APPENDIX A

Water Quality

1.0 INTRODUCTION

This appendix contains a summary of the data used to derive input water quality parameters to support the surface water modelling of the Mare Burn catchment and the associated opencast pits. This is not a comprehensive review of potentially relevant water quality data acquired at the MGP. A review of MGP water quality was undertaken in support of the water management modelling for the MPIII Project consenting process (Golder 2010b). In modelling the Mare Burn catchment, a few water quality parameters have been copied directly from the MPIII site wide water management report (Golder 2011a). Where this has occurred, the derivation has not been replicated in this appendix and only the water quality outcomes have been presented in the main body of this report.

It is important to recognise that the statistical water quality outcomes summarised in this appendix and applied to the water quality modelling are not necessarily geochemically stable. The trends in concentrations for the parameters listed in each table are not necessarily correlated. As such some of the parameters documented here may reach maximum values in samples where other parameters are at relatively low concentrations. This does not invalidate the use of these values as input parameters for the catchment water modelling. It is however important to take into account the geochemical stability of the modelled water quality outcomes when considering the environmental implications of the results.

General water quality trends for developing pit lakes and WRS seepage have been very consistent at different monitoring locations around the MGP. For this reason, the input water quality values for modelling of the Coronation North Project have been derived from data obtained from specific representative monitored sites.

In this appendix:

- The derivation of the undisturbed catchment water quality is presented in Section 2.0.
- The derivation of the pit water quality, for both the operational and post-closure periods is presented in Section 3.0.
- The derivation of the WRS seepage water quality is presented in Section 4.0.

2.0 UNDISTURBED CATCHMENT SURFACE WATER QUALITY

Water has been sampled from Mare Burn at monitoring point MB01 since December 2014, with the sampling program ongoing. The water quality analysis data from MB01 for the period from December 2014 to November 2015 has been reviewed (Table A1).

Mining development in the Mare Burn catchment commenced in late 2014 meaning the majority of the data may be not be representative of undisturbed catchment. Therefore the Mare Burn water quality data has also been compared to the water quality in Deepdell Creek at water quality control site DC01 (Table A2) upstream of the mining activities (Golder 2011a). This comparison confirmed that the Mare Burn data collected at MB01 between December 2014 and November 2015 is likely to be representative of undisturbed sub-catchments draining to Mare Burn.

Review of the general water quality trends for major ions (Figure A1) and dissolved metals and metalloids (Figure A2) has not identified any decreasing trends in water quality. This outcome supports the expectation that the Mare Burn data collected at MB01 between December 2014 and November 2015 is likely to be representative of undisturbed sub-catchments draining to Mare Burn. Concentrations for zinc, lead and cyanide$_{WAD}$ have frequently been below their respective laboratory detection limits.

Table A1: Summary of surface water quality at MB01 (2014-2015).

Parameter [1]	Minimum	Mean	95th Percentile	Maximum	Number of Samples
pH (unitless)	7.2	7.6	7.8	7.8	9
Conductivity (mS/m)	60	121	194	198	12
Calcium	4.0	11.3	19.2	19.2	12
Chloride	3.9	5.3	7.7	8.8	12
Magnesium	1.2	2.8	4.4	4.4	12
Potassium	0.4	1.7	4.7	6.2	12
Sodium	5.5	9.3	13.3	13.5	12
Sulphate	1.3	6.4	11.1	11.6	12
Cyanide $_{WAD}$	<0.001	0.0005 [2]	0.0014 [2]	0.0016	4
Arsenic	<0.001	0.0023	0.0050	0.0050	12
Copper	0.0006	0.0009	0.0014	0.0016	12
Iron	0.08	0.24	0.54	0.54	12
Lead	<0.0001	<0.0002	0.0010	0.0018	12
Zinc	<0.001	0.0009 [3]	0.0033 [3]	0.0055	5

Notes: 1) All units g/m^3 unless otherwise stated.
2) Calculated assuming values below the detection limit are 0.0005 g/m^3.
3) Calculated assuming values below the detection limit are 0.0005 g/m^3.

Table A2: Summary of surface water quality at DC01 (Golder 2011, R012)

Parameter	Minimum	Mean	95th Percentile	Maximum
pH (unitless)	6.2	7.8	8.4	8.7
Conductivity (mS/m)	64	150	200	270
Calcium	7.5	12	17	21
Chloride	7.3	11	15	18
Magnesium	3.0	4.3	5.4	7.4
Potassium	0.6	1.2	1.8	1.9
Sodium	9.6	12	15	21
Sulphate	1.3	4.5	11	15
Cyanide $_{WAD}$	<0.001	<0.005	<0.005	0.014
Arsenic	<0.001	<0.0029	0.0053	0.018
Copper	<0.0005	<0.0015	0.0055	0.0065
Iron	<0.040	<0.54	1.1	7.3
Lead	<0.0001	<0.00085	0.0035	0.0055
Zinc	<0.00006	<0.00083	0.0020	0.0023

Notes: All units g/m^3 unless otherwise stated. Concentrations for ions are total dissolved concentrations.

