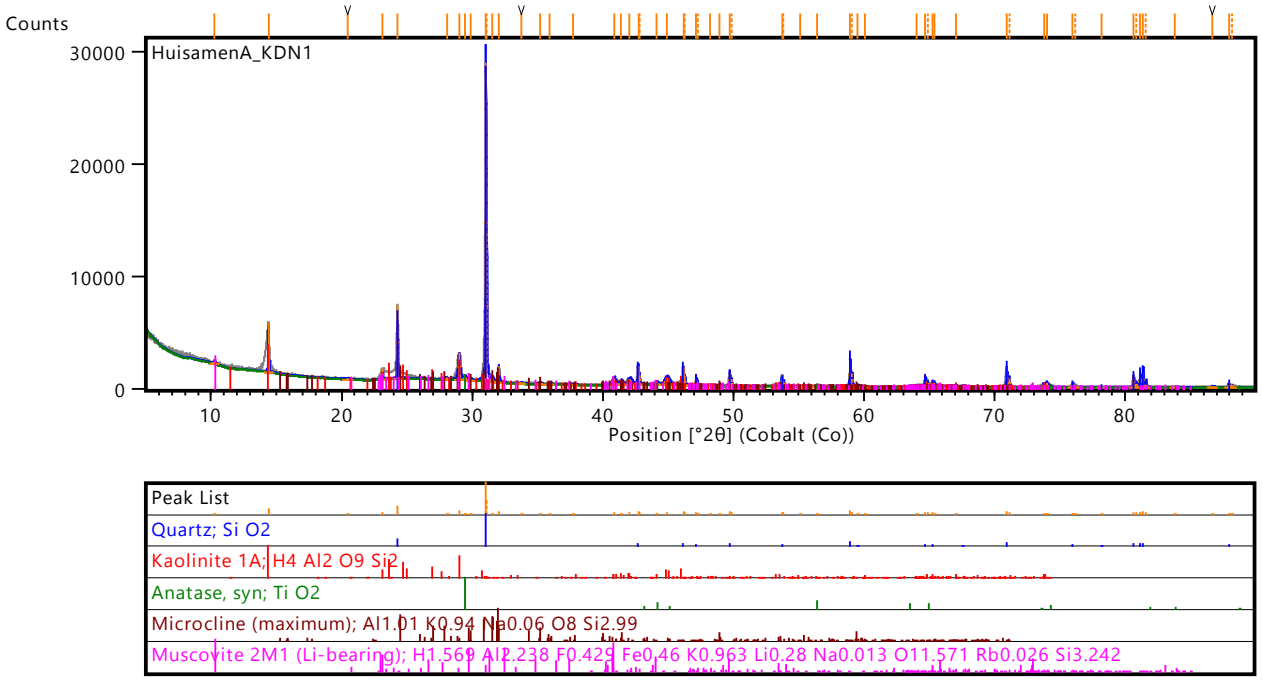
Quantitative Results:

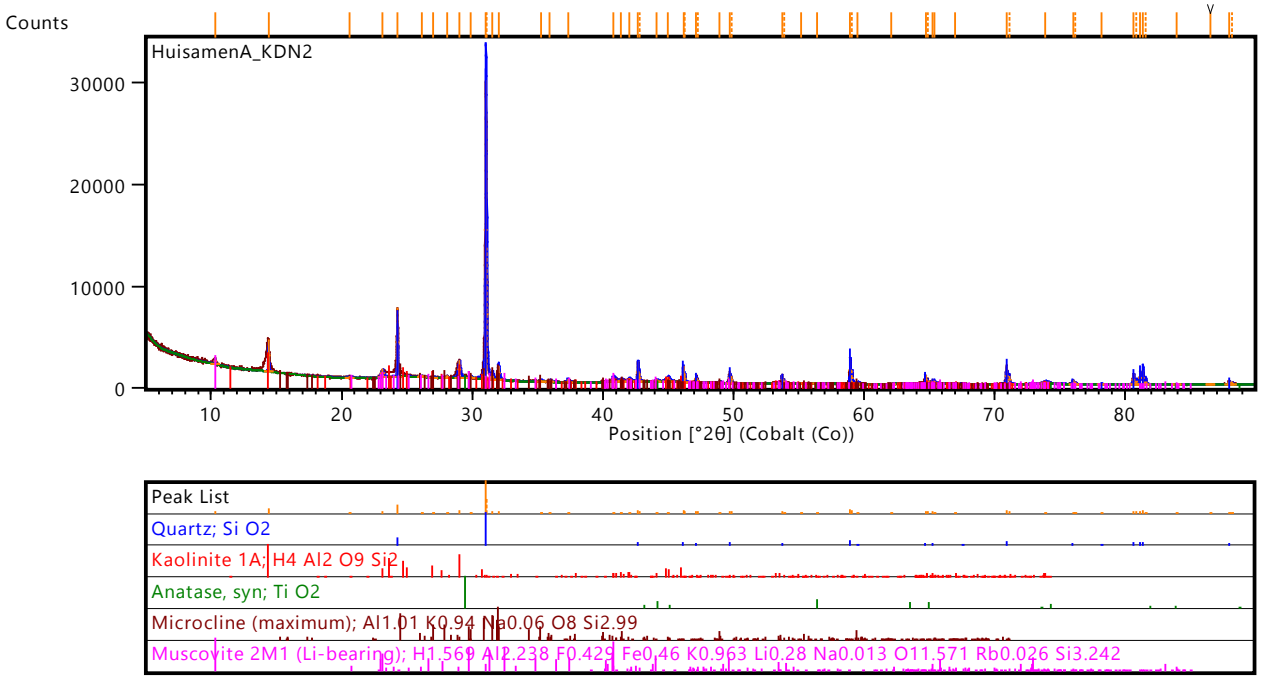
KDC1			**KDC2**			**KDC3**		
	weight%	3 σ error		weight%	3 σ error		weight%	3 σ error
Kaolinite	55.21	0.63	Anatase	1.75	0.19	Anatase	1.41	0.13
Muscovite	4.61	0.3	Kaolinite	59.6	0.75	Kaolinite	43.33	0.6
Quartz	40.18	0.54	Muscovite	4.81	0.6	Microcline	1.12	0.48
			Quartz	33.83	0.6	Muscovite	3.81	0.22
						Quartz	50.33	0.54
KDN1			**KDN2**					
	weight%	3 σ error		weight%	3 σ error			
Anatase	0.78	0.19	Anatase	0.69	0.17			
Kaolinite	43.32	0.66	Kaolinite	39.36	0.75			
Microcline	7.27	0.66	Microcline	7.02	0.57			
Muscovite	4.33	0.25	Muscovite	4.13	0.27			
Quartz	44.29	0.57	Quartz	48.8	0.6			




Counts
HuisamenA_KDC2
20000
10000
0
10
20
30
40
50
60
70
80
Position [°2θ] (Cobalt (Co))
Peak List
Quartz, syn; Si O2
Kaolinite 1A; H4 Al2 O9 Si2
Anatase, syn; Ti O2
Muscovite; K4.00 Al11.63 Si12.37 O40.00


Counts
HuisamenA_KDC3
30000
20000
10000
0
10
20
30
40
50
60
70
80
Position [°2θ] (Cobalt (Co))
Peak List
Quartz; Si O2
Kaolinite 1A; H4 Al2 O9 Si2
Anatase, syn; Ti O2
Microcline (maximum); Al1.01 K0.94 Na0.06 O8 Si2.99
Muscovite 2M1 (Li-bearing); H1.569 Al2.238 F0.429 Fe0.46 K0.963 Li0.28 Na0.013 O11.571 Rb0.026 Si3.242


Counts
HuisamenA_KDN1
30000
20000
10000
0
10
20
30
40
50
60
70
80
Position [°2θ] (Cobalt (Co))
Peak List
Quartz; Si O2
Kaolinite 1A; H4 Al2 O9 Si2
Anatase, syn; Ti O2
Microcline (maximum); Al1.01 K0.94 Na0.06 O8 Si2.99
Muscovite 2M1 (Li-bearing); H1.569 Al2.238 F0.429 Fe0.46 K0.963 Li0.28 Na0.013 O11.571 Rb0.026 Si3.242


Counts
HuisamenA_KDN2
30000
20000
10000
0
10
20
30
40
50
60
70
80
Position [°2θ] (Cobalt (Co))
Peak List
Quartz; Si O2
Kaolinite 1A; H4 Al2 O9 Si2
Anatase, syn; Ti O2
Microcline (maximum); Al1.01 K0.94 Na0.06 O8 Si2.99
Muscovite 2M1 (Li-bearing); H1.569 Al2.238 F0.429 Fe0.46 K0.963 Li0.28 Na0.013 O11.571 Rb0.026 Si3.242

UIS Analytical Services (Pty) Ltd • Reg. No. 2000/027788/07 • VAT No. 4920202969
13 Esdoring Nook, Highveld Technopark, Centurion • PO Box 8286, Centurion, 0046
Tel. +27 12 665 4291 • Fax. +27 12 665 4294 • info@uis-as.co.za • www.uis-as.co.za

Geo Pollution Technologies - Gauteng
81 Rauch Avenue, Georgeville, Meyerspark
Pretoria
0184
South Africa
Altus Huisamen
Tel : +27 12 804 8120
Fax : +27 12 804 8140
E-Mail : altus@gptglobal.com

FINAL CERTIFICATE OF ANALYSIS	
Report Date	2015-06-08
Date Required	2015-06-08
Contract No	
Order/Ref No	Altus PhD

T0184

Altus PhD

Notes
The results relate specifically to the items tested.
The report shall not be reproduced except in full, without the written approval of the laboratory.
[1] SANAS accredited analysis included in the SANAS Schedule of Accredition for this laboratory.
[2] Not SANAS accredited analysis and not included in the SANAS schedule of accreditation for this laboratory.
[3] Outsourced not performed by this laboratory.

Request ID: 12135 **Sample ID:** 434271 **Received:** 2015-05-29 **Matrix:** Rock **Page:** 1 / 2
Sample Number: Altus/PhD/Arnot/1 **Revision Number:** 1

Method: [1]UIS-EA-T001(pH) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.81		[1]pH Temperature	21.1	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	11.9	mSm	[1]Total Conductivity	11.9	mS/m

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	77.3	mg/l	[2]TDS by EC*7	83.2	mg/l

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	27.3	mg/l CaCO3

Method: [2]UIS-TEA-T001(Disolved Cations in Water by ICP-OES) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca	15	mg/l	[2]Fe	0.76	mg/l	[2]K	3.3	mg/l
[2]Mg	6.14	mg/l	[2]Mn	<0.05	mg/l	[2]Na	5.2	mg/l
[2]Si	6.81	mg/l						

Method: [1]UIS-EA-T008(Anions by Ion Chromatography) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]F	0.42	mg/l	[1]Cl	0.49	mg/l	[1]NO3	<0.3	mg/l
[1]SO4	27.5	mg/l						

Method: [2]UIS-CP-T002(Ion Balance Error) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	1.59	me/l	[2]Sum of Anions	1.55	me/l	[2]Ion Balance Error	1.39	%

Request ID: 12135 **Sample ID:** 434272 **Received:** 2015-05-29 **Matrix:** Rock **Page:** 1 / 2
Sample Number: Altus/PhD/Arnot/2 **Revision Number:** 1

Method: [1]UIS-EA-T001(pH) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	7.57		[1]pH Temperature	21.3	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	23.3	mSm	[1]Total Conductivity	23.3	mS/m

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	152	mg/l	[2]TDS by EC*7	163	mg/l

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	<0.6	mg/l CaCO3	[1]Total (M) Alkalinity	20	mg/l CaCO3

Method: [2]UIS-TEA-T001(Disolved Cations in Water by ICP-OES) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca	41.2	mg/l	[2]Fe	<0.05	mg/l	[2]K	1.65	mg/l
[2]Mg	6.54	mg/l	[2]Mn	<0.05	mg/l	[2]Na	2.01	mg/l
[2]Si	1.08	mg/l						

Method: [1]UIS-EA-T008(Anions by Ion Chromatography) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]F	0.4	mg/l	[1]Cl	0.9	mg/l	[1]NO3	<0.3	mg/l
[1]SO4	88.8	mg/l						

Method: [2]UIS-CP-T002(Ion Balance Error) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	2.73	me/l	[2]Sum of Anions	2.31	me/l	[2]Ion Balance Error	8.33	%

Request ID: 12135 **Sample ID:** 434273 **Received:** 2015-05-29 **Matrix:** Rock **Page:** 2 / 2
Sample Number: Altus/PhD/Arnot/3 **Revision Number:** 1

Method: [1]UIS-EA-T001(pH) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[1]pH	8.46		[1]pH Temperature	21.3	Deg C

Method: [1]UIS-EA-T001(Electrical Conductivity) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[1]Tot Cond @25C	12.9	mSm	[1]Total Conductivity	12.9	mS/m

Method: [2]UIS-CP-T001(Calculated Total Dissolved Solids from EC) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[2]TDS by EC*6.5	84.1	mg/l	[2]TDS by EC*7	90.6	mg/l

Method: [1]UIS-EA-T001(P and Total (M) Alkalinity) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit
[1]P Alkalinity	0.7	mg/l CaCO3	[1]Total (M) Alkalinity	59.9	mg/l CaCO3

Method: [2]UIS-TEA-T001(Disolved Cations in Water by ICP-OES) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Ca	17.4	mg/l	[2]Fe	0.05	mg/l	[2]K	1.32	mg/l
[2]Mg	7.45	mg/l	[2]Mn	<0.05	mg/l	[2]Na	1.81	mg/l
[2]Si	0.56	mg/l						

Method: [1]UIS-EA-T008(Anions by Ion Chromatography) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[1]F	0.34	mg/l	[1]Cl	1.19	mg/l	[1]NO3	<0.3	mg/l
[1]SO4	3.92	mg/l						

Method: [2]UIS-CP-T002(Ion Balance Error) **Completed:** 2015-06-08

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
[2]Sum of Cations	1.6	me/l	[2]Sum of Anions	1.17	me/l	[2]Ion Balance Error	15.4	%

Japie Oberholzer
AUTHORISED SIGNATORY

UNIVERSITY OF THE
FREE STATE
UNIVERSITEIT VAN DIE
VRYSTAAT
YUNIVESITHI YA
FREISTATA

UFS·UV
NATURAL AND
AGRICULTURAL SCIENCES
NATUUR- EN
LANDBOUWETENSKAPPE

WATER MANAGEMENT PLAN

Arnot Closed Colliery

Draft Report 1

06 March 2013

Report compiled for

AngloAmerican

Report number: UFS_IGS2013/03/WMP.4

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
NATURAL AND AGRICULTURAL SCIENCES
NATUUR- EN LANDBOUWETENSKAPPE

University of the Free State
Institute for Groundwater Studies
PO Box 339, Bloemfontein, 9301
Tel: +27 51 401 2175
Fax: +27 51 444 6538

06 March 2013
Our ref.: UFS_IGS2013/03/WMP.4

Anglo American
Thermal Coal
Closure Operations
Private Bag X9
Leraatsfontein
Witbank 1038
Tel: +27 13 691 5265
Email: jj.vanderwalt@angloamerican.com

FOR ATTENTION: Mr Johan van der Walt

Dear Sir,

WATER MANAGEMENT PLAN FOR ARNOT CLOSED COLLIERY

It is our pleasure to include one electronic copy of the first draft report UFS_IGS2013/03/WMP.4 "Water Management Plan – Arnot Closed Colliery". The final report will be submitted after personnel of Arnot Closed Colliery have had opportunity to comment on this draft report.

Yours sincerely,

F.D. Fourie
(Ph.D., Pr.Sci.Nat.)

Mobile: +27 82 322 0501
E-mail: fouriefd@ufs.ac.za

Copies: One (1) electronic copy to Anglo American

Executive Summary

The Institute for Groundwater Studies (IGS) was appointed by AngloAmerican to design a Water Management Plan (WMP) for Arnot Closed Colliery that incorporates information on all incoming, inherent and outgoing water from the colliery. During the development of the WMP, the following actions were taken:

- *A number of site visits were conducted.*
- *Previous in-house reports and communications as well as external consultant reports relevant to the current investigations were studied.*
- *A limited hydro-census was conducted in the vicinity of the backfilled and rehabilitated pits.*
- *The existing surface- and groundwater monitoring network was evaluated in terms of its suitability to achieve the aims of a groundwater monitoring programme.*
- *Representative soil samples were taken selected positions around the pits. These samples were submitted to an accredited laboratory for grain size analyses in order to obtain estimates of the hydraulic properties of the soils.*
- *Samples of the spoils and coal discards were taken at positions on the rehabilitated pits where the spoils were exposed. These samples were submitted to an accredited laboratory for acid-base analyses in order to evaluate the potential for acid mine drainage (AMD) from the pits.*
- *Magnetic data were recorded on four traverses at selected positions to investigate the presence and orientation of dolerite intrusives.*
- *Ten investigative and monitoring boreholes were drilled at selected sites. Geological borehole logs were compiled during drilling.*
- *Electrical conductivity (EC) profiling was done on existing and newly drilled boreholes to investigate stratification in the groundwater quality within the boreholes.*
- *Surface- and groundwater sampling was performed and the water samples were submitted to an accredited laboratory for chemical analyses.*
- *Hydraulic tests were performed on the ten newly drilled boreholes, as well as on those existing boreholes for which information on their construction could be found. The purpose of the hydraulic tests was to obtain information on the hydraulic properties of the rock formations surrounding the opencast pits.*
- *The current water reticulation system at Arnot Closed Colliery was investigated and documented.*
- *A sonar survey of the floor elevations of the dams that form part of the water reticulation system was conducted in order to calculate stage curves showing the volumes of water stored in these dams at various water levels.*
- *By considering all the results of the investigations, a conceptual geohydrological model for Arnot Closed Colliery was developed.*
- *The conceptual geohydrological model was used to inform the development of a numerical model to investigate groundwater flow patterns and potential contaminant plume migration in the vicinity of the backfilled pits.*
- *Groundwater and surface water balances were calculated for Arnot Closed Colliery.*
- *Future water management options for Arnot Closed Colliery were suggested.*

The results of the various phases of the investigation are summarised below:

Hydrocensus

During the hydrocensus 31 surface water sites and 56 groundwater sites were identified and visited. Of the 56 groundwater sites 38 are located within or in the vicinity of Pit 1, while 18 groundwater sites are located within or in the vicinity of Pit 2 (W&E). Where possible, the following information was captured for the different water sites: GPS coordinates, site photographs, site conditions. Additional information for the groundwater sites included: borehole construction, borehole protection, visibility, groundwater use and groundwater level. Surface sites were described in terms of their flow rates (river sites) and water levels (dam and pan sites). Observations regarding water quality and contaminant impacts were made at a number of sites.

Description of the current water reticulation system

The water reticulation system at Arnot Closed Colliery was described by incorporating information on the system of pumps and flowmeters that form part of the current water reticulation system. From the monthly flowmeter readings and dam level measurements, as well as information on rainfall and evaporation, a first estimate of the water make of the colliery was obtained. The water make for the period January to June 2012 was estimated at 4.90 Ml/day.

Pit and dam decant levels and storage capacities

Data from a digital terrain model (DTM) compiled during January 2012 were used to determine the decant levels of the three backfilled and rehabilitated pits at Arnot Closed Colliery. The decant levels of Pit 1, Pit 2W and Pit 2E were found to be 1 595.05, 1 602.42 and 1 607.40 mamsl, respectively. Stage curves were compiled for the three pits and it was found that the storage capacities of the pits are approximately 20 600 Ml (Pit 1), 2 800 Ml (Pit 2W) and 1 607 Ml (Pit 2E). These estimates assume that the pits are not compartmentalised; however, there is strong evidence that Pit 1 (and possibly the other two pits) is compartmentalised, in which case the storage capacities may be greater than the above estimates.

In order to determine the storage capacities of the dams within Pit 1, a sonar survey was undertaken to measure the floor elevations of the dams. Sonar surveys were conducted on the following dams: the Decant Dam, the T1 Dam, the Final Void, both parts of the T4 Pump dam and the T4 Dam. The results of the sonar survey were used along with the DTM recorded in January 2012 to determine the decant levels and stage curves of these dams.

The decant levels of the dams were found to be 1 595.4 mamsl (Decant Dam), 1 596.4 mamsl (T1 Dam), 1 597.4 mamsl (Final Void), 1 597.0 mamsl (T4 Dam), 1 604.5 mamsl (northern part of the T4 Pump dam), and 1 603.5 mamsl (southern part of the T4 Pump dam).

The storage capacities of the dams were determined to be 71.8 Ml (Decant Dam), 2 090 Ml (T1 Dam), 391 Ml (Final Void), 164 Ml (T4 Dam), 110 Ml (northern part of the T4 Pump dam), and 135 Ml (southern part of the T4 Pump dam).

Evaluation of the current water monitoring programme

The current monitoring programme was evaluated below in terms of the positions of the sampling sites and the density of the sampling network, the conditions of the sampling sites, the monitoring frequency employed, the depths at which samples are taken, the sampling procedures followed and the parameters analysed for during chemical analyses.

Some of the findings and recommendations were:

- *To evaluate possible contaminant impacts from the backfilled and rehabilitated pits on the water quality of the Bosman Spruit, additional sampling sites farther to the east along the Bosman Spruit are required.*

- *At least one site upstream from Pit 2E should be sampled to gain information on the background water quality.*

- *The Klein-Olifants River is currently sampled at only two sites located to the west and north-west of Pit 1. Since contaminant originating from Pit 1 could potentially impact on the water quality of the river at positions south of Pit 1, it is recommended that additional sampling sites along this river be included in the monitoring programme.*

- *In order to separate the upstream impacts on the Woestalleen Spruit from possible impacts originating from Arnot Closed Colliery, this river should be sampled at a position upstream from its confluence with the Klein-Olifants River.*

- *The Bliksem Pan, Steels Pan and Railway Pan should be included in the water monitoring programme.*

- *Groundwater monitoring sites are sparse to the north, south and south-west of the pit. The installation of additional monitoring boreholes should be considered.*

- *It is recommended that other existing boreholes be included in the monitoring programme. These boreholes could include some of the Alzu boreholes that occur in the areas south and south-west of Pit 1. To the north of Pit 1, borehole KGM_B10 could also be included to increase the density of the monitoring network.*

- *The new boreholes drilled as part of the current investigations should be included in the monitoring programme.*

- *Despite recent upgrades, many of the groundwater monitoring sites required further attention. All monitoring boreholes should be equipped with concrete plinths, marker posts, site numbers and lockable caps.*

- *It is recommended that marker post be installed at the surface water monitoring sites to ensure that the water samples are taken at the same locations during the different sampling events.*

- *Problems with the monitoring sites should be noted during the sampling events and reported to ensure that they receive attention before the next sampling event.*

- *Apart from the monthly sampling done by personnel of AngloAmerican, it is recommended that biannual monitoring be done by external consulting scientists, once during the wet season (November to January) and once during the dry season (May to July). The consulting scientists should compile detailed reports describing the conditions of the monitoring sites and the results of the chemical analyses performed on the water samples.*

- *Groundwater sites should be sampled at appropriate depths, as determined from electrical conductivity (EC) profiling and borehole logs.*

Installation of investigative and monitoring boreholes

During July 2012 investigative and monitoring boreholes were installed at 10 selected sites at Arnot Closed Colliery. The installation of these boreholes had a number of aims, namely to:

- *Increase the density of the groundwater monitoring network within and around the backfilled and rehabilitated pits,*

- *Provide information on the subsurface geology,*

- *Provide information on the geohydrological conditions at the site,*

- *Allow investigation of the hydraulic parameters of the aquifer system(s) present, and,*

- *Provide water level and water quality information that will be used to calibrate the numerical groundwater model to be constructed.*

Five of the 10 newly drilled boreholes encountered very similar geological conditions. A typical borehole log consisted of a few metres of yellow-brown to red-brown topsoil, followed by a few metres of subsoil (highly weathered sedimentary rocks), overlying various layers of Karoo rocks (sandstones, shales, coal). These materials are underlain by red-brown rhyolites. The only exceptions were boreholes B3 (no rhyolite intersected), boreholes B4 and B10 (drilled within the spoils of Pit 1) and boreholes B5 and B9 (dolerite intrusives encountered).

Water was struck during drilling at depths of 34 mbgl (B3), 25 mbgl (B4), 20 mbgl (B6), 15 mbgl (B7), 15 mbgl (B8), 22 mbgl (B9) and 22 mbgl (B10).

EC profiling of boreholes

In order to investigate possible stratification in the water quality within the boreholes, electrical conductivity (EC) profiling was done on all accessible boreholes forming part of the monitoring network at Arnot Closed Colliery. A total of 44 boreholes were EC profiled. These boreholes included 30 existing monitoring boreholes, four of Alzu's boreholes and the 10 new boreholes drilled during July 2012. The EC profiles clearly showed stratification of the water quality within most of the boreholes.

Based on the results of the EC profiling, sampling depths for each borehole were identified at which increased salt loads were apparent. The selection of the sampling depths of the new boreholes was done by also considering the geological and geohydrological conditions as revealed during drilling.

Hydraulic testing of boreholes

Hydraulic tests were conducted on the new boreholes drilled during July 2012 as well as on three existing monitoring boreholes for which the construction was known (information had been punched on the lids of these boreholes soon after construction). The purpose of the hydraulic tests was to obtain information on the hydraulic conductivities of the geological units in which the boreholes were drilled. Slug tests were performed on all 13 tested boreholes. Analyses of the hydraulic test data showed that the hydraulic conductivities of the intersected earth materials at the different boreholes differ significantly, ranging from 0.001 m/d to 1.138 m/d. Low hydraulic conductivities were observed at those boreholes that intersected dolerite. The geometric mean of the estimated hydraulic conductivities of the Karoo sedimentary rocks was found to be 0.039 m/d.

Groundwater and surface water quality

Water sampling from the various surface- and groundwater sites was done on 7, 13, 14 and 15 August 2012. Water samples were submitted to the chemical laboratories of the IGS on 16 August 2012 for inorganic parameter analyses. Some of the findings related to water quality were:

- *Most of the groundwater sites on and near Pit 1 show clear signs of contaminant impacts. The sulphate concentrations in most boreholes are high enough to classify the groundwater as Class 4 (poor quality) water. Apart from the high sulphate concentrations, the groundwater of the affected sites displays high calcium, magnesium and TDS concentrations and elevated EC values. High sodium concentrations are also observed at some boreholes.*

- *The pH values at most of the sites range between 6.1 and 8.2. However, very acidic conditions are observed at borehole AW09 near the southern coal discard site. The acidic conditions have led to the mobilisation of some trace metals. High iron, manganese and lead concentrations are observed at borehole AW09. It therefore appears that the coal discards are responsible for the generation of acidic conditions.*

- *High manganese concentrations are observed in all the affected sites, even where alkaline conditions prevail. It therefore appears that an elevated manganese concentration may be seen as a first indicator of impacts from mining activities.*

- *The concentrations of the major parameters at many of the sites clearly show stratification in the groundwater quality. Samples taken at the static water level generally have lower concentrations of the major parameters than the deeper samples. The lower concentrations for the samples from the static water level may be explained by the diluting effect of rainfall entering the borehole either directly or through seepage through the near-surface materials.*

- *The major parameters sulphate, magnesium, calcium, total hardness, EC and TDS may be identified as indicator parameters to use when evaluating whether a groundwater site has been impacted on by inorganic contaminants originating at Pit 1. Similarly, the minor parameters iron and manganese may be considered as indicator parameters.*

- *Compared to the groundwater sites at Pit 1, the groundwater sites in and in the vicinity of Pit 2 (W and E) are much less affected by contaminant impacts.*

- *The pH values at the groundwater sites near Pit 2 generally vary between 6.6 and 7.4, although slightly more acidic conditions do prevail at some sites.*

- *The presence of elevated fluoride concentrations at some sites north of Pit 2W may be due to an intrusive dolerite structure in this area.*

- *The groundwater quality at the Alzu boreholes is generally better that the water quality observed at the monitoring boreholes near Pit 1. This may be partly explained by the fact that the Alzu boreholes are/were production boreholes drilled to greater depths than the monitoring boreholes.*

- *Elevated sulphate concentrations are observed at Alzu boreholes BHZ08 and BHZ09.*

- *The pH values at the Alzu boreholes generally indicate alkaline conditions. Only at borehole BHZ09 is a slightly lower pH observed (6.5), but the conditions remain near-neutral.*

- *Apart from elevated manganese concentrations at some boreholes, the minor parameters concentrations at the Alzu boreholes are very low, indicating that little or no mobilisation of trace elements has occurred.*

- *The dams within Pit 1 contain water that has been exposed to extensive contaminant impacts. Sulphate concentrations are higher than 2 800 mg/l, while high concentrations of calcium and magnesium are also observed.*

- *The pans in the vicinity of Pit 1 contain water of a quality similar to the dams within Pit 1. The Bliksem Pan did in the past receive decant from the T1 Dam in the form of controlled release. However, the high sodium, chloride and potassium concentrations observed in the Bliksem Pan do seem to have another source since these concentrations are much greater than those observed in the dams within Pit 1. A possible source may be the chicken pens of Alzu which are located approximately 400 m upstream from the pan.*

- *The Steels Pan is highly contaminated. This pan is, however, used to dispose of the liquid wastes generated at Alzu's piggery. The observed high phosphate concentration is thus explained. Similar to the Bliksem Pan, high sodium, chloride and potassium concentrations are present in the water from this pan. The high sulphate and magnesium concentrations suggest that contaminants from Pit 1 have impacted on the water quality in the pan, either through surface runoff or subsurface seepage.*

- *The water quality at sampling sites along the Bosman Spruit indicates that contaminant impacts have occurred on this river. It should, however, be noted that the Bosman Spruit may be impacted on by contaminants from both Arnot Closed Colliery and the adjacent Kwagga Section of Optimum Colliery.*

- *The Klein-Olifants River is much more severely affected by contaminant impacts than the Bosman Spruit. Sulphate concentrations in excess of 950 mg/l are observed at three sampling sites along this river. However, other mines farther upstream along the river are likely to have affected the water quality in this river.*

Groundwater depths and elevations

Based on the measured groundwater levels in the vicinity of the rehabilitated opencast pits of Arnot Closed Colliery, it can be concluded that the regional groundwater flow in the vicinity of the pits is to the west and north-west.

Within Pit 1 the water elevations range between 1 596.55 and 1 601.44 mamsl. All the observed water elevations exceed the decant level of Pit 1 (1 595.05 mamsl). The water level elevations are higher in the southern and eastern parts of the pit than in the north-western part. The most likely explanation for this variation in the water elevation within Pit 1 is that the pit is compartmentalised.

The water level elevation in borehole B5 is almost 10 m higher that the elevation in nearby borehole B3, both drilled near the partial corridor that occurs near the northern perimeter of the pit. The drilling results have shown that this partial corridor, as well as the partial corridor near the southern perimeter in the vicinity of borehole B9, is associated with the presence of a dolerite intrusive. The observed elevated water level therefore suggests that the dolerite intrusive intersected by borehole B5 is associated with an aquifer that is hydraulically linked to a recharge zone that occurs at a much higher elevation than the decant level of Pit 1. It is therefore possible that the dolerite intrusive acts as, or is associated with, a preferential pathway for groundwater migration, causing an influx of groundwater into Pit 1.

Soil sampling

In order to gain information on the hydraulic properties of the soils in the vicinity of the opencast pits of Arnot Closed Colliery, thirteen soil samples were taken at selected positions and submitted to an accredited laboratory for grain size analyses. The results of the analyses were used to estimate the hydraulic conductivities of the soils. The geometric mean of the estimated soil hydraulic conductivities was found to be 0.375 m/d.

Acid-base accounting

Twelve samples of exposed spoils and coal discards were taken at positions on and near the backfilled and rehabilitated opencast pits of Arnot Closed Colliery during June 2012. These samples were submitted to an accredited laboratory for acid-base analyses. The purposed of the acid-base analyses was to determine the acid generation potential of the waste rock materials to evaluate the likelihood of acid mine drainage (AMD) from the pits.

The results of the acid-base accounting indicate that samples representing the exposed coal discards are likely to be acid generating. Samples from the spoils of the mining activities at the adjacent Kwagga Section of Optimum Colliery are also potentially acid generating. These spoils are currently exposed to atmospheric conditions since rehabilitation has not commenced. Oxidation of the exposed spoils is therefore likely to lead to acid generation.

Leach tests conducted on the samples of the spoils and coal discards showed that various trace elements may be released to the groundwater under oxidising and acidic conditions. These include iron, manganese and lead.

Geophysical investigations

Ground magnetic surveys were conducted at selected positions near the backfilled and rehabilitated opencast pits of Arnot Closed Colliery. The purpose of the magnetic surveys was to determine whether intrusive magmatic structures (e.g. dolerite dykes) cut across the pits. Such structures may act as barriers to groundwater flow in directions perpendicular to their strikes and may also be associated with preferential pathways for groundwater flow in directions parallel to their strikes.

The results of the magnetic survey revealed the presence of deep, broad magnetic structures. Although these structures do not extend to surface, they may have caused burning of the coal at the depths were mining was done. The results of the magnetic survey therefore suggest that, although the different pits are separated by corridors of rock material, these corridors are not due to dolerite intrusives that extend to the near-surface, acting as barriers to groundwater flow between the pits. The corridors are therefore likely to be formed by sedimentary rocks of the Karoo Supergroup with permeabilities greater than dolerite. Significant groundwater flow between the pits therefore appears likely.

Numerical modelling of groundwater flow and contaminant transport

The numerical flow and transport model was constructed to:

- *investigate the volumes of water leaving the backfilled pits through seepage into the topsoil and surrounding Karoo formations,*
- *gain insight into the subsurface flow patterns,*
- *investigate the migration of contaminant plumes away from the pits, and,*
- *obtain estimates of the salt loads that may impact on the natural surface water bodies along the groundwater pathway.*

The calibrated numerical model suggests that approximately 0.25 Ml/day seep from the backfilled opencast pits into the surrounding geological units. Results of the transient model indicate that contaminant migration in the Karoo formations is expected to be relatively slow with the contaminant plume confined to the immediate vicinity of the pits for the first two decades. Contaminant migration in the topsoil is expected to be even more limited. However, in time, impacts on the both the Bosman Spruit and the Klein-Olifants River are expected.

Due to its proximity to Pit 2W, the Bosman Spruit is particularly vulnerable to contaminant impacts. Within 55 years the sulphate concentration of the groundwater at an observation point along the Bosman Spruit may reach a value of 1 800 mg/l. Over a 100 year period, approximately 20 000 tonnes of sulphate may impact on the Bosman Spruit. This value equates to an average daily sulphate load of approximately 550 kg over the 100 year period.

The numerical model also suggests that contaminant impacts on the groundwater quality at the production boreholes of Alzu Enterprises may occur. The Alzu Windpump and borehole BHZ10 are the most likely abstraction boreholes to be impacted on by contaminant impacts along the groundwater pathway.

Water make and water balance

By making assumptions regarding the effective recharge through the spoils, the water make at Arnot Closed Colliery was estimated. During years of average rainfall, the water make is estimated at 6.4 Ml/day. During years of high rainfall the average water make increases to more than 8 Ml/day.

The water balance compiled for Arnot Closed Colliery (during years of average rainfall) indicates that rainfall recharge contributes approximately 20.9 Ml/day to the water system, while the net groundwater inflow to the pits contributes approximately 2.23 Ml/day. Water losses due to runoff, evaporation losses from the open water bodies and evaporation losses from the spoils constitute 1.67 Ml/day, 1.31 Ml/day and 13.71 Ml/day, respectively. The excess water is calculated to be 6.4 Ml/day.

From the salt balance compiled for Arnot Closed Colliery it is seen that approximately 7 790 kg/day of sulphate is removed from the backfilled pits. The estimated TDS load generated is approximately 11 130 kg/day.

Water management strategies

The recommended short-term water management strategy for Arnot Closed Colliery entails the following actions:

- *Address water quality issues at the colliery by a) continuing with the water monitoring programme, b) reducing the potential for acid generation at the coal discards and exposed spoils, and c) treating acidic decant if and when it occurs.*

- *Take further actions to limit surface- and groundwater ingress into the pits.*

- *Commence with the planting of Eucalyptus trees along the banks of the Decant Dam and the T1 Dam. Although significant water losses from the Eucalyptus plantation will only occur after a number of years of growth, it is recommended that the process be initiated as soon as possible.*

- *Construct dam walls and seepage interception trenches at the south-western decant points of the T2 Dam, T3 Dam and T4 Dam. These dams will only be employed for their storage capacities and evaporation surfaces during times of above average rainfall.*

- *Install a sprayer system along the banks of the T1 Dam.*

- *Continue with the current Mafube Offtake of approximately 1 Ml/day.*

- *Assuming zero water losses from the Eucalyptus plantation in the short-term and total evaporation losses at the sprayers similar to the current estimate of 3.68 Ml/day, a total volume of approximately 1.72 Ml/day will still be in excess at the colliery. It is recommended that this volume of water be included as Arnot Closed Colliery's contribution to the mine water load to be treated at the Mafube water treatment scheme.*

- *During periods of high rainfall when the above actions are not adequate to deal with the volumes of water entering the pits, it is recommended that water be pumped to the T4 Dam, T3, Dam and T2 Dam to increase the evaporation surface and to allow for a longer residence time within Pit 1. Should the buffer capacities of these dams be breached, excess pit water should be discarded in the Bliksem Pan, under the DWA prescriptions on water quantity and quality. Only when the storage capacity of the Bliksem Pan is inadequate to accommodate all the excess mine water, should controlled releases to the Klein-Olifants River be considered. Such releases should again be done under the prescribed conditions set by the DWA.*

Since pumping cannot be continued indefinitely, strategies involving such pumping should be seen as only short-term strategies. In the long term, after pumping has ceased, Arnot Closed Colliery is expected to have an excess water volume of between 4.3 and 4.6 Ml/day during years of average rainfall. If the Mafube water treatment facility has the capacity to process such a large volume of water originating from Arnot Closed Colliery, this option may be the only long-term, sustainable solution to dealing with the excess water at the colliery.

During periods of higher than average rainfall, the option of using the Bliksem Pan for its storage capacity may form part of the long-term water management plan. Only when the storage capacity of the pan is exceeded should controlled release of water to the Klein-Olifants River be considered. Controlled releases should adhere to the prescribed quantity and quality conditions set by the DWA.

TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 PROJECT DESCRIPTION 1
1.2 SCOPE OF WORK 1
1.3 PROJECT METHODOLOGY 2

2 SITE INFORMATION 4
2.1 GENERAL 4
2.2 REGIONAL SETTING 5
2.3 GEOLOGICAL SETTING 6
2.4 TOPOGRAPHY AND DRAINAGE 10
2.5 GEOHYDROLOGICAL CONDITIONS 14
2.6 CLIMATIC CONDITIONS 15
2.6.1 Rainfall 15
2.6.2 Evaporation 17

3 HYDROCENSUS 18
3.1 INTRODUCTION 18
3.2 SURFACE WATER SITES 18
3.3 GROUNDWATER SITES – PIT 1 24
3.4 GROUNDWATER SITES – PIT 2 (W&E) 36
3.5 SURFACE- AND GROUNDWATER USE AT ALZU 43
3.5.1 Maize Cultivation 43
3.5.2 Pig Farming 43
3.5.3 Egg Production 43
3.5.4 Human Consumption 43
3.5.5 Road Wetting 44

4 THE CURRENT WATER RETICULATION SYSTEM 45
4.1 INTRODUCTION 45
4.2 VOLUMES PUMPED 49
4.2.1 Decant Dam 50
4.2.2 T1 Dam 50
4.2.3 Final Void 51
4.2.4 T4 Pump 52
4.3 CHANGES IN DAM LEVELS AND VOLUMES 53
4.4 DIRECT RAINFALL RECHARGE TO DAMS 55
4.5 EVAPORATION LOSSES AT DAMS AND SPRAYERS 56
4.6 FIRST ESTIMATES OF THE WATER MAKE 57

5 PIT AND DAM DECANT LEVELS AND STORAGE CAPACITIES 61
5.1 PIT DECANT LEVELS AND CAPACITIES 61
5.2 DAM DECANT LEVELS AND CAPACITIES 63
5.2.1 Decant Dam 64
5.2.2 T1 Dam 64
5.2.3 Final Void 64
5.2.4 T4 Dam 64
5.2.5 T4 Pump 1 dam 64
5.2.6 T4 Pump 2 dam 64

6 EVALUATION OF THE CURRENT WATER MONITORING PROGRAMME 70
6.1 SURFACE- AND GROUNDWATER SAMPLING NETWORK 70
6.2 CONDITIONS OF MONITORING SITES 75
6.3 MONITORING FREQUENCY 75
6.4 SAMPLING DEPTHS 76
6.5 SAMPLING PROCEDURE 77
6.6 PARAMETERS INCLUDED IN THE CHEMICAL ANALYSES 77

7 INSTALLATION OF INVESTIGATIVE AND MONITORING BOREHOLES 79
7.1 INTRODUCTION 79
7.2 DRILLING RESULTS 79

8 EC PROFILING OF BOREHOLES 84

8.1 INTRODUCTION 84
8.2 RESULTS 84

9 HYDRAULIC TESTING OF BOREHOLES 87
9.1 INTRODUCTION 87
9.2 RESULTS 87

10 GROUNDWATER AND SURFACE WATER QUALITY 89
10.1 SURFACE- AND GROUNDWATER SAMPLING, AUGUST 2012 89
10.1.1 Water quality: groundwater monitoring sites, Pit 1 103
10.1.2 Water quality: groundwater monitoring sites, Pit 2 104
10.1.3 Water quality: groundwater from the Alzu boreholes 105
10.1.4 Water quality: groundwater from the new boreholes 106
10.1.5 Water quality: surface water sites 106
10.2 HISTORICAL WATER QUALITY DATA 113
10.2.1 Surface water sites: dams and pans within and near Pit 1 113
10.2.2 Groundwater monitoring sites within and near Pit 1 114
10.2.3 Alzu boreholes 116
10.2.4 Groundwater sites within and near Pit 2 117
10.2.5 River and stream sites 119

11 GROUNDWATER DEPTHS AND ELEVATIONS 121

12 SOIL SAMPLING 126
12.1 INTRODUCTION 126
12.2 RESULTS 126

13 ACID-BASE ACCOUNTING 129
13.1 INTRODUCTION 129
13.2 RESULTS 129

14 GEOPHYSICAL INVESTIGATIONS 134
14.1 INTRODUCTION 134
14.2 SURVEY GEOMETRY 134
14.3 SURVEY RESULTS 134

15 CONCEPTUAL GEOHYDROLOGICAL MODEL 140
15.1 MODEL UNITS 140
15.2 RECHARGE 141
15.3 HYDRAULIC PROPERTIES 141
15.4 WATER LEVELS 142
15.5 CONTAMINANT LEVELS 142

16 NUMERICAL MODELLING OF GROUNDWATER FLOW AND CONTAMINANT TRANSPORT 145
16.1 INTRODUCTION 145
16.2 MODEL CONSTRUCTION 145
16.3 BOUNDARY CONDITIONS 146
16.4 STEADY-STATE MODEL AND MODEL CALIBRATION 146
16.5 TRANSIENT MODEL 149

17 WATER MAKE AND WATER BALANCE 158
17.1 ESTIMATION OF THE WATER MAKE 158
17.2 WATER BALANCE 160
17.3 SALT BALANCE 161

18 WATER MANAGEMENT OPTIONS 164
18.1 INTRODUCTION 164
18.2 ACTIONS TO MANAGE WATER QUALITY 164
18.2.1 Surface- and groundwater monitoring 164
18.2.2 Reducing the potential for acid generation 164
18.2.3 Treating acidic water 165
18.3 ACTIONS TO LIMIT WATER INGRESS 165
18.3.1 Limiting groundwater influx along preferential pathways 165
18.3.2 Limiting surface water influx 166
18.3.3 Preventing ponding 166
18.3.4 Constructing contour berms on the ramps 166
18.4 ACTIONS TO INCREASE WATER LOSSES 167
18.4.1 Increasing the evaporation surfaces and storage capacities of open water bodies 167
18.4.2 Construction of evaporation ponds with sprayers 168

18.4.3 Employing sprayers at the T1 Dam to increase evaporation losses *169*
18.4.4 Planting Eucalyptus trees to increase evapo-transpiration losses *170*
18.4.5 Disposing of excess mine water into the Bliksem Pan *172*
18.4.6 Controlled release of pit water to the Klein-Olifants River *174*
18.4.7 Mafube offtake *174*
18.4.8 Power station cooling and ashing operations *175*
18.4.9 Joining the Mafube water management scheme *175*
18.5 SHORT-TERM WATER MANAGEMENT STRATEGY 175
18.6 LONG-TERM WATER MANAGEMENT STRATEGY 177

19 SUMMARY AND CONCLUSIONS 178

APPENDICES

APPENDIX A: **Maps and Plans**

APPENDIX B: **Borehole Logs**

APPENDIX C: **EC Profiling Results**

APPENDIX D: **Hydraulic Test Results**

APPENDIX E: **Water Quality Information**

LIST OF FIGURES

Figure 1. Regional setting of Arnot Closed Colliery. 7

Figure 2. Other coal mines bordering and in the vicinity of Arnot Closed Colliery. 8

Figure 3. Geological setting of Arnot Closed Colliery. 9

Figure 4. Drainage from quaternary sub-catchments B12A and B12B. 11

Figure 5. Topographic elevation within sub-catchments B12A and B12B. 12

Figure 6. The pre- and post-mining topography in the vicinity of Pit 1 of Arnot Closed Colliery. 13

Figure 7. The decant water level of Pit 1 shown against the post-mining topography. 14

Figure 8. Rainfall recorded at the Decant Dam 16

Figure 9. Surface water sites at and in the vicinity of Arnot Closed Colliery. 19

Figure 10. Groundwater sites within and in the vicinity of Pit 1. 26

Figure 11. Groundwater sites within and in the vicinity of Pit 2 (W & E). 37

Figure 12. Schematical representation of the current water reticulation system at Arnot Closed Colliery 46

Figure 13. Cross-section trace through the various dams within Pit 1. 47

Figure 14. Cross-section through the various dams within Pit 1 illustrating water reticulation and water gains and losses. 48

Figure 15. Decant levels of Pit 1, Pit 2W and Pit 2E. 61

Figure 16. Stage curve for Pit 1 62

Figure 17. Stage curve for Pit 2W. 62

Figure 18. Stage curve for Pit 2E. 63

Figure 19. Stage curve for the Decant Dam 65

Figure 20. Stage curve for the T1 Dam. 65

Figure 21. Stage curve for the Final Void 66

Figure 22. Stage curve for the T4 Dam. 66

Figure 23. Stage curve for the T4 Pump 1 dam (northern part of the T4 Pump dam). 67

Figure 24. Stage curve for the T4 Pump 2 dam (southern part of the T4 Pump dam). 67

Figure 25. Dams within Pit 1 with their decant levels and maximum capacities..... 68

Figure 26. Positions of the surface water monitoring sites included in the current monitoring programme at Arnot Closed Colliery..... 72

Figure 27. Positions of the groundwater monitoring sites near Pit 1 included in the current monitoring programme at Arnot Closed Colliery. 73

Figure 28. Positions of the groundwater monitoring sites near Pit 2 (W&E) included in the current monitoring programme at Arnot Closed Colliery. 74

Figure 29. Positions of the new investigative and monitoring boreholes at Arnot Closed Colliery. 80

Figure 30. Example of water quality stratification in borehole ANT-2. 85

Figure 31. Example of water quality stratification in borehole AW05. 85

Figure 32. Sulphate concentrations at the various surface water sites (August 2012). 108

Figure 33. Sulphate concentrations at the various groundwater sites within and near Pit 1 (August 2012). 109

Figure 34. Sulphate concentrations at the various groundwater sites within and near Pit 2 (August 2012). 110

Figure 35. Sulphate concentrations along the Bosman Spruit. 111

Figure 36. Sulphate concentrations along the Klein-Olifants River. 112

Figure 37. Sulphate concentrations at the dam and pan sites within and near Pit 1. 114

Figure 38. pH values at the dam and pan sites within and near Pit 1..... 114

Figure 39. Sulphate concentrations at the groundwater sites within and near Pit 1. 115

Figure 40. pH values at the groundwater sites within and near Pit 1. 116

Figure 41. Sulphate concentrations at the Alzu boreholes..... 116

Figure 42. pH values at the Alzu boreholes. 117

Figure 43. Sulphate concentrations at the groundwater sites within and near Pit 2. 118

Figure 44. pH values at the groundwater sites within and near Pit 2. 118

Figure 45. Sulphate concentrations at the river and stream sites. 119

Figure 46. pH values at the river and stream sites. 120

Figure 47. Groundwater elevations at Arnot Closed Colliery, August 2012. ..... *123*

Figure 48. Water elevations within the backfilled pits at Arnot Closed Colliery, August 2012. .. *124*

Figure 49. Positions in the vicinity of the backfilled and rehabilitated opencast pits where soil samples were taken for grain size analyses. *128*

Figure 50. Positions on and in the vicinity of the backfilled and rehabilitated opencast pits where rock samples were taken for acid-base accounting. *131*

Figure 51. Position and orientation of the magnetic traverse north of Pits 2W and 2E. *135*

Figure 52. Positions and orientations of the magnetic traverses south of Pit 1. ..... *136*

Figure 53. Magnetic data recorded along Traverse 01. ..... *137*

Figure 54. Magnetic data recorded along Traverse 02. ..... *138*

Figure 55. Magnetic data recorded along Traverse 03. ..... *138*

Figure 56. Magnetic data recorded along Traverse 04. ..... *139*

Figure 57. Schematic cross-section through Pit 1 illustrating the conceptual geohydrological model for Arnot Closed Colliery *143*

Figure 58. Position and orientation of the cross-section trace through Pit 1 used for the conceptual geohydrological model. *144*

Figure 59. Finite-element mesh and numerical model boundaries. *146*

Figure 60. Modelled and observed water levels for the calibrated steady-state model. *147*

Figure 61. Modelled water levels plotted against observed water levels for the calibrated steady-state model. *148*

Figure 62. Groundwater elevations of the calibrated steady-state model. *148*

Figure 63. Contaminant plume in the Karoo formations after 5 years. *149*

Figure 64. Contaminant plume in the Karoo formations after 10 years. *150*

Figure 65. Contaminant plume in the Karoo formations after 20 years. *150*

Figure 66. Contaminant plume in the Karoo formations after 50 years. *151*

Figure 67. Contaminant plume in the Karoo formations after 100 years. *151*

Figure 68. Contaminant plume in the topsoil after 5 years. *152*

Figure 69. Contaminant plume in the topsoil after 10 years. *152*

Figure 70. Contaminant plume in the topsoil after 20 years. *153*

Figure 71. Contaminant plume in the topsoil after 50 years..... 153

Figure 72. Contaminant plume in the topsoil after 100 years..... 154

Figure 73. Sulphate concentrations at observations points. 155

Figure 74. Cumulative sulphate loads impacting on the Bosman Spruit and Klein-Olifants River. 156

Figure 75. Positions of the abstraction boreholes of Alzu Enterprises relative to the contaminant plume as modelled after 100 years. 156

Figure 76. Modelled sulphate concentrations for the abstraction boreholes of Alzu Enterprises.157

Figure 77. Sulphate vs TDS concentrations of the dams in Pit 1. 162

Figure 78. Proposed Eucalyptus plantations on the banks of the T1 Dam and Decant Dam..... 173

LIST OF TABLES

Table 1. Monthly rainfall recorded at the Decant Dam of Arnot (Closed) Colliery..... 16

Table 2. Average monthly S-pan and lake evaporations..... 17

Table 3. Surface water sites visited during the hydrocensus..... 20

Table 4. Groundwater sites in the vicinity of Pit 1 visited during the hydrocensus..... 27

Table 5. Groundwater sites in the vicinity of Pit 2 (W & E) visited during the hydrocensus..... 38

Table 6. Volumes of water pumped from the Decant Dam..... 50

Table 7. Volumes of water pumped to the T1 Dam..... 51

Table 8. Volumes of water pumped from the T1 Dam..... 51

Table 9. Volumes of water pumped to the Final Void..... 52

Table 10. Volumes of water pumped from the Final Void..... 52

Table 11. Volumes of water pumped to the T4 Pump dam..... 53

Table 12. Volumes of water pumped from the T4 Pump dam..... 53

Table 13. Changes in water level of the Decant Dam..... 54

Table 14. Changes in water level of the T1 Dam..... 54

Table 15. Changes in water level of the Final Void..... 54

Table 16. Changes in water level of the T4 Pump dam..... 55

Table 17. Changes in water level of the T4 Dam..... 55

Table 18. Direct recharge to the dams within Pit 1..... 56

Table 19. Monthly evaporation losses from the dams within Pit 1..... 56

Table 20. Water losses and gains at the various dams within Pit 1..... 58

Table 21. Yardstick measurements of dam levels and the corresponding water level elevations (26 January 2012)..... 69

Table 22. Surface water sites included in the current monitoring programme..... 75

Table 23. Groundwater sites included in the current monitoring programme..... 76

Table 24. Major parameters to be analysed for during the monthly sampling runs..... 78

Table 25. Minor parameters to be analysed for at sites displaying low pH values and during the biannual sampling events..... 78

Table 26. Information on the 10 investigative and monitoring boreholes installed during July 2012..... 81

Table 27. Construction of the 10 investigative and monitoring boreholes installed during July 2012..... 81

Table 28. Suggested sampling depths as determined from the EC profiling..... 86

Table 29. Results of the analyses of the hydraulic test data..... 87

Table 30. Estimated hydraulic conductivities of the Karoo sedimentary rocks. 88

Table 31. Groundwater sites visited during the August 2012 sampling event. 90

Table 32. Surface water sites visited during the August 2012 sampling event..... 93

Table 33. Water quality table: groundwater monitoring sites within and in the vicinity of Pit 1 (major parameters). 95

Table 34. Water quality table: groundwater monitoring sites within and in the vicinity of Pit 1 (minor parameters). 96

Table 35. Water quality table: groundwater monitoring sites within and in the vicinity of Pit 2 (major parameters). 97

Table 36. Water quality table: groundwater monitoring sites within and in the vicinity of Pit 2 (minor parameters). 98

Table 37. Water quality table: Alzu groundwater sites (major parameters)..... 99

Table 38. Water quality table: Alzu groundwater sites (minor parameters)..... 99

Table 39. Water quality table: new boreholes (major parameters)..... 100

Table 40. Water quality table: new boreholes (minor parameters)..... 100

Table 41. Water quality table: surface water sites (major parameters). 101

Table 42. Water quality table: surface water sites (minor parameters). 102

Table 43. Classification system used to evaluate water quality classes..... 103

Table 44. Health and aesthetic effects associated with the water quality classes. 103

Table 45. Groundwater depths and elevations measured during August 2012..... 122

Table 46. Results of the grain size analyses and estimated soil hydraulic conductivities. 127

Table 47. Results of the acid-base analyses..... 129

Table 48. Interpreted acid generating potential of the rock samples. 130

Table 49. Constituents that may be released from the spoils and coal discards. 132

Table 50. Estimated hydraulic properties of the different units of the conceptual geohydrological model. 141

Table 51. Calibrated input parameters for the steady-state model..... 147

Table 52. Estimated recharge to the rehabilitated opencast pits at Arnot Closed Colliery, January to June 2012. 158

Table 53. Estimated recharge to the rehabilitated opencast pits at Arnot Closed Colliery, 2010. 159

Table 54. Estimated recharge to the rehabilitated opencast pits at Arnot Closed Colliery, based on the rainfall figures of 1987. 159

Table 55. Estimated water balance for Arnot Closed Colliery..... 161

Table 56. Estimated sulphate balance for Arnot Closed Colliery. 163

1 Introduction

1.1 Project Description

The Institute for Groundwater Studies (IGS) was appointed by AngloAmerican to design a Water Management Plan (WMP) for Arnot Closed Colliery that incorporates information on all incoming, inherent and outgoing water from the colliery.

1.2 Scope of Work

The Scope of Work for the development of the WMP is as specified in the document "A scope of work for implementation and design of a water management plan for Arnot Closed Operation" provided by Anglo American and entails the following:

- Compilation of a detailed water reticulation plan of the current system,
- Compilation of a subsurface flow plan,
- Compilation of a surface water plan,
- Calculation of the groundwater balance,
- Calculation of the surface water balance,
- Assessment of the current water monitoring network and the siting of additional monitoring points, if required,
- Calculation of the current volume of water in the mine,
- Numerical modelling of the potential pollution plume from areas backfilled with discard from Arnot Colliery,
- Numerical modelling of the potential pollution plume from the spoils in the backfilled opencast pits,
- Evaluation of management options with regard to the long-term sustainable use of water and possible risks associated with the water. These management options should be considered with the ultimate objective of working towards closure and should be evaluated against the current legal framework. Management options should be rated according to their economic viability and should take major stakeholders into consideration.

1.3 Project Methodology

During the development of a WMP for Arnot Closed Colliery, the following actions were taken:

- A number of site visits were conducted to allow familiarisation with the on-site conditions.
- Previous in-house reports and communications as well as external consultant reports relevant to the current investigations were studied. These included reports on the geological/geohydrological conditions at the site, as well as reports on previous geophysical investigations.
- A limited hydro-census was conducted in the vicinity of the backfilled and rehabilitated pits. The purpose of the hydro-census was to obtain information on the use of surface water and groundwater in the immediate vicinity of the pits, and to identify existing boreholes that may be used for groundwater monitoring.
- The existing surface- and groundwater monitoring network was evaluated in terms of its density and suitability to achieve the aims of a groundwater monitoring programme. Additional monitoring boreholes were sited and new surface water sampling points were suggested.
- Representative soil samples were taken selected positions around the pits. These samples were submitted to an accredited laboratory for grain size analyses in order to obtain estimates of the hydraulic properties of the soils.
- Samples of the spoils and coal discards were taken at positions on the rehabilitated pits where the spoils were exposed. These samples were submitted to an accredited laboratory for acid-base analyses in order to evaluate the potential for acid mine drainage (AMD) from the pits.
- Magnetic data were recorded on four traverses at selected positions to investigate the presence and orientation of dolerite intrusives.
- Ten investigative and monitoring boreholes were drilled at selected sites. Geological borehole logs were compiled during drilling.
- Electrical conductivity (EC) profiling was done on existing and newly drilled boreholes to investigate stratification in the groundwater quality within the boreholes.
- Surface- and groundwater sampling was performed and the water samples were submitted to an accredited laboratory for chemical analyses.
- Hydraulic tests were performed on the ten newly drilled boreholes, as well as on those existing boreholes for which information on their construction could be found. The purpose

of the hydraulic tests was to obtain information on the hydraulic properties of the rock formations surrounding the opencast pits in order to evaluate groundwater flow rates and potential contaminant plume migration.

- The current water reticulation system at Arnot Closed Colliery was investigated and documented.
- A sonar survey of the floor elevations of the dams that form part of the water reticulation system was conducted in order to calculate stage curves showing the volumes of water stored in these dams at various water levels.
- By considering all the results of the investigations, a conceptual geohydrological model for Arnot Closed Colliery was developed.
- The conceptual geohydrological model was used to inform the development of a numerical model to investigate groundwater flow patterns and potential contaminant plume migration in the vicinity of the backfilled pits.
- Groundwater and surface water balances were calculated for Arnot Closed Colliery by incorporating the results of the numerical modelling.
- Future water management options for Arnot Closed Colliery were suggested.
- A report (this document) was compiled summarising the results of the investigations.

2 Site Information

2.1 General

Opencast coal mining operations at Arnot Colliery commenced in the early 1970s. Two opencast pits were mined, namely Pit 1 and Pit 2 (West and East). Production from the opencast pits continued until 1992. After closure the pits were backfilled and rehabilitated, although some areas still remain to be rehabilitated. Rehabilitation involved the insloping of the ramps, optimisation of the free draining area, topsoiling and seeding with indigenous grass species.

Even at the time of mining concerns were expressed about the rapid rate at which groundwater was entering the pits. In a report dated 20 July 1988, Professor Frank Hodgson of the IGS noted that the water level in Pit 1 had risen by 3.5 m over the preceding summer. Based on his observations he predicted that decant would occur within two years.

Although Pit 1 did not decant while mining continued, the rise of the water level in Pit 1 continued to occur at a very rapid rate after cessation of mining. Very high rainfall (400 mm) was recorded during both January and February 2006. On 30 January 2006 decant from Pit 1 towards the Bosman Spruit commenced. Initially the decant rate was estimated at 0.50 M*l*/day, but by the end of February the decant rate had increased to approximately 3.0 M*l*/day. Photographs (Photo 1 to Photo 3) taken during March 2006 show the magnitude and impact of the decant.

Various actions have been taken since 1996 to address the problem of decant from Pit 1 and Pit 2. These actions included:

- Construction of contour berms to prevent clean water entering the ramps,
- Construction of levees and dam walls to increase the decant level,
- Evaporation from exposed surface water areas in the pits,
- Irrigation of mine water on the rehabilitated areas of Pit 1,
- Disposal of pit water in the Bliksem Pan and Railway Pan,
- Recirculation of pit water by means of pumping between the various voids,
- Controlled release of pit water to the Klein-Olifants River (introduced in 1997), and,
- Construction of a pipeline to pump pit water to Mafube Colliery for use at the colliery (2006/2007)

Photo 1. Decant from Pit 1, March 2006

Photo 2. Decant from Pit 1, March 2006

Photo 3. Decant from Pit 1, March 2006

2.2 Regional Setting

The regional setting of Arnot Closed Colliery is shown in Figure 1. The colliery is located in the Mpumalanga Province of South Africa, approximately 27 km south-east of the town of Middelburg The site may be reached by travelling along the N11 national road before turning off on a secondary road towards the entrance of Alzu Enterprises. Other nearby towns include Witbank (44 km west), Pullen's Hope (13.5 km south-west) and Hendrina (27 km south). Arnot Power Station is situated approximately 11.5 km east-south-east of the colliery.

Other nearby and adjacent coal mines include: Optimum Colliery (Kwagga Section), Exxaro Arnot Colliery, Xstrata Zonnebloem Colliery and Mafube Colliery (refer to Figure 2). These collieries and other stakeholders (Hatch, Coal of Africa, Eskom Arnot Power Station) are included in regional mine water management project that is currently being developed to address water management issues related to coal mining and power generation. The construction of a water treatment plant to treat water impacted on by mining activities is being considered as part of the regional water management strategy.

2.3 Geological Setting

The 1:250,000 geological map presented in this section is the intellectual property of the Council for Geoscience and is used by permission. Copyright and all rights are reserved by the said Council.

The geological setting of Arnot Closed Colliery is shown in Figure 3. The colliery is situated in the eastern portion of the Springs-Witbank Coalfield. From Figure 3 it is seen that the surface geology in the vicinity of the colliery is dominated by rocks belonging to the Ecca Formation of the Karoo Supergroup. These rocks predominantly consist of various shales (including carbonaceous shales), sandstones, conglomerates and coal layers. The sediments of the Karoo Supergroup were deposited on an irregular Pre-Karoo basin. The subsurface distribution of the sediments and coal seams is partly dependent on the basement topography.

The southern and western boundaries of the opencast pits run approximately parallel to exposures of volcanic rocks of the Pretoria Group that occur at positions where the major rivers have eroded away the overlying Karoo rocks and coal seams. These rocks are predominantly red rhyolites with some andesites.

Although no major faults or dyke intrusives have been mapped in the vicinity of the colliery, drilling results and geophysical investigations have revealed the presence of dolerite/diabase structures in the vicinity, and probably underlying, the opencast pits. Minor faults, displacing the coal seams by 1 or 2 metres were encountered during mining.

The weathered zone consists of varying proportions of topsoil, subsoil, clay and silty sands with the nature of this zone depending largely on the original lithology. Clays are thought to be derived from weathered shales and siltstones, while the more sandy materials are most probably due to the weathering of sandstones. The topsoil is typically a well-developed loamy soil horizon and may have a considerable thickness (> 6 m).

The No.1 and No.2 coal seams were mined during operations at the Arnot Colliery. The floors of the opencast pits at the colliery roughly correspond to the depths at which the bottom contact of the No.2 seam was encountered.

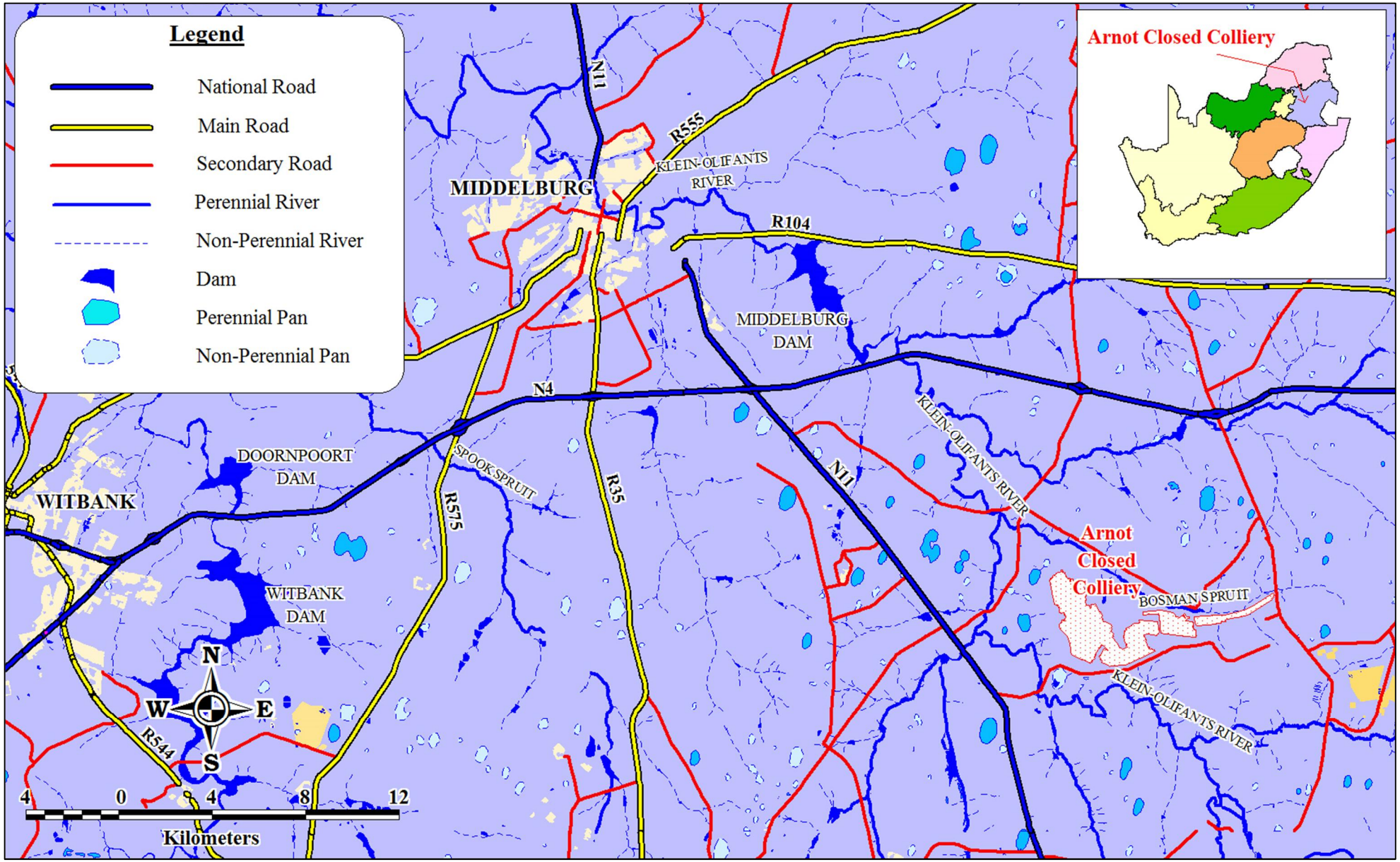


Figure 1. Regional setting of Arnot Closed Colliery.

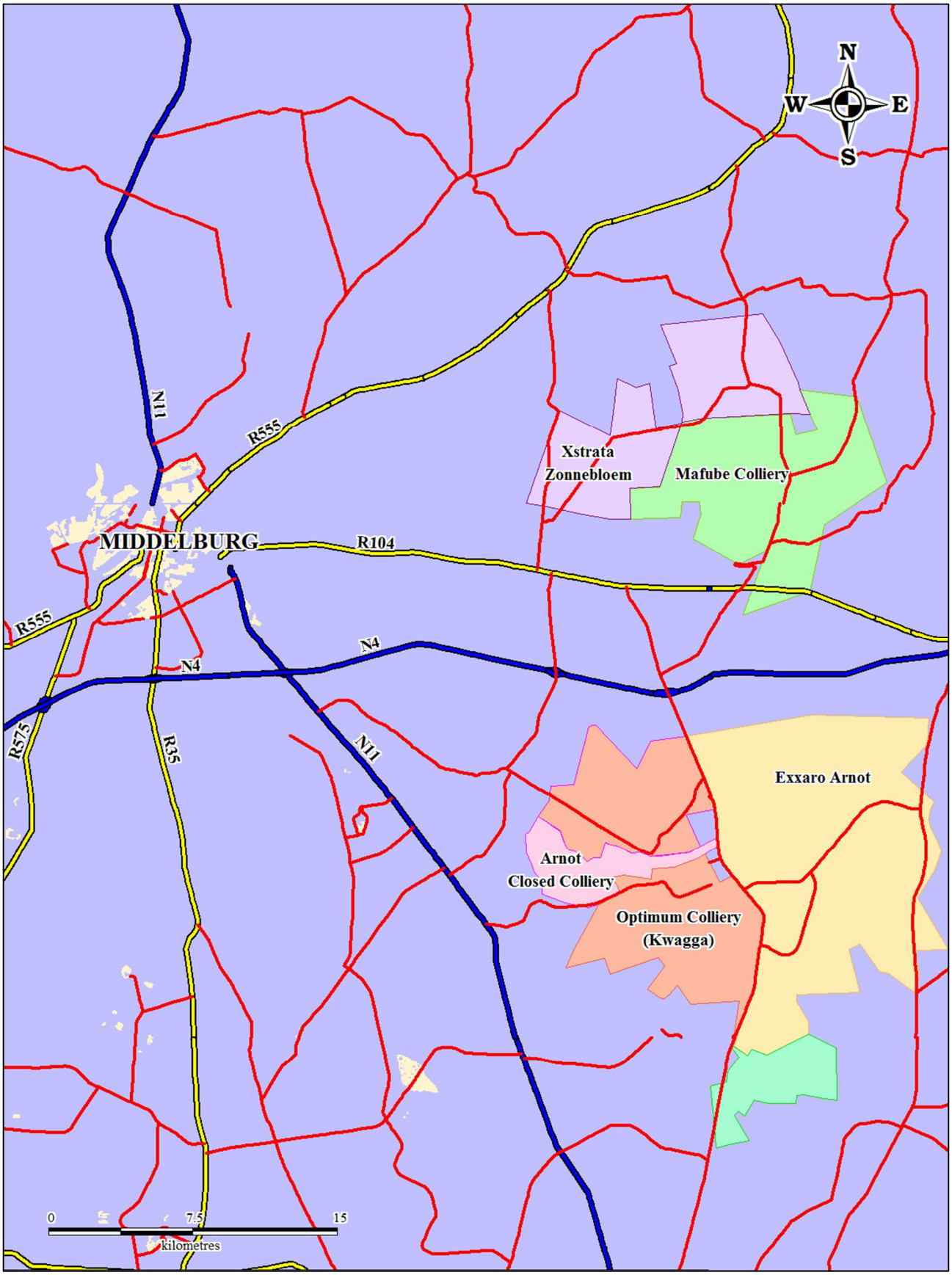


Figure 2. Other coal mines bordering and in the vicinity of Arnot Closed Colliery.

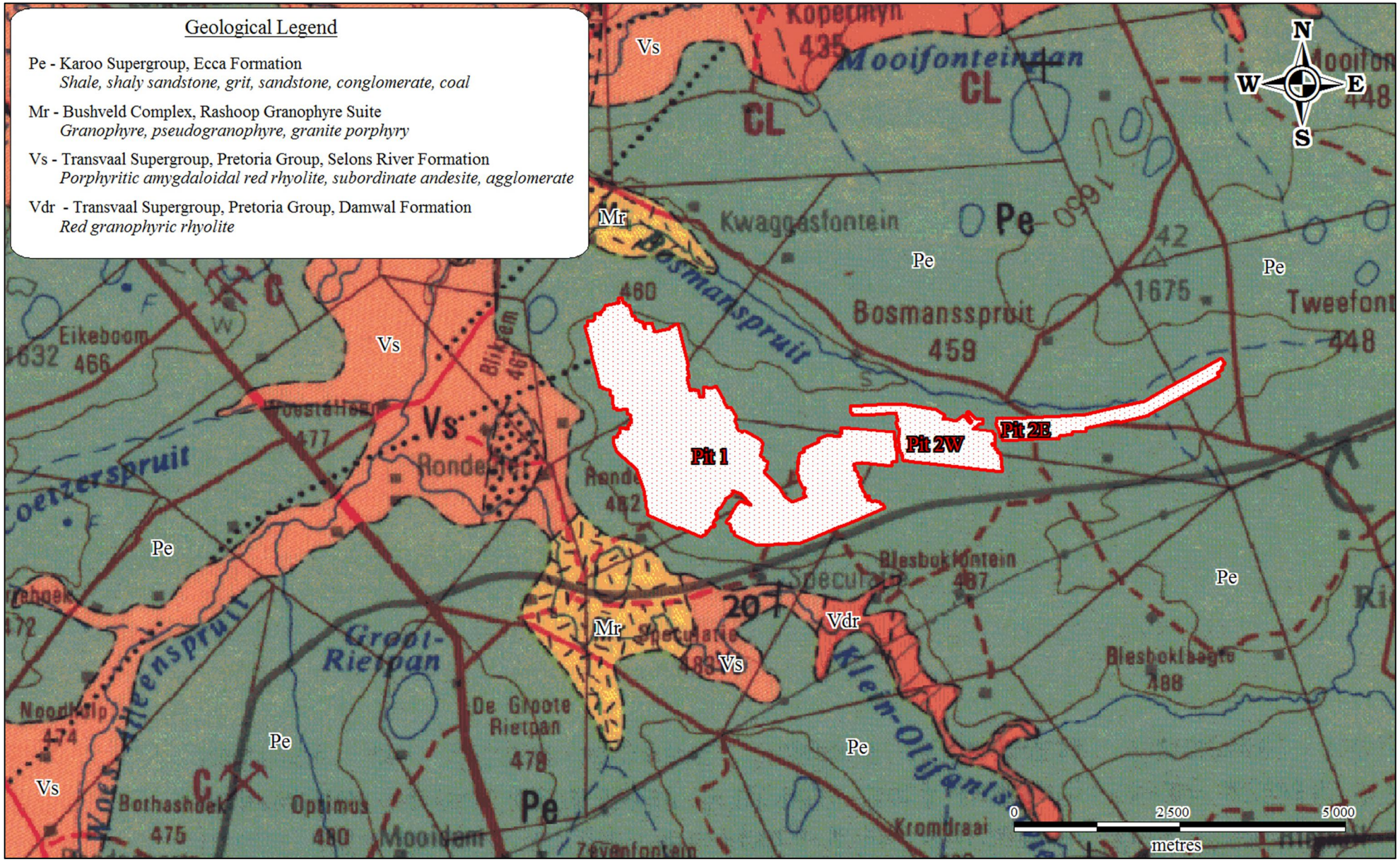


Figure 3. Geological setting of Arnot Closed Colliery.

2.4 Topography and Drainage

Arnot Closed Colliery falls within quaternary sub-catchment B12B and is drained by the river systems occurring within sub-catchments B12A and B12B. The colliery is located near the northern boundary of sub-catchment B12B, close to the position of confluence of all the river systems within sub-catchments B12A and B12B (see Figure 4). The major rivers that occur in these sub-catchments are the Klein-Olifants River, the Woestalleen Spruit, the Rietkuil Spruit and the Bosman Spruit. The Bosman Spruit flows past the colliery to the north, while the Klein-Olifants River and Woestalleen Spruit occur to the south and west of the colliery, respectively. These rivers all occur at lower elevations than the colliery and may receive runoff from the colliery.

The colliery is located in an area where the natural topographic elevation varies between approximately 1 595 metres above mean sea level (mamsl) and 1 635 mamsl, while the topographic elevations within sub-catchments B12B and B12A attain values in excess of 1 710 mamsl and 1 815 mamsl, respectively (see Figure 5). As such, the colliery is located at an elevation lower than 78% of the surface area of sub-catchments B12A and B12B. This is illustrated in Figure 5 where those parts of the sub-catchments all elevation higher than 1595 mamsl are coloured in green. It is therefore possible that groundwater recharge within most of the coloured area will be associated with hydraulic heads higher than the decant water level (1 595 mamsl) of Pit 1. This illustrates that regional hydraulic gradients towards the colliery are likely to exist.

Since the groundwater table normally emulates the surface topography under natural conditions, the hydraulic gradient can be expected to be near-parallel to the topographic gradient, again suggesting that much of the groundwater recharged within (especially) the eastern parts of sub-catchments B12A and B12B is likely to flow towards the colliery.

Sub-catchments B12A and B12B have surface areas of approximately 406 km^2 and 660 km^2, respectively. According to information from the Department of Water Affairs (DWA), the average annual groundwater recharge within these sub-catchments is 46.3 mm and 55.2 mm, respectively. These values translate to a total volume of groundwater recharge of approximately **151 M*l*/day**. Much of this groundwater recharge is expected to flow under the hydraulic gradient towards the lower parts of sub-catchment B12B where Arnot Closed Colliery is located and could contribute to the water make of the colliery.

The total surface area of the backfilled and rehabilitated opencast pits at Arnot Closed Colliery is approximately 10.57 km^2. Using the average recharge value of sub-catchment B12B (55.2 mm/a), a recharge volume of approximately **1.6 M*l*/day** is calculated for the pits. This value should be seen as a first estimate of the lower limit of the water make of Arnot Closed Colliery.

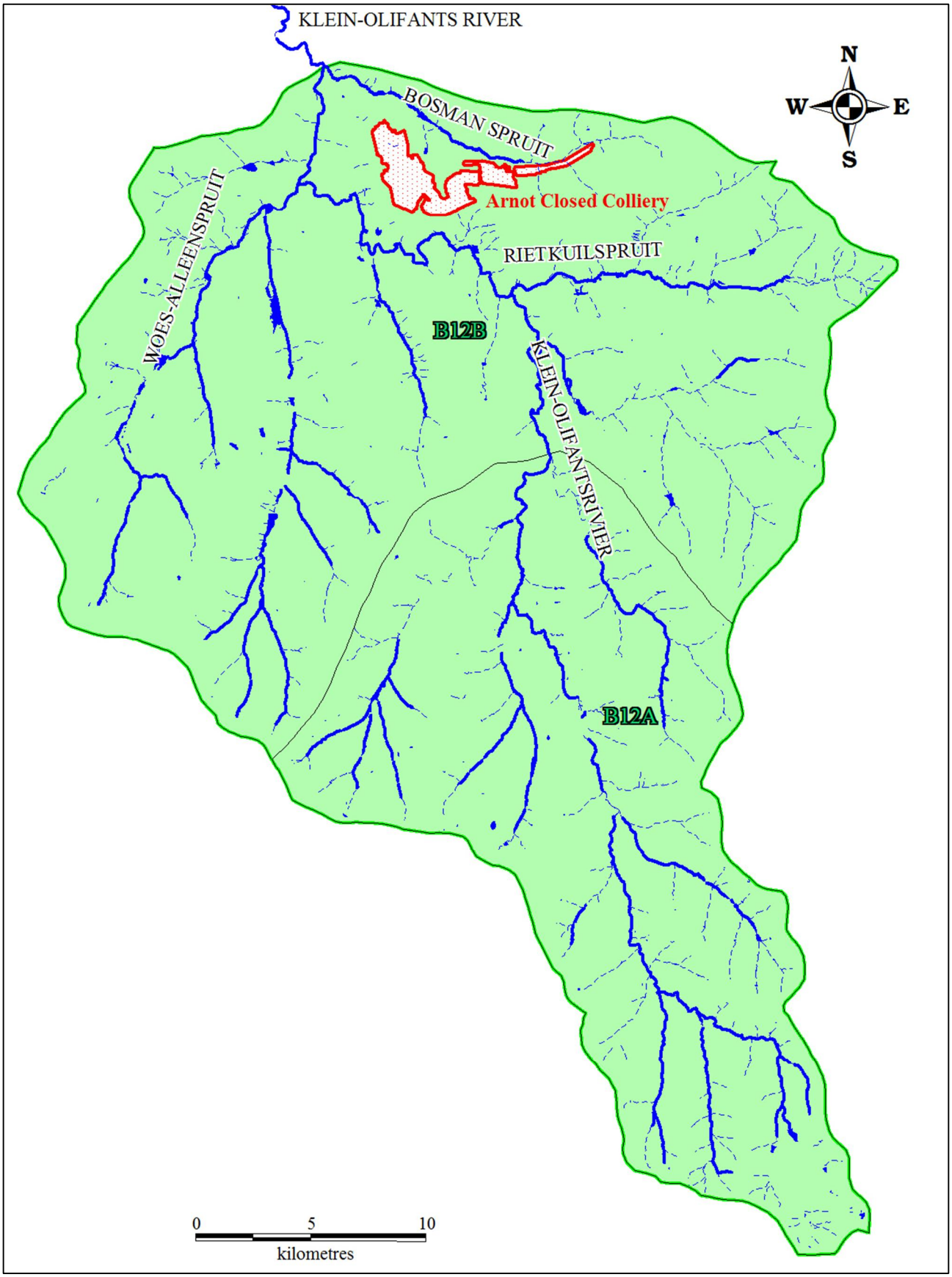


Figure 4. Drainage from quaternary sub-catchments B12A and B12B.

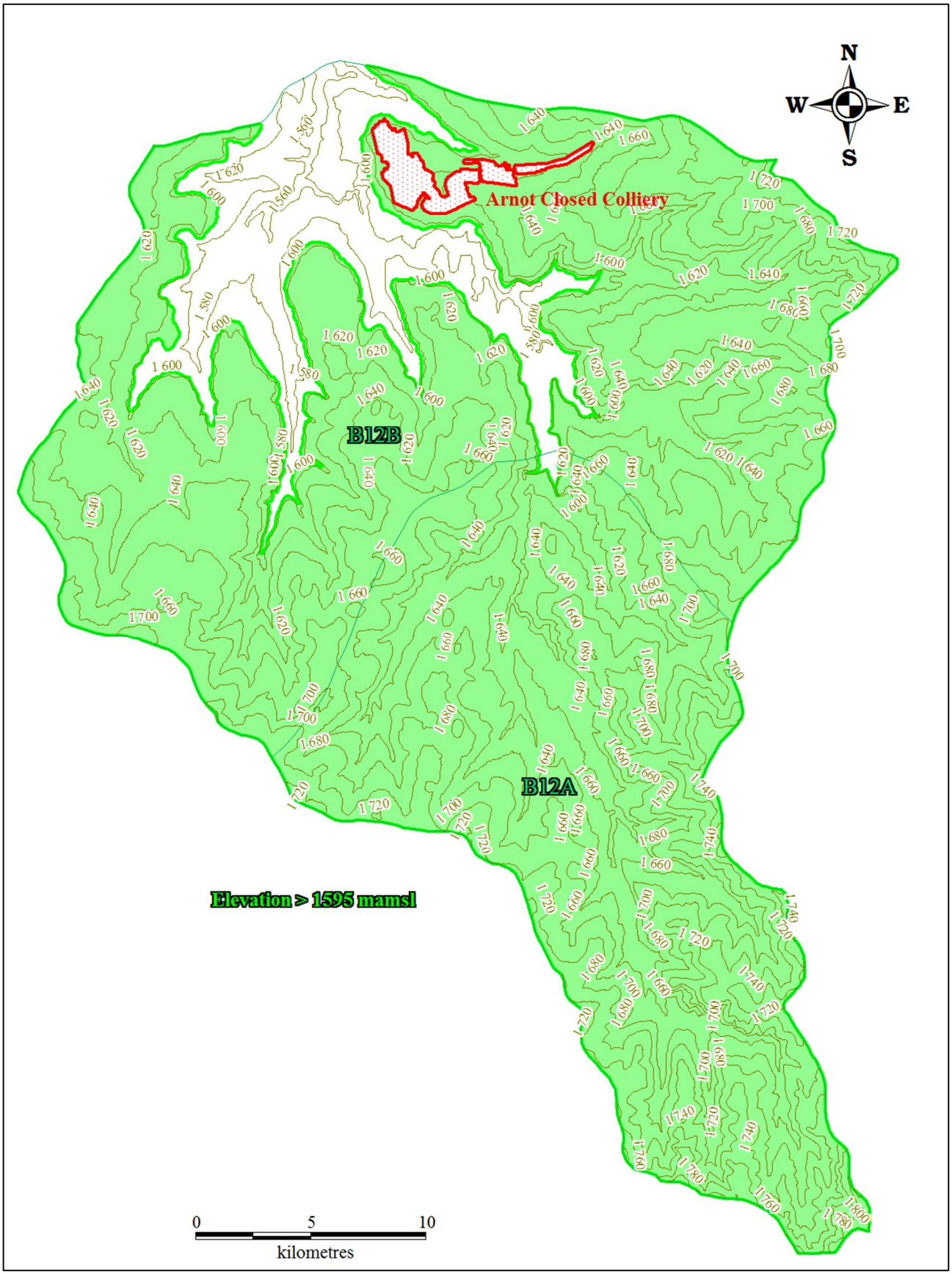


Figure 5. Topographic elevation within sub-catchments B12A and B12B.

The pre-mining (green) and post-mining (brown) topography in the vicinity of Pit 1 is shown in Figure 6 with the positions of the dams that form part of the current water reticulation system. From Figure 6 it can be seen that the local topographic gradient is such that surface runoff from the rehabilitated spoils could flow in a south-westerly direction towards the Klein-Olifants River, or in a north-easterly direction to the Bosman Spruit. Seepage (if any) from the backfilled pit is also likely to migrate in these directions.

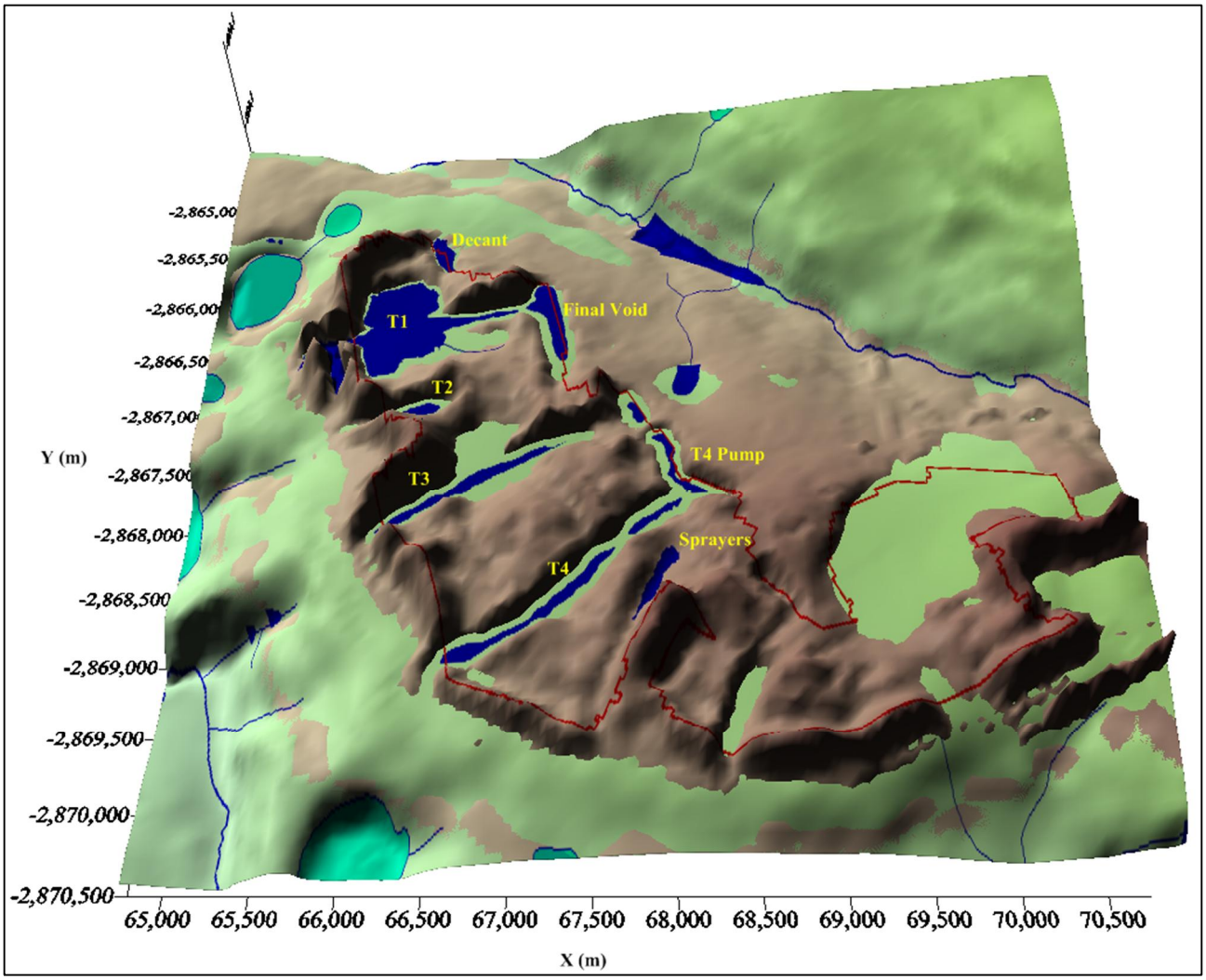


Figure 6. The pre- and post-mining topography in the vicinity of Pit 1 of Arnot Closed Colliery.

The elevation of the decant level of Pit 1 (1 595.05 mamsl) is shown in Figure 7 against the post-mining topography. It is seen that only the Decant Dam and the T1 Dam will contain water in significant quantities if the water level everywhere within Pit 1 reaches the decant level. This situation will occur under unmanaged conditions when all pumping of water is ceased and free decant is allowed to occur at the Decant Dam. Under these 'unmanaged' conditions water losses due to direct evaporation from open water bodies will be limited to the evaporation from the T1 Dam and the Decant Dam, and will be significantly lower than the current evaporation losses from the various dams within Pit 1 (shown in Figure 6).

However, there are indications that Pit 1 is compartmentalised (as will be discussed in Sections 4.6 and 11). The decant level of Pit 1 may therefore only represent the decant level of the final downstream compartment of the pit. Compartmentalisation may therefore cause the presence of open water in the other dams within Pit 1, even under 'unmanaged' conditions.

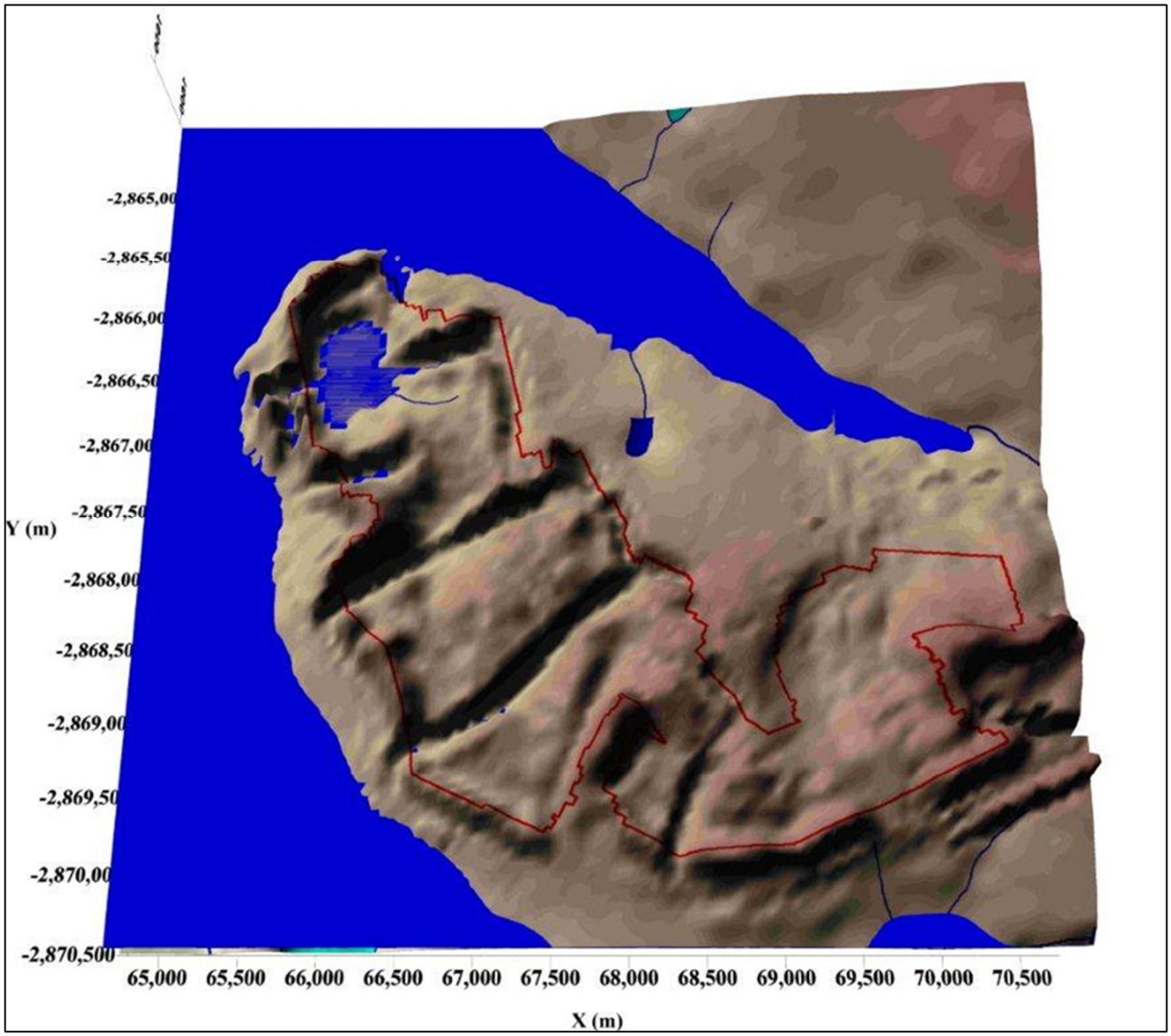


Figure 7. The decant water level of Pit 1 shown against the post-mining topography.

2.5 Geohydrological Conditions

Previous studies have indicated that the regional piezometric surface is topographically controlled with groundwater draining towards rivers and streams. Static water levels typically occur between 5 and 15 metres below ground level (mbgl). Four different aquifer systems have been identified namely:

- shallow perched aquifers,
- aquifers within the fractured Karoo rocks,
- aquifers associated with coal seams, and,

- aquifers associated with dolerite intrusions.

The shallow perched aquifers occur in two forms, namely at the interface between the soil and the bedrock or as alluvial aquifers. Groundwater flow patterns follow the topography with the groundwater table often occurring close to surface in topographic lows.

The fractured rock aquifers in the Karoo formations generally have moderate to low groundwater potentials. However, zones of increased permeability often occur along faults and geological contacts. When such zones are intersected, high groundwater flow rates may be encountered.

The aquifers associated with the coal seams often occur at the margins of the coal seams or at clastic partings within the coal seams. Due to its low permeability, the coal tends to act as an aquitard, leading to the collection of groundwater at its upper margin. During mining at Arnot Colliery, strong water flows were associated with some of the coal seams. This may be due to the shallow cover and enhanced recharge from the overlying fractured and weathered Karoo rocks. The sub-outcrops of the No.1 and No.2 coal seams along the Bosman Spruit may also cause surface water to enter the subsurface at places.

Dolerite intrusives are generally associated with an alteration of the host rock. Due to the high pressures and temperatures that occurred during intrusion, the sedimentary rocks adjacent to the intrusives can be expected to be extensively fractured. These fractured zones may act as preferential pathways for groundwater migration. Dolerite intrusives themselves may also act as aquifers if they are extensively jointed and fractured. This is often observed for dykes with a thickness of less than 10 m.

2.6 Climatic Conditions

2.6.1 Rainfall

Arnot Closed Colliery is located within the Eastern Transvaal Highveld in a summer rainfall region. Rain occurs in the form of mild to heavy showers and thunderstorms with maximum rainfall normally between the months of December and February. Heavy falls of greater than 100 mm in a 24-hour period are rare. Sleet may occur during cold spells, but the occurrence is rare and the falls are usually light. The winter months are normally dry.

The mean annual rainfall recorded at the Gemsbokfontein and Carolina weather stations over periods of 57 and 51 years is 774.0 mm and 755.5 mm, respectively. These values are approximately 10% higher than the mean annual precipitations (MAP) (697 mm) for quaternary sub-catchment B12B as listed by the DWA.

A rainfall gauge is currently present at the Decant Dam of Arnot Closed Colliery. The monthly rainfall figures recorded at this gauge over the six-month period from January to June 2012 are listed in Table 1 along with the rainfall figures recorded from October 1981 to February 1995, as well as during 2010. The average annual rainfall figure amounts to 649 mm.

The average rainfall figures for each month are displayed as a bar graph in Figure 8. Also shown are the rainfall figures recorded during 1987 when high rainfall was experienced. Even though the 1987 rainfall figures were much higher than the average values, these higher values do not represent extreme conditions. During 2006 rainfall figures exceeding 400 mm were recorded during both the months of January and February, leading to a major decant event (refer to Section 2.1).

Table 1. Monthly rainfall recorded at the Decant Dam of Arnot (Closed) Colliery.

Month	Rainfall (mm)																	
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	2010	2012	Average
Jan		177	108	99	84	75	145	42	77	159	125	72	47	100	112	174	98	106
Feb		77	22	55	122	120	76	38	115	71	59	102	120	90	66	54	59	78
Mar		75	55	55	38	53	131	88	7	93	107	56	80	108		64	64	72
Apr		5	0	10	0	48	22	67	35	73	23	28	19	14		147	11	33
May		0	0	0	30	0	10	0	8	7	12	0	7	0		47	0	8
Jun		0	0	18	8	13	0	18	74	0	26	0	0	0		0	0	10
Jul		5	16	16	0	0	0	3	0	0	0	0	0	0		0		3
Aug		0	27	8	1	0	67	0	18	0	0	28	7	0		0		11
Sep		5	0	12	50	2	119	39	3	5	19	19	27	18		0		23
Oct	55	65	93	132	50	87	89	154	78	62	27	71	177	71		47		84
Nov	66	62	268	70	60	121	174	53	178	85	44	92	159	91		59		105
Dec	101	61	153	106	140	63	175	108	190	108	82	143	69	109		127		116
Total		**532**	**742**	**581**	**583**	**582**	**1008**	**610**	**783**	**663**	**524**	**611**	**712**	**601**		**719**		**649**

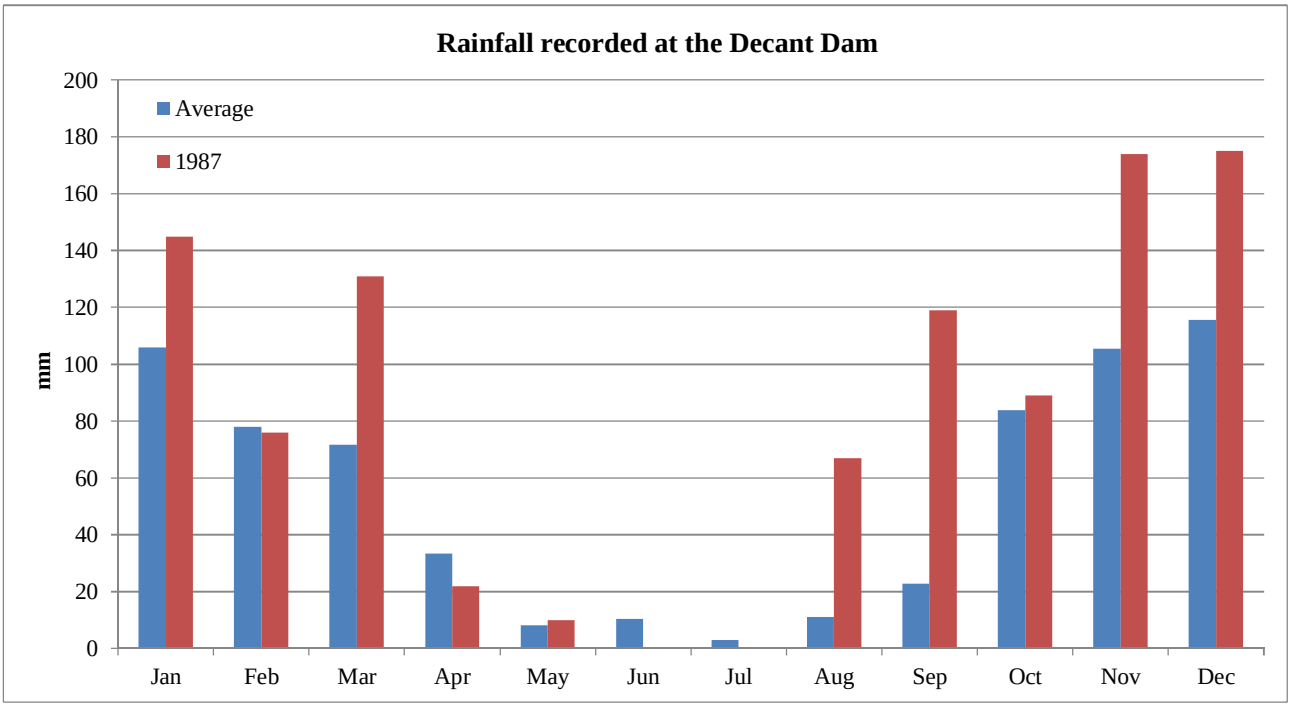


Figure 8. Rainfall recorded at the Decant Dam

2.6.2 Evaporation

The mean monthly evaporation figures for the study area are listed in Table 2. It is seen that the mean annual evaporation (MAE) amounts to 1 046 mm. This value is significantly higher than the mean annual precipitation (MAP). Large evaporation losses can therefore be expected from open water bodies at Arnot Closed Colliery.

Table 2. Average monthly S-pan and lake evaporations.

Month	S-Pan evaporation (mm)	Lake evaporation (mm)
Jan	164	115
Feb	140	98
Mar	135	95
Apr	104	73
May	86	60
Jun	67	47
Jul	78	55
Aug	108	76
Sep	137	96
Oct	155	109
Nov	150	105
Dec	170	119
Annual	**1 494**	**1 046**

3 Hydrocensus

3.1 Introduction

A limited hydrocensus was conducted at Arnot Closed Colliery to identify all existing surface- and groundwater sites in the immediate vicinity of the colliery, as well as current and potential water users that may be affected by past and present activities at the colliery. A number of surface- and groundwater sites are currently included a monthly monitoring programme conducted by personnel of AngloAmerican.

3.2 Surface Water Sites

The positions of the surface water sites in the vicinity of Arnot Closed Colliery are shown in Figure 9 while information on these sites is listed in Table 3. Site names in italic print are new names assigned to sites during the hydrocensus. Some of these sites may have other names in the database of Arnot Closed Colliery.

Photographs of some of the surface water sites visited during the hydrocensus are shown in Photo 4 to Photo 21. Some observations regarding the surface water sites are made below:

R01

Salt precipitation at site R01 indicates that water seeping from Pit 1 surfaces somewhere upstream from the Bliksem Pan and flows into this pan.

T2 Dam

Heavy salt precipitation occurs at the T2 Dam.

Filling point north of the T1 Dam

Salt precipitation is visible at surface at the filling point north of the T1 Dam, as well as in the adjacent ploughed land. The water at the filling point gravitates from a reservoir on the northern boundary of Pit 1. This reservoir receives water from the T1 Dam. Although the water at the filling point is supposed to be used only for fire fighting, road wetting to suppress dust, and rinsing of the piggery, employees of Alzu have been using the contaminated water to wash the trailers used to transport wastes from the piggery. These washing operations have led to the spillage of large volumes of contaminated water on surface, hence the observed salt precipitation.

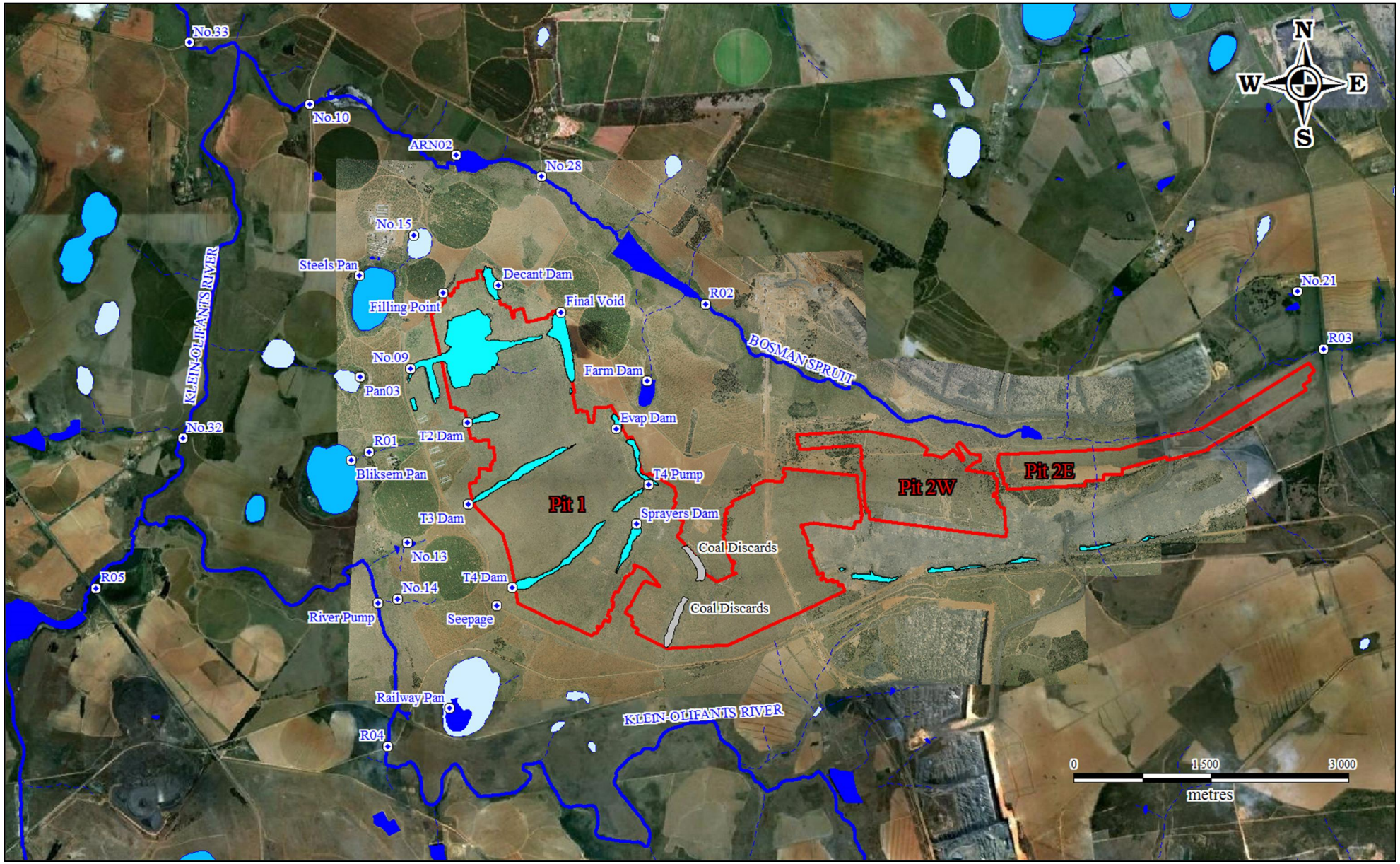


Figure 9. Surface water sites at and in the vicinity of Arnot Closed Colliery.

Table 3. Surface water sites visited during the hydrocensus.

Site Name	Site Description	Longitude (°E)	Latitude (°S)	Elevation (mamsl)	X_WGS84 (m)	Y_WGS84 (m)
R01	Non-perennial river flowing into the Bliksem Pan	29.64915	25.91717	1 580.0	65 037.79	-2 867 819.09
R02	Bosman Spruit downstream from Pit 2 (W & E)	29.68587	25.90262	1 589.0	68 725.28	-2 866 225.81
R03	Bosman Spruit upstream from Arnot Closed Colliery	29.75343	25.90707	1 631.0	75 492.30	-2 866 755.99
R04	Klein-Olifants River south-west of Pit 1	29.65113	25.94611	1 565.0	65 219.84	-2 871 026.38
R05	Woestallen Spruit upstream from Arnot Closed Colliery	29.61922	25.93064	1 553.0	62 032.00	-2 869 296.94
No.10	Bosman Spruit downstream from Arnot Closed Colliery	29.64259	25.88299	1 561.0	64 399.09	-2 864 029.02
No.14	Non-perennial stream flowing into the Klein-Olifants River	29.65222	25.93167	1 566.0	65 337.58	-2 869 426.76
No.28	Bosman Spruit north of Pit 1	29.66798	25.89011	1 579.0	66 939.67	-2 864 830.56
No.32	Klein-Olifants River west of Arnot Closed Colliery	29.62873	25.91580	1 551.0	62 992.60	-2 867 657.33
No.33	Klein-Olifants River downstream from confluence with Bosman Spruit	29.62949	25.87696	1 552.0	63 089.40	-2 863 354.60
ARN02	Farm dam in Bosman Spruit	29.65861	25.88802	1 576.0	66 001.82	-2 864 594.26
No.09	T1 Dam	29.65368	25.90893	1 596.0	65 496.21	-2 866 908.43
T2 Dam	T2 Dam	29.65983	25.91425	1 596.0	66 109.46	-2 867 500.92
T3 Dam	T3 Dam	29.65998	25.92233	1 596.5	66 119.99	-2 868 396.19
T4 Dam	T4 Dam	29.66473	25.93057	1 596.7	66 591.45	-2 869 311.30
T4 Pump	T4 Pump dam	29.67962	25.92040	1 602.0	68 088.78	-2 868 192.42
Decant Dam	Decant Dam	29.66325	25.90070	1 595.3	66 459.72	-2 866 001.43
Evap Dam	Evap Dam	29.67610	25.91487	1 600.0	67 739.28	-2 867 577.92
Farm Dam	Farm dam north of Pit 1	29.67950	25.91016	1 600.0	68 082.24	-2 867 057.63
Final Void	Final Void	29.67006	25.90344	1 596.8	67 140.57	-2 866 308.47
Sprayer Dam	Sprayer Dam	29.67834	25.92421	1 614.0	67 958.35	-2 868 613.87
No.13	Farm dam south-west of Pit 1	29.65326	25.92607	1 580.0	65 444.67	-2 868 807.18
No.21	Farm dam upstream from Arnot Closed Colliery	29.75053	25.90136	1 650.0	75 205.13	-2 866 121.80
No.15	Non-perennial pan north-east of Steels Pan	29.65403	25.89585	1 596.0	65 538.51	-2 865 459.46
Bliksem Pan	Bliksem Pan	29.64719	25.91798	1 568.0	64 841.27	-2 867 908.30
Pan03	Non-perennial pan west of the T1 Dam	29.64812	25.90979	1 585.0	64 938.53	-2 867 000.94
Railway Pan	Railway Pan	29.65786	25.94231	1 574.0	65 896.78	-2 870 608.74
Steels Pan	Steels Pan	29.64805	25.89981	1 583.7	64 937.09	-2 865 895.22
Filling Point	Filling point north of T1 Dam	29.65720	25.90153	1 600.0	65 853.02	-2 866 090.34
Seepage	Seepage from T4 Dam	29.66308	25.93229	1 598.7	66 424.99	-2 869 501.25
River Pump	Pump at Klein-Olifants River	29.65013	25.93205	1 558.0	65 127.80	-2 869 468.15

Photo 4. Salt precipitation at R01

Photo 5. Stagnant pool at site R02

Photo 6. Stagnant pool at site R03

Photo 7. Site R04

Photo 8. N0.09 (T1 Dam) at new dam wall

Photo 9. T2 Dam

Photo 10. Salt precipitation at the T2Dam

Photo 11. T3 Dam

Photo 12. T4 Pump dam

Photo 13. Evaporation Dam

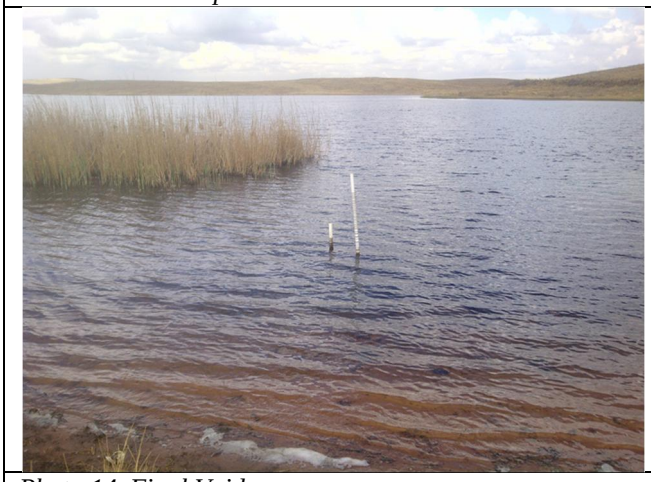


Photo 14. Final Void

Photo 15. Sprayer Dam

Photo 16. Surface sampling site No.13

Photo 17. Surface sampling site No.21

Photo 18. Filling Point north of the T1 Dam

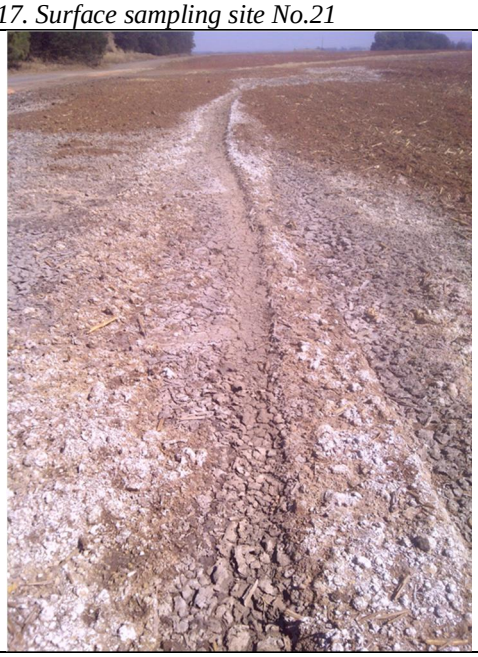


Photo 19. Salt precipitation near Filling Point

Photo 20. Seepage near the T4 Dam

Photo 21. Pump in the Klein-Olifants River

Seepage near the T4 Dam

During the hydrocensus, seepage was observed along the access road near the T4 Dam. This seepage originates from the T4 Dam. Salt precipitation was also noted.

Pump in the Klein-Olifants River

A pump for abstracting water from the Klein-Olifants River occurs west of the T4 Dam. All the irrigation water currently used at Alzu is taken from the Klein-Olifants River and three dams that occur within the Bosman Spruit. The volumes abstracted for irrigation are not currently known since no flowmeters or pumping records exist.

3.3 Groundwater Sites – Pit 1

The positions of the groundwater sites within and in the vicinity of Pit 1 are shown in Figure 10 while information on these sites is listed in Table 4. Photographs of the different groundwater sites are presented in Photo 22 to Photo 65. Observations relevant to the current investigation are made below:

General

It is recommended that all monitoring borehole sites be equipped with the following: concrete plinths, lockable caps, marker posts and site numbers. During the first half of 2012 many of the borehole sites were upgraded by the installation of metal fences around the boreholes. However, lockable caps are required at all the sites to prevent access to unauthorised persons. Concrete plinths are also needed to stabilise the casings and to prevent surface water entering the boreholes along the borehole casing. Boreholes located in thick vegetation (e.g. AW20) should be equipped with visible marker posts.

Monitoring borehole AW21

No indication of the existence of this borehole could be found during the hydrocensus. According to the GPS coordinates of borehole provided by personnel of AngloAmerican, the borehole is located within a ploughed land west of Pit 1. It is possible that this borehole was destroyed during farming activities.

Alzu production boreholes

Many of the production boreholes of Alzu have been damaged in one way or another. The brick constructions around some boreholes have collapsed (BHZ01, BHZ09 and BHZ11), some boreholes are blocked (BHZ11), and the plastic pipes of some boreholes have been damaged by fires (BHZ11 and BHZ12). These problems are, however, of greater concern to Alzu Enterprises than to Arnot

Closed Colliery since they do not affect the groundwater monitoring programme. The site ‘Alzu Windpump’ refers to an old windpump that is now equipped with a submersible electric pump.

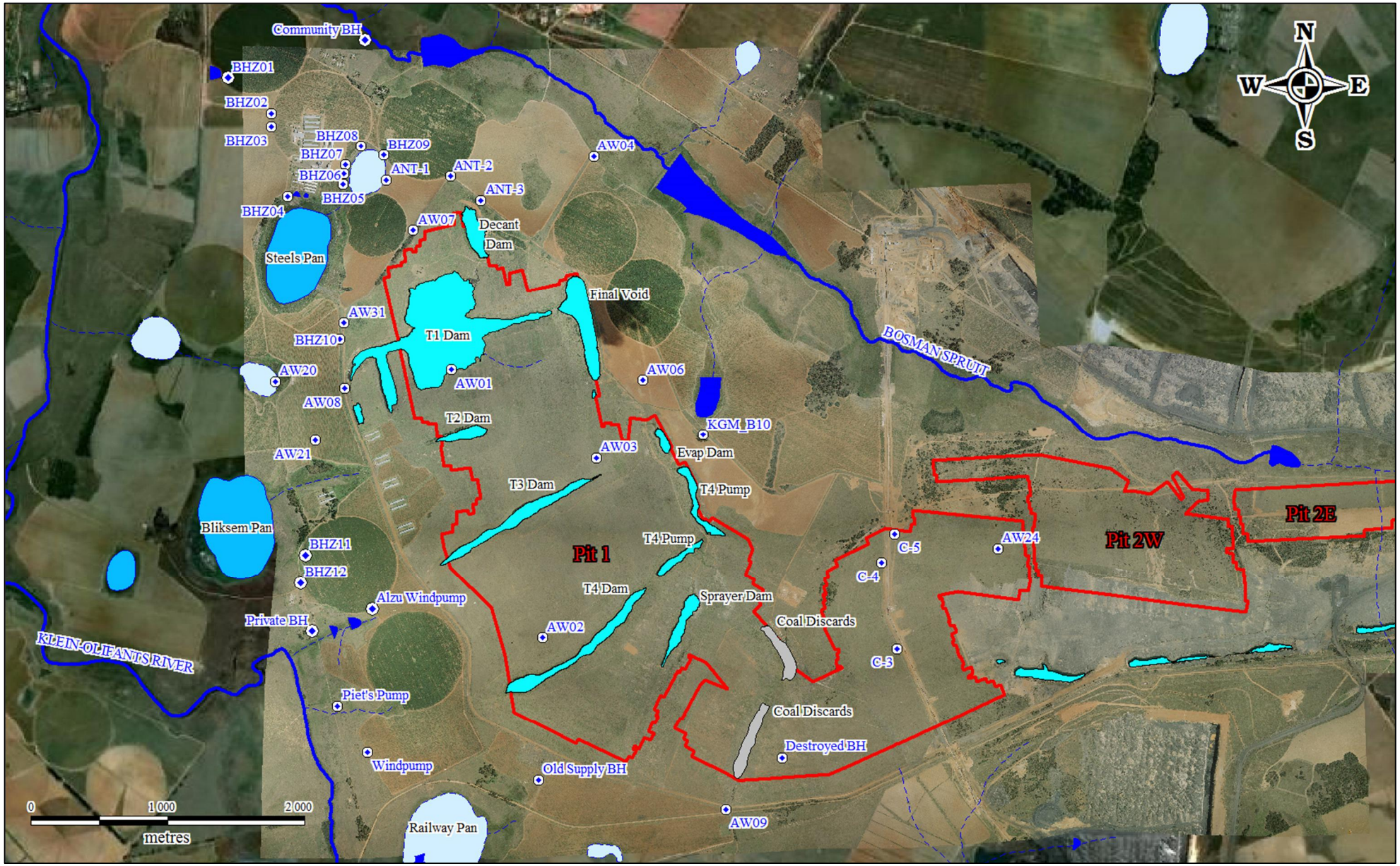


Figure 10. Groundwater sites within and in the vicinity of Pit 1.

Table 4. Groundwater sites in the vicinity of Pit 1 visited during the hydrocensus.

Site Name	Site Description	Longitude (°E)	Latitude (°S)	Elevation (mamsl)	X_WGS84 (m)	Y_WGS84 (m)
ANT-1 (ARN01)	Monitoring borehole east of non-perennial pan No.15	29.65600	25.89713	1 589.8	65 735.21	-2 865 602.26
ANT-2	Monitoring borehole north-west of Decant Dam	29.66068	25.89690	1 593.2	66 204.31	-2 865 579.12
ANT-3 (ARN03)	Monitoring borehole north of Decant Dam	29.66289	25.89850	1 595.1	66 424.89	-2 865 757.51
AW01	Monitoring borehole south of T1 Dam	29.66074	25.90956	1 596.8	66 203.27	-2 866 981.77
AW02	Monitoring borehole north-west of T4 Dam	29.66743	25.92713	1 611.5	66 863.68	-2 868 931.77
AW03	Monitoring borehole north-east of T3 Dam	29.67134	25.91538	1 618.7	67 262.07	-2 867 631.97
AW04	Monitoring borehole north of Final Void, near Bosman Spruit	29.67112	25.89561	1 586.3	67 251.23	-2 865 441.52
AW06	Monitoring borehole south-east of Final Void	29.67473	25.91024	1 605.2	67 604.65	-2 867 064.25
AW07	Monitoring borehole west of Decant Dam, north of T1 Dam	29.65794	25.90042	1 599.8	65 927.79	-2 865 967.73
AW08	Monitoring borehole south-west of T1 Dam	29.65298	25.91078	1 596.6	65 425.05	-2 867 113.05
AW09	Monitoring borehole south of coal discards area	29.68078	25.93839	1 605.4	68 194.65	-2 870 186.17
AW20	Monitoring borehole in non-perennial pan (Pan03) west of T1 Dam	29.64794	25.91033	1 584.8	64 920.30	-2 867 060.69
AW21	Monitoring borehole south-west of T1 Dam	29.65086	25.91419	1 590.5	65 210.75	-2 867 489.78
AW24	Monitoring borehole near eastern perimeter of Pit 1	29.70064	25.92127	1 618.2	70 194.26	-2 868 299.90
AW31	Monitoring borehole west of T1 Dam	29.65293	25.90652	1 597.7	65 422.39	-2 866 641.04
Alzu Windpump	Alzu supply borehole south-west of T3 Dam	29.65502	25.92525	1 585.0	65 621.40	-2 868 717.20
BHZ01	Alzu supply borehole north-west of packhouse	29.64448	25.89040	1 583.8	64 584.50	-2 864 850.90
BHZ02	Alzu supply borehole west of packhouse	29.64762	25.89276	1 589.0	64 897.86	-2 865 113.92
BHZ03	Alzu supply borehole west of packhouse	29.64763	25.89363	1 589.0	64 898.37	-2 865 210.32
BHZ04	Alzu supply borehole north of Steels Pan	29.64883	25.89824	1 585.6	65 016.11	-2 865 721.66
BHZ05	Supply borehole south-west of non-perennial pan No.15	29.65288	25.89739	1 588.0	65 422.42	-2 865 629.50
BHZ06	Alzu supply borehole west of non-perennial pan No.15	29.65294	25.89671	1 588.5	65 428.80	-2 865 554.19
BHZ07	Alzu supply borehole west of non-perennial pan No.15	29.65302	25.89615	1 588.8	65 437.13	-2 865 492.19
BHZ08	Supply borehole north-west of non-perennial pan No.15	29.65418	25.89492	1 588.5	65 554.05	-2 865 356.50
BHZ09	Supply borehole north-east of non-perennial pan No.15	29.65580	25.89549	1 588.6	65 716.08	-2 865 420.45
BHZ10	Alzu supply borehole west of T1 Dam	29.65263	25.90754	1 596.3	65 391.76	-2 866 753.91
BHZ11	Alzu supply borehole north of abbatoir	29.65014	25.92170	1 584.4	65 134.40	-2 868 321.40
BHZ12	Alzu supply borehole north of abbatoir	29.64976	25.92355	1 584.5	65 095.40	-2 868 526.20

Table 4 (cont.) *Groundwater sites in the vicinity of Pit 1 visited during the hydrocensus.*

Site Name	Site Description	Longitude (°E)	Latitude (°S)	Elevation (mamsl)	X_WGS84 (m)	Y_WGS84 (m)
C-3	Monitoring borehole in eastern parts of Pit 1 near conveyor	29.69324	25.92786	1 619.9	69 449.00	-2 869 026.07
C-4	Monitoring borehole in eastern parts of Pit 1 near conveyor	29.69210	25.92221	1 614.3	69 338.09	-2 868 399.50
C-5	Monitoring borehole in eastern parts of Pit 1 near conveyor	29.69307	25.92031	1 611.9	69 436.39	-2 868 189.51
Community BH	Supply borehole near Bosman Spruit	29.65447	25.88793	1 567.5	65 586.97	-2 864 582.21
Destroyed BH	Destroyed monitoring borehole east of the coal discards area	29.68485	25.93502	1 620.3	68 604.31	-2 869 814.93
KGM_B10	Monitoring borehole north-east of T4 Pump Dam	29.67911	25.91384	1 606.0	68 041.46	-2 867 465.37
Piet's Pump	Alzu supply borehole near Klein-Olifants River	29.65246	25.93162	1 567.5	65 361.46	-2 869 421.67
Private BH	Private borehole for household water supply	29.65057	25.92672	1 573.0	65 174.80	-2 868 877.80
Old Supply BH	Old supply borehole north-east of Railway Pan	29.66710	25.93649	1 594.8	66 825.34	-2 869 968.62
Windpump	Disused windpump near Klein-Olifants River	29.65461	25.93463	1 582.5	65 575.18	-2 869 756.23

Photo 22. Monitoring borehole ANT-1 after upgrade.

Photo 23. Monitoring borehole ANT-2 before upgrade.

Photo 24. Monitoring borehole ANT-2 after upgrade.

Photo 25. Monitoring borehole ANT-3 before upgrade.

Photo 26. Monitoring borehole AW01 before upgrade.

Photo 27. Monitoring borehole AW01 after upgrade

Photo 28. Monitoring borehole AW02.

Photo 29. Monitoring borehole AW03 before upgrade

Photo 30. Monitoring borehole AW03 after upgrade

Photo 31. Monitoring borehole AW04 after upgrade.

Photo 32. Monitoring borehole AW04.

Photo 33. Monitoring borehole AW06 before upgrade.

Photo 34. Monitoring borehole AW07.

Photo 35. Monitoring borehole AW08.

Photo 36. Monitoring borehole AW09

Photo 37. Monitoring borehole AW20

Photo 38. Monitoring borehole AW24 before upgrade

Photo 39. Monitoring borehole AW24 after upgrade

Photo 40. Monitoring borehole AW31

Photo 41. Alzu Windpump

Photo 42. Alzu borehole BHZ01

Photo 43. Alzu borehole BHZ02

Photo 44. Alzu borehole BHZ03

Photo 45. Alzu borehole BHZ04

Photo 46. Alzu borehole BHZ04

Photo 47. Alzu borehole BHZ05

Photo 48. Alzu borehole BHZ06

Photo 49. Alzu borehole BHZ07

Photo 50. Alzu borehole BHZ08

Photo 51. Alzu borehole BHZ09

Photo 52. BHZ10

Photo 53. BHZ11

Photo 54. Alzu borehole BHZ11 is blocked

Photo 55. Alzu borehole BHZ12

Photo 56. Monitoring borehole C-3

Photo 57. Monitoring borehole C-4

Photo 58. Monitoring borehole C-5

Photo 59. Community BH (Alzu)

Photo 60. Tank receiving water from Community BH

Photo 61. Monitoring borehole KGM_B10

Photo 62. Supply borehole south of Pit 1 (Piet's Pump)

Photo 63. Old Supply BH (Alzu)

Photo 64. Private BH (Piet du Toit)

Photo 65. Windpump (Alzu)

Monitoring borehole KGM_B10

This borehole was blocked with bee wax at a depth of approximately 7.4 mbgl. The bee wax should be removed to allow sampling of the groundwater at this site during future sampling events.

3.4 Groundwater Sites – Pit 2 (W&E)

The positions of the groundwater sites within and in the vicinity of Pit 2 (W&E) are shown in Figure 11 while information on these sites is listed in Table 5 Photographs of the different groundwater sites are presented in Photo 66 to Photo 89. Observations relevant to the current investigation are made below:

General

As the monitoring boreholes near Pit 1, all monitoring boreholes should be equipped with concrete plinths, lockable caps, marker posts and site numbers.

Monitoring borehole AW22

This borehole has no plinth and it appears that its casing has been pulled out, leaving an open hole (see Photo 73). The borehole is likely to collapse soon without its casing.

Monitoring borehole AW29

This monitoring borehole was infested with bees during the hydrocensus. The bees should be removed to allow sampling of the groundwater in this borehole during future sampling events.

Monitoring borehole AW30

Monitoring borehole AW30 has collapsed (see Photo 84). Re-drilling of this borehole should be considered.

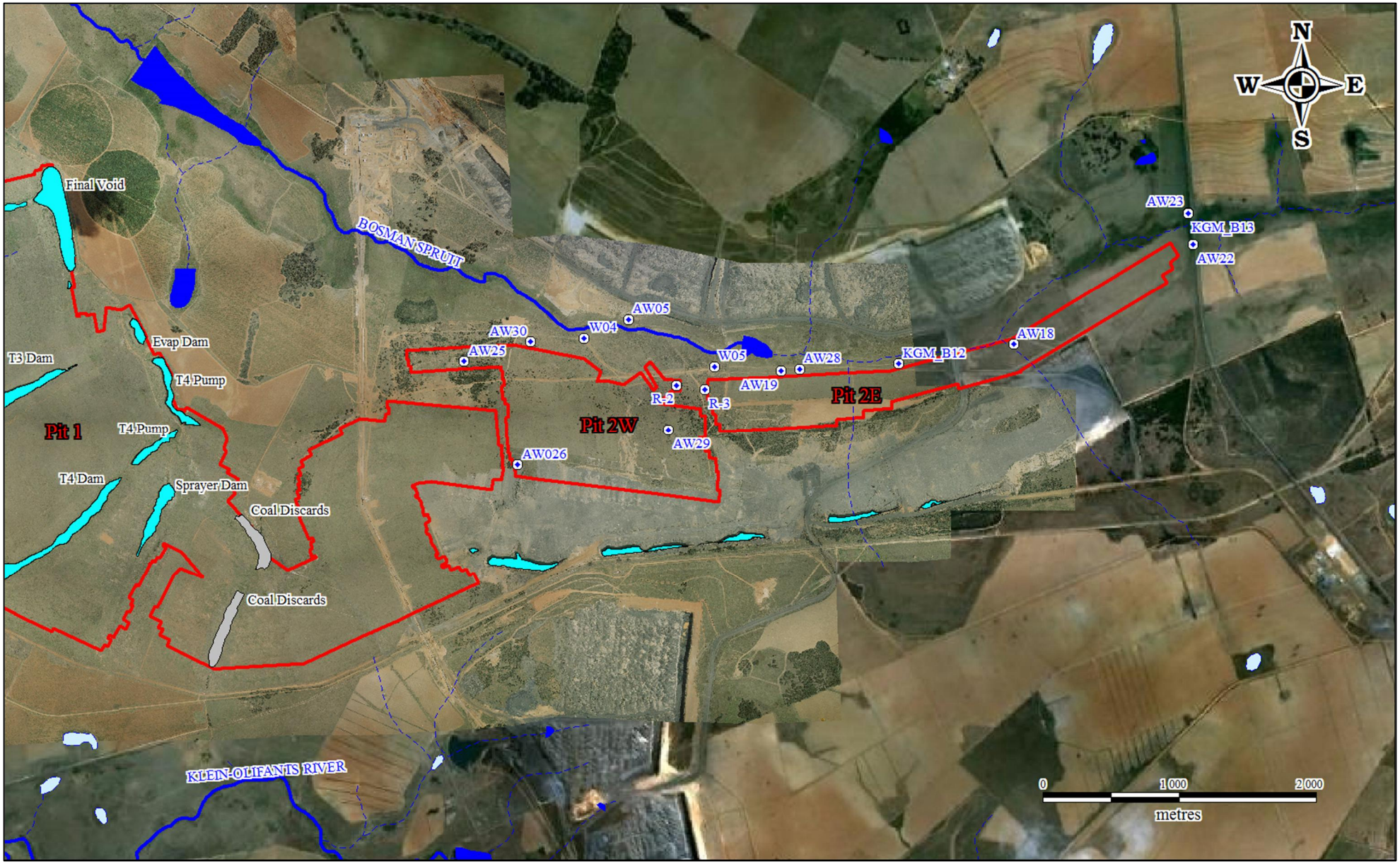


Figure 11. Groundwater sites within and in the vicinity of Pit 2 (W & E).

Table 5. Groundwater sites in the vicinity of Pit 2 (W & E) visited during the hydrocensus.

Site Name	Site Description	Longitude (°E)	Latitude (°S)	Elevation (mamsl)	X_WGS84 (m)	Y_WGS84 (m)
AW05	Monitoring borehole north of Pit 2E, across Bosman Spruit	29.74031	25.91508	1 620.0	74 172.64	-2 867 635.94
AW18	Monitoring borehole within Pit 2E	29.72329	25.91682	1 608.0	72 466.26	-2 867 819.20
AW19	Monitoring borehole north of Pit 2E	29.75344	25.90850	1 633.0	75 492.39	-2 866 914.42
AW22	Monitoring borehole east of Pit 2E	29.75310	25.90642	1 633.0	75 459.64	-2 866 683.78
AW23	Monitoring borehole east of Pit 2E	29.70005	25.91621	1 605.0	70 138.14	-2 867 738.98
AW25	Monitoring borehole within Pit 2W	29.70399	25.92306	1 623.1	70 528.82	-2 868 500.02
AW26	Monitoring borehole within Pit 2W, near south-western corner	29.72465	25.91672	1 609.0	72 602.58	-2 867 808.87
AW28	Monitoring borehole north of Pit 2E	29.71504	25.92073	1 614.9	71 637.31	-2 868 247.86
AW29	Monitoring borehole within Pit 2W, near eastern perimeter	29.70494	25.91492	1 604.5	70 628.85	-2 867 598.68
AW30	Destroyed monitoring borehole north of Pit 2W	29.70494	-25.91492	1 604.5	70 628.80	-2 867 598.60
KGM_B11	Monitoring borehole north of Pit 2E, across Bosman Spruit	29.71342	25.91374	1 604.9	71 479.21	-2 867 472.55
KGM_B12	Monitoring borehole north of Pit 2E	29.73187	25.91635	1 614.0	73 326.21	-2 867 771.90
KGM_B13	Monitoring borehole east of Pit 2E, adjacent to AW23	29.75311	25.90647	1 633.0	75 460.61	-2 866 689.32
R-1	Monitoring borehole near the eastern perimeter of Pit 2W	29.71842	25.92383	1 620.4	71 974.06	-2 868 593.17
R-2	Monitoring borehole near the eastern perimeter of Pit 2W	29.71561	25.91779	1 608.7	71 696.19	-2 867 922.45
R-3	Monitoring borehole near the western perimeter of Pit 2E	29.71770	25.91807	1 608.7	71 905.42	-2 867 954.61
W04	Trench north of Pit 2W	29.70883	25.91469	1 600.6	71 018.74	-2 867 575.30
W05	Trench at the Dosing Plant near north-western corner of Pit 2E	29.71839	25.91656	1 605.0	71 975.47	-2 867 787.70

Photo 66. Monitoring borehole AW05 before upgrade

Photo 67. Monitoring borehole AW05 After upgrade

Photo 68. Monitoring borehole AW09

Photo 69. Monitoring borehole AW18

Photo 70. Monitoring borehole AW19 before upgrade

Photo 71. Monitoring borehole AW19 after upgrade

Photo 72. Monitoring borehole AW22

Photo 73. Monitoring borehole AW22

Photo 74. Monitoring borehole AW23

Photo 75. Monitoring borehole KGM_B13

Photo 76. Monitoring borehole AW25 before upgrade

Photo 77. Monitoring borehole AW25 after upgrade

Photo 78. Monitoring borehole AW26

Photo 79. Monitoring borehole AW28 before upgrade

Photo 80. Monitoring borehole AW28 after upgrade

Photo 81. Monitoring borehole AW29

Photo 82. Monitoring borehole AW29

Photo 83. Monitoring borehole AW30

Photo 84. Monitoring borehole AW30

Photo 85. Monitoring borehole KGM_B11

Photo 86. Monitoring borehole KGM_B13

Photo 87. Monitoring borehole R-3

Photo 88. Monitoring site W04

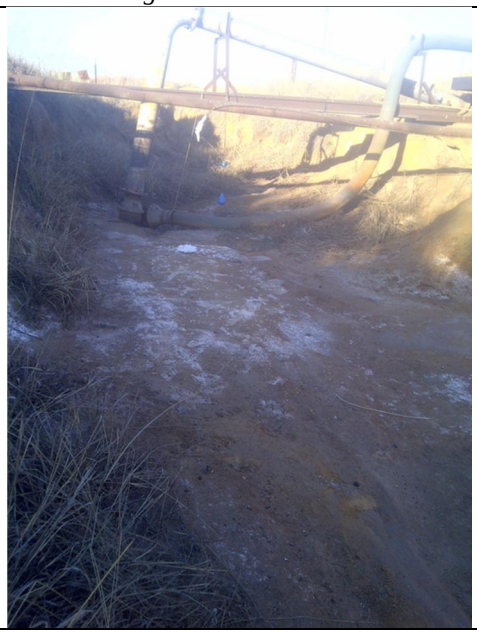


Photo 89. Monitoring site W05 - Dosing Plant

3.5 Surface- and Groundwater Use at Alzu

Various farming activities take place at Alzu. These include: maize cultivation, pig farming and egg production. All of these activities involve the use of water.

3.5.1 Maize Cultivation

Irrigation of the maize crops is done exclusively using surface water from the Klein-Olifants River and dams in the Bosman Spruit. Irrigation normally commences late in October after seeding and is done on an ad hoc basis until harvest time in the winter months, depending on the rainfall experienced. No estimates of the volumes of surface water used for irrigation are currently available.

3.5.2 Pig Farming

All drinking water at Alzu is a mixture of purified water pumped from a water treatment plant of Exxaro and groundwater abstracted from a number of production boreholes. The volumes of groundwater and purified water making up the mixture are currently unknown. The production boreholes currently employed for drinking water at the packing station are boreholes BHZ02, BHZ03, Piet's Pump and the Alzu Windpump. Water from these boreholes is pumped to a number of tanks near the abattoir from where it gravitates to the packing station. Approximately 90 000 *l*/day of drinking water are consumed by 6 000 pigs of various ages.

The piggery is rinsed using water from the T1 Dam. It is estimated that approximately 100 000 *l* are used daily for this purpose.

Waste generated at the piggery is transported to a facility on the banks of the Steels Pan where the solid waste materials are separated from the liquid waste. The solid waste materials are used to fertilize the maize fields while the liquid wastes are discarded in the Steels Pan.

3.5.3 Egg Production

Water from borehole BHZ10 is pumped to green tanks near the chicken pens adjacent to the western perimeter of Pit 1. Water from these tanks gravitate towards the pens where 80 000 hens consume approximately 19 200 *l* of groundwater per day.

At Alzu's operations north of the Bosman Spruit, groundwater is also used as drinking water for 380 000 hens consuming approximately 91 200 *l*/day.

3.5.4 Human Consumption

Approximately 330 people at Alzu consume the mixture of borehole water and purified water from Exxaro. The water is not only used for drinking purposes, but also domestic purposes and

sanitation. Assuming a consumption of 50 *l*/person/day, the human consumption is estimated at 16 250 *l*/day.

3.5.5 Road Wetting

Approximately 140 000 *l* of water from the T1 Dam are used for road wetting purposes. The main road that runs from the N11 past Alzu' entrance wetted to limit dust generation.

4 The Current Water Reticulation System

4.1 Introduction

The current water reticulation at Arnot Closed Colliery is restricted to activities at Pit 1. The water level in the Decant Dam is maintained well below the decant level by pumping water to both the T1 Dam and the Final Void. From these dams, water is pumped to the T4 Pump dam, from where it is pumped to the evaporation sprayers further to the south on Pit 1. Should the water level in the T4 Pump dam rise too much, the pipes carrying water to this dam may be diverted towards the Evaporation Dam.

From the T1 Dam water is also pumped for use at Mafube Colliery. In the past, excess water from the T1 Dam was also discharged as controlled release to the Klein Olifants River. Currently the water levels in the pits are managed so that controlled release no longer takes place. However, controlled releases may in future again be required when high rainfall occurs to avoid decant.

The current water reticulation system at Pit 1 is shown schematically in plan view in Figure 12. Flowmeters (numbered D1 to D6, T1A, T1B, V1 to V3, T4A, T4B) have been installed on all the pipelines carrying water between the dams, except on one pipeline along which water is pumped from the Final Void to the T4 Pump dam by means of a diesel pump (marked 'Diesel'). The water levels of the Decant Dam, T1 Dam, Final Void, T4 Pump dam and T4 Dam are measured daily by means of imbedded yardsticks marked at intervals of 0.025 m.

The water reticulation system at Pit 1 currently serves two purposes. Firstly, the water levels in the Decant Dam and T1 Dam are kept below their decant levels, and secondly, evaporation losses are increased through the additional free water surfaces created at the Final Void, T4 Pump dam, T4 Dam, Evaporation Dam and near the sprayers. The sprayers themselves also serve to increase the evaporation losses. However, much of water pumped to the mentioned dams seeps back through the spoils and flows down-gradient back to the Decant Dam and/or the T1 Dam. This circulation of water through the spoils is likely to have a detrimental effect on the water quality.

In Figure 13 the position of a trace is shown as a purple line through the various dams in Pit 1 that form part of the water reticulation system, starting at the Decant Dam in the north and zigzagging through the T1 Dam, Final Void, T2 Dam, T3 Dam, T4 Pump dam, T4 Dam and the perched dam form near the sprayers in the south. A cross-section through Pit 1 along this trace is shown in Figure 14. The water levels in the dams are those that were measured when a digital terrain model (DTM) was compiled at the end of January 2012. The cross-sectional view also shows the water inflows and outflows that need to be considered to determine the water make of the colliery.

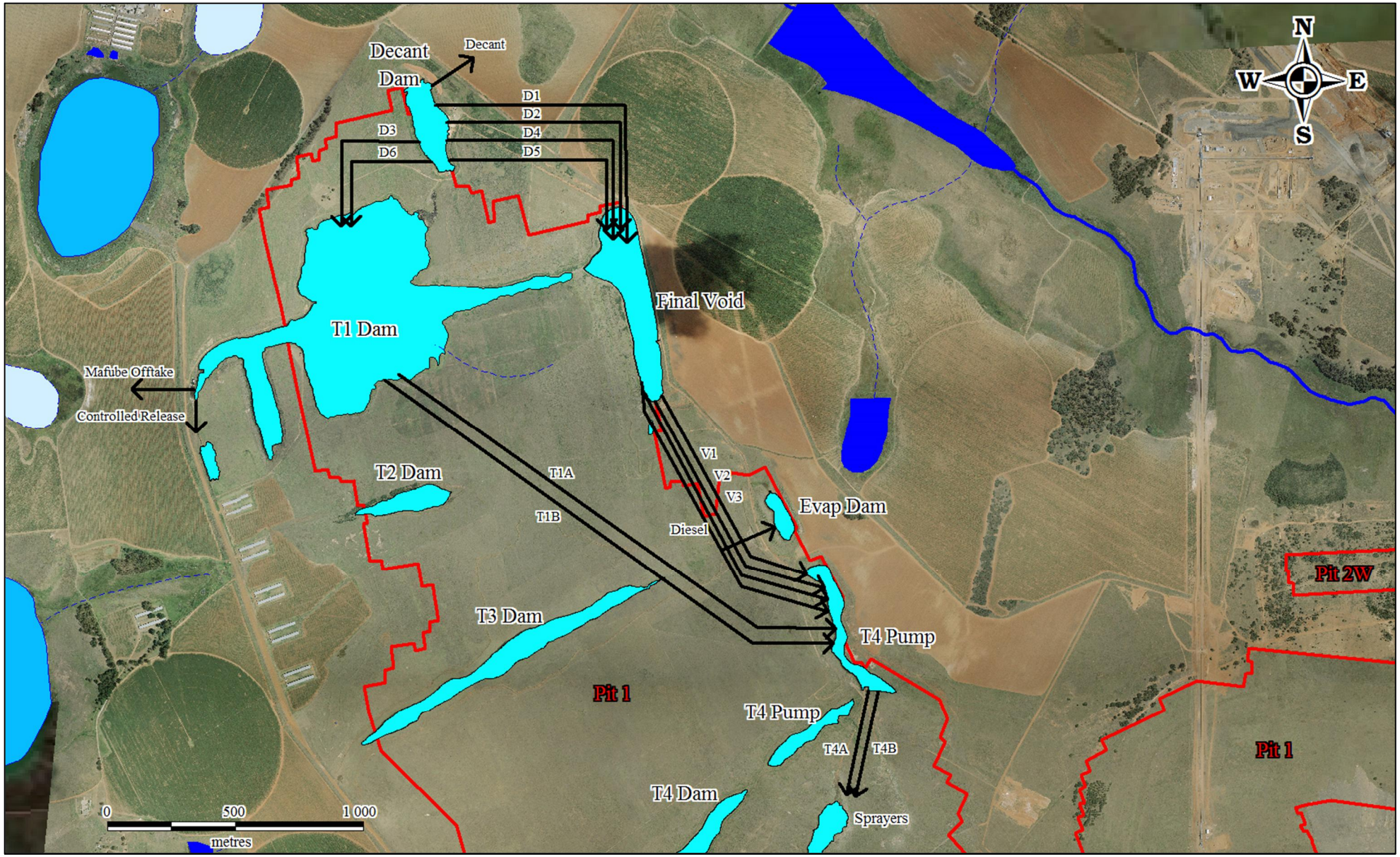


Figure 12. Schematical representation of the current water reticulation system at Arnot Closed Colliery

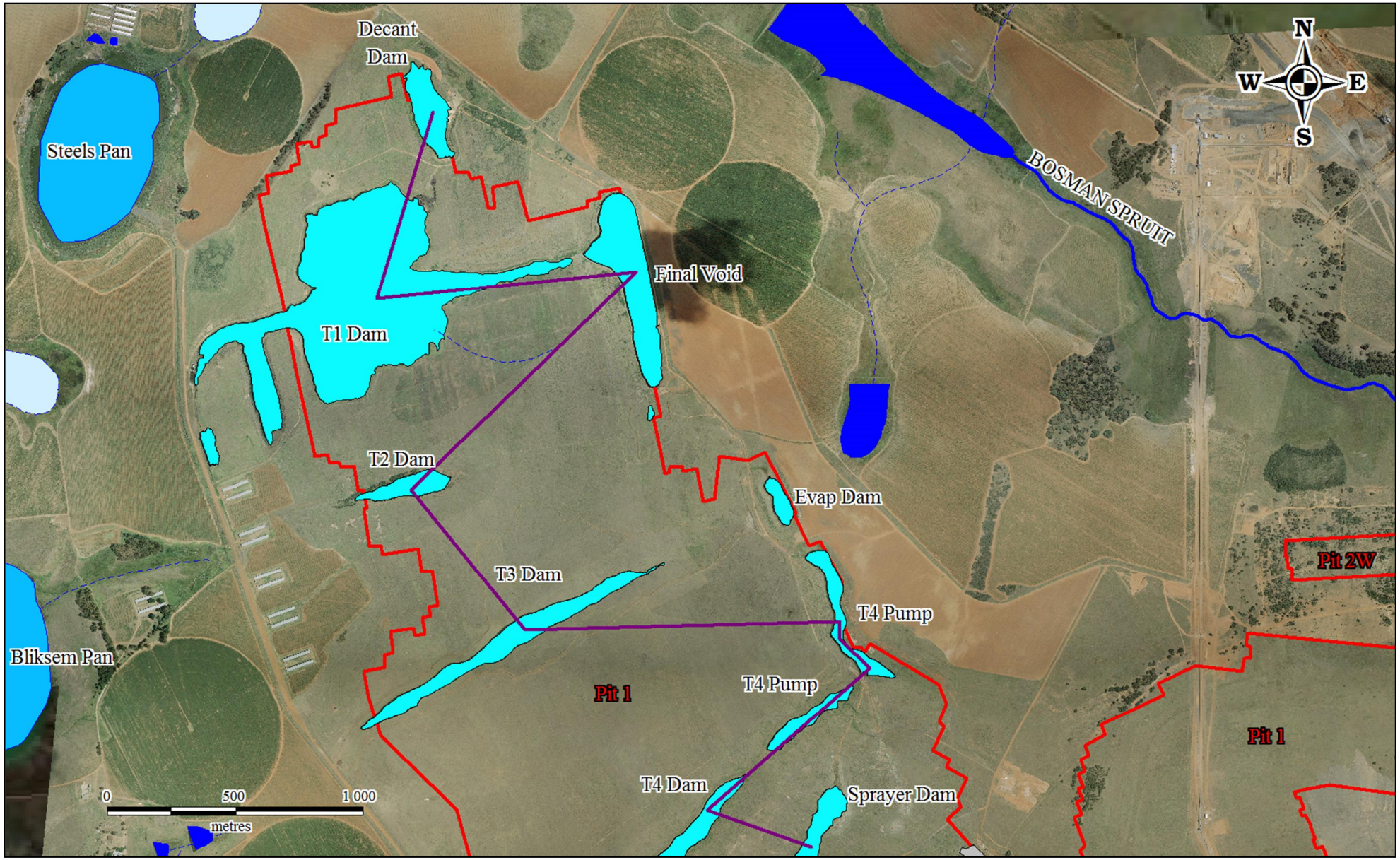


Figure 13. Cross-section trace through the various dams within Pit 1.

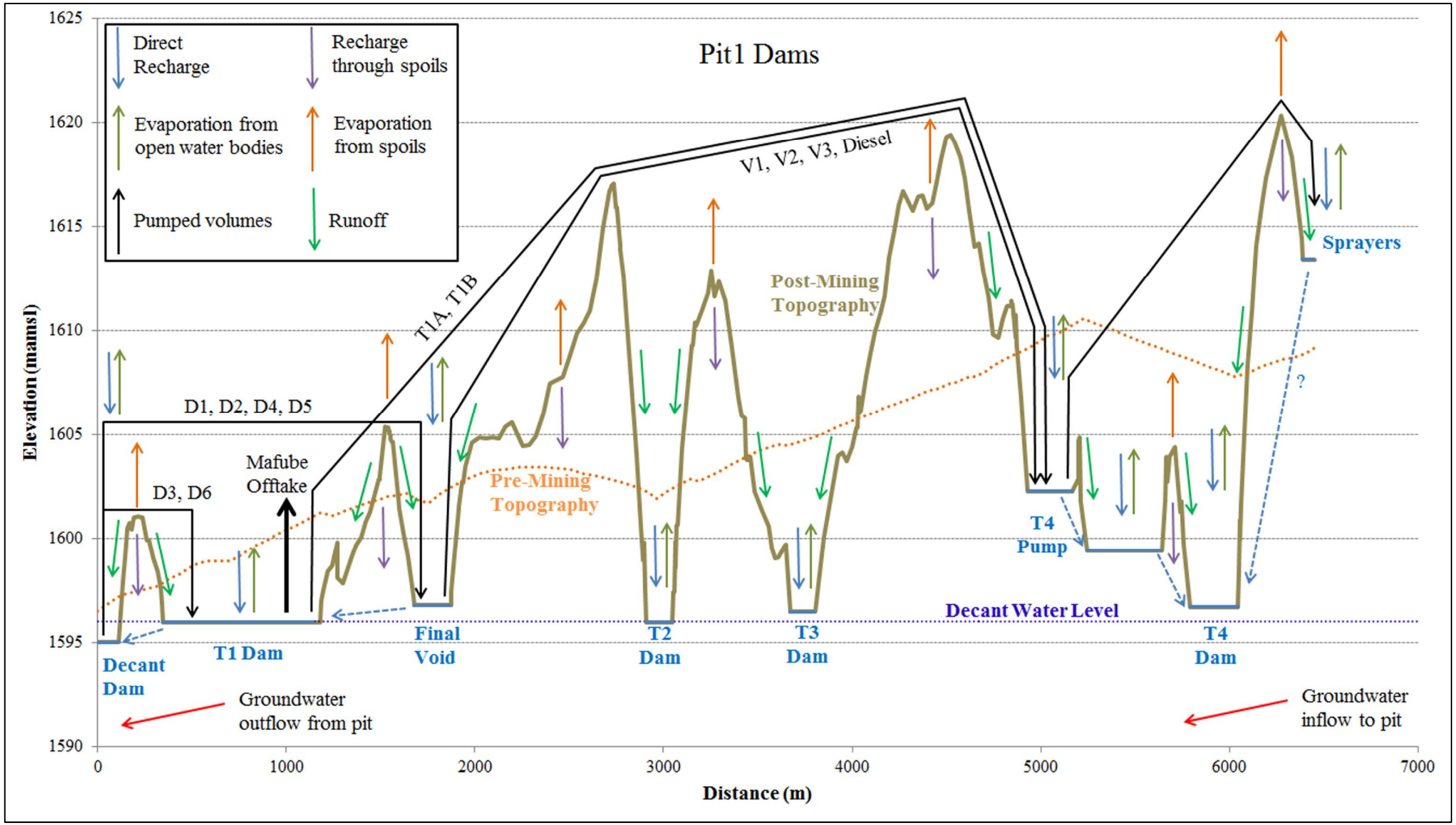


Figure 14. Cross-section through the various dams within Pit 1 illustrating water reticulation and water gains and losses.

Figure 14 shows how the water make of – Arnot Closed Colliery may be calculated as the difference between all inflows and all outflows:

Water make =

(*Direct dam recharge + recharge through spoils + groundwater inflow + runoff to dams*)

– (*Dam evaporation + evaporation from spoils + groundwater outflow*)

(1)

Equation (1) assumes that no storage changes occur within the spoils. This is a reasonable assumption since the hydraulic conductivity of the spoils is likely to be so high that any water seeping from the dams will simply flow vertically downward to the decant water level of Pit 1. A number of observations may be made From Figure 14:

- The water level of the Decant Dam was well below the decant level at the time the DTM was flown.
- The water levels in the Final Void, T4 Pump dam and the dam near the sprayers were well above the decant level of Decant Dam. These dams all receive water, directly or indirectly, from the Decant Dam. The dam at the sprayers had a water level of more than 13 m above the decant level. This existence of this perched dam shows that the permeability of the topsoil used during rehabilitation of the backfilled pits is adequately low to allow ponding.
- The water level in the T4 Dam was above the decant water level, indicating that this dam was receiving water from the T4 Pump dam (and possibly from the Sprayer Dam) as seepage through the spoils.
- The water level in the T3 Dam was also slightly higher than the decant level. This elevated water level is unexpected since the T3 Dam is located more than 800 m away from the T4 Pump dam. Due to the high permeability of spoils, it is highly unlikely that seepage from the T4 Pump dam was responsible for the raised water level in the T3 Dam. This observation suggests that Pit 1 is compartmentalised, and that various decant levels exist within the different compartments of the pit (also refer to Section 11 for more information on the compartmentalisation of Pit 1).

4.2 Volumes Pumped

The volumes of water that have been pumped to and from the various dams between January and June 2012 are summarised below. (Values in red correspond to missing or suspicious data that were replaced by the average values recorded during the other months.)

4.2.1 Decant Dam

Water is pumped from the Decant dam by means of six pumps. Four pumps (D1, D2, D4 and D5) pump water to the Final Void, while two pumps (D3, D6) pump to the T1 Dam. The volumes pumped from the Decant Dam between January and June 2012 are listed in Table 6.

From Table 6 it is seen that over a six-month period, approximately 3 600 000 m^3 of water was pumped from the Decant Dam. This volume translates to 600 000 m^3/month or 20 M*l*/day. In this period, T1 Dam received approximately 2 100 000 m^3 of water (11.7 M*l*/day), while approximately 1 500 000 m^3 of water (8.3 M*l*/day) was pumped to Final Void.

Table 6. Volumes of water pumped from the Decant Dam.

Month	Pumped from Decant Dam (m^3)					
	To T1		To Final Void			
	D3	D6	D1	D2	D4	D5
Jan-12	-205 427	-139 553	-72 917	-39 671	-49 520	-96 859
Feb-12	-191 127	-127 471	-67 973	-32 934	-44 435	-94 365
Mar-12	-188 414	-146 816	-68 505	-41 342	-48 481	-105 958
Apr-12	-207 951	-147 367	-64 749	-41 342	-47 194	-97 736
May-12	-210 655	-135 997	-51 828	-41 342	-38 804	-102 632
Jun-12	-217 589	-148 746	-39 945	-51 420	-46 129	-122 979
Total	**-1 221 163**	**-845 950**	**-365 917**	**-248 050**	**-274 563**	**-620 529**
	-2 067 113		**-1 509 059**			
	-3 576 172					

4.2.2 T1 Dam

The T1 Dam receives water from the Decant Dam. In turn, water is pumped from the T1 Dam to the T4 Pump Dam and Mafube Colliery. The volumes of water pumped to and from the T1 Dam during the period January to June 2012 are listed in Table 7 and Table 8, respectively.

Comparison of the total volumes pumped to and from the T1 Dam shows that this dam received approximately 1 372 000 m^3 of water more than was pumped from it in the six-month period. This volume translates to a daily excess of approximately 7.6 M*l*/day. The Mafube offtake for the six-month period equates to approximately 0.96 M*l*/day.

Table 7. Volumes of water pumped to the T1 Dam.

Month	Pumped to T1 Dam (m^3)	
	From Decant Dam	
	D3	D6
Jan-12	205 427	139 553
Feb-12	191 127	127 471
Mar-12	188 414	146 816
Apr-12	207 951	147 367
May-12	210 655	135 997
Jun-12	217 589	148 746
Total	**1 221 163**	**845 950**
	2 067 113	

Table 8. Volumes of water pumped from the T1 Dam.

Month	Pumped from T1 Dam (m^3)		
	To T4 Pump		To Mafube
	T1A	T1B	
Jan-12	-44 425	-36 861	-25 910
Feb-12	-32 633	-41 316	-19 447
Mar-12	-44 425	-31 004	-20 654
Apr-12	-46 059	-50 348	-27 060
May-12	-44 425	-47 451	-50 269
Jun-12	-54 584	-49 916	-28 668
Total	**-266 552**	**-256 896**	**-172 008**
	-523 448		**-172 008**
	-695 456		

4.2.3 Final Void

The Final Void receives water from the Decant Dam and water is in turn pumped from this dam to the T4 Pump dam. The volumes that have been pumped to and from the Final Void during the period January to June 2012 are summarised in Table 9 and Table 10, respectively. Due to faulty flowmeters there is a degree of uncertainty about more than half of the monthly volumes pumped from the Final Void, as displayed in Table 10. The diesel pump was not yet equipped with a flowmeter during the six-month period from January to June 2012. The volumes pumped by the diesel pump were estimated from a measurement of the pumping rate, and by assuming that the pump was operational for 70% of the months, as suggested by personnel of AngloAmerican.

Table 9. Volumes of water pumped to the Final Void.

Month	Pumped to Final Void (m^3)			
	From Decant Dam			
	D1	D2	D4	D5
Jan-12	72 917	39 671	49 520	96 859
Feb-12	67 973	32 934	44 435	94 365
Mar-12	68 505	41 342	48 481	105 958
Apr-12	64 749	41 342	47 194	97 736
May-12	51 828	41 342	38 804	102 632
Jun-12	39 945	51 420	46 129	122 979
Total	**365 917**	**248 050**	**274 563**	**620 529**
	1 509 059			

Table 10. Volumes of water pumped from the Final Void.

Month	Pumped from Final Void (m^3)			
	To T4 Pump			
	V1	V2	V3	Diesel
Jan-12	-88 179	-111 093	-85 311	-35 700
Feb-12	-72 546	-110 080	-59 897	-35 700
Mar-12	-89 892	-227 989	-151 942	-35 700
Apr-12	-89 892	-152 518	-86 651	-35 700
May-12	-89 892	-150 420	-85 311	-35 700
Jun-12	-108 950	-150 420	-42 753	-35 700
Total	**-539 350**	**-902 520**	**-511 865**	**-214 200**
	-2 167 935			

The pumping volumes listed in Table 9 and Table 10 suggest that the outflows from the Final Void exceeded the inflows by approximately 660 000 m^3 during the six-month period. This value corresponds to an average daily volume of approximately 3.7 M*l* and seems excessive. The estimates of the volumes of water pumped from the Final Void (red values in Table 10) may therefore be too large.

4.2.4 T4 Pump

The T4 Pump Dam receives water from the T1 Dam and the Final Void. From here, water is pumped to 20 sprayers located at a position farther to the south on Pit 1. The purpose of the sprayers is to increase the evaporation losses of water.

The volumes of water that were pumped to and from the T4 Pump dam during the period January to June 2012 are listed in Table 11 and Table 12, respectively. During this period the T4 Pump Dam received approximately 2 700 000 m^3 of water, while approximately 2 200 000 m^3 of water were pumped from this dam to the sprayers. The excess 500 000 m^3 of water equates to approximately 2.67 M*l*/day. However, it should again be emphasised that, due to flowmeter malfunction and the

absence of a flowmeter for the diesel pump, considerable uncertainty exists regarding the monthly volumes pumped from the Final Void to the T4 Pump dam.

Table 11. Volumes of water pumped to the T4 Pump dam.

Month	Pumped to T4 Pump (m^3)					
	From T1 Dam		From Final Void			
	T1A	T1B	V1	V2	V3	Diesel
Jan-12	44 425	36 861	88 179	111 093	85 311	35 700
Feb-12	32 633	41 316	72 546	110 080	59 897	35 700
Mar-12	44 425	31 004	89 892	227 989	151 942	35 700
Apr-12	46 059	50 348	89 892	152 518	86 651	35 700
May-12	44 425	47 451	89 892	150 420	85 311	35 700
Jun-12	54 584	49 916	108 950	150 420	42 753	35 700
Total	**266 552**	**256 896**	**539 350**	**902 520**	**511 865**	**214 200**
	523 448		**2 167 935**			
	2 691 383					

Table 12. Volumes of water pumped from the T4 Pump dam.

Month	Pumped from T4 Pump (m^3)	
	To Sprayers	
	T4A	T4B
Jan-12	-172 126	-142 623
Feb-12	-165 180	-155 426
Mar-12	-176 536	-207 228
Apr-12	-179 609	-389 147
May-12	-169 260	-58 548
Jun-12	-196 504	-197 734
Total	**-1 059 215**	**-1 150 706**
	-2 209 921	

4.3 Changes in Dam Levels and Volumes

Dam water levels at Arnot Closed Colliery are monitored on a daily basis. Embedded yardsticks, marked at 0.025 m intervals, are used to measure the water levels. The changes in the dam water levels during the period 1 January to 30 June 2012 are listed in Table 13 to Table 17 for the Decant Dam, the T1 Dam, the Final Void, the T4 Pump dam and the T4 Dam. Also listed in these tables are the estimated changes in the volumes of water held in these dams during this six-month period. These estimates were calculated by assuming that the free water surface areas of these dams (as per the DTM of January 2012) remained constant during the water level changes. As such, estimations of the volume changes for increasing water levels are likely to be underestimations while estimations for water level decreases are likely to be overestimations.

Table 13. Changes in water level of the Decant Dam.

Decant Dam (3.73 ha)					
Date	**Start Level**	**End Level**	**Level Change**	**Elevation Change (m)**	**Volume Change (m^3)**
Jan	8	9	1	0.025	933
Feb	9	15.5	6.5	0.1625	6 061
Mar	15.5	16.5	1	0.025	933
Apr	16.5	19	2.5	0.0625	2 331
May	19	16	-3	-0.075	-2 798
Jun	16	17	1	0.025	933
Total volume change for six-month period (m^3)					**8 393**

Table 14. Changes in water level of the T1 Dam.

T1 Dam (44.8 ha)					
Date	**Start Level**	**End Level**	**Level Change**	**Elevation Change (m)**	**Volume Change (m^3)**
Jan	6.5	8	1.5	0.0375	16 800
Feb	8	8	0	0	0
Mar	8	8	0	0	0
Apr	8	6	-2	-0.05	-22 400
May	6	6	0	0	0
Jun	6	7.5	1.5	0.0375	16 800
Total volume change for six-month period (m^3)					**11 200**

Table 15. Changes in water level of the Final Void.

Final Void (9.22 ha)					
Date	**Start Level**	**End Level**	**Level Change**	**Elevation Change (m)**	**Volume Change (m^3)**
Jan	22	1.5	-20.5	-0.5125	-47 253
Feb	1.5	5	3.5	0.0875	8 068
Mar	5	12	7	0.175	16 135
Apr	12	25	13	0.325	29 965
May	25	25	0	0	0
Jun	25	32	7	0.175	16 135
Total volume change for six-month period (m^3)					**23 050**

Table 16. Changes in water level of the T4 Pump dam.

T4 Pump (4.78 ha)					
Date	**Start Level**	**End Level**	**Level Change**	**Elevation Change (m)**	**Volume Change (m^3)**
Jan	23.5	44	20.5	0.5125	24 498
Feb	44	27	-17	-0.425	-20 315
Mar	27	31	4	0.1	4 780
Apr	31	14	-17	-0.425	-20 315
May	14	38	24	0.6	28 680
Jun	38	28	-10	-0.25	-11 950
Total volume change for six-month period (m^3)					**5 378**

Table 17. Changes in water level of the T4 Dam.

T4 Dam (7.84 ha)					
Date	**Start Level**	**End Level**	**Level Change**	**Elevation Change (m)**	**Volume Change (m^3)**
Jan	13.5	13	-0.5	-0.0125	-980
Feb	13	16	3	0.075	5 880
Mar	16	13	-3	-0.075	-5 880
Apr	13	13	0	0	0
May	13	13	0	0	0
Jun	13	13	0	0	0
Total volume change for six-month period (m^3)					**-980**

From the data listed in Table 13 to Table 17 it is seen that over the six-month period, all dams excluding the T4 Dam displayed volume increases. The total estimated volume increase for all these dams is approximately 47 000 m^3 of water. However, as stated above, this estimate should be seen as conservative since water level increases lead to underestimations of the volumes gained while water level decreases lead to overestimations of the volumes lost. It can therefore be concluded that during the six-month period, the water volume in all the dams increased by more than 47 000 m^3. This volume of water translates to a daily volume gain of more than 0.26 M*l*.

4.4 Direct Rainfall Recharge to Dams

The direct recharge to the various dams within Pit 1 over the period January to June 2012 is estimated in Table 18. The recharge estimates are calculated using the measured rainfall at the Decant Dam and assuming that the surface areas of the dams remained constant during the six-month period.

Table 18. Direct recharge to the dams within Pit 1.

Month	Decant Dam (m^3)	T1 Dam (m^3)	Final Void (m^3)	T2 Dam (m^3)	T3 Dam (m^3)	Evap Dam (m^3)	T4 Pump (m^3)	T4 Dam (m^3)	Sprayer Dam (m^3)
Jan	3 655	43 904	9 036	2 195	7 272	1 029	4 684	7 683	3 371
Feb	2 201	26 432	5 440	1 322	4 378	620	2 820	4 626	2 030
Mar	2 387	28 672	5 901	1 434	4 749	672	3 059	5 018	2 202
Apr	410	4 928	1 014	246	816	116	526	862	378
May	0	0	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0	0	0
Total	**8 654**	**103 936**	**21 390**	**5 197**	**17 214**	**2 436**	**11 090**	**18 189**	**7 981**
					196 086				

The total volume of direct recharge to the dams during the six-month period equals approximately 196 000 m^3. This volume translates to approximately 1.09 M*l*/day of direct rainfall recharge.

4.5 Evaporation Losses at Dams and Sprayers

The estimated volumes of water lost to evaporation from the different dams within Pit 1 of Arnot Closed Colliery are listed in Table 19. These estimates are based on the average monthly lake evaporation losses (as listed in Table 2) and assumes that the free water surface areas of these dams correspond to the their values as at the end of January 2012 when the DTM was compiled. Implicit to the latter assumption is the fact that increases in the water levels of the dams are likely to lead to slight underestimations of the evaporation losses, while decreases in the dam water levels may result in overestimations of the evaporation losses.

Table 19. Monthly evaporation losses from the dams within Pit 1.

Month	Decant Dam (m^3)	T1 Dam (m^3)	Final Void (m^3)	T2 Dam (m^3)	T3 Dam (m^3)	Evap Dam (m^3)	T4 Pump (m^3)	T4 Dam (m^3)	Sprayer Dam (m^3)
Jan	4 282	51 430	10 585	2 572	8 518	1 205	5 487	9 000	3 949
Feb	3 655	43 904	9 036	2 195	7 272	1 029	4 684	7 683	3 371
Mar	3 525	42 336	8 713	2 117	7 012	992	4 517	7 409	3 251
Apr	2 715	32 614	6 712	1 631	5 402	764	3 480	5 708	2 504
May	2 245	26 970	5 550	1 348	4 467	632	2 878	4 720	2 071
Jun	1 749	21 011	4 324	1 051	3 480	492	2 242	3 677	1 613
Total	**18 173**	**218 266**	**44 920**	**10 913**	**36 150**	**5 116**	**23 288**	**38 196**	**16 760**
					411 781				

The total estimated volume of water lost to evaporation during the six-month period of January to June 2012 amounts to approximately 412 000 m^3 of water. This volume is more than double the estimated direct rainfall recharge to the dams and equates to approximately 2.29 M*l*/day of evaporation losses.

Apart from the evaporation losses from the free surfaces of the dams, additional evaporation losses are incurred at the sprayers. Experience has shown that approximately 25% of water sprayed on rehabilitated spoils in the Mpumalanga Province filters through the spoils. The remaining 75% is accounted for in evaporation losses, transpiration losses and volume changes in ponding. The evaporation losses at the sprayers should be significantly higher than 20% of the water received. Using a conservative estimate of 30%, the total volume of water lost to evaporation at the sprayers equates to approximately 3.68 M*l*/day.

4.6 First Estimates of the Water Make

When considering the volume of water pumped from the Decant Dam during the six-month period (3 576 172 m^3, Table 6) against the volume change in the corresponding period (8 393 m^3, Table 13), it is clear that the change in the volume of water stored in the dam was negligibly small compared to the volume of water pumped from the dam. This shows that the volume of water received by the Decant Dam during this period was approximately equal to the volume of water removed from the dam by means of pumping to the T1 Dam and Final Void, evaporation losses and seepage losses. It can therefore be concluded that the Decant Dam received approximately 19.9 M*l*/day. This volume is expected to be much larger than the water make of Arnot Closed Colliery since a large percentage of the water pumped from the Decant Dam is simply recycled through the spoils.

A first estimate of Arnot Closed Colliery's water make may be obtained by considering only the water reticulation system, flowmeter readings, dam level changes, evaporation data and rainfall data. The change in the volume of water stored in any particular dam may be estimated from:

Storage change

= *(volume pumped to dam – volume pumped from dam)*
+ *(direct rainfall recharge to dam – evaporation losses from dam)*
+ *(other inflows – other outflows)*

(2)

'Other inflows' may include groundwater inflows, surface runoff reaching the dams, rainfall recharge reaching the dams through the spoils as well as seepage from other dams within the spoils, while 'other outflows' may include groundwater outflows through the spoils and evaporation losses from the spoils. Since the storage changes, volumes pumped rainfall recharge and evaporation losses have all been estimated, the term (other inflows – other outflows) may be calculated for each dam. This is done in Table 20 for the six-month period of January to June 2012. Since no

information is available on the storage changes in the perched dam near the sprayers, it is assumed that this value is zero.

The calculations done in Table 20 assume that there were no storage increases within the spoils and that the volume of water in the spoils of Pit 1 remained constant with the water level at or near the decant level.. This is a reasonable assumption since the hydraulic conductivity of the spoils is likely to be so high that any water seeping from the dams will simply flow vertically downward to the decant water level of Pit 1.

Table 20. Water losses and gains at the various dams within Pit 1.

Item	Decant Dam (m^3)	T1 Dam (m^3)	Final Void (m^3)	T2 Dam (m^3)	T3 Dam (m^3)	Evap Dam (m^3)	T4 Pump (m^3)	T4 Dam (m^3)	Sprayer Dam & Sprayers (m^3)
Storage Changes	8 393	11 200	23 050	~	~	~	5 378	-980	0
Evaporation Losses	18 173	218 266	44 920	10 913	36 150	5 116	23 288	38 196	679 736
Rainfall Recharge	8 654	103 936	21 390	5 197	17 214	2 436	11 090	18 189	7 981
Pumped To	0	2 067 113	1 509 059	0	0	0	2 691 383	0	2 209 921
Pumped From	3 576 172	695 456	2 167 935	0	0	0	2 209 921	0	0
other inflows - other outflows	**3 594 083**	**-1 246 127**	**705 455**	**5 716**	**18 936**	**2 680**	**-463 885**	**19 028**	**-1 538 166**
	1 097 719								

From the estimates shown in Table 20 it is seen that the 'other inflows' exceeded the 'other outflows' by more than a million cubic metres over the six-month period. The calculated difference corresponds to a daily volume of approximately 6.10 M*l*. Three dams exhibit conditions of larger outflows than inflow. The large volumes of 'other outflows' at the T1 Dam is probably due to the water flowing through the spoils to the Decant Dam where the water level is kept artificially low by pumping almost 20 M*l*/day to the T1 Dam and the Final Void. The T4 Pump dam is probably losing water through the spoils to the T4 Dam, while the perched dam at the sprayers also probably loses water through the spoils (refer to Figure 14).

A first estimate of the 'managed' water make of Arnot Closed Colliery may now be obtained from:

Water make = Direct dam recharge – dam evaporation + (*other inflows – other outflows*)

(3)

In Equation (3) evaporation losses at the sprayers are treated as a managed removal of water from the system, similar to the Mafube offtake. For the six-month period of January to June 2012 the total water make is estimated as 881 448 m^3. This volume translates to an average 'managed' water make of **4.90 M*l*/day** which is equal to the sum of the storage increases in the dams (0.26 M*l*/day),

the volumes of water pumped to Mafube Colliery (0.96 M*l*/day) and the estimated volumes of water lost to evaporation at the sprayers (3.68 M*l*/day).

Here it should be emphasised that uncertainty exists regarding the volume of water lost to evaporation at the sprayers. The estimated volume (3.68 M*l*/day) is based on the conservative assumption that the evaporation losses at the sprayers amount to 30% of the water received by the sprayers. If the true evaporation losses are 40% of the water received, the volume of water lost to evaporation will be 4.91 M*l*/day while the water make will increase to **6.13 M*l*/day**. This observation shows the importance of obtaining accurate estimates of the true percentage of evaporation losses at the sprayers in order to estimate the water make at Arnot Closed Colliery. (An evaporation figure of 30% is henceforth assumed in the calculations.)

Active management of the waters found in the dams within Pit 1 by continued pumping is a costly exercise that cannot be sustained indefinitely. To estimate the 'unmanaged' water make of Arnot Closed Colliery, the scenario should be considered when all pumping is ceased. Under these conditions, only the Decant Dam and the T1 Dam will contain significant water since the water level in the spoils will be at the decant level of Pit 1, assuming that the pit is not compartmentalised (see Figure 7). In addition, since the sprayers will no longer be operational, evaporation losses will be significantly reduced.

If evaporation losses from open water bodies occur only at the Decant Dam and the T1 Dam the evaporation losses will be reduced to approximately 1.31 M*l*/day (from approximately 5.95 M*l*/day, a reduction of 78%) and the water make will be significantly higher. It should also be noted that the recorded total rainfall for this six-month period (232 mm, Table 1) was well below the mean annual rainfall figures recorded at the Gemsbokfontein (774.0 mm) and Carolina (755.5 mm) weather stations. The annual rainfall recorded at the Decant Dam during 2010 (719 mm, Table 1) was also significantly higher. The 2010 value for the annual rainfall corresponds to a 55% increase ((719 mm/2 – 232 mm) / 232 mm) in the volume of water reaching the dams in Pit 1 through both direct recharge and recharge through the spoils. The estimated water make for the period January to June 2012 should therefore only be seen as representative of the managed water make during years in which low rainfall is experienced.

It should again be emphasised that the above estimation of the 'managed' water make is based on measurements of the volumes of water pumped between the various dams within Pit 1, dam level measurements, measured rainfall figures and mean evaporation figures, as well as assumptions regarding evaporation losses at the sprayers and unmeasured dam level changes. Since there are also uncertainties regarding some of the pumped volumes due to the malfunction or absence of

flowmeters, the above estimates for the water make should be seen as first estimates only. These values will be refined in Section 17 (Water Balances) of this report.

5 Pit and Dam Decant Levels and Storage Capacities

5.1 Pit Decant Levels and Capacities

In order to calculate the storage capacities and decant levels of the backfilled opencast pits at Arnot Colliery, the topographic elevation data from the DTM compiled during January 2012 and digitised elevation data of the pit floor elevations were used. The decant levels of Pit 1, Pit 2W and Pit 2E were found to be 1 595.05, 1 602.42 and 1 607.40 mamsl, respectively, as shown in Figure 15.

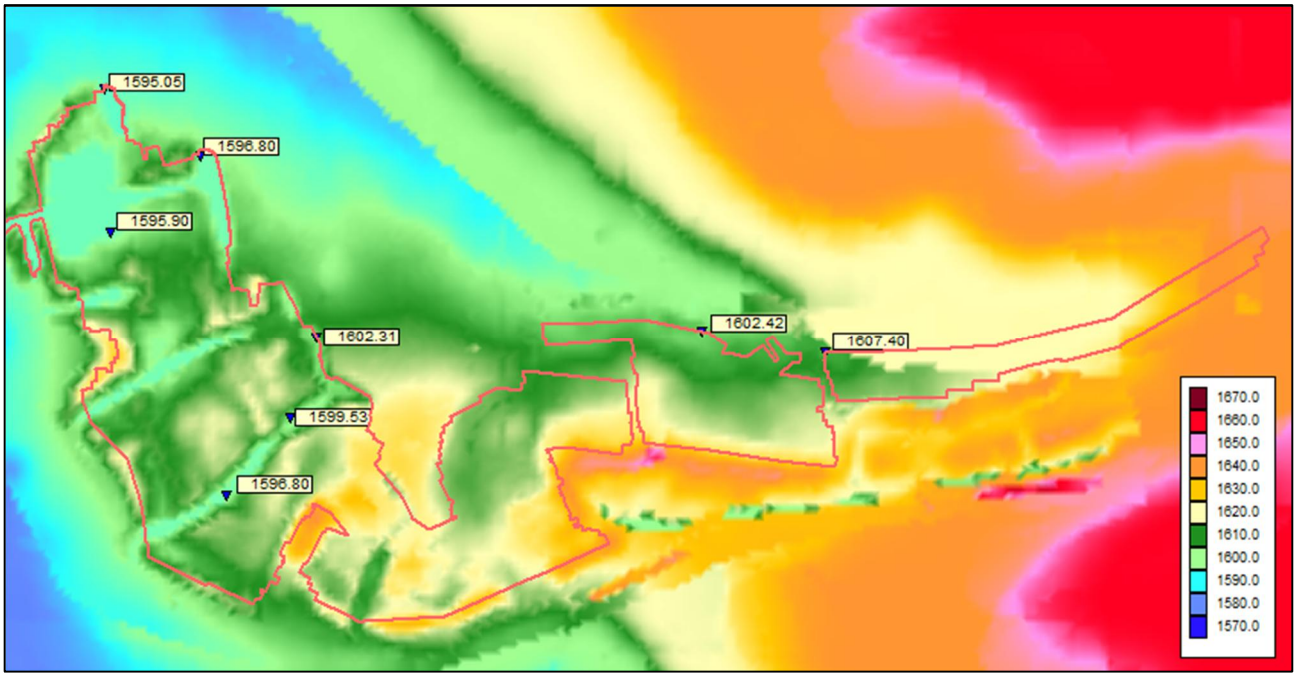


Figure 15. Decant levels of Pit 1, Pit 2W and Pit 2E.

Stage curves for the three pits are shown in Figure 16 (Pit 1), Figure 17 (Pit 2W) and Figure 18 (Pit 2E). These stage curves were calculated on the assumption that the void space within Pit 2W and Pit 2E constitutes 25% of the volume of the backfilled pits. A slightly higher void space percentage (26%) was assigned to Pit 1 to compensate for the presence of the various dams within this pit. The volumes of water stored in the pits when they are at their decant levels are seen to be approximately 20 600 M*l* (Pit 1), 2 800 M*l* (Pit 2W) and 1 607 M*l* (Pit 2E). A total maximum volume of approximately 25 000 M*l* can be stored when all three pits are at their decant levels.

The above estimates of the maximum volumes of water that can be stored within Pits 1 and 2 assume that the pits are not compartmentalised. There is, however, evidence that Pit 1 is indeed compartmentalised (refer to the discussion of Figure 14 in Section 4.1, as well as to Section 11) with the water cascading from one compartment to the next. This observation implies that the true storage capacity of the pits may be higher than the estimates given above.

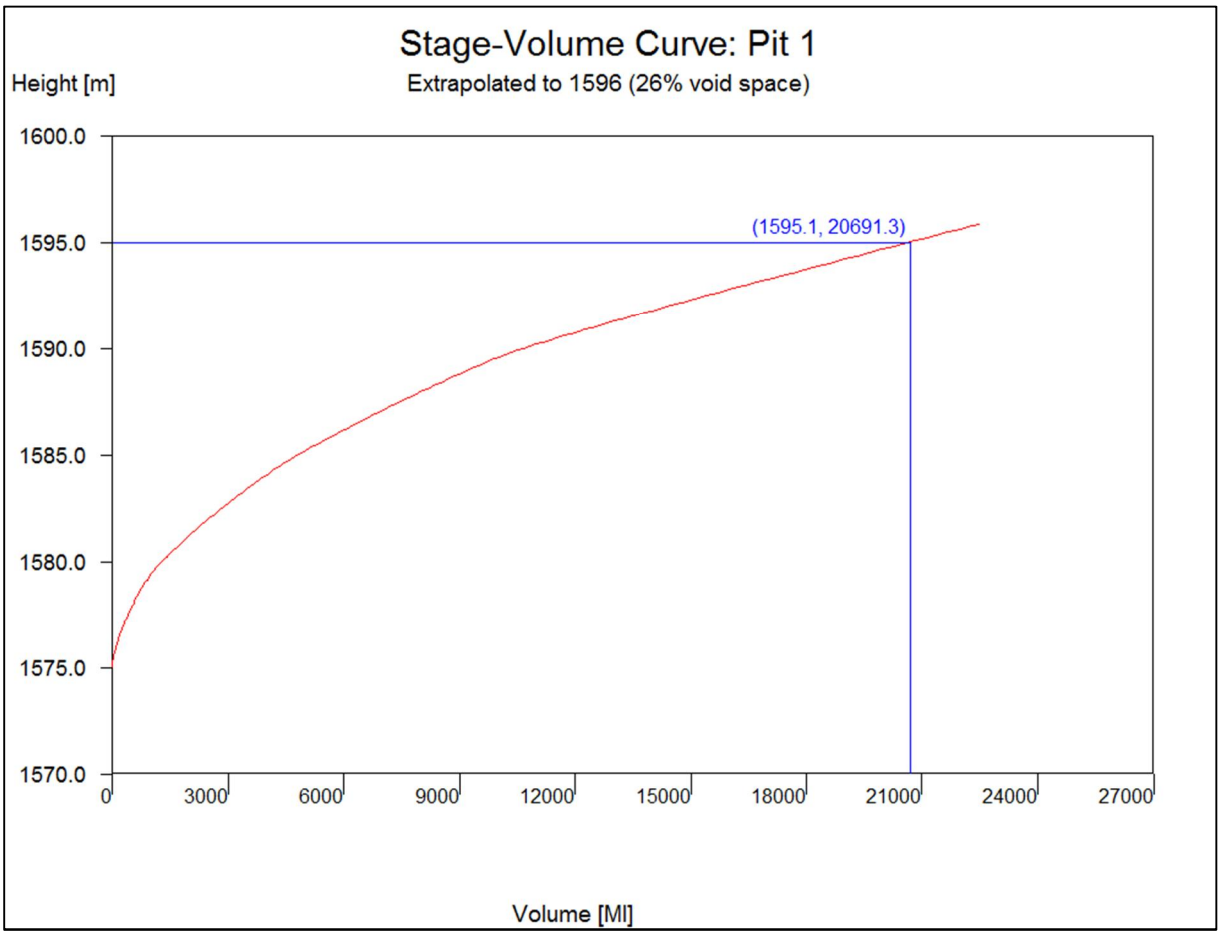


Figure 16. Stage curve for Pit 1.

