

Contents

Executive summary	iii
Acknowledgments	xiii
1 Introduction	1
2 Previous work	3
3 Field work	7
3.1 Introduction	7
3.2 Sediment sampling	8
<i>Introduction</i>	8
<i>Drilling</i>	8
<i>Auger and grab samples</i>	8
3.3 Hydrogeology	15
<i>Groundwater monitoring network</i>	15
<i>Piezometer design, construction and installation</i>	15
<i>Piezometer monitoring</i>	17
<i>Groundwater and surface-water sampling and field analysis</i>	17
<i>Field analytical procedures</i>	25
4 Laboratory analytical work	25
4.1 Water chemistry	25
4.2 Sediment chemistry and mineralogy	25
<i>Preparation procedures</i>	25
<i>Bulk chemical analysis</i>	25
<i>Microscopy</i>	29
<i>XRD</i>	29
<i>Electron microprobe analysis</i>	29
<i>In Lens Field Emission SEM</i>	29
<i>Leach tests</i>	30
5 Results	30
5.1 General	30
<i>Morphology and geology of the delta</i>	31
<i>Morphology and geology of river banks</i>	33
<i>King River – bottom sediments</i>	34
<i>Microbial activity</i>	34
<i>Pyrite oxidation rate</i>	37

5.2 Hydrology	38
5.3 Dimensions of tailings deposits	38
5.4 Analytical data	40
<i>Hydrogeochemistry</i>	40
<i>Acid generation</i>	48
<i>Sediment mineralogy and mineral chemistry</i>	49
<i>Leach tests</i>	59
<i>Sources of metals in groundwater</i>	71
6 Modelling	76
6.1 Hydrogeology	76
<i>Parameters for groundwater flow modelling</i>	76
<i>Approaches to modelling</i>	80
<i>Darcy flow modelling</i>	80
<i>Two-dimensional steady-state groundwater flow and solute transport modelling</i>	81
<i>Conclusions from hydrogeological modelling</i>	91
6.2 Geochemistry	92
<i>Introduction</i>	92
<i>Quality of the analytical data for groundwater samples</i>	93
<i>Predominant aqueous species</i>	93
<i>Mineral saturation states</i>	95
<i>Controls on groundwater composition</i>	96
7 Discussion	97
7.1 Acid production	97
7.2 Current impact of tailings on water quality	98
<i>Metal and acid fluxes from groundwater discharge</i>	98
<i>Metal and acid fluxes from surface runoff</i>	99
<i>Conclusions on metal and acid fluxes</i>	101
7.3 Predicted impact of tailings on water quality	101
7.4 Predicted impact of severe drought	102
7.5 Predicted impact of physical disturbance	102
<i>General</i>	102
<i>Erosion</i>	102
7.6 Acid neutralisation	103
7.7 Implications of study for revegetation	103

7.8 Potential remedial measures	104
<i>Sediment banks</i>	104
<i>Delta</i>	104
7.9 Considerations for future work	105
8 Conclusions	106
9 Recommendations	108
Appendixes	
Appendix 1 Sediment sample description and locations	112
Appendix 2 Geological logs of drillholes DEL-C1 and R-C1	119
Appendix 3 Spectra from XRD analysis*	
Appendix 4 Analytical data from microprobe analysis*	
Appendix 5 Spectra from IFESEM analysis*	
Appendix 6 Hydrogeological modelling*	
Appendix 7 Geochemical modelling*	
Appendix 8 Bibliography*	
References	121

Note: Appendixes 3 to 8 are not published with this report, but can be requested from **eriss.*