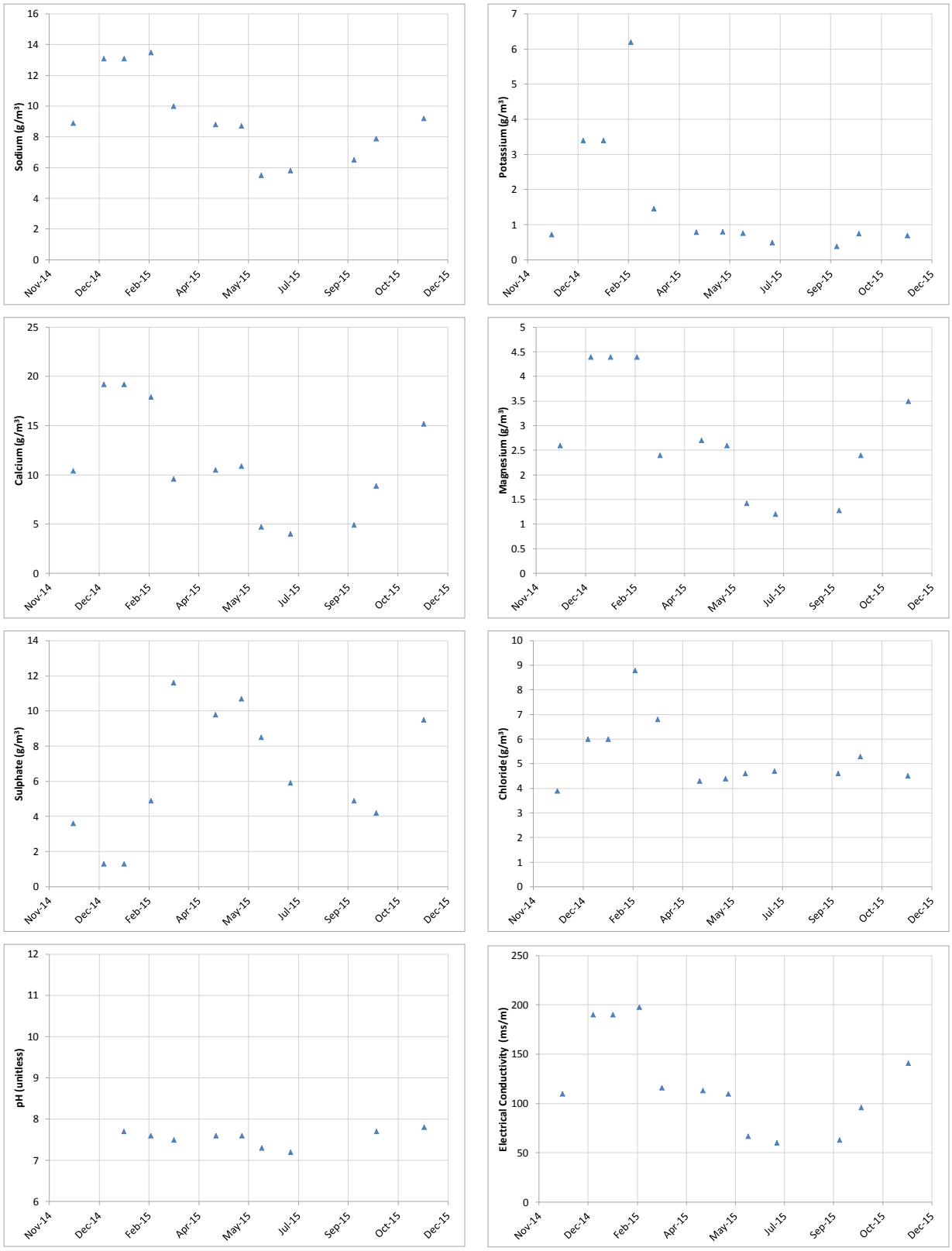

Figure A1: MB01 surface water quality – major ions and physicochemical parameters.

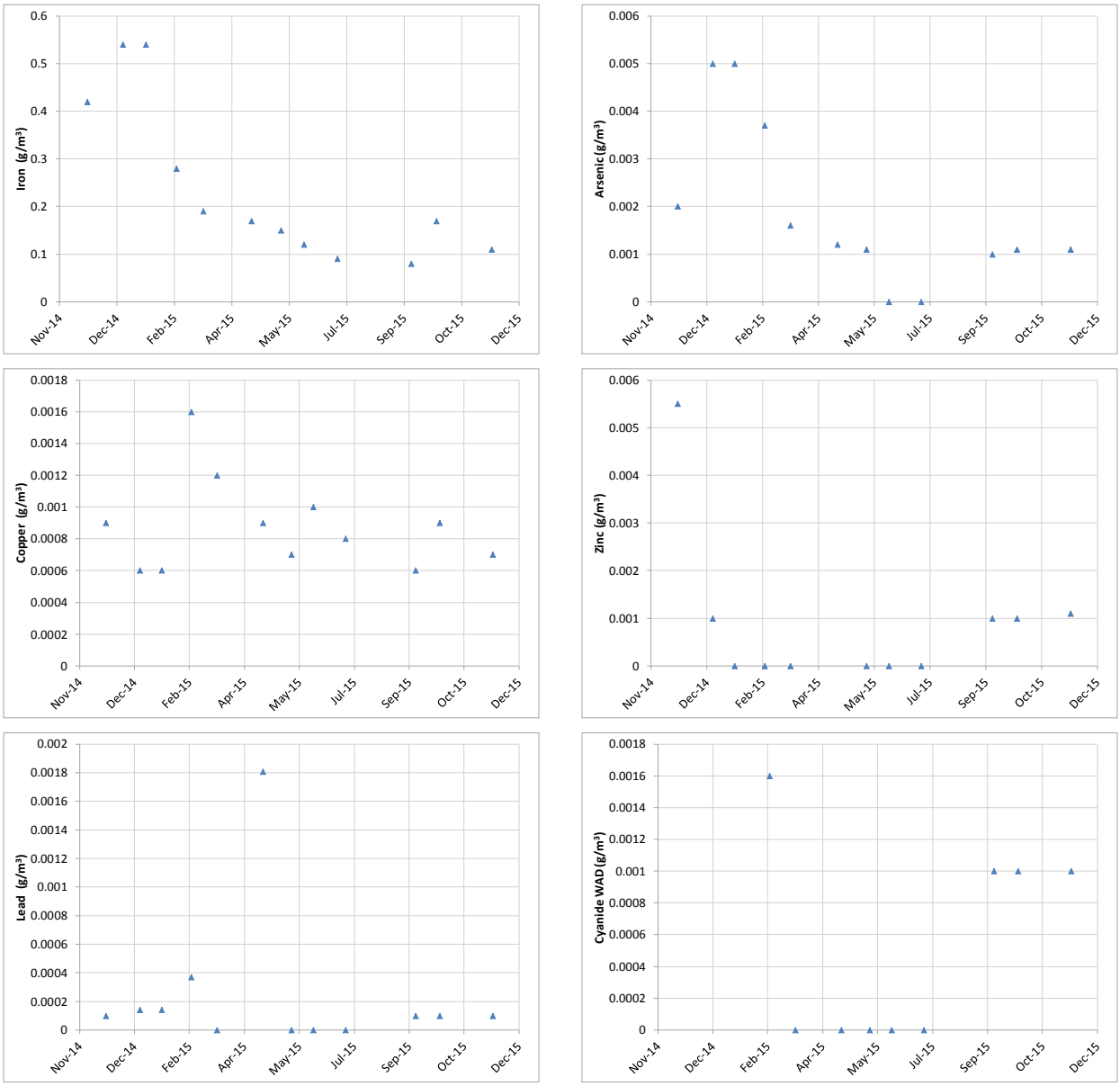

Figure A2: MB01 surface water quality – metals / metalloids and cyanide$_{WAD}$.

3.0 PIT WATER QUALITY

3.1 Operational Period

Pit water quality for Frasers Pit during its operational mining period is summarised in Table A3. This data has been used to characterise pit sump water quality for the Coronation North project during the planned operational period. The operational mining period in Frasers Pit of approximately 10 years between 1998 and 2008.

One outlier high value was removed from each of the cyanide, copper, iron and lead datasets, due to these values being substantially outside the normal ranges observed. Only one sampling round had a zinc analysis undertaken. As such the zinc value applied to the modelling must be treated with some caution.

Table A3: Summary of surface water quality in Frasers Pit during operations (1998 – 2008).

Parameter	Minimum	Average	95th Percentile	Maximum	Number of samples
pH (unitless)	7.2	8.1	8.8	9.8	28
Conductivity (mS/m)	324	732	941	1,080	28
Calcium	29.4	64.1	89.74	103	27
Chloride	1.7	11.4	18.9	19.8	24
Magnesium	14.9	35.7	51.0	51.1	27
Potassium	2.8	8.3	15.8	16.2	24
Sodium	4.9	35.1	54.7	71.5	24
Sulphate	24	176	301	308	28
Cyanide $_{WAD}$	<0.005	0.006	0.010	0.018	14
Arsenic	<0.005	0.18	0.537	0.803	27
Copper	<0.0005	0.002	0.002	0.002	6
Iron	<0.02	0.23	0.85	1.22	20
Lead	<0.001	<0.001	<0.001	0.002	17
Zinc	NA	0.04	NA	NA	1

Notes: All units g/m^3 unless otherwise stated. Concentrations for ions are total dissolved concentrations.