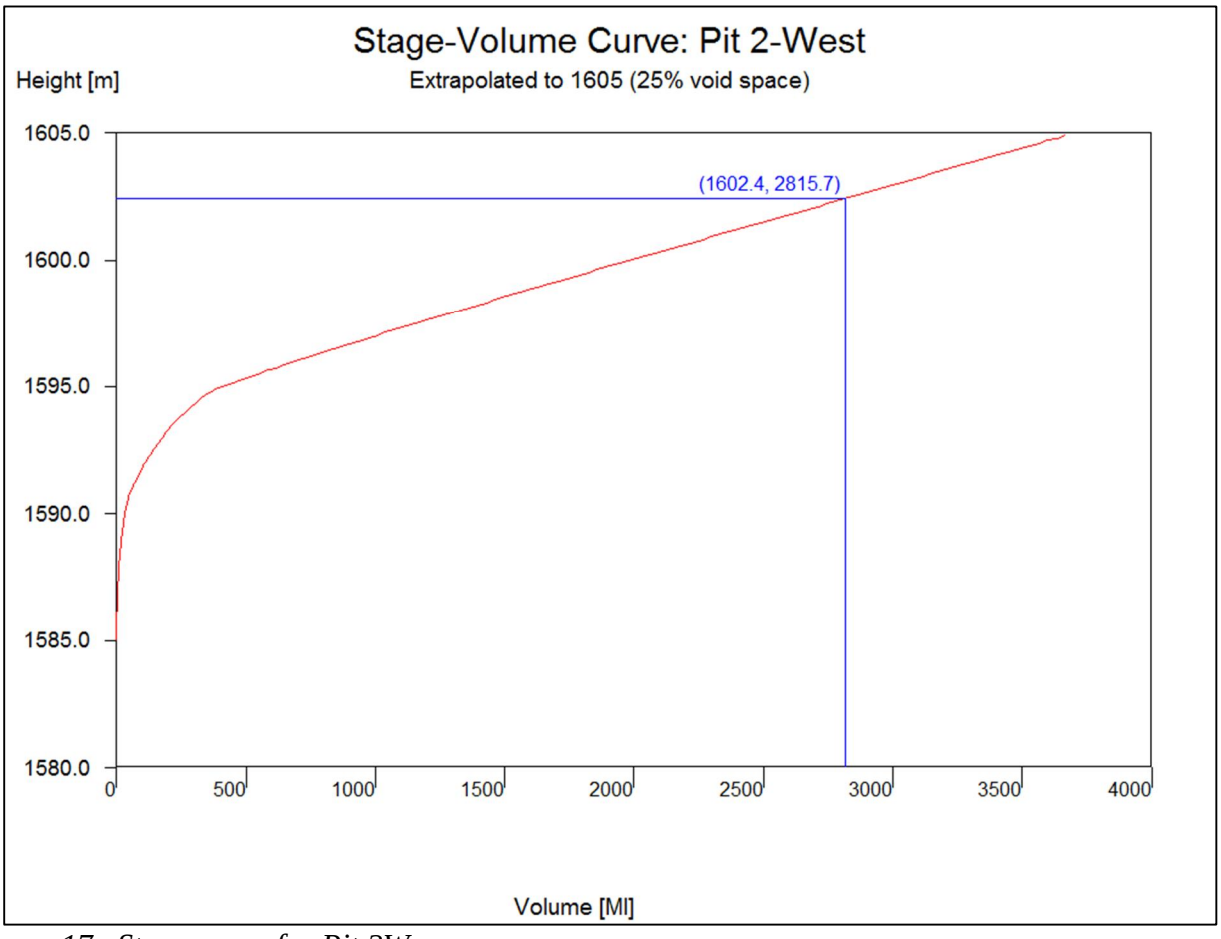


Figure 17. Stage curve for Pit 2W.

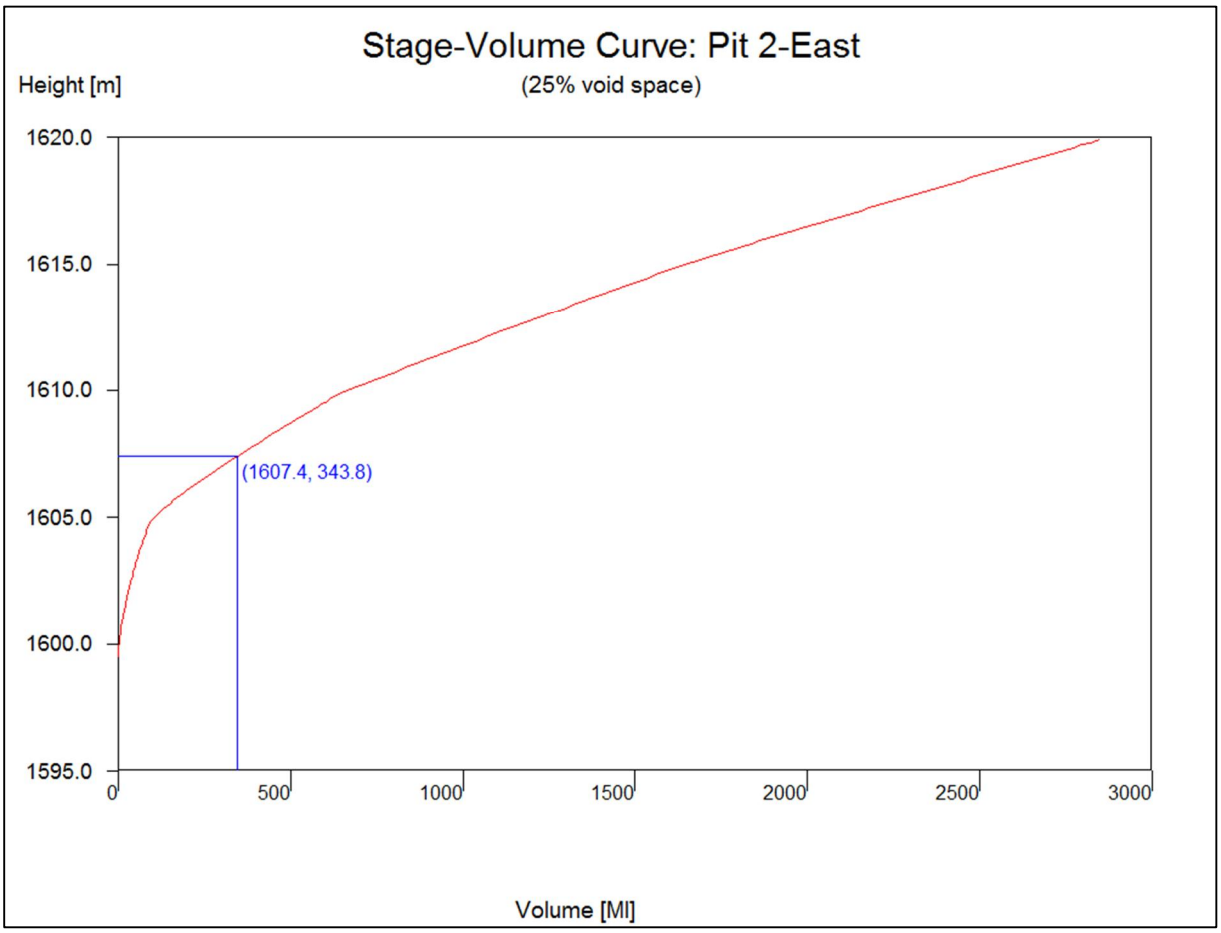


Figure 18. Stage curve for Pit 2E.

The above estimate of the total volume of water that can be stored in the pits allows a crude estimation of the lower limit of the water make of Arnot Closed Colliery. The time that elapsed since mining commenced in the early 1970s to the decant event of January 2006 is approximately 36 years, or 13 140 days. The minimum water make of the colliery is therefore approximately **1.90 M*l*/day**, 15.7% higher than the estimate obtained in Section 2.4 (1.6 M*l*/day). This new estimate disregards the volumes of water that were actively removed from the pits during mining.

5.2 Dam Decant Levels and Capacities

During September 2012 a sonar survey was undertaken to measure the floor elevations of the dams within Pit 1 that currently form part of the water reticulation system at Arnot Closed Colliery. The sonar survey was performed by GHT Consulting Scientists. The purpose of the survey was to allow calculation of the volumes of water stored in these dams for different water levels.

Sonar surveys were conducted on the following dams: the Decant Dam, T1 Dam, Final Void, T4 Pump dam and T4 Dam. The results of the sonar survey were used along with the DTM recorded in January 2012 to determine the decant levels and stage curves of these dams. Since January 2012 some alterations have been done to some of the dams. For example, a new wall was constructed at the decant point of the T1 Dam, effectively raising the decant level and increasing the total storage

volume. Some changes have also been made to the walls of the Decant Dam. Since no information on the new surface elevations of the dams is available, the discussions that follow are based on the conditions as they were at the time when the DTM was compiled.

5.2.1 Decant Dam

During the sonar survey the floor elevations of the Decant Dam were measured at 611 positions. The decant level of the dam was found to be 1 595.4 mamsl at which level the dam contains approximately 71.8 M*l* of water. The stage curve for the Decant Dam is shown in Figure 19.

5.2.2 T1 Dam

The floor elevations of the T1 Dam were measured at 2 922 positions. The decant level of the dam was found to be 1 596.4 mamsl. A maximum volume of approximately 2 090 M*l* can be stored in this dam when it is at full capacity. The stage curve for the Decant Dam is shown in Figure 20.

5.2.3 Final Void

The floor elevations of the Final Void were measured at 1 097 positions. The results of the sonar survey show that the decant level of the Final Void is 1 597.4 mamsl. At this level the dam can hold a maximum volume of approximately 391 M*l*. The stage curve for the Decant Dam is shown in Figure 21.

5.2.4 T4 Dam

The floor elevations of the T4 Dam were measured at 1 392 positions. The decant level of the dam was found to be 1 597 mamsl. The maximum capacity of the dam at decant level is approximately 164 M*l*. The stage curve for the T4 Dam is shown in Figure 22.

5.2.5 T4 Pump 1 dam

The floor elevations of the northern part of the T4 Pump dam (here called the T4 Pump 1 dam) were measured at 606 positions. The results of the sonar survey show that the decant level of the T4 Pump 1 dam is 1 604.5 mamsl. At this level the dam can hold a maximum volume of approximately 110 M*l*. The stage curve for the T4 Pump 1 dam is shown in Figure 23.

5.2.6 T4 Pump 2 dam

The floor elevations of the southern part of the T4 Pump dam (here called the T4 Pump 2 dam) were measured at 253 positions. The decant level of the dam was found to be 1 603.5 mamsl. The maximum capacity of the dam at decant level is approximately 135 M*l*. The stage curve for the T4 Pump 2 dam is shown in Figure 24.

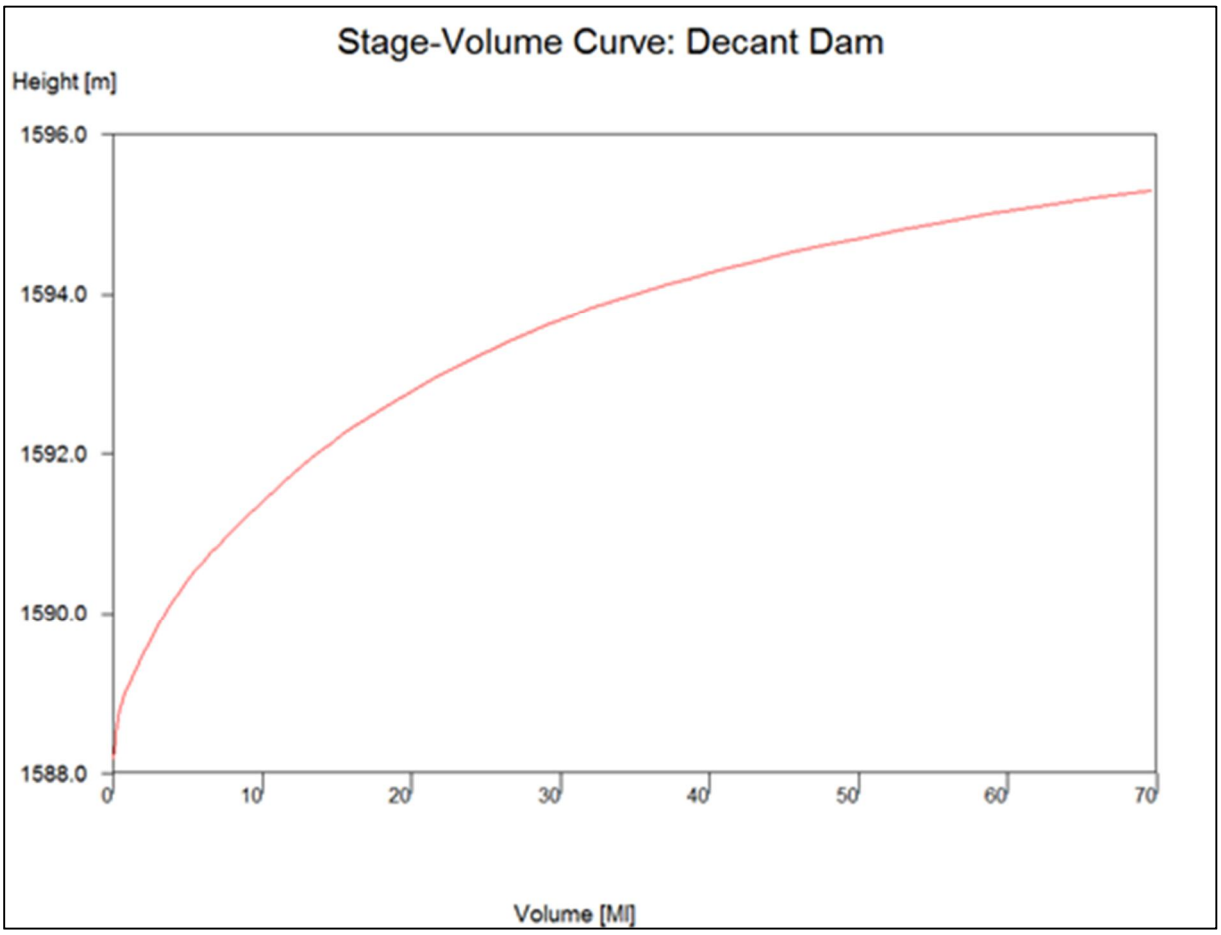


Figure 19. Stage curve for the Decant Dam.

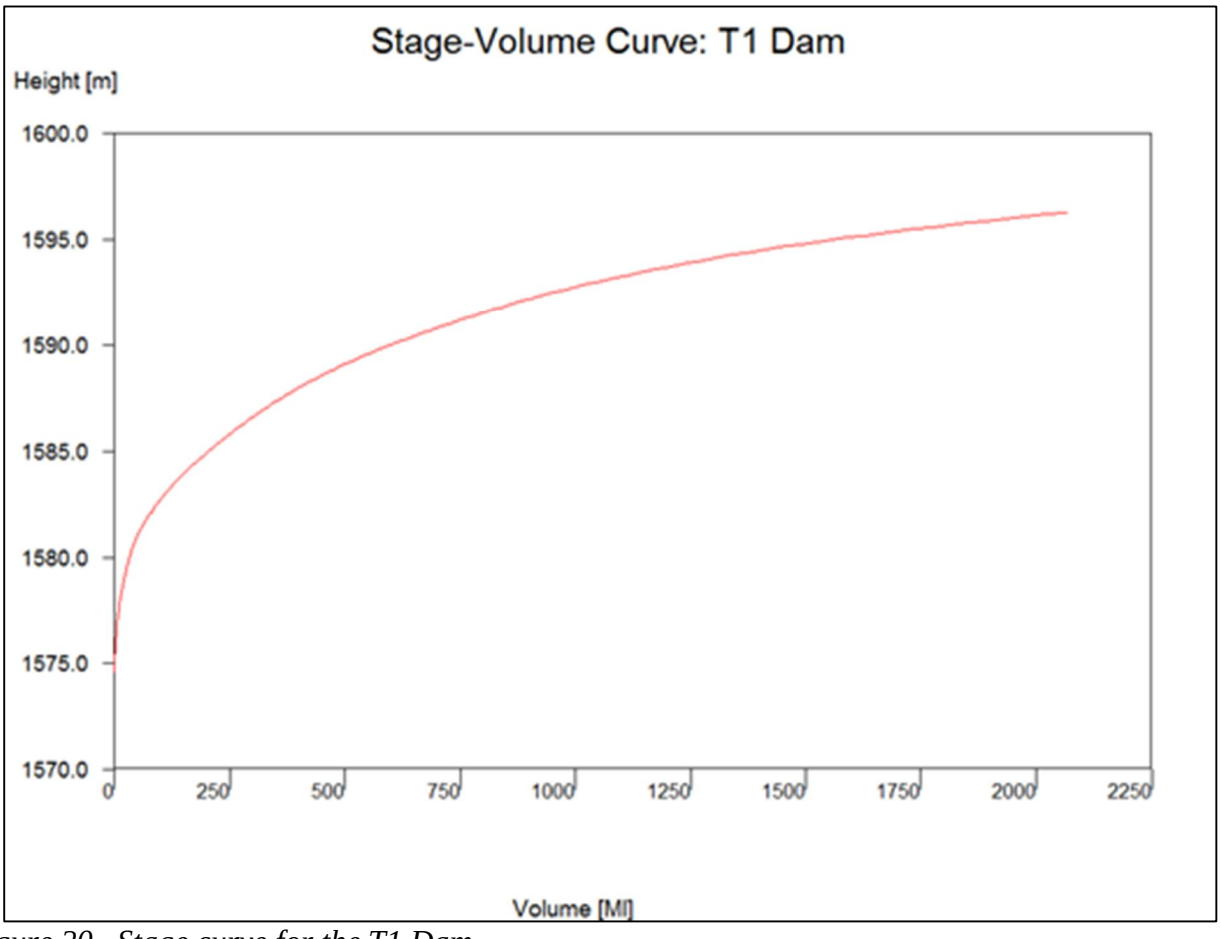


Figure 20. Stage curve for the T1 Dam.

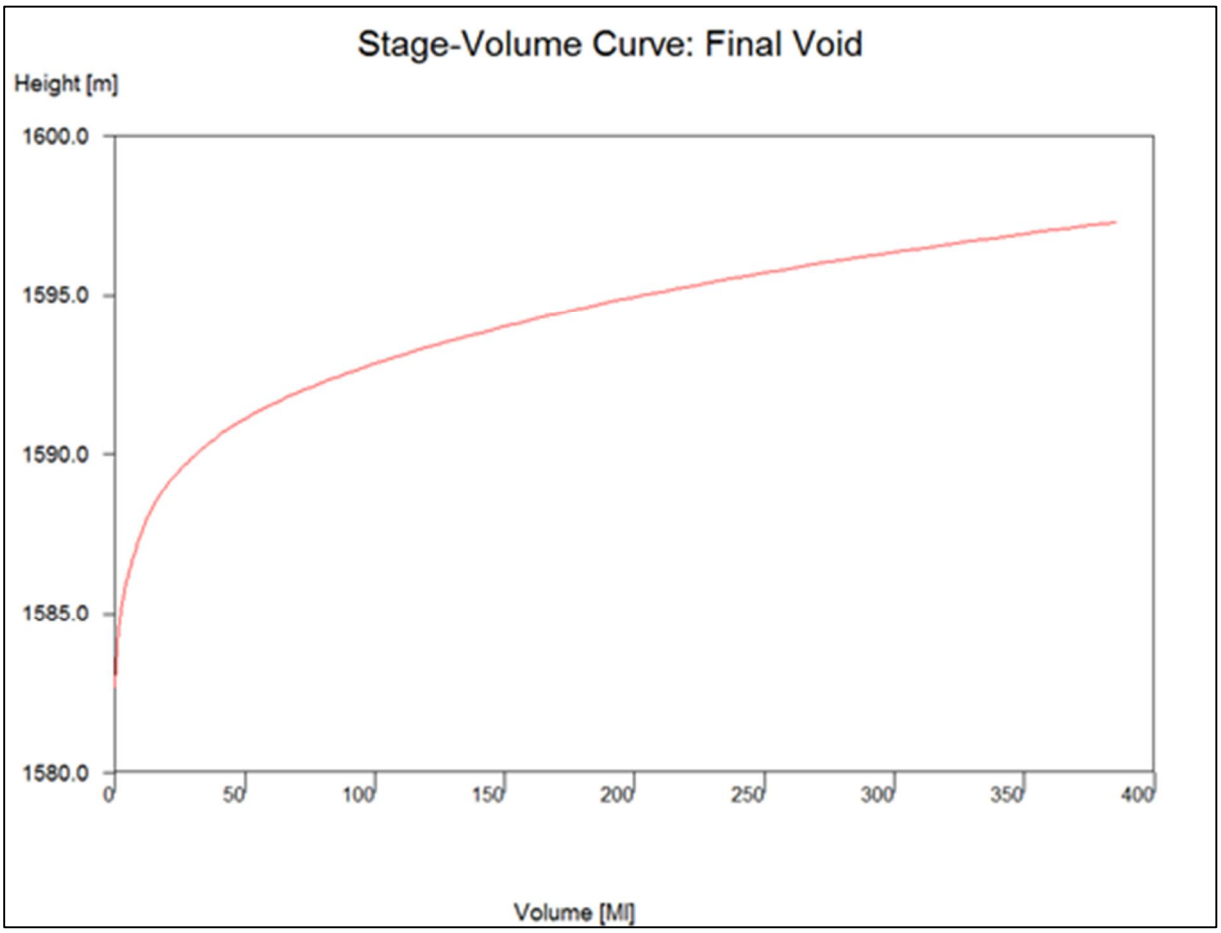


Figure 21. Stage curve for the Final Void.

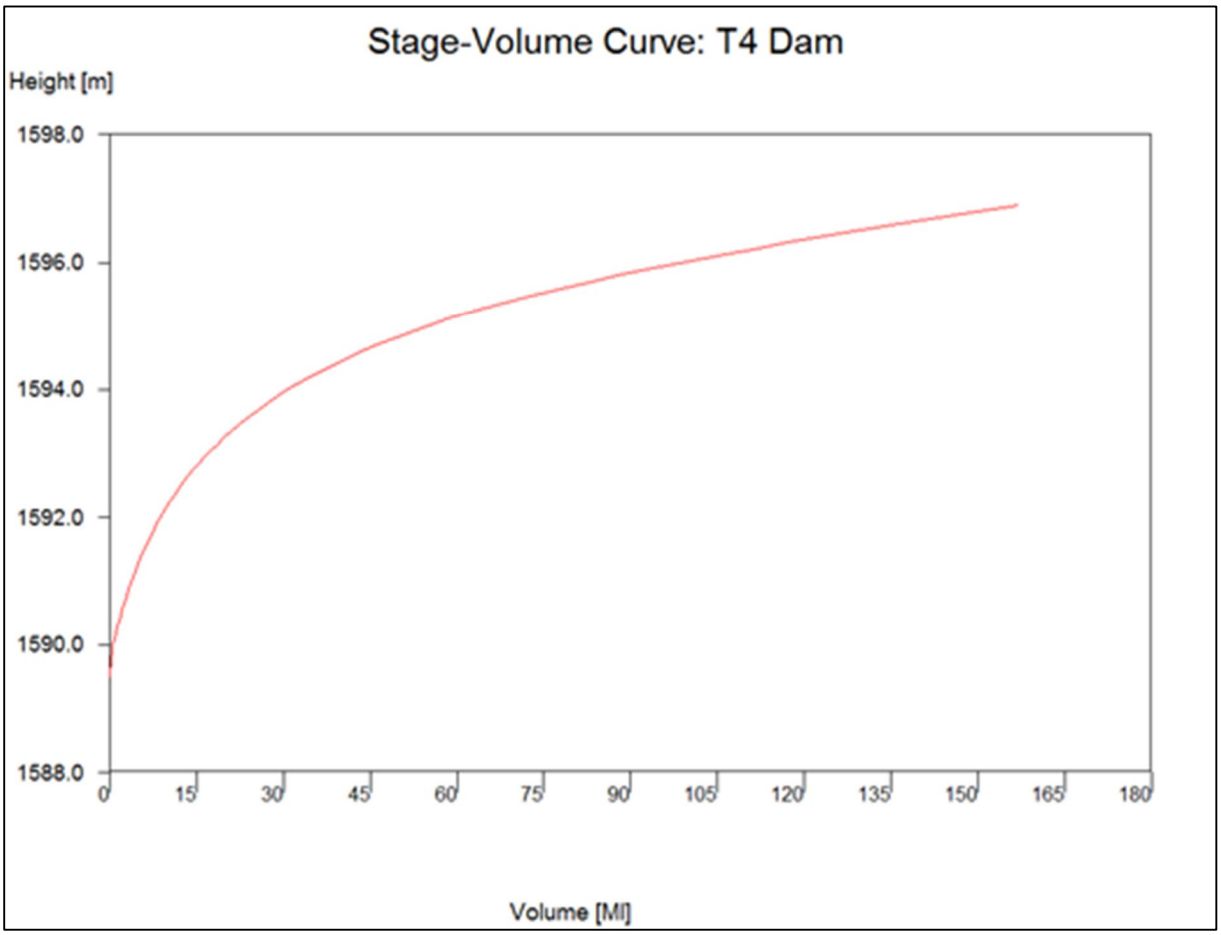


Figure 22. Stage curve for the T4 Dam.

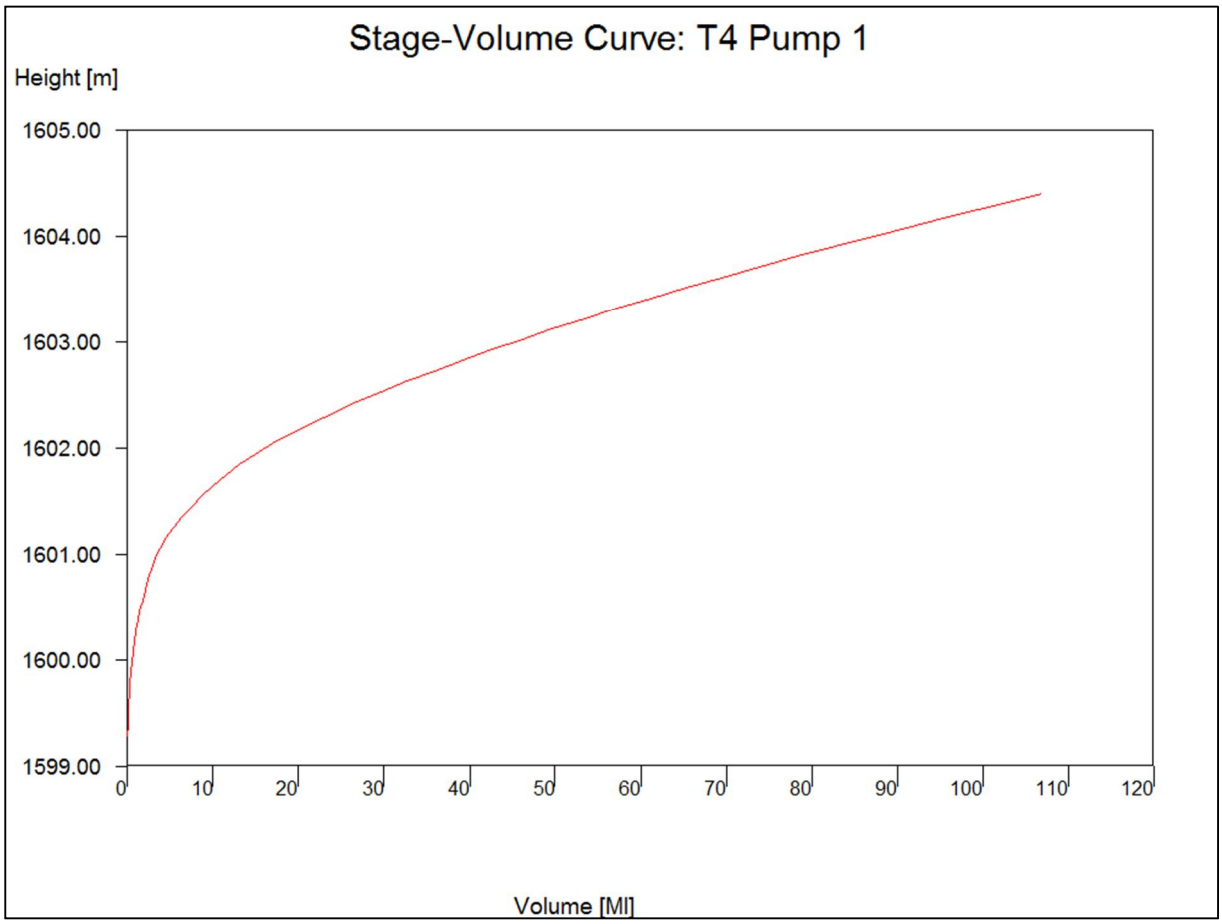


Figure 23. Stage curve for the T4 Pump 1 dam (northern part of the T4 Pump dam).

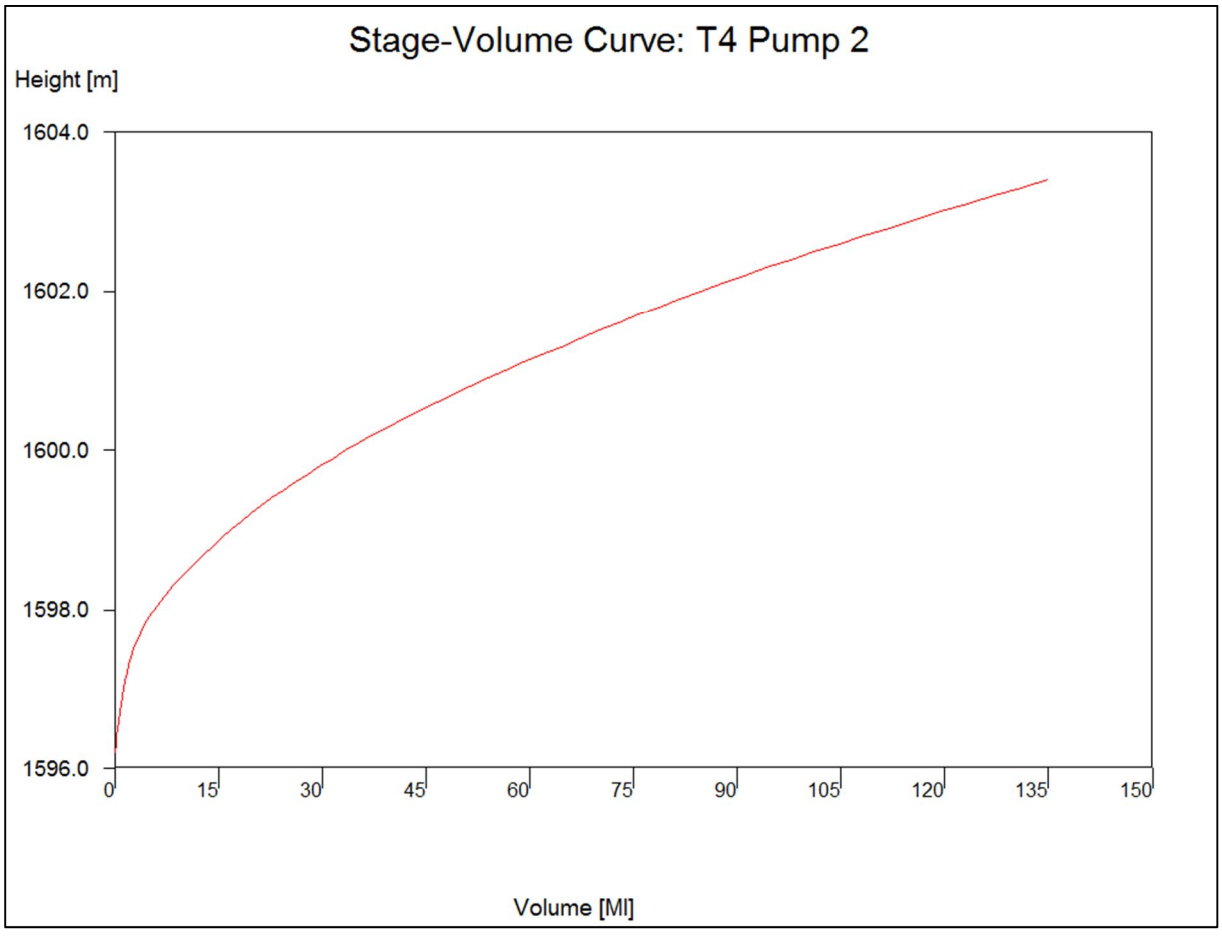


Figure 24. Stage curve for the T4 Pump 2 dam (southern part of the T4 Pump dam).

The different dams that form part of the water management system at Arnot Colliery are shown in Figure 25. It should be emphasised that the stage curves and the calculated capacities of the dams assume impermeable boundaries for the dam floors so that no inflows and outflows are allowed through the floors. In reality, the backfilled spoils have very high hydraulic conductivities and inflows and outflows through the spoils can be expected. This means that, for the dams with floor elevations lower than the decant levels of the backfilled pits, much more water will have to be pumped from the dams than indicated in the stage curves if a certain decrease in the water level is required. Conversely, when the water levels in the dams exceed the decant levels of the pits, the dams may receive more water than suggested by the stage curves since much of the water will drain away through the spoils.

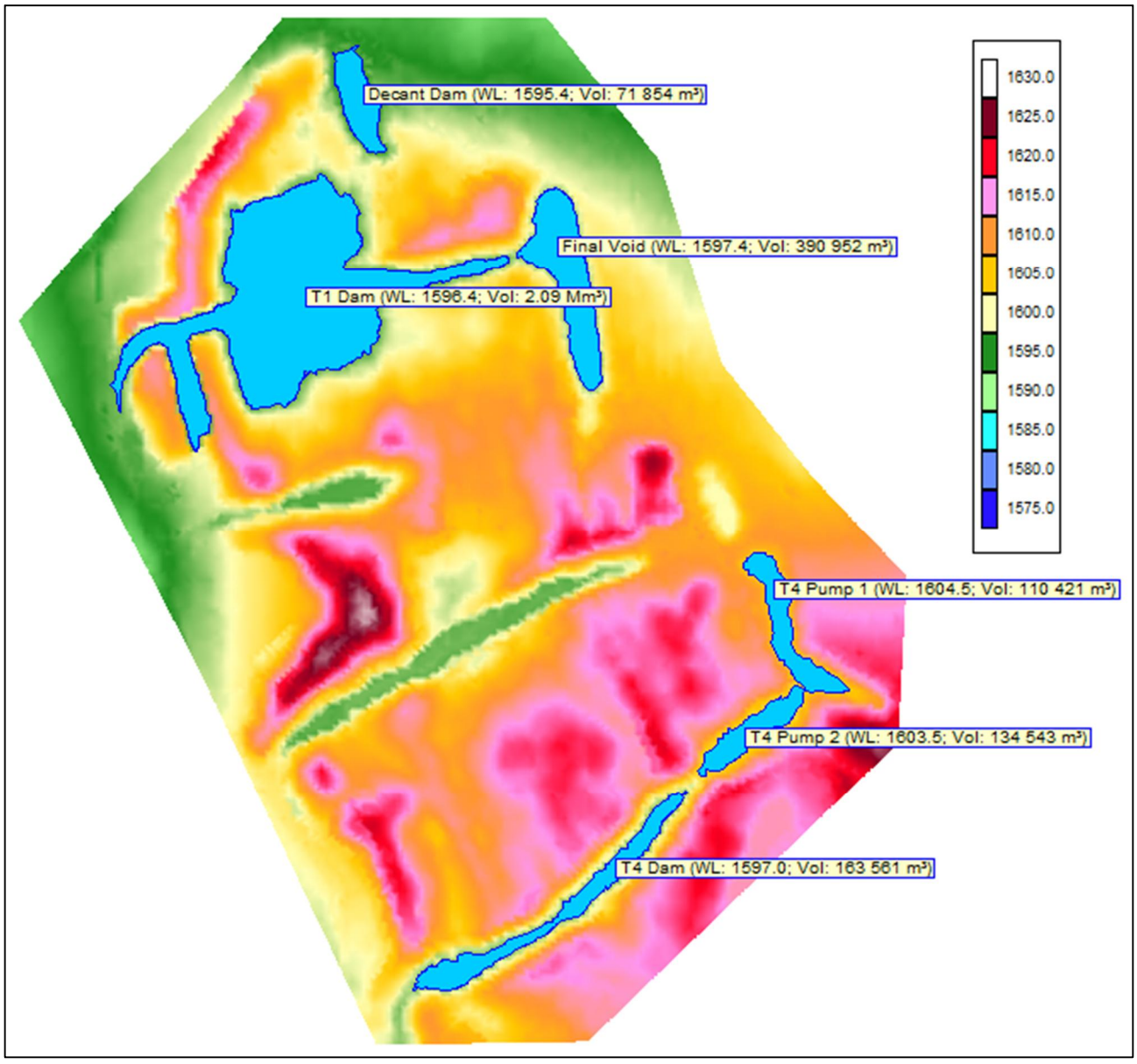


Figure 25. Dams within Pit 1 with their decant levels and maximum capacities.

Dam water levels at Arnot Closed Colliery are measured by means of embedded yardsticks, marked at 0.025 m intervals. To translate the yardstick measurements into elevations, the dam levels as they were at the time that the DTM was compiled (late January 2012) may be used to allow an approximate calibration. This is done in Table 21.

Table 21. Yardstick measurements of dam levels and the corresponding water level elevations (26 January 2012).

Dam	**Yardstick units (25 mm)**	**Elevation (mamsl)**
Decant	8	1595.01
T1 Dam	8	1595.97
Final Void	4	1596.79
T4 Dam	13	1596.71
T4 Pump	36	1602.29

6 Evaluation of the Current Water Monitoring Programme

Surface- and groundwater sampling at Arnot Closed Colliery is currently done on a monthly basis. The current monitoring programme is evaluated below in terms of the positions of the sampling sites and the density of the sampling network, the conditions of the sampling sites, the monitoring frequency employed, the depths at which samples are taken, the sampling procedures followed and the parameters analysed for during chemical analyses.

6.1 Surface- and Groundwater Sampling Network

The surface- and groundwater sites that are sampled as part of the current water monitoring programme are shown in Figure 26 (surface water sites), Figure 27 (Pit 1 groundwater sites) and Figure 28 (Pit 2 groundwater sites). Information on the surface- and groundwater sites is listed in Table 22 and Table 23, respectively. In these tables it is seen that 12 surface water sites and 31 groundwater sites form part of the current water monitoring programme. (Sites W04 and W05 are trenches which may contain both groundwater and surface water, but are treated here as groundwater sites since groundwater seepage has been observed in these trenches.)

The 12 surface water sites include a non-perennial pan, perennial and non-perennial rivers and dams. Although three sampling sites (No.10, ARN02 and No.28) are used to monitor the water quality of the Bosman Spruit, these sites all occur to the west of Pit 2 (W&E). To evaluate possible contaminant impacts from the backfilled and rehabilitated pits on the water quality of the Bosman Spruit, additional sampling sites farther to the east along the Bosman Spruit are required. At least one site upstream from Pit 2E should be sampled to gain information on the background water quality.

The Klein-Olifants River is currently sampled at only two sites (No.32 and No.33). These two sites are located to the west and north-west of Pit 1. Since contaminant originating from Pit 1 could potentially impact on the water quality of the river at positions south of Pit 1, it is recommended that additional sampling sites along this river be included in the monitoring programme. Since the Woestalleen Spruit is also known to be subject to contaminant impacts from mining and power generation activities upstream from Arnot Closed Colliery, this river should also be sampled at a position upstream from its confluence with the Klein-Olifants River. This should be done to separate the upstream impacts from possible impacts originating from Arnot Closed Colliery.

The Bliksem Pan, Steels Pan and Railway Pan should be included in the water monitoring programme, since contaminant impacts originating from Pit 1 could have detrimental effects on the water quality in these pans.

The current groundwater monitoring network in the vicinity of Pit 1 is dense north-west of the Decant Dam and the T1 Dam, but groundwater monitoring sites are sparse to the north, south and south-west of the pit. Only boreholes AW06 and AW04 monitor potential impacts on the groundwater quality to the north of Pit 1. A distance of more than 4 km separates borehole AW09 from the other boreholes to the south and south-west of Pit 1.

It is recommended that other existing boreholes be included in the monitoring programme. These boreholes could include some of the Alzu boreholes that occur in the areas south and south-west of Pit 1 (Old Supply Borehole, Windpump, Piet's Pump, Alzu Windpump, Private Borehole, BHZ11 and BHZ12; refer to Figure 10). To the north of Pit 1, borehole KGM_B10 could also be included to increase the density of the monitoring network.

During July 2012, 10 new boreholes were installed at Arnot Closed Colliery (to be discussed in Section 7). Boreholes B3, B5 and B6 should be included in the monitoring programme to increase the groundwater monitoring network density to the north of Pit 1, while the inclusion of boreholes B7, B8 and B9 will increase the monitoring network density to the south and south-west of Pit 1 (refer to Figure 29 for the positions of these boreholes).

New boreholes B4 and B10 should also be included in the monitoring programme. These boreholes will allow investigation of the impact of the coal discards on the water quality in Pit 1.

The groundwater monitoring network north of Pit 2 (W&E) is fairly dense. With the inclusion of new boreholes B1 and B11 (and possibly borehole KGM_B12) in the monitoring programme, the monitoring network should be adequately dense to detect and quantify contaminant impacts originating from Pit 2 (W&E).

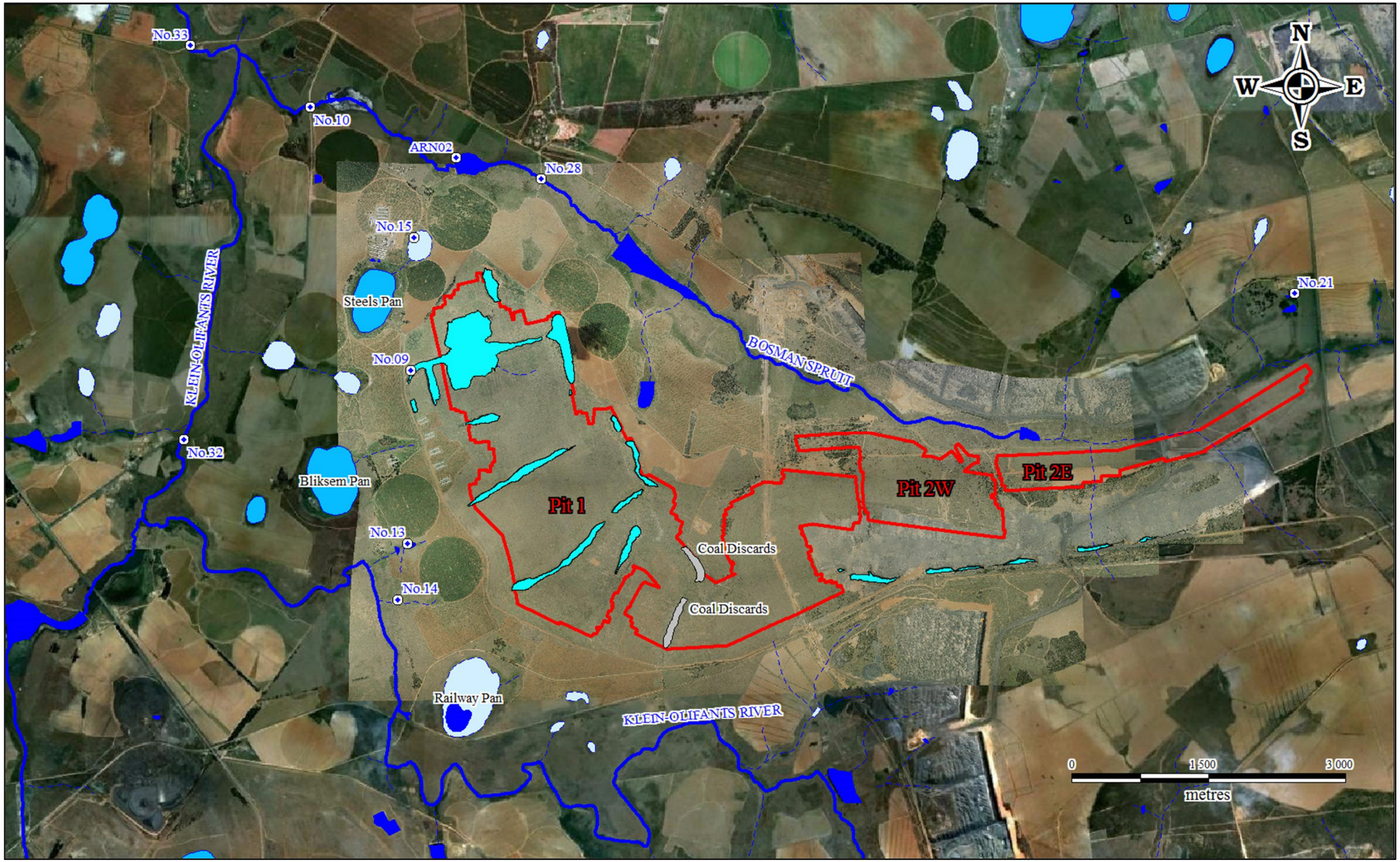


Figure 26. Positions of the surface water monitoring sites included in the current monitoring programme at Arnot Closed Colliery.

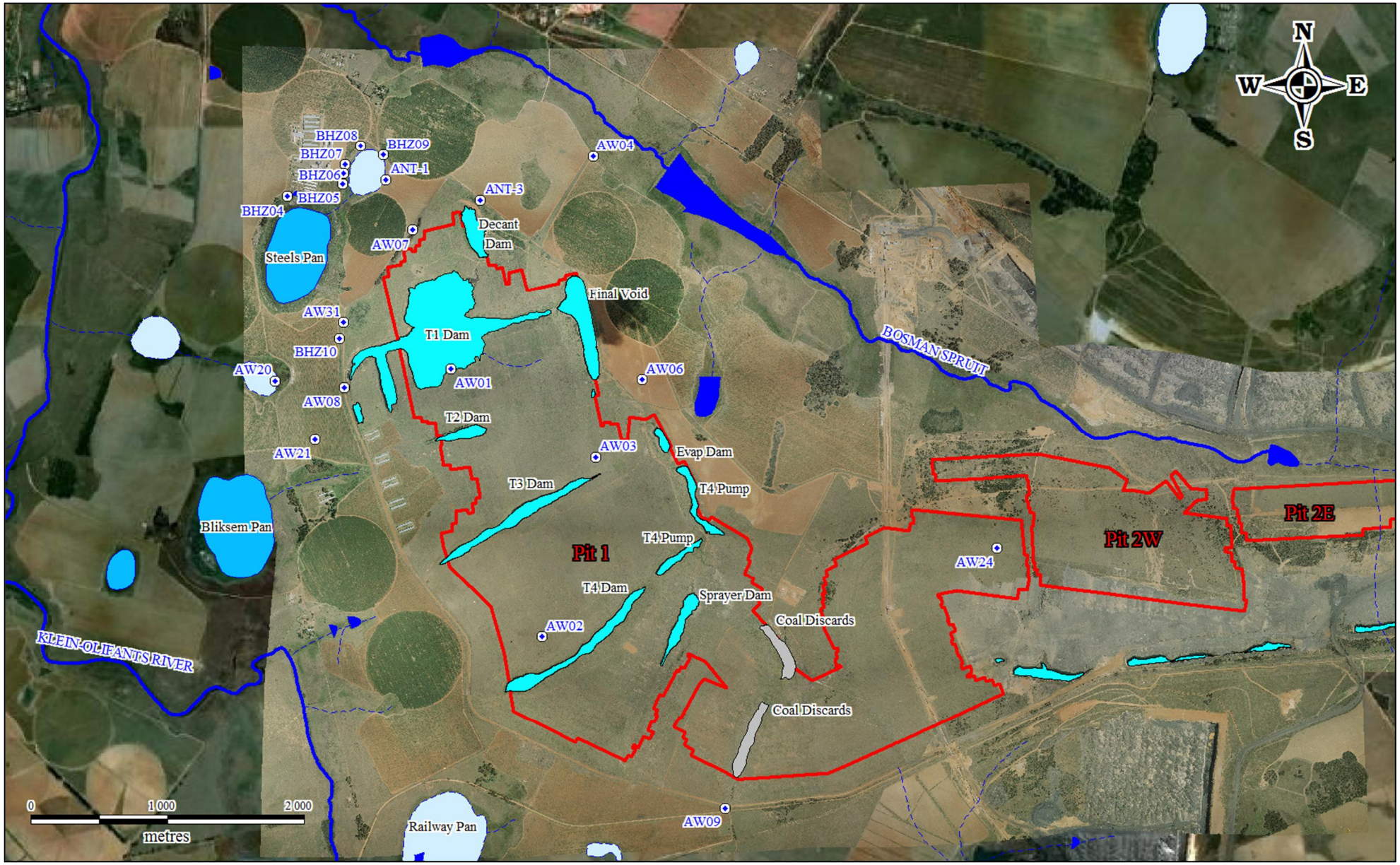


Figure 27. Positions of the groundwater monitoring sites near Pit 1 included in the current monitoring programme at Arnot Closed Colliery.

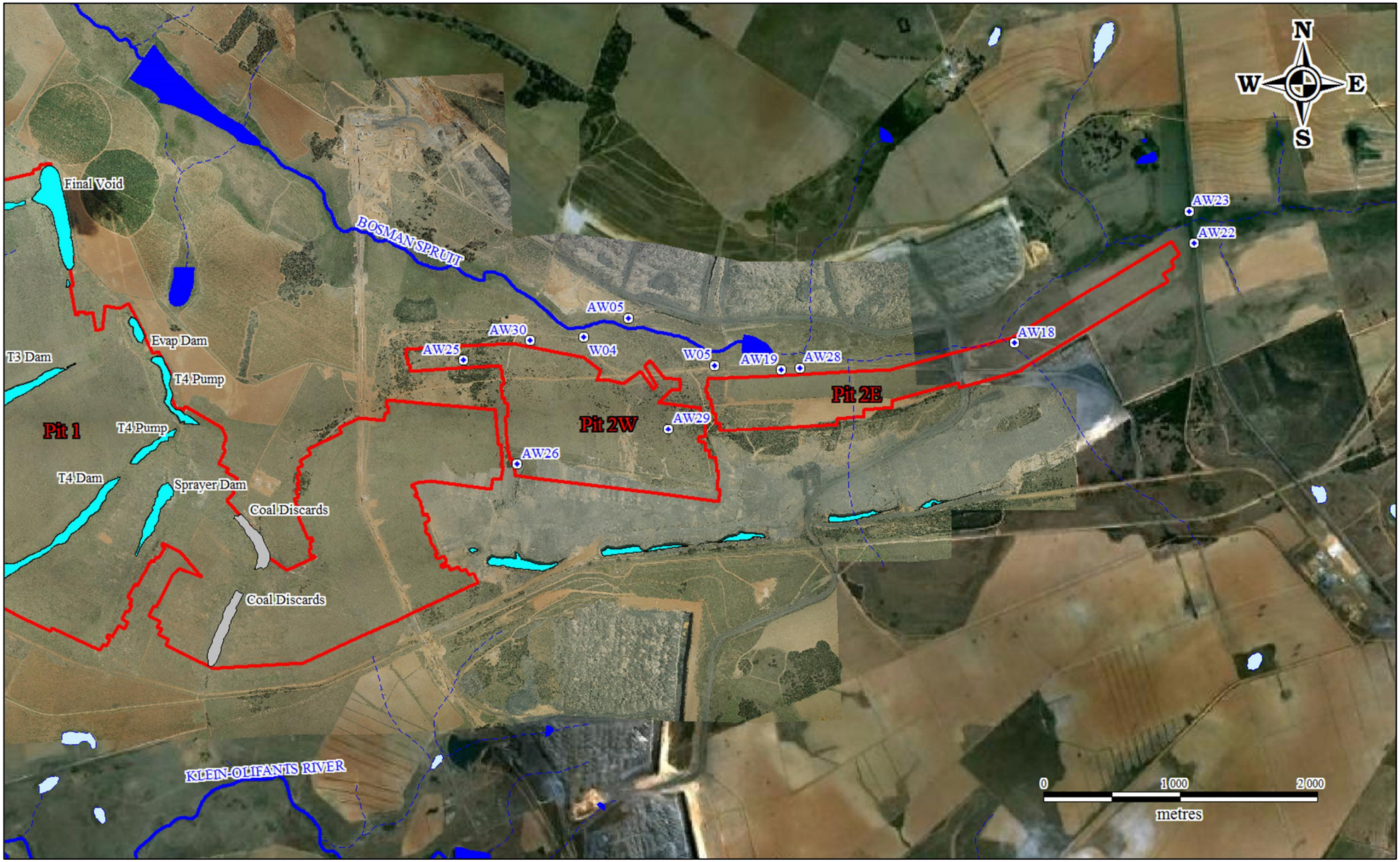


Figure 28. Positions of the groundwater monitoring sites near Pit 2 (W&E) included in the current monitoring programme at Arnot Closed Colliery.

Table 22. Surface water sites included in the current monitoring programme.

Number	Alt Number	Long (°E)	Lat (°S)	Description
ARN02		29.65861	25.88802	Dam in the Bosman Spruit
No.09	T1 Dam	29.65368	25.90893	T1 Dam
No.10		29.64259	25.88299	Bosman Spruit upstream from confluence with Klein-Olifants River
No.13		29.65326	25.92607	Farm dam south-west of Pit 1
No.14		29.65222	25.93167	Non-perennial river south-west of Pit 1
No.15		29.65403	25.89585	Non-perennial pan north-west of the T1 Dam and the Decant Dam
No.21		29.75053	25.90136	Farm dam north-east of Pit 2E
No.28		29.66798	25.89011	Bosman Spruit north of Pit 1
No.32		29.62873	25.91580	Klein-Olifants River upstream from confluence with Bosman Spruit
No.33		29.62949	25.87696	Klein-Olifants River downstream from confluence with Bosman Spruit

6.2 Conditions of Monitoring Sites

During the hydrocensus (Section 3) it was observed that despite recent upgrades, many of the groundwater monitoring sites required further attention. All monitoring boreholes should be equipped with concrete plinths, marker posts, site numbers and lockable caps. Lockable caps are particularly important to prevent unauthorised access to the boreholes. It is recommended that marker post also be installed at the surface sites to ensure that the water samples are taken at the same locations during the different sampling events.

Some of the boreholes were infested with bees and/or blocked by bee wax at the time of the hydrocensus. Such problems should be noted during the sampling events and reported to ensure that they receive attention before the next sampling event.

6.3 Monitoring Frequency

The monitoring frequency of the current monitoring programme (monthly sampling events) is deemed adequate to detect contaminant impacts of on the surface- and groundwater quality. These sampling events can be performed by personnel of AngloAmerican. However, it is recommended that biannual monitoring be done by external consulting scientists, once during the wet season (November to January) and once during the dry season (May to July). The consulting scientists should compile detailed reports describing the conditions of the monitoring sites and the results of the chemical analyses performed on the water samples.

Table 23. Groundwater sites included in the current monitoring programme.

Description	Number	Alternative number	Long (°E)	Lat (°S)
Pit 1 Monitoring Boreholes	ANT-1	ARN01	29.65602	25.89716
	ANT-3	ARN03	29.66289	25.89850
	AW01		29.66074	25.90956
	AW02		29.66743	25.92713
	AW03		29.67134	25.91538
	AW04		29.67112	25.89561
	AW06		29.67473	25.91024
	AW07		29.65794	25.90042
	AW08		29.65298	25.91078
	AW09		29.68078	25.93839
	AW20		29.64794	25.91033
	AW21		29.65086	25.91419
	AW24		29.70066	25.92128
	AW31		29.65293	25.90652
Pit 1 Alzu Boreholes	BHZ04		29.64883	25.89824
	BHZ05		29.65288	25.89739
	BHZ06		29.65294	25.89671
	BHZ07		29.65302	25.89615
	BHZ08		29.65418	25.89492
	BHZ09		29.65580	25.89549
	BHZ10		29.65263	25.90754
Pit 2 (W & E) Groundwater Sites	AW05		29.71210	25.91349
	AW18		29.74031	25.91508
	AW19		29.72329	25.91682
	AW22		29.75344	25.90850
	AW23		29.75310	25.90642
	AW25		29.70005	25.91621
	AW26		29.70399	25.92306
	AW28		29.72465	25.91672
	AW29		29.71504	25.92073
	AW30		29.70494	25.91492
	W04		29.70883	25.91469
	W05		29.71839	25.91656

6.4 Sampling Depths

In the current monitoring programme, all boreholes are sampled at the depth of the static water level (SWL). However, it is known that stratification in the groundwater quality often occurs within a borehole. Rainwater entering the boreholes often leads to a dilution effect which causes the water quality at the SWL to be better than at depth. In addition, preferential pathways may occur at some horizon(s) within the geological units intersected by the boreholes. Contaminant migration may occur along these pathways. For these reasons, electrical conductivity (EC) profiling should be

performed on all boreholes to identify the appropriate sampling depths that would yield a more accurate representation of the contaminant levels within the boreholes (EC profiling was done during the current investigations, as described in Section 8).

6.5 Sampling Procedure

During sampling, certain procedures should be followed:

- Make observations regarding the conditions of the monitoring site and take note of any problem that may require attention.
- Photographs of the existing problems at particular sites should be taken for the record.
- Make observations regarding conditions that may influence the water quality. For example, if seepage is observed at surface near an existing borehole, the presence of the seepage should be noted.
- Measure the static water level in the monitoring boreholes. Water level information is essential to evaluate where artificial recharge from the backfilled pits is occurring in the vicinity of the boreholes.
- Groundwater samples should be taken at depths as determined from the EC profiling conducted on these boreholes. Bailers that allow sampling at selected depths should be employed to take grab samples.
- Surface water samples should be taken at the same positions during the different sampling runs.
- The water levels and/or flow rates at the surface water sites should be recorded. Due to the concentrating effects of evaporation, stagnant water sites will have very different chemical signature than sites at which strong flows are observed.
- All water samples should be clearly marked with the site numbers. The samples should be submitted for chemical analyses within two days after the sampling event.

6.6 Parameters Included in the Chemical Analyses

Samples taken during the monthly monitoring programme should be analysed for the parameters listed in Table 24. It is recommended that complete anion/cation analyses be done in order to be able to calculate the ion balance errors of the analyses, since these errors provide an indication of the reliability of the analyses.

Table 24. Major parameters to be analysed for during the monthly sampling runs.

Cations	Anions	Other parameters
Calcium (Ca)	Sulphate (SO_4)	pH
Magnesium (Mg)	Nitrate (NO_3 _N)	EC
Sodium (Na)	Nitrite (NO_2 _N)	TDS
Potassium (K)	Phosphate (PO_4)	Alkalinity
Ammonia (NH_4 _N)	Chloride (Cl)	
	Fluoride (F)	

Apart from the above major parameters, it is recommended that water samples also be routinely analysed for the minor parameters iron (Fe), manganese (Mn) and lead (Pb). Water samples from sites that display low pH values should, however, be analysed for all the minor parameters listed in Table 25. It is recommended that all water samples be submitted for the complete minor parameter analyses during the biannual sampling events conducted by external consultants.

Table 25. Minor parameters to be analysed for at sites displaying low pH values and during the biannual sampling events.

Aliminium (Al)	Cromium (Cr)	Molybdenum (Mo)
Boron (B)	Copper (Cu)	Nickel (Ni)
Barium (Ba)	Iron (Fe)	Lead (Pb)
Bromide (Br)	Mercury (Hg)	Silica (Si)
Cobalt (Co)	Manganese (Mn)	Zinc (Zn)

7 Installation of Investigative and Monitoring Boreholes

7.1 Introduction

During July 2012 investigative and monitoring boreholes were installed at 10 selected sites at Arnot Closed Colliery. The installation of these boreholes had a number of aims, namely to:

- Increase the density of the groundwater monitoring network within and around the backfilled and rehabilitated pits,
- Provide information on the subsurface geology,
- Provide information on the geohydrological conditions at the site,
- Allow investigation of the hydraulic parameters of the aquifer system(s) present, and,
- Provide water level and water quality information that will be used to calibrate the numerical groundwater model to be constructed.

The positions of the new boreholes relative to the backfilled and rehabilitated opencast pits are shown in Figure 29 while site information on these boreholes is listed in Table 26. Table 27 summarises the construction of the boreholes. Photographs of the new boreholes are also shown in Photo 90 to Photo 96.

All boreholes were drilled to a depth of 40 m. Slotted casing was installed in each borehole from surface to the depth where the solid rock formation was encountered. All boreholes were equipped with concrete plinths, marker posts, site numbers and lockable caps. The parts of the borehole casings that occur above surface were painted bright red for clear visibility.

7.2 Drilling Results

The geological borehole logs of the 10 new boreholes are presented in **Appendix B**. Five of the 10 boreholes encountered very similar geological conditions. A typical borehole log consists of a few metres of yellow-brown to red-brown topsoil, followed by a few metres of subsoil (highly weathered sedimentary rocks), overlying various layers of Karoo rocks (sandstones, shales, coal). These materials are underlain by red-brown rhyolites. The only exceptions are boreholes B3 (no rhyolite intersected), boreholes B4 and B10 (drilled within the spoils of Pit 1) and boreholes B5 and B9 (dolerite intrusives encountered).

Water was struck during drilling at depths of 34 mbgl (B3), 25 mbgl (B4), 20 mbgl (B6), 15 mbgl (B7), 15 mbgl (B8), 22 mbgl (B9) and 22 mbgl (B10).

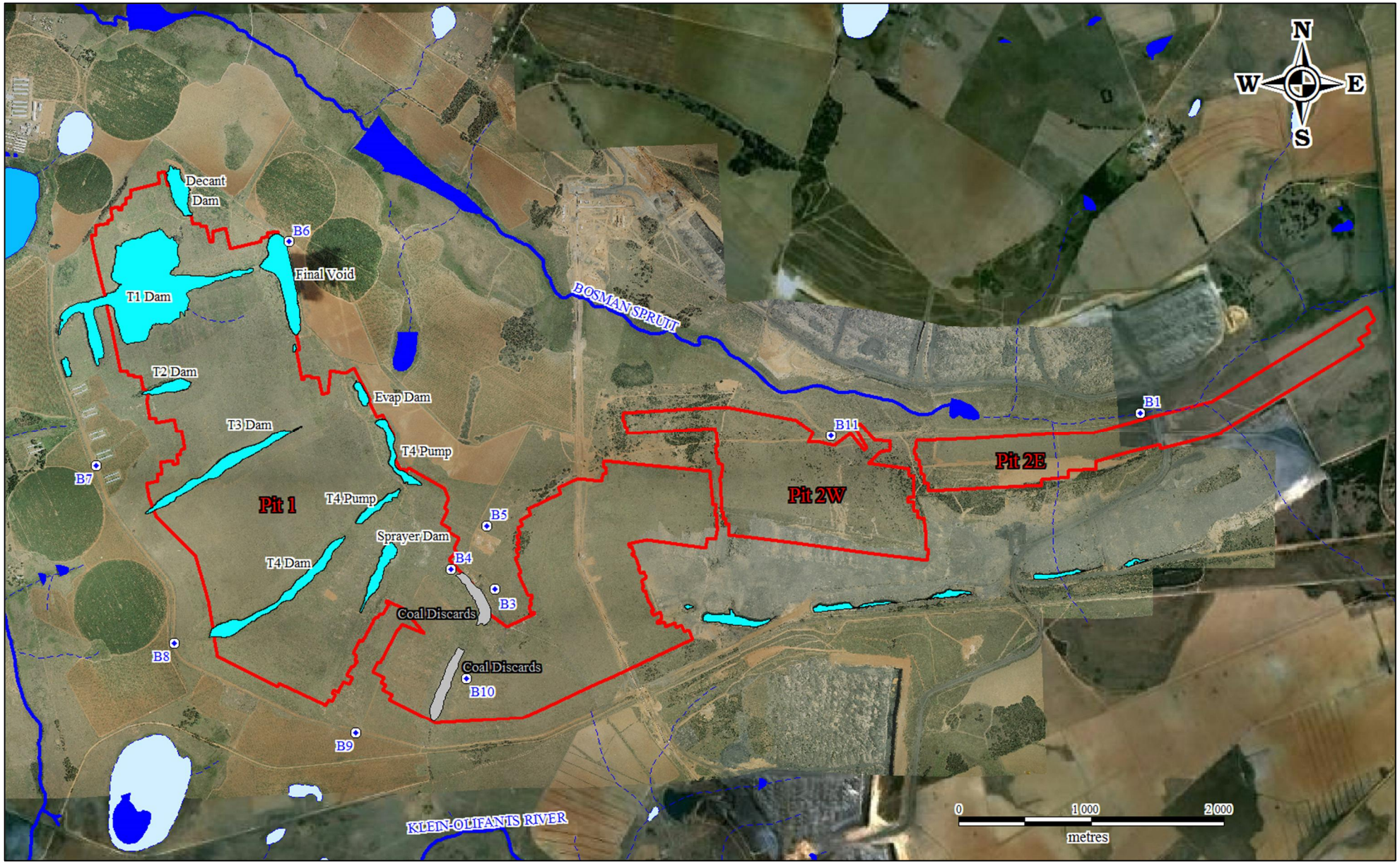


Figure 29. Positions of the new investigative and monitoring boreholes at Arnot Closed Colliery.

Table 26. Information on the 10 investigative and monitoring boreholes installed during July 2012.

Site Name	Site Description	Longitude (°E)	Latitude (°S)	Elevation (mamsl)	X_WGS84 (m)	Y_WGS84 (m)
B1	Investigative and monitoring borehole north of Pit 2E	29.73474	25.91553	1 615.5	73 614.27	-2 867 682.66
B3	Investigative and monitoring borehole east of the coal discard area	29.68620	25.92751	1 623.5	68 744.21	-2 868 983.14
B4	Investigative and monitoring borehole north-west of the coal discard area	29.68290	25.92610	1 624.2	68 414.12	-2 868 825.64
B5	Investigative and monitoring borehole north of the coal discard area	29.68561	25.92320	1 625.6	68 687.30	-2 868 505.76
B6	Investigative and monitoring borehole on eastern bank of Final Void	29.67073	25.90394	1 600.8	67 207.43	-2 866 364.21
B7	Investigative and monitoring borehole west of Pit 1 between T2 Dam and T3 Dam	29.65620	25.91910	1 597.6	65 743.07	-2 868 036.44
B8	Investigative and monitoring borehole west of Pit 1, west of T4 Dam	29.66208	25.93111	1 598.0	66 325.37	-2 869 369.45
B9	Investigative and monitoring borehole south of Pit 1, south-west of the coal discards	29.67577	25.93717	1 605.2	67 693.47	-2 870 048.40
B10	Investigative and monitoring borehole east of the coal discards	29.68406	25.93347	1 624.0	68 526.07	-2 869 642.56
B11	Investigative and monitoring borehole north of Pit 2W	29.71148	25.91706	1 607.5	71 282.83	-2 867 839.32

Table 27. Construction of the 10 investigative and monitoring boreholes installed during July 2012.

Site Name	Borehole Depth (m)	Borehole Diameter		Outer Casing Diameter		Casing Material	Casing Thickness	Casing Type
		254 mm	203 mm	219 mm	177 mm			
B1	40	0 - 20	20 - 40	0 - 20		Steel	4 mm	Slotted
B3	40	0 - 20	20 - 40		0 - 40	Steel	4 mm	Slotted
B4	40	0 - 40			0 - 40	Steel	4 mm	Slotted
B5	40	0 - 20	20 - 40	0 - 20		Steel	4 mm	Slotted
B6	40	0 - 20	20 - 40		0 - 40	Steel	4 mm	Slotted
B7	40	0 - 20	20 - 40		0 - 40	Steel	4 mm	Slotted
B8	40	0 - 20	20 - 40		0 - 40	Steel	4 mm	Slotted
B9	40	0 - 20	20 - 40	0 - 20		Steel	4 mm	Slotted
B10	40	0 - 40			0 - 40	Steel	4 mm	Slotted
B11	40	0 - 20	20 - 40	0 - 20		Steel	4 mm	Slotted

Photo 90. Newly installed borehole B01

Photo 91. Newly installed borehole B03

Photo 92. Newly installed borehole B05

Photo 93. Newly installed borehole B06

Photo 94. Newly installed borehole B07

Photo 95. Newly installed borehole B08

Photo 96. Newly installed borehole B09

Photo 97. Newly installed borehole B10

8 EC Profiling of Boreholes

8.1 Introduction

During the investigations at Arnot Closed Colliery, very little information on the construction of the existing monitoring boreholes could be obtained. In addition, although historical groundwater quality information is available, sampling appears to have been done at the static water level within each borehole. The water quality at surface within the boreholes may, however, not be representative of the groundwater quality within the geological units. Dilution from rainfall may have significantly reduced that contaminant concentrations in the shallower parts of the water column. Preferential groundwater migration and contaminant transport may also occur along more permeable zones within the borehole.

In order to investigate possible stratification in the water quality within the boreholes, electrical conductivity (EC) profiling was done on all accessible boreholes forming part of the monitoring network at Arnot Closed Colliery. A total of 44 boreholes were EC profiled. These boreholes included 30 existing monitoring boreholes, four of Alzu's boreholes and the 10 new boreholes drilled during July 2012.

8.2 Results

The results of the EC profiling are provided as graphs in **Appendix C**. The EC profiles clearly show stratification of the water quality within most of the boreholes. Some prominent changes in the electrical conductivity of the water are observed in many boreholes (e.g. ANT-1, ANT-2, ANT-3, AW02, AW05, AW07, AW19, B4, B6, B7, BHZ04, BHZ08, BHZ09, KGM_B13). In all these boreholes the water quality at the static water level (swl) is significantly better than at some deeper horizon. This observation clearly illustrates the importance of sampling the boreholes at depths that provide representative samples of the water quality. Samples from the static water level may create the illusion that contaminant impacts at a particular site have been less severe than is the case. Example of such water quality stratification is shown in Figure 30 and Figure 31 where the EC profiles of monitoring boreholes ANT-2 and AW05 are displayed. In these boreholes, water samples taken at depths greater than 13 mbgl (ANT-2) and 15 mbgl (AW05) will have significantly higher salt loads than samples taken at the static water levels of these boreholes.

Based on the results of the EC profiling, sampling depths for each borehole were identified at which increased salt loads were apparent. The selection of the sampling depths of the new boreholes was done by also considering the geological and geohydrological conditions as revealed during drilling. In order to allow comparison of the current water quality with the results of previous sampling

events, water samples were also taken at the static water levels of the existing monitoring boreholes. The sampling depths selected for the different boreholes are listed in Table 28.

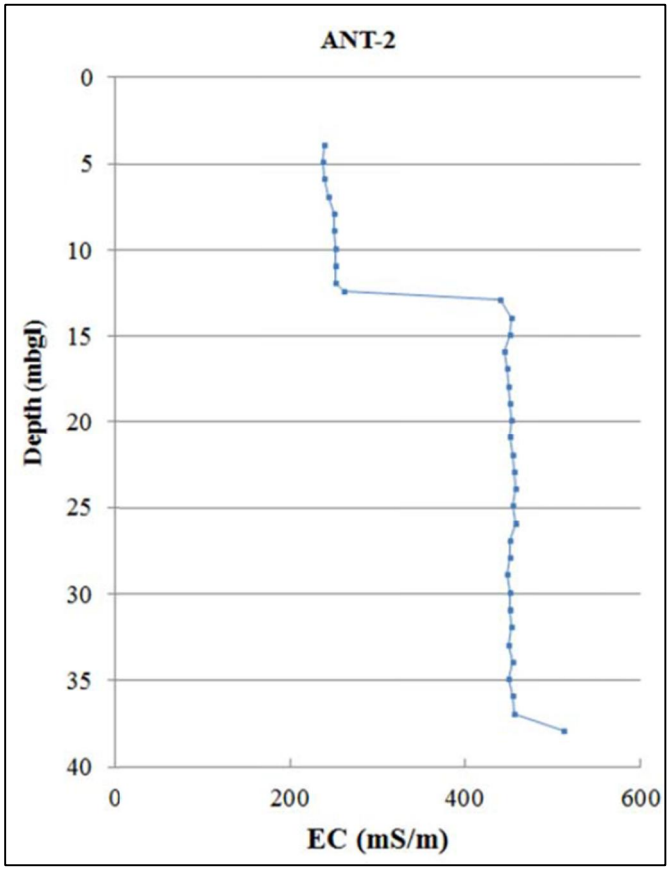


Figure 30. Example of water quality stratification in borehole ANT-2.

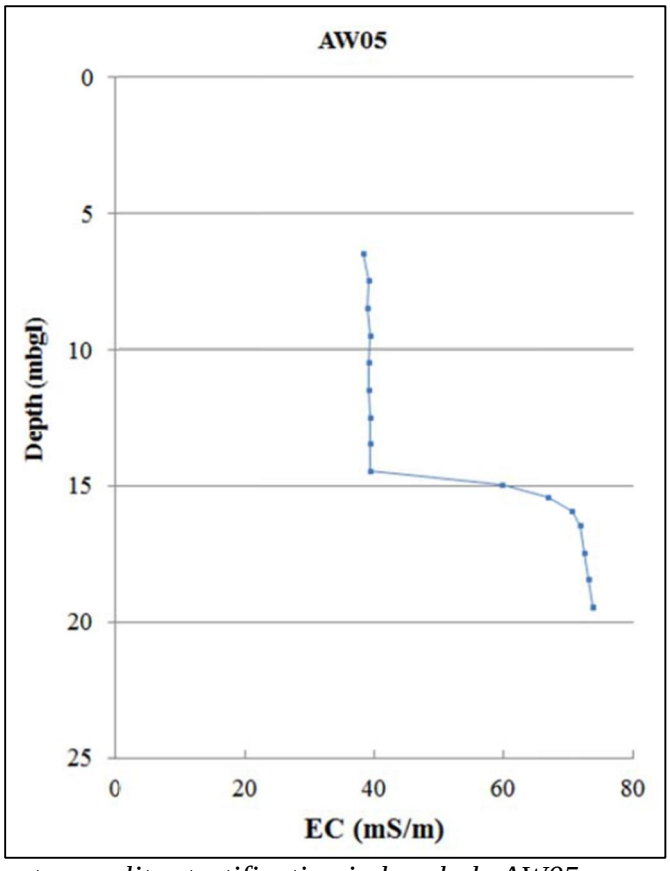


Figure 31. Example of water quality stratification in borehole AW05.

Table 28. Suggested sampling depths as determined from the EC profiling.

Description	Borehole Number	Sampling depths
Boreholes within and near Pit 1	ANT-1	Static water level and 30 metres below casing
	ANT-2	Static water level and 15 metres below casing
	ANT-3	Static water level and 16 metres below casing
	AW01	Static water level and 20 metres below casing
	AW02	Static water level and 30 metres below casing
	AW03	Static water level and 26 metres below casing
	AW04	Static water level and 15 metres below casing
	AW06	Static water level and 12 metres below casing
	AW07	Static water level and 19 metres below casing
	AW08	Static water level and 22 metres below casing
	AW09	Static water level and 17 metres below casing
	AW20	Static water level and 12 metres below casing
	AW24	Static water level and 24 metres below casing
	AW31	Static water level and 32 metres below casing
	C-3	Static water level and 22 metres below casing
	C-4	Static water level and 15 metres below casing
	C-5	Static water level and 17 metres below casing
Boreholes within and near Pit 2	AW05	Static water level and 18 metres below casing
	AW18	Static water level and 30 metres below casing
	AW19	Static water level and 18 metres below casing
	AW22	Static water level and 18 metres below casing
	AW23	Static water level and 17 metres below casing
	AW25	Static water level and 9 metres below casing
	AW26	Static water level and 21 metres below casing
	AW28	Static water level and 10 metres below casing
	KGM_B11	Static water level and 23 metres below casing
	KGM_B12	Static water level and 25 metres below casing
	R-2	Static water level and 10 metres below casing
Alzu Boreholes	BHZ04	Static water level and 42 metres below casing
	BHZ08	Static water level and 50 metres below casing
	BHZ09	Static water level and 30 metres below casing
	Old Supply BH	25 metres below casing
New Boreholes	B1	19 metres below casing
	B3	30 metres below casing
	B4	30 metres below casing
	B5	17 metres below casing
	B6	20 metres below casing
	B7	35 metres below casing
	B8	18 metres below casing
	B9	22 metres below casing
	B10	34 metres below casing
	B11	22 metres below casing

9 Hydraulic Testing of Boreholes

9.1 Introduction

Hydraulic tests were conducted on the new boreholes drilled during July 2012 as well as on three existing monitoring boreholes for which the construction was known (information had been punched on the lids of these boreholes soon after construction). The purpose of the hydraulic tests was to obtain information on the hydraulic conductivities of the geological units in which the boreholes were drilled. The hydraulic conductivities will be used to analyse the expected flow rates through these units and will be included as input parameters in the numerical model (Section 16).

9.2 Results

Slug tests were performed on all 13 tested boreholes. The results were analysed using the Bouwer-Rice curve fitting method (11 boreholes) as well as the recession time method (two boreholes). The results of the Bouwer-Rice curve fitting analyses are presented in **Appendix D**. The estimated hydraulic conductivities are listed in Table 29.

Table 29. Results of the analyses of the hydraulic test data.

Borehole #	Method	K (m/d)
B1	Bouwer-Rice curve fitting	0.014
B3	Bouwer-Rice curve fitting	0.188
B4	Recovery too fast to measure	~
B5	Bouwer-Rice curve fitting	0.009
B6	Bouwer-Rice curve fitting	0.018
B7	Bouwer-Rice curve fitting	0.026
B8	Bouwer-Rice curve fitting	0.001
B9	Bouwer-Rice curve fitting	0.006
B10	Recovery too fast to measure	~
B11	Bouwer-Rice curve fitting	1.138
ANT-1	Bouwer-Rice curve fitting	0.013
ANT-2	Recession time analysis	0.125
ANT-3	Recession time analysis	0.012

From the data in Table 29 it is seen that the hydraulic conductivities of the intersected earth materials at the different boreholes differ significantly, ranging from 0.001 m/d at borehole B8 to 1.138 m/d at borehole B11. Low hydraulic conductivities are observed at those boreholes that intersect dolerite (B5, 0.009 m/d; B9, 0.006 m/d). The recovery of the boreholes drilled in the spoils (B4 and B10) was too fast to be measured, showing that very high conductivities can be expected for the spoils in the backfilled pits.

In the absence of fractures, the rhyolites that are known to underlie most of the site, as well as the dolerite intrusives, are expected to have much lower hydraulic conductivities than the overlying Karoo sedimentary rocks. The hydraulic conductivities of the Karoo rocks may be estimated by considering only the portion of the borehole column intersecting Karoo rocks and attributing all flow to this portion. This is done in Table 30. Since no information is available on the geological units intersected in boreholes ANT-1, ANT-2 and ANT-3, the depth to the rhyolite in these boreholes is assumed to be similar to the depth observed in the closest new borehole, B6. The geometric mean of the estimated hydraulic conductivities of the Karoo sedimentary rocks is found to be 0.039 m/d. This value will be used as an input parameter during the construction of the numerical model to investigate the rate of groundwater migration and contaminant transport (Section 16).

Table 30. Estimated hydraulic conductivities of the Karoo sedimentary rocks.

Borehole #	**K for Karoo formations (m/d)**
B1	0.024
B3	0.188
B5	0.024
B6	0.027
B7	0.027
B8	0.002
B9	0.014
B11	1.686
ANT-1	0.019
ANT-2	0.185
ANT-3	0.018
Geometric mean	0.039

10 Groundwater and Surface Water Quality

10.1 Surface- and Groundwater Sampling, August 2012

Water sampling from the various surface- and groundwater sites was done on 7, 13, 14 and 15 August 2012. Water samples were submitted to the chemical laboratories of the IGS on 16 August 2012 for inorganic parameter analyses. Sampling information for the groundwater sites is presented in Table 31 while the information on the surface sites sampled is listed in Table 32. Site numbers in italic font are new sites numbers corresponding to sites that have not been included in the monthly sampling runs performed by personnel of AngloAmerican. It is possible that these sites had other numbers in the past.

The results of the inorganic chemical analyses performed on the surface- and groundwater samples are presented in Table 33 to Table 42. The results for the groundwater monitoring sites within and in the vicinity of Pit 1 are listed in Table 33 (major parameters) and Table 34 (minor parameters), while the groundwater monitoring sites within and in the vicinity of Pit 2 (W and E) are presented in Table 35 (major parameters) and Table 36 (minor parameters). The major and minor parameters of the analyses performed on the groundwater from the production boreholes of Alzu are listed in Table 37 and Table 38, respectively. The concentrations of the inorganic parameters of groundwater from the new boreholes drilled during 2012 are listed in Table 39 and Table 40, while Table 41 and Table 42 list the inorganic parameter concentrations observed in the sampled surface water sites. Values shown in italic font correspond to concentrations below the detection limits of the instruments used to perform the chemical analyses.

The data in Table 33 to Table 42 are colour-coded according to the “South Africa Water Quality Guidelines, Volume 1: Domestic Use, DWA&F, First Edition 1993” and the “South Africa Water Quality Guidelines, Volume 1: Domestic Use, DWA&F, Second Edition 1996”, as well as according to the publication “Quality of Domestic Water Supplies, DWA&F, Second Edition 1998”. A description of the various classes is given in Table 43 while the health and aesthetic effects associated with the use of water from the different classes are described in Table 44.

The results of the chemical analyses are discussed in Section 10.1.1 to Section 10.1.5.

Table 31. Groundwater sites visited during the August 2012 sampling event.

Date	Time	Number	Alternative number	Long (°E)	Lat (°S)	Casing height (m)	SWL (mb casing)	Sampling depth (mb casing)	Comments
2012/08/14	12:49	ANT-1	ARN01	29.65602	25.89716	0.310	6.76	swl + 30	
2012/08/07	13:05	ANT-2		29.66068	25.89690	0.155	3.40	swl + 15	
2012/08/07	13:30	ANT-3	ARN03	29.66289	25.89850	0.470	9.47	swl + 17	
2012/08/14	15:10	AW01		29.66074	25.90956	0.560	0.81	swl +20	
2012/08/13	15:34	AW02		29.66743	25.92713	0.650	14.81	swl + 30	
2012/08/07	14:00	AW03		29.67134	25.91538	0.430	22.18	swl + 26	
2012/08/14	13:59	AW04		29.67112	25.89561	0.540	2.45	swl + 15	
2012/08/14	10:23	AW05		29.71210	25.91349	0.550	6.60	swl + 18	
2012/08/07	15:00	AW06		29.67473	25.91024	1.020	8.11	swl + 12	
2012/08/14	13:12	AW07		29.65794	25.90042	0.320	3.14	swl + 19	
2012/08/14	11:00	AW08		29.65298	25.91078	0.400	2.09	swl + 22	
2012/08/13	15:15	AW09		29.68078	25.93839	0.420	8.44	swl +17	
2012/08/14	08:49	AW18		29.74031	25.91508	0.840	17.09	swl	
2012/08/07	16:00	AW19		29.72329	25.91682	0.270	7.99	swl + 18	
2012/08/15	08:00	AW20		29.64794	25.91033	0.450	0.45	swl + 12	
2012/08/13	13:05	AW21		29.65086	25.91419	~	~	~	Borehole destroyed
2012/08/15	08:45	AW22		29.75344	25.90850	0.640	0.00	swl + 18	
2012/08/15	08:20	AW23		29.75310	25.90642	0.340	2.60	swl + 17	
2012/08/14	16:16	AW24		29.70066	25.92128	0.250	17.07	swl + 24	
2012/08/14	13:50	AW25		29.70005	25.91621	0.170	6.45	swl + 9	
2012/08/14	16:20	AW26		29.70399	25.92306	0.260	17.06	swl + 21	
2012/08/14	08:20	AW28		29.72465	25.91672	0.840	9.72	swl + 9	
2012/08/14	15:52	AW29		29.71504	25.92073	~	~	~	Infested with bees
2012/08/14	14:00	AW30		29.70494	25.91492	~	~	~	Destroyed
2012/08/14	11:16	AW31		29.65293	25.90652	0.760	7.86	swl + 32	

Table 31 (cont.) *Groundwater sites visited during the August 2012 sampling event.*

Date	Time	Number	Alternative number	Long (°E)	Lat (°S)	Casing height (m)	SWL (mb casing)	Sampling depth (mb casing)	Comments
2012/08/14	09:42	B1		29.73474	25.91553	0.500	12.82	19	
2012/08/14	16:35	B3		29.63417	25.90806	0.650	23.84	30	
2012/08/14	16:50	B4		29.68292	25.92603	0.560	24.68	30	
2012/08/14	16:20	B5		29.68561	25.92320	0.620	16.08	17	
2012/08/14	14:21	B6		29.67073	25.90394	0.930	5.24	20	
2012/08/14	10:45	B7		29.65611	25.91917	0.770	10.26	35	
2012/08/14	09:55	B8		29.66209	25.93148	0.810	7.37	18	
2012/08/14	08:54	B9		29.67577	25.93717	0.950	11.19	22	
2012/10/04	14:32	B10		29.68270	25.93470	0.600	24.06	34	
2012/08/14	11:24	B11		29.71148	25.91706	0.440	6.38	22	
2012/10/05	08:08	BHZ01		29.64448	25.89040	0.140	~	~	Equipped with pump
2012/08/14	12:13	BHZ02		29.64762	25.89276	0.000	~	~	Not operational
2012/08/14	12:10	BHZ03		29.64763	25.89363	0.000	~	~	Equipped with pump
2012/08/14	11:53	BHZ04		29.64883	25.89824	0.000	1.94	swl + 42	
2012/08/14	12:00	BHZ05		29.65288	25.89739	0.270	3.48	~	Equipped with pump
2012/08/13	10:00	BHZ06		29.65294	25.89671	0.110	~	~	Equipped with pump
2012/08/14	12:10	BHZ07		29.65302	25.89615	0.380	3.55	~	Equipped with pump
2012/08/14	12:20	BHZ08		29.65418	25.89492	0.140	4.84	swl + 50	
2012/08/14	12:35	BHZ09		29.65580	25.89549	0.000	1.16	swl + 30	
2012/08/13	11:10	BHZ10		29.65263	25.90754	0.000	44.83	~	Equipped with pump.
2012/10/05	08:23	BHZ11		29.65014	25.92170	0.030	~	~	Blocked
2012/10/05	08:50	BHZ12		29.64976	25.92355	0.000	~	~	Not operational
2012/08/14	16:00	C-3		29.69324	25.92786	0.830	17.49	swl +22	
2012/08/14	15:45	C-4		29.69210	25.92221	0.650	13.46	swl + 15	
2012/08/14	15:30	C-5		29.69307	25.92031	0.900	11.61	swl + 17	

Table 31 (cont.) *Groundwater sites visited during the August 2012 sampling event.*

Date	Time	Number	Alternative number	Long (°E)	Lat (°S)	Casing height (m)	SWL (mb casing)	Sampling depth (mb casing)	Comments
2012/08/14	14:38	KGM B10		29.67911	25.91384	0.690	~	swl + 14	Blocked with bee wax at 8.08 mbc
2012/08/14	10:59	KGM B11		29.71342	25.91374	0.420	3.53	swl + 23	
2012/08/13	15:15	KGM B12		29.73187	25.91635	0.820	12.86	swl + 25	
2012/08/15	15:15	KGM B13		29.75311	25.90647	0.470	14.13	~	Borehole right next to AW23
2012/08/16	14:30	R-1		29.71842	25.92383	0.700	~	~	Dry
2012/08/14	13:20	R-2		29.71561	25.91779	0.800	6.90	swl + 10	
2012/08/13	15:30	R-3		29.71770	25.91807	~	~	~	Blocked with bee wax.
2012/08/14	08:09	Community BH		29.65447	25.88793	0.160	12.55	swl + EC	Water level not static. Sampled from tap
2012/08/14	09:40	Old Supply BH		29.66710	25.93649	0.350	5.03	25	
2012/08/14	10:17	Piet's Pump		29.65246	25.93162	~	~	pumped	Sampled at tap
2012/10/05	08:26	Alzu Windpump		29.65502	25.92525	0.250	~	~	Equipped with pump.
2012/08/14	10:10	Windpump		29.65461	25.93463	~	~	~	Not operational

Table 32. Surface water sites visited during the August 2012 sampling event.

Date	Time	Number	Alt Number	Long (°E)	Lat (°S)	Type	Comments
2012/08/07	09:25	ARN02		29.65861	25.88802	Dam	Moderate water level
2012/08/07	11:15	Decant Dam		29.66325	25.90070	Dam	Low water level
2012/08/07	11:30	Evap Dam		29.67610	25.91487	Dam	Low water level
2012/08/07	11:20	Final Void		29.67006	25.90344	Dam	Moderate water level
2012/08/07	11:05	No.09	T1 Dam	29.65368	25.90893	Dam	Moderate water level
2012/08/07	08:45	No.10		29.64259	25.88299	River	Flowing slowly
2012/08/07	15:10	No.13		29.65326	25.92607	Dam	Moderate water level
2012/08/07	15:18	No.14		29.65222	25.93167	River	Dry
2012/08/07	10:45	No.15		29.65403	25.89585	Dam	Low water level
2012/08/14	08:33	No.21		29.75053	25.90136	Dam	Not sampled
2012/08/07	09:22	No.28		29.66798	25.89011	River	Stagnant
2012/08/07	09:44	No.32		29.62873	25.91580	River	Flowing slowly
2012/08/07	08:55	No.33		29.62949	25.87696	River	Stagnant
2012/08/07	16:30	*Farm Dam*		29.67950	25.91016	Dam	Dry
2012/08/07	15:35	*R01*		29.64915	25.91717	River	Flowing moderately strongly
2012/08/14	13:37	*R02*		29.68587	25.90262	River	Flowing slowly
2012/08/15	09:05	*R03*		29.75343	25.90707	River	Stagnant
2012/08/07	09:58	*R05*		29.61922	25.93064	River	Flowing slowly
2012/08/14	09:04	*R04*		29.65135	25.94608	River	Flowing strongly
2012/08/07	10:25	*Steels Pan*		29.64805	25.89981	Pan	Moderate water level
2012/08/07	15:33	*Bliksem Pan*		29.64719	25.91798	Pan	Moderate water level
2012/08/07	16:40	*Pan03*		29.64812	25.90979	Pan	Dry
2012/08/08	14:36	*Railway Pan*		29.65786	25.94231	Pan	Dry

Table 32 (cont.) *Surface water sites visited during the August 2012 sampling event.*

Date	Time	Number	Alt Number	Long (°E)	Lat (°S)	Type	Comments
2012/08/07	12:15	T3 Dam		29.65998	25.92233	Dam	Low water level
2012/08/07	12:08	T4 Dam		29.66473	25.93057	Dam	Moderate water level
2012/08/07	11:45	T4 Pump		29.67962	25.92040	Dam	Moderate water level
2012/08/14	16:48	W04		29.70883	25.91469	Canal/Trench	Low water level
2012/08/14	16:38	W05		29.71839	25.91656	Canal/Trench	Dosing Plant. Dry
2012/08/14	08:39	*Seepage*		29.66308	25.93229	Seepage	Salt precipitation. Not sampled

Table 33. Water quality table: groundwater monitoring sites within and in the vicinity of Pit 1 (major parameters).

Site No.	Depth	Date	pH	EC	TDS	Na	Ca	Mg	K	NH_4-N	Cl	SO_4	F	NO_3-N	PO_4	T.Alk	TotalHard	Ionbal
	mbc			mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
ANT-1	swl	2012/08/14	7.9	88	474	22	32	45	15.7		27	3	0.0	*0.1*	*0.1*	328	264	4.4
ANT-1	30	2012/08/14	7.3	200	1559	51	161	171	18.3		20	951	*0.1*	*0.5*	*1.0*	189	1104	1.9
ANT-2	swl	2012/08/07	6.1	242	2049	95	208	220	11.5		30	1482	0.5	*0.5*	*1.0*	6	1424	2.2
ANT-2	15	2012/08/07	6.5	421	4075	112	406	428	26.7		24	2974	*0.1*	*0.5*	*1.0*	104	2771	2.3
ANT-3	swl	2012/08/07	6.7	105	772	38	61	88	14.2		9	548	*0.1*	*0.5*	*1.0*	17	514	1.9
ANT-3	16	2012/08/07	6.9	193	1657	33	255	140	16.3		9	1165	*0.1*	*0.5*	1.4	41	1209	1.9
AW01	swl	2012/08/14	7.6	500	5168	104	506	582	55.5		21	3561	0.4	*0.5*	*1.0*	340	3651	1.0
AW01	20	2012/08/14	7.6	507	5242	136	521	532	46.9		25	3572	0.2	*0.5*	*1.0*	404	3485	3.2
AW02	swl	2012/08/13	7.5	345	3317	44	331	399	33.7		15	2165	0.8	*0.5*	*1.0*	332	2464	0.4
AW02	30	2012/08/13	7.5	486	4853	82	465	532	43.8		18	3400	0.4	*0.5*	*1.0*	309	3346	3.2
AW03	swl	2012/08/07	8.0	363	3396	97	223	429	34.9		21	2364	0.2	*0.5*	*1.0*	228	2317	2.1
AW03	26	2012/08/07	6.6	385	3638	104	244	442	32.9		23	2775	0.1	*0.5*	*1.0*	17	2424	3.7
AW04	swl	2012/08/14	7.5	18	129	20	8	5	4.8		22	7	0.2	0.1	*0.1*	61	41	4.6
AW04	15	2012/08/14	7.7	18	124	21	8	4	4.5		20	4	0.3	0.1	*0.1*	62	37	4.2
AW06	swl	2012/08/07	7.0	15	99	12	6	5	5.8		18	13	0.0	0.6	*0.1*	35	36	4.8
AW06	12	2012/08/07	7.7	13	91	12	5	4	4.9		17	5	0.0	0.6	*0.1*	39	31	4.2
AW07	swl	2012/08/14	7.4	175	1396	66	132	144	27.7		46	883	*0.1*	*0.5*	*1.0*	100	920	1.3
AW07	19	2012/08/14	7.3	177	1429	68	137	149	28.7		50	906	0.1	*0.5*	*1.0*	94	952	1.9
AW08	swl	2012/08/14	6.7	452	4300	107	374	473	23.4		26	3205	*0.1*	*0.5*	*1.0*	89	2874	4.1
AW08	22	2012/08/14	6.7	451	4339	109	371	475	24.6		25	3250	*0.1*	*0.5*	*1.0*	82	2874	4.6
AW09	swl	2012/08/13	3.7	325	3081	43	462	245	15.0		15	2274	*0.1*	*0.5*	*1.0*	28	2159	2.6
AW09	17	2012/08/13	3.4	424	4372	37	351	217	9.9		22	3014	*0.1*	*0.5*	*1.0*	0	1766	0.1
AW20	swl	2012/08/15	7.6	638	5592	401	322	596	10.4		116	4011	0.3	*0.5*	*1.0*	139	3248	3.5
AW20	12	2012/08/15	7.5	638	5532	403	329	600	11.5		116	3935	0.4	*0.5*	*1.0*	142	3279	2.2
AW24	swl	2012/08/14	7.3	241	2212	22	249	214	31.7		15	700	0.2	30.3	*1.0*	846	1497	3.1
AW24	24	2012/08/14	7.2	328	2952	30	406	309	35.1		12	1572	0.3	5.0	*1.0*	565	2279	3.9
AW31	swl	2012/08/14	6.5	17	130	25	4	3	4.4		8	11	0.0	7.3	*0.1*	43	23	4.7
AW31	32	2012/08/14	6.6	16	121	25	3	2	4.5		8	4	0.1	6.3	*0.1*	46	17	5.0
C-3	swl	2012/08/14	6.4	354	3194	88	281	368	37.2		17	2257	*0.1*	*0.5*	*1.0*	148	2209	0.8
C-3	22	2012/08/14	6.4	354	3218	89	286	368	37.0		18	2266	*0.1*	*0.5*	*1.0*	151	2224	0.6
C-4	swl	2012/08/14	7.5	350	2708	247	141	281	49.9		116	1549	0.1	*0.5*	*1.0*	310	1504	0.8
C-4	15	2012/08/14	8.2	362	2955	255	135	287	49.7		143	1744	0.2	*0.5*	*1.0*	334	1515	4.5
C-5	swl	2012/08/14	7.7	186	1297	98	47	136	40.8		21	534	*0.1*	*0.5*	*1.0*	409	675	2.7
C-5	17	2012/08/14	7.7	179	1253	102	33	131	40.8		20	511	*0.1*	*0.5*	*1.0*	398	618	3.9

Table 34. Water quality table: groundwater monitoring sites within and in the vicinity of Pit 1 (minor parameters).

Site No.	Depth	Date	Al	Ba	Br	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Si	Zn
	mbc		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANT-1	swl	2012/08/14	0.017	0.025	0.250	*0.002*	*0.006*	0.003	0.389	0.466	*0.003*	*0.010*	*0.010*	1.613	0.009
ANT-1	30	2012/08/14	0.003	0.033	*0.400*	0.002	*0.006*	0.005	0.553	0.957	*0.003*	0.019	*0.010*	2.702	0.019
ANT-2	swl	2012/08/07	0.018	0.019	*0.400*	*0.002*	*0.006*	0.011	0.075	0.187	*0.003*	*0.010*	*0.010*	0.063	0.019
ANT-2	15	2012/08/07	0.003	0.016	*0.400*	0.025	*0.006*	0.017	1.200	3.274	*0.003*	0.076	*0.010*	4.040	0.035
ANT-3	swl	2012/08/07	0.003	0.009	*0.400*	*0.002*	*0.006*	0.006	0.089	0.066	*0.003*	*0.010*	*0.010*	0.096	0.015
ANT-3	16	2012/08/07	*0.001*	0.017	*0.400*	*0.002*	*0.006*	0.008	0.080	0.464	*0.003*	*0.010*	*0.010*	3.258	0.022
AW01	swl	2012/08/14	0.003	0.013	*0.400*	0.004	*0.006*	0.010	0.060	2.247	*0.003*	0.018	*0.010*	4.211	0.033
AW01	20	2012/08/14	*0.002*	0.015	*0.400*	0.022	*0.006*	0.006	0.060	7.607	*0.003*	0.016	*0.010*	5.135	0.087
AW02	swl	2012/08/13	0.000	0.010	*0.400*	*0.002*	*0.006*	0.014	0.059	0.139	*0.003*	*0.010*	*0.010*	4.915	0.139
AW02	30	2012/08/13	*0.002*	0.012	*0.400*	0.008	*0.006*	0.009	0.058	6.375	*0.003*	0.015	*0.010*	5.608	0.063
AW03	swl	2012/08/07	0.003	0.018	*0.400*	*0.002*	*0.006*	0.005	0.077	2.246	*0.003*	*0.010*	*0.010*	0.336	0.011
AW03	26	2012/08/07	0.004	0.019	*0.400*	*0.002*	*0.006*	0.018	0.325	2.284	*0.003*	*0.010*	*0.010*	0.139	0.018
AW04	swl	2012/08/14	0.002	0.031	0.320	*0.002*	*0.006*	0.003	0.070	0.004	*0.003*	*0.010*	*0.010*	2.203	0.005
AW04	15	2012/08/14	0.009	0.046	0.340	*0.002*	*0.006*	0.003	0.098	0.005	*0.003*	*0.010*	*0.010*	2.482	0.012
AW06	swl	2012/08/07	0.049	0.020	0.390	*0.002*	*0.006*	0.003	0.199	0.007	*0.003*	*0.010*	*0.010*	1.758	0.011
AW06	12	2012/08/07	0.138	0.020	0.450	*0.002*	*0.006*	0.002	0.546	0.009	*0.003*	*0.010*	*0.010*	1.849	0.009
AW07	swl	2012/08/14	0.006	0.029	0.130	*0.002*	*0.006*	0.007	0.060	0.529	*0.003*	*0.010*	*0.010*	0.544	0.013
AW07	19	2012/08/14	0.001	0.032	*0.400*	*0.002*	*0.006*	0.006	0.076	0.589	*0.003*	*0.010*	*0.010*	0.588	0.012
AW08	swl	2012/08/14	0.002	0.019	*0.400*	0.013	*0.006*	0.008	0.120	7.113	*0.003*	*0.010*	*0.010*	0.794	0.014
AW08	22	2012/08/14	0.005	0.014	*0.400*	0.010	*0.006*	0.008	0.264	6.943	*0.003*	*0.010*	*0.010*	0.788	0.015
AW09	swl	2012/08/13	0.065	0.026	*0.400*	*0.002*	*0.006*	0.071	0.171	2.807	*0.003*	*0.010*	0.032	1.383	0.085
AW09	17	2012/08/13	*0.033*	0.014	*0.400*	*0.002*	*0.006*	*0.008*	720	5.456	*0.003*	*0.010*	0.059	0.120	0.180
AW20	swl	2012/08/15	*0.012*	0.019	*0.400*	*0.002*	*0.006*	0.009	0.045	0.181	*0.003*	*0.010*	*0.010*	0.779	0.006
AW20	12	2012/08/15	*0.003*	0.018	*0.400*	*0.002*	*0.006*	0.009	0.103	0.285	*0.003*	*0.010*	*0.010*	0.845	0.016
AW24	swl	2012/08/14	0.004	0.030	*0.400*	*0.002*	*0.006*	0.010	0.055	0.926	*0.003*	*0.010*	*0.010*	2.889	0.044
AW24	24	2012/08/14	*0.001*	0.019	*0.400*	0.008	*0.006*	0.008	0.055	2.818	*0.003*	*0.010*	*0.010*	3.845	0.041
AW31	swl	2012/08/14	0.045	0.028	0.230	*0.002*	*0.006*	0.003	0.078	0.005	*0.003*	*0.010*	*0.010*	11.323	0.019
AW31	32	2012/08/14	0.033	0.029	0.130	*0.002*	*0.006*	0.003	0.065	0.004	*0.003*	*0.010*	*0.010*	11.659	0.048
C-3	swl	2012/08/14	0.000	0.015	*0.400*	*0.002*	*0.006*	0.008	1.889	0.607	*0.003*	*0.010*	*0.010*	1.439	0.015
C-3	22	2012/08/14	0.004	0.014	*0.400*	*0.002*	*0.006*	0.007	6.741	0.650	*0.003*	*0.010*	*0.010*	1.491	0.017
C-4	swl	2012/08/14	0.011	0.032	7.500	*0.002*	*0.006*	0.011	0.063	1.585	*0.003*	*0.010*	*0.010*	0.853	0.018
C-4	15	2012/08/14	0.011	0.017	9.380	*0.002*	*0.006*	0.007	0.064	1.047	*0.003*	*0.010*	*0.010*	0.560	0.016
C-5	swl	2012/08/14	0.015	0.032	*0.400*	*0.002*	*0.006*	0.006	0.086	0.545	*0.003*	*0.010*	*0.010*	0.814	0.014
C-5	17	2012/08/14	0.011	0.029	*0.400*	*0.002*	*0.006*	0.005	0.073	0.321	*0.003*	*0.010*	*0.010*	0.589	0.013

Table 35. Water quality table: groundwater monitoring sites within and in the vicinity of Pit 2 (major parameters).

Site No.	Depth	Date	pH	EC	TDS	Na	Ca	Mg	K	NH_4-N	Cl	SO_4	F	NO_3-N	PO_4	T.Alk	TotalHard	Ionbal
	mbc			mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
AW05	swl	2012/08/14	6.9	15	102	18	6	4	2.0		18	22	0.1	*0.1*	*0.1*	32	31	4.4
AW05	18	2012/08/14	7.3	92	649	128	36	18	3.5		9	336	1.4	*0.1*	*0.1*	117	165	3.6
AW18	swl	2012/08/14	6.9	45	262	8	35	17	8.1	0.02	3	23	0.1	0.1	*0.1*	162	155	3.0
AW18	30	2012/08/14	6.8	45	250	8	32	16	8.2	0.05	3	21	0.1	*0.1*	*0.1*	161	144	3.6
AW19	swl	2012/08/07	6.6	41	199	13	19	17	4.8		4	92	0.6	0.5	*0.1*	46	116	1.0
AW19	18	2012/08/07	6.6	42	211	12	20	19	3.8		3	95	0.5	0.3	*0.1*	55	127	0.6
AW22	swl	2012/08/15	6.0	12	89	17	3	2	3.4		18	6	0.1	7.0	*0.1*	8	16	4.5
AW22	18	2012/08/15	5.8	13	90	19	3	2	3.7		18	6	0.0	7.2	*0.1*	7	15	2.8
AW23	swl	2012/08/15	5.8	6	45	7	2	2	2.2		7	8	0.0	2.1	*0.1*	8	11	4.4
AW23	17	2012/08/15	5.8	4	36	6	1	1	1.9		8	1	0.0	2.1	*0.1*	8	9	3.6
AW25	swl	2012/08/14	6.6	29	168	5	23	11	4.9		4	46	*0.1*	*0.5*	*1.0*	58	102	0.3
AW25	9	2012/08/14	7.4	268	2246	30	289	218	17.5		9	1023	0.1	0.5	*1.0*	659	1616	0.1
AW26	swl	2012/08/14	7.2	227	1874	22	234	204	28.9		13	741	0.3	1.2	*1.0*	621	1421	3.5
AW26	21	2012/08/14	7.4	348	3091	29	418	316	34.5		11	1743	0.3	0.8	*1.0*	535	2340	2.2
AW28	swl	2012/08/14	7.0	48	303	17	6	9	7.8	30.3	12	1	0.1	0.1	*0.1*	207	53	1.8
AW28	10	2012/08/14	7.1	54	336	18	4	9	8.4	35.4	12	0	0.1	*0.1*	*0.1*	234	47	3.5
KGM_B11	swl	2012/08/14	6.2	44	254	36	18	15	5.7		11	149	0.1	*0.1*	*0.1*	19	104	1.4
KGM_B11	23	2012/08/14	6.4	45	256	36	20	15	5.4		10	143	0.1	*0.1*	*0.1*	27	112	2.2
KGM_B12	swl	2012/08/13	6.7	55	333	33	32	19	4.5		15	167	0.3	*0.1*	*0.1*	62	159	3.7
KGM_B12	25	2012/08/13	7.2	80	507	52	55	32	4.8		15	218	0.6	*0.1*	*0.1*	130	268	1.4
W04	surface	2012/08/14	7.2	28	185	12	15	14	12.2		13	48	1.1	*0.1*	*0.1*	69	94	0.5
R-2	swl	2012/08/14	7.0	79	477	21	51	46	5.8		8	321	0.2	*0.1*	*0.1*	25	314	0.3
R-2	10	2012/08/14	6.6	79	481	20	50	45	5.5		8	334	0.2	*0.1*	*0.1*	18	311	1.3

Table 36. Water quality table: groundwater monitoring sites within and in the vicinity of Pit 2 (minor parameters).

Site No.	Depth mbc	Date	Al mg/L	Ba mg/L	Br mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Mo mg/L	Ni mg/L	Pb mg/L	Si mg/L	Zn mg/L
AW05	swl	2012/08/14	0.002	0.006	0.159	*0.002*	*0.006*	0.002	0.055	0.087	*0.003*	*0.010*	*0.010*	0.201	0.008
AW05	18	2012/08/14	0.007	0.017	*0.040*	0.004	*0.006*	0.006	0.066	0.325	*0.003*	*0.010*	*0.010*	3.569	0.015
AW18	swl	2012/08/14	0.007	0.05	*0.040*	*0.002*	*0.006*	0.005	0.151	0.233	*0.003*	*0.010*	*0.010*	3.875	0.016
AW18	30	2012/08/14	0.010	0.094	*0.040*	*0.002*	*0.006*	0.004	0.357	0.184	*0.003*	*0.010*	*0.010*	4.066	0.015
AW19	swl	2012/08/07	0.016	0.027	0.045	0.008	*0.006*	0.005	0.068	0.457	*0.003*	0.016	*0.010*	2.549	0.022
AW19	18	2012/08/07	0.006	0.02	*0.040*	0.024	*0.006*	0.008	0.057	0.988	*0.003*	0.026	*0.010*	2.825	0.024
AW22	swl	2012/08/15	0.022	0.05	0.043	*0.002*	*0.006*	0.006	0.142	0.005	*0.003*	*0.010*	*0.010*	5.087	0.020
AW22	18	2012/08/15	0.032	0.043	*0.040*	*0.002*	*0.006*	0.004	0.329	0.007	*0.003*	*0.010*	*0.010*	5.021	0.019
AW23	swl	2012/08/15	0.014	0.034	*0.040*	*0.002*	*0.006*	0.004	0.058	0.022	*0.003*	*0.010*	*0.010*	4.231	0.034
AW23	17	2012/08/15	0.033	0.029	*0.040*	*0.002*	*0.006*	0.003	0.059	0.008	*0.003*	*0.010*	*0.010*	4.321	0.020
AW25	swl	2012/08/14	0.012	0.068	*0.400*	*0.002*	*0.006*	0.007	0.158	1.352	*0.003*	*0.010*	*0.010*	4.777	0.017
AW25	9	2012/08/14	0.006	0.033	*0.400*	*0.002*	*0.006*	0.005	0.133	4.168	*0.003*	*0.010*	*0.010*	4.926	0.008
AW26	swl	2012/08/14	*0.001*	0.058	*0.400*	0.010	*0.006*	0.004	0.083	1.134	*0.003*	0.014	*0.010*	2.268	0.010
AW26	21	2012/08/14	0.002	0.015	*0.400*	0.009	*0.006*	0.007	0.056	2.824	*0.003*	*0.010*	*0.010*	3.504	0.021
AW28	swl	2012/08/14	0.009	0.079	*0.040*	*0.002*	*0.006*	0.002	3.723	0.313	*0.003*	*0.010*	*0.010*	4.643	0.007
AW28	10	2012/08/14	0.017	0.047	*0.040*	*0.002*	*0.006*	0.002	5.033	0.240	*0.003*	*0.010*	*0.010*	4.771	0.007
KGM_B11	swl	2012/08/14	0.003	0.036	0.053	0.016	*0.006*	0.005	1.780	0.191	*0.003*	0.028	*0.010*	4.46	0.036
KGM_B11	23	2012/08/14	0.004	0.043	0.112	0.017	*0.006*	0.005	0.526	0.218	*0.003*	0.028	*0.010*	4.172	0.027
KGM_B12	swl	2012/08/13	0.007	0.04	0.065	0.003	*0.006*	0.006	0.056	0.229	*0.003*	0.012	*0.010*	6.883	0.024
KGM_B12	25	2012/08/13	0.008	0.044	0.158	0.006	*0.006*	0.005	0.058	0.370	*0.003*	0.011	*0.010*	5.468	0.017
W04	surface	2012/08/14	0.013	0.163	0.335	*0.002*	*0.006*	0.005	0.320	0.581	*0.003*	*0.010*	*0.010*	0.086	0.010
R-2	swl	2012/08/14	0.012	0.021	*0.040*	0.002	*0.006*	0.008	0.071	1.086	*0.003*	*0.010*	*0.010*	0.096	0.020
R-2	10	2012/08/14	0.010	0.02	0.116	0.009	*0.006*	0.009	0.053	1.137	*0.003*	0.018	*0.010*	0.209	0.024

Table 37. Water quality table: Alzu groundwater sites (major parameters).

Site No.	Depth	Date	pH	EC	TDS	Na	Ca	Mg	K	NH_4-N	Cl	SO_4	F	NO_3-N	PO_4	T.Alk	TotalHard	Ionbal
	mbc			mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
BHZ04	swl	2012/08/14	7.6	66	477	44	24	30	39.0		39	98	0.3	0.7	26.2	173	183	2.1
BHZ04	42	2012/08/14	7.8	68	487	45	25	32	41.1		41	107	0.2	1.1	22.3	170	191	1.7
BHZ08	swl	2012/08/14	7.5	140	957	116	69	72	14.6		55	568	*0.1*	*0.5*	1.1	63	468	1.1
BHZ08	50	2012/08/14	7.5	142	959	120	73	75	15.1		57	560	*0.1*	*0.5*	*1.0*	63	488	3.5
BHZ09	swl	2012/08/14	7.1	128	959	59	75	102	13.7		19	568	0.1	0.8	*1.0*	111	608	1.4
BHZ09	30	2012/08/14	6.5	227	1818	62	184	204	13.3		25	1194	*0.1*	17.4	*1.0*	57	1296	2.2
Community BH	~	2012/08/14	7.6	22	160	28	10	5	2.5		7	10	1.7	*0.1*	*0.1*	96	46	3.8
Old Supply BH	25	2012/08/14	7.0	18	127	13	13	5	3.3		6	14	0.1	*0.1*	*0.1*	60	53	4.3
Piet's Pump	~	2012/08/14	8.2	38	248	65	7	3	1.2		36	8	1.6	*0.1*	*0.1*	127	30	4.6

Table 38. Water quality table: Alzu groundwater sites (minor parameters).

Site No.	Depth	Date	Al	Ba	Br	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Si	Zn
	mbc		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
BHZ04	swl	2012/08/14	0.007	0.004	*0.040*	*0.002*	*0.006*	0.070	0.094	0.015	0.008	*0.01*	*0.010*	7.606	0.021
BHZ04	42	2012/08/14	0.014	0.004	*0.040*	*0.002*	*0.006*	0.191	0.156	0.015	0.008	*0.01*	*0.010*	7.344	0.022
BHZ08	swl	2012/08/14	0.009	0.014	*0.400*	*0.002*	*0.006*	0.017	0.060	0.866	*0.003*	*0.01*	*0.010*	1.421	0.026
BHZ08	50	2012/08/14	0.005	0.014	*0.400*	*0.002*	*0.006*	0.010	0.059	1.005	*0.003*	*0.01*	*0.010*	1.663	0.020
BHZ09	swl	2012/08/14	0.003	0.01	*0.400*	*0.002*	*0.006*	0.013	0.065	0.085	*0.003*	*0.01*	*0.010*	2.079	0.022
BHZ09	30	2012/08/14	0.006	0.02	0.775	0.012	*0.006*	0.020	0.059	0.628	*0.003*	0.043	*0.010*	5.666	0.183
Community BH	~	2012/08/14	0.007	0.151	*0.040*	*0.002*	*0.006*	0.003	0.076	0.006	*0.003*	*0.01*	*0.010*	11.261	0.012
Old Supply BH		2012/08/14	0.005	0.036	*0.040*	*0.002*	*0.006*	0.004	0.084	0.194	*0.003*	*0.01*	*0.010*	3.331	0.015
Piet's Pump	~	2012/08/14	0.008	0.032	0.199	*0.002*	*0.006*	0.004	0.049	0.012	*0.003*	*0.01*	*0.010*	8.376	0.016

Table 39. Water quality table: new boreholes (major parameters).

Site No.	Depth	Date	pH	EC	TDS	Na	Ca	Mg	K	NH_4-N	Cl	SO_4	F	NO_3-N	PO_4	T.Alk	TotalHard	Ionbal
	mbc			mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
B1	swl	2012/08/14	7.3	98	618	61	64	40	5.6		17	356	1.0	*0.5*	*1.0*	77	321	0.8
B1	19	2012/08/14	6.9	99	630	64	68	43	5.8		19	350	1.1	*0.1*	*0.1*	78	347	2.5
B3	30	2012/08/14	7.7	20	137	9	15	6	6.6		3	22	0.7	*0.1*	*0.1*	73	64	4.8
B4	30	2012/08/14	6.1	412	3592	85	356	376	42.1		18	2532	0.1	*0.5*	*1.0*	159	2433	0.8
B5	17	2012/08/14	6.7	7	50	6	4	2	3.2		2	2	0.1	*0.1*	*0.1*	31	17	3.7
B6	20	2012/08/14	6.9	364	2975	75	325	333	24.1		16	2096	0.3	*0.5*	*1.0*	107	2177	1.9
B7	35	2012/08/14	6.6	11	70	13	2	2	3.3		6	4	0.0	0.4	*0.1*	37	14	4.7
B8	18	2012/08/14	6.8	30	189	24	12	9	8.5		9	83	0.1	*0.1*	*0.1*	44	65	4.4
B9	22	2012/08/14	7.4	20	140	12	14	7	4.3		5	9	0.2	*0.1*	*0.1*	88	64	3.8
B10	34	2012/10/04	6.4	269	2568	43	305	245	25.9		13	1548	0.4	*0.5*	*1.0*	384	1768	2.4
B11	22	2012/08/14	5.6	110	781	20	91	67	7.8		1	553	*0.1*	*0.5*	*1.0*	9	502	4.5

Table 40. Water quality table: new boreholes (minor parameters).

Site No.	Depth	Date	Al	Ba	Br	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Si	Zn
	mbc		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
B1	swl	2012/08/14	0.014	0.082	*0.400*	0.002	*0.006*	0.007	0.090	0.558	*0.003*	*0.010*	*0.010*	1.844	0.026
B1	19	2012/08/14	0.010	0.075	0.128	0.003	*0.006*	0.011	0.069	0.551	*0.003*	*0.010*	*0.010*	1.884	0.020
B3	30	2012/08/14	0.008	0.106	*0.040*	*0.002*	*0.006*	0.005	0.056	0.033	0.008	*0.010*	*0.010*	2.057	0.012
B4	30	2012/08/14	*0.006*	0.023	*0.400*	0.065	*0.006*	0.011	3.655	25.477	*0.003*	0.044	*0.010*	7.62	0.085
B5	17	2012/08/14	0.013	0.059	*0.040*	*0.002*	*0.006*	0.003	0.074	0.090	*0.003*	*0.010*	*0.010*	7.143	0.015
B6	20	2012/08/14	*0.006*	0.035	*0.400*	0.015	*0.006*	0.009	0.093	1.997	*0.003*	0.012	*0.010*	1.688	0.019
B7	35	2012/08/14	0.026	0.067	0.041	0.003	*0.006*	0.003	0.093	0.081	*0.003*	*0.010*	*0.010*	4.26	0.014
B8	18	2012/08/14	0.011	0.037	0.039	*0.002*	*0.006*	0.002	0.079	0.617	*0.003*	*0.010*	*0.010*	1.917	0.004
B9	22	2012/08/14	0.054	0.139	*0.040*	*0.002*	*0.006*	0.005	0.273	0.182	*0.003*	*0.010*	*0.010*	13.162	0.018
B10	34	2012/10/04	0.001	0.027	*0.400*	0.010	*0.006*	0.018	0.071	2.956	*0.003*	*0.010*	*0.010*	4.686	0.135
B11	22	2012/08/14	0.138	0.092	*0.400*	0.326	*0.006*	0.017	24.934	11.730	*0.003*	0.193	0.015	12.276	0.251

Table 41. Water quality table: surface water sites (major parameters).

Site No.	Area	Date	pH	EC	TDS	Na	Ca	Mg	K	NH_4-N	Cl	SO_4	F	NO_3-N	PO_4	T.Alk	TotalHard	Ionbal
				mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
Decant Dam	Dams within and near Pit 1	2012/08/07	7.3	495	4149	100	408	453	37.0		23	2824	0.4	0.5	1.0	308	2878	1.7
Evap Dam		2012/08/07	8.1	502	4186	102	415	447	37.5		23	2912	0.2	0.5	1.0	252	2871	2.2
Final Void		2012/08/07	7.8	495	4183	99	407	445	35.3		24	2875	0.3	0.5	1.0	301	2839	3.0
No.09 - T1 Dam		2012/08/07	8.0	515	4932	112	492	517	46.7		26	3432	0.1	0.5	1.0	310	3350	3.0
T2 Dam		2012/08/07	8.2	661	5778	113	390	710	82.5		35	4191	0.1	0.5	1.0	261	3885	4.3
T3 Dam		2012/08/07	8.0	591	5483	124	514	620	60.4		26	3982	0.4	0.5	1.0	160	3826	1.5
T4 Dam		2012/08/07	7.8	550	4689	114	486	502	42.1		27	3377	0.4	0.5	1.0	145	3275	1.2
T4 Pump		2012/08/07	8.1	502	4166	97	397	439	36.8		24	2892	0.4	0.5	1.1	281	2793	3.9
Sprayer Dam		2012/08/07	8.3	510	4242	104	421	460	38.4		27	2906	0.3	0.5	1.0	289	2938	1.6
No.13		2012/08/07	6.7	50	304	13	30	27	5.3		7	196	0.1	0.1	0.1	25	186	3.7
R03	Bosman Spruit	2012/08/15	7.0	16	108	21	5	4	1.3		16	11	0.1	0.1	0.1	49	27	4.2
R02		2012/08/14	6.1	98	650	24	74	54	7.5		13	471	0.1	0.5	1.0	7	408	3.2
No.28		2012/08/07	5.6	101	653	28	89	41	12.7		38	419	0.1	0.5	1.3	6	392	3.0
ARN02		2012/08/07	7.5	73	514	38	52	49	5.7		18	288	0.1	0.5	1.0	67	330	4.1
No.10		2012/08/07	7.5	51	307	30	23	19	6.4		21	82	0.2	1.8	0.1	116	136	4.9
R04	Klein-Olifants River	2012/08/14	8.2	204	1519	60	184	144	14.0		33	953	0.1	0.5	1.0	135	1050	1.6
No.32		2012/08/07	7.7	212	1581	61	184	152	14.3		31	1012	0.2	0.5	1.0	131	1083	0.7
No.33		2012/08/07	8.1	202	1513	55	176	154	13.6		27	987	0.1	0.5	1.0	105	1069	2.1
R05	Woest-Alleen Spruit	2012/08/07	7.9	248	1921	69	206	194	16.5		36	1303	0.3	0.5	1.0	100	1311	0.4
R01	Non-perennial Stream	2012/08/07	7.8	242	1788	83	148	215	14.6		39	1218	0.1	1.4	1.0	65	1251	2.5
No.15	Pans near Pit 1	2012/08/07	7.2	491	4310	141	424	466	33.1		37	3055	0.1	0.5	1.0	158	2969	0.6
Steels Pan		2012/08/07	8.5	783	6335	546	98	649	348		437	2990	0.1	0.5	10.7	1259	2906	4.3
Bliksem Pan		2012/08/07	8.6	1105	7958	1571	82	489	132		1463	3432	1.1	0.5	1.0	785	2209	4.9

Table 42. Water quality table: surface water sites (minor parameters).

Site No.	Area	Date	Al mg/L	Ba mg/L	Br mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Mo mg/L	Ni mg/L	Pb mg/L	Si mg/L	Zn mg/L
Decant Dam	Dams within and near Pit 1	2012/08/07	0.002	0.016	*0.400*	*0.002*	*0.006*	0.006	0.065	0.509	*0.003*	*0.010*	*0.010*	3.122	0.020
Evap Dam		2012/08/07	0.011	0.012	*0.400*	*0.002*	*0.006*	0.007	0.052	0.012	*0.003*	*0.010*	*0.010*	1.978	0.017
Final Void		2012/08/07	0.011	0.013	*0.400*	*0.002*	*0.006*	0.009	0.053	0.967	*0.003*	*0.010*	*0.010*	2.733	0.022
No.09 - T1 Dam		2012/08/07	*0.001*	0.014	*0.400*	*0.002*	*0.006*	0.008	0.054	0.263	*0.003*	*0.010*	*0.010*	2.637	0.015
T2 Dam		2012/08/07	0.005	0.012	*0.400*	*0.002*	*0.006*	0.008	0.059	0.013	*0.003*	*0.010*	*0.010*	1.737	0.013
T3 Dam		2012/08/07	0.005	0.012	*0.400*	*0.002*	*0.006*	0.015	0.052	0.010	*0.003*	*0.010*	*0.010*	3.115	0.017
T4 Dam		2012/08/07	0.002	0.016	*0.400*	*0.002*	*0.006*	0.009	0.051	0.017	*0.003*	*0.010*	*0.010*	6.317	0.017
T4 Pump		2012/08/07	0.004	0.010	*0.400*	*0.002*	*0.006*	0.010	0.048	0.009	*0.003*	*0.010*	*0.010*	2.086	0.016
Sprayer Dam		2012/08/07	0.004	0.011	*0.400*	*0.002*	*0.006*	0.006	0.058	0.012	*0.003*	*0.010*	*0.010*	2.234	0.011
No.13		2012/08/07	0.006	0.025	0.111	*0.002*	*0.006*	0.007	0.057	0.011	*0.003*	*0.010*	*0.010*	0.946	0.020
R03	Bosman Spruit	2012/08/15	0.246	0.06	0.057	*0.002*	*0.006*	0.004	0.482	0.005	*0.003*	*0.010*	*0.010*	1.006	0.012
R02		2012/08/14	0.030	0.041	*0.400*	*0.002*	*0.006*	0.020	0.075	2.717	*0.003*	0.029	*0.010*	6.589	0.074
No.28		2012/08/07	0.027	0.054	*0.400*	0.154	*0.006*	0.012	0.060	19.583	*0.003*	0.14	*0.010*	12.837	0.382
ARN02		2012/08/07	0.012	0.034	*0.400*	*0.002*	*0.006*	0.009	0.058	0.015	*0.003*	*0.010*	*0.010*	1.661	0.014
No.10		2012/08/07	0.007	0.072	0.220	*0.002*	*0.006*	0.005	0.124	1.374	*0.003*	*0.010*	*0.010*	7.463	0.013
R04	Klein-Olifants River	2012/08/14	0.007	0.034	*0.400*	*0.002*	*0.006*	0.007	0.053	0.013	*0.003*	*0.010*	*0.010*	0.256	0.016
No.32		2012/08/07	0.013	0.035	*0.400*	*0.002*	*0.006*	0.008	0.054	0.015	*0.003*	*0.010*	*0.010*	0.148	0.022
No.33		2012/08/07	0.014	0.024	*0.400*	*0.002*	*0.006*	0.009	0.056	0.016	*0.003*	*0.010*	*0.010*	0.611	0.018
R05	Woest-Alleen Spruit	2012/08/07	0.016	0.024	*0.400*	*0.002*	*0.006*	0.018	0.054	0.012	*0.003*	*0.010*	*0.010*	0.190	0.022
R01	Non-perennial Stream	2012/08/07	0.009	0.037	*0.400*	*0.002*	*0.006*	0.011	0.058	0.014	*0.003*	*0.010*	*0.010*	3.052	0.022
No.15	Pans near Pit 1	2012/08/07	0.002	0.022	*0.400*	*0.002*	*0.006*	0.010	0.106	0.515	*0.003*	*0.010*	*0.010*	1.986	0.014
Steels Pan		2012/08/07	0.008	0.010	*0.400*	*0.002*	*0.006*	0.014	0.056	0.300	*0.003*	*0.010*	*0.010*	3.515	0.010
Bliksem Pan		2012/08/07	0.001	0.013	7.484	*0.002*	*0.006*	0.002	0.084	0.165	*0.003*	*0.010*	*0.010*	2.611	0.001

Table 43. Classification system used to evaluate water quality classes.

Quality of Domestic Water Supplies, DWA&F, Second Edition 1998	
Class 0	**- Ideal water quality** - Suitable for lifetime use.
Class 1	**- Good water quality** - Suitable for use, rare instances of negative effects.
Class 2	**- Marginal water quality** - Conditionally acceptable. Negative effects may occur in some sensitive groups
Class 3	**- Poor water quality** - Unsuitable for use without treatment. Chronic effects may occur.
Class 4	**- Dangerous water quality** - Totally unsuitable for use. Acute effects may occur.
South Africa Water Quality Guidelines, Volume 1: Domestic Use, DWA&F, First Edition 1993 & Second Edition 1996	
NR	**- Target water quality range** - No risk.
IR	**- Good water quality** - Insignificant risk. Suitable for use, rare instances of negative effects.
LR	**- Marginal water quality** - Allowable low risk. Negative effects may occur in some sensitive groups
HR	**- Poor water quality** - Unsuitable for use without treatment. Chronic effects may occur.

Table 44. Health and aesthetic effects associated with the water quality classes.

CLASS	DESCRIPTION	EFFECTS
CLASS 0	**Ideal water quality**	**Drinking Health:** No effects, suitable for many generations. **Drinking Aesthetic:** Water is pleasing. **Food preparation:** No effects. **Bathing:** No effects. **Laundry:** No effects.
CLASS 1	**Good water quality**	**Drinking Health:** Suitable for lifetime use. Rare instances of sub-clinical effects. **Drinking Aesthetic:** Some aesthetic effects may be apparent. **Food Preparation:** Suitable for lifetime use **Bathing:** Minor effects on bathing or on bath fixtures. **Laundry:** Minor effects on laundry or on fixtures.
CLASS 2	**Marginal water quality**	**Drinking Health:** May be used without health effects by the majority of individuals of all ages, but may cause effects in some individuals in sensitive groups. Some effects possible after lifetime use. **Drinking Aesthetic:** Poor taste and appearance are noticeable. **Food preparation:** May be used without health or aesthetic effects by the majority of individuals. **Bathing:** Slight effects on bathing or on bath fixtures. **Laundry:** Slight effects on laundry or on fixtures.
CLASS 3	**Poor water quality**	**Drinking Health:** Poses a risk of chronic health effects, especially in babies, children and the elderly. **Drinking Aesthetic:** Bad taste and appearance may lead to rejection of the water. **Food preparation:** Poses a risk of chronic health effects, especially in children and the elderly. **Bathing:** Significant effects on bathing or on bath fixtures. **Laundry:** Significant effects on laundry or on fixtures.
CLASS 4	**Unacceptable water quality**	**Drinking Health:** Severe acute health effects, even with short-term use. **Drinking Aesthetic:** Taste and appearance will lead to rejection of the water. **Food preparation:** Severe acute health effects, even with short-term use. **Bathing:** Serious effects on bathing or on bath fixtures. **Laundry:** Serious effects on laundry or on fixtures.

10.1.1 Water quality: groundwater monitoring sites, Pit 1

Apart from boreholes AW04, AW06 and AW31, all the groundwater sites on and near Pit 1 show clear signs of contaminant impacts (see Table 33 and Table 34). The sulphate concentrations in most boreholes are high enough to classify the groundwater as Class 4 water. Apart from the high sulphate concentrations, the groundwater of the affected sites displays high calcium, magnesium

and TDS concentrations and elevated EC values. High sodium concentrations are also observed at some boreholes. The origin of the high nitrate concentration at borehole AW24 is at present unknown.

The pH values at most of the sites range between 6.1 and 8.2. However, very acidic conditions are observed at borehole AW09 near the southern coal discard site. Both the samples taken at the static water level and at a depth of 17 mbc display pH values lower than 4.0. The acidic conditions have led to the mobilisation of some trace metals. High iron, manganese and lead concentrations are observed in the deeper groundwater sample from AW09 (see Table 34). It therefore appears that the coal discards are responsible for the generation of acidic conditions. The reason for the high iron concentrations observed at borehole C-3 is at present unknown.

High manganese concentrations are, however, observed in all the affected sites, even where alkaline conditions prevail. It therefore appears that an elevated manganese concentration may be seen as a first indicator of impacts from mining activities. The low concentrations of the minor parameters seen in boreholes AW04, AW06 and AW31 again show that these boreholes are the least affected by contaminants originating from Pit 1.

The concentrations of the major parameters at many of the sites clearly show stratification in the groundwater quality. Samples taken at the static water level generally have lower concentrations of the major parameters than the deeper samples. This is evident at boreholes ANT-1, ANT-2, ANT-3, AW02, AW03, AW09, AW24 and C-4. The lower concentrations for the samples from the static water level may be explained by the diluting effect of rainfall entering the borehole either directly or through seepage through the near-surface materials. However, at other affected sites (AW01, AW07, AW08, AW20, C-3 and C-5) the shallow and deep samples have very similar chemical signatures. The EC profiles of these boreholes (see Appendix C) generally support these observations.

From the data listed in Table 33 and Table 34 the major parameters sulphate, magnesium, calcium, total hardness, EC and TDS may be identified as indicator parameters to use when evaluating whether a groundwater site has been impacted on by inorganic contaminants originating at Pit 1. Similarly, the minor parameters iron and manganese may be considered as indicator parameters.

10.1.2 Water quality: groundwater monitoring sites, Pit 2

Compared to the groundwater sites at Pit 1, the groundwater sites in and in the vicinity of Pit 2 (W and E) are much less affected by contaminant impacts. Judging from the concentrations of the major parameters, only boreholes AW25 and AW26 show clear evidence of contaminant impacts with elevated sulphate, calcium, magnesium and TDS concentrations and high EC values. There

are also indications of lesser impacts at sites AW05, KGM_B12 and R-2. In addition, the concentrations of the minor parameters suggest contaminant impacts at sites AW28 and KGM_B11 where elevated iron concentrations are observed. Elevated ammonium concentrations are observed at site AW28 north of Pit 2E. The reason for the observed ammonium concentrations is not known at present.

The pH values at the groundwater sites near Pit 2 generally vary between 6.6 and 7.4, although slightly more acidic conditions do prevail near sites AW22 (5.8), AW23 (5.8) and KGM_B11 (6.2).

Elevated manganese concentrations are again observed at most sites, even at those sites that show no other evidence of contaminant impacts. This observation again supports the idea that the manganese concentration may be used as the first indicator for contaminant impacts on the groundwater.

It is interesting to note the presence of elevated fluoride concentrations at sites W04 and AW05, north of Pit 2W. Fluoride is often associated with dolerite, and the observed concentrations may be due to an intrusive dolerite structure in the area north of the pit. The presence of dolerite in this area was suggested by the magnetic data recorded along Traverse 01 near the corridor between Pit 2W and Pit 2E (to be discussed in Section 14).

10.1.3 Water quality: groundwater from the Alzu boreholes

The groundwater quality at the Alzu boreholes is generally better that the water quality observed at the monitoring boreholes near Pit 1 (refer to Table 37 and Table 38). This may be partly explained by the fact that the Alzu boreholes are/were production boreholes drilled to greater depths than the monitoring boreholes. Whereas the monitoring boreholes typically have depths of 40 m, some of the Alzu boreholes extend to depths of 60 m (BHZ08) and 70 m (BHZ04). These boreholes therefore intersect the rhyolites that underlie the Karoo rocks and possibly water-bearing fractures within the rhyolites.

Elevated sulphate concentrations are observed at boreholes BHZ08 and BHZ09. The deeper sample from BHZ09 is much more contaminated than the shallow sample with very high sulphate and magnesium concentrations. The high fluoride concentrations at the Community Borehole and Piet's Pump may be related to dolerite intrusions, although at present no information on such structures near these boreholes is available.

The pH values at the Alzu boreholes generally indicate alkaline conditions. Only at borehole BHZ09 is a slightly lower pH observed (6.5), but the conditions remain near-neutral Apart from elevated manganese concentrations at some boreholes, the minor parameters concentrations at the Alzu boreholes are very low, indicating that little or no mobilisation of trace elements has occurred.

10.1.4 Water quality: groundwater from the new boreholes

High levels of contamination are evident at new boreholes B4, B6 and B10 where very high concentrations of sulphate, calcium and magnesium are present (refer to Table 39 and Table 40). Boreholes B4 and B10 were drilled within the spoils of Pit 1. Since water flow in Pit 1 is generally from south-east to north-west, the observed water qualities at these boreholes are representative of the pit water quality upstream (B10) and downstream (B4) from the coal discards. The concentrations of all the major parameters are seen to be higher at B4 than at B10, indicating that the coal discards are contributing to water contamination within Pit 1.

The contaminant impacts at B6 are to be expected since this borehole occurs immediately adjacent to the Final Void. Seepage is likely to have affected the groundwater quality in the near vicinity of the dam.

Evidence for lesser contaminant impacts can be seen in the elevated sulphate concentrations at boreholes B1 and B11. These two boreholes respectively occur north of Pit 2E and Pit 2W. Borehole B1 displays elevated fluoride concentrations, similar to those observed at site W04 and AW05. Since these three sites all occur north of Pit 2W it seems that the observed fluoride concentrations have the same origin, possibly a nearby dolerite intrusive.

10.1.5 Water quality: surface water sites

In Table 41 and Table 42 the surface water sites are grouped together according to their types (dams, pans and rivers) and their positions relative to Pit 1.

From the data listed in these tables it is clear that all the dams within Pit 1 contain water that has been exposed to extensive contaminant impacts. Sulphate concentrations are higher than 2 800 mg/*l*, while high concentrations of calcium and magnesium are also observed. Only site No.13, a farm dam south-west of the T3 Dam, contains good quality water with little or no evidence for contaminant impacts.

The pans in the vicinity of Pit 1 contain water of a quality similar to the dams within Pit 1. Again the sulphate and magnesium concentrations are extremely high, but in addition very high sodium, chloride and potassium concentrations are also observed in the Bliksem Pan. This pan did in the past receive decant from the T1 Dam in the form of controlled release. It has a large surface area and the concentrating effect of high evaporation losses can therefore be expected. However, the high sodium, chloride and potassium concentrations do seem to have another source since the concentrations observed in the Bliksem Pan are much greater than those observed in the dams within Pit 1. A possible source may be the chicken pens of Alzu which are located approximately 400 m upstream from the pan.

The Steels Pan is highly contaminated. This pan is, however, used to dispose of the liquid wastes generated at Alzu's piggery. The observed high phosphate concentration is thus explained. Similar to the Bliksem Pan, high sodium, chloride and potassium concentrations are present in the water from this pan. The high sulphate and magnesium concentrations suggest that contaminants from Pit 1 have impacted on the water quality in the pan, either through surface runoff or subsurface seepage.

The No.15 pan is a non-perennial pan north-west of Pit 1 and east of Alzu's packing station. The water quality in the pan indicates that contaminant impacts have occurred on this surface water body. High sulphate and magnesium concentrations suggest that contaminated water from Pit 1 has negatively impacted on the water quality of this pan. However, activities at Alzu may also have contributed to the observed salt loads.

The current water qualities at the various monitoring sites of Arnot Closed Colliery are displayed graphically as maps of the sulphate concentrations recorded at the surface water sites (Figure 32) and groundwater sites in the vicinity of Pit 1 (Figure 33) and Pit 2 (Figure 34). From Figure 32 it is seen that the surface water sites within Pit 1 are heavily contaminated, as expected. Contaminant impacts on the pans west of Pit 1 are also apparent. The Klein-Olifants River and Woestalleen Spruit are also seen to be more contaminated than the Bosman Spruit.

From the distribution of contaminated groundwater sites within and around Pit 1, it appears that contaminant migration through the subsurface has been limited (refer to Figure 33). The sulphate plume does not appear to extend far beyond the boundaries of the backfilled opencast pit. Apart from borehole AW09, all the boreholes to the south of Pit 1 are seen to contain water of a good quality. Borehole AW06 occurs within 350 m from the northern pit boundary, but appears unaffected by contaminant impacts. A similar observation can be made regarding the water quality at borehole AW31 which is located within 350 m from the western boundary of the pit.

However, high sulphate concentrations in the boreholes north of the T1 Dam and Decant Dam indicate that contaminant migration has occurred in this direction. Borehole AW20 occurs within a pan and the water level in this borehole corresponds to the water level in the pan. The high sulphate concentrations observed in the water from this borehole may be due to contaminated surface water entering the subsurface along the borehole.

In Figure 34 it is seen that the groundwater in the vicinity of Pit 2 (W and E) has not been as strongly impacted on as the groundwater near Pit 1. Only the westernmost two boreholes (AW25 and AW26) display unacceptably high sulphate concentrations. However, these two boreholes occur within the spoils of Pit 2W and high sulphate concentrations are to be expected.

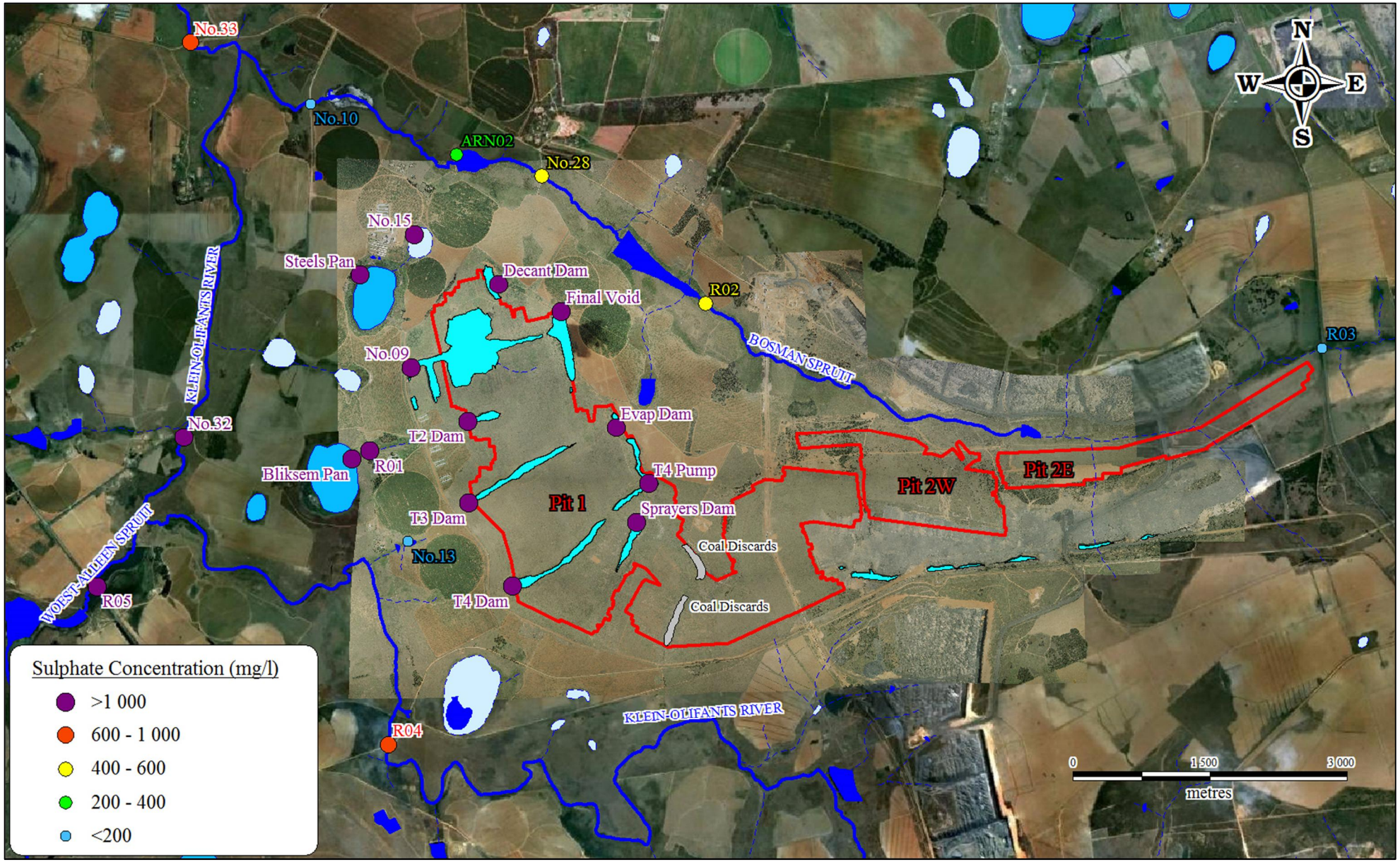


Figure 32. Sulphate concentrations at the various surface water sites (August 2012).

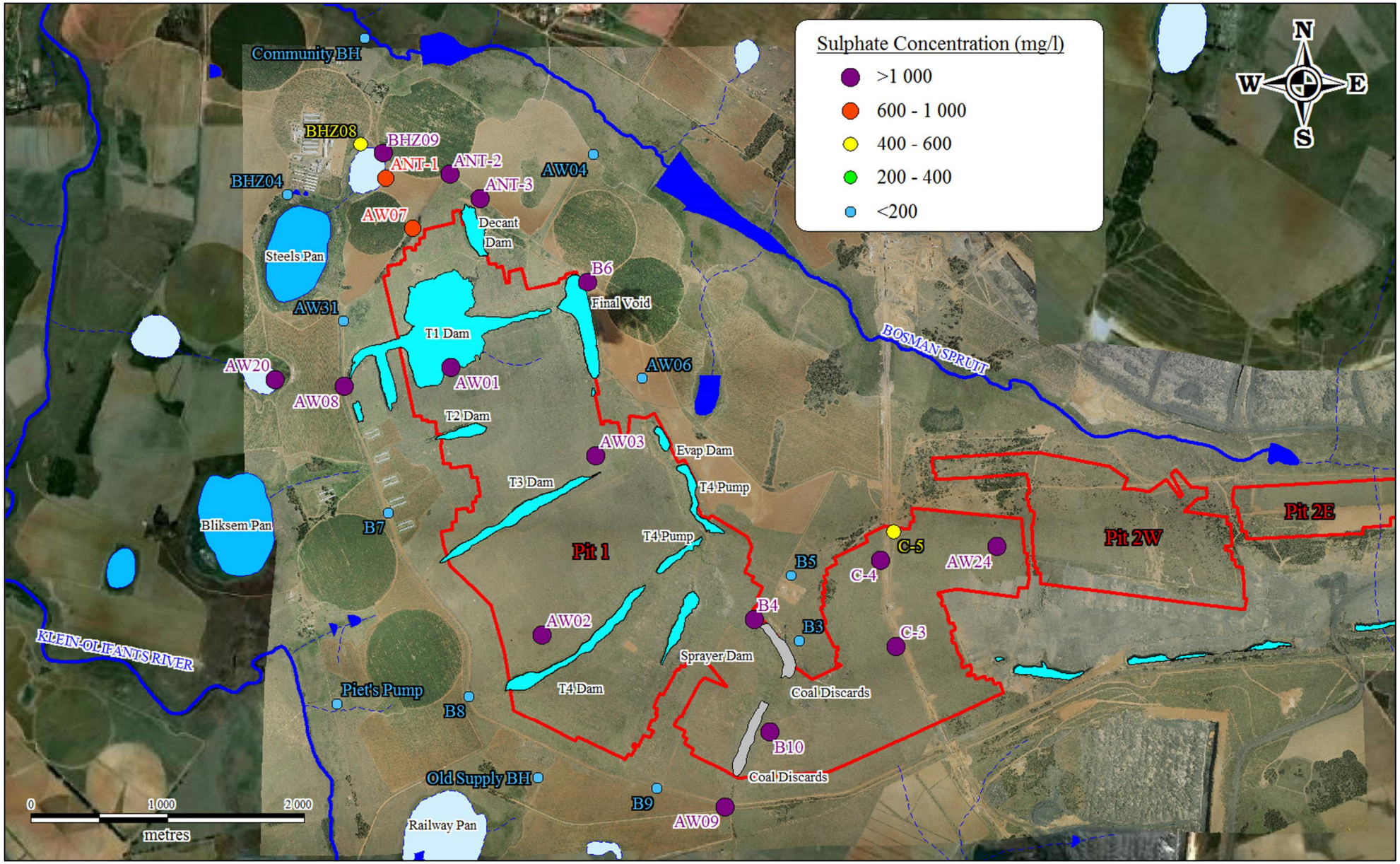


Figure 33. Sulphate concentrations at the various groundwater sites within and near Pit 1 (August 2012).

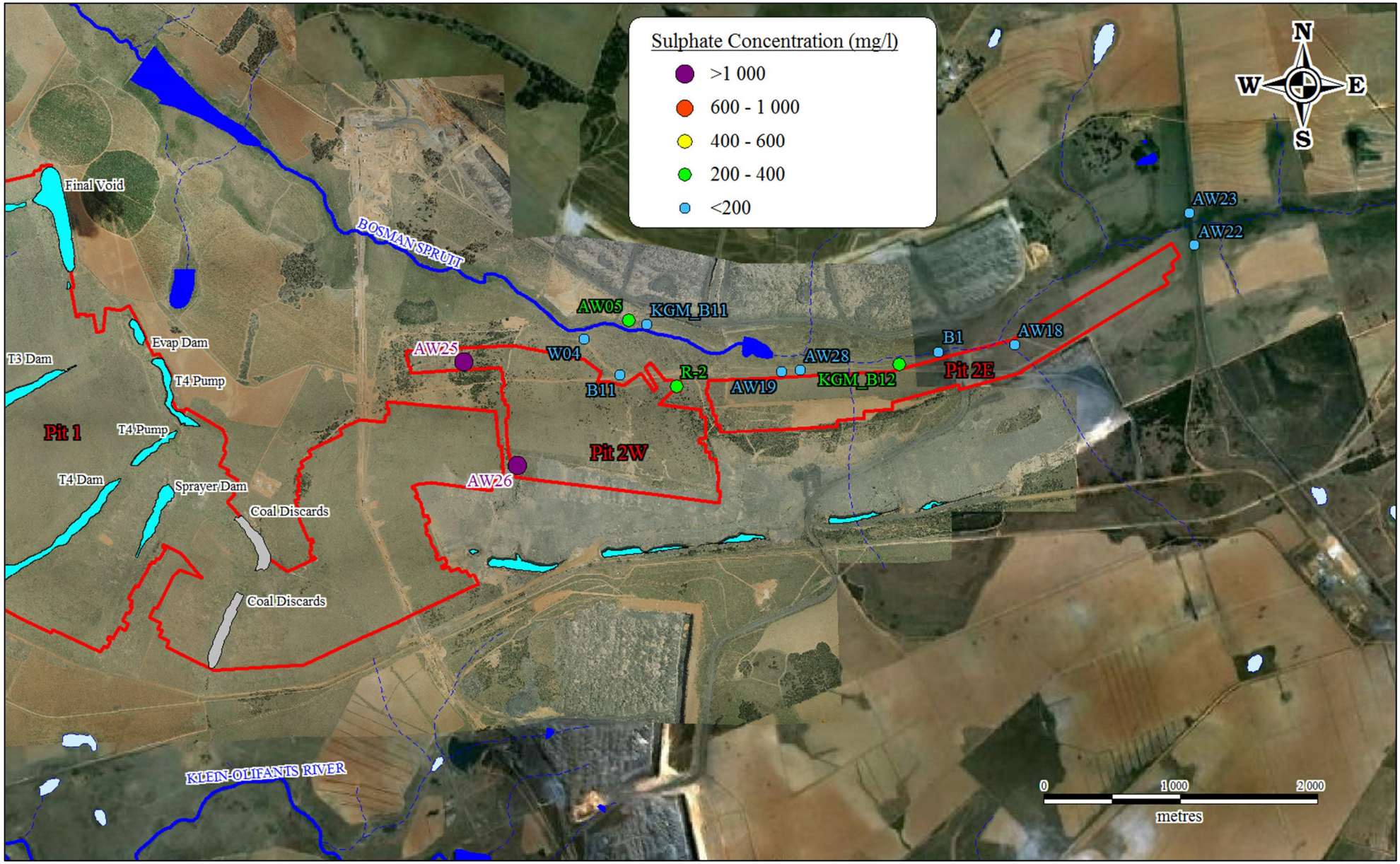


Figure 34. Sulphate concentrations at the various groundwater sites within and near Pit 2 (August 2012).

The water quality at sampling sites along the Bosman Spruit indicates that contaminant impacts have occurred on this river. The most upstream site (R03) has a sulphate concentration of only 11 mg/*l*, while the more downstream sites R02 and No.28 have sulphate values in excess of 400 mg/*l*. It should be emphasised that the water samples at the various sites were taken during the dry season (August 2012) and that the water at these sites was stagnant or flowing slowly. Evaporation losses may therefore have caused increases in the salt loads. It should also be noted that the Bosman Spruit may be impacted on by contaminants from both Arnot Closed Colliery and the adjacent Kwagga Section of Optimum Colliery (refer to Figure 2).

The sulphate concentrations along the Bosman Spruit are shown as a graph in Figure 35. It is seen that the sulphate concentration increases by more than 400 mg/*l* from site R03 to site R02. This implies that contaminants are reaching the Bosman Spruit somewhere between these two sits. Further downstream the sulphate concentration is seen to decrease through sites No.28 and ARN02 until the concentration at site No.10 reaches a value of only 82 mg/*l*. These observations suggest that clean water is reaching the Bosman Spruit at positions downstream from site R02. A number of non-perennial stream are known to be confluent with the Bosman Spruit downstream from R02 (see Figure 32). Water from these streams may be responsible for the observed dilution effect.

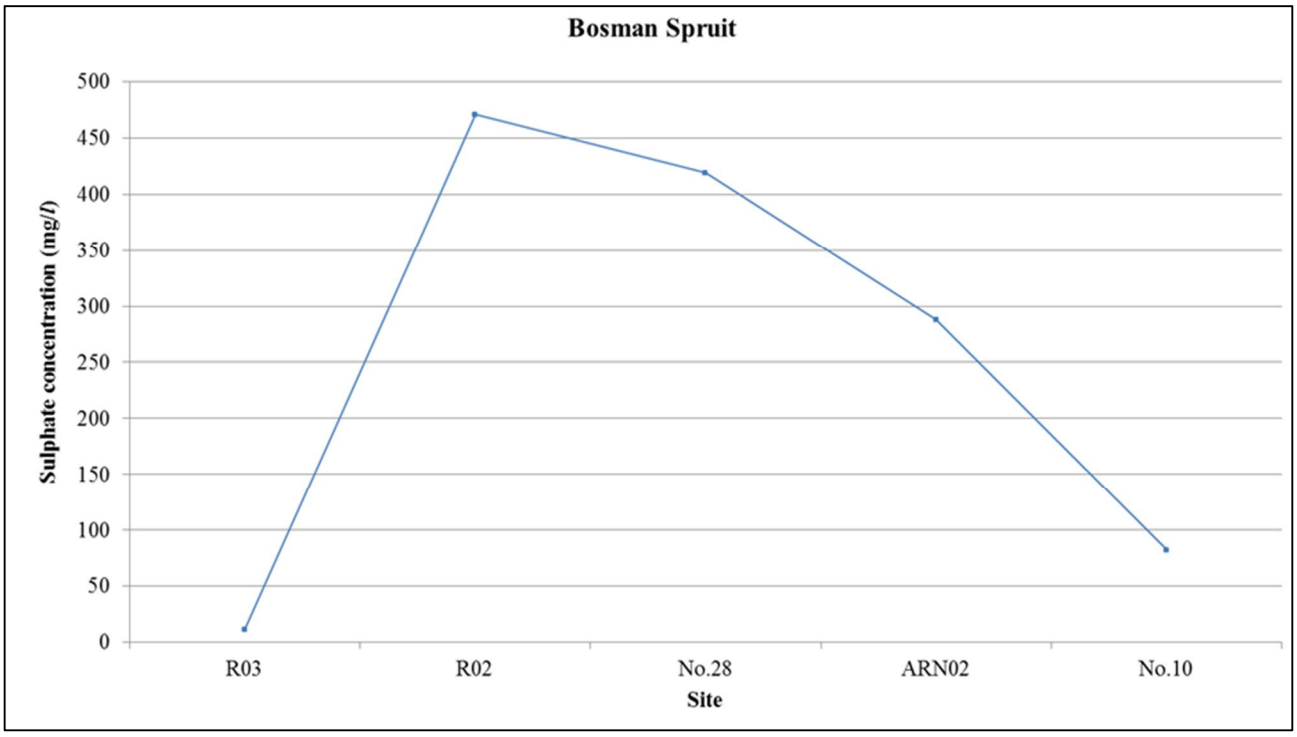


Figure 35. Sulphate concentrations along the Bosman Spruit.

The Klein-Olifants River is much more severely affected by contaminant impacts than the Bosman Spruit. Sulphate concentrations in excess of 950 mg/*l* are observed at all three sampling sites along this river. Site R04 is the most upstream site sampled during the latest sampling run. It is, however, not entirely upstream from Arnot Closed Colliery since contaminants from Pit 1 may

reach the river at positions farther to the east than site R02 (refer to Figure 32). Other mines farther upstream are also likely to have affected the water quality in this river.

The sulphate concentrations at the three sampling positions along the Klein-Olifants River are shown as a graph in Figure 36. The water quality at site No.32 is poorer than at site R04. This could indicate that contaminants originating at Pit 1 reach the river somewhere downstream from site R04. However, site No.32 occurs downstream from the position where the Woestalleen Spruit is confluent with the Klein-Olifants River. The high sulphate concentration observed at site R05 in the Woestalleen Spruit shows that this river has also been subject to contaminant impacts. Since the sulphate concentrations at site R05 is higher than at site R04, the increase in the sulphate concentration from site R04 to No.32 may be due to the confluence of the more contaminated Woestalleen Spruit.

A slight decrease in the sulphate concentration from site No.32 to No.33 is observed. This decrease may be due to the confluence of the Bosman Spruit with the Klein-Olifants River. As noted above, the sulphate concentration in the Bosman Spruit at site No.10 is low (82 mg/*l*) and dilution effects can therefore be expected at the confluence of the two rivers.

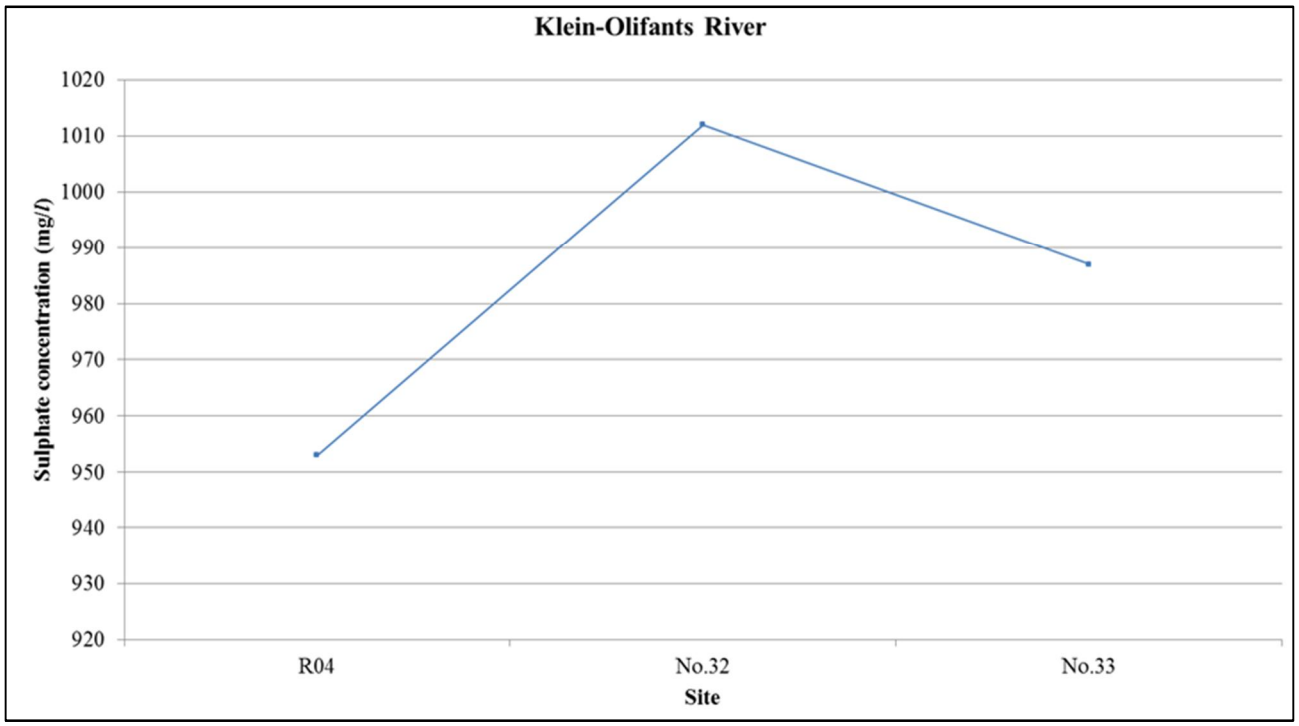


Figure 36. Sulphate concentrations along the Klein-Olifants River.

The non-perennial stream flowing into the Bliksem Pan is highly contaminated with a sulphate concentration of 1 218 mg/*l*. This is a clear indication that contaminants from Pit 1 are still impacting on the water quality of this pan.

10.2 Historical Water Quality Data

Water quality data dating back to the year 2000 was obtained from the database of Arnot Closed Colliery. These data appear in **Appendix E** and may be used along with the water quality data from the August 2012 sampling event to identify trends in the water quality at the various sites. It should be emphasised that the historical data are quite sparse and that the ion balance errors for many of the analyses are very large, indicating poor data quality. The reliability of the data may therefore be questioned. In addition, many of the sites listed in the database of Arnot Closed Colliery have names that do not correspond to the current site names and do not have coordinates to assist in locating the positions of these sites. Such sites were excluded from the data shown in **Appendix E**.

Since sulphate is the most significant indicator of contaminant impacts at Arnot Closed Colliery, only the trends in the sulphate concentrations and pH values at the different sites are considered in this section.

10.2.1 Surface water sites: dams and pans within and near Pit 1

The sulphate concentrations at the dam and pan sites within and in the vicinity of Pit 1 are shown as temporal graphs in Figure 37, while the pH values are shown in Figure 38. Large variations in the observed sulphate concentrations are apparent at Bliksem Pan, Steels Pan, the Decant Dam and the T1 Dam (sample No.09). These variations are to be expected at the pans where seasonal changes in the water volumes may cause fluctuations in the observed salt concentrations.

The sulphate concentration at the Final Void appears to have remained constant since 2006, but only two measurements are available. Although the water in the Bliksem Pan and Decant Dam had much lower sulphate concentrations during past sampling events, all the sampled surface water sites displayed sulphate concentrations in excess of 2 800 mg/*l* during the August 2012 sampling run.

The pH values at the surface sites within and near Pit 1 have generally remained above the neutral value of 7 since 2002. Only the T1 Dam (site No.09) and the Decant Dam have contained water with slightly lower pH values at times in the past. These pH values have, however, remained above 6, indicating that only slightly acidic conditions prevailed in these dames during these sampling events.

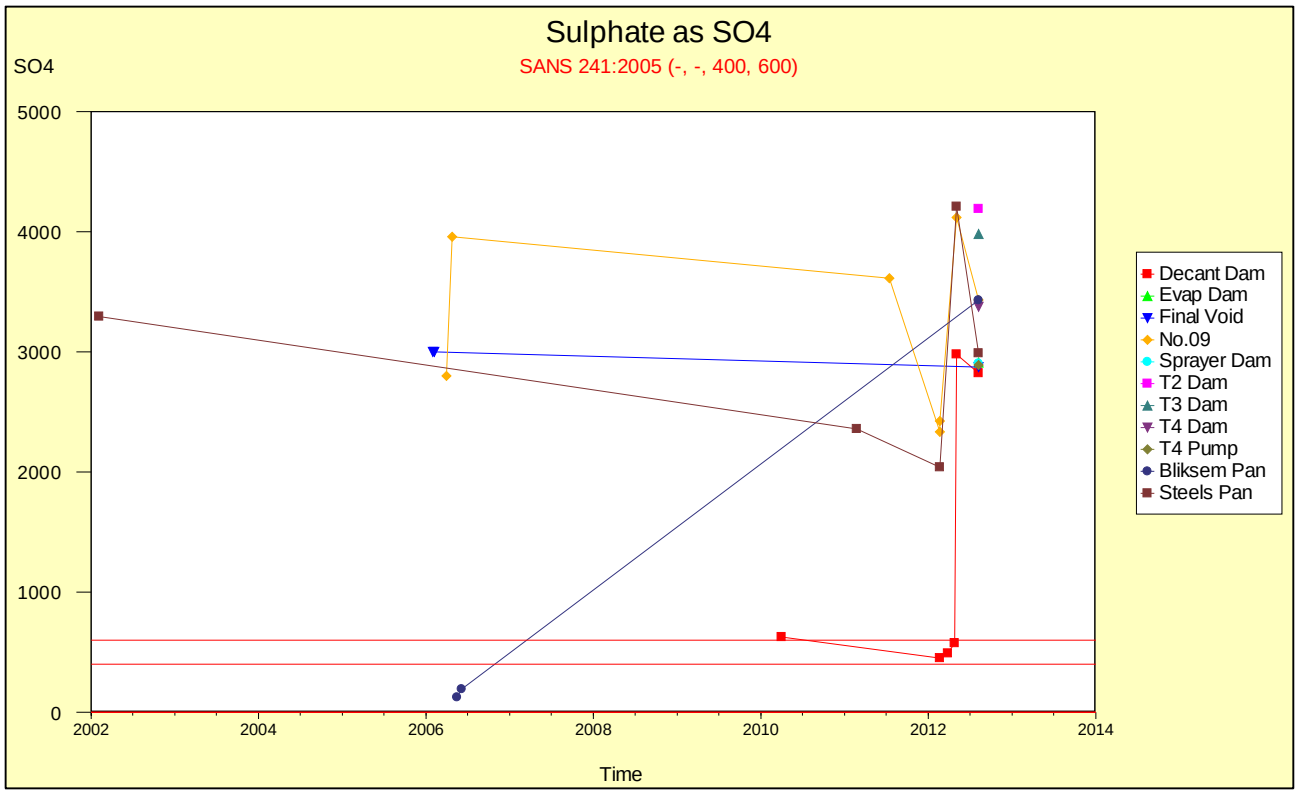


Figure 37. Sulphate concentrations at the dam and pan sites within and near Pit 1.

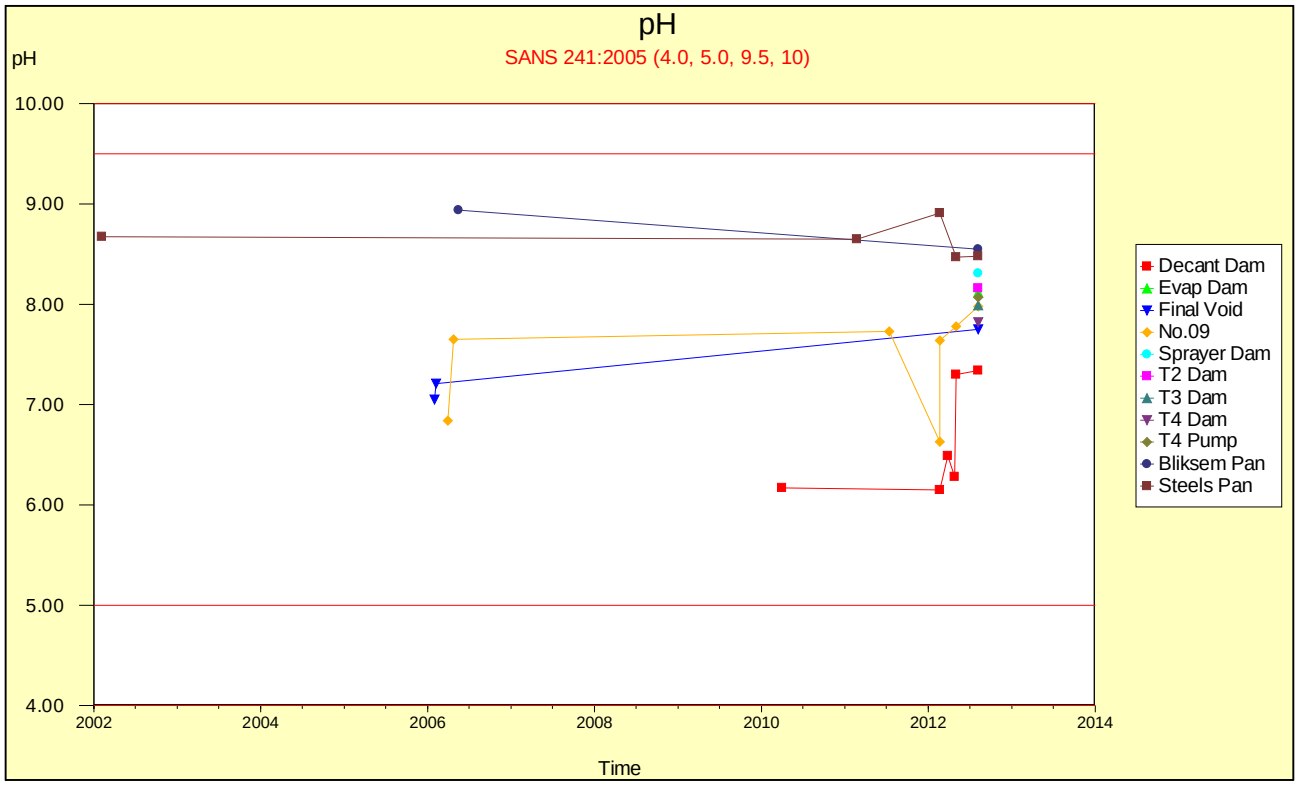


Figure 38. pH values at the dam and pan sites within and near Pit 1.

10.2.2 Groundwater monitoring sites within and near Pit 1

The sulphate concentrations and pH values at the groundwater monitoring sites within and in the vicinity of Pit 1 are shown as temporal graphs in Figure 39 and Figure 40. Large variability on the sulphate concentrations is observed at many of the sites. Increasing trends in the sulphate

concentrations are apparent for boreholes ANT-2, AW01, AW02, AW03, AW09, AW20 and AW24, indicating that the contaminant levels at these boreholes have increased over the time spanned by the sampling runs. Boreholes AW01, AW02, AW03 and AW24 occur within the spoils of Pit 1. The deteriorating water quality at these sites shows how the water quality within Pit 1 has been degrading over time.

The large variability in the sulphate concentrations observed at borehole AW08 may be due to its proximity to the T1 Dam. Increased seepage from the dam may be impacting on the groundwater quality in the vicinity of this borehole at times when higher water levels in the dam lead to higher hydraulic gradients and increased subsurface flow.

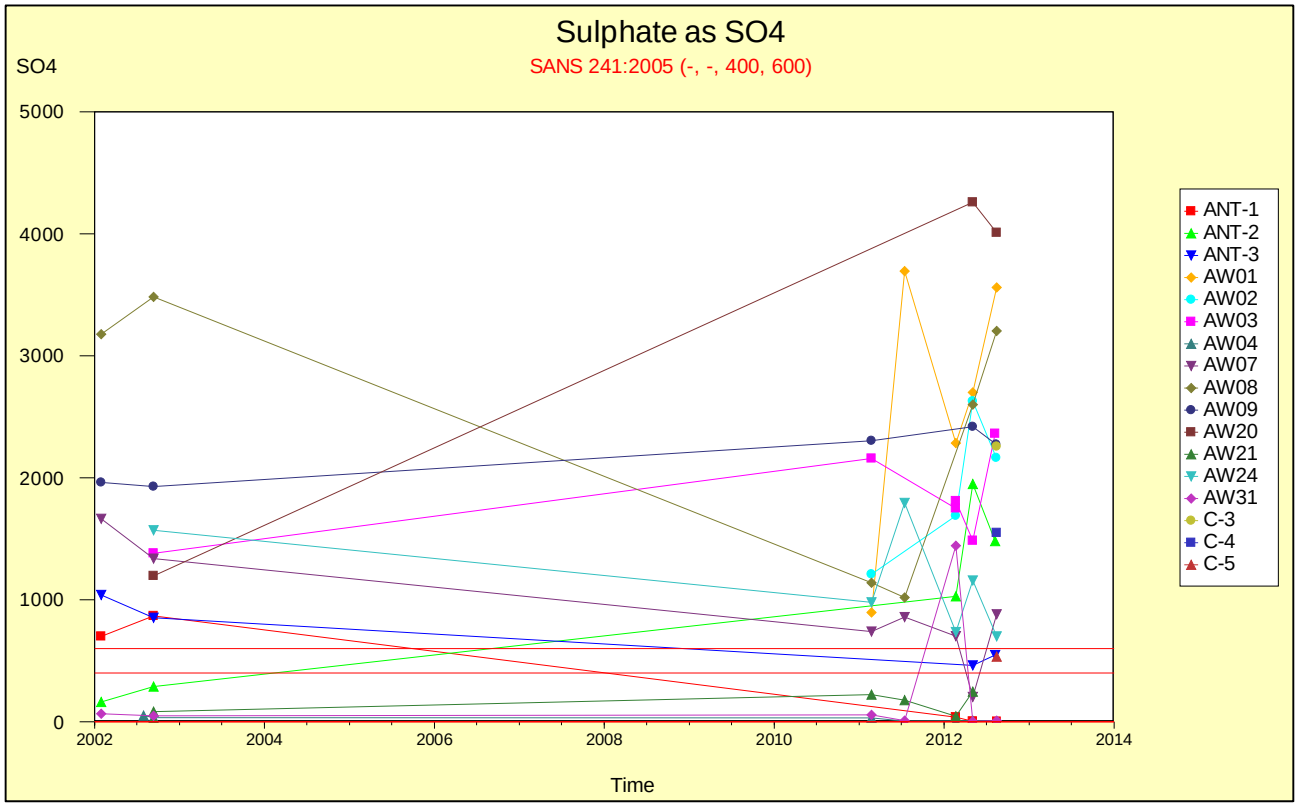


Figure 39. Sulphate concentrations at the groundwater sites within and near Pit 1.

Although large variability in the pH values is observed at most groundwater sites, the pH values at many of the groundwater sites display long-term decreasing trends. Such trends are particularly evident at boreholes AW09, AW20 and AW21. The decreasing pH at site AW09 is of concern as it suggests that the coal discards near this site are responsible for acid generation.

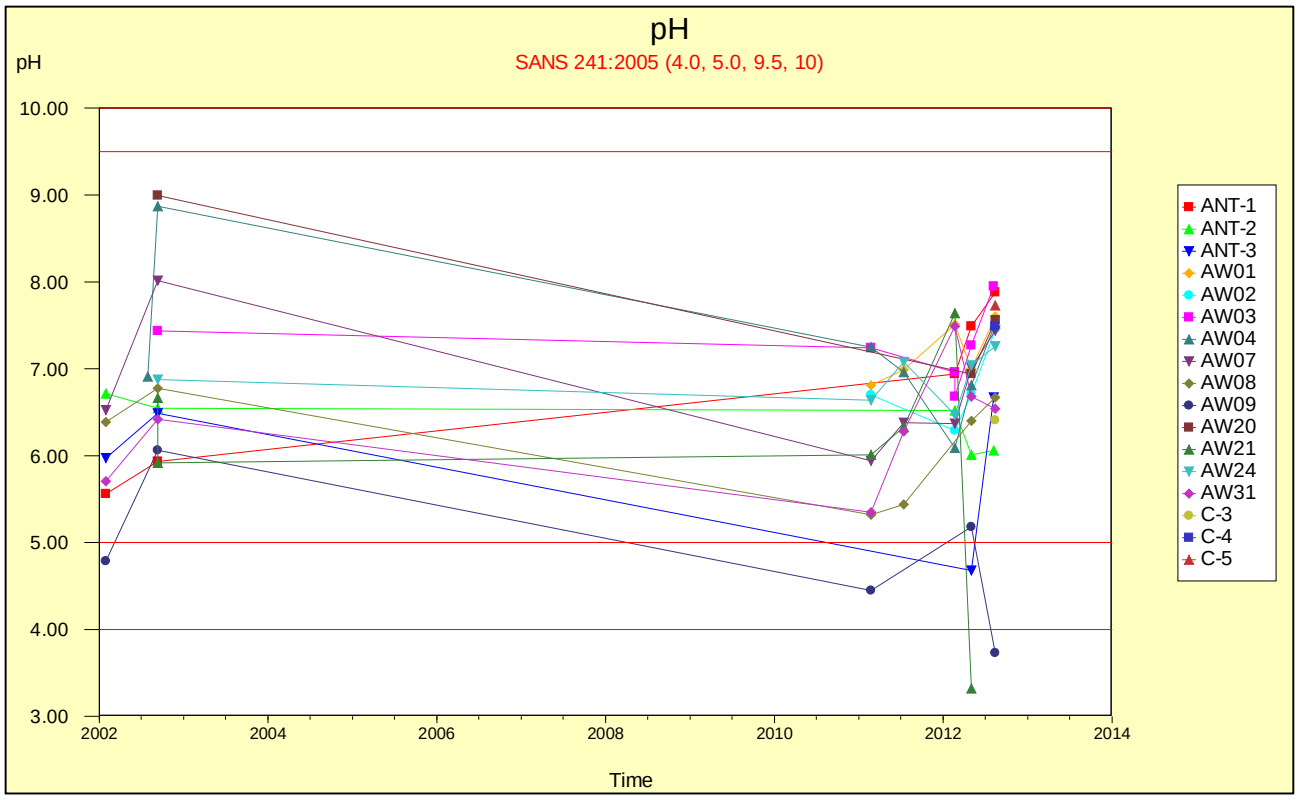


Figure 40. pH values at the groundwater sites within and near Pit 1.

10.2.3 Alzu boreholes

The sulphate concentrations and pH values at the production boreholes of Alzu are shown as temporal graphs in Figure 39 and Figure 40.

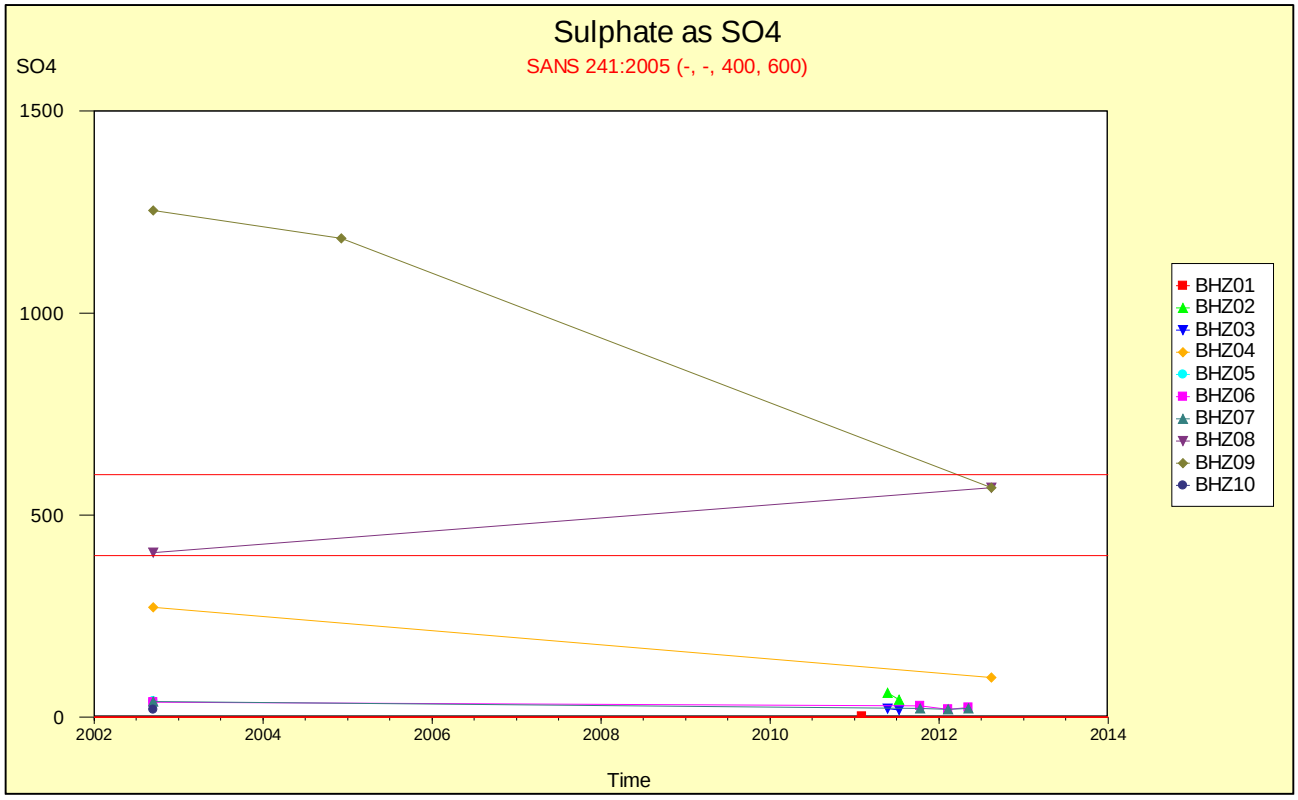


Figure 41. Sulphate concentrations at the Alzu boreholes.

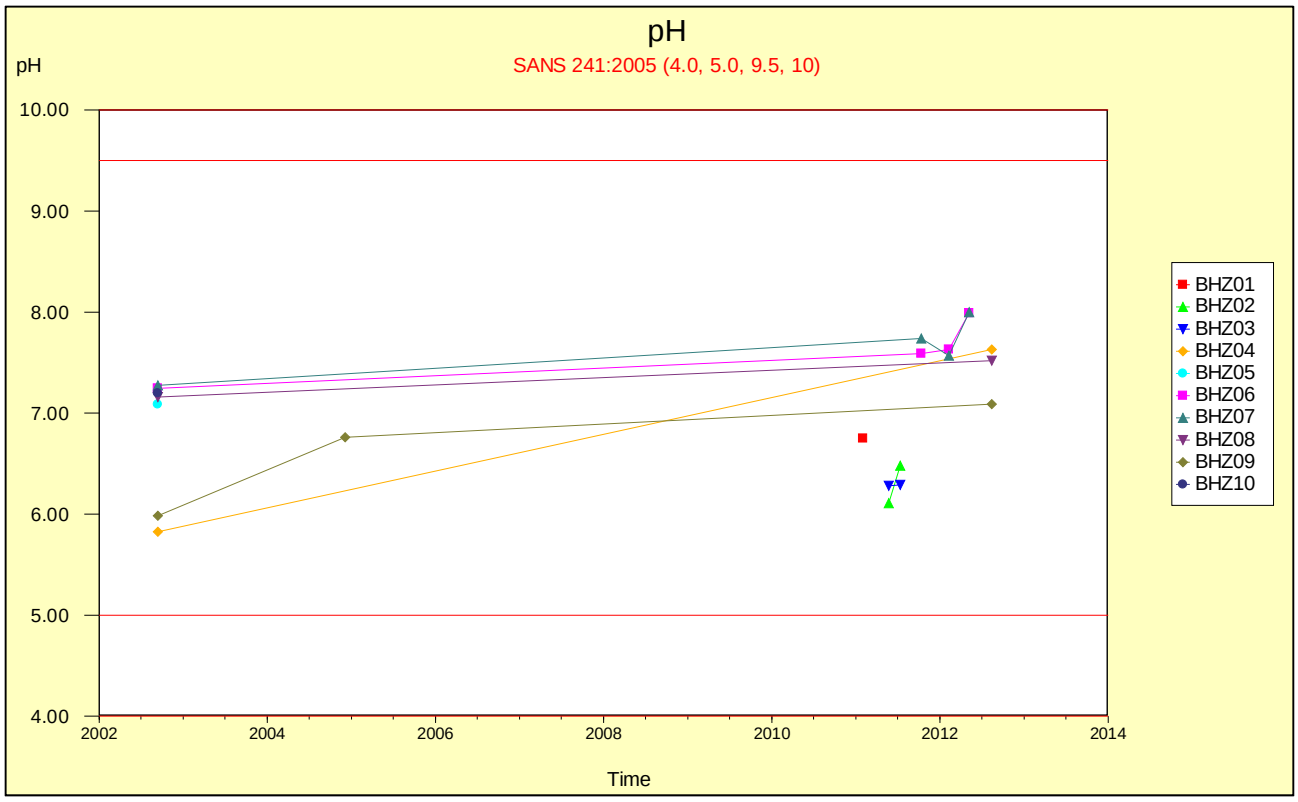


Figure 42. pH values at the Alzu boreholes.

Decreasing trends in the sulphate concentrations are evident at boreholes BHZ04 and BHZ09, suggesting that the intensity of contaminant impacts on the groundwater near these boreholes has decreased over time. However, an increasing trend is apparent at borehole BHZ08. Since boreholes BHZ08 and BHZ09 occur in close proximity to one another, the different trends in the sulphate concentrations at these boreholes is puzzling.

Stable or increasing trends in the pH values are apparent for all the Alzu boreholes for which more than one pH value is available. This observation shows that possible acid generation at Pit 1 has not had significant impacts on the groundwater sites of Alzu.

10.2.4 Groundwater sites within and near Pit 2

The sulphate concentrations at the groundwater sites within and in the vicinity of Pit 2 are shown as temporal graphs in Figure 43, while the pH values at these sites are shown in Figure 44. Large variability in the sulphate concentrations are again seen for many of the groundwater sites, particularly sites W04 and AW25. A decreasing trend at site AW19 suggests that the contaminant levels in the groundwater north of Pit 2E have decreased over time.

