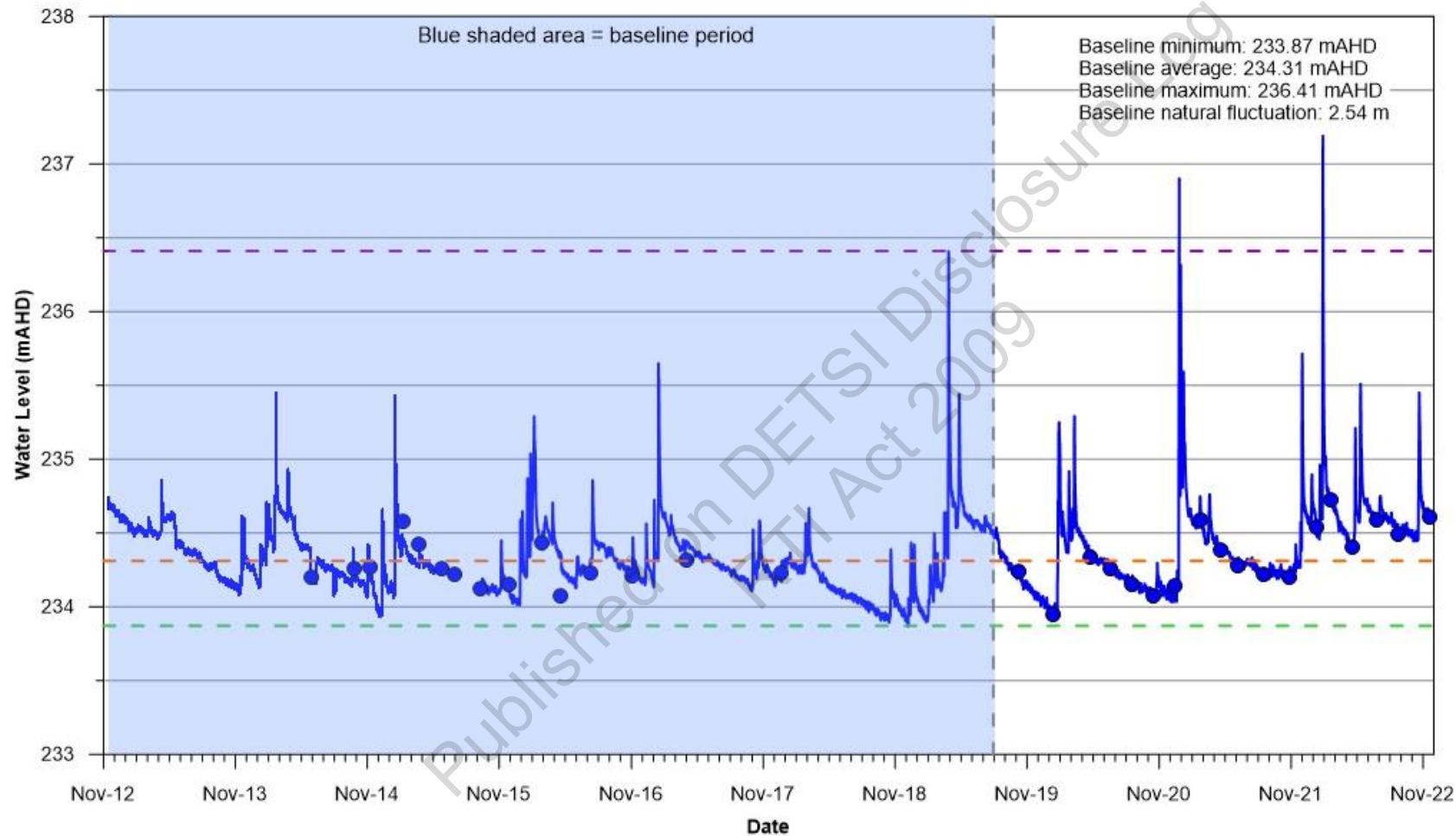


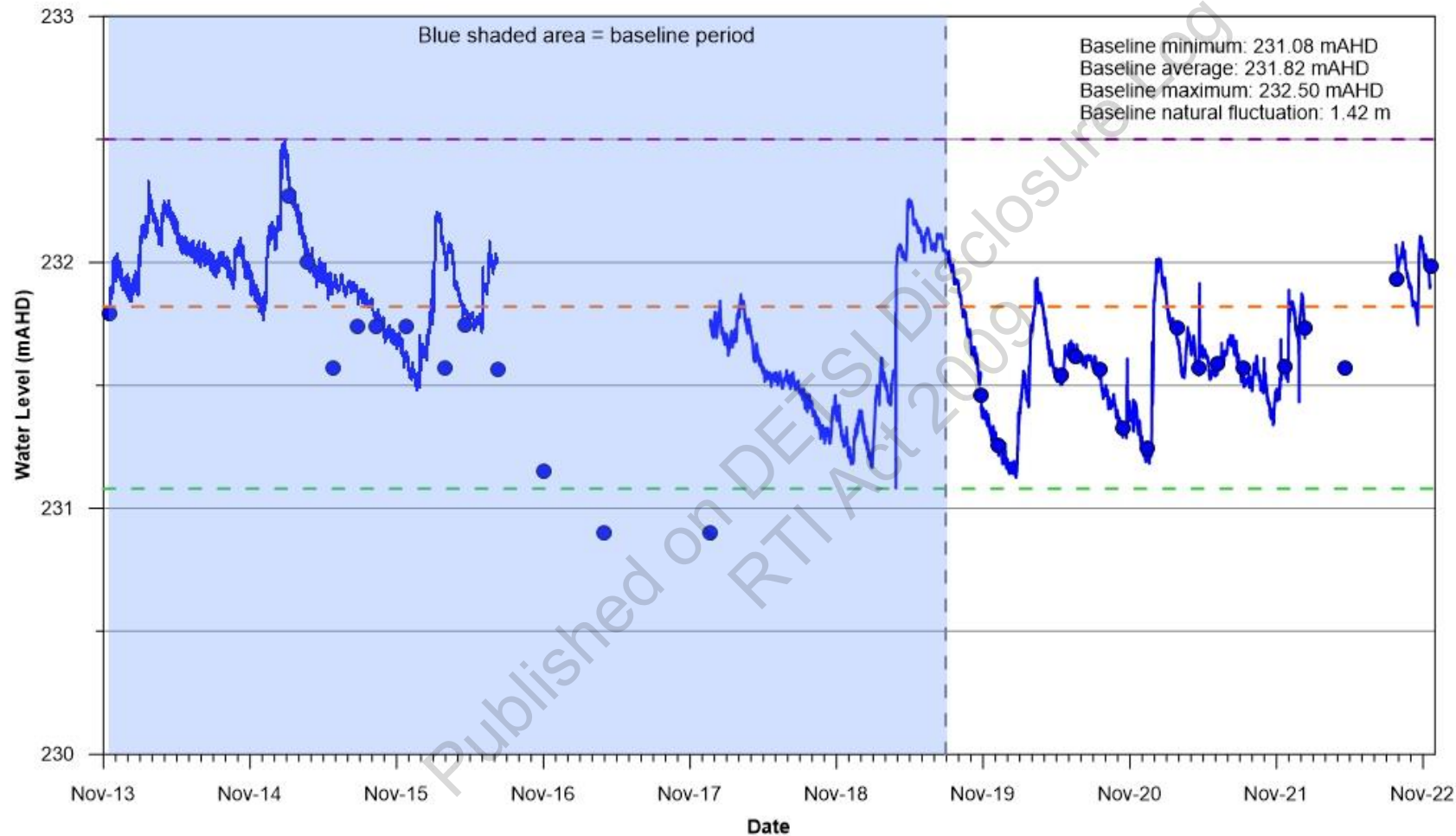
HD02 (Clematis)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- Average baseline logger water level