3.2 Post-closure Period

Pit water quality from the decommissioned Golder Bar Pit is summarised in Table A4. This data has been used to characterise the expected pit lake water quality for the Coronation North Project during the post-closure period.

Following closure of operations in Golden Bar Pit, the lake water quality has changed over time. Consequently only the latest water quality data has been included in the analysis (i.e., 2010 – 2015) as this is considered the most representative of the long term post-closure lake water characteristics. In addition, trends of increasing concentrations for some of the major ions have been observed

The results from one sampling round (3 April 2012) were omitted from the dataset as they did not reflect the likely water quality in Golden Bar Pit at the time of the sample, based on Golder's understanding of the pit lake water quality trends. Zinc analysis data is only available from two sampling rounds. As such the water quality projections for zinc must be treated with caution.

Table A4: Summary of surface water quality in Golder Bar Pit post-closure.

Parameter [1]	Minimum	Average	95th Percentile	Maximum	Number of samples
pH (unitless)	8.1	8.3	8.3	8.4	19
Conductivity (mS/m)	728	823	921	928	19
Calcium	75.0	78.9	82.3	85.0	19
Chloride	5.0	6.3	7.0	7.0	19
Magnesium	46	59.1	76.1	77.0	19
Potassium	3.6	4.1	4.8	5.0	19
Sodium	11.2	12.6	14.6	15.0	12
Sulphate	260	284	302	320	19
Cyanide $_{WAD}$	<0.001	<0.001	<0.001	<0.001	8
Arsenic	0.16	0.24	0.29	0.32	19
Copper [2]	<0.0005	0.0007	0.0013	0.0016	10
Iron	<0.02	0.035	0.13	0.16	18
Lead	<0.0001	0.00013	0.00023	0.00023	10
Zinc	0.002	0.006	0.0093	0.0093	2

Notes: 1) All units g/m^3 unless otherwise stated. Concentrations for ions are total dissolved concentrations.
2) Where values below the laboratory detection limit have been recorded, these have been accepted as being equal to the detection limit for the purpose of the statistical analysis unless all results were below the detection limit.

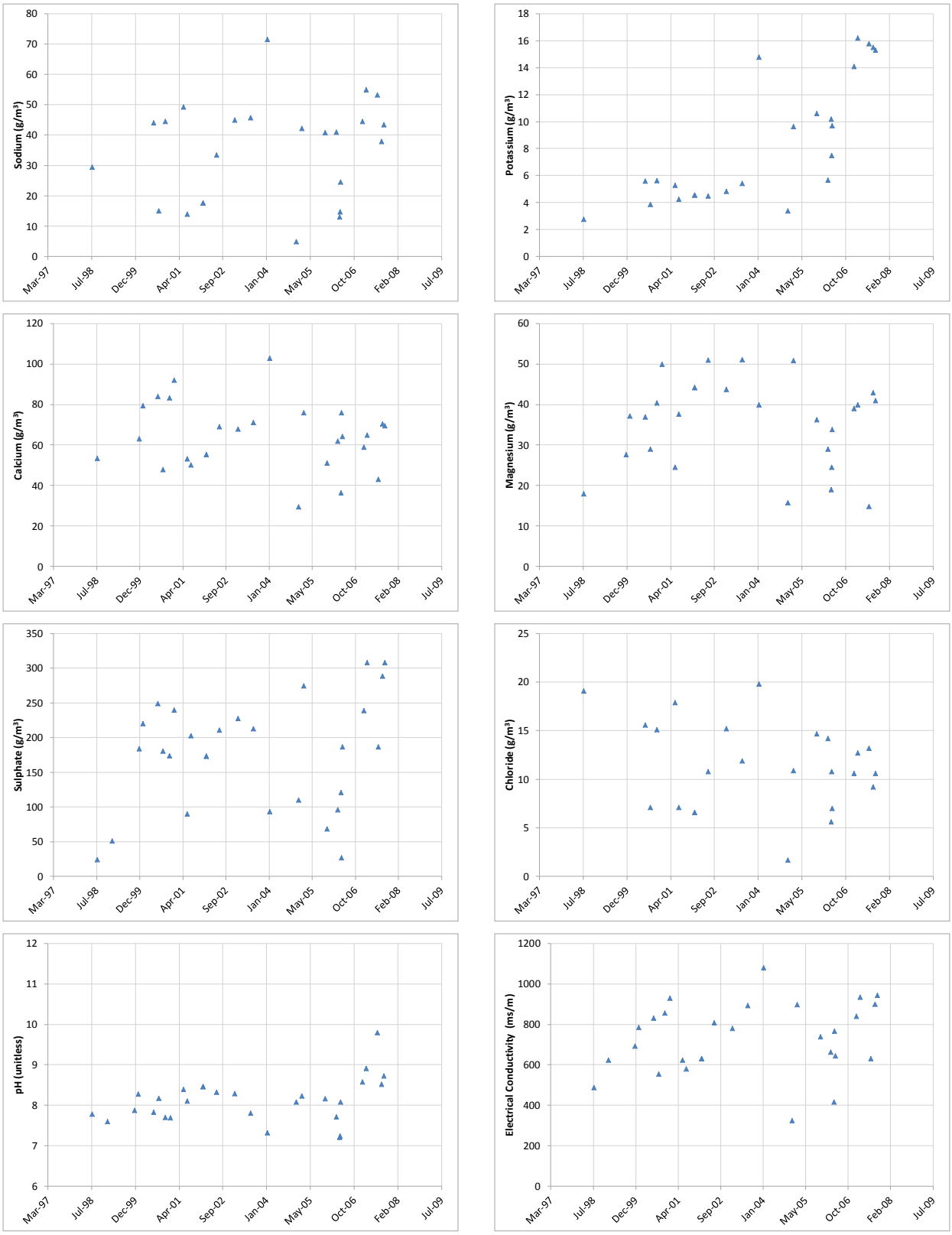

Figure A3: Frasers Pit surface water quality during operations – major ions and physicochemical parameters.