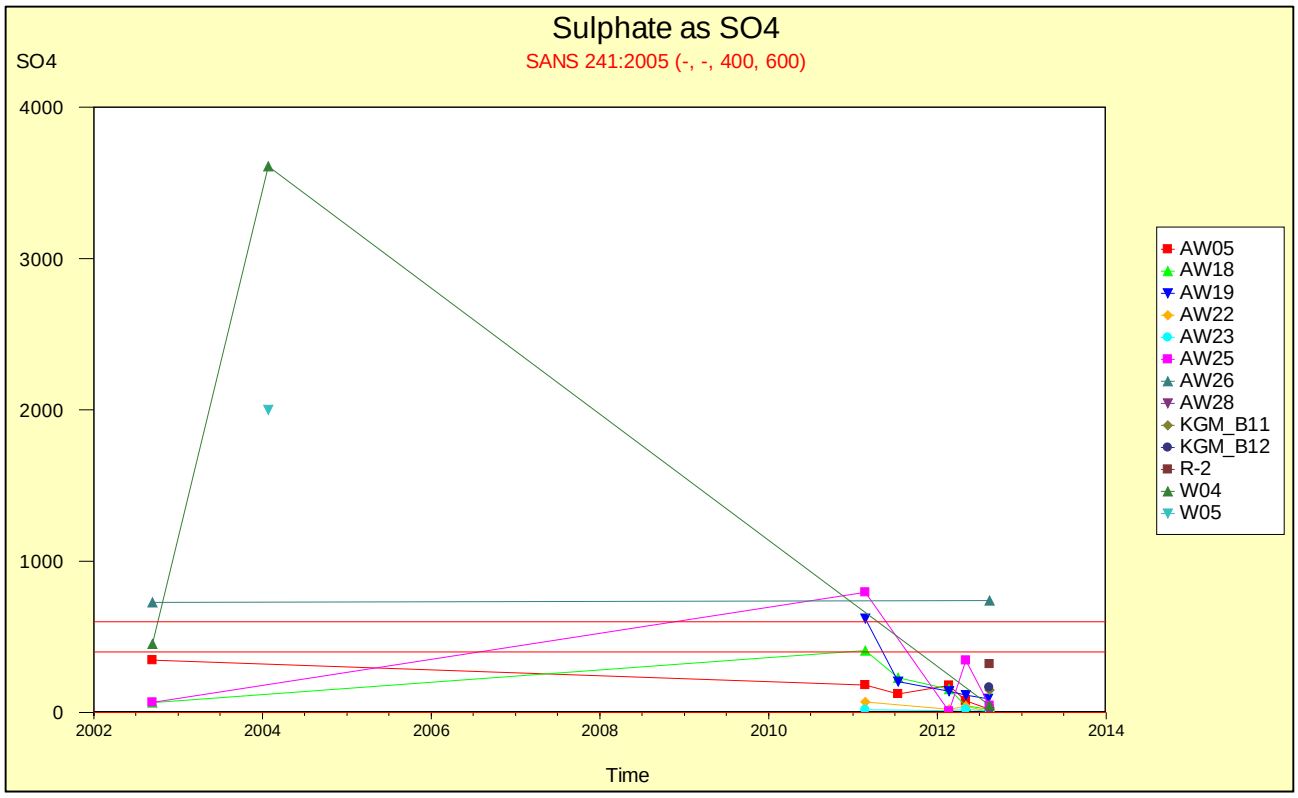


Figure 43. Sulphate concentrations at the groundwater sites within and near Pit 2.

The pH values at the groundwater sites within and near Pit 2 have been mostly stable during the time spanned by the sampling runs. Notable exceptions are sites W04, AW05 and AW19 where large variations have occurred at times. Site W04 is known to have contained acidic water in the past.

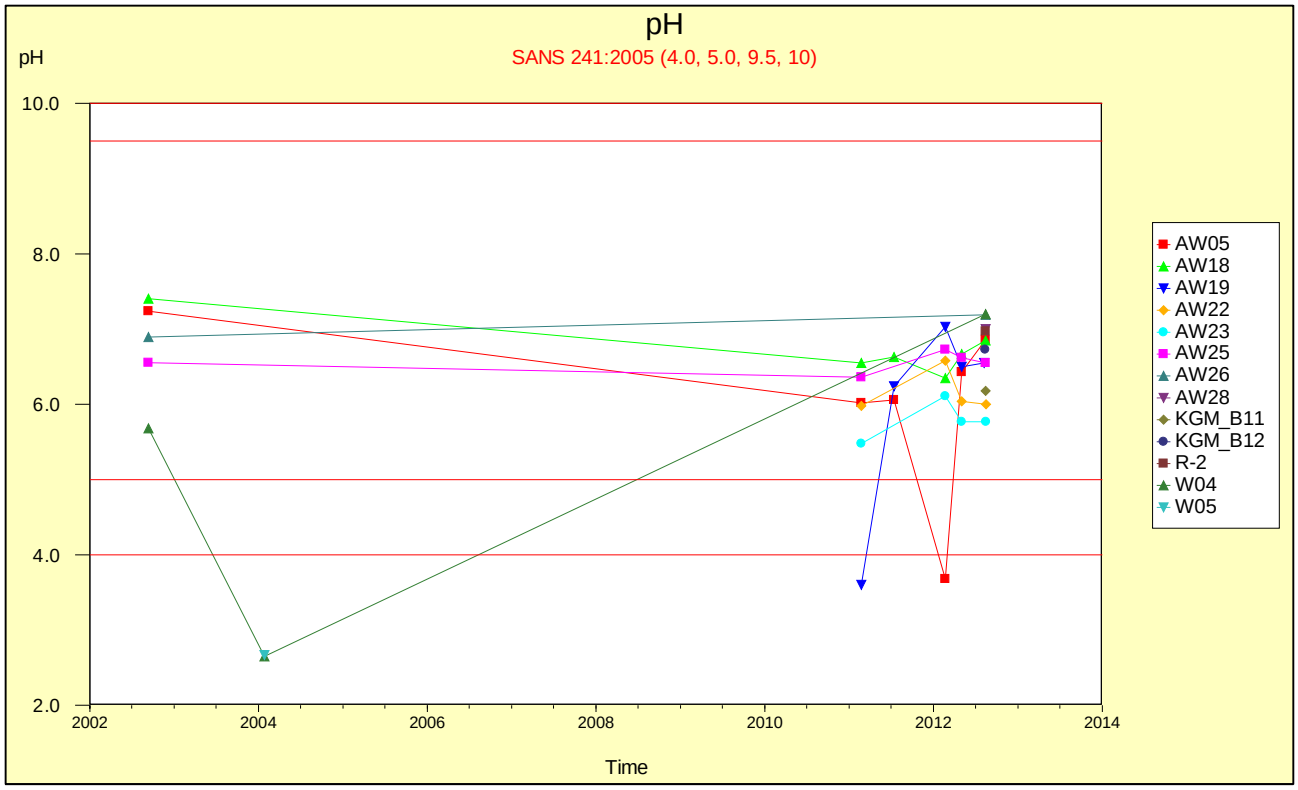


Figure 44. pH values at the groundwater sites within and near Pit 2.

10.2.5 River and stream sites

The sulphate concentrations at the river and stream sites are shown as temporal graphs in Figure 45 Figure 46. Unfortunately these sites have been sampled only a few times since 2000 and temporal data for only three sites in the Klein-Olifants River are available. Large variations in the sulphate concentrations are particularly apparent at sites No.32 and No.33. These variations are to be expected since seasonal rainfall causes the rivers to flow at significantly different rates during different times of the year. Site No.10 is seen to have significantly lower sulphate concentrations than the two up-stream sites.

Although some variations are observed, the pH values at the three river sites within the Klein-Olifants River have remained neutral to slightly alkaline over the time spanned by the sampling events. It therefore appears that the Klein-Olifants River has not subject to significant impacts of acidified waters due to activities at the various coal mines past which the river and its tributaries flow.

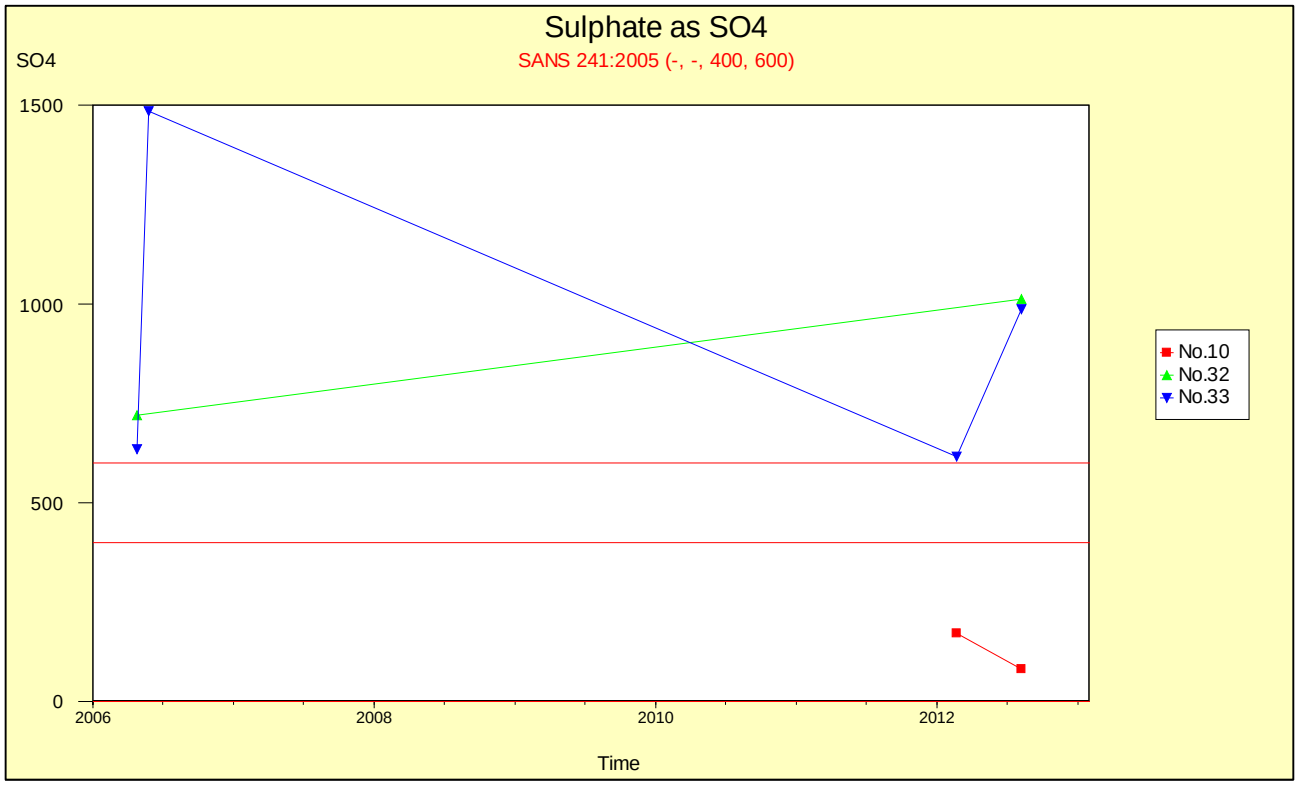


Figure 45. Sulphate concentrations at the river and stream sites.

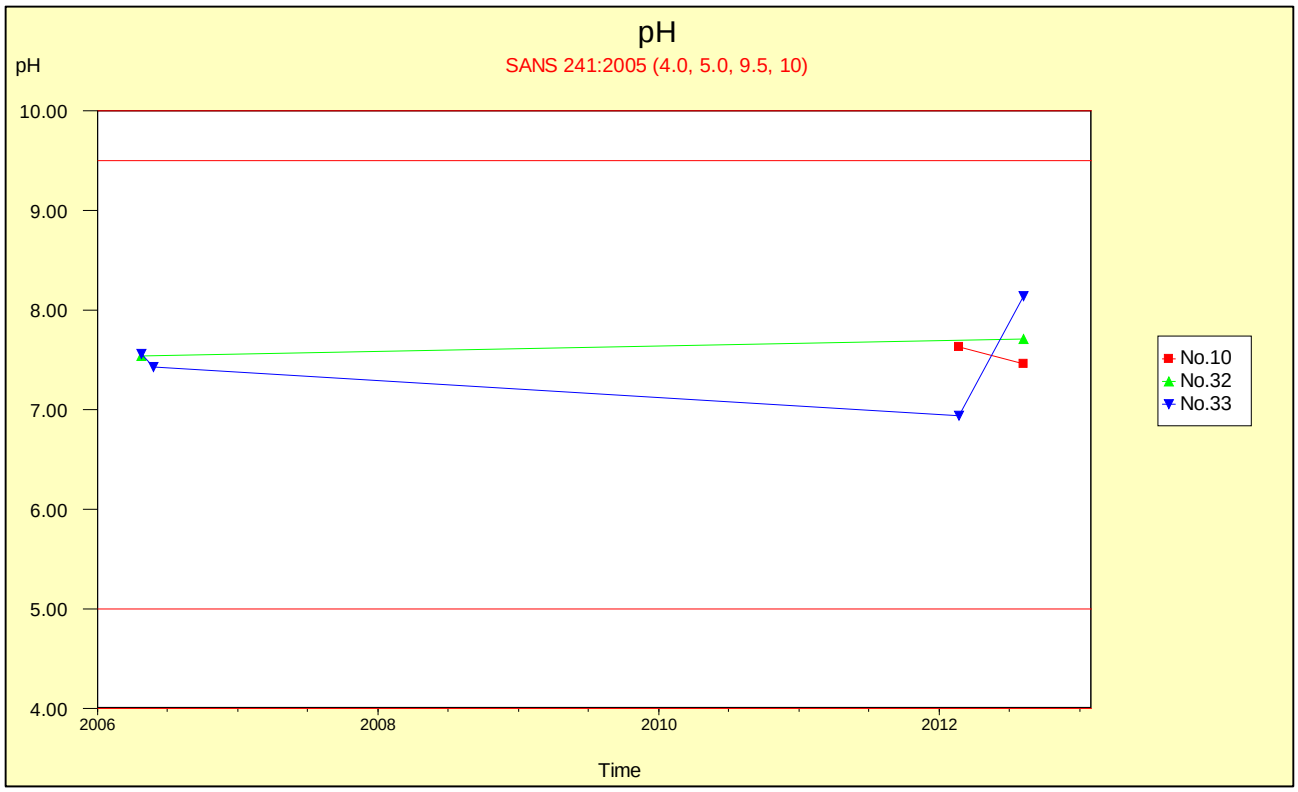


Figure 46. pH values at the river and stream sites.

11 Groundwater Depths and Elevations

The groundwater depths and elevations within and in the vicinity of the backfilled pits at Arnot Closed Colliery (as measured during August 2012) are listed in Table 45. In this table the groundwater sites are grouped according to their positions relative to the pits, and sorted within each group according to the values of the observed water elevations. A contour map of the water elevations is presented in Figure 47.

Within Pit 1 the water elevations range between 1 596.55 mamsl (AW01) and 1 601.44 mamsl (C-4 and AW24). All the observed water elevations exceed the decant level of Pit 1 (1 595.05 mamsl, refer to Section 5.1). The water level elevations are higher in the southern and eastern parts of the pit than in the north-western part. Although pumping from the Decant Dam and the T1 Dam in the north-western parts of Pit 1 may contribute to the existence of local artificial groundwater gradients towards the north-western parts of the pit, the high permeabilities of the backfilled spoils will limit the lateral extent of the zones of depression caused by pumping. The observed groundwater gradient within Pit 1 is therefore unlikely to be caused by water abstraction at the Decant Dam and the T1 Dam. This variation in the water elevation within Pit 1 may be explained by the fact that the pit is compartmentalised.

In a note to the mine manager (dated September 1998) the Section Geologist, DRW Dingemans, described the compartmentalisation of Pit 1. Mr Dingemans explained that the compartments developed partly due to natural separation of the No. 1 Seam floor into a series of subsidiary basins by the mining geometry and partly due to separation of the pit by the coal hauling ramps. The ramps act as impermeable barriers to in-pit water flow. In-pit water flow between the compartments occurs when the water level in the upstream compartments exceeds the lowest point of the ramp and cascades across the ramps into the downstream compartments.

The water elevations in the boreholes near Pit 1 vary between 1 551.47 mamsl (BHZ10) and 1 610.12 mamsl (B5). The low water elevation observed in boreholes BHZ10 is due to the fact that this borehole is a production borehole that is pumped daily. The water elevation observed in this borehole does therefore not represent static conditions. A similar observation may be made about the water elevation in the Community Borehole.

The water level elevation in borehole B5 is almost 10 m higher that the elevation in nearby borehole B3, both drilled near the partial corridor that occurs near the northern perimeter of the pit. The drilling results have shown that this partial corridor, as well as the partial corridor near the southern perimeter in the vicinity of borehole B9, is associated with the presence of a dolerite intrusive. The observed elevated water level therefore suggests that the dolerite intrusive intersected by borehole B5 is associated with an aquifer that is hydraulically linked to a recharge zone that occurs at a much

higher elevation than the decant level of Pit 1. It is therefore possible that the dolerite intrusive acts as, or is associated with, a preferential pathway for groundwater migration, causing an influx of groundwater into Pit 1.

Table 45. Groundwater depths and elevations measured during August 2012.

Area	Site Name	Longitude (°E)	Latitude (°S)	Elevation (mamsl)	X_WGS84 (m)	Y_WGS84 (m)	Casing height (m)	SWL (mbc)	SWL (mbgl)	Water elevation (mamsl)
Boreholes within Pit 1	AW01	29.66074	25.90956	1 596.8	66 203.27	-2 866 981.77	0.56	0.81	0.25	1 596.55
	AW03	29.67134	25.91538	1 618.7	67 262.07	-2 867 631.97	0.43	22.18	21.75	1 596.98
	AW02	29.66743	25.92713	1 611.5	66 863.68	-2 868 931.77	0.65	14.81	14.16	1 597.34
	B4	29.68290	25.92610	1 624.2	68 414.12	-2 868 825.64	0.56	24.68	24.12	1 600.08
	C-3	29.69324	25.92786	1 616.9	69 449.00	-2 869 026.07	0.83	17.49	16.66	1 600.26
	B10	29.68406	25.93347	1 624.0	68 526.07	-2 869 642.56	0.60	24.06	23.46	1 600.54
	C-5	29.69307	25.92031	1 611.9	69 436.39	-2 868 189.51	0.90	11.61	10.71	1 601.19
	AW24	29.70064	25.92127	1 618.2	70 194.26	-2 868 299.90	0.25	17.07	16.82	1 601.39
	C-4	29.69210	25.92221	1 614.3	69 338.09	-2 868 399.50	0.65	13.46	12.81	1 601.44
Boreholes near Pit 1	BHZ10	29.65263	25.90754	1 596.3	65 391.76	-2 866 753.91	0.00	44.83	44.83	1 551.47
	Community BH	29.65447	25.88793	1 567.5	65 586.97	-2 864 582.21	0.16	12.55	12.39	1 555.11
	ANT-1 (ARN01)	29.65600	25.89713	1 589.8	65 735.21	-2 865 602.26	0.31	6.76	6.45	1 583.35
	BHZ04	29.64883	25.89824	1 585.6	65 016.11	-2 865 721.66	0.00	1.94	1.94	1 583.66
	BHZ08	29.65418	25.89492	1 588.5	65 554.05	-2 865 356.50	0.14	4.84	4.70	1 583.80
	AW04	29.67112	25.89561	1 586.3	67 251.23	-2 865 441.52	0.54	2.45	1.91	1 584.39
	BHZ05	29.65288	25.89739	1 588.0	65 422.42	-2 865 629.50	0.27	3.48	3.21	1 584.79
	AW20	29.64794	25.91033	1 584.8	64 920.30	-2 867 060.69	0.45	0.45	0.00	1 584.80
	BHZ07	29.65302	25.89615	1 588.8	65 437.13	-2 865 492.19	0.38	3.55	3.17	1 585.63
	ANT-3 (ARN03)	29.66289	25.89850	1 595.1	66 424.89	-2 865 757.51	0.47	9.47	9.00	1 586.10
	BHZ09	29.65580	25.89549	1 588.6	65 716.08	-2 865 420.45	0.00	1.16	1.16	1 587.44
	B7	29.65620	25.91910	1 597.6	65 743.07	-2 868 036.44	0.77	10.26	9.49	1 588.06
	ANT-2	29.66068	25.89690	1 593.2	66 204.31	-2 865 579.12	0.16	3.40	3.25	1 589.96
	Old Supply BH	29.66710	25.93649	1 594.8	66 825.34	-2 869 968.62	0.35	5.03	4.68	1 590.12
	AW31	29.65293	25.90652	1 597.7	65 422.39	-2 866 641.04	0.76	7.86	7.10	1 590.60
	B8	29.66208	25.93111	1 598.0	66 325.37	-2 869 369.45	0.81	7.37	6.56	1 591.44
	AW08	29.65298	25.91078	1 596.6	65 425.05	-2 867 113.05	0.40	2.09	1.69	1 594.91
	B9	29.67577	25.93717	1 605.2	67 693.47	-2 870 048.40	0.95	11.19	10.24	1 594.96
	B6	29.67073	25.90394	1 600.8	67 207.43	-2 866 364.21	0.93	5.24	4.31	1 596.49
	AW07	29.65794	25.90042	1 599.8	65 927.79	-2 865 967.73	0.32	3.14	2.82	1 596.98
	AW09	29.68078	25.93839	1 605.4	68 194.65	-2 870 186.17	0.42	8.44	8.02	1 597.38
	AW06	29.67473	25.91024	1 605.2	67 604.65	-2 867 064.25	1.02	8.11	7.09	1 598.11
	B3	29.68620	25.92751	1 623.5	68 744.21	-2 868 983.14	0.65	23.84	23.19	1 600.31
	B5	29.68561	25.92320	1 625.6	68 687.30	-2 868 505.76	0.62	16.08	15.46	1 610.12
Boreholes within Pit 2W	AW25	29.70005	25.91621	1 605.0	70 138.14	-2 867 738.98	0.17	6.45	6.28	1 598.72
	R-2	29.71561	25.91779	1 608.7	71 696.19	-2 867 922.45	0.80	6.90	6.10	1 602.60
	AW26	29.70399	25.92306	1 623.1	70 528.82	-2 868 500.02	0.26	17.06	16.80	1 606.30
Boreholes near Pit 2W	AW05	29.71210	25.91349	1 605.0	71 347.10	-2 867 444.12	0.55	6.60	6.05	1 598.90
	B11	29.71148	25.91706	1 607.5	71 282.83	-2 867 839.32	0.44	6.38	5.94	1 601.56
	KGM_B11	29.71342	25.91374	1 604.9	71 479.20	-2 867 472.60	0.42	3.53	3.11	1 601.79
Boreholes within Pit 2E	AW18	29.74031	25.91508	1 620.0	74 172.64	-2 867 635.94	0.84	17.09	16.25	1 603.75
Boreholes near Pit 2E	AW28	29.72465	25.91672	1 609.0	72 602.58	-2 867 808.87	0.84	9.72	8.88	1 600.12
	AW19	29.72329	25.91682	1 608.0	72 466.26	-2 867 819.20	0.27	7.99	7.72	1 600.28
	KGM_B12	29.73187	25.91635	1 614.0	73 326.21	-2 867 771.90	0.82	12.86	12.04	1 601.96
	B1	29.73474	25.91553	1 615.1	73 614.27	-2 867 682.66	0.50	12.82	12.32	1 602.78
	KGM_B13	29.75311	25.90647	1 633.0	75 460.61	-2 866 689.32	0.47	14.13	13.66	1 619.34
	AW22	29.75344	25.90850	1 633.0	75 492.39	-2 866 914.42	0.00	8.77	8.77	1 624.23
	AW23	29.75310	25.90642	1 633.0	75 459.64	-2 866 683.78	0.34	2.60	2.26	1 630.74

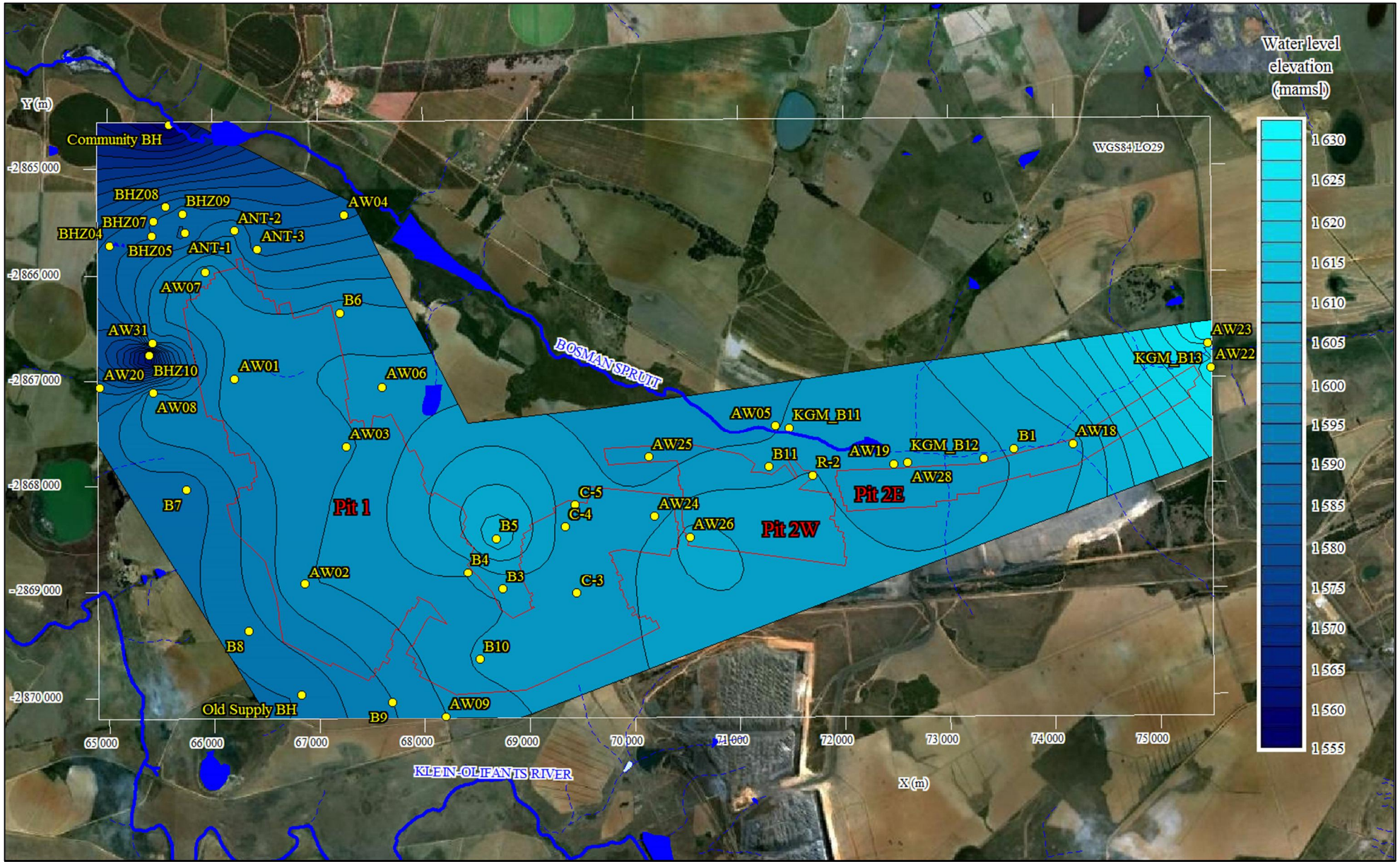


Figure 47. Groundwater elevations at Arnot Closed Colliery, August 2012.

The fact that no anomalously high water level elevation is observed in borehole B9 may indicate that, although this borehole intersected the dolerite intrusive, it did not intersect any preferential pathway hydraulically linked to recharge zones at higher elevations. Such pathways may, however, exist and may be contributing to groundwater influx into Pit 1.

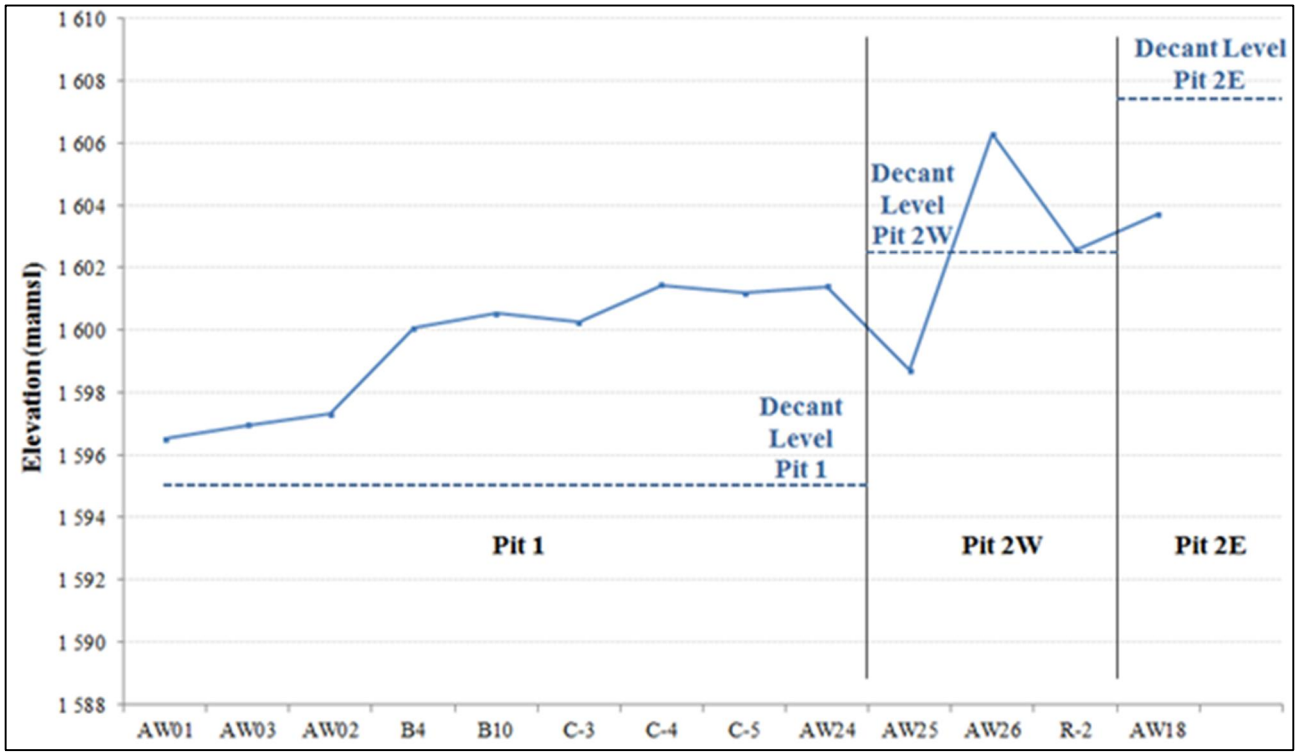


Figure 48. Water elevations within the backfilled pits at Arnot Closed Colliery, August 2012.

The water level elevations in the boreholes within Pit 2W are 1598.72 mamsl (AW25), 1 602.60 mamsl (R-2) and 1 606.30 mamsl (AW26). When these elevations are compared with the calculated decant level of Pit 2W (1 602.42 mamsl), it is seen that the water level within borehole AW25 is well below the decant level. This observation is unexpected since no pumping of water takes place from the pit. Due to the high hydraulic conductivities of the backfilled spoils in the pit, one would expect a near horizontal water level within the pit if it is not compartmentalised. The low water level recorded at borehole AW25 therefore suggests that Pit 2W is indeed compartmentalised.

The high water level elevation observed at borehole AW26 is as unexpected as the low water level elevation at borehole AW25. Both the water levels in boreholes AW25 and AW26 were measured on two occasions during 2012 (during the hydrocensus and during the sampling event) giving similar values during these measurements; it is therefore certain that the unexpected water levels are not due to measurement errors.

As was the case with borehole B5 near the partial corridor in Pit 1, the position of borehole AW26 immediately adjacent to the corridor separating Pit 1 and Pit 2W may provide an explanation for the

observed high water level elevation in this borehole. If the corridor is due to the presence of some geological structure that prevented mining (such as a dolerite dyke), it is possible that this structure may be acting as, or be associated with, a preferential pathway for groundwater migration. The observed water level elevation may therefore indicate that this pathway is hydraulically linked to a recharge zone at a higher elevation than the decant level of Pit 2W. Groundwater influx into Pit 2W could therefore be expected along this pathway.

Borehole AW18 is the only borehole known to be drilled within the spoils of Pit 2E. The water level elevation in this borehole (1 603.75 mamsl) is well below the decant level of the pit (1 607.40 mamsl). This observation suggests that the water level in Pit 2E is well below the decant level. However, the possibility that Pit 2E is compartmentalised cannot be ruled out. The water level observed in borehole AW18 may therefore be representative of only a single compartment within the pit. It is possible that other compartments exist in which the water level is closer to the decant level.

12 Soil Sampling

12.1 Introduction

In order to gain information on the hydraulic properties of the soils in the vicinity of the opencast pits of Arnot Closed Colliery, thirteen soil samples were taken at selected positions and submitted to an accredited laboratory for grain size analyses. The results of the analyses were used to estimate the hydraulic conductivities of the soils. These estimated parameter values will be used during the construction of the numerical groundwater model for Arnot Closed Colliery (Section 16).

The positions of the soil samples relative to the backfilled and rehabilitated pits are shown in Figure 49. The positions of the soil samples were chosen so as to obtain a good representation of the soil properties around the backfilled and rehabilitated opencast pits of Arnot Colliery.

12.2 Results

The results of the grain size analyses are listed in Table 46. Also listed in this table are the estimated hydraulic conductivities. These hydraulic conductivities were estimated by assuming an average porosity of 0.35 for the surface soils.

The grain size analyses show that the soils at Arnot Closed Colliery are generally sandy soils with a sand content of greater than 60% and high hydraulic conductivities. Only samples SS10 and SS11 have low sand content, high clay content and low hydraulic conductivities. Sample SS10 was taken north of Pit 2E and is the most eastern sample, while SS11 was taken near the south-western perimeter of Pit 1. These samples may represent localised zones of higher clay content and do not appear to be representative of the soil properties near the pits. The geometric mean of the estimated soil hydraulic conductivities, excluding the results from sites SS10 and SS11, is found to be 0.375 m/d.

Table 46. Results of the grain size analyses and estimated soil hydraulic conductivities.

Sample #	Percentage composition			Hydraulic conductivity (m/d)
	Clay	Silt	Sand	
SS1	22	15	63	0.154
SS2	16	17	67	0.322
SS3	17	12	71	0.436
SS4	19	9	72	0.408
SS5	19	10	71	0.408
SS6	19	13	68	0.322
SS7	18	12	70	0.423
SS8	18	11	71	0.423
SS9	15	14	71	0.456
SS10	33	19	48	0.008
SS11	37	12	51	0.007
SS12	14	12	74	0.463
SS13	12	11	77	0.471
Geometric mean (excl. samples SS10 & SS11)				0.375

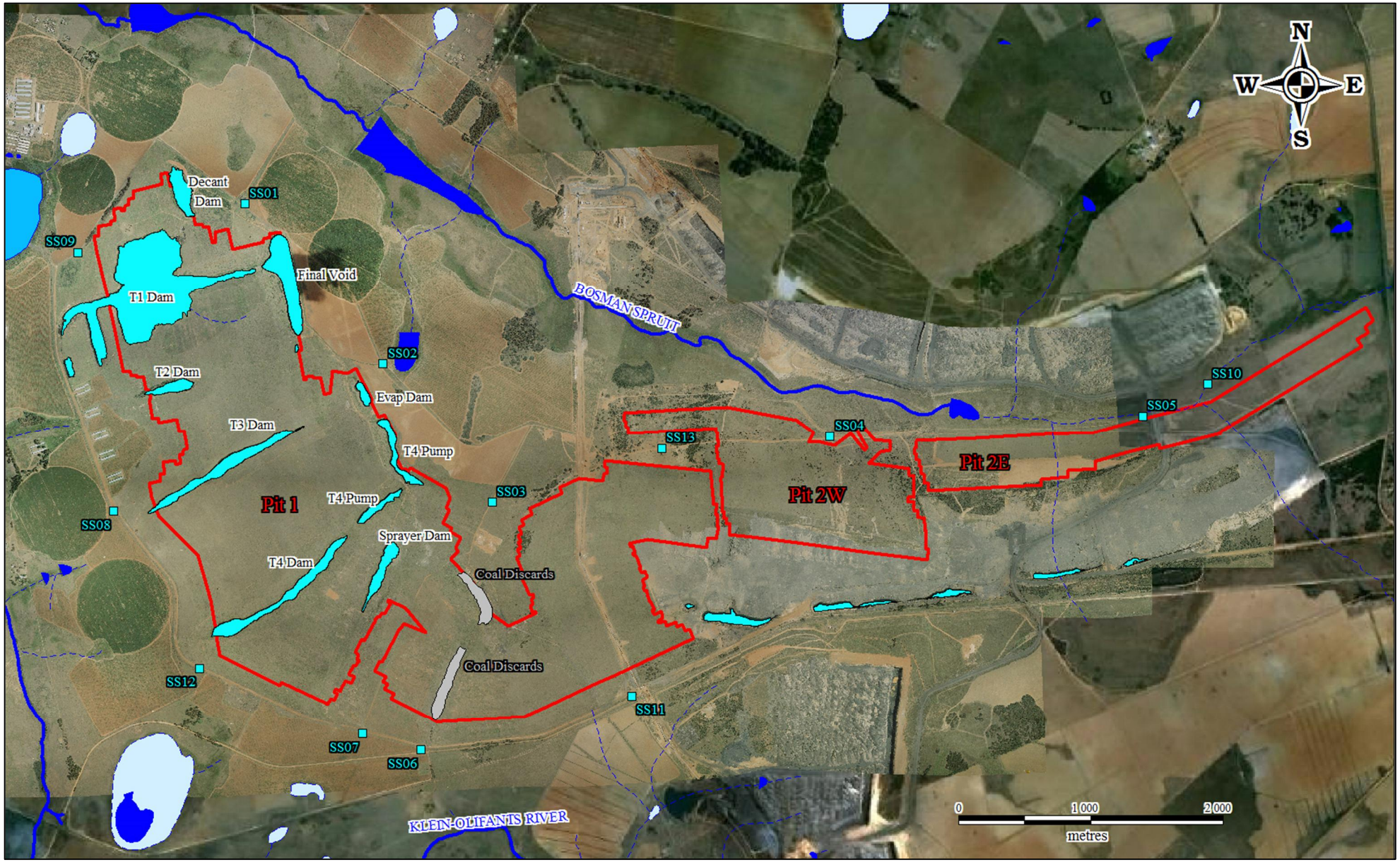


Figure 49. Positions in the vicinity of the backfilled and rehabilitated opencast pits where soil samples were taken for grain size analyses.

13 Acid-Base Accounting

13.1 Introduction

Twelve samples of exposed spoils and coal discards were taken at positions on and near the backfilled and rehabilitated opencast pits of Arnot Closed Colliery during June 2012. These samples were submitted to an accredited laboratory for acid-base analyses. The purposed of the acid-base analyses was to determine the acid generation potential of the waste rock materials to evaluate the likelihood of acid mine drainage (AMD) from the pits. The positions at which rock samples were taken are shown in Figure 50.

13.2 Results

The results of the acid-base analyses are summarised in Table 47. In this table the Acid and Base Potentials as well as the Net Neutralising Potential (NNP) of the samples are listed for both open systems in which gases are free to escape and closed systems. Unfortunately sample ABA04 was misplaced by the laboratory and no results are therefore available for this sample.

Table 47. Results of the acid-base analyses.

Sample #	Initial pH	Final pH	Acid Potential (Open)	Acid Potential (Closed)	Base Potential	NNP (Open)	NNP (Closed)
ABA01	7.03	2.08	1.125	2.249	4.103	2.979	1.854
ABA02	2.69	1.13	25.749	51.498	-33.041	-58.790	-84.539
ABA03	3.78	1.24	19.280	38.560	-25.710	-44.990	-64.270
ABA05	7.65	1.51	28.869	57.739	32.206	3.336	-25.533
ABA06	4.24	1.48	0.803	1.607	-8.360	-9.163	-9.967
ABA07	3.2	1.07	25.899	51.798	-24.872	-50.771	-76.670
ABA08	6.64	3.21	0.633	1.266	2.393	1.760	1.127
ABA09	4.03	1.28	23.646	47.292	-9.023	-32.669	-56.314
ABA10	7.08	2.21	1.542	3.084	3.370	1.828	0.287
ABA11	6.92	3.91	1.539	3.079	79.100	77.560	76.021
ABA12	7.12	3.77	1.241	2.482	16.295	15.054	13.813

Values expressed as kg/t $CaCO_3$ where applicable

In Table 48 the results of the acid-base analyses are used to evaluate the acid generating potential of the samples. The evaluation was done using the ABACUS (**A**cid **BA**se **A**ccounting **CU**mulative **S**creening) tool developed by the IGS. The acid generating potential of the rock samples is evaluated based on the pH values observed during laboratory analyses, the Net Neutralising Potentials (NNP) of the samples, and the Neutralization Potential Ratio (NPR) of the samples. A final verdict is obtained which indicates whether a particular sample has a high potential to be acid generating.

In Table 48 it is seen that samples ABA02, ABA03, ABA05 ABA07 and ABA09 are likely to be acid generating. Samples ABA02, ABA03 and ABA05 represent the exposed coal discards which appear to be responsible for acid generating conditions (refer to Section 10.1.1 where the acidic conditions observed at borehole AW09 where related to the coal discards). Samples ABA07 and ABA09 are spoils from the mining activities at the adjacent Kwagga Section of Optimum Colliery to the south of Pit 2E. These spoils are currently exposed to atmospheric conditions since rehabilitation has not commenced. Oxidation of the exposed spoils is therefore likely to lead to acid generation.

Table 48. Interpreted acid generating potential of the rock samples.

Sample #	pH values	Net Neutralising Potential	NPR (Open System)	NPR (Closed System)	Verdict
ABA01	Higher Risk Acid Generation	Verify with other tests	Acid under certain conditions	Acid under certain conditions	Very Low Risk
ABA02	Higher Risk Acid Generation	Potential Acid Generator	Likely Acid Generator	Likely Acid Generator	High Acid Potential
ABA03	Higher Risk Acid Generation	Potential Acid Generator	Likely Acid Generator	Likely Acid Generator	High Acid Potential
ABA05	Higher Risk Acid Generation	Potential Acid Generator	Acid under certain conditions	Likely Acid Generator	High Acid Potential
ABA06	Higher Risk Acid Generation	Verify with other tests	Likely Acid Generator	Likely Acid Generator	High Acid Potential
ABA07	Higher Risk Acid Generation	Potential Acid Generator	Likely Acid Generator	Likely Acid Generator	High Acid Potential
ABA08	Higher Risk Acid Generation	Verify with other tests	Acid under certain conditions	Acid under certain conditions	Very Low Risk
ABA09	Higher Risk Acid Generation	Potential Acid Generator	Likely Acid Generator	Likely Acid Generator	High Acid Potential
ABA10	Higher Risk Acid Generation	Verify with other tests	Acid under certain conditions	Acid under certain conditions	Very Low Risk
ABA11	Medium Risk Acid Generation	Probably Excess Neutralising Minerals	No Acid Potential	No Acid Potential	Very Low Risk
ABA12	Medium Risk Acid Generation	Verify with other tests	No Acid Potential	No Acid Potential	Very Low Risk

In Table 49 the chemical constituents that may be released from the spoils and coal discards are listed in kg/tonne. The potential release of these constituents is considered under three conditions, namely: constituents released due to their water solubilities (blue values), constituents released under full oxidation (green values) and constituents released under acidic conditions (red values). Blank entries indicate concentrations below the detection limits of the analytical techniques. As a first approximation, the blue values reflect the constituents that may be released within the saturated spoils below the decant water levels of the pits where little oxidation is likely to occur, the green values reflect the constituents that may be released from the spoils above the decant water levels of the pits where strong oxidising conditions prevail, and the red values reflect the constituents that may be released where strong acidic conditions exist, such as near the coal discards.

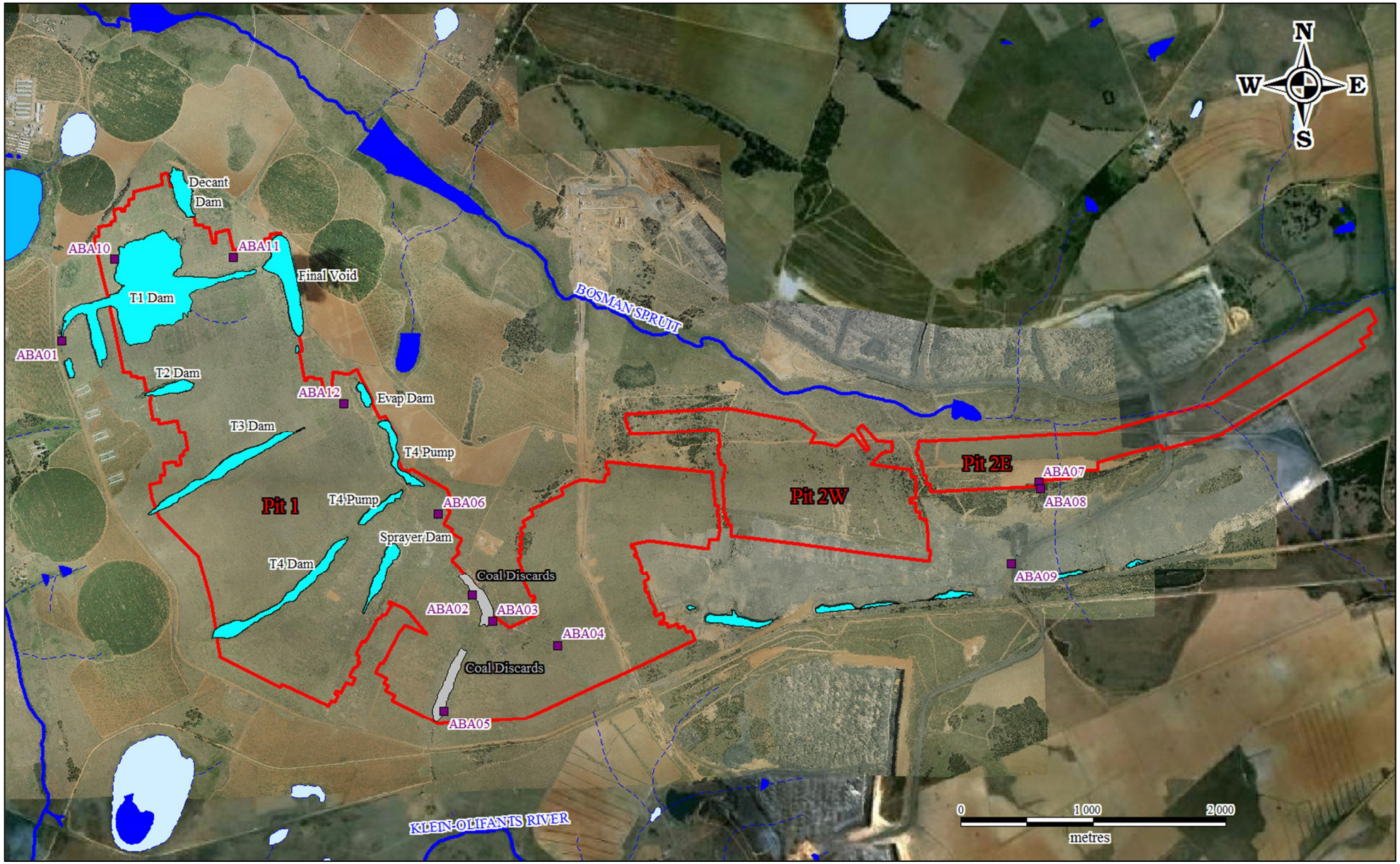


Figure 50. Positions on and in the vicinity of the backfilled and rehabilitated opencast pits where rock samples were taken for acid-base accounting.

Table 49. Constituents that may be released from the spoils and coal discards.

Condition	Sample number	Initial pH	Ag	Al	As	Ba	Be	Ca	Cd	Cr	Co	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	Sb	Se	Sn	Sr	Pb	V	Zn	SO_4
Water soluble constituents	ABA01	7.03		0.001		0.001		0.922						0.090		0.282	0.010		0.112					0.007				3.225
	ABA02	2.69		1.570				3.598		0.001	0.001		3.876	0.033	0.002	0.169	0.007		0.053	0.002				0.034		0.001	0.004	21.85
	ABA03	3.78		1.363				5.400			0.001		0.241	0.039	0.004	0.259	0.011		0.036	0.001				0.026			0.008	19.12
	ABA05	7.65		0.001		0.002		0.489					0.001	0.044	0.000	0.096	0.001		0.084					0.013				1.095
	ABA06	4.24		0.008				0.199					0.017	0.086	0.001	0.145	0.013		0.065	0.000				0.002			0.001	1.569
	ABA07	3.20		0.772				6.638			0.001		0.952	0.031	0.001	0.203	0.031		0.049	0.001				0.082			0.003	20.80
	ABA08	6.64		0.001				0.220					0.001	0.098		0.132	0.003		0.035					0.002			0.001	1.278
	ABA09	4.03		0.133				4.482			0.004		0.113	0.091	0.001	1.019	0.146		0.034	0.005				0.024			0.009	14.84
	ABA10	7.08		0.003		0.001		0.080					0.001	0.127		0.034	0.001		0.058					0.000				0.205
	ABA11	6.92		0.002				0.458					0.001	0.489		0.135	0.002		0.087					0.001				0.148
	ABA12	7.12						0.001						0.001		0.010			0.020									0.001
Condition	**Sample number**	**Final pH**	**Ag**	**Al**	**As**	**Ba**	**Be**	**Ca**	**Cd**	**Cr**	**Co**	**Cu**	**Fe**	**K**	**Li**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Sb**	**Se**	**Sn**	**Sr**	**Pb**	**V**	**Zn**	**SO_4**
Constituents released during complete oxidation	ABA01	2.08		0.646		0.014		1.319		0.002		0.002	0.221	0.139	0.002	0.247	0.115	0.002	0.093	0.002				0.011		0.004	0.004	1.080
	ABA02	1.13		0.862		0.011		0.003		0.001		0.001	6.275	0.172	0.001	0.067		0.002	0.164	0.001				0.027		0.001		24.72
	ABA03	1.24		5.720		0.007		0.097		0.002		0.003	2.749	0.157	0.002	0.067		0.002	0.175	0.001				0.028		0.003	0.001	18.51
	ABA05	1.51		0.899		0.020		8.185		0.002	0.001	0.004	7.948	0.086	0.001	3.172	0.044	0.002	0.238	0.005				0.088		0.002	0.008	27.71
	ABA06	1.48		1.104		0.007		0.174		0.001		0.001	0.422	0.073	0.001	0.040		0.002	0.041	0.002				0.003		0.001	0.001	0.771
	ABA07	1.07		1.372		0.013		2.197		0.002		0.002	7.083	0.179	0.001	0.063		0.002	0.211	0.001				0.107		0.004	0.002	24.86
	ABA08	3.21		1.392		0.038		0.541		0.001		0.001	0.210	0.217	0.002	0.304	0.302	0.002	0.102	0.002				0.006		0.001	0.001	0.608
	ABA09	1.28		2.360		0.014		0.369		0.002		0.002	8.381	0.132	0.002	0.137	0.049	0.002	0.198	0.002				0.012		0.003		22.70
	ABA10	2.21		1.390		0.017		0.876		0.001	0.001	0.001	0.436	0.347	0.002	0.253	0.109	0.002	0.028	0.002				0.005		0.001	0.002	1.480
	ABA11	3.91		0.150		0.003		5.597		0.004	0.001	0.004	0.059	0.407	0.001	0.695	0.066		0.795	0.003				0.006		0.009	0.019	1.551
	ABA12	3.77		0.371		0.006		2.671		0.003	0.008	0.005	0.036	0.344	0.003	0.890	0.065	0.001	0.938	0.017				0.008		0.011	0.031	1.200
Acid (H_2SO_4) soluble constituents	ABA01	1.77		2.560		0.001		4.080		0.003	0.205	0.030	3.847	0.293	0.004	0.756	0.220		0.281	0.151				0.066	0.001	0.004	0.006	No values - Sulphuric acid used to acidity samples
	ABA02	1.80		3.388		0.003		3.422		0.003	0.993	0.080	15.62	0.258	0.003	0.205	0.010		0.166	1.359				0.045	0.002	0.002	0.008	
	ABA03	1.89		8.043		0.001		5.603		0.004	0.001	0.002	2.857	0.177	0.007	0.343	0.011		0.123	0.002				0.037	0.001	0.002	0.014	
	ABA05	2.27		1.239		0.000		6.749		0.001	0.003	0.004	3.792	0.136	0.002	3.550	0.042		0.190	0.003				0.086	0.001	0.002	0.009	
	ABA06	1.66		2.856		0.001		0.279		0.008	0.328	0.045	5.062	0.232	0.003	0.283	0.026		0.197	0.344				0.008	0.001	0.003	0.006	
	ABA07	1.57		2.269		0.001		5.893		0.002	0.001	0.004	5.755	0.190	0.003	0.229	0.020		0.268					0.088	0.001	0.003	0.006	
	ABA08	1.90		5.618		0.000		1.512		0.004	0.006	0.006	3.689	0.464	0.004	0.851	0.680		0.116	0.003				0.013	0.001	0.004	0.009	
	ABA09	2.13		4.145		0.003		5.452		0.003	0.574	0.095	17.04	0.359	0.004	1.338	0.217		0.205	0.960				0.041	0.001	0.003	0.016	
	ABA10	1.86		4.069		0.001	0.001	1.954		0.004	0.010	0.010	4.647	0.769	0.005	0.752	0.272		0.165	0.008				0.010	0.001	0.004	0.024	
	ABA11	1.99		0.953		0.001		6.282		0.001	0.002	0.004	0.356	0.949	0.002	1.388	0.222		0.247	0.005				0.012	0.000	0.002	0.117	
	ABA12	2.56		2.377		0.001		4.731		0.001	0.043	0.032	5.398	0.433	0.003	1.931	0.443		0.201	0.105				0.021	0.000	0.004	0.023	

From the data listed in Table 49 it is seen that the for most of the samples of the spoils and coal discards the water soluble constituents that will preferentially be released under poorly oxidising conditions include aluminium, calcium, iron and sulphate, with smaller releases of potassium, lithium, magnesium, manganese, sodium and strontium. Small releases of barium, cobalt, nickel and zinc will occur for only certain samples. No releases of silver, arsenic, beryllium, cadmium, copper, molybdenum, antimony, selenium, tin or lead are expected under these conditions.

Under oxidizing conditions a number of additional constituents may be mobilised. These include barium, chromium, copper, molybdenum, nickel and vanadium. High iron releases can be expected from some of the samples representing the backfill materials (ABA02, ABA05, ABA07 and ABA09). These samples are all likely acid generators (refer to Table 48). Samples ABA02 and ABA05 represent the coal discards. As was noted in Sections 10.1.1 and 10.1.4, high concentrations of iron are indeed observed at boreholes B4 and AW09, down-gradient from the coal discards. Samples ABA07 and ABA09 represent the un-rehabilitated spoils of the Kwagga Section of Optimum Colliery. Leachate from these spoils may impact on the water quality of Pit 2 (W&E).

Under acidic conditions cobalt, manganese and lead may also be released. Large masses of iron may be released at sites ABA02 (coal discards) and ABA09 (un-rehabilitated spoils of the Kwagga Section). Acidic conditions are known to exist at groundwater site AW09 (see Table 33) where high iron and manganese concentration were recorded during August 2012 (see Table 34).

From the above observations it is clear that acidic conditions at Arnot Closed Colliery should be avoided as far as possible, since such conditions will cause the release of certain trace elements and lead to the degradation of the water quality. As far as acid generation is concerned, the coal discards within Pit 1 and the un-rehabilitated spoils of the Kwagga Section appear to be biggest concerns.

14 Geophysical Investigations

14.1 Introduction

Ground magnetic surveys were conducted at selected positions near the backfilled and rehabilitated opencast pits of Arnot Closed Colliery. The purpose of the magnetic surveys was to determine whether intrusive magmatic structures (e.g. dolerite dykes) cut across the pits. Such structures may act as barriers to groundwater flow in directions perpendicular to their strikes and may also be associated with preferential pathways for groundwater flow in directions parallel to their strikes. No historical data on the presence of such structures could be found in the archives of AngloAmerican, but the presence of three separate pits (Pit 1, Pit 2W and Pit2 E) suggests that linear geological features may indeed be present.

14.2 Survey Geometry

Magnetic data were recorded on Traverse 01 north of Pit 2W and Pit 2E, along a west/east strike across the corridor that separates these pits to investigate whether the existence of this corridor is due to a magnetic dyke (see Figure 51). Data were recorded using the Geotron G5 magnetometer on a station spacing of approximately 10 m.

Magnetic data were also recorded on two traverses (Traverses 02 and 03) to the south of Pit 1 at a position where the pit outline shows the presence of another corridor, albeit one that does not span the entire width of the pit (see Figure 52). Traverse 04 occurred within a corridor on the northern side of Pit 1 and extended past borehole B5. The dolerite encountered in boreholes B5 and B9 strongly suggests that these corridors are associated with dyke intrusives. Data were recorded using the GSM-19 Walkmag at a sampling rate of 0.5 s.

14.3 Survey Results

The results of the magnetic surveys conducted on Traverse 01 to Traverse 04 are shown as profile plots in Figure 53 to Figure 56. Although the data recorded on Traverse 01 display large variations in the magnetic field intensity, the spatial wavelength of the observed anomalies is in the order of hundreds of metres. This observation suggests that the magnetic features responsible for the anomalies are not thin, near-surface magnetic intrusives, such as dolerite dykes. If the corridor between Pits 2W and 2E is due to the presence of an intrusive, it is likely due to a deep, broad structure that may have caused burning of the coal at the shallower depths of opencast mining. The corridor may therefore represent the zone of burnt coal.

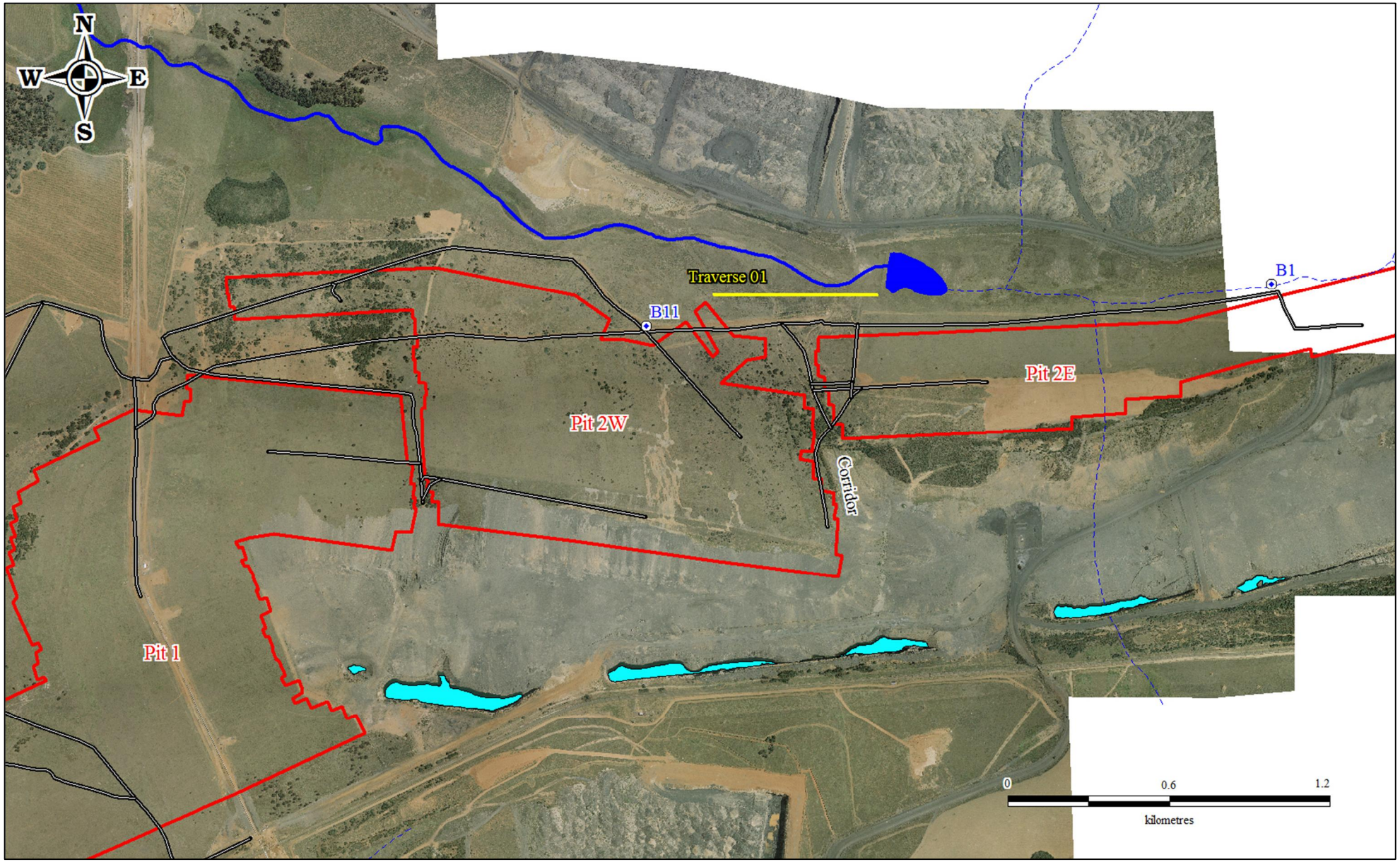


Figure 51. Position and orientation of the magnetic traverse north of Pits 2W and 2E.

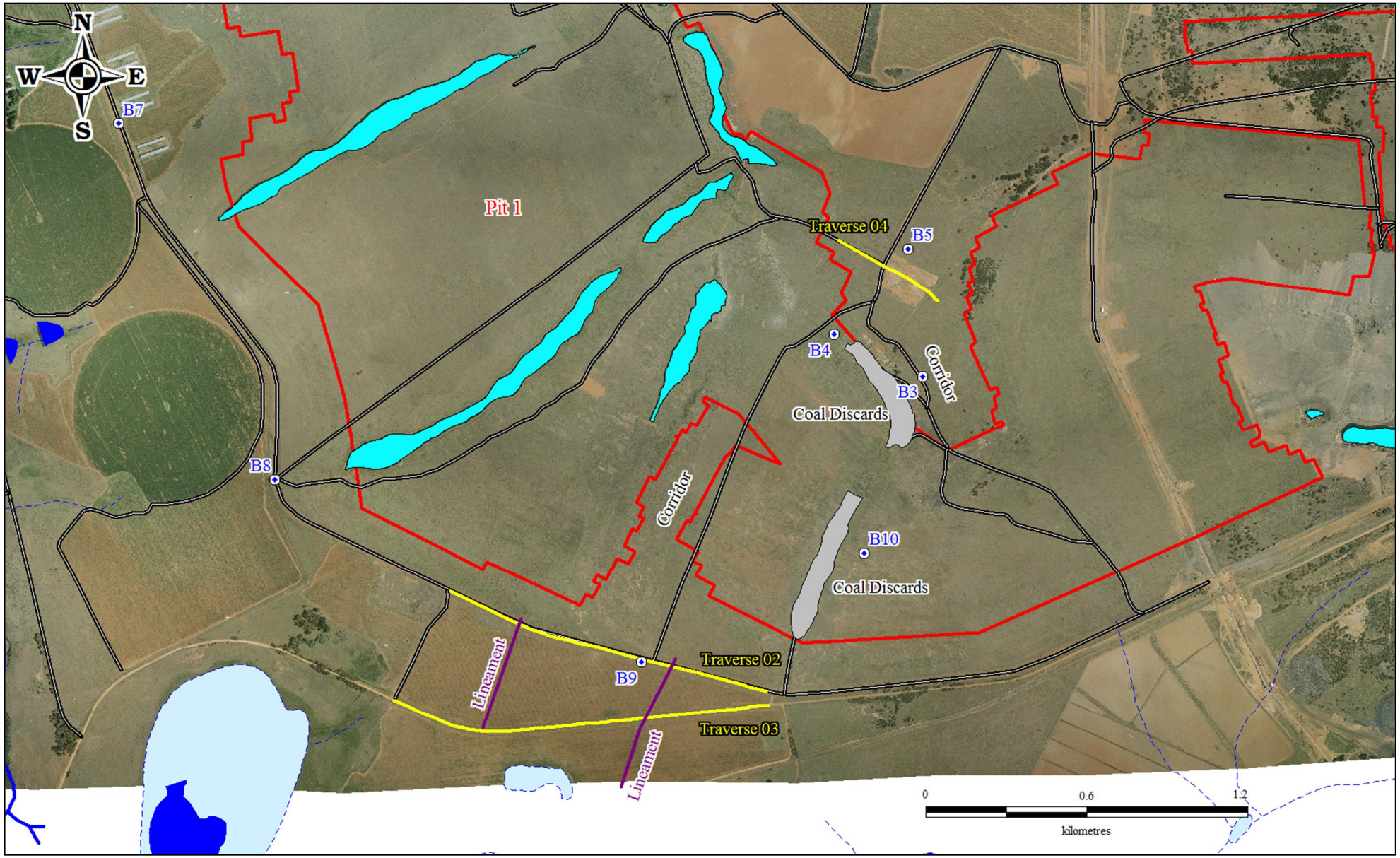


Figure 52. Positions and orientations of the magnetic traverses south of Pit 1.

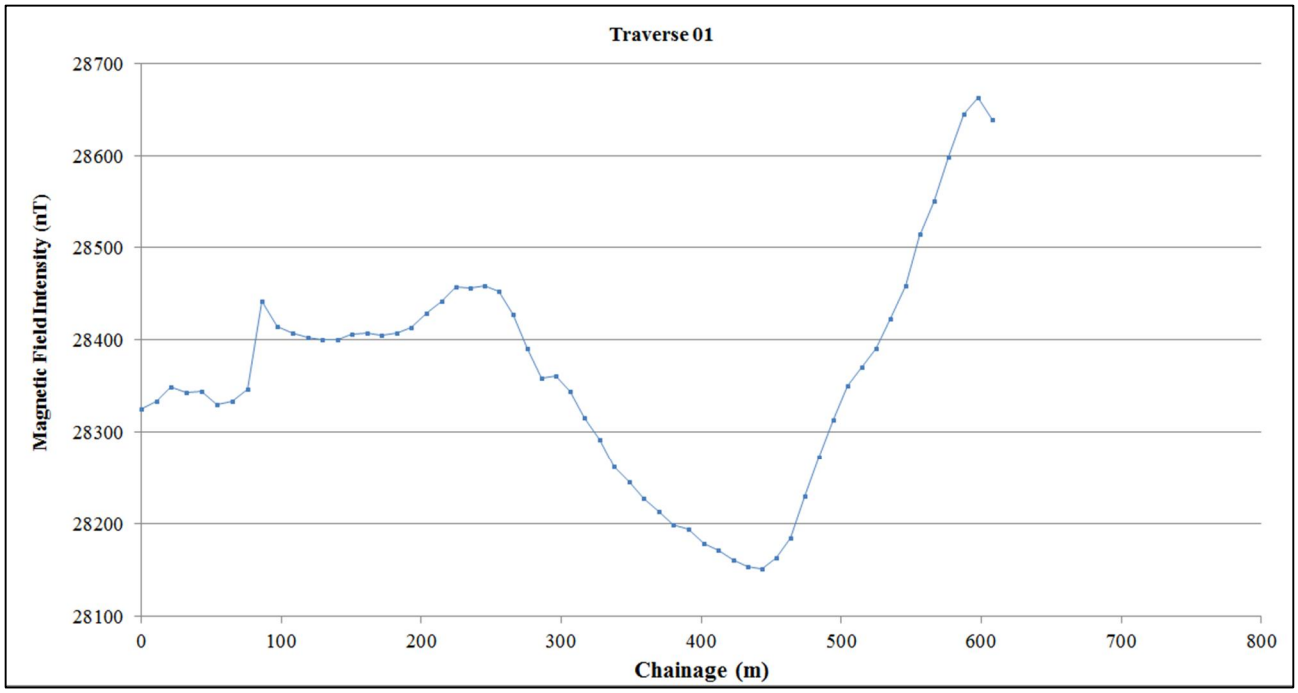


Figure 53. Magnetic data recorded along Traverse 01.

Several anomalies are observed on Traverses 02 and 03. The short wavelength anomalies observed at stations 316 m and 870 m on Traverse 02, as well as at position 945 m on Traverse 03 appear to be due buried infrastructure, possibly metal pipes. These anomalies correspond very well to the positions of lineaments that may be identified from the aerial photographs (refer to Figure 52).

Prominent anomalies are seen to occur on both Traverses 02 and 03 between stations 400 m and 600 m. The positions of these anomalies correspond well with the strike of the southern corridor in Pit 1. The large wavelengths of the anomalies suggest that the geological feature responsible for them does not extend to shallow depths. Dolerite was encountered during the drilling of borehole B9 at a depth of approximately 17 mbgl. These observations suggest that a dolerite intrusive is indeed responsible for the southern corridor in Pit 1, but that the intrusive is a broad structure that does not extend to surface. It may, however, have caused burning of the coal at the depths were mining was done, explaining the presence of the corridor.

Similar observations may be made regarding the origin of the magnetic anomalies observed along Traverse 04. Although the anomalies have large amplitudes, they also have large wavelengths, and appear to be due to broad structures that do not extend to surface. Dolerite was encountered in borehole B5 at a depth of 20 mbgl.

It may be concluded that the results of the magnetic survey suggest that, although the different pits are separated by corridors of rock material, these corridors are not due to dolerite intrusives that extend to the near-surface, acting as barriers to groundwater flow between the pits. The corridors are therefore likely to be formed by sedimentary rocks of the Karoo Supergroup with permeabilities greater than dolerite. Significant groundwater flow between the pits therefore appears likely.

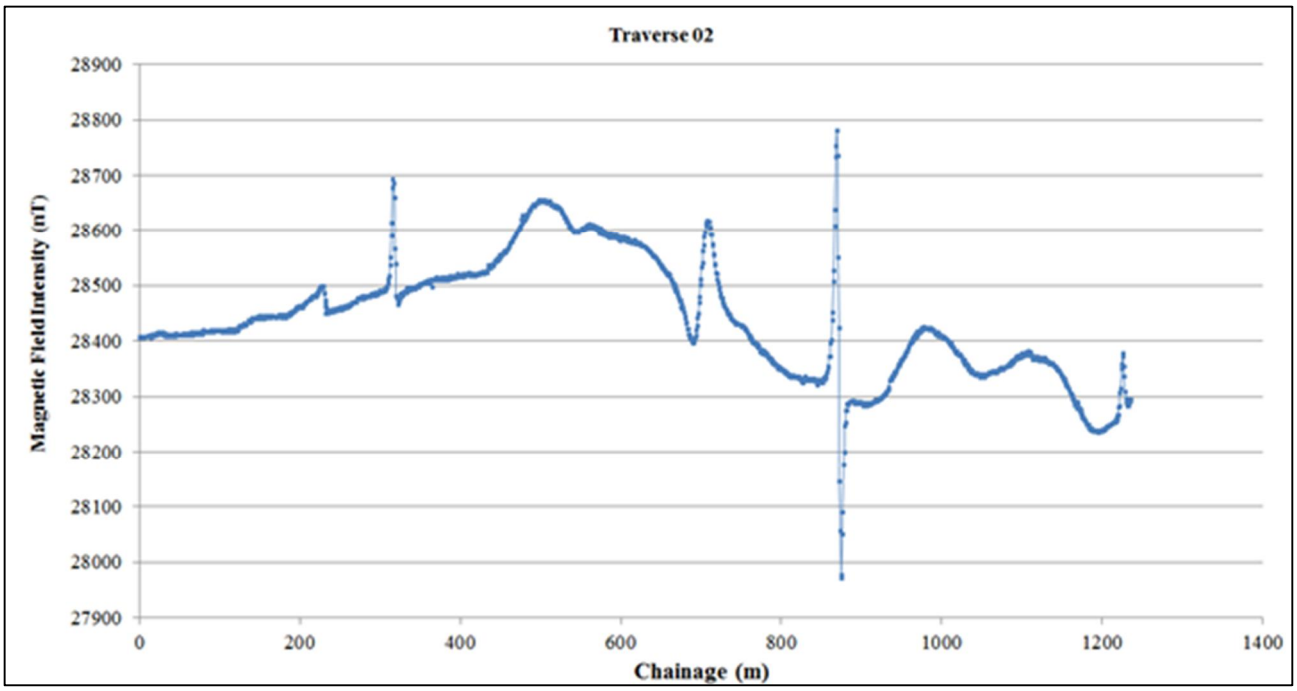


Figure 54. Magnetic data recorded along Traverse 02.

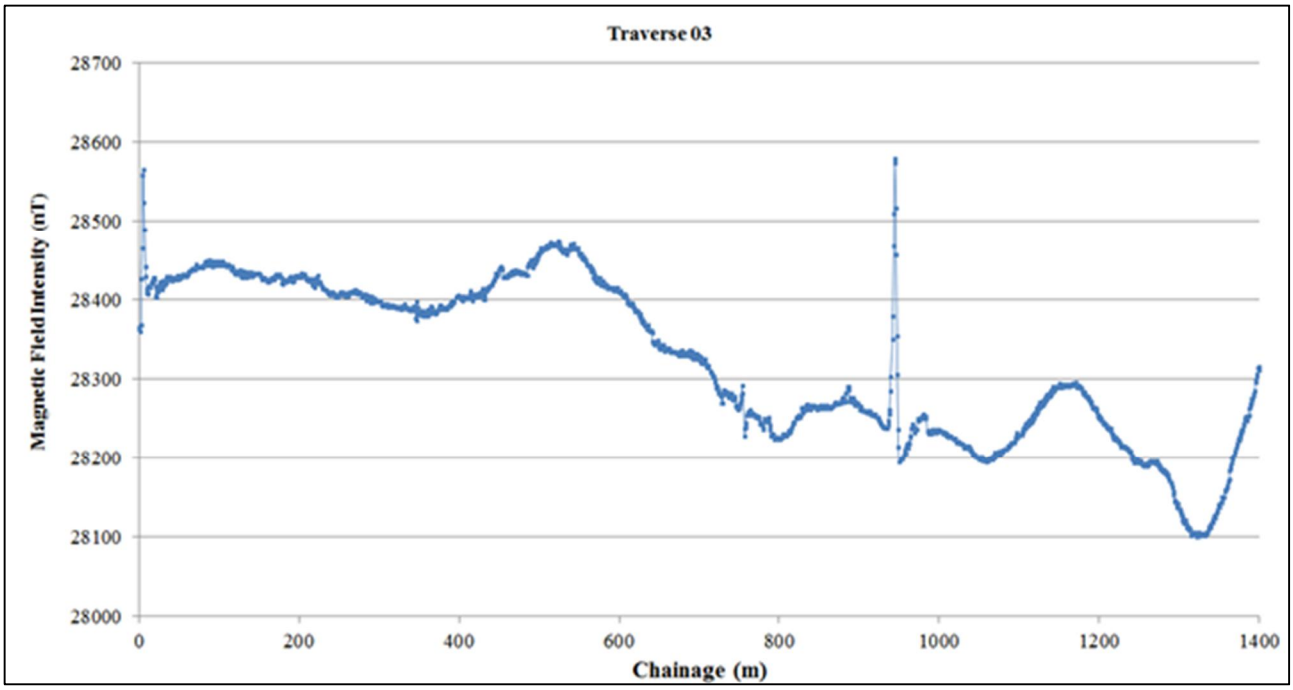


Figure 55. Magnetic data recorded along Traverse 03.

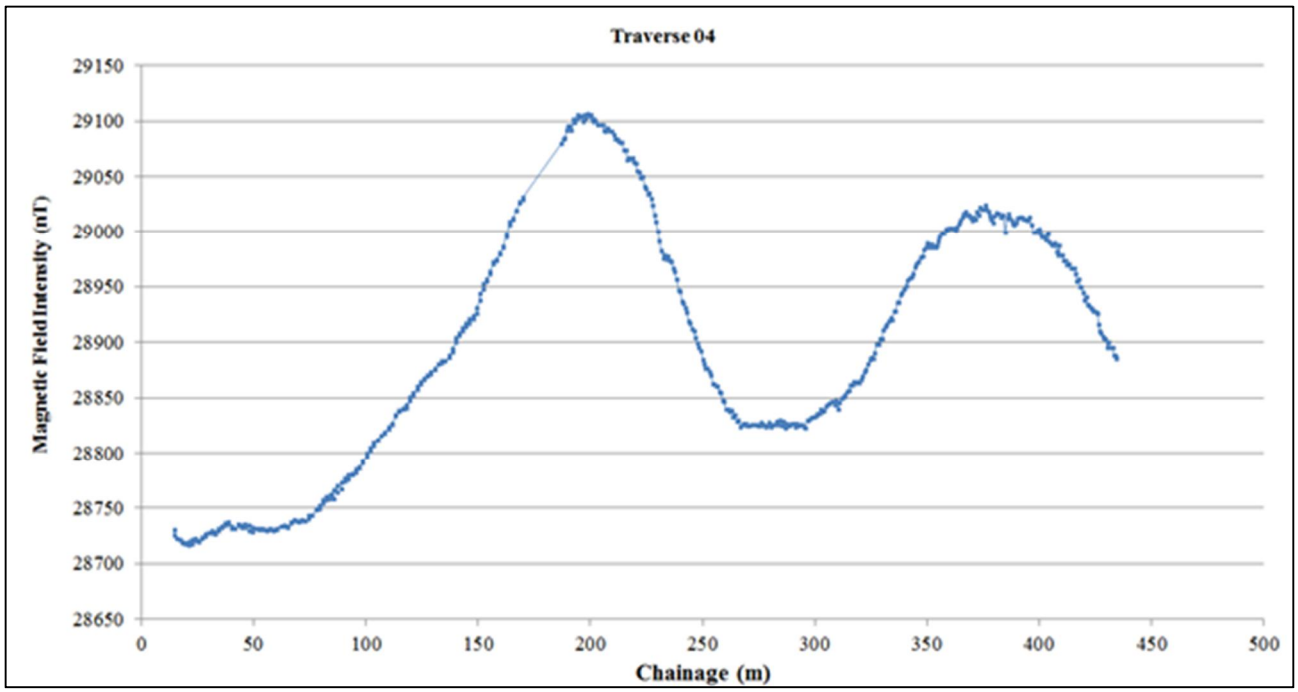


Figure 56. Magnetic data recorded along Traverse 04.

15 Conceptual Geohydrological Model

From the results of the field investigations and laboratory analyses, a conceptual geohydrological model may be compiled for Arnot Closed Colliery. This conceptual model is a simplified representation of the conditions at and in the vicinity of the backfilled pits, and will provide the framework during the development of the numerical flow and transport model (Section 16).

The conceptual geohydrological model for Arnot Closed Colliery is illustrated schematically in Figure 57 by considering a cross-section through Pit 1 and the adjacent and underlying geological units. The position and orientation of the cross-section trace is shown in Figure 58. The cross-section extends from south-west of the Klein-Olifants River, runs through Pit 1 and the T3 Dam, and terminates north-east of the Bosman Spruit.

Although only a single cross-section through Pit 1 is used to illustrate the conceptual model, similar conditions are assumed to exist at Pit 2W and Pit 2E

15.1 Model Units

The conceptual model incorporates four different units, namely a topsoil layer, the Karoo sedimentary rocks, the opencast pits backfilled with spoils, and the rhyolites that underlie the pits. Although dolerite was encountered during the drilling of boreholes B5 and B9, the presence of dolerite will not be included in the numerical model since the information on the positions and orientations of the dolerite structures is at present very limited. Although indications are that the dolerites may be associated with preferential pathways for groundwater ingress, the limited information does not allow for accurate modelling and may lead to model results that poorly describe the reality.

Topsoil layer

The thickness of this layer was estimated from the geological logs of the new boreholes drilled during July 2012. The drilling results showed that the topsoil is significantly thicker at positions south of Pit 1 (refer to the borehole logs in **Appendix B**). The topsoil replaced on the backfilled pits is assumed to be thinner than in the natural environment; this assumption is based on observations made in the field.

Karoo sedimentary rocks

The different sedimentary rocks of the Karoo Supergroup (sandstones, shales, mudstones, coal layers) that occur at Arnot Closed Colliery are treated as a single unit with average hydraulic properties as described in Section 9.

Rhyolite layer

The rhyolite layer that is known to underlie the rehabilitated opencast pits forms the bottommost layer of the conceptual model. The depth to the top of the layer was estimated from the geological borehole logs. Due to its crystalline nature, this layer is assumed to be much less permeable than the overlying Karoo rocks.

In the south-west the Klein-Olifants River has eroded through the Karoo rocks to expose the underlying rhyolites (refer to the geology map, Figure 3)

Backfilled spoils

The spoils that have been used to backfill the opencast pits constitute the fourth unit of the conceptual model. Even though some compaction was done prior to rehabilitation, the spoils are associated with very high porosities, hydraulic conductivities and storativities. In the numerical model, the hydraulic properties of the spoils will be of no significance, since constant head conditions will be assigned to the backfilled pits.

15.2 Recharge

The groundwater recharge through the undisturbed earth materials away from the pits is assumed to be approximately 8% of the mean annual rainfall, as indicated by the DWA for sub-catchment B12B. Groundwater recharge through the rehabilitated spoils is expected to be much higher, in the vicinity of 20% of the mean annual rainfall.

15.3 Hydraulic Properties

First estimates of the hydraulic properties (porosity, horizontal and vertical hydraulic conductivities (K_h anf K_v), storativity (S) and specific yield (S_y)) of the different geological units of the numerical model are listed in Table 50. These values will be refined during the calibration of the numerical model. Confined/semi-confined conditions are assigned to both the Karoo rocks and the rhyolite, while unconfined conditions are assumed to prevail in the topsoil.

Table 50. Estimated hydraulic properties of the different units of the conceptual geohydrological model.

Model unit	Porosity	K_h (m/day)	K_v (m/day)	S	S_y
Topsoil	0.30	0.375	0.375		0.25
Karoo Sedimentary Rocks	0.08	0.040	0.040	1.0E-04	
Rhyolite	0.05	0.010	0.010	1.0E-05	

15.4 Water Levels

The water levels within the spoils of Pit 2 (W & E) will be assumed to be constant at the decant levels of these pits. The water elevation in Pit 1 is known to increase from the north-west to the south-east, most likely due to the compartmentalisation of the pit (refer to Section 11). For the numerical model, the water levels in this pit will be approximated by numerically fitting a flat surface through the measured pit water levels. The flat surface will be representative of the constant head conditions within the pit.

The groundwater levels within the Karoo rocks emulate the local topography. Flow therefore predominantly takes place in directions away from the pits towards the Bosman Spruit and Klein-Olifants River, which are receiving streams. The groundwater influx into the pits along preferential pathways hydraulically linked to recharge zones at higher elevations will not be considered in the numerical model.

15.5 Contaminant Levels

From the water quality information presented in Table 33 it is seen that the elevated sulphate concentrations of the deeper samples from the different boreholes in Pit 1 range between 1 572 mg/L (borehole AW24) and 3 572 mg/*l* (borehole AW01). Since evaporation from the open water bodies within Pit 1 will have caused increases in the salt concentrations near these water bodies, the sulphate concentrations in nearby boreholes are likely to also be elevated. The observed water qualities in these boreholes may therefore not be representative of the water quality in the pit.

The average sulphate concentration for deeper samples from the boreholes within Pit 1 is 2 555 mg/*l*. For the purpose of numerical contaminant transport modelling, it will be assumed that the sulphate concentration of the pit water of Pit 1 is equal to 2 600 mg/*l*. Although lower concentrations were recorded in Pit 2W and Pit 2E, this value is will also be assigned to the pit water in these pits in order to model a worst case scenario for contaminant impacts.

.

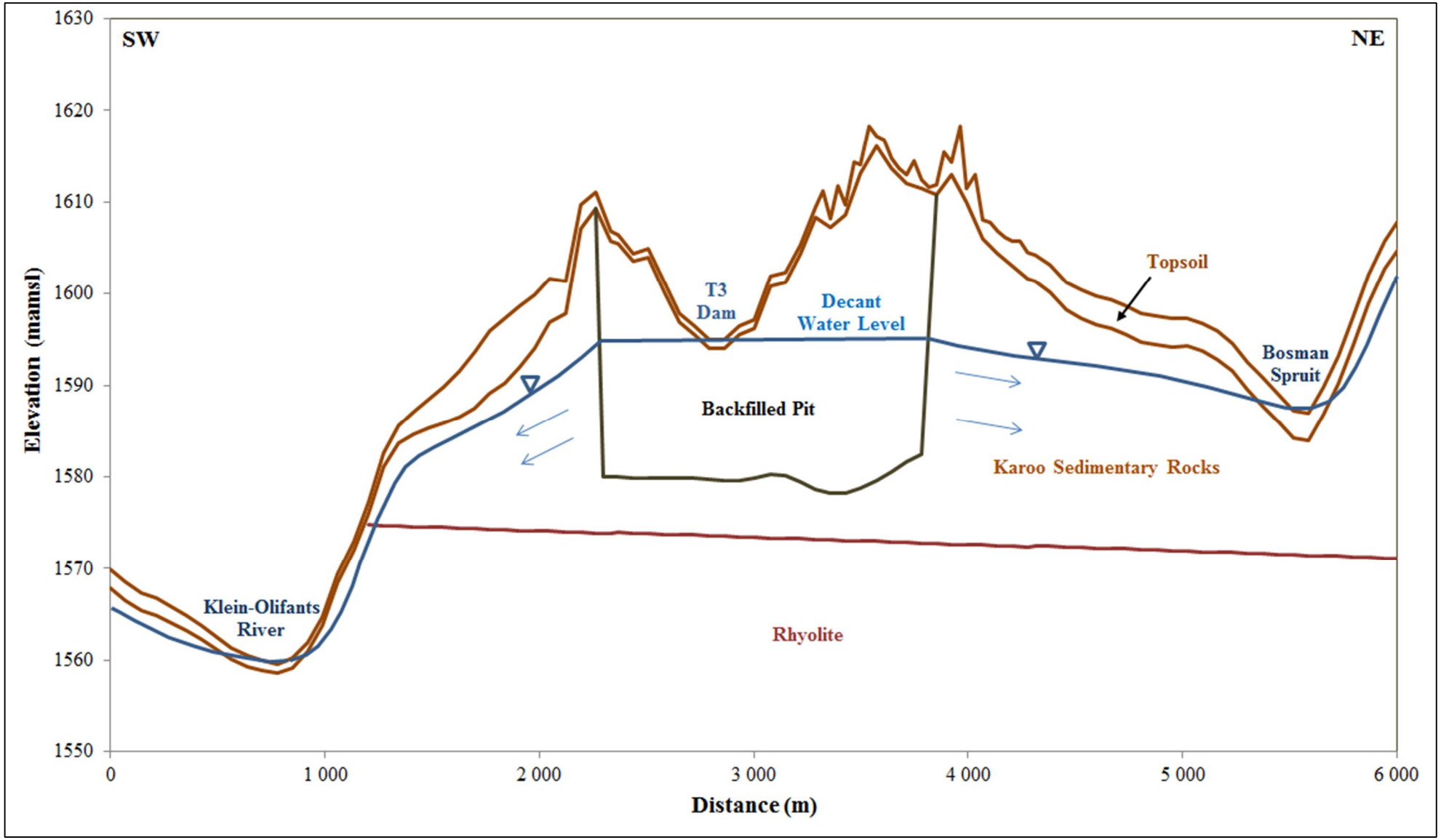


Figure 57. Schematic cross-section through Pit 1 illustrating the conceptual geohydrological model for Arnot Closed Colliery.

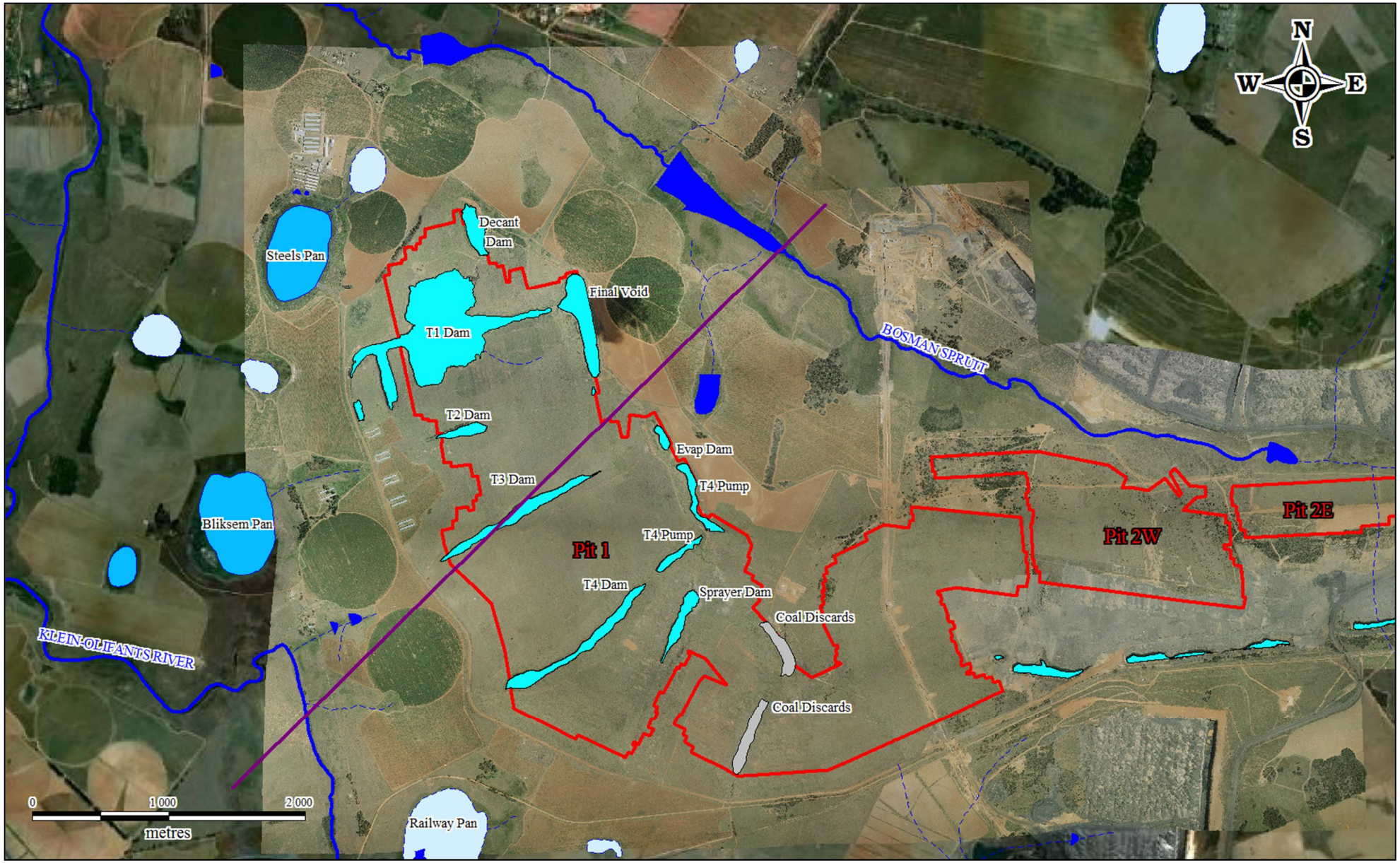


Figure 58. Position and orientation of the cross-section trace through Pit 1 used for the conceptual geohydrological model.

16 Numerical Modelling of Groundwater Flow and Contaminant Transport

16.1 Introduction

The numerical flow and transport model was constructed to:

- investigate the volumes of water leaving the backfilled pits through seepage into the topsoil and surrounding Karoo formations,
- gain insight into the subsurface flow patterns,
- investigate the migration of contaminant plumes away from the pits, and,
- obtain estimates of the salt loads that may impact on the natural surface water bodies along the groundwater pathway.

The numerical flow and transport modelling was done using the modelling software package FEflow. The software package employs a finite-element code to simulate saturated/unsaturated flow and mass transport through geological units with different hydraulic properties by using the continuity equation for groundwater flow in porous media.

16.2 Model Construction

The model domain is has spatial dimensions of approximately 15 765 m (west to east) by 10 140 m (south to north) with a vertical extent of approximately 230 mm vertically. The northern boundary of the model area is formed by the Bosman Spruit, while the southern and western boundaries are formed by the Klein-Olifants River. The eastern boundary was selected to be located approximately 2.5 km to the east of the easternmost boundary of Pit 2E.

The finite-element mesh consists of 149 413 elements and 935 030 nodes at six nodes per element over the model area. Local mesh refinement was applied around the perimeters of the pits where a steep gradient in the hydraulic heads and contaminant concentrations are likely to occur. Mesh refinement was also applied around the boreholes that may be impacted on by contaminants originating from the pits. The finite-element mesh and model boundaries are shown in Figure 59.

The numerical model consists of three layers, representing the topsoil layer, the Karoo formations and the rhyolites.

16.3 Boundary Conditions

The northern, southern and western boundaries of the model domain respectively correspond to the Bosman Spruit, the Klein-Olifants River upstream from its confluence with the Woestalleen Spruit, and the Klein-Olifants River downstream from its confluence with the Woestalleen Spruit. These boundaries are modelled as constant head boundaries with the head set at an elevation of 1 m below the surface elevation. This choice of boundary conditions assumes that the rivers are hydraulically connected to the groundwater system, as illustrated in the schematical representation of the conceptual model (refer to Figure 57). The eastern boundary of the model domain is treated as a water divide and no-flow conditions are accordingly assigned to this boundary.

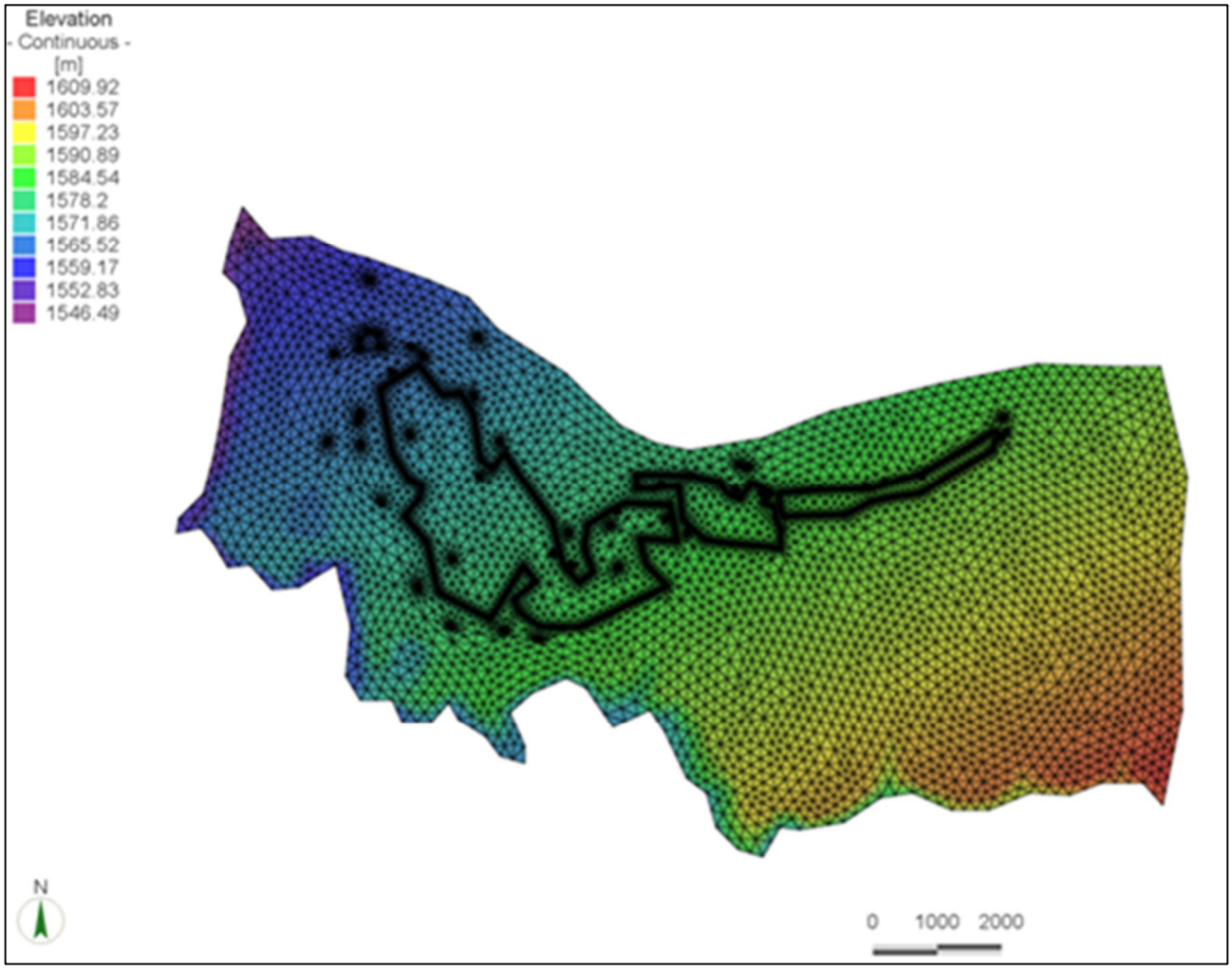


Figure 59. Finite-element mesh and numerical model boundaries.

16.4 Steady-State Model and Model Calibration

A steady-state model was run using estimates of the hydraulic properties of the different model units, as were obtained in Section 9 (Hydraulic Testing of Boreholes) and Section 12 (Soil Sampling). Initial estimates of the porosities of the different units were obtained from a literature study. The groundwater levels obtained from the steady-state model were compared with the

observed groundwater levels, and the hydraulic properties of the model units were adjusted until an acceptable fit between the modelled and observed water levels was obtained. These adjusted (calibrated) values for the hydraulic parameters are listed in Table 51. The model was calibrated with a recharge of 20.1 mm/a over the entire modelling domain, except the backfilled pits where constant head boundary conditions were assigned (refer to Section 15.4).

Table 51. Calibrated input parameters for the steady-state model.

Model layer	Layer thickness (m)	Porosity	Hydraulic conductivity (m/d)
Topsoil	2	0.30	0.375
Karoo formations	variable	0.05	0.039
Rhyolites	variable	0.12	0.012

The agreement between the modelled and observed water elevations is shown in Figure 60 and Figure 61. From Figure 60 and Figure 61 it is seen that that the modelled water groundwater elevations of the calibrated model give a reasonable representation of the observed water elevations within and in the vicinity of the rehabilitated opencast pits. The steady-state groundwater elevations of the calibrated model are shown as a contour plot in Figure 62. The regional groundwater gradient is seen to be directed from the south-east to the north-west of the model domain. Since, for modelling purposes, constant heads conditions were assigned to the backfilled pits, the groundwater elevation contours in the vicinity of these pits appear distorted when compared with the contours of the measured groundwater elevations (see Figure 47, Section 11).

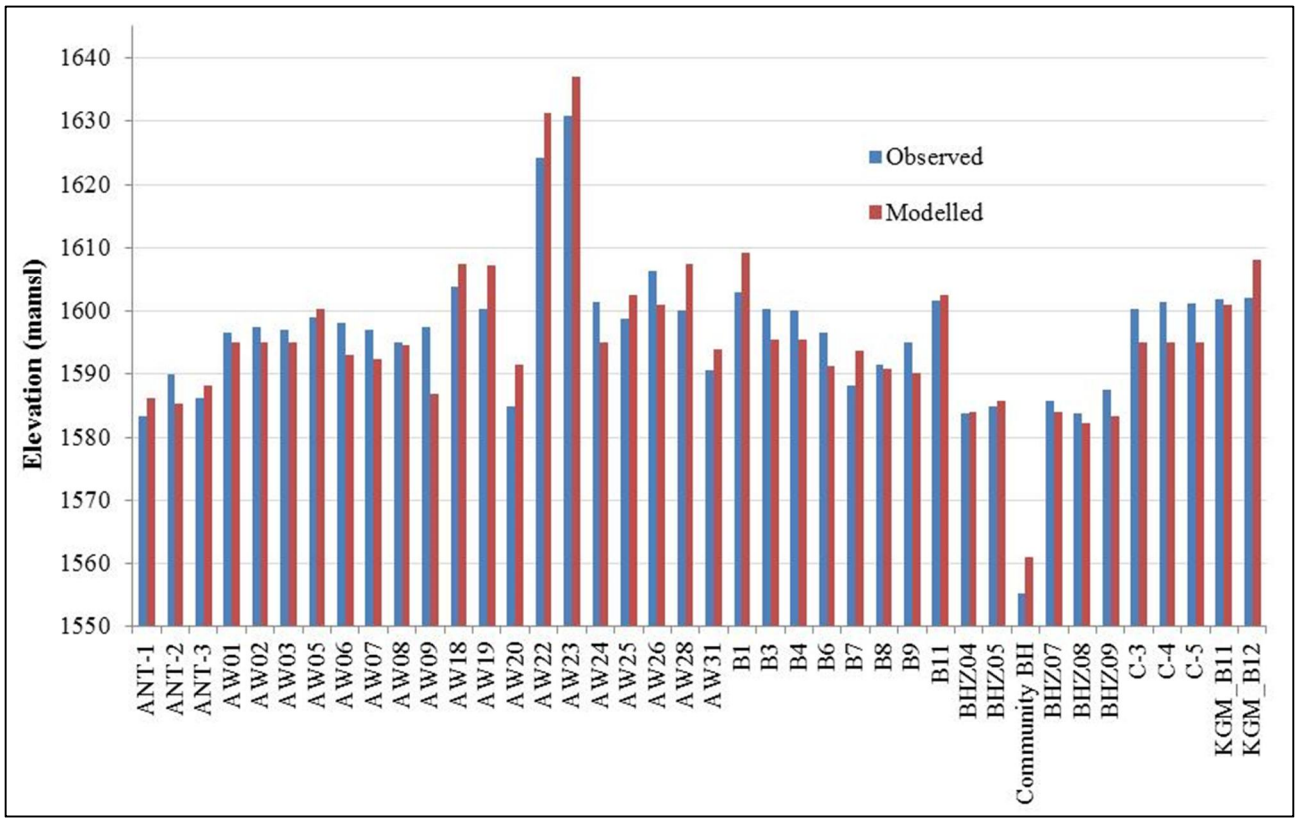


Figure 60. Modelled and observed water levels for the calibrated steady-state model.

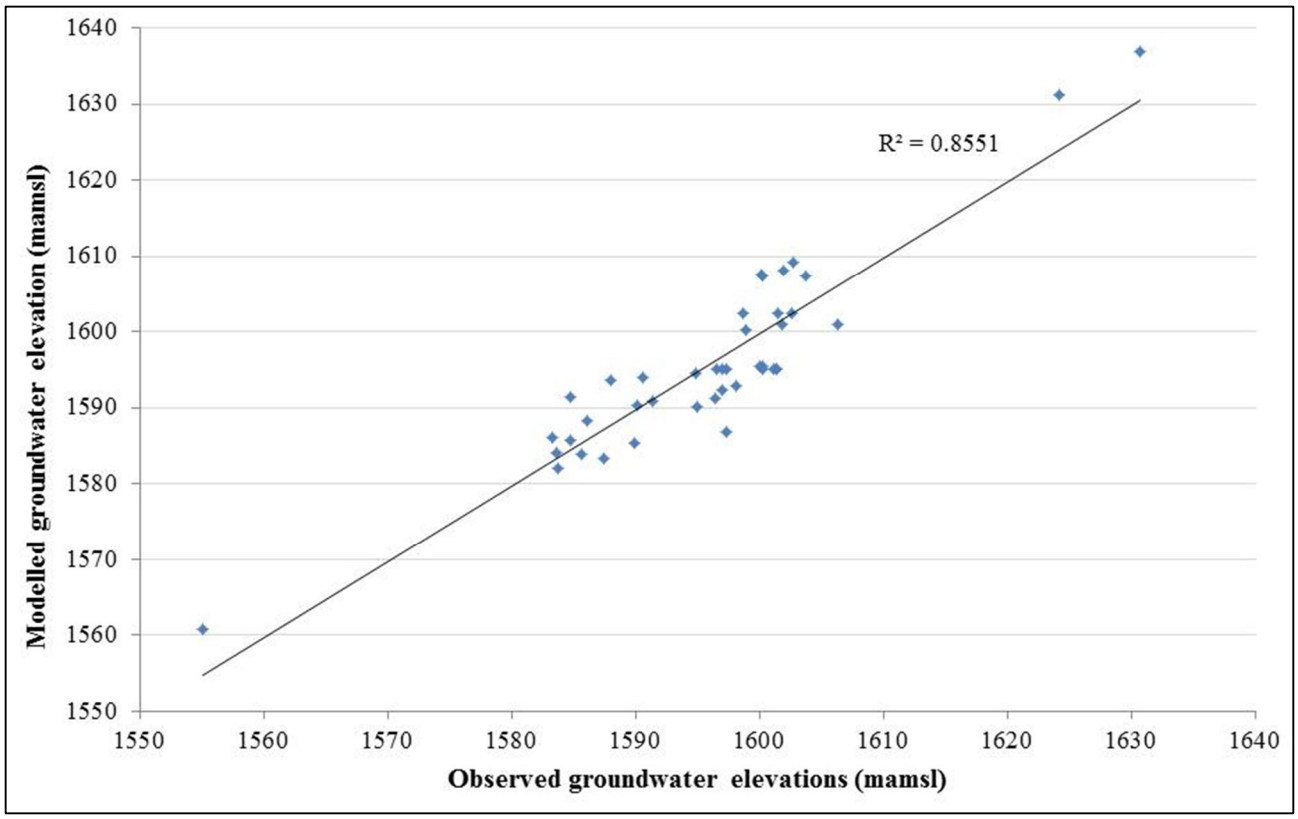


Figure 61. Modelled water levels plotted against observed water levels for the calibrated steady-state model.

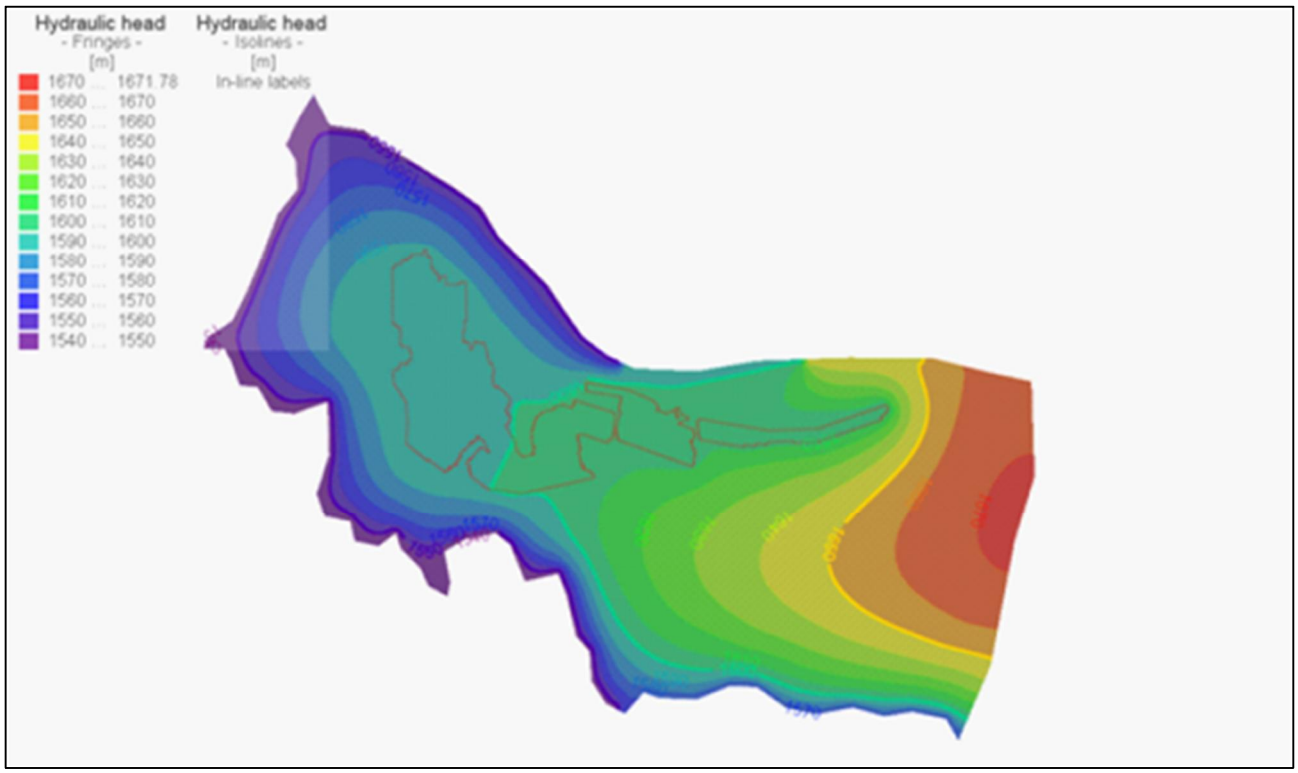


Figure 62. Groundwater elevations of the calibrated steady-state model.

The elevated water levels in the backfilled pits cause local hydraulic gradients from the pits to the nearby rivers. Groundwater flow is therefore expected to predominantly occur away from the pits into the surrounding geological units. The results of the steady-state numerical model indicate that

the volumes of groundwater entering the Karoo formations, rhyolites and topsoil layer are approximately 0.25 M*l*/day.

16.5 Transient Model

The ground flow and contaminant transport in and around pits was modelled for a 100-year period. To model the migration of the contaminant plume, a constant sulphate concentration of 2 600 mg/*l* was assigned to all three the rehabilitated pits. Although the current contaminant plume already extends beyond the boundaries of the rehabilitated opencast pits, and particularly to positions to the north-west of Pit 1 (refer to Figure 33 and Figure 34, Section 10.1), the numerical model considers the situation where, initially (at time = 0 days) all the contaminants are confined to the pits.

The migration of the contaminant plume within the Karoo formations after time intervals of 5, 10, 20, 50 and 100 years are shown in Figure 63 to Figure 67, while the migration of the contaminant plume within the topsoil layer is shown for the corresponding time periods in Figure 68 to Figure 72.

From Figure 63 to Figure 72 it is seen that contaminant migration in the Karoo formations is expected to be relatively slow with the contaminant plume confined to the immediate vicinity of the pits for the first two decades. Contaminant migration in the topsoil is expected to be even more limited. However, in time, impacts on the both the Bosman Spruit and the Klein-Olifants River are expected. Due to its proximity to Pit 2W, the Bosman Spruit is particularly vulnerable to contaminant impacts.

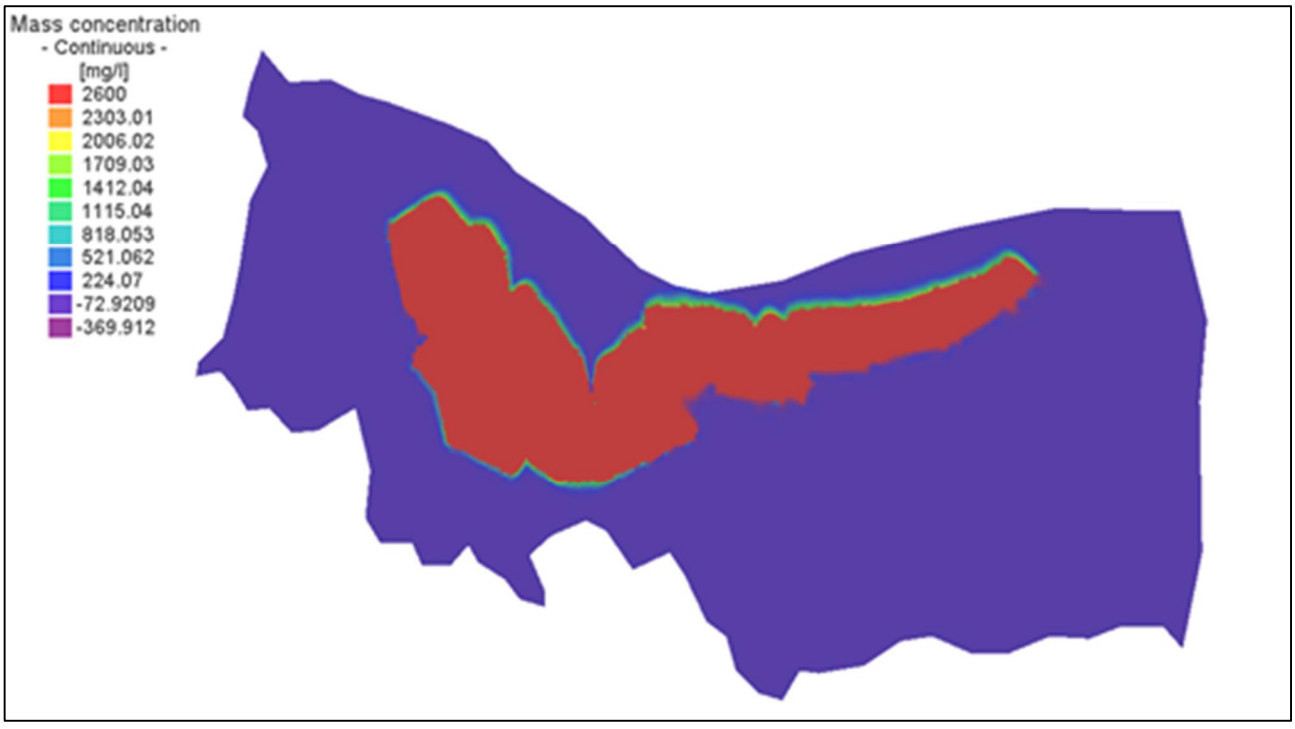


Figure 63. Contaminant plume in the Karoo formations after 5 years.

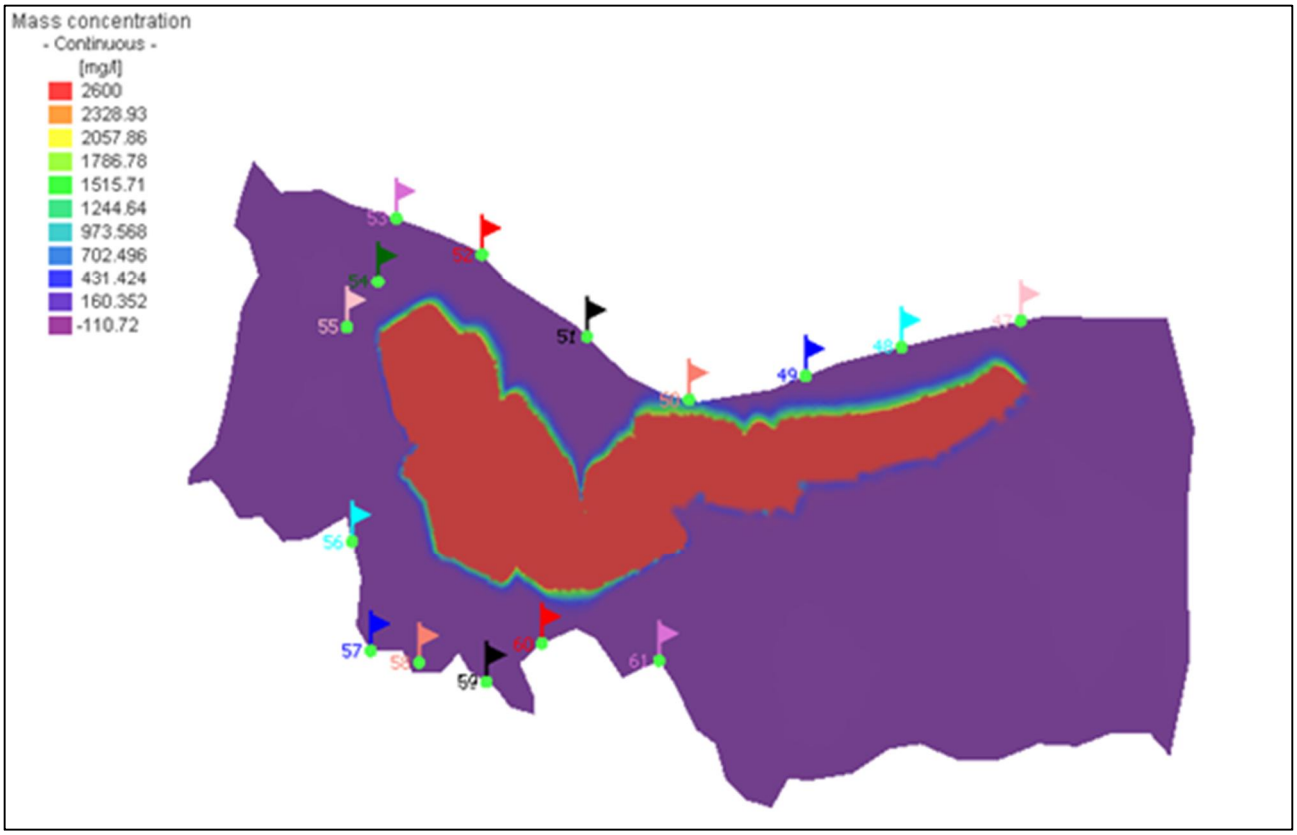


Figure 64. Contaminant plume in the Karoo formations after 10 years.

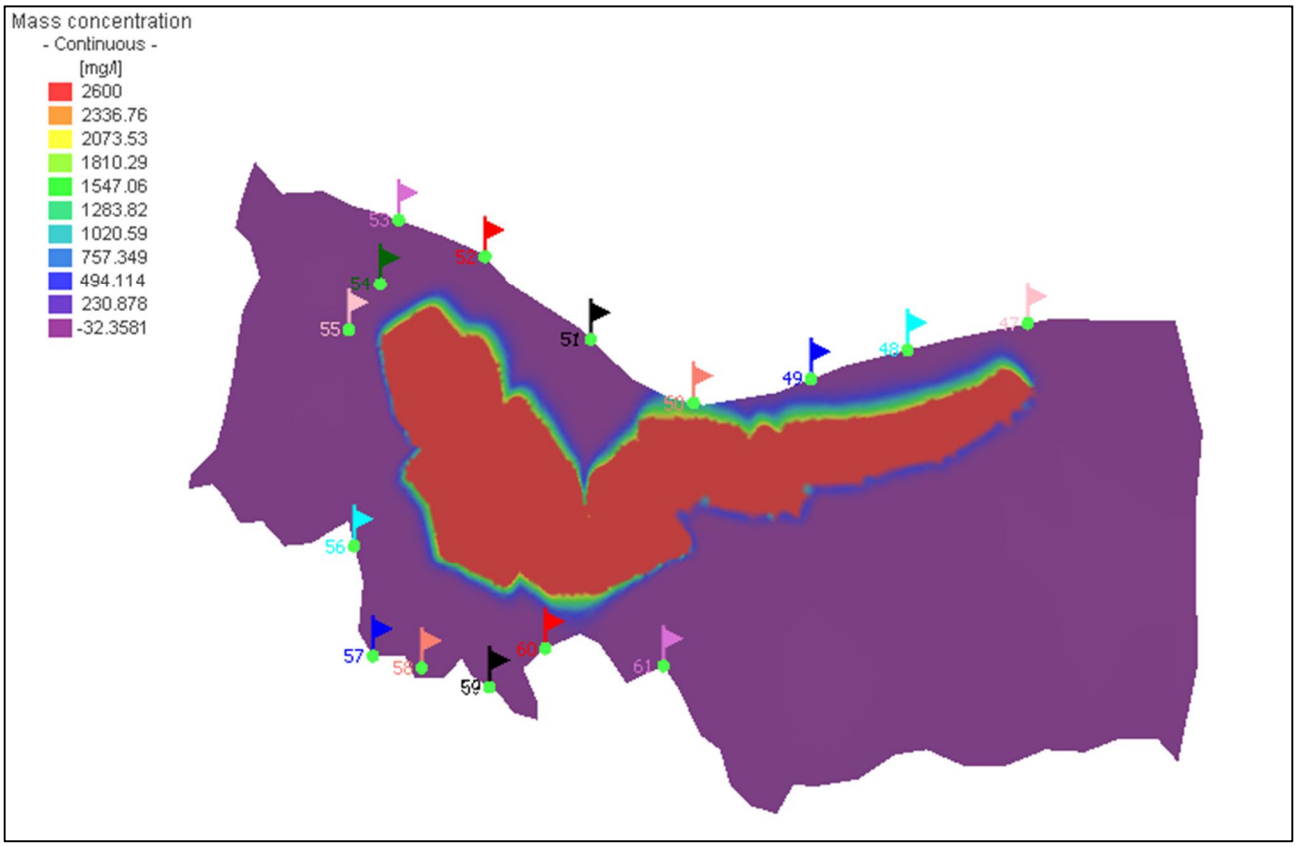


Figure 65. Contaminant plume in the Karoo formations after 20 years.

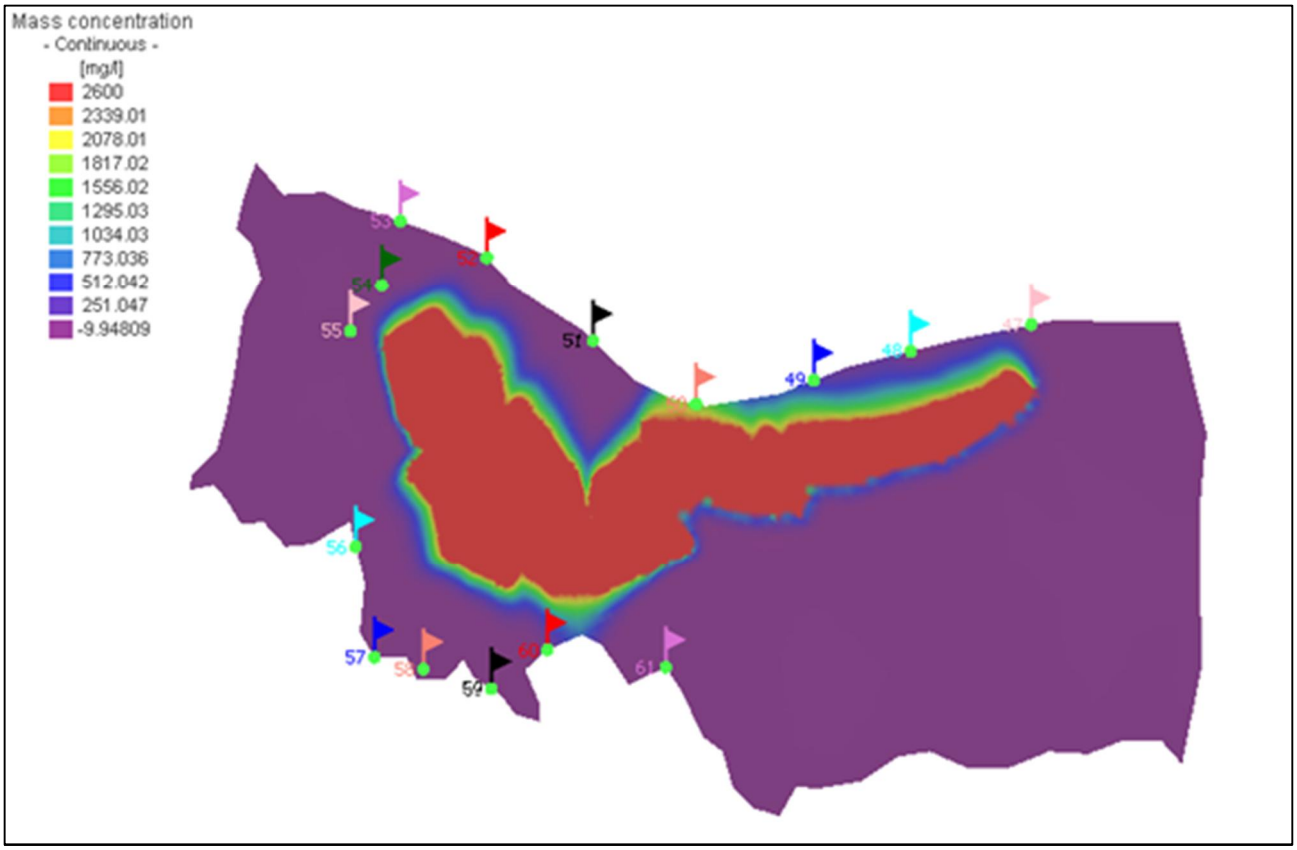


Figure 66. Contaminant plume in the Karoo formations after 50 years.

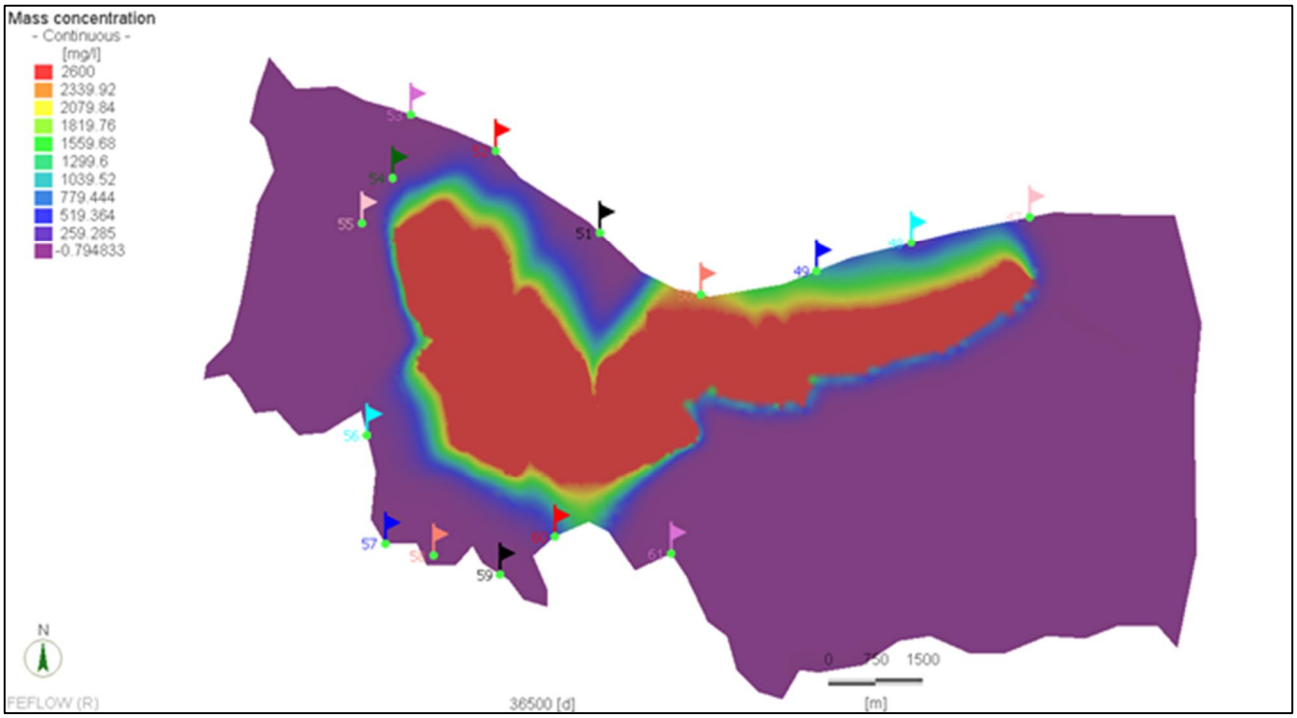


Figure 67. Contaminant plume in the Karoo formations after 100 years.

Figure 68. Contaminant plume in the topsoil after 5 years.

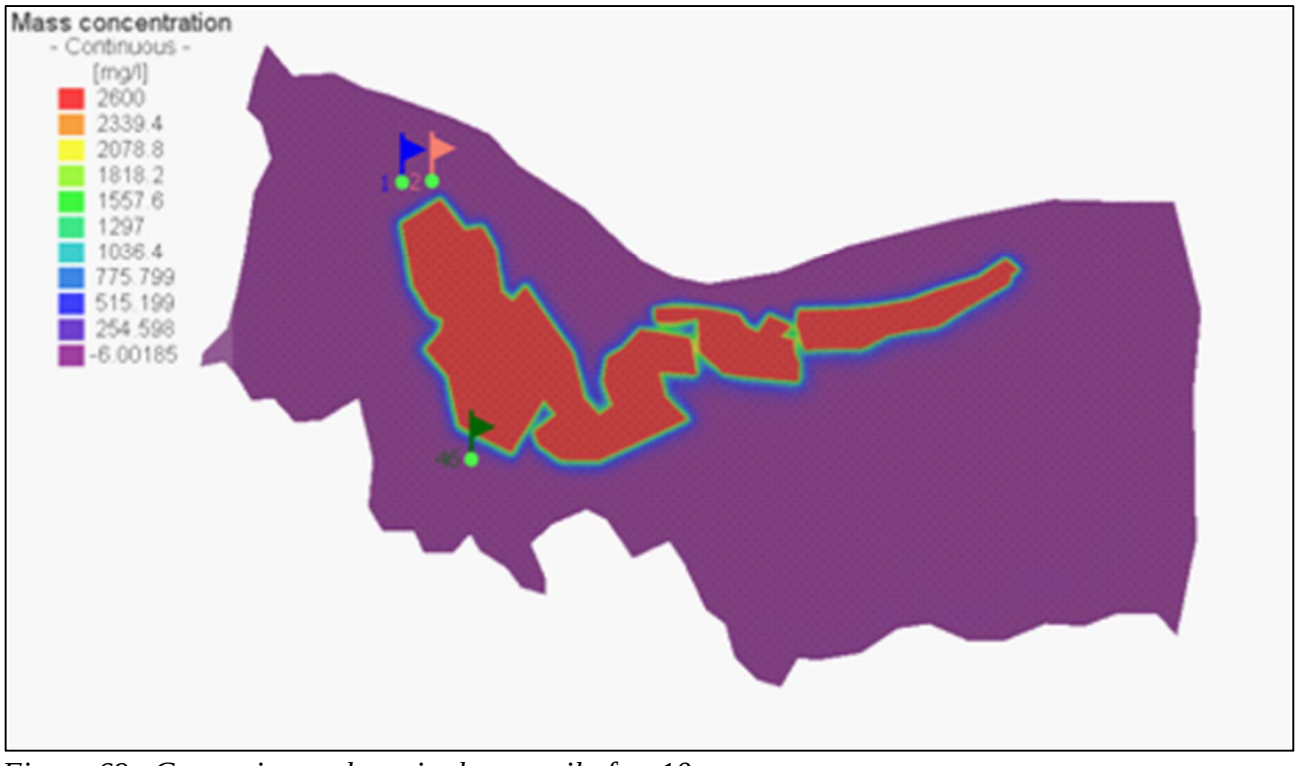


Figure 69. Contaminant plume in the topsoil after 10 years.

Figure 70. Contaminant plume in the topsoil after 20 years.

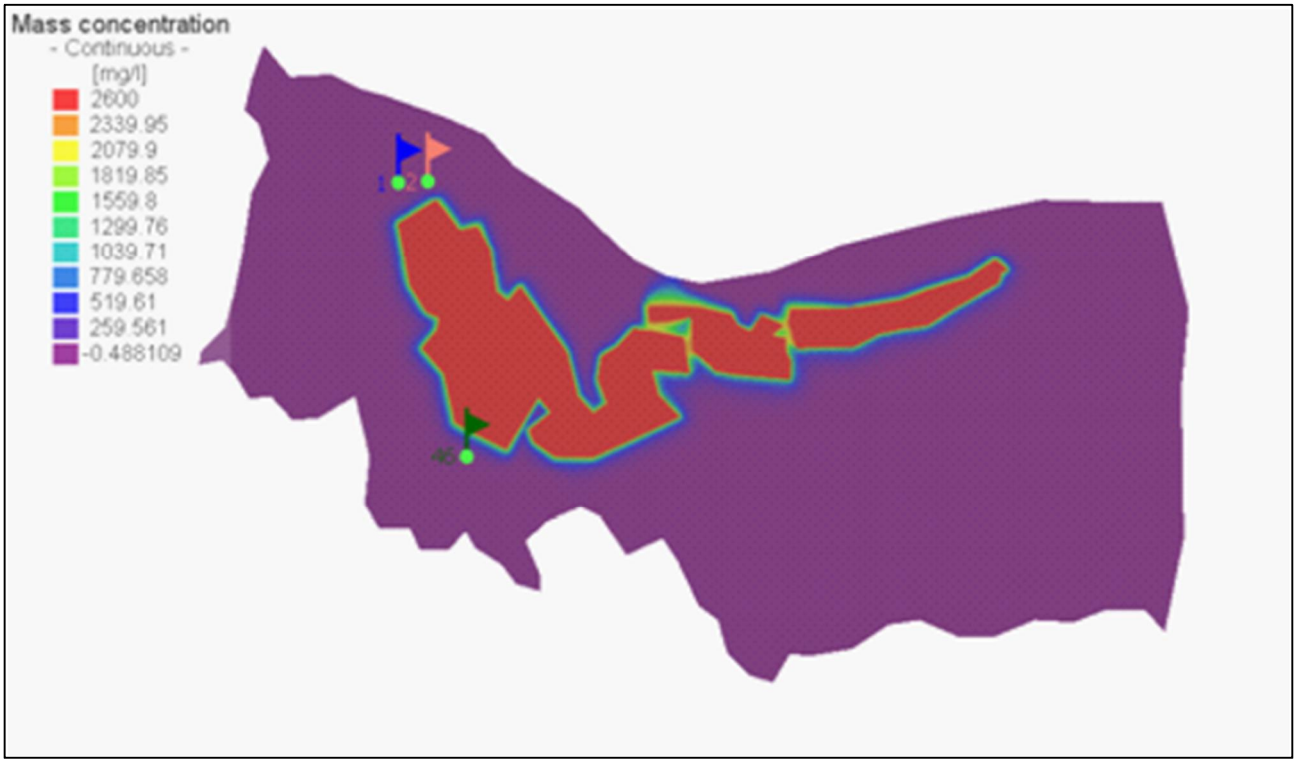


Figure 71. Contaminant plume in the topsoil after 50 years.

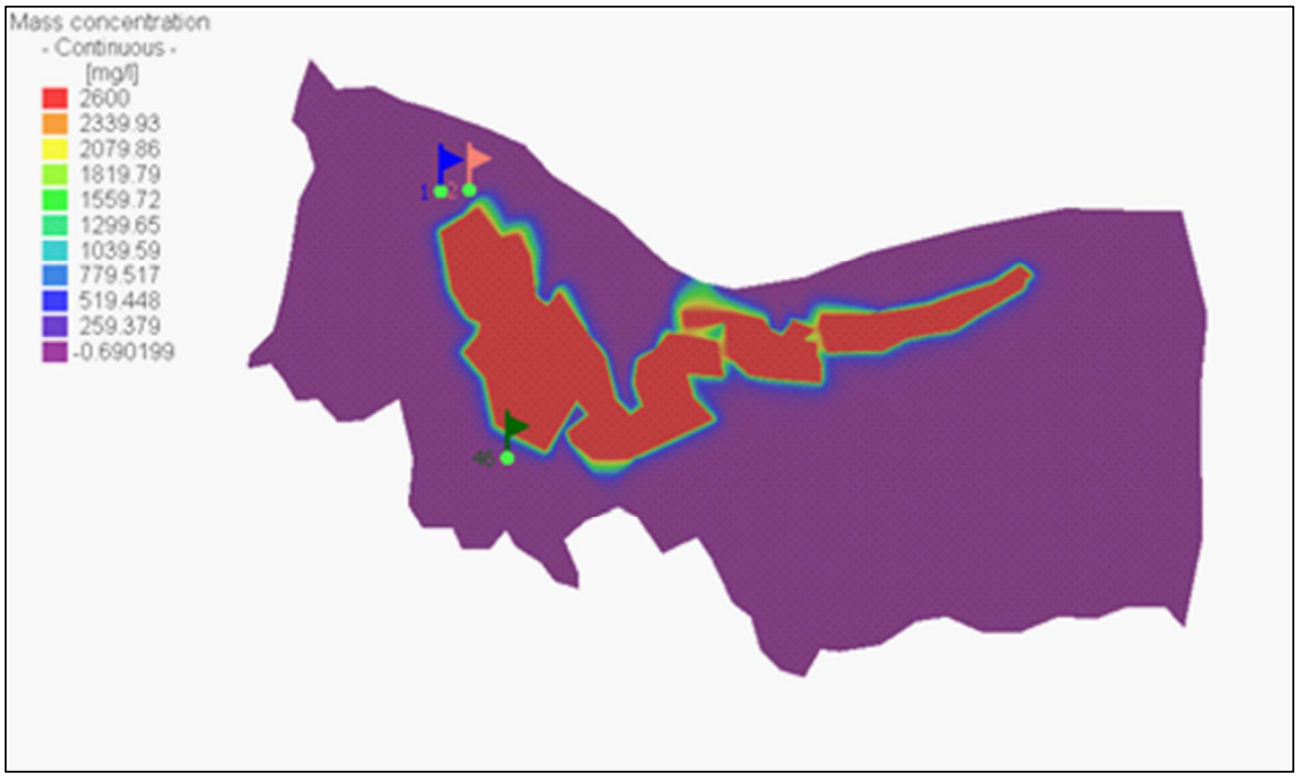


Figure 72. Contaminant plume in the topsoil after 100 years.

Temporal graphs of the sulphate concentrations at various observation points along the Bosman Spruit and Klein-Olifants River are presented in Figure 73. The positions of the observation points are shown in Figure 65. Observation point 50 is located within the Bosman Spruit at the position of closest proximity to Pit 2W. In Figure 73 it is seen that contaminant impacts at this position could be expected in as little as 5½ years (approximately 2 000 days). Within 55 years the sulphate concentration of the groundwater at observation point 50 may reach a value of 1 800 mg/*l*.

Observation point 60 occurs along the Klein-Olifants River near the southern perimeter of Pit 1 at a position where the river makes a bend towards the pit. The modelled sulphate concentration at this observation point suggest that contaminant impacts on the river along the groundwater pathway are not likely to occur before 33 years have elapsed. Even when impacts occur, the severity of such impacts is much less pronounced than the impacts on the Bosman Spruit. Even after 100 years, the sulphate concentration of the groundwater at observation point 60 is expected to be below 400 mg/*l*.

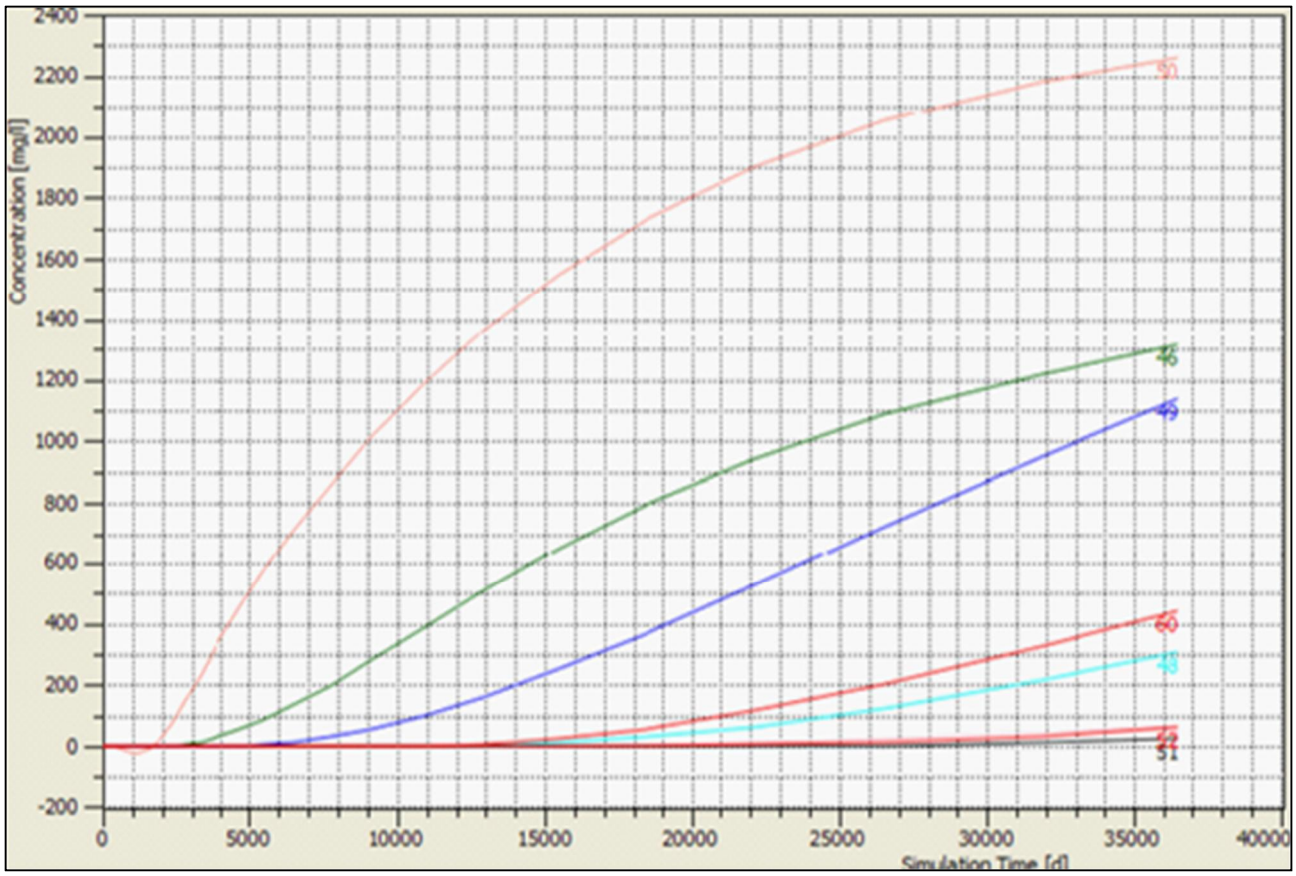


Figure 73. Sulphate concentrations at observations points.

The cumulative sulphate loads impacting on the Bosman Spruit and Klein-Olifants River are shown graphically in Figure 74. (The negative signs for the salt loads are simply a convention used by FEflow.) The results of the numerical model suggest that, over a 100 year period, approximately 20 000 tonnes of sulphate will impact on the Bosman Spruit. This value equates to an average daily sulphate load of approximately 550 kg (or a TDS load of approximately 785 kg) over the 100 year period. These salt loads will be transported along the Bosman Spruit and the Klein-Olifants River to the Middelburg Dam.

The numerical model suggests that the salt impact on the Klein-Olifants River along the groundwater pathway will be much smaller than the impact on the Bosman Spruit. Only approximately 700 tonnes of sulphate will have impacted on the Klein-Olifants River at positions to the south of Pit 1 after a period of 100 years. This value corresponds to an average daily sulphate load of less than 20 kg.

Possible contaminant impacts on the abstraction boreholes of Alzu Enterprises were also investigated with the numerical model. The positions of these boreholes are shown as flags in Figure 75. Flags number 1 to 6 correspond to the following six abstraction boreholes: BHZ01, BHZ02, BHZ03, BHZ10, BHZ11 and the Alzu Windpump. An average pumping rate of 0.25 *l*/s on a 24-hour period was assigned to each of the abstraction boreholes. This pumping rate was estimated from the known groundwater usage at Alzu Enterprises (refer to Section 3.5).

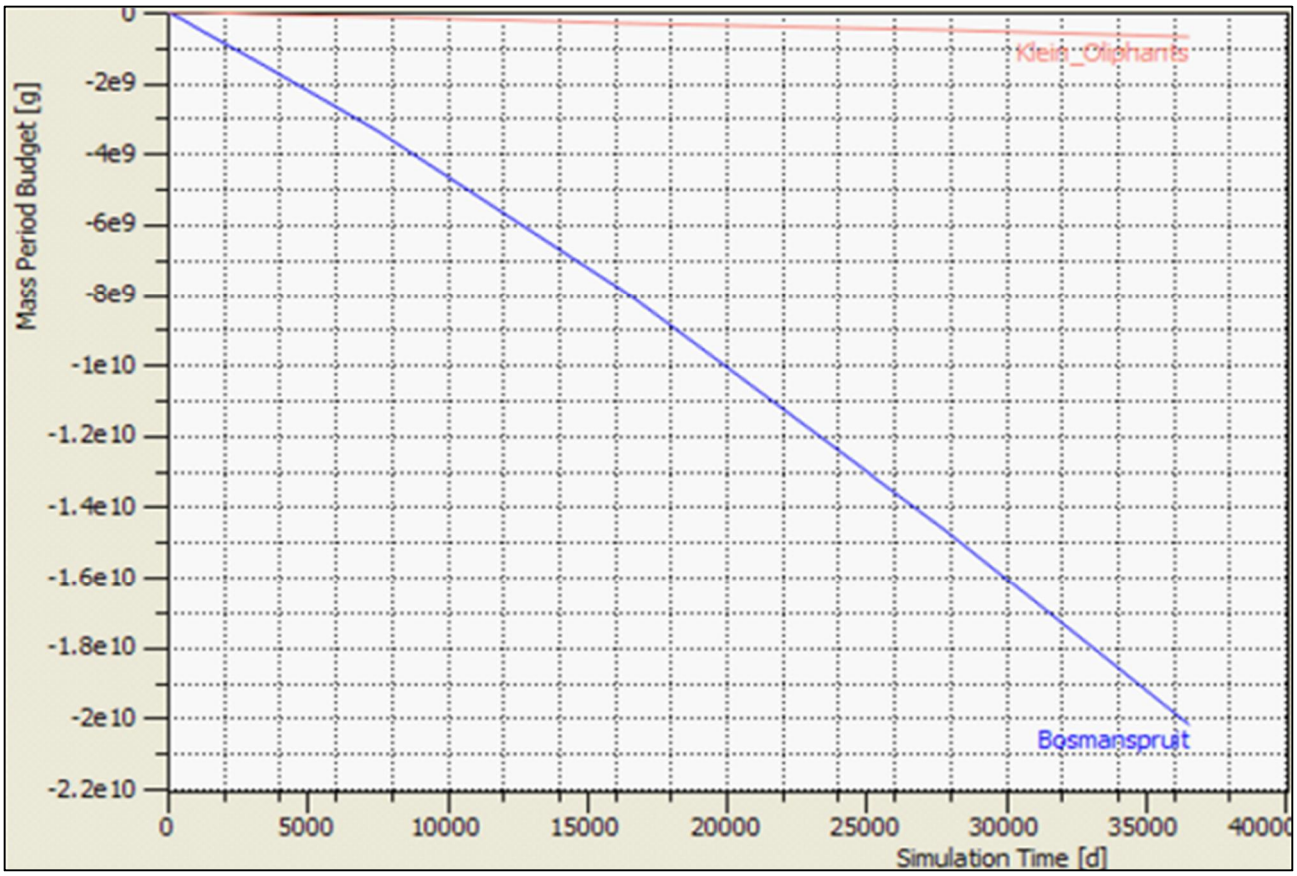


Figure 74. Cumulative sulphate loads impacting on the Bosman Spruit and Klein-Olifants River.

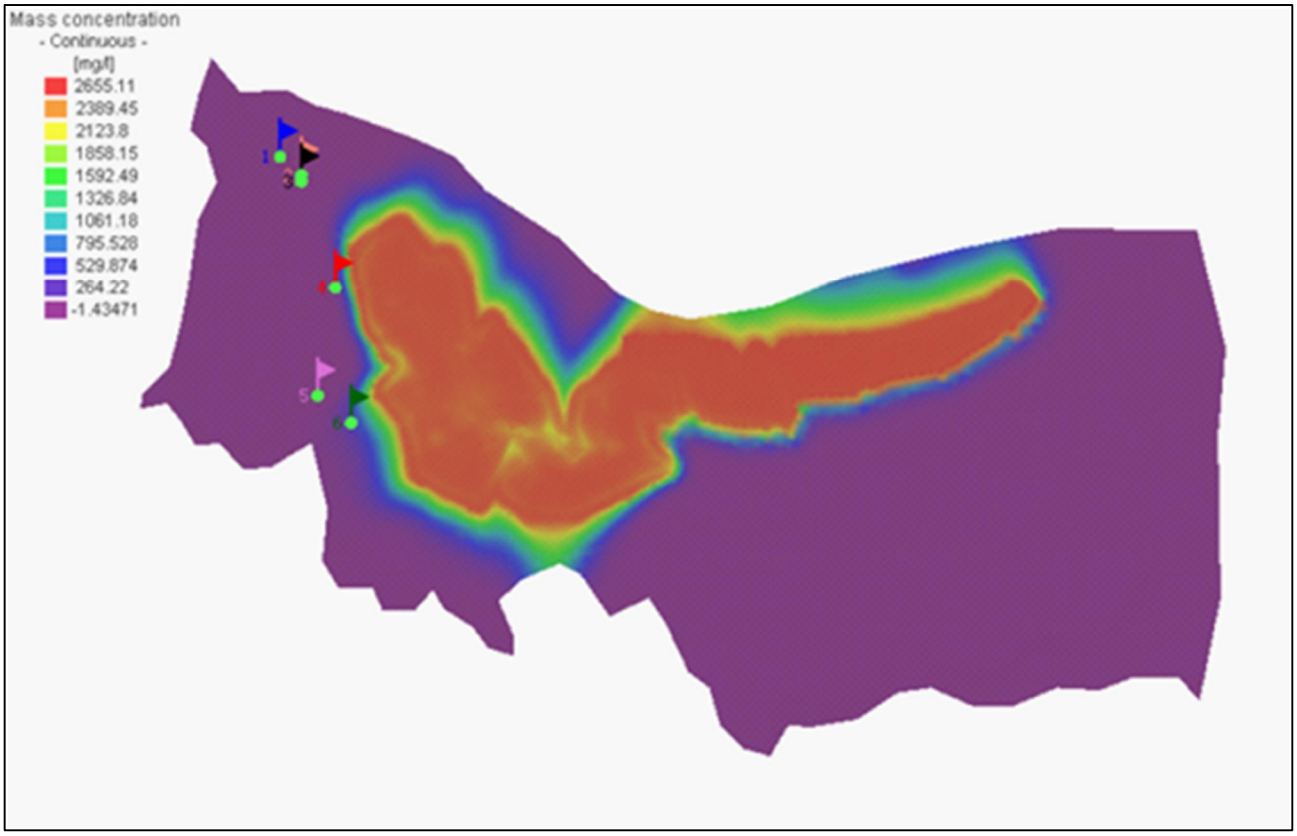


Figure 75. Positions of the abstraction boreholes of Alzu Enterprises relative to the contaminant plume as modelled after 100 years.

The modelled sulphate concentrations for the various abstraction boreholes are shown as graphs in Figure 76. From the graphs it appears that the Alzu Windpump (Flag 6) and borehole BHZ10 (Flag 4) are the most likely abstraction boreholes to be impacted on by contaminant impacts along the groundwater pathway. The numerical model suggests that the groundwater quality at the Alzu Windpump may start to deteriorate after approximately 25 years and that the sulphate concentration at this borehole may reach a value of approximately 100 mg/l after 55 years.

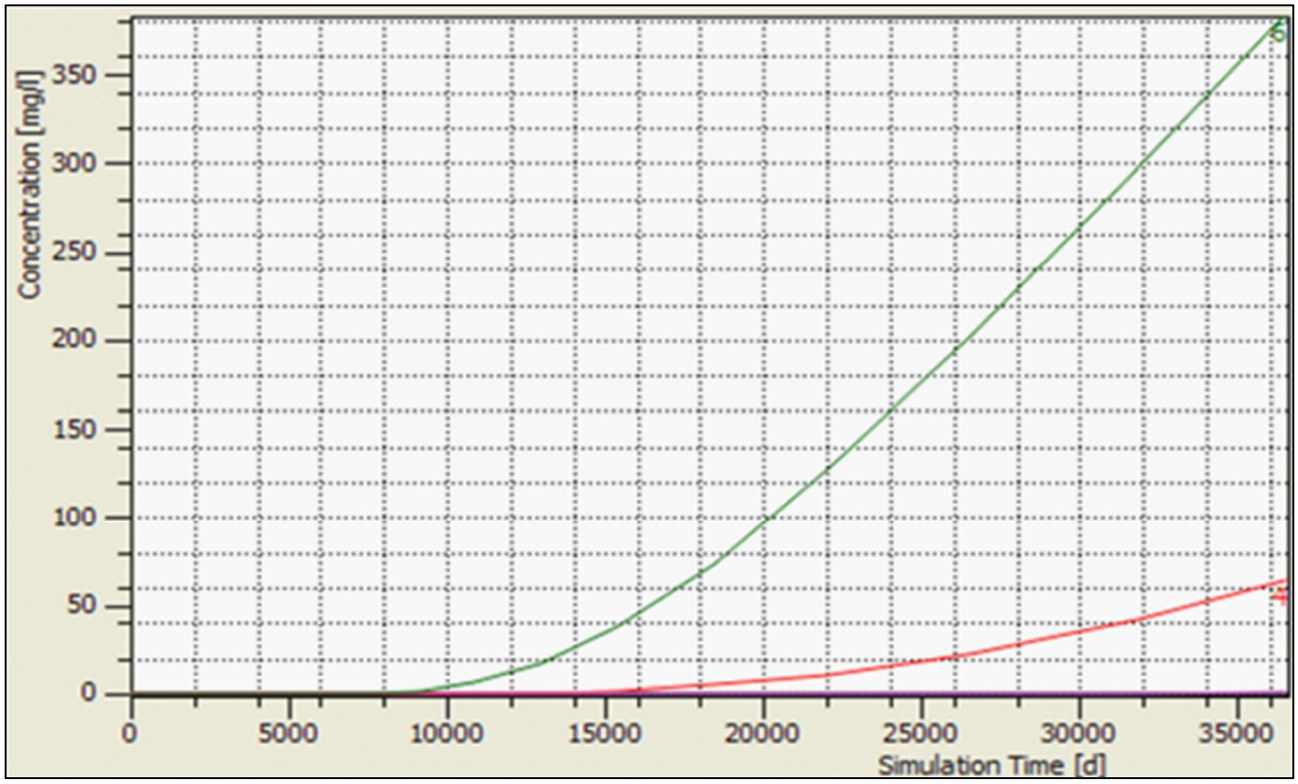


Figure 76. Modelled sulphate concentrations for the abstraction boreholes of Alzu Enterprises.

17 Water Make and Water Balance

17.1 Estimation of the Water Make

In Section 4.6 the current water make of Arnot Closed Colliery was estimated from an examination of the existing flowmeter measurements, measured dam levels, evaporation and rainfall figures. Some assumptions regarding the evaporation at the sprayers were also made during the estimation. The 'managed' water make of the colliery over the period January to June 2012 was estimated at **4.90 M*l*/day** (assuming evaporation losses of 30% at the sprayers). It was mentioned that this estimate should be seen as representative of the managed water make during years of low rainfall, with rainfall figures similar to the first six months of 2012.

The water make may also be estimated by making assumptions regarding the effective recharge through the spoils. Experience at opencast coal mines in Mpumalanga has shown that the effective recharge (recharge after evaporation) through rehabilitated spoils is approximately 20% of the rainfall. Using this recharge value for the spoils and assuming a rainfall figure of 720 mm, the recharge to Arnot Closed Colliery for the period January to June 2012 is estimated at 2.67 M*l*/day of which approximately 78% (2.07 M*l*/day) is through Pit 1 (see Table 52). This value is approximately 46% (2.23 M*l*/day) lower than the 'managed' water make (4.90 M*l*/day) for the corresponding period as estimated in Section 4.6. This observation strongly suggests that recharge alone cannot explain the observed volumes of water at Arnot Closed Colliery and that groundwater inflows contribute a significant percentage to the total water make.

Table 52. Estimated recharge to the rehabilitated opencast pits at Arnot Closed Colliery, January to June 2012.

Jan - June 2012: Recharge volumes (0.23 m rainfall; 20% recharge through spoils)

Site	Pit1	Pit2W	Pit2E	Total
Surface area (km^2)	8.195	1.375	1.003	**10.573**
Surface area (m^2)	8 195 000	1 375 000	1 003 000	**10 573 000**
Surface area (ha)	819.5	137.5	100.3	**1057.3**
Recharge (m^3)	376 970	63 250	46 138	**486 358**
Recharge (m^3/day)	2 071	348	254	**2 672**
Average recharge (M*l*/day)	2.07	0.35	0.25	**2.67**

In Table 53 the recharge volumes to the pits are estimated using the rainfall figures as recorded during 2010, and again assuming 20% recharge through the spoils. The total estimated recharge to the three pits now amounts to 4.17 M*l*/day. Assuming net groundwater inflows of a similar volume (2.23 M*l*/day) than during January to June 2012, the estimated water make increases to **6.40 M*l*/day**. This value may be seen as the estimated water make during years of average rainfall.

Table 53. Estimated recharge to the rehabilitated opencast pits at Arnot Closed Colliery, 2010.

2010: Recharge volumes (0.72 m rainfall; 20% recharge through rehabilitated spoils)				
Site	**Pit1**	**Pit2W**	**Pit2E**	**Total**
Surface area (km^2)	8.195	1.375	1.003	**10.573**
Surface area (m^2)	8 195 000	1 375 000	1 003 000	**10 573 000**
Surface area (ha)	819.5	137.5	100.3	**1057.3**
Average recharge (m^3/a)	1 180 080	198 000	144 432	**1 522 512**
Average recharge (m^3/day)	3 233	542	396	**4 171**
Average recharge (M*l*/day)	3.23	0.54	0.40	**4.17**

During years of high rainfall, similar to the conditions experienced during 1987, the recharge volumes may be as high as 5.84 M*l*/day (see Table 54) while the average water make increases to **8.07 M*l*/day**.

Table 54. Estimated recharge to the rehabilitated opencast pits at Arnot Closed Colliery, based on the rainfall figures of 1987.

1987: Recharge volumes (1.00 m rainfall; 20% recharge through rehabilitated spoils)				
Site	**Pit1**	**Pit2W**	**Pit2E**	**Total**
Surface area (km^2)	8.195	1.375	1.003	**10.573**
Surface area (m^2)	8 195 000	1 375 000	1 003 000	**10 573 000**
Surface area (ha)	819.5	137.5	100.3	**1057.3**
Average recharge (m^3/a)	1 652 112	277 200	200 600	**2 129 912**
Average recharge (m^3/day)	4 526	759	550	**5 835**
Average recharge (M*l*/day)	4.53	0.76	0.55	**5.84**

The above water make estimates for years of average and high rainfall may still underestimate the true values since it was assumed that the net groundwater inflow into the pits will remain similar to the inflow experienced during 2012 (2.23 M*l*/day). However, higher rainfall figures are likely to cause increases in the elevations of the groundwater table and hence the hydraulic heads in the aquifers from which flow occurs towards the pits. Larger volumes of groundwater inflows can therefore be expected during periods of high rainfall.

It should also be noted that, even though the 1987 rainfall figures were much higher than the average rainfall figures, they do not represent extreme conditions. During the two months of January and February 2006 more than 800 mm of rain was recorded at the Decant Dam. The extreme rainfall experienced during these two months led to the decant problems of early 2006.

17.2 Water Balance

Since the surface water and groundwater regimes are closely connected at Arnot Closed Colliery, both the surface water components and the groundwater components should be simultaneously considered when estimating the water balance of the colliery.

It is at present not known to what extent the different pits at Arnot Closed Colliery are hydraulically linked. The results of the drilling (Section 7) and geophysical investigations (Section 14) suggest that if dolerite intrusives are responsible for these corridors, the intrusives do not extend to surface and do not form barriers against inter-pit flow. The discussion on the groundwater levels recorded in the vicinities of the pits (refer to Section 11) introduced the idea that these corridors may indeed be associated with intrusives along which groundwater migration towards the pits may be occurring.

Since the volumes of inter-pit water flows can at this stage not be quantified with any certainty, all three pits are treated as a single entity in estimating the water balance. It is furthermore assumed that the water levels in the three pits are near their decant levels so that no additional storage of water takes place within the spoils. The absence of historical water level data for the boreholes within Pit 2W and Pit 2E makes the quantification of storage changes in these pits impossible. With the above assumptions, the Water Balance equation may be used to calculate the Excess Water, that is, the quantity of water that the colliery has to dispose of in one way or another:

$$\textit{Excess Water} = \textit{Rainfall} + (\textit{Groundwater inflows} - \textit{Groundwater outflows}) - \textit{Evaporation Losses} - \textit{Runoff} \quad (4)$$

In Section 17.1 the net groundwater inflow into the backfilled pits was estimated at 2.23 M*l*/day. To obtain first estimates of the magnitudes of the inflows and outflows, Darcy's equation may be applied. Using the average hydraulic gradient between the backfilled pits and the monitoring boreholes in the Karoo formations (i = 0.016), the geometric mean of the hydraulic conductivities of the Karoo formations (K = 0.039 m/day, Section 9.2) and a cross-sectional area (A = 574 200 m^2) corresponding to the combined surface area of the sides of the three pits below the decant water levels, the total groundwater outflow (Q) may be estimated from Darcy's equation ($Q = KiA$) at 0.36 M*l*/day. The estimated total groundwater inflow into the pits is therefore 2.59 M*l*/day.

Using Equation (4), the Excess Water for Arnot Closed Colliery is calculated in Table 55. The net groundwater inflows for the three pits are calculated by simply scaling the inflows according to the surface areas of the pits. This is, however, a crude approach since indications are that groundwater influx into the pits is occurring along preferential pathways, possible associated with dolerite intrusives (refer to drilling results, water levels and geophysics as discussed in Sections 7.2, 11 and 14.3).

Table 55. Estimated water balance for Arnot Closed Colliery.

Area	Pit 1	Pit 2W	Pit2E	Total
Surface area (ha)	819.5	137.5	100.3	1057.3
Rainfall (M*l*/day)	16.17	2.71	1.98	20.9
Groundwater Inflows - Groundwater Outflow (M*l*/day)	1.73	0.29	0.21	2.23
Runoff (M*l*/day)	1.29	0.22	0.16	1.67
Evaporation losses from open water bodies (M*l*/day)	1.31	0.00	0.00	1.31
Evaporation losses from spoils (M*l*/day)	10.33	1.95	1.42	13.71
Excess (M*l*/day)				**6.40**

In Table 55, the runoff and total evaporation figures were calculated by assuming that these values respectively correspond to approximately 10% and 90% of the combined runoff/evaporation losses (values similar to those used in the EMP). The evaporation from open water bodies considered only the evaporation from the Decant Dam and the T1 Dam (here it is assumed that the pits are not compartmentalised so that only these dams will contain significant water when the water level in Pit 1 is at the decant level when all pumping ceases). The rainfall figure corresponds to the rainfall expected during a year of average rainfall (720 mm).

The volume of Excess Water calculated in Table 55 (6.40 M*l*/day) represents the average volume of water that has to be managed at Arnot Closed Colliery during years of average rainfall. During years of high rainfall (such as experienced during 1987), this figure may increase to more than 7.2 M*l*/day. Extreme rainfall events (such as experienced during 2006) will significantly increase the volumes of water that have to be handled at the colliery during such events.

17.3 Salt Balance

The salt balance for Arnot Closed Colliery may be estimated from the measured pumping rates during the period January to June 2012 (Section 4.2), the water quality information (Section 10) and the estimated water balance (Section 17.2). In Figure 77 the sulphate concentrations recorded during August 2012 are plotted against the TDS concentrations. A linear relationship is observed with the sulphate concentration being, to a close approximation, equal to 70% of the TDS concentration. The sulphate concentration may therefore be used as an indicator of the TDS concentration. In Table 56 the sulphate balance for Arnot Closed Colliery is estimated. A number of assumptions are made:

- The average pit water concentration remained the same during the period January to June 2012.

- The groundwater flowing into the pits is assumed to be clean water with a sulphate concentration similar to the value recorded at borehole B5 during the August sampling event (2 mg/*l*, refer to Section 10.1).
- The average sulphate concentration of the pit water is assumed to be 2 600 mg/*l*. This concentration is lower than the average concentrations observed at the dams within Pit 1 since the concentrating influence of evaporation from open water bodies will have led to elevated concentrations that are not representative of the average pit water quality.
- The sulphate concentration of the Mafube Offtake is assumed to be equal to the sulphate concentration of the T1 Dam (3 430 mg/*l*).
- The sulphate concentration of the water reaching the sprayers is assumed to be similar to the concentration of the T4 Pump dam (~2 900 mg/*l*).
- It is assumed that only 10% of the salt loads removed through pumping to the sprayers will be effectively removed from the system. Most of the salts precipitating on the spoils near the Sprayer Dam are assumed to be mobilised back to the pit water during rainfall events.
- Finally, it assumed that recharge percolating through the spoils will pick up a salt load equivalent to a concentration of 1 867 mg/*l*. This value was calculated by balancing the salt loads added to and removed from the system.

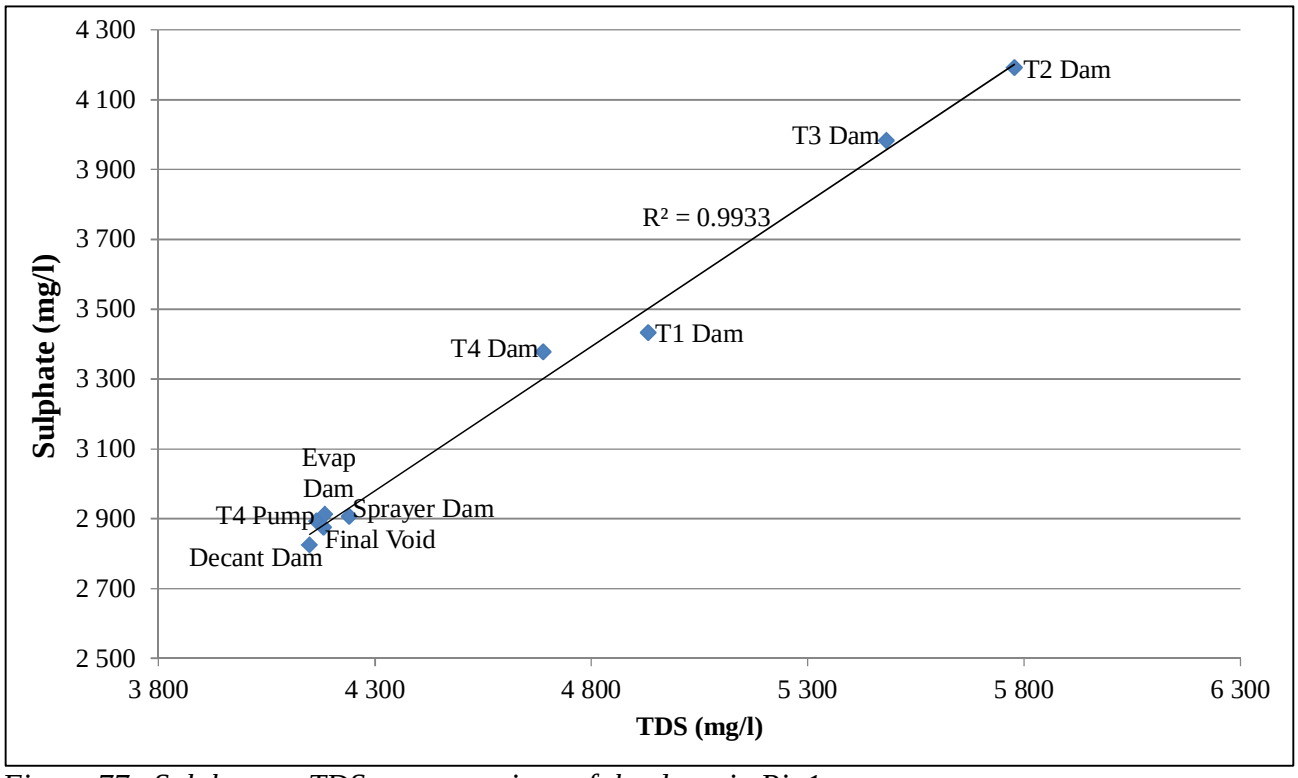


Figure 77. Sulphate vs TDS concentrations of the dams in Pit 1.

Table 56. Estimated sulphate balance for Arnot Closed Colliery.

	Sulphate loads added		Sulphate loads removed		
	Groundwater Inflow	Recharge	Groundwater Outflow	Mafube Offtake	Sprayers
Volume (M*l*/day)	2.59	4.17	0.36	0.96	12.28
Concentration (mg/*l*)	2	1 867	2 600	3 430	2 900
Sulphate load (kg/day)	5.18	7 785	936	3 293	3 561
Totals (kg/day)	**7 790**		**7 790**		

From Table 56 it is seen that approximately 7 790 kg/day of sulphate is removed from the backfilled pits at Arnot Closed Colliery. Taking the combined surface area of the pits (1 057.4 ha) into account, this sulphate load equates to 7.36 kg/ha/day, which is in very good agreement with the average value the sulphate loads (7 kg/ha/day) generated in the backfilled opencast coal mines in South Africa (Usher and Vermeulen, 2006). The estimated TDS load generated is approximately 11 130 kg/day.

18 Water Management Options

18.1 Introduction

In this section various water management options available to Arnot Closed Colliery are discussed. The water management options are subdivided into actions that a) address surface- and groundwater quality, b) may limit the ingress of surface water and groundwater into the pits, and c) actions focussed on the removal of excess water from the pits. Both short-term measures and long-term measures are considered. Here "short-term" refers to those measures that will require active management strategies, such as pumping water between the various dams within Pit 1. Since these active management actions cannot be continued indefinitely, long-term measures that may be applied to manage the excess water at the colliery after pumping has ceased are included in this discussion.

18.2 Actions to Manage Water Quality

18.2.1 Surface- and groundwater monitoring

Surface- and groundwater monitoring should be included in the water management programme of Arnot Closed Colliery. The surface- and groundwater monitoring programme proposed for the colliery was discussed in Section 6.

18.2.2 Reducing the potential for acid generation

Acid generation is especially prevalent when rock surfaces are exposed to atmospheric conditions. Exposure to oxygen and water lead to the oxidation of sulphates and, as a consequence, acid generation. Proper rehabilitation of spoils and coal discards is therefore essential to limit the potential for acid generation.

In Section 10.1.1 it was noted that the exposed coal discards within Pit 1 seem to have led to low pH values and the mobilisation of trace metals in the vicinity of the discards. It was also noted in Section 13.2 that exposed coal discards and un-rehabilitated spoils have the highest potential for acid generation at Arnot Closed Colliery.

Apart from the coal discards within Pit 1, exposed spoils occur in all three backfilled pits of Arnot Closed Colliery. In some places the spoils have been exposed due to surface erosion of the topsoil used during rehabilitation. In other areas it seems that limited, if any, rehabilitation was done. The exposed spoils of the Kwagga Section of Optimum Colliery along the southern perimeter of Pit 2W and Pit 2E have not been rehabilitated and may be actively contributing to the acidity of these pits.

To limit acid generation, the rehabilitation programme at Arnot Closed Colliery should be completed by ensuring that all exposed spoils are covered by topsoil of adequate thickness. Rehabilitated areas that have become exposed due to erosion should be re-habilitated.

The duration and extent of acid generation at the exposed spoils of the Kwagga Section of Optimum Colliery will depend on the rehabilitation programme of this colliery. Close cooperation with Optimum Colliery will be required to address possible acid generation at Arnot Closed Colliery.

18.2.3 Treating acidic water

Acidic decant has in the past occurred at positions north of Pit 2W. As explained above, the observed acidity may be due to the presence of spoils exposed to atmospheric conditions. Since acid generation is likely to continue (at least) as long as there are spoils exposed to oxidation, it is possible that acidic decant will again occur in the future when the pit water level exceeds the decant level after heavy rainfall events.

The dosing plant that occurs north of Pit 2W should always be kept in good working condition and should be on standby during the rainy season. Treatment of the acidic decant should be done by the addition of an alkaline agent, such as lime or NaOH, to the decant collected in the collection trench of the plant. Treated water should be pumped to one of the dams within Pit 1, as was done in the past.

18.3 Actions to Limit Water Ingress

18.3.1 Limiting groundwater influx along preferential pathways

The results of the drilling programme (Section 7) and geophysical investigations (Section 14), as well as the measured groundwater elevations (Section 11) suggest that groundwater is entering the backfilled pits along preferential pathways that may be associated with intrusive dolerites that occur near the corridors between the three pits, as well as near the partial corridors within Pit 1. The net volume of groundwater entering the pits along such pathways was estimated at approximately 2.23 M*l*/day (refer to Section 17.2).

If indeed groundwater ingress into the pits occurs along such structures, the volumes may be greatly reduced by the installation of grout curtains perpendicular to the strikes of such structures. This approach will require a) detailed geophysical investigations to locate and map the intrusive structures, as well as to determine their geometric aspects (width, dip), b) the installation of a number of boreholes across the mapped intrusives to depths exceeding the depth of the pit floors, and c) the injection of specialised grouting to effectively reduce the permeabilities of the rocks intersected by the boreholes.

Legal aspects

It is not foreseen that the installation of grout curtains will require any permitting or authorisation.

Costs

Although the costs of initiating detailed geophysical investigations and a drilling and grouting programme will be high (expected to be in the order of R1 500 000), the long-term benefit in terms of a significantly reduced water make may justify this expenditure.

18.3.2 Limiting surface water influx

Since Pit 1 occurs on a local topographic high, clean surface water runoff is unlikely to contribute to water ingress into the pit. However, spoils from the Kwagga Section of Optimum Colliery occur at surface near the south-eastern corner of the pit. These spoils occur at a higher topographic elevation than the south-eastern parts of Pit 1. Both surface water runoff and seepage through these spoils may lead to water ingress into Pit 1.

The spoils of the Kwagga Section extend along the entire southern boundary of Pit 2W and along a large percentage of the southern boundary of Pit 2E. Since natural drainage is from south to north at these pits, and since the spoils currently occurring at surface cause an increased artificial topographic gradient to the north, influx of surface runoff and seepage into Pit 2W and Pit 2E can be expected.

Addressing the problem of surface water influx will require close cooperation with Optimum Colliery since surface runoff and seepage is likely to impact on the pit water of Arnot Colliery for as long as the spoils occur at the southern boundary of Pit 2W and Pit 2E. Insight into the rehabilitation programme of Optimum Colliery will be required to gain an understanding of the potential duration and degree of impacts from the spoils.

18.3.3 Preventing ponding

Where possible, the rehabilitated landscape of the backfilled pits should be free of local depressions where surface water can accumulate after rainfall events. Ponding will create local hydraulic gradients and seepage through the spoils, thus contributing to the volumes of excess pit water. Although earth moving, landscape shaping and rehabilitation of the disturbed areas will be a costly exercise, having a free flowing surface topography will increase the rainfall runoff and reduce the effective recharge through the spoils.

18.3.4 Constructing contour berms on the ramps

To reduce surface runoff to the various dams within Pit 1, the construction of contour berms should be considered. These berms should run the entire lengths of the ramps and discharge the

intercepted water at positions to the sides of the pits from where free draining may occur. It may be necessary to also construct a canal system to collect the intercepted water to prevent damage to the maize fields adjacent to Pit 1.

18.4 Actions to Increase Water Losses

18.4.1 Increasing the evaporation surfaces and storage capacities of open water bodies

At present water from the Decant Dam and the T1 Dam is pumped (directly or via the Final Void) to the T4 Pump Dam (refer to Section 4). In this way the water level in the T4 Pump dam is raised significantly above the decant water level of Pit 1 (refer to Figure 14).

To increase the total evaporation surface from the open water bodies within Pit 1, additional pumping of water from the T1 Dam and the Decant Dam to the T2 Dam and T3 Dam should be considered. At the time that the DTM was compiled (late January 2012), the exposed surface areas of the water in the T2 Dam and the T3 Dam were 0.022 km^2 and 0.074 km^2, respectively. Referring back to Figure 6, it can be seen that if dam walls were constructed near the south-western decant points of these dams, the evaporation surfaces would be increased significantly, particularly for the T3 Dam. A dam wall with a top elevation greater than 1 601.5 mamsl will increase the potential evaporation surface of the T3 Dam by a factor of approximately 3.77 to 0.279 km^2, while a dam wall elevation greater than 1 600.0 mamsl will increase the potential evaporation surface of the T2 Dam by a factor of approximately 1.64 to 0.036 km^2. The maximum increase in the combined evaporation surface of these dams (0.219 km^2) could potentially increase the total average daily evaporation losses by approximately 0.63 M*l*/day.

Increasing the effective storage capacity and evaporation surface of the T4 Dam may also be achieved by raising the decant level through the construction of a dam wall at the south-western decant point. However, even if such a dam wall is constructed, it is recommended that no additional pumping of water to this dam be done. The available storage capacity of this dam may provide buffer capacity during periods of high rainfall.

One disadvantage of constructing dam walls to increase the evaporation surfaces of the T2 and T3 Dams is that the increased hydraulic head within the dams may lead to increased seepage to the surface and subsurface at positions down-gradient from the dams. Such seepage may impact on the nearby chicken batteries and maize plantations of Alzu Enterprises. It may therefore be necessary to construct seepage interception canals with return pumps in the vicinities of the raised dam walls.

18.4.2 Construction of evaporation ponds with sprayers

From Table 1 and Table 2 it is seen that evaporation losses from open water bodies greatly exceed the annual rainfall experienced at Arnot Closed Colliery. For a year of average rainfall (720 mm), the net loss due to evaporation is expected to be approximately 325 mm. When evaporation ponds are used along with sprayers specifically designed to increase evaporation losses, significant volumes of water can be removed from the system.

When designing evaporation ponds a number of factors need to be considered:

Location and available area

To limit the costs associated with pumping large volumes of water over great distances, it is advisable to construct the evaporation pond(s) close to the decant position(s). At Arnot Closed Colliery, the most suitable location for such pond(s) would be near the north-western perimeter of Pit 1, close to the Decant Dam and the T1 Dam. At present this area is utilised for maize farming by Alzu Enterprises. The construction of evaporation pond(s) would therefore require the purchase of productive agricultural land from Alzu Enterprises.

Sprayers

Water pumped to the evaporation pond(s) should be released through a sprayer system. Significant increases in the evaporation rates can be achieved by using appropriate sprayers. Sprayers should break the droplets to diameters of less than 50 microns in order to create a fine spray. A fine spray has increased buoyancy and is also more subject to evaporation losses due to temperature effects.

One disadvantage of fine sprays is that the water droplets may be transported beyond the boundaries of the evaporation ponds and may settle on the adjacent soils where salt precipitation may occur over time. This is of particular relevance to Arnot Closed Colliery where the adjacent soils constitute productive farm land. Sprayers should therefore preferable be located at positions towards the centre of the ponds.

Size

The size(s) of the evaporation pond(s) will depend on the volumes of water to be disposed, the costs involved in purchasing land for their construction, and the possibility of using these ponds for their buffer capacity during periods of high rainfall.

In terms of direct evaporation losses from open water bodies, an evaporation pond with a surface area of 1 ha will result in evaporation losses of only approximately 0.01 M*l*/day. This volume may, however, be increased by using black liner in the pond to increase the heat energy absorbed. To significantly increase the volumes of water lost to evaporation, sprayers will have to be employed.

An evaporation pond with a surface area of 1 ha and an average depth of 2 m will have a storage capacity of 20 M*l*. Evaporation ponds may therefore be more beneficial in terms of the additional buffer capacity that they can provide during periods of high rainfall than in terms of the evaporation losses that can be achieved.

Cleaning

Salt accumulating in the evaporation pond(s) will intermittently have to be removed and disposed at a suitable waste site. This will have to be done during the dry seasons when the buffer capacity of the pond(s) is not required.

Costs

The construction and maintenance of evaporation ponds with sprayers may be prohibitively costly. Costs associated with the construction alone may exceed R10 000 000 when site clearance, earthworks, pipelines, stormwater drainage, leak detection systems and fencing are included. This value excludes the costs of purchasing land and routine maintenance and cleaning of the ponds.

Legal aspects

Since contaminated water will be stored in the evaporation pond(s), water use licences will be required from the DWA. During cleaning of the pond(s) the salts that accumulate will have to be removed and disposed at a suitable waste disposal site. It may be possible to dispose of the salts in the T1 Dam since the increase in the salt load will not significantly increase the TDS concentration of the water in Pit 1 with its total capacity of more than 20 000 M*l* (refer to Section 5.1). Consultation with the DWA will be required if this option is considered.

18.4.3 Employing sprayers at the T1 Dam to increase evaporation losses

As discussed in Section 18.4.2, a number of problems and disadvantages are associated with the use of evaporation ponds to remove excess water. These include: construction costs, the availability and costs of land for the construction of the ponds, the limited storage capacity of the ponds, the disposal of salts, the need of an additional water use licence for the storage of contaminated water, and possible contamination of adjacent soils through wind drift.

For the above reasons it may be of much greater benefit to install sprayer systems along the shores of the T1 Dam to enhance evaporation losses. Water may be pumped over short distances directly from the T1 Dam to the sprayers. Much of the infrastructure required to implement this strategy is already present at the dam. Electrical power supply to the existing pumps at the T1 Dam may be used to power the pumps connected to the sprayers.

As seen in Section 4.5, evaporation losses at the sprayers currently employed by Arnot Closed Colliery are significant. Using a conservative estimate of 30% for evaporation losses, the volumes of water lost to evaporation at the sprayers was estimated at 3.68 M*l*/day. These volumes constitute almost 58% of the estimated excess water at the colliery (refer to Sections 17.1 and 17.2).

At present approximately 12.28 M*l*/day are pumped from the T4 Pump dam to the existing sprayers. The water in the T4 Pump Dam originates from the T1 Dam and the Decant Dam and is pumped over a distance of more than 2.5 km to eventually reach the sprayers. Although pumping the water to a position so far removed from the Decant Dam leads to a longer recycling time through the spoils, the benefit of the longer recycling time may not justify the high costs associated with pumping large volumes of water over such large distances. Similar evaporation water losses can be achieved by employing sprayer systems at the T1 Dam. The reduced pumping costs may justify the installation of additional sprayers to further increase the water losses.

If the strategy of using sprayers at the T1 Dam is initiated, it is recommended that the T4 Pump dam and the T4 Dam be kept available for their buffer storage capacities during times of heavy rainfalls. The pipes currently running from the T1 Dam to the T4 Pump dam should therefore be kept in place to be on standby for such eventualities.

18.4.4 Planting Eucalyptus trees to increase evapo-transpiration losses

Eucalyptus trees are known to grow fast and to consume large quantities of water. For this reason they have acquired a bad reputation in South Africa as intruder plants that may reduce the net groundwater recharge within a catchment. However, these plants may be effectively used to remove unwanted water from certain environments in the long term.

Water use

Sources differ greatly on the volumes of water used by Eucalyptus trees. The sap flow within a large, north-facing E. grandis tree with a particularly high leaf area was measured by the CSIR on a warm, dry spring day on Frankfort State Forest near Sabie, and found to total 722 *l*. Similarly, a very large E. grandis tree growing in an open area close to the Sabie River in the same vicinity was found to use 664 *l* on a warm summer day. These volumes are, however, not representative of the average volumes of water used by these trees. The average water used by 3-year old trees of the E. grandis plantation near Sabie was measured at 45.8 *l*/day. The daily water use was highly dependent on the humidity and ranged between approximately 30 *l*/day and 95 *l*/day. Sap flow rates of approximately 140 *l*/day were measured in a group of 9-year old trees.

It is known that the volumes of water used by Eucalyptus trees increase with the availability of water. This implies that Eucalyptus trees planted immediately adjacent to open water bodies are likely to consume more water than trees removed from such water bodies.

Legal aspects

Various Eucalyptus species occur in South Africa. Of the more than 200 Eucalyptus species that have been cultivated in South Africa, only seven species have been listed as 'declared invaders' and the revised Conservation of Agricultural Resources Act (CARA) and National Environmental Management Biodiversity Act (NEMBA) legislation is more specific in defining the conditions under which these species are declared invaders (SAPIA NEWS, 2009).

The CARA 2001 listed invasive species are: Eucalyptus camaldulensis (river red gum), E. cladocalyx (sugar gum), E. diversicolor (karri), E. grandis (saligna gum), E. conferruminata (previously misidentified as E. lehmannii (spider gum), E. paniculata (grey ironbark) and E. sideroxylon (black ironbark). The proposed invasive species list under NEMBA (April 2009) includes E. tereticornis (forest red gum) and excludes grey and black ironbarks since there is little evidence of their invasiveness. Spider gum, listed as a Category 1 plant (prohibited) in the Western Cape under CARA 2001, has been proposed as a Category 2 plant (permitted in demarcated areas) under NEMBA.

Most of the declared Eucalypts invade watercourses. River red gum, in particular, can form extensive stands along watercourses and is one of the primary target species for removal by the Working for Water programme, South Africa's largest and most costly alien plant control programme. River red gum is easily confused with forest red gum and coolibah (E. microtheca), both of which invade watercourses.

All the declared species are recognized as being valuable commercial or utility trees and may be cultivated. It is proposed under NEMBA that demarcation (and a permit) is only necessary for river red gum, saligna, karri and forest red gum where more than 50 stems occur within 5 000 square metres (0.5 ha). For sugar gum and spider gum it is proposed that demarcation is only necessary within 50 metres from fire-prone vegetation in the Fynbos, Grassland and Savannah biomes. All species are prohibited within riparian areas, wetlands, declared mountain catchment areas, designated high fire-risk areas, and within protected areas.

Proposed Eucalyptus plantations at Arnot Closed Colliery

The positions of proposed Eucalyptus plantations at Arnot Closed colliery are shown as thick red lines in Figure 78. The proposed plantations were positioned on the banks of the T1 Dam and Decant Dam, since these two open water bodies within Pit 1 will contain significant water after pumping is discontinued (refer to Figure 7). Only those stretches of the banks of the T1 Dam where

the topographic gradient is not too steep were selected. The eastern banks of the Decant Dam were not selected for the plantations since an embankment has been built in this area to intercept possible overflows from the Decant Dam during decant events.

Assuming that the Eucalyptus trees will be planted in four parallel rows with a spacing of 3 m between the rows and 3 m between the trees in each row, the total number of trees in the plantation will amount to approximately 4 850. Assuming an average daily use of 50 *l* per tree for 3-year old trees, the average evapo-transpiration loss than can be achieved is approximately **0.24 M*l*/day**. This volume may more than double in the long term as the water consumption of the trees increases as they grow older and bigger.

In Section 11 it was noted that the water levels measured in the boreholes and dams within Pit 1 strongly suggest that this pit is compartmentalised. The elevated water level of the T3 Dam (refer to (Figure 14, Section 4.1) is thought to represent the decant level of the particular compartment in which the T3 Dam is situated. This suggests that the T3 Dam is likely to remain an open water body containing significant volumes of water even after pumping is discontinued. Similar observations may be made regarding the T2 Dam. It may therefore be beneficial to also plant Eucalyptus trees on the banks of these two dams. In doing so, the water losses through evapo-transpiration may be greatly increased.