- Start of dewatering



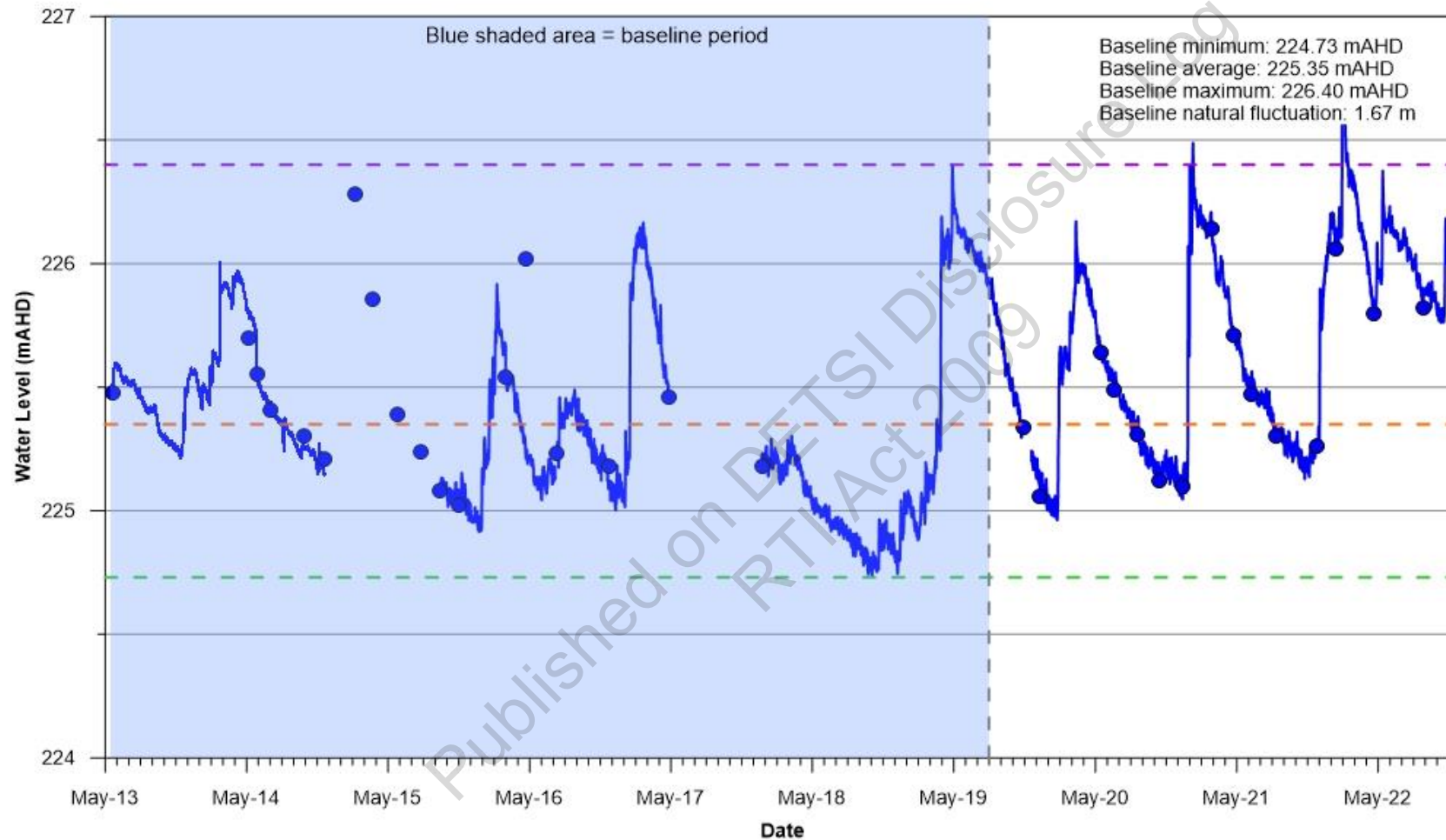
HD03A (Clematis)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- - - Average baseline logger water level
- - - Start of dewatering