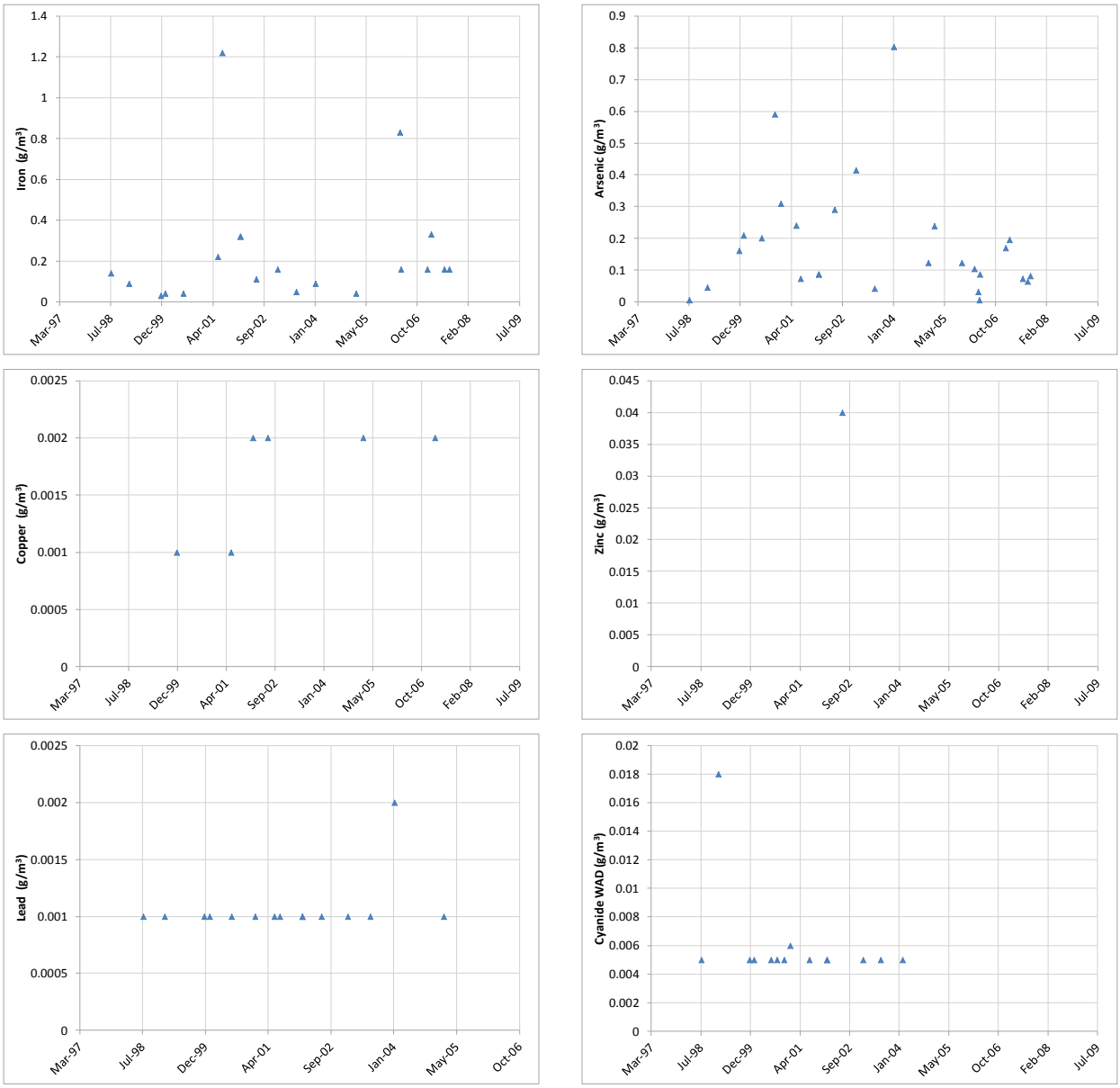

Figure A4: Frasers Pit surface water quality during operations – metals / metalloids and cyanide$_{WAD}$.

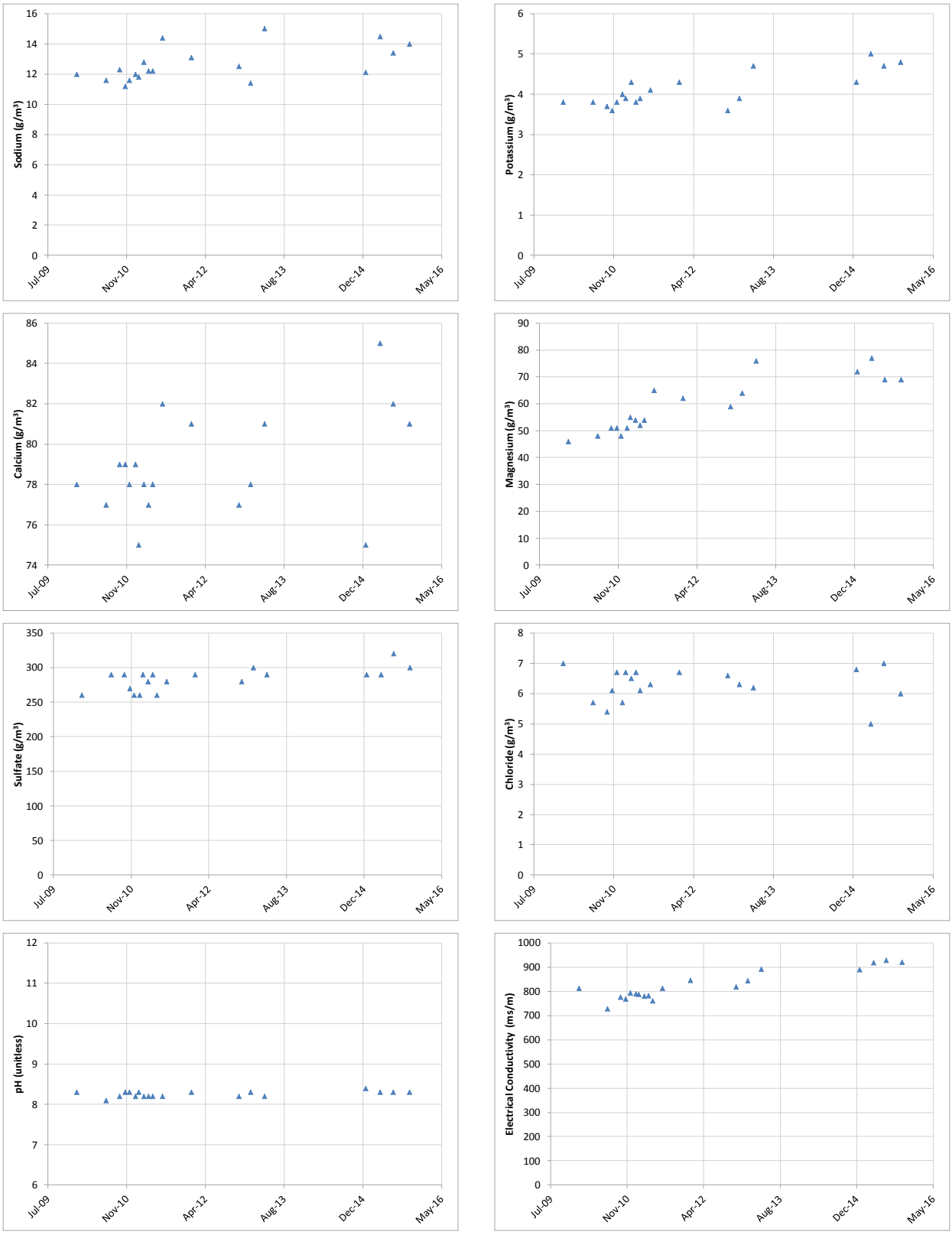

Figure A5: Golden Bar Pit lake water quality post-closure – major ions and physicochemical parameters.