Costs

The costs associated with using Eucalyptus trees to remove excess water are limited to the initial procurement of seedlings or young trees, site preparation and the labour costs of planting the trees and watering the seedlings. The total cost is expected to remain below R150 000.

18.4.5 Disposing of excess mine water into the Bliksem Pan

Although disposing of contaminated mine water into natural pans is not a preferred strategy, during times of heavy rainfall it may be necessary to make use of the Bliksem Pan for its storage capacity and large evaporation surface. Studies conducted in 1999 by L&W Environmental indicated that the Bliksem Pan is not sensitive and is a habitat that is well represented in the area of the colliery.

In June 2006 the DWAF approved the pumping of mine water from the T1 Dam to the Bliksem and Railway Pans if certain conditions were met. The DWAF recommended that water should preferentially be pumped to the Railway Pan and then to the Bliksem Pan. The mine had to ensure that the volume of water discharged into the Railway and Bliksem Pans did not cause a rise in the water levels above the maximum allowable levels (1 567.5 mams1 and 1 574.4 mamsl, respectively) as determined from ecological constraints.

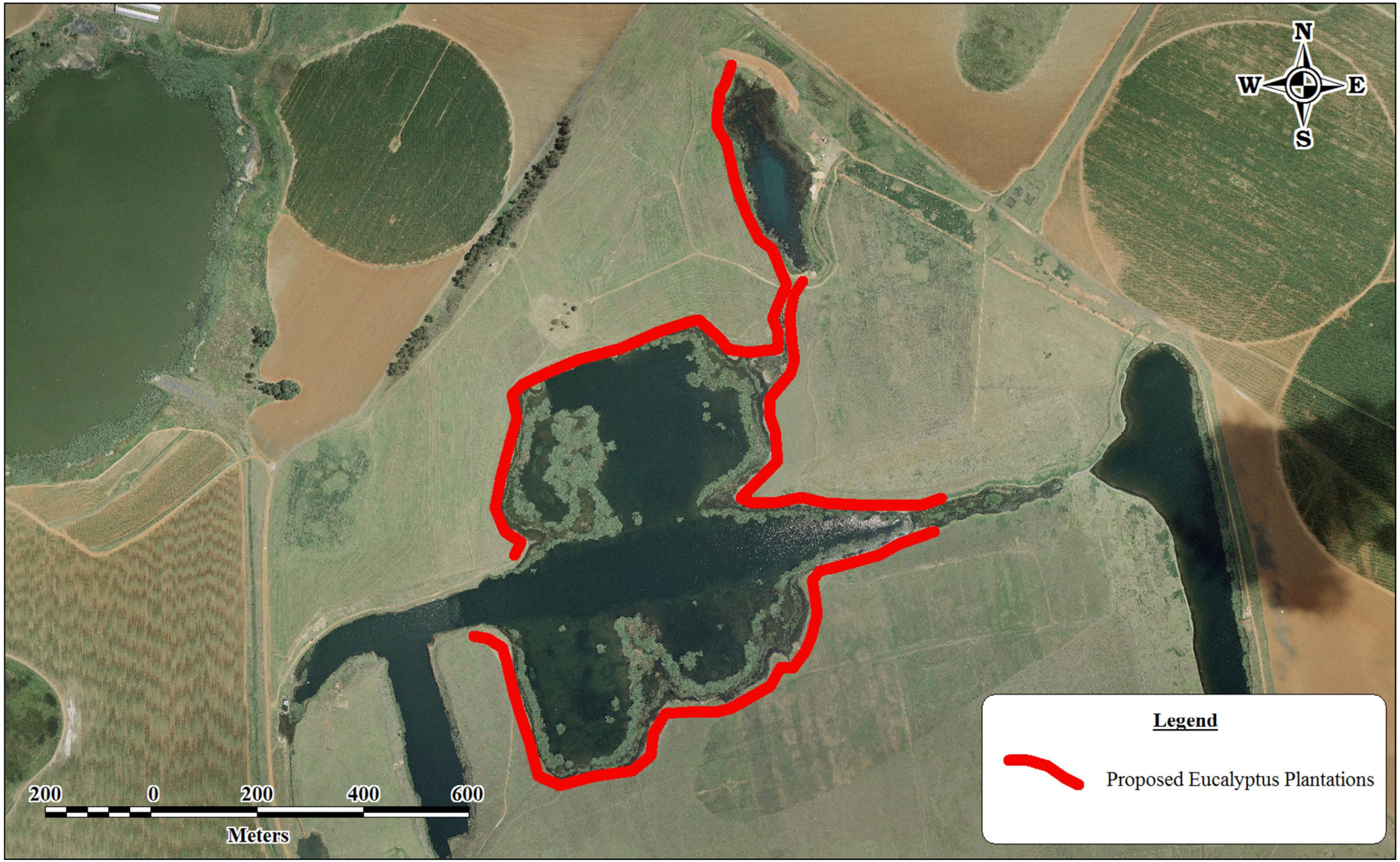


Figure 78. Proposed Eucalyptus plantations on the banks of the T1 Dam and Decant Dam.

The mine also had to ensure that the salinities of the pans did not exceed 3 000 mg/*l* and 5 000 mg/*l*, respectively, before discharge of pit water could commence. At the time, the estimate for the volume of water to be removed from the T1 Dam and disposed in the pans was 3 M*l*/day.

Later in 2006, after additional investigations, the ecological and operational constraints limited the volume of water that could be discharged and evaporated in die pans and the use of Railway Pan was excluded by the DWAF.

The surface area of the Bliksem Pan is approximately 32.5 ha. Water and salt balance modelling performed by L&W Environmental showed that, under the prescribed water level and salt constraints, the Bliksem Pan could receive an average annual volume of pit water of approximately 128 617 m^3 (~128.62 M*l*). The available storage capacity of the Bliksem Pan, under the prescribed environmental constraints, may be an option to dispose of excess pit water during periods of heavy rainfall.

18.4.6 Controlled release of pit water to the Klein-Olifants River

A controlled release scheme was introduced at Arnot Closed Colliery in 1997. The controlled release approach was sufficient for the low to average rainfall years, however, the modelling undertaken for the controlled release licence applications showed that excess water would be generated during high rainfall years. This was confirmed during 2000 when high rainfall was experienced.

In a letter to the DWA dated 25 February 2011, the mine closures manager of AngloAmerican (W van Burick) estimated that a release of 20 M*l* of pit water would cause to a salt load increase of 1 mg/*l* in the Middelburg Dam.

The option of controlled release of pit water should therefore be seen as a last resort in the water management strategy of Arnot Closed Colliery and should only be considered during periods of extreme rainfall. Authorisation from the DWA will be required and adherence to the prescribed conditions (quantity, quality) will be essential.

18.4.7 Mafube offtake

It is foreseen that Mafube Colliery will require water from Arnot Closed Colliery for their operations until around 2022. During the period January to June 2012, an average volume of 0.96 M*l*/day of pit water were pumped from the T1 Dam to Mafube Colliery. The limited timespan of this water management option should be considered when developing long-term water management strategies for Arnot Closed Colliery. It should also be taken into account that the

water demand of Mafube Colliery may decrease during periods of high rainfall. During such periods, alternative management actions may have to be employed to cope with the excess water.

18.4.8 Power station cooling and ashing operations

It is possible that excess mine water from Arnot Closed Colliery may be used in the ashing and/or cooling operations of Arnot Power Station. This possibility was considered during previous investigations. At the time it was concluded that the proposed pipeline routes would be mined through by the Kwagga Section adjacent to Pit 1. It was, however, suggested that the possibility of using pit water at the power station should be further investigated.

Depending on the water demand at Arnot Power Station and the expected lifetime of the power station, the construction of a pipeline may be an option for water management at Arnot Closed Colliery in the short to medium term.

18.4.9 Joining the Mafube water management scheme

The Mafube water treatment scheme involves various stakeholders including: Arnot Closed Colliery, Mafube Colliery, Coal of Africa, Arnot Power Station, Exxaro's Arnot Colliery, Optimum Colliery's Kwagga Section, Xstrata's Zonnebloem coal mine and Hatch (see Figure 2). The water management scheme takes into account the raw water requirements of each of the stakeholders, as well as the excess water from each of the stakeholders. As part of the water management scheme, the construction of a water treatment facility is envisaged. This treatment facility will receive excess water from the various collieries. After treatment, the purified water will be sold to interested parties. Calculations have shown that the running costs of the treatment facility will be met by the sale of the purified water. This water management option may therefore form part of a long-term, sustainable solution to the water management problems at Arnot Closed Colliery.

18.5 Short-term water management strategy

Short-term water management here refers to water management actions involving the pumping of water between the various open water bodies and sprayers in Pit 1 and includes the Mafube offtake. Since pumping cannot be continued indefinitely, strategies involving such pumping should be seen as only temporary.

In Section 17.2 the average volume of water to be managed at Arnot Closed Colliery during years of average rainfall was estimated 6.40 M*l*/day. To manage this water the following strategy is proposed:

1. Take all the recommended actions to address water quality at the colliery, as described in Section 18.2.

2. Where possible, and depending on the available budget, take the actions described in Section 18.3 to limit surface- and groundwater ingress into the pits.

3. Commence with the planting of Eucalyptus trees along the banks of the Decant Dam and the T1 Dam, as discussed in Section 18.4.4. Although significant water losses from the Eucalyptus plantation will only occur after a number of years of growth, it is recommended that the process be initiated as soon as possible.

4. Construct dam walls and seepage interception trenches at the south-western decant points of the T2 Dam, T3 Dam and T4 Dam, as discussed in Section 18.4.1. These dams will only be employed for their storage capacities and evaporation surfaces during times of above average rainfall. Since significant seepage is only expected when water is pumped to these dams, mobile pumps running on generators may be employed on an ad hoc basis to pump water from the trenches back to the dams.

5. Install a sprayer system along the banks of the T1 Dam. The volumes of water currently pumped to the T4 Pump dam and sprayers may be gradually decreased as more water is lost to evaporation at the sprayers of the T1 Dam. In this way the use of the sprayers near the T4 Pump dam may be phased out over time.

6. Continue with the current Mafube Offtake of approximately 1 M*l*/day.

7. Assuming zero water losses from the Eucalyptus plantation in the short-term and total evaporation losses at the sprayers similar to the current estimate of 3.68 M*l*/day, a total volume of approximately 1.72 M*l*/day is still in excess at the colliery (if it is assumed that the actions to limit water ingress into the pits were unsuccessful). It is recommended that this volume of water be included as Arnot Closed Colliery's contribution to the mine water load to be treated at the Mafube water treatment scheme.

8. During periods of high rainfall when the above actions are not adequate to deal with the volumes of water entering the pits, it is recommended that water be pumped to the T4 Dam, T3, Dam and T2 Dam to increase the evaporation surface and to allow for a longer residence time within Pit 1. Should the buffer capacities of these dams be breached, excess pit water should be discarded in the Bliksem Pan, under the DWA prescriptions on water quantity and quality. Only when the storage capacity of the Bliksem Pan is inadequate to accommodate all the excess mine water, should controlled releases to the Klein-Olifants River be considered. Such releases should again be done under the prescribed conditions set by the DWA.

18.6 Long-term water management strategy

Here long-term water management refers to actions taken once pumping between the dams and the sprayers within Pit 1 has ceased and no water is removed as part of the Mafube Offtake. It is assumed that by this time the Eucalyptus trees will be fully grown. Water quality monitoring is assumed to be an on-going process.

The water losses due to evapo-transpiration from the Eucalyptus plantation are expected to be approximately 0.50 M*l*/day (although this figure may be closer to 1 M*l*/day if trees are also planted on the banks of the T2 and T3 Dams). Assuming that Pit 1 is not compartmentalised, direct evaporation losses from the Decant Dam and the T1 Dam are expected to amount to approximately 1.31 M*l*/day. On the other hand, if Pit 1 is compartmentalised (as suggested by the pit water levels), the T3 Dam and T2 Dam may also contain significant quantities of water. In this case, the total evaporation losses may increase to approximately 1.58 M*l*/day.

If the actions taken to limit water ingress into the pits were unable to significantly reduce the volume of excess water at the colliery, between 4.30 and 4.60 M*l*/day of mine water will still remain to be disposed. If the Mafube water treatment facility has the capacity to process such a large volume of water originating from Arnot Closed Colliery, this option may be the only long-term, sustainable solution to dealing with the excess water at the colliery.

During periods of higher than average rainfall, the option of using the Bliksem Pan for its storage capacity may form part of the long-term water management plan. Only when the storage capacity of the pan is exceeded should controlled release of water to the Klein-Olifants River be considered. Controlled releases should adhere to the prescribed quantity and quality conditions set by the DWA.

19 Summary and Conclusions

The Institute for Groundwater Studies (IGS) was appointed by AngloAmerican to design a Water Management Plan (WMP) for Arnot Closed Colliery that incorporates information on all incoming, inherent and outgoing water from the colliery. During the development of the WMP, the following actions were taken:

- A number of site visits were conducted.
- Previous in-house reports and communications as well as external consultant reports relevant to the current investigations were studied.
- A limited hydro-census was conducted in the vicinity of the backfilled and rehabilitated pits.
- The existing surface- and groundwater monitoring network was evaluated in terms of its density and suitability to achieve the aims of a groundwater monitoring programme.
- Representative soil samples were taken selected positions around the pits. These samples were submitted to an accredited laboratory for grain size analyses in order to obtain estimates of the hydraulic properties of the soils.
- Samples of the spoils and coal discards were taken at positions on the rehabilitated pits where the spoils were exposed. These samples were submitted to an accredited laboratory for acid-base analyses in order to evaluate the potential for acid mine drainage (AMD) from the pits.
- Magnetic data were recorded on four traverses at selected positions to investigate the presence and orientation of dolerite intrusives.
- Ten investigative and monitoring boreholes were drilled at selected sites. Geological borehole logs were compiled during drilling.
- Electrical conductivity (EC) profiling was done on existing and newly drilled boreholes to investigate stratification in the groundwater quality within the boreholes.
- Surface- and groundwater sampling was performed and the water samples were submitted to an accredited laboratory for chemical analyses.
- Hydraulic tests were performed on the ten newly drilled boreholes, as well as on those existing boreholes for which information on their construction could be found. The purpose of the hydraulic tests was to obtain information on the hydraulic properties of the rock formations surrounding the opencast pits.

- The current water reticulation system at Arnot Closed Colliery was investigated and documented.
- A sonar survey of the floor elevations of the dams that form part of the water reticulation system was conducted in order to calculate stage curves showing the volumes of water stored in these dams at various water levels.
- By considering all the results of the investigations, a conceptual geohydrological model for Arnot Closed Colliery was developed.
- The conceptual geohydrological model was used to inform the development of a numerical model to investigate groundwater flow patterns and potential contaminant plume migration in the vicinity of the backfilled pits.
- Groundwater and surface water balances were calculated for Arnot Closed Colliery.
- Future water management options for Arnot Closed Colliery were suggested.

The results of the various phases of the investigation are summarised below:

Hydrocensus

During the hydrocensus 31 surface water sites and 56 groundwater sites were identified and visited. Of the 56 groundwater sites 38 are located within or in the vicinity of Pit 1, while 18 groundwater sites are located within or in the vicinity of Pit 2 (W&E). Where possible, the following information was captured for the different water sites: GPS coordinates, site photographs, site conditions. Additional information for the groundwater sites included: borehole construction, borehole protection, visibility, groundwater use and groundwater level. Surface sites were described in terms of their flow rates (river sites) and water levels (dam and pan sites). Observations regarding water quality and contaminant impacts were made at a number of sites.

Description of the current water reticulation system

The water reticulation system at Arnot Closed Colliery was described by incorporating information on the system of pumps and flowmeters that form part of the current water reticulation system. From the monthly flowmeter readings and dam level measurements, as well as information on rainfall and evaporation, a first estimate of the water make of the colliery was obtained. The water make for the period January to June 2012 was estimated at 4.90 M*l*/day.

Pit and dam decant levels and storage capacities

Data from a digital terrain model (DTM) compiled during January 2012 were used to determine the decant levels of the three backfilled and rehabilitated pits at Arnot Closed Colliery. The decant

levels of Pit 1, Pit 2W and Pit 2E were found to be 1 595.05, 1 602.42 and 1 607.40 mamsl, respectively. Stage curves were compiled for the three pits and it was found that the storage capacities of the pits are approximately 20 600 M*l* (Pit 1), 2 800 M*l* (Pit 2W) and 1 607 M*l* (Pit 2E). These estimates assume that the pits are not compartmentalised; however, there is strong evidence that Pit 1 (and possibly the other two pits) is compartmentalised, in which case the storage capacities may be greater than the above estimates.

In order to determine the storage capacities of the dams within Pit 1, a sonar survey was undertaken to measure the floor elevations of the dams. Sonar surveys were conducted on the following dams: the Decant Dam, the T1 Dam, the Final Void, both parts of the T4 Pump dam and the T4 Dam. The results of the sonar survey were used along with the DTM recorded in January 2012 to determine the decant levels and stage curves of these dams.

The decant levels of the dams were found to be 1 595.4 mamsl (Decant Dam), 1 596.4 mamsl (T1 Dam), 1 597.4 mamsl (Final Void), 1 597.0 mamsl (T4 Dam), 1 604.5 mamsl (northern part of the T4 Pump dam), and 1 603.5 mamsl (southern part of the T4 Pump dam).

The storage capacities of the dams were determined to be 71.8 M*l* (Decant Dam), 2 090 M*l* (T1 Dam), 391 M*l* (Final Void), 164 M*l* (T4 Dam), 110 M*l* (northern part of the T4 Pump dam), and 135 M*l* (southern part of the T4 Pump dam).

Evaluation of the current water monitoring programme

The current monitoring programme was evaluated below in terms of the positions of the sampling sites and the density of the sampling network, the conditions of the sampling sites, the monitoring frequency employed, the depths at which samples are taken, the sampling procedures followed and the parameters analysed for during chemical analyses.

Some of the findings and recommendations were:

- To evaluate possible contaminant impacts from the backfilled and rehabilitated pits on the water quality of the Bosman Spruit, additional sampling sites farther to the east along the Bosman Spruit are required.
- At least one site upstream from Pit 2E should be sampled to gain information on the background water quality.
- The Klein-Olifants River is currently sampled at only two sites located to the west and north-west of Pit 1. Since contaminant originating from Pit 1 could potentially impact on the water quality of the river at positions south of Pit 1, it is recommended that additional sampling sites along this river be included in the monitoring programme.

- In order to separate the upstream impacts on the Woestalleen Spruit from possible impacts originating from Arnot Closed Colliery, this river should be sampled at a position upstream from its confluence with the Klein-Olifants River.
- The Bliksem Pan, Steels Pan and Railway Pan should be included in the water monitoring programme.
- Groundwater monitoring sites are sparse to the north, south and south-west of the pit. The installation of additional monitoring boreholes should be considered.
- It is recommended that other existing boreholes be included in the monitoring programme. These boreholes could include some of the Alzu boreholes that occur in the areas south and south-west of Pit 1 (Old Supply Borehole, Windpump, Piet's Pump, Alzu Windpump, Private Borehole, BHZ11 and BHZ12). To the north of Pit 1, borehole KGM_B10 could also be included to increase the density of the monitoring network.
- The new boreholes drilled as part of the current investigations should be included in the monitoring programme.
- Despite recent upgrades, many of the groundwater monitoring sites required further attention. All monitoring boreholes should be equipped with concrete plinths, marker posts, site numbers and lockable caps. Lockable caps are particularly important to prevent unauthorised access to the boreholes.
- It is recommended that marker post be installed at the surface water monitoring sites to ensure that the water samples are taken at the same locations during the different sampling events.
- Problems with the monitoring sites should be noted during the sampling events and reported to ensure that they receive attention before the next sampling event.
- Apart from the monthly sampling done by personnel of AngloAmerican, it is recommended that biannual monitoring be done by external consulting scientists, once during the wet season (November to January) and once during the dry season (May to July). The consulting scientists should compile detailed reports describing the conditions of the monitoring sites and the results of the chemical analyses performed on the water samples.
- Groundwater sites should be sampled at appropriate depths, as determined from electrical conductivity (EC) profiling and borehole logs.

Installation of investigative and monitoring boreholes

During July 2012 investigative and monitoring boreholes were installed at 10 selected sites at Arnot Closed Colliery. The installation of these boreholes had a number of aims, namely to:

- Increase the density of the groundwater monitoring network within and around the backfilled and rehabilitated pits,
- Provide information on the subsurface geology,
- Provide information on the geohydrological conditions at the site,
- Allow investigation of the hydraulic parameters of the aquifer system(s) present, and,
- Provide water level and water quality information that will be used to calibrate the numerical groundwater model to be constructed.

Five of the 10 newly drilled boreholes encountered very similar geological conditions. A typical borehole log consisted of a few metres of yellow-brown to red-brown topsoil, followed by a few metres of subsoil (highly weathered sedimentary rocks), overlying various layers of Karoo rocks (sandstones, shales, coal). These materials are underlain by red-brown rhyolites. The only exceptions were boreholes B3 (no rhyolite intersected), boreholes B4 and B10 (drilled within the spoils of Pit 1) and boreholes B5 and B9 (dolerite intrusives encountered).

Water was struck during drilling at depths of 34 mbgl (B3), 25 mbgl (B4), 20 mbgl (B6), 15 mbgl (B7), 15 mbgl (B8), 22 mbgl (B9) and 22 mbgl (B10).

EC profiling of boreholes

In order to investigate possible stratification in the water quality within the boreholes, electrical conductivity (EC) profiling was done on all accessible boreholes forming part of the monitoring network at Arnot Closed Colliery. A total of 44 boreholes were EC profiled. These boreholes included 30 existing monitoring boreholes, four of Alzu's boreholes and the 10 new boreholes drilled during July 2012. The EC profiles clearly showed stratification of the water quality within most of the boreholes.

Based on the results of the EC profiling, sampling depths for each borehole were identified at which increased salt loads were apparent. The selection of the sampling depths of the new boreholes was done by also considering the geological and geohydrological conditions as revealed during drilling.

Hydraulic testing of boreholes

Hydraulic tests were conducted on the new boreholes drilled during July 2012 as well as on three existing monitoring boreholes for which the construction was known (information had been punched on the lids of these boreholes soon after construction). The purpose of the hydraulic tests was to obtain information on the hydraulic conductivities of the geological units in which the boreholes were drilled. Slug tests were performed on all 13 tested boreholes. Analyses of the hydraulic test data showed that the hydraulic conductivities of the intersected earth materials at the

different boreholes differ significantly, ranging from 0.001 m/d to 1.138 m/d. Low hydraulic conductivities were observed at those boreholes that intersected dolerite. The geometric mean of the estimated hydraulic conductivities of the Karoo sedimentary rocks was found to be 0.039 m/d.

Groundwater and surface water quality

Water sampling from the various surface- and groundwater sites was done on 7, 13, 14 and 15 August 2012. Water samples were submitted to the chemical laboratories of the IGS on 16 August 2012 for inorganic parameter analyses. Some of the findings related to water quality were:

- Most of the groundwater sites on and near Pit 1 show clear signs of contaminant impacts. The sulphate concentrations in most boreholes are high enough to classify the groundwater as Class 4 (poor quality) water. Apart from the high sulphate concentrations, the groundwater of the affected sites displays high calcium, magnesium and TDS concentrations and elevated EC values. High sodium concentrations are also observed at some boreholes.
- The pH values at most of the sites range between 6.1 and 8.2. However, very acidic conditions are observed at borehole AW09 near the southern coal discard site. The acidic conditions have led to the mobilisation of some trace metals. High iron, manganese and lead concentrations are observed at borehole AW09. It therefore appears that the coal discards are responsible for the generation of acidic conditions.
- High manganese concentrations are observed in all the affected sites, even where alkaline conditions prevail. It therefore appears that an elevated manganese concentration may be seen as a first indicator of impacts from mining activities.
- The concentrations of the major parameters at many of the sites clearly show stratification in the groundwater quality. Samples taken at the static water level generally have lower concentrations of the major parameters than the deeper samples. The lower concentrations for the samples from the static water level may be explained by the diluting effect of rainfall entering the borehole either directly or through seepage through the near-surface materials.
- The major parameters sulphate, magnesium, calcium, total hardness, EC and TDS may be identified as indicator parameters to use when evaluating whether a groundwater site has been impacted on by inorganic contaminants originating at Pit 1. Similarly, the minor parameters iron and manganese may be considered as indicator parameters.
- Compared to the groundwater sites at Pit 1, the groundwater sites in and in the vicinity of Pit 2 (W and E) are much less affected by contaminant impacts.
- The pH values at the groundwater sites near Pit 2 generally vary between 6.6 and 7.4, although slightly more acidic conditions do prevail at some sites.

- The presence of elevated fluoride concentrations at some sites north of Pit 2W may be due to an intrusive dolerite structure in this area.
- The groundwater quality at the Alzu boreholes is generally better that the water quality observed at the monitoring boreholes near Pit 1. This may be partly explained by the fact that the Alzu boreholes are/were production boreholes drilled to greater depths than the monitoring boreholes.
- Elevated sulphate concentrations are observed at boreholes BHZ08 and BHZ09.
- The pH values at the Alzu boreholes generally indicate alkaline conditions. Only at borehole BHZ09 is a slightly lower pH observed (6.5), but the conditions remain near-neutral.
- Apart from elevated manganese concentrations at some boreholes, the minor parameters concentrations at the Alzu boreholes are very low, indicating that little or no mobilisation of trace elements has occurred.
- The dams within Pit 1 contain water that has been exposed to extensive contaminant impacts. Sulphate concentrations are higher than 2 800 mg/*l*, while high concentrations of calcium and magnesium are also observed.
- The pans in the vicinity of Pit 1 contain water of a quality similar to the dams within Pit 1. The Bliksem Pan did in the past receive decant from the T1 Dam in the form of controlled release. However, the high sodium, chloride and potassium concentrations observed in the Bliksem Pan do seem to have another source since these concentrations are much greater than those observed in the dams within Pit 1. A possible source may be the chicken pens of Alzu which are located approximately 400 m upstream from the pan.
- The Steels Pan is highly contaminated. This pan is, however, used to dispose of the liquid wastes generated at Alzu's piggery. The observed high phosphate concentration is thus explained. Similar to the Bliksem Pan, high sodium, chloride and potassium concentrations are present in the water from this pan. The high sulphate and magnesium concentrations suggest that contaminants from Pit 1 have impacted on the water quality in the pan, either through surface runoff or subsurface seepage.
- The water quality at sampling sites along the Bosman Spruit indicates that contaminant impacts have occurred on this river. It should, however, be noted that the Bosman Spruit may be impacted on by contaminants from both Arnot Closed Colliery and the adjacent Kwagga Section of Optimum Colliery.

- The Klein-Olifants River is much more severely affected by contaminant impacts than the Bosman Spruit. Sulphate concentrations in excess of 950 mg/*l* are observed at three sampling sites along this river. However, other mines farther upstream along the river are likely to have affected the water quality in this river.

Groundwater depths and elevations

Based on the measured groundwater levels in the vicinity of the rehabilitated opencast pits of Arnot Closed Colliery, it can be concluded that the regional groundwater flow in the vicinity of the pits is to the west and north-west.

Within Pit 1 the water elevations range between 1 596.55 and 1 601.44 mamsl. All the observed water elevations exceed the decant level of Pit 1 (1 595.05 mamsl). The water level elevations are higher in the southern and eastern parts of the pit than in the north-western part. The most likely explanation for this variation in the water elevation within Pit 1 is that the pit is compartmentalised.

The water level elevation in borehole B5 is almost 10 m higher that the elevation in nearby borehole B3, both drilled near the partial corridor that occurs near the northern perimeter of the pit. The drilling results have shown that this partial corridor, as well as the partial corridor near the southern perimeter in the vicinity of borehole B9, is associated with the presence of a dolerite intrusive. The observed elevated water level therefore suggests that the dolerite intrusive intersected by borehole B5 is associated with an aquifer that is hydraulically linked to a recharge zone that occurs at a much higher elevation than the decant level of Pit 1. It is therefore possible that the dolerite intrusive acts as, or is associated with, a preferential pathway for groundwater migration, causing an influx of groundwater into Pit 1.

Soil sampling

In order to gain information on the hydraulic properties of the soils in the vicinity of the opencast pits of Arnot Closed Colliery, thirteen soil samples were taken at selected positions and submitted to an accredited laboratory for grain size analyses. The results of the analyses were used to estimate the hydraulic conductivities of the soils. The geometric mean of the estimated soil hydraulic conductivities was found to be 0.375 m/d.

Acid-base accounting

Twelve samples of exposed spoils and coal discards were taken at positions on and near the backfilled and rehabilitated opencast pits of Arnot Closed Colliery during June 2012. These samples were submitted to an accredited laboratory for acid-base analyses. The purposed of the acid-base analyses was to determine the acid generation potential of the waste rock materials to evaluate the likelihood of acid mine drainage (AMD) from the pits.

The results of the acid-base accounting indicate that samples representing the exposed coal discards are likely to be acid generating. Samples from the spoils of the mining activities at the adjacent Kwagga Section of Optimum Colliery are also potentially acid generating. These spoils are currently exposed to atmospheric conditions since rehabilitation has not commenced. Oxidation of the exposed spoils is therefore likely to lead to acid generation.

Leach tests conducted on the samples of the spoils and coal discards showed that various trace elements may be released to the groundwater under oxidising and acidic conditions. These include iron, manganese and lead.

Geophysical investigations

Ground magnetic surveys were conducted at selected positions near the backfilled and rehabilitated opencast pits of Arnot Closed Colliery. The purpose of the magnetic surveys was to determine whether intrusive magmatic structures (e.g. dolerite dykes) cut across the pits. Such structures may act as barriers to groundwater flow in directions perpendicular to their strikes and may also be associated with preferential pathways for groundwater flow in directions parallel to their strikes.

The results of the magnetic survey revealed the presence of deep, broad magnetic structures. Although these structures do not extend to surface, they may have caused burning of the coal at the depths were mining was done. The results of the magnetic survey therefore suggest that, although the different pits are separated by corridors of rock material, these corridors are not due to dolerite intrusives that extend to the near-surface, acting as barriers to groundwater flow between the pits. The corridors are therefore likely to be formed by sedimentary rocks of the Karoo Supergroup with permeabilities greater than dolerite. Significant groundwater flow between the pits therefore appears likely.

Numerical modelling of groundwater flow and contaminant transport

The numerical flow and transport model was constructed to:

- investigate the volumes of water leaving the backfilled pits through seepage into the topsoil and surrounding Karoo formations,
- gain insight into the subsurface flow patterns,
- investigate the migration of contaminant plumes away from the pits, and,
- obtain estimates of the salt loads that may impact on the natural surface water bodies along the groundwater pathway.

The calibrated numerical model suggests that approximately 0.25 M*l*/day seep from the backfilled opencast pits into the surrounding geological units. Results of the transient model indicate that

contaminant migration in the Karoo formations is expected to be relatively slow with the contaminant plume confined to the immediate vicinity of the pits for the first two decades. Contaminant migration in the topsoil is expected to be even more limited. However, in time, impacts on the both the Bosman Spruit and the Klein-Olifants River are expected.

Due to its proximity to Pit 2W, the Bosman Spruit is particularly vulnerable to contaminant impacts. Within 55 years the sulphate concentration of the groundwater at an observation point along the Bosman Spruit may reach a value of 1 800 mg/*l*. Over a 100 year period, approximately 20 000 tonnes of sulphate may impact on the Bosman Spruit. This value equates to an average daily sulphate load of approximately 550 kg over the 100 year period.

The numerical model also suggests that contaminant impacts on the groundwater quality at the production boreholes of Alzu Enterprises may occur. The Alzu Windpump and borehole BHZ10 are the most likely abstraction boreholes to be impacted on by contaminant impacts along the groundwater pathway.

Water make and water balance

By making assumptions regarding the effective recharge through the spoils, the water make at Arnot Closed Colliery was estimated. During years of average rainfall, the water make is estimated at 6.4 M*l*/day. During years of high rainfall the average water make increases to more than 8 M*l*/day.

The water balance compiled for Arnot Closed Colliery (during years of average rainfall) indicates that rainfall recharge contributes approximately 20.9 M*l*/day to the water system, while the net groundwater inflow to the pits contributes approximately 2.23 M*l*/day. Water losses due to runoff, evaporation losses from the open water bodies and evaporation losses from the spoils constitute 1.67 M*l*/day, 1.31 M*l*/day and 13.71 M*l*/day, respectively. The excess water is calculated to be 6.4 M*l*/day.

From the salt balance compiled for Arnot Closed Colliery it is seen that approximately 7 790 kg/day of sulphate is removed from the backfilled pits. The estimated TDS load generated is approximately 11 130 kg/day.

Water management strategies

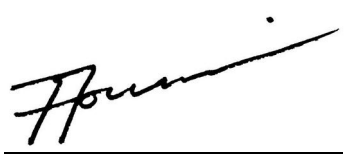
The recommended short-term water management strategy for Arnot Closed Colliery entails the following actions:

- Address water quality issues at the colliery by a) continuing with the water monitoring programme, b) reducing the potential for acid generation at the coal discards and exposed spoils, and c) treating acidic decant if and when it occurs.

- Take further actions to limit surface- and groundwater ingress into the pits.
- Commence with the planting of Eucalyptus trees along the banks of the Decant Dam and the T1 Dam. Although significant water losses from the Eucalyptus plantation will only occur after a number of years of growth, it is recommended that the process be initiated as soon as possible.
- Construct dam walls and seepage interception trenches at the south-western decant points of the T2 Dam, T3 Dam and T4 Dam. These dams will only be employed for their storage capacities and evaporation surfaces during times of above average rainfall.
- Install a sprayer system along the banks of the T1 Dam.
- Continue with the current Mafube Offtake of approximately 1 M*l*/day.
- Assuming zero water losses from the Eucalyptus plantation in the short-term and total evaporation losses at the sprayers similar to the current estimate of 3.68 Ml/day, a total volume of approximately 1.72 M*l*/day will still be in excess at the colliery. It is recommended that this volume of water be included as Arnot Closed Colliery's contribution to the mine water load to be treated at the Mafube water treatment scheme.
- During periods of high rainfall when the above actions are not adequate to deal with the volumes of water entering the pits, it is recommended that water be pumped to the T4 Dam, T3, Dam and T2 Dam to increase the evaporation surface and to allow for a longer residence time within Pit 1. Should the buffer capacities of these dams be breached, excess pit water should be discarded in the Bliksem Pan, under the DWA prescriptions on water quantity and quality. Only when the storage capacity of the Bliksem Pan is inadequate to accommodate all the excess mine water, should controlled releases to the Klein-Olifants River be considered. Such releases should again be done under the prescribed conditions set by the DWA.

Since pumping cannot be continued indefinitely, strategies involving such pumping should be seen as only short-term strategies. In the long term, after pumping has ceased, Arnot Closed Colliery is expected to have an excess water volume of between 4.3 and 4.6 M*l*/day during years of average rainfall. If the Mafube water treatment facility has the capacity to process such a large volume of water originating from Arnot Closed Colliery, this option may be the only long-term, sustainable solution to dealing with the excess water at the colliery.

During periods of higher than average rainfall, the option of using the Bliksem Pan for its storage capacity may form part of the long-term water management plan. Only when the storage capacity of the pan is exceeded should controlled release of water to the Klein-Olifants River be considered. Controlled releases should adhere to the prescribed quantity and quality conditions set by the DWA.

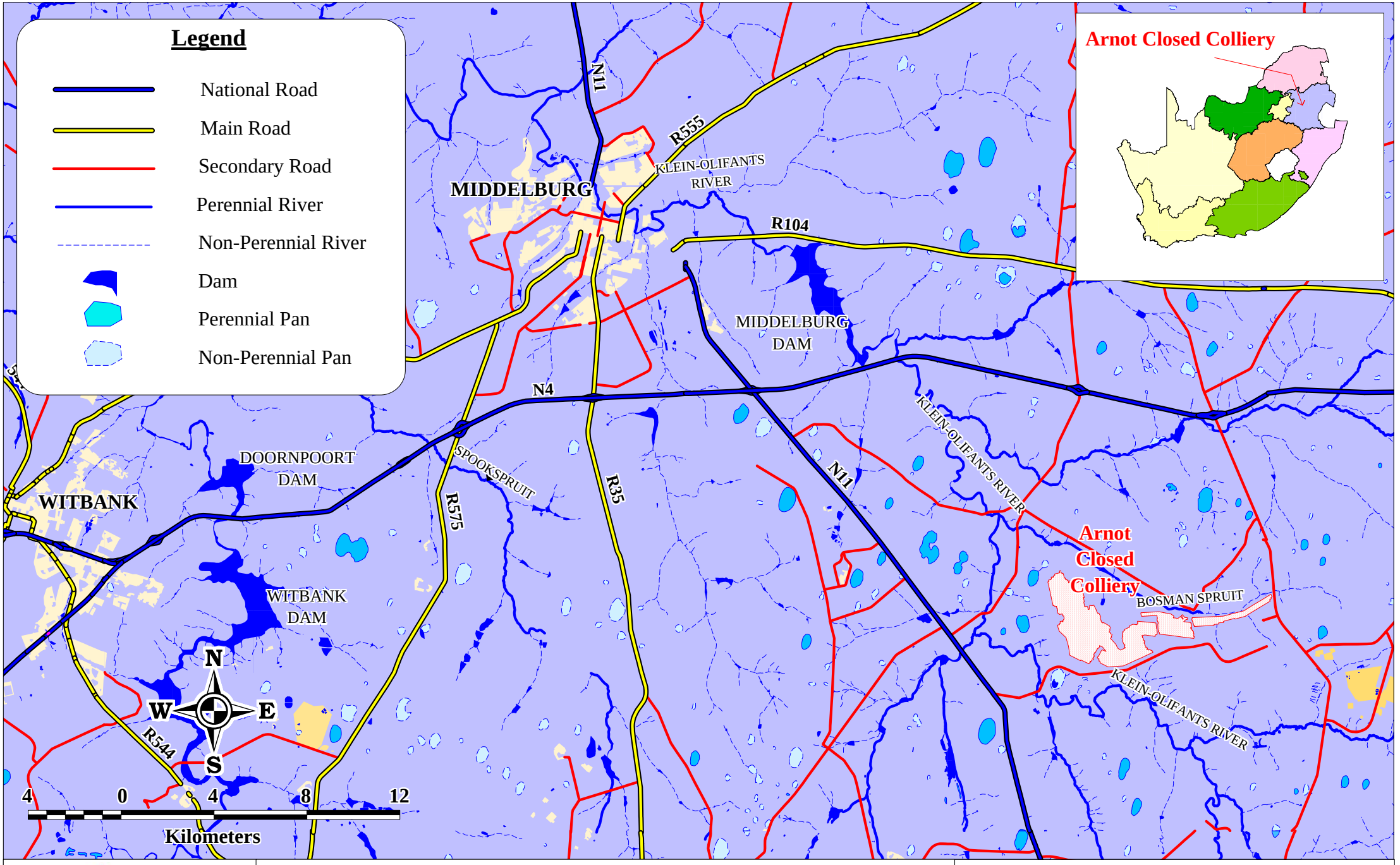


FD Fourie
(Ph.D. Pr.Sci.Nat.)

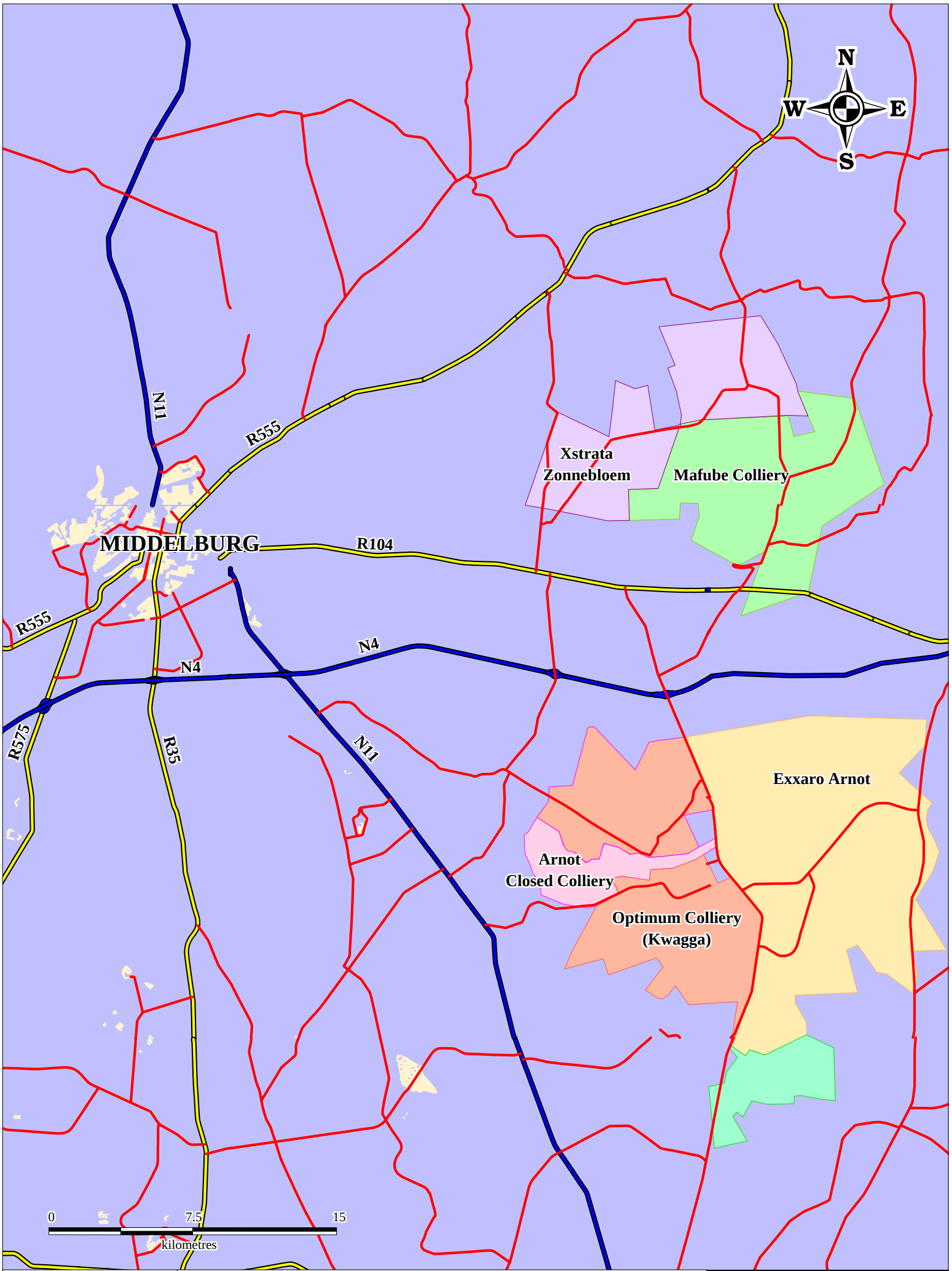
06 March 2013
Date

APPENDIX A

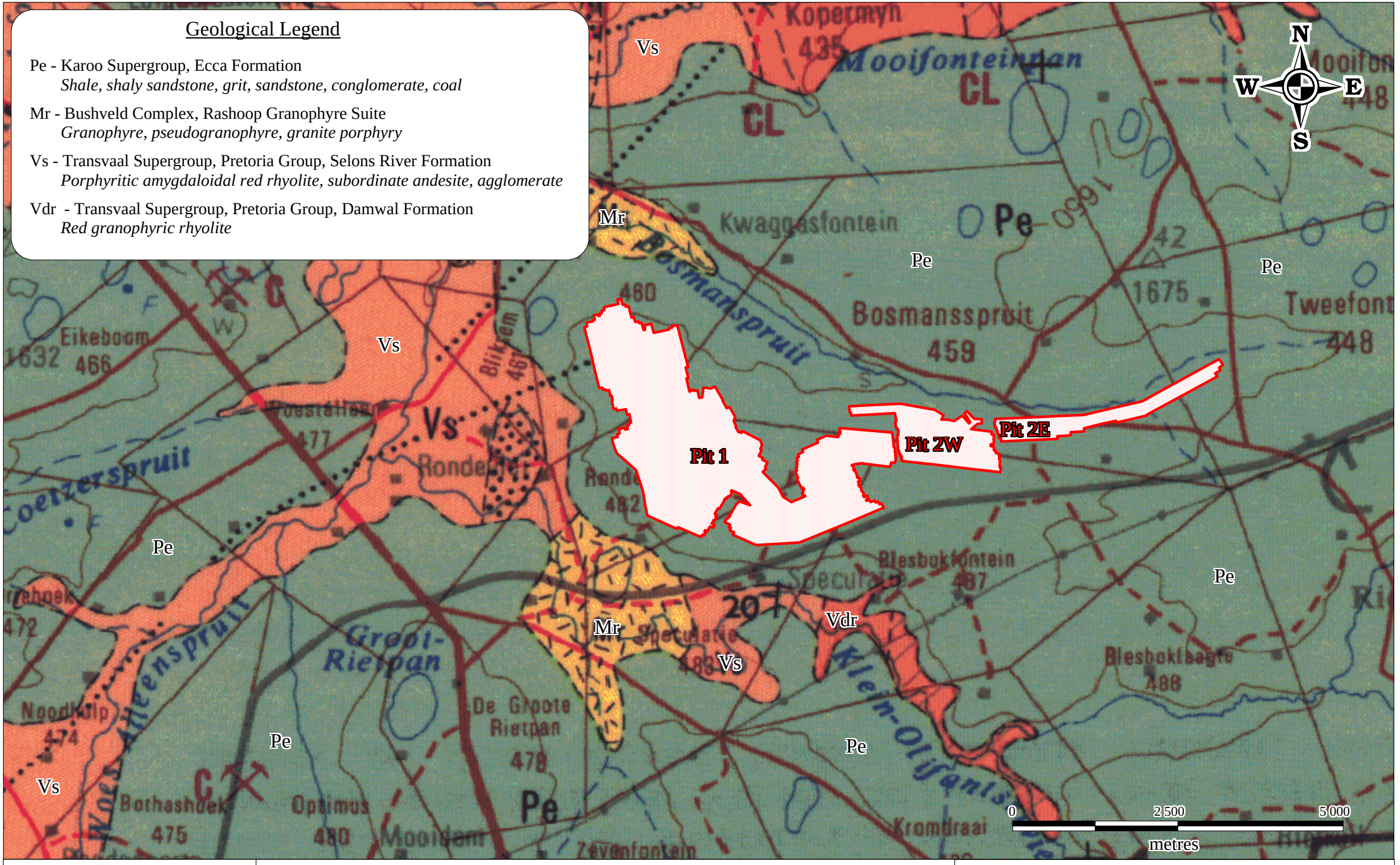
Maps and Plans



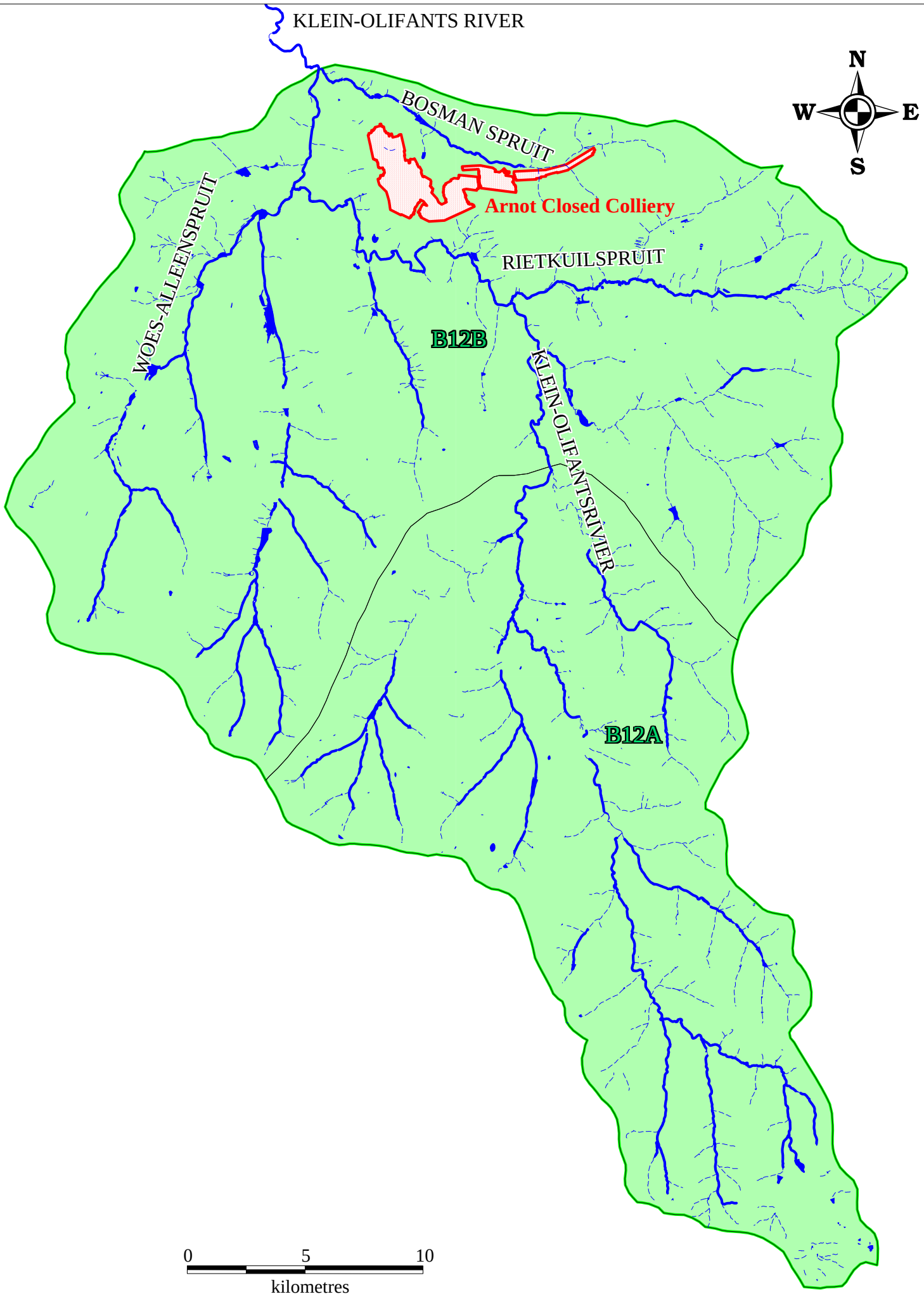
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Sept 2012
	Map Title:	Regional Setting	
	Map No.:	M001ACC	Signed:



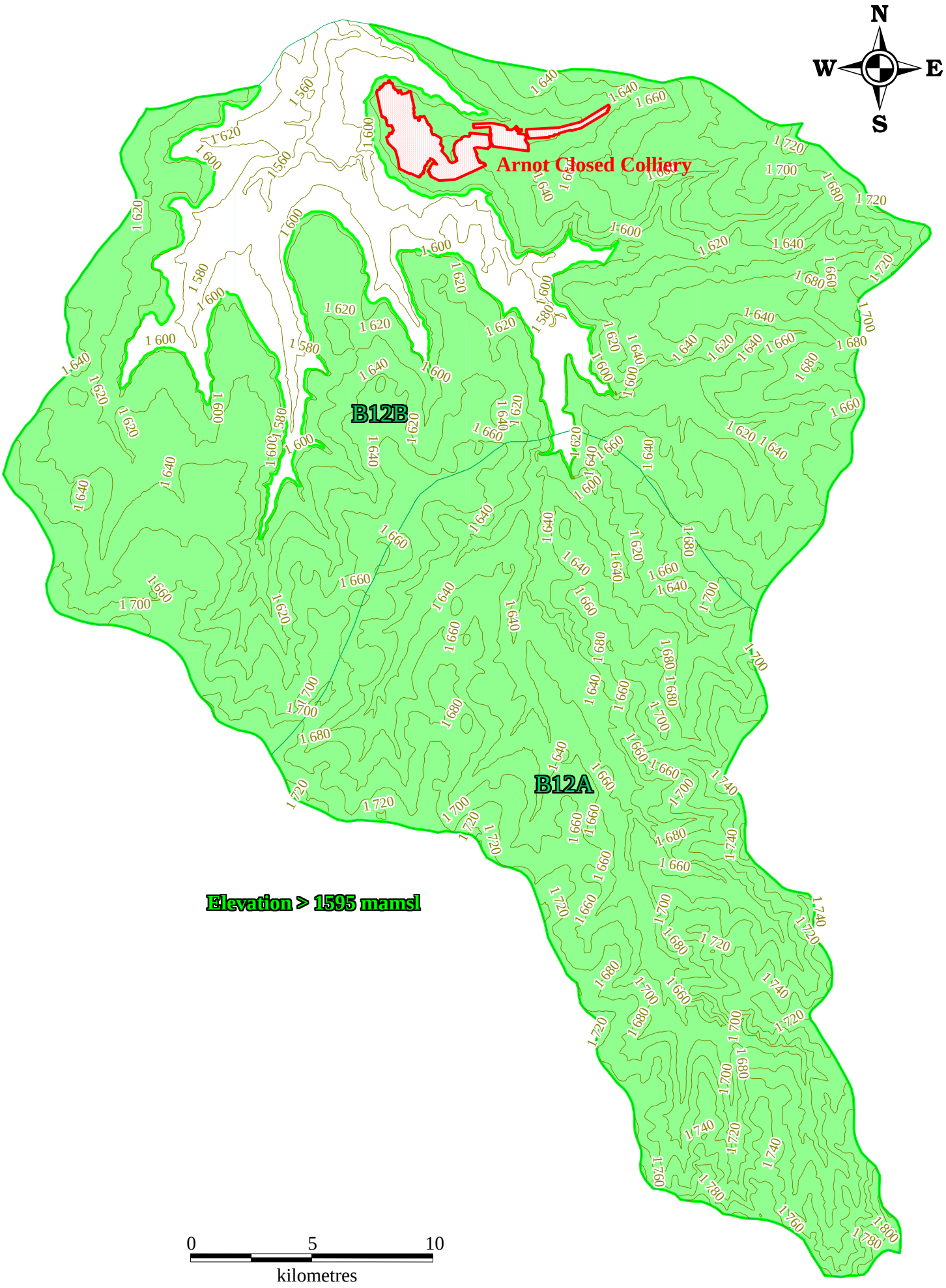
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:** Arnot Closed Colliery - Water Management Plan **Map Title:** Mining Boundaries **Map No.:** M002ACC	Compiled by: FD Fourie Signed:



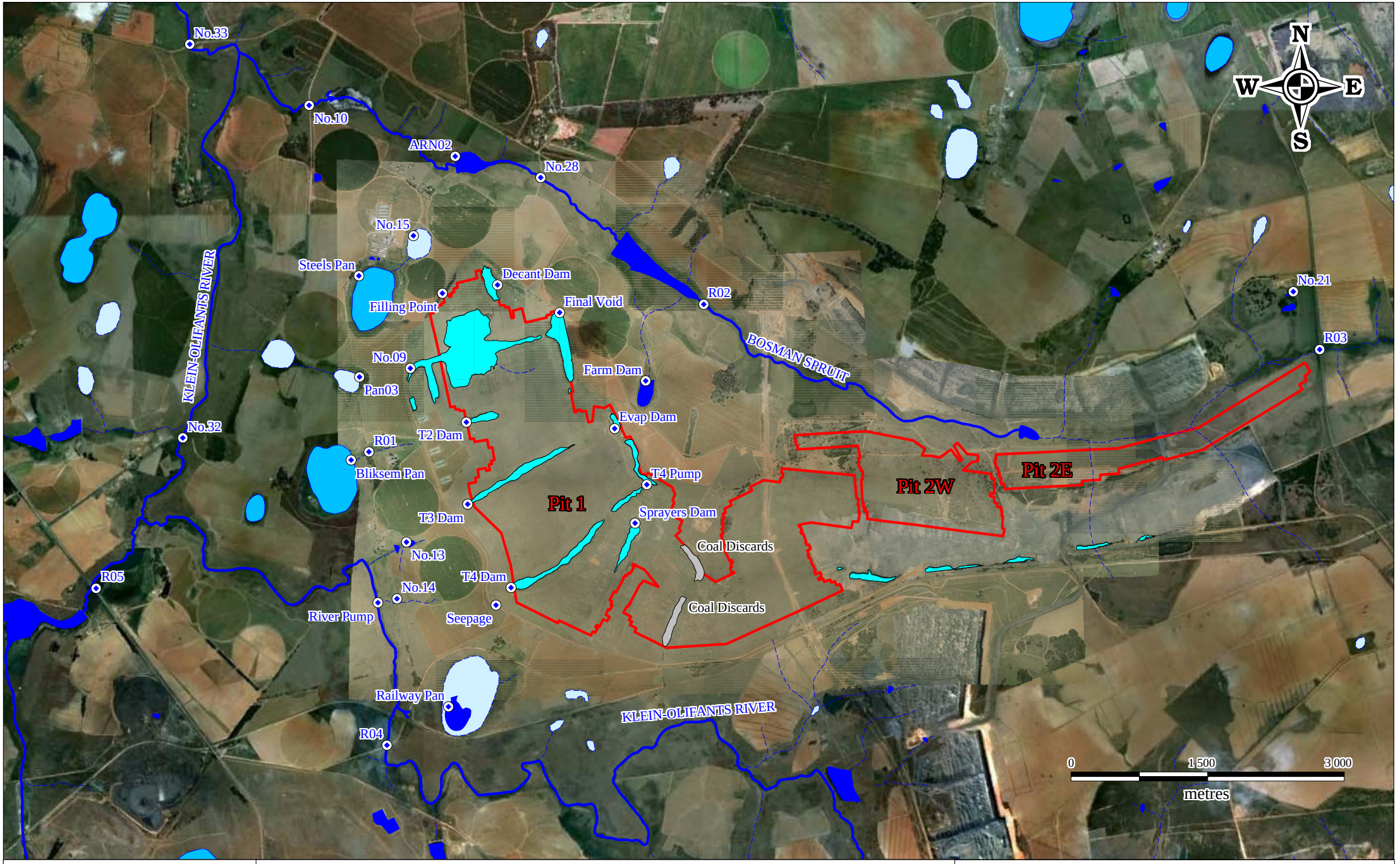
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Sept 2012
	Map Title:	Geological Setting	
	Map No.:	M003ACC	Signed:



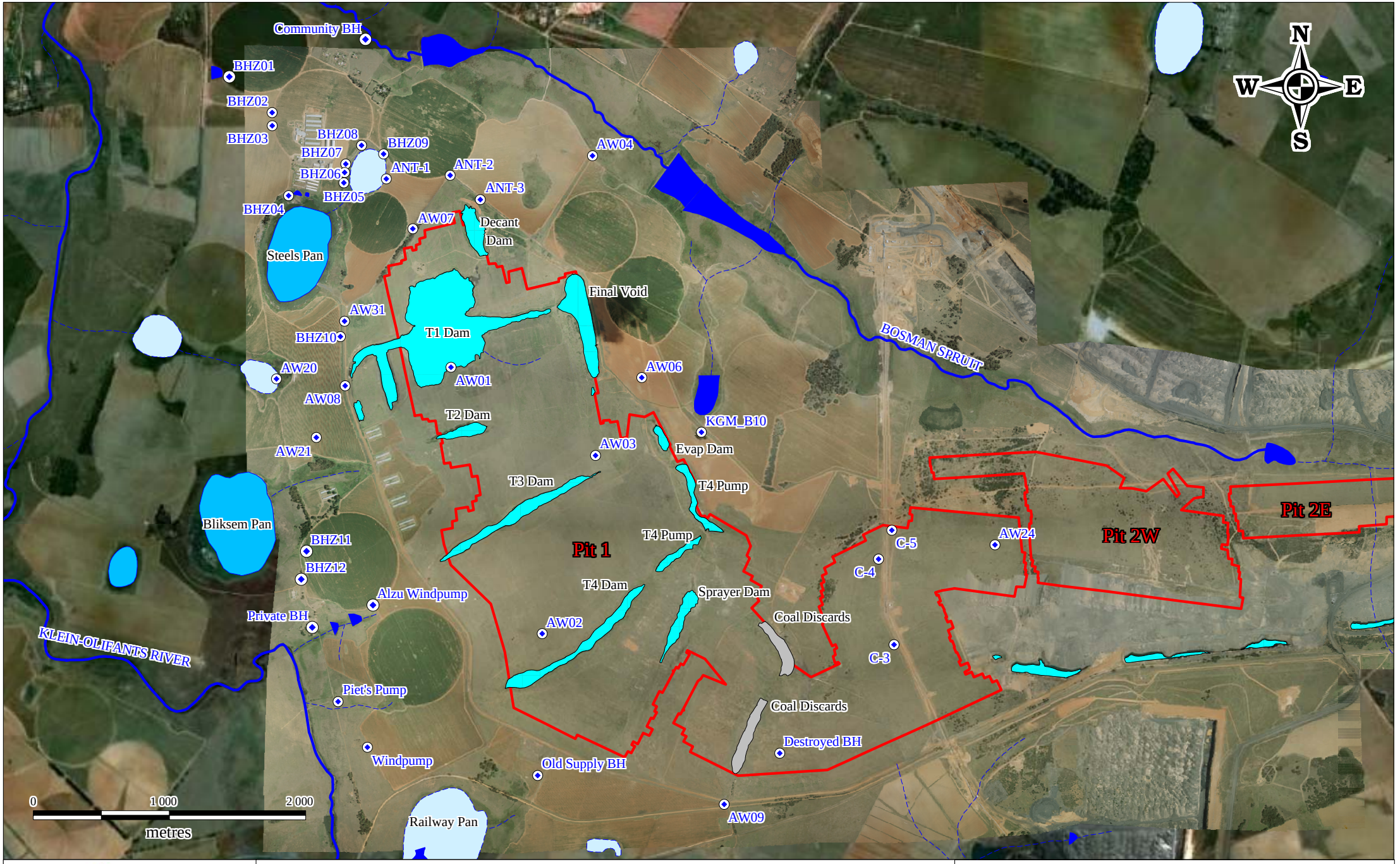
Project:	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie
Map Title:	Drainage	
Map No.:	M004ACC	Signed:



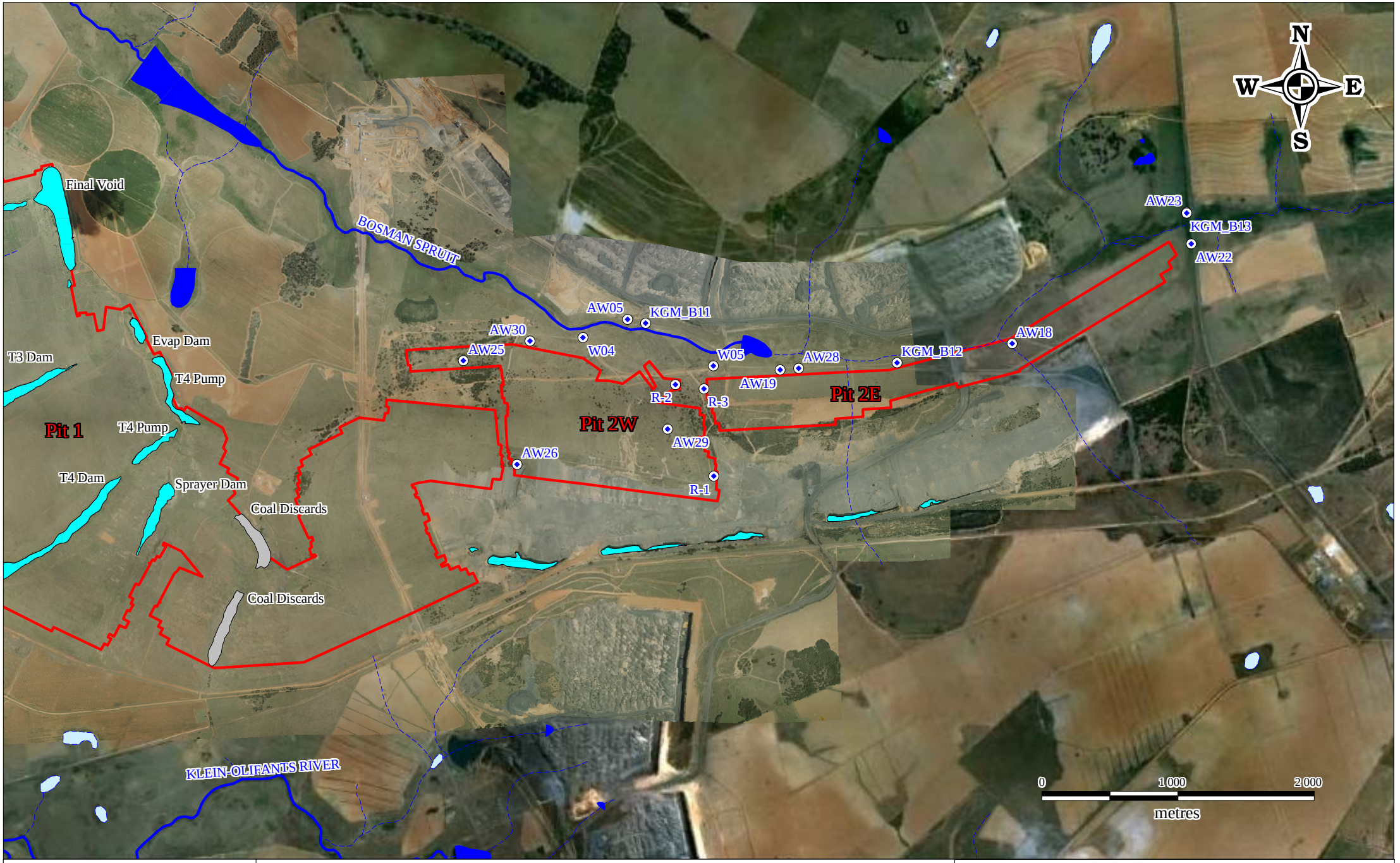
Project:	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie
Map Title:	Potential Recharge Zones	
Map No.:	M005ACC	Signed:



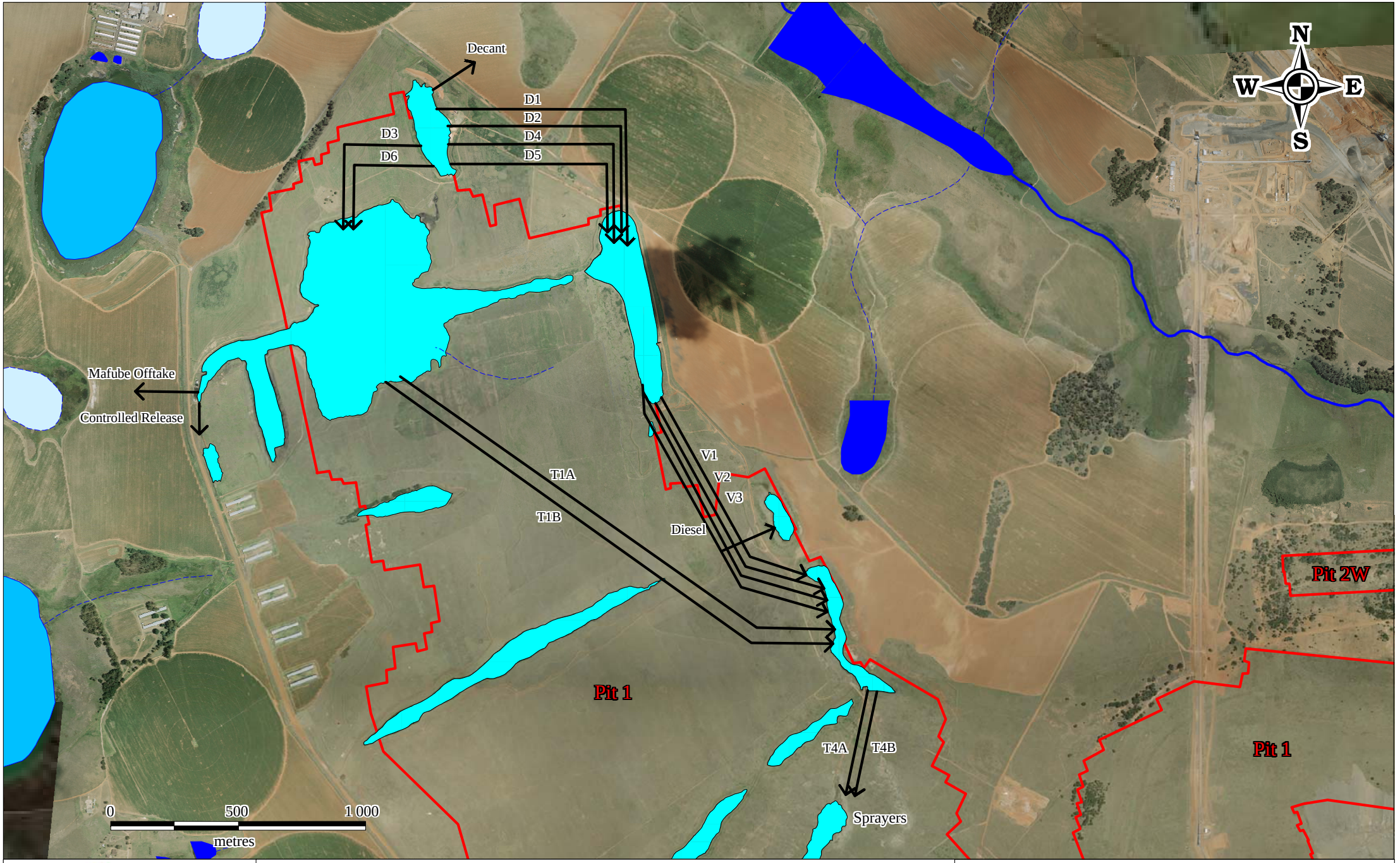
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Sept 2012
	Map Title:	Surface Water Sites	
	Map No.:	M006ACC	Signed:



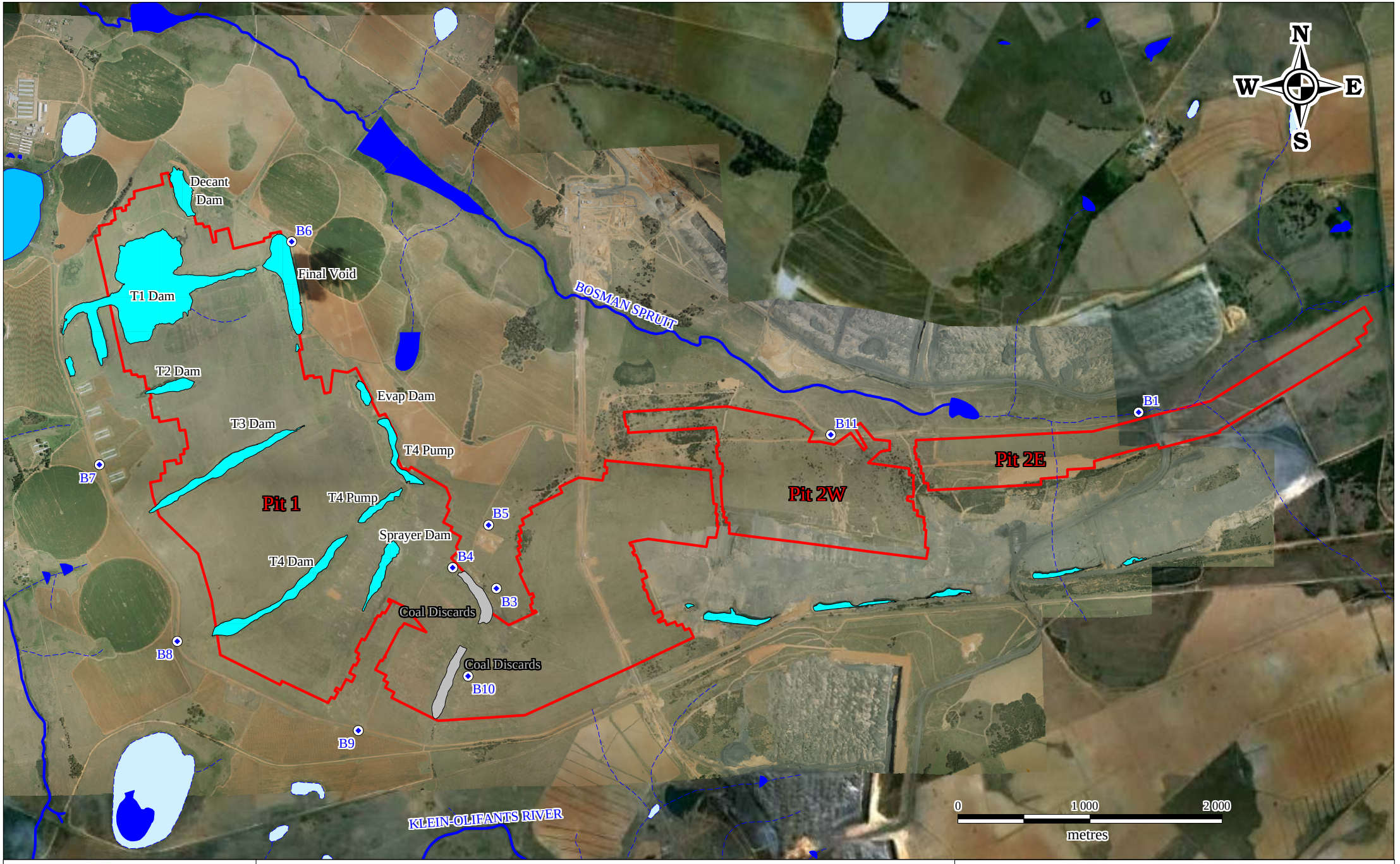
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Sept 2012
	Map Title:	Groundwater Sites near Pit 1	
	Map No.:	M007ACC	Signed:



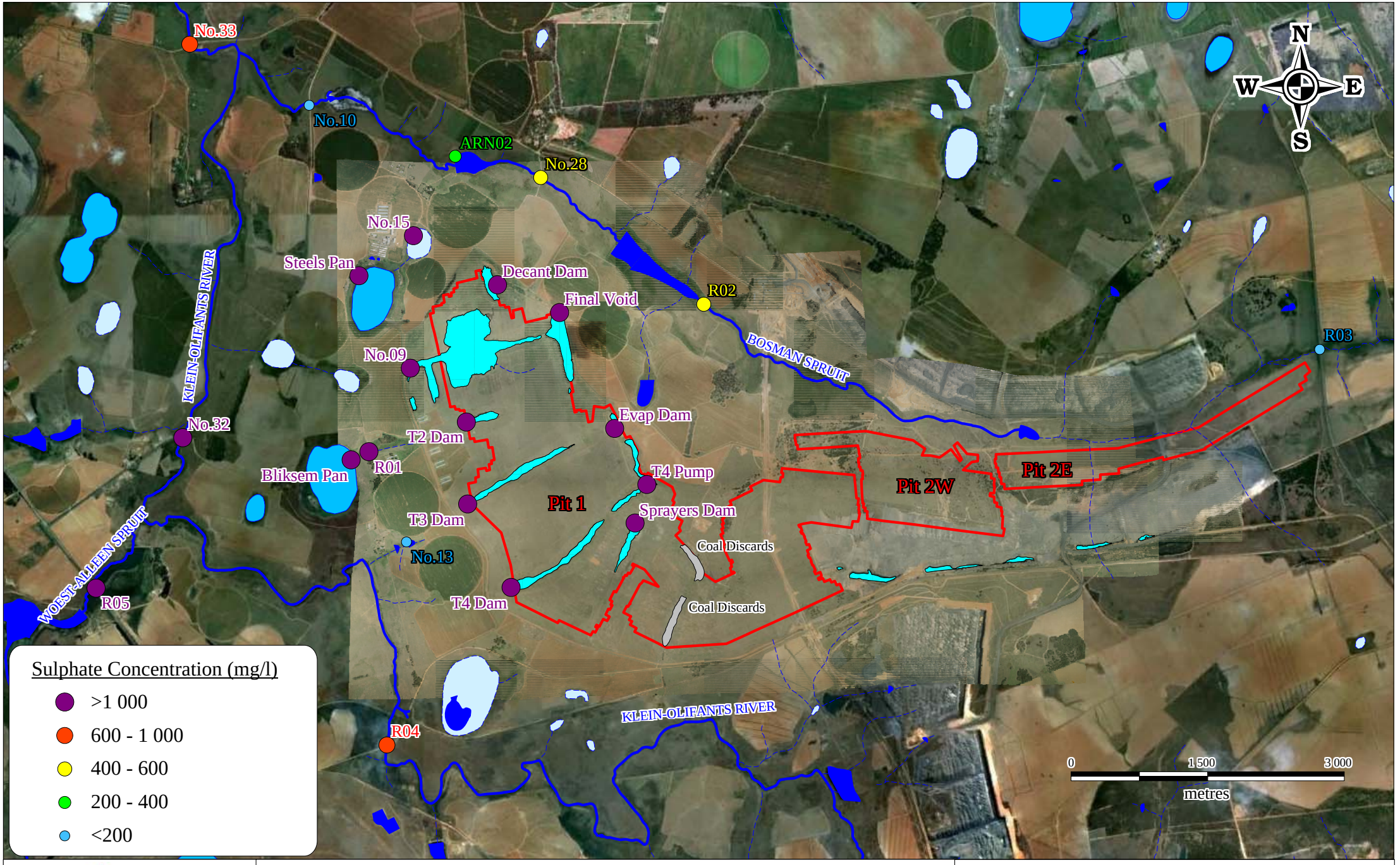
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Sept 2012
	Map Title:	Groundwater Sites near Pit 2 (W & E)	
	Map No.:	M008ACC	Signed:



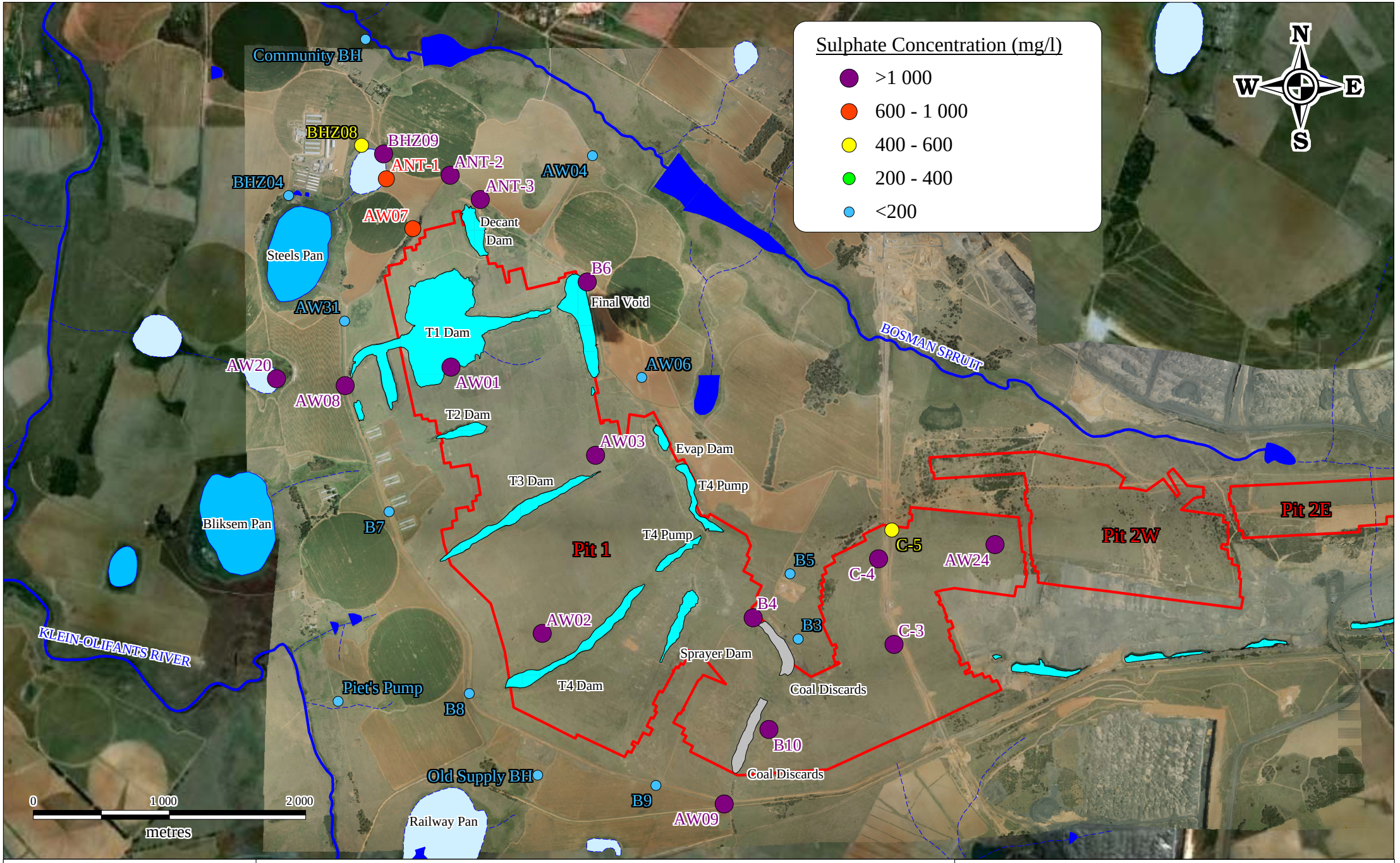
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Aug 2012
	Map Title:	Water Reticulation	
	Map No.:	M009ACC	Signed:



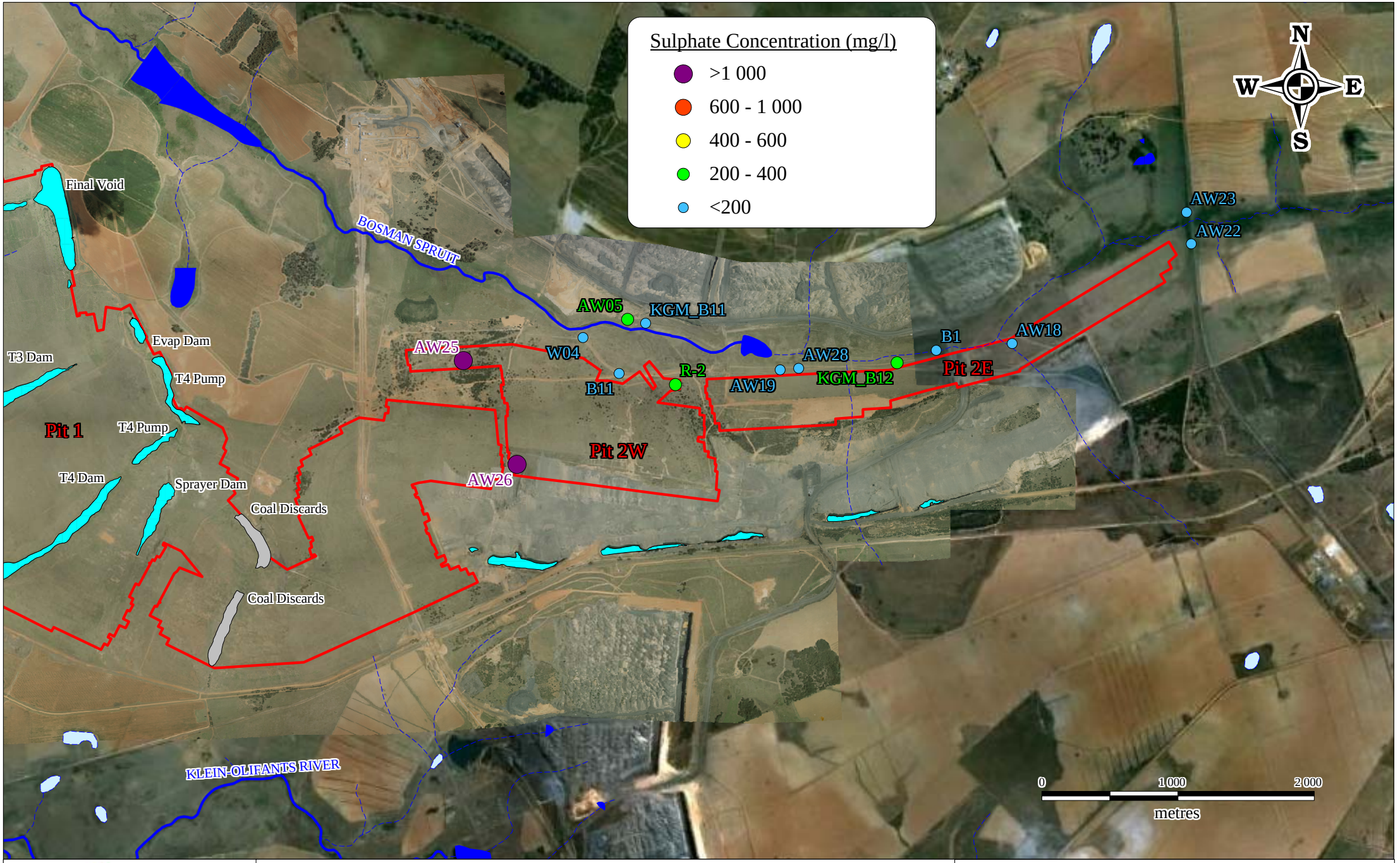
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Sept 2012
	Map Title:	Positions of New Investigative and Monitoring Boreholes	
	Map No.:	M010ACC	Signed:



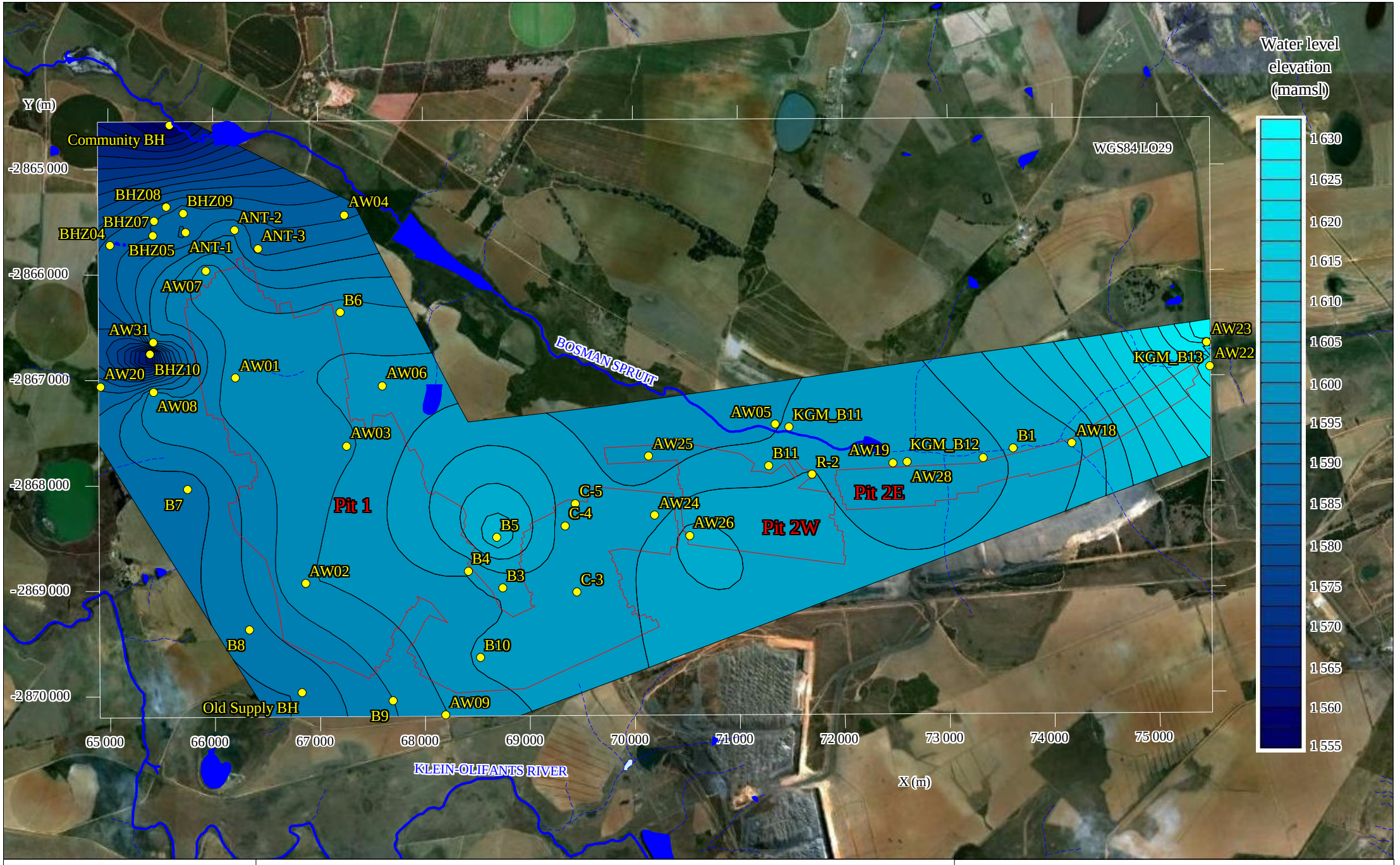
Project:	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Oct 2012
Map Title:	Sulphate Concentrations: Surface Water Sites	
Map No.:	M011ACC	Signed:



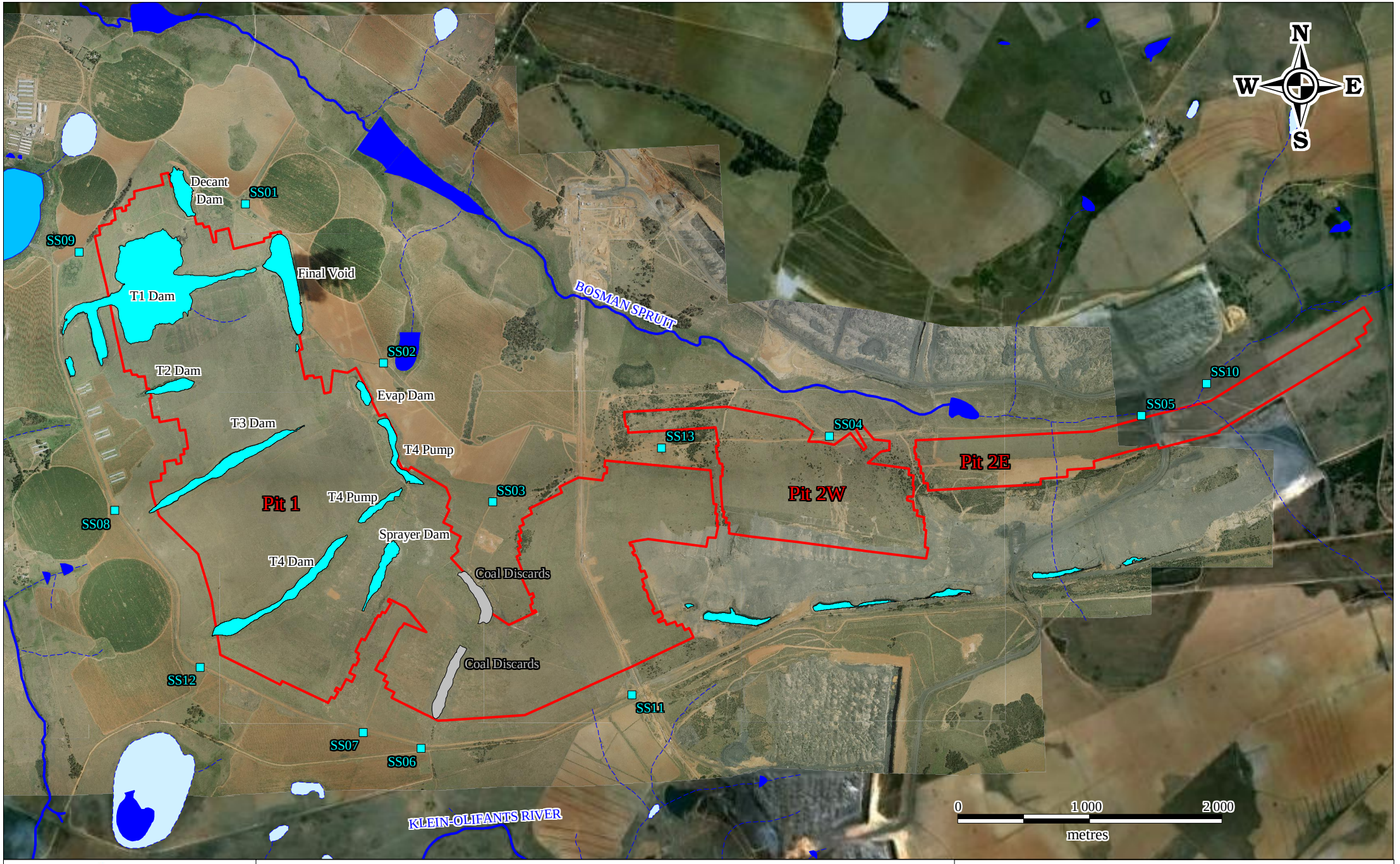
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Oct 2012
	Map Title:	Sulphate Concentrations: Groundwater Sites near Pit 1	
	Map No.:	M012ACC	Signed:



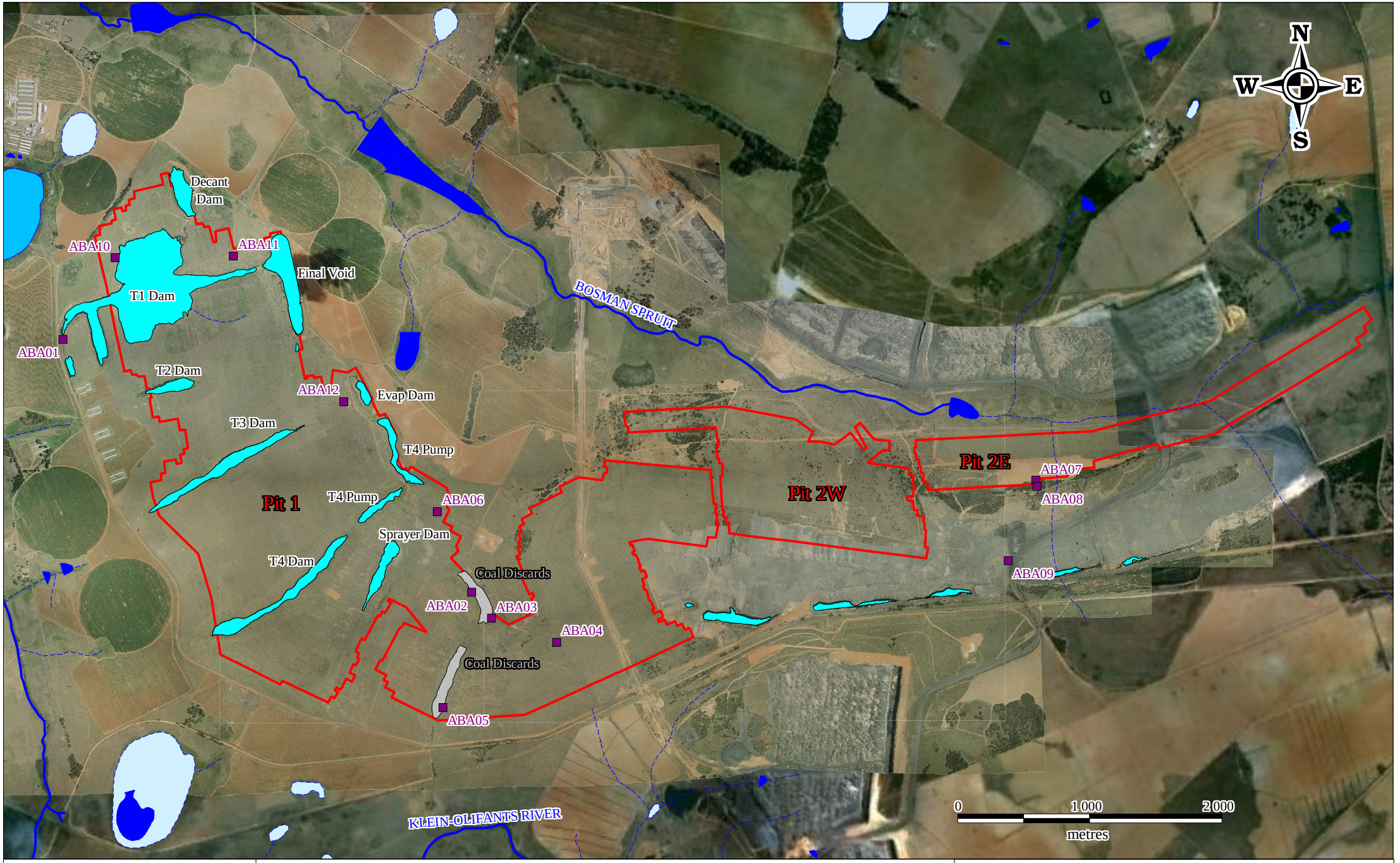
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Oct 2012
	Map Title:	Sulphate Concentrations: Groundwater Sites near Pit 2 (W & E)	
	Map No.:	M013ACC	Signed:



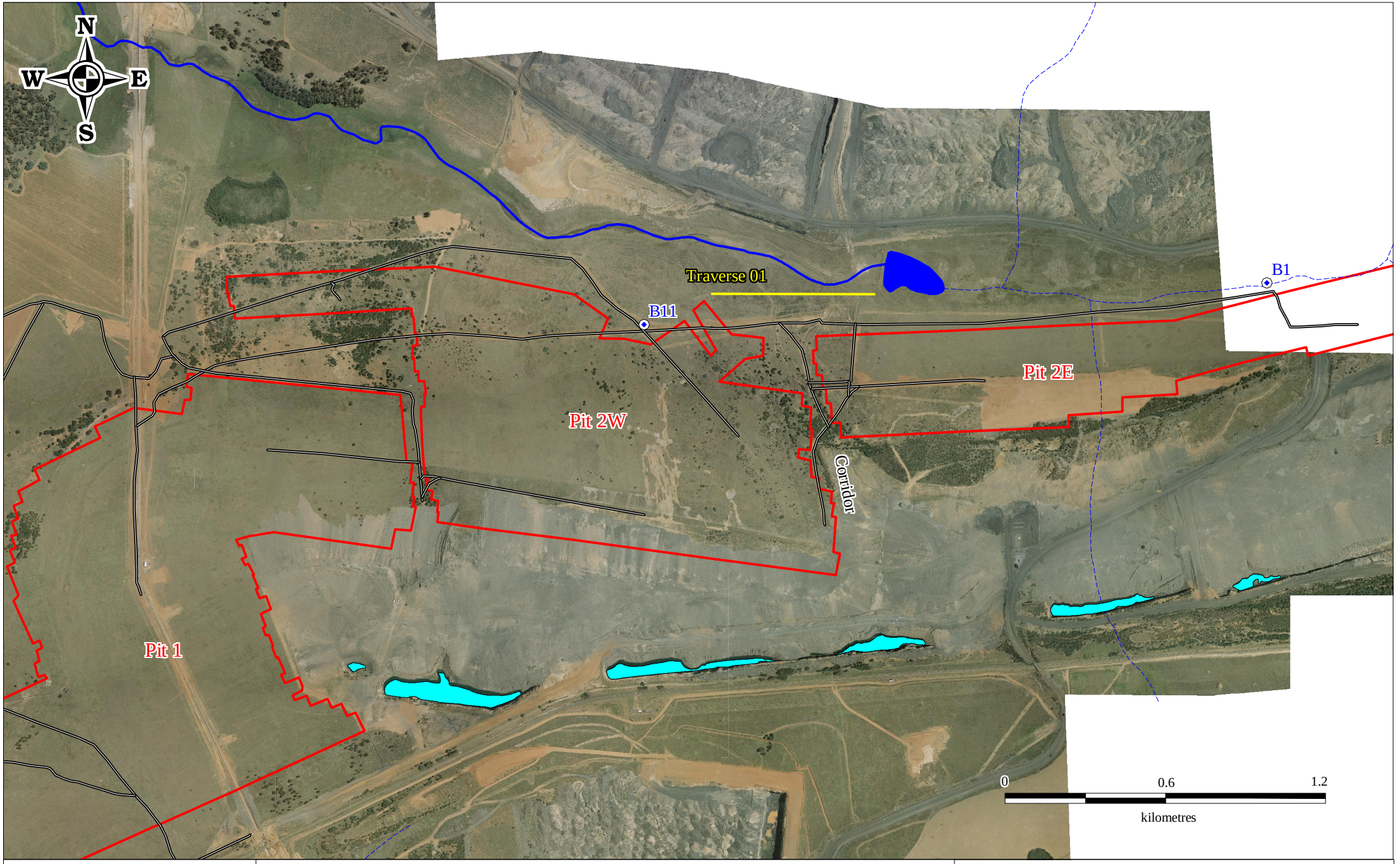
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Nov 2012
	Map Title:	Groundwater Elevations, August 2012	
	Map No.:	M014ACC	Signed:



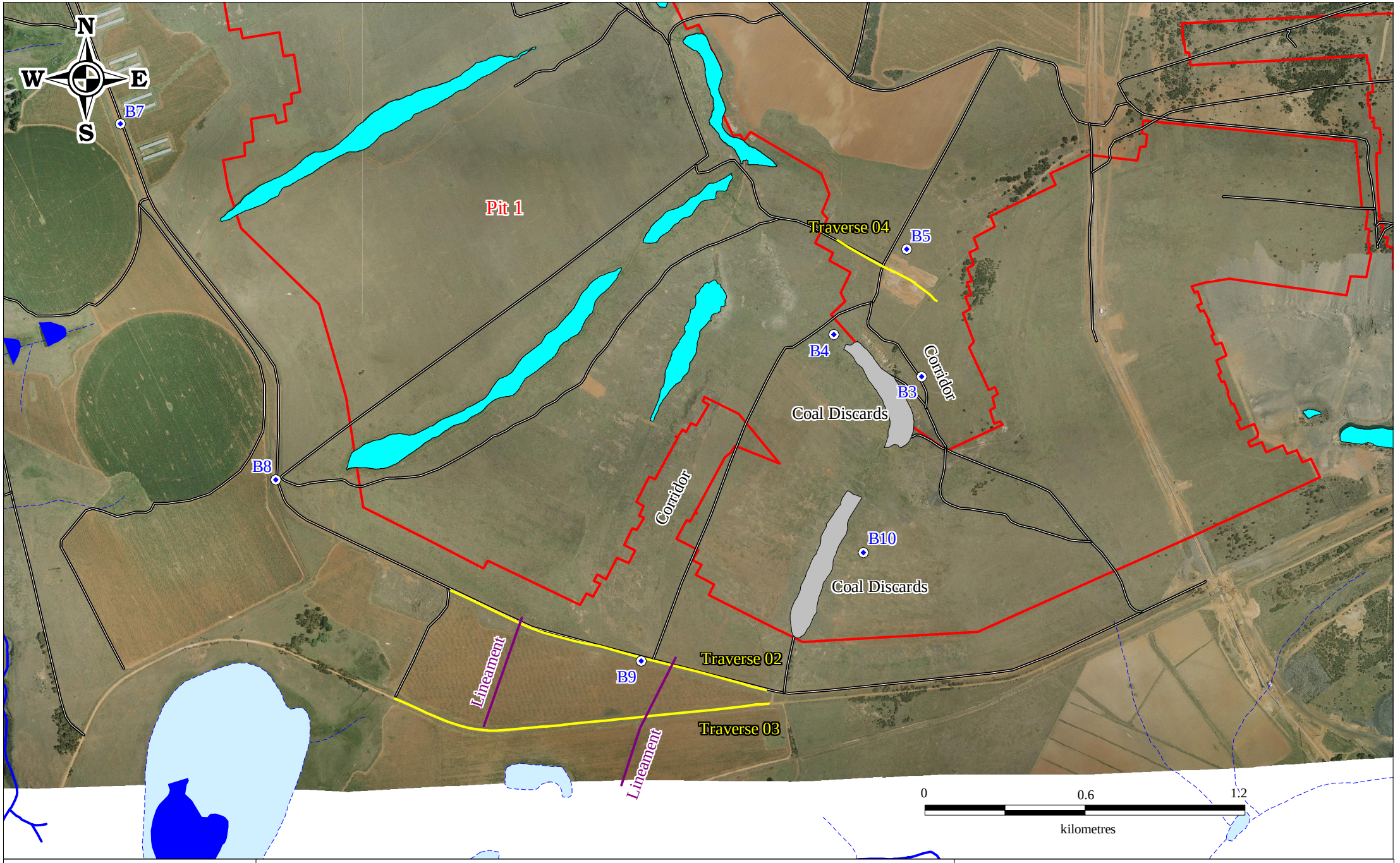
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Sept 2012
	Map Title:	Positions of Samples for Grain Size Analyses	
	Map No.:	M015ACC	Signed:



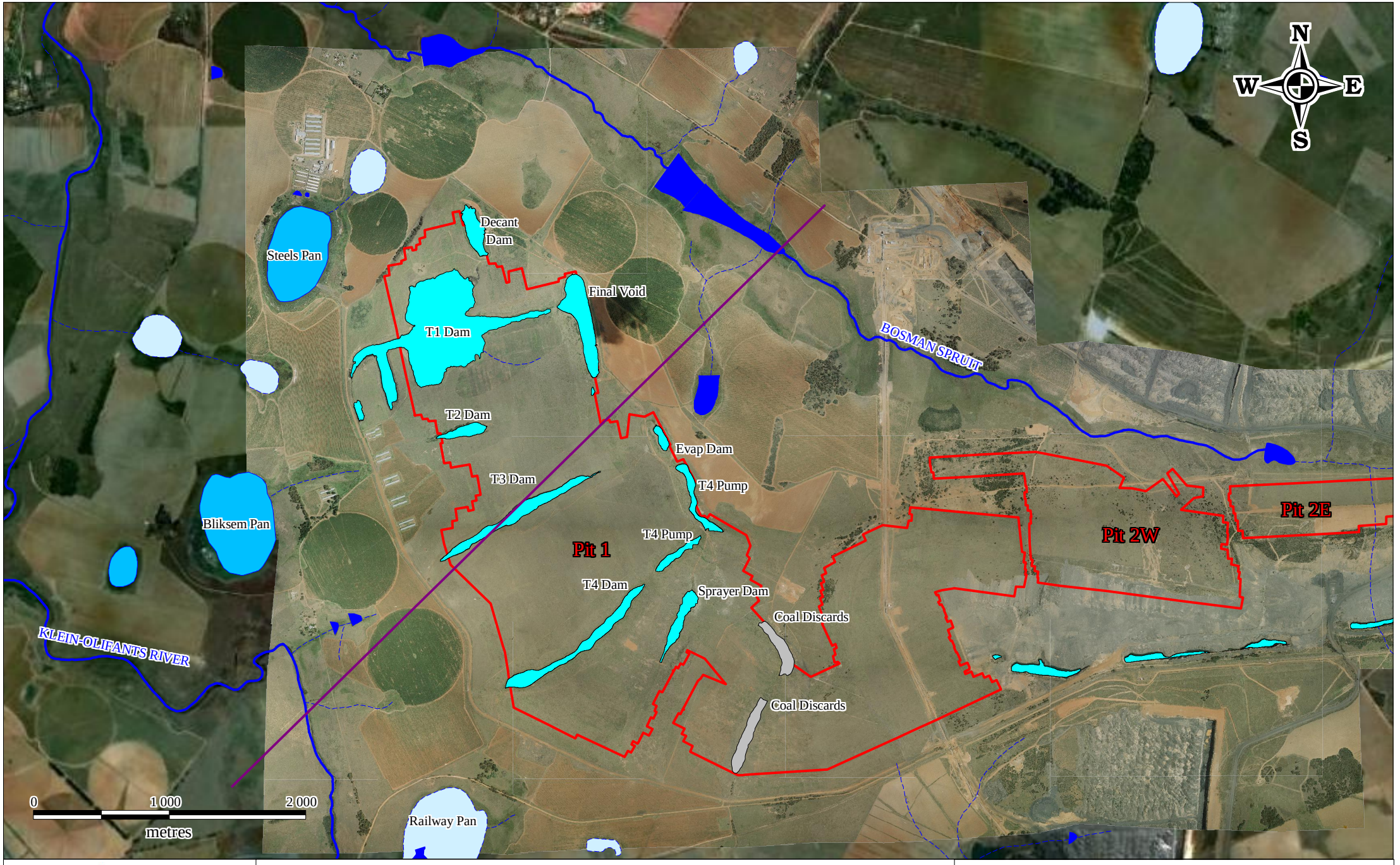
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Sept 2012
	Map Title:	Positions of Samples for Acid-Base Accounting	
	Map No.:	M016ACC	Signed:



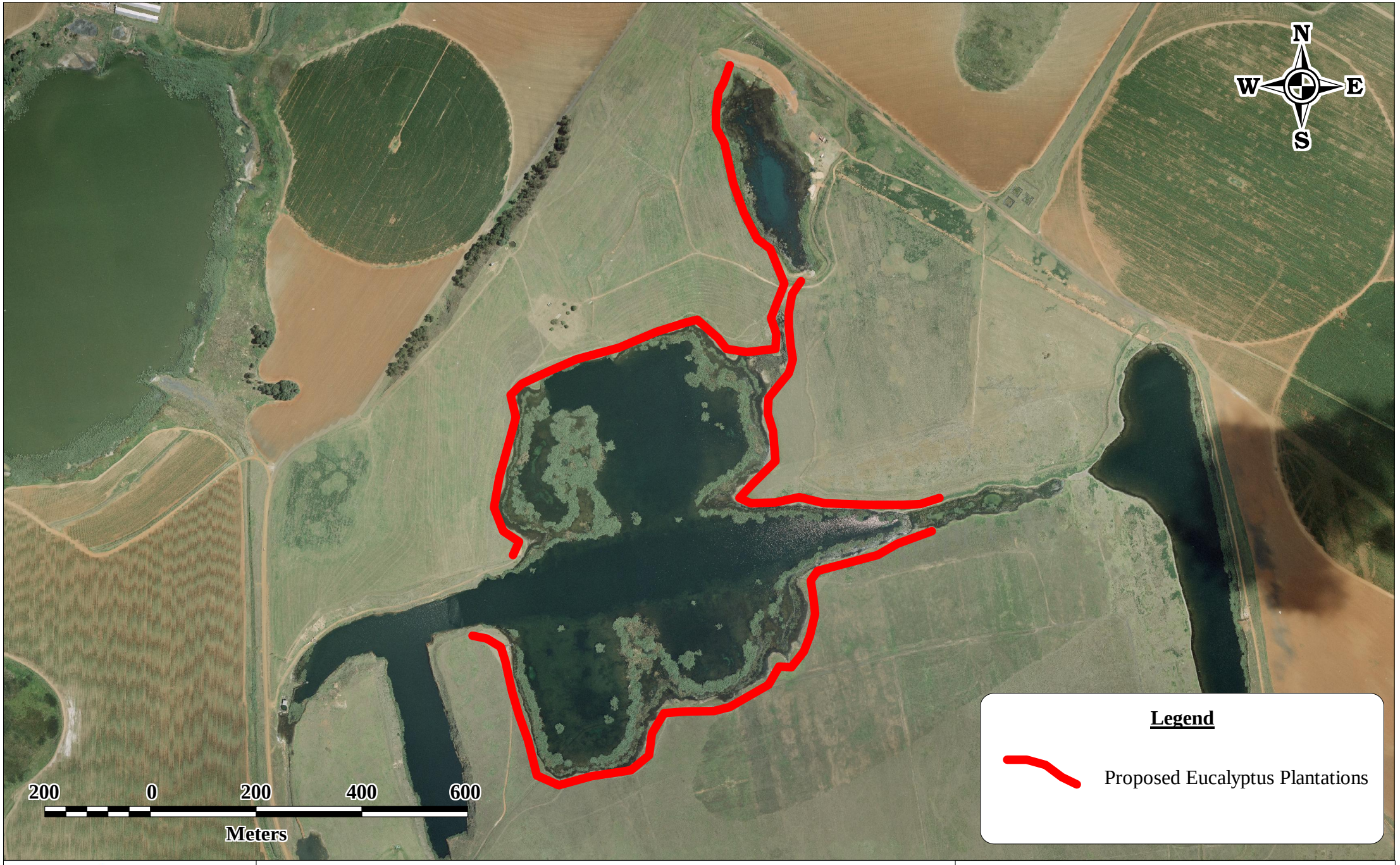
IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Sept 2012
	Map Title:	Magnetic Traverse North of Pit 2W and Pit 2E	
	Map No.:	M017ACC	Signed:



IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Oct 2012
	Map Title:	Magnetic Traverses near the Corridors in Pit 1	
	Map No.:	M018ACC	Signed:



IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Nov 2012
	Map Title:	Cross-Section Trace through Pit 1	
	Map No.:	M019ACC	Signed:



IGS INSTITUTE FOR GROUNDWATER STUDIES	**Project:**	Arnot Closed Colliery - Water Management Plan	Compiled by: FD Fourie Date: Dec 2012
	Map Title:	Proposed Eucalyptus Plantations	
	Map No.:	M020ACC	Signed:

APPENDIX B

Borehole Logs

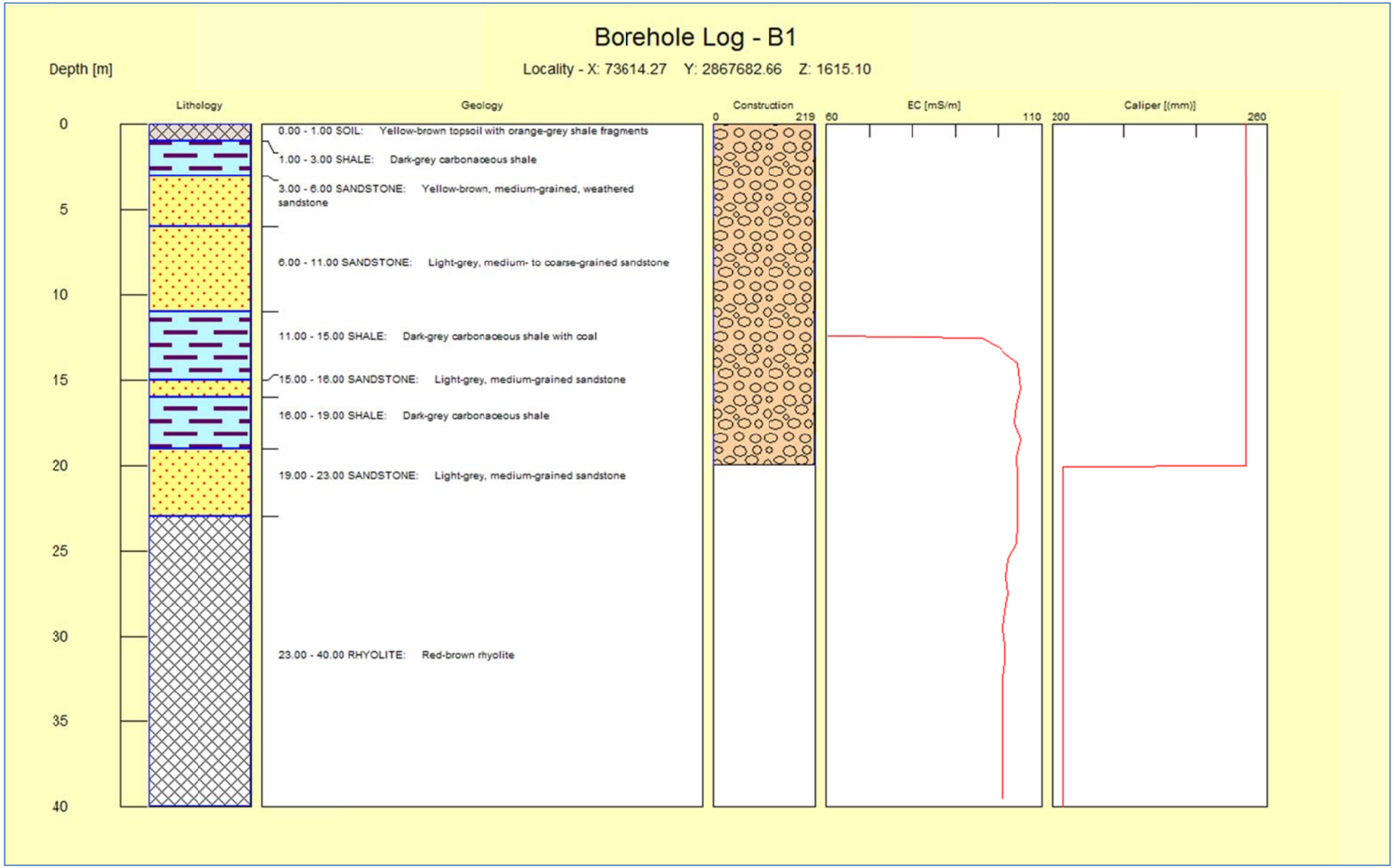


Figure B1. Geological log of borehole B1.

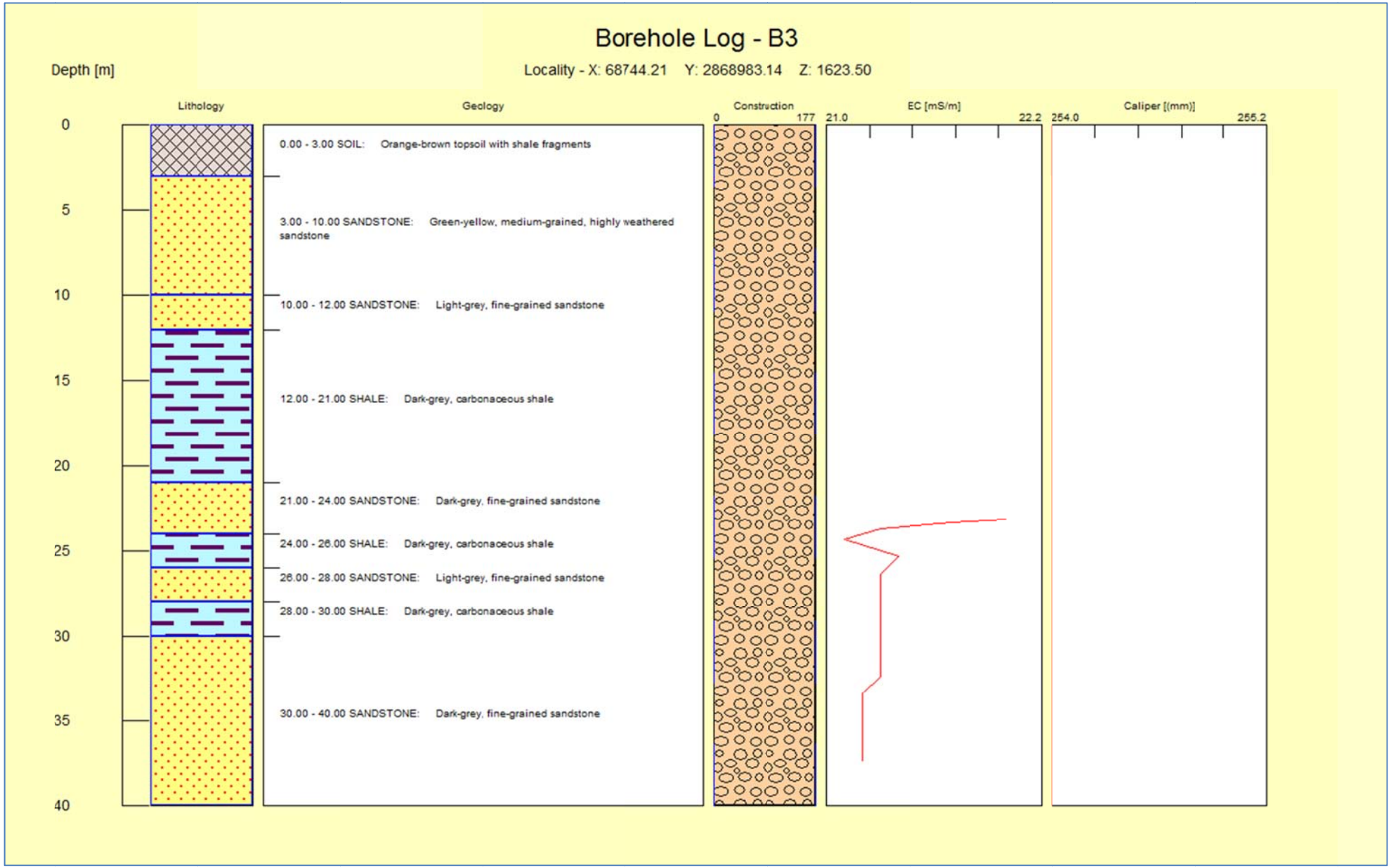


Figure B2. Geological log of borehole B3.

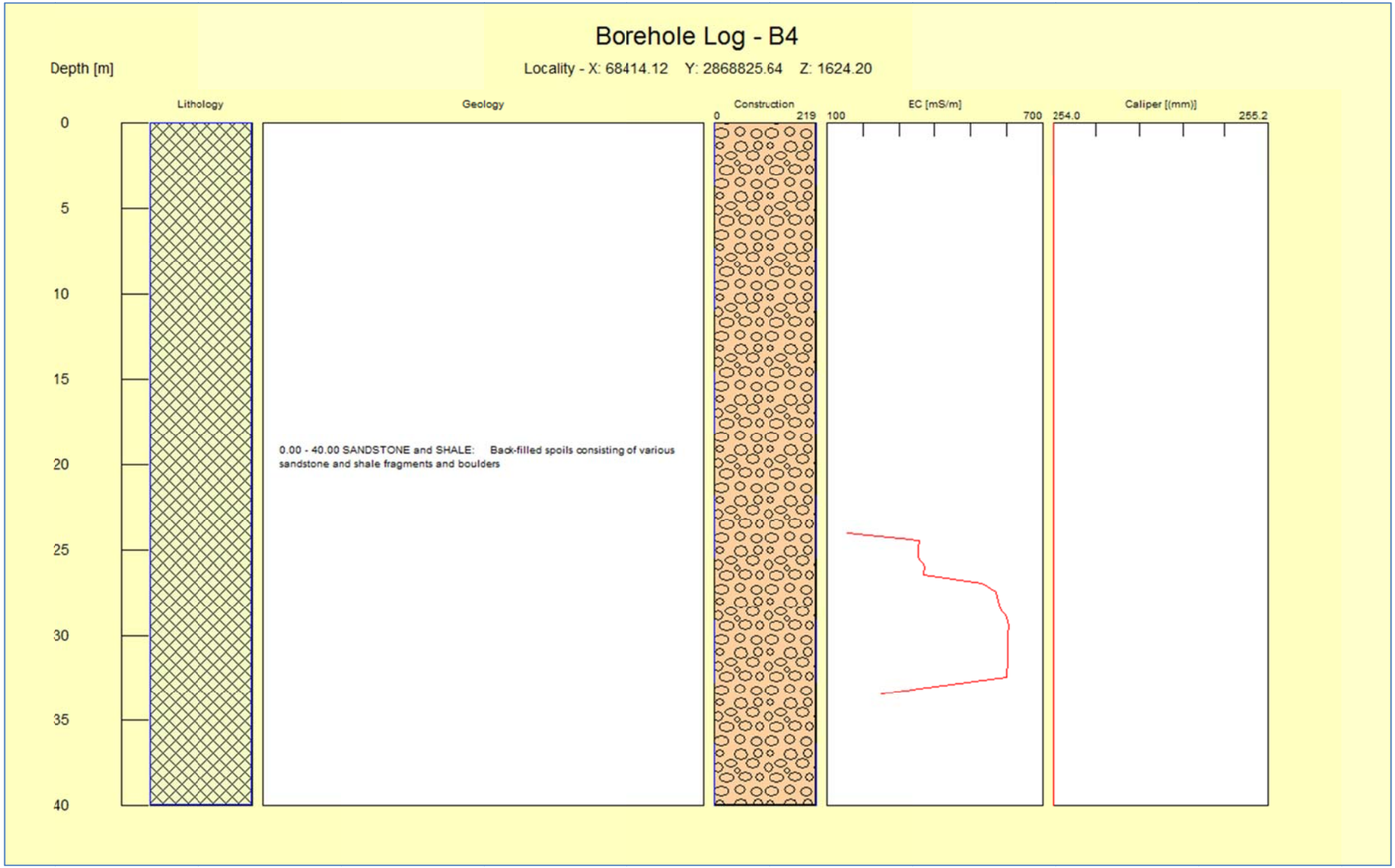


Figure B3. Geological log of borehole B4.

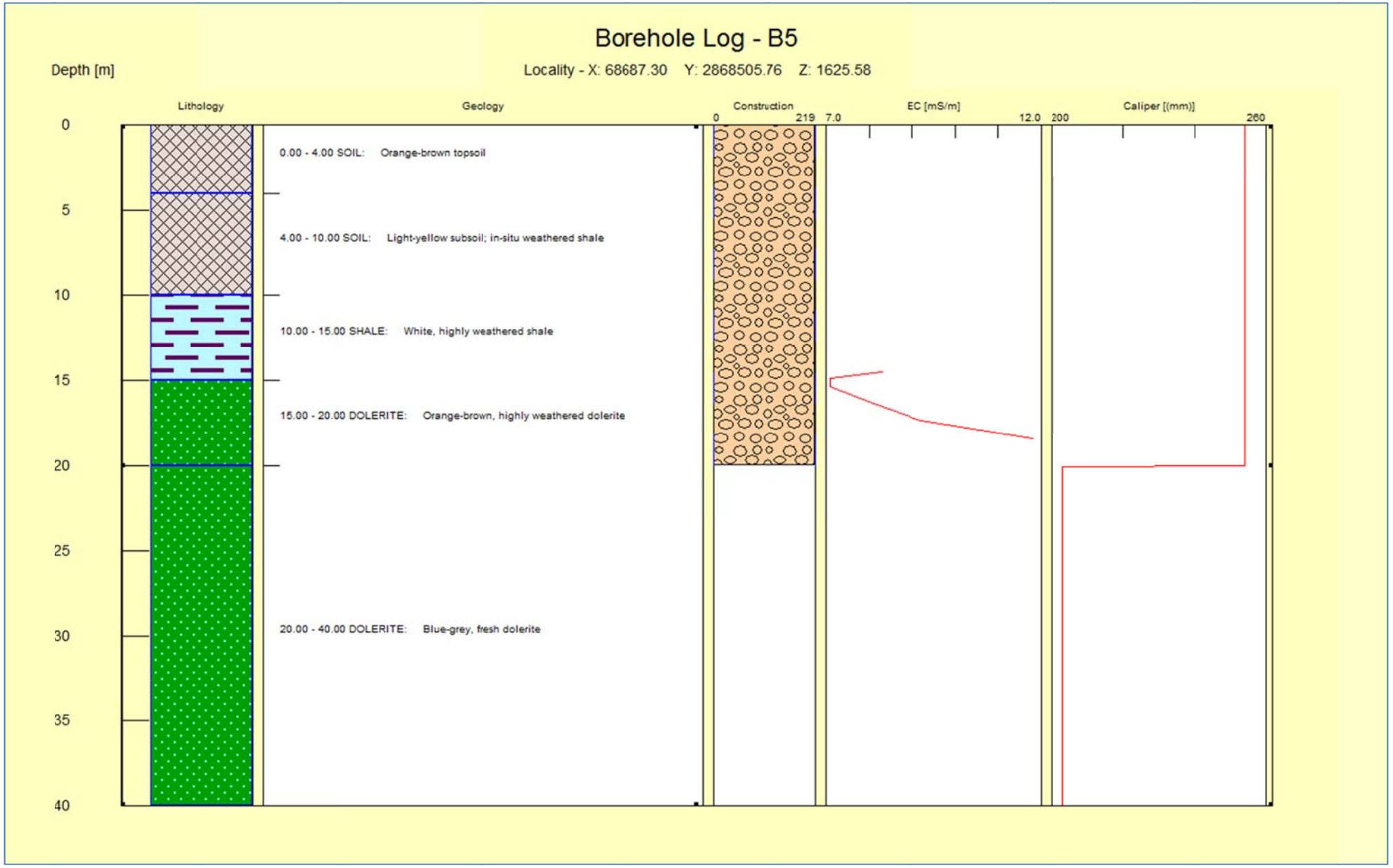


Figure B4. Geological log of borehole B5.

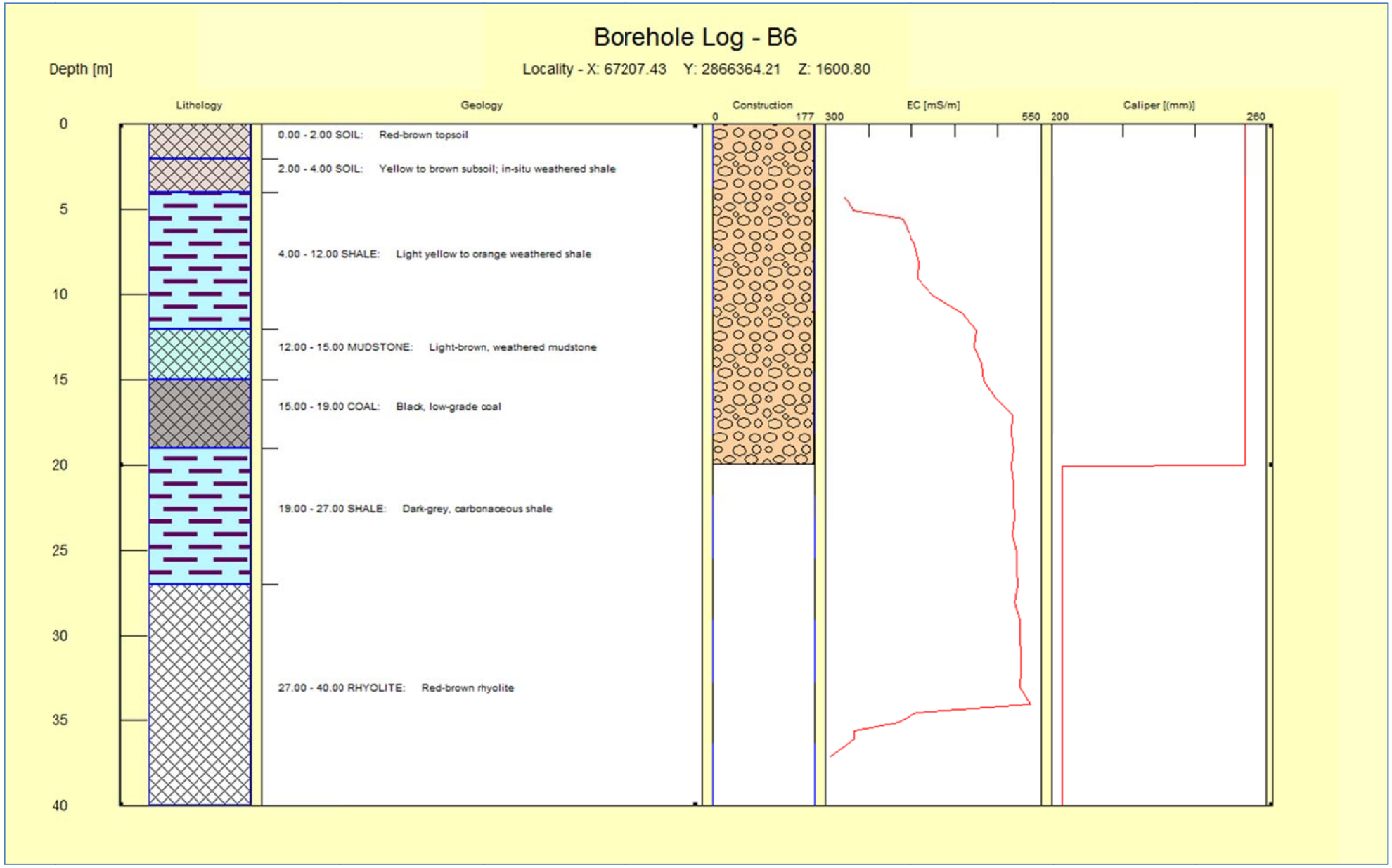


Figure B5. Geological log of borehole B6.

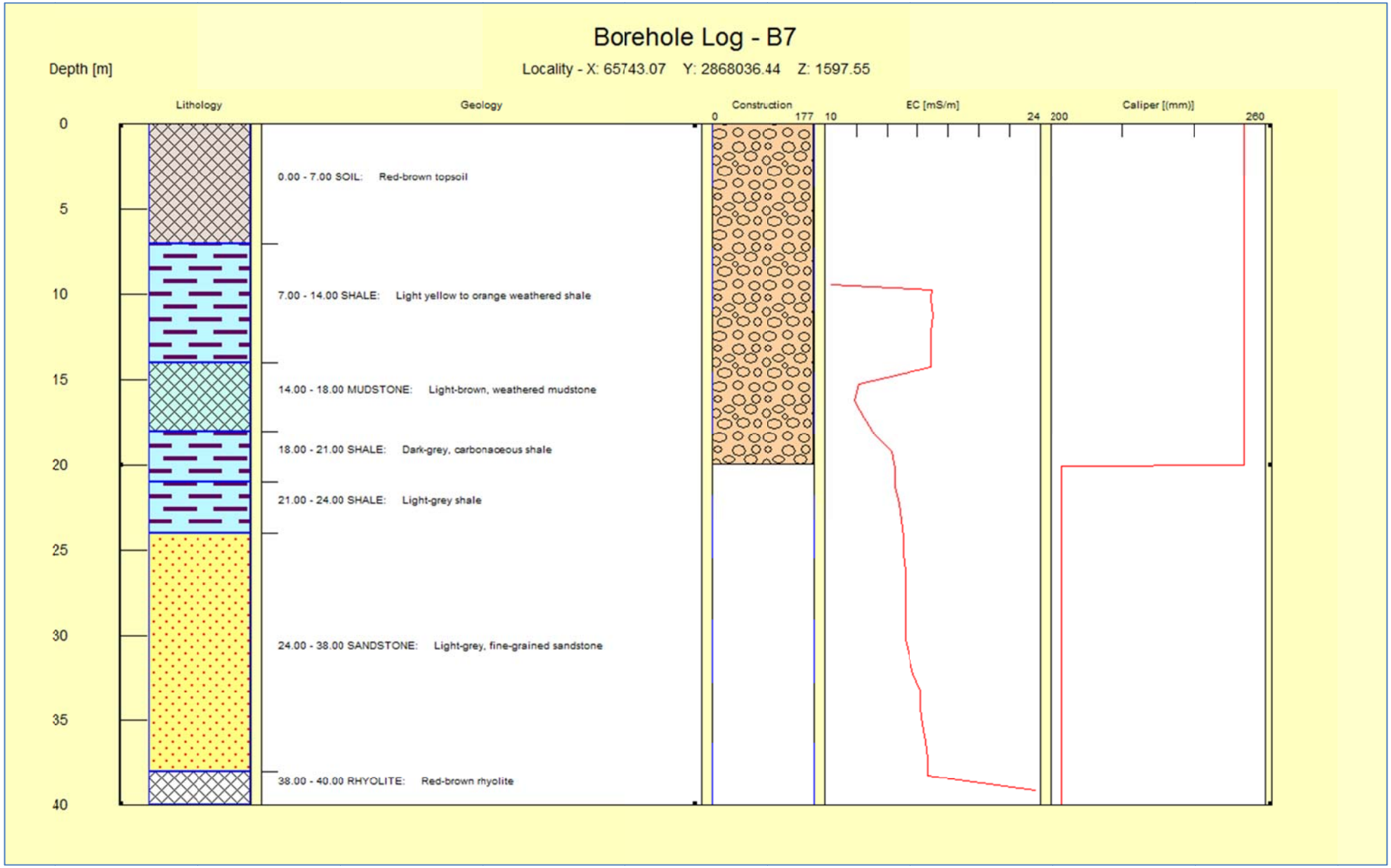


Figure B6. Geological log of borehole B7.

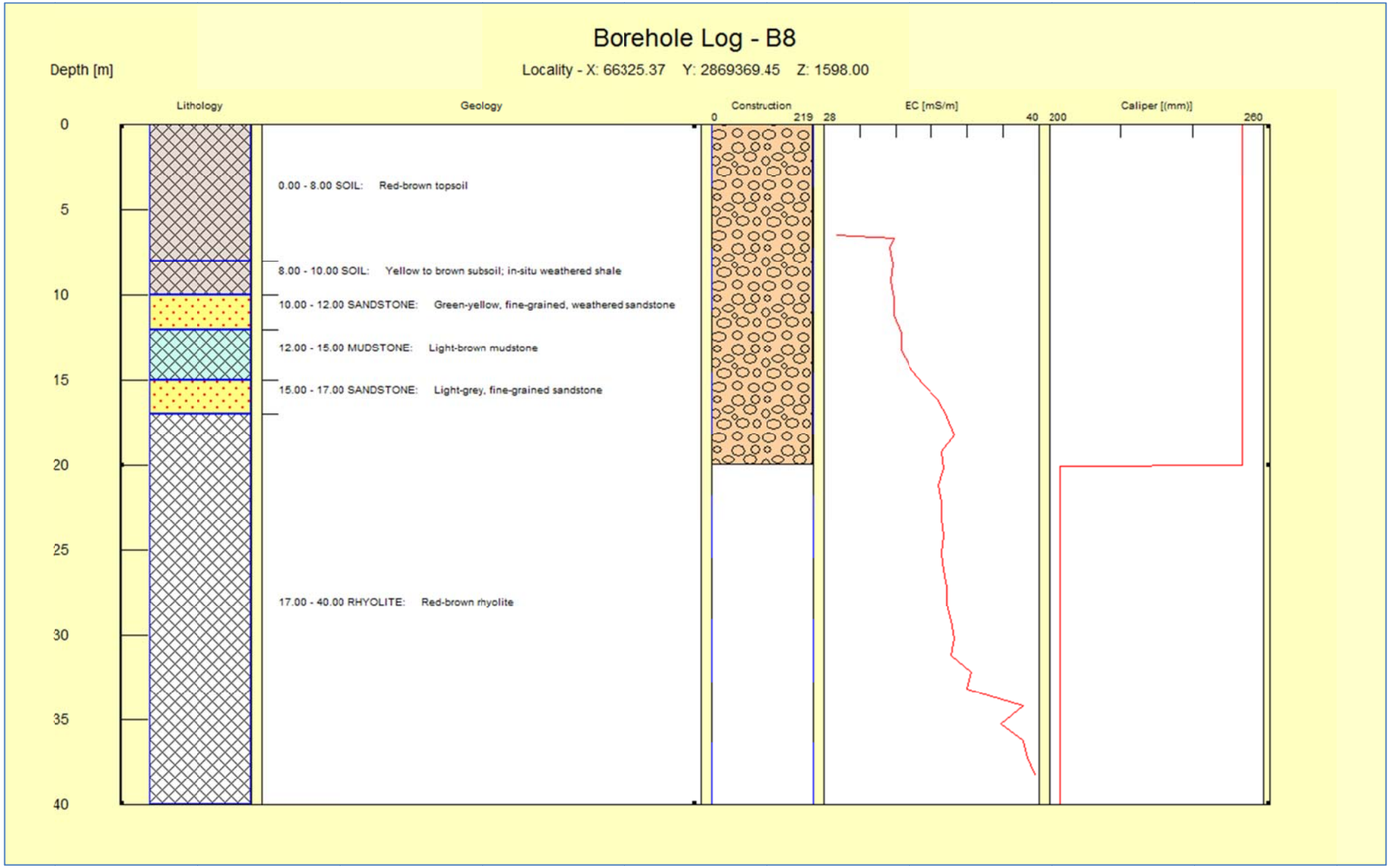


Figure B7. Geological log of borehole B8.

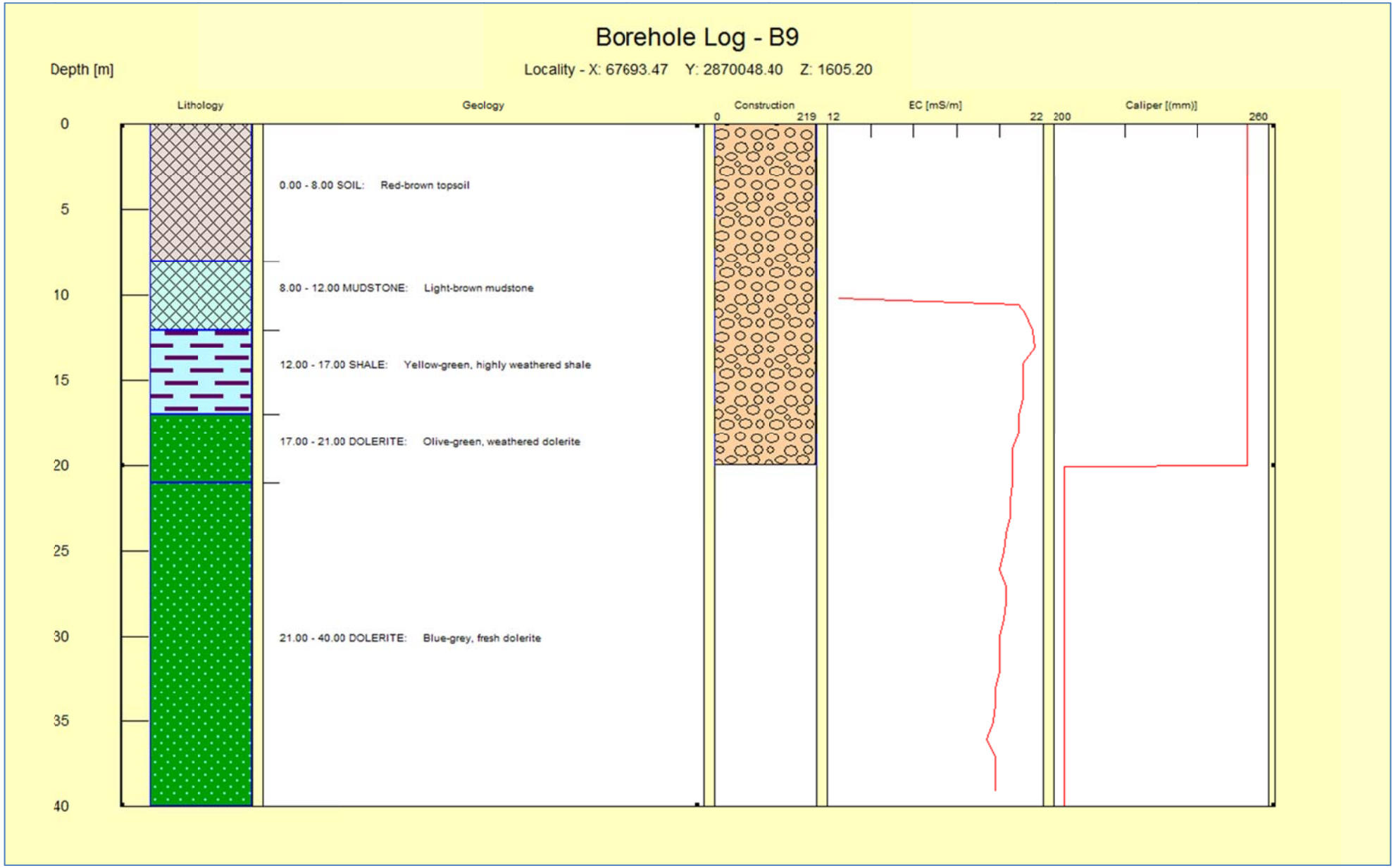


Figure B8. Geological log of borehole B9.

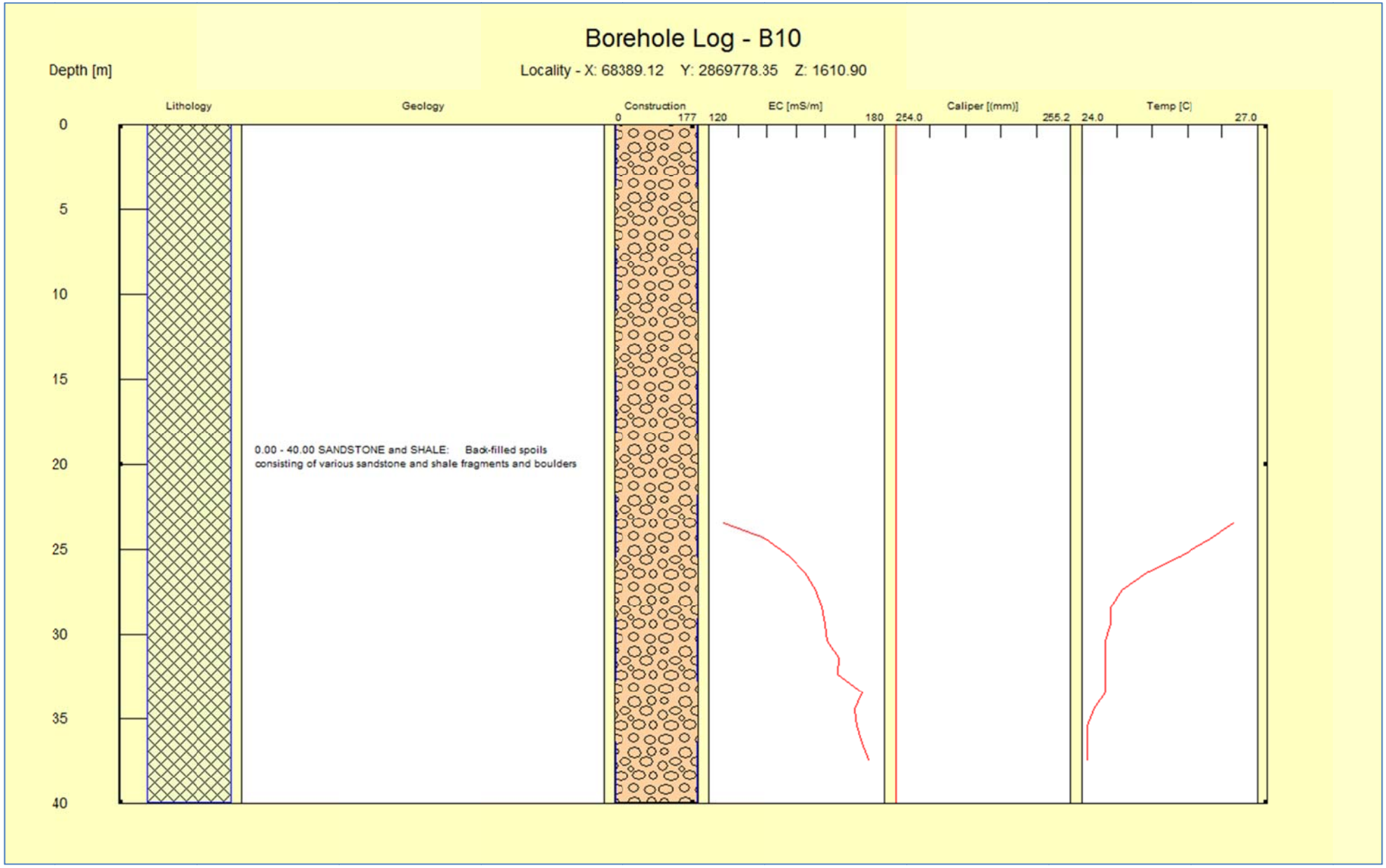


Figure B9. Geological log of borehole B10.

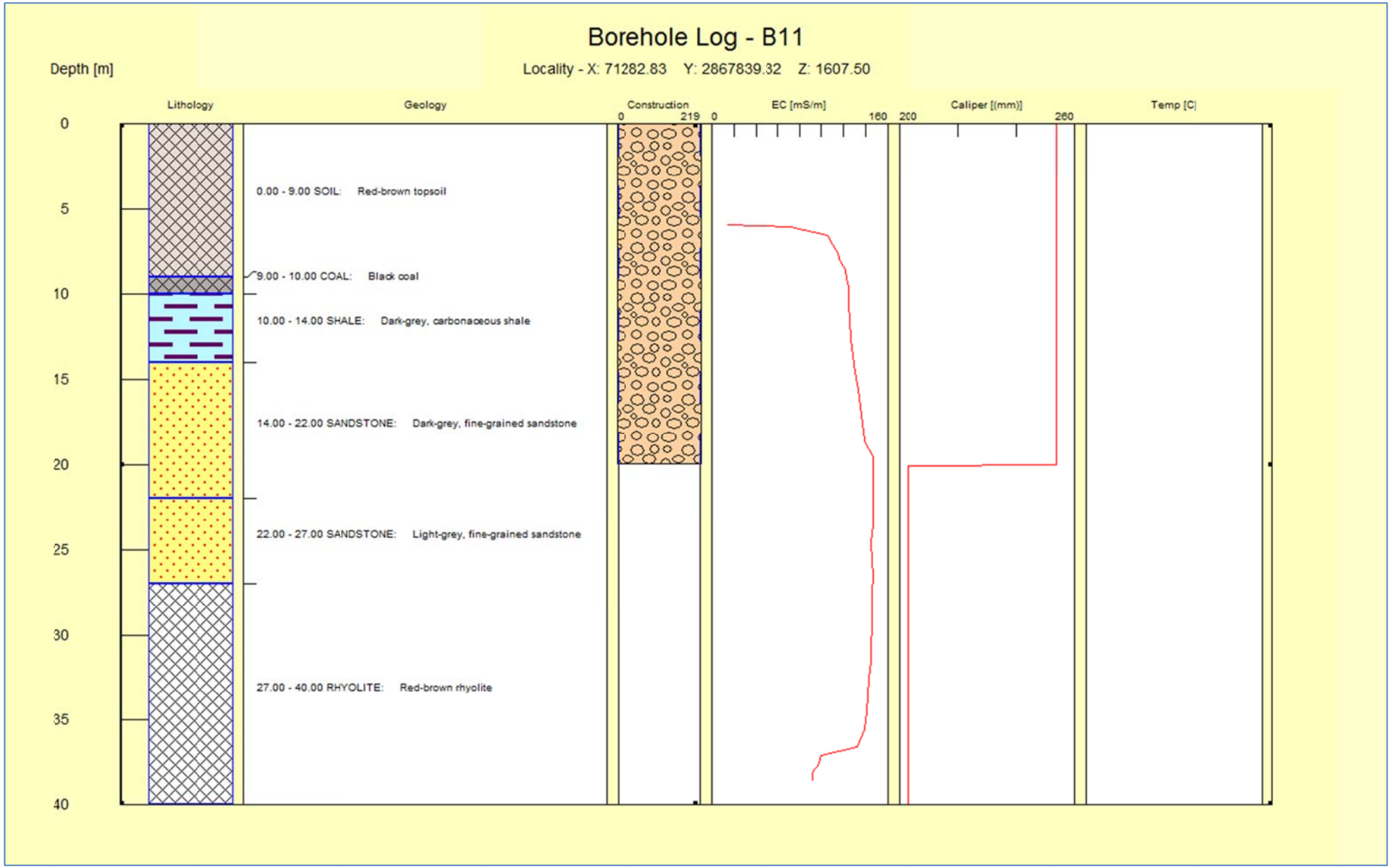


Figure B10. Geological log of borehole B11.

APPENDIX C

EC Profiling Results

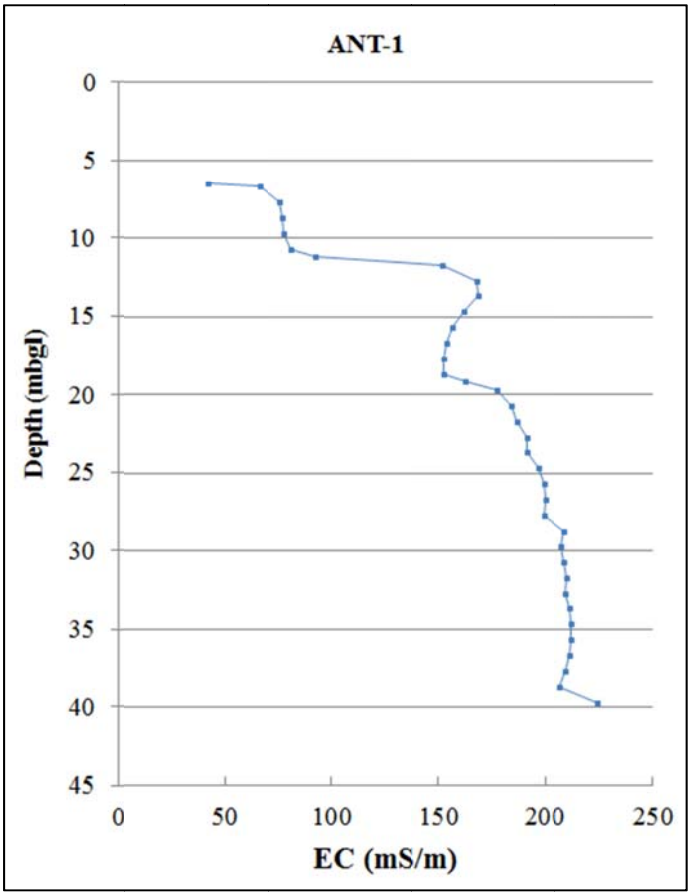


Figure C1. EC profile of borehole ANT-1.

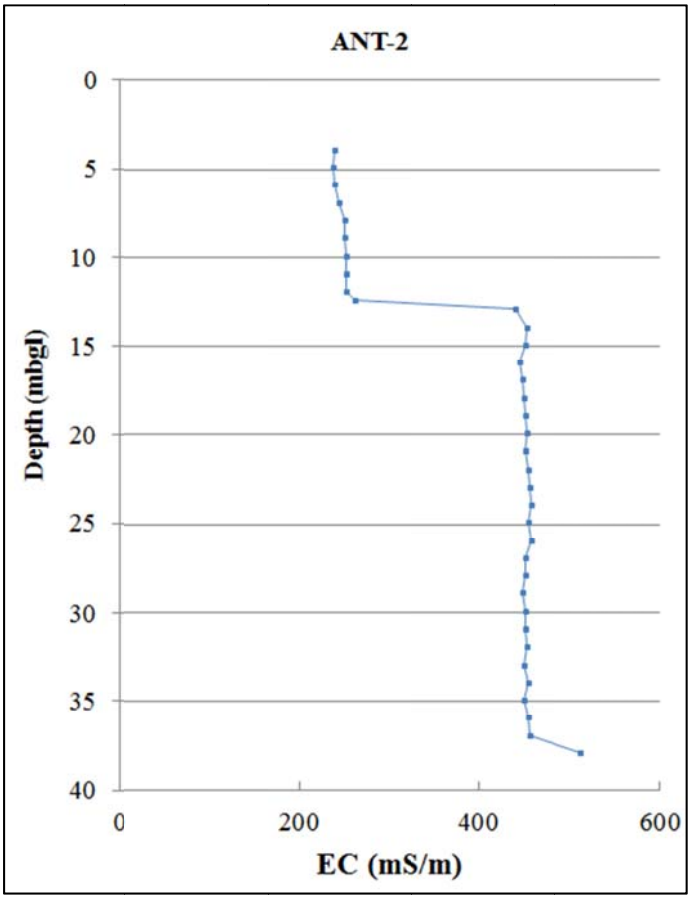


Figure C2. EC profile of borehole ANT-2.

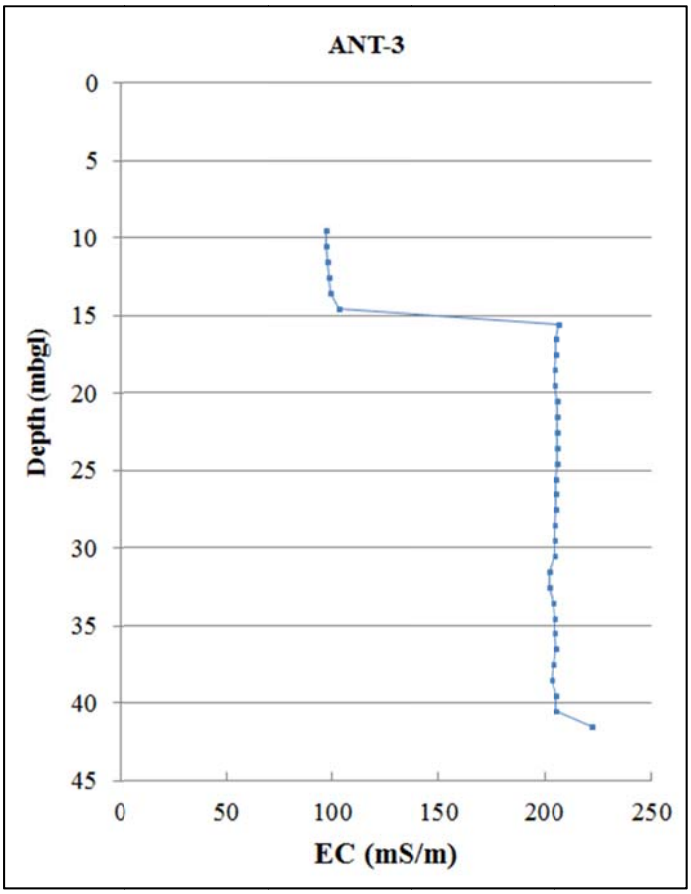


Figure C3. EC profile of borehole ANT-3.

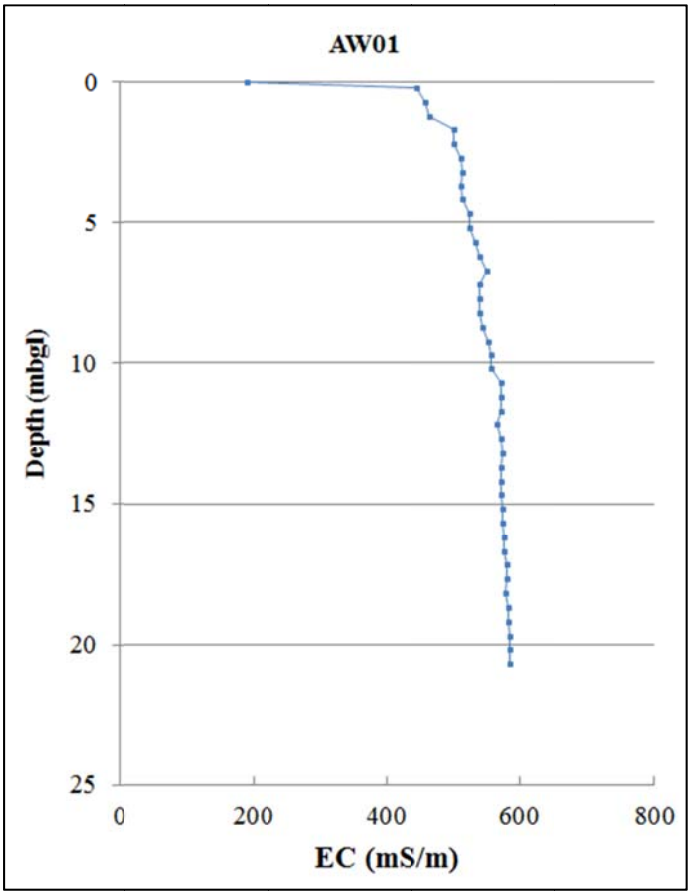


Figure C4. EC profile of borehole AW01.

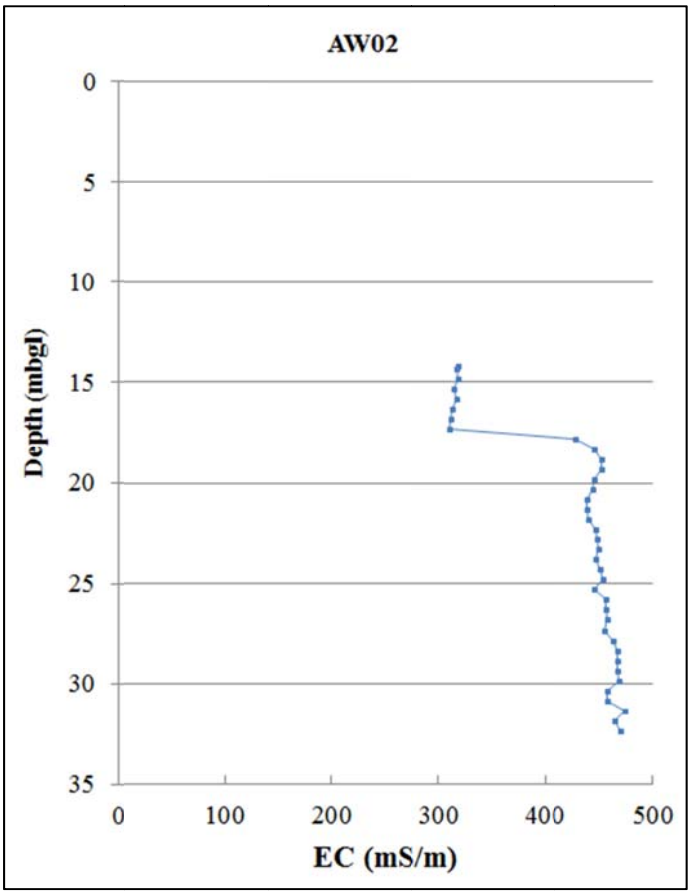


Figure C5. EC profile of borehole AW02.

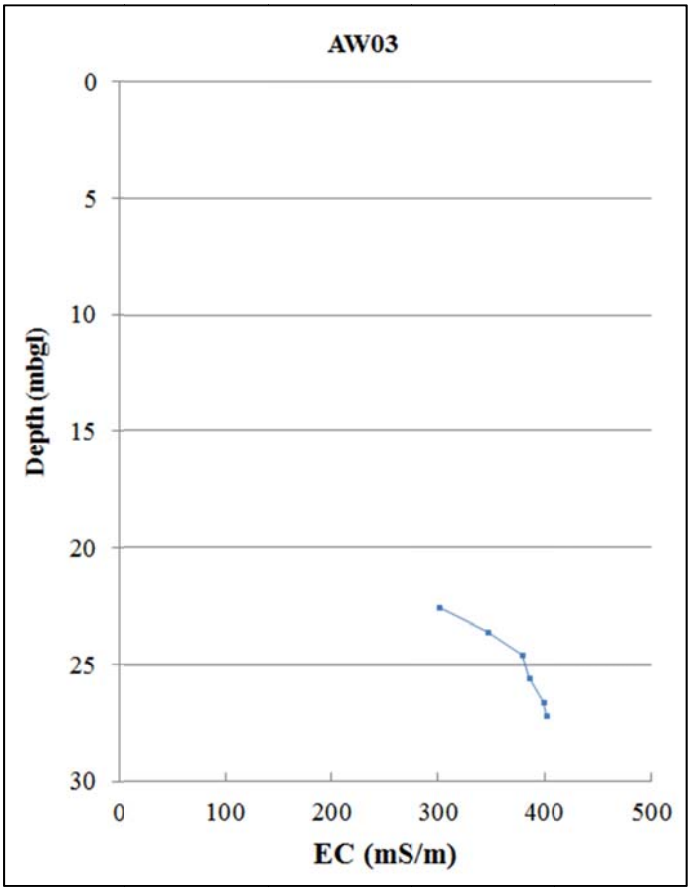


Figure C6. EC profile of borehole AW03.

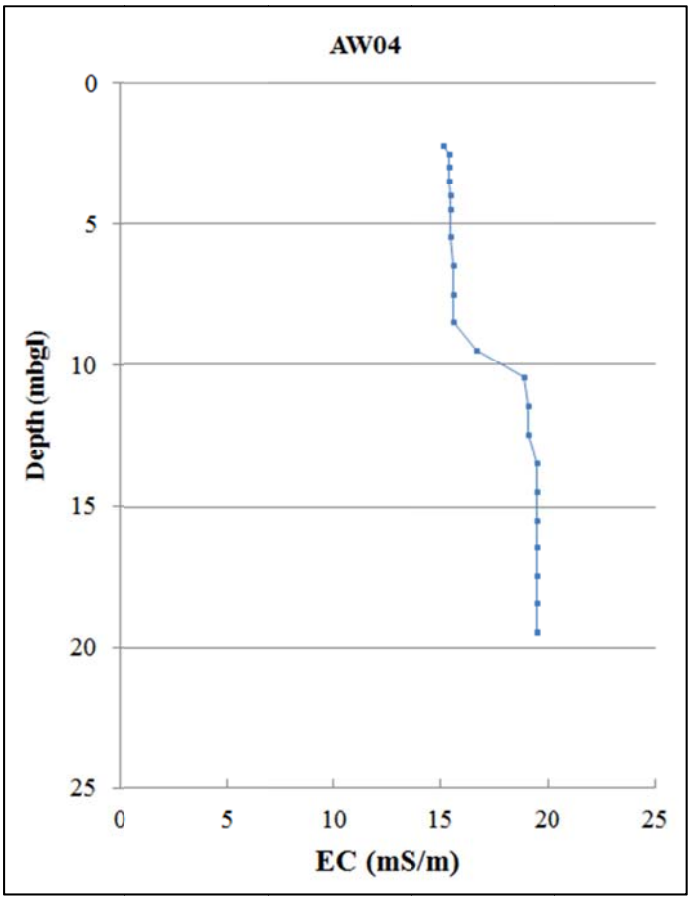


Figure C7. EC profile of borehole AW04.

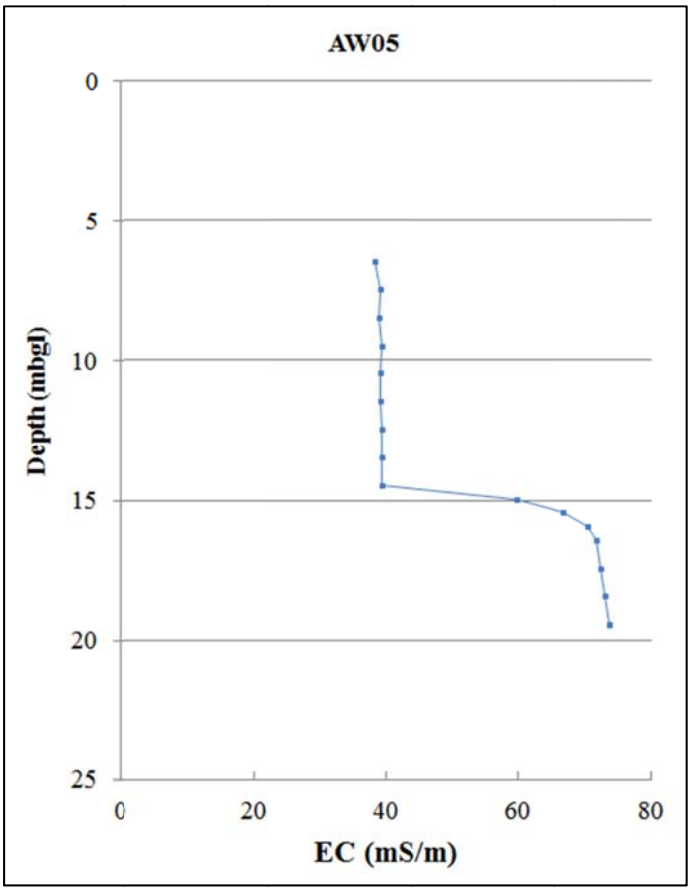


Figure C8. EC profile of borehole AW05.

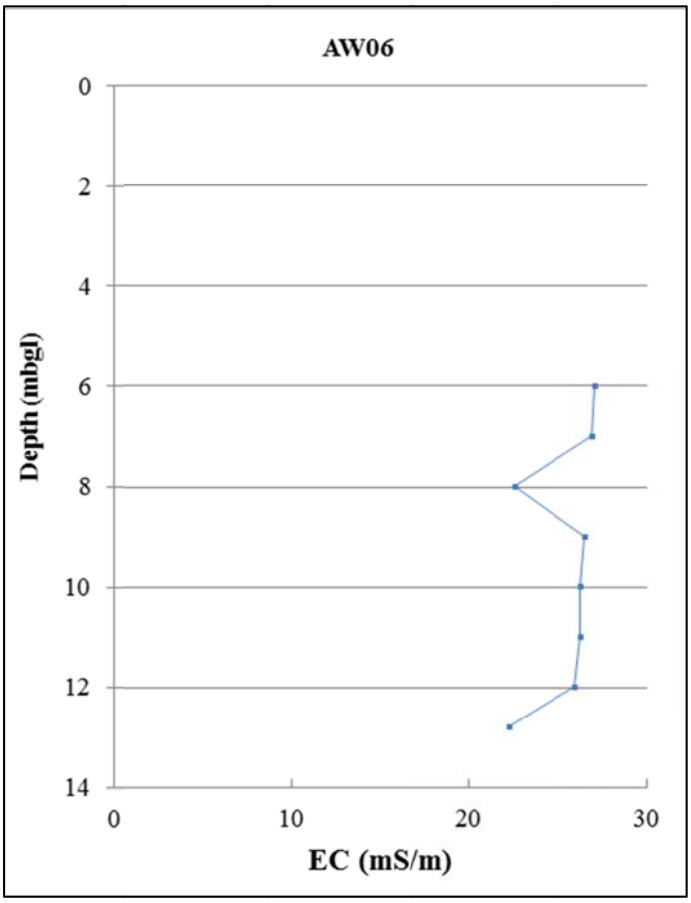


Figure C9. EC profile of borehole AW06.

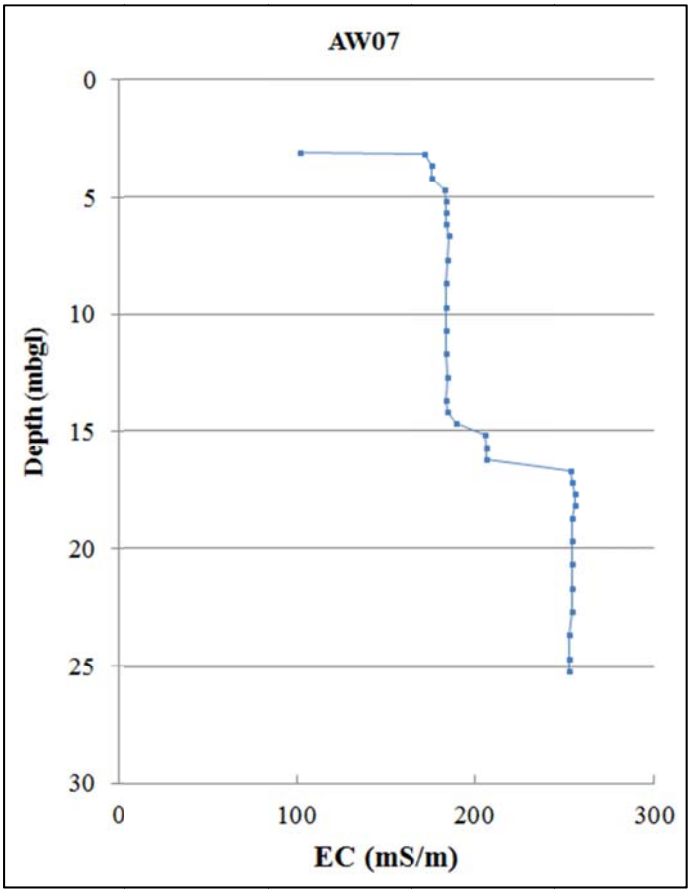


Figure C10. EC profile of borehole AW07.

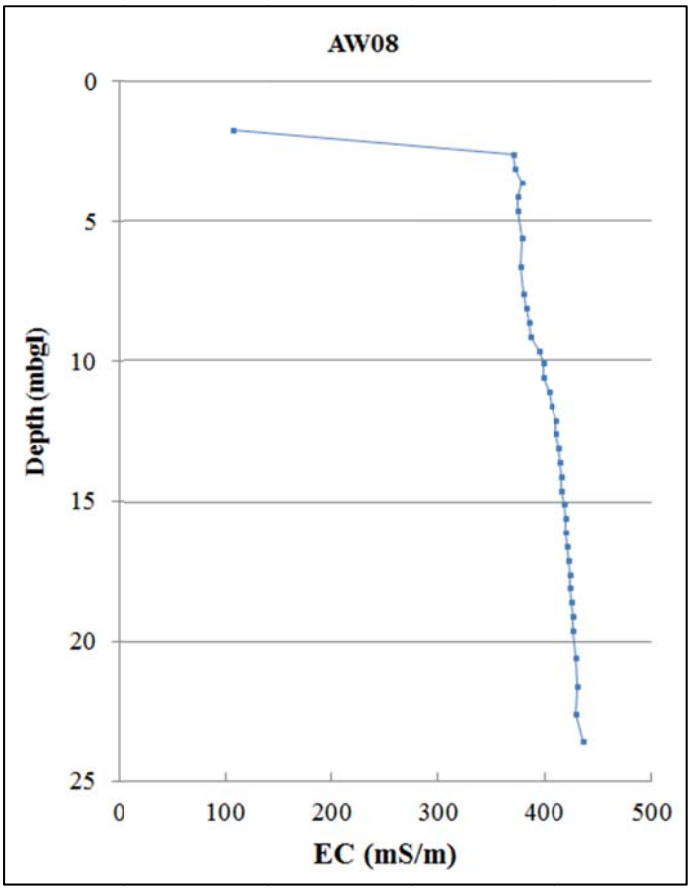


Figure C11. EC profile of borehole AW08.

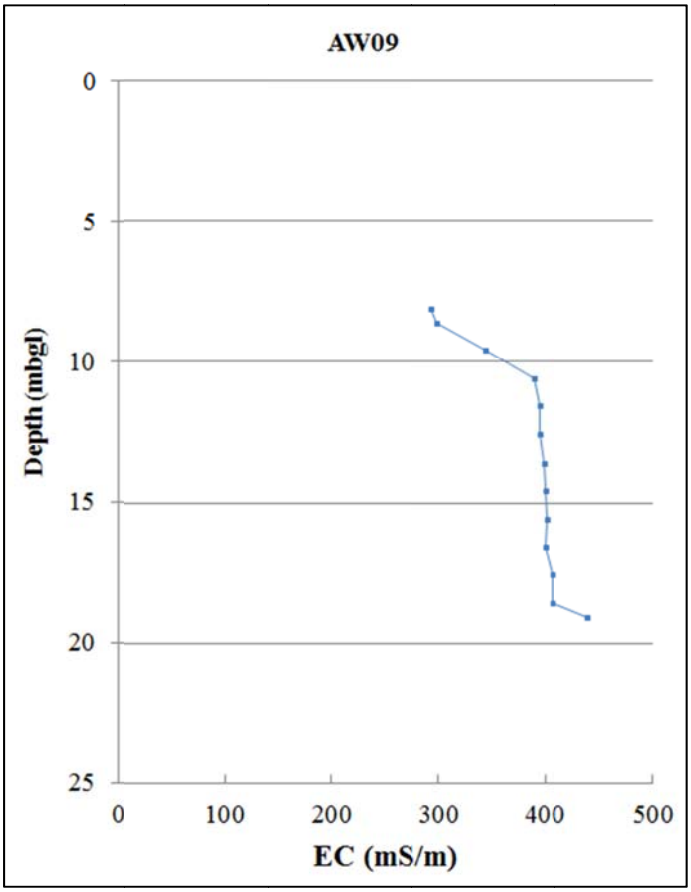


Figure C12. EC profile of borehole AW09.

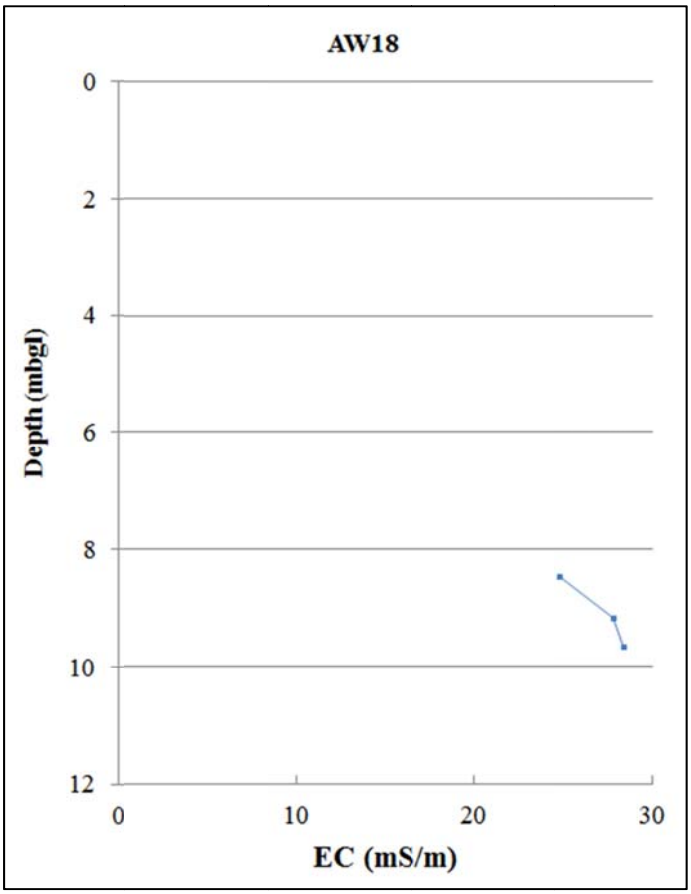


Figure C13. EC profile of borehole AW18.

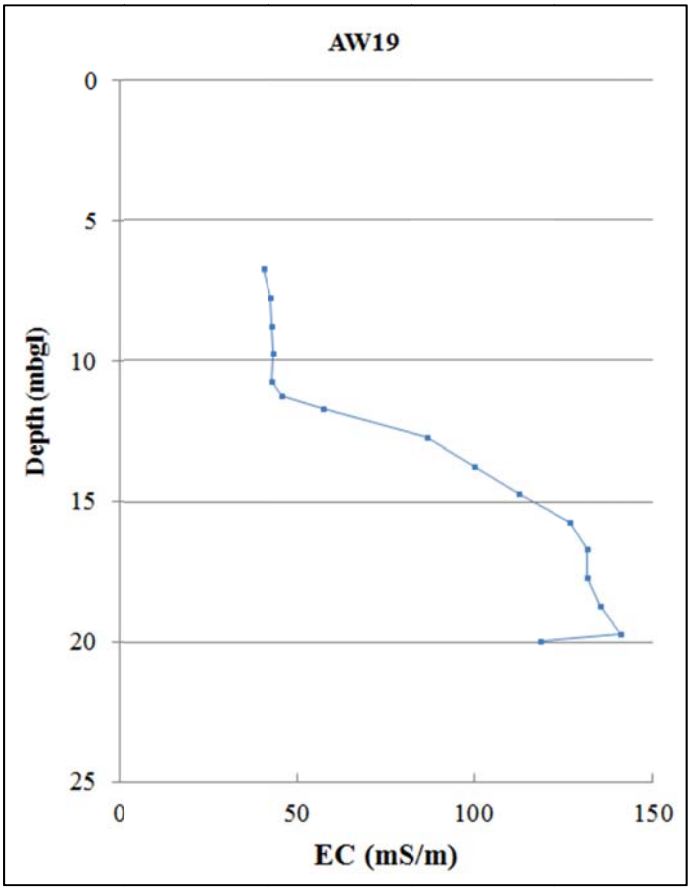


Figure C14. EC profile of borehole AW19.

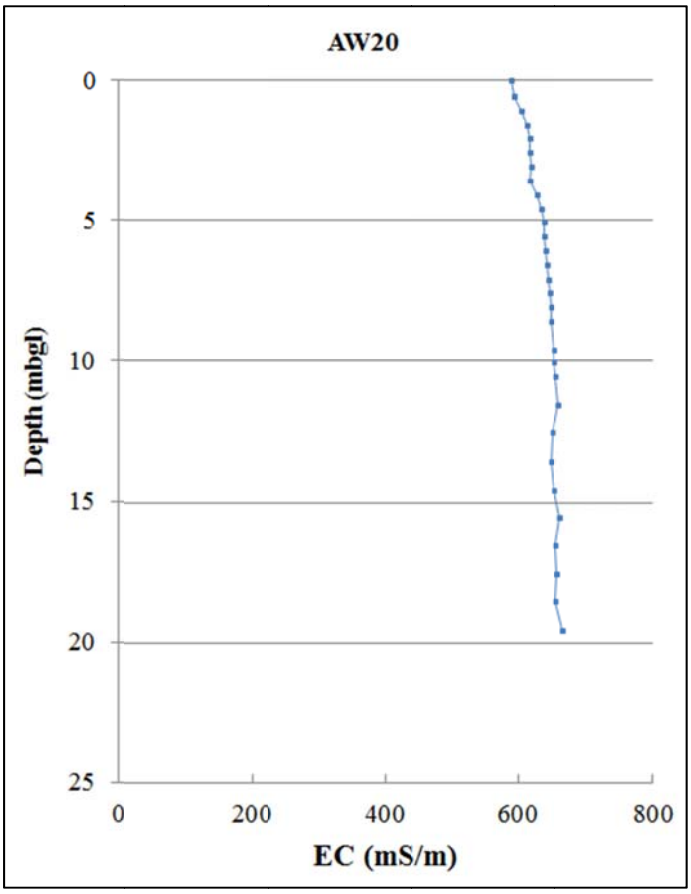


Figure C15. EC profile of borehole AW20.

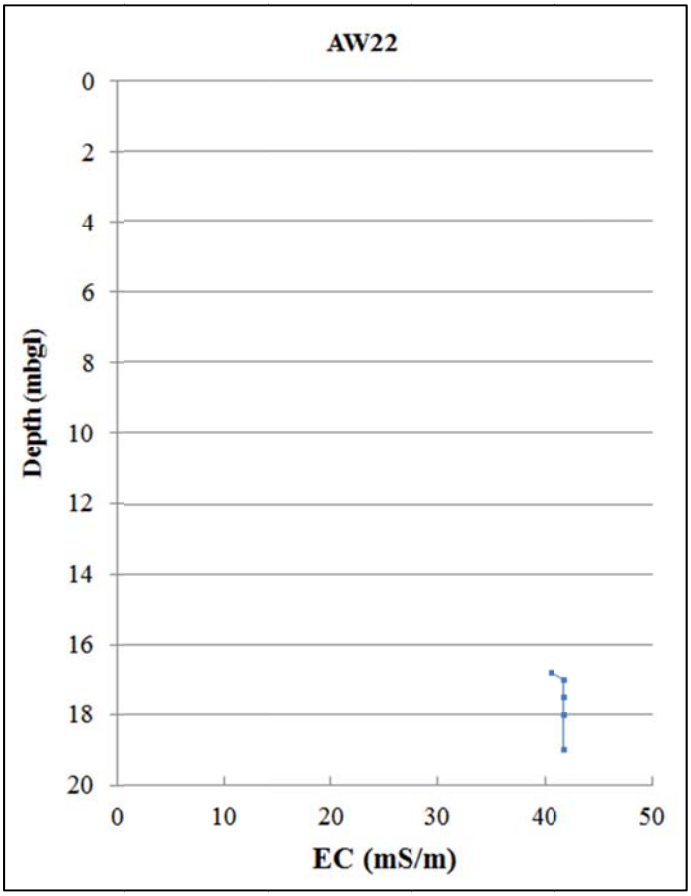


Figure C16. EC profile of borehole AW22.

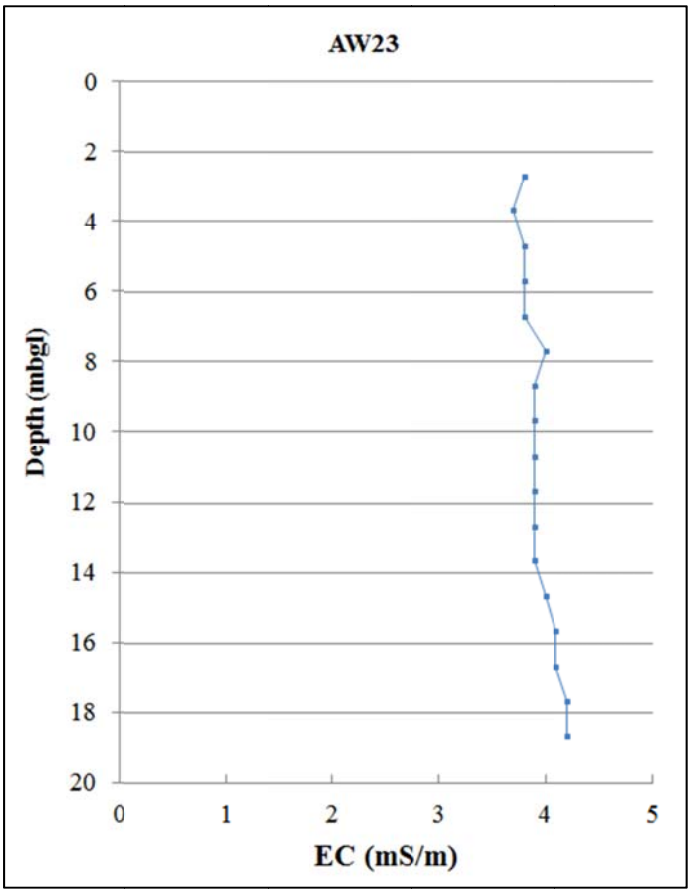


Figure C17. EC profile of borehole AW23.

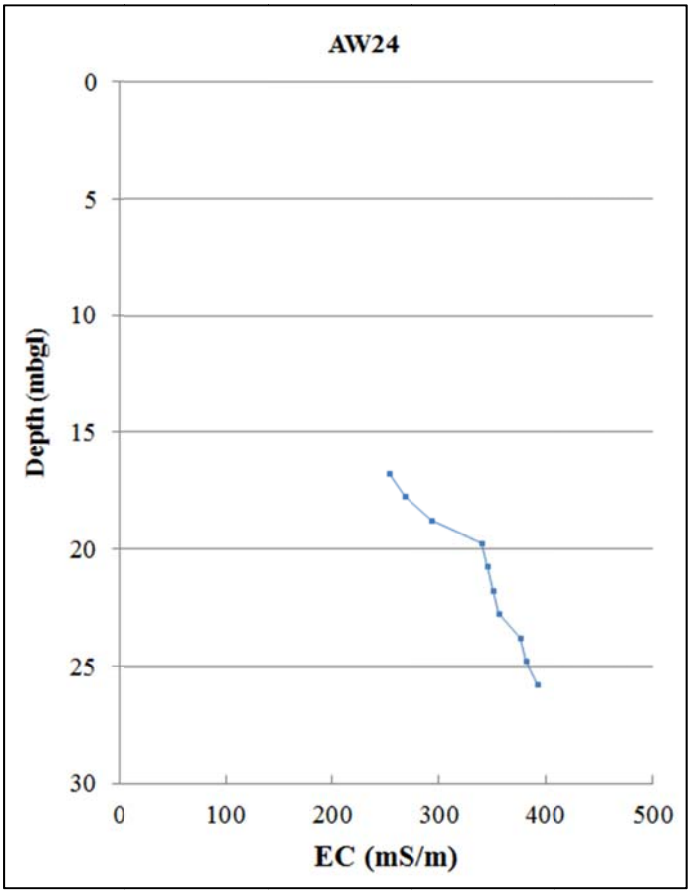


Figure C18. EC profile of borehole AW24.