HD03B (Alluvium)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- Average baseline logger water level
- - - Start of dewatering



Appendix C

Water quality trigger level exceedances

Table C.1 Water quality trigger exceedances – June 2022 monitoring round

Aquifer	Monitoring Bore	Parameter	Units	Trigger Level	February 2022	April /May 2022	June 2022	During dewatering Mann-Kendall trend	Bore has water level dewatering impact?	Proximity to mine disturbance footprint <2 km
Alluvium	C027P1	Arsenic	µg/L	13	4	14	13	No trend	No	No
		>C10-C40	µg/L	100	<100	120	170	No trend		
	C14027SP	Electrical Conductivity	µS/cm	50740	48500	54300	52000	Increasing	No	No
		Sulphate	mg/L	2200	2200	2290	2200	No trend		
	C14028SP	Electrical Conductivity	µS/cm	45000	44800	47500	46200	No trend	No	No
	C19001SP	Boron	µg/L	2133	2450	2350	2290	Increasing	No	Yes
		Electrical Conductivity	µS/cm	24880	27800	29100	28000	Increasing		
		Sulphate	mg/L	820	896	852	853	Increasing		
		Iron	µg/L	60	60	70	130	Increasing		
		Total dissolved solids	mg/L	16170	17500	17400	16300	Increasing		
Bandanna Formation	C008P2	Boron	µg/L	266	280	290	280	No trend	Yes	Yes
	C032P2	Boron	µg/L	370	360	410	400	Increasing	No	No
	C035P2	Boron	µg/L	261	260	320	310	Increasing	No	No
	C19027SP	Aluminium	µg/L	55	80	80	120	No trend	No	No
		pH (field)	pH units	6.0 – 9.0	10.70	10.57	10.80	Increasing		
	C847SP	Electrical Conductivity	µS/cm	358	351	387	361	Increasing	No	No
		Boron	µg/L	110	100	130	140	Increasing		
Clematis Sandstone	C14011SP	Cobalt	µg/L	2	2	2	2	No trend	No	No
	C14012SP	Boron	µg/L	120	160	120	140	No trend	No	No

Table C.1 Water quality trigger exceedances – June 2022 monitoring round

Aquifer	Monitoring Bore	Parameter	Units	Trigger Level	February 2022	April /May 2022	June 2022	During dewatering Mann-Kendall trend	Bore has water level dewatering impact?	Proximity to mine disturbance footprint <2 km
Colinlea Sandstone	C14013SP	Electrical Conductivity	µS/cm	490	512	501	495	Increasing	No	No
		Boron	µg/L	120	150	130	140	Increasing		
		Cobalt	µg/L	4	4	4	4	No trend		
		Electrical Conductivity	µS/cm	410	415	419	424	Increasing		
	C14021SP	Boron	µg/L	130	130	160	160	Increasing	No	No
		Cobalt	µg/L	2	2	2	2	Increasing		
	C14033SP	Electrical Conductivity	µS/cm	377	381	394	388	No trend	No	No
		Electrical Conductivity	µS/cm	667	670	680	681	Increasing		
	C18001SP	Boron	µg/L	120	110	150	140	No trend	No	No
		Total Dissolved Solids	mg/L	379	334	384	400	No trend		
		Electrical Conductivity	µS/cm	380	382	384	383	Increasing		
	C18002SP	Boron	µg/L	65	60	70	70	No trend	No	No
		Iron	µg/L	1297	5530	2660	1590	Increasing		
	C006P3R	Boron	µg/L	160	210	a	170	Increasing	Yes	Yes
		Electrical Conductivity	µS/cm	1030	1260	a	1320	Increasing		
		Total dissolved solids	mg/L	631	720	a	708	No trend		
Colinlea Sandstone	C011P3	Boron	µg/L	450	500	470	470	Increasing	No	No
	C034P3	Iron	µg/L	2796	2690	2860	2940	No trend	No	No
	C19029SP	Iron	µg/L	165	280	260	350	No trend	Yes	Yes