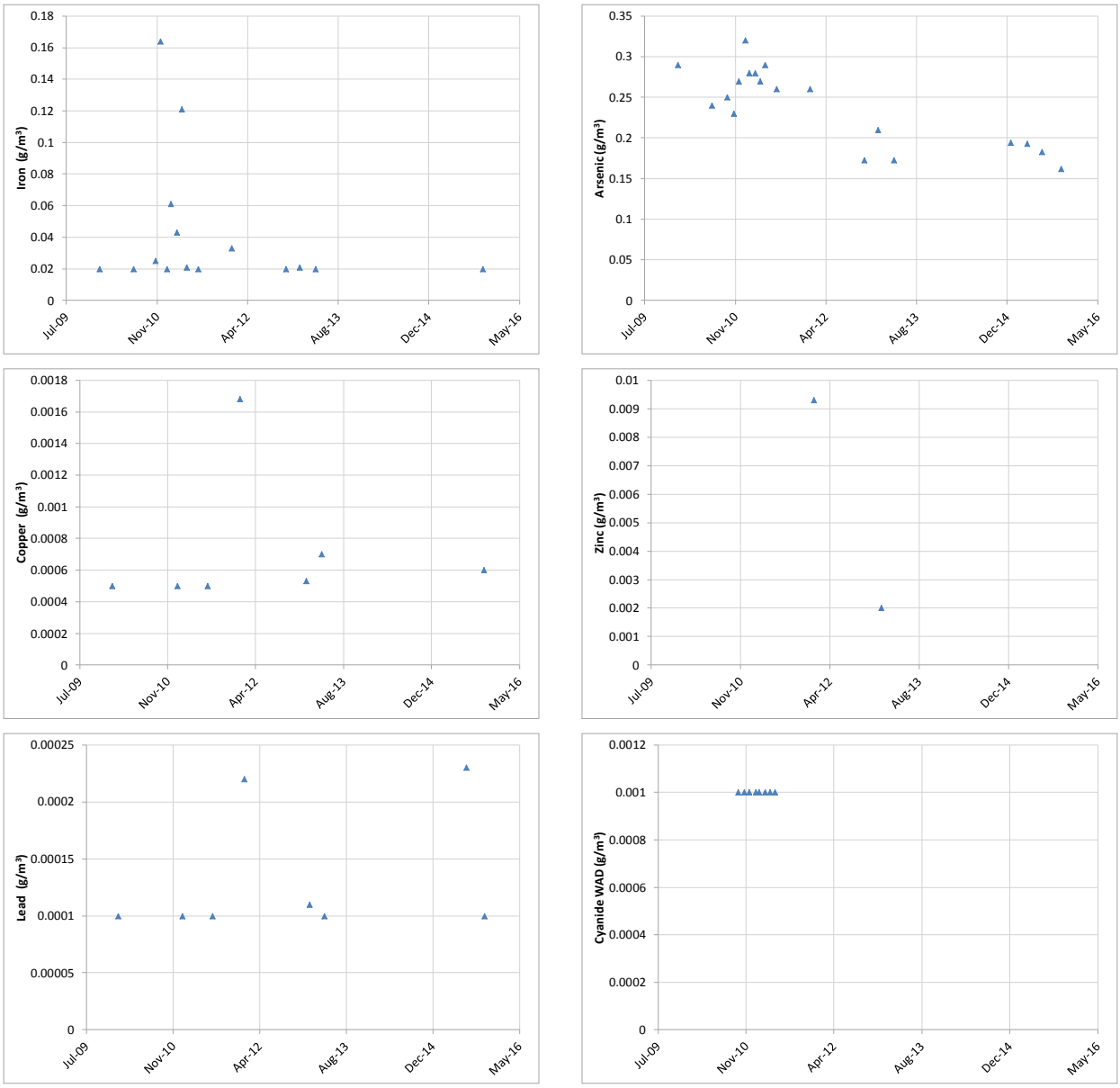

Figure A6: Golden Bar Pit lake water quality post-closure – metals / metalloids and cyanide$_{WAD}$.

4.0 WRS SEEPAGE WATER QUALITY

4.1 Operational Period

The construction of the Clydesdale WRS began upstream from the Clydesdale silt pond in 2003. Water quality monitoring data from Clydesdale silt pond for the period between 2003 and 2008 is considered to represent WRs seepage for approximately the first 5 years following the start of construction (Table A5). No data is available from Clydesdale silt pond during this period for cyanide or zinc. Cyanide levels were below the laboratory detection limit (<0.001 g/m^3) and zinc was not included in the analyte list. For operational modelling purposes, values for these parameters have been taken from the Northern Gully dataset summarised in Table A6.

The water quality in Clydesdale silt pond changed between 2003 and 2008. Specifically, the concentrations of several major ions in the silt pond water increased during this period (Figure A7). For this reason, the modelling has incorporated the 95th percentile concentrations from this dataset to represent the projected water quality toward the end of the operational period of the Coronation North WRS. Iron and arsenic concentrations remained relatively low (Figure A8) during the operational period of Clydesdale WRS.

4.2 Post-closure Period

Seepage data from the Northern Gully WRS is summarised in Table A6. The Northern Gully WRS was the first WRS to be developed at the Macraes site and is likely the best indicator of long term WRS seepage water quality. It must be noted here that some low grade ore stockpiles were constructed on top of the Northern Gully WRS. The seepage data may therefore indicate higher concentrations of some analytes than would occur on stockpiles not used for ore stockpiling.

Table A5: Summary of water quality in Clydesdale silt pond (2003-2008).

Parameter	Minimum	Average	95th Percentile	Maximum	Number of samples
pH (unitless)	6.4	7.7	8.3	8.4	19
Conductivity (mS/m)	98	663	1,224	1,273	19
Calcium	13.8	67.9	125.4	129.0	19
Chloride	6.1	10.9	14.4	14.9	19
Magnesium	6.4	45.8	101.2	103	19
Potassium	2.0	4.6	5.9	6.0	19
Sodium	14.3	19.9	26.4	29.0	19
Sulphate	2	238	611	612	2
Cyanide $_{WAD}$	N/A	N/A	N/A	N/A	N/A
Arsenic	<0.001	0.008	0.025	0.044	15
Copper	0.00089	0.022	0.073	0.085	4
Iron	0.02	0.29	1.34	1.70	14
Lead	0.0001	0.016	0.050	0.059	4
Zinc	N/A	N/A	N/A	N/A	N/A

Notes: All units g/m^3 unless otherwise stated. Concentrations for ions are total dissolved concentrations. N/A – no data available.

Table A6: Summary of seepage water quality in Northern Gully western seepage point (2010-2016).

Parameter	Minimum	Average	95th Percentile	Maximum	Number of samples
pH (unitless)	7.4	7.8	8.0	8.1	15
Conductivity (mS/m)	3,170	3,797	4,036	4,050	15
Calcium	420	471	514	570	15
Chloride	11.0	15.0	24.8	50.0	15
Magnesium	350	428	466	480	15
Potassium	10.7	12.4	14.3	14.9	15
Sodium	56.0	62.8	68.2	71.0	15
Sulphate	2,300	2,520	2,900	2,900	15
Cyanide $_{WAD}$	0.001	0.001	0.002	0.002	6
Arsenic	0.003	0.009	0.013	0.013	15
Copper	0.001	0.002	0.005	0.006	8
Iron	0.13	0.76	2.2	2.7	15
Lead	<0.00021	<0.00052	0.00094	0.001	8
Zinc	0.021	0.033	0.043	0.044	7

Notes: All units g/m^3 unless otherwise stated. Concentrations for ions are total dissolved concentrations.