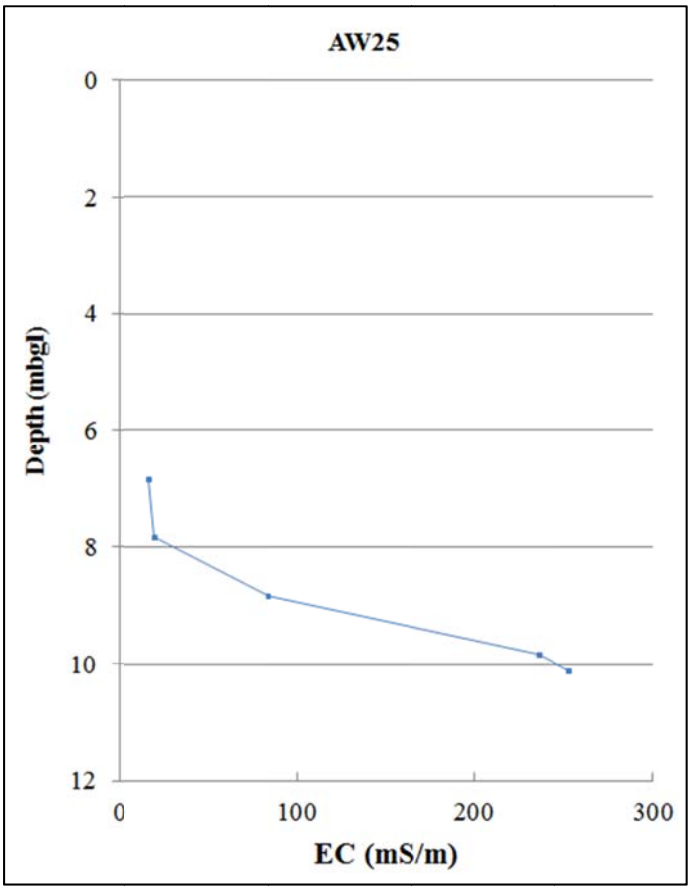


Figure C19. EC profile of borehole AW25.

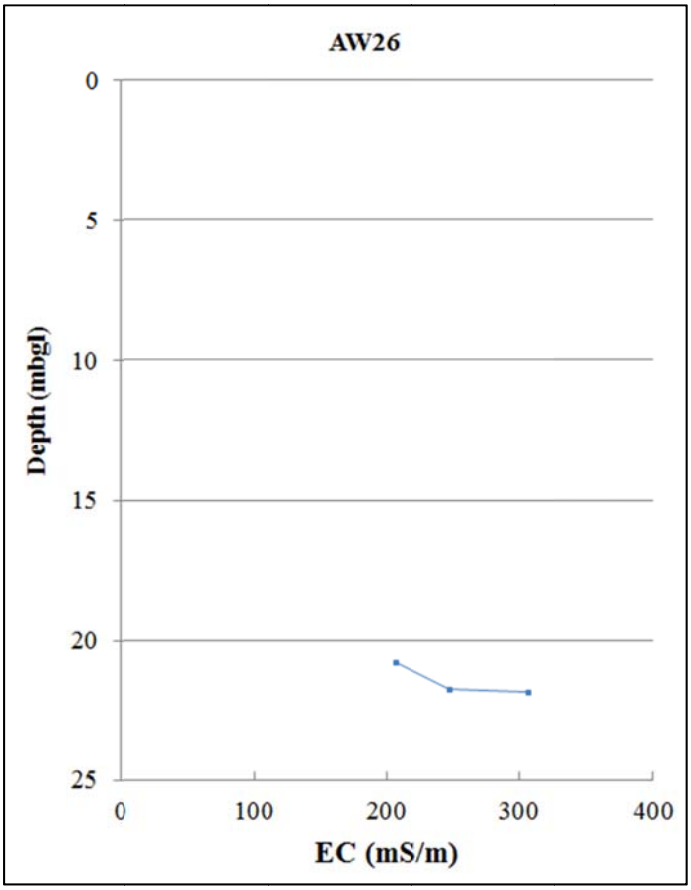


Figure C20. EC profile of borehole AW26.

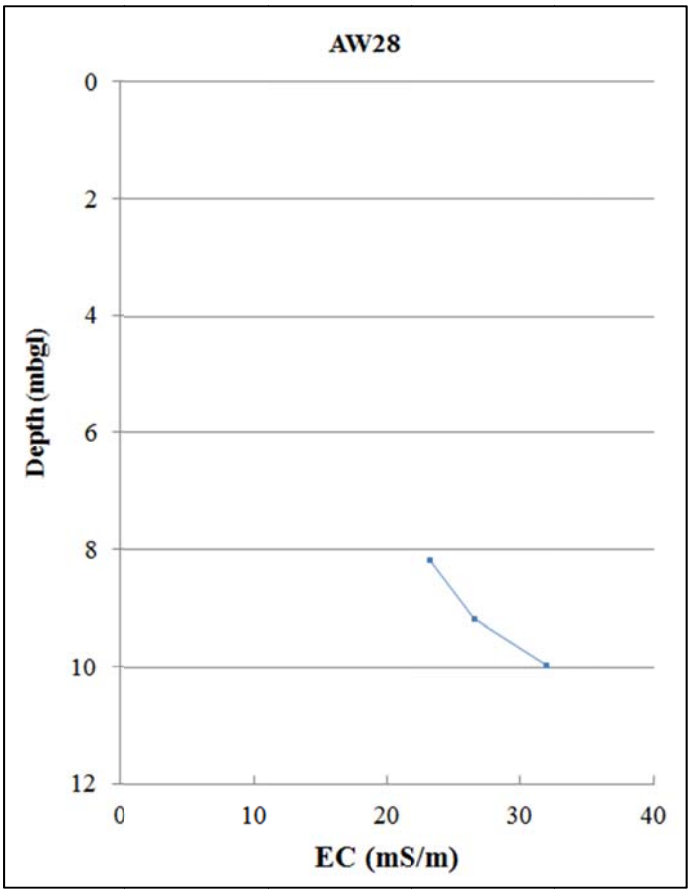


Figure C21. EC profile of borehole AW28.

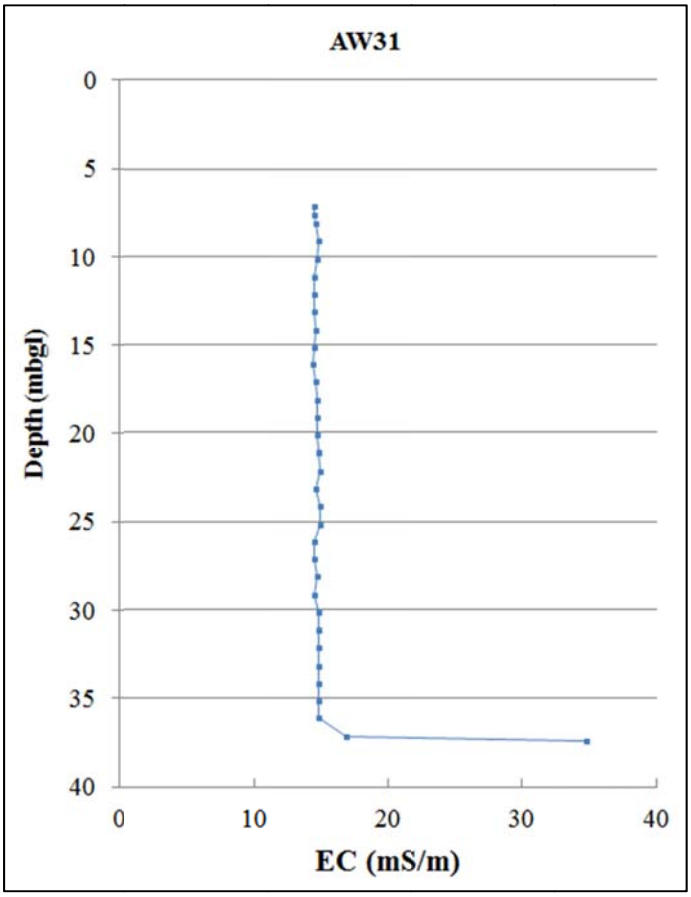


Figure C22. EC profile of borehole AW31.

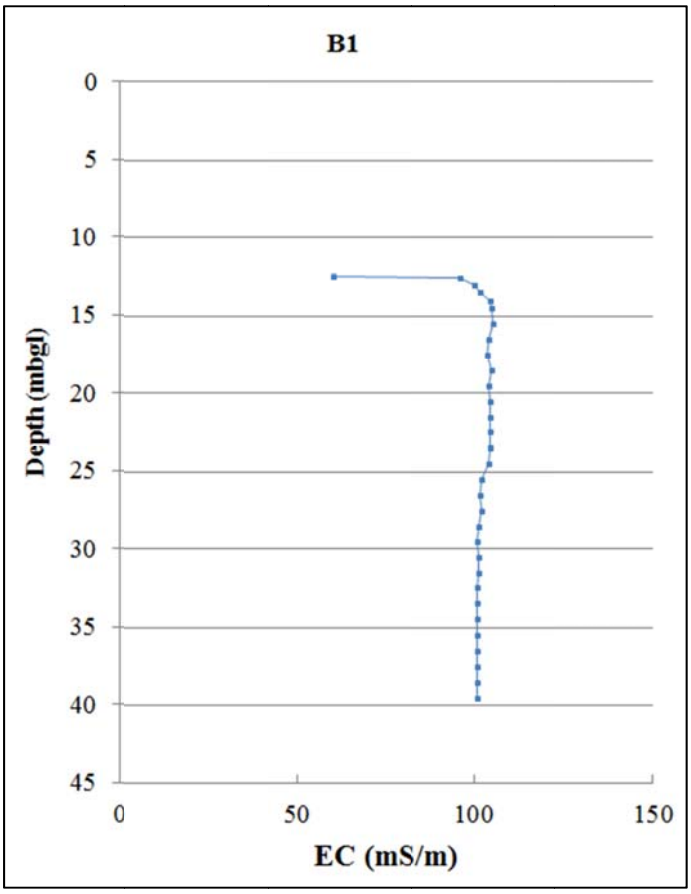


Figure C23. EC profile of borehole B1.

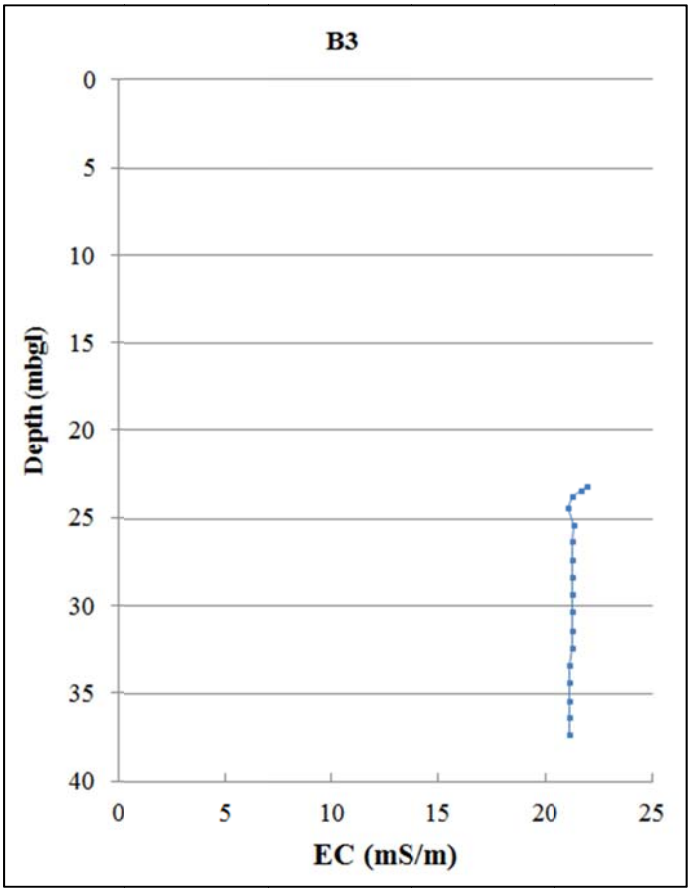


Figure C24. EC profile of borehole B3.

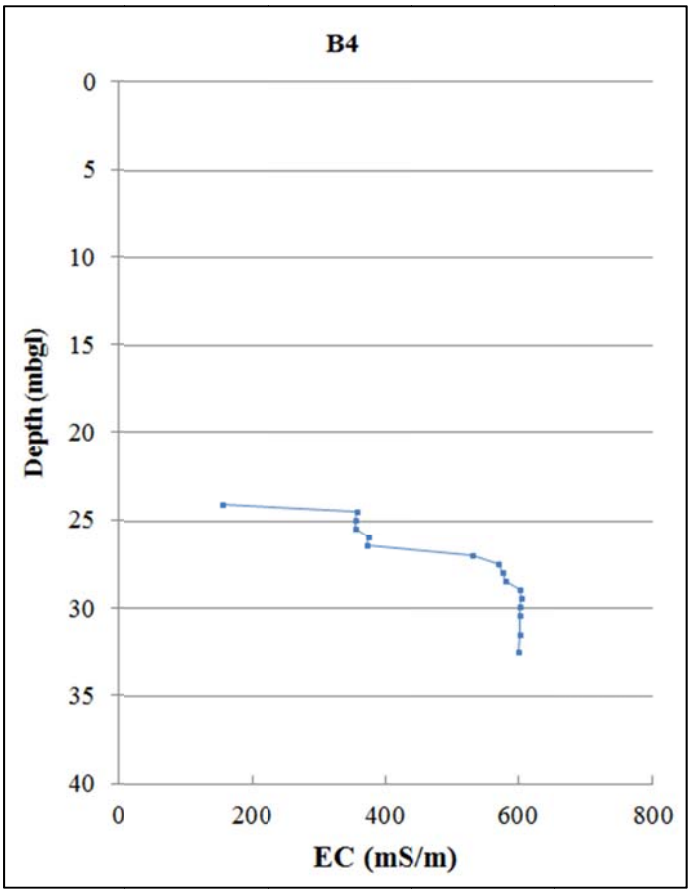


Figure C25. EC profile of borehole B4.

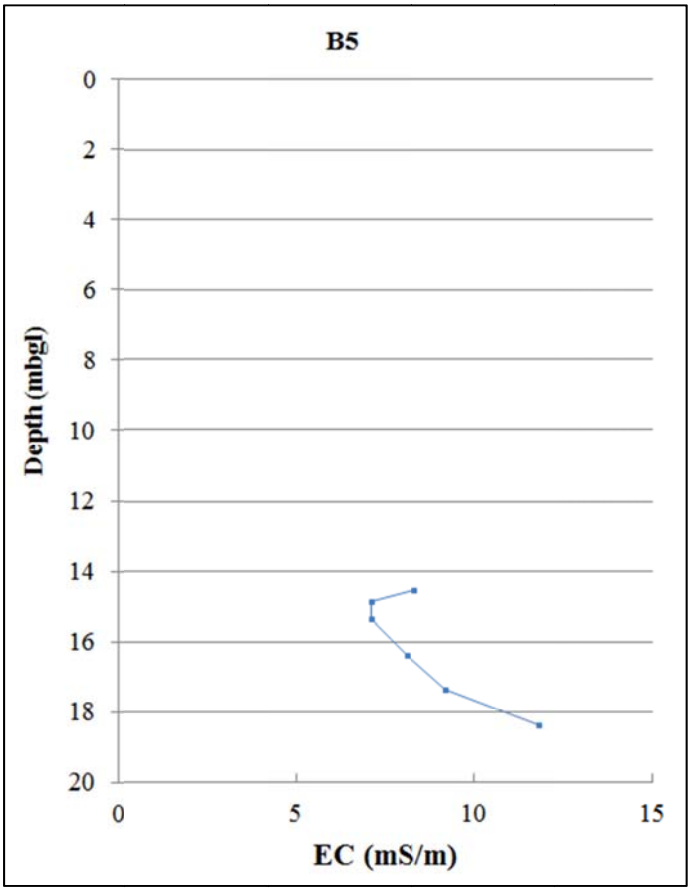


Figure C26. EC profile of borehole B5.

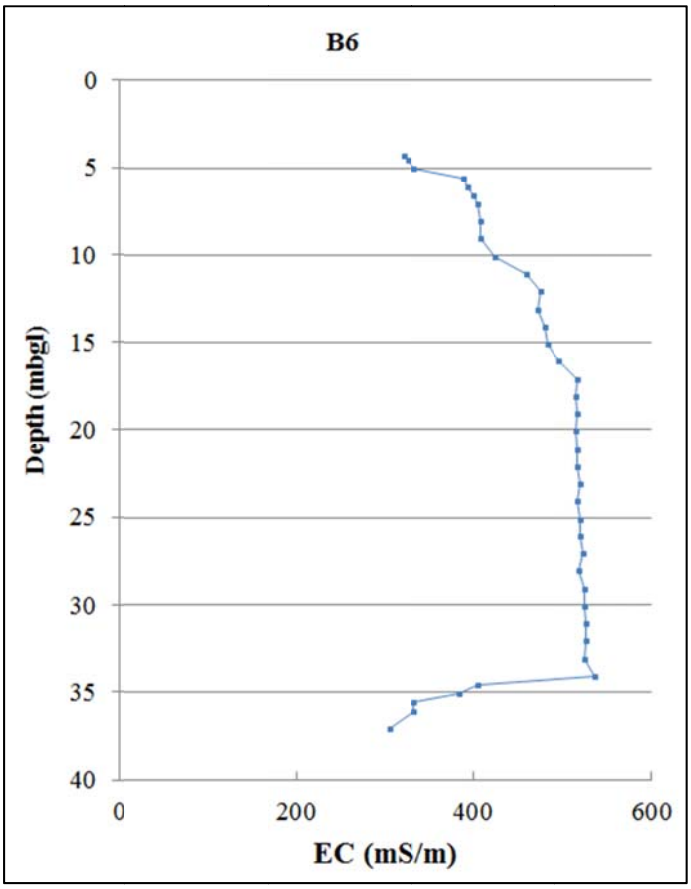


Figure C27. EC profile of borehole B6.

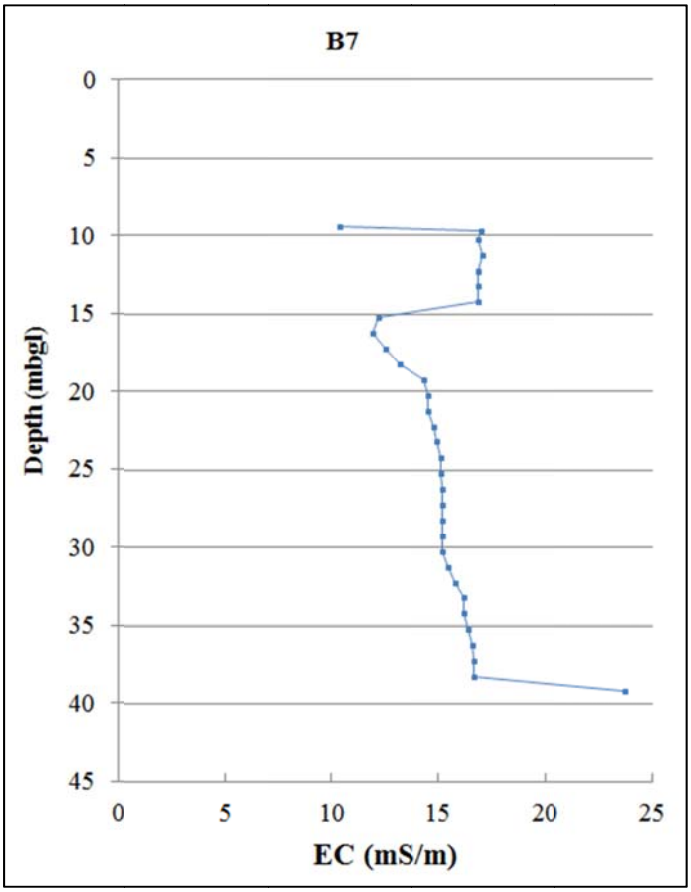


Figure C28. EC profile of borehole B7.

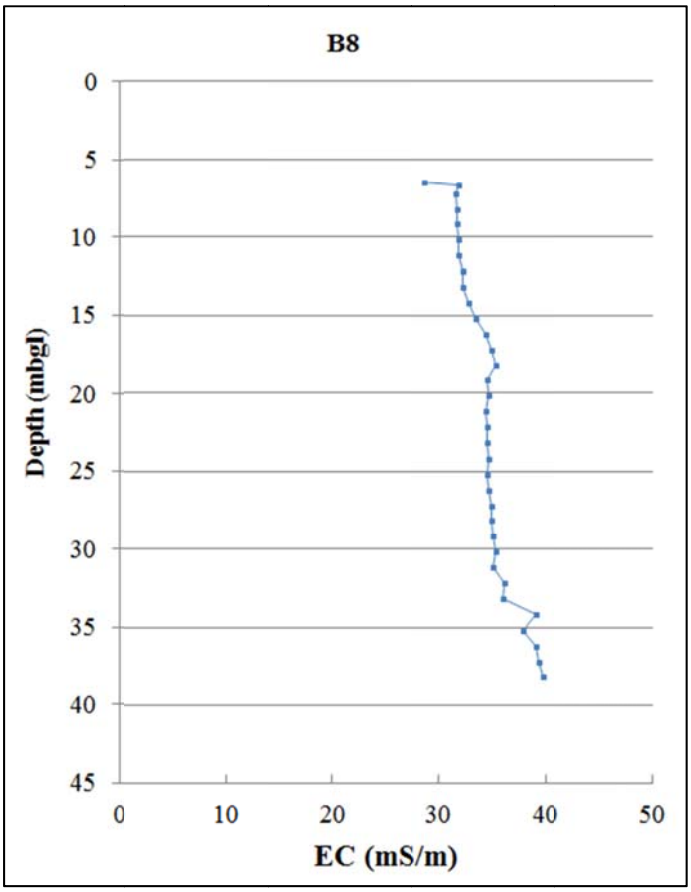


Figure C29. EC profile of borehole B8.

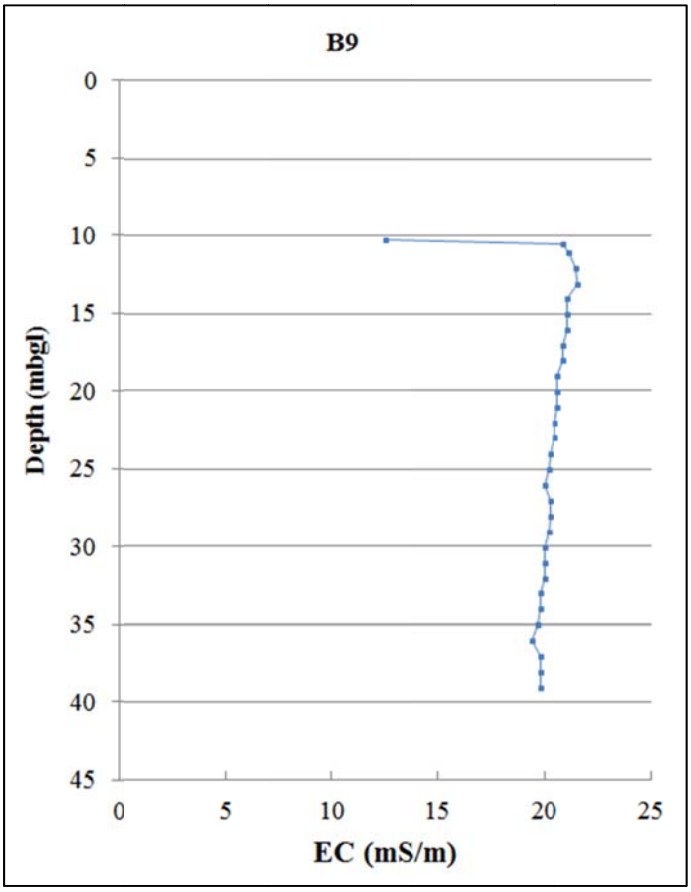


Figure C30. EC profile of borehole B9.

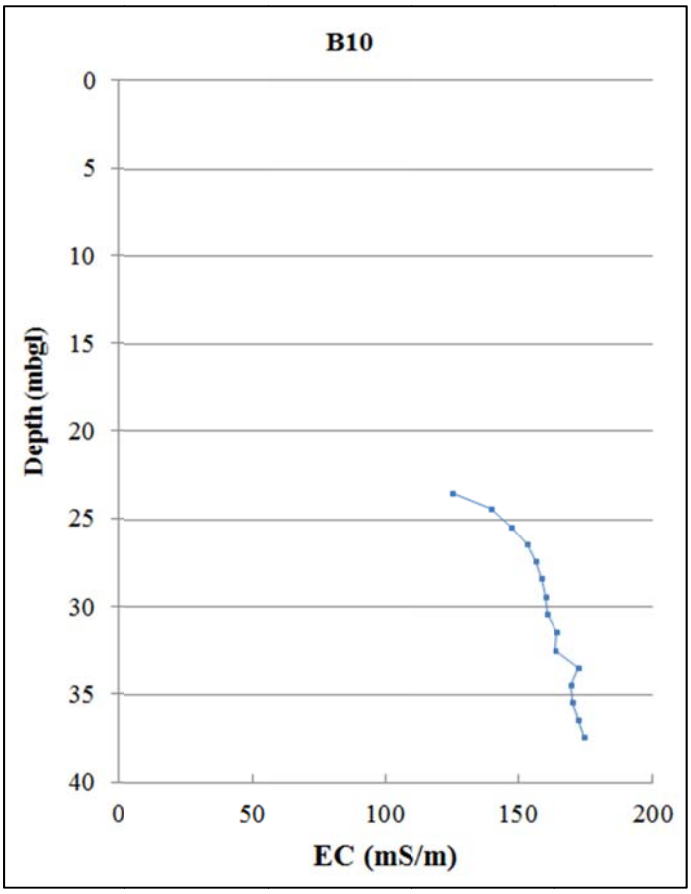


Figure C31. EC profile of borehole B10.

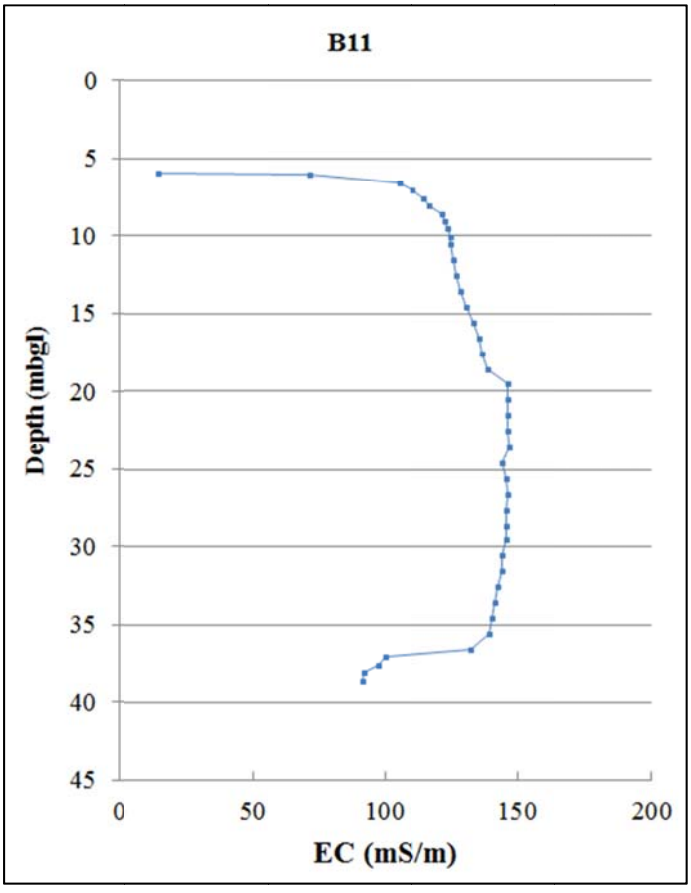


Figure C32. EC profile of borehole B11.

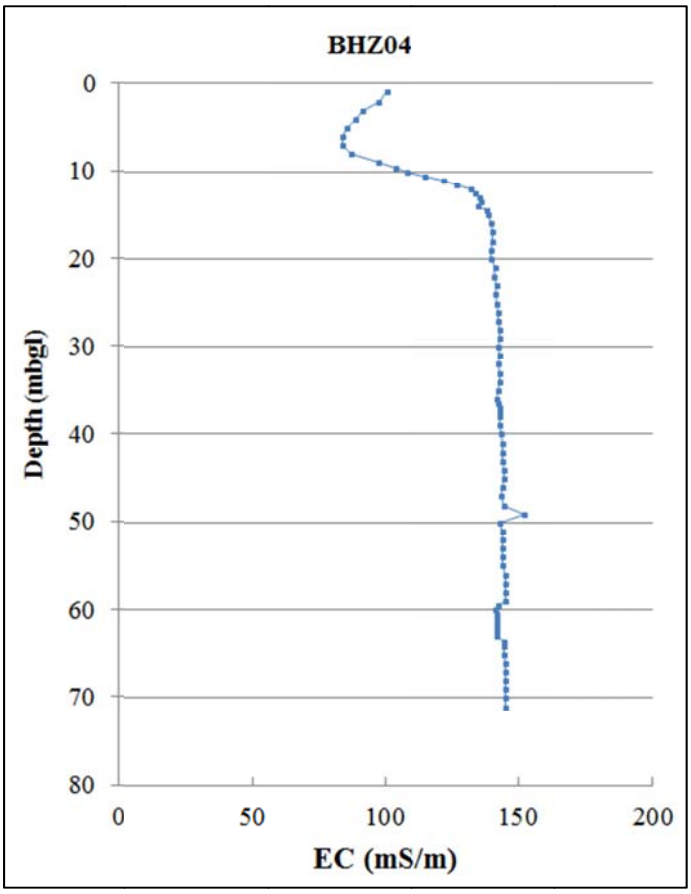


Figure C33. EC profile of borehole BHZ04.

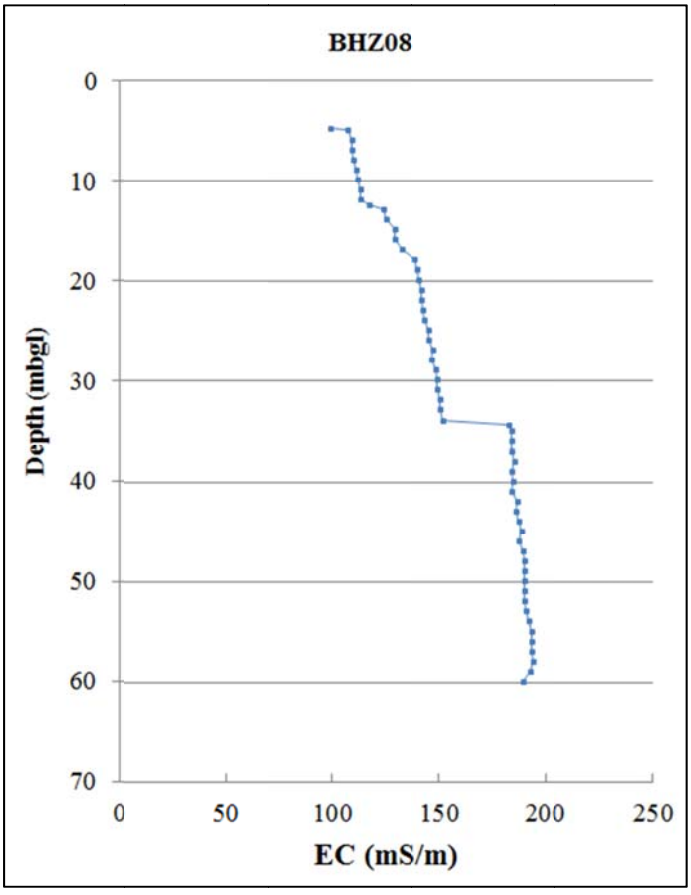


Figure C34. EC profile of borehole BHZ08.

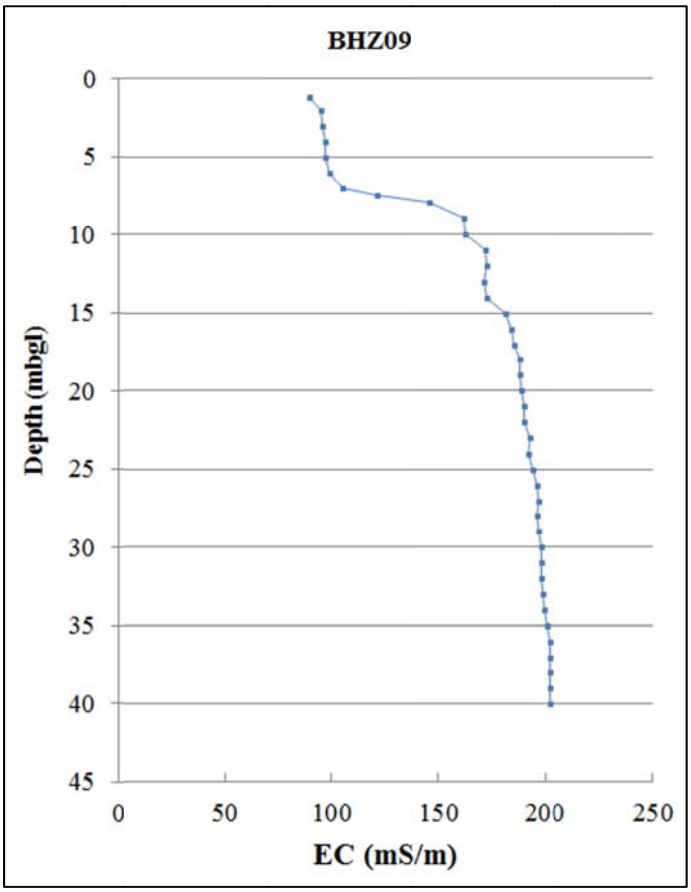


Figure C35. EC profile of borehole BHZ09.

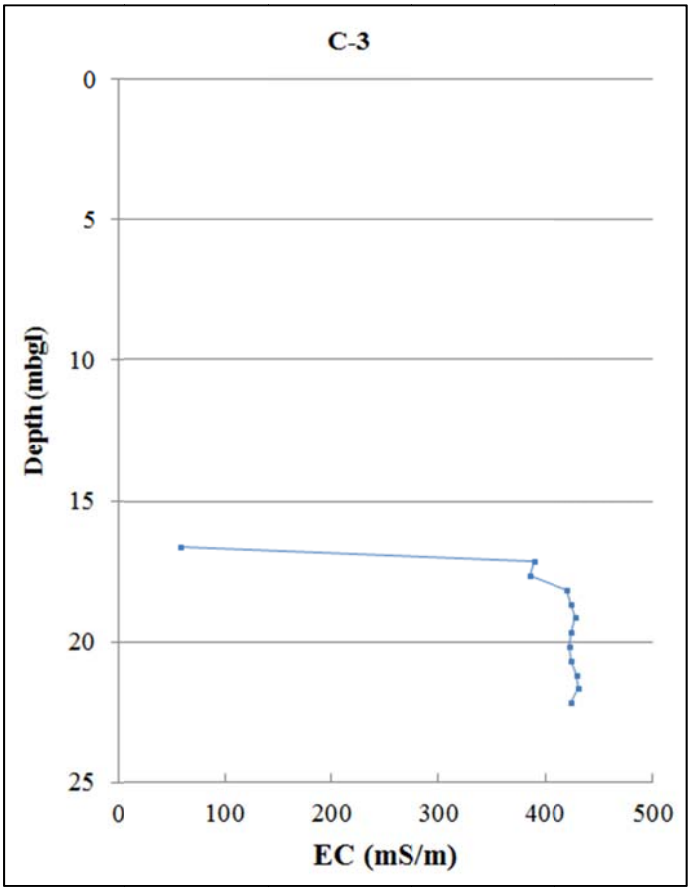


Figure C36. EC profile of borehole C-3.

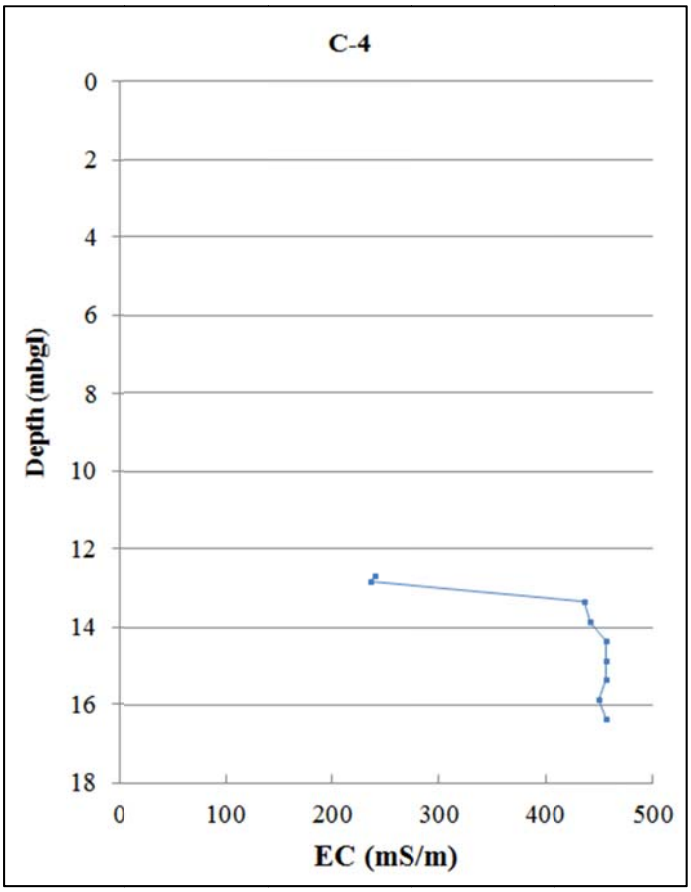


Figure C37. EC profile of borehole C-4.

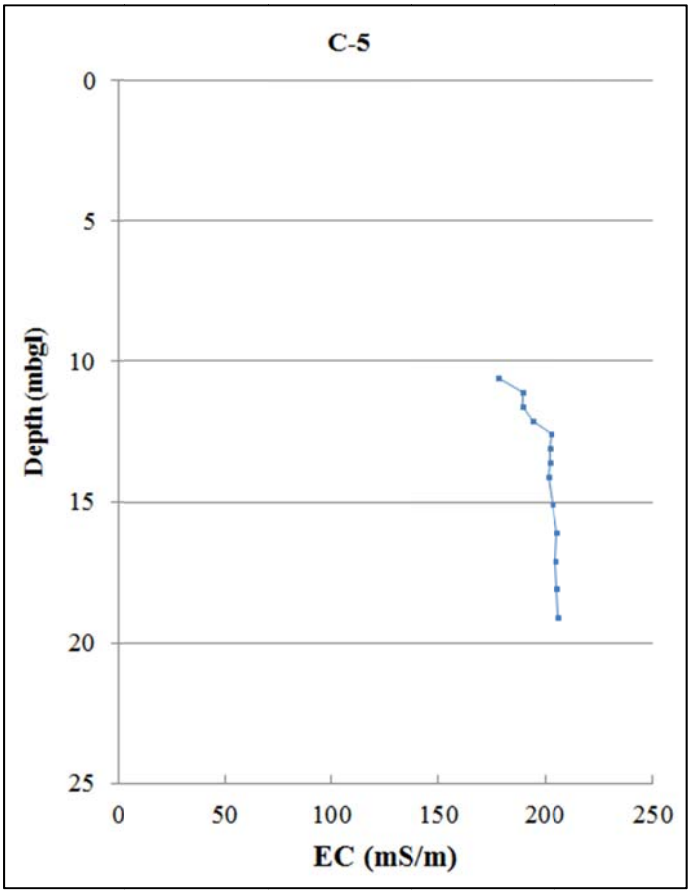


Figure C38. EC profile of borehole C-5.

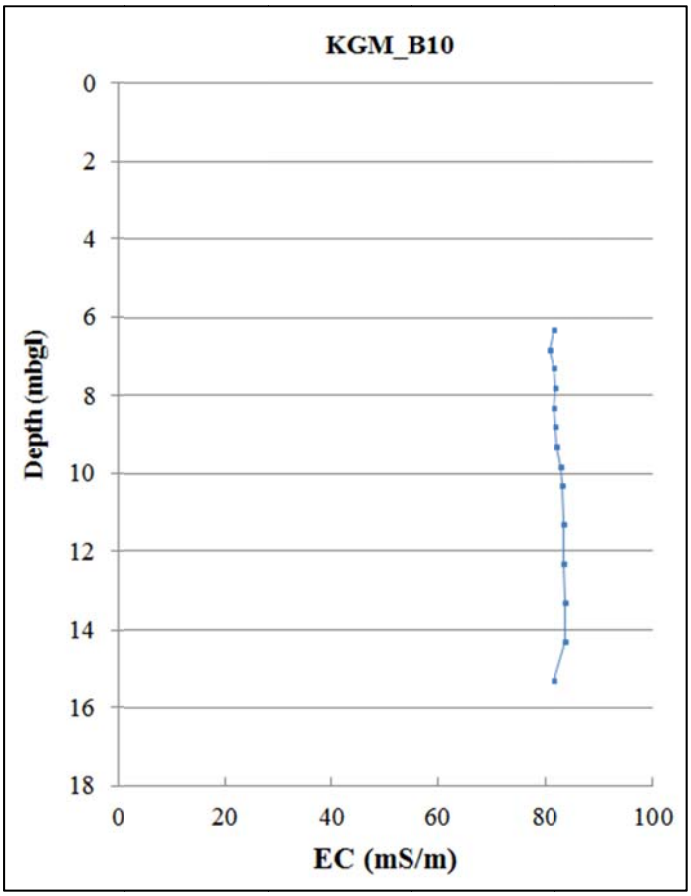


Figure C39. EC profile of borehole KGM_B10.

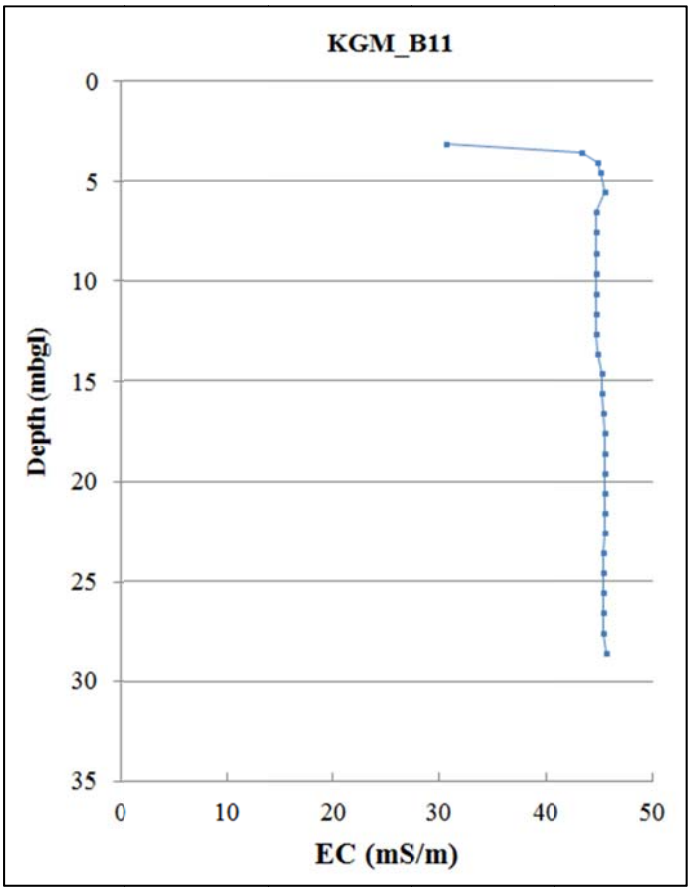


Figure C40. EC profile of borehole KGM_B11.

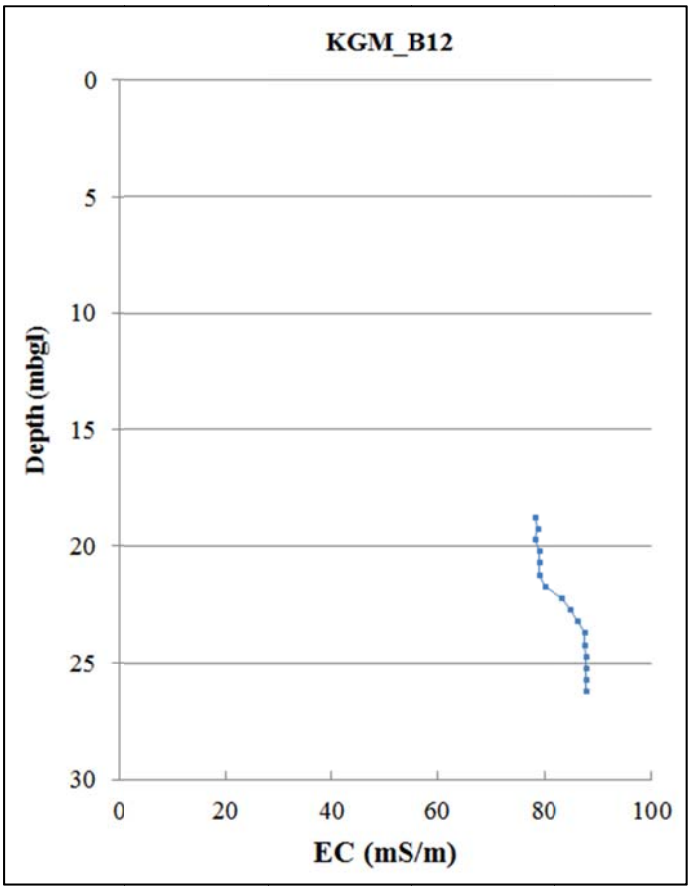


Figure C41. EC profile of borehole KGM_B12.

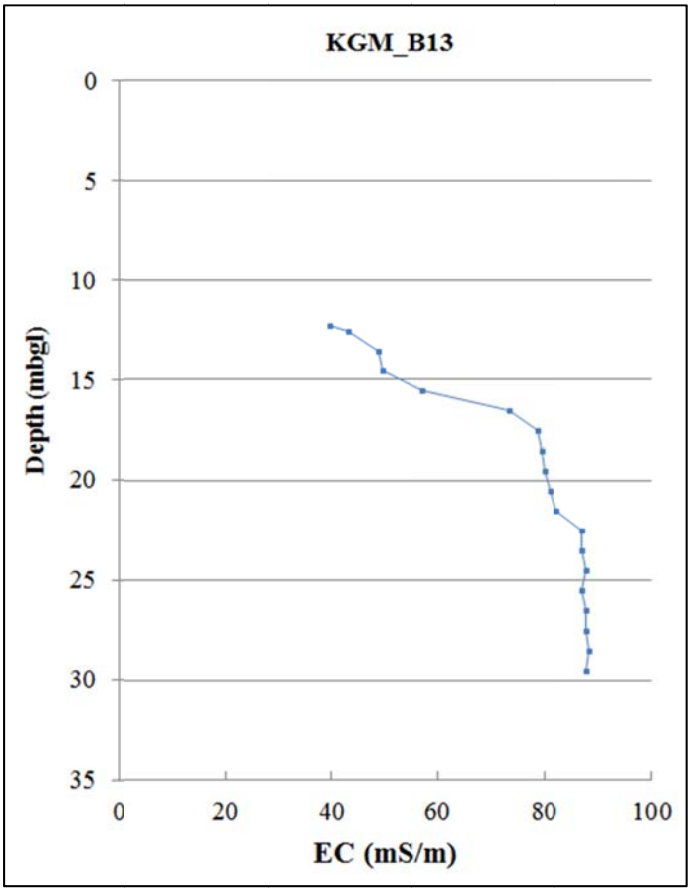


Figure C42. EC profile of borehole KGM_B13.

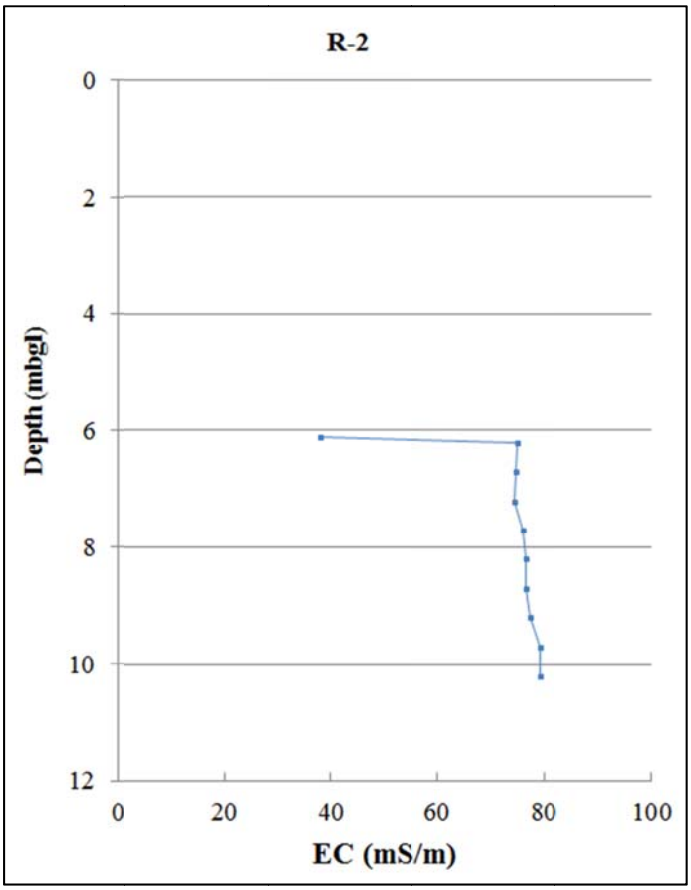


Figure C43. EC profile of borehole R-2.

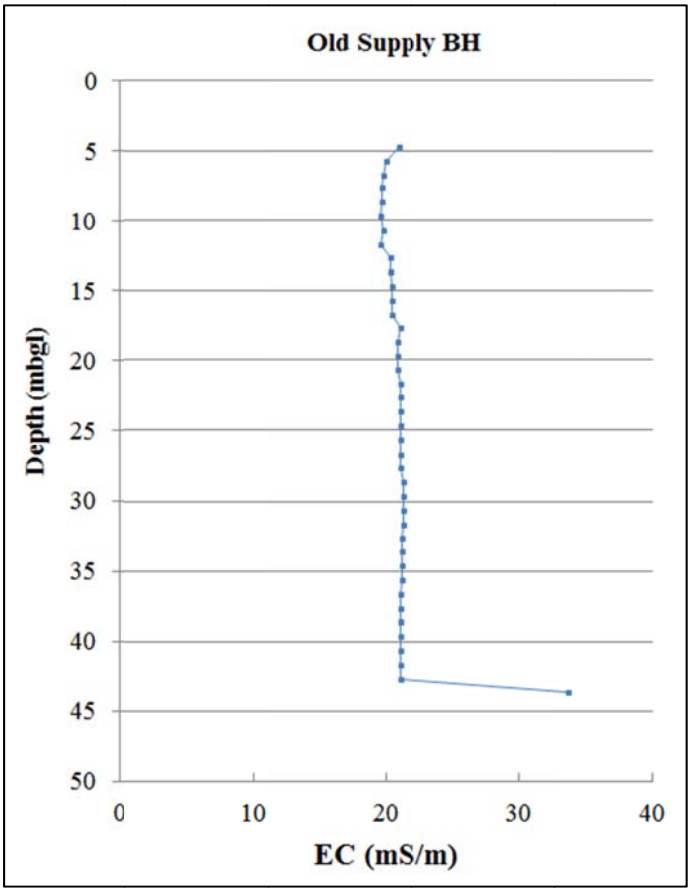


Figure C44. EC profile of the Old Supply Borehole.

APPENDIX D

Hydraulic Test Results

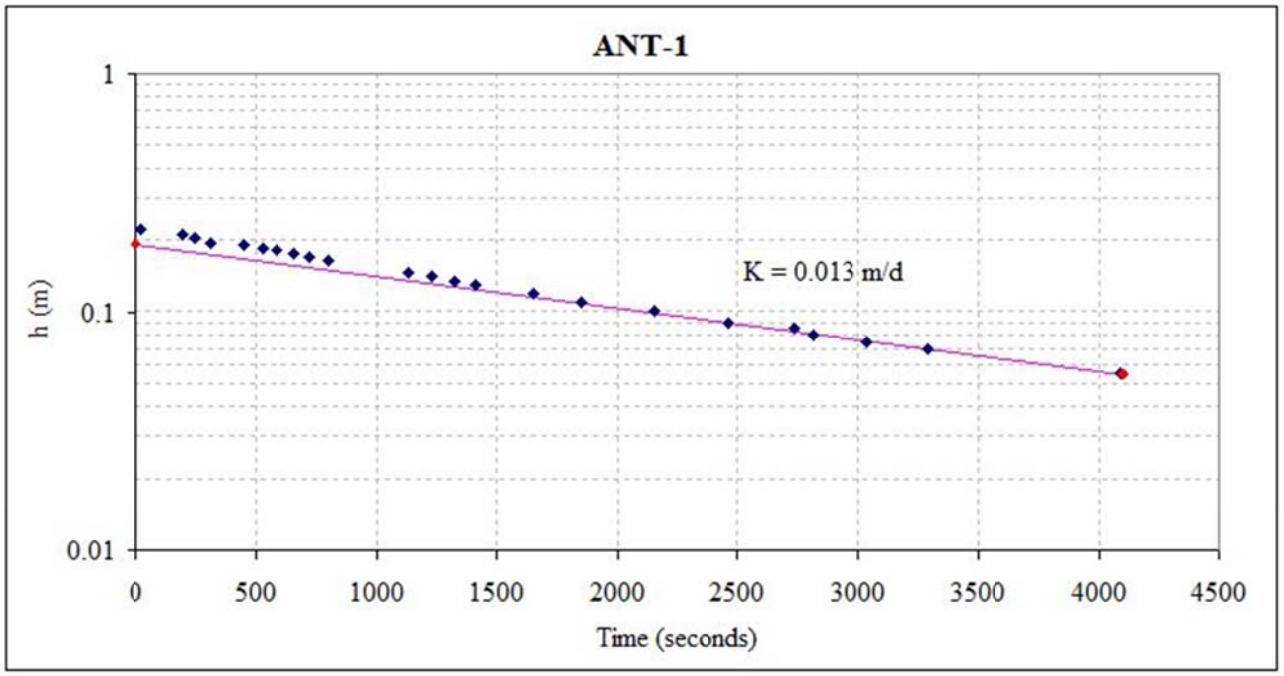


Figure D1. Analysis of slug test performed on borehole ANT-1.

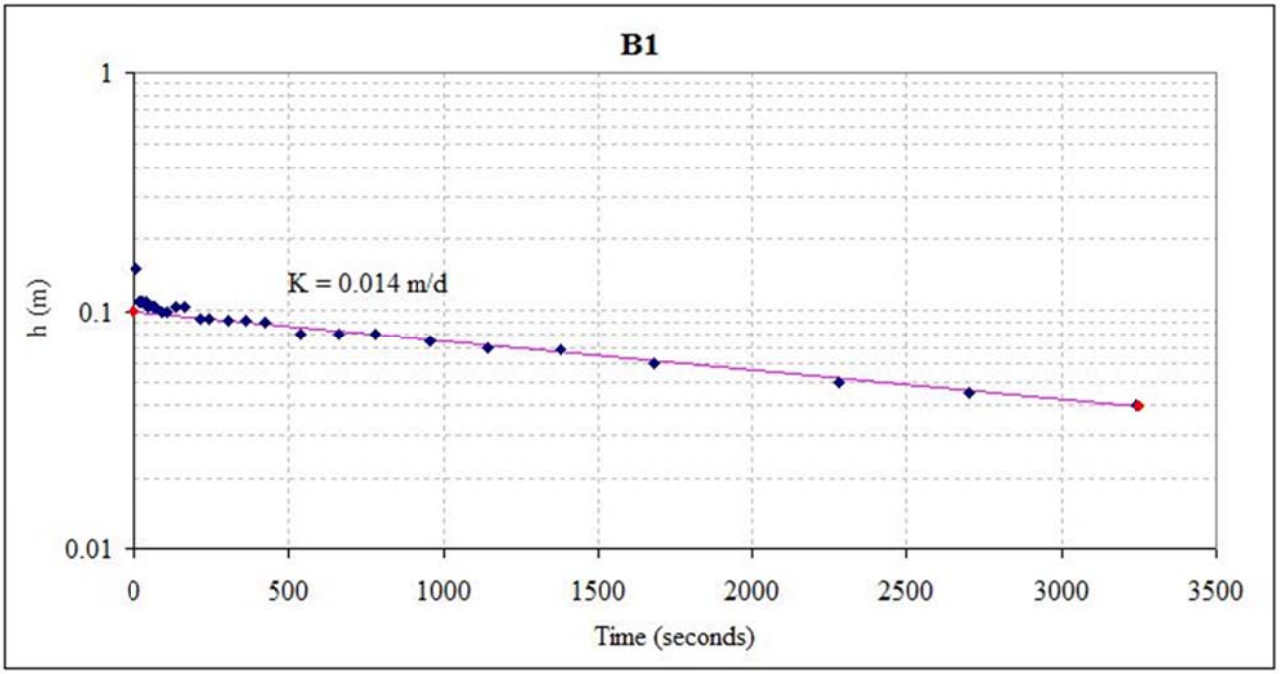


Figure D2. Analysis of slug test performed on borehole B1.

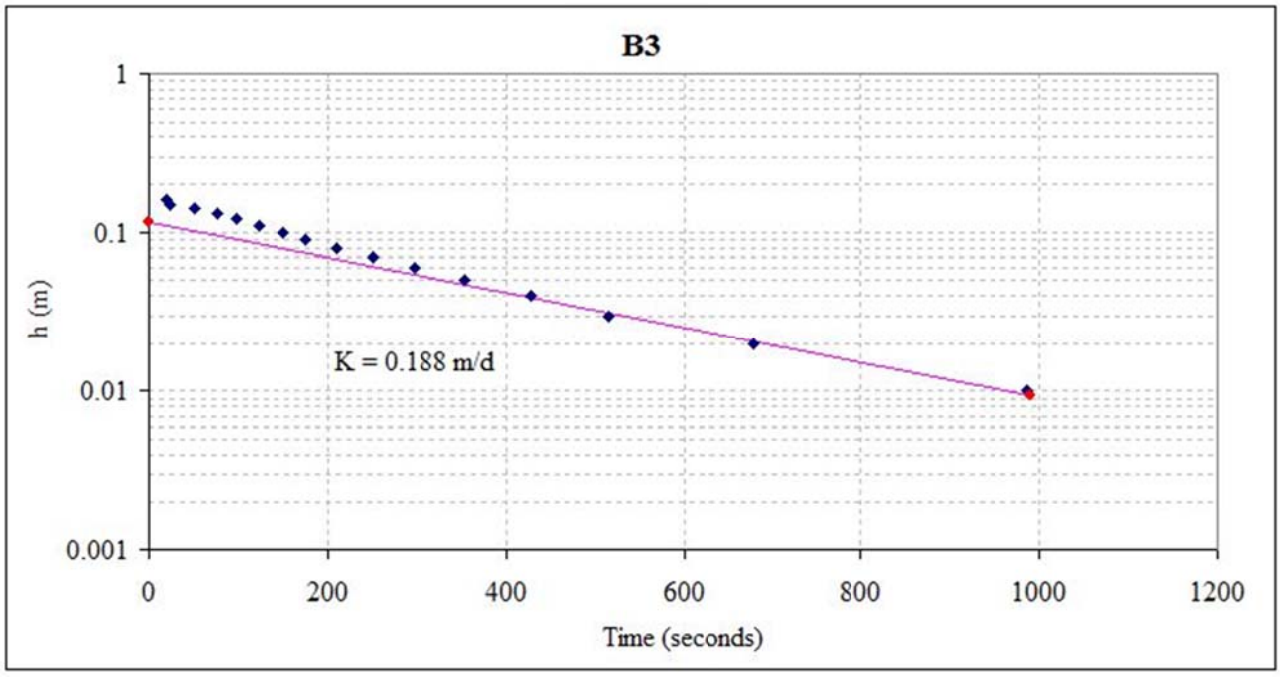


Figure D3. Analysis of slug test performed on borehole B3.

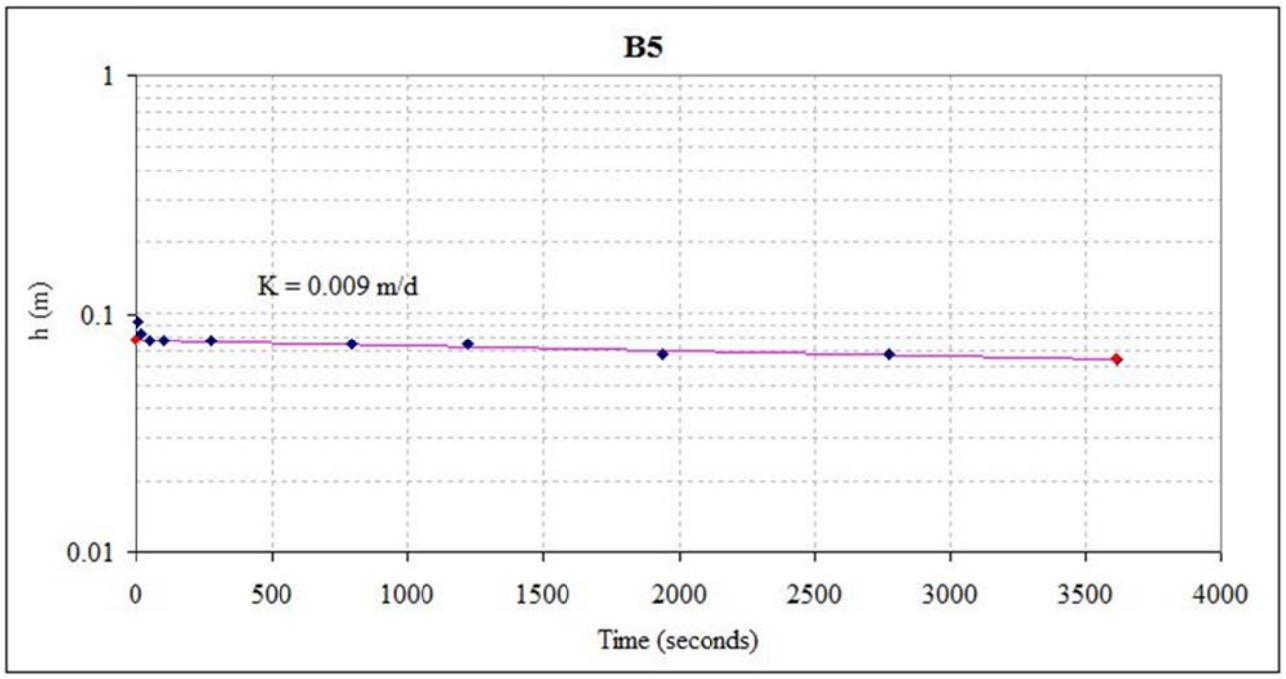


Figure D4. Analysis of slug test performed on borehole B5.

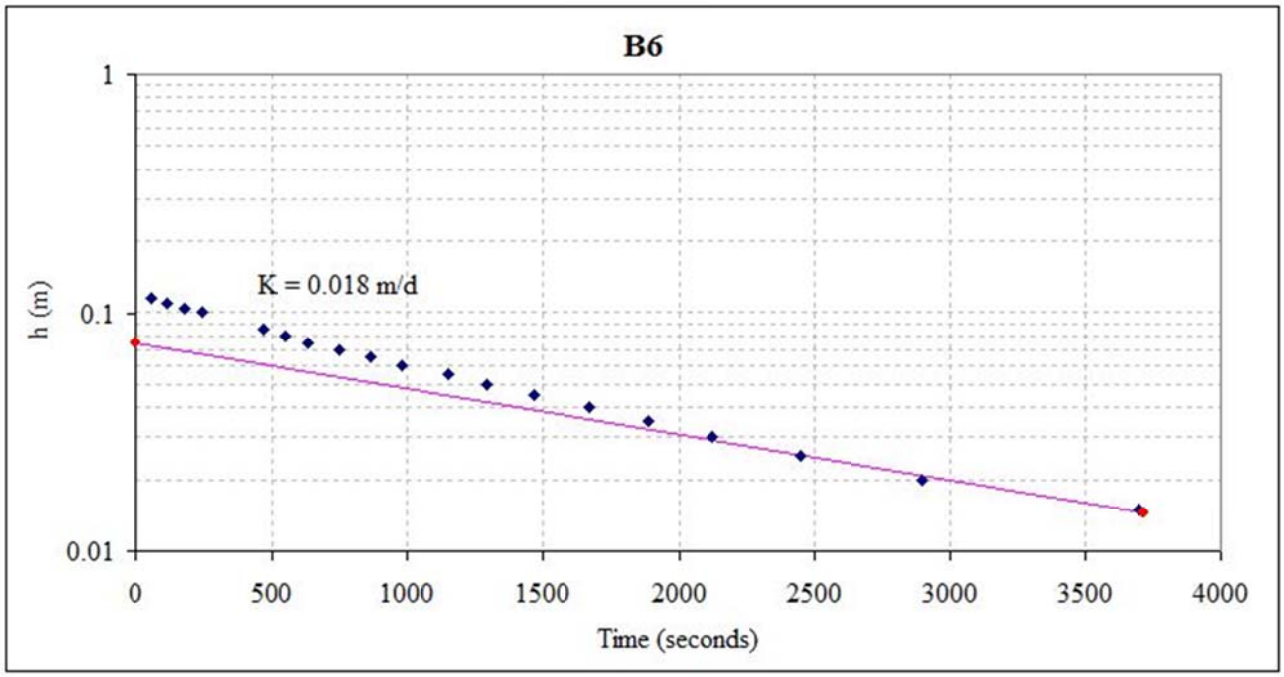


Figure D5. Analysis of slug test performed on borehole B6.

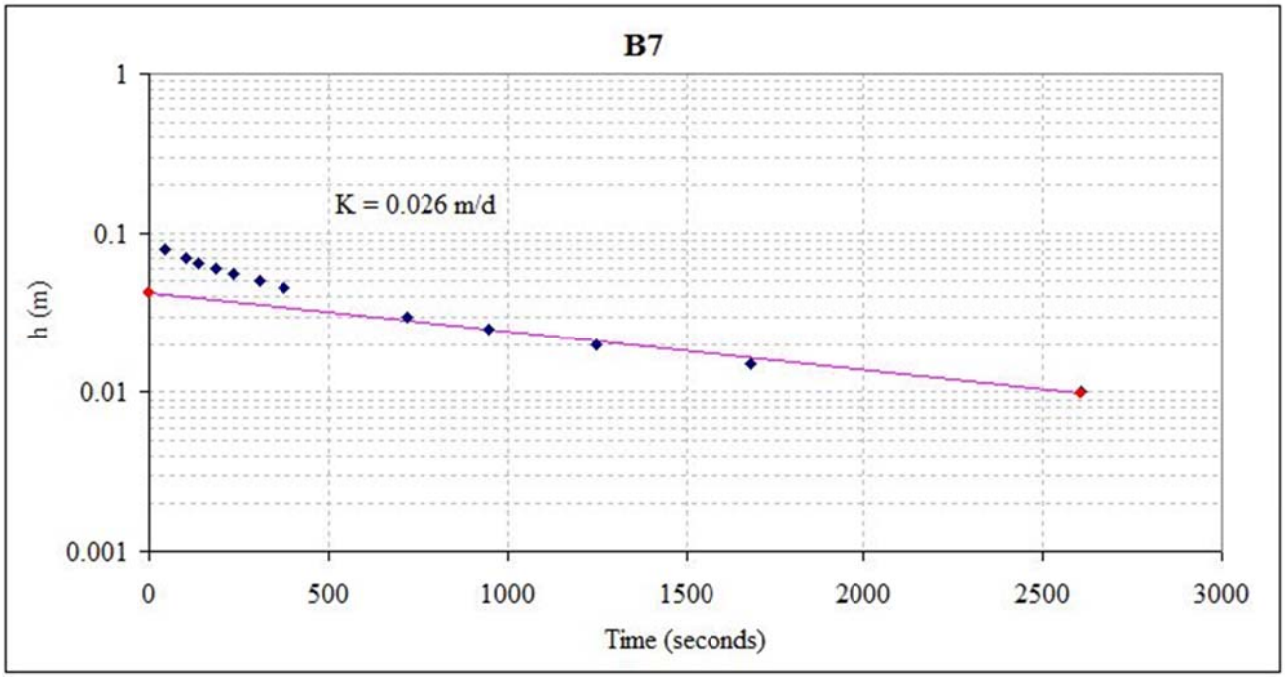


Figure D6. Analysis of slug test performed on borehole B7.

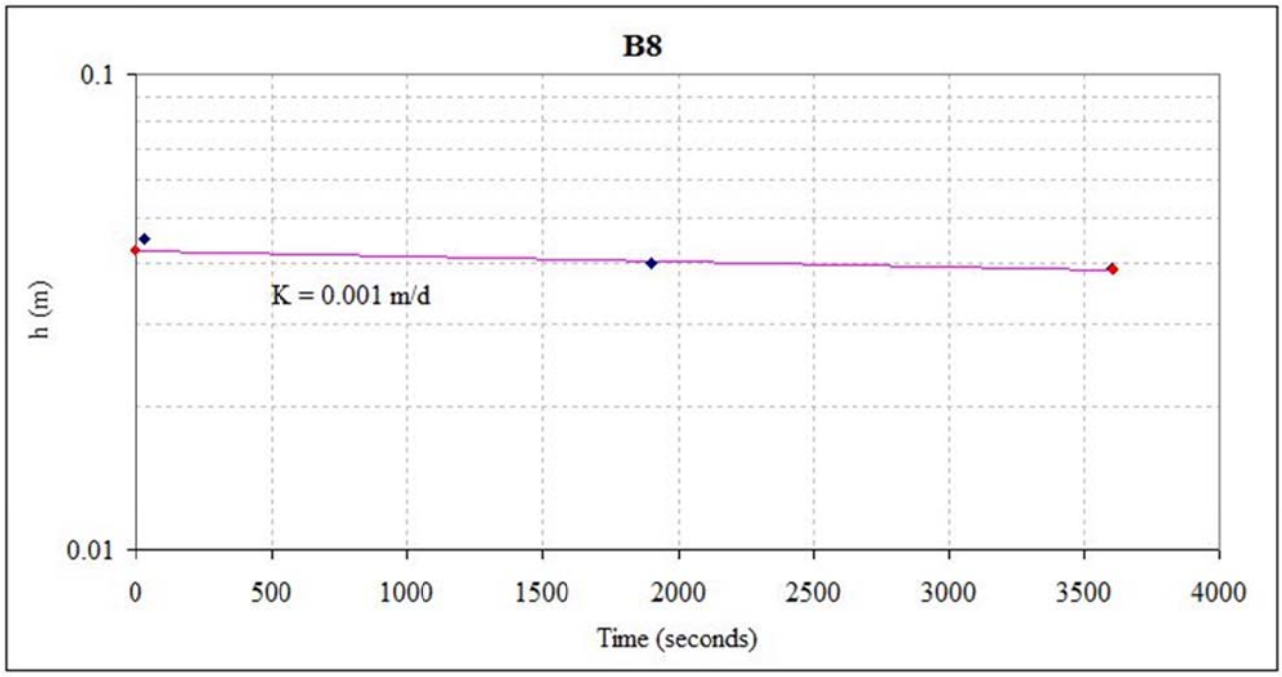


Figure D7. Analysis of slug test performed on borehole B8.

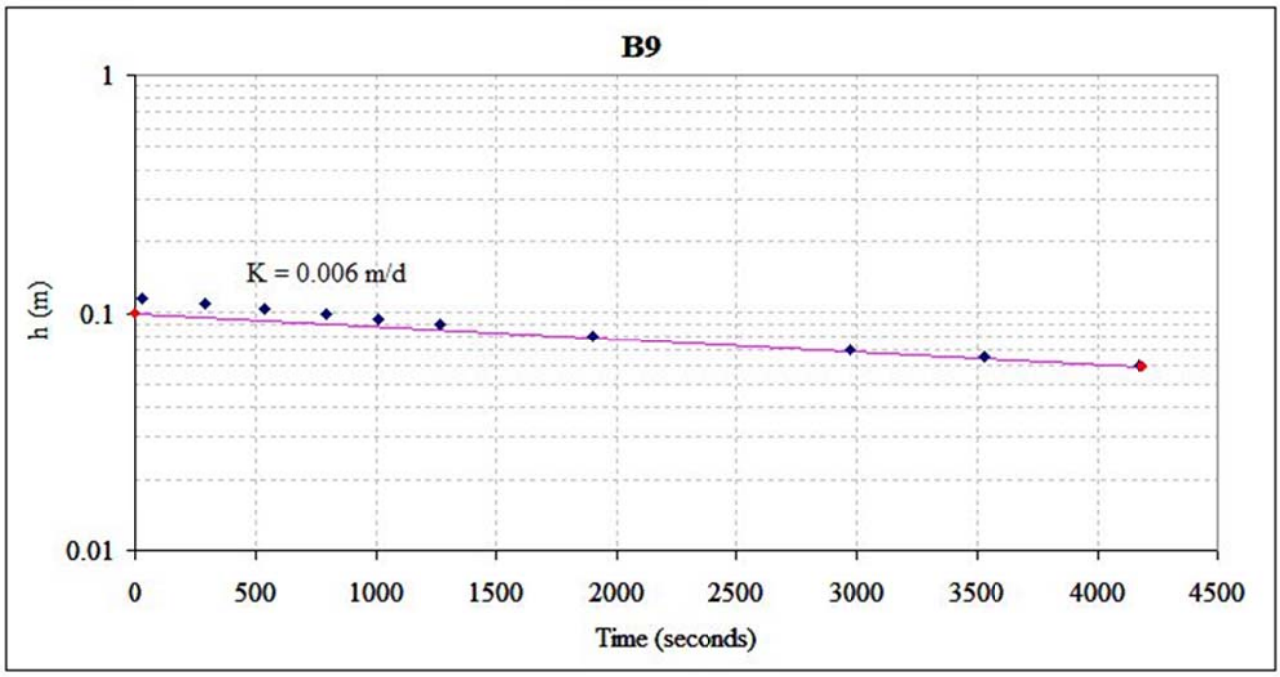


Figure D8. Analysis of slug test performed on borehole B9.

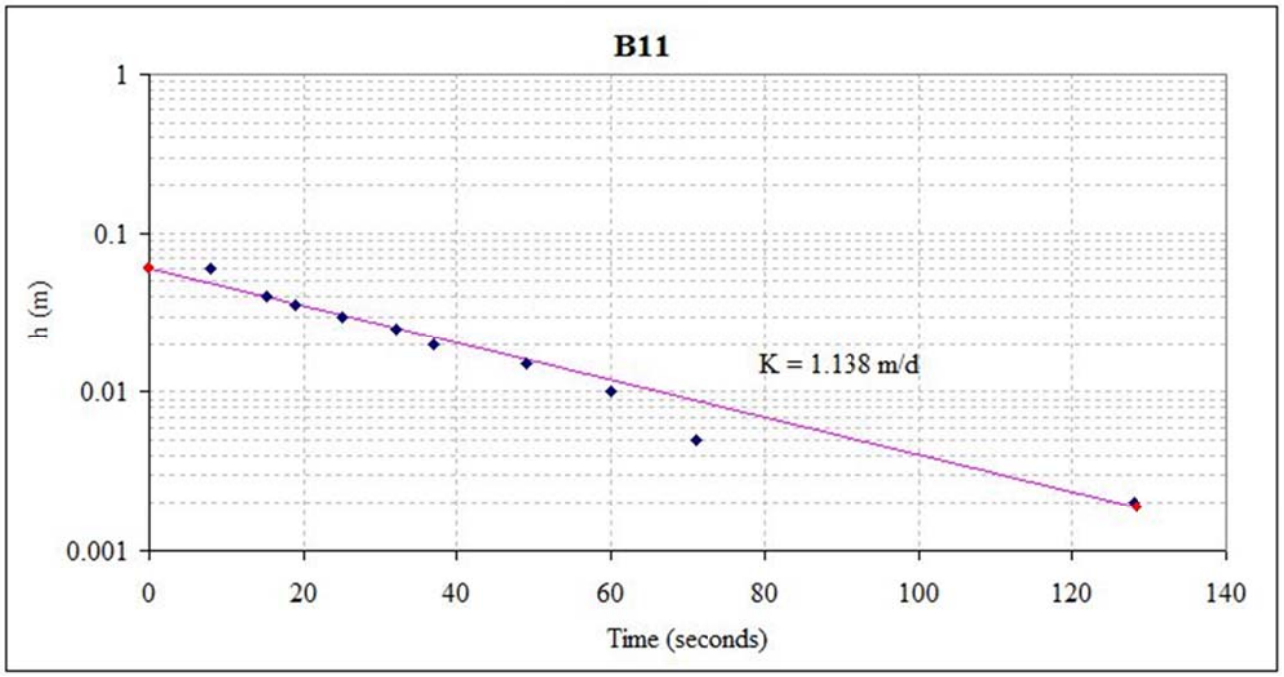


Figure D9. Analysis of slug test performed on borehole B11.

APPENDIX E

Water Quality Information

SiteName	Date	pH	EC	TDS	Ca	Mg	Na	K	PALK	MALK	F	Cl	NO2_N	NO3_N	PO4	SO4	N_Ammonia	CaHard	MgHard	Al	B	Ba	Br	Co	Cr	Cu	Fe	Mo	Mn	Ni	Pb	Si	Zn
ANT-1	2002/01/30	5.56	150	1048	146	90	30	10.6		26		10				700				0.128							3.166		1.355				
ANT-1	2002/09/12	5.93	97	1259	123	101	44	6.7		21		13				869		308	417	0.070							0.130		1.210				
ANT-2	2002/01/30	6.72	42	225	59	18	25	2.0		96		8				164				0.042							2.830		1.258				
ANT-2	2002/09/12	6.55	74	591	55	39	34	2.8		69		31				289		137	161	0.060							0.290		0.630				
ANT-3	2002/01/30	5.97	188	1466	245	139	41	19.0		76		6				1041				0.090							29.028		1.325				
ANT-3	2002/09/12	6.49	134	1271	121	94	42	8.0		80		5				853		303	387	0.050							10.380		0.730				
AW18	2002/09/12	7.41	41	299	24	15	32	2.1		132		5				65		59	62	0.010							0.330		1.260				
AW20	2002/09/12	8.99	559	4795	344	142	43	7.7		111		75				1198		858	585	0.290							0.010		6.260				
AW21	2002/09/12	5.92	36	131	20	7	35	3.3		64		16				84		20	14	0.036							26.066		0.948				
AW21	2002/09/12	6.67	34	245	8	4	22	1.4		70		9				21				0.020							0.180		0.370				
AW24	2002/09/12	6.88	257	2966	325	197	43	16.6		464		11				1570		811	810	0.270							0.260		3.440				
AW25	2002/09/12	6.55	77	523	42	22	22	4.7		314		2				67		104	89	0.030							0.350		2.030				
AW26	2002/09/12	6.89	185	1675	181	122	32	19.3		692		4				729		452	502	0.130							0.040		1.110				
AW03	2002/09/12	7.44	270	2584	123	290	45	21.7		542		6				1382		308	1195	0.010							0.690		1.910				
AW31	2002/01/30	5.71	20	156	12	4	29	3.5		20		10				67				0.225							0.247		0.037				
AW31	2002/09/12	6.42	39	232	6	3	32	2.5		62		8				50		16	13	0.390							0.200		0.000				
AW32	2002/07/30	6.01	198	1899	183	236	37	8.8		21		10				1452		456	972	0.010							0.042		0.464				
AW33	2002/07/30	5.17	35	263	16	11	58	3.2		6		108				26		40	44	0.051							0.044		0.063				
AW04	2002/07/30	6.91	18	92	18	5	25	4.2		64		6				52				0.142							1.363		0.050				
AW04	2002/09/12	8.87	73	86	8	3	27	1.9		5		6				35		21	12	0.100							1.080		0.000				
AW05	2002/09/12	7.24	57	442	43	31	56	2.9		50		8				347		107	129	0.010							1.080		1.110				
AW06	2002/09/12	7.14	27	197	7	3	23	2.3		24		2				36		17	14	0.010							0.150		0.010				
AW07	2002/01/30	6.52	305	2546	237	308	113	0.0		56		36				1665				0.020							2.666		1.363				
AW07	2002/09/12	8.02	177	2050	115	182	85	19.6		34		19				1338		287	750	0.010							0.220		0.410				
AW08	2002/01/30	6.39	466	4691	329	447	159	19.1		122		20				3178				0.080							3.510		17.320				
AW08	2002/09/12	6.78	385	4680	346	491	174	19.2		120		2				3484		864	2022	0.010							15.340		11.050				
AW09	2002/01/30	4.79	312	2927	417	168	42	16.4		2		10				1964				0.010							97.220		5.320				
AW09	2002/09/12	6.06	268	3072	346	491	174	19.2		59		2				1930		864	2022	0.010							15.344		11.048				
BHZ10	2002/09/13	7.20	66	398	26	13	43	5.2		226		9				19		65	56	0.010							0.350		0.170				
BHZ04	2002/09/13	5.83	70	509	41	33	50	6.0		18		26				272		102	134	0.010							0.020		0.490				
BHZ05	2002/09/13	7.09	52	304	33	15	55	4.2		198		38				40		83	62	0.010							0.010		0.010				
BHZ06	2002/09/13	7.25	42	247	26	12	50	2.6		200		15				37		64	49	0.010							0.010		0.010				
BHZ07	2002/09/13	7.27	40	235	27	11	45	2.1		196		11				39		66	46	0.010							0.010		0.010				
BHZ08	2002/09/13	7.16	80	644	46	32	86	10.8		86		18				407		114	130	0.030							0.540		0.150				
BHZ09	2002/09/13	5.98	182	1519	173	146	56	8.4		68		20				1254		432	600	0.030							0.030		1.130				
BHZ09	2004/12/05	6.76	224	2300	191	183	67	13.5		35		22				1185		476	754	0.010							0.010		1.108				
Bliksem Pan	2006/05/16	8.94	114	774	42	24	181	22.6		270		46				126		105	99	0.097							3.655		0.009				
Bliksem Pan	2006/06/06			974								180				194																

SiteName	Date	pH	EC	TDS	Ca	Mg	Na	K	PALK	MALK	F	Cl	NO2_N	NO3_N	PO4	SO4	N_Ammonia	CaHard	MgHard	Al	B	Ba	Br	Co	Cr	Cu	Fe	Mo	Mn	Ni	Pb	Si	Zn
Final Void	2006/01/31	7.05	425	5938	432	671	133	46.4		152		30				3000		1080	2764	0.320							0.530		0.745				
Final Void	2006/02/07	7.21	478	5550	509	669	151	43.2		175		34				3000		1271	2754	0.026							0.053		0.058				
No.32	2006/04/25	7.54	138	1349	120	113	33	10.2		110		18				720		301	465	0.066							0.001		0.001				
No.33	2006/04/25	7.56	130	1211	114	105	33	9.8		102		19				635		284	433	0.082							0.001		0.001				
No.33	2006/05/26	7.43	269	2817	239	225	53	14.3		153		26				1485		596	926	0.046							0.010		0.010				
No.09	2006/03/31	6.84	386	6011	376	554	179	49.1		157		24				2800		938	2279	0.010							0.010		0.469				
No.09	2006/04/25	7.65	503	6082	418	563	176	48.9		200		28				3960		1044	2319	0.082							0.026		0.001				
Steels Pan	2002/02/05	8.67	744	7050	164	625	498	189.6		832		298				3295				0.030							0.021		0.187				
W04	2004/01/27	2.65	464	6638	236	237	86	7.1		0		40				3610		590	978	140.060							721.456		40.784				
W05	2004/01/27	2.67	322	3331	159	144	68	4.5		0		40				2000		397	595	102.485							108.609		29.778				
W04	2002/09/12	5.68	83	695	48	48	28	1.5		4		5				454		120	196	0.040							0.380		4.350				
ANT-1	2012/02/21	6.94	111	427	39	46	19	10.1		406		32				39				0.003							12.161		1.990				
ANT-1	2012/05/03	7.49	95	388	38	45	21	10.2		202		25				5				0.000							0.436		0.990				
ANT-2	2012/02/21	6.52	223	2218	193	194	90	9.7		29		27				1030				0.003							0.965		0.750				
ANT-2	2012/05/03	6.01	207	2186	196	197	92	9.8		5		26				1950				0.000							0.041		0.780				
ANT-3	2012/05/03	4.68	97	863	75	73	34	9.7		7		9				463				0.000							0.575		0.460				
AW01	2011/02/23	6.81	176	1679	197	138	34	17.1		88		8				898				0.020							0.795		4.800				
AW01	2011/07/15	6.99	461	5750	497	507	134	36.7		223		22				3695				0.010							0.000		0.020				
AW01	2012/02/21	7.51	484	5869	504	559	143	33.8		415		22				2285				0.008							0.162		13.400				
AW01	2012/05/03	7.00	436	5751	516	534	130	35.5		408		19		0.0	0.2	2700	0.5			0.000	0.270						0.000		0.930				
AW18	2011/02/23	6.55	88	695	82	56	30	6.0		275		15				411				0.000							0.320		1.630				
AW18	2011/07/15	6.63	66	523	75	37	17	8.9		96		7				230				0.010							0.200		0.550				
AW18	2012/02/21	6.35	38	251	37	17	6	4.2		14		3				154				0.036							0.207		0.210				
AW18	2012/05/03	6.67	35	250	39	17	7	5.0		207		3				45				0.000							0.021		0.290				
AW19	2011/02/23	3.60	95	784	113	52	9	0.8		0		3				621				0.595							0.710		9.580				
AW19	2011/07/15	6.24	49	462	37	32	17	3.0		22		3				204				0.020							0.790		1.800				
AW19	2012/02/21	7.03	0	324	29	27	11	2.9		69		3				142				0.171							0.419		0.810				
AW19	2012/05/03	6.50	37	281	25	25	14	3.4		98		2				116				0.000							0.000		1.550				
AW02	2011/02/23	6.70	430	5291	197	202	81	33.8		91		16				1210				0.015							0.050		5.440				
AW02	2012/02/21	6.29	362	4233	353	219	27	0.0		124		14				1690				0.015							0.051		0.660				
AW02	2012/05/03	6.71	314	3764	332	413	50	21.9		419		11		0.1	0.2	2630	0.4			0.000	0.310						0.053		0.350				
AW20	2012/05/03	6.94	549	7257	341	702	422	13.7		170		71				4260				0.000							0.537		0.290				
AW21	2011/02/23	6.01	60	403	22	25	59	6.1		3		59				224				0.000							0.276		0.370				
AW21	2011/07/15	6.33	74	618	31	34	65	3.4		50		72				179				0.022							0.457		0.500				
AW21	2012/02/21	7.64	42	248	17	19	27	2.4		108		39				46				0.006							0.034		0.100				
AW21	2012/05/03	3.32	0	281	18	22	35	3.2		0		44		0.0	0.2	247	0.3			0.000	0.010						0.015		0.000				
AW22	2011/02/23	5.98	19	118	9	5	17	2.3		3		13				70				0.015							2.084		1.780				
AW22	2012/02/21	6.58	9	69	2	1	7	1.0		12		8				22				0.799							1.844		0.010				

SiteName	Date	pH	EC	TDS	Ca	Mg	Na	K	PALK	MALK	F	Cl	NO2_N	NO3_N	PO4	SO4	N_Ammonia	CaHard	MgHard	Al	B	Ba	Br	Co	Cr	Cu	Fe	Mo	Mn	Ni	Pb	Si	Zn
AW22	2012/05/03	6.04	12	98	5	3	13	1.8		14		9				42				0.000							0.081		0.000				
AW23	2011/02/23	5.48	4	32	2	1	7	1.1		0		6				19				0.000							0.020		0.100				
AW23	2012/02/21	6.11	4	30	2	1	2	0.7		2		4				12				0.369							1.287		0.120				
AW23	2012/05/03	5.77	4	46	2	1	4	1.0		10		5				22				0.079							0.040		0.010				
AW24	2011/02/23	6.64	267	2801	299	221	30	24.1		667		13				980				0.480							0.115		0.880				
AW24	2011/07/15	7.08	307	3327	399	264	35	23.5		390		12				1795				0.025							0.140		2.000				
AW24	2012/02/21	6.47	257	2455	273	197	23	17.8		685		13				737				2.406							1.006		0.970				
AW24	2012/05/03	7.04	234	2363	308	219	26	20.7		913		11		30.5	0.2	1160	0.4			0.000	0.250						0.026		1.090				
AW25	2011/02/23	6.36	135	1292	164	100	20	8.0		17		5				795				0.620							0.340		9.920				
AW25	2012/02/21	6.73	18	75	4	3	17	2.5		40		8				8				0.042							0.150		0.020				
AW25	2012/05/03	6.62	101	856	58	37	7	3.4		62		3				346				0.000							0.142		2.120				
AW03	2011/02/23	7.24	325	3474	187	393	98	23.8		82		20				2160				0.165							0.660		1.940				
AW03	2012/02/21	6.68	336	4219	339	386	98	9.5		33		23				1810				0.011							1.480		9.670				
AW03	2012/02/21	6.96	360	2846	367	382	93	9.9		22		9				1750				0.022							1.883		10.610				
AW03	2012/05/03	7.27	272	2818	131	378	73	25.1		607		12		174.0	0.2	1485	1.9			0.000	0.080						0.155		1.010				
AW31	2011/02/23	5.35	19	195	6	5	20	2.4		0		10				57				0.020							1.526		0.190				
AW31	2011/07/15	6.28	18	144	4	3	27	2.8		40		8				10				0.103							0.018		0.020				
AW31	2012/02/21	7.49	316	3568	195	400	92	21.5		401		18				1445				0.015							0.340		2.530				
AW31	2012/05/03	6.68	16	151	4	3	21	2.8		50		6		5.2	0.2	5	0.3			0.000	0.010						0.000		0.020				
AW04	2011/02/23	7.25	21	110	9	6	19	3.6		52		18				34				0.020							0.330		0.030				
AW04	2011/07/15	6.96	19	257	10	8	19	3.0		52		19				6				0.010							0.140		0.020				
AW04	2012/02/21	6.09	21	79	9	6	13	2.9		41		18				8				0.006							0.029		0.000				
AW04	2012/05/03	6.81	17	125	9	5	16	3.0		69		16		0.0	0.2	11	0.3			0.000	0.020						0.048		0.000				
AW05	2011/02/23	6.02	44	299	24	17	38	2.4		35		15				183				0.000							0.270		0.870				
AW05	2011/07/15	6.06	34	297	17	14	25	1.9		10		16				123				0.030							0.597		0.550				
AW05	2012/02/21	3.68	57	336	27	20	21	2.0		0		21				180				0.389							0.933		3.090				
AW05	2012/05/03	6.43	29	204	16	13	9	0.8		26		20				77				0.000							0.000		0.800				
AW07	2011/02/23	5.94	114	957	50	101	49	12.2		19		32				741				0.010							0.815		0.380				
AW07	2011/07/15	6.38	145	1547	107	130	47	13.4		22		19				860				0.025							0.320		0.540				
AW07	2012/02/21	6.37	127	1234	98	113	37	13.9		13		15				703				0.016							0.036		0.400				
AW07	2012/05/03	7.01	62	451	46	36	30	12.8		151		15				206				0.000							0.061		0.030				
AW08	2011/02/23	5.32	175	1689	157	147	49	17.3		17		14				1140				0.030							15.290		2.380				
AW08	2011/07/15	5.44	167	1719	170	134	46	13.5		11		25				1020				0.011							5.514		1.830				
AW08	2012/05/03	6.40	391	5096	432	509	120	14.3		105		23		0.0	0.2	2600	0.9			0.000	0.010						0.318		11.920				
AW09	2011/02/23	4.45	364	5304	228	96	29	7.5		0		24				2305				0.020							378.520		11.780				
AW09	2012/05/03	5.18	348	4950	380	200	46	9.4		561		14		0.0	0.2	2420	1.3			0.000	0.310						707.050		5.900				

SiteName	Date	pH	EC	TDS	Ca	Mg	Na	K	PALK	MALK	F	Cl	NO2_N	NO3_N	PO4	SO4	N_Ammonia	CaHard	MgHard	Al	B	Ba	Br	Co	Cr	Cu	Fe	Mo	Mn	Ni	Pb	Si	Zn
Decant Dam	2012/02/21	6.15	111	1118	198	29	10	2.9		359		6				451				0.068							0.000		1.240				
Decant Dam	2012/03/27	6.49	118	1061	242	33	16	4.0		52		8		2.9	0.3	492	0.4			0.027	0.060						0.116		1.390				
Decant Dam	2012/04/25	6.28	86	1024	235	31	13	4.0		25		8		2.2	0.3	576	0.2			0.054	0.060						0.011		1.290				
Decant Dam	2012/05/03	7.30	438	5667	499	527	127	30.0		503		18				2980				0.000							0.000		0.020				
Decant Dam	2010/04/01	6.17	134	1239	268	36	23	4.1		70		7				627				0.110							0.006		1.690				
No.10	2012/02/21	7.63	56	437	40	27	23	4.3		4		14				172				0.005							0.000		0.010				
No.33	2012/02/21	6.94	152	1393	136	109	37	7.4		47		16				616				0.028							0.000		0.010				
Steels Pan	2012/02/21	8.91	653	6710	80	715	486	203.4		1590		300				2040				0.017							0.000		0.170				
Steels Pan	2011/02/23	8.65	629	6474	112	368	478	207.1		542		205				2360				0.010							0.003		0.230				
Steels Pan	2012/05/03	8.47	650	7120	122	734	515	181.9		0		284				4210				0.000							0.000		0.250				
No.09	2012/02/21	7.64	470	6042	497	597	137	34.2		219		20				2425				0.010							0.000		0.020				
No.09	2012/05/03	7.78	455	5976	503	563	123	35.4		435		20				4120				0.000							0.000		0.080				
No.09	2011/07/15	7.73	465	5825	489	491	123	37.4		235		18				3615				0.010							0.010		0.030				
No.09	2012/02/21	6.63	479	5941	491	555	126	32.3		85		20				2335				0.005							0.000		0.010				
ANT-1	2012/08/14	7.88	88	474	32	45	22	15.7	0.0	328	0.03	27	<0.01	<0.05	<0.1	3		80	184	0.017		0.025	0.251	<0.002	<0.006	0.003	0.389	<0.003	0.466	<0.01	<0.01	1.613	0.009
ANT-1 deep	2012/08/14	7.26	200	1558	161	171	51	18.3	0.0	189	<0.1	20	<0.1	<0.5		951		402	701	0.003		0.033	<0.4	0.002	<0.006	0.005	0.553	<0.003	0.957	0.019	<0.01	2.702	0.019
ANT-2	2012/08/07	6.06	242	2049	208	220	95	11.5	0.0	6	0.52	30	<0.1	<0.5		1482		520	903	0.018		0.019	<0.4	<0.002	<0.006	0.011	0.075	<0.003	0.187	<0.01	<0.01	0.063	0.019
ANT-2 deep	2012/08/07	6.51	421	4075	406	428	112	26.7	0.0	104	<0.1	24	<0.1	<0.5		2974		1016	1755	0.003		0.016	<0.4	0.025	<0.006	0.017	1.200	<0.003	3.274	0.076	<0.01	4.040	0.035
ANT-3	2012/08/07	6.67	105	772	61	88	38	14.2	0.0	17	<0.1	9	<0.1	<0.5		548		153	361	0.003		0.009	<0.4	<0.002	<0.006	0.006	0.089	<0.003	0.066	<0.01	<0.01	0.096	0.015
ANT-3 deep	2012/08/07	6.94	193	1657	254	140	33	16.3	0.0	41	<0.1	9	<0.1	<0.5	1.4	1165		636	573	<0.001		0.017	<0.4	<0.002	<0.006	0.008	0.080	<0.003	0.464	<0.01	<0.01	3.258	0.022
ARN02	2012/08/07	7.49	73	514	52	49	38	5.7	0.0	67	0.12	18	<0.1	<0.5		288		130	200	0.012		0.034	<0.4	<0.002	<0.006	0.009	0.058	<0.003	0.015	<0.01	<0.01	1.661	0.014
AW01	2012/08/14	7.60	500	5168	506	582	104	55.5	0.0	340	0.36	21	<0.1	<0.5		3561		1266	2385	0.003		0.013	<0.4	0.004	<0.006	0.010	0.060	<0.003	2.247	0.018	<0.01	4.211	0.033
AW01 deep	2012/08/14	7.56	507	5242	521	532	136	46.9	0.0	404	0.24	25	<0.1	<0.5		3572		1303	2181	<0.002		0.015	<0.4	0.022	<0.006	0.006	0.060	<0.003	7.607	0.016	<0.01	5.135	0.087
AW02	2012/08/13	7.45	345	3317	331	399	44	33.7	0.0	332	0.76	15	<0.1	<0.5		2165		827	1637	0.000		0.010	<0.4	<0.002	<0.006	0.014	0.059	<0.003	0.139	<0.01	<0.01	4.915	0.139
AW02 deep	2012/08/13	7.50	486	4853	465	532	81	43.8	0.0	309	0.42	18	<0.1	<0.5		3400		1163	2183	<0.002		0.012	<0.4	0.008	<0.006	0.009	0.058	<0.003	6.375	0.015	<0.01	5.608	0.063
AW03	2012/08/07	7.95	363	3396	223	429	97	34.9	0.0	228	0.17	21	<0.1	<0.5		2364		557	1760	0.003		0.018	<0.4	<0.002	<0.006	0.005	0.077	<0.003	2.246	<0.01	<0.01	0.336	0.011
AW03 deep	2012/08/07	6.61	385	3638	244	442	104	32.9	0.0	17	0.14	23	<0.1	<0.5		2775		610	1814	0.004		0.019	<0.4	<0.002	<0.006	0.018	0.325	<0.003	2.284	<0.01	<0.01	0.139	0.018
AW04	2012/08/14	7.52	18	129	8	5	20	4.8	0.0	61	0.22	22	<0.01	0.1	<0.1	7		20	21	0.002		0.031	0.316	<0.002	<0.006	0.003	0.070	<0.003	0.004	<0.01	<0.01	2.203	0.005
AW04 deep	2012/08/14	7.72	18	124	7	4	21	4.5	0.0	62	0.28	20	<0.01	0.1	<0.1	4		19	18	0.009		0.046	0.336	<0.002	<0.006	0.003	0.098	<0.003	0.005	<0.01	<0.01	2.482	0.012
AW05	2012/08/14	6.86	15	102	6	4	18	2.0	0.0	32	0.08	18	<0.01	<0.05	<0.1	22		14	17	0.002		0.006	0.159	<0.002	<0.006	0.002	0.055	<0.003	0.087	<0.01	<0.01	0.201	0.008
AW05 deep	2012/08/14	7.27	92	649	36	18	128	3.5	0.0	117	1.37	9	<0.01	<0.05	<0.1	336		90	75	0.007		0.017	<0.04	0.004	<0.006	0.006	0.066	<0.003	0.325	<0.01	<0.01	3.569	0.015
AW06	2012/08/07	6.97	15	98	6	5	12	5.8	0.0	35	0.04	18	<0.01	0.6	<0.1	13		16	21	0.049		0.020	0.388	<0.002	<0.006	0.003	0.199	<0.003	0.007	<0.01	<0.01	1.758	0.011
AW06 deep	2012/08/07	7.73	13	91	5	4	12	4.9	0.0	39	0.03	17	<0.01	0.6	<0.1	5		14	18	0.138		0.020	0.448	<0.002	<0.006	0.002	0.546	<0.003	0.009	<0.01	<0.01	1.849	0.009
AW07	2012/08/14	7.44	175	1396	132	144	66	27.7	0.0	100	<0.1	46	<0.1	<0.5		883		330	590	0.006		0.029	0.131	<0.002	<0.006	0.007	0.060	<0.003	0.529	<0.01	<0.01	0.544	0.013
AW07 deep	2012/08/14	7.29	177	1429	137	149	68	28.7	0.0	94	0.13	50	<0.1	<0.5		906		342	610	0.001		0.032	<0.4	<0.002	<0.006	0.006	0.076	<0.003	0.589	<0.01	<0.01	0.588	0.012
AW08	2012/08/14	6.67	452	4300	374	473	107	23.4	0.0	89	<0.1	26	<0.1	<0.5		3205		936	1938	0.002		0.019	<0.4	0.013	<0.006	0.008	0.120	<0.003	7.113	<0.01	<0.01	0.794	0.014
AW08 deep	2012/08/14	6.65	451	4339	371	475	109	24.6	0.0	82	<0.1	25	<0.1	<0.5		3250		928	1947	0.005		0.014	<0.4	0.010	<0.006	0.008	0.264	<0.003	6.943	<0.01	<0.01	0.788	0.015
AW09	2012/08/13	3.73	325	3080	462	245	42	15.0	0.0	28	<0.1	15	<0.1	<0.5		2274		1154	1005	0.065		0.026	<0.4	<0.002	<0.006	0.071	0.171	<0.003	2.807	<0.01	0.032	1.383	0.085

SiteName	Date	pH	EC	TDS	Ca	Mg	Na	K	PALK	MALK	F	Cl	NO2_N	NO3_N	PO4	SO4	N_Ammonia	CaHard	MgHard	Al	B	Ba	Br	Co	Cr	Cu	Fe	Mo	Mn	Ni	Pb	Si	Zn
AW09 deep	2012/08/13	3.41	424	4372	351	217	37	9.9	0.0	0	<0.1	22	<0.1	<0.5		3014		878	888	<0.033		0.014	<0.4	<0.002	<0.006	<0.008	719.665	<0.003	5.456	<0.01	0.059	0.120	0.180
AW18	2012/08/14	6.85	45	262	35	17	8	8.1	0.0	162	0.09	3	1.6	0.1	<0.1	23	0.0	87	68	0.007		0.050	<0.04	<0.002	<0.006	0.005	0.151	<0.003	0.233	<0.01	<0.01	3.875	0.016
AW18 deep	2012/08/14	6.82	45	250	32	16	8	8.2	0.0	161	0.13	3	0.2	<0.05	<0.1	21	0.0	79	65	0.010		0.094	<0.04	<0.002	<0.006	0.004	0.357	<0.003	0.184	<0.01	<0.01	4.066	0.015
AW19	2012/08/07	6.55	41	199	19	17	13	4.8	0.0	46	0.62	4	<0.01	0.5	<0.1	92		47	69	0.016		0.027	0.045	0.008	<0.006	0.005	0.068	<0.003	0.457	0.016	<0.01	2.549	0.022
AW19 deep	2012/08/07	6.63	42	211	20	19	12	3.8	0.0	55	0.50	3	<0.01	0.3	<0.1	95		51	76	0.006		0.020	<0.04	0.024	<0.006	0.008	0.057	<0.003	0.988	0.026	<0.01	2.825	0.024
AW20	2012/08/15	7.56	638	5592	322	596	401	10.4	0.0	139	0.33	116	<0.1	<0.5		4011		806	2442	<0.012		0.019	<0.4	<0.002	<0.006	0.009	0.045	<0.003	0.181	<0.01	<0.01	0.779	0.006
AW20 deep	2012/08/15	7.46	638	5532	329	600	403	11.5	0.0	142	0.36	116	<0.1	<0.5		3935		821	2458	<0.002		0.018	<0.4	<0.002	<0.006	0.009	0.103	<0.003	0.285	<0.01	<0.01	0.845	0.016
AW22	2012/08/15	6.00	12	89	3	2	17	3.4	0.0	8	0.06	18	<0.01	7.0	<0.1	6		8	8	0.022		0.050	0.043	<0.002	<0.006	0.006	0.142	<0.003	0.005	<0.01	<0.01	5.087	0.020
AW22 deep	2012/08/15	5.81	13	90	3	2	19	3.7	0.0	7	0.03	18	<0.01	7.2	<0.1	6		7	8	0.032		0.043	<0.04	<0.002	<0.006	0.004	0.329	<0.003	0.007	<0.01	<0.01	5.021	0.019
AW23	2012/08/15	5.77	6	45	2	2	7	2.2	0.0	8	0.01	7	<0.01	2.1	<0.1	8		5	7	0.014		0.034	<0.04	<0.002	<0.006	0.004	0.058	<0.003	0.022	<0.01	<0.01	4.231	0.034
AW23 deep	2012/08/15	5.79	4	36	1	1	6	1.9	0.0	8	0.01	8	<0.01	2.1	<0.1	1		3	6	0.033		0.029	<0.04	<0.002	<0.006	0.003	0.059	<0.003	0.008	<0.01	<0.01	4.321	0.020
AW24	2012/08/14	7.26	241	2212	249	214	22	31.7	0.0	846	0.15	15	0.2	30.3		700		622	876	0.004		0.030	<0.4	<0.002	<0.006	0.010	0.055	<0.003	0.926	<0.01	<0.01	2.889	0.044
AW24 deep	2012/08/14	7.20	328	2951	406	309	30	35.1	0.0	565	0.27	12	<0.1	5.0		1572		1014	1265	<0.001		0.019	<0.4	0.008	<0.006	0.008	0.055	<0.003	2.818	<0.01	<0.01	3.845	0.041
AW25	2012/08/14	6.55	29	168	23	11	5	4.9	0.0	58	<0.1	4	4.5	<0.5		46		57	45	0.012		0.068	<0.4	<0.002	<0.006	0.007	0.158	<0.003	1.352	<0.01	<0.01	4.777	0.017
AW25 deep	2012/08/14	7.36	268	2246	289	218	30	17.5	0.0	659	0.13	9	<0.1	<0.5		1023		723	893	0.006		0.033	<0.4	<0.002	<0.006	0.005	0.133	<0.003	4.168	<0.01	<0.01	4.926	0.008
AW26	2012/08/14	7.19	227	1874	233	204	21	28.9	0.0	621	0.28	13	1.2	1.2		741		584	837	<0.001		0.058	<0.4	0.010	<0.006	0.004	0.083	<0.003	1.134	0.014	<0.01	2.268	0.010
AW26 deep	2012/08/14	7.35	348	3091	418	315	29	34.5	0.0	535	0.29	11	<0.1	0.8		1743		1046	1293	0.002		0.015	<0.4	0.009	<0.006	0.007	0.056	<0.003	2.824	<0.01	<0.01	3.504	0.021
AW28	2012/08/14	7.00	48	303	6	9	17	7.8	0.0	207	0.07	12	<0.01	0.1	<0.1	1	30.3	15	38	0.009		0.079	<0.04	<0.002	<0.006	0.002	3.723	<0.003	0.313	<0.01	<0.01	4.643	0.007
AW28 deep	2012/08/14	7.11	54	336	4	9	18	8.4	0.0	234	0.07	12	<0.01	<0.05	<0.1	0	35.4	11	36	0.017		0.047	<0.04	<0.002	<0.006	0.002	5.033	<0.003	0.240	<0.01	<0.01	4.771	0.007
AW31	2012/08/14	6.54	17	130	4	3	25	4.4	0.0	43	0.03	8	<0.01	7.3	<0.1	11		10	13	0.045		0.028	0.230	<0.002	<0.006	0.003	0.078	<0.003	0.005	<0.01	<0.01	11.323	0.019
AW31 deep	2012/08/14	6.55	16	121	3	2	25	4.5	0.0	46	0.08	8	<0.01	6.3	<0.1	4		8	9	0.033		0.029	0.130	<0.002	<0.006	0.003	0.065	<0.003	0.004	<0.01	<0.01	11.659	0.048
B1	2012/08/14	6.90	99	630	68	43	64	5.8	0.0	78	1.12	19	<0.01	<0.05	<0.1	350		171	176	0.010		0.075	0.128	0.003	<0.006	0.011	0.069	<0.003	0.551	<0.01	<0.01	1.884	0.020
B3	2012/08/14	7.70	20	137	15	6	9	6.6	0.0	73	0.68	3	0.0	<0.05	<0.1	22		38	26	0.008		0.106	<0.04	<0.002	<0.006	0.005	0.056	0.008	0.033	<0.01	<0.01	2.057	0.012
B4	2012/08/14	6.07	412	3592	356	376	85	42.1	0.0	159	0.14	18	<0.1	<0.5		2532		890	1543	<0.006		0.023	<0.4	0.065	<0.006	0.011	3.655	<0.003	25.477	0.044	<0.01	7.620	0.085
B5	2012/08/14	6.72	7	50	4	2	6	3.2	0.0	31	0.05	2	<0.01	<0.05	<0.1	2		9	8	0.013		0.059	<0.04	<0.002	<0.006	0.003	0.074	<0.003	0.090	<0.01	<0.01	7.143	0.015
B6	2012/08/14	6.89	364	2975	325	333	75	24.1	0.0	107	0.26	16	<0.1	<0.5		2096		813	1364	<0.006		0.035	<0.4	0.015	<0.006	0.009	0.093	<0.003	1.997	0.012	<0.01	1.688	0.019
B7	2012/08/14	6.59	11	70	2	2	13	3.3	0.0	37	0.04	6	0.0	0.4	<0.1	4		6	8	0.026		0.067	0.041	0.003	<0.006	0.003	0.093	<0.003	0.081	<0.01	<0.01	4.260	0.014
B8	2012/08/14	6.75	30	189	12	9	24	8.5	0.0	44	0.09	9	<0.01	<0.05	<0.1	83		29	35	0.011		0.037	0.039	<0.002	<0.006	0.002	0.079	<0.003	0.617	<0.01	<0.01	1.917	0.004
B9	2012/08/14	7.41	20	140	14	7	12	4.3	0.0	88	0.20	5	<0.01	<0.05	<0.1	9		36	28	0.054		0.139	<0.04	<0.002	<0.006	0.005	0.273	<0.003	0.182	<0.01	<0.01	13.162	0.018
B11	2012/08/14	5.64	110	781	91	67	20	7.8	0.0	9	<0.1	1	<0.1	<0.5		553		228	275	0.138		0.092	<0.4	0.326	<0.006	0.017	24.934	<0.003	11.730	0.193	0.015	12.276	0.251
BHZ04	2012/08/14	7.63	66	477	24	30	44	39.0	0.0	173	0.27	39	<0.01	0.7	26.2	98		59	124	0.007		0.004	<0.04	<0.002	<0.006	0.070	0.094	0.008	0.015	<0.01	<0.01	7.606	0.021
BHZ04 deep	2012/08/14	7.76	68	487	25	32	45	41.1	0.0	170	0.18	41	<0.01	1.1	22.3	107		61	130	0.014		0.004	<0.04	<0.002	<0.006	0.191	0.156	0.008	0.015	<0.01	<0.01	7.344	0.022
Community BH	2012/08/14	7.58	22	160	10	5	28	2.5	0.0	96	1.73	7	<0.01	<0.05	<0.1	10		24	22	0.007		0.151	<0.04	<0.002	<0.006	0.003	0.076	<0.003	0.006	<0.01	<0.01	11.261	0.012
BHZ08	2012/08/14	7.52	140	957	69	72	116	14.6	0.0	63	<0.1	55	<0.1	<0.5	1.1	568		174	295	0.009		0.014	<0.4	<0.002	<0.006	0.017	0.060	<0.003	0.866	<0.01	<0.01	1.421	0.026
BHZ08 deep	2012/08/14	7.48	142	959	73	75	120	15.1	0.0	63	<0.1	57	<0.1	<0.5		560		182	306	0.005		0.014	<0.4	<0.002	<0.006	0.010	0.059	<0.003	1.005	<0.01	<0.01	1.663	0.020
BHZ09	2012/08/14	7.09	128	959	75	102	59	13.7	0.0	111	0.12	19	2.0	0.8		568		188	419	0.003		0.010	<0.4	<0.002	<0.006	0.013	0.065	0.003	0.085	<0.01	<0.01	2.079	0.022
BHZ09 deep	2012/08/14	6.45	227	1818	184	204	62	13.3	0.0	57	<0.1	25	0.4	17.4		1194		459	837	0.006		0.020	0.775	0.012	<0.006	0.020	0.059	<0.003	0.628	0.043	<0.01	5.666	0.183

SiteName	Date	pH	EC	TDS	Ca	Mg	Na	K	PALK	MALK	F	Cl	NO2_N	NO3_N	PO4	SO4	N_Ammonia	CaHard	MgHard	Al	B	Ba	Br	Co	Cr	Cu	Fe	Mo	Mn	Ni	Pb	Si	Zn
C-4	2012/08/14	7.49	350	2707	141	281	247	49.9	0.0	310	0.12	116	1.8	<0.5		1549		353	1151	0.011		0.032	7.502	<0.002	<0.006	0.011	0.063	<0.003	1.585	<0.01	<0.01	0.853	0.018
C-4 deep	2012/08/14	8.22	362	2955	135	287	254	49.7	0.0	334	0.17	143	<0.1	<0.5		1744		337	1178	0.011		0.017	9.383	<0.002	<0.006	0.007	0.064	<0.003	1.047	<0.01	<0.01	0.560	0.016
C-5	2012/08/14	7.73	186	1297	47	136	98	40.8	0.0	409	<0.1	21	3.1	<0.5		534		116	558	0.015		0.032	<0.4	<0.002	<0.006	0.006	0.086	<0.003	0.545	<0.01	<0.01	0.814	0.014
C-5 deep	2012/08/14	7.74	179	1253	32	131	102	40.8	0.0	398	<0.1	20	4.9	<0.5		511		81	536	0.011		0.029	<0.4	<0.002	<0.006	0.005	0.073	<0.003	0.321	<0.01	<0.01	0.589	0.013
KGM_B11	2012/08/14	6.18	44	254	18	15	36	5.7	0.0	19	0.08	11	<0.01	<0.05	<0.1	149		44	60	0.003		0.036	0.053	0.016	<0.006	0.005	1.780	<0.003	0.191	0.028	<0.01	4.460	0.036
KGM_B11 deep	2012/08/14	6.35	45	256	20	15	36	5.4	0.0	27	0.10	10	<0.01	<0.05	<0.1	143		50	62	0.004		0.043	0.112	0.017	<0.006	0.005	0.526	<0.003	0.218	0.028	<0.01	4.172	0.027
KGM_B12	2012/08/13	6.73	55	333	32	19	33	4.5	0.0	62	0.31	15	<0.01	<0.05	<0.1	167		80	79	0.007		0.040	0.065	0.003	<0.006	0.006	0.056	<0.003	0.229	0.012	<0.01	6.883	0.024
KGM_B12 deep	2012/08/13	7.19	80	507	55	32	52	4.8	0.0	130	0.59	15	<0.01	<0.05	<0.1	218		139	130	0.008		0.044	0.158	0.006	<0.006	0.005	0.058	<0.003	0.370	0.011	<0.01	5.468	0.017
R-2	2012/08/14	6.97	79	477	51	46	21	5.8	0.0	25	0.16	8	<0.01	<0.05	<0.1	321		127	187	0.012		0.021	<0.04	0.002	<0.006	0.008	0.071	<0.003	1.086	<0.01	<0.01	0.096	0.020
R-2 deep	2012/08/14	6.64	79	481	50	45	20	5.5	0.0	18	0.20	8	<0.01	<0.05	<0.1	334		126	186	0.010		0.020	0.116	0.009	<0.006	0.009	0.053	<0.003	1.137	0.018	<0.01	0.209	0.024
Old Supply BH	2012/08/14	6.99	18	127	13	5	13	3.3	0.0	60	0.09	6	2.8	<0.05	<0.1	14		33	20	0.005		0.036	<0.04	<0.002	<0.006	0.004	0.084	<0.003	0.194	<0.01	<0.01	3.331	0.015
Piet's Pump	2012/08/14	8.18	38	248	7	3	65	1.2	0.0	127	1.61	36	<0.01	<0.05	<0.1	8		17	13	0.008		0.032	0.199	<0.002	<0.006	0.004	0.049	<0.003	0.012	<0.01	<0.01	8.376	0.016
Decant Dam	2012/08/07	7.34	495	4149	408	453	99	37.0	0.0	308	0.44	23	<0.1	<0.5		2824		1019	1858	0.002		0.016	<0.4	<0.002	<0.006	0.006	0.065	<0.003	0.509	<0.01	<0.01	3.122	0.020
Evap Dam	2012/08/07	8.12	502	4186	415	447	102	37.5	0.0	252	0.18	23	<0.1	<0.5		2912		1038	1833	0.011		0.012	<0.4	<0.002	<0.006	0.007	0.052	<0.003	0.012	<0.01	<0.01	1.978	0.017
Final Void	2012/08/07	7.75	495	4183	407	445	99	35.3	0.0	301	0.30	24	<0.1	<0.5		2875		1016	1823	0.011		0.013	<0.4	<0.002	<0.006	0.009	0.053	<0.003	0.967	<0.01	<0.01	2.733	0.022
No.09	2012/08/07	7.98	515	4932	492	517	112	46.7	0.0	310	0.14	26	<0.1	<0.5		3432		1230	2120	<0.001		0.014	<0.4	<0.002	<0.006	0.008	0.054	<0.003	0.263	<0.01	<0.01	2.637	0.015
No.10	2012/08/07	7.46	51	307	23	19	30	6.4	0.0	116	0.17	21	<0.01	1.8	<0.1	82		57	79	0.007		0.072	0.220	<0.002	<0.006	0.005	0.124	<0.003	1.374	<0.01	<0.01	7.463	0.013
No.13	2012/08/07	6.70	50	304	30	27	13	5.3	0.0	25	<0.1	7	<0.01	<0.05	<0.1	196		75	110	0.006		0.025	0.111	<0.002	<0.006	0.007	0.057	<0.003	0.011	<0.01	<0.01	0.946	0.020
No.15	2012/08/07	7.24	491	4310	424	466	141	33.1	0.0	158	0.14	37	<0.1	<0.5		3055		1059	1910	0.002		0.022	<0.4	<0.002	<0.006	0.010	0.106	<0.003	0.515	<0.01	<0.01	1.986	0.014
No.28	2012/08/07	5.61	101	653	89	41	28	12.7	0.0	6	0.14	38	<0.1	<0.5	1.3	419		222	170	0.027		0.054	<0.4	0.154	<0.006	0.012	0.060	<0.003	19.583	0.140	<0.01	12.837	0.382
No.32	2012/08/07	7.71	212	1581	184	152	61	14.3	0.0	131	0.23	31	<0.1	<0.5		1012		461	622	0.013		0.035	<0.4	<0.002	<0.006	0.008	0.054	<0.003	0.015	<0.01	<0.01	0.148	0.022
No.33	2012/08/07	8.14	202	1513	175	154	55	13.6	0.0	105	<0.1	27	<0.1	<0.5		987		439	631	0.014		0.024	<0.4	<0.002	<0.006	0.009	0.056	<0.003	0.016	<0.01	<0.01	0.611	0.018
R05	2012/08/07	7.86	248	1921	206	194	69	16.5	0.0	100	0.25	36	<0.1	<0.5		1303		516	794	0.016		0.024	<0.4	<0.002	<0.006	0.018	0.054	<0.003	0.012	<0.01	<0.01	0.190	0.022
R04	2012/08/14	8.15	204	1519	184	144	60	14.0	0.0	135	<0.1	33	<0.1	<0.5		953		459	591	0.007		0.034	<0.4	<0.002	<0.006	0.007	0.053	<0.003	0.013	<0.01	<0.01	0.256	0.016
B1 swl	2012/08/14	7.30	98	618	64	40	61	5.6	0.0	77	0.99	17	<0.1	<0.5		356		159	162	0.014		0.082	<0.4	0.002	<0.006	0.007	0.090	<0.003	0.558	<0.01	<0.01	1.844	0.026
R01	2012/08/07	7.82	242	1788	148	215	83	14.6	0.0	65	<0.1	39	<0.1	1.4		1218		369	882	0.009		0.037	<0.4	<0.002	<0.006	0.011	0.058	<0.003	0.014	<0.01	<0.01	3.052	0.022
R02	2012/08/14	6.07	98	650	74	54	24	7.5	0.0	7	<0.1	13	<0.1	<0.5		471		185	223	0.030		0.041	<0.4	<0.002	<0.006	0.020	0.075	<0.003	2.717	0.029	<0.01	6.589	0.074
R03	2012/08/15	6.99	16	108	5	3	21	1.3	0.0	49	0.08	16	<0.01	<0.05	<0.1	11		12	14	0.246		0.060	0.057	<0.002	<0.006	0.004	0.482	<0.003	0.005	<0.01	<0.01	1.006	0.012
Steels Pan	2012/08/07	8.48	783	6335	98	649	546	347.8	83.4	1259	0.14	437	<0.1	<0.5	10.7	2990		246	2660	0.008		0.010	<0.4	<0.002	<0.006	0.014	0.056	<0.003	0.300	<0.01	<0.01	3.515	0.010
Bliksem Pan	2012/08/07	8.55	1105	7958	82	489	1571	131.7	34.4	785	1.06	1463	<0.1	<0.5		3432		205	2005	0.001		0.013	7.484	<0.002	<0.006	0.002	0.084	<0.003	0.165	<0.01	<0.01	2.611	0.001
Sprayer Dam	2012/08/07	8.31	510	4242	421	460	104	38.4	3.4	289	0.25	27	<0.1	<0.5		2906		1053	1885	0.004		0.011	<0.4	<0.002	<0.006	0.006	0.058	<0.003	0.012	<0.01	<0.01	2.234	0.011
T2 Dam	2012/08/07	8.16	661	5778	390	710	113	82.5	0.0	261	<0.1	35	<0.1	<0.5		4191		974	2910	0.005		0.012	<0.4	<0.002	<0.006	0.008	0.059	<0.003	0.013	<0.01	<0.01	1.737	0.013
T3 Dam	2012/08/07	7.99	591	5483	514	620	124	60.4	0.0	160	0.38	26	<0.1	<0.5		3982		1284	2542	0.005		0.012	<0.4	<0.002	<0.006	0.015	0.052	<0.003	0.010	<0.01	<0.01	3.115	0.017
T4 Dam	2012/08/07	7.82	550	4689	486	502	114	42.1	0.0	145	0.42	27	<0.1	<0.5		3377		1215	2060	0.002		0.016	<0.4	<0.002	<0.006	0.009	0.051	<0.003	0.017	<0.01	<0.01	6.317	0.017
T4 Pump	2012/08/07	8.07	502	4166	397	439	96	36.8	0.0	281	0.36	24	<0.1	<0.5	1.1	2892		993	1801	0.004		0.010	<0.4	<0.002	<0.006	0.010	0.048	<0.003	0.009	<0.01	<0.01	2.086	0.016
W04	2012/08/14	7.20	28	185	15	14	12	12.2	0.0	69	1.14	13	<0.01	<0.05	<0.1	48		37	57	0.013		0.163	0.340	<0.002	<0.006	0.005	0.320	<0.003	0.581	<0.01	<0.01	0.086	0.010

SiteName	Date	pH	EC	TDS	Ca	Mg	Na	K	PALK	MALK	F	Cl	NO2_N	NO3_N	PO4	SO4	N_Ammonia	CaHard	MgHard	Al	B	Ba	Br	Co	Cr	Cu	Fe	Mo	Mn	Ni	Pb	Si	Zn
B10	2012/10/04	6.44	269	185	15	14	12	12.2	0.0	69	1.14	13	<0.01	<0.05	<0.1	48		763	1005	0.013		0.163	0.340	<0.002	<0.006	0.005	0.320	<0.003	0.581	<0.010	<0.010	0.086	0.010
BHZ01	2011/02/02	6.75	7	56	3	2	9	2.9		21	<0.2	4		3.3		2		7	7	0.030							<0.01		<0.01				
BHZ02	2011/05/24	6.11	60	464	29	25	43	11.4		13	<0.2	33		49.0		61		73	102	0.020							<0.01		0.100				
BHZ03	2011/05/24	6.28	25	164	12	8	18	8.5		19	<0.2	14		14.8		21		30	31	<0.01							0.890		0.020				
BHZ02	2011/07/13	6.48	38	262	20	13	24	8.6		19	0.25	19		24.2		43		50	55	<0.01							0.010		0.030				
BHZ03	2011/07/13	6.29	25	164	9	6	19	8.7		17	<0.2	16		14.3		18		23	26	<0.01							0.040		<0.01				
BHZ06	2011/10/12	7.59	49	278	43	20	40	6.0		214	0.49	21		<0.01		28		106	84	<0.01							0.110		<0.01				
BHZ07	2011/10/12	7.74	45	268	39	18	33	5.4		211	0.45	16		<0.01		22		96	74	<0.01							<0.01		<0.01				
BHZ06	2012/02/09	7.63	28	196	13	7	38	4.5		69	0.80	24		9.5		19		32	29	<0.01							0.070		0.030				
BHZ07	2012/02/09	7.57	28	192	12	8	35	4.2		69	0.81	23		9.5		19		31	32	<0.01							<0.01		0.020				
BHZ06	2012/05/07	7.99	30	188	15	7	34	3.4		84	0.73	21		4.9		24		37	29	0.050							<0.01		<0.01				
BHZ07	2012/05/07	8.00	30	184	14	7	34	3.4		74	0.72	26		4.9		22		34	29	0.050							<0.01		<0.01				

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Faculty of Natural & Agricultural Sciences
XRD & XRF Facility
Department of Geology
Pretoria 0002, South Africa

Direct Telephone: (012) 420-2722
Direct Telefax: (012) 362 5219
E-Mail: wiebke.grote@up.ac.za
http://www.up.ac.za/academic/science

CLIENT: Altus Huisamen

DATE: 7 June 2015

SAMPLES: 3 Samples

ANALYSIS: Qualitative and Quantitative XRD (mineralogy)

After crushing the sample with a jaw crusher, a representative sample was milled in a tungsten carbide vessel and prepared according to the standardized Panalytical backloading system, which provides nearly random distribution of the particles.

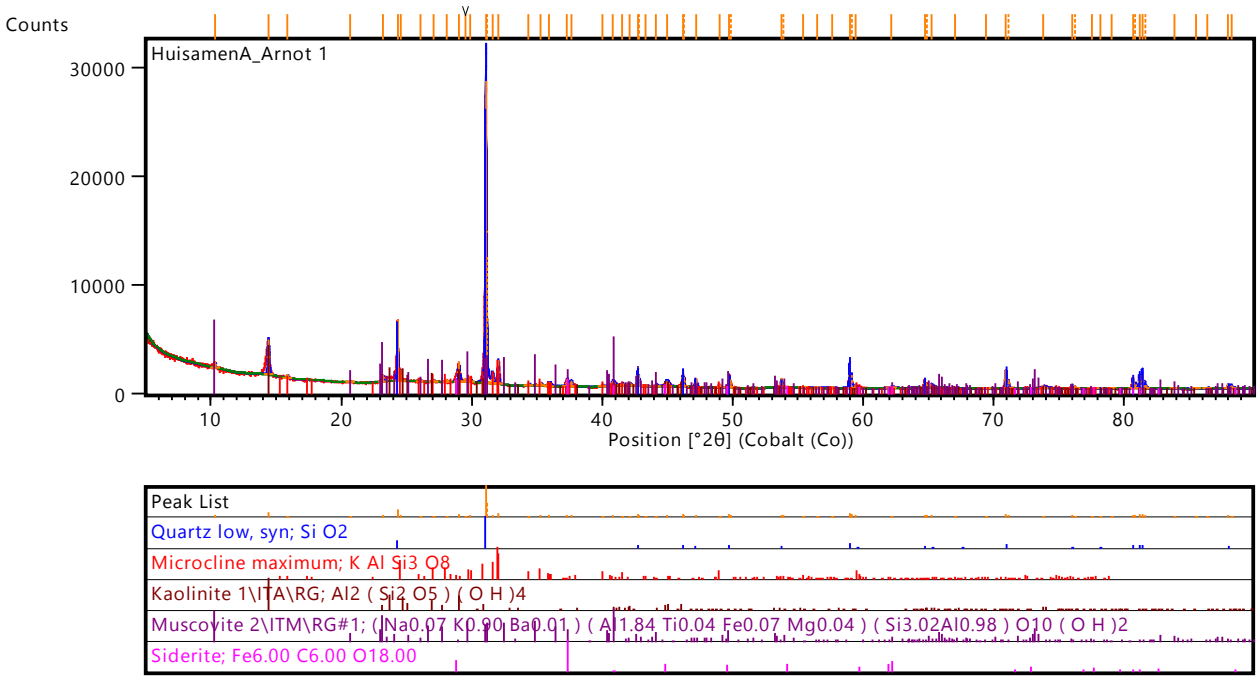
The sample was analyzed using a PANalytical X'Pert Pro powder diffractometer in θ–θ configuration with an X'Celerator detector and variable divergence- and fixed receiving slits with Fe filtered Co-Kα radiation (λ=1.789Å). The phases were identified using X'Pert Highscore plus software. The diffraction traces with the identified phases follow below.

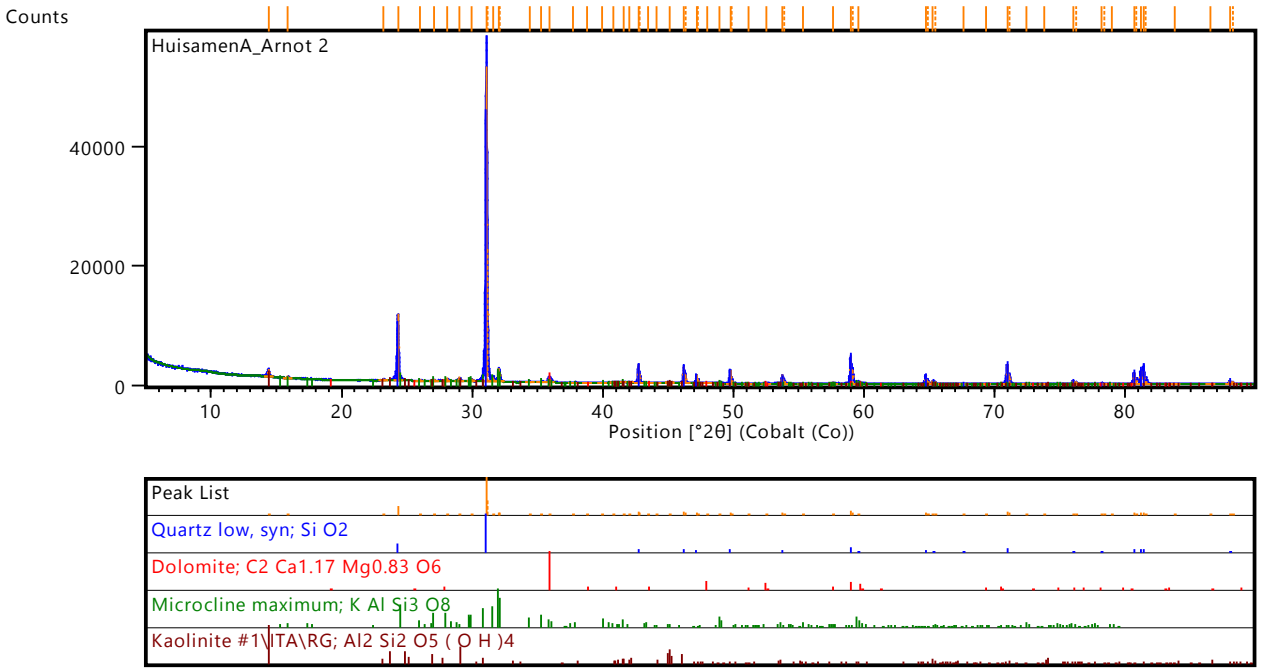
The relative phase amounts (weight%) were estimated using the Rietveld method (Autoquan Program). Errors are on the 3 sigma level in the column to the right of the amount. The quantitative results are listed below.

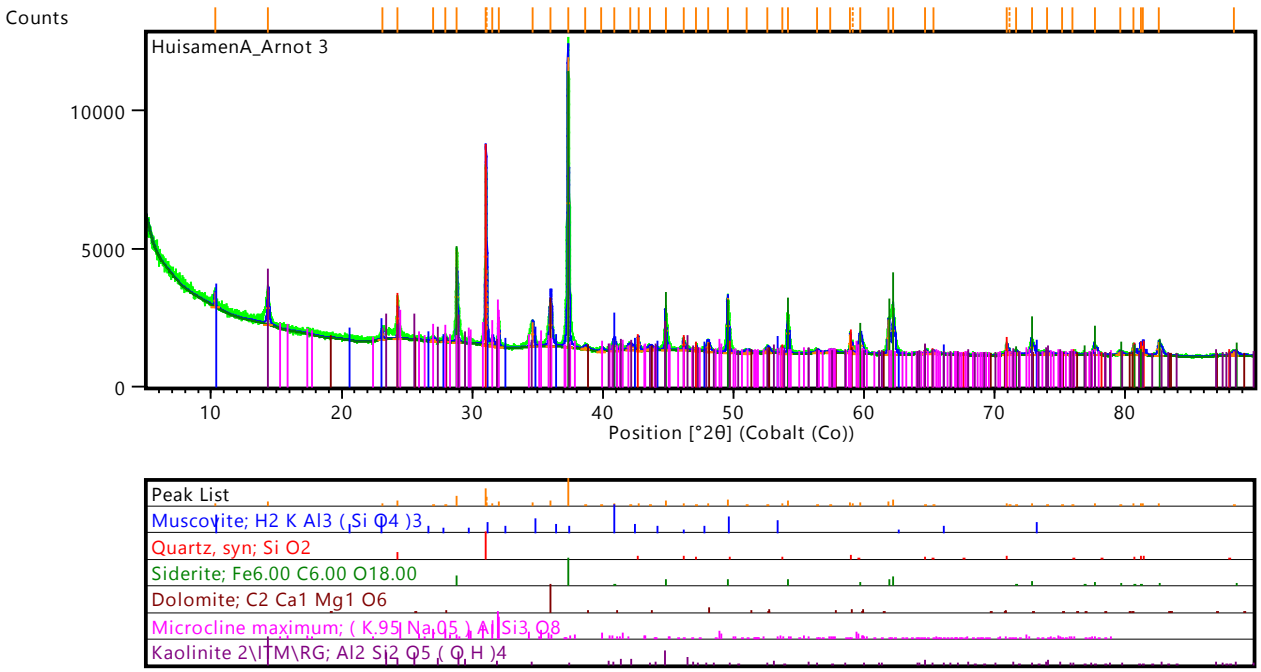
If you have any questions, kindly contact the laboratory.

Analyst:

Wiebke Grote


Counts
HuisamenA_Arnot 1
30000
20000
10000
0
10
20
30
40
50
60
70
80
Position [°2θ] (Cobalt (Co))
Peak List
Quartz low, syn; Si O2
Microcline maximum; K Al Si3 O8
Kaolinite 1\ITA\RG; Al2 (Si2 O5) (O H)4
Muscovite 2\ITM\RG#1; (Na0.07 K0.90 Ba0.01) (Al1.84 Ti0.04 Fe0.07 Mg0.04) (Si3.02Al0.98) O10 (O H)2
Siderite; Fe6.00 C6.00 O18.00


Counts
HuisamenA_Arnot 2
40000
20000
0
10
20
30
40
50
60
70
80
Position [°2θ] (Cobalt (Co))
Peak List
Quartz low, syn; Si O2
Dolomite; C2 Ca1.17 Mg0.83 O6
Microcline maximum; K Al Si3 O8
Kaolinite #1\ITA\RG; Al2 Si2 O5 (O H)4



Quantitative Results:

Arnot 1			**Arnot 2**			**Arnot 3**		
	weight%	3 σ error		weight%	3 σ error		weight%	3 σ error
Kaolinite	24.68	0.84	Dolomite	4.39	0.29	Dolomite	11.33	0.81
Microcline	16.24	0.99	Kaolinite	9.19	0.51	Kaolinite	13.19	0.84
Muscovite	7.1	0.75	Microcline	8.9	0.66	Microcline	5.9	0.6
Quartz	47.25	0.93	Quartz	77.53	0.69	Muscovite	3.1	0.42
Siderite	4.72	0.36				Quartz	15.14	0.66
						Siderite	51.35	0.9

APPENDIX E: Groundwater Monitoring Data

Ground water monitoring point MW 2

Borehole	DATE	TDS mg/l	NO3 mg/l	Cl mg/l	Alkalinity mg/l	F mg/l	SO4 mg/l	Hardness mg/l
MW2	10.08.2002	104	0,01	4	82	0,01	3,3	66
MW2	20.11.2002	140	0,01	3	116	0,1	11,3	103
MW2	28.02.2003	174	0,1	5	134	0,01	16	142
MW2	15.05.2003	108	0,73	5	82	0,01	5,3	79
MW2	21.08.2003	128	0,01	3	110	0,51	3,8	60
MW2	12.11.2003	128	0,01	1	100	0,77	5,2	52
MW2	23.02.2004	125	0,01	2	101	0,53	4,8	55
MW2	15.05.2004	122	0,1	3	104	0,83	2,9	47
MW2	15.08.2004	134	0,1	3	106	0,96	6,5	50
MW2	15.11.2004	120	0,37	3	99	1,19	5,4	46
MW2	15.02.2005	Pipe						
MW2	15.05.2005	174	0,31	4	144	1,06	17,5	43
MW2	15.08.2005	150	0,1	3	122	1,03	10,7	65
MW2	15.11.2005	174	0,21	8	150	0,84	15,1	55
MW2	15.02.2006	136	0,1	3	103	0,82	12,6	53
MW2	15.05.2006	156	0,11	4	100	1,26	18,7	60
MW2	15.11.2006	146	0,1	3	102	0,93	13,8	58
MW2	15.02.2008	180	0,27	3	108	0,96	26,8	77
MW2	15.05.2008	176	0,1	3	106	0,96	28	64
MW2	13.11.2008	170	0,43	5	110	0,7	24,1	62
MW2	13.02.2009	160	0,39	5	105	0,68	23,8	60
MW2	14.05.2009	140	0,1	4	97	0,74	16,2	56
MW2	17.08.2009	140	0,1	4	96	0,76	13,5	54
MW2	20.11.2009	138	0,1	5	96	0,99	18	55
MW2	19.02.2010	138	0,1	4	100	0,63	13,1	59
MW2	17.05.2010	128	0,1	4	89	0,65	11,9	54
MW2	19.08.2010	130	0,22	3	83	0,55	17,2	55
MW2	25.11.2010	122	0,14	5	89	0,51	11,3	55
MW2	17.02.2011							
MW2	20.05.2011							
MW2	19.08.2011							
MW2	10.11.2011							
MW2	14.02.2012							
MW2	20.05.2012							
MW2	14.08.2012	192	0,1	6	116	0,74	34,2	74
MW2	06.11.2012	134	0,45	4,5	91	0,56	16,9	61
MW2	14.02.2013	170	2,77	5,17	97	0,64	22,4	76
MW2	14.05.2013	128	0,38	4,7	91	0,53	7,5	58
MW2	12.08.2013	118	0,44	4,32	88	0,48	7	52
MW2	14.11.2013	122	0,12	5,93	83	0,5	14,4	51
MW2	19.02.2014	106	0,27	4,77	80	0,53	5,8	59
MW2	13.05.2014	116	0,28	4,72	94	0,49	5,95	52

Ground water monitoring point MW 3

	DATE	TDS mg/l	NO3 mg/l	Cl mg/l	Alkalinity mg/l	F mg/l	SO4 mg/l	Hardness mg/l
MW3	15.05.2003	252	0,1	7	184	7,8	4,3	2

MW3	21.08.2003	192	0,01	4	153	5,3	4,3	8
MW3	12.11.2003	193	0,01	4	150	5,2	4,3	8
MW3	23.02.2004	195	0,01	5	151	5,6	4,5	8
MW3	15.05.2004	118	0,12	3	88	1,61	3,4	5
MW3	15.08.2004	108	2,5	7	18	0,2	36,8	40
MW3	15.11.2004	Dry						
MW3	15.02.2005	76	0,1	4	55	0,2	5,6	34
MW3	15.05.2005	94	0,4	3	65	0,2	16,4	33
MW3	15.08.2005	94	0,1	3	70	0,2	10,5	45
MW3	15.11.2005	100	0,16	3	80	0,2	10	47
MW3	15.02.2006	96	0,11	3	66	0,2	11,4	44
MW3	15.05.2006	92	0,26	3	58	0,52	12,8	47
MW3	15.08.2006	98	0,29	4	68	0,2	11,7	44
MW3	15.11.2006	68	0,38	5	32	0,2	13,2	30
MW3	15.02.2007	86	0,16	3	60	0,22	10,6	43
MW3	15.05.2007	88	0,19	3	57	0,2	12	40
MW3	15.08.2007	74	0,39	3	48	0,2	10	36
MW3	15.11.2007	80	0,22	3	50	0,22	9,71	40
MW3	15.02.2008	90	0,3	3	56	0,2	9,1	49
MW3	15.05.2008	96	0,2	5	58	0,2	13,8	247
MW3	20.08.2008	88	0,12	6	58	0,2	11,2	48
MW3	13.11.2008	96	0,24	7	58	0,2	12,6	45
MW3	13.02.2009	86	0,18	5	53	0,2	11,3	42
MW3	14.05.2009	98	0,26	5	61	0,2	15,8	46
MW3	17.08.2009	102	0,2	6	62	0,2	14,5	62
MW3	20.11.2009	110	0,1	6	68	0,41	18,5	49
MW3	19.02.2010	110	0,11	5	56	0,2	25,7	56
MW3	17.05.2010	104	0,31	5	53	0,2	21,3	50
MW3	19.08.2010	130	0,22	3	83	0,55	17,2	55
MW3	25.11.2010	112	0,52	7	59	0,2	25,2	56
MW3	17.02.2011	118	0,51	6	61	0,2	28,9	64
MW3	20.05.2011	156	0,61	13	62	0,2	45,3	86
MW3	19.08.2011	140	0,59	6	60	0,27	38,7	67
MW3	10.11.2011	148	0,66	9	65	0,2	42,1	80
MW3	14.02.2012	112	0,93	5	53	0,31	29,4	60
MW3	15.05.2012	130	0,59	4,9	61	0,2	34,9	68
MW3	14.08.2012	138	0,75	6,9	64	0,2	37,6	67
MW3	06.11.2012	128	0,8	5,5	59	0,2	33,8	64
MW3	14.02.2013	162	1,14	6,53	66	0,2	48,4	95
MW3	14.05.2013	130	1,01	6	59	0,2	34,2	60
MW3	12.08.2013	130	0,88	5,7	55	0,2	39,9	63
MW3	14.11.2013	144	0,59	7,4	59	0,2	44,5	64
MW3	19.02.2014	132	0,63	6,07	51	0,2	44	79
MW3	13.05.2014	114	0,71	5,32	48	0,2	33,1	49

Ground water monitoring point MW 4

	DATE	TDS mg/l	NO3 mg/l	Cl mg/l	Alkalinity mg/l	F mg/l	SO4 mg/l	Hardness mg/l
MW4	10.08.2002	98	0,69	5	70	0,01	9,3	67

MW4	20.11.2002	94	0,9	4	74	0,01	4	67
MW4	28.02.2003	92	0,52	5	70	0,01	5,3	73
MW4	15.05.2003	98	0,62	6	72	0,01	4,5	64
MW4	21.08.2003	84	0,47	2	68	0,01	2,4	58
MW4	12.11.2003	80	0,51	4	70	0,01	3,1	53
MW4	23.02.2004	82	0,73	2	66	0,2	1,9	54
MW4	02.05.2004	blocked						
MW4	15.08.2004	82	0,33	3	66	0,2	2	56
MW4	15.11.2004	88	0,67	5	68	0,2	2,4	60
MW4	15.02.2005	78	0,73	4	58	0,2	1,3	51
MW4	15.05.2005	118	6,4	5	78	0,2	3,2	58
MW4	15.08.2005	82	0,41	4	70	0,2	0,76	57
MW4	15.11.2005	92	0,72	4	72	0,2	2,4	63
MW4	15.02.2006	82	0,01	3	66	0,2	6,11	56
MW4	15.05.2006	76	0,64	3	56	0,45	5,02	52
MW4	15.08.2006	94	0,6	4	75	0,2	3,83	62
MW4	15.11.2006	84	0,1	4	64	0,2	4,5	60
MW4	15.02.2007	82	0,25	3	70	0,2	1	54
MW4	15.05.2007	86	0,62	3	65	0,2	4,7	54
MW4	15.08.2007	84	0,72	3	58	0,2	3,02	57
MW4	15.11.2007	74	0,5	3	51	0,2	3,74	51
MW4	15.02.2008	78	0,25	5	54	0,2	3	49
MW4	15.05.2008	66	0,1	3	52	0,2	3,7	44
MW4	20.08.2008	74	0,19	3	62	0,2	1	52
MW4	13.11.2008	78	0,52	5	60	0,2	1	54
MW4	13.02.2009	64	0,1	5	50	0,2	1	37
MW4	14.05.2009	66	0,1	4	52	0,2	3,5	62
MW4	17.08.2009	60	0,1	4	43	0,2	3,4	97
MW4	Dry							
MW4	19.02.2010	84	0,13	4	68	0,2	4,3	54
MW4	17.05.2010	72	0,1	4	62	0,2	1,6	47
MW4	19.08.2010	60	0,16	4	45	0,2	1,8	39
MW4	25.11.2010	62	0,1	5	49	0,2	1,6	33
MW4	17.02.2011	76	0,15	5	55	0,2	3	45
MW4	20.05.2011	72	0,1	6	53	0,2	3,8	45
MW4	19.08.2011	68	0,1	6	46	0,23	3,8	38
MW4	10.11.2011	88	0,22	7	63	0,2	7	63
MW4	14.02.2012	88	0,18	7	57	0,45	11,7	58
MW4	15.05.2012	70	0,1	5,9	50	0,2	3,7	42
MW4	14.08.2012	62	0,1	10	36	0,2	5,64	40
MW4	06.11.2012	52	0,1	11	27	0,2	2,98	25
MW4	14.02.2013	72	0,15	9,93	49	0,2	5,01	45
MW4	14.05.2013	84	0,19	11	56	0,2	4,3	56
MW4	12.08.2013	100	0,76	10	66	0,2	7,32	62
MW4	14.11.2013	126	1,45	13,1	68	0,2	12,6	71
MW4	19.02.2014	92	0,47	8,41	57	0,2	6,21	63
MW4	13.05.2014	76	0,33	6,38	58	0,2	3,11	41

Ground water monitoring point MW 5

		TDS	NO3	Cl	Alkalinity	F	SO4	Hardness
	DATE	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
MW5	05.11.2001	119,3	0,78	6,95	75	0,03	21,96	86,1
MW5	08.02.2002	368	0,12	6	46	0,03	200	198
MW5	17.05.2002	286	0,1	4	106	0,01	107	185
MW5	10.08.2002	232	0,01	5	130	0,1	45,9	146
MW5	20.11.2002	218	0,01	4	152	0,1	30,6	153
MW5	28.02.2003	410	0,1	4	74	0,03	215	245
MW5	03.05.2003	242	0,1	6	130	0,01	54,8	186
MW5	21.08.2003	204	0,01	1	168	0,01	29,6	165
MW5	12.11.2003	180	0,01	1	166	0,2	4,8	146
MW5	23.02.2004	206	0,1	2	142	0,2	33,8	134
MW5	15.05.2004	164	0,1	4	144	0,2	6,2	111
MW5	15.08.2004	208	0,1	1	168	0,22	15,9	151
MW5	15.11.2004	166	2,1	3	116	0,28	9,4	98
MW5	15.02.2005	108	2,7	3	60	0,2	7,2	48
MW5	15.05.2005	116	2	4	102	0,2	5,2	53
MW5	15.08.2005	122	3,37	3	88	0,2	5,1	69
MW5	15.11.2005	126	1,6	4	113	0,2	3,3	81
MW5	15.02.2006	108	0,1	3	96	0,2	2,08	56
MW5	15.05.2006	98	0,24	2	74	0,2	5,89	50
MW5	15.08.2006	120	0,18	3	99	0,2	2,5	70
MW5	15.11.2006	158	0,35	2	144	0,2	1,2	118
MW5	15.02.2007	118	0,12	2	97	0,2	3,4	66
MW5	15.05.2007	128	0,46	2	110	0,2	3,1	80
MW5	15.08.2007	172	0,17	2	146	0,2	3,44	122
MW5	15.11.2007	178	0,26	3	142	0,22	3,96	150
MW5	15.02.2008	156	0,84	3	124	0,2	4,4	110
MW5	15.05.2008	154	0,24	3	126	0,2	8,3	106
MW5	20.08.2008	150	0,1	2	124	0,2	3,4	107
MW5	13.11.2008	148	0,39	4	127	0,2	2,5	99
MW5	13.02.2009	130	0,5	3	113	0,2	2,6	79
MW5	14.05.2009	150	0,1	3	128	0,2	2	97
MW5	17.08.2009	160	0,99	4	137	0,2	3,6	109
MW5	20.11.2009	144	0,1	4	119	0,52	12,2	103
MW5	19.02.2010	118	0,44	3	60	0,2	22,6	66
MW5	17.05.2010	108	0,1	3	74	0,2	14,6	72
MW5	19.08.2010	98	0,1	2	72	0,2	9,6	70
MW5	25.11.2010	114	0,1	4	87	0,2	5,8	70
MW5	17.02.2011	98	0,1	4	55	0,2	16	63
MW5	20.05.2011	72	0,1	6	53	0,2	3,8	45
MW5	19.08.2011	102	0,1	3	72	0,22	9,5	65
MW5	10.11.2011	112	0,19	4	89	0,2	6,67	77
MW5	14.02.2012	94	0,56	3	58	0,35	12,1	52
MW5	15.05.2012	140	0,1	4	118	0,2	2,5	80
MW5	14.08.2012	134	0,1	5,8	107	0,48	5,02	73
MW5	06.11.2012	122	2,05	6,2	92	0,2	11,3	81
MW5	14.02.2013	146	1,17	6,69	110	0,2	6,05	87

MW5	14.05.2013	286	0,1	9,6	247	0,2	9,9	150
MW5	12.08.2013	244	0,32	8,22	205	0,2	3,6	153
MW5	14.11.2013	238	15,3	7,91	79	0,2	6,83	97
MW5	19.02.2014	96	3,29	3,69	49	0,2	10,7	67
MW5	13.05.2014	98	3,02	3,57	48	0,2	12,8	48

Ground water monitoring point MW 6

		TDS	NO3	Cl	Alkalinity	F	SO4	Hardness
	DATE	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
MW6	05.11.2001	384,8	0,02	4,12	125	0,16	196,18	228
MW6	08.02.2002	308	7,5	9	26	0,01	141	146
MW6	17.05.2002	430	1,1	7	40	0,01	254	215
MW6	10.08.2002	413	0,09	7	42	0,01	225	227
MW6	20.11.2002	726	0,49	11	78	0,1	433	448
MW6	28.02.2003	422	2,1	8	62	0,03	203	249
MW6	03.05.2003	74	0,16	6	50	0,01	4,5	17
MW6	21.08.2003	Dry						
MW6	12.11.2003	288	0,37	2	58	0,2	126	147
MW6	23.02.2004	232	0,1	4	140	0,2	49	151
MW6	15.05.2004	354	0,29	4	58	0,2	179	201
MW6	15.08.2004	192	0,1	3	48	0,2	84,9	91
MW6	15.11.2004	580	1,1	5	86	0,36	358	370
MW6	15.02.2005	680	3,4	5	35	0,3	380	414
MW6	15.05.2005	498	1,1	6	41	0,32	317	266

Ground water monitoring point MW 8

		TDS	NO3	Cl	Alkalinity	F	SO4	Hardness
	DATE	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
MW8	17.05.2002	116	0,1	6	70	0,01	15,3	68
MW8	10.08.2002	104	0,01	6	76	0,07	6,7	71
MW8	20.11.2002	112	0,01	4	86	0,13	9,3	66
MW8	28.02.2003	108	0,01	5	82	0,1	8,7	65
MW8	15.05.2003	84	0,1	8	58	0,03	6,4	46
MW8	21.08.2003	78	0,01	4	62	0,01	2,4	44
MW8	12.11.2003	82	0,94	1	62	0,2	7,2	50
MW8	23.02.2004	68	0,45	6	10	0,2	27,6	34
MW8	15.05.2004	90	0,1	6	46	0,2	22,4	60
MW8	15.08.2004	98	0,1	7	54	0,2	17,1	61
MW8	15.11.2004	68	0,58	9	18	0,2	15,6	30
MW8	15.02.2005	66	0,1	8	32	0,2	7,7	34
MW8	15.05.2005	90	0,1	9	79	0,2	2,6	46
MW8	15.08.2005	80	0,1	8	60	0,2	2,43	48
MW8	15.11.2005	84	0,1	7	58	0,2	4,7	49
MW8	15.02.2006	52	0,4	6	22	0,2	10,9	24
MW8	15.05.2006	66	0,1	3	42	0,2	7,06	43
MW8	15.08.2006	82	0,15	6	64	0,2	2,1	50
MW8	15.11.2006	10	0,1	3	5	0,2	2,6	22

MW8	15.02.2007	78	0,1	5	42	0,2	15,3	46
MW8	15.05.2007	74	0,1	5	47	0,2	11,7	43
MW8	15.08.2007	74	0,1	5	52	0,2	6,84	44
MW8	15.11.2007	68	0,62	6	15	0,2	23,2	29
MW8	15.02.2008	120	0,1	6	36	0,2	42,3	72
MW8	15.05.2008	98	0,1	5	32	0,2	32,9	55
MW8	20.08.2008	94	0,1	4	54	0,2	22	61
MW8	13.11.2008	72	1,1	6	10	0,2	28,5	34
MW8	13.02.2009	110	0,1	5	31	0,2	40,8	56
MW8	14.05.2009	98	0,16	6	52	0,2	19,8	58
MW8	17.08.2009	78	0,1	5	54	0,2	6,5	46
MW8	20.11.2009	110	0,12	7	28	0,49	48,1	69
MW8	19.02.2010	0	0,1	6	56	0,2	30,2	68
MW8	17.05.2010	92	0,1	6	43	0,2	25,5	55
MW8	19.08.2010	94	0,1	6	58	0,2	14,6	55
MW8	25.11.2010	96	0,1	6	66	0,2	10,1	54
MW8	17.02.2011	106	0,1	7	55	0,2	21,2	61
MW8	20.05.2011	88	0,1	6	60	0,2	7,3	56
MW8	19.08.2011	84	0,1	5	54	0,23	7,8	47
MW8	10.11.2011	92	0,1	6	70	0,2	5,8	59
MW8	14.02.2012	116	2,18	7	32	0,32	35,6	58
MW8	15.05.2012	90	0,1	4,9	65	0,2	8	52
MW8	14.08.2012	78	0,1	6	62	0,2	1,11	44
MW8	06.11.2012	104	0,1	8,3	53	0,2	23,6	64
MW8	14.02.2013	120	0,79	8,39	60	0,2	24	76
MW8	14.05.2013	92	0,1	7,9	60	0,2	10,1	60
MW8	12.08.2013	80	0,1	6,66	60	0,2	7,09	45
MW8	14.11.2013	98	0,25	8,98	47	0,2	21	50
MW8	19.02.2014	280	0,22	9,04	151	0,47	12,5	164
MW8	13.05.2014	102	0,1	7,32	70	0,2	5,07	50

Groundwater monitoring point MW10

		TDS	NO3	Cl	Alkalinity	F	SO4	Hardness
	DATE	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
MW10	25.11.2010	2086	0,18	7	6	0,66	1590	1492
MW10	17.02.2011	1284	0,1	6	27	0,49	776	816
MW10	20.05.2011	1016	0,1	5	13	0,49	696	637
MW10	19.08.2011	820	0,1	5	26	0,57	503	538
MW10	10.11.2011	886	0,1	5	27	0,4	572	571
MW10	14.02.2012	938	0,19	6	23	0,66	620	570
MW10	15.05.2012	848	0,1	9,1	19	0,37	557	554
MW10	14.08.2012	842	0,1	5,4	26	0,45	587	530
MW10	06.11.2012	952	0,1	6	19	0,38	622	641
MW10	14.02.2013	1028	0,24	6,05	17	0,49	668	698
MW10	14.05.2013	662	0,12	6,2	25	0,47	431	423
MW10	12.08.2013	524	0,1	4,82	46	0,36	326	321
MW10	14.11.2013	798	0,15	6,06	42	0,29	476	459
MW10	19.02.2014	568	0,1	5,9	25	0,34	369	401
MW10	13.05.2014	412	0,1	5,1	36	0,37	261	243

Groundwater monitoring point MW11

	DATE	TDS mg/l	NO3 mg/l	Cl mg/l	Alkalinity mg/l	F mg/l	SO4 mg/l	Hardness mg/l
MW11	25.11.2010	134	0,16	9	78	0,2	22,1	87
MW11	17.02.2011	306	0,1	7	66	0,2	141	198
MW11	20.05.2011	140	0,1	8	71	0,2	30,6	88
MW11	19.08.2011	138	0,1	8	63	0,46	36,5	85
MW11	10.11.2011	172	0,1	8	72	0,2	51,6	118
MW11	14.02.2012	178	0,21	7	74	0,42	63	116
MW11	15.05.2012	132	0,1	7,7	80	0,2	17,1	83
MW11	14.08.2012	178	0,13	8,8	96	0,2	35,9	103
MW11	06.11.2012	238	0,1	8,7	76	0,2	104	168
MW11	14.02.2013	324	0,24	9,08	84	0,2	142	235
MW11	14.05.2013	144	0,1	8,9	95	0,2	18,7	96
MW11	12.08.2013	148	0,1	8,45	105	0,2	20	100
MW11	14.11.2013	166	0,14	9,37	61	0,2	63	104
MW11	19.02.2014	362	0,11	9,34	41	0,2	204	263
MW11	13.05.2014	298	0,1	10,1	44	0,2	165	199

Groundwater monitoring point MW12

	DATE	TDS mg/l	NO3 mg/l	Cl mg/l	Alkalinity mg/l	F mg/l	SO4 mg/l	Hardness mg/l
MW12	25.11.2010	672	0,1	6	129	0,48	336	414
MW12	17.02.2011	1260	0,1	6	119	0,33	760	914
MW12	20.05.2011	1290	0,1	6	86	0,25	790	954
MW12	19.08.2011	712	0,1	6	92	0,62	432	530
MW12	10.11.2011	802	0,16	5	87	0,37	499	551
MW12	14.02.2012	814	0,28	6	108	0,62	500	526
MW12	15.05.2012	684	0,1	4	128	0,33	366	464
MW12	14.08.2012	456	0,1	5,9	109	0,44	239	318
MW12	06.11.2012	582	0,1	6	97	0,28	352	406
MW12	14.02.2013	1520	0,99	5,15	86	0,25	1039	1211
MW12	14.05.2013	1020	0,1	5,8	82	0,21	628	494
MW12	12.08.2013	642	0,1	5,65	74	0,29	3,85	402
MW12	14.11.2013	774	0,22	6,97	62	0,23	498	480
MW12	19.02.2014	1586	0,1	5,25	70	0,2	1064	1222
MW12	13.05.2014	1062	0,1	5,34	69	0,2	792	866

Groundwater monitoring point MW13

	DATE	TDS mg/l	NO3 mg/l	Cl mg/l	Alkalinity mg/l	F mg/l	SO4 mg/l	Hardness mg/l
MW13	25.11.2010	88	0,1	5	59	0,22	17,1	38
MW13	17.02.2011	74	0,1	5	48	0,33	6,8	39
MW13	20.05.2011	62	0,1	4	41	0,24	4,6	28
MW13	19.08.2011	64	0,1	4	39	0,41	8,1	32

MW13	10.11.2011	60	0,1	5	37	0,2	6,5	35
MW13	14.02.2012	66	0,25	4	40	0,36	7,3	27
MW13	15.05.2012	48	0,1	3,4	32	0,2	4,51	23
MW13	14.08.2012	72	0,1	5,7	45	0,2	8,72	31
MW13	06.11.2012	Inaccessible						
MW13	14.02.2013	Inaccessible						
MW13	14.05.2013	Destroyed						

Groundwater monitoring point MW14

		TDS	NO3	Cl	Alkalinity	F	SO4	Hardness
	DATE	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
MW14	25.11.2010	82	0,1	33	23	0,2	1	42
MW14	17.02.2011	164	0,1	70	19	0,2	8,5	46
MW14	20.05.2011	158	0,1	44	26	0,2	31,4	60
MW14	19.08.2011	118	0,1	40	33	0,36	9,1	33
MW14	10.11.2011	122	0,1	42	36	0,2	8,82	43
MW14	14.02.2012	134	0,22	32	51	0,39	15,7	79
MW14	15.05.2012	84	0,1	15	31	0,2	16,8	41
MW14	14.08.2012	124	0,1	13	49	0,2	31,4	66
MW14	06.11.2012	98	0,1	12	57	0,2	17,9	57
MW14	14.02.2013	180	0,17	28,5	48	0,2	14,8	73
MW14	14.05.2013	114	0,63	48	17	0,2	8	60
MW14	13.08.2013	130	0,1	18	67	0,2	16,6	64
MW14	14.11.2013	104	0,18	16,4	59	0,2	12,7	63
MW14	19.02.2014	126	0,11	26,1	59	0,2	11,5	83
MW14	13.05.2014	246	0,1	118	7	0,2	13,9	54

Groundwater monitoring point MW15

		TDS	NO3	Cl	Alkalinity	F	SO4	Hardness
	DATE	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
MW15	25.11.2010	104	0,1	4	81	0,2	7,6	59
MW15	17.02.2011	126	0,1	3	86	0,2	12,2	78
MW15	20.05.2011	108	0,1	4	88	0,23	3,4	68
MW15	19.08.2011	108	0,1	3	86	0,42	4,4	65
MW15	10.11.2011	112	0,1	5	95	0,21	4,4	75
MW15	14.02.2012	128	0,2	4	99	0,48	8,19	76
MW15	15.05.2012	102	0,1	3,1	84	0,2	3,86	76
MW15	14.08.2012	128	0,1	4,1	98	0,2	9,63	75
MW15	06.11.2012	42	0,18	4,2	23	0,2	5,91	16
MW15	14.02.2013	122	0,85	5,41	92	0,24	7,35	79
MW15	14.05.2013	90	0,1	4,6	70	0,22	5,5	50
MW15	13.08.2013	90	0,1	4,06	74	0,2	3,69	53
MW15	14.11.2013	94	0,1	4,88	78	0,2	3,02	59
MW15	19.02.2014	102	0,1	4,31	82	0,23	3,14	70
MW15	13.05.2014	102	0,1	4,02	78	0,2	6,01	51

Groundwater monitoring point MW16

	DATE	TDS mg/l	NO3 mg/l	Cl mg/l	Alkalinity mg/l	F mg/l	SO4 mg/l	Hardness mg/l
MW16	25.11.2010	416	0,1	11	106	1,24	184	164
MW16	17.02.2011	366	0,98	13	106	1,55	139	127
MW16	20.05.2011	236	0,16	13	131	2,2	43,7	43
MW16	19.08.2011	234	0,1	13	99	2,7	54,4	19
MW16	10.11.2011	214	0,1	15	64	2,49	69,2	24
MW16	14.02.2012	196	0,29	14	101	2,31	36,4	17
MW16	15.05.2012	196	0,1	13	101	2,57	30,5	12
MW16	14.08.2012	224	0,1	15	98	2,79	45,6	16
MW16	06.11.2012	326	0,23	14	177	1,56	95,2	149
MW16	14.02.2013	Inaccessible						
MW16	14.05.2013	Inaccessible						
MW16	13.08.2013	Inaccessible						
MW16	14.11.2013	746	0,24	8,09	205	0,33	292	492
MW16	19.02.2014	412	1,26	20,4	110	0,23	182	285
MW16	13.05.2014	592	0,1	12	92	0,21	392	422

Groundwater monitoring point MW17

	DATE	TDS mg/l	NO3 mg/l	Cl mg/l	Alkalinity mg/l	F mg/l	SO4 mg/l	Hardness mg/l
	DATE	176	0,21	4	130	0,24	20,5	117
MW17	25.11.2010	150	0,11	4	117	0,33	11,1	15
MW17	17.02.2011	130	0,1	4	101	0,25	8,1	85
MW17	20.05.2011	116	0,1	3	91	0,45	5,5	76
MW17	19.08.2011	124	0,1	5	93	0,2	6,4	82
MW17	10.11.2011	106	0,16	4	81	0,54	8,2	65
MW17	14.02.2012	100	0,1	3,3	80	0,2	4,35	64
MW17	15.05.2012	116	0,1	3,9	88	0,2	2,79	64
MW17	14.08.2012	78	0,19	4,1	63	0,2	7,96	61
MW17	06.11.2012	166	9,87	4,58	86	0,22	6,2	90
MW17	14.02.2013	112	0,16	4,8	87	0,22	7	69
MW17	14.05.2013	106	0,12	3,39	85	0,2	4,05	61
MW17	13.08.2013	112	0,16	4,45	93	0,2	4,31	73
MW17	14.11.2013	112	0,16	4,45	93	0,2	4,31	73
MW17	19.02.2014	112	0,18	4,38	93	0,47	5,47	84
MW17	13.05.2014	112	0,15	4	86	0,2	6,94	61

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
13,1	8,11	5,08	1,62	0,75	0,01	18,9	7,09	0,01
23,7	10,7	4,8	3,76	0,01	0,06	23,4	7,02	0,01
33,7	14,1	4,48	3,83	1,39	0,38	25,8	7,28	0,02
18,3	8,14	3,97	2,82	1,04	0,01	18,51	7,47	0,01
15,1	5,45	23,1	3,19	0,31	0,08	22,8	8,08	0,01
12,9	4,91	26,3	2,51	0,01	0,01	22	8	0,01
13,8	5,01	20,5	2,81	0,01	0,01	22,4	8,01	0,01
11,3	4,73	26,5	3,15	0,01	0,05	21,5	8,5	0,06
11,9	4,94	27,6	2,89	0,04	0,04	22,2	8,85	0,1
11,7	4,27	24,7	2,76	0,01	0,03	21,9	7,97	0,05
8,4	5,27	29	3	0,02	0,03	22,3	7,87	0,04
15,6	6,42	26,9	2,74	0,23	0,02	22,3	7,78	0,01
13,5	5,07	25,5	2,52	0,01	0,02	23,6	8,01	0,1
12,5	5,27	26,3	2,75	0,01	0,02	23,4	8,04	0,02
14	6,15	27,5	2,73	0,04	0,03	24,2	7,69	0,09
13,8	5,75	24,6	2,31	0,03	0,01	23,2	8,24	0,01
17,9	7,67	33,6	3,07	0,01	0,01	28	8,16	0,08
15,3	6,32	30,7	2,95	0,01	0,01	28,8	8,14	0,01
14,7	6,04	30,5	2,9	0,01	0,01	25,7	8,13	0,01
14,3	5,73	30	2,93	0,01	0,02	25,9	7,98	0,01
13,4	5,66	26,1	2,54	0,01	0,01	22,93	8,07	0,01
12,8	5,26	24,1	2,63	0,01	0,01	21,6	8,08	0,01
12,8	5,69	24,9	2,71	0,01	0,01	21,1	7,62	0,01
13,6	5,98	21,8	2,68	0,01	0,01	19,8	7,9	0,05
12,7	5,42	22	2,87	0,01	0,01	19,8	7,92	0,01
13	5,62	19,8	2,83	0,01	0,01	20,1	7,59	0,01
13,3	5,25	20,8	3,02	0,01	0,04	18,3	7,76	0,01
17,1	7,6	32	3,25	0,03	0,03	29,3	8,04	0,04
13,2	6,88	19,3	3,56	0,01	0,01	19,4	7,7	0,01
18,7	7,14	26,8	3,67	0,01	0,05	22,6	8,03	0,07
13,8	5,68	18,7	3,12	0,14	0,05	18,4	7,5	0,07
12,2	5,28	18,3	3,14	0,03	0,02	18	7,73	0,06
12,4	4,85	20,2	3,19	0,02	0,01	18,5	7,3	0,01
12,6	6,7	18,8	3	0,04	0,01	17,4	7,77	0,08
11,9	5,24	21,9	3,41	0,05	0,02	17,9	7,84	0,15

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
0,93	0,01	97,7	0,21	1,03	0,01	41,6	8,76	0,01

2,88	0,24	78,1	1,15	0,01	0,02	33,9	8,93	0,01
2,65	0,37	78,5	1,26	0,01	0,01	34,6	8,76	0,01
2,6	0,41	78,1	1,27	0,01	0,01	32,9	8,77	0,01
1,87	0,01	40,9	1,17	0,01	0,04	19,04	8,19	0,05
7,25	5,41	12,9	5,73	0,01	0,08	17,9	6,53	0,08
7,84	3,37	10,8	2,87	0,19	0,12	13,8	7,3	0,01
6,98	3,81	10,3	3,23	0,16	0,07	12,82	7,61	0,02
10,63	4,39	13,2	3,01	0,14	0,07	14,6	7,63	0,01
10,3	5,19	16,5	4	0,01	0,08	15,3	7,8	0,15
9,06	5,08	13,3	3,03	0,02	0,03	15,18	7,54	0,01
10	5,28	9,82	3,11	0,16	0,05	13,9	7,46	0,08
10	4,67	14,3	2,82	0,01	0,01	15,15	7,41	0,01
6,17	3,68	7,6	2,2	0,22	0,01	12,22	7,4	0,01
9,44	4,61	10,9	3,22	0,08	0,03	14,86	7,73	0,01
8,89	4,47	11,2	2,91	0,01	0,03	14,94	7,51	0,08
8,04	3,79	9,37	3,29	0,21	0,03	12,7	7,22	0,01
9,18	4,21	12	2,99	0,02	0,01	14,92	7,54	0,03
10,6	5,49	11,1	3,06	0,03	0,01	14,4	7,43	0,08
9,74	4,77	11,4	3,1	0,01	0,01	15,68	7,58	0,01
10,6	5,37	9,02	3,09	0,15	0,01	14,9	7,44	0,01
10,2	4,8	13,5	3,15	0,01	0,01	16,1	7,87	0,01
9,5	4,45	12,1	3,15	0,01	0,02	15	7,56	0,01
9,86	5,09	13,1	2,88	0,01	0,01	15,99	7,68	0,01
9,95	4,93	14,9	3,03	0,01	0,01	16,7	7,76	0,01
10,4	5,6	16	3,2	0,06	0,01	16,8	7,21	0,01
11,4	6,76	10,4	2,96	0,03	0,01	13,9	7,53	0,06
10,4	5,94	10,8	3,55	0,01	0,01	15,96	7,59	0,01
13	5,62	19,8	2,83	0,01	0,01	20,1	7,59	0,01
12,1	6,34	13,2	3,88	0,4	0,03	17,4	7,82	0,01
13,4	7,49	11,5	3,66	0,01	0,01	18	7,4	0,01
17,7	10,1	14,2	4,23	0,02	0,01	23,7	7,25	0,01
14	7,73	13,6	3,9	0,04	0,01	21,4	7,62	0,01
17,2	9,06	14,4	4,14	0,01	0,03	20,3	7,55	0,03
12	7,25	11,2	3,4	0,04	0	16,6	7,63	0,03
14,8	7,52	13	3,58	0,01	0,01	19,4	7,77	0,04
13,5	8,15	15,7	3,69	0,03	0,01	20,2	7,82	0,03
13,2	7,52	15,6	4,36	0,01	0,01	19,4	7,7	0,01
20,4	10,6	18,8	5,47	0,04	0,03	22,1	7,84	0,07
13	6,69	14,3	4	0,17	0,03	19,6	7,26	0,09
13,2	7,3	15,2	4,09	0,04	0,01	21,2	7,53	0,05
13,5	7,18	16,9	4,54	2,23	0,02	20,8	7,16	0,01
15	10,2	14,8	4,36	0,01	0,01	21,2	7,3	0,07
9,91	5,82	13,9	3,88	0,08	0,02	17,4	7,54	0,14

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
13,9	7,87	5,26	1,42	0,01	0,01	16,94	7,15	0,01

15,5	6,76	5,48	1,2	0,01	0,01	16,78	7,22	0,01
17,3	7,25	4,46	1,1	0,01	0,01	15,6	7,47	0,05
15,8	6,13	6,7	0,74	1,48	4,97	15,6	7,56	0,01
14,3	5,42	5,85	1,24	0,01	0,04	14,67	7,33	0,01
14,2	5,31	5,68	1,33	0,01	0,01	15,26	7,45	0,01
13,7	4,96	5,42	1,57	0,01	0,14	14,48	7,05	0,01
13,5	5,38	5,69	1,17	0,01	0,04	14,17	6,96	0,11
14,5	5,73	5,6	1,11	0,01	0,03	15,2	7,36	0,07
12,5	4,94	5,22	1,04	0,24	0,07	14	7,76	0,01
13,8	5,73	6,26	1,02	0,3	0,04	13,44	7,04	0,03
13,7	5,59	5,73	0,91	0,44	0,04	12,69	7,22	0,01
14,9	6,21	6,09	1,1	0,13	0,02	14,11	7,43	0,09
12,4	6,18	5,44	1,36	0,01	0,06	12,5	7,43	0,01
11,5	5,51	5,6	1,05	0,36	0,01	12,4	7,06	0,08
14,6	6,2	6,99	0,8	0,63	0,01	14,4	7,16	0,01
14	6,01	5,03	0,61	2,38	0,07	14,76	7	0,01
13,2	5,03	6	0,48	0,43	0,08	13,77	7,74	0,01
12,7	5,5	6,3	1,11	0,14	0	14,1	7,59	0,1
13,5	5,54	5,86	1,2	0,14	0,03	14,05	6,76	0,01
12	5,06	5,9	1	0,52	0,02	13,4	7,63	0,09
11,6	4,95	8,26	1,51	0,29	0,01	12,11	7,6	0,09
11,2	3,85	5,06	2,06	0,09	0,03	14,2	7,55	0,01
12,6	4,99	5,21	0,88	0,19	0,01	12,4	6,97	0,02
12,7	5,25	7,35	1,06	0,11	0,01	13,47	7,59	0,01
9,11	3,51	6,86	1,23	0,25	0,01	11,2	7,16	0,01
9,19	3,63	7,25	1,58	0,39	0,04	10,82	7,37	0,02
8,64	3,8	6,03	1,11	0,01	0,04	10,8	7,79	0,01
12,3	5,63	7,55	1,02	0,15	0,01	12,5	7,25	0,06
11,1	4,71	6,98	0,95	0,16	0,08	12,1	7,23	0,01
9,37	3,85	4,54	0,87	0,16	0,04	10,1	7,3	0,01
7,74	3,36	7,94	1,5	0,14	0,03	9,2	7,58	0,01
10,5	4,61	7,95	0,76	0,4	0,01	11,1	7,92	0,01
10,5	4,71	7,44	0,89	0,14	0,01	11,4	7,12	0,01
9,44	3,34	6,09	0,82	1,05	0,02	10,4	7,2	0,01
12,3	5,98	8,56	1,07	2,07	0,04	11,3	7,22	0,05
12,8	6,25	7,19	0,77	0,14	0,01	11,6	7,36	0,02
10,2	4,01	6,38	0,69	0,04	0,09	11	7,27	0,04
9,85	3,63	5,09	0,65	0,12	0,03	9,28	7,23	0,03
6,07	2,47	8,12	1,19	0,01	0,01	8,5	7,46	0,05
11,3	4,05	8,23	1,98	0,05	0,05	15,2	7,67	0,07
13,2	5,62	8,92	3,02	0,58	0,08	11,7	7,19	0,14
14,6	6,23	8,93	1,41	0,41	0,07	17	6,82	0,1
16,5	7,36	10,1	1,61	0,21	0,01	18,1	7,31	0,1
13,7	6,88	9,26	1,11	0,13	0,01	14	7,11	0,08
9,6	4,15	10	1,2	0,18	0,03	11,7	7,19	0,13

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
19,62	9,03	7,99	4,36	0,16	1,1	19	6,76	0,01
43,9	21,4	12,1	2,26	3,49	2,24	55,1	6,21	0,03
35,6	23,3	9,44	1,9	0,27	1,32	43,2	7,04	0,01
29,5	17,6	9,52	1,43	0,01	1,03	35	6,99	0,01
33,9	16,6	9,75	3,43	0,01	0,96	34,3	7,08	0,01
58	24,3	8,67	3,75	0,01	4,47	52,5	6,73	0,08
40,2	20,8	9,4	3,88	1,04	0,95	50,3	7,53	0,01
34,3	19,3	10,8	4,42	0,01	1,25	40,1	7,38	0,01
30,3	17,1	11,3	3,73	0,01	0,71	34,7	7,58	0,01
19,6	20,7	11,8	6,93	0,01	0,54	40,7	7,98	0,01
18,8	15,5	11,2	6,69	0,11	0,1	30,2	8,83	0,05
35,1	15,2	10,7	3,88	0,04	0,77	35,8	7,68	0,08
19,5	11,8	10,9	3,97	0,01	0,14	25,6	7,69	0,03
9,51	5,86	9,39	4,27	0,18	0,15	16,7	7,26	0,01
6,74	6,35	11,6	5,34	0,01	0,04	17,4	8,29	0
15,9	7	10,6	4,33	0,76	0,17	17,88	7,31	0,01
17,4	9,1	12,3	6,07	0,01	0,01	17,6	7,76	0,08
12,2	7,4	12,5	5,14	0,01	0,05	16,64	8,23	0,02
10,9	5,63	10,4	5,05	0,02	0,01	15	7,78	0,09
16,3	7,1	10,4	4,3	0,01	0,06	19,93	7,89	0,01
27,2	12,1	10,3	3,27	0,05	0,19	27,4	7,9	0,01
13,3	8,12	12,6	5,56	0,01	0,08	19,23	8,33	0,01
17	9,23	10,3	3,62	0,01	0,08	22,6	7,98	0,07
29,7	11,6	10,7	3,15	0,04	0,58	29,2	7,32	0,01
31,1	12,7	11,7	3,32	0,2	0,47	30,2	7,82	0,02
24,9	11,6	12,2	3,85	0,01	0,11	24,5	7,92	0,07
26	10,2	10,4	3,31	0,2	0,19	25,4	7,89	0,01
25,3	10,8	10,7	3,65	0,01	0,01	24,5	7,9	0,01
22,7	10,2	12,1	4,15	0,01	0,01	24	8,22	0,01
17,8	8,43	11,9	4,47	0,01	0,06	22,1	7,84	0,01
22	10,2	11,8	4,17	0,01	0,25	25,62	7,85	0,01
26,2	10,8	11,9	4,24	0,01	0,2	27,4	7,76	0,01
25,6	9,42	11,6	4,82	0,01	0,18	24,2	7,63	0,01
20,9	3,37	4,45	4,61	0,08	0,01	15,5	7,26	0,05
22,4	3,98	5,17	4,35	0,01	0,01	17,26	7,93	0,01
21,5	3,88	2,94	4,39	0,01	0,03	16,5	7,73	0,01
21,8	3,94	6,36	5,08	0,02	0,02	15,8	7,92	0,01
20,5	2,89	4,17	4,9	0,31	0,01	14	7,62	0,01
10,5	4,71	7,44	0,89	0,14	0,01	11,4	7,12	0,01
21,4	2,98	3,86	5,45	0,15	0,07	16,1	7,74	0,01
22,7	4,96	7,19	5,39	0,03	0,04	16,5	7,82	0,03
15,6	3,15	5,31	5,37	0,06	0,03	13,4	7,75	0,06
22,9	5,63	5,94	7,44	4,81	0,56	29,3	7,28	0,04
21	4,96	6,54	7,7	4,57	0,44	32,3	7,4	0,03
24,2	4,89	8,12	8,05	0,01	0,01	26	7,42	0,05
26,1	5,28	7,87	10,6	6,49	0,26	26,7	7,09	0,07

33,9	15,8	18,9	13,3	13,6	0,43	52,5	7,1	0,09
34	16,6	12,3	12,4	10,6	0,11	46,1	7,45	0,05
25,8	8	12,2	10,9	0,3	0,12	36,6	7,23	0,07
21,2	3,37	4,24	5,92	0,05	0,18	14,6	6,79	0,09
16,3	1,81	4,46	6,37	1,3	0,09	14,4	7,05	0,14

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
59,03	19,63	22,65	7,12	0,07	0,15	47	7,73	0,01
22	22,2	23	3,51	0,01	0,07	43,2	6,32	0,01
41,6	26,9	29,4	3,61	0,01	0,2	62,5	7,06	0,01
38,4	25,7	28,3	3,88	0,01	0,01	64,4	6,99	0,01
99	48,9	30,9	8,8	0,85	0,33	90,8	6,87	0,01
54,3	27,5	21,1	5,83	0,01	0,1	55,1	6,92	0,07
4,47	1,56	15,3	3,47	1,08	0,01	12,17	7,62	0,01
24,3	21	23	7,02	0,01	0,02	41,4	8,28	0,01
19,7	24,9	20,6	6,55	0,01	0,32	38,4	7,67	0,01
35,6	27,2	23,6	6,16	0,1	0,15	54,1	7,64	0,04
17	12	21	4,93	0,04	0,06	31	8,01	0,09
60,7	53,1	24,2	6,68	0,01	0,76	81,4	7,62	0,04
62,2	62,9	23,3	7,27	0,13	1,06	90,8	6,4	0,01
39,7	40,5	28,7	7,44	0,03	0,23	64,2	7,07	0,02

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
15,4	7,28	6,7	1,31	0,01	0,17	19,1	7,7	0,01
14,5	8,55	6,82	1,18	0,01	0,01	19,17	7,58	0,01
16,8	5,92	10,6	2,87	0,01	0,01	18,76	7,77	0,01
15,6	5,82	8,12	1,98	0,01	0,01	19,21	7,65	0,01
10,4	4,92	8,3	2,94	1,04	0,01	14,3	7,83	0,01
10,8	4,17	7,41	3,21	0,01	0,09	13,73	8,21	0,01
12,7	4,26	10,2	2,48	0,01	0,1	14,95	7,55	0,01
6,94	4	4,04	3,18	0,01	0,3	12,5	6,22	0,01
12,5	7,01	6,02	3,18	0,01	0,08	17,08	7,96	0,03
14,5	6,19	7,27	3,2	0,01	0,18	17,28	7,78	0,08
6,72	3,35	5,21	2,57	0,01	0,01	11,25	7,4	0,03
7,72	3,52	4,78	2,55	0,13	0,17	11,6	7,49	0,01
8,7	4,57	6,72	2,99	0,01	0,2	12,8	7,49	0,01
11,4	4,5	7,55	2,82	0,14	0,18	13,77	7,4	0,01
11,8	4,85	6,92	2,85	0,01	0,28	13,31	7,51	0,08
4,25	3,37	5,49	2,36	0,48	0,07	8,17	6,63	0,01
9,51	4,58	5,48	2,98	0,08	0,16	11,67	6,95	0,06
12,7	4,41	7,4	2,7	0,01	0,12	12,6	7,65	0,01
0,01	0,45	1,34	0,94	0,1	0,01	2,87	6,68	0,06

11,7	4,18	5,32	2,83	0,01	0,21	13,4	8,04	0,01
9,52	4,5	6,02	3,03	0,01	0,2	13,3	7,73	0,07
10,8	4,21	6,18	3,05	0,02	0,2	13,49	7,47	0,01
6,19	3,45	4,3	2,98	1,01	0,11	10,4	6,41	0,03
16,1	7,83	6,2	3,98	0,14	0,31	77,8	7,56	0,07
11,9	5,97	4,4	3,93	0,11	0,25	15,4	7,01	0,01
14,8	5,89	5,47	3,2	0,01	0,16	15,6	7,2	0,01
7,1	3,84	4,84	2,85	0,01	0,08	10,76	6,82	0,01
12,7	5,91	5,76	3,46	0,6	0,33	16,6	6,54	0,01
13,5	6	6,82	3,12	0,47	0,16	16,14	7,5	0,01
10,3	4,9	5,99	2,91	0,01	0,06	13,4	7,93	0,01
14,7	7,76	6,51	4,43	1,17	0,33	18,4	6,46	0,01
15,9	6,89	7,13	3,4	0,13	0,23	17,1	7,2	0,05
12	6,02	6,5	3,82	0,14	0,24	15,4	7,22	0,01
13	5,46	7,19	3,35	0,01	0,18	14,7	7,62	0,01
14,5	4,38	8,93	3,28	0,03	0,14	13,4	7,51	0,01
14	6,24	7,43	3,52	0,01	0,22	15,3	7,15	0,01
12,7	5,93	8,47	3,41	0,01	0,12	14,3	7,79	0,01
10,7	4,9	6,98	3,27	0,18	0,14	13,6	7,67	0,01
13,2	6,37	9,24	3,24	0,01	0,14	13,4	7,48	0,05
12,3	6,61	7,38	4,53	0,09	0,22	15,7	6,69	0,07
11,7	5,61	7,88	3,55	0,01	0,13	14,5	7,48	0,05
9,68	4,73	7,93	2,92	0,03	0,1	13,2	7,62	0,03
15,4	6,29	9,84	4,17	0,01	0,16	15,8	7,54	0,05
18,4	7,21	10,3	5,09	0,4	0,27	16,8	7,73	0,09
13,5	6,28	9,52	4,36	0,42	0,14	13,9	7,26	0,09
10,9	4,24	9,22	3,32	0,47	0,13	12,9	7,27	0,06
11,4	5,27	8,24	3,76	0,58	0,19	14,5	7,17	0,11
39,3	16	9,07	7,01	46	0,96	50,5	6,73	0,07
10,9	5,62	8,28	4,6	4,37	0,27	15,2	6,91	0,16