Table C.1 Water quality trigger exceedances – June 2022 monitoring round

Aquifer	Monitoring Bore	Parameter	Units	Trigger Level	February 2022	April /May 2022	June 2022	During dewatering Mann-Kendall trend	Bore has water level dewatering impact?	Proximity to mine disturbance footprint <2 km
Dunda Beds	C848SP	Boron	µg/L	190	180	200	230	Increasing	No	No
	C022P1	Boron	µg/L	130	120	130	150	No trend	No	No
	C027P2	Boron	µg/L	210	180	240	230	Increasing	No	No
	C14023SP	Electrical Conductivity	µS/cm	748	714	759	757	Increasing	No	No
	C180117SP	Iron	µg/L	1498	2100	1710	2280	Increasing	No	No
	C19015SP	Boron	µg/L	100	100	100	110	No trend	No	No
		Electrical Conductivity	µS/cm	712	697	726	712	No trend		
		Total Dissolved Solids	mg/L	398	390	413	400	No trend		
Joe Joe Group	C14003SP	C6-C10	µg/L	20	<20	150	180	Increasing	No	No
		Electrical Conductivity	µS/cm	53230	51900	53800	54200	No trend		
		Total dissolved solids	mg/L	43245	45800	43400	50700	No trend		
	C14006SP	Boron	µg/L	502	440	550	510	No trend	No	No
	C14008SP	Boron	µg/L	112	90	120	120	Increasing	No	No
		Cobalt	µg/L	10	10	11	10	No trend		
		Nickel	µg/L	11	13	14	12	No trend		
	C14015SP	Iron	µg/L	580	630	710	640	No trend	No	No
	C14017SP	Iron	µg/L	540	670	650	620	Increasing	No	No
	C14032SP	Boron	µg/L	170	220	210	200	No trend	No	No
		Cobalt	µg/L	1.4	3	3	3	No trend		

Table C.1 Water quality trigger exceedances – June 2022 monitoring round

Aquifer	Monitoring Bore	Parameter	Units	Trigger Level	February 2022	April /May 2022	June 2022	During dewatering Mann-Kendall trend	Bore has water level dewatering impact?	Proximity to mine disturbance footprint <2 km
Rewan	C180119SP	Iron	µg/L	1370	3750	7410	5090	No trend	No	No
		Zinc	µg/L	2000	3740	6440	5250	No trend		
	C180123SP	Boron	µg/L	356	430	400	430	No trend	No	No
	C914001SPR	Electrical Conductivity	µS/cm	21300	17900	22600	21900	No trend	No	No
	C914030SPR	Nickel	µg/L	11	12	12	12	No trend	No	No
		Boron	µg/L	92	120	100	110	No trend		
	C9180124SPR	Iron	µg/L	110	210	340	5230	Increasing	No	No
		Electrical Conductivity	µS/cm	473	469	482	493	No trend		
	C035P1	Boron	µg/L	710	690	750	720	No trend	No	No
	C556P1	Cobalt	µg/L	5	6	5	5	No trend	No	No
Tertiary	C029P2	Iron	µg/L	1440	1520	1610	1590	No trend	No	No
	C18005SP	Electrical Conductivity	µS/cm	53150	51900	54200	53400	Increasing	No	Yes
		Iron	µg/L	170	100	170	240	Increasing		
		Nickel	µg/L	37	20	56	64	No trend		
	C18006SP	Iron	µg/L	674	850	a	840	Increasing	No	Yes
	C18009SP	Boron	µg/L	1328	1510	1340	1690	Increasing	No	Yes
	C558P1	Boron	µg/L	840	850	960	850	No trend	No	No
	C9180121SPR	Iron	µg/L	344	550	780	360	No trend	No	No
	C9845SPR	Electrical Conductivity	µS/cm	2000	1960	2010	2010	Increasing	No	No

Table C.1 Water quality trigger exceedances – June 2022 monitoring round

Aquifer	Monitoring Bore	Parameter	Units	Trigger Level	February 2022	April /May 2022	June 2022	During dewatering Mann-Kendall trend	Bore has water level dewatering impact?	Proximity to mine disturbance footprint <2 km
		Boron	µg/L	240	230	280	270	Increasing		
		Nitrate	mg/L	0.1	0.11	0.12	0.1	Decreasing		