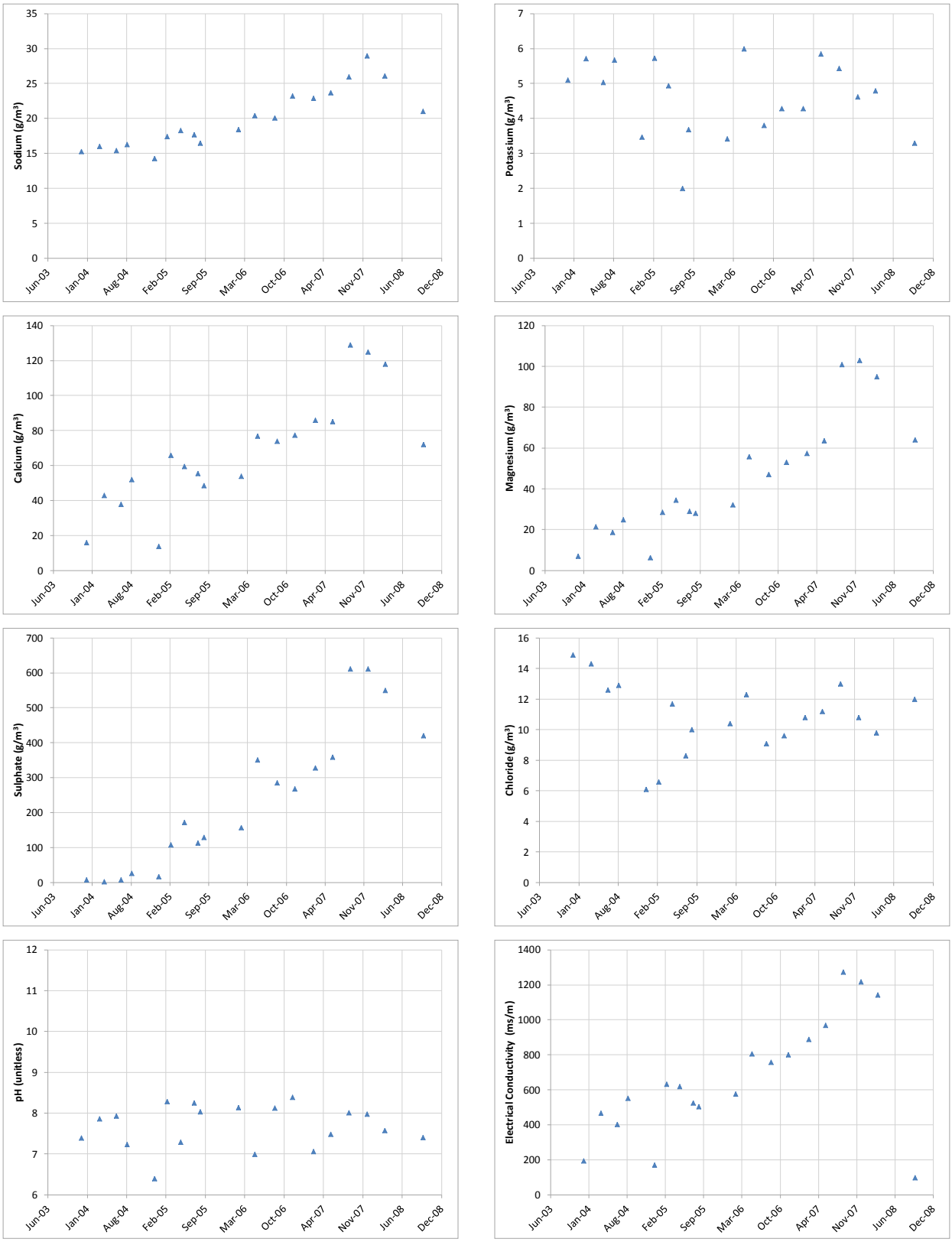

Figure A7: Clydesdale silt pond water quality during operations – major ions and physicochemical parameters.

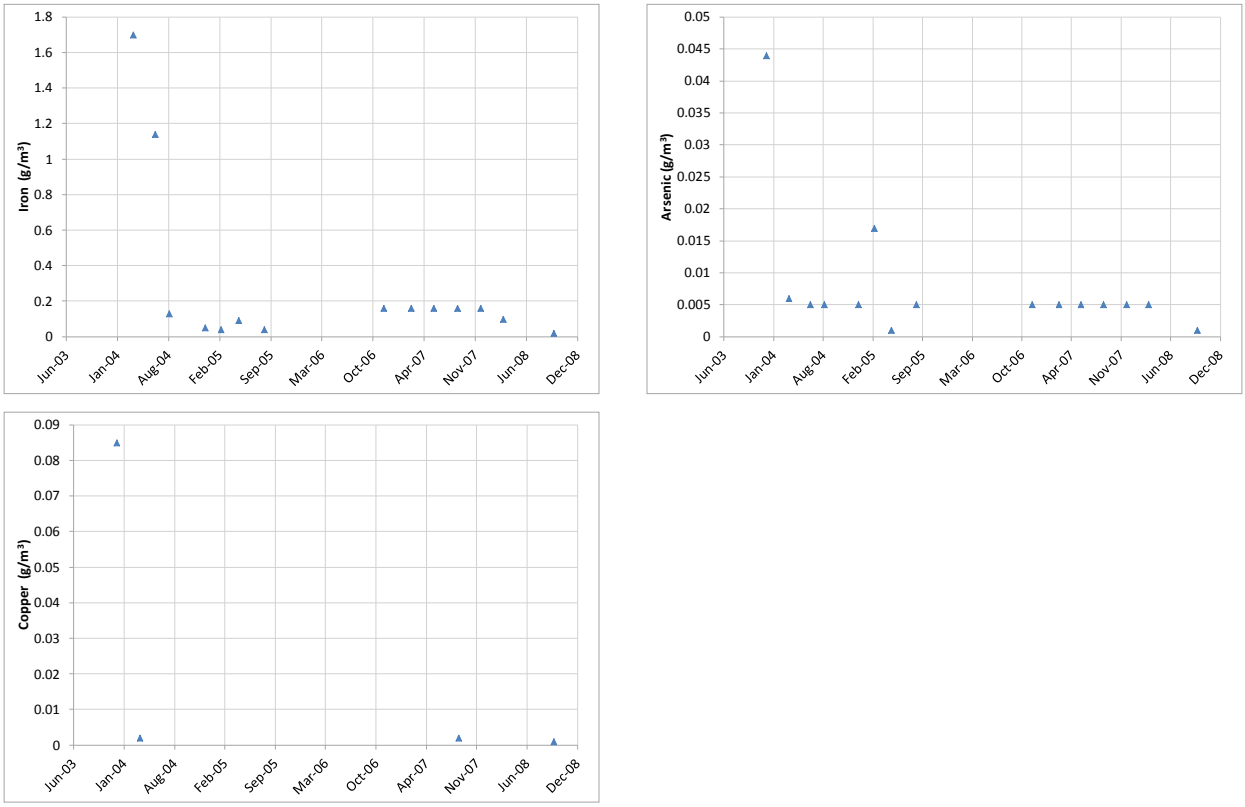

Figure A8: Clydesdale silt pond water quality during operations – metals / metalloids.