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
296	183	12,9	22,3	27,6	51,6	233	5,73	0,07
166	97,5	11,7	14,7	7,82	26,9	145	5,9	0,13
135	72,8	11,3	13,2	3,17	20,4	118	6,13	0,01
118	59	10,1	11,2	1,35	15	99,8	6,24	0,01
125	62,9	12,2	11,3	0,15	15,6	107	6,24	0,05
125	62,8	12,4	11,8	0,39	14,9	113	6,39	0,03
122	60,5	11,7	11,3	0,29	14	110	6,47	0,06
116	58,4	12,3	11,3	0,12	12,1	103,8	6,42	0,03
142	69,7	15,1	13,6	0,01	14,4	110	6,01	0,04
155	75,5	15,2	15,8	0,18	14,5	107	6,72	0,1
89,6	48,3	12,8	12,2	0,15	8,26	88,2	6,58	0,1
67,9	36,9	11,7	10,2	0,76	3	71,4	7,14	0,08
101	50,3	13,1	12	29,2	8,16	89,3	6,64	0,7
86,4	45	13,8	11,6	0,05	2,43	76,3	7,12	0,08
56,6	24,8	15,3	12,9	0,04	0,11	58,2	7,26	0,16

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
23,1	7,13	10,8	1,95	0,84	0,04	20,6	7	0,01
46,5	20	10,8	2,04	0,01	0,51	41,4	6,81	0,01
20,2	9,35	9,64	1,15	0,09	0,1	20,4	6,99	0,01
20,5	8,2	8,79	1,34	0,37	0,16	20,6	7,07	0,01
26,8	12,3	10,8	1,54	0,01	0,12	25,2	7,04	0,03
26,3	12,2	10,6	1,35	0,22	0,15	27,7	7,35	0,05
19,7	8,36	8,03	0,99	0,27	0,11	20,4	7,53	0,06
23,6	10,65	12,4	2,25	0,1	0,15	22,3	7,29	0,03
39,4	17	13,3	1,82	0,16	0,08	34,8	7,43	0,05
49,4	27,3	14,1	1,91	0,3	0,22	40,9	7,66	0,09
22,3	9,83	10,9	1,41	0,43	0,26	22,1	7,34	0,02
25,3	8,89	11,1	1,23	0,66	0,21	21,8	7,12	0,06
23,6	10,9	12,9	1,7	1,59	0,05	25,6	7,08	0,1
51	33,3	12,4	1,28	0,02	0,18	49,7	6,81	0,08
36,6	26,2	14,4	1,68	1,7	0,23	45,5	6,82	0,17

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
101	39,4	29,8	11,3	0,01	0,44	81,6	7,24	0,01
137	139	20,8	7,2	0,2	1,2	147	7,21	0,01
115	162	21,9	6,33	0,01	1,18	150	1,09	0,01
66,7	88,2	17,2	7,3	1,96	0,81	95,3	7,24	0,01
74,3	88,8	19,9	7,69	0,31	0,66	98,2	7,21	0,03
69,3	85,7	20,8	7,28	0,11	0,59	98,6	7,71	0,04
71,8	69,1	16,2	7,91	0,01	0,84	89,6	7,79	0,05
47,7	48,3	17,2	7,66	0,07	0,32	66,1	7,99	0,04
61,2	61,5	19,1	8,22	0,49	0,36	77,8	7,87	0,07
147	205	25,5	9,04	0,14	1,05	160	7,95	0,12
71,8	120	26,1	7,37	0,25	0,64	128	7,27	0,14
41,7	72,3	18,8	6,69	0,03	0,29	83,2	7,9	0,08
60,1	80,3	20,3	6,91	0,72	0,47	90,4	7,02	0,17
125	221	28,6	6,4	0,38	1,09	183	7,15	0,35
84,9	159	25,5	4,97	0,12	0,82	147	7,08	0,18

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
9,27	3,71	6,58	3,3	1,28	0,07	11,4	6,88	3,93
9,84	3,29	7,32	4,08	0,01	0,01	11,1	7,89	0,01
6,14	3,21	8,06	3,1	0,14	0,04	8,64	6,68	0,03
6,66	3,56	6,51	2,98	0,27	0,05	9,59	6,92	0,01

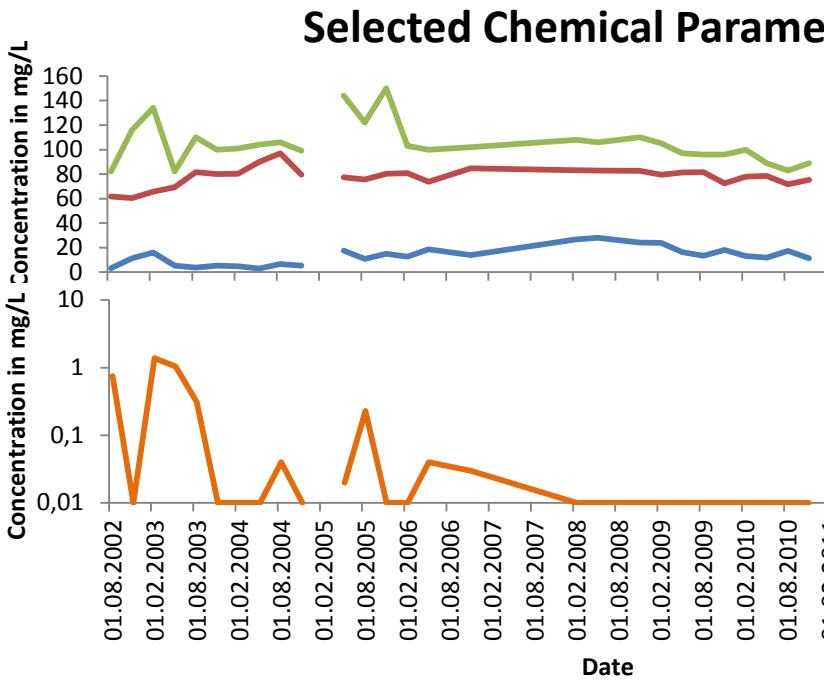
7,78	3,98	7,58	3,09	0,04	0,05	9	6,84	0,05
5,89	2,92	8,78	3,65	0,09	0,06	9,03	7,25	0,07
4,89	2,58	6,18	2,58	0,15	0,01	7,83	7,15	0,07
6,56	3,64	9,06	3,84	0,09	0,04	8,63	6,76	0,03

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
8,99	4,9	7,61	4,48	0,04	0,56	15,9	6,02	0,01
7,93	6,31	31,3	3,73	0,01	0,42	29,2	5,41	0,01
13,1	6,68	23,9	3,43	0,01	0,57	24,2	6,14	0,01
6	4,39	24,5	4,19	0,13	0,17	21,2	7,28	0,01
8,26	5,24	23,2	3,71	0,01	0,17	19,6	7,28	0,03
18,1	8,3	10	4,66	0,02	0,68	18,3	7,06	0,03
9,4	4,37	8,17	4,73	0,01	0,55	15,9	6,68	0,05
15,5	6,74	10	2,74	0,03	0,57	17,8	6,64	0,03
13,9	5,5	11	2,81	0,72	0,58	15,7	6,74	0,5
20,4	5,46	13,9	3,17	54,4	0,85	38,1	5,06	0,13
10	8,63	9,26	11,6	1,03	0,45	17,6	6,77	0,28
15,9	5,96	10,9	2,93	4,49	0,64	19,2	6,62	0,17
15,6	5,91	10,9	2,89	1,4	0,59	16,7	6,92	0,11
20	8,07	10,8	2,7	0,07	0,83	20,4	6,88	0,07
8,9	7,82	62,9	6,03	0,04	0,39	42	5,94	0,15

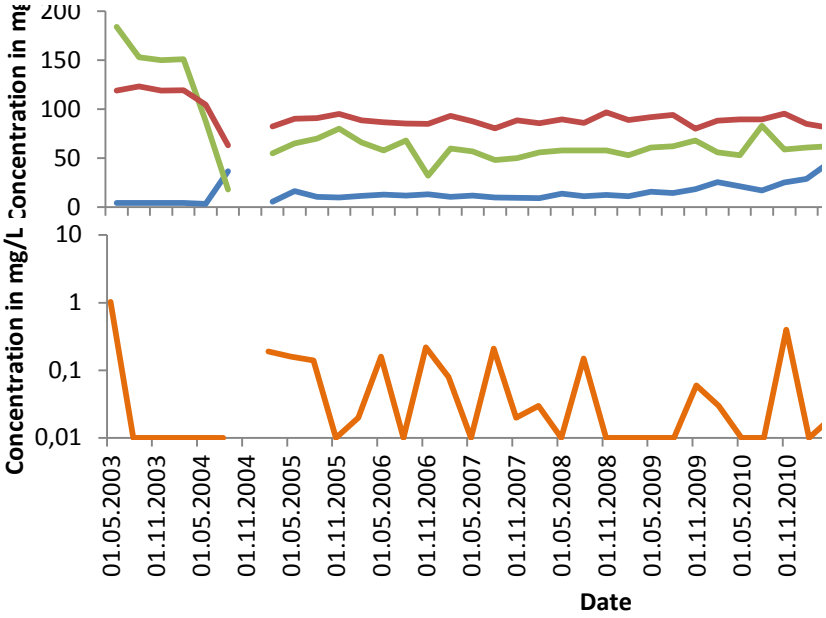
Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
16,2	4,69	8,16	3,54	0,39	0,06	15,1	7,9	0,57
21	6,42	11,8	3,56	1,26	0,12	19,2	4,61	0,1
17,3	6,15	10,9	3,62	0,01	0,01	16,9	7,93	0,01
17	5,56	9,35	3,75	0,03	0,01	17,5	7,94	0,01
18	7,33	12,4	3,89	0,02	0,02	17,2	8	0,05
18,3	7,18	11,4	3,61	0,01	0,01	17,4	8,04	0,03
16,5	6,02	9,4	3,6	0,02	0,01	17,3	8,13	0,07
18,6	7,03	10,6	3,78	0,02	0,01	18,8	7,99	0,04
3,28	1,92	6,56	1,57	0,11	0,01	7,69	7,79	0,2
20,2	6,89	13,6	4,97	0,09	0,1	16,5	8,2	0,09
12,8	4,41	10,6	4,15	0,56	0,09	14,4	7,54	0,06
13,3	4,81	10,9	3,62	0,11	0,07	15,7	7,67	0,07
14,3	5,52	11,8	3,77	0,24	0,03	15,2	7,37	0,15
17	6,6	11,1	4,14	0,06	0,01	15,8	7,98	0,08
12,4	4,74	11,6	3,98	0,16	0,03	15,6	7,86	0,17

Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
36,6	17,8	59,4	5,86	0,01	1,38	59	7,24	0,01
26,4	14,8	63,3	3,6	0,01	0,49	52,7	7,37	0,01
8,25	5,45	66,8	2,31	0,02	0,01	36,1	8,61	0,04
3,88	2,29	67,3	3,11	0,05	0,01	35,7	9,4	0,06
5,05	2,68	66,3	2,67	0,01	0,02	32,8	8,92	0,16
4,12	1,77	60,9	1,69	0,06	0	29,9	8,01	0,13
3,06	0,94	58,6	2,26	0,03	0,01	31,6	9,45	0,21
3,91	1,41	63,9	2,7	0,34	0,01	33,4	9,2	0,11
27,2	19,7	65,8	5,3	0,01	0,29	52,6	7,6	0,06
90,1	65	16,3	12,5	3,1	6,85	89,1	6,75	0,15
54,5	36,1	19,6	11,5	0,03	4,66	61,4	7,39	0,09
73,2	58	18	14,1	0,21	11,1	90,7	6,1	0,17

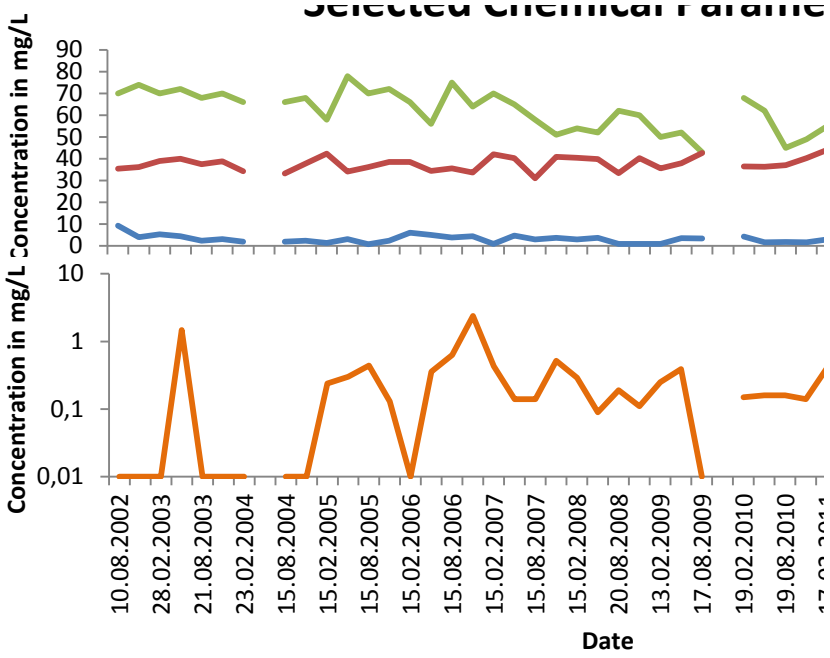
Ca	Mg	Na	K	Fe	Mn	Ec	pH	Al
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mS/m		mg/l
30,4	10	8,85	6,49	0,01	0,27	26,9	7,72	0,01
27,4	8,96	9,71	5,22	0,01	0,11	22,8	7,49	0,1
21,7	7,57	9,94	4,88	0,02	0,01	19,9	7,65	0,01
19,7	6,48	8,23	4,84	0,04	0,01	18,6	7,93	0,01
20,5	7,49	10,6	4,76	0,01	0,02	17,1	7,64	0,08
16,2	6,04	8,84	4,4	0,01	0,01	17,2	7,71	0,02
15,9	5,86	8,35	4,19	0,01	0,01	16,4	7,3	0,06
16,3	5,66	8,95	4,22	0,01	0,08	16,4	7,75	0,03
15	5,79	4,5	4,88	0,01	0,01	16,4	7,79	0,02
23,3	7,73	11,3	5,8	0,06	0,03	17,8	8,4	0,09
17,2	6,25	9,5	5,59	0,18	0,03	17,2	7,56	0,12
15,3	5,65	9,33	4,35	0,05	0,02	16,6	7,53	0,06
18,1	6,9	10,6	4,95	0,07	0,02	17	7,34	0,1
18,1	6,9	10,6	4,95	0,07	0,02	17	7,34	0,1
20,8	7,72	9,83	4,63	0,03	0,02	18,1	7,63	0,1
14,8	5,87	10,6	5,13	0,03	0,09	17,2	7,44	0,13

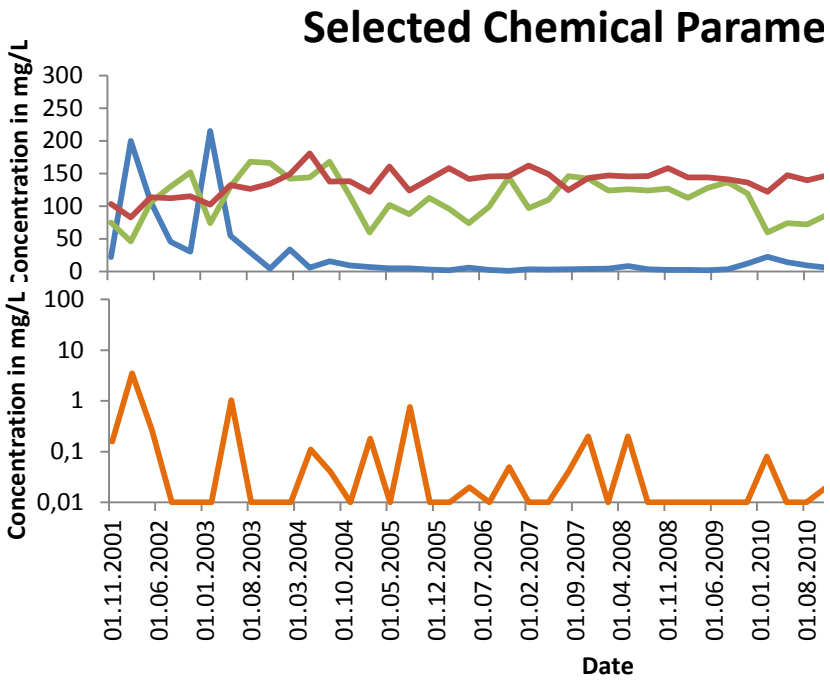

Selected Chemical Parame
Concentration in mg/L
160
140
120
100
80
60
40
20
0
10
1
0,1
0,01
01.08.2002
01.02.2003
01.08.2003
01.02.2004
01.08.2004
01.02.2005
01.08.2005
01.02.2006
01.08.2006
01.02.2007
01.08.2007
01.02.2008
01.08.2008
01.02.2009
01.08.2009
01.02.2010
01.08.2010
Date

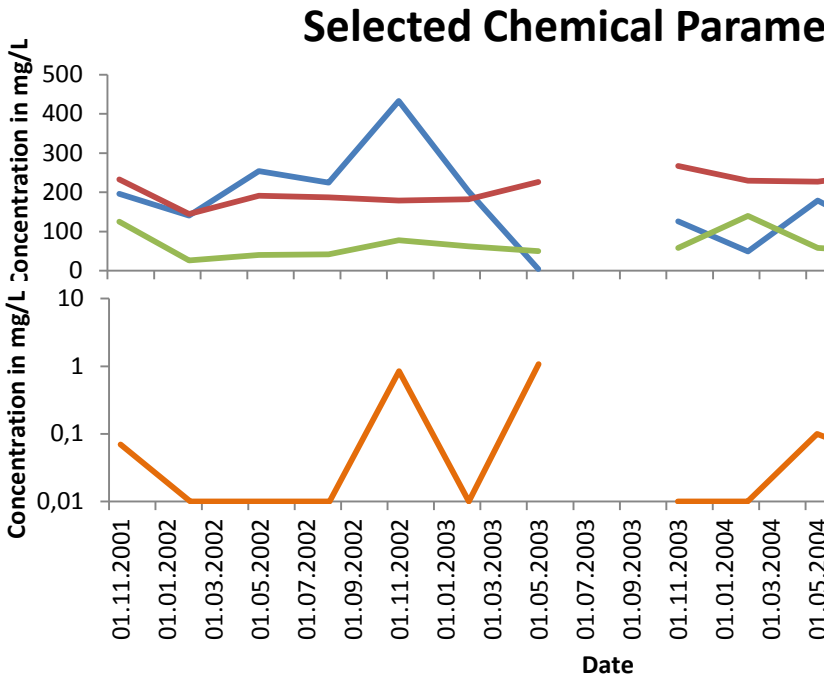
Selected Chemical Parame

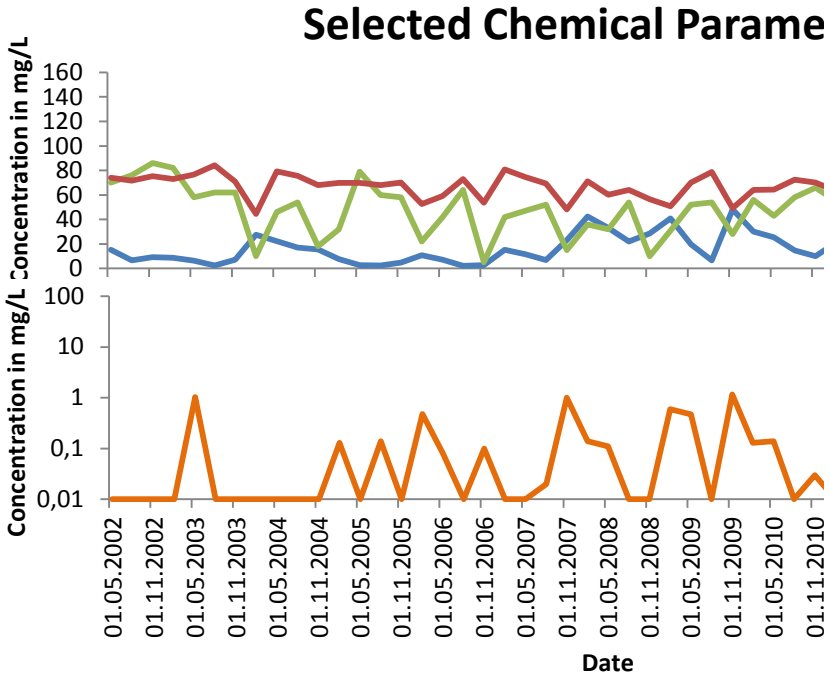


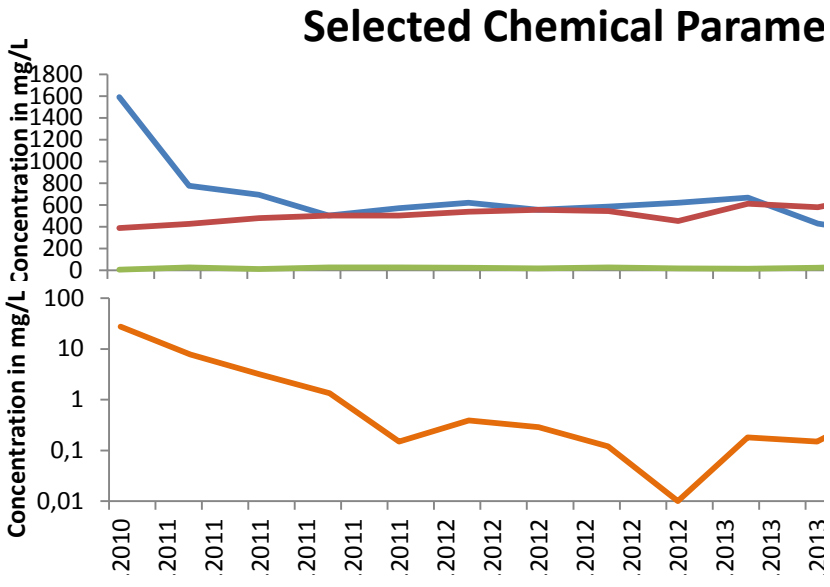
Selected Chemical Parame

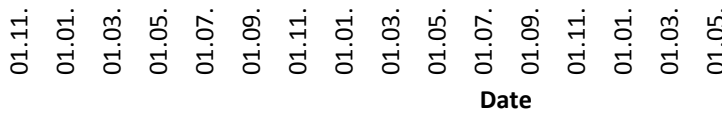

Concentration in mg/L
90
80
70
60
50
40
30
20
10
0
10
1
0,1
0,01
10.08.2002
28.02.2003
21.08.2003
23.02.2004
15.08.2004
15.02.2005
15.08.2005
15.02.2006
15.08.2006
15.02.2007
15.08.2007
15.02.2008
20.08.2008
13.02.2009
17.08.2009
19.02.2010
19.08.2010
Date

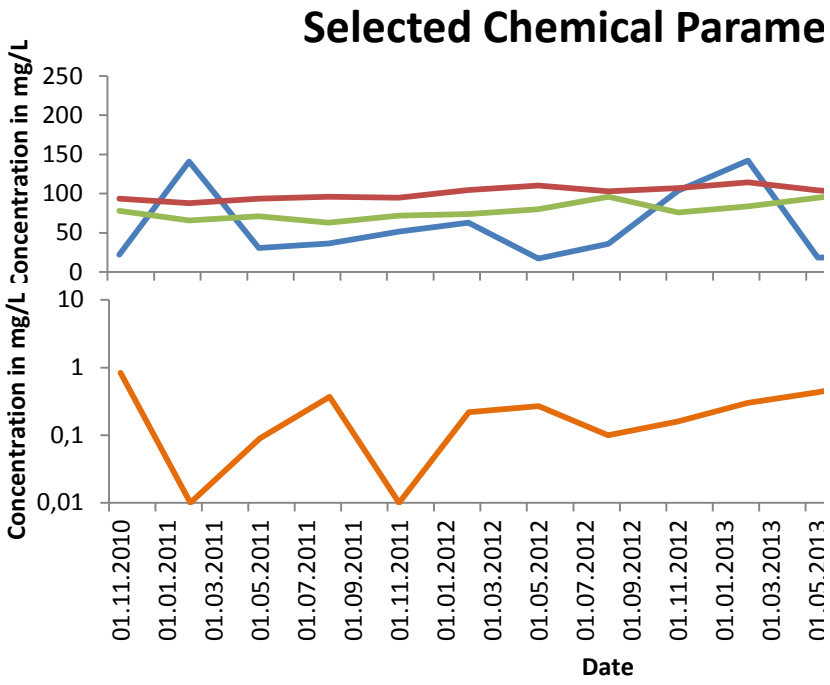

Selected Chemical Parame
Concentration in mg/L
300
250
200
150
100
50
0
100
10
1
0,1
0,01
01.11.2001
01.06.2002
01.01.2003
01.08.2003
01.03.2004
01.10.2004
01.05.2005
01.12.2005
01.07.2006
01.02.2007
01.09.2007
01.04.2008
01.11.2008
01.06.2009
01.01.2010
01.08.2010
Date

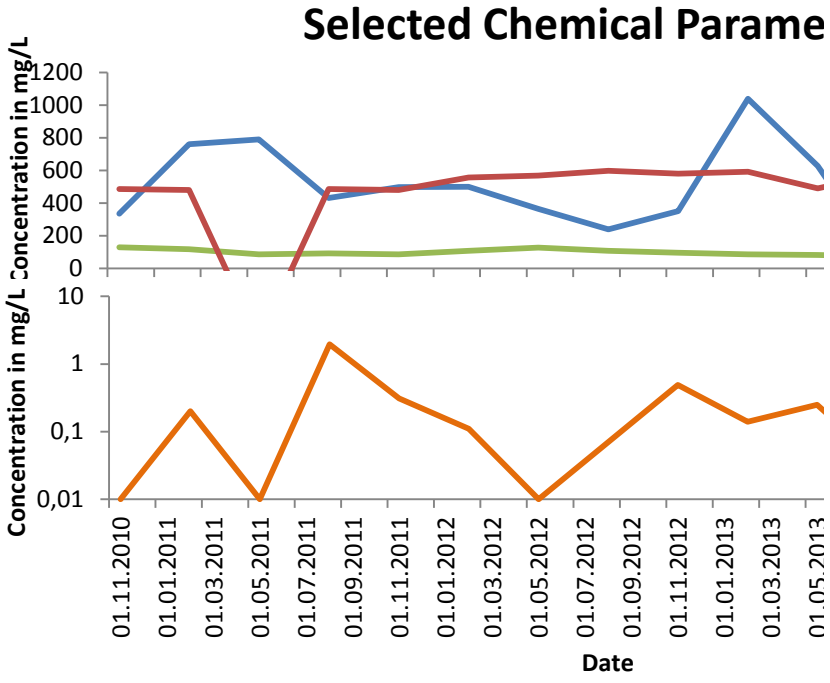

Selected Chemical Parame
Concentration in mg/L
500
400
300
200
100
0
10
1
0,1
0,01
01.11.2001
01.01.2002
01.03.2002
01.05.2002
01.07.2002
01.09.2002
01.11.2002
01.01.2003
01.03.2003
01.05.2003
01.07.2003
01.09.2003
01.11.2003
01.01.2004
01.03.2004
Date


Selected Chemical Parame
Concentration in mg/L
160
140
120
100
80
60
40
20
0
100
10
1
0,1
0,01
01.05.2002
01.11.2002
01.05.2003
01.11.2003
01.05.2004
01.11.2004
01.05.2005
01.11.2005
01.05.2006
01.11.2006
01.05.2007
01.11.2007
01.05.2008
01.11.2008
01.05.2009
01.11.2009
01.05.2010
01.11.2010
Date

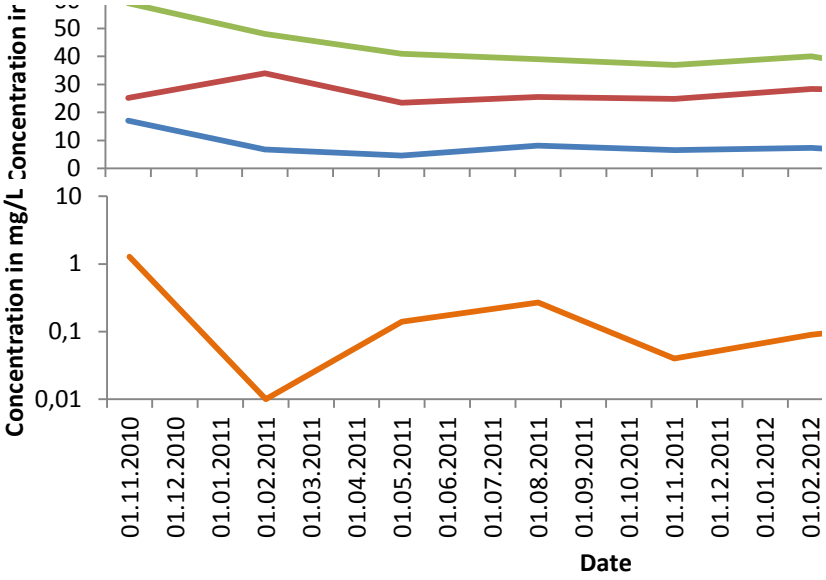

Selected Chemical Parame
Concentration in mg/L
1800
1600
1400
1200
1000
800
600
400
200
0
Concentration in mg/L
100
10
1
0,1
0,01
2010
2011
2011
2011
2011
2011
2011
2012
2012
2012
2012
2012
2012
2013
2013
2013

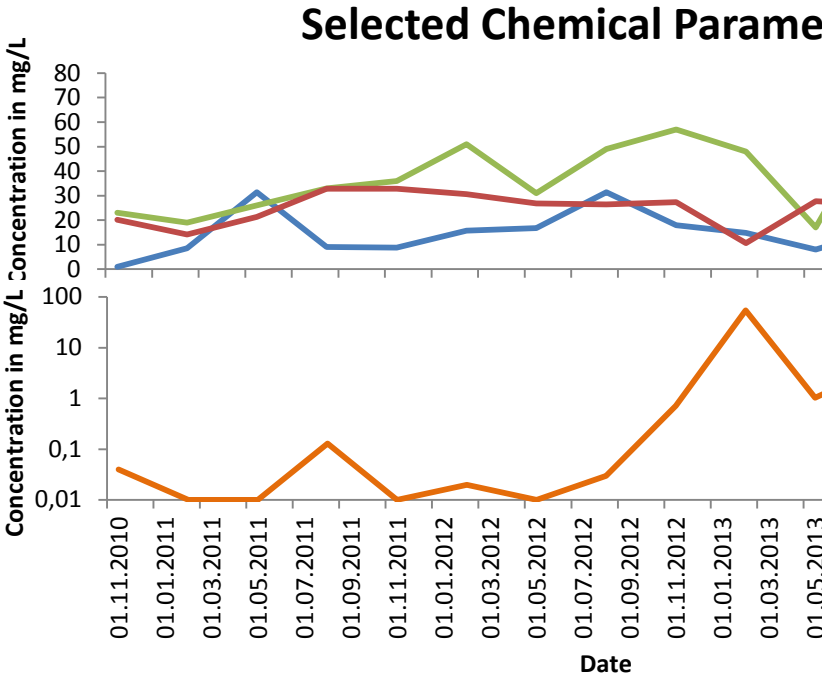

01.11.
01.01.
01.03.
01.05.
01.07.
01.09.
01.11.
01.01.
01.03.
01.05.
01.07.
01.09.
01.11.
01.01.
01.03.
01.05.
Date

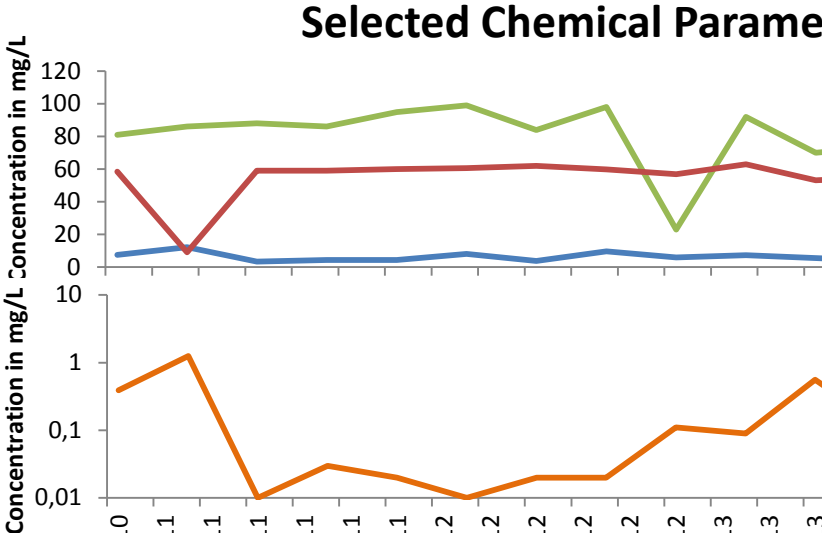

Selected Chemical Parame
Concentration in mg/L
250
200
150
100
50
0
10
1
0,1
0,01
01.11.2010
01.01.2011
01.03.2011
01.05.2011
01.07.2011
01.09.2011
01.11.2011
01.01.2012
01.03.2012
01.05.2012
01.07.2012
01.09.2012
01.11.2012
01.01.2013
01.03.2013
01.05.2013
Date

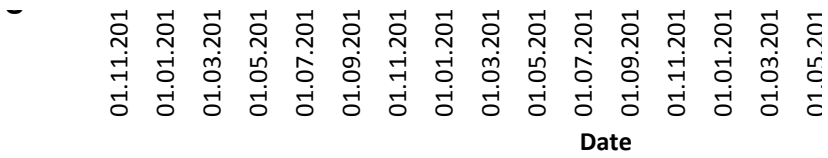

Selected Chemical Parame
Concentration in mg/L
1200
1000
800
600
400
200
0
10
1
0,1
0,01
01.11.2010
01.01.2011
01.03.2011
01.05.2011
01.07.2011
01.09.2011
01.11.2011
01.01.2012
01.03.2012
01.05.2012
01.07.2012
01.09.2012
01.11.2012
01.01.2013
01.03.2013
01.05.2013
Date

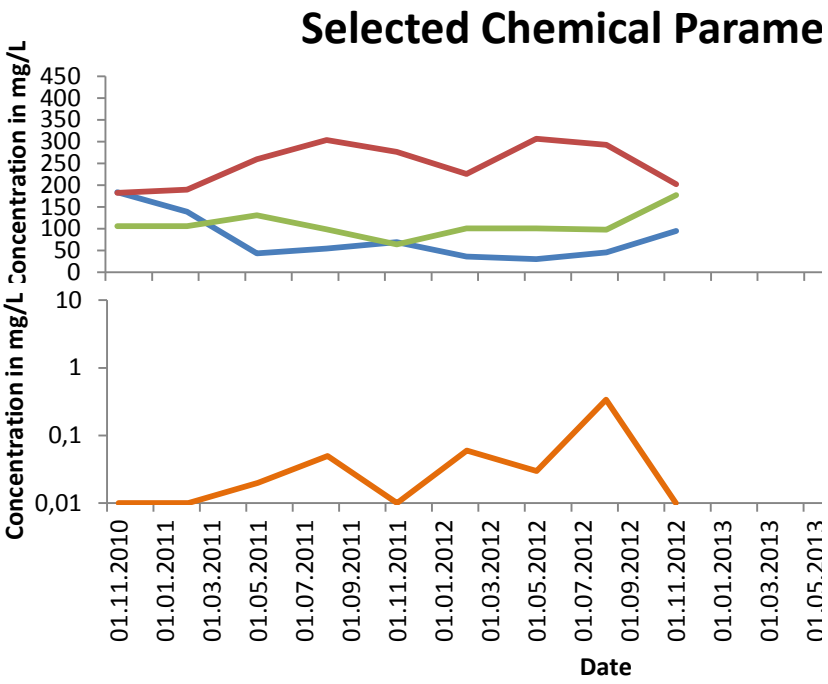
Selected Chemical Parame
mg/L
70
60

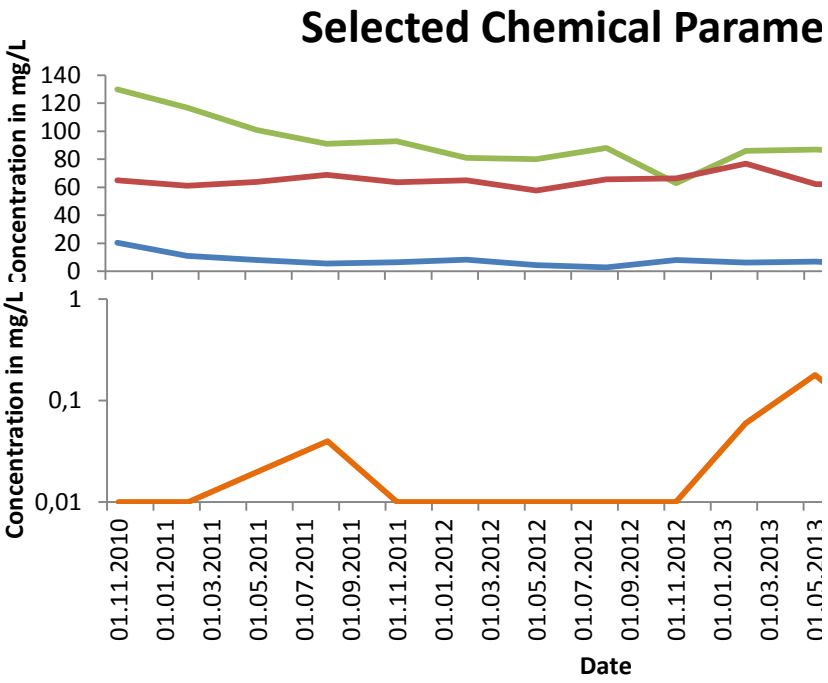

Concentration in mg/L Concentration ir
50
40
30
20
10
0
10
1
0,1
0,01
01.11.2010
01.12.2010
01.01.2011
01.02.2011
01.03.2011
01.04.2011
01.05.2011
01.06.2011
01.07.2011
01.08.2011
01.09.2011
01.10.2011
01.11.2011
01.12.2011
01.01.2012
01.02.2012
Date


Selected Chemical Parame
Concentration in mg/L Concentration in mg/L
80
70
60
50
40
30
20
10
0
100
10
1
0,1
0,01
01.11.2010
01.01.2011
01.03.2011
01.05.2011
01.07.2011
01.09.2011
01.11.2011
01.01.2012
01.03.2012
01.05.2012
01.07.2012
01.09.2012
01.11.2012
01.01.2013
01.03.2013
Date

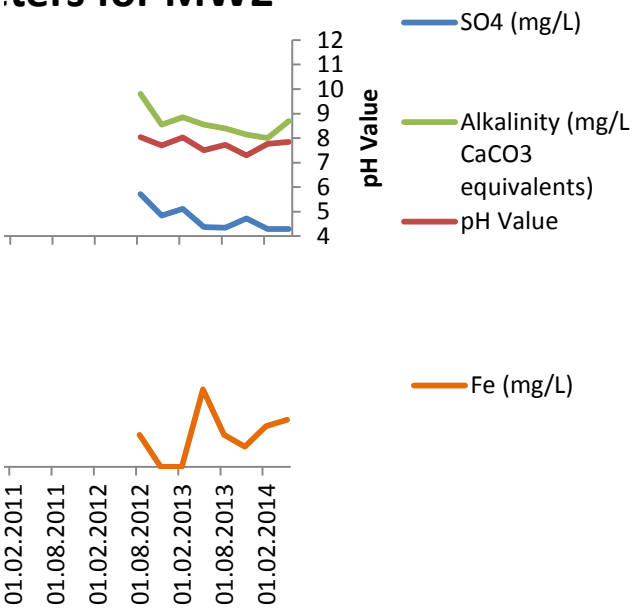

Selected Chemical Parame
Concentration in mg/L Concentration in mg/L
120
100
80
60
40
20
0
10
1
0,1
0,01


01.11.201
01.01.201
01.03.201
01.05.201
01.07.201
01.09.201
01.11.201
01.01.201
01.03.201
01.05.201
01.07.201
01.09.201
01.11.201
01.01.201
01.03.201
01.05.201
Date

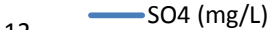

Selected Chemical Parame
Concentration in mg/L
450
400
350
300
250
200
150
100
50
0
Concentration in mg/L
10
1
0,1
0,01
01.11.2010
01.01.2011
01.03.2011
01.05.2011
01.07.2011
01.09.2011
01.11.2011
01.01.2012
01.03.2012
01.05.2012
01.07.2012
01.09.2012
01.11.2012
01.01.2013
01.03.2013
01.05.2013
Date

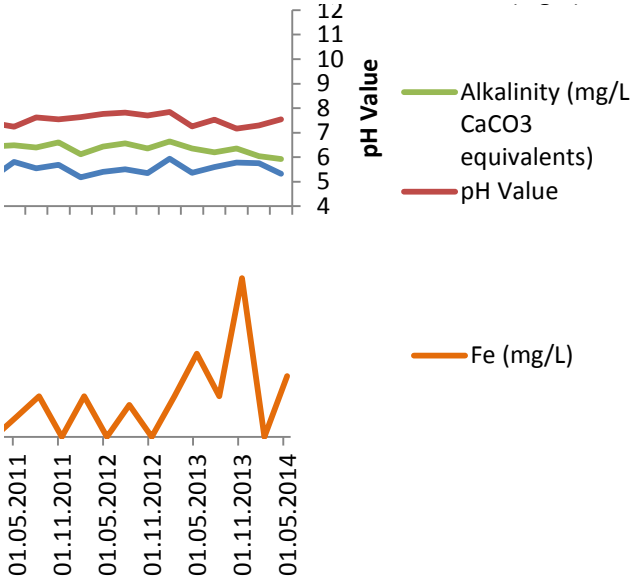

Selected Chemical Parame
Concentration in mg/L
140
120
100
80
60
40
20
0
Concentration in mg/L
1
0,1
0,01
01.11.2010
01.01.2011
01.03.2011
01.05.2011
01.07.2011
01.09.2011
01.11.2011
01.01.2012
01.03.2012
01.05.2012
01.07.2012
01.09.2012
01.11.2012
01.01.2013
01.03.2013
01.05.2013
Date

ters for MW2

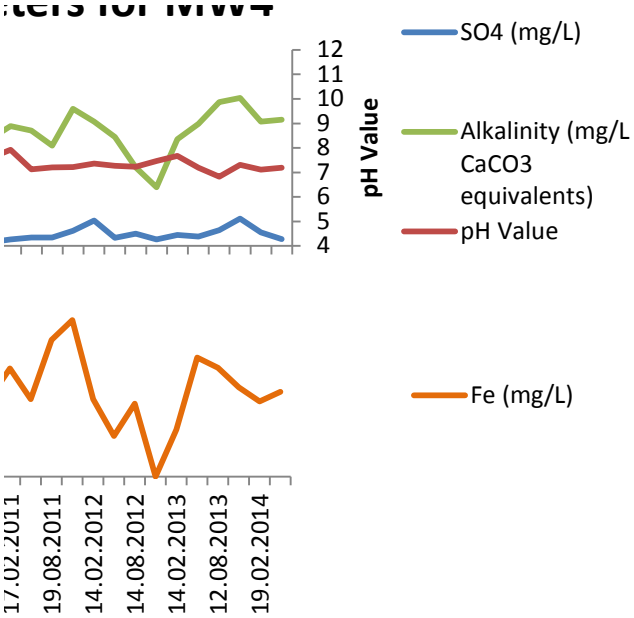


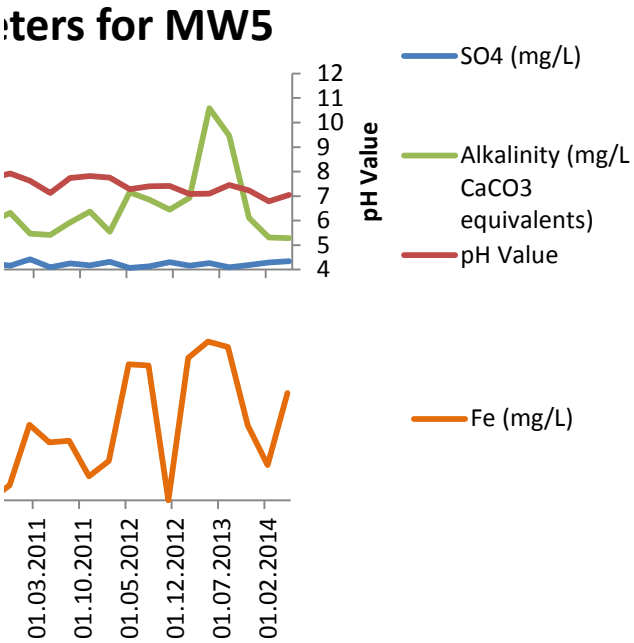
ters for MW3

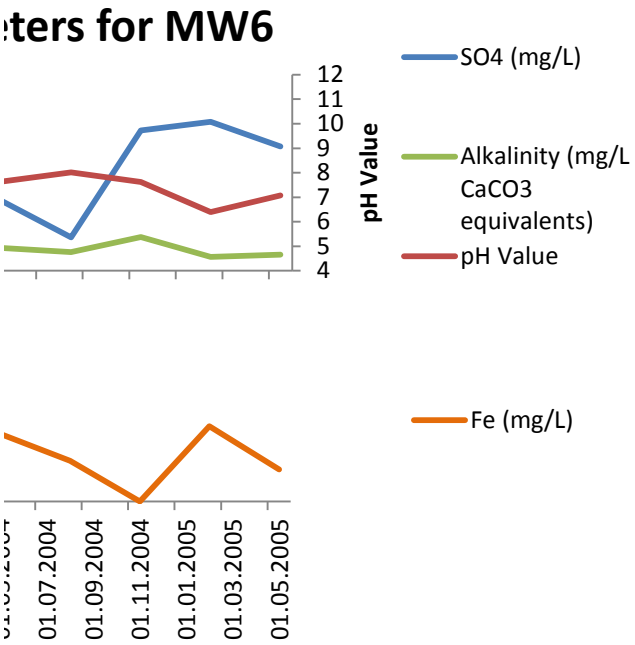


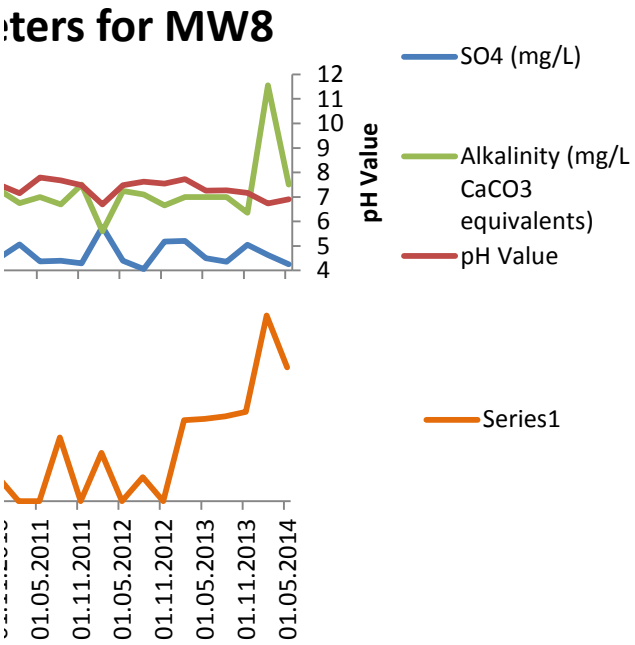


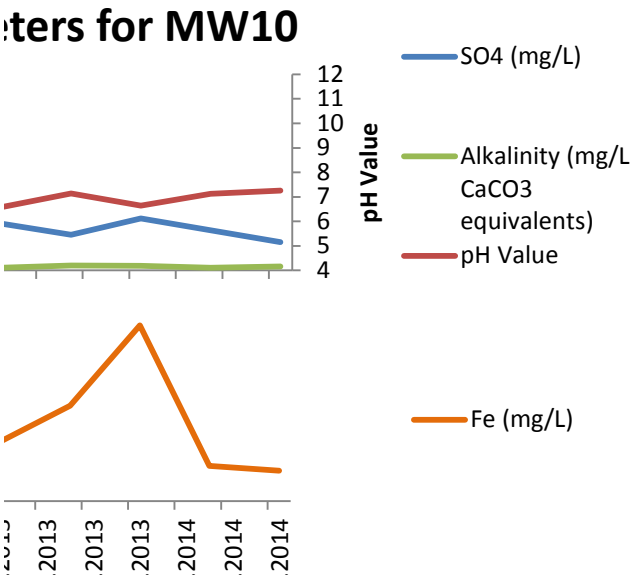
ıters for MW4


12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
19.08.2011
14.02.2012
14.08.2012
14.02.2013
12.08.2013
19.02.2014


eters for MW5
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.03.2011
01.10.2011
01.05.2012
01.12.2012
01.07.2013
01.02.2014

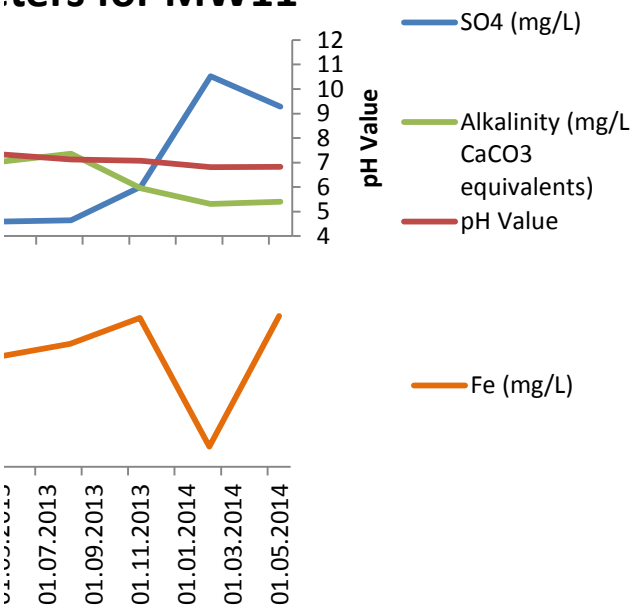

ters for MW6
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.07.2004
01.09.2004
01.11.2004
01.01.2005
01.03.2005
01.05.2005


ters for MW8
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Series1
01.05.2011
01.11.2011
01.05.2012
01.11.2012
01.05.2013
01.11.2013
01.05.2014

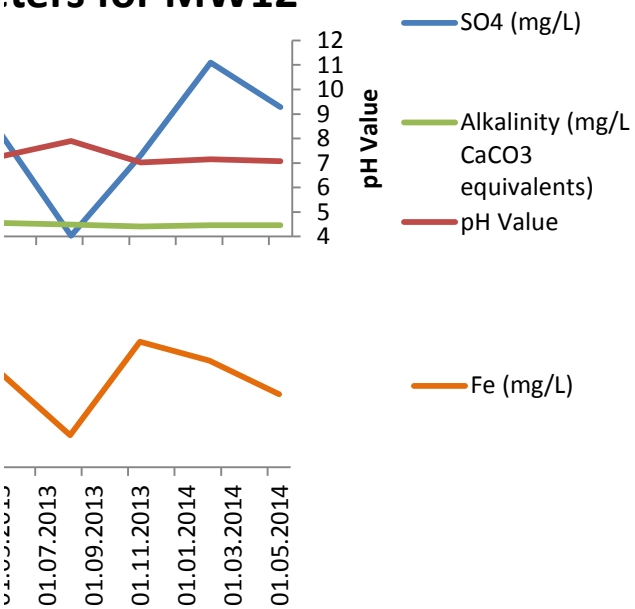

ters for MW10
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
2013
2013
2013
2014
2014
2014

01.07.
01.09.
01.11.
01.01.
01.03.
01.05.

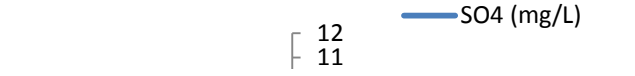
ters for MW11

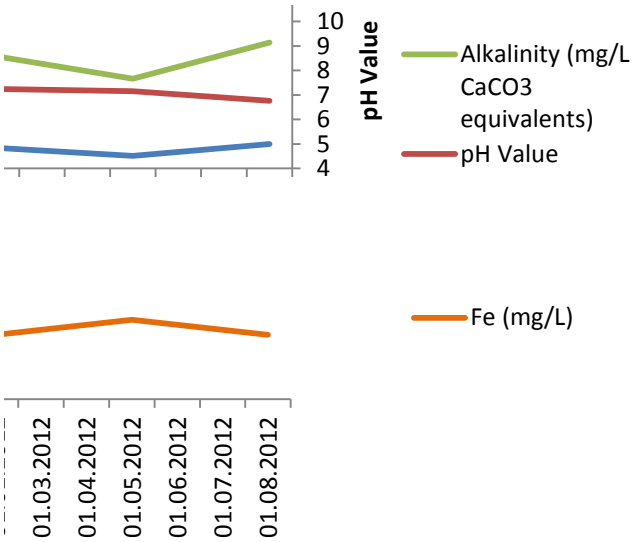


ters for MW12

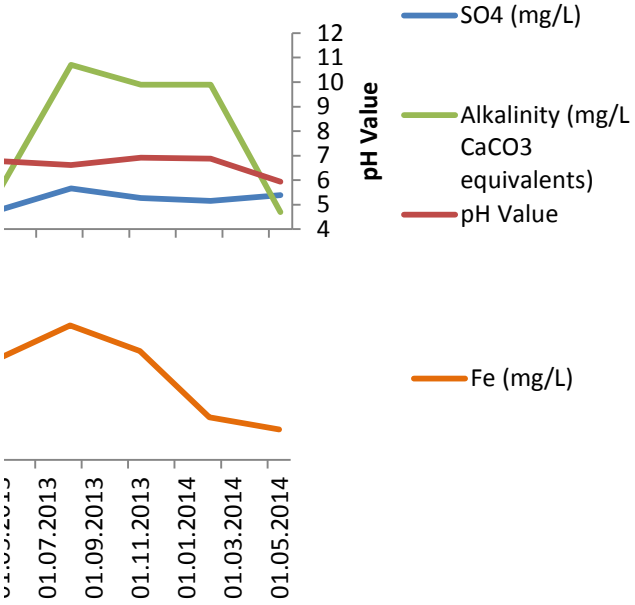


ters for MW13

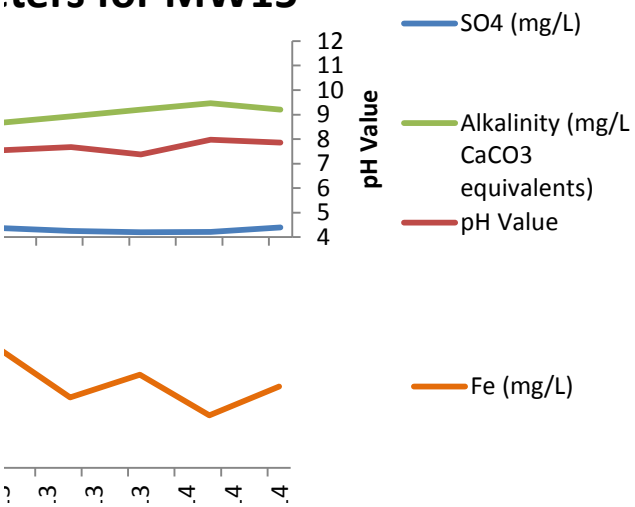


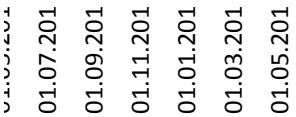


ters for MW14

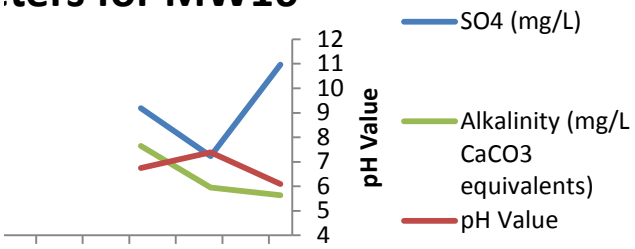


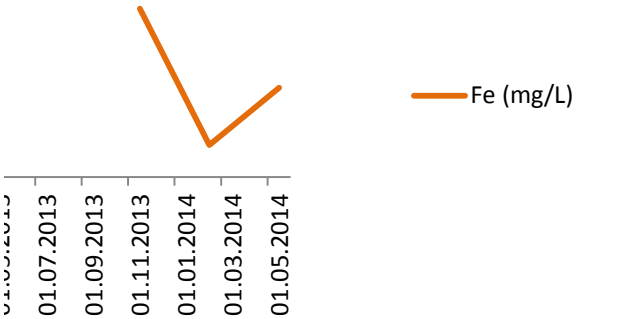
ters for MW15



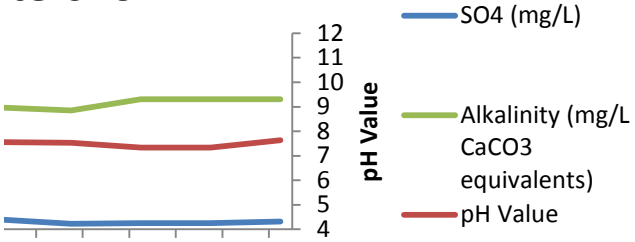


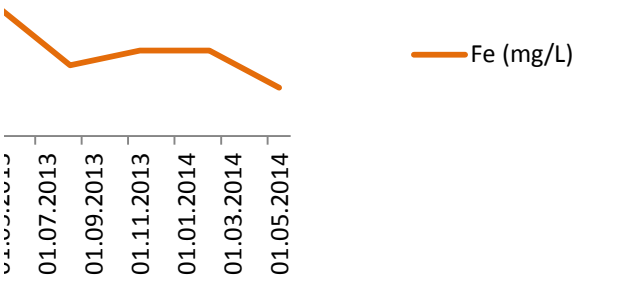
ters for MW16





ters for MW17





Borehole	Date	EC	Alkalinity	Fe	Mn	pH	Cl
KRW012	04.06.2014	50,44	13,65	0	5,41	5,75	8,62
KRW012	13.05.2014	53,93	15,15	0	4,49	5,93	4,75
KRW012	15.04.2014	50,96	16,25	0,5269	4,63	6,16	3,37
KRW012	18.03.2014	50,05	0	0,0398	0	5,94	5,24
KRW012	18.02.2014	58,63	0	0,019	2,68	5,77	4,05
KRW012	16.01.2014	49,2	11	0,1	2,22	5,61	5,01
KRW012	02.12.2013	49,2	11	0,1	2,22	5,61	5,01
KRW012	13.11.2013	52,24	0,3	0,01	2,06	6,36	3,28
KRW012	16.10.2013	58,66	17,97	0,0132	2,23	6,8	3,21
KRW012	20.09.2013	51,8	10,97	0,0446	0,74	6,46	1,52
KRW012	13.08.2013	46,69	3,83	0	0	6,21	3,28
KRW012	16.07.2013	33,66	35,51	0,0265	0,94	6,5	2,68
KRW012	11.06.2013	32,99	13,8	0,0998	1,05	6,24	3,12
KRW012	21.05.2013	32,29	5,8	0,2462	1,13	6,22	3,31
KRW012	29.04.2013	23,73	14,51	0,322	0,66	4,83	6,22
KRW012	13.03.2013	29,08	33,81	0,2483	1,31	6,38	2,49
KRW012	04.02.2013	24,78	46,5	0,141	1,1	6,66	3,86
KRW012	08.01.2013	36,06	51,47	20,9552	1,62	6,71	3,2
KRW012	03.12.2012	26,45	50,99	0,0461	0,96	6,73	6,76
KRW012	05.11.2012	24,55	60,18	0,0362	0,72	6,88	1,39
KRW012	01.10.2012	18,95	41,47	0,084	0,11	6,43	1,78
KRW012	04.09.2012	16,54	54,15	0,2887	0,08	6,6	-0,07
KRW012	01.08.2012	16,23	66,25	0,0878	0,16	6,66	3,5
KRW012	02.07.2012	16,3	99,41	0,1365	0,01	6,71	2,44
KRW012	05.06.2012	16,08	79,85	0,0296	0,01	6,6	2,36
KRW012	02.05.2012	17,92	105,25	0,0632	0,2	6,79	5,87
KRW012	10.04.2012	16,62	68,35	1,0145	0,5	6,62	38,72
KRW012	06.03.2012	13,08	69,69	1,2549	0,37	7,01	4,94
KRW012	07.02.2012	18,62	53,99	1,0831	0,74	6,7	1,74
KRW012	05.12.2011	17,29	85,14	0,1913	0,42	6,55	1,68
KRW012	02.11.2011	17,4	55,92	0,2235	0,04	6,57	2,97
KRW012	03.10.2011	18	84,6	0,083	0,01	6,41	2,71
KRW012	12.09.2011	18,53	59,6	0,0443	0	6,9	2,53
KRW012	03.08.2011	17,42	61,12	0,0573	0,02	6,92	1,88
KRW012	04.07.2011	21,68	77,51	0,1135	0,12	6,61	5,54
KRW012	12.05.2011	17,67	49,3	0,056	0	6,84	4,12
KRW012	12.04.2011	12,6	35,6	0	0	6,67	2,09
KRW012	03.03.2011	13,59	56,28	0,02	0,12	6,64	3,28
KRW012	12.01.2011	4,93	12,53	0	0,02	6,49	2,38
KRW012	01.12.2010	17,33	69,91	0	0,19	6,63	3,13
KRW012	03.11.2010	19,04	57,8	0,037	0,16	6,34	4,24
KRW012	06.10.2010	35,63	73,2	0,58	0,32	7,21	3,96
KRW012	06.09.2010	0,1	47,02	0	0,44	5,62	2,33
KRW012	04.08.2010	18,08	40,06	0,1278	0,25	6,34	2,84
KRW012	07.07.2010	18	29,75	0	0,01	6,23	3,93
KRW012	24.06.2010	23,53	69,03	0,0338	0,01	7,4	3,9
KRW012	08.06.2010	15,16	52,36	0,25	0,4	6,67	4,85
KRW012	19.05.2010	16,87	57,59	0,0346	0	7,84	2,56
KRW012	09.03.2010	9,36	5,2	0,1446	0,17	6,26	2,48

KRW012	17.02.2010	8,79	12,49	0,0592	0,16	6,14	1,96
KRW012	21.01.2010	11,67	29,96	0,2872	0,13	6,28	2,31
KRW012	07.12.2009	15,94	58,95	0,0445	0,48	6,27	3,65
KRW012	21.10.2009	19,26	77,76	0,0884	0,68	6,57	1,81
KRW012	15.09.2009	17,34	44,78	0,0588	0,01	6,52	2,57
KRW012	12.08.2009	44,68	53,42	0,0227	0	6,33	32,58
KRW012	14.04.2009	10,6	20,83	0,124	0,538	6,09	3,07
KRW012	22.10.2008	21,03	48,35	0,01	0,042	6,27	46,12
KRW012	20.05.2008	17,693	79,15	2,21	0,24	6,67	6,19
KRW012	07.04.2008	18,88	76,27	0,051	0,029	8,03	5,84
KRW012	14.02.2008	8	20,73	0,031	0,02	7,01	4,61
KRW012	12.11.2007	15,65	39,81	0,053	0,025	6,21	7,37
KRW012	13.09.2007	14,99	49,59	0,089	0,054	6,66	14,74
KRW012	20.08.2007	13,793	74,56	0,083	0,011	6,77	3,99
KRW012	12.06.2007	19,32	65,74	0,013	0,178	7,08	6,4
KRW012	15.05.2007	18,62	62,82	0,946	0,102	7,23	2
KRW012	18.04.2007	17,92	64,01	0,033	0,477	7,32	5,455
KRW012	19.03.2007	17,76	79,83	0,01	0,113	8,62	5,665
KRW012	16.01.2007	17,26	66,33	0,02	0,34	7,33	2
KRW012	02.10.2006	8,02	39,58	0,102	0,375	7,06	8,82
KRW012	23.08.2006	17,58	59,71	0,05	0,006	6,71	4,9
KRW012	07.08.2006	18,09	82,85	0,057	0,003	6,94	4,73
KRW012	31.05.2006	18,61		0,001	0,048		4
KRW012	18.04.2006	9,24	22,01	0,01	0,09	5,69	6
KRW012	17.11.2005	21,6	87,09	0,017	0,023	7,02	7,32
KRW012	22.09.2005	2,87	79,97	0,01	0,067	6,92	22,76
KRW012	14.04.2005	21,2	77,53	0,01	0,01	6,81	2
KRW012	05.12.2004	22,89	12	0,01	0,178	6,919	2
KRW012	30.01.2004	22,76	87	0,01	0,01	7,017	2
KRW012	09.12.2003	19,85	103	0,01	0,061	7,2	2
KRW012	18.11.2003	22,38	111	0,01	0,01	6,259	2
KRW012	20.10.2003	19,36	91	0,01	0,01	7,385	2
KRW012	22.09.2003	20,83	95	0,825	0,002	7,75	34
KRW012	14.07.2003	20,69	97	0,699	0,01	7,104	2
KRW012	06.05.2003	17,67	61	0,01	0,01	6,192	6
KRW012	19.05.2002	19,25	71	0,033	0,142	6,539	2
KRW012	31.01.2002	16,76	44			5,921	
KRW012	12.11.2001	20,16	68	0,01	0,243	6,394	4
KRW012	15.09.2001	17,33	66	0,005	0,318	6,346	6
KRW012	10.05.2001	18,19				6,759	
KRW012	19.03.2001	16,37	41	0,062	0,512	6,959	3
KRW012	09.03.2001	16,51	20	0,489	0,709	6,313	4
KRW012	17.01.2001		10	0,02	0,522		3
KRW014	04.06.2014	38,08	0	0,0089	4,09	4,12	10,5
KRW014	13.05.2014	35,69	0	0	2,72	4,3	6,27
KRW014	15.04.2014	29,4	0	0	2,32	4,73	3,74
KRW014	18.03.2014	28,41	0	0,0101	1,93	4,97	5,43
KRW014	18.02.2014	32,98	0	0	1,97	4,81	4,04

KRW014	16.01.2014	31	3,52	0,43	3,01	4,85	5,81
KRW014	02.12.2013	31	5	0,43	3,01	4,85	5,81
KRW014	13.11.2013	71,36	0	0,04	6,26	4,52	5,47
KRW014	16.10.2013	71,4	5,02	0	4,14	4,38	5,55
KRW014	20.09.2013	77,5	0,39	0,0128	5,47	5,34	2,09
KRW014	13.08.2013	69,83	0	0	6,31	4,26	6,06
KRW014	16.07.2013	56,18	0	0,11	6,43	4,71	4,69
KRW014	11.06.2013	54,96	0	0,0767	8,77	4,33	5,57
KRW014	22.05.2013	66,58	0	0,2355	10,02	4,55	6,28
KRW014	29.04.2013	57,79	0	0,0204	9,5	3,48	8,38
KRW014	13.03.2013	71,15	11,9	0,131	9,42	5,17	5,17
KRW014	04.02.2013	60,72	33,4	0,0709	8,81	6,06	6,93
KRW014	08.01.2013	68,26	30,97	0,987	8,09	5,68	6,61
KRW014	03.12.2012	62,42	23,85	0,0205	6,75	6,28	6,91
KRW014	05.11.2012	7,14	143,66	0,0078	5,18	5,78	5,98
KRW014	01.10.2012	56,55	6,8	0,0461	8,6	5,23	5,37
KRW014	04.09.2012	53,69	81,04	0	4,22	6,69	0,76
KRW014	01.08.2012	45,59	0	0,0768	5,56	4,34	6,21
KRW014	02.07.2012	41,9	0	0,0705	4,94	4,31	6,21
KRW014	05.06.2012	55,5	0	0,0527	9,26	4,58	6,19
KRW014	02.05.2012	61,32	0	0,0496	9,77	4,4	13,56
KRW014	10.04.2012	57,65	1,81	0,0273	9,79	4,76	9,12
KRW014	06.03.2012	25,81	5,17	0,1146	8,82	4,87	6,54
KRW014	07.02.2012	77,88	127,32	1,1381	4,9	6,44	6,85
KRW014	05.12.2011	76,17	150,22	0,5325	4,94	6,63	7,41
KRW014	02.11.2011	78,23	153,53	0,1514	4,98	6,64	6,4
KRW014	03.10.2011	78,97	228,26	0,0427	5,3	6,6	9,09
KRW014	12.09.2011	76,28	123,57	0,0161	5,57	6,84	7,36
KRW014	03.08.2011	75,12	159,7	0,0562	5,18	7,25	6,94
KRW014	04.07.2011	85,92	92,39	0,0598	5,18	6,52	8,2
KRW014	12.05.2011	61,62	143,48	0,0019	4,57	6,68	9,48
KRW014	12.04.2011	73,62	176,84	0,01	5,41	6,75	7,34
KRW014	03.03.2011	72,93	199,73	0,12	5,61	6,9	8,17
KRW014	12.01.2011	30,9	27,56	0,028	1,38	6,41	4,34
KRW014	01.12.2010	59	62,16	0	4,45	6,44	5,63
KRW014	03.11.2010	78,23	209,62	0,01	5,76	6,65	8,54
KRW014	06.10.2010	80,72	213,15	0,54	5,89	7,42	9,46
KRW014	06.09.2010	76,02	174,39	0,02	5,45	6,44	9,97
KRW014	04.08.2010	12,46	46,04	0,1114	5,57	6,4	9,05
KRW014	07.07.2010	68,29	121,17	0,159	5,64	6,69	6,94
KRW014	24.06.2010	72,89	228,25	0,4197	5,42	6,65	7,65
KRW014	08.06.2010	36,33	58,97	0,06	2,22	6,52	8,77
KRW014	19.05.2010	48,23	75,89	0,1955	3,41	6,51	5,08
KRW014	09.03.2010	33,12	20,65	0,1518	2,24	5,91	4,13
KRW014	17.02.2010	21,28	5,79	0,2606	1,1	5,7	2,42
KRW014	21.01.2010	41,24	17,53	0,0922	3,25	5,5	4,4
KRW014	07.12.2009	80,54	125,41	0,094	6,76	6,36	7,53
KRW014	18.11.2009	9,74	155,17	0,0923	7,88	6,56	10,26
KRW014	21.10.2009	92,18	160,81	0,9126	9,16	6,58	7,79
KRW014	15.09.2009	97,13	131,76	0,5624	9,15	6,62	7,89

KRW014	12.08.2009	93,5	141,95	1,6244	7,88	6,36	26,48
KRW014	14.04.2009	65,52	275,99	7,816	3,907	6,86	8,77
KRW014	22.10.2008	123,42	361,22	0,032	9,846	7,12	25,16
KRW014	20.05.2008	46,361	4,89	0,1	7,2	4,9	12,23
KRW014	07.04.2008	32,86	1,95	0,024	3,996	4,69	7,72
KRW014	27.03.2008	33,33	0,87	0,003	3,536	4,66	7,07
KRW014	14.02.2008	28,83	0	0,087	3,034	4,28	7,68
KRW014	12.11.2007	34,57	0	0,328	2,444	3,85	4,61
KRW014	13.09.2007	64,1	0	43,198	11,538	4,4	12,84
KRW014	20.08.2007	60,965	0	8,65	11,57	4,7	7,99
KRW014	12.06.2007	63,35	0,88	0,01	9,767	4,55	6,92
KRW014	15.05.2007	64,55	0	10,45	9,619	4,28	4
KRW014	18.04.2007	59,85	0	7,825	8,187	4,43	6,935
KRW014	19.03.2007	62,2	0	3	0,01	4,37	7,075
KRW014	16.01.2007	76,06	0	22,39	12,12	4,13	6
KRW014	14.11.2006	53,24	335,57	0,389	6,026	7,07	8,025
KRW014	02.10.2006	88,78	336,6	1,055	7,675	7,1	4
KRW014	23.08.2006	92,17	348,63	0,641	8,708	7,05	9,21
KRW014	07.08.2006	90,46	397,1	0,524	9,015	7,37	9,53
KRW014	31.05.2006	56,58		0,336	9,873		2
KRW014	18.04.2006	36,4	10,77	0,536	6,82	5,22	7
KRW014	31.01.2006	52,46	28,87	0,005	3,683	5,67	8
KRW014	25.11.2005	139,92	650,55	1,16	14,975	6,9	52,93
KRW014	22.09.2005	168,4	558,19	0,051	10,17	7,13	5,11
KRW014	25.08.2005	149,5	772	0,01	9,129	7,09	39,96
KRW014	25.04.2005	0,48	305,1	2,935	11,24	6,49	6
KRW014	05.12.2004	89,4	0	0,01	12,25	4,246	6
KRW014	15.09.2004	131,6	14	0,01	12,22	4,97	4
KRW014	17.05.2004	54,4	0	0,01	9,444	4,053	28
KRW014	18.04.2004	60,2	0	0,01	8,595	4,167	6
KRW014	21.03.2004	51,9	0	0,01	9,304	4,134	44
KRW014	30.01.2004	97,3	0	0,01	14,02	4,011	8
KRW014	08.12.2003	85	0	0,01	12,495	4	6
KRW014	17.11.2003	109	0	0,01	12,529	4,2	66
KRW014	20.10.2003	83,9	0	0,01	13,709	4,303	6
KRW014	22.09.2003	88,2	0	0,057	13,979	4,463	2
KRW014	14.07.2003	73,6	0	0,109	12,937	4	6
KRW014	06.05.2003	67,1	0	0,049	12,867	3,666	12
KRW014	19.05.2002	32,18	0	0,009	3,33	4,393	2
KRW014	12.11.2001	65,5	7	0,01	5,472	5,356	6
KRW014	10.05.2001	61,7	12		5,845	5,983	3
KRW014	19.04.2001	53,3	18	0,035	6,708	5,413	4
KRW014	19.03.2001	39,4	71	0,054	4,454	6,873	5
KRW014	21.02.2001						3
KRW014	17.01.2001	46					
KRW014	15.12.2000	38,5	2	0,094	3,921	5,458	8
KRW014	16.11.2000	49,8	4	0,058	5,933	5,462	4
KRW024	15.04.2014	4,9	20,01	0	0,04	5,87	4,42

KRW024	18.03.2014	8,55	4,86	0,0231	0,05	5,63	7,24
KRW024	18.02.2014	6	18,3	0	0,04	5,26	4,58
KRW024	16.01.2014	3,53	19	0,02	0,03	6,2	7,21
KRW024	02.12.2013	3,53	11,3	0,02	0,03	6,2	7,21
KRW024	13.11.2013	2,64	0	0,35	0,04	6,07	2,98
KRW024	16.10.2013	3,34	11,79	1,2488	0,01	6,3	3,08
KRW024	20.09.2013	3,07	7,6	0,0281	0	5,92	1,66
KRW024	13.08.2013	2,78	5,14	0	0,01	5,53	3,4
KRW024	16.07.2013	2,25	0,05	0	0,01	5,23	2,02
KRW024	11.06.2013	10,01	0	0,0149	0,04	4,56	2,98
KRW024	22.05.2013	4,57	0	0,0687	0,05	4,75	3,04
KRW024	29.04.2013	3,97	0	0,0108	0,03	3,2	6,91
KRW024	13.03.2013	4,48	0,47	0	0,02	4,44	3,49
KRW024	08.01.2013	5,21	0	0,0265	0,1	4,72	3,69
KRW024	03.12.2012	4,34	0,68	0,0365	0,04	4,65	2,46
KRW024	05.11.2012	4,06	0	0,0108	0,05	4,42	2,85
KRW024	04.09.2012	2,43	1,32	0,0062	0,03	5,47	0,96
KRW024	01.08.2012	2,98	3,5	0	0,04	5,36	3,78
KRW024	02.07.2012	4,63	0	0,0156	0,03	4,32	4,2
KRW024	05.06.2012	5,73	0	0	0,03	4,37	3,86
KRW024	02.05.2012	4,96	0	0	0,04	4,65	9,82
KRW024	10.04.2012	3,75	2,58	0	0,04	4,87	6,26
KRW024	06.03.2012	2,17	3,55	2,9303	2,35	4,58	5,91
KRW024	07.02.2012	5,09	9,1	0,0168	0,05	4,7	2,89
KRW024	05.12.2011	4,58	7,55	0,0252	0,04	4,78	4,01
KRW024	02.11.2011	5,53	9,33	0,0172	0,05	4,22	4,29
KRW024	03.10.2011	10,49	28	1,4574	0,13	6,23	9,3
KRW024	12.09.2011	5,05	19,96	0,0123	0,04	6,13	5,11
KRW024	03.08.2011	4,88	3	0,0197	0,05	5,29	3,01
KRW024	04.07.2011	3,94	7,94	0,0083	0,04	5,66	6,43
KRW024	12.05.2011	5,29	4,14	0,0091	0,06	5,44	6,72
KRW024	12.04.2011	7,09	19,2	0,03	0,02	5,85	3,87
KRW024	03.03.2011	5,6	4,31	0	0,05	5,05	5
KRW024	12.01.2011	10,64	6,72	0,02	0,06	5,5	6,25
KRW024	01.12.2010	4,63	21,54	0,027	0,04	6,06	4,56
KRW024	03.11.2010	18,34	27,17	0,34	0,05	6,45	6,74
KRW024	06.10.2010	10,6	21,17	0,87	0,06	6,54	5,28
KRW024	06.09.2010	3,09	1,74	0,06	0,05	4,94	5,42
KRW024	04.08.2010	16,22	6,44	0,0136	0,06	5,55	3,98
KRW024	07.07.2010	4,86	3,15	0	0,05	4,84	4,68
KRW024	24.06.2010	6,23	4,84	0,0418	0,04	5	5,71
KRW024	08.06.2010	7,36	4,94	0,01	0,05	5,25	8,39
KRW024	19.05.2010	74,14	254,28	0,4158	2,17	6,93	5,19
KRW024	09.03.2010	4,84	10,09	0,0244	0,03	4,72	3,74
KRW024	17.02.2010	5,88	2,56	0,0254	0,04	4,87	4,12
KRW024	21.01.2010	22,04	57,86	0,0819	0,35	6,7	2,52
KRW024	07.12.2009	5,02	0,71	0,0119	0,04	4,59	4,6
KRW024	18.11.2009	0,47	11,14	0,0295	0,04	4,93	5,42
KRW024	21.10.2009	20,32	4,98	0,0154	0,04	5,28	48,31
KRW024	15.09.2009	4,26	5,72	0,0126	0,05	5,76	3,18

KRW024	12.08.2009	3,75	3,13	0,0238	0,03	5,02	8,81
KRW024	14.04.2009	3,88	36,75	0,05	0,057	5,09	4,13
KRW024	22.10.2008	5,52	14,03	0,065	0,07	7,41	3,26
KRW024	20.05.2008	5,678	5,72	0,01	0,06	6,13	9,91
KRW024	07.04.2008	5,98	5,81	0,008	0,052	5,58	6,48
KRW024	27.03.2008	6,91	12,86	0,01	0,071	6,16	5,55
KRW024	14.02.2008	3,86	11,71	0,037	0,045	5,68	6,69
KRW024	12.11.2007	5,39	3,2	0,013	0,044	6	4,56
KRW024	13.09.2007	8,11	13	0,13	0,049	5,28	5,99
KRW024	20.08.2007	4,53	8,53	0,579	0,053	6,44	0,17
KRW024	12.06.2007	3,42	2,18	0,01	0,013	6,04	6,405
KRW024	15.05.2007	1,45	4,05	0,18	0,018	5,42	2
KRW024	18.04.2007	1,2	4,4	0,012	0,015	5,56	2
KRW024	19.03.2007	2,64	7,95	0,01	0,052	5,89	5,96
KRW024	16.01.2007	2,56	4,35	0,127	0,021	5,91	6
KRW024	14.11.2006	3,86	30,11	0,096	0,018	9,18	5,88
KRW024	02.10.2006	1,24	3,4	0,168	0,001	5,38	4
KRW024	23.08.2006	1,58	3,43	0,076	0,005	5,32	2
KRW024	07.08.2006	6,29	22,4	0,137	0,05	6,49	4,65
KRW024	25.11.2005	3,61	15,13	0,085	0,044	5,98	6,68
KRW024	22.09.2005	14,89	28,43	0,068	0,168	6,45	5,4
KRW024	25.08.2005	2,79	9	0,01	0,056	5,78	3
KRW024	18.01.2005	3,06	2,35	0,01	0,049	5,93	2
KRW024	05.12.2004	4,25	8	0,01	0,031	5,906	4
KRW024	15.09.2004	8,74	14	0,01	0,042	6,147	2
KRW024	17.11.2003	2,31	8	0,01	0,01	4,867	2
KRW024	20.10.2003	12,83	65	0,219	0,01	6,484	2
KRW024	22.09.2003	2,63	28	0,458	0,01	6,09	2
KRW024	14.07.2003	23,42	26	4,1	0,561	6,299	4
KRW024	10.05.2001			0,01	0,047		
KRW024	19.04.2001	10,02	12	0,01	0,255	5,725	3
KRW024	19.03.2001	10,27	73	0,036	0,066	7,431	2
KRW024	15.12.2000	3,74	4	0,023	0,013	5,311	2

KRW026	04.06.2014	2,13	2,49	0,0044	0	5,97	4,47
KRW026	13.05.2014	3,21	9,37	0	0,01	5,75	4,75
KRW026	15.04.2014	3,54	0,02	0	0,14	6,12	2,32
KRW026	18.03.2014	2,66	14,11	0,0382	0,01	5,54	4,81
KRW026	18.02.2014	11,58	1,67	0	0,97	4,9	8,7
KRW026	16.01.2014	9,56	6	0,04	0,93	5,36	4,3
KRW026	02.12.2013	9,56	6	0,04	0,93	5,36	4,3
KRW026	13.11.2013	21,36	0	0,01	2,77	4,73	2,32
KRW026	16.10.2013	19,04	0	0	1,58	5,06	2,03
KRW026	20.09.2013	19,42	0	0,0193	1,37	4,96	1,5
KRW026	13.08.2013	17,66	0,11	0	1,56	5,05	2,45
KRW026	16.07.2013	12,43	0,21	0,1195	0,17	5,48	2,14
KRW026	11.06.2013	12,41	0,41	0,0828	1,4	5,41	27,37
KRW026	22.05.2013	12,45	21,18	0,1411	1,43	5,54	0,83
KRW026	29.04.2013	11,88	0	0,0221	1,19	4,7	2,97

KRW026	13.03.2013	11,89	6,04	0,0396	1,34	5,38	1,78
KRW026	04.02.2013	8,82	9,68	0,1748	1,1	6	1,75
KRW026	08.01.2013	9,46	13,94	0,6543	0,91	5,99	2,72
KRW026	03.12.2012	13,84	3,55	0	1,47	5,31	2,4
KRW026	05.11.2012	16,92	3,36	0,095	1,93	4,64	2,38
KRW026	01.10.2012	21,52	0	0,0065	3,06	4,55	1,39
KRW026	04.09.2012	20,24	0	0,0063	3,24	4,9	0,02
KRW026	01.08.2012	34,39	0	0,7427	5,93	4,25	3,22
KRW026	02.07.2012	14,71	0	0,1247	1,99	5,99	4,76
KRW026	05.06.2012	40,71	0	0,1058	6,01	4,28	2,24
KRW026	02.05.2012	32,68	4,81	0	4,48	5,48	11,28
KRW026	10.04.2012	30,03	58,81	0,8695	2,55	6,48	5,85
KRW026	06.03.2012	9,34	6,48	0,0057	1,74	5,69	2,26
KRW026	07.02.2012	2,64	14,1	0,0065	0,07	5,72	1
KRW026	05.12.2011	3,32	6,72	0,0482	0,06	5,83	1,83
KRW026	02.11.2011	3,01	10,57	0,0572	0,02	5,32	3,92
KRW026	03.10.2011	2,04	3,07	0,0196	0,02	5,76	2,44
KRW026	12.09.2011	1,96	6,35	0	0,01	5,96	3,53
KRW026	03.08.2011	1,72	4,23	0,0495	0,01	5,88	1,98
KRW026	04.07.2011	1,52	2,49	0,0301	0,01	5,84	5,57
KRW026	12.05.2011	1,71	9,51	0,0154	0,01	5,99	3,89
KRW026	12.04.2011	3	7,62	0	0,01	5,8	2,9
KRW026	03.03.2011	2,3	4,99	0,004	0,02	5,98	3,99
KRW026	12.01.2011	2,24	5,13	0,006	0,01	6,11	3,09
KRW026	01.12.2010	2,02	3,78	0,01	0,01	6,18	2,86
KRW026	03.11.2010	2,8	9,75	0	0,01	5,97	4,1
KRW026	06.10.2010	3,02	8,09	0,09	0,01	6,06	3,42
KRW026	06.09.2010	2,59	3,35	0,04	0,01	5,05	2,58
KRW026	04.08.2010	1,77	9,04	0,1792	0,01	5,83	2,44
KRW026	07.07.2010	2,04	9,27	0	0,01	5,64	2,84
KRW026	24.06.2010	2,73	9,11	0,0311	0,01	5,84	3,29
KRW026	08.06.2010	15,13	11,94	0,0528	0,02	5,92	5,1
KRW026	19.05.2010	2,34	10,45	0,0886	0,01	5,82	3,49
KRW026	09.03.2010	2,05	9,56	0,0232	0,01	5,91	1,96
KRW026	17.02.2010	2,35	7,57	0,0441	0,01	5,99	2,32
KRW026	21.01.2010	2,44	10,67	0,0471	0,01	5,75	2,34
KRW026	07.12.2009	2,07	10,84	0,0369	0,01	5,8	2,9
KRW026	18.11.2009	0,22	16,97	0,0442	0,01	5,91	4,16
KRW026	21.10.2009	2,51	9,32	0,087	0,02	5,89	2,35
KRW026	15.09.2009	1,75	6,68	0,1026	0,02	5,87	2,25
KRW026	12.08.2009	1,81	11,41	0,0339	0,01	5,88	9,08
KRW026	14.04.2009	2,16	15,28	0,042	0,037	5,95	4,14
KRW026	26.01.2009	3,35	10,24	0,046	0,011	5,89	2,38
KRW026	22.10.2008	3,57	7,02	0,101	0,016	6,35	1,99
KRW026	20.05.2008	6,318	39,5	0,01	0,01	8,29	11,31
KRW026	07.04.2008	3,23	7,88	0,021	0,016	6,41	6,06
KRW026	27.03.2008	5,6	21,66	0,027	0,011	7,88	4,98
KRW026	14.02.2008	2,49	4,87	0,094	0,014	6,45	5,94
KRW026	12.11.2007	3,38	3,35	0,34	0,033	5,99	4,35
KRW026	11.10.2007	1,97	9,12	0,2	0,032	5,73	4,5

KRW026	13.09.2007	8,18	7,3	0,338	0,018	5,24	3,99
KRW026	20.08.2007	0,912	8,28	0,4	0,023	5,91	1,99
KRW026	12.06.2007	4,88	13,12	0,329	0,022	6,28	6,405
KRW026	24.05.2007	2,74	2,4	0,317	0,026	7,02	2
KRW026	18.04.2007	1,56	5,71	0,386	0,015	5,98	2
KRW026	19.03.2007	2,23	6,89	0,654	0,023	5,88	5,83
KRW026	16.01.2007	2,15	4,22	0,252	0,024	6,46	6
KRW026	14.11.2006	2,03	10,28	0,548	0,05	6,56	5,765
KRW026	10.10.2006	1,6	9,68	0,01	0,01	6,14	4
KRW026	02.10.2006	1,13	8,26	0,757	0,01	6,09	4
KRW026	22.08.2006	2,17	0,43	0,736	0,045	5,97	4
KRW026	07.08.2006	1,72	8,53	0,244	0,045	5,97	4,64
KRW026	31.05.2006	2,21		0,001	0,006		4
KRW026	18.04.2006	1,58	13,35	0,01	0,01	5,59	6
KRW026	31.01.2006	3,31	3,68	0,008	0,01	6,21	4
KRW026	25.11.2005	3,02	5,39	0,454	0,071	5,89	5,78
KRW026	22.09.2005	14,89	7,62	0,094	0,031	6,05	4,44
KRW026	25.08.2005	2,71	2,68	0,202	0,041	5,87	6
KRW026	14.04.2005	2,76	6	0,01	0,02	6,13	2
KRW026	18.01.2005	6,21	40	0,01	0,055	9,76	2
KRW026	05.12.2004	6,85	18	0,01	0,079	6,353	48
KRW026	15.09.2004	4,45	6	0,045	0,035	5,492	2
KRW026	17.05.2004	8,35	20	0,01	0,01	6,205	2
KRW026	18.04.2004	4,98	14	0,01	0,01	6,119	2
KRW026	30.01.2004	4,34	8	0,22	0,01	5,994	2
KRW026	09.12.2003	3,45	12	0,184	0,01	6,7	4
KRW026	17.11.2003	2,58	24	0,184	0,01	5,138	2
KRW026	20.10.2003	2,52	14	0,01	0,01	6,051	2
KRW026	22.09.2003	1,91	44	0,907	0,01	6,227	2
KRW026	14.07.2003	4,86	26	0,01	0,01	5,805	2
KRW026	10.05.2003	5,88	17	0,01	0,01	6	6
KRW026	18.03.2003	2,76	7	0,01	0,01	5,756	1
KRW026	19.05.2002	7,23	6	0,259	0,024	5,737	2
KRW026	15.09.2001	2,53	2	0,069	0,004	5,561	6
KRW026	10.05.2001		6			6,259	
KRW026	19.04.2001	3,78	8	0,03	0,025	5,667	3
KRW026	19.03.2001	9,94	41	0,071	0,071	7,51	2
KRW026	05.03.2001	4,89	11	0,019	0,003	6,4	2
KRW026	19.01.2001	399,2	36	0,087	4,518	7,016	4
KRW026	15.12.2000	4,95	10	0,071	0,015	7,721	2
KRW027	04.06.2014	0,89	0,55	0,0071	0	5,43	4,26
KRW027	13.05.2014	1,23	3,75	0,0054	0	5,23	4,49
KRW027	15.04.2014	1,12	1,32	0,0039	0	6,01	2,39
KRW027	18.03.2014	1,93	12,48	0,0075	0,01	5,41	1,25
KRW027	18.02.2014	1,5	6,47	0	0	5,4	2,84
KRW027	16.01.2014	1,64	0,12	0,01	0,01	5,77	4
KRW027	02.12.2013	1,64	1,2	0,01	0,01	5,77	4
KRW027	13.11.2013	0,78	0	0,01	0,02	6,06	2,4

KRW027	16.10.2013	2,53	0	0,0581	0	5,87	2,39
KRW027	20.09.2013	3,04	7,61	0,0924	0	5,99	1,53
KRW027	13.08.2013	9,9	0	0	0	4,17	4,24
KRW027	16.07.2013	1,04	7,95	0,0942	0,02	5,89	1,86
KRW027	11.06.2013	2,09	10,3	0,0592	0,02	5,82	1,96
KRW027	22.05.2013	1,36	5,42	0,0558	0,01	5,07	0,39
KRW027	29.04.2013	0,95	0	1,7523	0	4,56	2,29
KRW027	13.03.2013	1,03	7,04	0,0132	0	5,39	1,63
KRW027	04.02.2013	0,82	5,54	3,6	0,01	5,63	1,58
KRW027	08.01.2013	0,98	3,21	0,1087	0,01	5,33	2,23
KRW027	03.12.2012	1,45	4,49	0,1095	0	5,87	3,07
KRW027	05.11.2012	0,88	3,07	0,0596	0,01	5,49	1,82
KRW027	01.10.2012	0,99	2,96	0,0441	0	5,36	1,46
KRW027	04.09.2012	0,84	1,27	0,0388	0,01	5,48	0,04
KRW027	01.08.2012	1,05	3,34	0,0008	0	5,4	3,06
KRW027	02.07.2012	1,02	9,87	0,1486	0,01	5,45	3,67
KRW027	05.06.2012	0,68	2,23	0	0,01	5,49	1,64
KRW027	02.05.2012	0,92	2,48	0,015	0,01	5,52	6,42
KRW027	10.04.2012	0,73	22,47	0	0,01	5,35	2,93
KRW027	06.03.2012	2,4	4,04	0	0,01	5,77	1,51
KRW027	07.02.2012	0,84	10,4	0,0131	0	5,2	0,5
KRW027	05.12.2011	0,98	24,33	0,0349	0	5,26	1,51
KRW027	02.11.2011	1,02	7,68	0,0549	0,01	4,92	2,38
KRW027	03.10.2011	0,84	4,86	0,0324	0	5,13	1,69
KRW027	12.09.2011	0,88	2,97	0,0037	0	5,45	3,13
KRW027	03.08.2011	1,05	3,53	0,0378	0,01	5,29	1,68
KRW027	04.07.2011	0,92	0,09	0,0388	0,01	5,77	5,59
KRW027	12.05.2011	1,56	6,13	0,0273	0,01	6,02	4,02
KRW027	12.04.2011	2,28	7,66	0,0045	0,01	5,76	2,8
KRW027	03.03.2011	1,78	3,1	0,02	0	5,92	4,65
KRW027	12.01.2011	2,36	0,52	0	0,02	5,63	2,3
KRW027	01.12.2010	1,47	10,12	0,01	0,01	5,6	2,42
KRW027	03.11.2010	2,63	24,55	0,12	0,01	5,65	2,97
KRW027	06.10.2010	2,41	1,82	0	0,01	5,54	2,98
KRW027	06.09.2010	17,66	28,99	0,73	0,02	5,69	4,63
KRW027	04.08.2010	3,9	16,12	0,6217	0,01	5,94	5,32
KRW027	07.07.2010	1,35	4,54	0,1355	0,01	5,4	2,66
KRW027	24.06.2010	1,87	1,94	0,0839	0	5,47	3,52
KRW027	08.06.2010	3,39	12,33	0,07	0,01	5,99	5,31
KRW027	19.05.2010	2,17	10,69	0,031	0,01	5,93	3,3
KRW027	09.03.2010	1,38	6,88	0,1089	0	5,67	2,85
KRW027	17.02.2010	2,24	5,73	0,03	0,02	5,76	2,22
KRW027	21.01.2010	1,84	4,54	0,0265	0,01	5,46	2,49
KRW027	07.12.2009	1,1	4,11	0,0132	0	5,27	3,62
KRW027	18.11.2009	0,77	12,95	0,0174	0,01	5,09	3,69
KRW027	21.10.2009	3,61	3,72	0,0195	0	5,33	6,78
KRW027	15.09.2009	2,54	6,11	0,0709	0,02	5,99	2,2
KRW027	12.08.2009	0,94	4,81	0	0	5,31	8,91
KRW027	14.04.2009	0,67	3,9	0,016	0,007	5,45	8,34
KRW027	26.01.2009	2,96	6,62	0,023	0,012	4,64	0,47

KRW027	22.10.2008	3,15	2,98	0,01	0,011	5,78	46,43
KRW027	20.05.2008	4,123	26,35	0,02	0	8,52	12,78
KRW027	07.04.2008	1,63	6,98	0,021	0,016	6,13	5,77
KRW027	27.03.2008	3,74	12,66	0,01	0,018	6,7	4,51
KRW027	14.02.2008	1,77	6,89	0,168	0,014	6,22	4,64
KRW027	12.11.2007	1,75	4,45	0,094	0,011	5,49	5,9
KRW027	11.10.2007	1	4,54	0,081	0,004	5,33	3,2
KRW027	13.09.2007	1,54	5,55	0,185	0,03	5,61	4,99
KRW027	20.08.2007	0,882	4,6	0,076	0,01	5,38	5,99
KRW027	12.06.2007	3,23	4,56	0,058	0,018	6,03	6,46
KRW027	24.05.2007	0,91	0,7	0,01	0,01	5,62	2
KRW027	18.04.2007	0,73	2,85	0,553	0,03	5,38	2
KRW027	19.03.2007	1,43	4,21	0,088	0,012	5,54	4
KRW027	16.01.2007	4,28	3	0,092	0,002	5,58	4
KRW027	14.11.2006	1,56	0	0,041	0,01	3,66	5,6
KRW027	02.10.2006	0,85	5,03	0,164	0,01	5,57	4
KRW027	22.08.2006	1,38	9,52	0,184	0,025	5,93	2
KRW027	07.08.2006	0,86	4,02	0,01	0,001	5,47	4,57
KRW027	31.05.2006	0,74		0,005	0,001		4
KRW027	18.04.2006	0,77	5,41	0,01	0,01	5,51	4
KRW027	31.01.2006	2,57	0,54	0,318	1,309	6,12	4
KRW027	17.11.2005	1,91	3,07	0,159	0,021	6,25	7,39
KRW027	22.09.2005	14,89	4,1	0,01	0,021	5,69	6,1
KRW027	25.08.2005	1,63	10	0,01	0,03	5,71	5,29
KRW027	14.04.2005	3,66	13,23	0,01	0,015	6,22	2
KRW027	18.01.2005	3,93	12,69	0,01	0,046	6,15	2
KRW027	05.12.2004	4,13	12	0,01	0,039	6,282	2
KRW027	15.09.2004	6,97	4	0,01	0,167	5,08	2
KRW027	17.05.2004	11,26	71	0,01	0,01	10,281	2
KRW027	18.04.2004	6,75	26	0,01	0,01	9,147	4
KRW027	30.01.2004	2,26	27,5	0,14	1,27	5,191	2
KRW027	19.05.2002	2,66	2	0,5	0,01	5,255	2
KRW027	31.01.2002	5,27	0			4,033	
KRW027	15.09.2001	2,52	2	0,43	0,037	5,394	8
KRW027	10.05.2001	2,69	4		0,008		
KRW027	19.03.2001	8,86	47	0,056	0,062	7,579	1
KRW027	09.03.2001	133,8	4	0,274	0,404	6,8	4
KRW027	19.01.2001	29,37	4	0,076	0,039	6,905	2
KRW028	04.06.2014	9,24	4,06	16,7574	0,66	6,14	6,92
KRW028	13.05.2014	10,09	42,28	1,7205	0,22	6,13	6,05
KRW028	15.04.2014	9,3	2,61	1,2573	0,49	6,3	2,95
KRW028	18.03.2014	11,67	72,42	0,1825	0,46	6,17	3,73
KRW028	18.02.2014	21,67	160,18	0,1516	0,68	5,82	3,49
KRW028	16.01.2014	21,9	112	0,14	0,89	6,58	4,3
KRW028	02.12.2013	21,9	112	0,14	0,89	6,58	4,3
KRW028	13.11.2013	25,69	126	0,04	0,88	7,33	3,01
KRW028	16.10.2013	30,75	124,02	0,3843	0,7	7,11	2,66
KRW028	20.09.2013	42,98	191,83	0,0255	0,92	6,88	1,57

KRW028	13.08.2013	32,58	82,6	0	0,84	6,51	5,67
KRW028	16.07.2013	27,9	173,41	0,0333	0,95	6,5	3,3
KRW028	11.06.2013	29,84	88,81	0,168	1,05	6,33	3,06
KRW028	22.05.2013	29,32	58,17	0,1254	1,09	6,34	1,86
KRW028	29.04.2013	19,33	30,3	0,0297	0,84	6,1	5,16
KRW028	13.03.2013	19,48	153,71	0,0185	0,82	6,33	1,99
KRW028	04.02.2013	21,63	85,98	0,1564	1,05	6,66	2,28
KRW028	08.01.2013	19,87	99,61	0,1378	0,93	6,39	2,79
KRW028	03.12.2012	17,01	100,25	0,013	0,77	6,43	3,15
KRW028	05.11.2012	19,96	106,08	3,239	1	6,5	2,34
KRW028	01.10.2012	20,72	51,47	0,3621	1,03	6,43	2,64
KRW028	04.09.2012	35,53	155,88	0,0859	1,29	6,62	-0,03
KRW028	01.08.2012	32,06	127,24	0,1472	1,25	6,64	4,08
KRW028	02.07.2012	25	67,64	0,0845	0,87	6,4	5,99
KRW028	05.06.2012	36,56	263,68	0,1904	1,24	6,66	3,14
KRW028	02.05.2012	18,96	75,53	0	0,89	6,47	6,26
KRW028	10.04.2012	23,54	109,25	0,2118	0,99	6,25	5,11
KRW028	06.03.2012	25,25	148,4	0,199	1,05	6,78	2,94
KRW028	07.02.2012	11,58	47,95	0,0495	0,62	6,1	0,95
KRW028	05.12.2011	8,94	128,25	0,0115	0,6	5,96	3,14
KRW028	02.11.2011	8,37	52,32	0,0159	0,57	5,74	3,86
KRW028	03.10.2011	6,56	27,61	0,1122	0,52	5,87	2,45
KRW028	12.09.2011	26,63	60,51	0,119	0,99	6,5	5,05
KRW028	03.08.2011	16,66	32,91	1,1285	0,85	6,4	3,38
KRW028	04.07.2011	5,43	22,59	0,7193	0,28	6,07	5,85
KRW028	12.05.2011	1,84	8,48	0,3788	0,07	5,44	2,86
KRW028	12.04.2011	2,58	3,99	0,38	0,02	5,2	2,12
KRW028	03.03.2011	1,47	6,16	0,61	0,04	5,12	2,97
KRW028	12.01.2011	15,79	105,93	0,099	1,6	6,29	3,16
KRW028	01.12.2010	39,45	136,11	0,22	1,43	6,7	4,01
KRW028	03.11.2010	31,62	155,18	0,36	1,35	6,95	4,69
KRW028	06.10.2010	31,75	147,71	0,36	1,22	6,98	3,57
KRW028	06.09.2010	23,86	73,14	0,56	1	6,13	4,28
KRW028	04.08.2010	24,55	38,86	0,4851	0,96	6,26	3,51
KRW028	07.07.2010	7,91	71,2	3,7015	0,45	5,89	4,99
KRW028	24.06.2010	8,41	19,41	6,0887	0,52	5,96	3,66
KRW028	08.06.2010	3,29	8,23	0,57	0,07	5,57	4,57
KRW028	19.05.2010	2,33	37,35	3,581	0,05	5,18	2,85
KRW028	09.03.2010	19,36	95,83	3,4513	0,67	6,33	2,75
KRW028	17.02.2010	9,96	43,44	1,4052	0,66	6,06	2,33
KRW028	21.01.2010	19,22	102,81	0,1743	1,56	6,04	4,22
KRW028	07.12.2009	24,44	40,52	0,3247	1,44	6,15	3,11
KRW028	18.11.2009	22,99	27,9	0,5885	1,36	6,18	5,44
KRW028	21.10.2009	30,67	56,33	2,2767	1,66	6,33	6,17
KRW028	15.09.2009	21,63	62,18	0,7991	1,69	6,21	2,63
KRW028	12.08.2009	44,77	149,66	0,7965	1,3	6,39	8,81
KRW028	14.04.2009	18,11	81,87	4,01	1,27	6,18	7,89
KRW028	26.01.2009	28,15	206,67	0,52	1,46	6,3	4,08
KRW028	22.10.2008	49,15	165,46	0,337	1,502	6,54	4,64
KRW028	20.05.2008	14,669	42,91	1,57	0,64	6,3	9,23

KRW028	07.04.2008	2,62	4,65	0,231	0,127	5,69	5,63
KRW028	27.03.2008	13,4	60,38	4,165	0,945	6,4	5,24
KRW028	14.02.2008	22,8	93,05	3,988	1,373	6,65	5,79
KRW028	12.11.2007	80,9	283,22	1,372	1,482	6,67	4,28
KRW028	11.10.2007	85,5	289,11	1,212	1,628	6,62	9,94
KRW028	13.09.2007	78,97	267,63	1,109	1,88	6,66	12,13
KRW028	20.08.2007	80,793	341,47	7,345	1,946	6,82	9,99
KRW028	12.06.2007	90,5	332,64	8,899	1,643	6,78	8,255
KRW028	24.05.2007	59,85	81,89	2,503	1,475	6,73	4
KRW028	18.04.2007	31,18	93,01	1,961	1,56	6,64	4
KRW028	19.03.2007	45,19	167,47	0,253	1,221	6,77	6,95
KRW028	16.01.2007	17,67	55,9	0,685	1,288	6,68	2
KRW028	14.11.2006	12,13	42,46	0,545	0,03	6,39	6
KRW028	02.10.2006	12,78	84,76	0,697	2,013	6,25	9,51
KRW028	22.08.2006	18,7	101,61	4,081	1,971	6,16	4
KRW028	31.05.2006	19,23		3,876	1,68		2
KRW028	18.04.2006	10,11	66,81	0,718	0,65	5,67	6
KRW028	31.01.2006	42,67	208,52	0,01	0,64	6,74	6
KRW028	17.11.2005	53,29	322,39	0,098	1,356	7,68	7,35
KRW028	22.09.2005	14,89	206,65	0,245	1,557	6,87	5,21
KRW028	25.08.2005	39,82	188,28	0,346	1,427	6,7	6,55
KRW028	14.04.2005	43,76	220,96	0,146	2,019	6,89	4
KRW028	18.01.2005	47,41	202,22	0,01	1,546	6,71	40
KRW028	05.12.2004	48	247	0,01	1,691	6,574	4
KRW028	15.09.2004	49,9	226	0,01	1,725	5,914	2
KRW028	17.05.2004	39,9	194	0,159	1,538	6,692	2
KRW028	18.04.2004	40,7	196	0,01	0,843	6,164	6
KRW028	30.01.2004	55,8	6	0,01	0,01	6,489	2
KRW028	19.05.2002	29,36	150	0,014	1,214	6,111	2
KRW028	31.01.2002	38,01	173			6,346	
KRW028	15.09.2001	15,82	74	0,058	0,532	6,03	6
KRW028	10.05.2001		84		0,566	6,351	2
KRW028	19.03.2001	20,27	88	0,03	0,762	6,943	3
KRW028	09.03.2001	12,98	71	0,075	1,004	6,766	2
KRW028	19.01.2001	34,75	160	1,96	1,058	6,615	21
KRW029	04.06.2014	13,84			0,61		4,84
KRW029	13.05.2014	15,12			0,59		4,42
KRW029	15.04.2014	4,58			0,11		1,5
KRW029	18.03.2014	5,82			0,18		3,65
KRW029	18.02.2014	14,23			0,62		9,54
KRW029	16.01.2014	13,8			0,85		3,41
KRW029	02.12.2013	13,8			0,85		3,41
KRW029	13.11.2013	49,6	0	0,06	4,34	3,88	2,46
KRW029	16.10.2013	58,53	0	1,3525	0,82	3,94	2,44
KRW029	20.09.2013	59,7	0	0,0874	3,54	3,85	1,66
KRW029	13.08.2013	58,9	0	0,1104	2,97	3,61	4,17
KRW029	16.07.2013	44,44	0	0	2,91	3,82	2,51
KRW029	11.06.2013	39,03	0	0,2191	2,43	3,8	2,22

KRW029	22.05.2013	38,91	0	0,1418	2,27	3,8	0,66
KRW029	29.04.2013	25,71	0	0,0585	1,65	3,93	0,97
KRW029	13.03.2013	15,17	0	0,0331	0,68	4,16	2,17
KRW029	04.02.2013	7,8	0	0,018	0,31	4,42	1,49
KRW029	08.01.2013	2,36	21,03	0,0518	0,05	5,21	2,34
KRW029	03.12.2012	17,02	0	0	0,6	4,13	2,1
KRW029	05.11.2012	17,42	0	0,0219	0,72	3,96	1,93
KRW029	01.10.2012	20,05	0	0,0205	0,86	3,91	1,45
KRW029	04.09.2012	22,12	0	0,3874	1,09	3,8	0,21
KRW029	01.08.2012	13,33	0	0,3484	0,57	4,31	3,07
KRW029	02.07.2012	9,64	0	0,0121	0,35	4,32	0,91
KRW029	05.06.2012	7,34	0	0,0015	0,23	4,45	1,7
KRW029	02.05.2012	3,42	13,21	0	0,12	5,05	7,05
KRW029	10.04.2012	2,27	11,8	0	0,11	5,09	3,36
KRW029	06.03.2012	3,49	5,55	0	0,13	5,69	1,73
KRW029	07.02.2012	2,04	12,85	0,0246	0,17	5,49	0,99
KRW029	05.12.2011	6,31	49,55	0,0418	0,33	5,02	3,88
KRW029	02.11.2011	4,54	11,58	0,0378	0,52	4,84	3,83
KRW029	03.10.2011	6,08	0	0,0419	0,19	4,46	1,88
KRW029	12.09.2011	5,54	3,38	0,0252	0,17	5,25	3,24
KRW029	03.08.2011	5,84	0	0,1149	0,17	4,51	1,79
KRW029	04.07.2011	4,44	0	0,029	0,17	4,78	7,08
KRW029	12.05.2011	16,39	48,45	0,0865	0,09	7,09	4,95
KRW029	12.04.2011	4,18	7,74	0	0,22	6,04	2,53
KRW029	03.03.2011	4,19	1,83	0,03	0,18	5,75	7,5
KRW029	12.01.2011	4,01	8,1	0,05	0,27	5,79	2,75
KRW029	01.12.2010	2,68	6,74	0	0,28	5,71	3,09
KRW029	03.11.2010	4,09	15,44	0	0,29	5,58	3,24
KRW029	06.10.2010	8,46	4,83	0,03	0,41	5,13	3,04
KRW029	06.09.2010	4,22	4,54	0	0,66	5,38	2,15
KRW029	04.08.2010	3,9	7,18	0,033	0,74	5,64	2,41
KRW029	07.07.2010	9,33	1,93	0,0176	5,3	4,78	2,55
KRW029	24.06.2010	5,35	0,6	0,1785	0,9	5,63	3,97
KRW029	08.06.2010	3,69	3,78	0,08	0,21	5,51	5,64
KRW029	19.05.2010	7,29	9,04	0,0136	1,29	6,06	2,67
KRW029	09.03.2010	13,22	33,59	2,5897	1,29	6,37	2,86
KRW029	17.02.2010	1,96	0	0,69	0,55	4,61	4,1
KRW029	21.01.2010	13,72	46,02	1,8943	2,08	6,23	4,09
KRW029	07.12.2009	8,94	0	0,0305	0,27	4,29	2,18
KRW029	18.11.2009	1,29	12,71	0,0521	0,39	4,2	3,62
KRW029	21.10.2009	18,53	0,46	0,0181	0,35	4,63	21,17
KRW029	15.09.2009	25,99	41,33	0,2672	0,35	5,73	2,21
KRW029	12.08.2009	7,49	0	0	0,17	5,89	10,42
KRW029	14.04.2009	4,03	5,05	0,016	0,102	5,37	9,49
KRW029	26.01.2009	13,58	0	0,026	0,172	4,33	2,44
KRW029	22.10.2008	13,09	0	0,01	0,421	4,44	40,99
KRW029	20.05.2008	10,167	42,06	0,01	0	9,84	9,09
KRW029	07.04.2008	6,72	9,15	0,101	0,061	6,39	5,9
KRW029	27.03.2008	7,35	9,94	0,01	0,053	6,44	4,36
KRW029	14.02.2008	5,7	0,01	0,01	0,064	6,06	4,29

KRW029	12.11.2007	18,62	2,58	0,053	0,612	4,79	4,32
KRW029	13.09.2007	17,58	0,84	0,084	0,816	4,69	15,28
KRW029	20.08.2007	16,77	0,78	0,09	0,704	4,74	5,99
KRW029	12.06.2007	13,03	7,08	0,164	0,496	4,87	6,42
KRW029	24.05.2007	11,86	0	0,01	0,464	4,44	2
KRW029	18.04.2007	15,42	0	0,087	0,624	4,22	4
KRW029	27.03.2007	14,58	0	0,037	0,55	4,38	6,14
KRW029	16.01.2007	15,86	0	0,161	0,539	4,17	4
KRW029	14.11.2006	9,11	7,57	0,072	0,538	5,69	5,615
KRW029	02.10.2006	8,49	0,6	0,014	0,511	4,64	10,88
KRW029	22.08.2006	9,69	1,31	0,01	0,363	4,67	2
KRW029	07.08.2006	13,65	0	0,307	0,499	4,44	3,38
KRW029	31.05.2006	8,22		0,011	0,236		4
KRW029	18.04.2006	1,53	3,28	1,304	0,29	5,15	6
KRW029	31.01.2006	16,08	4,68	0,021	0,197	5,22	4
KRW029	17.11.2005	19,2	0,54	0,031	0,905	5,07	7,46
KRW029	29.09.2005	5,1	0	8,694	7,339	3,22	14,78
KRW029	25.08.2005	2,18	0	0,01	0,754	4,22	5,68
KRW029	14.04.2005	4,2	8,5	0,01	0,026	6,17	2
KRW029	18.01.2005	20,52	57,83	0,01	0,21	6,91	2
KRW029	05.12.2004	15,93	12	0,01	0,378	5,792	2
KRW029	15.09.2004	12,84	0	0,01	0,305	4,056	2
KRW029	17.05.2004	12,36	30	14,702	0,189	6,617	2
KRW029	18.04.2004	14,17	22	0,01	0,01	8,106	2
KRW029	21.03.2004	17,86	10	0,36	0,07	5,329	2
KRW029	30.01.2004	12,9	8	0,01	0,01	4,582	2
KRW029	08.12.2003	18,99	0	0,01	0,469	4,4	4
KRW029	17.11.2003	19,61	0	0,01	0,434	3,617	8
KRW029	20.10.2003	19,03	0	0,01	0,417	3,907	2
KRW029	22.09.2003	17,1	0	1,6	0,438	4,508	2
KRW029	13.08.2003	16,27	0	0,01	0,155	4,002	2
KRW029	14.07.2003	10,19	22	0,01	0,111	4,717	2
KRW029	06.05.2003	10,64	4	0,01	0,002	5,233	6
KRW029	18.03.2003	7,67	4	0,01	0,01	5,746	2
KRW029	19.05.2002	19,39	0	0,033	0,5	4,009	2
KRW029	31.01.2002	4,59	2			5,143	
KRW029	15.09.2001	11,81	0	0,01	0,245	3,823	8
KRW029	10.05.2001			0,049			
KRW029	19.03.2001	11,76	59	0,131	0,118	7,382	4
KRW029	05.03.2001	9,8	9	0,001	0,011	6,2	6
KRW029	17.01.2001	5,11			0,067		2
KRW029	15.12.2000	7,33	2	0,482	0,104	5,976	2
KRW030	04.06.2014	7,15	0	0,1768	0,37	4,73	4,92
KRW030	13.05.2014	8,25	0,77	0	0,34	4,72	5,61
KRW030	15.04.2014	8,24	0	0,0035	0,4	4,58	3,03
KRW030	18.03.2014	8,32	13,06	0,0122	0,32	4,54	4,74
KRW030	18.02.2014	9,21	2,13	0	0,4	4,48	6,63
KRW030	16.01.2014	8,01	1,89	0,01	0,54	5,05	5,67

KRW030	02.12.2013	8,01	0,9	0,01	0,54	5,05	5,67
KRW030	13.11.2013	7,27	0	0,14	0,41	4,14	3,52
KRW030	16.10.2013	5,32	5,68	0,0294	0,1	5,85	3,31
KRW030	20.09.2013	4,87	4,9	0,0144	0,04	5,07	3,26
KRW030	13.08.2013	7,65	0,09	0,0261	0,2	5,94	6,1
KRW030	16.07.2013	6,33	0,43	0	0,34	5	3,8
KRW030	11.06.2013	10,53	25,48	0,0546	0,44	6,04	3,97
KRW030	21.05.2013	15,01	12,56	0,4689	0,49	6,12	3,93
KRW030	29.04.2013	22,32	55,43	0,1222	0,31	6,43	7,39
KRW030	13.03.2013	14,26	58,09	1,0809	0,36	6,34	3,39
KRW030	04.02.2013	7,91	0	0,0358	0,48	4,8	2,86
KRW030	08.01.2013	8,82	0	0,0414	0,52	4,67	3,63
KRW030	03.12.2012	7,66	1,33	0	0,38	4,78	3,83
KRW030	05.11.2012	7,55	0	0,0267	0,45	4,7	4,04
KRW030	01.10.2012	8,14	0	0	0,48	4,64	2,84
KRW030	04.09.2012	5,29	0	0,0144	0,25	4,69	0,61
KRW030	01.08.2012	5,97	0,85	0	0,31	5,23	4,75
KRW030	02.07.2012	6,94	0	0,0027	0,29	4,7	7,23
KRW030	05.06.2012	6,91	2,32	0	0,4	5,12	4,44
KRW030	02.05.2012	8,22	12,08	0	0,5	5,87	8,08
KRW030	10.04.2012	8,14	18,45	0,0195	0,42	5,66	6,84
KRW030	06.03.2012	5,62	3,61	0	0,53	4,93	3,63
KRW030	07.02.2012	10,25	10,85	0,0233	0,56	4,86	2,82
KRW030	05.12.2011	11,42	8,57	0,0009	0,61	4,56	5,11
KRW030	02.11.2011	11,2	10,26	0,0492	0,77	4,11	3,97
KRW030	03.10.2011	13,46	0	0,0283	0,73	4,2	4,18
KRW030	12.09.2011	10,43	0	0,0047	0,7	4,49	4,2
KRW030	03.08.2011	10,15	0	0	0,55	4,28	2,36
KRW030	04.07.2011	8,09	0	0,023	0,62	4,57	6,8
KRW030	12.05.2011	11,33	0	0,1281	0,58	4,74	6,14
KRW030	12.04.2011	11,92	0	0,0155	0,52	4,14	2,99
KRW030	03.03.2011	7,62	1,05	0,004	0,41	4,62	3,52
KRW030	12.01.2011	6,97	0	0,01	0,39	4,56	3,13
KRW030	01.12.2010	11,69	0	0,01	0,67	4,55	4,41
KRW030	06.10.2010	12,08	0	0,02	0,72	4,65	4,18
KRW030	06.09.2010	5,22	0,05	0,002	0,69	4,44	3,18
KRW030	04.08.2010	10,55	0	0,0417	0,64	4,41	3,19
KRW030	07.07.2010	8,03	0	0,0211	0,56	4,63	4,85
KRW030	24.06.2010	9,15	12,33	0,0393	0,55	4,62	4,32
KRW030	08.06.2010	7,03	0,13	0,05	0,37	4,82	6,01
KRW030	19.05.2010	9,83	22,16	0,0734	0,96	6,33	2,64
KRW030	09.03.2010	8,08	12,82	0,0618	0,31	5,01	3,29
KRW030	17.02.2010	8,49	7,23	0,06	0,29	5,16	4,72
KRW030	21.01.2010	10,85	51,26	0,0566	0,45	5,27	3,31
KRW030	07.12.2009	8,22	3,9	0,0135	0,41	4,91	3,46
KRW030	18.11.2009	6,53	9,45	0,6722	0,34	4,8	4,8
KRW030	21.10.2009	7,09	4,05	0,0633	0,32	4,89	3,71
KRW030	15.09.2009	8,33	15,11	0,0233	0,4	5,55	3,06
KRW030	12.08.2009	7,99	0	0,0117	0,28	4,54	6,96
KRW030	14.04.2009	4,36	6,3	0,073	0,213	5,31	9,8

KRW030	26.01.2009	13,244	0	0,05	0,16	4,16	42,87
KRW030	22.10.2008	6,01	3,52	0,064	0,11	5,49	40,25
KRW030	20.05.2008	10,012	35,6	0,01	0	9,36	6,38
KRW030	07.04.2008	6,54	5,82	0,353	0,073	6,37	5,97
KRW030	27.03.2008	9,74	15,77	0,38	0,057	6,51	5,37
KRW030	14.02.2008	1,93	2,66	0,01	0,017	5,75	4,73
KRW030	12.11.2007	2,45	6,49	0,024	0,4	5,69	4,34
KRW030	11.10.2007	27,02	6,6	0,058	0,04	5,61	2,97
KRW030	13.09.2007	2,11	3,62	0,111	0,031	5,49	14,87
KRW030	20.08.2007	0,832	5,1	0,156	0,08	5,58	0,46
KRW030	12.06.2007	2,27	8,52	0,013	0,035	5,66	2
KRW030	24.05.2007	2,75	4,32	0,011	0,068	6,93	2
KRW030	18.04.2007	3,57	1,45	0,047	0,06	4,91	5,55
KRW030	27.03.2007	1,94	1,69	0,041	0,045	5,85	6
KRW030	16.01.2007	4,84	5,59	0,243	0,083	5,77	4
KRW030	14.11.2006	7,87	55,58	0,084	0,161	7,24	4
KRW030	02.10.2006	10,84	62,91	0,01	0,13	7,19	4
KRW030	22.08.2006	12,14	28,95	0,843	0,075	6,48	2
KRW030	07.08.2006	13,46	40,99	0,606	0,061	6,89	4,24
KRW030	31.05.2006			0,441	0,022		4
KRW030	18.04.2006	4,81	30,13	1,066	0,028	5,55	6
KRW030	31.01.2006	6,72	18,07	0,211	0,75	6,39	4
KRW030	17.11.2005	17,06	137,6	0,171	0,017	9,65	7,29
KRW030	29.09.2005	5,1	17,85	0,625	0,38	6,17	5,08
KRW030	25.08.2005	2,26	11	0,01	0,04	5,7	5,68
KRW030	14.04.2005	11,6	26,79	0,382	0,026	6,36	4
KRW030	18.01.2005	4,81	42	0,01	0,048	6,1	2
KRW030	05.12.2004	5,47	36	0,01	0,088	5,649	2
KRW030	15.09.2004	4,88	6	0,01	0,045	5,107	2
KRW030	17.05.2004	6,08	32	10,603	0,01	8,854	2
KRW030	18.04.2004	11,5	48	0,01	0,01	9,642	2
KRW030	21.03.2004	4,74	30	0,01	0,01	6,218	2
KRW030	30.01.2004	3,45	12	0,01	0,01	5,636	2
KRW030	08.12.2003	6,12	22	0,01	0,01	6,1	4
KRW030	17.11.2003	6,67	28	0,01	0,01	5,316	2
KRW030	20.10.2003	1,92	10	0,01	0,01	5,48	2
KRW030	22.09.2003	2,07	29	0,01	0,01	6,085	2
KRW030	13.08.2003	4,09	42	0,01	0,01	6,468	2
KRW030	14.07.2003	3,81	32	0,01	0,01	5,794	2
KRW030	06.05.2003	2,43	2	0,01	0,01	4,914	4
KRW030	18.03.2003	1,89	4	0,01	0,01	5,276	1
KRW030	19.05.2002	4,75	2	0,022	0,01	4,77	2
KRW030	15.09.2001	28,3	2	0,01	0,001	5,4	6
KRW030	10.05.2001		54		0,016		
KRW030	19.03.2001	8,97	41	0,048	0,04	7,373	2
KRW030	05.03.2001	4,4	4	0,494	0,008	5,6	2
KRW030	17.01.2001	3,17			0,004		3
KRW030	15.12.2000	4,8	2	0,597	0,019	4,951	2

KRW031	04.06.2014	11,11	39,84	0,8909	0,02	6,37	3,94
KRW031	13.05.2014	14,41	64,75	0	0	7,57	4,35
KRW031	15.04.2014	12,83	57,22	0,0688	0,01	6,73	1,65
KRW031	18.03.2014	14,12	12,51	0,024	0,4	6,08	2,65
KRW031	18.02.2014	16,08	84,29	0,0458	0,33	6,24	2,61
KRW031	16.01.2014	12,5	66	0,01	0,14	6,61	3,7
KRW031	02.12.2013	12,5	66	0,01	0,14	6,61	3,7
KRW031	13.11.2013	14,87	52,04	0,01	0,1	6,8	2,7
KRW031	16.10.2013	13,6	56,69	0	0	7,22	2,28
KRW031	19.09.2013	13,1	34,35	0,1297	0	6,96	21,16
KRW031	13.08.2013	16,13	53,13	0	0	7,22	2,81
KRW031	16.07.2013	12,18	69,37	0,0946	0,02	6,9	1,92
KRW031	11.06.2013	11,48	58,62	0,256	0,02	6,68	1,96
KRW031	21.05.2013	12	40,05	0,0645	0,11	6,41	2,81
KRW031	29.04.2013	11,95	53,99	0,2821	0,02	6,44	3,12
KRW031	13.03.2013	12,77	46,48	0,1854	0,2	6,57	1,55
KRW031	04.02.2013	11,26	55,29	0,1451	0,28	7,02	2,01
KRW031	08.01.2013	12,02	52,94	0,46	0,28	6,79	2,06
KRW031	03.12.2012	11,42	55,22	0,0026	0,23	7,17	2,24
KRW031	05.11.2012	11,69	51,69	0,0889	0,02	7,15	1,98
KRW031	01.10.2012	11,96	61,22	0,0598	0,01	6,68	1,4
KRW031	04.09.2012	11,42	52,65	0,2242	0,03	7,05	0,8
KRW031	01.08.2012	11,26	50,5	0,1334	0,02	6,82	3,36
KRW031	02.07.2012	11,69	87,56	0,2416	0,02	6,66	4,29
KRW031	05.06.2012	11,26	55,76	0,0468	0,07	6,57	2,25
KRW031	02.05.2012	12,84	53,91	0,0214	0,12	6,74	7,43
KRW031	10.04.2012	13,27	46,01	0,2582	0,12	6,97	4,53
KRW031	06.03.2012	9,69	69,7	0,0764	0,11	6,92	1,77
KRW031	07.02.2012	13,65	49,56	0,7034	0,16	6,4	1,15
KRW031	05.12.2011	14,1	78,13	0,4703	0,13	6,6	1,92
KRW031	02.11.2011	12,92	43,54	0,0508	0,18	6,32	3,05
KRW031	03.10.2011	12,66	57,54	0,417	0,2	6,31	2,13
KRW031	12.09.2011	13,02	42,89	0,2635	0	7,16	3,15
KRW031	03.08.2011	12,05	36,29	0,2711	0,06	6,76	2,03
KRW031	04.07.2011	9,98	41,8	0,5483	0,01	6,42	6,01
KRW031	12.05.2011	13,79	38,02	0,2035	0	6,68	3,61
KRW031	12.04.2011	13,59	53,97	0,1738	0	6,86	1,83
KRW031	03.03.2011	12,23	62,43	0,11	0,12	6,81	4,36
KRW031	12.01.2011	13,07	73,94	0,25	2,26	6,83	3,58
KRW031	01.12.2010	12,78	61,25	0,02	0,06	6,91	2,26
KRW031	03.11.2010	13,33	69,88	0,43	0,14	6,88	2,73
KRW031	06.10.2010	16,62	113,77	0,17	0,13	6,94	3,18
KRW031	06.09.2010	12,89	36	0,27	0,13	5,91	2,14
KRW031	04.08.2010	10,35	66,05	0,6843	0,03	6,27	2,23
KRW031	07.07.2010	11,1	53,21	0,2707	0,02	6,18	2,35
KRW031	24.06.2010	13,21	76,64	0,6037	0,02	6,36	3,68
KRW031	08.06.2010	12,74	57,05	0,385	0,47	6,7	6,02
KRW031	19.05.2010	14,05	157	0,2614	0,28	6,62	3,16
KRW031	09.03.2010	15,26	65,84	0,1064	1,72	6,75	3,08
KRW031	17.02.2010	15,66	46,71	0,18	0,25	6,72	4,18

KRW031	21.01.2010	14,9	59,96	0,0381	0,55	6,67	2,31
KRW031	07.12.2009	15,79	89,79	0,1499	0,2	6,3	2,5
KRW031	18.11.2009	1,58	83,34	0,104	0,08	6,87	4,35
KRW031	21.10.2009	13,81	59,53	0,1044	0,27	6,6	2,89
KRW031	15.09.2009	12,19	40,2	0,8707	0,01	6,31	2,2
KRW031	12.08.2009	12,31	50,36	0,0893	0	6,28	8,05
KRW031	14.04.2009	11,75	48,77	0,951	0,993	6,62	3,08
KRW031	26.01.2009	12,55	39,75	0,12	0,29	6,35	2,31
KRW031	22.10.2008	12,9	59,71	0,698	0,023	6,41	2,14
KRW031	07.04.2008	11,37	22,16	0,018	0,486	6,79	5,68
KRW031	27.03.2008	5,36	6,79	0,076	0,053	6	4,79
KRW031	14.02.2008	9,16	29,13	0,01	0,026	6,6	5,02
KRW031	12.11.2007	11,64	15,98	0,206	0,029	6,14	12,45
KRW031	11.10.2007	11,47	32,74	0,027	0,004	6,18	11,87
KRW031	17.09.2007	10,16	38,78	0,079	0,018	6,59	12,63
KRW031	20.08.2007	11,54	49,82	0,108	0,01	6,83	0,66
KRW031	24.05.2007	11,59	46,29	0,132	0,51	6,83	2
KRW031	18.04.2007	12,19	53,19	0,454	0,166	7,58	2
KRW031	27.03.2007	12,37	51,7	0,806	0,251	6,84	6,175
KRW031	16.01.2007	12,66	55,65	0,051	0,04	7,52	2
KRW031	14.11.2006	7,88	60,84	0,237	0,078	7,67	5,805
KRW031	02.10.2006	9,37	55,68	0,178	0,01	7,33	4
KRW031	22.08.2006	12,19	60,79	0,306	0,037	7,27	2
KRW031	07.08.2006	12,37	57,5	0,211	0,009	7,21	3,2
KRW031	31.05.2006	17,1		17,85	0,461		4
KRW031	18.04.2006	10,45	31,38	0,104	0,402	5,62	6
KRW031	12.01.2006	214,41	0	6,235	34,34	4,32	24,9
KRW031	17.11.2005	13,62	124,02	0,665	0,003	7,97	7,28
KRW031	29.09.2005	14,7	50,57	0,485	0,174	6,6	4,13
KRW031	25.08.2005	1,28	39,93	0,002	0,026	6,21	5,34
KRW031	14.04.2005	14,21	56,57	0,01	0,01	6,61	2
KRW031	18.01.2005	16,07	75,92	0,01	0,08	7,13	2
KRW031	15.09.2004	15,42	49	0,284	0,064	6,092	2
KRW031	17.05.2004	14,69	71	0,556	0,01	7,993	2
KRW031	18.04.2004	13,98	55	0,02	0,01	8,829	4
KRW031	21.03.2004	11,64	59	0,01	0,01	6,978	2
KRW031	30.01.2004	14,68	61	0,07	0,17	7,118	2
KRW031	08.12.2003	11,13	57	1,451	0,01	6,2	2
KRW031	17.11.2003	12,91	63	0,189	0,01	6,238	2
KRW031	20.10.2003	11,55	61	0,55	0,01	6,802	2
KRW031	22.09.2003	11,38	49	0,039	0,01	7,938	2
KRW031	13.08.2003	11,34	51	0,451	0,01	6,662	2
KRW031	14.07.2003	11,71	61	0,03	0,01	6,833	2
KRW031	06.05.2003	11,93	41	0,01	0,01	6,053	5
KRW031	18.03.2003	11,68	34	0,01	0,01	6,588	1
KRW031	19.05.2002	12,17	58	0,053	0,01	6,252	2
KRW031	15.09.2001	10,24	47	1,075	0,074	6,334	8
KRW031	10.05.2001			0,092	0,012		
KRW031	09.03.2001	15,59	0	0,047	0,528	3,958	2
KRW031	17.01.2001		6				

KRW031	18.12.2000	32,12	0	15,452	0,505	3,234	2
KRW034	04.06.2014	57,42	0	0,5649	2,03	3,1	4,48
KRW034	13.05.2014	47,78	0	0,3767	1,69	3,34	4,92
KRW034	15.04.2014	46,23	0	0,1208	1,64	3,41	1,8
KRW034	18.02.2014	43,7	30,46	0,1407	1,16	5,72	2,75
KRW034	16.01.2014	37,9	0	0,1	1,86	3,52	3,55
KRW034	02.12.2013	37,9	0	0,1	1,86	3,52	3,55
KRW034	13.11.2013	88,8	0	0,49	4,88	2,96	2,78
KRW034	16.10.2013	8,61	0	13,9761	4,89	4,61	2,59
KRW034	19.09.2013	81,33	0	0,3891	3,55	3,17	1,5
KRW034	13.08.2013	81,48	20	0,4365	3,74	3,23	2,83
KRW034	16.07.2013	63,02	0	0,2068	3,12	3,66	2,61
KRW034	11.06.2013	49,47	0	1,3224	3,52	3,48	2,67
KRW034	21.05.2013	50,44	0	11,046	3,67	3,61	3,02
KRW034	29.04.2013	46,38	0	0,3756	2,82	3,44	2,84
KRW034	13.03.2013	36,4	0	0,5508	2,11	3,6	2,03
KRW034	04.02.2013	31,62	0	3,523	2,03	4,43	1,82
KRW034	03.12.2012	32,37	0	1,3733	2,06	4,54	2,49
KRW034	05.11.2012	40,53	6,17	7,5036	2,99	5,13	2,43
KRW034	01.10.2012	38,5	0	0,0608	2,82	3,97	1,71
KRW034	04.09.2012	33,61	0	0,4687	2,98	4,64	-0,04
KRW034	01.08.2012	27,21	12,75	0,1476	1,83	5,92	3,52
KRW034	02.07.2012	24,89	4,93	0,1943	1,25	5,8	4,48
KRW034	02.05.2012	20,54	28,33	0,0112	0,61	6,46	10,09
KRW034	10.04.2012	20,93	9,31	0,1514	0,64	6,3	4,87
KRW034	06.03.2012	15,06	20,02	0,0074	0,13	6,55	3,97
KRW034	07.02.2012	23,41	20,75	0,4673	0,89	6,12	1,31
KRW034	05.12.2011	24,37	46,8	0,2953	0,63	6,64	2,09
KRW034	02.11.2011	24,24	45,16	0,3344	0,59	6,44	3,45
KRW034	03.10.2011	24,08	22,61	0,0703	0,61	6,13	2,52
KRW034	12.09.2011	24,75	13,38	0,0374	0,52	6,43	2,62
KRW034	03.08.2011	20,19	20,09	0,0054	0,46	6,62	1,9
KRW034	04.07.2011	25,27	15,45	0,0478	0,56	6,28	5,7
KRW034	12.05.2011	15,86	30,96	0,0754	0,09	6,81	2,27
KRW034	12.04.2011	17,76	58,44	0	0,02	6,68	2,19
KRW034	03.03.2011	25,03	33,44	0,13	0,94	6,41	3,1
KRW034	12.01.2011	19,79	35,35	19,46	0,44	6,42	3,12
KRW034	01.12.2010	19,5	3,99	0,02	0,3	6,21	3,88
KRW034	03.11.2010	20,34	21,22	0,24	0,32	6,11	3,13
KRW034	06.10.2010	22,76	45,55	0,06	0,33	6,28	3,91
KRW034	06.09.2010	20,92	9,29	0,004	0,26	5,23	2,35
KRW034	04.08.2010	19,95	36,09	0,2216	0,28	6,14	2,27
KRW034	07.07.2010	18,53	21,04	0,0135	0,09	6,04	2,68
KRW034	24.06.2010	18,96	65,4	0,1252	0,16	6,3	3,45
KRW034	08.06.2010	28,39	48,73	0,26	0,97	5,95	4,13
KRW034	19.05.2010	11,13	0	0,0171	0,1	4,23	3,31
KRW034	09.03.2010	20,53	71,19	0,1184	0,19	6,69	2,46
KRW034	17.02.2010	22,09	41,88	0,03	0,24	6,64	3,93

KRW034	07.12.2009	22,35	27,35	0,0265	0,62	6,07	2,55
KRW034	18.11.2009	2,49	55,06	0,0345	0,66	6,71	4,72
KRW034	21.10.2009	23,41	55,52	0,0423	0,66	6,55	2,42
KRW034	15.09.2009	21,13	30,19	0,1157	0,54	6,16	2,57
KRW034	12.08.2009	21,34	58,86	0,4846	0,39	6,25	10,33
KRW034	14.02.2008	15,14	20,67	0,01	0,208	6,55	4,63
KRW034	19.11.2007	26,9	33,52	0,2	0,26	5,03	4,24
KRW034	11.10.2007	52,74	30,63	0,151	0,231	6,52	11,76
KRW034	17.09.2007	12,37	21,55	0,64	0,293	6,18	12,38
KRW034	20.08.2007	10,633	14,09	0,502	0,247	6,35	0,52
KRW034	15.05.2007	11,37	37,38	0,488	0,136	7,31	2
KRW034	18.04.2007	11,21	42,22	0,017	0,096	7,86	2
KRW034	27.03.2007	11,75	30,14	0,19	0,171	6,47	6,285
KRW034	16.01.2007	12,55	53,59	0,01	0,001	7,11	2
KRW034	14.11.2006	7,41	43,73	0,039	0,292	7,15	4
KRW034	02.10.2006	10,49	48,12	0,101	0,289	7,42	4
KRW034	22.08.2006	11,42	32,67	0,155	0,223	6,84	2
KRW034	07.08.2006	8,86	15,55	0,01	0,08	6,35	4,53
KRW034	31.05.2006			0	0,02		2
KRW034	18.04.2006	9,46	8,18	0,01	0,065	5,53	6
KRW034	25.11.2005	14,82	14,31	0,18	0,37	6,45	5,78
KRW034	29.09.2005	16,5	19,54	0,433	0,377	5,87	4,46
KRW034	25.08.2005	1,62	4	0,155	0,396	5,97	4,1
KRW034	25.04.2005	0,48	66,02	0,01	0,013	7,35	2
KRW034	18.01.2005	13,56	36	0,01	0,012	10,11	2
KRW034	15.09.2004	18,59	14	0,01	0,544	5,701	2
KRW034	17.05.2004	15,69	22	0,105	0,01	9,206	4
KRW034	18.04.2004	18,43	16	0,01	0,362	5,931	6
KRW034	30.01.2004	20,39	46	0,1	0,17	6,805	2
KRW034	09.12.2003	11,45	26	0,01	0,018	6,5	2
KRW034	18.11.2003	16,93	65	0,069	0,085	6,558	2
KRW034	20.10.2003	13,74	46	0,01	0,01	6,884	2
KRW034	22.09.2003	12,79	26	0,01	0,01	7,397	2
KRW034	14.08.2003	11,9	32	0,109	0,01	6,452	2
KRW034	14.07.2003	12,56	51	0,03	0,01	8,94	4
KRW034	18.03.2003	10,72	32	0,01	0,019	6,802	1
KRW034	12.12.2002	15,91	30	0,01	0,04	6,741	20
KRW034	19.05.2002	16,16	40	0,015	0,049	6,457	2
KRW034	12.11.2001	14,62	34	0,01	0,198	6,131	4
KRW034	10.05.2001					6,712	
KRW034	10.04.2001	21,9	37	0,106	0,153	7,133	3
KRW034	21.02.2001			0,028	0,133		3
KRW034	19.01.2001	33,11	34	0,102	0,254	5,744	3
KRW034	18.12.2000	15,08	37	0,104	0,123	6,486	2
KRW035	04.06.2014	1,74	6,19	0,0018	0,01	5,65	4,36
KRW035	13.05.2014	2,56	9,19	0	0,01	5,66	6,21
KRW035	15.04.2014	2,55	8,58	0,015	0,01	5,88	2,23
KRW035	18.03.2014	7,88	0	0,0977	0,09	5,65	4,09

KRW035	18.02.2014	14,4	85,15	0,0818	0,08	6,05	3,07
KRW035	16.01.2014	15,3	86	0,83	0,1	6,46	4,7
KRW035	02.12.2013	15,3	66	0,83	0,1	6,46	4,7
KRW035	13.11.2013	17,01	0	0,01	0,11	4,56	3,21
KRW035	16.10.2013	4,92	5,65	0,3183	0	6,53	2,49
KRW035	19.09.2013	11,28	38,91	0	0	6,59	5,7
KRW035	13.08.2013	4,83	16,33	0	0,05	6,01	2,95
KRW035	16.07.2013	3,89	9,41	0	0,04	5,82	2,5
KRW035	11.06.2013	5,24	31,49	0,0709	0,08	5,95	2,57
KRW035	21.05.2013	4,7	22,55	0,2077	0,06	5,81	3,19
KRW035	29.04.2013	3,92	16,75	0,0235	0,03	5,71	4,92
KRW035	13.03.2013	6,84	30,23	0,0791	0,08	6,06	2,03
KRW035	04.02.2013	5,26	1,27	0	0,01	6,22	1,84
KRW035	08.01.2013	6,41	28,65	0,1108	0,07	6,29	2,96
KRW035	03.12.2012	5,59	29,2	0,0831	0,06	6,24	2,58
KRW035	05.11.2012	4,32	17,7	0	0,09	6,15	2,6
KRW035	01.10.2012	3,6	12,95	0	0,06	5,92	1,83
KRW035	04.09.2012	2,83	6,94	0,182	0,06	5,95	-0,05
KRW035	01.08.2012	3,53	15,71	0,4577	0,05	5,95	3,87
KRW035	02.07.2012	3,05	5,42	0,1264	0,03	6,08	5,79
KRW035	05.06.2012	5,02	18,05	0,176	0,09	5,95	2,69
KRW035	02.05.2012	3,84	19,77	0,3442	0,07	5,98	6,34
KRW035	10.04.2012	3,53	18,8	0,2395	0,03	6,06	1,99
KRW035	06.03.2012	3,55	20,6	0,3067	0,04	5,91	2,69
KRW035	07.02.2012	2,94	18,2	0,1569	0,03	5,6	1,62
KRW035	05.12.2011	7,52	7,13	4,8933	0,09	5,74	6,19
KRW035	02.11.2011	2,86	5,81	0,0636	0,01	5,36	3,68
KRW035	03.10.2011	2,33	0,03	0,0179	0,01	5,7	3,23
KRW035	12.09.2011	3,84	0,02	0,004	0,04	6,06	3,01
KRW035	03.08.2011	1,92	7,73	0	0,01	5,74	2,33
KRW035	04.07.2011	1,97	0,76	0,0575	0,01	5,69	6,01
KRW035	12.05.2011	5,54	11,19	0,5396	0,05	6,03	6,34
KRW035	12.04.2011	4,64	11,19	0,0065	0,01	6,1	3,49
KRW035	03.03.2011	5,68	4,9	0,008	0,04	5,89	4
KRW035	12.01.2011	6,94	11,05	0	0,05	5,68	2,85
KRW035	01.12.2010	5,57	25,04	0,02	0,1	6,19	3,89
KRW035	03.11.2010	7,66	20,19	0,02	0,02	6,22	5,43
KRW035	06.10.2010	10,79	81,33	0,09	0,01	6,55	3,64
KRW035	06.09.2010	4,39	6,7	0,02	0,01	5,43	2,75
KRW035	04.08.2010	3,39	0,02	0,1681	0,02	5,05	3,77
KRW035	07.07.2010	2,5	7,4	0,0282	0,01	5,58	4,41
KRW035	24.06.2010	2,9	2,43	0,0936	0,01	5,66	4
KRW035	08.06.2010	4,01	7,41	0,055	0,02	5,77	6,35
KRW035	08.06.2010	4,01	7,41	0,055	0,02	5,77	6,35
KRW035	19.05.2010	4,32	21,13	0,0226	0,03	5,68	2,84
KRW035	09.03.2010	3,59	28,59	0,3713	0,02	5,76	2,75
KRW035	17.02.2010	10,18	37,99	1,2931	0,04	6,19	4,75
KRW035	21.01.2010	43,75	19,02	0,1123	0,05	5,92	2,64
KRW035	07.12.2009	4,81	14,82	0,0468	0,05	5,85	2,66
KRW035	18.11.2009	0,52	24,25	0,0112	0,05	6,14	5,17

KRW035	21.10.2009	4,33	36,08	0,0829	0,04	6,14	2,17
KRW035	15.09.2009	2,75	9,11	0,0594	0,04	5,78	2,5
KRW035	12.08.2009	6,21	35,53	0,659	0,02	5,97	8,15
KRW035	14.04.2009	17,19	56,73	0,812	0,062	5,7	3,89
KRW035	26.01.2009	18,377	0	2,175	0,053	4,19	40,03
KRW035	28.10.2008	5,81	4,48	0,366	0,009	6,05	41,62
KRW035	07.04.2008	2,62	11,14	0,02	0,032	5,29	5,83
KRW035	14.02.2008	4,91	11,41	0,01	0,04	6,07	4,74
KRW035	12.11.2007	44,35	129,13	8,353	0,473	6,48	6,37
KRW035	11.10.2007	52,74	180,76	14,514	0,522	6,58	10,12
KRW035	17.09.2007	57,36	218,64	23,081	0,536	7,03	10,52
KRW035	20.08.2007	12,36	45,02	2,88	0,504	7,26	2,39
KRW035	15.05.2007	10,02	18,55	3,398	0,552	6,7	4
KRW035	18.04.2007	8,45	24,8	0,146	0,434	6,7	4
KRW035	27.03.2007	8,38	25,83	0,016	0,139	6,41	6,26
KRW035	16.01.2007	7,45	18,41	0,021	0,022	6,64	2
KRW035	02.10.2006	9,33	59,84	0,286	0,078	7,98	2
KRW035	22.08.2006	3,97	12,65	0,198	0,034	6,74	2
KRW035	07.08.2006	3,84	13,62	0,408	0,057	6,08	4,87
KRW035	18.04.2006	2,22	0	0,01	0,047	4,39	6
KRW035	17.11.2005	21,1	107,89	0,17	0,363	6,99	7,3
KRW035	29.09.2005	16,4	54,06	0,01	0,189	6,65	4,37
KRW035	25.08.2005	1,68	57,62	0,01	0,183	6,39	5,55
KRW035	14.04.2005	10,72	35,97	0,01	0,509	6,34	2
KRW035	20.01.2005	11,13	40,94	0,01	0,035	6,61	20
KRW035	05.12.2004	11,01	8	0,01	0,086	6,185	2
KRW035	15.09.2004	17,31	61	0,01	0,141	6,479	2
KRW035	17.05.2004	298,9	0	0,143	34,931	3,67	14
KRW035	18.04.2004	7,82	24	0,01	0,01	5,978	2
KRW035	21.03.2004	11,88	42	0,01	0,61	6,23	2
KRW035	30.01.2004	12,62	44	0,01	0,01	6,351	2
KRW035	08.12.2003	89,1	38	0,875	0,01	6,4	2
KRW035	18.11.2003	11,23	44	0,01	0,01	6,186	4
KRW035	20.10.2003	8,21	34	0,01	0,01	6,312	2
KRW035	22.09.2003	7,27	28	0,01	0,01	6,798	2
KRW035	13.08.2003	5,07	32	0,01	0,01	5,754	4
KRW035	14.07.2003	7,5	40	0,01	0,01	6,333	2
KRW035	06.05.2003	4,76	9	0,12	0,01	5,035	6
KRW035	18.03.2003	3,72	7	0,01	0,01	5,552	1
KRW035	19.05.2002	12,17	48	0,09	0,141	6,472	2
KRW035	12.11.2001	8,95	20	0,01	0,01	6,305	2
KRW035	10.05.2001	4,06	6	0,038	0,019	6,716	4
KRW035	02.04.2001	6,81	8	0,082	0,034	5,992	2
KRW035	21.02.2001				0,144	5,8	
KRW035	19.01.2001	376,2	32	0,149	2,325	5,666	8
KRW036	04.06.2014	36,89	0	0	1,14	4,76	3,39
KRW036	13.05.2014	39,86	0	0,0093	1,28	4,83	1,66
KRW036	15.04.2014	42,82	0	0	1,31	4,93	1,82

KRW036	18.03.2014	54,9	15,53	0,0065	1,41	6,06	6,69
KRW036	18.02.2014	63,46	101,19	0	2,2	6,3	3,29
KRW036	16.01.2014	48,5	163	0,03	2,66	6,82	5,03
KRW036	02.12.2013	48,5	163	0,03	2,66	6,82	5,03
KRW036	13.11.2013	52,15	47,39	0,01	2,26	6,59	3,96
KRW036	16.10.2013	56,98	56,21	0	1,78	6,92	3,04
KRW036	19.09.2013	58,7	119,98	0,0265	1,7	6,99	2,79
KRW036	13.08.2013	62,05	75,23	0,0004	1,53	6,57	5,25
KRW036	16.07.2013	60,33	106,67	0,0157	1,49	6,74	3,05
KRW036	10.06.2013	55,34	129,24	0,0563	1,9	6,7	3,96
KRW036	21.05.2013	55,59	67,13	0,1292	1,8	6,66	7,28
KRW036	29.04.2013	53,66	20,84	0,072	1,95	5,03	3,37
KRW036	13.03.2013	55,59	24,87	0,0248	1,98	6,28	2,96
KRW036	04.02.2013	50,55	25,62	0,1337	1,73	6,49	3,47
KRW036	08.01.2013	54,73	57,5	0,3438	1,78	6,6	9,05
KRW036	03.12.2012	55,22	33,36	1,6087	1,51	6,58	3,09
KRW036	05.11.2012	53,21	3,38	0,2743	2,09	5,09	2,86
KRW036	01.10.2012	51,03	0	0,0049	1,29	4,75	1,61
KRW036	04.09.2012	51,74	0	0,0183	1,38	4,91	7,07
KRW036	01.08.2012	44,11	0	0,074	1,54	4,87	3,36
KRW036	02.07.2012	48,21	0	0,0077	1,74	4,96	3,23
KRW036	05.06.2012	43,72	0	0,0155	1,68	4,85	4,8
KRW036	02.05.2012	46,66	0	0,0262	1,81	4,7	6,01
KRW036	10.04.2012	48,02	9,55	0	1,79	4,54	3,56
KRW036	06.03.2012	18,54	2,02	0,0014	2,08	4,79	1,38
KRW036	07.02.2012	51,28	14,9	0,0654	2,2	5,38	1,68
KRW036	05.12.2011	45,44	0	0,0383	1,93	4,96	1,69
KRW036	02.11.2011	44,93	0,08	0,0285	1,89	5,07	3,01
KRW036	03.10.2011	43,91	5,42	0,0194	1,83	5,34	2,49
KRW036	12.09.2011	43,27	5,18	0,023	1,75	5,59	2,4
KRW036	03.08.2011	38,9	1,22	0	1,96	6,16	1,84
KRW036	04.07.2011	46,54	5,08	0,0157	1,8	5,23	6,15
KRW036	12.05.2011	33,48	12,43	0,0182	1,6	5,87	3,57
KRW036	12.04.2011	32,39	7,09	0,01	1,26	6,26	1,84
KRW036	03.03.2011	20,45	11,88	0,028	0,51	6,3	3,03
KRW036	12.01.2011	21,84	26,26	0,1365	1,14	6,37	2,74
KRW036	01.12.2010	43,5	7,84	0,004	2,96	5,46	2,54
KRW036	03.11.2010	42,29	0	0	1,41	4,76	2,78
KRW036	06.10.2010	30,45	0	0,07	1,49	3,92	2,88
KRW036	06.09.2010	20,25	1,27	0,002	1,3	4,59	2,07
KRW036	04.08.2010	35,45	0,16	0,0167	0,69	5,07	3,55
KRW036	07.07.2010	27,98	9,23	0,0032	0,15	5,5	2,37
KRW036	24.06.2010	26,08	4,43	0,0102	0,1	5,8	3,38
KRW036	19.05.2010	12,49	15,61	0,0611	0,56	5,52	3,76
KRW036	09.03.2010	27,5	17,53	0,0202	0,03	6,32	2,08
KRW036	17.02.2010	35,86	6,03	0,0391	0,39	5,34	3,96
KRW036	21.01.2010	44,34	3,39	0,2004	1,73	4,73	2,18
KRW036	07.12.2009	59,88	24,3	0,0631	8,55	5,61	2,67
KRW036	18.11.2009	6,04	0	0,0293	2,31	4,56	3,76
KRW036	21.10.2009	54,7	0,65	0,0206	2,18	4,53	2,05

KRW036	15.09.2009	54,73	0	0,0141	2,09	4,46	2,4
KRW036	12.08.2009	51,03	2,07	0,0225	1,9	4,6	26,58
KRW036	14.02.2008	16,03	7,02	0,01	0,042	6,31	4,59
KRW036	19.11.2007	18,573	7,39	0,1	0,68	5,72	4,49
KRW036	11.10.2007	57,65	1,98	0,076	0,7	4,73	11,57
KRW036	17.09.2007	52,25	51,19	0,051	1,183	4,88	12,33
KRW036	20.08.2007	57,198	2,88	0,046	1,425	4,77	6,99
KRW036	15.05.2007	58,77	1,1	0,166	1,501	4,71	4
KRW036	18.04.2007	57,93	1,37	0,041	1,785	4,74	5,45
KRW036	27.03.2007	59,29	1,83	0,01	1,769	4,84	6,135
KRW036	16.01.2007	59,59	1,04	0,107	1,809	4,69	4
KRW036	14.11.2006	32,21	1,76	0,034	1,946	4,94	5,77
KRW036	02.10.2006	35,19	2,91	0,025	2,106	5,15	10,17
KRW036	22.08.2006	52,25	2,39	0,01	1,895	5,27	2
KRW036	07.08.2006	53,98	2,29	0,003	2,4	4,86	4,75
KRW036	18.04.2006	34,25	32,22	0,001	0,484	5,58	6
KRW036	25.11.2005	49,66	2,69	0,176	1,093	4,84	6,91
KRW036	29.09.2005	110,2	0	5,176	5,391	3,14	9,9
KRW036	25.08.2005	6,85	1,16	0,062	1,741	5,14	5,87
KRW036	25.04.2005	0,48	3,49	0,01	1,957	5,03	4
KRW036	18.01.2005	63,2	12	0,052	2,182	5,77	4
KRW036	05.12.2004	62,6	5	0,01	1,889	5,48	4
KRW036	15.09.2004	69,8	0	0,01	2,32	4,25	2
KRW036	17.05.2004	66,4	6	0,01	1,443	5,184	2
KRW036	18.04.2004	52,6	14	0,01	0,608	5,711	6
KRW036	30.01.2004	49,4	49	0,01	0,62	6,347	2
KRW036	09.12.2003	39,6	4	0,01	1,03	5,4	2
KRW036	18.11.2003	58,7	14	0,283	0,905	5,23	2
KRW036	20.10.2003	52,1	12	0,01	1,08	4,712	2
KRW036	22.09.2003	58,1	26	0,384	1,108	5,526	2
KRW036	13.08.2003	55,4	26	0,01	0,879	4,725	2
KRW036	14.07.2003	60,8	55	0,24	1,126	5,711	8
KRW036	06.05.2003	59,9	0	2,05	2,121	3,896	4
KRW036	12.12.2002	66,9	44	3,05	2,32	6,26	2
KRW036	19.05.2002	55,9	10	3,804	1,935	5,718	2
KRW036	12.11.2001	60,3	0	0,191	1,62	3,987	2
KRW036	10.05.2001				1,775	5,154	
KRW036	10.04.2001	73,9	65	0,104	2,132	6,856	3
KRW036	21.02.2001				2,6		
KRW036	19.01.2001	66,8	0	1,169		3,837	13
KRW036	18.12.2000	56,4	0	0,095	2,966	4,318	2
KRW038	04.06.2014	6,8	2,4	0,0007	0	5,99	3,85
KRW038	13.05.2014	14,38	0	0	0,53	4,46	4,33
KRW038	15.04.2014	10,26	30,13	0	0,01	6,38	2,12
KRW038	18.03.2014	19,3	95,18	3,0504	0,09	6,35	5,09
KRW038	18.02.2014	8,44	22,99	0	0,06	5,78	2,41
KRW038	16.01.2014	6,95	4,21	0,01	0,11	6,63	3,6
KRW038	02.12.2013	6,95	5	0,01	0,11	6,63	3,6

KRW038	13.11.2013	21,43	0	0,03	0,27	3,35	2,48
KRW038	16.10.2013	2,68	0	0	0	4,53	2,15
KRW038	19.09.2013	25,19	0	0,4725	0,06	3,39	4,46
KRW038	13.08.2013	24,69	0	0,1194	0,17	3,36	3,79
KRW038	16.07.2013	19,9	0	0	1,37	3,63	2,3
KRW038	10.06.2013	11,56	4,87	9,9021	0,24	5,42	2,54
KRW038	21.05.2013	11,12	8,65	13,1368	0,17	5,64	3,07
KRW038	29.04.2013	10,24	0	0,848	0,08	2,81	2,62
KRW038	13.03.2013	9,18	0	1,3949	0,14	4,31	1,91
KRW038	04.02.2013	16,16	0	8,9492	0,27	3,65	1,48
KRW038	08.01.2013	11,26	0	10,0514	0,17	5,76	2,42
KRW038	03.12.2012	22,76	0	0,693	0,18	3,36	1,94
KRW038	05.11.2012	25,13	0	1,6335	0,21	3,09	2,12
KRW038	01.10.2012	23,07	0	0,3463	0,21	3,25	1,25
KRW038	04.09.2012	18,78	0	0,2843	0,26	3,28	-0,03
KRW038	01.08.2012	16,85	0	0,1333	0,2	3,7	3,14
KRW038	02.07.2012	15,27	0	0,4074	0,16	3,78	4,8
KRW038	05.06.2012	13,46	0	0,2314	0,19	3,79	1,84
KRW038	02.05.2012	0,1	1,23	1,1213	0,16	5,54	4,79
KRW038	10.04.2012	9,2	10,9	2,753	0,19	5,15	3,35
KRW038	06.03.2012	6,61	0	0,3866	0,31	3,62	0,86
KRW038	07.02.2012	14,1	13,85	13,9882	0,36	5,68	1,02
KRW038	05.12.2011	14,82	13,83	20,5321	0,3	5,92	3,23
KRW038	02.11.2011	14,78	9,09	14,9622	0,34	5,66	2,98
KRW038	03.10.2011	14,29	0	8,9765	0,33	4,91	2
KRW038	12.09.2011	24,78	0	0,0931	0,27	3,47	2,14
KRW038	03.08.2011	19,33	0	9,8078	0,32	3,38	1,41
KRW038	04.07.2011	33,35	0	0,9632	0,39	3,2	5,41
KRW038	12.05.2011	9,29	7,76	0,0231	0,12	6,08	3,06
KRW038	12.04.2011	14,57	1,01	0	0,4	4,86	1,74
KRW038	03.03.2011	19,87	0	0,6779	0,45	3,7	2,8
KRW038	12.01.2011	18,72	0	0,23	0,32	3,79	2,72
KRW038	01.12.2010	27,34	0	0,23	0,47	3,6	3,01
KRW038	03.11.2010	32,52	0	1,05	0,41	3,42	3,75
KRW038	06.10.2010	40,47	0	2,16	0,39	3,2	3,7
KRW038	06.09.2010	19,17	0	4,199	0,4	3,1	4,28
KRW038	04.08.2010	39,06	0	2,057	0,67	3,35	2,06
KRW038	07.07.2010	30,89	0	0,4901	0,43	5,75	2,15
KRW038	24.06.2010	13,33	10,22	0,52	0,27	5,86	2,54
KRW038	08.06.2010	19,96	0	11,185	0,43	4,65	4,43
KRW038	19.05.2010	11,7	10,12	0,1144	0,12	6,09	2,36
KRW038	09.03.2010	14,11	1,4	0,5882	0,27	6,12	2,5
KRW038	17.02.2010	16,05	13,16	1,5788	0,36	6,05	1,8
KRW038	21.01.2010	17,23	16,93	2,1254	0,47	5,98	1,92
KRW038	07.12.2009	25,14	0	0,2619	0,46	3,72	2,98
KRW038	18.11.2009	22,45	11,06	1,0579	0,48	4,85	3,07
KRW038	21.10.2009	27,38	0	27,0356	0,43	4,36	2,44
KRW038	15.09.2009	42,29	0	0,9715	0,43	3,05	14,98
KRW038	12.08.2009	32,7	0	0,4812	0,38	3,18	39,82
KRW038	14.04.2009	16,02	0	5,35	0,489	4,03	8,87

KRW038	26.01.2009	24,47	0	19,474	0,55	5,54	2,32
KRW038	28.10.2008	57,08	0	14,991	0,453	3	36,77
KRW038	07.04.2008	10,85	27,17	0,624	0,711	6,51	5,58
KRW038	27.03.2008	18,36	6,77	0,26	0,558	6,3	4,06
KRW038	14.02.2008	19,43	0	1,138	0,612	4,01	4,43
KRW038	12.11.2007	34,1	4,47	47,57	0,656	5,52	10,46
KRW038	09.10.2007	36,4	0	58,686	0,495	4,2	4,27
KRW038	20.08.2007	35,698	0	8,023	0,675	3,37	6
KRW038	12.06.2007	107,16	289,76	0,01	0,01	11,66	6,41
KRW038	15.05.2007	33,48	0	18,6	0,503	3,46	2
KRW038	18.04.2007	24,44	0	9,168	0,601	4,36	5,36
KRW038	19.03.2007	21,63	24,86	0,131	0,011	8,67	6,025
KRW038	16.01.2007	38,89	0	0,772	0,892	3,32	2
KRW038	02.10.2006	43,31	17,51	2,604	2,702	7,18	10,31
KRW038	22.08.2006	49,15	0	24,209	0,642	3,13	2
KRW038	07.08.2006	47,78	0	1,11	0,654	3,15	4,3
KRW038	31.05.2006			0,001	0,576		2
KRW038	18.04.2006	17,02	0	0,001	0,96	4,54	6
KRW038	31.01.2006	21,91	2,24	0,007	0,069	5,09	2
KRW038	17.11.2005	57,99	0	0,532	0,838	3,49	7,55
KRW038	29.09.2005	83,1	0	7,297	0,997	3,03	3,54
KRW038	25.08.2005	8,2	0	4,818	0,701	3,05	5,02
KRW038	14.04.2005	33,95	0	17,21	0,71	4,41	2
KRW038	20.01.2005	31,95	8,14	12,36	0,567	5,8	2
KRW038	05.12.2004	48,9	0	7,929	0,806	3,561	2
KRW038	15.09.2004	37,63	16	9,448	0,675	5,36	2
KRW038	17.05.2004	51	192	1,709	0,116	7,127	2
KRW038	18.04.2004	46,4	44	5,574	0,043	6,092	2
KRW038	21.03.2004	32,21	0	0,01	0,05	3,431	2
KRW038	30.01.2004	38,34	0	0,03	0,2	3,515	2
KRW038	08.12.2003	47,7	0	1,35	0,454	3,2	2
KRW038	17.11.2003	48,8	0	0,849	0,549	3,096	24
KRW038	20.10.2003	55,6	0	3,587	0,616	3,204	2
KRW038	22.09.2003	55,2	0	1,339	0,462	3,311	2
KRW038	13.08.2003	45,9	0	0,428	0,367	3,023	6
KRW038	14.07.2003	39,7	0	2,72	0,48	4,525	2
KRW038	10.05.2003	30,06	0	0,01	0,139	3,7	2
KRW038	19.05.2002	21,26	6	0,062	0,121	6,121	2
KRW038	06.04.2002	18,79	0	0,01	0,294	4,407	2
KRW038	31.01.2002	24,47	0			4,131	
KRW038	12.11.2001	22,45	0	0,111	0,284	3,822	2
KRW038	10.05.2001	20,34	18	0,022	0,15	5,414	2
KRW038	10.04.2001	35,81	10	0,839	0,287	7,165	3
KRW038	21.02.2001					3,8	2
KRW038	17.01.2001	19,58		7,592			2
KRW039	04.06.2014	17,65	0	0,1081	0,66	3,95	5,46
KRW039	13.05.2014	8,42	20,03	0	0	5,88	4,54
KRW039	15.04.2014	13,09	0	0,0783	0,45	4,28	2,76

KRW039	18.03.2014	12,92	0	0,0543	0,37	4,38	4,58
KRW039	18.02.2014	22,16	19,32	0	0,63	4,28	3,05
KRW039	16.01.2014	16	0	0,04	0,66	4,71	4,28
KRW039	02.12.2013	16	0	0,04	0,66	4,71	4,28
KRW039	13.11.2013	12,65	0	0,01	0,35	4,46	3,1
KRW039	16.10.2013	38,67	0	0,1127	0,23		2,82
KRW039	19.09.2013	15,35	0	0,0436	0,2	4,47	2,67
KRW039	13.08.2013	16,67	0	0,0231	0,39	4,36	4,59
KRW039	16.07.2013	16,38	0	0,1341	0,37	4,34	2,55
KRW039	10.06.2013	1,62	0	0,015	0,53	5,63	2,81
KRW039	21.05.2013	16,5	0	0,1115	0,6	4,16	2,91
KRW039	29.04.2013	14,61	0	0,0276	0,51	4,38	3,56
KRW039	13.03.2013	24,39	0	4,0621	0,64	3,58	2,28
KRW039	04.02.2013	14,64	0	0,0902	0,47	4,42	2,11
KRW039	08.01.2013	15,49	0	0,1254	0,47	4,36	2,9
KRW039	03.12.2012	15,34	0	0	0,41	4,41	2,62
KRW039	05.11.2012	16,45	0	0	0,55	4,09	2,75
KRW039	01.10.2012	16,54	0	0,2592	0,58	4,15	1,83
KRW039	04.09.2012	16,23	0	0,0455	0,63	4,02	1,78
KRW039	01.08.2012	16,62	0	0,0245	0,68	4,25	3,65
KRW039	02.07.2012	21,33	0	0,2995	0,75	3,86	2,02
KRW039	05.06.2012	18,87	0	0,0732	0,71	4,01	2,73
KRW039	02.05.2012	24,43	0	0,1635	0,85	3,87	13,77
KRW039	10.04.2012	26,22	0	3,9228	0,89	3,56	5,46
KRW039	06.03.2012	19,26	0	1,3164	0,9	3,01	2,3
KRW039	07.02.2012	24,55	3,45	1,2689	0,96	3,98	1,31
KRW039	05.12.2011	22,37	0	1,7371	1	3,9	2,19
KRW039	02.11.2011	24,09	0	1,5048	1,06	3,62	3,62
KRW039	03.10.2011	25,24	0	0,1186	1,11	3,88	2,44
KRW039	12.09.2011	23,9	0	0,0137	0,81	3,89	2,82
KRW039	03.08.2011	22,21	0	0,001	1,06	4,03	2,23
KRW039	04.07.2011	28,06	0	1,2805	0,94	3,64	5,63
KRW039	12.05.2011	13,08	0	0,0446	0,55	4,63	4,37
KRW039	12.04.2011	184,17	11,26	0,02	0,16	5,66	2,58
KRW039	03.03.2011	13,34	0	0,1618	0,58	4,35	3,11
KRW039	12.01.2011	29,34	52,95	0,16	0,34	6,12	4,64
KRW039	01.12.2010	18,61	0	0,02	0,72	4,22	4,1
KRW039	03.11.2010	22,34	0	0,34	0,78	3,94	5,34
KRW039	06.10.2010	21,67	0	0,21	0,76	3,94	3,87
KRW039	06.09.2010	10,61	0	0,22	0,75	3,82	4,96
KRW039	04.08.2010	22,13	9,81	1,3522	0,86	4,03	3
KRW039	07.07.2010	20,06	0	0,1246	0,76	3,98	2,66
KRW039	24.06.2010	19,41	0	1,0541	0,69	4,13	3,45
KRW039	08.06.2010	4,97	4,51	0,0169	0,07	5,79	4,52
KRW039	19.05.2010	7,1	3,76	0,0185	0,02	5,13	5,3
KRW039	09.03.2010	19,52	19,67	0,4093	0,64	4,06	3,4
KRW039	17.02.2010	20,66	0	0,08	0,69	4,18	4,71
KRW039	21.01.2010	18,47	0	0,0481	0,66	4,15	2,88
KRW039	07.12.2009	24,9	0	0,0863	0,7	3,69	3,5
KRW039	18.11.2009	2,36	11,06	0,1435	0,68	4,04	5,07

KRW039	21.10.2009	20,23	0	0,4193	0,73	4,12	2,75
KRW039	15.09.2009	19,7	13,31	0,0276	0,67	5,02	2,54
KRW039	12.08.2009	20,25	0	0,1675	0,73	3,92	29,38
KRW039	14.04.2009	5,62	12,44	0,196	0,643	6,33	3,59
KRW039	26.01.2009	16,1	0	0,466	0,485	4,37	2,78
KRW039	28.10.2008	16,7	0	0,651	0,338	4,29	37,96
KRW039	20.05.2008	13,344	4,32	0,3	0,5	4,95	9,93
KRW039	07.04.2008	8,94	0,78	0,004	0,21	6,16	6,28
KRW039	27.03.2008	21,63	14,88	0,189	0,763	6,25	4,37
KRW039	14.02.2008	5,02	1,02	0,015	0,093	4,68	5
KRW039	19.11.2007	1,284	6,75	0,66	0,19	5,64	4,55
KRW039	09.10.2007	11,81	0	0,23	0,161	4,25	4,3
KRW039	13.09.2007	12,96	1,32	1,1	0,185	4,93	13,82
KRW039	20.08.2007	9,163	16,93	0,187	0,227	5,89	0,46
KRW039	12.06.2007	20,35	45,98	0,011	0,063	7,31	6,48
KRW039	22.05.2007	11,97	0	0,086	0,281	4,53	4
KRW039	18.04.2007	11,64	4,13	0,055	0,349	4,94	5,56
KRW039	19.03.2007	22,55	50,57	0,511	0,26	7,32	5,58
KRW039	16.01.2007	17,34	0	0,027	1,257	3,98	4
KRW039	14.11.2006	7,84	0	0,534	0,336	4,33	5,875
KRW039	02.10.2006	13,52	0	1,999	0,533	4,28	10,11
KRW039	23.08.2006	10,79	0	0,126	0,362	4,5	6,68
KRW039	31.05.2006			0,001	0,239		4
KRW039	18.04.2006	4,66	1,52	0,001	0,074	4,77	6
KRW039	31.01.2006	5,54	7,44	0,008	3,859	5,7	2
KRW039	17.11.2005	5,39	16,1	0,01	0,006	6,42	7,32
KRW039	29.09.2005	2,8	3,42	0,01	0,042	5,24	4,46
KRW039	30.08.2005	2,6	6,1	0,01	0,001	5,78	4,15
KRW039	25.04.2005	0,48	19,15	0,01	0,111	5,81	2
KRW039	20.01.2005	4,26	34	0,549	0,201	6,28	4
KRW039	15.09.2004	6,52	14	0,01	0,105	5,443	2
KRW039	17.05.2004	6,67	14	0,471	0,01	6,434	2
KRW039	18.04.2004	6,12	12	0,01	0,01	5,772	4
KRW039	21.03.2004	8,3	10	0,01	0,01	4,967	2
KRW039	30.01.2004	5,7	18	0,79	0,01	5,528	4
KRW039	08.12.2003	5,51	24	0,515	0,01	6	2
KRW039	17.11.2003	9,84	38	0,027	0,01	6,321	6
KRW039	20.10.2003	12,21	0	0,01	0,01	3,815	2
KRW039	22.09.2003	4,69	20	0,01	0,01	5,791	4
KRW039	13.08.2003	3,36	33	0,01	0,01	5,54	6
KRW039	14.07.2003	4,23	24	0,01	0,01	5,849	2
KRW039	06.05.2003	2,47	4	0,01	0,01	4,81	3
KRW039	19.05.2002	21,56	81	1,063	0,077	6,594	2
KRW039	31.01.2002	6,44	12			5,387	
KRW039	12.11.2001	16,31	64	4,088	0,442	6,03	4
KRW039	10.05.2001	5,83	20	0,1	0,038	5,746	4
KRW039	10.04.2001	6,75	14	0,608	0,064	6,805	4
KRW039	21.02.2001	12,16	4	0,083	0,018		
KRW039	17.01.2001		6	0,385	0,337		

KRW040	04.06.2014	2,34	4,25	0,0172	0,01	5,2	4,13
KRW040	13.05.2014	2,81	4,44	0	0,01	5,38	4,89
KRW040	15.04.2014	2,15	6,56	0,0039	0,01	5,96	2,01
KRW040	18.03.2014	7,14	0	0,0864	0,03	3,88	4,38
KRW040	18.02.2014	6,26	18,3	0,3366	0,03	4,24	2,99
KRW040	16.01.2014	1,6	3,64	0,01	0,01	5,69	4,52
KRW040	02.12.2013	1,6	5	0,01	0,01	5,69	4,52
KRW040	13.11.2013	1,88	0	1,34	0,05	5,48	3,03
KRW040	16.10.2013	1,83	0,76	0	4,74	6,55	2,39
KRW040	19.09.2013	8,98	0	0,7758	0	3,92	1,56
KRW040	13.08.2013	10,09	0	0,7613	0,04	3,82	4,96
KRW040	16.07.2013	1,83	3,77	0	0	6	2,47
KRW040	10.06.2013	5,96	0,41	0,2893	0,05	5,75	2,38
KRW040	21.05.2013	2,34	4,17	0,1562	0,01	5,11	2,88
KRW040	29.04.2013	2,11	0	0,1378	0,01	3,85	1,2
KRW040	13.03.2013	1,92	7,09	0,0524	0,01	5,87	2,13
KRW040	04.02.2013	4,16	0	0	0,02	4,6	1,77
KRW040	08.01.2013	18,26	0	18,9788	0,14	4,23	2,82
KRW040	03.12.2012	17,02	0	13,2293	0,1	4,1	2,52
KRW040	05.11.2012	14,16	0	10,0546	0,06	3,38	2,48
KRW040	01.10.2012	14,91	0	0,8384	0,05	3,42	1,64
KRW040	04.09.2012	6,71	0	1,2411	0,06	4,08	-0,09
KRW040	01.08.2012	7,99	0	2,5371	0,04	3,9	3,74
KRW040	02.07.2012	3,95	0	1,6498	0,03	4,52	1,91
KRW040	05.06.2012	4,92	0	0,0713	0,02	4,16	2,26
KRW040	02.05.2012	5,67	0	0,9871	0,03	4,13	41,06
KRW040	10.04.2012	4,14	0	1,899	0,03	4,59	3,73
KRW040	06.03.2012	1,66	0	0,9869	0,02	4,2	1,86
KRW040	07.02.2012	4,53	7,35	1,4288	0,03	4,59	1,34
KRW040	05.12.2011	9,21	0	8,9828	0,06	4,28	1,55
KRW040	02.11.2011	1,45	2,89	0,0132	0	5,54	2,98
KRW040	03.10.2011	5,41	0	4,3202	0,03	4,7	2,41
KRW040	12.09.2011	14,97	0	0,1994	0,06	3,58	2,16
KRW040	03.08.2011	5,51	0	0,021	0,04	4,94	1,68
KRW040	04.07.2011	7,47	0	3,1	0,04	4,24	5,45
KRW040	12.05.2011	4,03	2,53	0,043	0,01	5,45	4,13
KRW040	12.04.2011	4,28	1,3	0,025	0,02	4,85	1,92
KRW040	03.03.2011	3,07	2,83	0,01	0,01	5,43	3,2
KRW040	12.01.2011	5,59	0	0,09	0,05	4,38	2,7
KRW040	01.12.2010	3,56	0	0,1	0,02	4,62	3,64
KRW040	03.11.2010	2,46	5,56	0,15	0	5,9	4,69
KRW040	06.10.2010	3,19	0,35	0,13	1,12	5,34	3,3
KRW040	06.09.2010	2,31	3,29	0,17	0	5,52	5,77
KRW040	04.08.2010	3,21	6,13	0,0086	0,01	5,85	2,73
KRW040	07.07.2010	2,19	6,57	0,0013	0	5,12	2,22
KRW040	24.06.2010	2,39	2,11	0,0609	0,01	5,61	4,14
KRW040	08.06.2010	3,66	1,64	0	0,01	5,02	4,19
KRW040	19.05.2010	1,8	3,9	0,0074	0,01	5,61	2,73
KRW040	09.03.2010	2,39	7,66	0,0121	0,01	5,2	2,43

KRW040	17.02.2010	2,3	3,96	0,4666	0,02	5,5	2,13
KRW040	21.01.2010	2,51	4,89	0,2166	0,03	5,55	2,58
KRW040	07.12.2009	1,94	5,11	0,1825	0	6,63	2,43
KRW040	18.11.2009	1,23	9,79	0,0328	0	5,62	4,06
KRW040	21.10.2009	1,88	7,1	0,0248	0	5,76	2,26
KRW040	15.09.2009	2,86	2,01	0,6049	0,03	4,76	2,3
KRW040	12.08.2009	1,25	8,41	0,0286	0	5,62	5,91
KRW040	15.04.2009	1,62	4,11	0,053	0,009	6,15	1,77
KRW040	26.01.2009	3,2	8,63	0,026	0,007	5,87	2,53
KRW040	28.10.2008	3,57	0	0,165	0,003	5,69	34,39
KRW040	20.05.2008	5,612	5,39	0,21	0,11	5,64	8,16
KRW040	27.03.2008	2,35	0,52	0,08	0,007	7,1	4,57
KRW040	14.02.2008	3,26	7,93	0,01	0,016	6,45	4,62
KRW040	19.11.2007	8,399	10,17	0,61	0,02	5,73	4,42
KRW040	09.10.2007	2,69	4,63	0,141	0,05	5,75	4,27
KRW040	13.09.2007	2,01	7,22	0,074	0,012	5,89	4,99
KRW040	20.08.2007	3,046	4,95	0,068	0,033	6,34	0,35
KRW040	12.06.2007	8,1	14,02	0,046	0,004	6,75	6,4
KRW040	22.05.2007	4,77	0	1,55	0,046	4,2	2
KRW040	18.04.2007	4,66	0	2,372	0,051	4,55	4
KRW040	19.03.2007	6,57	10,22	0,096	0,053	6,92	5,52
KRW040	16.01.2007	1,57	0,82	0,41	0,01	6,11	2
KRW040	02.10.2006	1,78	9,17	0,143	0,001	6,18	2
KRW040	23.08.2006	2,87	1,69	0,907	0,046	4,95	4,81
KRW040	07.08.2006	1,39	6,79	0,022	0,005	5,72	4,16
KRW040	31.05.2006			0,001	0,023		2
KRW040	18.04.2006	1,44	7,62	0,001	0,001	5,48	2
KRW040	31.01.2006	3,34	5,43	0,001	0,01	6,27	2
KRW040	25.11.2005	13,94	33,88	0,312	0,107	6,17	6,08
KRW040	29.09.2005	5,73	13,45	0,01	0,158	5,83	4,33
KRW040	30.08.2005	0,57	6,2	0,072	0,109	5,77	3,97
KRW040	25.04.2005	0,48		0,01	0,012		6
KRW040	20.01.2005	5,54	24,3	1,579	0,275	6,67	4
KRW040	05.12.2004	4,37	18	0,01	0,02	6,271	2
KRW040	15.09.2004	8,18	20	0,01	0,029	7,443	2
KRW040	17.05.2004	7,86	69	0,01	0,01		2
KRW040	18.04.2004	282,6		0,01	0,01		36
KRW040	21.03.2004	4,28	36	0,01	0,01	6,668	2
KRW040	30.01.2004	2,73	24	0,01	0,01	5,719	2
KRW040	08.12.2003	5,41	0	3,633	0,08	4	6
KRW040	17.11.2003	2,3	30	0,03	0,01	6,429	6
KRW040	20.10.2003	1,84	10	0,01	0,01	5,633	2
KRW040	22.09.2003	6,96	36	0,108	0,01	7,181	2
KRW040	13.08.2003	3,36	12	0,01	0,01	5,242	2
KRW040	14.07.2003	4,76	30	0,47	0,01	6,458	1
KRW040	06.05.2003	2,65	2	0,01	0,01	4,921	4
KRW040	19.05.2002	5,06	2	0,602	0,01	5,088	2
KRW040	31.01.2002	3,53	0			4,559	
KRW040	12.11.2001	3,17	2	0,01	0,01	5,326	2
KRW040	10.05.2001	3,37	10	0,01	0,004	5,922	2

KRW040	19.04.2001	3,48	6	0,013	0,002	5,747	2
KRW040	21.02.2001		2	0,01	0,01	6,4	
KRW040	17.01.2001			0,061			2
KRW040	15.12.2000	3,16	4	0,05	0,01	5,846	2
KRW041	04.06.2014	3	6,3	0,0324	0,01	5,7	4,63
KRW041	13.05.2014	3,55	0	0,1347	0	4,92	5,07
KRW041	15.04.2014	2,35	2,26	0,0052	0	6,27	3,4
KRW041	18.03.2014	3,31	0	0,0259	0	5,34	5,69
KRW041	18.02.2014	4,65	10,66	0	0	5,8	4
KRW041	16.01.2014	4,96	13	0,01	0,01	6,27	6,53
KRW041	02.12.2013	4,96	13	0,01	0,01	6,27	6,53
KRW041	13.11.2013	6,98	10,61	0,02	0,02	6,46	4,37
KRW041	16.10.2013	6,69	4,88	0,95	0	6,62	4,24
KRW041	19.09.2013	6,8	3,85	0,0492	0	6,28	4,15
KRW041	13.08.2013	7,08	11,31	0,096	0	6,01	5,9
KRW041	16.07.2013	6,33	12,04	0,0081	0	6,08	4,12
KRW041	10.06.2013	8,8	17,03	0,1118	0,01	6,28	4,48
KRW041	21.05.2013	6,15	11,61	0	0,01	5,66	4,04
KRW041	29.04.2013	5,86	0	0,0189	0,01	4,73	4,42
KRW041	13.03.2013	6,77	16,79	0	0,01	5,97	2,85
KRW041	04.02.2013	6,03	1,93	0	0	6,25	4,35
KRW041	08.01.2013	6,47	12,81	0,0467	0,01	6,17	4,16
KRW041	03.12.2012	7,24	11,77	0,3479	0	5,8	4,72
KRW041	05.11.2012	6,38	1,06	0,036	0,01	6,12	4,64
KRW041	01.10.2012	6,47	10,83	0	1,19	5,99	3,65
KRW041	04.09.2012	6,53	3,43	0,037	0,02	6,16	-0,02
KRW041	01.08.2012	6,41	13,08	0,1443	0,01	5,84	4,99
KRW041	02.07.2012	6,09	1,21	0,0219	0,01	6,03	4,38
KRW041	05.06.2012	5,44	5,23	0,0145	0,01	6,06	4,5
KRW041	02.05.2012	7,59	0,39	0	0,01	5,99	11,4
KRW041	10.04.2012	5,41	15	0	0,01	6,14	6,61
KRW041	06.03.2012	7,49	10,67	0	0,01	6,11	4,09
KRW041	07.02.2012	5,98	19,45	0,0531	0,01	5,81	3,43
KRW041	05.12.2011	5,35	0,43	0,0643	0,01	5,94	6
KRW041	02.11.2011	5,48	9,15	0,0225	0,01	5,7	4,31
KRW041	03.10.2011	4,99	2,75	0,0293	0,01	5,91	4,52
KRW041	12.09.2011	4,57	6,75	0,0018	0,01	6,04	4,17
KRW041	03.08.2011	3,6	3,8	0,011	0,01	6,05	3,48
KRW041	04.07.2011	2,78	4,64	0,0553	0,01	5,74	6,45
KRW041	12.05.2011	4,14	5,71	0,0271	0,01	5,79	5,51
KRW041	12.04.2011	3,29	5,92	0,01	0	5,67	3,5
KRW041	03.03.2011	3,44	6,11	0,0783	0,01	5,84	4,21
KRW041	12.01.2011	3,43	7,72	0,02	0,01	5,91	3,78
KRW041	01.12.2010	3,93	10,12	0,01	0,01	6,09	4,46
KRW041	03.11.2010	4,78	6,45	0,07	0,02	5,8	5,43
KRW041	06.10.2010	5,95	0	1,24	0,02	4,74	4,95
KRW041	06.09.2010	4,56	6,44	0,26	0	5,64	4,07
KRW041	04.08.2010	3,86	7,22	0,0958	0,01	5,86	3,64