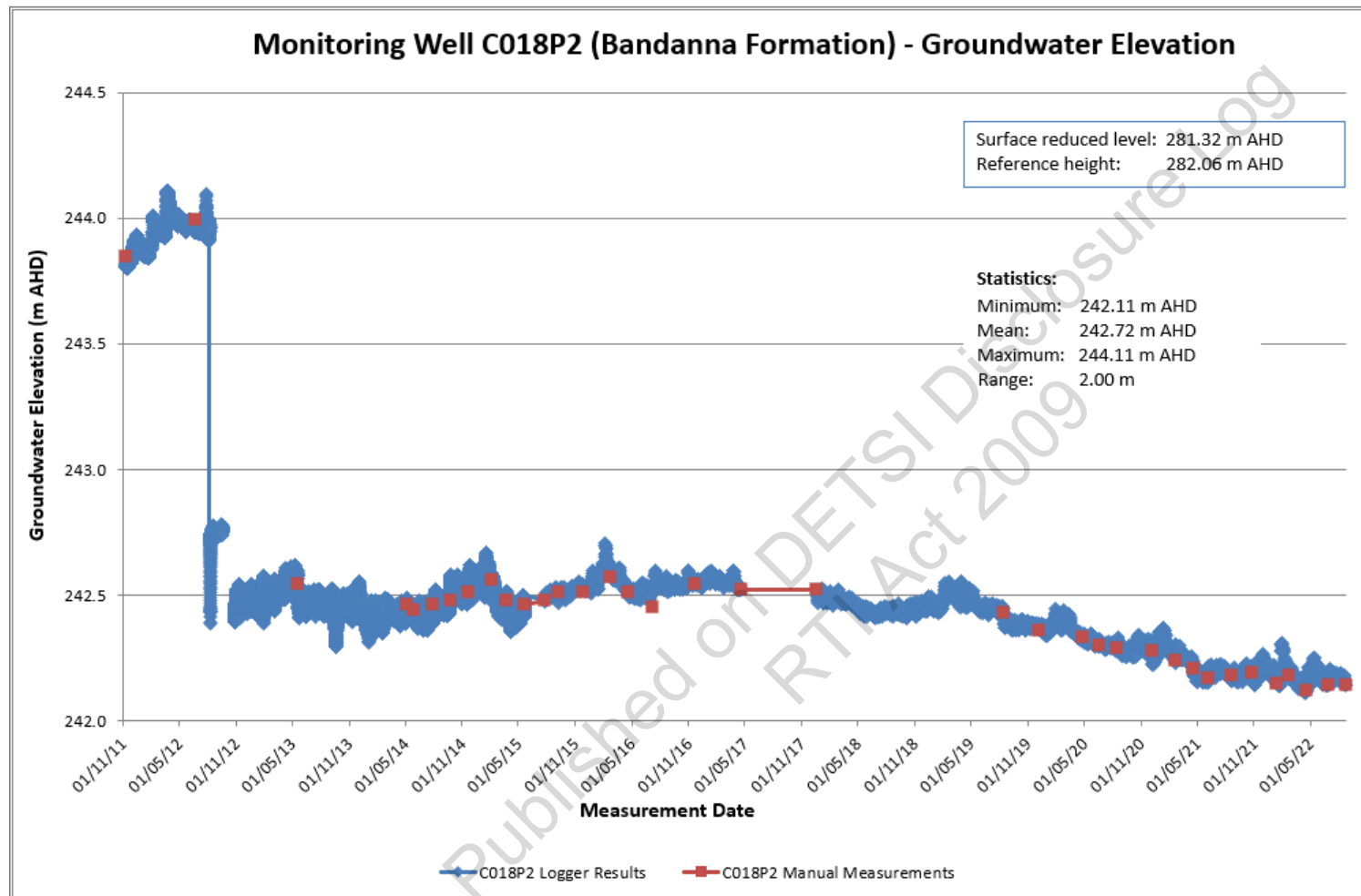
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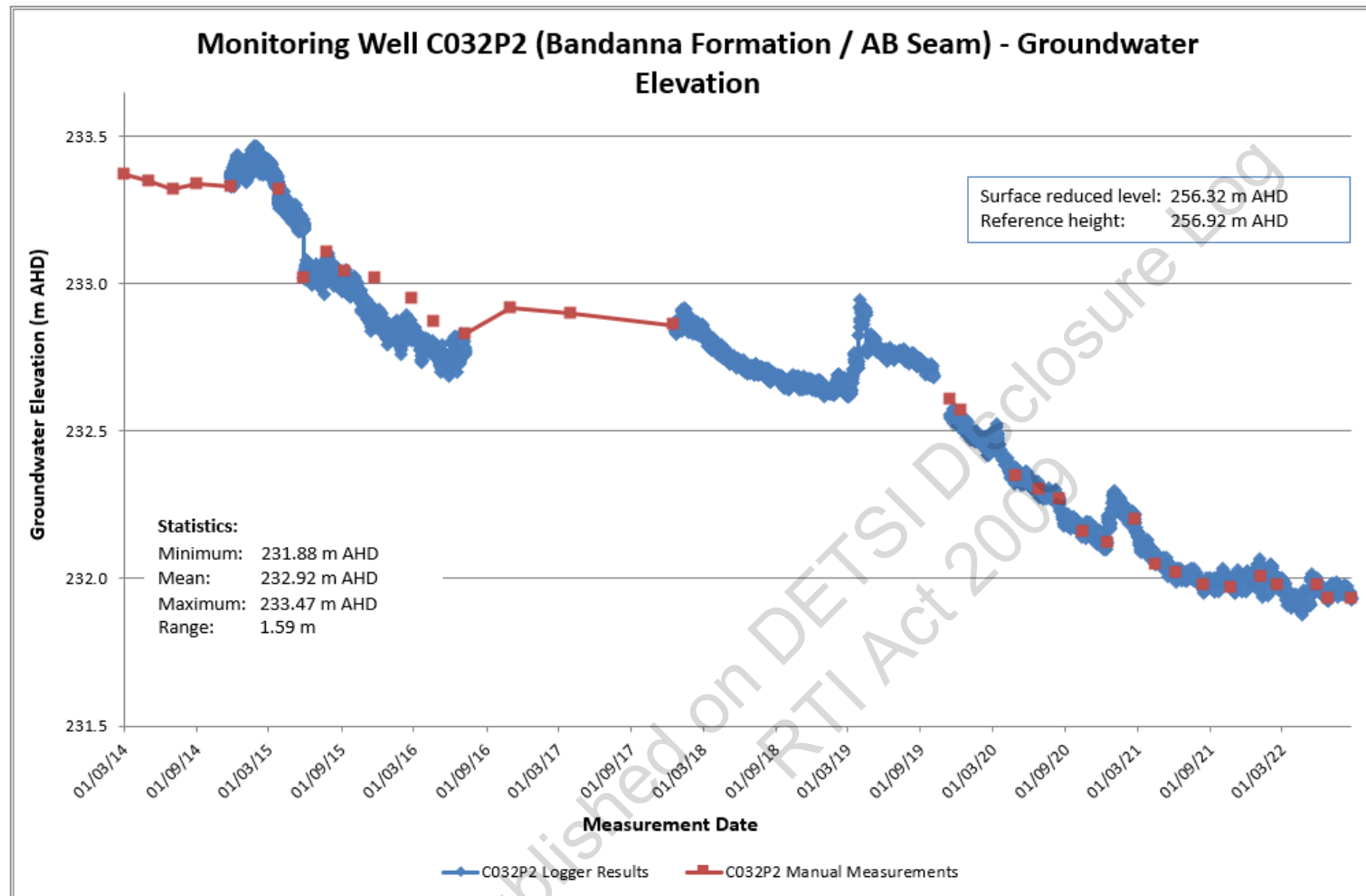
- Values highlighted in red have either reached or exceeded the trigger values.
- <LOR = value reported at less than the laboratory limit of reporting (LOR).
 - a = sample unable to be collected due to impeded access to the bore following rainfall.
- Yellow highlighted cells indicate two consecutive results reach or exceed trigger level and therefore Step 1 investigation is required.
- Monitoring bores with green shading show increasing parameter trend together with water level dewatering impact and/or located within 2 km of mine disturbance, thus requiring a detailed assessment.