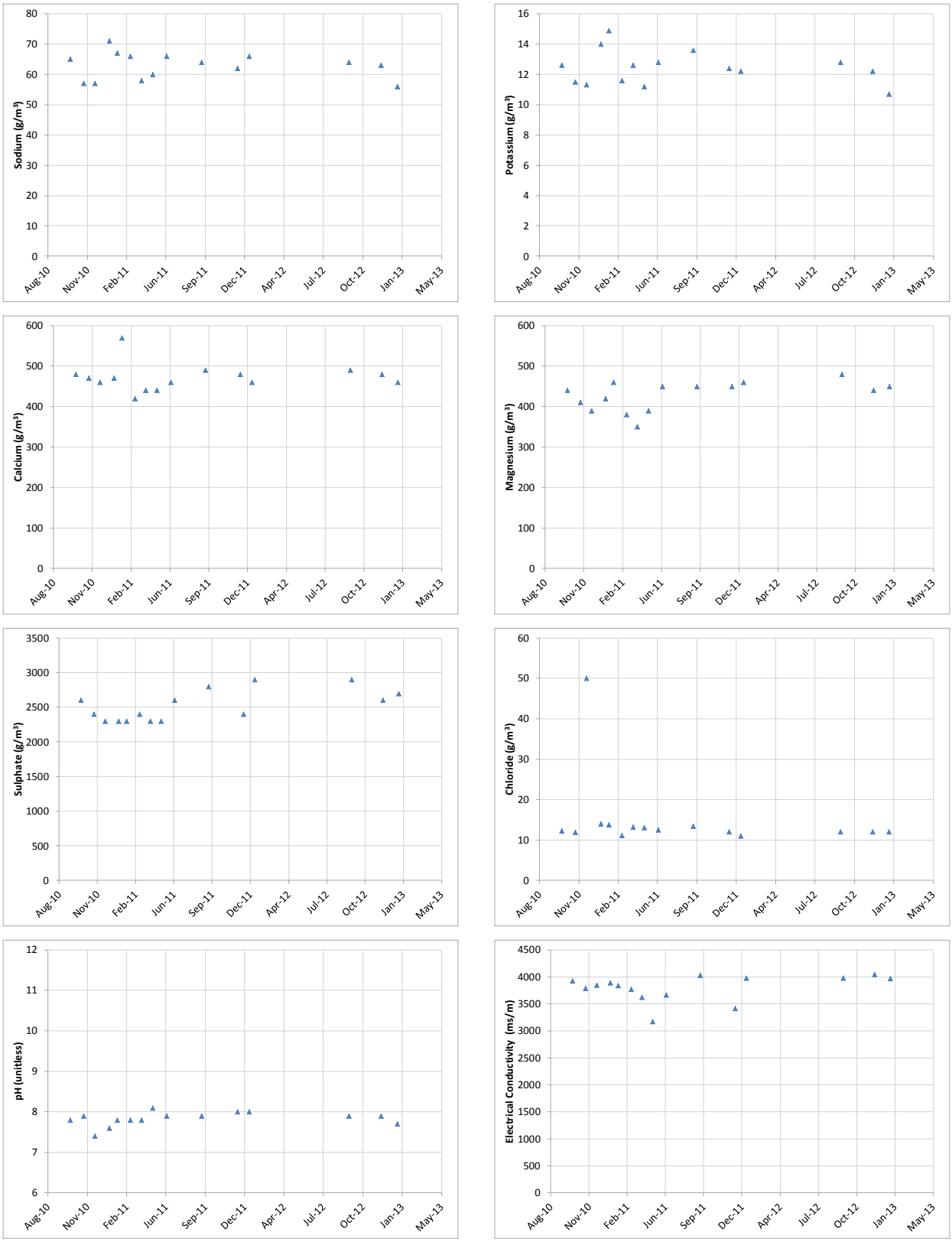

Figure A9: Northern Gully silt pond water quality – major ions and physicochemical parameters.

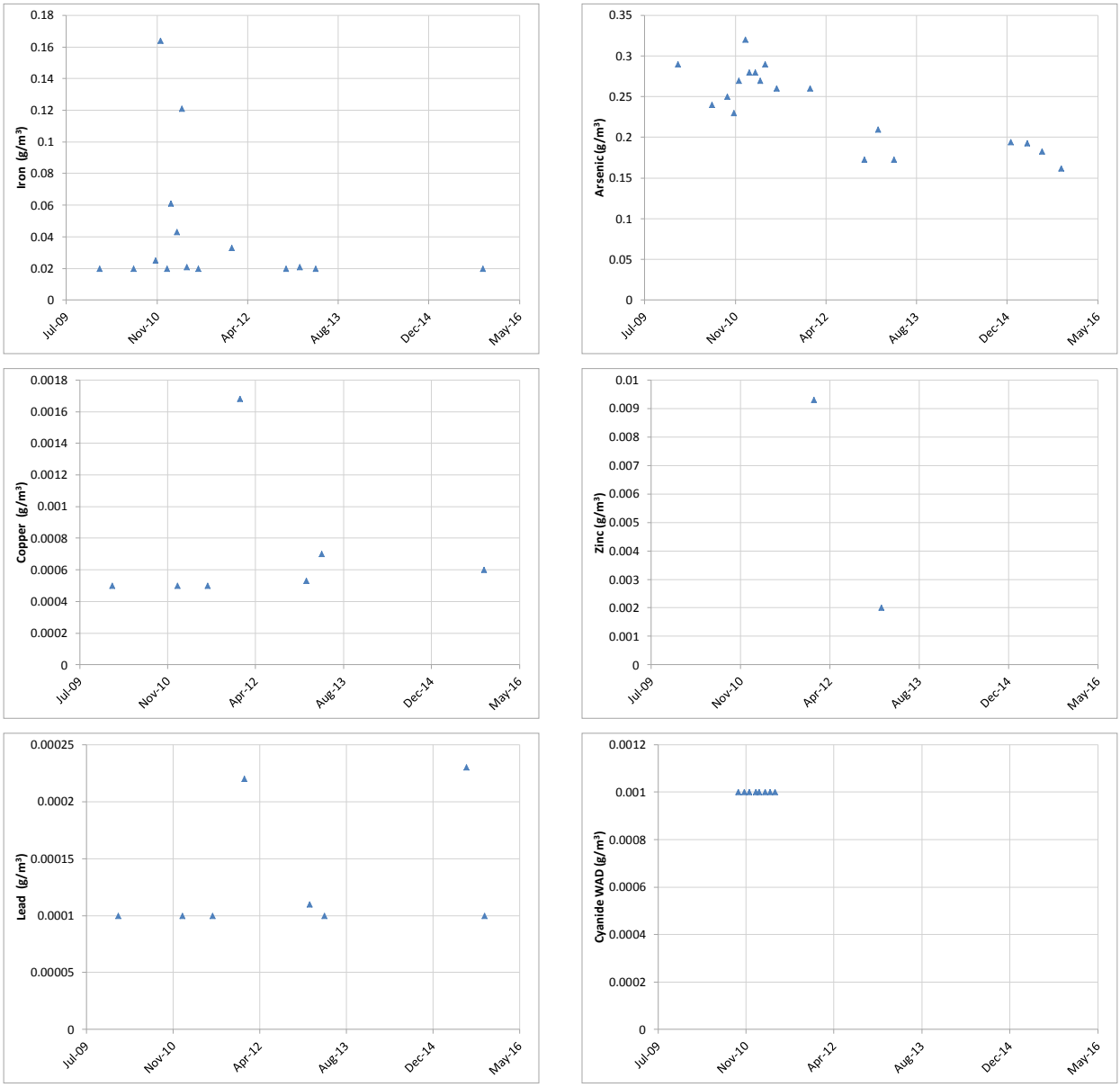

Figure A10: Northern Gully silt pond water quality during operations – metals / metalloids and cyanide$_{WAD}$.