KRW041	07.07.2010	2,7	6,94	0,0003	0	5,79	3,21
KRW041	24.06.2010	3,49	4,3	0,0205	0,01	5,68	4,27
KRW041	08.06.2010	3,61	5,6	0,049	0,01	5,68	5,95
KRW041	19.05.2010	2,68	9,19	0,0719	0,01	5,85	3,14
KRW041	09.03.2010	5,73	21,32	0,1457	0,02	6,17	3,76
KRW041	17.02.2010	7,07	4,72	0,06	0,02	6,09	3,38
KRW041	21.01.2010	7,63	16,22	0,0633	0,06	5,91	3,88
KRW041	07.12.2009	6,81	31,77	0,1738	0,02	6,01	5,87
KRW041	18.11.2009	5,7	13,22	0,1307	0,02	6,15	6,19
KRW041	21.10.2009	6,53	30,93	0,0324	0,02	6,19	3,48
KRW041	15.09.2009	6,75	23,15	0,2785	0,04	5,87	3,41
KRW041	12.08.2009	5,44	34,98	0,0746	0,02	5,91	10,44
KRW041	15.04.2009	2,83	5,79	0,127	0,109	5,29	12,1
KRW041	26.01.2009	6,66	18,93	0,82	0,052	6,07	3,62
KRW041	28.10.2008	7,31	10,42	0,003	0,004	5,96	40,54
KRW041	20.05.2008	4,422	8,99	0,08	0,02	6,21	9,62
KRW041	27.03.2008	3,35	1,15	0,133	0,006	6,28	5,47
KRW041	14.02.2008	6,18	17,52	0,059	0,014	6,63	5,45
KRW041	19.11.2007	197,57	0	0,03	0,08	2,48	5,47
KRW041	09.10.2007	8,03	1,78	0,017	0,005	5,95	4,49
KRW041	13.09.2007	6,88	14,18	0,08	0,026	6,01	13,4
KRW041	20.08.2007	8,14	6,87	0,04	0,023	6,08	0,41
KRW041	12.06.2007	9,51	13,18	0,01	0,005	6,21	6,6
KRW041	22.05.2007	6,75	24,23	0,625	0,107	6,11	2
KRW041	18.04.2007	8,03	10,37	0,021	0,062	6,15	4
KRW041	19.03.2007	9,37	14,15	0,027	0,037	6,5	6,21
KRW041	16.01.2007	5,73	9,08	0,161	0,026	6,53	2
KRW041	14.11.2006	3,53	14,39	0,053	0,01	6,68	6,265
KRW041	02.10.2006	6,75	14,38	0,04	0,023	6,71	4
KRW041	23.08.2006	3,97	9,86	0,123	0,009	5,99	5,37
KRW041	07.08.2006	4,42	5,61	0,038	0,011	6,42	4,76
KRW041	31.05.2006			0,001	0,01		2
KRW041	18.04.2006	3,95	14,06	0,026	0,196	5,54	7
KRW041	31.01.2006	6,94	16,98	0,01	0,013	6,1	20
KRW041	25.11.2005	16,98	62,76	0,125	0,074	6,39	7,37
KRW041	29.09.2005	12,22	64	0,136	0,051	7,74	5,98
KRW041	30.08.2005	2,1	53,15	0,01	0,053	6,8	5,83
KRW041	26.04.2005	0,48	26,16	0,128	0,049	6,08	6
KRW041	20.01.2005	11,03	53	0,01	0,19	6,78	2
KRW041	05.12.2004	12,86	53	0,01	0,053	6,276	2
KRW041	15.09.2004	17,42	46	0,079	0,11	5,844	23,39
KRW041	17.05.2004	26,45	129	30,257	0,397	7,012	2
KRW041	18.04.2004	17,7	40	0,01	0,01	9,867	4
KRW041	21.03.2004	12,89	91	0,01	0,01	6,689	2
KRW041	30.01.2004	15,06	61	0,84	0,64	6,514	4
KRW041	08.12.2003	12,47	40	0,009	0,01	6,5	2
KRW041	17.11.2003	10,22	46	0,01	0,01	6,994	6
KRW041	20.10.2003	8,77	30	0,01	0,01	6,291	2
KRW041	22.09.2003	8,03	32	0,01	0,01	6,791	2
KRW041	13.08.2003	6,94	12	0,01	0,01	5,807	6

KRW041	14.07.2003	7,81	40	0,07	0,01	6,293	6
KRW041	06.05.2003	7,63	13	0,01	0,01	5,111	8
KRW041	19.05.2002	22,71	67	1,323	0,082	5,682	4
KRW041	31.01.2002	18,26	61			5,762	
KRW041	12.11.2001	12,03	27	0,01	0,008	5,764	4
KRW041	10.05.2001	26,04	62	0,281	0,155	6,351	2
KRW041	19.04.2001	6,38	14	0,014	0,012	5,49	4
KRW041	21.02.2001	5,14		0,021		7	4
KRW041	17.01.2001					5,534	4
KRW041	15.12.2000	4,82	10	0,089	0,008	6,12	2
KRW043	04.06.2014	4,26	3,78	0,013	0	5,99	6,41
KRW043	13.05.2014	5,02	2,52	0	0	5,84	5,46
KRW043	15.04.2014	3,04	5,02	0	0,01	5,8	4,22
KRW043	18.03.2014	2,51	0	0,0223	0,01	4,94	3,73
KRW043	18.02.2014	12,6	21,7	0,0534	0,06	6,19	4,88
KRW043	16.01.2014	3,68	15	0,01	0,01	6,4	6,46
KRW043	02.12.2013	3,68	15	0,01	0,01	6,4	6,46
KRW043	13.11.2013	13,49	50,34	0,01	0,02	6,8	5,07
KRW043	16.10.2013	15,7	50,88	1,5433	0,02	7,54	4,83
KRW043	19.09.2013	13,27	50,1	0	0	6,89	7,55
KRW043	13.08.2013	11,63	27,58	0	0	6,56	7,46
KRW043	16.07.2013	8,11	29,44	0,0769	0,02	6,56	4,19
KRW043	10.06.2013	8,87	22,79	0,0999	0,07	6,38	5,11
KRW043	21.05.2013	4,55	12,87	0	0	5,95	4,2
KRW043	29.04.2013	4,22	2,01	0	0,01	6	5,47
KRW043	13.03.2013	13,09	42,5	0,0554	0,21	6,55	4,58
KRW043	04.02.2013	9,28	31,93	0,0808	0,09	6,78	5,1
KRW043	08.01.2013	11,32	36,56	0,0298	0,1	6,75	6,35
KRW043	03.12.2012	8,53	26,91	0,0218	0,01	6,78	5,64
KRW043	05.11.2012	12,96	47,64	0	0	7,23	5,95
KRW043	01.10.2012	11,69	33,7	0	0	6,67	4,46
KRW043	04.09.2012	10,35	33,74	0,0771	0	7,01	0,19
KRW043	01.08.2012	8,98	24,78	0	0,01	6,63	6,28
KRW043	02.07.2012	6,26	15,47	0,0101	0	6,32	6,2
KRW043	05.06.2012	14,57	58,47	0,0526	0,07	6,62	5,97
KRW043	02.05.2012	10,36	16,9	0,0109	0,02	6,62	24,27
KRW043	10.04.2012	8,18	17,47	0	0,01	6,61	6,78
KRW043	06.03.2012	8,82	46	0,0193	0,03	6,99	5,27
KRW043	07.02.2012	9,82	13,13	0,0453	0,03	6,24	4,37
KRW043	05.12.2011	13,8	41,02	0,0487	0,02	6,83	7,68
KRW043	02.11.2011	0,09	40,19	0,0116	0,01	6,43	5,04
KRW043	03.10.2011	13,71	49,5	0,0374	0,01	6,41	6,11
KRW043	12.09.2011	13,75	38,14	0,0115	0	7,22	4,77
KRW043	03.08.2011	10,17	61,7	0,0311	0,01	6,67	4,41
KRW043	04.07.2011	7,15	13,58	0,0245	0,01	6,29	9,24
KRW043	12.05.2011	5,37	7,48	0,0039	0,01	5,98	7,53
KRW043	12.04.2011	5,08	5,29	0	0,01	5,58	5,57
KRW043	03.03.2011	4,51	2,15	0,53	0,02	5,49	4,45

KRW043	12.01.2011	2,95	4,75	0,006	0,01	5,78	2,57
KRW043	01.12.2010	5,03	10,07	0,02	0,01	6,06	5,36
KRW043	03.11.2010	7,88	20,02	0,002	0,01	6,26	7,68
KRW043	06.10.2010	12,89	50,04	0,005	0,02	7,15	7,49
KRW043	06.09.2010	11,26	6,4	2,95	0	6,1	7,06
KRW043	04.08.2010	9,97	56,08	0,0476	0,02	6,61	5,72
KRW043	07.07.2010	6,5	19,01	0,0003	0,01	6,01	5,12
KRW043	24.06.2010	5,02	11,1	0,0099	0,01	5,91	6,07
KRW043	08.06.2010	3,91	5,41	0,007	0,01	5,59	4,13
KRW043	19.05.2010	2,69	4,82	0,0187	0,02	5,46	2,51
KRW043	09.03.2010	3,8	13,29	0,0046	0,01	5,78	4,49
KRW043	17.02.2010	4,71	4,87	0,24	0,02	5,58	4,13
KRW043	21.01.2010	4,65	10,83	0,1738	0,03	5,96	4,51
KRW043	07.12.2009	8,22	14,82	0,2272	0,41	6,08	7,82
KRW043	18.11.2009	11,81	59,67	0,0957	0,05	6,54	7,43
KRW043	21.10.2009	10,77	33,63	0,0615	0,02	6,48	6,03
KRW043	15.09.2009	12,03	25,69	0,0112	0	6,12	4,85
KRW043	12.08.2009	10,5	21,8	0,0167	0	6,18	27,78
KRW043	15.04.2009	5,92	0	2,868	0,053	4,55	13,08
KRW043	26.01.2009	6,18	8,85	0,029	0,026	5,85	4,74
KRW043	28.10.2008	14	92,3	0,147	0,026	6,54	4,74
KRW043	20.05.2008	7,033	17,72	0,19	0,03	6,32	11,38
KRW043	27.03.2008	4,26	6,82	0,01	0,019	6,36	6,92
KRW043	14.02.2008	8,38	31,13	0,131	0,018	10,05	4,89
KRW043	12.11.2007	12,73	23,16	0,106	0,012	6,01	6,62
KRW043	09.10.2007	14,17	41,49	0,006	0,006	7,03	4,74
KRW043	13.09.2007	12,31	30,23	0,056	0,016	6,39	12,68
KRW043	20.08.2007	12,43	29,3	0,478	0,033	6,39	1,41
KRW043	12.06.2007	8,74	19,78	0,024	0,103	6,35	7,245
KRW043	22.05.2007	6,12	8,66	0,892	0,143	6,56	6
KRW043	18.04.2007	5,7	10,99	0,108	0,14	6,61	4
KRW043	19.03.2007	10,54	40,71	0,298	0,045	8,84	5
KRW043	16.01.2007	7,66	19,07	0,034	0,099	6,72	4
KRW043	14.11.2006	7,14	43,39	0,265	0,255	6,99	7,135
KRW043	02.10.2006	13,27	46,25	0,035	0,44	7,18	2
KRW043	23.08.2006	13,33	37,01	0,369	0,928	6,6	6,62
KRW043	07.08.2006	12,25	41,85	0,071	1,129	6,66	7,35
KRW043	31.05.2006			0,588	0,087		6
KRW043	18.04.2006	1,55	8,64	0,001	0,001	5,54	6
KRW043	31.01.2006	4,01	11,82	0,016	0,01	5,91	4
KRW043	25.11.2005	12,11	49,16	0,155	0,043	6,27	8,05
KRW043	29.09.2005	17,3	65	0,01	0,024	7,55	6,96
KRW043	30.08.2005	1,65	50,12	0,01	0,628	6,74	6,62
KRW043	26.04.2005	0,48	58,37	0,01	0,112	7,95	8
KRW043	20.01.2005	16,29	59,32	0,01	0,19	6,99	6
KRW043	05.12.2004	18,64	57	0,01	0,02	6,517	6
KRW043	15.09.2004	20,87	49	0,01	0,038	6,311	23,71
KRW043	17.05.2004	8,42	28	0,01	0,01	7,238	4
KRW043	18.04.2004	9,32	20	0,01	0,01	8,013	6
KRW043	21.03.2004	6,09	102	0,01	0,01	8,925	2

KRW043	30.01.2004	11,95	36	14,07	0,47	6,744	4
KRW043	08.12.2003	12,9	51	0,01	0,118	6,9	6
KRW043	17.11.2003	15,1	61	0,01	0,01	7,655	8
KRW043	20.10.2003	15,62	63	0,01	0,01	7,457	4
KRW043	22.09.2003	17,22	73	0,01	0,01	7,669	4
KRW043	14.08.2003	17,12	61	0,01	0,01	6,795	6
KRW043	14.07.2003	12,93	26	0,01	0,01	6,856	6
KRW043	12.02.2003	9,12	9	0,01	0,01	6,358	4
KRW043	19.05.2002	18,34	65	0,096	0,121	6,428	6
KRW043	12.11.2001	14,73	29	0,01	0,01	6,411	6
KRW043	10.05.2001	9,25	24	0,007	0,015	6,506	6
KRW043	19.04.2001	6,33	10	0,05	0,036	5,659	6
KRW043	21.02.2001	6,6	6	0,026	0,007	5,8	6
KRW043	17.01.2001	5,07					6
KRW043	15.12.2000	6,3	6	0,017	0,016	6,326	4
KRW047	29.04.2013	31,25	58,88	6,5169	2,64	5,1	14,51
KRW047	13.03.2013	64,8	123,15	0	3,68	6,62	4,86
KRW047	04.02.2013	59,85	151,26	0,0789	3,18	7,18	7,33
KRW047	08.01.2013	65,13	128,76	0,1827	3,26	6,89	7,1
KRW047	03.12.2012	59,85	164,42	0,0328	2,55	7,22	6,95
KRW047	05.11.2012	65,13	182,13	0,1014	2,3	7,4	5,73
KRW047	01.10.2012	57,9	50,75	0	5,31	6,38	5,31
KRW047	04.09.2012	52,72	0	0,0203	8	4,38	1,03
KRW047	01.08.2012	49,37	42,14	0	2,92	6,3	6,78
KRW047	02.07.2012	45,59	100,61	0,0785	2,64	6,53	7,96
KRW047	05.06.2012	52,48	132,83	0,0188	3,71	6,57	6,72
KRW047	02.05.2012	57,93	168,49	0	4,17	6,58	13,7
KRW047	10.04.2012	54,49	118,65	0,0013	4,03	6,55	10,47
KRW047	06.03.2012	42,5	122,12	0	2,93	6,74	7,76
KRW047	07.02.2012	72,89	150,65	0,3985	3,55	6,62	6,6
KRW047	05.12.2011	73,98	215,25	0,157	3,12	6,82	9,14
KRW047	02.11.2011	66,51	233,78	0,0645	1,96	6,62	6,26
KRW047	03.10.2011	72,86	257,42	0,1182	3,47	6,68	8,88
KRW047	12.09.2011	70,3	142,46	0,0293	3,61	6,85	7,74
KRW047	03.08.2011	69,41	182,35	0,1858	3,26	7,14	7,78
KRW047	04.07.2011	59,1	164,24	0,2616	2,96	6,72	7,8
KRW047	12.05.2011	31,63	51,17	0,0127	1,27	6,68	6,11
KRW047	12.04.2011	56,45	52,71	0,011	1,36	6,43	5,79
KRW047	03.03.2011	45,4	166,21	0,04	2,91	6,55	5,65
KRW047	12.01.2011	42,29	125,41	0,28	0,2	6,74	6,72
KRW047	01.12.2010	3,34	18,98	0,3	0,06	6,08	3,02
KRW047	03.11.2010	8,82	76,87	0,58	0,47	6,53	4,13
KRW047	06.10.2010	21,97	29,2	0,01	0,02	6,1	3,32
KRW047	06.09.2010	4,87	7,34	0,06	0,01	5,51	4,11
KRW047	04.08.2010	3,24	7,4	0,0813	0,01	5,71	2,22
KRW047	07.07.2010	1,79	7,2	0,0234	0,01	5,51	2,27
KRW047	24.06.2010	4,16	4,3	0,1152	0,06	5,77	3,45
KRW047	08.06.2010	42,26	213,18	0,49	0,53	7,05	8,57

KRW047	19.05.2010	2,07	10,54	0,0663	0,03	5,53	4,09
KRW047	09.03.2010	2,35	27,85	0,1615	0,09	5,61	2
KRW047	17.02.2010	2,61	6,77	0,9243	0,06	5,6	2,08
KRW047	21.01.2010	3,22	9,25	0,2989	0,09	5,61	2,49
KRW047	07.12.2009	3,52	11,23	0,923	0,08	6,54	3,02
KRW047	18.11.2009	0,37	11,91	0,9572	0,01	6,07	4,74
KRW047	21.10.2009	5,22	29,6	0,95	0,05	6,08	2,6
KRW047	15.09.2009	6,84	15,66	0,0953	0,43	5,65	2,55
KRW047	12.08.2009	7,63	8,99	0,2885	0,03	6,55	22,91
KRW047	14.04.2009	2,37	11,88	0,1	0,04	5,8	5,4
KRW047	22.10.2008	9,33	31,09	0,848	0,355	6,11	35,43
KRW047	20.05.2008	43,89	6,71	9,84	6,99	5,21	9,91
KRW047	07.04.2008	4,68	38,41	0,868	0,055	6,21	5,73
KRW047	27.03.2008	11,38	44,41	0,267	0,093	6,65	4,21
KRW047	14.02.2008	9,93	41,1	0,553	0,019	6,84	4,93
KRW047	12.11.2007	10,6	23,09	0,014	0,015	6,34	4,27
KRW047	13.09.2007	10,06	28,17	0,074	0,031	6,28	14,92
KRW047	20.08.2007	10,74	29,17	0,193	0,086	6,28	0,72
KRW047	12.06.2007	10,95	34,21	0,01	0,01	6,51	6,41
KRW047	15.05.2007	9,97	32,3	0,228	0,011	7,06	2
KRW047	18.04.2007	9,5	39,61	0,139	0,012	7,1	2
KRW047	19.03.2007	10,89	40,44	0,141	0,009	6,84	5,56
KRW047	16.01.2007	10,21	42,27	1,148	0,011	7,26	2
KRW047	14.11.2006	10,06	89,46	0,086	0,023	9,79	5,785
KRW047	02.10.2006	9,81	37,86	0,015	0,069	7,08	2
KRW047	23.08.2006	9,15	28,84	0,014	0,006	6,55	5,45
KRW047	31.05.2006				0,639		2
KRW047	18.04.2006	7,38	15,52	0,001	0,001	5,68	6
KRW047	31.01.2006	9,55	43,51	3,561	0,465	6,63	4
KRW047	25.11.2005	10,97	44,43	0,115	0,121	6,29	6,51
KRW047	22.09.2005	1,02	40,85	0,01	0,022	6,62	4,76
KRW047	30.08.2005	6,4	43,05	0,01	0,001	6,82	3,97
KRW047	26.04.2005	0,48	60	0,01	0,044	6,8	2
KRW047	05.12.2004	13,64	48	0,01	0,04	5,957	4
KRW047	15.09.2004	21,21	73	0,198	0,773	6,537	21,88
KRW047	17.05.2004	13,67	65	0,01	0,01	7,687	2
KRW047	18.04.2004	14,18	55	0,01	0,01	6,995	2
KRW047	21.03.2004	10,75	90	0,01	0,01	6,822	2
KRW047	30.01.2004	11,31	51	0,01	0,01	7,03	2
KRW047	08.12.2003	9,65	49	0,393	0,01	7,1	2
KRW047	17.11.2003	9,14	57	0,01	0,01	7,042	4
KRW047	20.10.2003	9,56	49	0,01	0,01	7,067	2
KRW047	22.09.2003	9,99	53	0,01	0,01	7,341	2
KRW047	14.07.2003	10,02	48	0,01	0,01	6,681	2
KRW047	06.05.2003	9,54	22	0,01	0,01	5,851	3
KRW047	12.02.2003	13,74	49,5	0,01	0	6,502	1
KRW047	19.05.2002	9,45	42	0,216	0,26	5,999	2
KRW047	10.05.2001				0,012	6,213	6
KRW047	19.04.2001	18,24	101	0,124	0,137	5,964	2
KRW047	21.02.2001	5,84	2	0,045	0,018	6,1	2

KRW047	17.01.2001	4,41		0,031		5,795	2
KRW047	15.12.2000	7,29	12	0,111	0,128	6,578	2
KRW049	04.06.2014	55,5	95,84	0,0215	1,42	6,52	8,14
KRW049	13.05.2014	60,78	100,7	0	1,07	6,45	8,25
KRW049	15.04.2014	62,88	131,81	0,0012	1,66	6,78	6,2
KRW049	18.03.2014	61,81	69,11	0,0052	1,44	6,43	8,43
KRW049	18.02.2014	81,52	98,8	0	1,55	6,27	6,47
KRW049	16.01.2014	64,1	161	0,01	1,98	6,91	8,54
KRW049	02.12.2013	64,1	161	0,01	1,98	6,91	8,54
KRW049	13.11.2013	62,87	125,79	0,12	1,97	6,61	6,43
KRW049	16.10.2013	62,56	123,79	0,0906	0,69	7,57	6,24
KRW049	20.09.2013	69,65	165,16	0,0115	1,22	7,13	1,93
KRW049	13.08.2013	66,51	113,62	0	1,07	6,73	6,56
KRW049	16.07.2013	53,59	163,81	0	1,21	6,88	6,45
KRW049	11.06.2013	60,28	210,23	0,0209	1,58	7,04	6,99
KRW049	22.05.2013	64,83	221,84	0,0429	1,57	6,98	6,63
KRW049	29.04.2013	58,97	110,16	0,0326	1,66	5,39	5,57
KRW049	13.03.2013	64,6	220,25	0,0289	1,37	7,19	6,4
KRW049	04.02.2013	59,29	208,88	0,0524	1,37	7,65	8,14
KRW049	08.01.2013	63,63	208,03	0,0808	1,22	7,35	6,87
KRW049	03.12.2012	58,71	217,79	0,0277	1,01	7,49	4,37
KRW049	05.11.2012	62,45	216,89	0,027	1,12	7,58	5,47
KRW049	01.10.2012	60,12	199,09	0	1,13	7,03	5,68
KRW049	04.09.2012	56,02	198,46	0,0155	1,1	7,22	1,16
KRW049	01.08.2012	57,08	123,37	0,0747	1,12	6,84	6,59
KRW049	02.07.2012	53,96	266,51	0,2862	1,05	7,01	8,35
KRW049	05.06.2012	50,77	141,07	0,2559	0,97	7,41	6,44
KRW049	02.05.2012	57,93	341,23	0,2592	0,95	6,9	11,1
KRW049	10.04.2012	53,74	251,11	0,6125	0,82	6,67	8,59
KRW049	06.03.2012	40,55	169,72	0,1709	0,73	6,98	7,98
KRW049	07.02.2012	57,93	202,9	0,8385	0,39	6,66	6
KRW049	05.12.2011	61,59	256,86	0,2329	0,27	6,88	8,57
KRW049	02.11.2011	57,87	208,19	0,1724	0,27	6,58	6,75
KRW049	03.10.2011	60,42	329,69	0,2042	0,3	6,73	8,38
KRW049	12.09.2011	59,77	200,04	0,2476	0,4	6,98	6,86
KRW049	03.08.2011	60,78	227,85	1,1069	0,28	7,06	7
KRW049	04.07.2011	55,13	235,91	0,5162	0,31	6,83	9,56
KRW049	12.05.2011	45,82	40,64	0,0077	3,25	6,56	7,73
KRW049	12.04.2011	94,81	299,4	0,01	0,09	6,99	7,5
KRW049	03.03.2011	60,83	316,42	0,68	0,32	6,8	6,99
KRW049	12.01.2011	63,5	346,71	0,3	0,26	6,94	7,65
KRW049	01.12.2010	66,17	300,1	0,36	0,3	6,9	7,24
KRW049	06.10.2010	67,92	320,22	0,91	0,34	7,01	9,51
KRW049	06.09.2010	65,42	249,87	0,91	0,31	6,55	9,59
KRW049	04.08.2010	15,86	30,16	1,199	0,38	6,12	3,03
KRW049	07.07.2010	57,65	390,35	0,6692	0,32	6,5	7,79
KRW049	24.06.2010	65,16	280,55	0,803	0,28	6,71	9,26
KRW049	08.06.2010	61,21	301,97	0,375	0,29	7,01	10,37

KRW049	19.05.2010	68,29	315,53	1,0074	0,29	6,83	7,62
KRW049	09.03.2010	71,85	303,19	1,4704	0,29	6,73	7,35
KRW049	17.02.2010	77,8	159,04	0,26	0,31	6,58	7,52
KRW049	21.01.2010	73,05	187,89	0,8454	0,32	6,52	9,99
KRW049	07.12.2009	77,19	390,41	1,0842	0,33	6,6	9,97
KRW049	18.11.2009	8	306,65	0,6951	0,32	6,63	10,68
KRW049	21.10.2009	72,59	279,88	3,0869	0,36	6,63	7,73
KRW049	15.09.2009	75,68	410,22	0,7604	0,33	6,38	7,39
KRW049	12.08.2009	75,72	408,78	1,2951	0,27	6,77	12,22
KRW049	14.04.2009	75,05	570,69	0,213	0,376	6,53	9,34
KRW049	22.10.2008	65,65	179,47	0,01	1,936	6,45	124,21
KRW049	20.05.2008	63,545	249,8	13,91	0,53	6,33	17,49
KRW049	07.04.2008	57,14	210,51	13,317	0,393	6,49	8,82
KRW049	27.03.2008	56,6	261,86	9,333	0,38	6,31	8,67
KRW049	14.02.2008	52,07	161,82	1,09	0,314	6,31	8,79
KRW049	12.11.2007	46,68	183,56	0,39	0,192	6,8	6,29
KRW049	13.09.2007	43,72	192,05	0,331	0,171	6,81	13,13
KRW049	20.08.2007	44,96	209,18	0,274	0,162	6,95	0,73
KRW049	12.06.2007	49,15	215,89	0,025	0,194	7,23	6,965
KRW049	15.05.2007	47,34	179,57	0,529	0,328	7,11	6
KRW049	18.04.2007	45,82	187,45	0,066	0,189	7,05	2
KRW049	19.03.2007	47,55	193,98	0,215	0,205	7,09	6,615
KRW049	16.01.2007	45,39	173,27	0,034	0,165	7,06	6
KRW049	14.11.2006	27,21	217,34	1,53	0,225	7,27	6,89
KRW049	02.10.2006	42,69	232,01	0,138	0,191	7,22	8,76
KRW049	23.08.2006	46,43	282,01	0,026	0,142	6,75	6,47
KRW049	31.05.2006	44,33		0,098	0,255		2
KRW049	18.04.2006	33,91	162,35	0,067	0,173	5,94	7
KRW049	31.01.2006	42,67	199,18	1,061	0,014	6,8	4
KRW049	25.11.2005	48,04	237,73	0,905	0,379	6,66	8,75
KRW049	21.09.2005	4,77	248,53	0,363	0,257	7,07	5,36
KRW049	25.08.2005	5,24	246,94	0,01	0,22	7,02	8
KRW049	26.04.2005	0,48	194,44	0,4	0,53	6,44	8
KRW049	05.12.2004	46,8	87	0,01	0,23	6,397	6
KRW049	15.09.2004	55,2	251	3,676	0,426	5,877	28,52
KRW049	17.05.2004	40,6	228	0,639	0,057	6,658	4
KRW049	18.04.2004	47,2	224	0,45	0,049	6,656	8
KRW049	21.03.2004	44,8	192	0,01	0,853	6,534	6
KRW049	30.01.2004	49	234	160,11	5,28	6,723	4
KRW049	08.12.2003	36,3	212	0,19	0,072	6,8	2
KRW049	17.11.2003	36,8	222	0,11	6,528	7,004	6
KRW049	20.10.2003	39,6	218	0,01	0,01	6,675	2
KRW049	22.09.2003	42,9	226	0,381	0,094	7,147	6
KRW049	14.07.2003	24,12	204	0,38	0,097	6,269	6
KRW049	06.05.2003	41	186	9,462	0,38	5,649	4
KRW049	12.02.2003	36,6	194	0,3	0,2	6,249	4
KRW049	19.05.2002	6,27	42	0,059	0,435	6,07	2
KRW049	10.05.2001	16,34	88	1,108	0,138	6,407	2
KRW049	19.04.2001	23,77	111	1,272	0,225	6,021	5
KRW049	19.03.2001	26,13	135	2,005	0,296	7,011	4

KRW049	21.02.2001						
KRW049	17.01.2001	15,52					
KRW049	15.12.2000	17,62	72	0,092	0,134	7,058	4
KRW049	16.11.2000	17,51	122	1,904	0,112	6,471	2
WP054	02.07.2014	469,19	0	552,2488	64,09	2,64	5,11
WP054	17.06.2014	558,31	0	447,45	86,2	2,42	4,25
WP054	19.05.2014	501,2	0	367,19	92,56	2,39	3,88
WP054	17.03.2014	403,47	0	196,712	74,32	2,55	4,84
WP054	11.02.2014	427,27	0	60,5003	1,39	2,46	4,35
WP054	06.11.2013	498,64	0	280	90	2,31	3,4
WP054	14.10.2013	505,98	0	337,934	0,34	2,53	2,69
WP054	16.09.2013	450,67	0	276,504	65,32	2,42	3,78
WP054	07.08.2013	352,66	0	187,257	38,58	2,38	2,62
WP054	15.07.2013	401,38	0	298,339	66,55	2,53	4,7
WP054	05.06.2013	357,85	0	288,9655	99	2,58	2,19
WP054	13.05.2013	426,76	0	415,235	112,11	2,43	2,81
WP054	24.04.2013	377,21	0	146,8045	97,96	2,34	3,8
WP054	27.03.2013	435,44	0	227,599	107,87	2,38	2,43
WP054	11.02.2013	418,12	0	407,7365	162,59	2,47	3,19
WP054	14.01.2013	402,52	0	266,427	160,49	2,57	3,36
WP054	10.12.2012	404,51	0	290,4105	82,61	2,5	4,4
WP054	13.11.2012	391,34	0	321,862	63,36	2,45	5,44
WP054	09.10.2012	414,01	0	306,3613	100,04	2,53	2,95
WP054	11.09.2012	450,28	0	261,06	70,42	2,5	3
WP054	07.08.2012	429,85	0	234,411	84,92	2,45	2,46
WP054	09.07.2012	333,62	0	422,8605	80,44	2,62	3,14
WP054	11.06.2012	306,6	0	184,4643	52,82	2,41	2,99
WP054	08.05.2012	320,06	0	166,0508	41,99	2,56	2,92
WP054	11.04.2012	311,18	0	434,5458	37,62	2,4	3,42
WP054	19.03.2012	275,43	0	180,833	45,61	2,46	4,69
WP054	09.02.2012	292,69	0	252,2845	71,33	2,7	1,53
WP054	09.01.2012	387,68	0	309,4308	75,63	2,76	2,32
WP054	08.12.2011	327,26	0	289,3595	71,68	2,54	4,87
WP054	08.12.2011	327,26	0	289,3595	71,68	2,54	4,87
WP054	09.11.2011	253,18	0	150,0683	36,85	2,87	2,52
WP054	10.10.2011	366,46	0	355,994	71,58	2,75	2,41
WP054	15.09.2011	248,17	0	90,2068	41,62	2,63	2,86
WP054	10.08.2011	431,09	0	349,4027	97,72	2,51	3,92
WP054	06.07.2011	465,55	0	615,3687	95,16	2,69	3,1
WP054	12.05.2011	446,52	0	326,476	136,91	2,66	4,26
WP054	14.04.2011	538,72	0	732,617	87,47	2,55	3,52
WP054	09.03.2011	442,05	0	346,3195	82,47	2,4	3,4
WP054	10.02.2011	339,04	0	175,2695	48,22	2,54	2,63
WP054	11.01.2011	181,26	0	0,105	0,06	2,58	3,49
WP054	06.12.2010	223,01	0	73,66	26,53	2,73	4,47
WP054	08.11.2010	474,25	0	89,9501	27,21	4,03	2,08
WP054	11.10.2010	240,21	0	140,28	37,48	2,65	3,55
WP054	07.09.2010	165,76	215,54	31,9	16,95	2,59	1,91

WP054	12.08.2010	137,73	0	99,6633	17,39	3,01	2,06
WP054	08.07.2010	216,65	0	133,022	10,88	4,1	6,47
WP054	22.06.2010	198,66	0	98,067	19,39	3,1	2,74
WP054	18.05.2010	290,2	0	215,947	35,28	2,79	2,85
WP054	08.04.2010	221,95	0	165,3448	32,4	2,74	2,4
WP054	01.03.2010	390,06	0	410,19	46,28	2,63	3,45
WP054	04.01.2010	0,1	29,85	251,914	53,38	4,7	3,93
WP054	23.06.2009	324,52	0	492,8455	27,34	2,67	31,07
WP054	05.12.2008	928,96	0	1657,83	35,03	2,06	49,78
WP054	27.08.2008	308,12	17,63	23,44	13,98	5,71	4,41
WP054	08.07.2008	233,77	18,48	0,121	1,632	7,75	34,58
WP054	05.12.2001	177,3	0	22,551	17,12	3,412	70
WP054	15.11.2001	226,8	0	22,644	12,813	3,337	540
WP054	03.10.2001	148,3	0	44,006	5,898	2,876	58
WP054	11.07.2001	163,7	0	47,714	5,141	2,696	41
WP054	30.05.2001	248	61	0,205	0,011	10,017	8
WP054	18.05.2001	621	0	1093,1	11,14	2,743	6
WP054	17.05.2001	167,2	0	44,972	4,003	2,738	4
WP054	07.05.2001	144,7	0	18,435	1,266	2,774	80
WP054	28.03.2001	133,9	0	44,255	3,072	2,7	60
WP054	12.03.2001	752	0	3,813	3,897	6,9	3
WP054	02.03.2001	142,8	0	21,424	3,124	2,7	4
WP054	11.12.2000	132,5	0	44,8	2,903	2,534	60
WP054	07.11.2000	158,5	0	48,626	3,08	2,947	50

Mg	Na	Al	Ca	SO4	NH4	K	NO3	PO4
21,65	9,79	0,1115	52,38	271	0,21	21,3284		0,48
22,87	9,7	0,0546	53,52	243	0,24	15,0525		0,21
19,86	7,61		48,49	211		16,7852		1,85
18,97	9,25	0	47,02	219	1,02	21,5057	0,44	0,19
18,67	7,83	0	43,98	206		17,9748	0,22	0,26
20	10,2	0,21	48,1	204		12,5	0,61	0,1
20	10,2	0,21	48,1	204		12,5	0,61	0,1
20,26	9,21	0,01	51,12	254		13,4	0,42	0,25
20,55	8,53	0,0315	59,94	252		12,3991	0,5	0,54
16,35	11,31	0,0088	43,56	201,9		10,0822	0,22	0,13
14,87	7,98	0,0004	39,63	172	0,33	10,6239	0,03	
12,46	11,76	0,0042	33,68	154	0,17	9,286	0,47	0,42
12,26	8,19	0,0116	32,87	139	0,09	7,2612	0,71	0,46
11,01	10,15	0,0128	28,78	118	0,27	6,2952	0,55	0,24
8,46	10,67	0,1789	22,73	60,07	0,17	6,3345	0,41	0,42
9,31	7,98	0,0003	26,4	87,23	0,47	5,6972	0,3	0,33
7,49	8,18	0,0069	23,13	58,68	0,36	5,2293	0,51	0
10,7	10,25	4,8145	29,42	106	0,48	6,1695	0,4	0,09
8,28	7,68	0,0033	23,69	116	4,04	5,5429	0,84	0,05
7,04	7,86	0,0453	22,04	50,45	0,53	4,9683	0,14	0,14
5,49	6,7	0	15,95	29,33	0,31	4,9168	0,27	-0,99
5,36	7,09	0,0016	16,07	11,67	0,59	4,952	0,36	0,25
5,51	8,63	0,0132	16,2	13,1	0,33	4,9628	0	0,25
5,55	10,61	0,0052	15,95	18,65	0,29	5,1972	0,32	0,2
5,14	6,04	0,0054	16,25	8,83	0,27	4,5918	0,42	0,37
5,35	8,72	0,0072	16,6	11,335	0,32	5,0707	0,33	0,28
5,47	10,11	0,011	16,71	11,75	0,6	5,607	7,29	0,38
4,88	9,23	0,0136	15,25	11,255	0,5	4,4084	0,39	0,25
5,35	7,14	0,1778	14,91	13,63	1,65	4,8318	0,32	0,04
5,66	11,25	0,0207	16,13	8,465		5,2861		
6,01	9,54	0,0086	17,18	10,115		5,4085		
5,72	9,83	0,0185	16,32	18,325		5,3353		
5,5	9,59	0,0042	17,21	13,64		5,0565		
5,26	8,93	0,0102	16,22	7,975		5,0954		
5,4	10,51	0,0139	17,08	8,885		5,7219		
5,29	8,44	0	15,75	23,01		5,5386		
3,33	5,42	0	10,07	14,12		3,41		
3,91	7,76	0	11,87	27,99		3,685		
1,17	2,75	0	4,2	12,29	0	1,42	1,16	0,32
5,16	7,89	0	15,73	11,25		5,37		
6,19	9,18	0	18,45	19,88		5,54		
5,78	10,41	0	18,71	28,065		5,39		
0,45	6,62	0	19,05	28,79		5,57		
5,91	6,6	0,0013	18,86	38,28		5,8431		
5,83	6,72	0	17,47	58,72		4,9013		
5,63	8,42	0	18,87	26,56		5,0065		
4,66	7,61	0	14,14	30,99		4,18		
4,6	5,28	0,0094	14,46	13,555		3,8046		
2,27	5,99	0,0195	7,26	34,16		3,0659		

1,94	4,82	0	6,46	27,1		2,022		
2,85	3,85	0,0349	9,48	16,095		2,9758		
4,7	6,81	0,0064	14,95	20,63		4,6071		
5,96	7,67	0,0237	17,35	27,16		4,6818		
5,03	6,1	0,0226	17,4	31,15		4,4013		
4,8	27,49	0,01	14,64	30,665		4,9004		
1,683	3,832	0,059	11,94	28,83		1,269		
6,113	6,706	0,093	21,437	15,02		4,462		
5,79	6,98	3,9	12,71	30,52		4,81		
4,839	5,723	0,206	20,313	13,28		4,236		
1,551	1,844	0,07	9,453	7,91		1,578		
2,972	4,155	0,023	12,541	24		2,908		
5,218	7,176	0,087	15,796	21,56		4,339		
5,239	6,63	0,029	17,286	24		4,282		
6,076	6,952	0,092	17,203	33,975		4,059		
4,546	6,346	0,095	14,644	23		3,824		
4,591	6,674	0,01	15,174	18		3,931		
5,329	7,294	0,049	16,291	6		4,01		
4,81	8,86	0,07	15,38	9		3,22		
2,72	4,67	0,03	16,21	28,16		1,805		
4,289	7,146	0,036	13,908	6		4,473		
5,355	8,202	0,01	17,076	10		4,915		
5,798	8,857	0,001	18,13	28		7,426		
2,954	6,944	0,01	11,36	18		4,798		
5,434	8,607	0,046	21,579	47		6,18		
8,611	12,32	0,045	23,01	49		8,3		
3,692	8,643	0,01	24,87	24		6,885		
6,378	19,51	0,042	22,8	90		8,178		
0,01	11,86	2,09	16,11	27		4,73		
0,01	14,284	0,01	10,645	19		4,976		
0,01	32,923	0,01	9,573	16		5,271		
0,01	30,5	0,01	8,225	26		5,351		
0,01	35,405	0,095	16,176	27		5,357		
4,354	31,391	0,146	17,93	15		4,603		
1,322	32,589	0,114	15,044	31		4,46		
3,953	25,776	0,01	14,815	158		3,101		
				42				
3,817	7,577	0,146	11,617	43		2,891		
5,394	17,068	0,234	17,509	43		3,385		
4,538	16,524	0,053		54				
4,549	16,043	0,044	20,85	52		1,98		
5,394	13,053	0,583	13,639	52		1,952		
11,25	8,32	7,2626	32,35	206	0,41	7,6787		0,63
10,99	9,78	3,6346	28,56	147	0,7	6,442		0,2
8,64	6,51		23,5	112		5,5921		1,85
8,09	8,49	0,7648	22,62	112	1,89	6,2067	0,57	0,2
8,16	6,3	0,739	21,04	111		5,1475	0,55	0,25

9,46	9,48	1,41	25,3	139		4,52	0,66	0,1
9,46	9,48	1,41	25,3	139		4,52	0,66	0,1
24,8	20,32	2,14	65,42	359		14,3	4,17	0,29
23,2	17,8	0,4592	60,83	319		12,9901	1,17	0,41
23,05	20,51	1,5559	59,5	341,5		12,005	1,33	0,11
21,29	12,15	9,4838	48,74	300	0,41	13,172	3,66	
19,39	16,02	7,2766	45,39	308	2,08	9,7	2,02	0,43
19,82	9,92	9,4966	41,28	247	1,06	9,4072	4,14	0,46
23,53	14,31	5,2976	55,84	281	2,55	8,5377	2,61	0,94
22,95	17,66	2,1603	54,15	277	2,07	8,817	2,16	0,39
22,52	14,63	2,1241	56,45	333	3,73	8,0629	1,13	0,33
20,76	16,34	1,1182	56,3	225	0,42	7,8716	0,99	0
23,14	19,43	1,3342	57,61	296	4,19	8,635	0,87	0,11
20,65	17,83	0,2868	51,73	210,4	5,57	8,4051	0,73	0,19
23,3	25,65	0,0425	61,22	201	5,78	9,4553	0,2	0,15
21,27	14,46	1,6502	45,66	268	2,76	8,595	1,53	-0,96
21,49	19,62	0,2593	49,09	211	5,17	9,0281	1,4	0,23
16,03	12,08	7,9587	30,8	231	1	8,9124	2,21	0,25
15,35	12,75	8,0789	29,25	199	0,79	9,7073	2,72	0,22
22,51	11,6	5,3299	48,38	271	2,52	7,5765	2,47	0,38
22,27	12,95	9,7014	48,06	284	1,75	7,9886	5,03	0,3
24,17	15,53	4,6466	55,23	286	2,72	8,5623	5,97	0,39
22,19	11,04	2,7218	49,41	279	2,59	6,0522	4,74	0,22
28,63	28,01	0,0056	72,45	190	12,28	9,9731	0,38	0,24
29,97	32,67	0,0255	76,66	183,5		10,4075		
30,96	28,99	0,031	79,16	183,5		11,4284		
29,97	28,78	0,0498	77,48	196,5		10,5611		
28,05	26,26	0,0046	76,51	180		9,7138		
26,68	24,69	0,0107	73,46	165,5		9,9322		
27,2	24,56	0,0151	77,44	207,5		9,8175		
25,2	20,04	0	65,35	167,5		9,8157		
26,37	21,59	0	69,91	169,5		9,6094		
26,65	23,54	0	71,76	302,88		9,56		
10,29	9,16	0,01	30,16	183,5	0	4,435	29,54	0,23
21,63	17,56	0,01	60,17	151,5		8,63		
30,32	23,96	0	82,25	193,5		10,49		
27,26	22,98	0,13	74,7	193,66		10,56		
25,2	20,48	0	69,34	207,33		10,4		
23,87	20,12	0	68	199,145		10,6548		
25,12	19,62	0	67,21	195,145		8,8526		
25,53	20,51	0	75,57	207,935		9,3623		
13,68	11,5	0	36,71	121,5		12,255		
13,84	11,86	0,0053	39,76	133,835		5,8386		
8,44	11,49	0	25,48	125,44		4,5322		
3,85	5,81	0,11	12,99	67,18		2,238		
10,31	8,67	0	32,39	155,3		4,5569		
26,42	21,55	0,0161	75,05	227,39		9,731		
31,65	25,78	0	85,81	297		10,9069		
32,52	24,34	0,0229	92,8	258,365		10,5607		
28,73	18,53	0,0176	83,08	224,55		10,6964		

26,16	40,74	0,0658	74,48	234,1	10,9161	
11,447	16,41	0,045	57,12	33,59	8,07	
29,552	16,07	0,063	81,08	150,23	11,041	
15,75	16,82	3,26	47,37	245,6	4,78	
8,044	4,535	3,376	29,167	154,99	2,102	
6,991	4,257	3,378	26,845	149,84	1,8	
5,559	2,711	6,882	17,486	126,75	1,131	
4,703	3,083	5,658	15,173	162	0,795	
19,28	12,479	2,84	40,519	330	6,868	
22,006	11,891	4,678	45,759	310	7,085	
17,45	11,282	6,45	39,443	370,105	6,349	
15,538	10,623	7,324	31,211	302	6,214	
14,17	11,492	6,522	27,192	288	6,135	
19,301	11,875	9,194	40,836	296	6,692	
22,32	19,1	7,32	52,53	460	6,35	
30,222	30,269	0,121	79,596	96,155	11,241	
26,309	21,834	0,06	61,62	8,77	8,85	
24,566	21,377	0,036	60,226	68	9,747	
25,834	19,323	0,021	57,947	10	10,23	
17,27	7,415	0,163	37,5	235	7,715	
11,16	5,279	0,49	24,08	133	6,868	
0,01	2,355	0,029	6,01	247	0,635	
26,19	18,817	0,364	57,606	100	14,2	
29,74	21,52	0,058	64,06	160	25,46	
25,21	24,28	0,01	43,71	90	25,08	
30,31	35,3	0,146	70,32	380	34,11	
35,19	27,99	17,89	93,54	574	13,74	
45,39	52,59	1,401	160,5	706	14,95	
6,794	20,806	21,286	43,224	302	3,543	
4,694	10,203	14,064	44,517	288	3,134	
9,741	17,689	18,493	38,259	296	2,848	
22,43	36,64	32,93	64,89	496	7,94	
27,156	68,561	15,718	82,474	546	53,547	
30,073	48,862	13,088	92,566	536	9,754	
24,622	26,849	24,595	69,228	508	8,293	
24,419	37,025	29,402	66,917	526	8,992	
20,917	30,873	24,793	51,77	368	7,108	
16,583	29,326	25,044	41,341	438	4,657	
7,339	22,267	2,726	25,309	12	2,447	
16,555	14,487	1,402	48,778	379	6,963	
		1,066	55,281		6,685	
21,11	22,051	0,574	64,264	297	7,878	
13,377	21,465	0,082	47,091	211	5,421	
				220		
	17,895		42,814			
11,081	12,98	0,926	31,178	177	4,371	
15,526	8,127	1,225	42,662	249	6,283	
1,39	3,88		2,27	4	0,9644	1,85

2,42	8,75	0,0272	4,16	17,88	1,19	0,8666	3,47	0,19
1,34	4,13	0,0082	1,83	2,66		0,9601	3	0,24
0,67	6,04	0,06	1,71	5,72	1,08	0,53	0,1	0,1
0,67	6,04	0,06	1,71	5,72		0,53	0,1	0,1
0,36	3,02	0,01	0,63	3,61		0,72	1,21	0,23
0,9	3,47	0,4806	1,79	2,96		1,3717	1,21	0,29
1,32	4,08	0,0257	1,25	6,7		0,6322	1,26	0,12
0,31	2,45	0,0016	0,56	-0,66	0,24	0,6112	1,38	
0,2	4,54	0,0053	0,48	0,13	0,18	0,399	1,76	0,41
0,66	3,01	0,0274	1,6	7,99	0,02	0,3244	3,11	0,46
0,82	3,12	0,0467	1,74	2,99	0,32	0,3688	3,89	0,96
1,03	5,61	0,0492	1,81	3,54	0,21	0,3811	3,77	0,41
0,81	5,86	0,1097	1,63	0,89	0,37	0,334	2,67	0,31
1,11	5,02	0,0671	2,26	22,62	0,31	0,4574	3,54	0,1
0,98	3,38	0,0646	1,53	30,45	0,57	0,2909	0,24	0,03
0,96	4,58	0,0814	1,73	3,67	0,3	0,36	4,57	0,14
0,49	1,99	0,5742	0,95	5,67	0,37	0,366	2,31	0,22
0,6	3,18	0,0188	1,44	1,57	0,36	0,3207	1,65	0,25
0,68	4,19	0,0524	1,08	10,72	0,33	0,3401	2,32	0,21
0,74	1,86	0,0134	1,93	12,2	0,44	0,2962	1,56	0,37
0,91	3,27	0,0317	1,71	0	0,59	0,3183	9,46	0,26
0,91	3,64	0,0668	1,35	2,975	0,44	0,3515	7,91	0,39
3,05	5,05	0,665	2,24	2,845	0,53	0,3858	3,8	0,24
1,05	2,67	0,0876	1,26	1,19	1,05	0,3377	4,16	0,04
1,27	4,56	0,1003	2,21	14,5		0,4284		
1,38	4,2	0,0804	2,17	13,5		0,8052		
1,21	5,36	4,3256	2,36	28,3		2,5762		
1,42	6,19	0,0046	4,44	5,145		0,403		
1,3	3,91	0,0901	1,99	12,68		0,3671		
1,31	4,86	0,0495	2,24	7,7		0,4337		
1,69	4,55	0,0002	2,4	4,51		0,4726		
1,18	4,1	0	3,09	3,89		0,3464		
1,54	6,95	0,01	2,86	17,89		0,48		
4,11	3,94	0,02	6,66	35,05	0	0,36	3,88	0,31
1,32	3,37	0,01	2,52	4,03		0,5		
1,7	5,85	0,01	4,31	6,55		0,88		
1,24	4,78	0,1	2,16	4,93		1,12		
1,06	4,57	0,12	1,86	7,64		0,42		
1,46	3,98	0,0641	2,55	25,49		0,6311		
1,51	3,76	0,0623	1,97	18,54		0,3267		
1,72	5,65	0,0327	2,99	19,56		0,458		
2,99	4,1	0,035	4,53	20,69		0,884		
22,79	29,82	0,0082	71,37	99,235		11,0967		
1,09	6,68	0,0571	1,78	13,22		0,4892		
1,61	3,11	0	2,04	13,5		0,38		
7,66	6,85	0	18,77	32,08		4,8647		
1,22	4,47	0,0811	1,78	19,11		0,3877		
1,21	5,09	0,1457	2,02	9,3		0,5248		
0,93	3,7	0,0457	1,77	2,62		21,7251		
0,97	3,41	0,0331	3,89	15,89		0,3848		

1,05	4,55	0,0631	1,79	32,155		0,4196		
1,073	4,316	0,071	1,767	0,35		0,421		
1,117	2,828	0,121	4,066	11,46		0,368		
1,26	2,09	0,13	7,64	19,58		0,45		
1,946	2,381	0,028	4,322	19,88		0,371		
1,84	2,522	0,089	5,432	17,09		0,502		
0,94	2,231	0,066	5,107	13,85		0,403		
0,665	2,03	0,07	6,394	19		0,306		
1,305	2,269	0,035	3,456	14,32		0,56		
0,894	1,505	0,287	4,55	22		1,726		
0,537	1,596	0,01	5,632	20		0,214		
0,529	1,502	0,004	1,166	8		0,284		
0,228	1,413	0,01	1,098	8		0,202		
1,311	3,292	0,028	3,844	15		0,626		
1,127	4,112	0,053	2,567	8		0,495		
1,14	2,328	0,11	11,19	7		0,373		
0,01	2,65	0,138	3,203	14		0,235		
0,02	2,086	0,047	1,04	6		0,257		
1,611	3,095	0,003	7,808	4		1,236		
0,257	2,147	0,026	4,052	17		0,592		
3,352	2,749	0,037	11,84	13		3,278		
0,064	4,068	0,01	1,805	10		0,151		
0,01	2,775	0,17	2,645	16		0,827		
0,309	11,03	0,054	3,525	22		0,36		
0,441	25,7	0,029	10,76	36		0,761		
0,01	6,481	0,01	0,01	5		0,863		
0,01	32,476	0,064	7,163	24		2,631		
0,01	27,622	0,338	0,01	46		0,818		
8,922	32,209	0,03	18,575	66		3,69		
	12,763	0,028		36				
2,583	12,482	0,05	10,14	42		0,733		
1,463	13,701	0,197	16,694	12		0,24		
0,235	7,837	0,124	0,976	25		0,137		

0,33	3,82	0,0003	1,28	6	0,18	0,2553		0,63
0,66	3,84	0,0269	2,06	5,24	0,15	0,3149		0,14
1,02	3,04		2,69	21,52	0,32	0,4057		0,46
0,44	7	0,0828	1,41	5,12	0,27	0,252	0,11	0,19
4,06	6,54	0,2267	5,89	39,34	0,17	1,1008	0,11	0,26
3,23	7,82	0,12	6,07	51,8	0,2	0,62	0,31	0,1
3,23	7,82	0,12	6,07	51,8	0,2	0,62	0,31	0,1
8,88	6,74	0,55	12,93	98,7	0,29	1,68	0,1	0,26
6,98	6,14	0,4818	11,06	77,97	0,2	2,0134	0	0,6
6,1	7,87	0,2174	10,72	81,54	0,2	1,4601		0,1
6,11	5,29	0,3409	9,52	70,55	0,26	1,2544	0,27	
2,4	8,45	1,1951	6,04	56,89	0,17	2,387	0,02	0,41
4,98	5,25	0,0996	8,96	721	0,45	0,7082	20,83	0,45
4,65	5,32	0,0693	8,26	49,76	0,51	0,672	1,06	0,96
4,57	8,21	0,1553	7,82	53,69	0,99	0,6436	0,46	0,79

4,37	5,06	0,2013	7,78	47,69	0,44	0,5736	0,37	0,33
3,29	4,6	0,0744	7,17	23,09	0,38	0,4725	0	0
2,99	6,01	0,0433	6,48	30,86	0,58	0,4863	0	0,11
4,93	5,05	0,1977	9,14	55,81	0,45	0,6426	0,36	0,05
18,52	6,05	0,4762	27,32	103	0,47	2,6562	0,32	0,14
8,5	4,32	1,3628	13,07	89,88	0,71	0,881	0,16	0,02
8,81	4,78	1,0068	14,34	93,64	1,53	1,0932	0,87	0,21
15,53	7,72	2,3749	26,96	162	1,08	1,7503	0	0,25
5,68	10,04	0	13,93	60,26	1,13	1,2219	1,72	0,23
17,19	8,49	1,9118	37,16	217,5	0,91	2,8055	0,34	0,37
12,61	9,35	0,3766	27,46	137,5	1,96	2,5092	1,48	0,27
7,63	9,52	0,0678	16,24	65,76	14,87	2,999	0,24	0,54
4,69	3,68	0,2136	10,29	66,135	0,85	0,814	0,07	0,25
0,35	1,2	0,0168	1,55	4,39	0,94	0,1341	0,38	0,06
0,64	2,76	0,054	2,5	9,895		0,3057		
0,39	2,71	0,0196	1,82	2,4		0,9844		
0,34	2,78	0,0233	1,62	9		0,2284		
0,35	3,74	0,0035	1,94	3,49		0,1728		
0,29	1,98	0,0499	1,43	7,39		0,0905		
0,27	1,91	0,0454	1,46	6,84		0,1072		
0,27	2,42	0	1,38	9,5		0,1315		
0,27	2,79	0	1,4	4,36		0,072		
0,42	11,46	0	2,17	21,39		0,1		
0,35	2,7	0,03	1,72	1,45	0	0,07	0,03	0,32
0,35	2,49	0,02	1,41	4,09		0,26		
0,41	5,04	0,06	1,72	4		0,25		
0,32	2,32	0,15	0,36	5,78		0,14		
0,27	1,82	0,06	1,27	4,15		0,14		
0,26	2,01	0,2804	1,23	2,81		0,1259		
0,27	2,14	0,0399	1,48	11,05		0,0826		
0,3	2,81	0,037	1,67	2,72		0,1299		
0,39	2,61	0,06	2,12	8,21		0,13		
0,98	5,23	0,0086	2,88	11,12		0,176		
0,25	4,15	0,0198	0,95	3,455		0,1409		
0,3	3,54	0,0864	1,18	9,64		0,1422		
0,31	2,08	0	1,37	10,475		0,1697		
0,35	3	0,0628	1,38	1,88		0,2514		
0,52	3,88	0,0403	1,82	1,94		0,251		
0,36	1,76	0,1452	1,79	4,54		0,1729		
0,36	1,19	0,1633	2,76	3,8		0,138		
0,02	16,01	0,0637	0,37	31,56		0,165		
0,316	3,753	0,116	2,001	4,9		0,211		
0,348	1,333	0,057	2,025	2,03		0,14		
0,344	1,141	0,449	2,056	4,6		0,175		
0,68	9,11	0,16	11,69	3,88		0,23		
0,541	1,636	0,059	4,158	0,96		0,121		
0,659	1,693	0,141	7,277	0		0,124		
0,528	1,67	0,169	2,681	2,88		0,142		
0,456	1,292	0,458	4,08	21,6		0,356		
0,178	1,91	0,158	3,98	11,6		0,195		

0,761	1,493	0,513	2,124	9,99		0,245		
1,282	1,72	0,527	3,278	12		0,253		
0,01	0,543	0,304	7,584	3		0,1		
0,904	2,711	0,397	4,404	26		0,355		
0,39	1,368	0,325	1,766	9		0,189		
1,722	2,73	0,765	3,89	12		0,506		
0,387	5,278	0,153	2,15	8		0,139		
0,01	1,887	0,03	5,434	4		0,382		
0,01	1,42	0,972	2,39	8		0,3		
0,01	1,63	1,002	2,85	12		0,248		
0,12	1,284	0,674	2,89	12		0,171		
1,803	1,54	0,261	1,63	7		1,563		
0,001	1,749	0,001	1,843	13		0,138		
0,085	1,802	0,054	1,679	13		0,135		
0,01	1,304	0,063	5,894	3		0,333		
0,505	1,761	0,083	4,958	27		0,403		
0,2	1,375	0,271	2,515	16		0,196		
0,138	4,357	2,581	4,214	14		0,01		
0,01	1,957	0,01	0,521	4		0,328		
1,08	11,56	0,547	9,992	11		1,806		
1,058	24	0,045	8,346	14		1,603		
0,381	27,25	0,256	6,393	18		0,572		
0,01	15,696	0,01	0,151	24		0,488		
0,01	11,44	0,12	0,01	22		0,476		
0,01	7,72	0,42	0,01	16		1,01		
0,01	2,79	0,403	0,01	14		0,953		
0,01	16,34	0,544	0,01	8		0,592		
0,01	21,04	0,095	0,01	6		0,882		
0,01	22,044	1,207	0,01	6		0,575		
0,01	19,69	0,096	2,773	27		0,629		
0,01	18	0,05	3,726	15		0,699		
0,01	21,256	0,01	2,669	7		0,539		
0,183	18,398	0,351	3,723	16		0,316		
0,444	11,103	0,24	2,162	26		0,297		
1,261			4,282	32		0,162		
1,74	12,176	0,064	6,841	39		0,4		
1,617	13,251	0,119	13,673	18		0,177		
1,695	12,168	0,098	6,78	35		0,258		
137,663	41,659	0,545	899,97	30,36		5,785		
0,697	7,684	0,134	3,907	23		0,253		

0,04	2,97	0,0082	0,27	4,18	0,14	0,1606		0,63
0,13	3,12	0,0035	0,36	3	0,17	0,2163		0,19
0,12	1,98		0,58	4,39	0,32	0,1914		0,39
0,27	5,27	0,0347	0,91	6,25	0,32	0,3474	0,08	0,28
0,13	2,29	0,018	0,43	0,46	0,15	0,3237	0,29	0,27
0,01	4,11	0,04	0,23	5,42	0,2	0,29	0,29	0,1
0,01	4,11	0,04	0,23	5,42	0,2	0,29	0,29	0,1
0,07	1,64	0,01	0,16	1,96	0,28	0,12	0,26	0,23

0,09	1,57	0,6701	0,16	11,51	0,17	0,1915	0,27	0,37
0,35	3,83	0,2203	2,26	7,99	0,55	0,3441	1,09	0,17
0,12	1,42	0,0314	0,35	14,34	0,24	0,3011	0,33	
0,18	5,81	0,0883	0,65	7,56	0,2	0,385	0,45	0,43
0,3	1,8	0,0563	1,74	3,29	0,75	0,1998	0,9	0,46
0,51	2,03	0,0367	0,84	4,24	0,31	0,2416	1,21	0,96
0,15	3,68	0,0928	0,51	13,85	0,73	0,1646	0,74	0,64
0,11	1,89	0,0569	0,22	1,34	0,25	0,1444	0,48	0,33
0,16	3,43	0,25	0,41	7,08	0,37	0,1126	0,57	0
0,16	3,19	0,3084	0,57	3,83	0,3	0,1368	0,35	0,12
0,23	2,26	0,273	1,11	4,99	1,39	0,1296	0,14	0,04
0,08	1,93	0,0631	0,75	6,99	0,29	0,2024	0,46	0,14
0,07	0,52	0,3029	0,21	1,88	0,31	0,1422	1,33	-0,95
0,11	0,63	0,4427	0,36	9,26	0,34	0,1419	0,49	0,21
0,08	1,65	0,0332	0,29	10,06	0,33	0,1377	0,19	0,25
0,16	3,15	0,4357	0,5	3,26	0,37	0,17	0,39	0,21
0,1	0,58	0,0154	0,32	4,16	0,26	0,1158	0,38	0,37
0,14	1,36	0,0263	0,35	0	0,29	0,1312	0,32	0,26
0,13	1,9	0,034	5,22	0,245	0,28	0,191	0,29	0,39
0,12	0,94	0,0145	0,41	3,815	0,31	0,1064	0,33	0,24
0,06	0,41	0,0236	0,07	0,275	0,68	0,0842	0,84	0,05
0,13	3,55	0,1239	0,44	0,11		0,1144		
0,13	1,62	0,0677	0,5	2,3		0,1559		
0,12	1,58	0,0698	0,37	5,46		0,1359		
0,19	3,1	0,0097	0,91	2,205		0,1381		
0,13	1,38	0,0428	0,45	7,19		0,1251		
0,23	3,19	0,0689	0,74	8,505		0,1328		
0,16	2,02	0,0009	0,82	3,68		0,1556		
0,19	2,29	0	1,05	4,42		0,085		
0,29	4,14	0,04	1,5	6,22		0,13		
0,34	2,21	0,01	1,4	9,39	0	0,3	0,31	0,33
0,21	1,58	0,01	0,88	3,46		0,17		
0,35	4,05	0,04	1,13	3,595		0,3		
1,93	2,74	0,01	0,55	18,97		0,16		
0,7	4,64	0,23	3,65	23,15		0,36		
0,32	4,98	1,5376	0,88	7,26		1,2769		
0,12	2,15	0,3317	0,49	14,23		0,1307		
0,12	2,66	0,2064	0,42	3,705		0,1575		
0,3	2,14	0,17	3,06	8,45		0,2		
0,24	1,53	0,0432	1,36	1,6		0,0522		
0,14	3,22	0,2971	0,57	7,6		0,1436		
0,1	1,5	0,02	0,56	0,85		0,145		
0,09	1,62	0	0,41	7,56		0,0783		
6,01	3,06	0,0209	4,2	22,64		0,1772		
0,27	3,31	0	0,85	1,34		0,2264		
0,15	3,01	0,06	0,51	3,51		3,2919		
0,18	3,23	0,2134	1,63	9,52		0,2		
0	15,06	0,0192	0	31,805		0,1421		
0,012	2,395	0,073	0,35	0,16		0,098		
0,175	1,16	0,04	1,634	8,46		0,135		

0,184	26,59	0,114	1,018	10,73		0,13		
0,28	9,86	0,2	6,92	5,63		0,26		
0,218	0,918	0,068	2,031	2,19		0,084		
0,325	1,031	0,074	5,54	0		0,145		
0,479	0,97	0,267	2,217	3,33		0,271		
0,476	1,161	0,249	1,381	9,2		0,273		
0,037	0,535	0,253	0,01	1,7		0,109		
0,705	1,43	0,429	2,631	7,97		0,284		
1,678	1,659	0,162	3,181	11		0,257		
0,01	0,282	0,063	4,652	6		0,099		
0,638	1,867	0,022	1,516	11		0,241		
0,222	0,902	0,088	0,931	7		0,121		
1,035	2,156	0,066	2,786	11		0,392		
0,72	3,036	0,01	1,547	6		0,344		
0,01	1,103	0,068	2,419	12		0,19		
0,01	1,6	0,272	2,24	13		0,222		
0,01	1,12	0,114	0,01	2		0,174		
0,01	1,336	0,01	1,363	5		0,359		
2,369	1,922	0,075	1,945	10		0,241		
0,01	1,252	0,066	0,01	8		0,109		
13,147	10,751	0,236	52,573	4		8,999		
0,01	1,164	0,555	2,796	15		0,296		
0,01	0,731	0,044	1,603	12		0,258		
0,565	3,683	0,01	2,798	12		0,01		
0,01	1,707	0,003	3,942	5		0,447		
0,01	1,721	0,067	5,616	8		0,479		
0,489	9,056	0,027	5,38	27		0,505		
0,318	27,88	0,01	7,989	28		0,559		
0,01	15,196	0,334	10,283	13		0,473		
0,01	13,35	0,329	0,01	25		0,74		
7,79	39,6	0,09	40,91	8		9,83		
0,01	17,635	1,354	2,698	33		0,245		
				49				
0,965	11,398	0,977	3,475	34		0,195		
	12,69					0,277		
1,636	13,446	0,144	14,146	20		0,212		
2,609	9,302	1,005	6,957	39		0,178		
0,238	9,258	0,124	2,364	20		0,348		

2,6	6,02	0,2496	10,67	104,93	0,23	6,1895		0,63
2,35	6,21	1,1841	8,46	25,16	0,22	5,3604		0,22
2,36	4,14		9,44	63,59	0,44	5,397		0,46
2,77	11,02	0,0569	9,44	8,19	0,33	6,1011	0,14	0,27
4,67	7,15	0,0505	17,13	2,43	0,21	9,063	0,07	0,26
6,26	9,1	0,07	23,6	8,88	0,2	9,63	1,38	0,1
6,26	9,1	0,07	23,6	8,88	0,2	9,63	1,38	0,1
7,54	7,93	0,01	27,6	4,99	0,28	12	2,94	0,24
8,26	16,17	0,0053	29,03	11,99	2,01	14,3332	2,5	0,4
10,36	11,28	0,0116	38,56	46,8	3,77	11,1536	0,12	0,13

8,51	7,51	0,0232	31,42	47,43	0,29	10,9237	4,03	
9,49	11,97	0,0044	36,02	8,99	3,38	10,46	0,12	0,44
8,8	7,96	0,0313	11,76	49,91	3,59	7,4603	0,6	0,46
7,4	7,13	0,003	27,72	51,04	2,92	6,0797	0,92	0,97
5,07	6,69	0,0065	18,75	43,92	1,68	4,9832	1,42	0,4
5,35	8,9	0,0001	20,6	3,91	0,47	4,6862	0,37	0,37
5,64	5,63	0,0126	24,27	6,06	0,61	4,7872	0,24	0
4,8	7,98	0	18,34	0,63	1,99	4,5032	0,05	0,12
3,97	4,75	0	15,59	6,99	1,7	3,7099	0,14	0,04
5,15	6,42	0,0316	21,19	9,54	2,03	4,6645	0,11	0,16
5,63	4,45	0	21,22	31,55	2,21	4,7489	0,1	-0,92
11,77	7,81	0,2821	42,18	9,41	4,14	7,8249	0,16	0,22
10,11	8,21	0	36,99	13,23	3,61	7,2136	0	0,28
4,98	7,9	0	18,25	16,08	2,28	4,4387	0,26	0,22
12,07	7,74	0,0056	43,55	7,68	4,89	7,8096	0,34	0,38
4,92	5,84	0,0002	19,51	5,42	2,34	4,3244	0	0,27
6,6	7	0,007	25,46	8,33	3,18	5,4301	0,03	0,42
9,54	6,59	0	34,39	4,61	3,71	5,7043	0,02	0,26
2,67	2,08	0,0005	10,14	2,18	3,04	2,6795	0,24	0,06
2,35	3,42	0,0075	9,15	1,105		2,2635		
2,06	3,33	0,0026	8,17	1,695		2,8449		
1,67	3,1	0,0079	6,58	11,035		1,6797		
8,82	10,42	0	31,01	39,72		5,5571		
5,07	5,71	0,0422	18,77	29,9		3,7802		
1,75	5,64	0,0283	6,72	11,565		1,9724		
0,42	2,26	0,333	1,58	7,56		0,318		
0,24	1,51	0,255	1,05	7,2		0,102		
0,45	2,97	0,36	1,92	19,64		0,175		
4,05	5,48	0,01	17,03	6,21	0,63	3,85	0,04	0,32
12,01	9,12	0,01	45,92	6,23		9,2		
10,83	10,34	0	39,27	8,025		7,36		
9	9,49	0,01	34,74	1,755		6,98		
6,56	8,38	0	26,1	12,07		5,69		
6,18	7,66	0,003	24,57	62,14		5,7865		
2,41	7,56	0,038	8,76	23,58		2,3557		
2,06	4,25	0,0944	9,66	45,26		2,0382		
0,45	1,91	0,665	2,03	42,32		0,295		
0,4	1,48	1,1038	2,44	25,78		0,1967		
4,64	9,56	0,3054	21,39	16,51		4,4721		
2,35	8,96	0,134	9,09	19,82		2,869		
4,46	6,71	0	19,41	7,71		5,1191		
6,2	8,18	0,0283	24,13	68,79		5,9908		
7,07	10,53	0	4,92	23,245		6,4453		
8,84	9,9	0,0065	30,57	131,73		6,4802		
5,22	6,09	0,0199	24,13	30,11		3,9906		
6,22	6,65	0	40,36	33,18		8,7737		
4,243	7,347	0,188	19,183	23,58		3,358		
6,29	32	0,07	26,06	11,99		4,82		
13,135	11,468	0,014	46,36	27,85		7,499		
1,56	10,47	0,2	31,55	62,6		0,8		

0,377	0,924	0,833	35,88	82,1	0,336	
1,709	3,023	1,151	22,64	22,5	0,767	
4,993	5,928	0,078	19,49	11,05	4,822	
16,266	13,747	0,009	55,853	74,08	11,347	
16,645	12,806	0,01	55,623	7,23	11,725	
16,63	14,364	0,037	57,173	18,5	11,282	
20,582	15,943	0,018	60,237	30	11,241	
14,561	12,745	0,017	50,586	8	10,352	
16,891	13,935	0,01	46,798	242	9,035	
6,932	7,043	0,057	23,55	45	5,115	
12,395	17,24	0,004	41,215	21,65	7,619	
0,01	0,01	0,054	27,673	42	3,914	
4,269	6,221	0,141	20,919	70	0,2	
2,975	5,252	0,355	16,162	31,41	3,031	
3,046	5,845	0,058	17,832	13	3,231	
16,68	8,927	0,001	31,64	25	6,306	
1,8	5,244	0,121	12,73	26	6,331	
4,919	2,26	0,362	19,171	24	1,777	
15,461	11,877	0,02	65,562	21	10,811	
14,18	11,11	0,028	49,42	17	14,06	
14,16	14,86	0,003	47,72	15	11,42	
13,56	11,38	0,01	53,13	22	13,72	
14,59	23,09	0,081	54,68	16	14,71	
15,01	18,65	0,021	56,53	78	14,29	
13,71	35,86	0,01	51,52	17	12,82	
0,658	19,254	0,01	46,481	25	6,432	
0,01	17,375	0,01	30,12	37	8,629	
0,01	5	0,12	0,01	7,3	0,58	
4,638	19,611	0,01	26,331	15	3,272	
				39		
4,051	12,951	0,764	19,465	38	2,365	
					2,43	
3,451	14,158	0,059	24,674	14	1,945	
6,56	12,079	0,327	17,454	47	2,111	
9,491	14,403	0,464	37,863	19	4,963	

3,43	4,6	3,3455	6,87		0,23	1,5259		0,63
3,58	4,46	3,1954	6,74		0,21	1,1855		0,21
1,7	2,02		4,11		0,32	0,7083		0,47
1,5	7,85	0,0553	3,83		0,34	0,7354	0,55	0,23
3,82	3,11	2,1088	8,18		0,22	1,2992	0,84	0,26
3,7	5,47	0,61	11,7		0,2	0,82	0,79	0,1
3,7	5,47	0,61	11,7		0,2	0,82	0,79	0,1
14,45	3,8	21	26,81	344,99	0,44	3,71	0,38	0,29
17,9	12,48	0	35,71	278	0,45	10,992	0,38	0,29
16,47	6,64	22,1801	31,06	312,5	0,2	4,4233	0,52	0,14
15,87	3,56	24,8415	25,44	368	0,3	3,2521	0,64	
11,96	6	21,1343	18,78	237	0,19	1,9824	0,52	0,44
11,73	3,4	14,9787	17,68	279	0,02	1,4799	1,03	0,47

11,83	5,71	13,53	18,48	195	0,35	1,4456	0	0,96
8,72	3,91	7,9203	14,1	123	0,33	0,9449	0	1,06
4,31	2,9	2,9417	7,31	60,78	0,45	0,5285	0,65	0,33
2,14	2,11	0,91	5,15	27,83	0,72	0,313	0,35	0
0,49	3,92	0,0715	1,31	5,45	0,3	0,1889	0,47	0,11
4,53	2,64	3,8212	7,12	64,33	0,27	0,5232	0,34	0,03
4,76	3,29	4,4601	7,3	75,91	0,28	0,7524	0,53	0,15
5,9	1,63	5,7226	8,27	74,04	0,59	0,6488	0,07	-0,91
7,21	1,71	7,5567	9,9	135	0,68	0,6801	0,55	0,24
4,51	3,01	2,6478	7,79	54,4	0,32	0,5738	0	0,26
1,24	2,01	1,4746	5,79	33,38	0,34	0,4671	0,15	0,21
1,94	1,5	0,78	3,98	33,765	0,28	0,3432	0,36	0,37
0,85	2,05	0,2079	1,98	7,565	0,29	0,1878	0,41	0,25
0,59	2,18	0,0859	1,47	7,14	0,29	0,2247	0,42	0,39
0,31	1,19	0,0169	1,11	5,7	0,36	0,1058	0,4	0,23
0,33	0,71	0,0232	1,06	3,08	0,84	0,1388	0,5	0,04
1,05	2,34	0,1816	2,7	13,67		0,2538		
1,12	2,1	0,085	3,02	8,93		1,0796		
1,42	2,3	0,5258	2,92	19,115		0,3293		
1,52	3,89	0,2064	5,35	19,04		0,362		
1,42	1,9	0,5806	3,1	16,33		0,3257		
1,51	2,96	0,5289	3,98	13,875		0,3626		
1,43	33,99	0,4846	4,7	21,085		0,7147		
0,74	2,44	0	4,44	14,76		0,27		
0,6	6,03	0,01	2,68	13,89		0,66		
0,61	1,82	0,02	1,72	12,71	0,13	0,21	0,34	0,31
0,72	2,43	0,02	2,16	4,98		0,29		
1,03	5,37	0,03	3,14	8,665		0,41		
1,85	2,53	0,28	4,73	23,115		0,57		
0,94	1,59	0,02	2,8	16,07		0,28		
0,9	2,16	0,0083	2,66	10,63		0,3259		
2,96	2,49	0,5258	5,96	53,98		0,42		
1,28	3,86	0,0038	3,99	43,25		0,5978		
0,52	1,66	0	1,53	7,11		0,19		
1,16	1,37	0,0025	4,24	10,255		0,2687		
1,94	6,35	0,0519	7,5	18,615		0,6208		
1,23	3,08	0,08	4,8	52,63		0,9124		
2,28	2,54	0	6,36	18,6		0,6414		
2,13	1,85	1,3728	4,71	46,26		0,4244		
3	4,04	2,7171	6,57	45,04		0,7084		
2,79	3,04	1,6697	6,22	36,935		11,4601		
2,54	1,43	1,4246	6,34	32,69		0,4006		
1,59	3,01	0,4498	3,55	33,23		0,4498		
1,427	2,994	0,089	3,333	13,96		0,308		
1,799	1,526	0,226	4,915	33,13		0,445		
3,501	29,79	1,629	8,723	52,45		0,51		
1,09	6,98	0,28	14,63	15,17		0,25		
2,064	1,456	0,037	8,002	19,07		0,378		
2,021	1,28	0,021	8,019	26		0,39		
1,746	1,252	0,032	5,918	42,8		0,427		

4,775	2,184	1,109	14,465	72,4		1,866		
6,127	2,463	1,202	15,92	80,12		1,91		
5,565	2,049	1,564	14,054	62		1,685		
2,651	0,983	0,665	9,145	43		0,59		
3,683	3,766	0,962	9,935	77		0,831		
3,36	1,806	1,769	7,381	63		0,696		
6,249	2,062	1,69	11,406	71,055		0,705		
5,498	9,875	2,073	8,546	78		1,098		
3,599	1,866	0,906	16,306	41		0,7		
4,15	14,36	1,471	8,101	63		0,555		
2,56	1,652	0,901	7,82	45		0,471		
3,785	2,326	0,525	11,367	61		1,429		
1,421	1,709	0,391	5,145	36		0,883		
4,536	7,868	0,869	4,639	24		1,418		
0,577	2,382	0,024	16,673	57		0,563		
5,838	2,676	2,01	18,377	89		1,659		
6,429	4,616	5,349	17,01	132,42		2,704		
8,257	8,182	3,549	12,92	112		0,884		
0,01	1,842	0,01	2,362	5		0,677		
5,244	13,54	0,251	32,68	60		1,448		
4,469	14,34	0,159	19,02	73		1,223		
2,847	28,15	0,781	10,9	52		1,206		
0,01	16,335	0,887	8,537	43		0,871		
0,01	5,318	0,01	12,02	44		0,979		
0,01	15,34	0,12	6,11	69		0,82		
0,01	7,18	21,72	4,68	56		1,01		
0,01	24,936	1,159	8,259	102		2,292		
0,01	18,73	1,55	7,199	69		1,213		
0,01	30,529	2,382	8,791	87		1,533		
0,01	26,611	3,052	8,333	77		1,283		
0,234	16,984	0,846	5,587	87		1,274		
1,074	24,975	0,26	6,189	43		0,944		
0,149	24,385	0,137	2,917	47		1,131		
0,836	23,357	0,002	4,983	35		0,871		
4,005	16,886	2,364	11,012	86		0,668		
				36				
3,673	11,674	0,959	11,322	68		0,458		
2,287	12,923			39				
1,986	13,973	0,259	16,738	17		0,289		
1,776	12,527	0,017	1,964	23		0,281		
			4,785			0,334		
1,482	7,31	0,112	5,416	37		0,363		
1,95	4,03	0,2781	5,09	35,65	0,21	1,658		0,64
2,12	3,11	0,2157	3,24	26,42	0,27	1,5794		0,18
2,01	2,63		4,94	31,22	0,35	1,5223		0,47
1,67	6,19	0,1397	4,12	11,23	0,55	1,3794	4,58	0,2
2,16	3,5	0,2089	5,24	12,87	0,23	1,7421	5,14	0,26
1,6	4,81	0,15	4,21	17,2	0,2	0,21	5,07	0,1

1,6	4,81	0,15	4,21	17,2	0,2	0,21	5,07	0,1
0,97	3,38	0,52	2,29	16,65	0,29	1,43	2,3	0,27
1,1	4,61	0,1228	2,36	6,39	1,14	2,1837	2,92	0,36
0,97	4,61	0,0354	2,64	9,82	0,2	1,28	2,46	0,12
1,38	2,89	0,1011	3,19	18,52	0,63	1,5868	2,12	
1,38	4,76	0,0568	3,61	12,98	0,53	1,0019	0,59	0,43
2,24	3,41	0,0146	6,19	16,53	3,64	1,0019	0	0,47
2,26	3,42	0,0874	5,64	60,03	9,78	1,4149	0,3	0,4
2,53	8,34	0,041	6,67	18,4	19,26	2,277	0,4	0,79
2,33	6,96	0,0109	6,51	8,81	8,5	1,4393	0,23	0,5
2,39	2,92	0,24	6,36	21,55	0,56	0,8038	3,33	0
2,48	5,16	0,2677	6,09	13,22	0,42	0,8523	4,07	0,1
1,95	3,17	0,2342	4,6	14,55	0,54	0,7433	4,6	0,03
1,99	3,96	0,2333	4,47	14,88	0,41	0,999	4,7	0,16
2,15	2,13	0,3224	4,33	15,68	0,45	0,8199	3,73	
1,43	2,19	0,3663	3,13	7,56	0,33	0,905	2,63	0,21
1,62	3,45	0,1589	3,8	10,53	0,38	0,8852	2,09	0,25
1,91	6,2	0,189	4,32	19,19	0,52	1,072	2,23	0,23
1,78	1,89	0,1893	4,64	19,385	0,64	0,7727	1,23	0,37
2,2	2,74	0,0732	5,33	20,905	1,27	0,916	0,13	0,27
2,3	6,06	0,084	5,81	21,97	1,69	1,1436	0,26	0,39
2,24	2,44	0,2467	5,84	22,68	0,71	0,7836	2,54	0,22
2,27	1,88	0,3317	4,78	23,63	4,2	0,8981	2,32	0,05
2,93	5,39	0,3912	6,79	29,64		1,0775		
3,23	3,48	0,4844	7,04	29,7		1,1929		
3,15	3,58	0,5295	6,72	31,55		1,1702		
3,1	4,75	0,3925	7,56	27,605		1,1037		
2,99	6,24	0,3911	6,53	37,78		1,3642		
2,74	4,11	0,4304	6,32	23,84		1,2333		
2,8	3,83	0,3803	6,14	28,65		1,3092		
2,26	2,52	0,4	5,05	20,21		1,029		
2,07	3,74	0,18	5,18	20,33		0,94		
1,7	2,14	0,24	4,18	45,52	0,68	0,75	1,29	0,31
3,37	4,32	0,5	7,34	34,81		1,53		
3,09	3,48	0,5	6,77	36,08		1,35		
2,74	3,24	0,45	5,83	30,16		1,31		
2,56	4,16	0,4295	5,48	55,14		1,349		
2,43	3,71	0,2886	4,76	44,12		1,188		
2,39	4,88	0,2632	5,29	21,6		1,2398		
1,84	2,69	0,17	4,65	29,5		0,83		
3,12	2,31	0,0027	14,21	21,55		1,5334		
1,95	7,32	0,1672	4,56	27,33		1,3927		
1,35	3,19	0,0912	4,09	20,78		1,1791		
2,04	3,17	0,2187	4,26	17,43		1,0675		
2,24	3,78	0,3156	4,26	34,6		1,1501		
1,86	4,85	0,2194	3,69	21,41		1,2554		
1,7	3,28	0,1953	3,46	41,5		1,1139		
1,85	3,52	0,0805	6,43	16,84		1,0391		
1,8	4,63	0,2144	3,71	30,81		1,1694		
0,919	4,765	0,068	2,199	22,9		0,755		

1	26,9	0,03	3,25	13,89	0,87
0,659	2,919	0,056	16,19	12,01	0,668
1,09	6,25	0,05	15,84	15,35	0,69
0,639	2,114	0,018	4,004	9,39	0,543
0,586	1,843	0,065	3,659	9,76	0,658
0,261	1,043	0,035	1,493	9,05	0,408
0,268	1,229	0,04	3,69	12	0,321
0,192	0,941	0,04	3,72	13,7	0,323
0,756	2,108	0,053	2,241	3,68	0,423
0,313	1,567	0,044	1,364	9,99	0,43
0,01	0,87	0,013	2,073	6	0,24
1,349	5,215	0,01	3,816	25	0,464
0,721	1,63	0,052	1,805	10	0,328
0,678	1,958	0,033	2,941	10	0,41
1,671	3,873	0,063	6,297	28,44	0,798
1,43	2,459	0,021	15,544	4	0,724
0,18	2,65	0,01	20,91	8	0,76
1,73	3,02	0,021	5,75	16	0,788
1,03	4,98	0,01	7,45	7	1,139
1,103	2,776	0,001	5,644	14	13,65
0,267	1,99	0,027	4,971	10	0,66
4,78	2,639	0,714	25,304	4	1,929
1,006	2,112	0,151	26,675	30	0,93
0,67	2,62	0,2	4,111	27,6	1,188
1,483	5,277	0,005	2,879	14	0,136
0,01	3,165	0,01	3,099	6	2,577
1,265	13,89	0,436	8,467	10	1,021
0,983	11,97	0,031	5,624	24	1,359
0,405	32,13	0,01	7,354	15	1,11
0,01	14,797	0,695	0,941	19	0,594
0,01	4,483	0,01	7,648	25	0,763
0,01	13,937	0,01	0,01	13	0,56
0,01	7,91	0,4	0,01	11	0,91
0,01	10,676	0,01	0,01	19	0,901
0,01	25,196	0,01	0,01	11	0,97
0,01	23,22	0,021	0,01	15	0,929
0,01	24,828	0,01	0,01	14	0,795
0,01	15,489	0,01	0,01	11	0,84
0,01	23,901	0,041	2,478	15	0,716
0,01	23,489	0,045	0,01	18	0,705
0,01	26,944	0,03	3,443	7	0,672
0,187	18,994	0,015	2,976	16	0,401
0,708	11,233	0,088	3,159	30	0,246
			4,141		0,22
1,741	13,322	0,095	12,652	37	0,283
1,608	12,657	0,054	1,756	28	0,242
					0,231
0,518	7,572	0,095	2,301	32	0,269

3,48	4,78	0,0781	12,6	32,18	0,22	8,931		0,7
3,81	5,49	0	12,99	9,64	0,24	8,7738		0,23
3,93	3,28		14,41	9,59	0,48	8,9916		0,54
3,62	3,54	0,0091	14,01	47,73	0,29	7,8241	0,06	0,23
3,87	3,45	0,0106	13,9	6,17	0,2	8,8247	0,16	0,27
4,26	5,41	0,03	14,7	11,2	0,2	8,41	0,11	0,1
4,26	5,41	0,03	14,7	11,2	0,2	8,41	0,11	0,1
3,9	3,75	0,01	13,5	11,7	0,34	8,85	0,1	0,23
2,69	8,85	0	9,46	10,02	0,31	1,4295	0	0,38
3,14	4,82	0,0019	11,2	9,28	0,2	7,546	0	0,15
3,43	3,15	0,0208	12,14	7,05	0,41	7,7647	0,15	
3,76	6,17	0	13,26	6,49	0,18	6,679	0,19	0,44
3,46	2,95	0,0124	11,84	7,34	0,09	4,8694	0,61	0,45
3,75	3,48	0,0048	12,74	8,6	0,2	4,7525	0,49	0,22
3,59	4,04	0,1226	11,81	12,3	0,15	4,8498	0,4	0,42
3,39	6,47	0,0011	11,84	4,4	0,37	4,3712	0,29	0,34
3,52	3,78	0,0093	14,4	15,01	0,4	4,4437	0,3	0
3,48	4,86	0,0007	11,93	4,64	0,28	4,4234	0,01	0,1
2,96	2,99	0	10,11	6,82	0,29	4,0234	0	0,07
3,46	3,72	0,0282	12,45	4,49	0,27	4,5662	0,21	0,14
3,64	2,06	0	11,78	9,6	0,26	4,5987	0,11	-0,78
3,81	2,21	0,501	12,94	7,35	0,37	4,7663	0,48	0,23
3,62	3,49	0,0165	12,4	9,52	0,31	4,7511	0	0,28
4,01	5,79	0,0091	13,52	12,32	0,31	5,0793	0,12	0,26
3,36	2,24	0,0005	12,61	2,43	0,23	4,0847	0,34	0,39
3,85	3,17	0	14,37	6,55	0,28	4,62	0,83	0,29
3,85	3,34	0,003	14,18	1,86	0,32	4,8352	0,07	0,39
3,39	2,73	0	12,69	4,29	0,31	3,6637	0	0,36
3,74	1,88	0,0003	12,76	7,325	3,03	4,5085	0,13	0,06
3,94	1,05	0	13,33	0,66		4,7251		
4,1	3,45	0,0027	14,24	4,72		4,9062		
4,02	3,43	0,015	12,91	14,36		4,8698		
3,92	5,24	0,0041	14,12	4,535		4,5432		
3,94	6,69	0,0329	13,58	19,32		4,7499		
3,81	5,24	0,0169	13,41	12,045		4,6104		
3,76	3,46	0	13,11	7,19		5,0096		
3,6	2,64	0	12,87	7,22		4,85		
0,29	6,21	0	13,65	4,91		5,02		
3,77	4,53	0	13,68	8,48	0,07	5	0,07	0,34
3,87	3,06	0,01	14,06	7,925		5,32		
4,61	5,39	0	15,79	10,205		5,65		
3,7	2,97	0,02	13,73	2,225		4,94		
3,57	2,86	0,01	12,91	16		5,47		
3,4	3,93	0	11,89	5,02		5,1857		
3,94	3,32	0	13,51	15,9		4,9107		
4,42	5,41	0	15,96	11,12		5,2303		
4,06	3,64	0	14,29	8,13		5,03		
5,75	3,22	0,0079	27,83	2,33		4,3195		
4,28	6,97	0	15,52	3,28		6,6367		
3,39	3,78	0,0055	12,44	8,37		5,2861		

4,07	3,52	0	15,55	6,055	5,1797
5,13	4,2	0,0206	18,59	1,39	5,3922
4,68	5,08	0,1061	16,42	3,555	5,9363
4,65	4,37	0	16,5	14,22	5,2198
3,64	2,5	0,0227	13,58	21,29	4,2087
3,18	18,17	0	11,21	30,97	4,9085
3,568	4,167	0,051	13,176	10,47	3,863
3,625	1,976	0,065	11,09	8,6	4,451
3,774	3,095	0,04	14,172	5,52	5,229
2,951	2,298	0,021	11,474	20,9	4,179
0,815	1,682	0,4	3,893	18,2	1,679
2,287	1,706	0,03	9,439	11,59	4,307
2,495	2,174	0,031	9,217	32,73	3,587
2,317	1,622	0,01	7,04	1,4	3,351
3,217	2,454	0,028	12,083	3,01	3,617
2,889	2,553	0,048	11,035	13	3,956
3,968	6,298	1,576	11,863	33	3,193
2,765	2,463	0,01	9,446	2	3,489
3,806	3,078	0,003	11,725	15	3,605
2,873	7,217	0,077	10,272	10	2,837
4,71	2,87	0,306	14,73	12	3,5
3,2	3,11	0,048	11,762	7	3,604
4,87	3,77	0,04	13,75	9	3,147
3,277	4,667	0,006	13,873	6	4,209
5,225	4,424	1,118	21,97	36	7,356
3,097	3,128	0,021	13,29	18	7,053
51,447	20,448	28,242	437,481	1620	3,982
3,662	2,917	0,036	16,523	20	4,551
3,716	3,181	0,01	16,05	27,68	7,601
3,691	5,819	0,003	13,4	19	4,676
2,398	3,01	0,01	13,69	15	9,697
4,576	13,74	0,451	24,27	34	7,315
2,855	29,24	0,01	13,87	26	7,378
0,01	15,94	0,01	10,713	18	5,076
0,01	235,909	0,01	4,373	24	6,393
0,01	12,23	0,01	4,81	13	4,24
0,01	12,48	0,01	6,58	15	15,06
0,01	4,297	0,01	9,934	14	4,151
0,01	19,12	0,01	3,447	17	3,788
0,01	28,14	0,01	5,714	10	6,025
0,01	26,763	0,01	8,101	16	4,467
0,01	15,409	0,01	5,951	13	3,238
1,448	22,864	0,03	9,899	16	3,804
0,01	25,721	0,056	7,466	19	3,682
1,11	21,835	0,013	9,296	12	2,976
2,97	22,083	0,006	12,302	19	3,46
3,044	11,683	0,898	12,515	45	2,956
3,273				25	
6,503	11,736	0,326	19,332	104	1,306
			10,33	39	2,763

4,706	8,478	0,56	15,698	123		1,207		
12,63	9,55	0,1737	25,72	176	0,59	14,212		0,66
12,46	10,61	0,1159	23,61	196	0,58	12,9893		0,25
11,83	7,45		22,37	130	0,55	13,9768		0,55
10,59	8,1	0,0142	40,27	150	0,23	15,2201	0,09	0,26
10,5	10,3	0,44	19,7	160	0,32	12,1	0,1	0,1
10,5	10,3	0,44	19,7	160	0,32	12,1	0,1	0,1
24,7	8,55	2,19	42,96	321	1,06	12,2	0,1	0,49
26,46	8,69	3,1112	35,69	382	1,09	10,471	0,09	0,28
24,33	11,84	3,3313	42,88	315	1,07	9,6823	0	0,14
24,12	6,8	2,9841	41,83	283	1,38	9,2685	0,03	
20,42	11,44	1,605	37,63	248	1,22	9,38	0,14	0,45
18,38	7,83	0,3214	33,19	186	0,91	6,8128	0	0,45
17,74	8,29	0,2115	31,42	180	0,93	6,751	0,44	0,25
16,26	10,83	0,365	28,94	162	1,2	7,0651	0,27	1,71
9,64	7,22	0,1466	18,12	137	0,59	5,8291	0,2	0,33
11,97	7,24	0,1431	23,52	143	0,82	5,761	0,14	1,27
10,71	6,8	0,0115	21,59	138	0,82	5,3669	0,28	0,03
16,07	8,32	0,0228	32,45	168	1,09	6,6896	0,15	0,15
15,04	6,18	0,0418	25,68	156	0,79	6,1111	0,13	
15,85	6,7	1,0979	27,79	202	0,86	6,5034	0,61	0,21
12,02	7,6	0,0498	22,65	133	1,23	6,2789	0	0,24
10,48	9,68	0,0177	18,37	121	0,53	6,6461	-0,09	0,32
7,77	6,68	0	14,62	70,425	0,38	5,7954	1,21	0,27
7,42	6,63	0,0009	13,23	71,485	0,61	5,7855	0,26	0,39
7,89	6,5	0,0068	15,1	60,97	0,7	1,2474	2,21	0,25
8,7	5,57	0	13,93	68,075	1,83	5,9239	0,29	0
10,35	7,55	0,026	17,66	72,675		6,5525		
9,8	7,17	0,0104	17,13	47,71		6,1356		
9,9	7,39	0,0187	19,05	105		6,1713		
9,78	6,95	0,0055	17,77	83,39		5,5106		
7,48	9,68	0,0231	17,23	64,665		5,7763		
7,3	7,84	0,0071	19,49	61,74		5,3296		
5,61	6,54	0	14,01	40,09		5,0369		
5,78	6,11	0	16,25	36,1		4,7386		
10,53	8,19	0	25,54	101,22		6,53		
6,78	5,68	0,01	19,46	147	0,04	5,98	0,09	0,32
7,01	7,31	0,01	13,81	76,57		7,02		
8,4	8,83	0	15,49	75,92		7,19		
7,53	6,78	0,01	15,56	66,155		7,31		
7,55	6,08	0	15,57	64,77		6,6		
6,49	7,77	0	13,18	69,74		6,6035		
6,73	7,29	0	13,79	71,12		5,5961		
7,4	8,46	0	17,35	37,2		5,3382		
9,89	6,87	0	22,03	105,22		6,245		
2,4	2,3	0,1706	6,97	46,18		0,8009		
7,22	10,09	0	18,21	29,86		5,8085		
6,08	7,1	0,006	15,45	32,29		5,1255		

9,26	7,8	0,001	19,02	73,5		5,4568		
8,23	8,06	0	16,99	45,335		5,5359		
8,21	7,09	0	17,84	46,81		5,0075		
7,68	5,96	0,0163	18,01	65,19		4,5503		
6,29	23,48	0	14,17	38,44		4,5178		
4,59	4,715	0,037	12,52	37		4,197		
5,66	4,89	0,013	10,35	36,65		2,48		
4,171	3,669	0,01	6,765	44,92		1,99		
5,22	5,382	0,01	10,803	41,82		2,27		
4,941	5,504	0,031	9,705	40		2,748		
3,874	4,496	0,161	10,324	21		2,353		
3,227	4,399	0,01	6,767	5		2,108		
4,488	4,717	0,01	8,906	26		1,977		
6,126	15,146	0,017	10,699	22,1		2,273		
1,56	4,759	0,02	10,511	7		2,761		
5,36	5,2	0,051	10,583	22		2,377		
2,97	3,73	0,019	10,19	10		2,358		
2,29	6,165	0,01	6,915	21		3,192		
0,01	1,773	0,002	5,527	23		1,309		
3,96	5,237	0,01	10,18	23		4,275		
4,957	4,713	0,021	12,799	56		2,319		
4,844	6,424	0,065	13,12	60,62		3,834		
5,449	8,354	0,01	12,39	60		2,579		
3,286	14,02	0,086	11,85	24		2,502		
3,646	13,88	0,061	16,18	48		2,38		
5,438	33,91	0,01	14,31	77		4,02		
0,01	19,328	0,01	6,031	46		2,006		
0,01	6,743	0,01	3,925	74		2,265		
0,01	11,48	0,01	8,24	68		3,18		
0,01	14,644	0,01	0,466	45		2,299		
0,01	17,47	0,01	2,01	18		2,14		
0,01	17,22	0,01	1,507	18		2,96		
0,01	19,5	0,01	5,095	35		2,263		
1,377	18,179	0,256	5,088	37		1,451		
0,01	18,2	0,16	6,59	18		1,37		
2,541	23,642	0,057	7,916	19		1,445		
4,98	16,1	0,02	11	47		1,61		
3,23	20,859	0,007	9,093	40		1,103		
2,931	4,102	0,216	7,403	33		0,949		
3,638				37				
4,941	15,12	0,029	15,566	60		1,198		
6,41	9,53	0,191	16,36	39		1,472		
3,078	10,654	0,017	9,013	35		1,188		
0,23	5,11	0,0021	0,92	5,5	0,18	0,8527		0,63
0,37	3,13	0	1,17	3,27	0,06	0,8875		0,38
0,5	2,16		1,46	4,1	0,17	1,0506		1,84
1,45	4,67	0,0278	4,59	33,19	1,52	1,9777	0,31	0,21

2,33	3,36	0,0045	8,41	2,63	5,14	3,5298	0,15	0,27
2,24	5,54	0,02	7,34	4,16	8,83	3,84	0,1	0,38
2,24	5,54	0,02	7,34	4,16	8,83	3,84	0,1	0,38
1,8	3,38	0,01	5,64	26,35	0,31	3,68	4,49	0,24
0,82	5,8	0	2,84	21,82	0,31	8,1012	2,67	0,37
3	5,62	0	11,86	5,36	0,22	2,9585	0,88	0,14
1,07	2,24	0,0038	3,64	14,92	0,57	1,8138	0,02	
0,64	4,31	0	1,71	8,86	0,2	1,177	0,43	0,42
1,44	2,57	0,0046	4,93	2,61	0,61	1,2539	0,64	0,46
1,16	3,16	0,0148	3,99	10,49	0,57	1,0785	0,48	0,22
0,77	4,65	0,0066	2,33	0,7	0,97	0,9828	0,46	0,44
1,64	3,79	0,008	5,74	7,37	0,72	1,1141	0,29	0,33
1,38	2,53	0,005	5,47	22,16	0,91	1,032	0,49	0,12
1,59	5,6	0,0263	5,29	8,13	1,33	1,2648	0,17	0,1
1,27	2,57	0	3,71	11,42	1,58	1,0193	0,13	0,01
1,18	3	0	3,94	6,7	0,38	0,9681	0,1	0,14
0,92	1,07	0	2,69	11,62	0,33	0,7655	0,16	-0,99
0,7	1,02	0,815	2,1	20,32	0,21	0,7123	0,23	0,21
1,1	3,64	0	3,4	7,14	0,3	0,8539	0	0,25
0,91	6,07	0	2,48	12,46	0,37	0,8287	0,08	0,22
1,38	1,17	0,0044	4,66	18,75	0,27	0,8854	0,34	0,36
1,15	2,26	0,0043	3,59	13,405	0,34	0,8	0	0,16
4,01	8,2	0,007	11,26	94,89	0,29	0,8532	3,68	0,41
0,87	2,28	0,0041	2,94	5,47	0,3	0,7252	0	0,24
0,6	0,99	0,0127	1,78	7,195	1	0,7702	0,3	0,06
1,12	2,89	0,0412	3,19	23,57		0,9035		
0,65	2,33	0,0164	1,85	5,595		0,5748		
0,51	2,32	0,0203	1,45	12,05		0,5572		
0,58	2,2	0,0021	3,77	21,38		0,4021		
0,34	7,19	0,032	1,11	6,35		0,3995		
1,28	3,32	0,03	2,17	10,375		0,5587		
0,66	2,56	0	2,47	4,555		0,7448		
0,74	1,68	0	2,01	9,14		0,64		
1,31	3,75	0	3,82	22,85		0,96		
2,15	2,83	0,02	6,98	48,97	0	0,55	0,18	0,32
1,51	2,58	0	6,34	4,24		0,82		
1,91	2,33	0	8,57	11,33		0,65		
2,52	2,56	0,11	14,2	12,655		0,73		
0,4	1,8	0,01	1,61	6,85		0,55		
0,47	2,72	0,0421	1,4	18,81		0,4895		
0,42	2,04	0	1,71	4,51		0,3777		
0,4	3,43	0,0103	1,32	6,5		0,3772		
1,29	2,1	0,03	4	20,48		0,33		
1,29	2,1	0,03	4	20,48		0,33		
0,94	1,67	0,0142	3,2	7,355		0,3887		
0,74	4,65	0	2,93	6,59		0,7083		
1,31	4,69	0	4,44	7,03		1,1914		
1,01	2,26	0	3,37	7,48		0,8378		
1,13	2,36	0,0063	3,72	12,93		1,0175		
1,17	4,31	0	3,79	3,755		1,2486		

2,01	5,08	0	3,2	5,07		0,864	
0,58	1,37	0,022	2,94	18		0,5115	
0,55	17,21	0	2,08	31,31		0,9316	
1,359	7,54	0,068	6,239	10,43		1,278	
1,342	2,001	0,051	5,797	9,72		1,146	
1,178	31,427	0,032	3,681	15,74		0,953	
5,12	1,077	0,025	22,05	50,74		0,218	
1,114	1,185	0,055	6,075	10,77		0,462	
8,382	5,259	0,017	30,41	23,81		4,443	
9,68	5,417	0,01	33,693	33,49		5,49	
11,462	7,01	0,021	51,812	25,9		5,925	
2,64	7,457	0,046	36,025	83		1,05	
3,925	2,519	0,99	18,447	64		1,572	
2,204	2,364	0,039	23,888	52		1,393	
2,951	3,852	0,002	8,954	25		1,395	
2,081	5,044	0,091	8,051	28,47		1,044	
0,01	7,11	0,13	16,186	8		1,158	
2,2	2,63	0,069	5,11	9		0,735	
0,87	2,25	0,08	3,903	5		1,083	
0,913	2,289	0,028	13,94	32		1,216	
3,925	3,399	0,016	28,581	19		2,666	
5,066	4,715	0,005	20,49	27,42		4,009	
5,328	8,085	0,022	18,43	17		2,341	
2,099	3,435	0,01	11,43	27		3,2	
3,302	13,08	0,074	15,2	17		3,262	
2,98	11,54	0,029	12,85	53		2,754	
3,244	32	0,013	19,32	31		3,291	
155,279	70,545	1,768	522,447			7,894	
0,01	11,054	0,01	0,01	18		1,089	
0,01	15,43	0,01	4,57	35		1,89	
0,01	10,78	0,01	4,67	25		2,48	
0,01	20,579	0,01	3,048	25		2,691	
0,01	26,899	0,01	4,624	12		2,029	
0,01	14,03	0,01	0,278	7		1,741	
0,01	21	0,01	3,014	22		1,656	
0,01	15,063	0,047	0,751	15		0,947	
0,01	16,76	0,02	2,72	13		1,19	
0,01	27,577	0,102	1,88	21		1,641	
0,013	25,548	0,038	4,178	8		1,021	
2,484	20,997	0,001	11,055	24		1,226	
1,769	2,389	0,121	6,083	36		0,73	
1,27	13,208	0,052	4,116	31		0,332	
1,75	21,772	0,03	7,544	63		0,645	
		0,004	10,082				
99,098	43,036	0,498	979,193			6,328	

23,54	6,34	0,9077	32,23	190	0,19	4,2533	0,67
25,37	7,76	0,9552	34,57	212	0,14	4,2797	0,18
24,13	4,53		34,19	182	0,79	4,5695	1,87

30,71	7,5	0,0229	44,83	218	0,53	15,6023	0,58	0,27
29,49	7,91	0	44,5	162	1,46	12,6036	0,75	0,27
30,2	10,6	0,03	44,5	90,1	0,2	11,9	3,33	0,1
30,2	10,6	0,03	44,5	90,1	0,2	11,9	3,33	0,1
27,46	8,84	0,01	41,49	178	0,3	12,2	8	0,41
30,54	7,48	0,0155	46,24	323	3,53	10,6644	0,28	0,39
29,01	7,68	0,0225	47,06	176	3,45	9,5907	0,03	0,16
28,57	6,58	0,0212	43,63	97	0,46	10,8927	41,89	
27,85	9,58	0,0196	41,7	197	9,57	8,77	0,12	0,53
30,19	7,11	0,007	44,92	185	9,92	6,8321	0	0,58
31,31	7,34	0,0396	42,26	181	4,37	6,1274	0,46	0,31
30,75	7,35	0,0145	43,42	172	4,89	5,8159	0,23	0,8
29,48	6,38	0,0405	44,74	232	2,66	4,3068	0,21	0,35
30,53	7,83	0,0267	50,05	214	2,91	4,0891	0,15	1,28
29	9,38	0,0556	45,47	197	4,37	4,5364	0,22	0,18
27,71	6,22	0,0112	41,93	214	4,43	4,5861	-0,49	0,15
5,94	5,52	0,5629	10,21	62,4	0,36	0,851	2,19	0,2
32,79	4,71	0,8253	43,34	245	0,28	3,9714	0,31	
32,81	4,65	1,0129	44,05	278	0,29	10,8509	0,81	0,21
31,16	5,86	0,8048	42,31	256	0,32	3,1027	0	0,35
32,86	8,36	0,729	45,17	249	0,31	4,3621	0,21	0,37
27,52	3,86	0,8639	37,76	225	0,61	3,7885	0,41	0,48
29,41	4,87	1,1733	40,7	235	0,3	2,2408	0,09	0,26
28,05	5,15	1,124	39,35	250,5	0,45	2,2002	0	0,38
26,59	5,49	0,9903	37,12	237	0,35	2,334	0,06	0,26
33,32	3,94	0,5923	45,92	270	1,46	2,3319	0,36	0,31
31,8	5,3	0,7765	40,44	239,5		2,6449		
29,29	4,95	0,4065	38,67	195		2,4907		
28,45	5,26	0,4409	36,38	206		2,5536		
26,61	5,51	0,2111	35,48	200		2,5081		
25,44	4,95	0,0915	37,66	172		2,3996		
23,06	5,51	0,5336	33,17	188		2,1156		
20,9	4,87	0,0301	27,93	149,5		2,1359		
18,35	4,41	0,02	22,45	122,5		1,7046		
12,17	6,03	0	19,25	93,59		1,065		
11,8	4,72	0	18,36	157	0,11	1,17	0,08	0,31
27	5,01	0,21	36,87	211,5		2,79		
29,46	7,38	0,94	40,22	178,22		2,41		
24,9	4,82	0,91	34,22	184,26		2		
23,34	4,37	0,83	31,02	193,83		2,01		
19,67	7,38	0,4138	26,7	166,56		1,8552		
17,66	4,64	0,041	22,58	120,025		1,3698		
17,01	6,67	0	23,26	111,97		1,4066		
4,95	3,82	1,0001	11,04	38,545		2,0784		
16,62	9,03	0,0019	20,64	95,325		1,6593		
21,61	8,22	0,2154	27,13	149,415		1,7218		
26,27	5,6	1,7372	35,01	198,74		1,9671		
40,71	7,83	0,1716	50,86	257,64		2,9809		
37,6	8,7	2,1029	48,7	318,71		3,212		
41,24	10,22	1,5598	54,99	277,005		2,8117		

36,96	5,78	1,4932	48,31	255,83		2,5814		
32,31	23,51	1,1279	42,47	236,125		2,6376		
7,9	3,181	0,081	12,602	56,04		0,828		
26,22	6,44	0,6	34,13	268,13		5,79		
26,901	5,268	0,627	32,087	262,38		5,794		
37,651	6,784	0,701	47,899	282		6,096		
36,216	6,745	1,236	45,265	260		5,764		
28,666	4,182	0,979	34,206	233		2,638		
29,194	4,347	0,927	32,723	222		2,557		
32,995	5,017	0,979	38,745	282,85		2,438		
47,181	11,154	0,607	64,736	393		2,571		
44,408	5,745	1,296	44,261	300		2,848		
33,591	4,24	0,755	36,484	263,33		2,22		
27,49	4,31	0,675	41,87	183		1,878		
38,218	5,767	0,907	46,845	273		2,663		
3,339	3,108	7,712	8,892	102		2,342		
35,942	8,603	0,705	45,517	268		7,631		
41,9	8,514	1,787	52	307,67		11,95		
40,05	11,34	0,777	51,13	220		7,541		
40,63	16,5	0,846	57,5	293		6,74		
41,81	7,033	0,438	61,68	229		5,864		
43,81	13,38	0,179	60,5	260		7,236		
40,79	32,86	1,088	56,86	288		5,159		
25,135	18,104	0,343	47,94	252		5,617		
8,218	16,64	0,01	30,895	237		8,658		
9,14	15,08	0,18	27,39	166		8,66		
21,159	34,517	0,01	32,81	45		7,972		
22,248	14,399	0,025	37,211	232		6,752		
27,526	16,35	0,399	39,914	208		7,544		
25,638	36,82	0,584	40,815	249		7,02		
23,491	21,481	0,16	35,649	289		5,201		
29,382	32,25	0,263	44,122	284		5,374		
33,448	34,068	1,678	50,896	280		3,852		
33,4	16,2	0,01	59,7	220		5,01		
29,348	21,601	0,191	41,632	306		2,222		
21,788	4,429	0,924	35,292	335		1,729		
		0,988		347				
35,567	17,155	0,178	73,145	296		2,122		
				309		1,943		
30,478	12,081		50,618	319		1,705		
28,132	10,221	1,587	51,637	328		1,349		
1,23	4,6	0	7,29	41,12	0,17	3,7852		0,64
5,21	4,55	1,2621	7,27	68,41	0,21	2,6109		0,19
1,75	3,18		8,18	8,96	0,98	4,0849		1,83
1,74	6,11	0,0326	6,61	8,18	13,21	4,6343	0,15	0,21
1,37	2,84	0,0031	6,29	17,8	0,28	2,9403	0,14	0,26
1,7	4,11	0,04	6,54	33,6	0,42	2,63	0,12	0,1
1,7	4,11	0,04	6,54	33,6	0,42	2,63	0,12	0,1

2,23	3,13	0,7	5,22	52,6	0,39	3,14	0,1	0,28
1,98	9,05	0	5,19	98,24	0,34	2,0799	0,1	0,39
2,35	4,67	0,5577	6,23	58,41	0,23	2,8312	0	0,1
2,22	2,59	0,5912	5,66	61,57	0,35	2,9503	0,18	
5,77	5,97	0,1598	9,3	39,5	0,2	1,05	0,09	0,43
2,36	2,58	0,1506	6,55	49,79	0,05	1,7839	0,81	0,45
1,86	3,18	0,0331	5,55	47,05	0,29	1,5486	0,42	0
1,65	5,29	0,2777	5,89	38,08	0,76	1,4246	0,41	0,7
1,56	3,21	0,13	6,18	27,63	0,47	1,4203	0,27	0,34
2,45	2,77	0,1746	8,45	47,75	0,51	1,5334	-0,65	1,25
2,13	4,93	0,1086	6,72	44,91	0,54	1,5492	0	0,07
2,23	2,72	0,4258	5,7	37,46	0,42	1,3963	0,07	0,01
2,22	3,91	0,2656	5,35	43,24	0,3	1,8986	0,1	0,15
2,35	1,7	1,0989	5,07	58,88	0,3	1,4966	0,09	
2,69	1,98	1,8841	5,91	40,39	0,43	1,8007	0,38	0,21
2,41	3,22	1,5827	7,66	47,54	0,34	1,644	0	0,28
2,5	6,63	0,694	8,47	41,52	0,34	1,9571	0,1	0,26
1,91	1,71	0,3432	6,84	38,86	0,4	1,5214	0,34	0,39
2,02	2,76	0,3214	7,01	37,34	0,5	1,5309	0	0,29
2,13	2,96	0,0407	6,78	36,75	0,55	1,5347	0,14	0,4
2,62	3,65	0,2073	7,81	41,51	0,52	1,5951	0	0,24
2,94	1,46	0,0222	7,16	60,27	1,75	1,4434	0,78	0,2
3,08	2,94	0,0134	7,6	62		2,3049		
3,39	3,06	0,0276	9,16	49,64		1,8443		
3,77	3,29	0,0866	9,01	53,535		2,1642		
3,75	3,04	0,3817	9,92	57,3		1,6827		
3,85	6,18	0,043	10,24	71,24		2,1387		
3,72	2,75	0,2031	9,51	57,745		1,8929		
2,77	3,39	0	7,84	44,22		1,8258		
3,86	3,44	0,115	9,98	54,52		1,8098		
4,6	4,67	0,025	12,44	63,24		1,975		
2,92	2,91	0,43	8,13	138,5	4,34	1,56	0,18	0,31
4,49	3,79	1,15	12,17	87,87		2,559		
5,44	6,27	1,3	13,33	102		2,708		
4,91	8,36	0,35	15,73	81,5		2,47		
4,2	7,33	1,39	11,88	85,06		2,2		
5,55	4,73	1,1265	12,71	98,425		2,3273		
4,59	3,6	1,604	11,44	83,67		2,1412		
4,56	5,78	0,18	13,28	55,845		2,25		
4,21	3,35	0	10,82	101		1,86		
3,69	2,57	0,0032	10,19	29,985		1,6835		
4,32	5,66	0,0147	10,87	47,93		2,5614		
5	5,67	0	12,51	54,705		2,2958		
5,57	3,29	0	14,05	56,205		2,1256		
5,65	5,41	0,0679	13,64	82,47		2,4968		
5,97	5,01	1,588	15,46	86,315		2,6454		
5,52	4,07	0,2776	14,94	129,89		2,5601		
5,01	2,49	1,2613	14,5	77,82		1,7968		
5,04	28,63	1,5933	14,24	86,33		2,546		
4,71	4,536	0,039	13,544	75,67		1,34		

5,125	2,601	0,251	15,008	101,39		2,198	
6,22	30,445	0,947	17,68	132,59		2,418	
4,764	6,02	0,02	48,22	94,32		2,03	
4,168	2,4	0,122	17,659	71,25		2,781	
4,406	2,102	0,031	16,156	66,69		2,018	
5,43	2,421	0,018	15,207	162,8		2,181	
5,996	2,785	0,138	14,093	168,96		2,57	
5,89	2,892	0,04	19,478	140		2,559	
0,01	3,621	0,1	109,616	32		2,19	
4,932	2,788	0,306	14,344	119		1,763	
5,502	3,143	0,172	14,521	97		1,872	
5,354	9,394	0,059	24,387	81,705		2,336	
6,339	10,43	0,564	15,603	127,27		2,499	
5,912	12,215	0,321	43,575	151,03		2,385	
5,81	3,133	0,7	22,51	192		1,968	
7,657	3,743	1,753	24,02	158		3,022	
4,584	3,761	0,001	20,16	74		3,8	
4,659	3,161	0,093	21,65	109		3,447	
1,183	1,848	0,049	8,261	92		0,395	
7,265	3,63	3,606	38,732	222		2,38	
7,848	3,757	4,667	23,32	216,6		3,965	
6,841	8,756	4,429	19,7	242		3,488	
7,866	4,486	0,128	24,42	164		5,435	
8,556	12,08	0,012	36,29	144		4,352	
9,191	11,39	2,111	31,54	184		3,922	
7,238	5,09	0,01	29,17	159		5,09	
0,01	18,396	0,01	30,127	25		5,319	
0,01	14,366	0,05	23,156	141		5,571	
1,79	15,56	0,24	22,45	122		2,53	
0,01	7,66	0,96	16,6	118		2,86	
0,712	29,689	2,615	24,405	164		3,286	
1,323	24,483	3,071	23,604	177		3,047	
8,823	19,7	5,924	21,694	198		3,289	
0,432	28,916	2,43	24,206	173		3,154	
4,935	17,306	1,395	21,641	182		2,114	
3,59	16,5	4,74	25,55	130		2,02	
1,519	22,36	4,196	18,83	75		2,294	
2,789	19,374	0,01	14,807	74		1,649	
4,148	18,485	0,334	19,714	116		1,857	
				107			
3,369	5,734	0,939	12,658	92		1,786	
3,619	14,705	0,058	12,73	58		1,132	
4,944	13,987	0,049	17,636	78		1,423	
5,553	12,315		17,945				
5,573	11,699	0,352					

5,99	5,46	1,8298	8,46	76,95	0,2	3,3109	0,63
1,53	5,02	0	7,66	29,18	0,23	3,7992	0,22
3,88	3,16		6,07	49,87	0,15	2,0083	1,83

3,82	5,09	0,8143	6,71	69,45	0,36	1,8495	0,37	0,21
7,12	3,99	1,5629	8,98	67,33	0,18	4,2114	0,45	0,27
5,09	4,44	0,98	5,5	69,8	0,2	2,98	0,5	0,1
5,09	4,44	0,98	5,5	69,8	0,2	2,98	0,5	0,1
4,5	4,45	0,23	5,56	58	0,3	5,58	0,44	0,25
5,15	4,43	2,0041	6,83	64,05	0,34	4,4992	0,38	0,29
4,71	6,79	0,4504	6,08	53,19	0,21	4,9858	0,46	0,14
5,39	3,95	0,9482	6,57	55,75	0,33	5,2092	0,74	
5,3	6,49	1,1023	5,81	66,77	0,19	3,68	0,59	0,43
6,06	4,02	0,9975	7,2	59,64	0,01	2,8918	1,12	0,46
6,75	5,78	1,0837	8,31	89,16	0,21	2,8235	0,83	0,23
5,66	4,91	0,8575	7,33	49,69	0,19	2,9421	0,85	0,41
6,63	5,04	2,1439	8,57	83,27	0,37	2,513	0,7	0,32
6,14	4,02	0,9132	8,61	52,69	0,44	2,5733	0,18	1,27
5,72	6,19	0,8039	7,57	51,55	0,3	2,649	0,6	0,11
5,45	3,76	0,8843	6,42	56,8	0,46	2,3719	0,79	0,04
6,09	4,72	1,1039	6,73	56,18	0,28	2,7723	0,83	0,14
6,62	2,64	1,368	6,79	67,64	0,29	2,3997	0,61	-0,99
7,34	2,9	1,8701	7,9	59,74	0,21	2,6292	0,88	0,22
7,43	4,11	1,3811	9,09	71,39	0,32	2,5083	0,53	0,27
8,28	5,58	2,0559	9,79	95,17	0,29	2,8701	0,63	0,21
7,25	2,32	1,7356	8,74	82,695	0,27	2,3008	0,51	0,37
8,4	3,58	2,4315	10,34	90,635	0,29	2,418	1,53	0,27
8,82	4,82	2,4284	11,25	92,54	0,38	2,7524	1,09	0,39
8,23	3,58	3,9385	14,29	142,5	0,37	2,1437	0,72	0,24
8,86	2,6	2,72	9,38	89,12	1,39	2,1593	0,78	0,01
9,47	4,06	2,745	10,71	86,78		2,4535		
9,36	3,95	3,0918	10,81	77,645		2,7212		
9,38	3,8	3,3912	10,39	78,025		2,1862		
9,39	4,13	2,2225	11,96	79,65		1,6358		
3,26	3,82	3,0551	11,64	74,075		1,7773		
7,77	3,44	2,931	10,21	86,34		1,8664		
4,76	3,18	1,2	6,62	56,33		1,1419		
1,5	2,97	0,105	4,21	26,82		0,5917		
4,47	4,15	1,165	8,34	92,03		0,86		
4,65	6,45	0,07	7,4	104,5	21,15	1,27	0,06	1,31
7,55	4,55	1,68	9,43	70,17		2,539		
8,81	5,56	3,26	10,05	95,05		2,71		
7,18	3,81	2,52	9	80,155		2,09		
6,7	4,29	2,82	8,57	78,28		2,08		
6,9	3,52	3,0662	8,88	75,575		1,8802		
7,23	3,73	2,3306	8,57	92,63		1,4221		
6,72	4,17	2,3096	9,2	98,55		1,3143		
0,72	2,22	0	2,84	21,5		0,23		
0,31	2	0,0412	0,88	16,875		0,1106		
6,59	6,41	2,2906	8,8	56,91		2,2121		
7,17	7,24	1,71	10,5	91,22		1,96		
6,39	3,95	2,0372	7,62	71,2		2,0139		
7,83	5,64	3,3941	9,43	112		2,428		
7,74	5,83	3,7796	8,7	83,85		2,8579		

7,64	4,2	2,4843	8,97	92,42	2,2652
7,42	3,34	1,7454	9,11	65,28	1,9886
7,51	22,06	2,0458	10,49	91,04	1,9586
5,973	5,016	1,723	6,862	57,21	1,32
5,59	3,276	1,286	8,148	53,53	1,932
5,229	29,6	0,921	7,511	53,65	2,576
4,9	10	0,39	10,23	62,42	0,3
2,431	2,425	0,037	7,229	26,09	0,842
8,084	9,261	0,021	15,6	82,93	2,299
0,86	1,595	0,38	3,882	14,89	0,482
2,92	3,16	0,94	4,88	40,1	2,22
3,079	3,827	0,16	6,069	48	1,51
4,35	4,971	0,324	7,946	43,63	2,218
2,799	3,174	0,128	12,45	38	2,278
2,53	2,317	0,149	24,489	45,82	1,918
4,61	6,638	0,109	7,481	71	1,805
3,818	3,347	0,237	5,988	45	1,88
4,161	3,444	0,072	27,953	52	1,918
5,362	9,984	1,464	6,247	70	1,768
1,72	3,677	1,036	5,62	38	2,144
4,4	4,01	0,975	6,254	58,99	1,84
3,361	3,399	0,305	5,704	44	1,823
2,677	3,696	0,206	6,146	37	1,504
1,129	2,838	0,057	3,813	23,2	0,768
0,01	1,969	0,018	4,345	13	1,026
0,411	2,398	0,015	9,549	27	0,218
0,01	2,276	0,044	2,555	27,86	0,352
0,01	1,753	0,003	2,472	17	0,716
0,01	5,444	0,081	5,112	25	1,199
1,566	13,78	0,255	6,721	24	0,751
0,623	27,49	0,01	7,028	24	0,981
0,01	15,433	0,93	0,816	20	0,535
0,01	11,53	0,01	0,01	29	0,477
0,01	14,23	0,01	1,15	32	0,45
0,01	5,09	0,01	0,01	21	0,88
0,01	20,742	0,01	0,01	16	1,351
0,01	26,954	0,01	0,01	28	1,464
0,01	12,62	0,01	0,01	34	0,911
0,01	19	0,331	0,01	24	0,995
0,01	13,694	0,021	0,01	10	0,645
0,01	16,71	0,07	0,86	11	0,74
0,01	24,268	0,032	0,01	21	0,656
3,374	28,833	0,014	12,736	27	3,348
				53	
3,448	3,498	0,251	11,228	41	1,567
1,583	12,584	0,02	4,907	28	0,419
1,604	12,096	0,094	6,495	25	0,478
2,107				37	0,4
			9,329	52	

0,17	4,19	0	0,59	8,11	0,17	1,343		0,64
0,22	4,44	0	0,62	10,08	0,21	1,1111		0,2
0,25	4,39		0,6	4,3	0,14	1,1639		1,84
0,43	4,56	0,3214	1,33	39,36	0,31	1,0916	0,89	0,18
0,26	2,76	0,09	0,67	6,63	0,18	1,1907	0,94	0,25
0,11	4,97	0,01	0,88	5,89	0,2	0,85	1,07	0,1
0,11	3,97	0,01	0,88	5,89	0,2	0,85	1,07	0,1
0,18	2,93	0,96	0,32	11,97	0,3	0,89	0,48	0,24
0,13	2,59	0,0115	0,37	9,23	0,31	0,5746	0,12	0,7
0,5	5,02	0,2871	1,13	38,06	0,23	0,9848	0,53	0,12
0,47	2,61	0,8386	1,56	27,09	0,12	0,9894	0,73	
0,13	3,92	0,0095	0,06	4,32	0,18	0,75	0,59	0,44
0,19	2,27	0,0181	0,53	8,51	0,08	0,4894	1,11	0,44
0,12	2,44	0,108	0,66	3,13	0,2	0,4995	0,94	0,22
0,24	5,94	0,053	0,72	20,74	0,3	0,4332	0	1,07
0,18	2,47	0,0042	0,33	0,36	0,37	0,424	0,7	0,33
0,33	2,5	0,37	1,31	9,07	0,45	0,4464	0,69	1,27
1,09	5,25	4,5728	3,67	65,06	0,33	0,569	0,77	0,1
0,66	2,6	4,8062	1,84	61,15	0,43	0,4548	0,77	0,04
0,26	3,27	2,1036	1,12	35,89	0,29	0,6219	0,52	0,14
0,31	1,52	2,6714	0,7	32,26	0,32	0,4654	0,82	0,13
0,27	1,51	1,2181	0,89	26,33	1,65	0,6724	0,75	0,22
0,45	3,13	0,7482	2,65	23,05	0,33	0,4641	0,32	0,25
0,45	4,92	0,3177	1,19	27,43	0,31	0,5036	0,35	0,21
0,26	1,31	0,365	1,18	9,375	0,26	0,3948	0,42	0,37
0,35	9,58	0,4082	17,92	3,525	0,3	0,4604	6,49	0,25
0,42	3,52	0,4345	1,27	14,805	0,29	0,4918	1,38	0,38
0,26	1,95	0,2245	0,85	15,655	0,28	0,2794	0,6	0,21
0,21	1,3	0,3358	0,62	15,815	1,11	0,4263	1,31	0,02
0,74	4,44	2,14	2,34	79,55		0,4984		
0,14	2,57	0,0055	0,42	1,965		0,3579		
0,44	2,66	0,8435	1,14	22,6		0,4103		
0,5	2,61	2,2245	1,14	35,495		0,3774		
0,37	2,08	1,0406	1,19	17,55		0,4015		
0,64	4,26	0,9397	2,07	28,55		0,4798		
0,16	2,4	0	0,45	2,78		0,5317		
0,24	2,3	0,085	0,59	11,76		0,47		
0,19	3,4	0	0,51	5,45		0,49		
0,39	2,27	0,43	1,05	25,45	0,24	0,63	0,91	0,31
0,34	2,79	0,18	1,04	10,59		0,55		
0,25	4,43	0,01	0,69	10,45		0,502		
0,63	3,21	0,76	1,07	17,68		0,5		
4,19	3,33	0	0,47	15,11		0,38		
0,11	2,37	0,0111	0,28	2,125		0,5201		
0,1	2,47	0	0,21	1,445		0,4159		
0,17	4,22	0	0,69	6,12		0,4177		
0,18	2,4	0	0,32	2,92		0,45		
0,11	1,56	0,0093	0,31	1,73		0,3176		
0,16	4,39	0,0034	0,54	5,615		0,5621		

0,19	3,11	0,0712	0,67	5,695	0,4681
0,24	2,11	0,311	0,76	8,775	0,5615
7,96	2,48	0,0136	3,5	24,74	0,4263
0,18	3,89	0	0,42	1,485	0,4502
0,14	2,82	0,007	0,43	6,51	0,3789
0,26	1,93	0,3432	1,44	7,395	0,4
0,32	11,66	0,0191	0,74	32,365	0,3795
0,045	0,96	0,022	1,07	3,83	0,337
0,187	1,61	0,021	1,071	2,13	0,455
0,641	25,772	0,007	1,587	17,39	0,581
0,47	6,99	0,08	6,27	16,37	0,36
0,214	1,264	0,174	1,384	2,47	0,434
0,354	1,32	0,084	3,985	2,09	0,575
0,07	2,74	0,06	9,01	26	0,51
0,84	3,01	0,042	2,36	16,4	0,56
0,838	1,863	0,096	2,186	2,71	0,645
0,742	1,758	0,065	6,79	29,99	0,592
1,394	4,733	0,071	11,863	34,62	0,461
1,147	3,1	0,123	4,76	33	0,404
0,587	1,925	0,207	2,036	21	0,434
0,671	1,935	0,026	9,104	18	0,488
0,632	5,72	0,272	0,93	20	0,535
0,01	1,659	0,11	1,024	4	0,496
0,118	2,32	0,629	0,01	11	0,526
0,148	2,167	0,05	1,008	3	0,552
0,001	2,5	0,001	1,566	10	0,962
0,068	2,359	0,002	0,792	4	0,705
261,378	3,198	0,015	5,425	3	4,138
1,166	2,843	0,01	6,376	36	1,345
0,887	3,358	0,051	48,79	31,08	1,645
0,01	5,238	0,01	4,004	26	0,282
0,1	2,28	0,291	62,19	11	0,668
1,721	12,95	0,691	8,351	27	1,243
0,554	11,69	0,038	6,068	33	0,823
0,561	27,1	0,017	12,21	22	1,21
0,01	16,878	0,108	0,97	10	0,785
0,01	11,249	0,01	217,843	28	1,042
0,01	12,78	0,01	0,01	9	0,79
0,01	5,07	0,01	0,01	10	0,81
3,15	16,71	0,667	6,537	18	1,299
0,01	23,16	0,13	0,01	4	0,9
0,01	17,24	0,16	0,01	5	1,016
0,01	20	0,071	1,147	10	1,023
0,01	15,122	0,068	0,01	7	0,688
0,01	16,79	0,07	2,19	19	0,18
0,01	24,378	0,065	0,01	15	0,882
0,511	20,236	0,094	3,355	30	0,663
				32	
0,512	1,775	0,096	1,378	29	0,247
0,977	12,773	0,015	3,479	26	0,364

1,424	13,129	0,067	4,733	44		0,758		
				36				
0,323	11,596	0,111	2,888			0,298		
0,096	11,295	0,056	1,24	26		0,316		
0,23	4,26	0,001	0,61	6,92	0,14	3,0558		0,63
0,25	3,81	0,0164	0,63	18,39	0,16	2,3544		0,19
0,25	2,9		0,5	4,56	0,14	1,8987		1,84
0,26	4,42	0,0172	0,6	24,79	0,32	2,5112	0	0,2
0,62	3,2	0,0039	1,76	8,18	0,19	4,2651	0,32	0,26
1,13	5,42	0,01	2,79	14,9	0,2	6,26	0,42	0,1
1,13	5,42	0,01	2,79	14,9	0,2	6,26	0,42	0,1
1,48	3,64	0,01	3,28	15	0,33	7,76	0,49	0,24
1,26	3,63	0,0616	3,1	23,81	0,32	3,1195	0,44	0,38
1,11	4,51	0,0039	3,13	16,11	0,2	5,9668	0,73	0,14
1,11	3	0,0218	2,95	16,77	0,14	6,3854	0,68	
0,94	5,46	0,0002	1,91	14,27	0,18	4,686	0,56	0,42
1,14	2,86	0,0164	3,04	12,87	0,08	3,8638	1,04	0,45
1,16	3,45	0,0152	3,04	10,88	0,21	3,7406	0,9	0,23
1,14	5,35	0,0041	2,89	20,46	0,72	3,4256	0,98	0,87
1,36	3,42	0,0002	3,75	9,4	0,27	3,542	0,6	0,34
1,17	3,71	0,009	3,64	9,77	0,4	3,6071	0,79	1,26
1,25	5,12	0,0221	3,57	7,79	0,27	3,471	0,59	0,12
1,21	3,17	0	2,98	23,44	0,41	3,2852	0,58	0
1,25	3,7	0,0143	3,32	15,6	0,28	3,6711	0,68	0,14
1,23	2,03	0	2,75	10,6	0,32	3,5304	-0,18	1,08
1,25	1,91	0,2672	3,18	15,75	0,22	3,5259	1,19	0,22
1,33	3,27	0,0058	4,06	21,95	0,3	3,604	0,26	0,22
1,4	5,4	0	3,12	22,9	0,3	3,8246	0,51	0,21
1,02	1,78	0,0362	2,9	14,64	0,26	2,9335	0,45	0,37
1,04	2,87	0,0004	2,49	12,54	0,29	2,964	0,3	0,26
0,99	3,46	0,0019	2,37	6,265	0,29	3,0695	0,58	0,38
0,88	2,07	0,0015	2,76	15	0,3	2,2982	0,63	0,22
0,99	1,88	0,0023	2,19	16,455	1,06	2,9397	0,55	0,01
1,18	3,47	0,0268	2,7	13,385		3,3273		
1,2	3,77	0,009	3,28	9,64		3,1463		
0,99	3,15	0,0203	2,25	13,945		2,8277		
0,81	3,23	0	1,53	18,88		2,2922		
0,62	2,94	0,0092	1,54	8,085		1,8059		
0,42	4,77	0,0321	1,14	11,065		1,2613		
0,19	2,69	0	0,56	1,88		0,7098		
0,24	2,71	0	0,68	4,83		0,52		
0,3	3,7	0	0,97	11,5		0,57		
0,44	2,55	0,005	0,94	7,21	0,18	0,88	0,28	0,32
0,71	3,19	0,015	1,91	7,99		2,406		
0,77	5,02	0,08	2,97	15,45		2,35		
0,57	4,27	0,13	1,96	32,36		1,83		
0,26	3,57	0,01	0,81	18,11		1,15		
0,31	2,48	0,0287	0,78	14,13		1,1338		

0,27	2,72	0	0,61	7,98	0,6296
0,48	3,69	0	1,42	5,65	0,7799
0,33	2,57	0	0,76	3,97	0,55
0,46	1,71	0,0032	1,16	1,13	0,5097
0,87	6,66	0	2,5	3,03	3,1073
0,58	3,01	0	1,79	22,64	2,28
0,97	3,17	0	2,91	13,555	2,7633
1	5,62	0,0146	2,88	4,765	2,9911
0,96	4,58	0	2,55	8,17	3,0125
0,81	3,99	0	2,4	5,17	2,4054
0,85	2,17	0,0157	3,33	8,67	2,1264
0,93	18,32	0,0659	2,28	31,165	2,4216
0,27	1,144	0,036	2,812	9,87	1,065
0,913	2,266	0,036	3,189	4,32	2,346
1,2	21,981	0,005	2,779	15,97	3,493
0,59	7,8	0,22	4,07	15,9	1,04
0,399	1,619	1,155	1,839	12,68	1,369
1,039	1,861	0,125	5,864	3,94	2,217
3,6	4,56	0,03	6,45	32,6	3,4
1,23	1,961	0,01	2,592	23	3,667
1,74	2,647	0,106	4,886	11,4	3,322
1,279	2,202	0,05	6,084	25,99	3,242
2,316	6,301	0,006	9,437	34,665	2,601
2,585	8,868	0,386	13,268	43	2,535
1,446	2,75	0,01	4,508	21	2,966
1,358	2,333	0,012	8,506	20,13	3,048
1,559	5,385	0,247	3,861	28,85	1,989
0,95	2,776	0,142	4,894	6	2,356
0,01	2,244	0,027	5,857	7	1,926
0,326	2,468	0,088	1,82	2	1,817
0,399	2,634	0,01	2,622	8	2,151
0,001	2,769	0,001	2,436	14	3,139
2,561	3,08	0,01	4,55	24	4,717
0,01	3,556	0,013	4,153	8	0,573
1,613	2,893	0,059	8,011	24	4,243
1,648	7,52	0,06	7,854	28,05	8,329
1,381	8,688	0,01	7,237	21	6,889
1,925	14,93	0,009	9,32	27	7,625
5,46	15,41	0,208	20,01	30	3,999
2,914	12,65	0,038	12,07	33	7,838
2,115	30,96	0,01	11,74	27,76	7,342
0,01	17,572	2,602	16,263	25	5,421
0,01	7	0,301	0,624	75	4,224
0,01	16,67	0,01	4,02	16	5,38
0,01	7,66	0,35	9,16	17	5,66
0,01	9,227	0,01	0,679	42	5,389
0,01	25,786	0,01	0,157	7	5,14
0,01	24,7	0,054	0,01	13	5,528
0,01	21	0,035	1,685	17	4,279
0,01	16,907	0,063	1,002	18	2,689

0,01	15,96	0,19	4,91	18		2,82		
0,01	31,09	0,061	3,467	27		3,847		
2,766	21,8	0,143	10,661	25		3,654		
				31				
1,818	3,102	0,198	5,713	27		2,396		
3,121	15,592	0,011	10,336	14		4,635		
2,381	13,629	0,041	7,378	44		2,698		
0,549								
1,036			4,777					
0,999	8,084	0,047	3,22	27		1,555		
0,98	5,02	0,0028	3,19	13,82	0,17	1,3175		0,62
1,14	4,22	0	3,49	22,1	0,17	1,2154		0,19
0,36	3,44		1,11	3,01	0,19	0,5762		1,84
0,19	3,77	0,0101	0,49	11,1	0,29	0,1959	1,55	0,22
3,16	5,25	0	10,5	30,75	0,17	2,9788	0,68	0,26
1,16	6,3	0,02	3,52	4,37	0,2	1,07	1,33	0,1
1,16	6,3	0,02	3,52	4,37	0,2	1,07	1,33	0,1
3,93	5,69	0,01	13,23	8,24	0,26	3,35	0,18	0,25
2,82	9,27	0,3329	9,54	17,31	0,31	3,4131	0,2	0,4
3,77	8,39	0,0034	13,33	7,6	0,23	3,1508	0,13	0,15
2,95	4,92	0,0115	10,46	15,48	0,15	2,5344	0,67	
1,98	6,81	0,0689	6,2	7,42	0,19	1,5	0,74	0,42
2,48	4,57	0,0337	8,86	9,97	0,04	1,3246	1,26	0,45
0,98	6,36	0,0077	3,47	1,9	0,2	0,7157	2,06	0,23
1,02	4,74	0,0025	3,35	1,82	0,18	0,8869	2	0,41
3,74	4,78	0,0032	13,82	4,64	0,36	1,6	0,47	0,33
2,86	5,19	0,0183	10,61	6,37	0,41	1,2678	0,82	10,15
3,32	6,98	0,0174	11,08	7,34	0,34	1,4277	0,49	0,11
2,26	4,69	0	7,14	15,62	0,53	0,9769	0,86	0,01
3,69	6	0,0198	13,17	11,13	0,21	1,7187	0,36	0,15
3,48	4,45	0	11,54	2,65	0,27	1,6264	0,41	-0,73
2,95	3,94	0,3662	9,86	30,83	0,23	1,4134	0,8	0,22
2,85	5,4	0	10,15	18,82	0,3	1,36	0,5	0,24
1,73	7,82	0,0188	5,13	17,59	0,28	0,9416	1,06	0,21
4,96	4,77	0,0122	16,33	32,28	0,49	2,1995	0,45	0,37
3,02	11,2	0,0025	16,38	8,85	0,31	1,3218	12,1	0,27
2,28	7,04	0,0113	7,29	15,595	0,29	1,1985	1,6	0,39
3,09	3,93	0,0028	10,8	12,995	0,28	1,2111	1,72	0,22
2,56	3,65	0,0011	7,87	13,04	1,03	1,1398	0,95	0,05
4,82	6,94	0,2512	15,11	14,21		2,1623		
5,01	7,06	0,0175	15,85	11,47		2,0527		
4,55	6,41	0,0774	14,22	29,105		1,9712		
3,99	6,24	0,0182	16,59	8,505		1,6022		
2,94	5,21	0,0229	9,86	6,68		1,3098		
2,26	5,58	0,0165	7,63	6,35		1,0931		
0,55	4,02	0	1,75	2,87		0,3654		
0,39	4,25	0	1,3	5,42		0,24		
0,48	4,7	0,035	1,91	22,83		0,21		

0,01	2,54	0,02	1,32	7,28	0	0,14	1,22	0,32
1,01	4,05	0,01	3,43	15,94		0,66		
2,2	7,13	0	6,11	7,9		1,15		
3,82	8,1	0,02	13,55	5,4		2,14		
2,95	6,26	0,03	9,76	16		1,7		
2,75	13,02	0,0457	8,44	11,495		1,3578		
1,51	5,08	0	4,54	8,765		0,7718		
0,85	5,22	0	3	4,08		0,4422		
0,28	2,91	0,015	0,99	3,34		0,1		
0,31	1,93	0,0413	0,88	5,67		0,1104		
0,57	5,85	0,0073	2,1	5,545		0,4012		
0,83	5,24	0,4595	2,85	17,89		0,3815		
0,77	3,79	0,0406	2,71	6,375		0,4091		
1,84	7,37	0,0092	5,72	19,87		1,0993		
4	7,27	0	13,03	6,305		2,2571		
3,12	5,85	0,0081	10,58	5,795		1,4427		
3,68	5,08	0,0129	2,13	7,445		1,4907		
3,05	19,68	0,0126	9,47	31,045		1,5256		
0,375	3,262	0,106	2,129	13,09		0,24		
0,797	3,338	0,021	3,633	11,21		0,749		
4,129	28,573	0,016	12,889	13,67		2,252		
1,56	9,76	0,45	8,39	28,9		0,56		
0,344	2,639	0,034	4,06	6		0,115		
0,558	3,153	0,344	10,628	3,86		0,193		
2,965	3,783	0,028	10,912	29		1,571		
3,047	3,611	0,01	9,931	8,16		1,771		
4,048	4,728	0,065	13,539	34		1,544		
3,274	3,928	0,126	15,408	49,99		1,434		
2,391	6,642	0,017	9,863	34,45		0,722		
2,105	4,299	0,328	11,98	41		0,682		
1,008	3,15	0,005	4,383	11		0,484		
1,359	3,159	0,04	13,358	6		0,517		
2,57	7,112	0,092	6,059	28,46		0,801		
0,88	5,572	0,279	13,14	8		1,601		
0,01	3,957	0,027	11,633	5		1,631		
3,314	4,635	0,033	12,411	12		1,682		
3,508	4,965	0,01	12,519	9		1,683		
3,204	4,704	0,036	11,96	16		2,071		
0,001	2,577	0,001	0,753	4		0,142		
3,272	5,475	0,044	9,73	21		1,342		
4,09	4,55	0,025	17,216	23		2,083		
4,871	6,307	0,059	18,54	28,36		3,443		
3,47	7,48	0,01	15,28	19		1,534		
4,06	13,89	0,015	18,66	17		2,903		
6,056	17,41	0,208	22,01	33		3,999		
5,641	13,98	0,05	23,15	35		3,268		
4,578	34,47	0,01	18,82	34,84		4,079		
0,01	16,626	0,01	1,472	16		0,643		
0,01	4,29	0,01	0,01	14		1,149		
0,01	17,39	0,33	4,45	14		0,45		

0,01	8,76	1,07	11,04	16		1,49
0,01	9,685	0,01	9,106	27		2,569
0,01	12,903	0,01	7,135	20		1,933
0,01	26,7	0,01	9,696	14,9		2,632
0,01	28	0,01	13,314	18		2,534
2,691	18,771	0,184	12,963	33		1,687
0,999	26,649	0,141	11,865	16		1,517
1,49	17,1	0,02	5,07	29		0,7
4,059	13,74	0,02	14,47	28		1,512
2,508	3,205	0,06	9,183	33		0,839
1,881	14,564	0,007	6,952	23		0,676
1,693	13,728	0,054	6,898	40		0,995
1,848	14,008	0,049	7,095	18		0,728
	12,876		12,971			0,352
0,954	9,161	0,212	4,342	27		0,52

8,21	17,27	2,5691	28,03	102,6	7,97	5,2126	0,32	1,1
21,18	20,5	0,0353	53,73	215	5,98	8,4	0,6	0,34
18,71	21,22	0,1998	52,48	158	0,36	8,0076	0,6	0
21,02	25,38	0,1811	53,41	166	6,98	8,8687	0	0,11
18,82	21	0,1018	48,23	109	5,55	8,3291	0,29	0,16
19,94	24,66	0,0335	53,77	125	6,91	8,5704	0,14	0,2
20,93	17,98	0,031	47,51	201	4,43	8,7424	1	-0,91
21,54	13,61	3,9076	45,06	284	2,4	8,6748	2,36	0,24
18,72	20,42	0,0733	42,35	172	3,99	8,7296	0,71	0,24
18,43	21,34	0,3614	42,07	165	4,05	9,4724	1,37	0,26
20,79	19,35	0,0432	50,9	168,5	5,64	8,3592	0,69	0,37
20,88	21,9	0,0694	52,59	168	5,45	8,5176	2,46	0,28
21,07	24,11	0,0902	54,02	145	5,66	8,7884	2,8	0,4
17,71	20,26	0,034	45,48	137,5	5,28	6,867	6,34	0,23
24,98	27,99	0,0036	66,2	142	12,38	9,9598	0,69	0,13
24,13	30,95	0,006	67,45	118,5		11,0389		
21,27	30,87	0,0051	64,33	74,175		12,3205		
24,55	29,37	0,012	68,2	136,5		10,8234		
25,06	30,41	0,0025	72,69	123,5		10,6123		
22,42	27,07	0,0141	67,06	118,5		10,6747		
22,03	27,04	0,0095	68,22	118		11,4251		
11,33	11,86	0	31,33	60,74		6,8804		
11,34	15	0	33,05	51,42		5,7165		
16,27	16,55	0	44,22	91,2		7,03		
11,51	21,53	0	40,69	21,64	7,66	8,45	8,95	0,34
0,74	2,54	0,38	4,62	15,53		10,6		
2,11	3,14	0,25	7,18	6,17		1,32		
0,5	2,28	0,05	1,88	7,915		0,45		
0,44	6,43	0,07	1,28	6,145		0,42		
0,28	2,11	0,1009	0,83	7,57		0,3065		
0,23	2,35	0,0917	0,69	22,26		0,2153		
0,66	4,01	0,1101	2,09	18,19		0,4074		
10,8	19,79	0	39,18	18,25		9,24		

0,19	1,89	0,0685	0,59	2,025	0,1358
0,36	4,41	0,128	0,94	3,185	0,5784
0,12	1,82	0,35	0,36	16,87	0,55
0,48	2,08	0,1753	1,47	16,3	0,77
0,87	2,76	1,1063	2,85	16,02	0,9921
0,79	2,73	1,7131	2,63	15,025	1,098
1,26	2,53	1	4,36	18,915	1,0736
1,91	2,32	0,0849	1,74	4,465	1,1085
2,06	15,21	0,2808	6,82	30,81	1,3173
0,429	3,131	0,202	1,741	6,72	0,3
1,765	10,82	0,292	12,23	13,13	2,332
10,59	15,37	0,76	50,76	195,28	2,78
3,759	4,909	1,476	10,276	11,68	1,272
3,298	4,329	0,484	9,642	9,48	1,086
3,455	4,574	0,952	8,621	7,92	1,374
2,913	4,173	0,019	7,146	26	1,078
4,218	5,461	0,091	9,612	9,88	1,15
3,478	4,71	0,061	8,343	20,99	1,208
5,785	11,095	0,006	12,463	34,205	0,884
2,682	4,438	0,088	6,493	15	0,946
2,885	4,862	0,003	6,026	6	0,943
3,286	4,83	0,041	9,059	11	1,012
3,8	6,815	1,498	6,708	19	0,974
3,807	6,667	0,147	24,576	10	1,775
0,01	4,665	0,052	7,678	3	1,119
3,278	5,307	0,07	7,192	11	1,142
1,127	4,208	0,019	9,327	17	2,576
2,791	5,431	0,001	7,193	21,7	1,789
7,852	3,928	0,882	31,553	15	2,07
2,691	3,532	0,023	13,717	16	1,512
3,421	5,688	0,028	8,954	13	1,841
1,972	5,033	0,035	8,615	16	1,107
3,949	17,88	0,013	15,96	16	2,073
3,662	16,43	0,011	10,85	37	1,919
3,401	31,08	0,01	25,74	33,22	3,739
0,01	18,681	0,01	7,833	11	1,425
0,01	7,111	0,01	1,554	18	1,484
0,01	17,385	0,327	4,449	15	0,454
0,01	11,54	0,19	0,94	14	1,29
0,01	28,77	0,01	0,125	10	1,446
0,01	18,13	0,01	0,01	14	1,186
0,01	17,989	0,01	2,413	18	1,487
0,01	27,989	0,01	4,126	18	1,475
1,499	25,878	0,193	7,132	17	1,479
0,01	26,576	0,104	4,228	33	1,508
3,77	17,5	0,01	9,33	46	1,58
15,567	13,01	0,428	15,263	29	1,08
2,478					
3,758	30,389	0,118	17,626	41	1,666
1,578	13,518	0,047	5,865	38	0,903

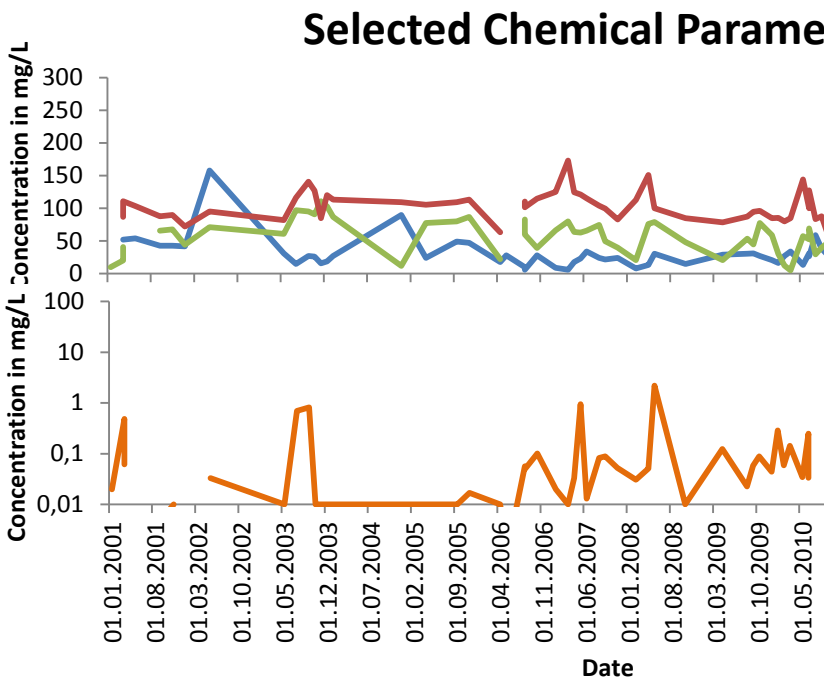
2,064								
2,016	9,421	0,426	5,165	35		0,79		
22,75	23,67	0,0193	59,35	189	0,2	17,0862		0,64
24,14	26,15	0	59,73	169	0,16	15,6743		0,44
23,23	23,41		61,63	169		16,7194		1,85
19,77	24,6	0,0288	50,13	162	0,29	17,6408	4,96	0,21
24,87	25,68	0,0112	63,4	177		18,0431	2,87	0,31
26,6	30	0,04	64,7	170		14	2,29	0,15
26,6	30	0,04	64,7	170		14	2,29	0,15
21,64	25,04	0,53	55,6	171		14,6	3,6	0,24
20,83	23,76	0,0125	55,09	174		12,849	4,2	0,32
20,8	27,12	0,0116	54,98	107,4		12,7157	5,09	0,21
20,99	23,99	0,0118	53,39	169	0,2	14,207	7,06	
18,78	28,56	0,0501	48,35	135	0,18	6,32	24,53	0,46
25,5	30,26	0,0402	56,67	64	4,23	10,206	39,08	0,48
21,69	25,36	0,0242	55,64	131	7,77	8,8931	0,78	0,98
21,63	25,72	0,0146	55,85	128	4,04	8,3675	18,51	1,09
20,58	25,38	0,0159	52,67	145	7,22	8,6439	-0,04	0,46
18,79	24,61	0,0319	53,54	110	0,37	8,2952	0,35	0
19,78	26,91	0,0334	50,89	110	8,22	8,9068	0,16	0,24
18,41	23,21	0,0252	47,68	0	0,25	8,5342	2,83	0,01
20,22	26,46	0,0222	54,48	101	7,1	9,1257	0,07	0,25
20,81	24,61	0	51,97	102	7,01	9,1413	1,01	-0,74
22,11	26,19	0,1822	55,59	119	7,7	9,4676	-0,07	0,32
20,84	26,24	0,0107	53,05	101	6,76	8,8054	0,11	0,33
21,38	28,72	0	54,59	115	6,82	9,2707	-0,09	0,4
19,34	23,5	0,0094	50,53	121,5	3,39	8,7677	5,1	0,39
19,5	26,58	0,0047	53,47	91,24	7,28	8,717	0,68	0,32
18,01	27,17	0,0094	50,2	84,12	7,31	8,6244	0,08	0,43
17,11	24,98	0,0109	47,82	69,405	6,95	8,251	5,1	0,27
15,68	28,2	0,0129	49,9	25,42	12,44	10,1666	0,21	0,14
14,92	31,68	0,002	52,61	11,04		11,5959		
15,47	32,71	0,0042	54,79	22,51		12,844		
14,88	31,52	0,0101	53,66	13,5		11,7359		
14,71	31,02	0,001	55,24	46,305		11,1562		
14,52	32,77	0,0094	54,94	10,495		11,8083		
15,22	32,37	0,0105	59,23	9,065		12,0014		
17,63	15,03	0	46,31	133		6,9247		
14,18	29,63	0	51,91	7,98		11,5255		
15,44	31,78	0	57,78	23,72		12,125		
15,3	31,81	0	58,09	11,25	12,95	12,745	0,3	0,36
16,01	31,52	0,01	60,96	5,99		13,85		
15,97	32,53	0,01	60,76	7,65		13,09		
15,07	29,55	0	58	14,835		13,68		
4	5,16	0,0377	14,55	20,22		2,679		
16,22	32,98	0	60,73	11,485		12,892		
15,94	33,7	0	66,18	7,715		12,9945		
15,41	31,26	0	55,76	16,97		12,255		

15,3	29,67	0,007	59,18	6,895	12,1057
16,83	39,5	0,0057	62,96	11,84	15,6361
15,91	31,69	0	60,98	21,54	13,7696
16,25	33,26	0,0179	63,39	10,765	14,4537
17,8	37,25	0,004	68,45	6,31	15,0591
17,74	36,08	0	68,44	21,04	14,513
19,41	34,58	0,0095	70,69	19,57	14,2375
17,7	31,58	0,0173	71,71	8,27	13,1749
16,27	56,69	0,0227	62,7	30,85	14,1996
16,347	32,59	0,043	67,082	6,9	13,853
17,984	30,148	3,516	61,631	72,37	37,23
14,054	46,329	0,14	53,468	38,6	14,14
10,944	21,903	0,136	39,105	27,08	11,429
10,86	22,251	0,05	41,137	47,81	10,862
10,558	23,483	0,035	36,492	21,83	11,523
8,559	23,854	0,01	34,182	14,83	7,87
10,902	29,112	0,076	38,74	15,71	8,499
11,221	30,302	0,013	39,945	6,69	8,799
9,245	27,038	0,012	37,408	2	7,207
9,447	25,921	0,01	32,328	53	7,938
7,794	24,877	0,01	26,7	6	7,348
9,697	26,097	0,007	36,98	20,715	8
12,36	28,863	0,031	37,368	30,89	7,933
10,871	29,474	0,14	39,291	12	8,41
8,584	23,352	0,05	29,599	27,7	8,032
9,524	25,76	0,074	33,033	2	8,708
11,37	31	0,001	43,06	8	14,93
9,41	26,18	0,01	36,6	11	13,91
0,01	1,535	1,137	4,409	39	0,406
11,549	26,012	0,032	41,984	20	9,717
11,57	30,1	0,034	42,51	144	16,46
11,21	31,73	0,01	42,21	21	13,91
12,72	31,29	0,02	49,25	43	17,84
3,286	13,71	0,01	13,01	26	2,698
10,44	58,65	0,01	45,96	48,58	19,23
1,343	34,953	0,337	36,225	18	8,999
0,01	21,387	0,01	26,335	27	9,239
0,108	15,275	0,01	14,874	21	2,033
9,93	26,14	13,14	36,58	19	9,1
2,773	46,336	0,01	28,537	17	9,553
5,198	26,7	0,242	30,119	19	9,003
3,254	48,726	0,01	30,151	10	10,411
1,665	44,386	0,01	30,165	12	8,779
5,328	46,264	0,01	31,867	28	8,44
5,745	40,226	0,451	29,706	35	8,605
8,77	30,5	0,01	26,6	50	10,9
10,057	13,731	0,1	19,504	30	1,287
4,303	21,521	0,049	14,922	26	3,024
4,564	20,185	0,043	22,039	37	3,774
4,675	20,604	0,073	26,574	4	3,352

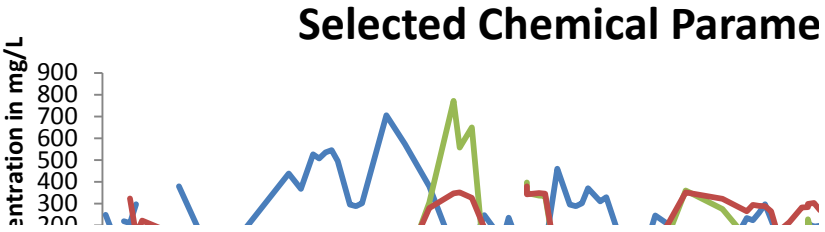
5,139			17,441			3,848		
4,774	18,748	0,024	14,525			3,221		
3,852	16,284	0,052	13,599	42		3,736		
2,894	8,513	0,033	10,046	12		3,562		
166,07	7,88	260,6263	268,48	5484	4,81	11,5136	0,09	0,4
188,12	11,03	245,712	320,44	4988	30,65	11,4166	0	1,26
181,34	10,45	235,962	327,09	4711	18,3	12,7181		0,45
137,76	15,5	175,297	206,08	2521	8,6	12,2466	0,39	0,24
125,44	8,03	90,969	196,11	3120	10,63	10,1858	0,22	0,37
129,72	12,38	187	212,63	3393	10,07	8,13	0,17	0,3
188,23	19,12	189,5954	254,03	4250	13,85	55,024	0,11	1
115,9	10,41	201,031	212,52	3890	16,37	7,9513		0,38
70,1	8,11	157,843	118,34	2816,5	13,18	5,733	0,13	
88,91	14,69	254,7528	169,24	3690	16,81	4,4992	0,29	0,66
122,82	15,46	178,646	189,22	3800	13,81	4,9549	0,14	0,49
138,83	16,45	210,993	230,64	3530	15,44	5,0965	0,28	1
142,24	23,44	112,491	327,84	3570	13,8	5,4666	0,31	0,15
131,34	12,63	183,902	214,47	2920	13,59	5,0994	-0,13	0,43
96,27	13,79	186,447	119,59	2690	21,54	5,5226	1	0,45
179,4	18,56	187,343	290,13	2610	13,07	5,4667	0,05	0,26
133,18	15,42	193,222	215,1	3490	17,17	3,7563	-0,66	0,53
111,29	14,02	215,238	186,18	3200	20,45	3,0886	0,26	0,44
153,13	11,75	192,3335	252,92	2640	16,54	4,6228	0,14	1,2
148,13	9,73	159,647	223,55	2670	21,2	4,4674	1,21	0,7
164,9	11,88	175,039	254,61	2800	20,61	4,4004	-0,19	0,42
118,48	14,23	217,059	203,37	3290	19,6	4,5976	0,03	0,34
95,66	11,44	195,9495	162,98	2700	16,79	4,7178	0,04	0,42
84,64	12,14	151,4125	144,08	2130	16,51	4,1173	0,9	0,35
77,82	12,35	177,4505	140,58	2890	14,65	4,2411	4,6	0,62
93,09	11,32	116,7715	147,88	1570	15,6	4,4193	0,08	0,7
133,27	9,7	162,709	201,03	2190	22,79	3,8339	0,69	0,74
195,17	15,71	135,2955	288,17	2765		5,0536		
116,21	13,91	151,6515	194,11	2045		5,5489		
116,21	13,91	151,6515	194,11	2045		5,5489		
79,69	9,57	101,033	127,44	2875		3,168		
131,93	11,97	144,703	229,93	2525		5,8643		
93,22	6,47	58,7802	106,63	1330		3,8764		
234,59	14,69	161,5605	296,36	3335		7,721		
218,15	12,97	254,3935	270,38	5005		5,8875		
344,85	14,26	106,913	354,71	2985		10,1152		
202,81	14,28	301,75	267,81	3840		5,02		
165,23	17,9	201,585	239,55	4080		3,14		
94,76	15,9	136,89	241,37	1670		3,075		
3,78	8,71	0,575	50,86	735	5,07	1,18	0	0,31
63,03	5,29	75,66	91,95	2330		3,23		
63,55	8,35	105,18	108,98	2965		1,9166		
77,48	8,46	117,27	130,15	2890		3,08		
37,88	12,6	47,15	75,58	896,82		2,31		

40,45	4,18	36,0602	51,37	770,695	2,6236
36,9	10,36	85,2777	105,01	1067	3,2193
58,25	18,87	49,5656	300,4	1354,8	3,3739
80,09	17,66	120,5769	237,34	2245	2,8798
71,84	13,54	68,0602	132,89	1352,35	4,0718
96,14	17,23	176,06	159	2865	3,97
119,6	15,03	81,2428	147,51	1440,9	5,7234
65,47	34,7	162,2635	143,01	7100	5,0742
62,7	48,54	415,41	179,26	7040	3,9
54,663	51,499	0,061	619,2	1560	4,4
39,566	56,531	0,365	651,177	1760	3,681
38,127	19,295	82,781	278,415	1557	3,662
46,797	5,896	132,024	95,818	1994	1,355
10,01	17,574	83,734	37,029	769	1,139
9,025	15,354	76,7	41,803	749	0,974
5,943	17,519	2,08	767,423	1704	4,319
230,52	44,51	177,26	337,87	5470	6,49
9,021	16,646	72,065	38,386	595	1,171
11,535	16,707	51,778	45,36	547	2,185
10,085	12,631	67,011	42,321	595	1,206
10,052	12,48	58,075	109,527	774	1,256
9,752	12,85	35,635	38,13	684	1,003
8,474	15,074	66,684	38,577	592	0,921
6,147	2,467	67,661	26,496	665	0,856

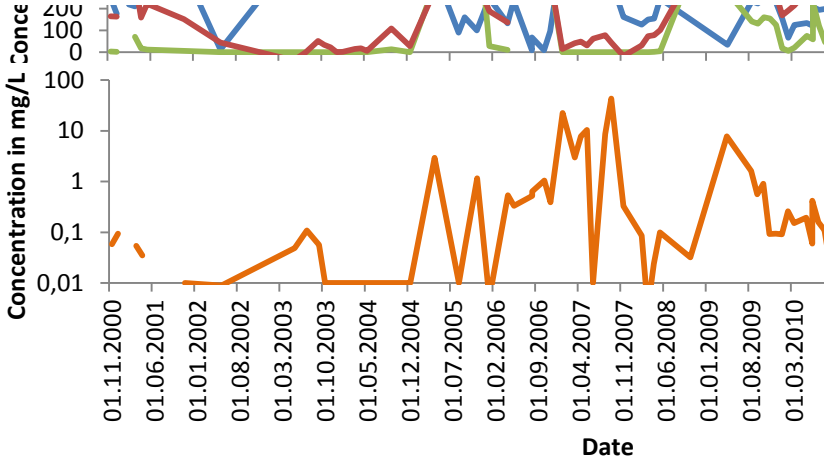
Temp	F
17	0,74
19,5	0,65
21,9	0,41
23,3	0,37
23,2	0,32
25	1,13
25	1,13
24,1	0,35
24,4	1,29
25,2	0,44
20,9	0,14
19,3	1,26
22,2	0,54
23,5	0,03
19,5	0,43
23,3	0,71
22,45	4,74
25,03	1,29
22,68	0,04
22,77	0,61
21,82	0,45
24,24	0,15
22,58	0,47
21,97	0,04
21,32	0,81
21,22	0,54
20,91	0,36
22,23	0,32
23,07	0,01
21,9	
21,3	
23,3	
23,5	
21,1	
18,2	
24,62	
23,36	
21,93	
21,8	0,36
22,49	
22,14	
24,7	
17,96	
18,9	
20,23	
21,14	
23,8	
23,61	
23,2	



25,9	
24,6	
24,54	
22,4	
24,19	
22,35	
24,38	
21,35	
20,9	
21,09	
20,11	
23,16	
22,93	
21,5	
21,22	
23,91	
23,14	
24,34	
22,86	
26,39	
21,99	
21,58	
22,39	
26,72	
24,39	
24,52	
21,9	
23,2	
27,3	
24,8	
19,6	
25	
14,9	
16,8	
16,9	0,07
19,5	0,07
21,9	0,01
23,6	0,09
23,1	0,03



25	0,94
25	0,94
24,1	0,01
24,3	0,25
25	0,32
21,2	0,44
18,7	0,34
22,3	0,26
24,6	0,27
19,5	0,29
24,1	0,88
22,45	4,29
25,36	1,66
22,86	0,79
22,43	0,69
21,86	1,63
24,43	0,39
22,33	1,06
21,87	0,04
20,81	0,26
21,14	2,18
21,01	20,19
36,8	1,64
22,58	1,3
21,7	
21,6	
23,36	
23,4	
21,2	
18,5	
24,49	
23,6	
22,05	
22,76	0,2
22,49	
22,25	
23,7	
21,8	
22,9	
17,41	
21,25	
23,7	
21,6	
23,3	
27,5	
24,5	
23,99	
22,3	
22	
24,14	



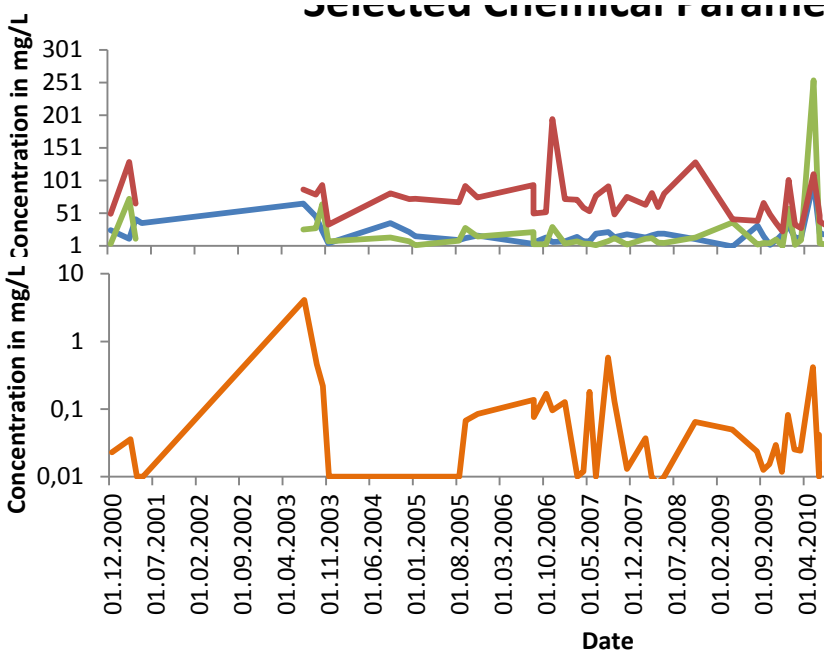
22,32
23,76
21,23
20,2
21,11
24,2
19,9
23,16
23,06
21,8
21,39
22
23,83
24,31
22,93
24,49
23,04
21,89
21,61

22,38
23,77
23,94
25,07
24,37
20,64
21,9
24,2
14,4
19
21,9
23,1
27,1
24,5
19,6
25
14,6
15,2

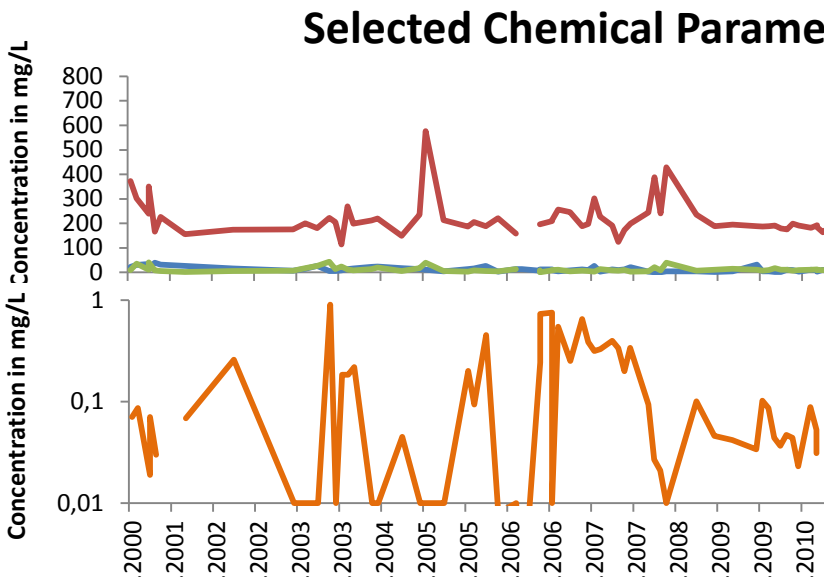
22,1 0,03

Selected Chemical Parame

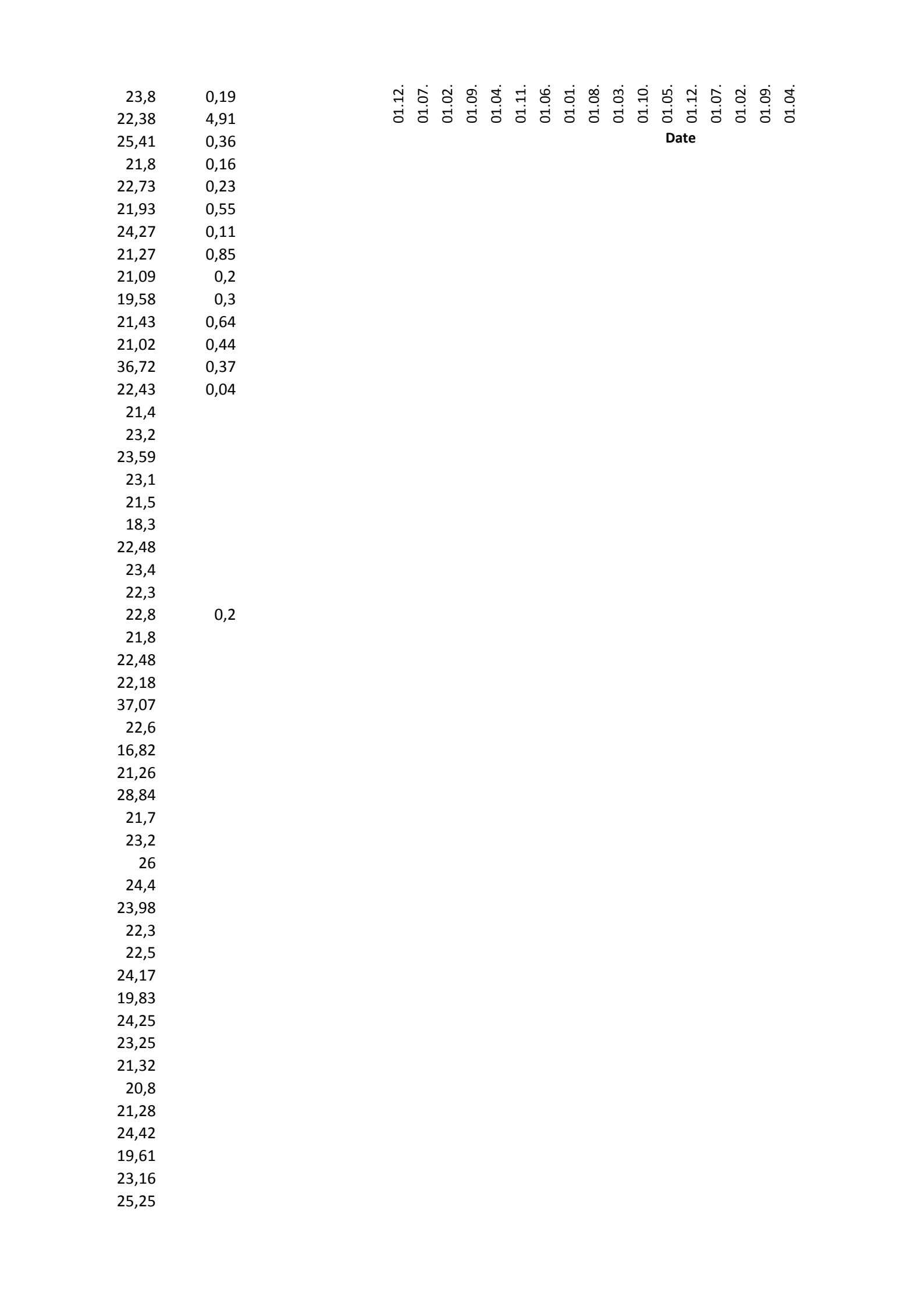
23,4	0,06
23,2	0,03
25	0,2
25	0,2
24	0,13
24,5	0,08
25,1	0,09
21,4	0,05
18,8	0,07
21,9	0,05
24,4	0,16
20,2	0,03
24	0,06
25,3	0,27
22,01	0,82
22,63	0,1
24,37	0,05
21,58	0,05
20,97	0,03
19,8	0,02
21,55	0,06
21,22	0,05
36,7	0,04
22,5	0,01
21,5	
23,5	
24,03	
23,6	
21,3	
17,9	
23,39	
23,4	
22,7	
22,8	0,2
21,9	
22,36	
23,7	
36,7	
22,7	
17,27	
21,37	
23,9	
21,1	
23,3	
25,9	
23,8	
24	
22,3	
22,4	
24,01	



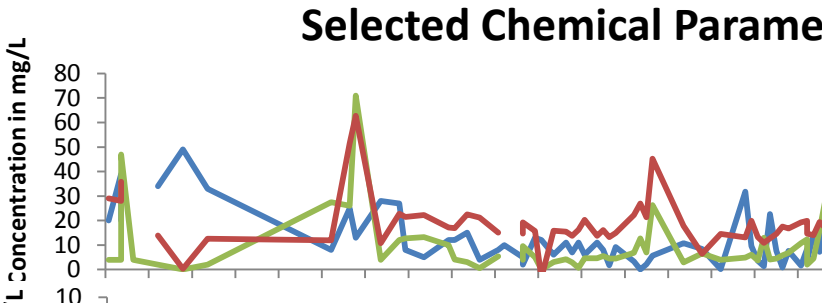
19,95	
23,67	
21,3	
20,3	
21,24	
24,34	
19,73	
23,13	
23,05	
24,17	
21,69	
23,78	
23,09	
24,46	
23,02	
24,56	
26,5	
21,71	
21,66	
23,9	
25,02	
24,56	
21,66	
21,9	
24,2	
24	
19,9	
24,8	
17,1	
16,9	0,05
20,3	0,09
21,6	0,04
23,5	0,05
23,9	0,02
25	0,25
25	0,25
24	0,01
22,9	0,31
25	0,1
21,2	0,14
18,7	0,3
21,7	0,14
23,8	0,22
20	0,14



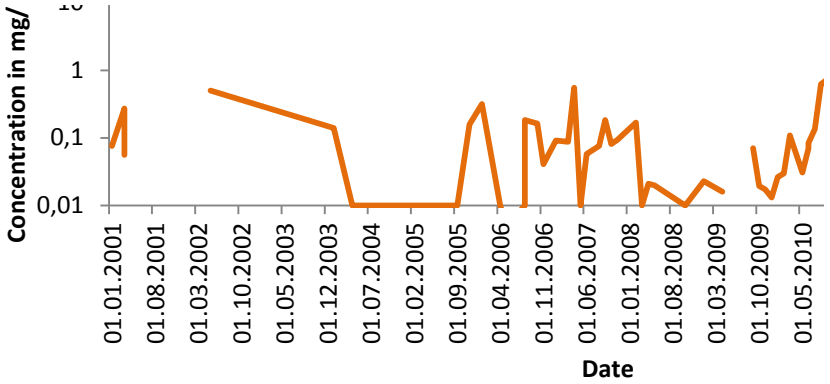
23,8	0,19
22,38	4,91
25,41	0,36
21,8	0,16
22,73	0,23
21,93	0,55
24,27	0,11
21,27	0,85
21,09	0,2
19,58	0,3
21,43	0,64
21,02	0,44
36,72	0,37
22,43	0,04
21,4	
23,2	
23,59	
23,1	
21,5	
18,3	
22,48	
23,4	
22,3	
22,8	0,2
21,8	
22,48	
22,18	
37,07	
22,6	
16,82	
21,26	
28,84	
21,7	
23,2	
26	
24,4	
23,98	
22,3	
22,5	
24,17	
19,83	
24,25	
23,25	
21,32	
20,8	
21,28	
24,42	
19,61	
23,16	
25,25	



23,04	
21,7	
21,97	
22,09	
23,09	
24,55	
23,33	
24,62	
20,23	
26,51	
21,93	
22,23	
22,14	
23,75	
23,86	
24,96	
24,57	
24,57	
21,65	
21,9	
24,5	
14	
19,1	
22,8	
27,3	
24	
20,1	
24,7	
14,6	
17,8	
25,6	
16,9	0,02
20,3	0,05
21,4	0,02
23,5	0,04
23,8	0,03
25	0,2
25	0,2
24,15	0

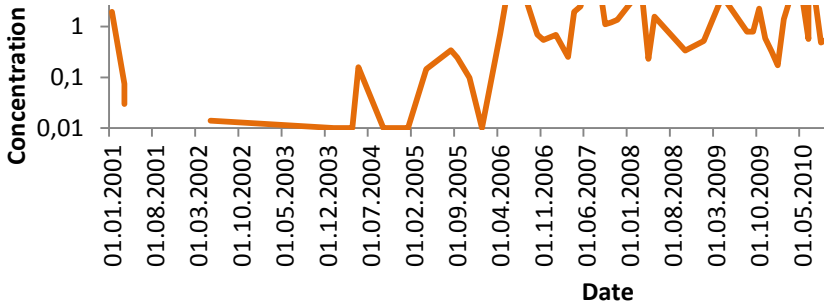


23	0,06
24,9	0,05
20,7	0,05
18,8	0,07
22	0,04
23,7	0,1
20	0,03
23,8	0,03
22,3	5,61
25,3	0,13
22,04	0,06
22,67	0,07
21,83	0,05
24,3	0,03
20,67	0,04
20,59	0,03
19,41	0,01
21,59	0,08
21,16	0,04
36,69	0,03
22,33	0,02
22,53	
22,9	
23,48	
23,1	
21,3	
18,2	
22,92	
23,3	
22,2	
22,9	3,64
21,6	
22,36	
22,25	
37,09	
22,8	
16,52	
21,36	
28,91	
21,7	
23	
27,4	
24,4	
24,01	
18,5	
22,1	
24,29	
19,7	
24,55	
23,34	



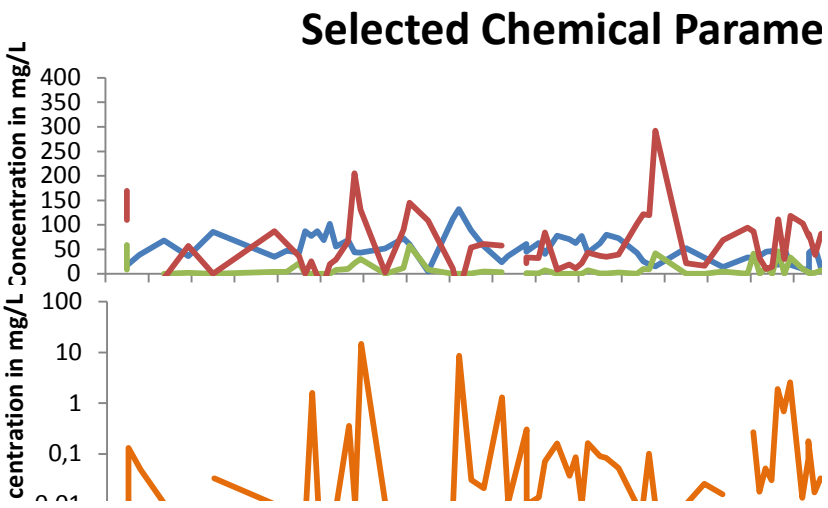
21,12	
20,9	
21,43	
24,41	
19,61	
23,11	
25,14	
24,08	
22	
23,11	
21,98	
23,03	
24,56	
23,4	
23,82	
26,53	
22,1	
22,16	
22,31	
23,66	
26,82	
24,86	
24,45	
24,59	
21,68	
21,9	
24,4	
14,2	
19,3	
23,3	

20,8	0,17
18,6	0,57
22,3	0,24
22,5	0,32
23,2	0,11
23,8	0,3
22,12	4,81
25,02	0,42
22	0,26
22,53	0,35
21,8	0,27
24,41	0,18
21,16	0,2
21,75	0,16
19,41	0,13
21,44	0,26
21,3	0,2
21,84	0,13
22,26	0
22,05	
22,6	
23,71	
23,2	
21,3	
14,1	
23,12	
24,05	
21,7	
22,73	0,57
21,7	
22,28	
23,5	
21,8	
22,7	
17,04	
19,31	
28,7	
21,2	
23,4	
26	
24,4	
23,16	
18,64	
22,6	
24,34	
19,55	
24,76	
23,36	
21,11	
21	

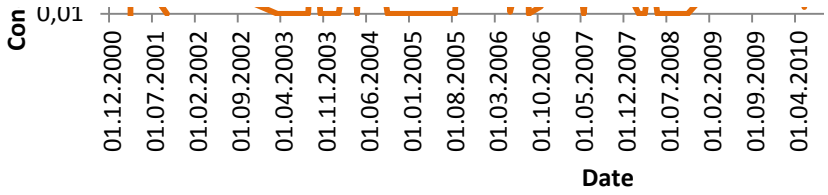


21,53
24,58
19,54
22,98
25,01
23,87
22,4
23,08
21,91
22,91
24,59
23,43
24,73
26,59
22,15
22,27
23,64
26,9
24,79
24,44
24,61
21,8
22
24,2
15
19,6
23,3

17	0,03
20,1	0,05
21,5	0,06
23,6	0,1
23,6	0,01
25	0,91
25	0,91
24,2	0
23	0,38
24,6	0,17
20,7	0,18
18,6	0,15
22,5	0,14

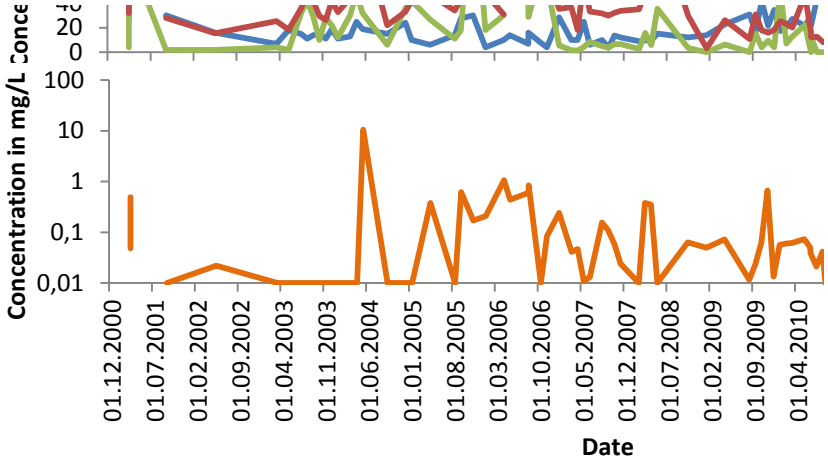


23,7	0,2
19,9	0,05
23,6	0,13
22,13	5,31
24,66	0,15
22,14	0,12
22,17	0,19
21,58	0,6
24,03	0,09
21,07	0,41
22,16	0,2
19,52	0,15
21,33	0,13
21,13	0,07
36,7	0,04
22,31	0
22,07	
22,8	
23,82	
23,3	
21,2	
14	
23,19	
24,08	
21,4	
22,86	0,2
21,6	
22,13	
24,35	
36,72	
22,6	
17,11	
19,46	
28,94	
21,3	
23,3	
26,7	
24,3	
23,24	
21,8	
22,1	
24,7	
19,48	
24,48	
23,5	
21,07	
21,4	
24,89	
24,77	
21,52	



23,18	
23,61	
23,44	
23,13	
21,87	
22,94	
24,52	
23,41	
24,78	
26,63	
21,85	
22,03	
22,25	
23,61	
26,99	
22,87	
24,36	
24,7	
21,91	
22,1	
24,4	
15,4	
19,3	
22	
23,1	
26,5	
26,4	
20,4	
24,8	
18,2	
14,9	
14,9	
25,6	

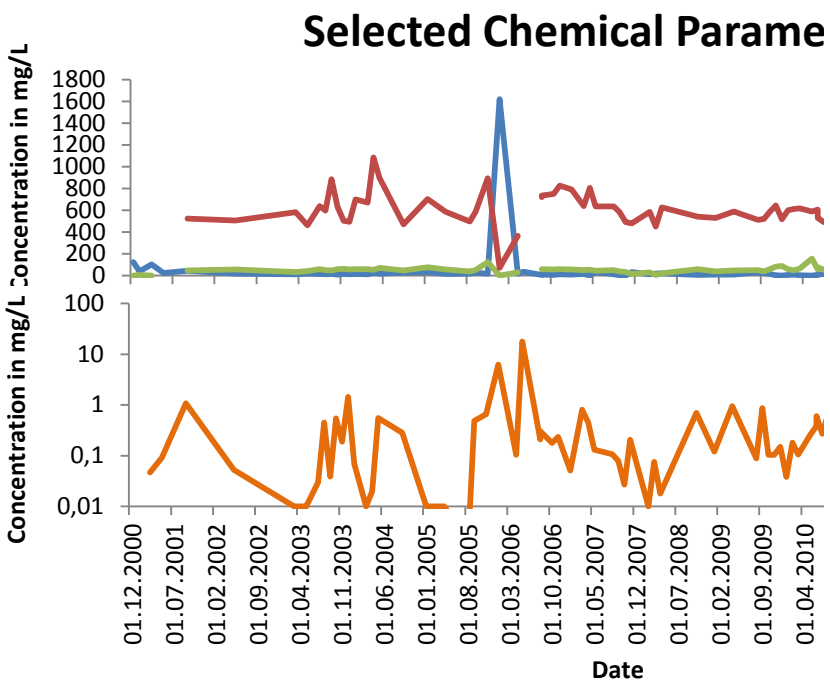
25	0,31
24,2	0
22,8	0,13
24,5	0,18
22,2	0,19
18,4	0,14
20,9	0,3
23,1	0,3
22,6	0,17
23,6	0,29
22,03	5,22
23,29	0,18
22,3	0,11
22,68	0,16
22,19	0,26
24,39	0,06
21,03	0,16
22,31	0,12
19,57	0,15
21,36	0,29
21,04	0,22
37,08	0,24
22,31	0,01
22,1	
22,7	
23,66	
23	
20	
14	
24,64	
24,07	
21,4	
22,4	0,21
22,68	
24,25	
36,75	
22,2	
17,22	
19,75	
23,4	
24,2	
23,1	
26	
24,1	
23,25	
18,3	
23	
25,24	
19,4	
24,4	