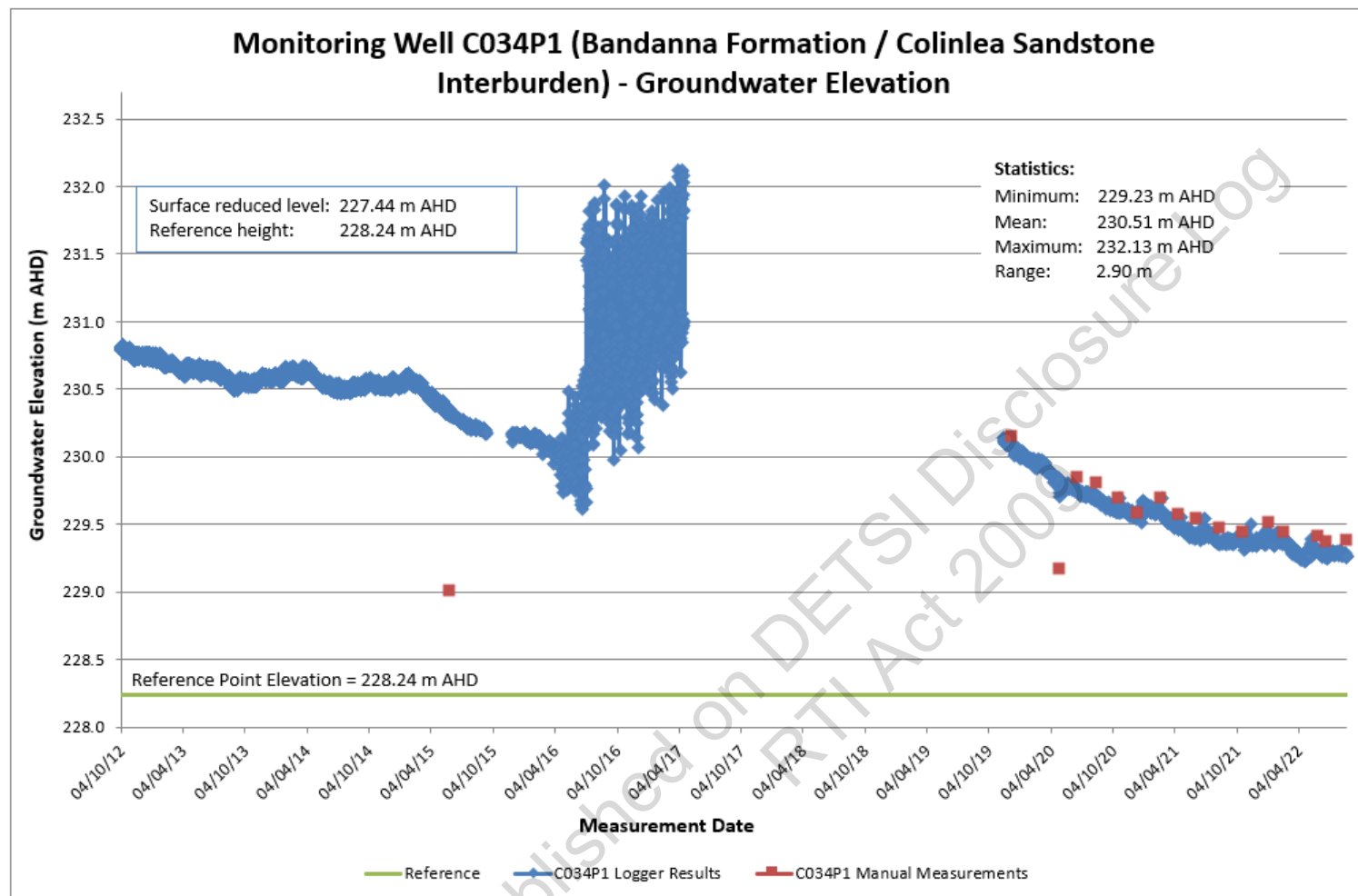
Appendix D

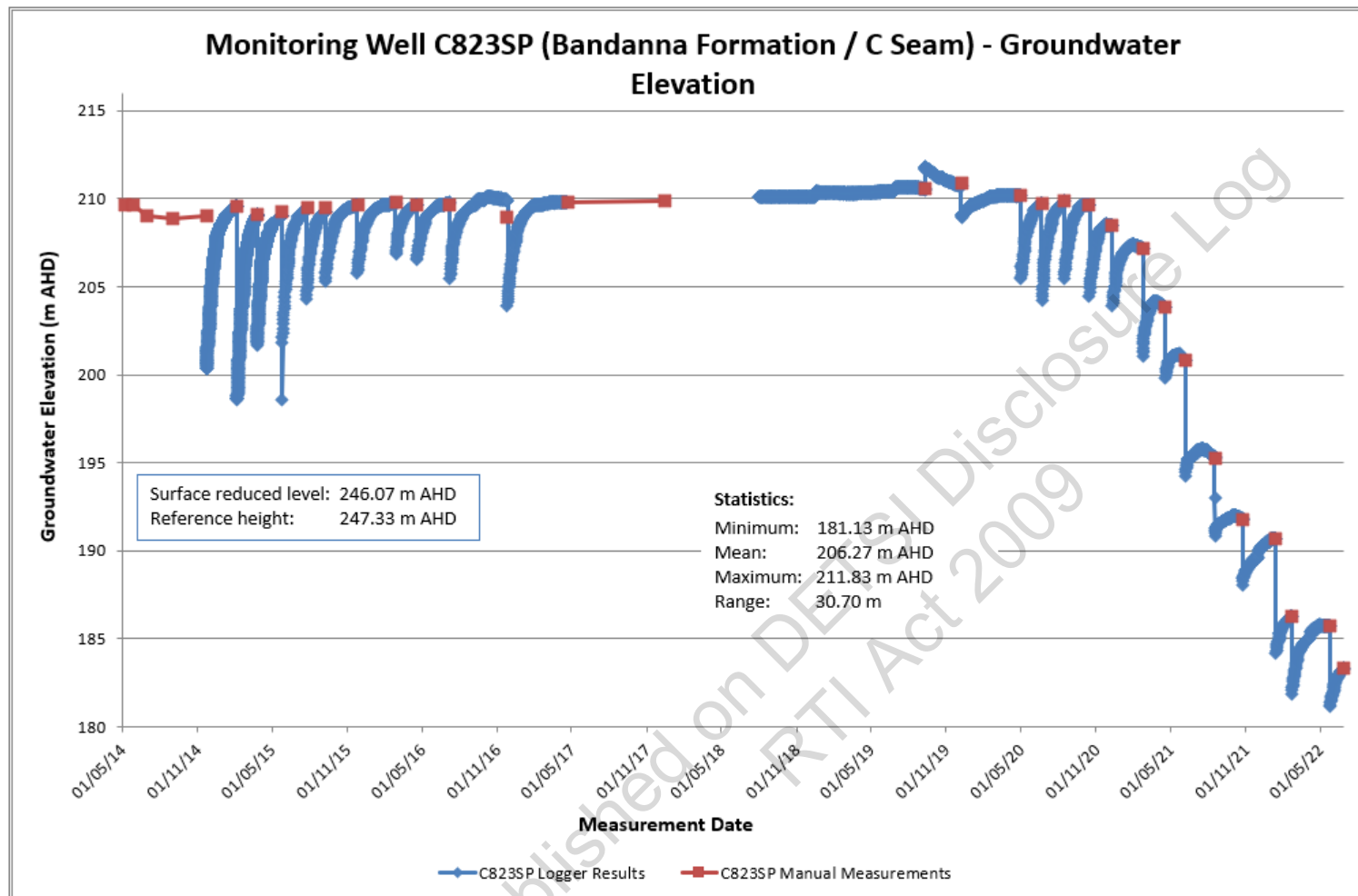