Plates

Plate 1	View from the north-west margin of the south lobe of the delta	9
Plate 2	View of the downstream end of Bank N, looking down river	9
Plate 3	View of Bank H, looking downstream	10
Plate 4	View of Bank D, looking upstream	10
Plate 5	View of the installation of DEL-C1 on the north lobe of the delta	32
Plate 6	Vertical profile through part of the unsaturated zone in Bank H	32
Plate 7	Typical surface expression of foresets on the south lobe of the delta	35
Plate 8	View looking up the King River on Bank H	35
Plate 9	View of fresh sulphidic tailings on the surface of Bank D	36
Plate 10	View of the downstream end of Bank H during a period of heavy rainfall	36
Plate 11	View of the discrete occurrence of a gaseous emission from the delta	39
Plate 12	View of groundwater seepage from the delta	39
Plate 13	Reflected light photomicrograph of sample DT-1	54
Plate 14	Reflected light photomicrograph of sample DT-1	54
Plate 15	Reflected light photomicrograph of sample DEL-WS3-S	56
Plate 16	Reflected light photomicrograph of sample DEL-WS3-S	56
Plate 17	Back scattered electron and X-ray mapping images of a slag grain	60
Plate 18	X-ray map of a slag fragment	61
Plate 19	IFESEM photomicrograph of sample DEL-WS12-S	66
Plate 20	IFESEM photomicrograph of sample DT-1	66
Plate 21	IFESEM photomicrograph of sample DT-1	67
Plate 22	IFESEM photomicrograph of sample DT-1	67
Plate 23	IFESEM photomicrograph of sample DEL-S9	68
Plate 24	IFESEM photomicrograph of sample DEL-WS5-S	68
Plate 25	IFESEM photomicrograph of sample DEL-WS12-S	69
Plate 26	IFESEM photomicrograph of sample DEL-WS12-S	69
Plate 27	IFESEM photomicrograph of sample D-S-8	70
Plate 28	IFESEM photomicrograph of sample DEL-WS5-S	70
Plate 29	IFESEM photomicrograph of sample DEL-WS5-S	71
Plate 30	IFESEM photomicrograph of sample DEL-WS12-S	72
Plate 31	IFESEM photomicrograph of sample DEL-WS12-S	72
Plate 32	IFESEM photomicrograph of sample DEL-WS12-S	73
Plate 33	IFESEM photomicrograph of sample DEL-WS12-S	73

Figures

Figure 1	Location plan showing the King River catchment below Lake Burbury	2
Figure 2	Location of surface sampling traverse lines and drillhole on the King River delta	11
Figure 3	Location and designation of the King River sediment banks	12
Figure 4	Piezometer locations on the King River sediment banks	13
Figure 5	Location of drillholes (by Helen Locher)	14
Figure 6	Piezometer locations on the King River delta	16
Figure 7	Design of piezometers	19
Figure 8	Cross section of Bank R showing piezometers	19
Figure 9	Cross section of Bank N showing piezometers	20
Figure 10	Cross section of Bank N showing piezometers	20
Figure 11	Cross section of Bank H showing piezometers	21
Figure 12	Cross section of Bank D showing piezometers	21
Figure 13	Longitudinal section of Bank D showing piezometers	22
Figure 14	Cross section of south lobe of the delta showing piezometers perpendicular to King River	22
Figure 15	Cross section of south lobe of the delta showing piezometers perpendicular to Macquarie Harbour	23
Figure 16	Miscellaneous piezometers from the south lobe of the delta	23
Figure 17	Cross section of north lobe of the delta showing piezometers perpendicular to Macquarie Harbour	24
Figure 18	Cross section of north lobe of the delta showing piezometers near Macquarie Harbour	24
Figure 19	pH of the upper layer of groundwater in the King River delta	26
Figure 20	Electrical conductivity of the upper layer of groundwater in the King River delta	27
Figure 21	Redox potential of the upper layer of groundwater in the King River delta	28
Figure 22	Regional annual rainfall for the study area	40
Figure 23	Location of regional water monitoring stations	46
Figure 24	Surface characteristics of the King River bed	58
Figure 25	Graphical analysis of hydraulic head for the delta and banks	82
Figure 26	Bank R – hydraulic gradient and fluxes	83
Figure 27	Bank D – hydraulic gradient and fluxes	84
Figure 28	Bank N – hydraulic gradient and fluxes	85
Figure 29	Bank H – hydraulic gradient and fluxes	86

Figure 30 South lobe of delta – hydraulic gradient and fluxes perpendicular to King River	88
Figure 31 South lobe of delta – hydraulic gradient and fluxes perpendicular to Macquarie Harbour	89
Figure 32 North lobe of delta – hydraulic gradient and fluxes perpendicular to Macquarie Harbour	90

Tables

Table 1 Field data from piezometers	18
Table 2 Dimensions of tailings deposits	41
Table 3 Groundwater and surface-water chemistry – analytical results	42
Table 4 Groundwater and surface-water chemistry – field and laboratory parameters	50
Table 5 Sediment chemistry	62
Table 6 Analytical results from distilled water leach	64
Table 7 Analytical results from dilute sulphuric acid leach	64
Table 8 pH and conductivity results from the distilled water leach	74
Table 9 pH and conductivity results from the dilute sulphuric acid leach	75
Table 10 Analytical results from ammonium acetate leach	76
Table 11 pH, conductivity and redox potential results from the ammonium acetate leach	77
Table 12 Hydraulic conductivity values	78
Table 13 Slug test calculations	79
Table 14 Mass transfer calculations	100