23,5
22
21,4
21,65
23,61
21,36
23,34
24,96
23,3
23,4
23,18
16,83
22,93
24,53
23,48
24,87
26,69
21,77
22,14

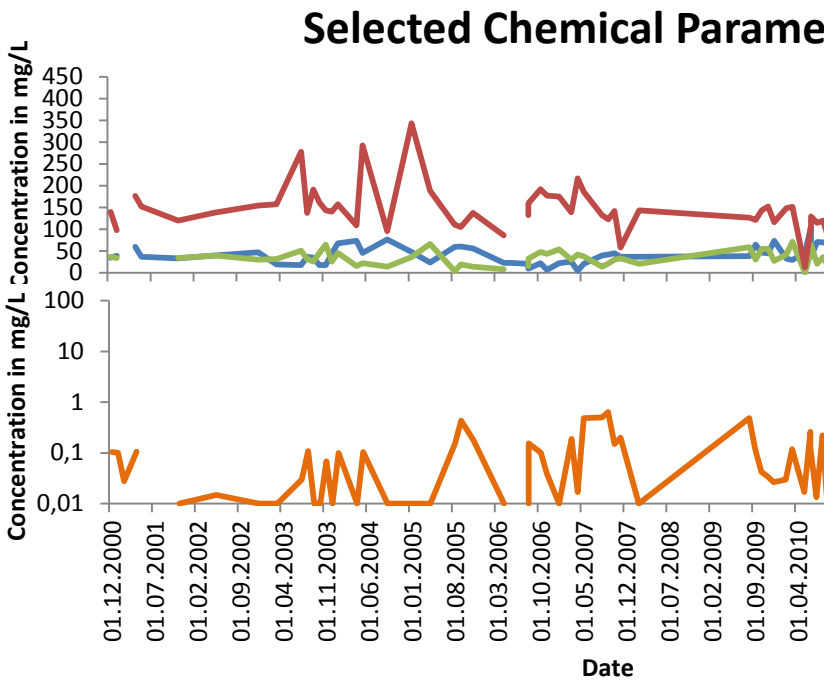
22,01
23,49
26,94
24,86
24,4
24,7
22,01
22
23,8
14,4
19,2
22,2
22,9
26,5
23,5
20,2
25
17,9
15,4
14,9
25,7

17	0,05
20	0,14
21,4	0,03
24,3	0,05
23,5	0,05
25	0,22
25	0,22
24,2	0,02
22,9	0,16
24,4	0,05
21	0,23
22,2	0,31
20,8	0,13
22,9	0,15
22,4	0,06
23,7	0,11
21,93	5,31
23,09	0,13
22,39	0,13
22,84	0,15
22,17	0,11
24,39	0,08
20,98	0,09
22,48	0,08
19,48	0,06
21,27	0,13
23,64	0,09
22,5	0,07
22,35	0,05
22,11	
22,5	
22,97	
23,6	
19,6	
13,8	
24,4	
23,9	
21,7	
22,5	0,21
22,4	
22	
22,65	
21,89	
18,4	
17,24	
19,92	
24,2	
23,8	
23	
26,1	

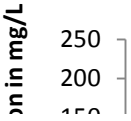


23,8
23,25
21,8
22,4
25,27
19,31
23,05
23,5
21,96
21,75
23,72
21,03
23,46
24,92
22,35
23,3
21,57
22,94
24,43
23,73
24,86
26,65
23,26
22,65
20,24
21,64
22,75
27,05
24,92
24,36
24,73
22,07
23,8
14,4
19,1
21,9
23
27
23,8
20,1
24,6
17,9
16,2
14,7
25,7

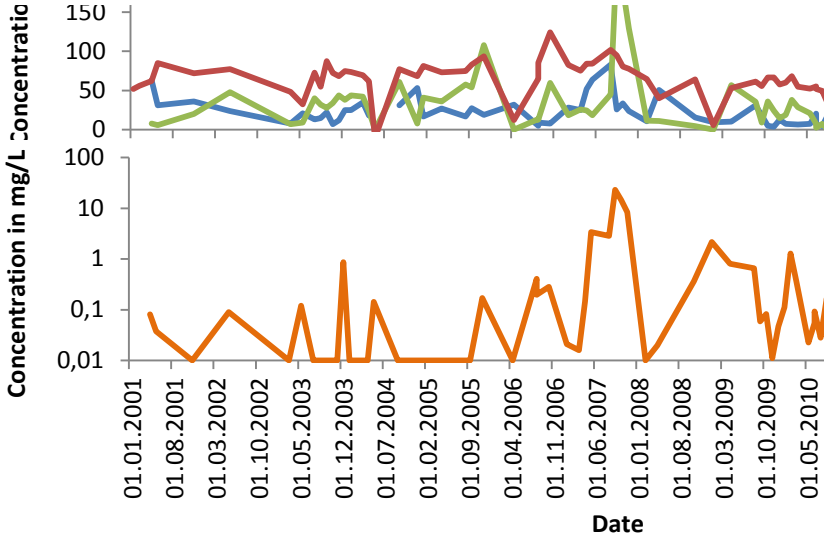
17	0,15
20,1	0,23
21,5	0,16
23,5	0,22
25	0,5
25	0,5
24,4	0,02
22,8	0,63
22,9	0,11
21,3	0,36
21,8	0,6
22,5	0,36
23,2	0,69
19,8	0,1
25,7	0,27
23,76	4,61
22,7	0,53
22,84	0,66
23,04	0,65
25,2	0,37
20,81	0,3
22,76	0,15
21,93	0,24
22,54	0,18
22,22	0,15
23,19	0,01
21,5	
22,2	
23,06	
22,8	
19,9	
19	
23,3	
23,63	
21,68	
22,8	0,33
22,09	
21,9	
24,2	
21,41	
21,7	
20,15	
20,2	
26,39	
23,8	
24,6	
26	



23,25	
22	
23,5	
25,01	
19,2	
21,2	
21,9	
24,53	
22,55	
23,3	
23,79	
22,99	
24,36	
23,62	
24,76	
26,65	
23,67	
22,46	
22,13	
24,06	
25,05	
24,19	
20,64	
22,49	
23,8	
14,4	
19,1	
23,1	
27,3	
23,8	
19,8	
25	
18,2	
14,3	
25,8	
19,9	
17,1	0,08
20,3	1,4
21,5	0,04
24,4	0,07



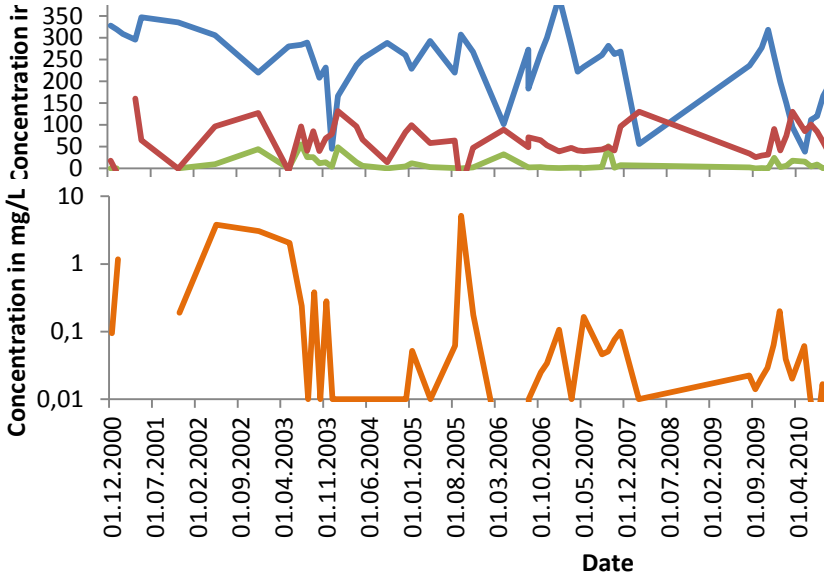
23,5	0,07
25	0,28
25	0,28
24,2	0,05
22,7	0,27
24,4	0,08
21,3	0,16
22,2	0,38
20,9	0,2
23,2	0,25
22,1	0,05
25,2	0,18
23,63	4,97
23,1	0,18
22,91	0,19
22,87	0,29
22,35	0,21
25,2	0,15
20,74	0,14
22,71	0,1
21,3	0,16
21,84	0,14
22,15	0,1
22,38	0,09
22,91	0,04
22,03	
21,9	
22,93	
22,8	
20,3	
13,2	
24,67	
23,93	
21,5	
22,9	0,2
22,27	
21,79	
24	
36,85	
21,6	
17,16	
20,44	
24,3	
24,3	
21,4	
24,4	
25,9	
24,3	
23,42	
22,3	



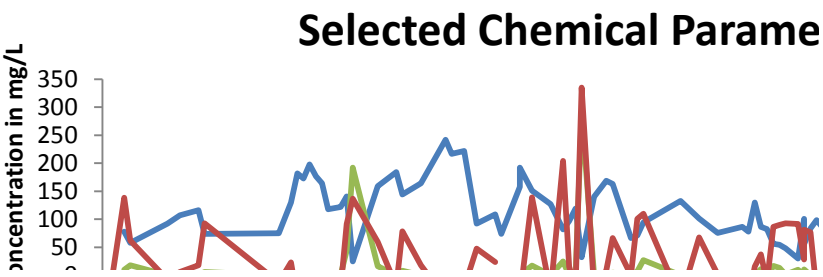
22,1		
24,93		
19,13		
24,02		
23,8		
21,98		
22,18		
21,16		
23,69		
24,52		
21,64		
23,4		
24,45		
23		
24,34		
23,35		
26,65		
23,87		
22,93		
22,82		
27,03		
25,18		
23,91		
23,69		
22,16		
21,8		
23,9		
14,2		
19		
21,9		
23,2		
27		
24		
19,6		
25		
17,9		
14,1		
16,2		
26		
17,2	0,07	
20,4	0,05	
21,9	0,02	

Selected Chemical Parame

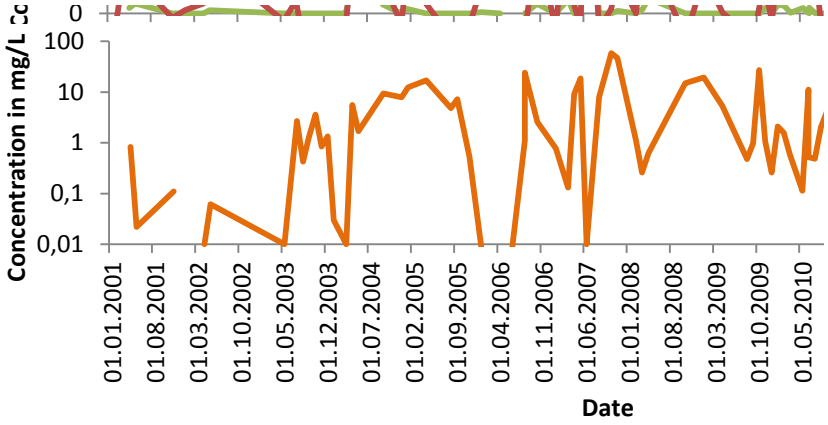
25	0,17
23,2	0,22
25	0,93
25	0,93
24,1	0,23
22,7	0,62
22,7	0,01
21,8	0,8
22,1	1,62
21,4	0,71
23,3	0,65
19,7	0,29
25,1	0,67
23,66	4,45
22,91	0,56
24,53	0,74
22,68	0,37
22,08	0,71
25,03	0,12
20,19	0,56
22,57	0,38
20,94	0,03
21,89	0,66
21,92	0,47
36,95	0,44
22,86	0,02
21,5	
21,8	
22,97	
22,4	
20,3	
19	
23,36	
24,02	
21,52	
22,65	0,33
22,18	
21,79	
24,09	
36,86	
21,5	
20,04	
20,62	
21,43	
24,4	
25,9	
24	
23,49	
22,1	
22	



24,96	
23,14	
21,09	
21,9	
24,48	
22,13	
23,4	
23,84	
23,09	
24,29	
23,33	
24,63	
26,64	
23,95	
21,51	
22,6	
24,34	
25,29	
22,99	
20,69	
22,57	
21,8	
24,1	
14	
19,2	
24,6	
27,4	
23,6	
19,2	
24,7	
17,8	
16,8	
15,8	
19,5	
17,2	0,59
20,6	0,04
21,6	0,32
24,6	0,44
23,5	0,2
25	0,57
25	0,57



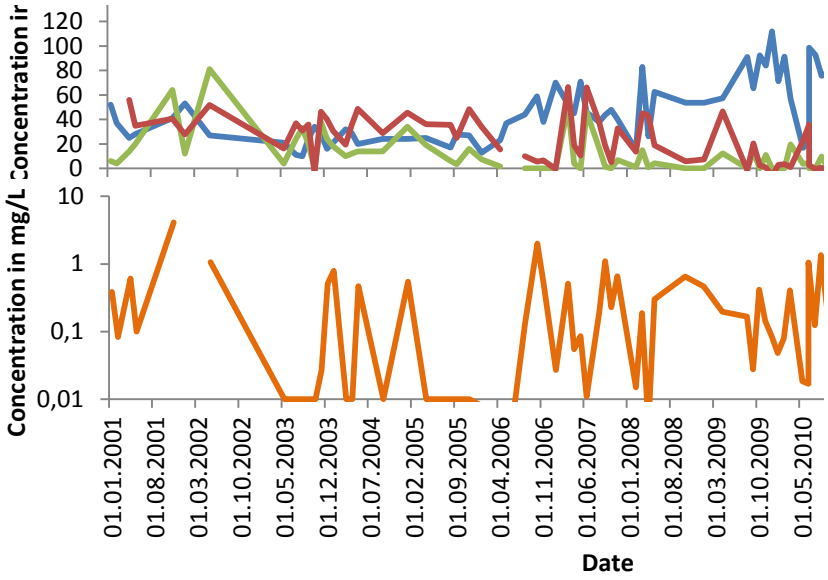
24,2	0
22,8	0,13
24,3	0,13
21,3	0,08
22,1	0,15
21,4	0,24
23,4	0,42
19,5	0,1
24,8	0,16
23,5	5,25
23,06	0,17
23,05	0,13
22,75	0,15
21,6	0,2
24,69	0,04
20,41	0,49
23,69	0,2
20,59	0
18,68	0,62
21,51	0,4
37	0,25
22,7	0,42
21,5	
21,9	
23,09	
22,6	
20,1	
18,7	
23,41	
24,17	
21,65	
22,6	0,2
22,35	
21,77	
24,3	
36,89	
22,86	
20,05	
20,86	
27,2	
21,4	
24,4	
25,9	
24,4	
24,13	
18,63	
22,4	
24,28	
22,9	
24,11	



20,62		
20,98		
21,37		
24,07		
20,93		
21,12		
23,43		
18,7		
23,2		
23,84		
23,23		
24,59		
23,28		
24,24		
22,54		
21,45		
22,73		
23,55		
27,05		
25,34		
22,37		
23,53		
22,11		
22,2		
23,9		
16,9		
19,3		
21,9		
23		
27,2		
27,5		
19,5		
24,7		
17,8		
13,7		
18,2		
17,2	0,04	
20,4	0,57	
21,8	0	

Selected Chemical Parame

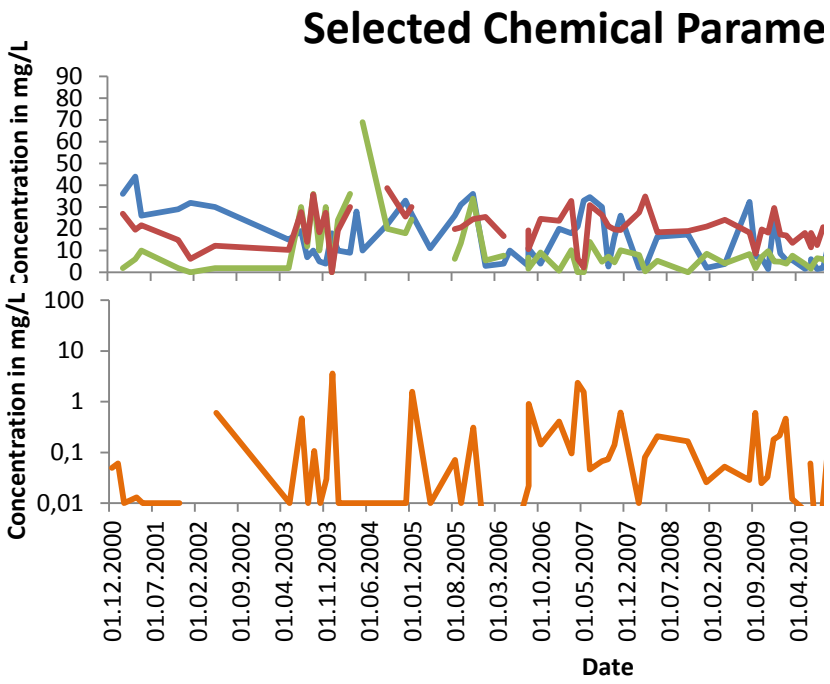
25,1	0,04
23,4	0,01
25	0,51
25	0,51
24,4	0
22,9	0,19
23,3	0
21,2	0,13
21,8	0,12
21,9	0,12
23	0,21
21,8	0,05
24,3	0,13
23,39	5,19
22,91	0,16
24,42	0,16
22,82	0,21
21,68	0,45
24,75	0,06
20,57	0,46
23,71	0,26
20,06	0,26
21,9	0,66
21,39	0,48
36,96	0,33
22,74	0
21,6	
22	
23,13	
22,7	
20,4	
18,9	
24,3	
22	
21,78	
22,9	0,52
22,71	
21,75	
24,1	
36,69	
22,61	
20,11	
21,03	
28,78	
21,7	
24,4	
25,9	
24,4	
24,14	
22,4	



22,8
25,01
22,91
24,29
20,82
21,74
21,6
24,91
24,1
20,98
21,9
23,05
22,22
19,4
23,19
21,09
23,66
24,19
23,16
24,71
23,97
22,25

22,77
23,61
26,43
25,33
23,76
20,73
22,08
23,9
17,1
19,5
21,8
23,2
27,7
24,6
19,5
24,7
17,9
14,1
14,2

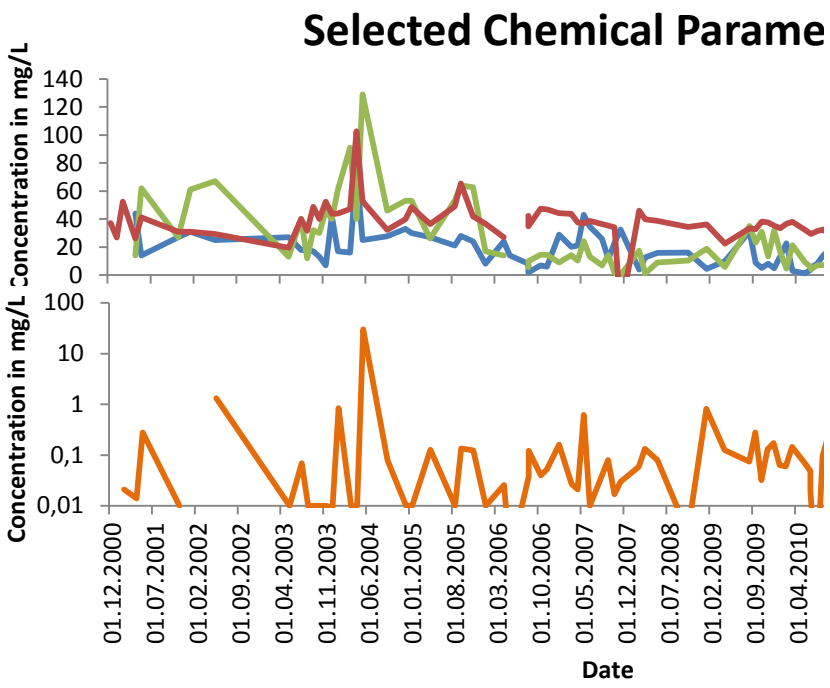
17,1	0,01
20,5	0,01
21,5	0,01
24,8	0,01
23,6	0
25	0,2
25	0,2
24,6	0
22,5	0,03
23,8	0,01
21,3	0,02
22,1	0,06
21,8	0,03
23,1	0,06
19,7	0,02
24,3	0,03
23,07	5,92
22,89	0,06
24,1	0,05
22,67	0,09
21,6	0,07
24,56	0,02
20,68	0,05
23,13	0,02
19,72	0,03
21,9	0,11
21,17	0,04
36,97	0,04
22,65	0,02
21,7	
22,5	
22,88	
23,5	
21,2	
18,7	
24,24	
24,19	
21,8	
22,57	0,2
22,68	
21,59	
22,73	
36,95	
23,09	
19,97	
20,87	
28,1	
21,9	
23,4	



25,9
24,4
23,54
18,58
23,1
24,82
22,88
21,66
20,81
22,21
21,6
22,96
20,98
21,8
22,75
22
20,2
23,18
21,1
23,71
25,24
23,05
23,84
21,82
21,72

22,85
23,68
23,44
23,23
23,93
20,74
22,03
21,8
24,2
17
19,7
21,8
23,1
27,3
24,9
19,8
24,6
17,8
14,8
15

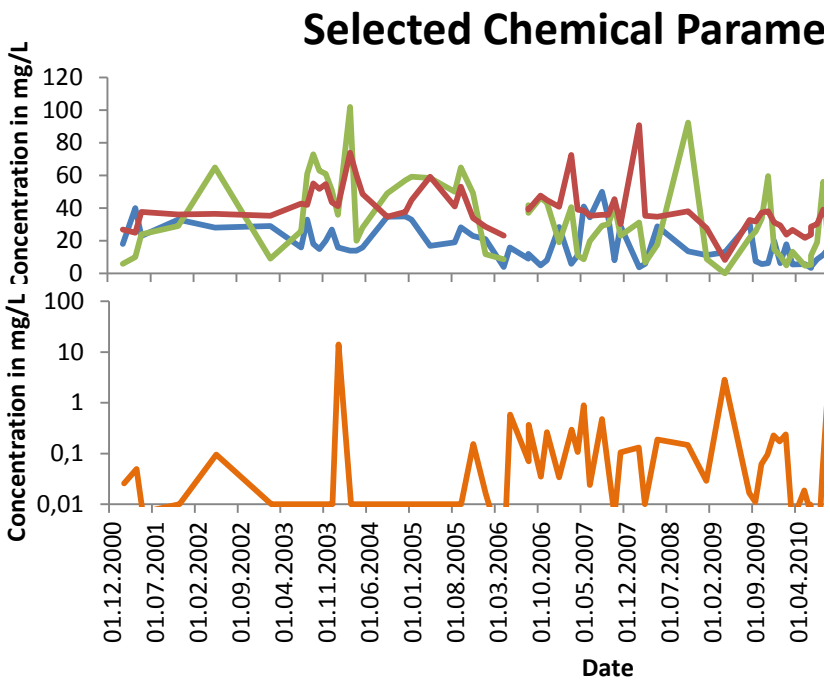
17,1	0,02
20,6	0,01
21,6	0,01
24,9	0,01
23,2	0,01
25	0,2
25	0,2
24,65	0
22,5	0,03
23,9	0,2
21,5	0,03
22,1	0,07
21,8	0,03
23,3	0,06
19,5	0,02
24,3	0,03
22,89	5,84
22,86	0,05
23,45	0,04
22,22	0,08
21,42	0,04
24,64	0,02
20,79	0,04
23,13	0,03
19,77	0,06
22,75	0,09
21,19	0,06
36,9	0,03
22,58	0,04
21,3	
22,4	
23,14	
23,5	
21,5	
18,4	
24,41	
23,5	
21,68	
22,8	0,2
21,8	
21,4	
22,66	
37	
23,39	



20
20,99
27,59
23,8
23,5
27,4
24,4
24,22
18,7
22,9
24,71
22,77
20,73
20,95
21,83
21,6
22,76
19,59
21,9
22,45
21,82
20,27
23,14
21,07
23,81
25,09
22,97
24,64
23,76
22,34
22,71

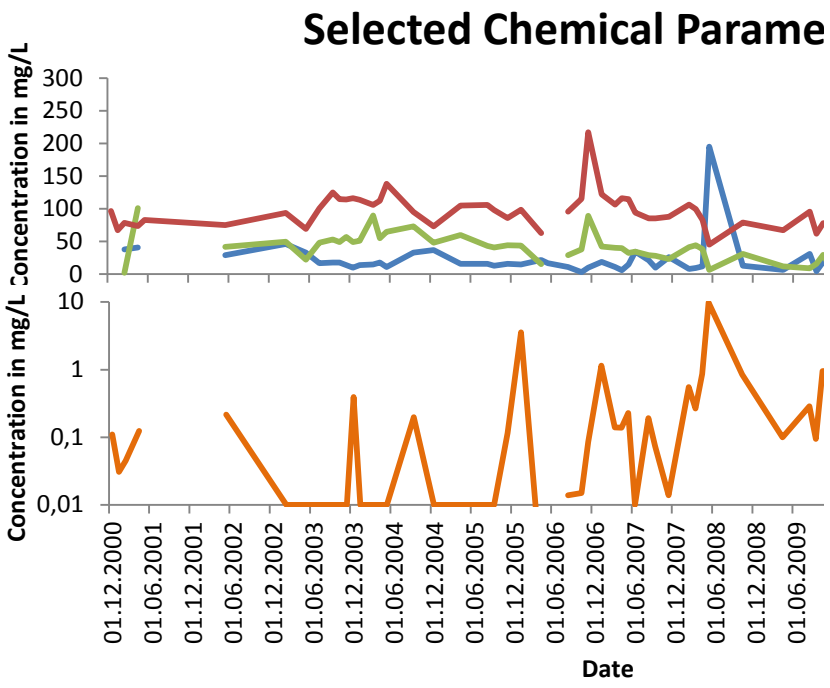
22,64
23,94
23,34
23,23
24,11
20,89
21,9
21,8
23,8
17,1
19,5
22,1
23,8
27
24,7
19,2
24,4
17,9

15,6	
16	
17,2	0,12
20,5	0,08
21,65	0,01
25	0,01
23,5	0,15
25	0,24
25	0,24
24,7	0,27
22,7	1,04
24,05	0,12
21,6	0,48
22,2	1,16
21,9	0,43
23,5	0,68
22	0,13
24,1	0,73
22,97	4,61
22,82	0,4
23,32	0,28
22,56	0,62
21,49	0,62
24,64	0,37
20,74	0,46
22,62	0,14
19,62	1,2
22,65	0,53
24,08	0,36
22,16	0,39
22,68	0,03
21,5	
22,3	
23,26	
23,5	
21,3	
17,5	
24,25	
23,5	
21,64	



22,73	0,2
21,8	
21,42	
23,7	
22,43	
23,3	
19,83	
21,14	
27,63	
22,4	
23,4	
26	
24,6	
24,49	
18,72	
22,5	
24,68	
22,51	
21,44	
21,07	
21,75	
21,7	
22,43	
19,57	
23,61	
24,54	
21,61	
20,57	
22,99	
21,07	
23,91	
24,97	
22,94	
24,45	
23,73	
22,33	
21,75	
22,59	
24,07	
23,25	
23,16	
23,86	
20,48	
21,92	
21,9	
24	
16,9	
19,4	
22,1	

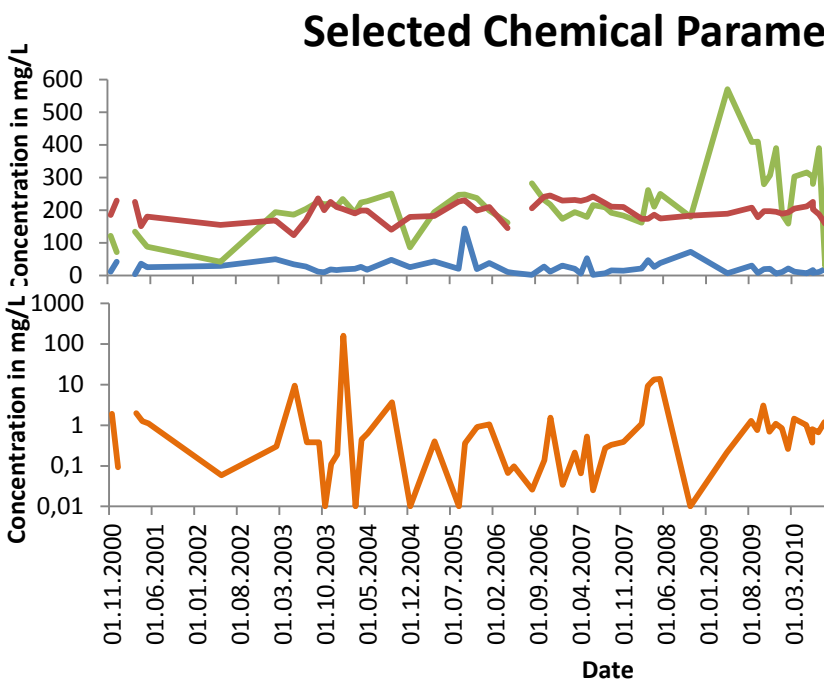
22,9	
27,2	
25,8	
20,2	
24,5	
18	
15,9	
25,3	
19,5	0,14
23,5	1,05
21,92	4,45
24,7	1,01
22,05	1,11
22,81	0,55
22,79	1,02
24,16	0,19
21,66	0,62
22,37	0,29
19,61	0,49
21,27	0,84
21,17	0,85
22,26	0,67
23,41	0,14
22,53	
22,2	
23,45	
23,5	
21,3	
17,9	
24,54	
23,6	
22	
23,39	0,2
21,8	
22,7	
23,7	
36,86	
22,97	
16,68	
20,48	
24,1	



22,8
23,4
27,1
24,5
24,34
22,3
23,2
24,45
22,45
22,87
21,56
21,8
21,57
22,61
22,56
24,11
21,36
20,89
23,11
24,52
24,18
24,86
22,92
24,59
23,64
22,18

22,58
24,06
23,27
24,74
23,78
20,54
21,9
24
16,7
19,6
22
23
27
25,1
19,8
25
15,3
15,2
25,7

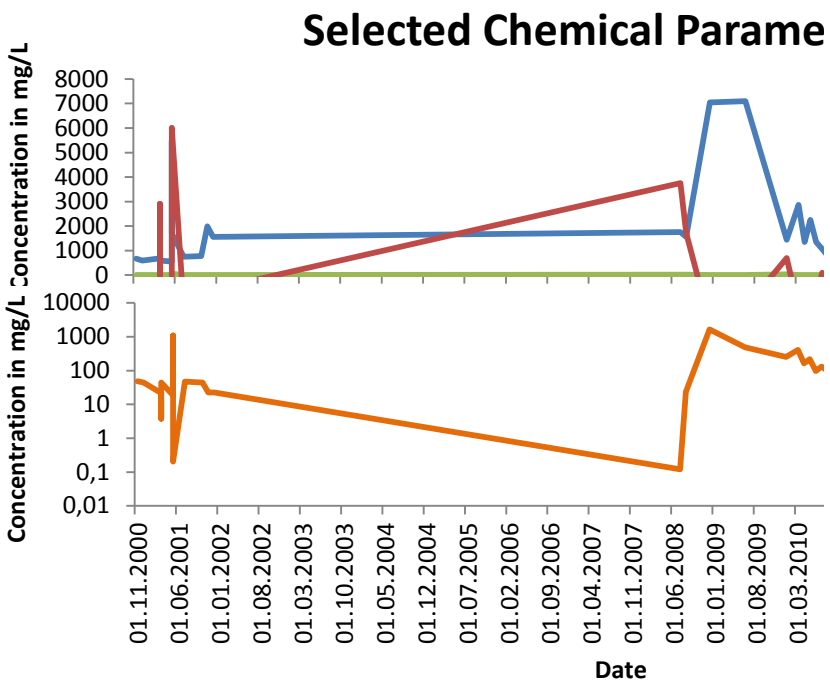
17	0,09
19,4	0,19
22	0,11
23,5	0,15
23	0,08
25	0,37
25	0,37
25,2	0,01
24,3	0,26
25	0,16
21,2	0,29
18,3	0,59
22	0,31
23,8	0,27
19,8	0,15
23,3	0,33
21,92	4,84
24,45	0,47
22,01	0,63
22,79	0,38
22,87	0,28
24,26	0,21
24,86	0,22
22,15	0,16
21,77	0,13
21,3	0,28
21,13	0,19
22,08	0,16
23,37	0,09
22,39	
22	
23,66	
23,3	
21,3	
17,6	
24,49	
23,7	
21,7	
22,7	0,2
22	
24,39	
22,03	
23,14	
17,06	
20,49	
24,2	



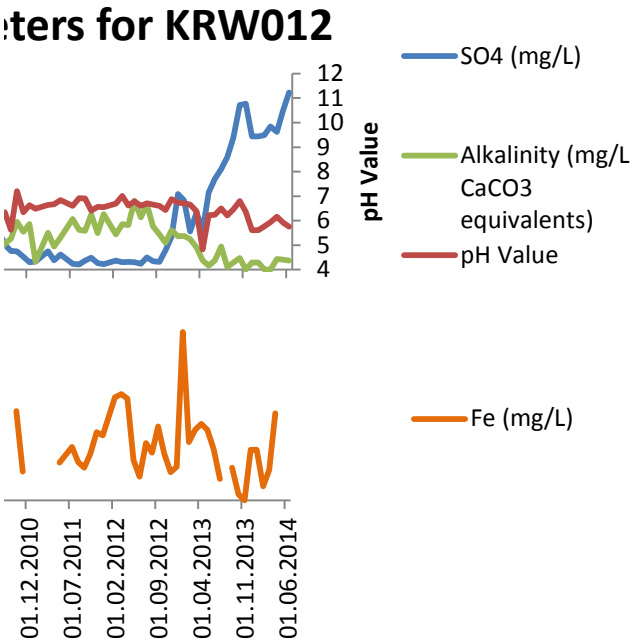
23,2
23,1
26,9
24,4
24,41
22,4
22
24,45
20,85
24,14
21,49
22,2
24,6
22,89
22,14
23,82
20,88
21,39
23,25
24,69
24,41
24,84
22,98
24,45
23,41
21,5

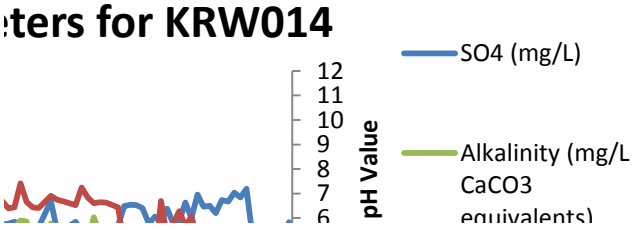
22,55
24,02
23,86
24,49
21,68
21,22
21,8
23,7
17,4
19,5
21,9
23,1
27,3
24,6
19,9
25
15,8
15,8
25,5

18,6	0,01
20,7	0,01
19,7	0,01
22,3	0,01
21,5	0
24,8	0
22	0,01
22,5	0,01
22,5	0,02
20	0,02
18,7	0,01
22,6	0,01
21,8	0,02
21,4	0,02
24,88	0,02
22,65	0,1
24,29	0,03
21,67	0,03
24,32	0,03
26,68	0,04
23,43	0,04
21,55	0
21,95	0,02
21,41	0,01
23,89	0
20,77	1,14
21,5	0,01
24,34	
23,66	
23,66	
21,9	
19,96	
21,1	
18,3	
18	
23,56	
22,38	
23,2	
23,19	
22,43	0,2
23,7	
22,53	
21,47	
22,4	

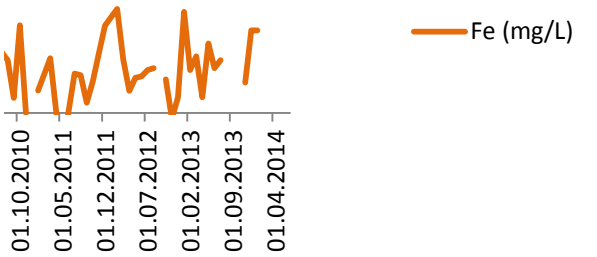


22,7
20,52
17,6
21,5
22,73
22,8
23,63
22,54
16,5
22,69
17,95

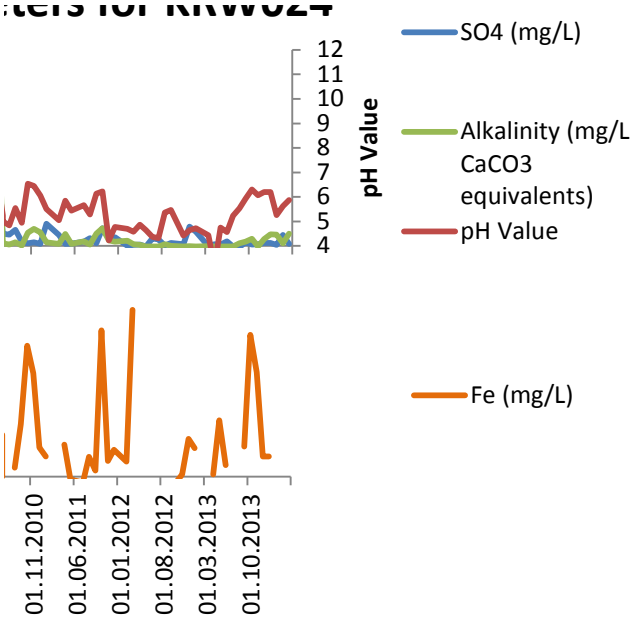

ters for KRW012
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.12.2010
01.07.2011
01.02.2012
01.09.2012
01.04.2013
01.11.2013
01.06.2014

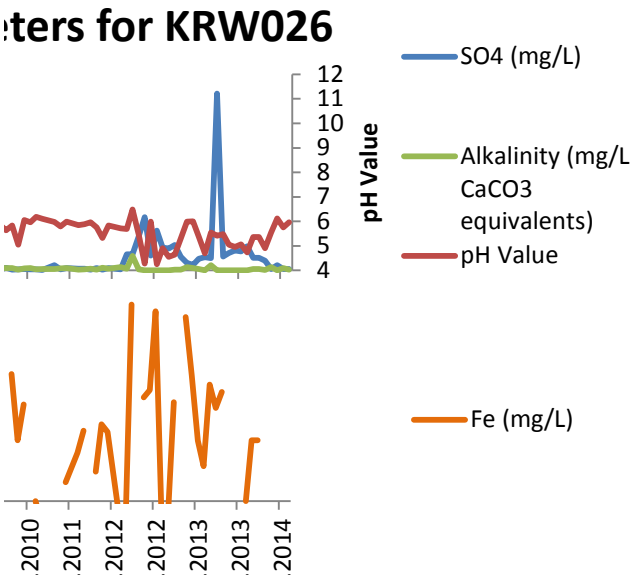

ters for KRW014
12
11
10
9
8
7
6
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)

equivalents)
5
4
pH Value

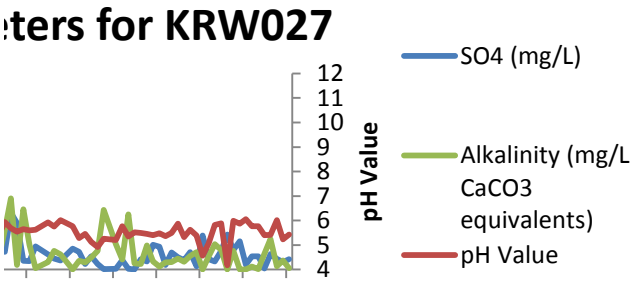

Fe (mg/L)
01.10.2010
01.05.2011
01.12.2011
01.07.2012
01.02.2013
01.09.2013
01.04.2014

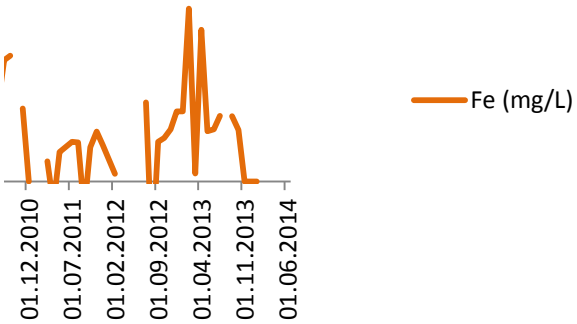
ters for KRW024

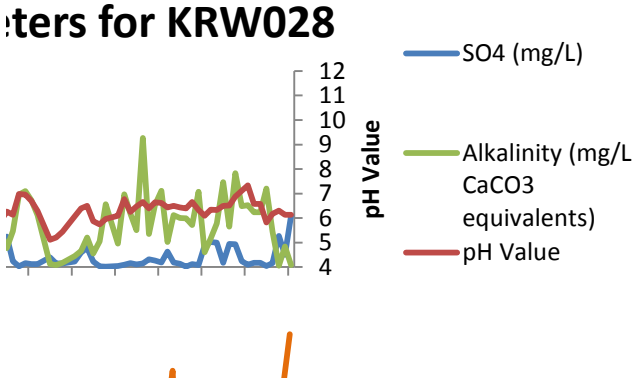

12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.11.2010
01.06.2011
01.01.2012
01.08.2012
01.03.2013
01.10.2013

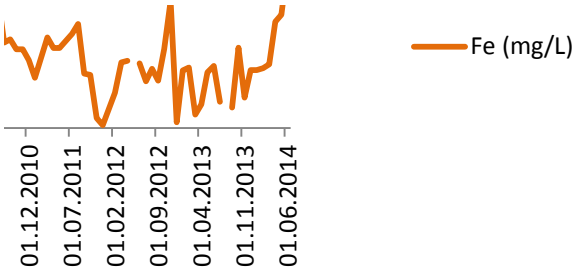

ters for KRW026
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
2010
2011
2012
2012
2013
2013
2014

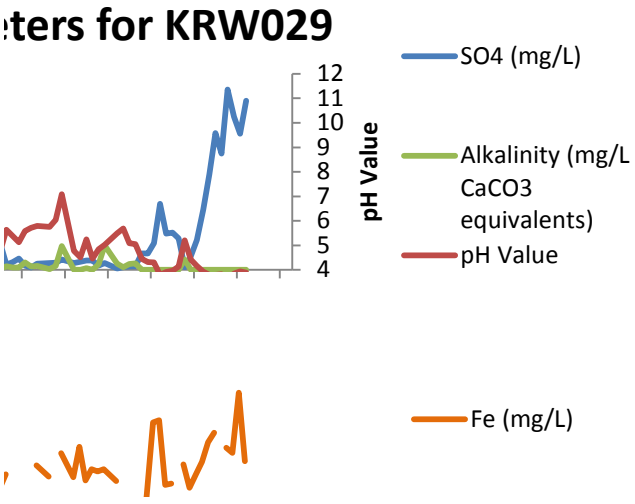
01.11.
01.06.
01.01.
01.08.
01.03.
01.10.
01.05.


ters for KRW027
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value

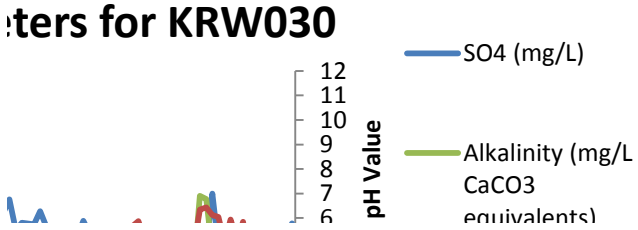

Fe (mg/L)
01.12.2010
01.07.2011
01.02.2012
01.09.2012
01.04.2013
01.11.2013
01.06.2014


ters for KRW028
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value

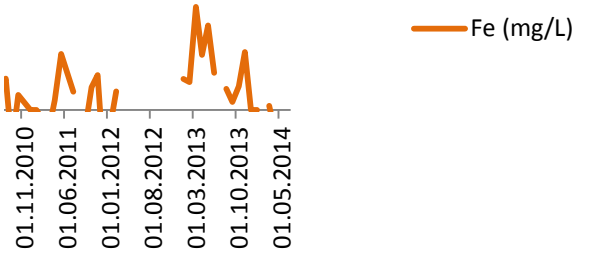

Fe (mg/L)
01.12.2010
01.07.2011
01.02.2012
01.09.2012
01.04.2013
01.11.2013
01.06.2014


eters for KRW029
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)

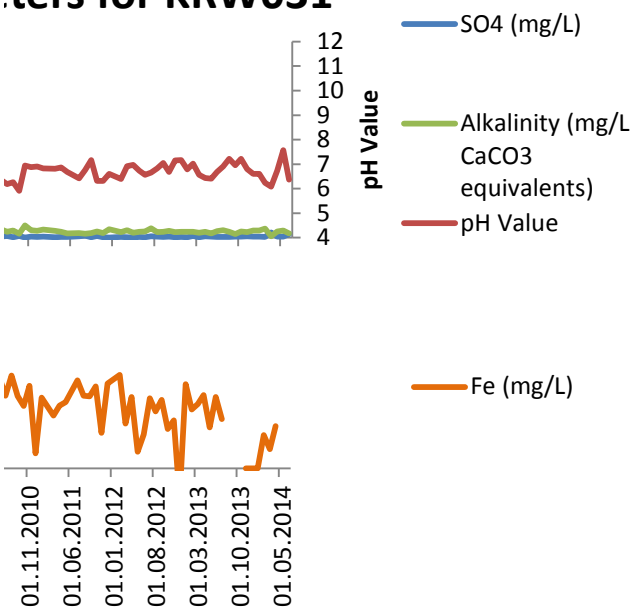
01.11.2010
01.06.2011
01.01.2012
01.08.2012
01.03.2013
01.10.2013
01.05.2014

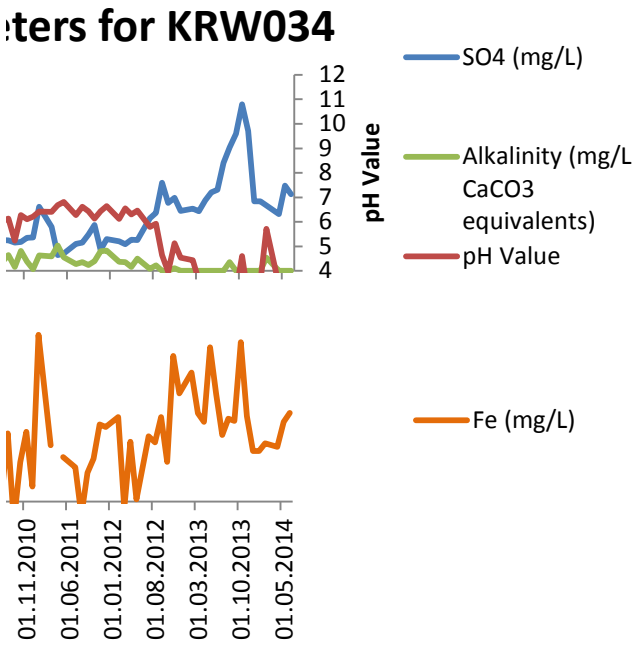

ters for KRW030
12
11
10
9
8
7
6
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)

6
5
4
equivalents)
pH Value

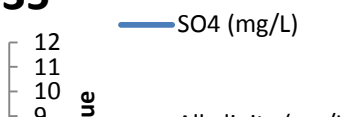

Fe (mg/L)
01.11.2010
01.06.2011
01.01.2012
01.08.2012
01.03.2013
01.10.2013
01.05.2014

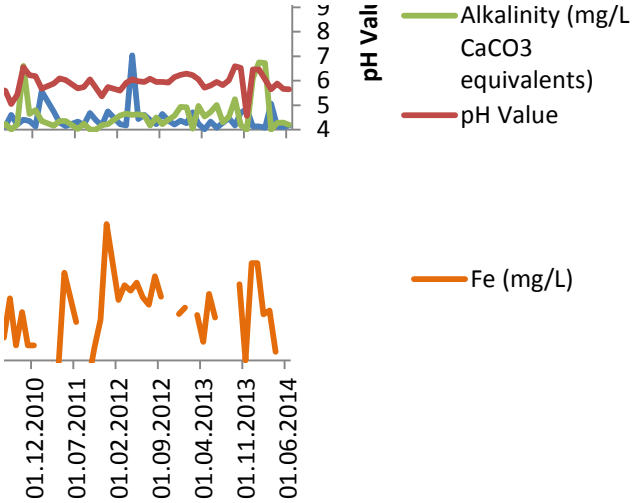
ters for KRW031



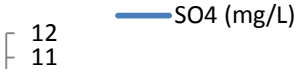

ters for KRW034
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.11.2010
01.06.2011
01.01.2012
01.08.2012
01.03.2013
01.10.2013
01.05.2014

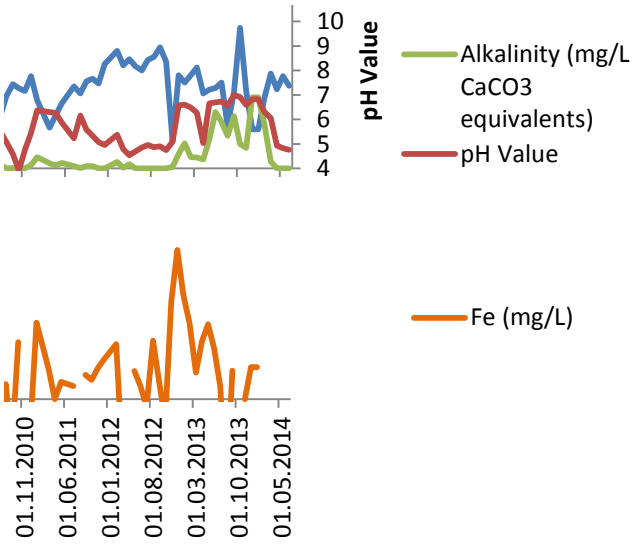
ters for KRW035

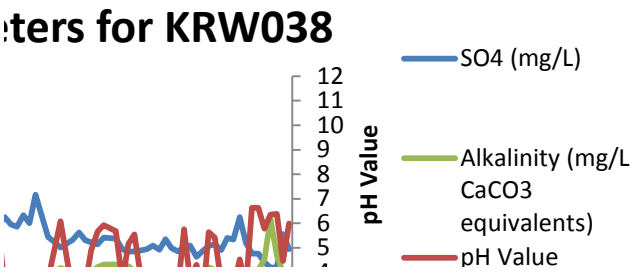


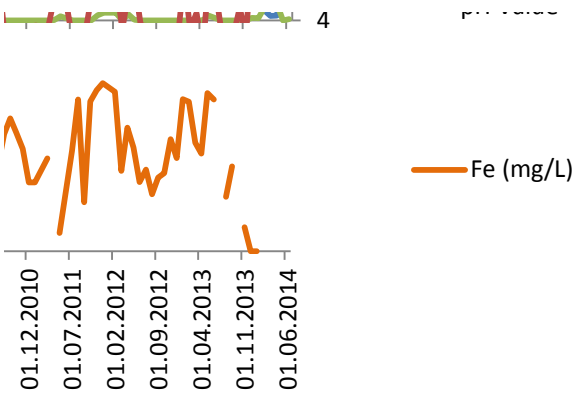

8
7
6
5
4
pH Valı
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.12.2010
01.07.2011
01.02.2012
01.09.2012
01.04.2013
01.11.2013
01.06.2014

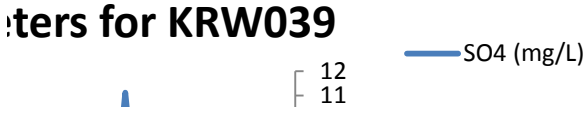
ters for KRW036

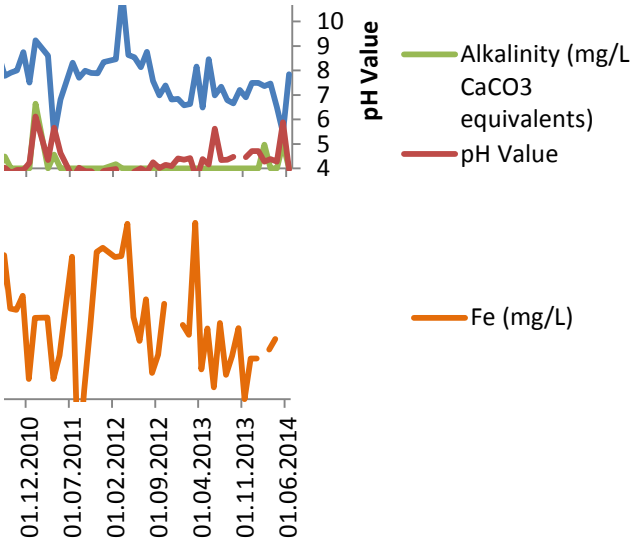


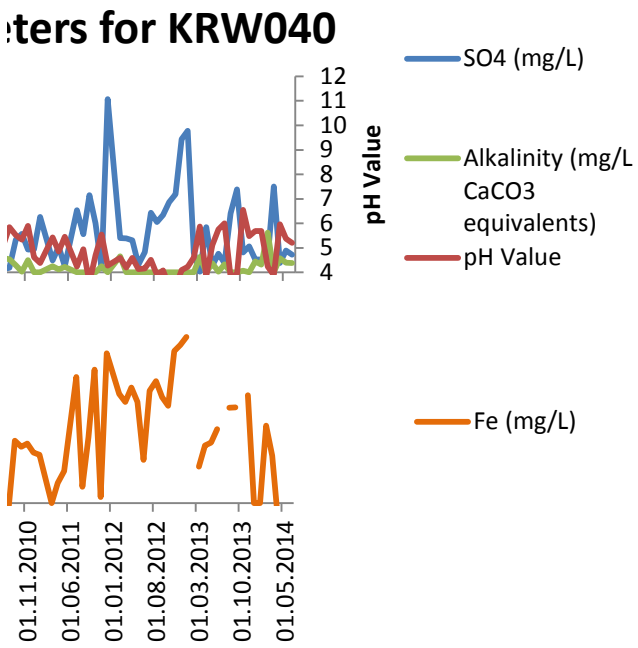

10
9
8
7
6
5
4
pH Value
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.11.2010
01.06.2011
01.01.2012
01.08.2012
01.03.2013
01.10.2013
01.05.2014


eters for KRW038
12
11
10
9
8
7
6
5
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value

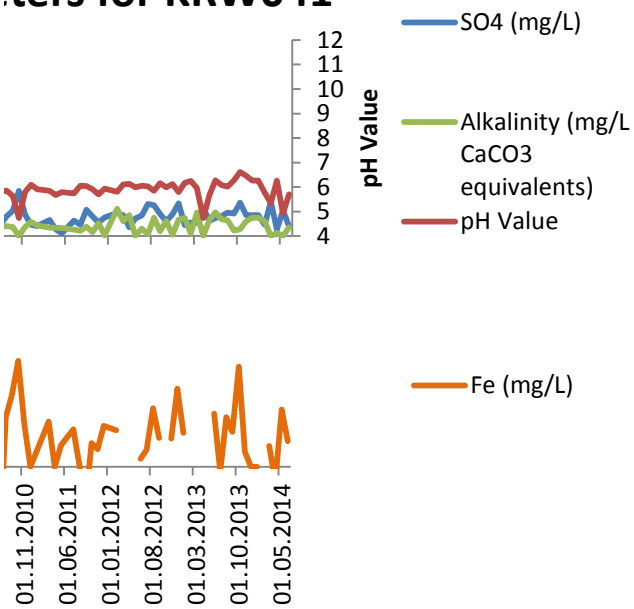

4
Fe (mg/L)
01.12.2010
01.07.2011
01.02.2012
01.09.2012
01.04.2013
01.11.2013
01.06.2014

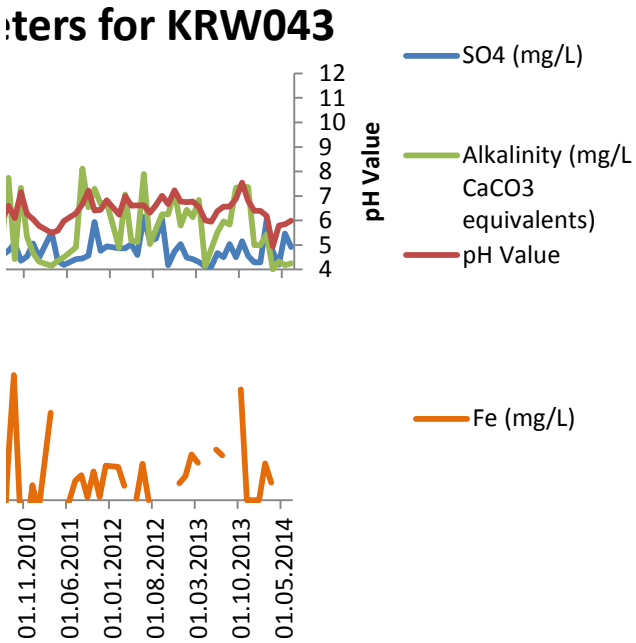

ters for KRW039
SO4 (mg/L)
12
11

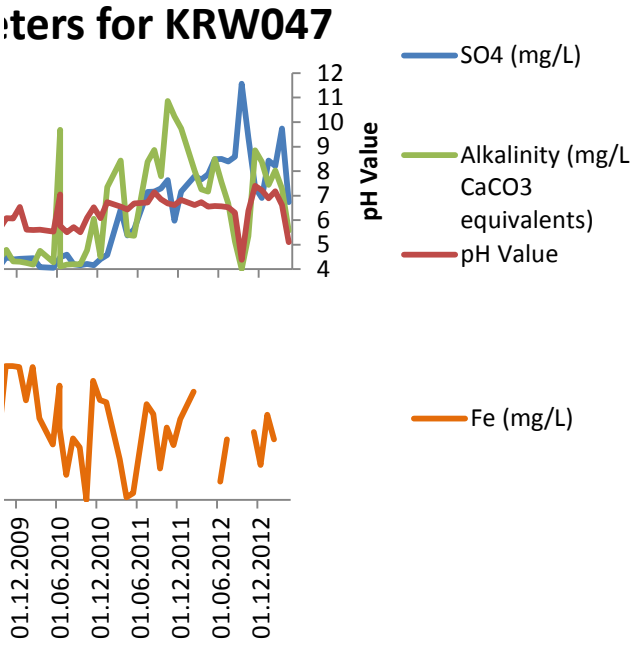

10
9
8
7
6
5
4
pH Value
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.12.2010
01.07.2011
01.02.2012
01.09.2012
01.04.2013
01.11.2013
01.06.2014


ters for KRW040
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.11.2010
01.06.2011
01.01.2012
01.08.2012
01.03.2013
01.10.2013
01.05.2014

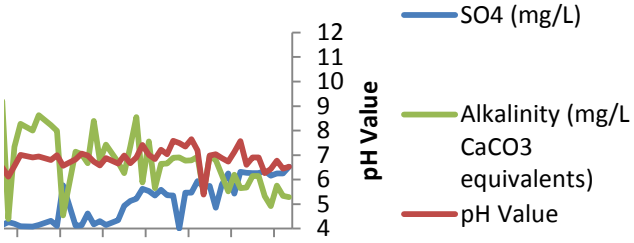
ters for KRW041

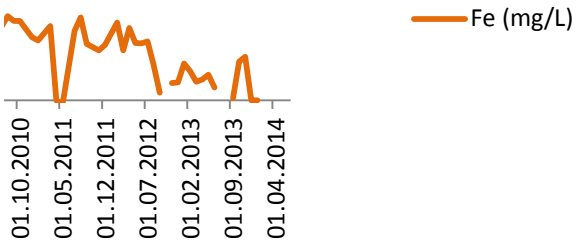


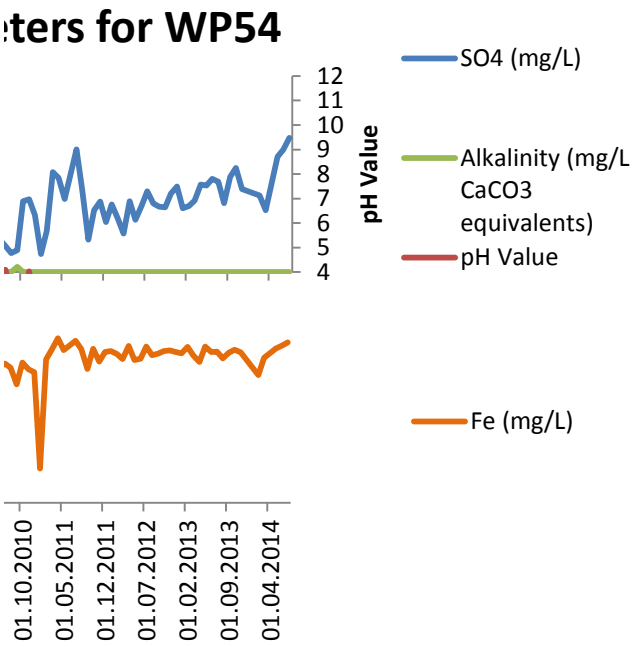

ters for KRW043
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.11.2010
01.06.2011
01.01.2012
01.08.2012
01.03.2013
01.10.2013
01.05.2014


ters for KRW047
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.12.2009
01.06.2010
01.12.2010
01.06.2011
01.12.2011
01.06.2012
01.12.2012

ters for KRW049






ters for WP54
12
11
10
9
8
7
6
5
4
pH Value
SO4 (mg/L)
Alkalinity (mg/L CaCO3 equivalents)
pH Value
Fe (mg/L)
01.10.2010
01.05.2011
01.12.2011
01.07.2012
01.02.2013
01.09.2013
01.04.2014

Borehole	Date	pH	EC	TDS	Alkalinit	Ca	Mg	Na
AW1	07.06.1989	7,4	338	4091	615	550	340	125
AW1	07.06.1989	7,5	344	4207	605	660	282	118
AW1	07.06.1989	7,2	349	4223	575	685	267	115
AW1	14.02.1990	7,38	411	4462	496	484	315	314
AW1	14.02.1990	6,98	417	4532	498	496	306	308
AW1	21.08.1990	7,48	428	2996	90	292	224	213
AW1	21.08.1990	7,75	477	3339	100	318	217	174
AW1	22.10.1990	7,92	447	3129	106	462	313	282
AW1	22.10.1990	8,15	479	3353		481	326	344
AW1	31.03.1991	7,75	477	2877		318	894	174
AW1	22.10.1991	8,15	479	3353	262	481	326	344
AW1	22.10.1991	7,92	447	3129		462	313	282
AW1	31.01.1992	6,87	450	4610		484,5	389	340
AW1	30.06.1992	7,08	421	4426		412,4	322	340
AW1	23.02.1994	6,7	522		816	444,3	313,2	511
AW1	12.01.1995	6,6	514		1046	435,2	304,5	458,8
AW1	24.03.1995	8,1	565	4646	1052	407	354	503
AW1	01.08.1995	7,38	520	4630	856	458	377	341
AW1	31.08.1995	7,51	495	4820	882	411	367	368
AW1	29.09.1995	7,29	533	4849	714	437	358	395
AW1	29.09.1995	7,29	533	4890	714	437	358	395
AW1	18.10.1995	7,42	509	4610	982	445	365	303
AW1	30.11.1995	7,34	537	4710	772	420	351	366
AW1	22.12.1995	7,62	520	4464	826	463	351	330
AW1	04.01.1996	7,5	503	4270	922	416	314	313
AW1	10.05.1996	7,35	541		786	381	367	354
AW1	24.07.1996	7,69	537		712	397	349	342
AW1	14.10.1996	7,2	535		762	444	359	359
AW1	09.12.1996	7,08	553		650	428	368	356
AW1	08.04.1997	7,37	571		440	450	346	368
AW1	26.08.1997	7,55	537	4812	700	418	364	523
AW1	02.12.1997	6,96	544	4938	442	470	401	489
AW1	15.01.1998	6,8	430	4234	654	467,7	267,4	419,6
AW1	06.02.1998	6,6	514	4473	652	422,1	255,6	389,6
AW1	12.03.1998	7,1	541	5114	596	463	424	473
AW1	08.04.1998	7	483	4447	366	617,4	484,09	355,48
AW1	22.05.1998	7,03	507	4784	714	418	377	419
AW1	28.05.1998	6,4	53	441	36	38,86	29,52	20,7
AW1	26.06.1998	7	466	5073	734			
AW1	24.07.1998	7,33	554	5118	720	431	373	451
AW1	28.07.1998	8,06	7,8	48	10	1,58	1,71	3,61
AW1	25.08.1998	7,28	556	5120	460	432	360	420
AW1	15.09.1998	7,43	560	5208	710	476	395	483
AW1	13.10.1998	7,44	567	5280	620	439	387	469
AW1	26.11.1998	7,46	575	5082	650	478	412	490
AW1	13.05.1999	7,3	573	4942	630	468	429	429
AW1	29.06.1999	7,19	561	4790	636	454	407	436
AW1	29.06.1999	7,19	561	4790	636	454	407	436
AW1	26.07.1999	7	579	4974	522	467	430	390

AW1	12.10.1999	7,4	574	4726	616	489	410	442
AW1	12.11.1999	7,23	579	4612	626	450	415	412
AW1	18.01.2000	7,17	579	4790	614	467	422	427
AW1	14.03.2000	6,88	565	4696	598	511	441	362
AW1	13.04.2000	6,88	529	4362	532	460	420	327
AW1	13.06.2000	6,92	538	4558	572	394	375	344
AW1	06.07.2000	7,32	542	4690	564	443	449	246
AW1	27.07.2000	7,12	543	4604	570	496	431	274
AW1	06.09.2000	7,06	545	4516	572	518	453	204
AW1	04.12.2002	7,15	502	4834	562	496	454	134
AW1	01.12.2003	6,96	496	5088	503	498	164	50,9
AW1	01.01.2004	7,19	486	5200	496	507	151	52,8
AW1	01.02.2004	6,75	382	3522	378	355	111	40,4
AW1	01.03.2004	7,14	434	4240	482	386	128	45,2
AW1	01.04.2004	7,43	446	4756	506	431	141	50
AW1	01.05.2004	6,91	467	4885	544	455	149	50,5
AW1	01.06.2004	7,18	486	4822	454	506	473	163
AW1	01.08.2004	7,21	509	4430	554	457	446	195
AW1	01.09.2004	7,04	519	5096	584	524	524	286
AW1	01.10.2004	6,9	504	4670	556	466	480	192
AW1	01.11.2004	7,15	498	4644	316	522	500	133
AW1	01.12.2004	6,95	487	4882	322	458	509	133
AW1	01.01.2005	6,94	309	2970	335	261	68	32,5
AW1	01.02.2005	6,91	392	3848	433	370	96,4	41,3
AW1	01.03.2005	6,91	398	3942	428	355	89,6	39
AW1	01.04.2005	6,82	411	4298	433	387	101	40,5
AW1	01.05.2005	7,37	428	3860	459	390	96	40,8
AW1	01.06.2005							
AW1	01.07.2005	6,98	495	4514	451	406	194	41,7
AW1	01.08.2005	7,02	498	4896	488	451	205	42,5
AW1	01.09.2005							
AW1	01.10.2005	7,15	484	4870	483	463	139	46,7
AW1	01.11.2005	7	466	4814	508	494	121	51
AW1	01.12.2005	6,88	452	3862	460	443	98	42,6
AW1	01.01.2006	6,91	340	3352	613	401	345	95,5
AW10	30.09.1992	7,2	66	367		36	21,2	53,3
AW10	22.02.1993	7,5	39	216		21,2	7,4	36,1
AW10	10.03.1993	7,5	39	216	178	21,2	7,4	36,1
AW10	26.05.1993	7,9	39		190	25,5	8,5	47,9
AW10	02.09.1993	7,5	40		166	24,8	10	41,2
AW10	30.11.1993	6,4	39		220	22,33	8,18	49,4
AW10	24.03.1994	7,6	42		218	22,2	11	44
AW10	12.08.1994	7,2	38		74	26,3	14,6	18,9
AW10	03.11.1994	6,9	64		198	37,7	20,6	43,9
AW10	05.01.1995	7,6	58		190	38,6	15,8	40,9
AW10	16.02.1995	6,8	59		180	42,2	18,6	46,9
AW10	24.03.1995	7,93	58,7	366	212	44,9	18	46,6
AW10	21.04.1995	7,86	56,5	362	216	45,9	17,6	51,4
AW10	19.05.1995	8,01	56,3	352	210	42,1	17,4	45,7

AW10	28.07.1995	7,81	56,3	364	216	41,2	17,7	49,2
AW10	31.08.1995	7,91	58	360	198	41,2	18,4	44,6
AW10	29.09.1995	7,56	57,9	360	194	43,7	19,1	45,7
AW10	18.10.1995	7,77	54,6	348	188	40,8	18,6	41,6
AW10	30.11.1995	7,39	55,6	334	176	34,7	16,1	42,2
AW10	22.12.1995	7,98	54,5	282	178	36	15,2	28,8
AW10	04.01.1996	7,58	45	258	160	30	14,9	35,1
AW10	10.05.1996	7,14	34,3		118	19,6	9,8	26,5
AW10	24.07.1996	7,14	24,5		104	15	6,2	19,8
AW10	14.10.1996	7,36	55,7		110	40,3	21,6	25,3
AW10	09.12.1996	7,73	25,1		104	14,7	6,6	21,8
AW10	08.04.1997	8,07	23,7		108	13,4	6,2	23,4
AW10	26.08.1997	7,45	34,1	228	58	18,6	14,2	20,4
AW10	02.12.1997	7,92	27,4	168	112	18,4	8,4	24,7
AW10	14.01.1998	7,5	26	288	108	20,92	12,1	25,54
AW10	06.02.1998	6,8	25	194	116	18,95	6,24	24,81
AW10	12.03.1998	7,92	31,7	182	114	20,4	12,8	26,7
AW10	08.04.1998	7,4	44	413	92	33,42	29,7	24,13
AW10	22.05.1998	8,18	21,9	142	108	16,9	9,03	16,6
AW10	28.05.1998	6,9	69	372	414	47,65	22,01	31,98
AW10	26.06.1998	7,6	21	111	106			
AW10	24.07.1998	8,27	24,7	144	110	17,6	8,06	21,5
AW10	25.08.1998	8,24	24,8	146	112	16,4	6,86	23,9
AW10	15.09.1998	8	25,9	164	116	17,6	6,94	24,8
AW10	13.10.1998	8,17	26,9	170	116	17,4	6,92	25,3
AW10	26.11.1998	7,91	27,8	152	118	18,7	7,33	24,2
AW10	13.05.1999	7,97	28,8	156	114	24	10,7	14,9
AW10	29.06.1999	7,83	27,6	148	116	18,5	7,11	23,9
AW10	29.06.1999	7,83	27,6	148	116	18,5	7,11	23,9
AW10	26.07.1999	7,96	30,9	154	120	19,8	7,7	24,4
AW10	12.10.1999	8,14	31,3	166	122	19,9	7,65	29,8
AW10	12.11.1999	7,82	30,7	160	118	18,9	6,68	28,6
AW10	18.01.2000	8,14	33,8	184	122	22,8	9,73	28,2
AW10	14.03.2000	7,91	23,6	136	96	19,7	6,83	14,4
AW10	13.04.2000	7,84	22,2	130	92	18,2	6,45	12,5
AW10	13.06.2000	7	26,8	148	112	16,5	8,3	13
AW10	06.07.2000	7,74	27,1	150	144	18,3	9,12	14,7
AW10	27.07.2000	7,28	25,2	148	110	19,6	8,69	12,9
AW10	06.09.2000	7,53	25,7	152	116	19,1	8,92	14,1
AW12	10.03.1993	7,4	72	455	220	60,6	32,4	25,8
AW12	26.05.1993	7,8	77		206	64,1	35,8	35,6
AW12	02.09.1993	8	69		202	74	35,4	27,4
AW12	30.11.1993	6,5	74		242	73,8	32,4	37
AW12	24.03.1994	7,7	56		216	42,9	26,8	23,4
AW12	03.11.1994	6,9	62		168	41,1	31,5	24,8
AW12	05.01.1995	7,3	84		198	64,2	36,4	36,8
AW12	16.02.1995	7,4	78		194	63,5	36,6	32,4
AW12	24.03.1995	8,23	75,1	486	228	64,9	35,8	29,4
AW12	21.04.1995	7,68	70,7	454	220	61,9	33,1	28,3

AW12	19.05.1995	7,69	67,9	438	218	55,9	33,8	26,7
AW12	28.07.1995	7,92	69,4	434	204	61,2	35,7	30,7
AW12	31.08.1995	8,02	59,1	396	182	47,6	27,7	23,7
AW12	29.09.1995	7,88	57	366	176	48,2	25,5	22,4
AW12	18.10.1995	7,73	48,6	328	160	38,6	23,2	18
AW12	30.11.1995	6,96	19,1	96	52	15,1	4,9	7,4
AW12	22.12.1995	8,03	29,6	188	106	25,8	11	8,1
AW12	04.01.1996	6,86	10,2	52	40	8,2	2,8	3,4
AW12	10.05.1996	7,74	58,9		154	51,9	14,6	26,9
AW12	24.07.1996	7,24	12,9		52	7,4	4,1	5,9
AW12	14.10.1996	6,85	12,9		50	11,8	3,6	5,3
AW12	09.12.1996	7,42	14,1		54	8,8	4,6	5,9
AW12	08.04.1997	7,42	20,2		78	16	6,2	8,6
AW12	02.12.1997	6,95	11,3	70	46	8,5	4,2	5,3
AW12	14.01.1998	7,4	11	109	56	9,76	4,69	11,37
AW12	06.02.1998	6,7	12	98	4	8	4,28	10,65
AW12	12.03.1998	7,32	19,8	118	82	16,7	7,6	7,1
AW12	08.04.1998	7,3	24	215	98	25,14	10,33	17,06
AW12	22.05.1998	7,6	19,5	116	66	15,8	7,53	4,81
AW12	26.06.1998	6,9	9	47	48			
AW12	24.07.1998	7,92	45,3	266	132	33,4	25,6	16,2
AW12	25.08.1998	7,86	33,4	212	114	22,9	19,7	14,8
AW12	15.09.1998	8	53	370	150	40,6	30,3	24,6
AW12	13.10.1998	8,01	39,4	258	142	30,6	23,8	15,7
AW12	26.11.1998	7,44	27,9	160	114	19,9	14,5	8,3
AW12	13.05.1999	7,55	50	322	150	54,6	27,3	10,1
AW12	29.06.1999	6,39	12,8	74	44	8,58	4,04	2,62
AW12	29.06.1999	6,39	12,8	74	44	8,58	4,04	2,62
AW12	26.07.1999	7,57	60,3	366	174	52,6	30,2	22,1
AW12	12.10.1999	8,03	63,2	374	180	51	31	28,4
AW12	12.11.1999	7,45	20,1	112	84	15,3	8,9	6,91
AW12	13.06.2000	6,58	19,6	104	64	7,06	4,61	4,02
AW12	06.07.2000	6,96	19,1	104	68	7,12	4,89	4,61
AW12	27.07.2000	7,21	26,2	154	108	17,2	10,1	5,42
AW12	06.09.2000	7,41	46,8	280	186	39,9	21,2	14,6
AW13	30.06.1992	7,67	62	432		62,5	19,9	44
AW13	30.09.1992	8,3	448	3918	100	520	388	113
AW13	30.09.1992	7,3	81	444		57,2	22,2	39,3
AW13	26.05.1993	7,8	67		180	65,4	19,5	43,8
AW13	02.09.1993	8	67		178	80,5	25	39,1
AW13	30.11.1993	6,7	74		236	75,8	24,5	44,3
AW13	24.03.1994	7,6	63		224	53,1	22,6	32,6
AW13	03.11.1994	7	73		210	63,6	29,2	35,6
AW13	05.01.1995	6,9	80		188	70	25,2	41,8
AW13	16.02.1995	6,9	83		172	79,8	28,2	41,9
AW13	24.03.1995	8,53	81,6	538	220	83,2	28	43
AW13	21.04.1995	7,56	76	492	210	79,8	26,1	42,9
AW13	19.05.1995	7,49	74,9	486	208	77	24,9	40,2
AW13	28.07.1995	7,81	77,7	494	206	80,9	27,4	43,1

AW13	31.08.1995	7,66	77,4	512	204	78	25,9	37,9
AW13	29.09.1995	7,67	78,2	520	216	82,6	25,1	38,2
AW13	18.10.1995	7,62	78,4	528	214	83,8	26,8	41,9
AW13	30.11.1995	7,44	65	404	162	56,2	20,3	30,4
AW13	22.12.1995	7,47	49,6	318	138	43,8	12,9	15,6
AW13	08.01.1996	7,44	57	388	160	52,1	14,1	25,4
AW13	10.05.1996	7,19	75		192	76,3	21,2	34,4
AW13	14.10.1996	7,38	70,3		188	71,3	21,9	36,6
AW13	09.12.1996	7,45	77,8		198	78,7	22,8	36,9
AW13	08.04.1997	7,94	77,3		210	72,1	23,4	41,8
AW13	02.12.1997	7,08	68,9	442	192	77,9	21,9	36,2
AW13	14.01.1998	7,1	47	339	148	54,35	16,11	28,71
AW13	06.02.1998	6,4	61	402	166	56,29	15,72	33,58
AW13	12.03.1998	7,12	66,5	450	184	75	20,5	34,4
AW13	08.04.1998	7,1	65	438	158	79,21	20,03	34,77
AW13	22.05.1998	7,33	52,7	382	156	60,3	19,1	31,1
AW13	26.06.1998	7	39	306	154			
AW13	26.11.1998	6,97	80,2	474	204	87,5	25,4	33,1
AW13	13.05.1999	7,15	56,4	370	166	81,7	15,4	16
AW13	29.06.1999	6,09	12,7	66	46	10,2	4,2	2,59
AW13	29.06.1999	6,09	12,9	66	46	10,2	4,2	2,59
AW13	26.07.1999	0,01	54,5	330	142	57,3	17,1	23,2
AW13	12.10.1999	7,39	70,4	432	184	71,7	23,4	36
AW13	12.11.1999	6,84	30,5	172	124	24,6	12,1	11,5
AW13	18.01.2000	7,45	11,2	60	34	7,64	3,92	3,5
AW13	14.03.2000	6,19	9,5	52	30	6,16	3,24	2,91
AW13	13.04.2000	6,33	9,9	54	28	6,39	3,22	2,54
AW13	13.06.2000	6,79	8,8	58	22	4,22	1,96	1,7
AW13	06.07.2000	7,09	8,4	56	20	4,45	2,15	2,04
AW13	27.07.2000	7,04	9,1	60	18	4,77	3,21	2,22
AW13	06.09.2000	6,33	11,4	74	26	8,1	3,33	2,6
AW14	30.06.1992	7,48	30,3	188		29,6	11,7	16,6
AW14	30.09.1992	7,6	46	242		27	13	22
AW14	22.02.1993	7,7	26	157		20,7	9,7	14
AW14	10.03.1993	7,7	26	157	136	20,7	9,7	14
AW14	26.05.1993	7,9	34		144	28,5	11,4	22,3
AW14	02.09.1993	7,8	32		140	23,6	12,5	24,8
AW14	30.11.1993	6,8	24		122	17	7,2	18,8
AW14	08.04.1994	5,5	26		180	24,9	9,3	27,1
AW14	01.08.1995	7,28	32,4	192	168	22,6	12,6	19,7
AW14	31.08.1995	7,7	34,5	232	164	26,6	12,9	19,3
AW14	29.09.1995	7,69	33,4	230	162	27,3	13,4	20,2
AW14	18.10.1995	7,42	33,7	210	170	26,3	13,7	21,4
AW14	30.11.1995	6,97	14,3	88	32	8,9	3,3	7,6
AW14	22.12.1995	7,61	20,9	124	94	15,7	6,9	8,7
AW14	04.01.1996	6,58	11,3	76	36	8,1	3,6	5,4
AW14	10.05.1996	6,41	13,6		38	5,9	4	8,7
AW14	24.07.1996	7,47	19,5		76	12,7	7,3	9,6
AW14	14.10.1996	7,87	31,9		118	21,1	10,4	18,3

AW14	09.12.1996	6,97	14,5		48	6,9	4,8	3,7
AW14	02.12.1997	6,63	15,3	86	46	12,2	5,4	4,4
AW14	14.01.1998	7,1	26	198	84	23,26	9,4	16,35
AW14	06.02.1998	6,5	24	198	88	19,74	8,42	14,64
AW14	12.03.1998	7,83	28,4	164	126	29,9	14	7,4
AW14	08.04.1998	7,6	29	263	130	38,93	13,71	16,13
AW14	22.05.1998	7,7	30,5	174	132	33,9	15,5	4,58
AW14	26.06.1998	7,2	27	69	132			
AW14	24.07.1998	7,79	35,1	194	146	35,3	17,9	3,98
AW14	25.08.1998	7,63	59,5	384	174	71,8	23,7	15,6
AW14	15.09.1998	7,82	36,8	228	162	43,4	18,6	4,45
AW14	13.10.1998	7,87	37,8	232	162	43,5	18,1	4,84
AW14	26.11.1998	7,51	38,3	216	162	42,8	18,9	4,58
AW14	13.05.1999	7,58	39,2	224	146	44,9	20	2,77
AW14	29.06.1999	7,24	40	242	148	48,9	19,6	3,24
AW14	29.06.1999	7,24	40	242	148	48,9	19,6	3,24
AW14	26.07.1999	7,49	42,6	246	154	49,7	20,2	3,94
AW14	12.10.1999	7,53	43,6	276	148	53,2	20,9	4,84
AW14	12.11.1999	7,76	44,9	260	146	50,2	19,7	4,75
AW14	18.01.2000	6,51	15,4	82	34	10,9	6,28	3,13
AW14	14.03.2000	6,35	14,9	96	44	8,02	6,31	3,22
AW14	13.04.2000	6,5	13,3	86	22	6,68	5,45	2,9
AW14	13.06.2000	7,24	20,7	134	66	15	9,33	3,01
AW14	06.07.2000	7,71	26,1	194	90	23,4	12,6	3,49
AW14	27.07.2000	7,49	32,6	234	120	32,9	16	3,22
AW14	06.09.2000	7,7	40,5	296	132	47,2	20,1	4,41
AW15	30.06.1992	3,13	462			477	530	136
AW15	30.09.1992	3	612	5531	0	520	287	147
AW15	29.06.1999	7,21	105	694	230	153	35	35,5
AW15	29.06.1999	7,21	105	694	230	153	35	35,5
AW15	26.07.1999	7,3	107,3	738	226	151	33,7	35,1
AW15	12.11.1999	8,12	107,5	716	254	125	33,5	35,5
AW15	18.01.2000	8,01	106,7	704	252	127	32,4	28,2
AW15	14.03.2000	7,38	109,5	768	222	137	35,8	34
AW15	13.04.2000	7,38	111,4	832	232	153	34,1	30,6
AW15	13.06.2000	7,3	105,4	716	222	142	32	30,4
AW15	06.07.2000	7,41	110,2	826	244	153	34,1	32
AW15	27.07.2000	7,28	110,4	748	242	160	34,9	29,4
AW15	06.09.2000	7,26	111,6	840	236	171	37	37,3
AW18	30.03.1990	4,4	105		0	49,6	20,9	16
AW18	30.06.1990	4,7	57		0	38	25	17
AW18	30.09.1990	3,6	92		0	90	53	18
AW18	31.12.1990	2,64	174		0	147	102	42
AW18	30.06.1991	2,16	293		0	168,2	161,4	37
AW18	30.09.1991	4,87	96	718	6	76,1	43,3	60
AW18	30.06.1992	3,07	363	2258	0	380,4	252,7	100
AW18	30.09.1992	7,9	217	1739	55	244	129	28,4
AW18	22.02.1993	5,4	122	1120		103	78,1	12,6

AW18	10.03.1993	5,4	122	1120		103	78,1	12,6
AW18	26.05.1993	5,5	70		36	56,6	42,1	7
AW18	02.09.1993	7,5	31		44	14,6	11,3	25,4
AW18	24.03.1994	7,1	135		30	106,7	88,1	14,8
AW18	23.06.1994	6	111		18	88,8	84,2	22,8
AW18	12.08.1994	7	64		120	47,6	42,7	13,5
AW18	13.10.1994	6,6	118		276	74,8	89,8	44,1
AW18	25.11.1994	6,6	122		166	111,3	127,7	27,7
AW18	05.01.1995	6,9	108		192	76,9	79,9	28,2
AW18	02.02.1995	6	96		216	59,6	68,6	18,5
AW18	13.03.1995	6,38	113,8		160	96,7	83,6	13,6
AW18	28.07.1995	7,39	79,2	508	372	57,8	62,2	11,8
AW18	31.08.1995	7,55	72,6	536	366	50,7	51,8	11,2
AW18	29.09.1995	7,67	96,3	688	314	86,1	78,1	20,6
AW18	18.10.1995	7,04	95,9	668	286	78,9	66,9	17,2
AW18	30.11.1995	6,94	79,1	482	252	51,7	48,7	13,7
AW18	22.12.1995	7,12	74,4	466	242	51,3	41,6	8,4
AW18	04.01.1996	6,69	80	552	180	66,8	55	10,5
AW18	10.05.1996	6,02	330		18	362	183	38,5
AW18	24.07.1996	6,17	352		20	400	204	38,7
AW18	14.10.1996	6,97	361		178	409	309	30,6
AW18	09.12.1996	6,48	308		118	314	247	28,2
AW18	08.04.1997	7,19	341		202	376	257	31,4
AW18	26.08.1997	7,63	247	2108	398	205	241	35,2
AW18	05.12.1997	8,2	177,5	1526	266	162	184	28
AW18	14.01.1998	6,6	102	955	92	85,25	60,35	29,39
AW18	06.02.1998	6	112	1017	118	109,5	67,61	34,67
AW18	12.03.1998	6,5	133,5	1078	152	138	86,7	30,3
AW18	08.04.1998	6,5	199	1779	180	364,65	140,15	29,42
AW18	22.05.1998	6,51	248	2246	262	312	188	24,5
AW18	26.06.1998	6,7	177	1616	394			
AW18	24.07.1998	7,04	219	1704	402	203	171	24,7
AW18	25.08.1998	7,05	188,4	1450	398	158	169	28,1
AW18	15.09.1998	7,23	197,2	1596	472	192	181	30,2
AW18	13.10.1998	7,19	187,2	1444	482	157	176	27,8
AW18	26.11.1998	7,03	175,9	1240	436	125	161	28,3
AW18	13.05.1999	6,94	101,2	612	390	102	51,3	11,1
AW18	29.06.1999	6,67	96,7	550	412	56,7	74,9	20,4
AW18	29.06.1999	6,67	96,7	550	412	56,7	74,9	20,4
AW18	26.07.1999	6,85	101,9	574	412	58,6	73,7	23,3
AW18	12.10.1999	7,2	99,1	558	410	56,5	76,7	26,3
AW18	12.10.1999	7,2	99,1	558	410	56,5	76,7	26,3
AW18	12.11.1999	7,31	87,5	510	390	54,1	64,3	25,4
AW18	18.01.2000	6,57	53,2	272	184	35,5	29,5	7,49
AW18	14.03.2000	6,18	137,4	1050	82	141	81,6	26,6
AW18	13.04.2000	6,18	171,8	1330	70	171	93,3	29
AW18	13.06.2000	6,26	187,6	1226		207	115	31,3
AW18	13.07.2000	6,34	185	1384	94	211	122	34
AW18	27.07.2000	6,68	171,3	1318	98	195	116	29,6
AW18	06.09.2000	6,41	165	1284	98	197	114	32,5

AW18	04.12.2002	7,14	72,4	456	382	26,3	57,4	23,2
AW18	01.08.2004	7	45,4	260	224	37	20,7	8,03
AW18	01.09.2004	6,89	50,2	328	246	48	20,7	16,4
AW18	01.10.2004	6,78	54,7	328	238	51,1	26,9	9,11
AW18	01.11.2004	6,3	26,9	166	100	30,9	8,29	2,75
AW18	01.12.2004	6,63	27,4	172	126	25,5	5,15	3,1
AW18	01.01.2005	6,49	17,2	112	62	17	5,68	2,01
AW18	01.02.2005	6,6	21,8	132	91	23,3	7,58	3,39
AW18	01.03.2005	6,45	26,3	152	113	22,6	10,6	4,74
AW18	01.04.2005	6,43	33,6	194	159	35,9	14,3	5,23
AW18	01.05.2005	6,42	36,1	236	216	37,5	15,4	5,32
AW18	01.06.2005							
AW18	01.07.2005	6,5	37	232	204	36	17,1	6,32
AW18	01.08.2005	6,63	37,1	240	214	30,6	18,4	7,66
AW18	01.09.2005							
AW18	01.10.2005	6,64	40,6	246	224	31,1	21	9,8
AW18	01.11.2005	6,81	43	360	238	35,9	22,9	9,57
AW18	01.12.2005	6,75	48,2	286	252	38,4	22,7	9,34
AW18	01.01.2006	6,25	22	166	126	22,7	10	2,58
AW19	27.04.1990	6,53	31,5		58	29,6	19,9	8
AW19	30.06.1990	6,1	31		58	29,6	19,9	8
AW19	30.09.1990	3,6	72		0	39	21	54
AW19	31.12.1990	7,66	86		98	94	53	11
AW19	30.06.1991	3,2	46,5		0	20	19	8,6
AW19	22.02.1993	5,1	20	118		4,1	2,3	22,7
AW19	10.03.1993	5,1	20	118	20	4,1	2,3	22,7
AW19	26.05.1993	5,1	22		48	8,4	19,5	12,5
AW19	02.09.1993	4,2	215		0	190,1	152,9	18,9
AW19	30.11.1993	6,7	34		36	18,02	10,08	29,6
AW19	24.03.1994	7,2	23		48	47	7,7	17,1
AW19	23.06.1994	6,3	18		50	7,1	7	18,5
AW19	12.08.1994	7,2	21		40	8,1	7,3	18
AW19	13.10.1994	6,9	27		78	11,6	11,1	17,5
AW19	25.11.1994	6,8	23		84	12,3	5,9	23,7
AW19	05.01.1995	6,4	28		96	4,8	8,1	27,1
AW19	02.02.1995	5,7	29		92	12,8	11,7	23,7
AW19	13.03.1995	6,61	25,6		110	12,3	8,4	20
AW19	28.07.1995	7,18	27,1	174	122	12,2	11	19,2
AW19	31.08.1995	7,22	27,5	164	132	13,7	11,7	19
AW19	29.09.1995	7,29	26,9	182	138	14,9	10,1	25,4
AW19	18.10.1995	6,91	26	174	112	13,1	9,8	22,3
AW19	30.11.1995	6,99	24,8	146	110	13,2	7,6	21,2
AW19	22.12.1995	7,08	21	128	84	9,6	5,4	14,7
AW19	04.01.1996	6,14	33	166	60	14,3	11,6	21,6
AW19	10.05.1996	4,55	172,7		0	189	84,6	16,5
AW19	24.07.1996	4,67	140,7		8	136	72,9	16,9
AW19	14.10.1996	5,18	77,5		18	51,8	37,9	18,1
AW19	09.12.1996	5,95	105,5		28	81,8	54,6	21,9
AW19	08.04.1997	6,75	52,7		32	23,9	19,6	20,3

AW19	26.08.1997	7,54	32,8	198	50	20,4	14	28,1
AW19	05.12.1997	6,87	52,5	348	36	35,3	27,3	21
AW19	14.01.1998	6,2	26	212	6	17,23	10,41	14,4
AW19	06.02.1998	5,8	25	238	4	16,26	12,19	24,83
AW19	12.03.1998	6,25	34,1	252	8	21,7	13	9,2
AW19	08.04.1998	6,2	36	291	16	22,32	11,87	15,46
AW19	22.05.1998	6,12	27,4	188	20	18,9	12,8	9,13
AW19	26.06.1998	6,3	28	9	40			
AW19	24.07.1998	6,48	25,2	160	36	16,6	10,9	11,8
AW19	24.07.1998	6,48	25,2	160	36	16,6	10,9	11,8
AW19	25.08.1998	6,37	24,6	158	40	14,8	9,59	16,9
AW19	15.09.1998	6,46	25	162	48	14,3	9,71	16,5
AW19	13.10.1998	6,54	26	166	48	13,4	9,86	14,9
AW19	26.11.1998	6,17	26,1	160	52	13,7	9,82	14,1
AW19	13.05.1999	6,4	26,2	164	86	13,2	10,01	15,7
AW19	29.06.1999	6,27	22,2	126	80	9,87	8,62	15,1
AW19	29.06.1999	6,27	22,2	126	80	9,87	8,62	15,1
AW19	26.07.1999	6,45	25,4	128	86	11,9	9,76	16,9
AW19	12.10.1999	7,29	25	138	92	13,2	8,76	17,9
AW19	12.10.1999	7,29	25	138	92	13,2	8,76	17,9
AW19	12.11.1999	7,11	23,3	130	90	12,1	7,86	17,8
AW19	18.01.2000	4,84	135,4	954	4	131	73,8	16
AW19	14.03.2000	5,42	129,7	960	6	139	64,3	5,4
AW19	13.04.2000	5,65	127,1	1036	26	133	61,1	4,95
AW19	13.06.2000	6,03	117,1	924		106	49,6	5,17
AW19	13.07.2000	6,14	117,8	950	64	107	50,9	6,68
AW19	27.07.2000	6,09	118,7	972	56	111	52,5	6,69
AW19	06.09.2000	5,98	125,7	1074	38	133	58,8	9,59
AW19	04.12.2002	7,16	35,1	218	130	24,1	17,1	11,4
AW19	01.08.2004	6,96	38,4	252	12	21,4	20,7	18
AW19	01.09.2004	7,75	37,7	266	24	20,5	21,9	25,7
AW19	01.10.2004	6,1	69,8	466	36	45,3	30,1	21,1
AW19	01.11.2004	6,34	55,8	352	46	40	30,7	18
AW19	01.12.2004	6,78	37,1	262	21	22,3	20,8	18,4
AW19	01.01.2005	6,15	90,2	648	49	72,9	48,3	20,4
AW19	01.02.2005	4,63	110,3	782	19	106	64,2	9,18
AW19	01.03.2005	5,29	100,3	770	5	110	58,3	12
AW19	01.04.2005	6,07	66,8	550	7	58	46,8	17,4
AW19	01.05.2005	6,02	54,3	354	9	35,3	33,5	18
AW19	01.06.2005							
AW19	01.07.2005	6,4	43,5	356	95	25,4	36,1	30,1
AW19	01.08.2005	7,03	41,8	272	23	24,4	23,7	19,3
AW19	01.09.2005							
AW19	01.10.2005	5,78	73,3	488	22	55,5	37,6	19,6
AW19	01.11.2005	6,47	113,7	926	107	114	65,6	52,1
AW19	01.12.2005	5,68	99,2	704	27	94,7	55,2	21,4
AW19	01.01.2006	4,44	136	1180	35	167	79,8	8,13
AW2	14.02.1990	7,38	207	1962	358	237	169	51
AW2	21.08.1990	8,07	365	2555	36	372	326	34

AW2	22.10.1990	7,8	367	2569		419	356	41
AW2	31.03.1991	8,07	365	3353		372	326	34
AW2	21.08.1991	7,8	367	2569	52	419	356	41
AW2	21.08.1991	8,07	365	2555	36	372	326	34
AW2	31.01.1992	7,26	368	4238		496,5	423	84
AW2	30.06.1992	7,18	265	2748	408	336,3	238,1	44
AW2	30.09.1992	6,9	363	3164	131	370	344	67
AW2	10.03.1993	6,8	375	4363	240	472,8	463,5	61,8
AW2	26.05.1993	7,4	426		206	554	504	77
AW2	02.09.1993	6,8	300		308	337,6	328,4	40,7
AW2	30.11.1993	6,2	350		336	445,9	410,5	64,2
AW2	24.03.1994	7,4	351		404	408,1	379,4	48,5
AW2	23.06.1994	6,8	381		244	497,1	389	58,9
AW2	12.08.1994	7,4	355		330	453,3	345,2	49,5
AW2	13.10.1994	6,9	402		360	440,6	410,6	65,8
AW2	12.01.1995	6,3	435		314	527,8	496,9	68
AW2	23.02.1995	6,5	464		328	502,4	400,1	71,3
AW2	24.03.1995	7,84	432	4126	356	480	447	54,9
AW2	01.08.1995	7,13	483	4060	466	420	402	177
AW2	31.08.1995	7,3	502	4218	488	410	388	180
AW2	29.09.1995	7,13	409	3810	356	431	378	52,8
AW2	18.10.1995	6,98	459	4116	368	450	466	67,7
AW2	30.11.1995	7,22	444	4268	344	434	448	51,3
AW2	22.12.1995	7,19	471	4378	400	499	469	61,1
AW2	04.01.1996	6,99	368	3408	354	408	340	41,5
AW2	10.05.1996	6,62	370		326	386	334	43,5
AW2	24.07.1996	7,09	417		318	406	410	50,4
AW2	14.10.1996	7,08	468		410	438	442	136
AW2	09.12.1996	6,92	473		338	451	503	60
AW2	08.04.1997	7,15	499		342	466	473	58,6
AW2	26.08.1997	7,58	503	4952	374	474	532	91,9
AW2	05.12.1997	7,3	564	5652	402	513	680	101,6
AW2	15.01.1998	6,8	520	4855	372	519,1	661,3	68,2
AW2	06.02.1998	6,4	518	5059	368	475,1	598	67,1
AW2	12.03.1998	6,7	533	4626	418	489	683	84,9
AW2	08.04.1998	6,6	524	4908	298	631,41	674,97	59,91
AW2	22.05.1998	6,8	530	5564	390	483	675	69,4
AW2	28.05.1998	5,9	90	767	30	89,75	55,21	24,51
AW2	24.07.1998	7,02	573	5820	384	470	783	73,9
AW2	28.07.1998	6,36	6,2	42	6	2,66	2,06	3,42
AW2	25.08.1998	7,1	579	6318	368	502	768	76,8
AW2	15.09.1998	7,19	594	6046	392	536	783	84,6
AW2	13.10.1998	7,11	583	6384	380	514	789	78,4
AW2	26.11.1998	7,16	584	5822	400	527	799	73,9
AW2	13.05.1999	7,19	577	5276	374	470	705	44,7
AW2	26.07.1999	7,01	578	5250	370	485	723	72,3
AW2	12.10.1999	7,23	569	5086	362	510	657	84,4
AW2	12.11.1999	7,12	565	4920	358	487	640	72,1
AW2	18.01.2000	7,79	561	4896	332	460	590	78,4
AW2	14.03.2000	6,7	533	4624	298	485	612	79,2

AW2	13.04.2000	6,84	570	5016	388	478	626	71,6
AW2	13.04.2000	6,84	570	5016	388	478	626	71,6
AW2	13.06.2000	6,96	567	5054	372	448	637	64,7
AW2	06.07.2000	7,22	581	5146	366	475	697	75,8
AW2	27.07.2000	7,01	586	5178	356	502	733	86,9
AW2	06.09.2000	6,86	595	5238	368	516	714	118
AW2	04.12.2002	7,04	549	5612	346	465	654	66,5
AW2	04.06.2004	6,95	544	5736	356	513	698	74
AW2	04.08.2004	7,05	539	4788	368	432	645	62,1
AW2	04.09.2004	7	537	5554	364	526	784	76,3
AW2	04.10.2004	6,88	531	4990	354	460	657	68,5
AW2	04.11.2004	6,99	539	5272	335	509	693	72
AW2	04.12.2004	6,9	537	5874	248	467	776	77,4
AW2	01.01.2005	6,9	487	5072	414	573	61,7	49,2
AW2	01.02.2005	7,21	468	4844	424	559	61,8	49,8
AW2	01.03.2005	6,71	525	5564	488	608	65,1	52,5
AW2	01.04.2005	8,35	516	5696	385	559	63,9	51,2
AW2	01.05.2005	6,81	532	5030	512	670	69,4	54,6
AW2	01.06.2005							
AW2	01.07.2005	6,89	541	5294	457	627	71,7	53,5
AW2	01.08.2005	6,9	538	5588	473	641	68,5	51,8
AW2	01.09.2005							
AW2	01.10.2005	7,07	536	5760	472	686	67,1	51,2
AW2	01.11.2005	6,91	525	5604	477	742	68,5	52,3
AW2	01.12.2005	6,75	529	5402	462	718	65,8	49,7
AW2	01.01.2006	6,83	531	5372	424	480	642	70,4
AW20	04.04.1993	9,4	371	2500	940	4,4	21,8	990
AW20	26.05.1993	7,9	951		2268	26,1	102	2208
AW20	02.09.1993	8,2	886		2380	20,5	96,4	2250
AW20	30.11.1993	6,7	810		5400	19,58	88,7	2150
AW20	24.03.1994	7,8	681	0	2308	15,3	71	1894
AW20	23.06.1994	8	759		1982	24,9	86,4	2475
AW20	12.08.1994	7,9	772		2000	25,4	69,4	1571
AW20	13.10.1994	7,8	825		2154	19,8	87,4	1917
AW20	25.11.1994	8	793		1968	19,1	112,1	2134
AW20	12.01.1995	7,4	860		1860	25,3	72,1	2418
AW20	23.02.1995	8,3	891		1800	25,8	75,2	1549
AW20	24.03.1995	8,42	853	5440	1950	23,8	104	1867
AW20	19.05.1995	8,3	855	5482	1920	20,9	110	1878
AW20	01.08.1995	8,35	803	4884	1760	18,4	97,8	1690
AW20	31.08.1995	8,5	807	5004	1728	20,8	98,4	1720
AW20	29.09.1995	8,43	879	5628	1910	21,7	122	1808
AW20	18.10.1995	8,33	806	5120	1743	17,8	105	1948
AW20	30.11.1995	8,47	780	4460	1660	15	93,2	1550
AW20	22.12.1995	8,99	750	4340	1580	12,8	70,3	1325
AW20	04.01.1996	9,31	335	1980	762	4,2	26,9	752
AW20	10.05.1996	9,59	292		734	2	10	504
AW20	24.07.1996	8,64	837		1684	14,8	92,7	1436
AW20	14.10.1996	8,51	783		1620	12,4	92,8	1615

AW20	09.12.1996	9,52	372		814	1,7	21,9	602
AW20	08.04.1997	9,59	195,5		608	2,4	13,2	394
AW20	26.08.1997	8,66	800	5374	1590	16,1	101	1885
AW20	02.12.1997	9,61	170,2	1076	522	0,97	11,9	408
AW20	14.01.1998	9,4	141	804	522	1,66	7,39	346,4
AW20	06.02.1998	8,8	176	898	506	1,41	6,23	335,6
AW20	12.03.1998	9,46	189,8	1176	630	2,1	13,6	446
AW20	22.05.1998	8,59	678	4450	1330	8,61	88,2	1380
AW20	26.06.1998	8,5	640	4565	1396			
AW20	24.07.1998	8,68	795	4924	1470	13,7	94,6	1646
AW20	25.08.1998	8,78	802	5240	1500	13,3	96,4	1730
AW20	15.09.1998	8,87	853	5346	1500	15,9	107	1630
AW20	13.10.1998	8,9	430	2802	504	7,92	74,6	862
AW20	26.11.1998	9,17	406	2390	462	4,8	58,7	796
AW20	13.05.1999	8,4	505	2890	522	11,8	81,02	886
AW20	29.06.1999	8,42	727	4296	1140	17,5	105	1420
AW20	29.06.1999	8,42	727	4296	1140	17,5	105	1420
AW20	21.07.1999	8,64	691	4118	922	17,1	91,1	1300
AW20	12.10.1999	8,59	761	4326	1216	20,5	97,2	1388
AW20	12.11.1999	8,68	736	4052	1172	17,8	91,6	1260
AW20	18.01.2000	9,61	82	438	254	3,25	1,69	1,54
AW20	14.03.2000	9,79	72,3	424	236	1,88	1,39	144
AW20	13.06.2000	9,76	268	1524	470	2,83	10,2	461
AW20	06.07.2000	9,63	465	2636	720	2,73	26,6	765
AW20	27.07.2000	8,66	118,7	4490	1210	10,7	90,7	1300
AW20	06.09.2000	8,75	730	4776	1260	17,3	92	1850
AW20	12.09.2002	8,994	559	4795	111	343,69	142,16	43,45
AW20	01.08.2004	8,9	623	4042	920	7,8	96	1184
AW20	01.09.2004	8,98	622	4616	930	12,1	109	1575
AW20	01.10.2004	8,87	583	3872	890	4,03	84,9	1157
AW20	01.11.2004	9,56	511	3336	826	2,89	65,7	1000
AW20	01.12.2004	9,54	523	3158	924	1,42	66,3	1124
AW20	01.01.2005	9,77	116,4	722	367	2,12	13,4	233
AW20	01.02.2005	10,08	167	1052	510	2,75	17,4	328
AW20	01.03.2005	9,74	199,5	1404	777	2	18,8	473
AW20	01.04.2005	9,74	199,5	1404	777	2	18,8	473
AW20	01.05.2005	9,5	506	3154	1010	3,28	50,5	1077
AW20	01.06.2005							
AW20	01.07.2005	8,89	630	4294	928	7,86	100	1295
AW20	01.08.2005	8,94	621	4280	1075	6,81	96,4	1391
AW20	01.09.2005							
AW20	01.10.2005	8,92	620	496	912	6,56	94,5	1192
AW20	01.11.2005	9,2	552	3720	872	4,57	80,8	1106
AW20	01.12.2005	9,37	601	3488	870	4,06	80,8	1028
AW21	22.02.1993	7,1	34	210		29	10,7	19,6
AW21	10.03.1993	7,1	34	210	136	29	10,7	19,6
AW21	26.05.1993	7,7	93		264	21,1	15,3	178,9
AW21	02.09.1993	7,7	46		176	19,4	11,1	32
AW21	30.11.1993	6,8	62		240	17,44	10,59	87,7

AW21	24.03.1994	8,1	43		176	12,4	11,9	46,8
AW21	23.06.1994	7	29		128	4,4	12,3	30,3
AW21	12.08.1994	7,9	34		120	12	9,7	43,8
AW21	13.10.1994	7,9	29		116	12,9	10,9	31,2
AW21	25.11.1994	7,6	25		116	18,2	8,6	19,1
AW21	12.01.1995	7	43		156	24,2	72,1	22,6
AW21	23.02.1995	7,1	49		150	25,5	23,1	26,6
AW21	24.03.1995	8,03	40,9	256	148	27	18,3	18,8
AW21	19.05.1995	7,19	27,3	174	150	17,3	10,6	17,7
AW21	01.08.1995	7,4	24,9	168	136	13,6	8,9	20,7
AW21	31.08.1995	7,48	84,4	574	170	56,8	41,3	53,6
AW21	29.09.1995	7,85	44,8	296	164	18,1	15,4	54,4
AW21	18.10.1995	7,89	178,4	1240	432	18,2	30,4	377
AW21	30.11.1995	7,76	146,9	858	364	16,1	22,3	254
AW21	22.12.1995	7,88	34,7	214	146	18,8	13,1	18,7
AW21	04.01.1996	7,42	42,7	258	154	30,4	21,9	18
AW21	10.05.1996	6,71	19,6		76	10	5,8	11,4
AW21	24.07.1996	7,6	52,8		68	30,7	29,4	17
AW21	14.10.1996	7,32	19,2		56	10	5,1	12,5
AW21	09.12.1996	6,92	55,5		90	31,4	30,4	20,2
AW21	08.04.1997	6,85	26,7		74	11,4	8,7	15,8
AW21	26.08.1997	7,58	24,8	148	72	12,9	8,4	17,1
AW21	02.12.1997	6,47	22,6	116	42	10,4	6,37	14
AW21	14.01.1998	7,1	50	233	60	23,09	27,32	18,19
AW21	06.02.1998	7,1	44	344	56	25,68	19,96	46,16
AW21	12.03.1998	6,67	55,7	372	86	39,4	25,8	35,6
AW21	08.04.1998	6,7	85	617	116	65,87	45,71	52,71
AW21	22.05.1998	6,95	22,1	128	64	9,68	7,3	20,4
AW21	26.06.1998	6,8	32	19	74			
AW21	24.07.1998	6,97	23,1	130	68	10,8	7,93	14,8
AW21	25.08.1998	6,54	21,3	126	66	10,5	7,32	13,9
AW21	15.09.1998	6,68	21,7	134	66	11,4	8,16	16,4
AW21	13.10.1998	6,75	22	132	70	11,3	8,18	13,7
AW21	26.11.1998	6,42	22,6	126	72	11,9	8,01	13,4
AW21	13.05.1999	6,56	22,8	128	76	13,1	7,53	15,2
AW21	29.06.1999	6,27	24,2	136	74	14,7	8,69	16,2
AW21	29.06.1999	6,27	24,2	136	74	14,7	8,69	15,2
AW21	26.07.1999	6,41	21,8	124	70	12,1	8,08	13,6
AW21	12.10.1999	7,11	23,6	134	70	10	7,83	18,2
AW21	12.10.1999	7,11	23,6	134	70	10	7,83	18,2
AW21	12.11.1999	7,05	22,4	116	60	11,1	5,75	15,3
AW21	18.01.2000	7,34	13,4	70	26	6,9	2,54	11,4
AW21	14.03.2000	6,14	19,9	118	32	5,05	4,06	12,4
AW21	13.04.2000	6,05	18,7	114	30	2,77	2,84	10,7
AW21	13.06.2000	6,34	20,3	108	42	4,74	3,29	11,7
AW21	06.07.2000	6,56	25,4	122	46	8	6,11	13,6
AW21	27.07.2000	6,48	25,1	120	44	7,93	6,02	13,3
AW21	06.09.2000	6,01	22,6	116	35	9,2	5,18	14,8
AW21	30.01.2002	5,918	35,78	131	64	20,332	7,23	35,091
AW21	04.12.2002	6,67	17,42	134	62	8,51	5,2	8,3

AW21	01.08.2004	6,84	27,1	192	46	9,75	7,55	27,9
AW21	01.09.2004	6,78	26,1	220	54	8,1	8,42	30
AW21	01.10.2004	6,57	25,7	168	14	8,92	7,84	20,2
AW21	01.11.2004	6,49	21,6	156	49	8,2	7,05	18,3
AW21	01.12.2004	6,8	16,57	136	44	6,5	3,69	17,7
AW21	01.02.2005	6,32	25,8	178	36	4,45	2,88	35
AW21	01.03.2005	6,16	31,6	206	47	7,47	6,46	36,8
AW21	01.04.2005	8,19	26,1	178	46	8,59	4,84	34,8
AW21	01.05.2005	6,34	26,3	202	68	7,64	4,89	22,8
AW21	01.06.2005							
AW21	01.07.2005	6,32	18,72	172	69	7,78	4,24	16,8
AW21	01.08.2005	6,32	16,3	150	58	7,35	3,89	14,6
AW21	01.09.2005							
AW21	01.10.2005	6,24	14,83	132	56	6,88	3,01	13,6
AW21	01.11.2005	6,49	14,7	142	66	7,79	3,79	13,2
AW21	01.12.2005	6,34	16,04	126	60	7,87	4,13	12,9
AW22	22.02.1993	5,4	50	364		38	25,6	15
AW22	10.03.1993	5,4	50	364	20	38	25,6	15
AW22	26.05.1993	6,2	6		10	4,1	1,2	6,3
AW22	02.09.1993	7,6	19		28	9,6	4,4	15,2
AW22	30.11.1993	6,8	10		22	1,98	0,83	13,4
AW22	24.03.1994	8,2	16		18	7,1	4,8	10,3
AW22	23.06.1994	7,3	18		70	4,8	8,1	13,7
AW22	12.08.1994	7,8	8		20	2,7	2,2	8
AW22	13.10.1994	7,7	14		30	6,7	2,4	13,5
AW22	25.11.1994	7,3	12		30	5	1,9	14,5
AW22	05.01.1995	5,6	10		14	4,8	1,8	13,7
AW22	02.02.1995	5,2	9		14	4	1,9	14,9
AW22	13.03.1995	6,56	11,8		18	3,6	1,8	7,7
AW22	21.04.1995	7,04	10,7	67	26	3,2	1,7	8,3
AW22	19.05.1995	6,94	10,1	60	26	2,3	2	8,2
AW22	28.07.1995	7,23	20,1	122	36	11,4	7	11,4
AW22	31.08.1995	6,93	10,1	58	26	3,7	2,2	8,6
AW22	29.09.1995	7,42	20,7	108	42	10,8	9,4	12,3
AW22	18.10.1995	7,09	19,7	102	38	9,3	8,4	12,9
AW22	30.11.1995	7,14	17,8	80	34	7	5,7	9,2
AW22	22.12.1995	6,91	10,2	50	16	3,8	2,6	7
AW22	04.01.1996	7,31	19,3	108	44	14,2	6,6	6,4
AW22	10.05.1996	6,68	19,4		52	12,7	5,2	10,4
AW22	24.07.1996	7,83	26,3		58	20,9	8	10,5
AW22	14.10.1996	6,55	41,6		20	23,3	20,4	7,6
AW22	09.12.1996	6,6	13,2		29	5,6	2,8	10,5
AW22	08.04.1997	7,06	9,1		14	1,6	0,8	9,7
AW22	26.08.1997	7,82	11,7	58	18	3,3	1,6	13,1
AW22	05.12.1997	7,04	83,3	564	126	72,6	65,3	12,3
AW22	12.03.1998	6,47	10,3	46	16	3,7	1,2	10
AW22	08.04.1998	6,5	7	64	30	5,07	1,68	14,07
AW22	22.05.1998	6,55	8,1	40	4	2,02	0,9	6,72
AW22	26.06.1998	6,5	11	8	36			

AW22	24.07.1998	6,47	11	60	24	3,46	2,17	9,1
AW22	25.08.1998	6,33	11,2	64	26	3,13	2,11	8,97
AW22	15.09.1998	6,03	10,2	62	18	2,87	1,8	9,94
AW22	13.10.1998	6,1	9,6	60	12	2,67	1,02	8,39
AW22	26.11.1998	7,13	19,6	92	48	18,5	1,79	9,04
AW22	13.05.1999	6,28	10,5	56	14	3,96	1,37	8,23
AW22	29.06.1999	5,63	9,3	44	8	2,53	1,33	7,9
AW22	29.06.1999	5,63	9,3	44	8	2,53	1,33	7,9
AW22	26.07.1999	5,72	11,6	52	12	3,27	1,24	9,58
AW22	12.10.1999	6,66	11,6	62	14	10	7,83	18,2
AW22	12.10.1999	6,66	11,6	62	14	10	7,83	18,2
AW22	12.11.1999	6,51	1084	58	10	2,08	1,17	10,1
AW22	18.01.2000	7,02	341	2742		416	266	28,1
AW22	14.03.2000	6,8	347	2808		408	306	34,5
AW22	13.04.2000	6,71	23,6	208	88	19,8	6,93	8,55
AW22	13.06.2000	6,59	14,8	96	36	9,09	3,94	4,19
AW22	13.07.2000	6,72	12,6	90	30	7,67	3,57	4,05
AW22	27.07.2000	6,64	11,2	78	24	6,57	2,87	4,49
AW22	04.12.2002	6,3	12,34	70	8	5,01	2,77	6,86
AW22	01.08.2004	6,87	10,71	80	20	3,16	0,56	12
AW22	01.09.2004	7,14	16,82	118	28	5,09	1,51	16
AW22	01.10.2004	6,36	11,58	82	14	1,27	0,01	11,8
AW22	01.11.2004	6,46	11,96	72	15	3,36	0,66	12,8
AW22	01.12.2004	6,6	12,09	78	19	1,83	0,72	13,2
AW22	01.01.2005	6,48	25	196	43	18,2	7,56	12,6
AW22	01.02.2005	6,45	17,32	132	27	9,41	4,36	12,6
AW22	01.03.2005	6,33	12,69	102	35	5,32	2,37	11,4
AW22	01.04.2005	6,21	10,81	74	20	3,19	0,65	12,3
AW22	01.05.2005	5,99	9,98	70	11	2,87	0,85	11,1
AW22	01.06.2005							
AW22	01.07.2005	6,09	10,09	112	27	8,73	1,2	12,2
AW22	01.08.2005	6,3	10,1	82	24	4,73	1,95	12,2
AW22	01.09.2005							
AW22	01.10.2005	6,08	11,76	120	40	3,13	0,66	11,3
AW22	01.11.2005	6,73	12,15	80	14	3,62	1,34	13,7
AW22	01.12.2005	6,26	11,9	62	5	2,55	1,2	12,4
AW22	01.01.2006	6,36	12,56	82	8	5,69	2,58	7,44
AW23	10.03.1993	6,6	20	150	20	8,2	5,9	12,4
AW23	24.03.1994	8,1	7		8	3,7	2,4	7,2
AW23	23.06.1994	6,2	11		24	5,4	4,6	7,3
AW23	12.08.1994	7,4	6		10	2,1	2	6,9
AW23	13.10.1994	7,6	6		8	1,8	1,1	7,6
AW23	25.11.1994	6,8	5		10	10,1	0,8	4,3
AW23	05.01.1995	4,9	6		8	2,7	2,7	1,1
AW23	02.02.1995	6,3	14		52	20,4	2	9,5
AW23	13.03.1995	6,54	6,6		12	1,2	0,7	5,3
AW23	21.04.1995	5,98	6,3	36	16	1,8	1,1	4,4
AW23	19.05.1995	6,01	5,5	38	16	1,3	1,1	4,6
AW23	28.07.1995	6,71	6,3	30	18	1,74	1,17	4,8

AW23	31.08.1995	7,11	6,4	36	16	2,1	1,4	4,4
AW23	29.09.1995	6,72	6,7	42	14	2,8	2,1	6,4
AW23	18.10.1995	6,83	7,2	44	14	3	1,6	5,2
AW23	30.11.1995	6,48	6,9	40	16	1,9	0,8	6,6
AW23	22.12.1995	7,2	9,6	48	20	4,6	2,8	4,7
AW23	04.01.1996	6,94	7	34	14	2,6	0,4	7,1
AW23	10.05.1996	5,84	30,9		12	19,1	9,4	10
AW23	24.07.1996	7,01	5,9		15	1,8	0,6	6,4
AW23	14.10.1996	6,25	7,9		12	3,4	1,1	4,6
AW23	09.12.1996	6,52	6,8		18	0,9	0,3	9,9
AW23	08.04.1997	6,82	6		13	1,1	0,6	6,9
AW23	26.08.1997	7,68	7,5	40	17	1,6	1	9
AW23	05.12.1997	7,61	13,4	74	26	7,9	4,5	5,4
AW23	14.01.1998	7	14	139	18	8,28	6,35	11,7
AW23	06.02.1998	6,9	20	183	16	14,51	9,69	17,3
AW23	12.03.1998	6,14	16,3	94	24	12,5	5,5	4,7
AW23	08.04.1998	6,1	26	253	26	30,55	14,06	13,01
AW23	22.05.1998	6,92	10,3	50	26	6,3	2,73	5,98
AW23	26.06.1998	6,8	10	13	40			
AW23	24.07.1998	7,17	12	68	32	4,9	3,08	8,16
AW23	25.08.1998	7,09	13,5	78	34	5,86	3,67	10,1
AW23	15.09.1998	7,17	14,2	80	38	7,09	3,83	10,7
AW23	13.10.1998	6,74	9,6	56	18	2,94	2,68	6,1
AW23	26.11.1998	6,07	9,8	48	16	2,84	2,55	5,23
AW23	13.05.1999	5,63	7,8	44	10	1,14	0,56	4,77
AW23	29.06.1999	5,97	18,5	112	54	2,6	1,48	8,57
AW23	29.06.1999	5,97	18,5	112	54	2,6	1,48	8,57
AW23	26.07.1999	5,76	22,1	204	70	2,24	1,91	5,62
AW23	12.10.1999	6,45	10,6	70	38	2,37	1,71	5,77
AW23	12.11.1999	6,34	9,1	66	26	3,09	1,88	6,11
AW23	18.01.2000	6,11	8,1	62	20	1,85	0,95	2,38
AW23	14.03.2000	6,1	7,1	60	18	3,41	0,94	2,84
AW23	13.04.2000	5,98	6,7	48	10	4,19	1,25	3,28
AW23	13.06.2000	5,96	5,7	40	8	0,76	0,38	2,44
AW23	13.07.2000	6,33	5,7	42	8	0,98	0,6	2,56
AW23	27.07.2000	6,17	5,9	38	8	2,08	1,13	3,17
AW23	04.12.2002	6,59	19,6	144	52	10,5	5,73	11,6
AW23	01.08.2004	6,58	6,18	50	10	2,92	0,43	4,66
AW23	01.09.2004	6,67	6,89	70	14	2,27	1,42	6,8
AW23	01.10.2004	6,09	7,41	60	10	1,8	0,16	3,61
AW23	01.11.2004	6,06	7,23	52	10	3,57	0,8	4,56
AW23	01.12.2004	6,71	8,69	48	5	1,66	1,88	5,03
AW23	01.01.2005	7,07	4,15	40	5	1,96	0,4	5,3
AW23	01.02.2005	7,05	4,18	28	5	0,64	0,01	4,38
AW23	01.03.2005	6,42	7,2	50	12	2,62	2,13	5,91
AW23	01.04.2005	5,99	7,57	54	12	3,08	1,55	5,68
AW23	01.05.2005	6,05	4,96	38	12	1,12	0,13	4,48
AW23	01.06.2005							
AW23	01.07.2005	5,92	5,33	44	10	4,67	1,03	5,03
AW23	01.08.2005	5,87	6,74	52	12	3,86	1,37	4,66

AW23	01.09.2005							
AW23	01.10.2005	6	7,7	50	11	373	2,67	4,58
AW23	01.11.2005	6,55	10,2	66	12	4,58	2,29	6,37
AW23	01.12.2005	6,49	8,59	68	18	3,26	1,49	8,48
AW23	01.01.2006	6,59	5,98	52	26	3,28	0,01	5,64
AW24	02.03.1995	7,9	156		840	140,2	57,6	148,6
AW24	24.07.1996	7,67	414		402	476	348	39,9
AW24	14.10.1996	7,76	419		454	520	342	37,7
AW24	09.12.1996	7,43	415		520	489	341	43,9
AW24	26.08.1997	7,92	399	3694	450	464	362	48,9
AW24	02.12.1997	6,73	412	3784	372	495	386	44,5
AW24	14.01.1998	6,3	296	3021	432	473,6	254,7	42,2
AW24	06.02.1998	6,6	335	3126	412	411,7	229,1	43,44
AW24	22.05.1998	6,87	349	3472	422	467	324	34,1
AW24	26.06.1998	6,8	286	3359	452			
AW24	24.07.1998	7,16	367	3194	424	414	315	33,6
AW24	24.07.1998	7,16	367	3194	424	414	315	33,6
AW24	25.08.1998	7,03	370	3510	438	460	318	36,3
AW24	15.09.1998	7,2	385	3598	440	457	315	36,3
AW24	13.10.1998	7,39	327	3046	384	388	264	34,9
AW24	26.11.1998	6,98	371	3172	372	448	318	33,3
AW24	13.05.1999	7,01	350	2802	430	430	264	33,5
AW24	29.06.1999	7,09	377	2906	406	425	279	32,1
AW24	29.06.1999	7,09	377	2906	406	425	279	32,1
AW24	26.07.1999	6,9	359	2832	336	410	271	30,9
AW24	12.10.1999	7,35	348	2726	436	415	257	35,4
AW24	12.11.1999	7,21	349	2924	444	424	291	32,6
AW24	18.01.2000	7,32	34	2742	438	416	266	28,1
AW24	18.01.2000	7,32	34	2742	438	416	266	28,1
AW24	14.03.2000	6,12	12,6	92	30	8,43	2,44	6,84
AW24	14.03.2000	6,12	12,6	92	30	8,43	2,44	6,84
AW24	13.04.2000	6,9	359	2984	438	433	271	27
AW24	13.04.2000	6,9	359	2984	438	433	271	27
AW24	13.07.2000	6,92	379	3176	450	419	293	28,1
AW24	13.07.2000	6,92	379	3176	450	419	293	28,1
AW24	27.07.2000	6,87	379	3182	422	521	323	28,4
AW24	27.07.2000	6,87	379	3182	422	521	323	28,4
AW24	06.09.2000	6,82	379	3174	462	506	323	33,5
AW24	06.09.2000	6,82	379	3174	462	506	323	33,5
AW24	04.12.2002	6,92	238	2206	362	268	164	19,1
AW24	01.08.2004	7,13	258	2200	458	321	202	26,8
AW24	01.09.2004	7,13	259	2518	472	339	232	35,2
AW24	01.10.2004	7,04	258	2286	450	316	209	26
AW24	01.11.2004	6,85	262	2294	454	330	208	27
AW24	01.12.2004	7,27	259	2206	289	292	228	27,8
AW24	01.01.2005	6,9	265	2690	437	341	222	26,8
AW24	01.02.2005	7,03	262	2570	428	373	236	26,5
AW24	01.03.2005	6,82	265	2634	365	364	223	25,9
AW24	01.05.2005	6,93	303	2642	357	402	240	27,9

AW24	01.06.2005							
AW24	01.07.2005	6,96	296	2590	328	386	246	28,8
AW24	01.08.2005	7,05	262	2638	296	374	242	28,4
AW24	01.09.2005							
AW24	01.10.2005	6,97	261	2630	473	365	232	28,1
AW24	01.11.2005	6,99	259	2528	412	377	249	29,7
AW24	01.12.2005	6,9	259	2602	459	348	229	27,4
AW24	01.01.2006	6,98	311	3034	633	401	205	30,8
AW25	01.08.1995	6,25	185,5	1740	62	184	116	14,7
AW25	31.08.1995	5,76	176,9	1602	10	186	118	14,7
AW25	29.09.1995	3,44	188,1	1788		207	122	18,6
AW25	18.10.1995	5,79	217	1810	8	214	140	17,7
AW25	30.11.1995	2,95	248	2008	0	230	144	15,4
AW25	22.12.1995	3,1	246	1954	0	224	149	12,3
AW25	04.01.1996	5,01	190,3	1908	6	220	137	11,8
AW25	10.05.1996	5,11	195,4		6	230	136	15,3
AW25	14.10.1996	6,65	213		4	224	126	13
AW25	09.12.1996	6,9	188,3		172	198	110	18,1
AW25	26.08.1997	3,65	112,9	834	0	99,5	70,4	17,8
AW25	02.12.1997	7,07	285	2382	480	329	251	32,2
AW25	14.01.1998	4,6	165	1825	0	145,1	107,3	14,51
AW25	06.02.1998	4,2	218	2351	0	165,6	128,6	16,51
AW25	08.04.1998	4,6	155	1489	0	139,82	96,72	15,56
AW25	22.05.1998	6,12	41,2	356	16	44,7	23,9	2,77
AW25	26.06.1998	6,2	42	198	36			
AW25	24.07.1998	5,01	163,2	1644	4	141	107	9,51
AW25	25.08.1998	5,13	185,1	1952	6	181	133	12,6
AW25	15.09.1998	3,82	175,8	1784	8	182	132	14,6
AW25	13.10.1998	4,04	171	1640	8	166	117	12,2
AW25	26.11.1998	6,12	15,3	88	16	15,1	3,6	0,83
AW25	13.05.1999	4,34	178,2	1888		164	123	10,4
AW25	29.06.1999	5,01	172,5	1832	4	163	118	10
AW25	29.06.1999	5,01	172,5	1832	4	163	118	10
AW25	26.07.1999	4,92	191,2	2052	6	172	129	12,4
AW25	12.10.1999	2,99	215	1650	0	162	118	15,4
AW25	12.11.1999	3,04	195,5	1582	0	170	121	13,9
AW25	18.01.2000	6,13	12,1	64	14	9,74	2,23	0,56
AW25	18.01.2000	6,13	12,1	64	14	9,74	2,23	0,56
AW25	14.03.2000	5,48	15,6	102	14	11,3	3,4	0,41
AW25	14.03.2000	5,48						
AW25	14.03.2000	5,48	15,6	102	14	11,3	3,4	0,41
AW25	13.07.2000	7,68	20,1	124	12	17,1	5,83	1,74
AW25	13.07.2000	7,68	20,1	124	12	17,1	5,83	1,74
AW25	27.07.2000	5,98	20,3	126	12	18,5	6,72	1,76
AW25	27.07.2000	5,98	20,3	126	12	18,5	6,72	1,76
AW25	06.09.2000	5,67	23,1	166	14	21,6	8,24	2,66
AW25	06.09.2000	5,67	23,1	166	14	21,6	8,24	2,66
AW25	04.12.2002	6,77	57,3	358	188	53,1	27,9	5,05
AW25	01.08.2004	7,1	30,5	188	66	25	10,6	3,71

AW25	01.09.2004	6,98	35,8	268	82	31	16,5	10,8
AW25	01.10.2004	6,8	40,6	266	82	35,4	16,7	3,79
AW25	01.11.2004	6,62	45,5	298	88	40,8	21	4,96
AW25	01.12.2004	6,91	43,6	282	81	61,6	43,5	13,2
AW25	01.01.2005	6,84	16,34	114	38	18,8	4,62	1,39
AW25	01.02.2005	6,38	17,91	122	33	19,8	5,08	1,88
AW25	01.03.2005	6,18	18,79	142	36	21	6,53	3,18
AW25	01.04.2005	6,84	292	2636	426	395	264	30,3
AW25	01.07.2005	5,95	125	818	68,9	42,8	7,1	19,4
AW25	01.08.2005	6,23	128,7	584	74,3	51,3	8,82	17,8
AW25	01.09.2005							
AW25	01.10.2005	6,3	113,1	550	55,2	35	8,25	16,6
AW25	01.11.2005	7,33	118,4	520	65,7	40,5	7,59	17,2
AW25	01.12.2005	7	154,5	934	102,1	64,6	8,7	19,8
AW25	01.01.2006	6,43	19,23	154	73	21,3	4,79	1,21
AW26	02.03.1995	7,2	249		290	260	177,4	52,6
AW26	14.10.1996	7,76	289		560	382	253	31,5
AW26	09.12.1996	7,61	330		568	349	249	32,1
AW26	14.01.1998	6,2	240	2229	550	345,7	191,8	31,28
AW26	29.06.1999	7,09	217	1502	677	227	168	17,2
AW26	29.06.1999	7,09	217	1502	677	227	168	17,2
AW26	13.07.2000	6,98	234	1630	600	222	176	16,1
AW26	27.07.2000	6,84	281	2150	474	329	222	18,7
AW26	06.09.2000	7,07	276	2218	572	342	225	22,1
AW26	04.12.2002	7,21	240	1686	328	227	160	19,4
AW26	01.08.2004	7,35	172,8	1240	616	198	118	15,6
AW26	01.09.2004	7,24	183,2	1370	742	213	132	20,1
AW26	01.01.2005	6,95	142,4	1028	409	167	88	110
AW26	01.02.2005	7,01	181,2	1484	457	226	133	15,3
AW26	01.03.2005	6,85	194,8	1560	430	231	137	16,2
AW26	01.04.2005	7,03	211	1696	880	224	155	16,7
AW27	21.02.1997	6,2	35,6		28	15	13	9,4
AW27	08.04.1997	7,15	40		88	7,4	8,7	41,2
AW27	26.08.1997	7,29	50,6	280	116	18,7	14,6	57,9
AW27	22.05.1998	6,59	35,6	232	18	16,9	18,3	7,79
AW27	26.06.1998	6,7	37	227	76			
AW27	24.07.1998	6,79	43,8	292	58	24,2	18,2	21,6
AW27	25.08.1998	7,05	49,5	316	112	19,5	16,9	44,5
AW27	15.09.1998	6,45	45,4	300	58	22,1	21,4	18,7
AW27	13.10.1998	6,74	39,3	260	30	17,9	20,2	10,8
AW27	26.11.1998	6,25	42,1	274	38	18,7	19,3	15,2
AW27	13.05.1999	5,9	39,1	262	28	17,09	18,01	11,02
AW27	29.06.1999	6,9	51,4	122	24	11,5	8,11	8,2
AW27	29.06.1999	6,9	51,4	122	24	11,05	8,11	8,2
AW27	26.07.1999	6,9	56,3	316	172	26	16,9	51,5
AW27	12.10.1999	7,59	56,9	344	172	24,9	16,7	59,3
AW27	12.11.1999	7,26	54,9	302	160	23,8	14,2	59,8
AW27	18.01.2000	4,91	51,7	296	4	24,1	14,9	10,8

AW27	14.03.2000	5,31	38,8	228	12	17,3	12,6	7,75
AW27	13.06.2000	6,77	42,9	280	44	20,2	18,6	10,6
AW27	13.07.2000	7,55	39,5	226	18	17	15,1	7,34
AW27	27.07.2000	6,05	39,9	232	20	18,5	18,6	6,88
AW27	06.09.2000	7,08	46,8	274	54	30,3	19,9	10,1
AW28	21.02.1997	6,28	111,5		40	72,1	50,8	54,9
AW28	08.04.1997	5,62	124,9		6	83,6	63,4	65,3
AW28	22.05.1998	6,57	52,7	416	34	43,4	32,6	20,3
AW28	26.06.1998	6,2	43	255	38			
AW28	24.07.1998	6,28	44,4	294	30	32,3	21,2	14,8
AW28	25.08.1998	6,07	39,3	280	30	26,4	20,7	16,5
AW28	15.09.1998	5,98	36	266	36	24,1	17,1	13,3
AW28	13.10.1998	6,22	26,7	188	26	16,4	12,2	9,23
AW28	26.11.1998	5,83	25,6	156	29	14,7	11,5	7,68
AW28	13.05.1999	5,77	26,3	188	26	14,01	10,02	11,05
AW28	29.06.1999	5,88	19,6	280	136	26,2	17,5	40,4
AW28	29.06.1999	5,88	19,6	280	136	26,2	17,5	40,4
AW28	26.07.1999	5,83	19,9	138	22	10	7,06	5,89
AW28	12.10.1999	6,47	17,3	124	18	13,6	5,7	4,48
AW28	12.11.1999	6,35	15,3	86	12	7,81	3,95	3,85
AW28	18.01.2000	3,7	139,2	1486	0	118	47,3	6,19
AW28	14.03.2000	3,45	186,9	1930	0	159	106	7,14
AW28	13.04.2000	3,66	117	1356	0	81,3	38,6	3,29
AW28	13.06.2000	3,79	124,2	1048	0	91,5	53,4	22,9
AW28	13.07.2000	3,83	116,4	1014	0	84,2	50,2	25,9
AW28	27.07.2000	3,58	116,5	994	0	84,7	49,5	24,5
AW28	06.09.2000	4,24	117,1	1032	0	97,2	54,5	28,7
AW3	31.03.1988	6,3	330		64	523	570	80
AW3	31.03.1988	6,8	305		236	545	482	62
AW3	07.06.1989	7,2	463	7011	920	865	697	98
AW3	07.06.1989	7,8	507	7775	645	960	812	111
AW3	14.02.1990	6,46	373	4323	262	472	511	47
AW3	14.02.1990	5,28	491	6026	13	418	638	83
AW3	21.08.1990	2,9	516			317	492	54
AW3	21.08.1990	7,34	399	2793		337	393	36
AW3	22.10.1990	6,99	437	3059	75	451	521	57
AW3	22.10.1990	3,03	506			450	567	68
AW3	31.03.1991	2,9	516	4794		0	492	54
AW3	21.08.1991	2,9	516	4794	0	317	492	54
AW3	21.08.1991	7,34	399	2793	54	337	393	36
AW3	22.10.1991	6,99	437	4647	75	451	521	57
AW3	22.10.1991	3,03	506	5323	0	450	567	68
AW3	06.02.1998	6,5	367	3515	72	196,5	441,7	42,49
AW3	28.05.1998	4	97	823		77	52,87	24,62
AW3	12.10.1999	8,02	19,4	94	72	11,9	5,73	7,48
AW3	18.01.2000	7,93	26,7	128	78	21,6	8,88	8,89
AW3	14.03.2000	7,48	19,8	118	60	13,6	5,31	6,63
AW3	04.12.2002	7,19	291	2568	242	181	320	22,9

AW3	04.06.2004	7,18	486	4822	798	506	295	30,8
AW3	04.08.2004	7,64	288	2316	278	147	288	25,9
AW3	04.09.2004	7,41	285	2506	188	173	354	33,3
AW3	04.10.2004	7,03	280	2362	152	145	337	28,6
AW3	04.11.2004	7,53	265	2338	317	172	336	28,9
AW3	04.12.2004	7,32	264	2078	276	144	328	29,2
AW3	01.01.2005	7,19	264	2574	170	319	27,4	36,9
AW3	01.02.2005	7,15	289	2670	193	349	31,2	38,8
AW3	01.03.2005	6,88	263	2680	197	302	27,3	33,9
AW3	01.04.2005	6,91	260	2646	209	350	31	39,3
AW3	01.05.2005	6,77	300	2714	270	306	28,6	35,2
AW3	01.06.2005							
AW3	01.07.2005	6,9	299	3070	277	330	30	33,9
AW3	01.08.2005	6,86	300	2922	272	313	28,8	32,9
AW3	01.09.2005							
AW3	01.10.2005	7,29	289	2670	234	304	28,2	33,9
AW3	01.11.2005	6,97	290	2692	262	320	29,4	33,1
AW3	01.12.2005	6,8	260	2554	245	304	27,8	31,2
AW3	01.01.2006	7	309	2818	409	246	364	32,6
AW30	08.04.1997	7,35	129		248	70,4	48,1	118
AW30	05.12.1997	7,63	126,2	886	256	97,7	62,8	98,1
AW30	14.01.1998	6,6	139	1186	212	126,4	75,2	85,67
AW30	06.02.1998	6,5	166	1318	180	124,2	76,7	80,34
AW30	12.03.1998	6,94	149,3	1178	244	135	85,5	92,5
AW30	08.04.1998	6,5	146	1337	148	173,66	95,11	69,82
AW30	22.05.1998	7,37	151,6	1274	242	146	95,8	87,3
AW30	26.06.1998	6,9	124	1138	274			
AW30	24.07.1998	7,21	149,1	1136	252	128	82,6	78,3
AW30	25.08.1998	8,37	143,3	1224	238	136	89,8	77,9
AW30	15.09.1998	7,01	157,4	1262	232	147	95	72,2
AW30	13.10.1998	7,21	158,3	1284	230	151	99	67,9
AW30	26.11.1998	6,87	163,1	1172	228	132	93	56,7
AW30	13.05.1999	6,72	163,6	1230	228	152	97	70,08
AW30	29.06.1999	6,78	164,3	1250	214	163	102	61,6
AW30	29.06.1999	6,78	164,3	1250	214	163	102	61,6
AW30	26.07.1999	6,68	177,3	1372	212	176	117	60,4
AW30	12.10.1999	7,07	214	1544	210	195	133	64,2
AW30	12.10.1999	7,07	214	1544	210	195	133	64,2
AW30	12.11.1999	6,89	227	1746	192	218	154	54,4
AW30	18.01.2000	4,28	307	2718	2	308	194	37,9
AW30	14.03.2000	3,8	339	3662	0	338	174	40,4
AW30	13.04.2000	4	322	3114	0	294	158	33,4
AW30	13.06.2000	3,94	308	3248	0	317	161	24,9
AW30	13.07.2000	4,08	308	3256	0	321	167	33,6
AW30	27.07.2000	4,06	306	3236	0	224	169	34,4
AW30	06.09.2000	4,23	295	3164	0	343	174	52,9
AW30	04.12.2002	6,23	296	2800	26	291	248	47,7
AW30	01.08.2004	6,28	298	2618	58	287	251	42,3
AW30	01.09.2004	6,31	294	3116	56	320	295	61,8

AW30	01.10.2004	5,71	285	2594	32	275	250	37,8
AW30	01.11.2004	5,54	293	2642	47	300	253	39,1
AW30	01.12.2004	5,94	292	1460	40	311	291	39,7
AW30	01.01.2005	5,95	262	2696	44	252	236	32,4
AW30	01.02.2005	5,61	259	2752	30	285	254	35,4
AW30	01.03.2005	5,26	262	2720	17	280	236	34
AW30	01.04.2005	5,52	260	2618	27	240	234	36,1
AW30	01.05.2005	5,83	287	2660	38	271	241	42,8
AW30	01.06.2005							
AW30	01.07.2005	5,9	261	2840	52	289	260	47,3
AW30	01.08.2005	6	259	2562	61	275	251	46,3
AW30	01.09.2005							
AW30	01.10.2005	5,54	258	2798	45	269	846	34,8
AW30	01.11.2005	5,81	259	2800	48	286	269	38,4
AW30	01.12.2005	5,79	258	2584	58	261	247	33,9
AW30	01.01.2006	5,54	248	2380	72	274	226	30,7
AW31	21.02.1997	6,17	27,6		32	2,6	2,2	25,2
AW31	08.04.1997	6,81	27		54	4,4	5,2	26,6
AW31	26.08.1997	7,2	33,7	220	92	13,3	15,6	32,5
AW31	05.12.1997	8,1	36,4	216	66	15,3	18	22,5
AW31	14.01.1998	6,6	30	177	40	9,16	8,75	28,78
AW31	06.02.1998	5,7	36	218	30	10,74	11,85	31,31
AW31	12.03.1998	6,22	31,8	184	26	10,8	12,7	34,6
AW31	08.04.1998	6,5	63	464	44	36,53	41,58	27,37
AW31	22.05.1998	7,17	19,4	118	44	5,3	6,46	17
AW31	26.06.1998	6,5	23	84	66			
AW31	24.07.1998	6,62	19,8	112	52	4,67	5,34	20,1
AW31	25.08.1998	6,48	19,4	124	64	7,52	3,85	23,6
AW31	15.09.1998	6,31	19,7	130	74	4,72	4,64	22,3
AW31	13.10.1998	6,6	19,6	130	78	4,11	4,5	20
AW31	26.11.1998	6,18	20,2	128	82	4,94	4,73	21,7
AW31	13.05.1999	6,11	19,2	120	60	4,25	3,61	20,08
AW31	29.06.1999	6,11	19,4	104	62	4,23	3,64	19
AW31	29.06.1999	6,11	19,4	104	62	4,23	3,64	19
AW31	26.07.1999	6,47	17,6	118	70	4,32	4,33	20,3
AW31	12.10.1999	6,93	19,1	134	74	5,55	4,12	21,7
AW31	12.11.1999	6,87	18,3	128	78	6,22	3,24	23,9
AW31	18.01.2000	6,53	24,6	156	88	8,57	6,22	25,1
AW31	14.03.2000	5,88	32,5	194	14	10,5	8,55	20,5
AW31	13.04.2000	5,94	25,3	140	14	7,13	5,97	12,8
AW31	13.06.2000	6,38	1261	82	18	2,95	2,58	9,07
AW31	06.07.2000	6,82	9,1	68	12	1,26	1,12	5,99
AW31	27.07.2000	5,93	10,4	72	14	2,02	1,57	5,89
AW31	06.09.2000	6,23	9,8	70	16	2,84	1,84	5,94
AW31	30.01.2002	5,706	20,08	156	20	11,807	4,275	29,418
AW31	04.12.2002	6,79	20,8	152	66	7,84	5,35	18,4
AW31	01.08.2004	6,9	19,02	148	42	4,81	3,1	23,4
AW31	01.09.2004	6,85	18,34	182	54	6,05	2,97	32,9
AW31	01.10.2004	6,52	18,16	190	56	2,11	1,53	20,5

AW31	01.11.2004	6,4	18,69	182	53	4,34	2,8	25,3
AW31	01.12.2004	6,66	22,8	220	42	4,85	5,94	26,9
AW31	01.01.2005	6,81	15,46	108	7	3,82	2,24	17,8
AW31	01.02.2005	6,24	13,32	92	6	2,44	1,03	16,7
AW31	01.03.2005	6	13,18	180	8	3,79	2,53	16,3
AW31	01.04.2005	6,2	10,71	80	6	2,52	1,42	15,9
AW31	01.05.2005	6,3	12,68	124	18	2,6	1,59	17
AW31	01.06.2005							
AW31	01.07.2005	6,87	26,1	250	105	27,1	3	23,1
AW31	01.08.2005	6,5	17,5	148	58	3,81	2,93	23,9
AW31	01.09.2005							
AW31	01.10.2005	6,46	18,06	190	69	4,66	2,66	24,7
AW31	01.11.2005	6,61	18,09	186	68	4,63	3,23	26,1
AW31	01.12.2005	6,42	17,88	184	68	4,03	2,98	23,9
AW32	05.12.1997	7,5	27,2	158	48	17,4	11,7	9,8
AW32	14.01.1998	5,8	237	2388	20	174,2	325,2	28,99
AW32	06.02.1998	5,5	256	2379	22	165,8	247,3	37,99
AW32	12.03.1998	5,73	107,5	804	20	78,9	106	10,7
AW32	08.04.1998	6	253	2391	20	225,92	320,04	27,25
AW32	22.05.1998	6,76	289	2882	28	222	351	26,3
AW32	26.06.1998	6,1	235	2747	30			
AW32	24.07.1998	6,08	311	2748	24	219	356	24,3
AW32	25.08.1998	5,94	288	2782	26	213	330	25,9
AW32	15.09.1998	6,1	286	2414	30	192	286	23,4
AW32	13.10.1998	6,45	232	2202	22	168	257	20,3
AW32	26.11.1998	6,07	239	1870	28	159	232	17,6
AW32	13.05.1999	6,35	254	2016	46	182	265	26
AW32	29.06.1999	6,14	278	2432	28	213	319	21,3
AW32	29.06.1999	6,14	278	2432	28	213	319	21,3
AW32	26.07.1999	5,86	290	2380	26	216	314	21,6
AW32	12.10.1999	6,33	264	2132	24	182	263	22,3
AW32	12.11.1999	6,21	218	1740	26	149	226	17,2
AW32	18.01.2000	5,9	250	2030	24	178	259	17,1
AW32	14.03.2000	6,15	169,2	1396	32	133	180	13,5
AW32	13.04.2000	6,08	217	1678	50	150	207	16,4
AW32	13.06.2000	6,19	236	1944	42	185	262	21,3
AW32	13.07.2000	5,69	290	2512	26	209	325	24
AW32	27.07.2000	5,68	293	2570	26	196	305	28,3
AW32	06.09.2000	5,86	290	2422	28	228	339	29,1
AW32	30.07.2002	6,006	197,7	1899	21	182,615	235,941	37,013
AW32	04.12.2002	6,65	236	2244	26	128	253	19
AW33	14.01.1998	5,3	6	63	4	2,08	1,41	10,4
AW33	06.02.1998	5,3	8	81	4	4,6	3,2	22,1
AW33	12.03.1998	6	6,9	34	6	2,7	1,4	4,4
AW33	08.04.1998	6	8	79	4	2,19	1,32	11,96
AW33	22.05.1998	6,83	5,1	32	2	1,14	1,29	1,59
AW33	26.06.1998	3,4	18	17				
AW33	24.07.1998	5,9	5,1	34	4	1,85	1,46	3,58

AW33	25.08.1998	5,89	9,2	60	14	5,02	1,72	4,67
AW33	15.09.1998	5,45	8,4	52	8	2,32	1,86	3,86
AW33	13.10.1998	5,7	6,3	44	6	1,98	1,02	3,11
AW33	26.11.1998	5,41	10,3	68	8	3,87	2,74	4,45
AW33	13.05.1999	6,04	8,4	52	4	2,08	2,25	2,82
AW33	29.06.1999	5,46	8,6	56	6	2,51	2,71	2,29
AW33	29.06.1999	5,46	8,7	56	6	2,54	2,71	2,29
AW33	12.10.1999	6,5	8,3	58	8	3,23	1,72	4,81
AW33	12.11.1999	6,16	10,9	66	10	4,18	1,84	5,19
AW33	18.01.2000	5,3	14,5	82	4	7,26	3,51	5,09
AW33	14.03.2000	5,19	9,3	56	6	5,23	1,82	3,97
AW33	13.04.2000	5,26	9,5	58	6	5,68	2,44	3,46
AW33	13.06.2000	5,37	13,2	86	6	2,97	3,27	8,33
AW33	13.07.2000	5,36	15,5	92	6	3,43	3,58	8,56
AW33	27.07.2000	5,68	293	2570	26	196	305	28,3
AW33	06.09.2000	5,79	18,7	116	10	5,74	4,73	10,7
AW33	30.07.2002	5,169	34,5	263	6	16,219	10,713	57,873
AW33	04.12.2002	6,35	42,1	246	8	10,2	11,6	40,8
AW35	24.07.1998	7,06	44,2	272	84	31,6	19	13,7
AW35	25.08.1998	6,72	40,6	268	86	31,7	19,8	15,6
AW35	15.09.1998	6,63	41,5	270	90	31,8	19,5	14,9
AW35	13.10.1998	6,93	39,2	256	90	30,1	18,9	14,2
AW35	26.11.1998	6,73	42,4	252	96	33,5	17,6	13,9
AW35	29.06.1999	6,99	36,5	194	142	29,9	16,8	11,1
AW35	29.06.1999	6,99	36,5	194	142	29,9	16,8	11,1
AW35	26.07.1999	6,91	42,9	210	154	32,7	18,4	14,3
AW35	12.10.1999	7,2	44,3	246	128	31,2	19,7	18,8
AW35	12.11.1999	7,15	44,2	240	116	31,3	18,3	17,5
AW35	18.01.2000	6,96	34,4	238	104	32,6	18,1	15,6
AW35	14.03.2000	7,12	42,1	242	140	33,7	17,7	10,3
AW35	04.04.2000	7,69	45,9	270	150	31,4	17,9	9,82
AW35	13.06.2000	7,61	36,8	242	142	31,7	17,1	9,13
AW35	06.07.2000	7,13	41,6	270	108	31,6	18	10,8
AW35	27.07.2000	7,12	46,2	314	82	33	18,1	13,3
AW35	06.09.2000	6,29	80,8	538	24	59,2	27,8	61,8
AW35	30.07.2002	6,421	50,1	398	75	51,366	28,507	149,546
AW35	04.12.2002	6,67	62,5	466	72	44,5	25,8	27,6
AW36	22.05.1998	8,26	95,4	766	120	87,5	55,6	57,8
AW36	26.06.1998	7,1	90	761	112			
AW36	24.07.1998	6,92	156,8	1232	126	166	85,5	51,2
AW36	25.08.1998	6,7	154,3	1332	124	174	89,3	58,7
AW36	15.09.1998	6,78	152,8	1138	130	176	88,1	55,3
AW36	13.10.1998	7,1	142,3	1206	140	163	80,7	48,7
AW36	26.11.1998	7,02	128,9	860	114	113	65,1	43,2
AW36	13.05.1999	7,76	84,9	538	54	37,07	52,01	49,08
AW36	29.06.1999	7,99	92	630	24	52,9	57,5	50,5
AW36	29.06.1999	7,99	92	630	24	52,9	57,5	50,5
AW36	26.07.1999	7,29	108,4	744	70	79,4	63,4	54,5

AW36	12.10.1999	7,43	120,7	832	132	105	64,8	63,2
AW36	12.11.1999	7,88	93,6	538	72	55,8	33,1	61,8
AW36	18.01.2000	7,71	67,6	356	28	34,3	16,2	38,5
AW36	14.03.2000	7,72	67,6	404	20	33,3	28,8	42,9
AW36	13.04.2000	8,37	65,9	394	18	28,4	25,4	37,9
AW36	13.06.2000	8,33	72,3	474	54	36,1	30,5	37,4
AW36	06.07.2000	7,34	95,7	648	168	84,6	40,9	43,6
AW36	27.07.2000	7,1	99,3	676	168	84,2	38,7	50,4
AW36	06.09.2000	7,3	102,4	712	172	106	47,5	61,6
AW37	26.07.1999	7,21	137	1096	178	171	55,2	68,2
AW37	12.10.1999	7,87	183,7	1402	222	267	79,2	87,2
AW37	18.01.2000	8,58	63	334	28	50,7	18,9	18,4
AW37	14.03.2000	10,67	74,3	544	54	154	0,26	11,6
AW37	13.06.2000	8,15	69,4	454	52	81,1	20	14,4
AW38	15.09.1998	6,93	24,5	136	96	17,6	9,93	11,9
AW38	13.10.1998	7,39	29,1	168	120	22,3	13,8	11,7
AW38	26.11.1998	7,03	29,7	144	112	21,4	12,4	10,3
AW38	13.05.1999	7,09	24	116	78	15,05	8,72	12,9
AW38	29.06.1999	7,03	23,9	118	84	15,5	9,3	12,1
AW38	29.06.1999	7,03	23,9	118	84	15,5	9,3	12,1
AW38	26.07.1999	7,1	29,7	156	100	20,2	13,3	15,3
AW38	12.10.1999	7,91	31,7	174	112	24,7	14,3	17,1
AW38	12.11.1999	7,58	30	162	106	22,3	11,7	16,3
AW38	13.04.2000	8,1	33,1	180	90	19,4	16,2	12,4
AW38	13.06.2000	7,72	30	162	84	18,7	12,9	9,88
AW38	13.07.2000	6,86	29,4	160	82	18,7	12,4	10,8
AW38	27.07.2000	7,38	29,3	170	82	17,4	14	12,3
AW38	06.09.2000	8,04	26,9	146	84	20,2	11	11,6
AW38	30.07.2002	7,505	32,2	236	134	21,068	15,27	34,056
AW38	04.12.2002	7,24	31,4	182	132	23,5	15,7	13,7
AW4	21.08.1990	8,32	25	175	137	25	9	18
AW4	21.08.1990	8,23	25	175	136	25	10	17
AW4	22.10.1990	8,45	30	210	140	36	11	22
AW4	22.10.1990	8,29	26	182	132	33	8	21
AW4	31.03.1991	8,23	25	238		25	10	17
AW4	21.08.1991	8,32	25	175	137	25	9	18
AW4	21.08.1991	8,32	25	175	136	25	10	17
AW4	22.10.1991	8,45	30	210	140	36	11	22
AW4	22.10.1991	8,29	26	182	132	33	8	21
AW4	31.01.1992	7,3	190,1	2040		236,2	194,4	55,8
AW4	31.03.1992	7,91	31,6	216	42,8	32,8	10,7	14
AW4	30.09.1992	7,3	42	3	85	21	5,4	25
AW4	10.03.1993	7	138	1095	92	118,7	74,4	57,9
AW4	04.04.1993	7,1	104	762	88	78,9	49	52,3
AW4	26.05.1993	7	151		100	135	94,4	71,6
AW4	02.09.1993	6,9	165		110	133,2	103,1	65,3
AW4	24.03.1994	7,6	120		190	86,5	76,5	52,4

AW4	23.06.1994	7,7	19		66	4,1	9,3	15,8
AW4	12.08.1994	7,5	92		126	68,8	59	37,8
AW4	13.10.1994	7	92		108	60,8	59,2	39,4
AW4	25.11.1994	6,3	93		144	85,9	76,4	49,6
AW4	05.01.1995	7,2	151		170	147,7	97,2	69,9
AW4	02.02.1995	6,9	188		224	146,6	121,7	77,4
AW4	13.03.1995	6,4	106,9		156	87,8	67,4	51
AW4	28.07.1995	7,78	97,2	640	136	75,6	60,2	43,2
AW4	31.08.1995	7,74	94,3	638	136	74,1	54,3	39,8
AW4	29.09.1995	7,84	29,9	192	62	20,8	11,8	18,3
AW4	18.10.1995	7,7	28,8	162	74	19	11	17
AW4	30.11.1995	7,8	29,7	166	88	16,3	11,4	19,2
AW4	22.12.1995	7,63	22,8	122	70	11,3	6,8	11,5
AW4	04.01.1996	7,73	58,8	354	78	40,8	21,9	21,2
AW4	10.05.1996	7,14	32,4		66	19,3	11,6	18,1
AW4	24.07.1996	7,61	32		82	20,6	11,5	16,8
AW4	14.10.1996	7,34	33,3		70	19,2	12,4	15,2
AW4	09.12.1996	7,76	27,4		76	17,8	10,4	14,2
AW4	08.04.1997	7,43	36,3		82	27,1	11,8	17,1
AW4	26.08.1997	8,24	28,9	160	80	18,4	10,6	19,5
AW4	02.12.1997	7,73	25,8	158	76	17,9	9,6	16,3
AW4	15.01.1998	7,3	36	255	88	29,89	15,34	23,78
AW4	06.02.1998	6,8	34	256	74	24,23	12,19	25,18
AW4	12.03.1998	8,01	24,7	174	88	21,1	12,6	15,7
AW4	08.04.1998	7,6	32	239	86	20,98	9,33	18,97
AW4	22.05.1998	7,71	20,9	126	70	22,7	12,8	7,12
AW4	28.05.1998	5,7	8	67	8	1,97	1,45	10,14
AW4	26.06.1998	7	26	96	78			
AW4	24.07.1998	7,7	21,4	132	70	19,5	6,77	12,8
AW4	25.08.1998	7,52	22,4	138	72	15,8	8,86	14,6
AW4	15.09.1998	7,62	22,2	136	74	15,5	7,77	15,1
AW4	13.10.1998	7,58	21,2	130	68	14,1	7,1	12,3
AW4	26.11.1998	7,51	25	136	86	17,3	8,36	13,7
AW4	13.05.1999	7,4	19,1	114	72	15,1	9,41	6,49
AW4	29.06.1999	7,16	19,2	106	68	14,3	5,91	10,5
AW4	29.06.1999	7,16	19,2	106	68	14,3	5,91	10,5
AW4	26.07.1999	7,47	19,2	98	70	13,7	6,01	10,6
AW4	12.11.1999	7,97	19,8	106	72	13,8	5,83	12,3
AW4	13.04.2000	7,6	19	104	58	13,9	5,63	7,88
AW4	13.06.2000	7,77	17,1	96	54	13,9	4,75	6,73
AW4	06.07.2000	8,07	1832	98	54	13,1	5,42	8,38
AW4	27.07.2000	8,09	17,9	102	54	12,5	5,14	8,23
AW4	06.09.2000	8,29	19,7	114	60	14,2	6,56	8,65
AW4	30.01.2002	6,912	17,77	92	64	18,126	5,025	25,334
AW4	04.12.2002	8,21	17,8	130	58	14,9	4,69	9,04
AW4	04.06.2004	7,89	19,71	152	64	12,2	5,85	15,7
AW4	04.08.2004	8,25	18,28	140	68	11,4	4,42	13,1
AW4	04.09.2004	7,98	17,41	152	70	11,5	4,58	16,7
AW4	04.10.2004	7,68	17,75	148	66	11,02	4,44	14
AW4	04.11.2004	7,62	23,4	178	72	14,1	8,06	16,1

AW4	04.12.2004	7,61	19,32	124	75	11,9	4,93	15,5
AW4	01.01.2005	7,31	25,5	212	87	21,2	8,17	12,7
AW4	01.02.2005	7,82	20	172	81	13,9	4,83	15
AW4	01.03.2005	7,55	20,7	172	83	15,2	6,83	15,2
AW4	01.04.2005	7,69	18,78	168	79	13,5	5,37	16,5
AW4	01.05.2005	7,64	18,9	196	96	13,8	5,9	15,3
AW4	01.07.2005	7,72	19,88	162	76	13,9	6,58	15,9
AW4	01.08.2005	7,76	19,8	170	98	16,8	6,99	15,5
AW4	01.10.2005	7,85	18,16	194	92	15,1	6,64	16,2
AW4	01.11.2005	7,75	18,01	158	75	12,4	5,37	14,6
AW4	01.12.2005	7,54	17,45	158	80	13,1	4,73	14
AW4	01.01.2006	7	19,12	166	50	15,2	5,79	8,54
AW5	21.08.1990	6,68	9	63	18	12	7	15
AW5	21.08.1990	6,18	9	63	7	11	9	16
AW5	21.08.1990	6,44	10	70	7	9	6	13
AW5	22.10.1990	6,48	15	175	8	16	11	18
AW5	22.10.1990	6,69	26	175	11	17	12	18
AW5	22.10.1990	6,69	26	182	23	20	12	17
AW5	31.03.1991	2,8	6,4	110		58	9	6
AW5	21.08.1991	6,18	9	63	7	11	9	16
AW5	21.08.1991	6,69	26	182	23	20	12	17
AW5	21.08.1991	6,68	9	63	18	12	7	15
AW5	21.08.1991	6,44	10	70	7	9	6	13
AW5	22.10.1991	6,48	25	175	11	17	12	18
AW5	22.10.1991	6,56	25	175	8	16	11	18
AW5	31.01.1992	6,85	11	204		6,4	2,9	7
AW5	30.06.1992	7,2	12,8	106	499,6	10,4	1,9	7
AW5	30.09.1992	7,2	12,9	107	499,6	10,4	1,9	7
AW5	10.03.1993	4,9	29	205		17,2	9,5	17,8
AW5	26.05.1993	5,6	10		10	5,3	1,9	10
AW5	02.09.1993	6,5	11		10	5,8	4,8	10,8
AW5	30.11.1993	6,3	21		18	16,7	5,77	10,4
AW5	24.03.1994	7,9	3		32	14,7	16,2	13
AW5	23.06.1994	6,1	66		10	44,8	42	28,9
AW5	12.08.1994	7,4	46		14	38,8	29,4	18
AW5	13.10.1994	7,1	13		22	5,5	4,9	5
AW5	25.11.1994	6,4	19		20	14,8	7,2	15,9
AW5	05.01.1995	5,9	29		22	121,7	12,3	15,9
AW5	02.02.1995	5,6	31		20	18,2	13,7	14,9
AW5	13.03.1995	6,41	17,2		38	6,4	5	8,7
AW5	28.07.1995	6,75	44	266	44	32,3	21,3	16,9
AW5	31.08.1995	6,92	40,6	252	34	22,7	19,1	16,6
AW5	29.09.1995	6,91	41,6	276	32	25,8	20,9	17,8
AW5	18.10.1995	6,41	35,8	230	22	19,8	16,9	15
AW5	30.11.1995	7,16	17,4	98	20	10,3	4	6,9
AW5	22.12.1995	7,25	17	94	18	7,9	5,9	5,2
AW5	04.01.1996	6,49	10	62	8	5,4	2,5	4,7
AW5	10.05.1996	6,48	8,5		6	3,6	1,9	5,4
AW5	24.07.1996	7,14	22,3		18	11,8	8,3	10,5

AW5	14.10.1996	7,5	51,6		46	28,2	22,1	22,9
AW5	09.12.1996	6,99	15,9		24	3,1	4	5,4
AW5	26.08.1997	8,15	137,9	1036	278	102	85,8	78,6
AW5	02.12.1997	6,51	14,8	78	14	7,69	5,81	4,74
AW5	15.01.1998	7,4	19	186	40	16,09	10,19	11,8
AW5	06.02.1998	6,7	16	133	12	8,39	5,54	15,68
AW5	12.03.1998	6,28	23,4	156	18	14,3	9,1	5,8
AW5	08.04.1998	6,6	23	227	20	15,93	9,06	14,24
AW5	22.05.1998	6,81	36,1	242	42	31,4	22,1	8,44
AW5	28.05.1998	5	47	424	4	38,71	28,31	17,75
AW5	26.06.1998	6,5	55	465	70			
AW5	24.07.1998	6,97	76,4	526	40	44,8	36,4	43,4
AW5	25.08.1998	6,61	80	566	50	50,6	42,4	53,3
AW5	15.09.1998	6,66	81,6	602	46	59,4	43,9	56,1
AW5	13.10.1998	6,91	80,9	592	44	58,2	43,1	48,5
AW5	26.11.1998	6,44	78,8	520	36	53,4	42	38,2
AW5	13.05.1999	6,51	30,6	164	36	21,2	9,6	7,44
AW5	29.06.1999	6,1	38,5	224	42	22,8	16,9	17,6
AW5	29.06.1999	6,1	38,5	224	42	22,8	16,9	17,6
AW5	26.07.1999	6,53	47,1	270	48	25,4	19,1	24,7
AW5	12.10.1999	6,8	51,7	314	38	28,2	22	26,4
AW5	12.11.1999	6,8	49,5	292	26	27,4	21,5	24,6
AW5	18.01.2000	6,28	11,8	66	12	7,64	3,19	5,46
AW5	14.03.2000	6,35	10,6	60	14	6,43	2,97	4,12
AW5	13.04.2000	6,88	11,4	58	12	5,61	2,89	4,25
AW5	13.06.2000	7,23	11,4	74	24	6,63	4,98	5,42
AW5	13.07.2000	6,33	11,7	70	22	6,04	3,7	5,2
AW5	27.07.2000	7,76	12,5	78	26	6,74	4,15	5,49
AW5	06.09.2000	7,16	15,5	94	32	3,94	9,69	9,69
AW5	04.12.2002	7,02	68,1	496	32	42,1	36,2	28,9
AW5	01.12.2003	6,68	62,9	480	49,2	28,3	48,4	4,18
AW5	01.01.2004	5,6	21	144	2	11,7	10,02	12
AW5	01.02.2004	6,77	12,24	64	8	7,58	1,89	5,97
AW5	01.03.2004	7,04	14,74	82	18	9,36	2,26	8,06
AW5	01.04.2004	7,59	12,43	72	28	7,41	2,24	10,4
AW5	01.05.2004	7,19	22,7	128	34	10,6	5,45	17,3
AW5	01.06.2004	7,28	49,3	322	60	25,1	19	44,7
AW5	01.07.2004							
AW5	01.08.2004	7,61	68,2	434	86	31,4	23,7	62,6
AW5	01.09.2004	7,55	65,9	452	90	32,7	24,8	74,6
AW5	01.10.2004	7,38	56,8	354	82	22,2	16,8	60,1
AW5	01.11.2004	6,33	4,36	26	5	2,45	0,15	0,98
AW5	01.12.2004	6,46	6,28	38	3	2,13	0,5	2,51
AW5	01.01.2005	7,54	7,62	50	11	8,81	1,49	1,56
AW5	01.02.2005	6,86	6,62	44	8	6,56	0,24	2,09
AW5	01.03.2005	7,13	8,52	56	26	6,9	2,09	6,96
AW5	01.04.2005	7,21	9,14	50	25	5,09	0,82	7,92
AW5	01.05.2005	7,65	9,97	58	27	4,82	1,11	11,1
AW5	01.06.2005							
AW5	01.07.2005	7,76	11,87	68	45	5,51	1,97	15,6

AW5	01.08.2005	7,89	11,5	72	44	5,13	2,54	14,7
AW5	01.09.2005							
AW5	01.10.2005	7,61	10,25	70	40	5,27	2,5	13,4
AW5	01.11.2005	7,21	9,85	62	30	4,94	1,85	8,37
AW5	01.12.2005	7,24	9,48	58	36	4,56	1,68	9,5
AW5	01.01.2006	5,3	8,07	42	7	4,71	1,83	4,4
AW6	21.08.1990	6,86	68	476	11	60	47	24
AW6	21.08.1990	7,05	67	469	12	59	46	24
AW6	22.10.1990	6,73	49	343	21	38	30	25
AW6	22.10.1990	6,81	48	336	23	34	27	25
AW6	30.03.1991	6,86	68	552		60	47	24
AW6	21.08.1991	6,86	68	476		60	47	24
AW6	21.08.1991	7,05	67	469		59	46	24
AW6	22.10.1991	6,81	48	336		34	27	25
AW6	22.10.1991	6,73	49	343		38	30	25
AW6	31.01.1992	6,85	11	204		6,4	2,9	7
AW6	30.06.1992	6,76	10,7	90	579,6	4,8	3,4	7,5
AW6	10.03.1993	6,6	112	880	20	96,1	66,6	32,6
AW6	04.04.1993	6,7	40	230	18	17,5	15,6	17,1
AW6	26.05.1993	6,3	23		20	12,6	8,7	12,6
AW6	02.09.1993	6,7	348		118	162,1	380,1	50,4
AW6	05.01.1995	5,9	13		18	4,9	4,4	11,1
AW6	02.02.1995	6,4	22		62	21	6,2	12,1
AW6	13.03.1995	6,43	10,6		22	2,7	2,1	5,7
AW6	29.09.1995	7,37	8,6	68	26	5,1	2,8	8
AW6	18.10.1995	6,86	7,2	52	24	3	1,8	5,8
AW6	30.11.1995	7,14	21,3	140	26	9,6	9,4	10
AW6	22.12.1995	6,63	64,5	376	34	37,8	39	11,8
AW6	04.01.1996	6,7	54,6	348	20	32,4	32	17,1
AW6	10.05.1996	6,57	49		36	30,2	24,9	15,9
AW6	24.07.1996	7,11	44,8		22	26,2	23,4	14,5
AW6	14.10.1996	7,1	73,5		48	38,9	33,8	41,3
AW6	09.12.1996	6,7	31,6		24	19,7	16,3	9,3
AW6	08.04.1997	6,72	34,9		12	21,4	14,99	9,6
AW6	22.05.1998	6,16	19,1	138	20	17,9	13,2	3,24
AW6	28.05.1998	5,6	47	417	6	36,5	27,35	15,11
AW6	26.06.1998	5,8	18	125	6			
AW6	24.07.1998	6,04	21,1	132	6	10,5	12,1	6,98
AW6	25.08.1998	6,78	20,1	130	14	9,39	11,4	9,1
AW6	15.09.1998	6,62	15,9	104	16	6,53	6,72	8,54
AW6	13.10.1998	6,79	19	128	16	8,93	9,77	7,86
AW6	13.05.1999	6,13	15,7	84	12	9,58	6,86	3,52
AW6	29.06.1999	6,06	14,3	74	12	6,49	5,5	5,82
AW6	29.06.1999	6,06	14,3	74	12	6,49	5,5	5,82
AW6	26.07.1999	6,41	13,7	78	12	6,29	5,17	5,97
AW6	12.10.1999	7,22	10,7	58	16	6,47	3,28	5,52
AW6	12.11.1999	7,09	10,3	50	12	5,26	2,93	3,76
AW6	27.07.2000	7,24	15,5	72	14	7,77	6,38	1,99
AW6	06.09.2000	6,74	15,3	88	16	9,73	6,73	2,68

AW6	04.12.2002	7,17	20,4	144	32	10,5	9,72	5,94
AW6	01.05.2004	6,33	18,84	102	8	11,6	7,24	5,85
AW6	01.06.2004	6,61	17,66	102	8	9,23	7,43	6,63
AW6	01.08.2004	7,1	15,87	96	14	7,23	6,01	7,6
AW6	01.09.2004	7,21	17,27	134	22	9,23	7,44	8,87
AW6	01.10.2004	6,92	17,71	112	22	7,84	6,3	6,67
AW6	01.07.2005	7,11	11,22	92	24	5,68	3,78	6,44
AW6	01.08.2005	7,58	11,7	74	31	7,13	4,17	5,72
AW6	01.09.2005							
AW6	01.10.2005	7,53	13,91	96	40	7,74	5,03	5,76
AW6	01.11.2005							
AW6	01.12.2005	7,57	12,86	110	69,9	6,78	5,4	6,33
AW7	30.01.1992	7,59	64	364		58,5	29,6	29
AW7	30.06.1992	7,73	35,5	186	36,4	37,6	12,6	14,3
AW7	30.09.1992	7,2	43	204	40	31	12,2	24
AW7	22.02.1993	7,1	64	449	118	51,2	28,6	27,2
AW7	10.03.1993	7,1	64	449	120	51,2	28,6	27,2
AW7	26.05.1993	7,5	39	0	158	35,4	13,9	16,9
AW7	02.09.1993	7,3	42		146	30,8	15,5	16,3
AW7	30.11.1993	6,3	34		178	28,8	10,71	18,3
AW7	24.03.1994	7,8	39		188	30,3	17,2	18,4
AW7	23.06.1994	7,4	42		216	25,4	20,7	18,9
AW7	12.08.1994	7,2	48		192	38,7	23,1	20
AW7	13.10.1994	6,9	38		182	24,5	18	11,4
AW7	25.11.1994	7,1	40		198	30,1	15,7	19,1
AW7	12.01.1995	7,1	45		172	31,7	20,1	17,9
AW7	23.02.1995	7,3	47		196	32	18,6	20,8
AW7	24.03.1995	8,06	43,2	270	214	35,8	18	15,6
AW7	19.05.1995	7,48	42,6	264	210	35,2	18,2	14,7
AW7	01.08.1995	7,91	45	288	210	34,7	21,4	16,6
AW7	31.08.1995	7,87	50,8	320	202	42,8	24,2	17,8
AW7	29.09.1995	7,93	43,2	282	212	35,4	22,9	18,6
AW7	18.10.1995	7,7	41,3	248	202	33,6	17,2	13,5
AW7	30.11.1995	7,74	44,4	242	210	32,2	17,9	16
AW7	22.12.1995	8,16	41,8	254	202	34,8	17,7	11,1
AW7	04.01.1996	7,68	109	760	264	76,1	55,4	62,5
AW7	04.01.1996	7,74	61,9	350	94	36,1	35,2	25,6
AW7	10.05.1996	7,42	57,2		132	31,7	25,9	24,8
AW7	24.07.1996	8,01	47,8		156	27,4	24,3	21,1
AW7	14.10.1996	7,78	40,1		174	22,4	18,7	18,7
AW7	09.12.1996	8,03	47,9		208	27,7	23,9	19,6
AW7	08.04.1997	7,94	41		156	25,8	20,8	18,8
AW7	26.08.1997	8,37	36,3	208	156	24,3	19,5	24,3
AW7	02.12.1997	7,96	47	286	190	32,9	29,6	19,9
AW7	14.01.1998	7,4	31	227	192	21,85	19,27	21,14
AW7	06.02.1998	6,8	37	243	180	20,53	16,78	21,76
AW7	12.03.1998	8,13	34,7	212	178	25	19,4	15,3
AW7	08.04.1998	7,6	36	236	140	29,95	20,97	11,15
AW7	22.05.1998	7,76	37,1	216	198	35,1	23,2	9,36

AW7	28.05.1998	5,7	44	409	6	36,93	25,88	15,1
AW7	26.06.1998	7,6	31	188	186			
AW7	24.07.1998	8,27	41,6	236	200	27,4	22,9	17,5
AW7	25.08.1998	8,23	48	294	200	31,5	27,6	19,1
AW7	15.09.1998	8,14	55,3	358	210	40,7	34,3	21,4
AW7	13.10.1998	8,03	61,5	398	214	44,3	36,9	21,3
AW7	26.11.1998	7,92	65,1	390	214	49,3	40,1	19,4
AW7	13.05.1999	7,73	75,2	576	228	94,1	53,6	14,1
AW7	29.06.1999	7,71	89,9	560	244	69	60,3	21,9
AW7	29.06.1999	7,71	89,9	560	244	69	60,3	21,9
AW7	26.07.1999	7,97	101,2	674	246	79,2	70	30,6
AW7	12.10.1999	7,92	122	814	210	92	87,1	40,1
AW7	12.11.1999	7,77	129,7	850	196	92	96,4	38,8
AW7	18.01.2000	7,64	133,1	880	152	92,6	97,6	32
AW7	14.03.2000	7,33	111,5	774	90	71,5	104	17,5
AW7	13.04.2000	7	94	706	36	42,4	87,1	15,2
AW7	13.06.2000	7,52	77	504	56	36,4	58,7	14,8
AW7	06.07.2000	8,31	78,1	510	78	40,4	66	16,9
AW7	27.07.2000	7,88	74,4	496	76	39,1	57,5	14,4
AW7	06.09.2000	8,29	72,3	490	88	45,4	55,3	16,9
AW7	30.01.2002	6,524	305,3	2546	56	237,025	308,031	112,909
AW7	04.12.2002	7,15	179,5	1662	28	98,4	170	56,9
AW7	01.12.2003	6,5	276	2706	88	226	253	111
AW7	01.01.2004	6,86	390	2822	130	328	375	120
AW7	01.02.2004	6,6	366	3476	108	275	347	140
AW7	01.03.2004	6,98	233	2130	68	203	199	75,6
AW7	01.04.2004	6,39	304	3136	30	269	313	121
AW7	01.05.2004	6,77	202	1606	40	128	170	89,6
AW7	01.06.2004	7,86	199,7	1728	86	170	161	64
AW7	01.07.2004							
AW7	01.08.2004	8,11	154	1170	92	120	109	45
AW7	01.09.2004	7	111,5	898	28	102	76,9	40
AW7	01.10.2004	6,71	106,2	696	40	75,9	52,6	37,9
AW7	01.11.2004	7,56	136,2	890	147	100	87,1	40,2
AW7	01.12.2004	7,67	109,2	788	103	93	68,3	44,3
AW7	01.01.2005	8,22	41,7	272	104	31,4	17,4	11,9
AW7	01.02.2005	7,45	103	742	173	79,5	70,7	37,5
AW7	01.03.2005	5,47	133	986	124	83,9	96,2	48,7
AW7	01.04.2005	7,13	138	1050	80	74,9	117	66,5
AW7	01.05.2005	7,34	142,5	1060	79	67,2	125	65
AW7	01.06.2005							
AW7	01.07.2005	7,69	69,7	544	99	46	46	30
AW7	01.08.2005	7,51	95,9	772	129	68	68,7	30,6
AW7	01.09.2005							
AW7	01.10.2005	7,59	95,8	704	137	74,3	67,2	30,4
AW7	01.11.2005	7,48	100,3	772	108	58	78,8	39,5
AW7	01.12.2005	7,49	99,7	852	99	47,5	75,7	39,7
AW7	01.01.2006	7,3	98,6	660	114	49,8	77,5	45,3
AW8	30.01.1992	7,51	25,7	184		20	8,3	24,7

AW8	30.06.1992	6,42	225	2094	114,8	204	165	102
AW8	30.09.1992	6,3	194	1533	43	136	132	79
AW8	22.02.1993	6,2	133	1099	96	87,4	95,5	64,6
AW8	10.03.1993	6,2	133	1099	24	87,4	95,5	64,6
AW8	26.05.1993	6,8	129		56	87,5	83,5	62,5
AW8	02.09.1993	6,8	103		50	79	67,9	49,4
AW8	30.11.1993	6,4	101		50	69,6	69,8	52,5
AW8	24.03.1994	7,5	124		58	78,9	91,9	48,3
AW8	23.06.1994	6,8	153		40	143,5	138,6	57,9
AW8	12.08.1994	7,1	127		40	94,6	90,8	47,3
AW8	13.10.1994	6,6	104		42	83,5	69	55,2
AW8	25.11.1994	6,9	91		54	64,2	67,2	56,7
AW8	12.01.1995	6,7	94		56	64	72,7	58,2
AW8	23.02.1995	6,8	114		104	46,7	52,6	101,2
AW8	24.03.1995	7,22	96,8	638	94	59,1	58,7	50,7
AW8	19.05.1995	7,28	81,8	518	100	43,4	47,3	43,8
AW8	01.08.1995	7,73	110,5	672	178	62,7	66,7	58
AW8	31.08.1995	7,84	54,5	342	162	31,4	25,2	21,6
AW8	29.09.1995	7,83	87,3	587	158	52,9	51,7	46,8
AW8	18.10.1995	7,73	87,8	596	166	51,5	49,6	46,7
AW8	30.11.1995	7,66	114	756	172	65,9	60,6	56,9
AW8	22.12.1995	7,98	60	332	114	30,9	32	19,7
AW8	10.05.1996	7,71	111,3		112	67,3	72,8	44
AW8	24.07.1996	7,77	154,7		124	96,3	105	64,5
AW8	14.10.1996	8,1	127,2		102	78,6	96,7	38,7
AW8	09.12.1996	7,62	134,4		110	82,1	92	51,6
AW8	08.04.1997	7,79	139,5		104	85	108	48
AW8	26.08.1997	7,96	105,3	722	48	59	87	44,3
AW8	02.12.1997	7,33	180,9	1482	210	135	144	106
AW8	14.01.1998	7,4	97	856	90	69,15	81,78	43,88
AW8	06.02.1998	6,7	86	678	66	46,91	57,84	29,71
AW8	12.03.1998	7,29	105,1	874	68	75,1	103	41,9
AW8	08.04.1998	7,1	116	988	70	86,41	100,68	34,83
AW8	22.05.1998	7,54	119,4	1022	80	67,5	149	26
AW8	28.05.1998	5,8	41	372	6	33,91	25,29	14,71
AW8	26.06.1998	7,5	96	929	88			
AW8	24.07.1998	7,88	117,8	850	74	55,9	98,3	45,6
AW8	25.08.1998	7,56	113,3	868	76	53,5	97,6	52,2
AW8	15.09.1998	8,06	108,7	846	76	51	94,6	50,1
AW8	13.10.1998	8,02	94,8	724	76	47,3	86,9	37,6
AW8	26.11.1998	7,83	92,2	648	70	43	79,7	31,6
AW8	13.05.1999	7,78	127,5	904	53	88,1	112	24,4
AW8	29.06.1999	7,66	115,3	786	40	44,8	108	33,4
AW8	29.06.1999	7,66	115,3	786	40	44,8	108	33,4
AW8	26.07.1999	7,94	107,2	772	40	43,8	101	36
AW8	12.10.1999	7,66	101,7	776	46	43,2	94,5	55,3
AW8	12.11.1999	7,74	96,8	630	50	32,3	75,6	46,1
AW8	18.01.2000	7,5	87,2	586	58	35	68,9	24,2
AW8	14.03.2000	7,41	91,7	640	58	45,9	85,1	20,9
AW8	13.04.2000	7,21	67,9	504	62	29,7	56,5	13,2

AW9	14.10.1996	6,69	37,5			42	29,2	15,1	9
AW9	09.12.1996	6,86	52,4			24	44,3	22,2	9,8
AW9	08.04.1997	6,58	105,4			8	99,9	51,8	16,7
AW9	26.08.1997	6,65	164,1	1344		30	199	98,1	28,9
AW9	02.12.1997	6,86	76,9	564		34	94,5	43,3	14,9
AW9	14.01.1998	7,6	10	63		36	5,76	3	11,77
AW9	06.02.1998	6,2	136	1194		18	170,1	62,2	22,07
AW9	12.03.1998	6,51	146	1242		26	190	89,8	17,8
AW9	08.04.1998	6,3	140	1255		26	227,68	83,61	21,82
AW9	22.05.1998	6,33	149,4	1406		28	201	97,9	16,9
AW9	28.05.1998	6	39	353		12	30,02	23,03	14,29
AW9	26.06.1998	6,4	139	1568		24			
AW9	24.07.1998	7,14	193,5	1674		60	250	128	19,8
AW9	25.08.1998	7,16	242	2294		72	348	158	26,4
AW9	15.09.1998	7,25	251	2282		74	358	169	27,9
AW9	13.10.1998	7,15	255	2396		68	362	174	28,3
AW9	26.11.1998	6,79	264	2344		48	387	177	24,2
AW9	13.05.1999	7,13	276	2330		44	372	196	15,7
AW9	29.06.1999	6,86	277	2352		43	388	193	23,1
AW9	29.06.1999	6,86	277	2352		43	388	193	23,9
AW9	26.07.1999	7,09	288	1816		34	395	189	27,3
AW9	12.10.1999	6,97	290	2526		34	408	207	31,5
AW9	12.11.1999	6,96	291	2378		36	394	190	27,2
AW9	18.01.2000	7,25	26,9	132		52	24,4	8,78	4,05
AW9	14.03.2000	7,29	16,1	100		44	14,7	3,99	3,22
AW9	13.04.2000	7,11	16,2	112		50	14,3	4,9	3,59
AW9	13.06.2000	6,49	215	1674		22	280	128	16,1
AW9	06.07.2000	6,7	299	1784		16	309	139	22,2
AW9	27.07.2000	6,55	234	1856		26	322	143	21
AW9	06.09.2000	6,26	253	2036		20	358	165	28,1
AW9	30.01.2002	4,788	312,4	2927		2	416,79	168,28	41,71
AW9	04.12.2002	5,62	260	2512		10	355	155	21,3
AW9	01.08.2004	5,21	213	1790		5	252	113	19
AW9	01.09.2004	5,57	210	2006		6	288	115	28,1
AW9	01.10.2004	4,12	217	1998	Nil		273	112	19,5
AW9	01.11.2004	7,34	132,3	1020		22	179	69,3	15,2
AW9	01.12.2004	3,68	212	2024	Nil		271	120	18,3
AW9	01.01.2005	7,7	16,44	94		51	12	6,82	3,97
AW9	01.02.2005	7,27	42,9	282		28	41,8	22,1	6,29
AW9	01.03.2005	7,29	21,5	134		37	15,9	12	5,31
AW9	01.04.2005	7,48	22,5	142		43	19,9	12,1	4,47
AW9	01.05.2005	6,04	143,1	1132		20	152	72	8,8
AW9	01.06.2005								
AW9	01.07.2005	7,04	45,9	314		45	43,7	28,2	6,57
AW9	01.08.2005	3,57	221	222		23	208	90,3	13,5
AW9	01.09.2005								
AW9	01.10.2005	5,33	224	2280		6	198	89,1	12,9
AW9	01.11.2005	5,27	242	2712		5	208	96,6	14,6
AW9	01.12.2005	5,48	250	2758		9	198	92,9	13,6
AW9	01.01.2006	7,26	20,2	132		70	15,7	10,8	4,79

ted Chemical Parameters for AW10