APPENDIX B

Pit Elevation, Area, Volume Assumptions

Table B1: Coronation Pit.

Elevation	Area	Cumulative Volume
m	m²	m³
562.5	0	0
565	33,306	71,639
570	37,732	249,234
575	48,818	465,609
580	71,582	766,609
585	109,861	1,220,216
590	116,319	1,785,666
595	122,909	2,383,736
600	154,638	3,077,604
605	161,587	3,868,166
610	168,510	4,693,409
615	175,453	5,553,316
620	193,294	6,475,184
625	207,273	7,476,601
630	234,002	8,579,789
635	253,935	9,799,631
640	279,320	11,132,769

Table B2: Coronation Stage 5 Pit.

Elevation	Area	Cumulative Volume
m	m²	m³
550	0	0
555	19,205	96,972
560	31,886	221,731
565	45,838	412,637
570	57,419	674,866
575	78,578	1,026,666
580	102,365	1,474,653
585	124,845	2,026,374
590	150,570	2,721,906
595	186,236	3,550,766
600	206,947	4,539,205
605	225,732	5,624,178
610	240,744	6,786,706
615	260,738	8,032,370
620	300,874	9,436,394
625	321,556	10,992,604
630	348,375	12,669,041
632.5	352,999	13,195,947

Table B3: Coronation North Pit.

Elevation	Area	Cumulative Volume
m	m²	m³
467	0	0
470	35,240	113,617
475	45,305	316,004
480	49,386	554,770
485	55,628	815,997
490	72,180	1,121,608
495	80,946	1,500,981
500	103,992	1,981,323
505	109,854	2,518,979
510	126,914	3,123,671
515	152,822	3,845,099
520	219,421	4,688,172
525	227,099	5,808,114
530	237,832	6,969,001
535	268,832	8,204,098
540	276,552	9,571,458
545	284,444	10,978,066
550	304,268	12,460,922
555	315,863	14,018,421
560	361,397	15,725,987
565	381,809	17,599,914
570	405,564	19,550,903
575	414,987	21,606,931
580	422,718	23,286,109

APPENDIX C

Pit Groundwater Inflows

APPENDIX C
Opencast pit and pit lake net seepage flows

These calculated net seepage rates presented in this appendix are a combination of:

- Groundwater inflows to the pit lake based on the area of influence calculations presented in Appendix D of the Coronation North groundwater assessment (Golder 2016a).
- Seepage outflows from the pit lake as the water level approaches the overflow elevation presented in Appendix E of the Coronation North groundwater assessment (Golder 2016a).

These net seepage rates correspond to those documented in Appendix f of the Coronation North groundwater assessment (Golder 2016a).

The calculated net seepage rates to the consented Coronation Pit and pit lake are presented in Table C1.

Table C1: Groundwater flow to and from consented Coronation Pit lake.

Pit lake surface elevation (mRL)	Groundwater inflow [1] (m^3/day)	Groundwater outflow [2] (m^3/day)	Net groundwater flow (m^3/day)
640 (overflow elevation)	95	-2.31	92
637.5	100	-1.80	99
635	106	-1.10	105
632.5	112	-0.52	111
630	117	-0.21	117
627.5	123	-0.11	123
625	129	-0.05	129
622.5	135	-0.01	135
620	140		140
617.5	146		146
615	152		152
612.5	157		157
610	163		163
607.5	169		169
605	174		174
602.5	180		180
600	186		186
597.5	191		191
595	197		197
592.5	203		203
590	208		208
587.5	214		214
585	220		220
582.5	225		225
580	231		231
577.5	237		237
575	242		242
572.5	248		248
570	254		254
567.5	259		259
565	265		265
562.5 (pit base)	271		271

Notes 1) Inflows calculated for pit lake when empty and at overflow. Inflows at intermediate elevations based on linear interpolation between the two end points.
2) Outflows calculated stepwise as presented in Appendix E of the Coronation North groundwater report (Golder 2016a) and defined here as negative flows toward the pit.

The net seepage rates to CS5 and pit lake are presented in Table C2.

Table C2: Groundwater flows to and from Coronation Pit Stage 5 lake.

Pit lake surface elevation (mRL)	Groundwater inflow (1) (m^3/day)	Groundwater outflow to East (2) (m^3/day)	Groundwater outflow to Deepdell Creek (2) (m^3/day)	Net groundwater flow (m^3/day)
632.5	130	-0.30	-0.32	130
630	136	-0.20	-0.20	136
627.5	142	-0.10	-0.11	142
625	148	-0.03	-0.05	148
622.5	154	0.00	-0.01	154
620	160	0.00	0.00	160
617.5	166			166
615	172			172
612.5	178			178
610	184			184
607.5	190			190
605	196			196
602.5	202			202
600	208			208
597.5	214			214
595	221			221
592.5	227			227
590	233			233
587.5	239			239
585	245			245
582.5	251			251
580	257			257
577.5	263			263
575	269			269
572.5	275			275
570	281			281
567.5	287			287
565	293			293
562.5	299			299

Notes 1) Inflows calculated for pit lake when empty and at overflow. Inflows at intermediate elevations based on linear interpolation between the two end points.
2) Outflows calculated stepwise as presented in Appendix E of the Coronation North groundwater report (Golder 2016a) and defined here as negative flows toward the pit.

The net seepage rates to the planned Coronation North Pit and pit lake are presented in Table C3.

Table C3: Groundwater flows to and from Coronation North Pit lake.

Pit lake elevation (mRL)	Groundwater inflow [1] (m^3/day)	Groundwater outflow [2] (m^3/day)	Net groundwater flow (m^3/day)
580	94	-18.06	76
577.5	99	-13.21	86
575	104	-9.34	94
572.5	109	-6.35	102
570	114	-4.23	109
567.5	119	-2.82	116
565	124	-1.92	122
562.5	128	-1.48	127
560	133	-1.20	132
557.5	138	-0.87	137
555	143	-0.59	143
552.5	148	-0.35	148
550	153	-0.16	153
547.5	158	-0.06	158
545	163	-0.02	163
542.5	168	-0.01	168
540	173	0.00	173
537.5	178		178
535	183		183
532.5	188		188
530	193		193
527.5	198		198
525	203		203
522.5	208		208
520	212		212
517.5	217		217
515	222		222
512.5	227		227
510	232		232
507.5	237		237
505	242		242
502.5	247		247
500	252		252
497.5	257		257
495	262		262
492.5	267		267
490	272		272
487.5	277		277

Pit lake elevation (mRL)	Groundwater inflow (1) (m^3/day)	Groundwater outflow (2) (m^3/day)	Net groundwater flow (m^3/day)
485	282		282
482.5	287		287
480	291		291
477.5	296		296
475	301		301
472.5	306		306
470	311		311
467.5	316		316

Notes 1) Inflows calculated for pit lake when empty and at overflow. Inflows at intermediate elevations based on linear interpolation between the two end points.
2) Outflows calculated stepwise as presented in Appendix E of the Coronation North groundwater report (Golder 2016a) and defined here as negative flows toward the pit.