Logger data validation hydrographs

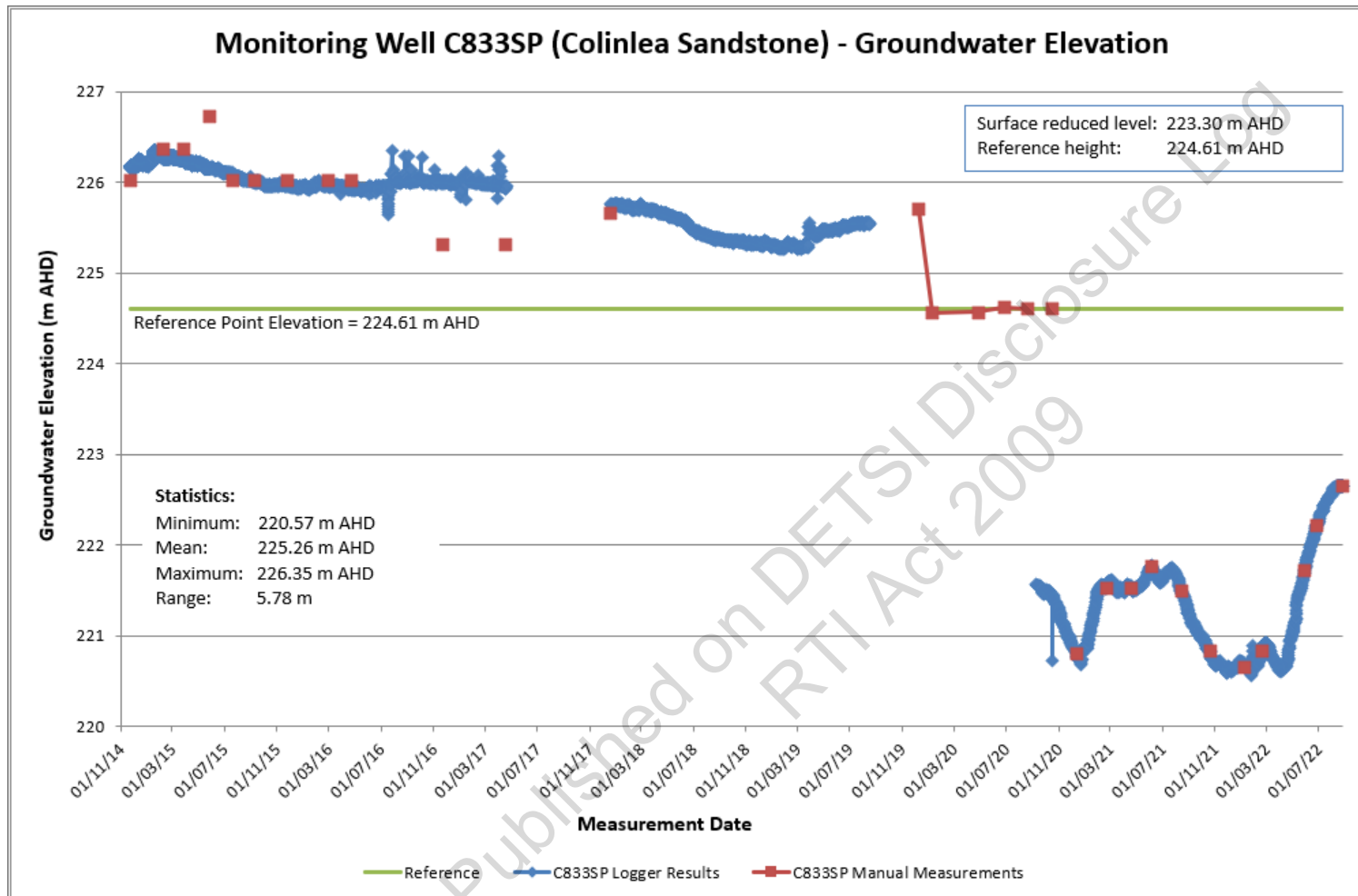
D.1 Bandanna Formation

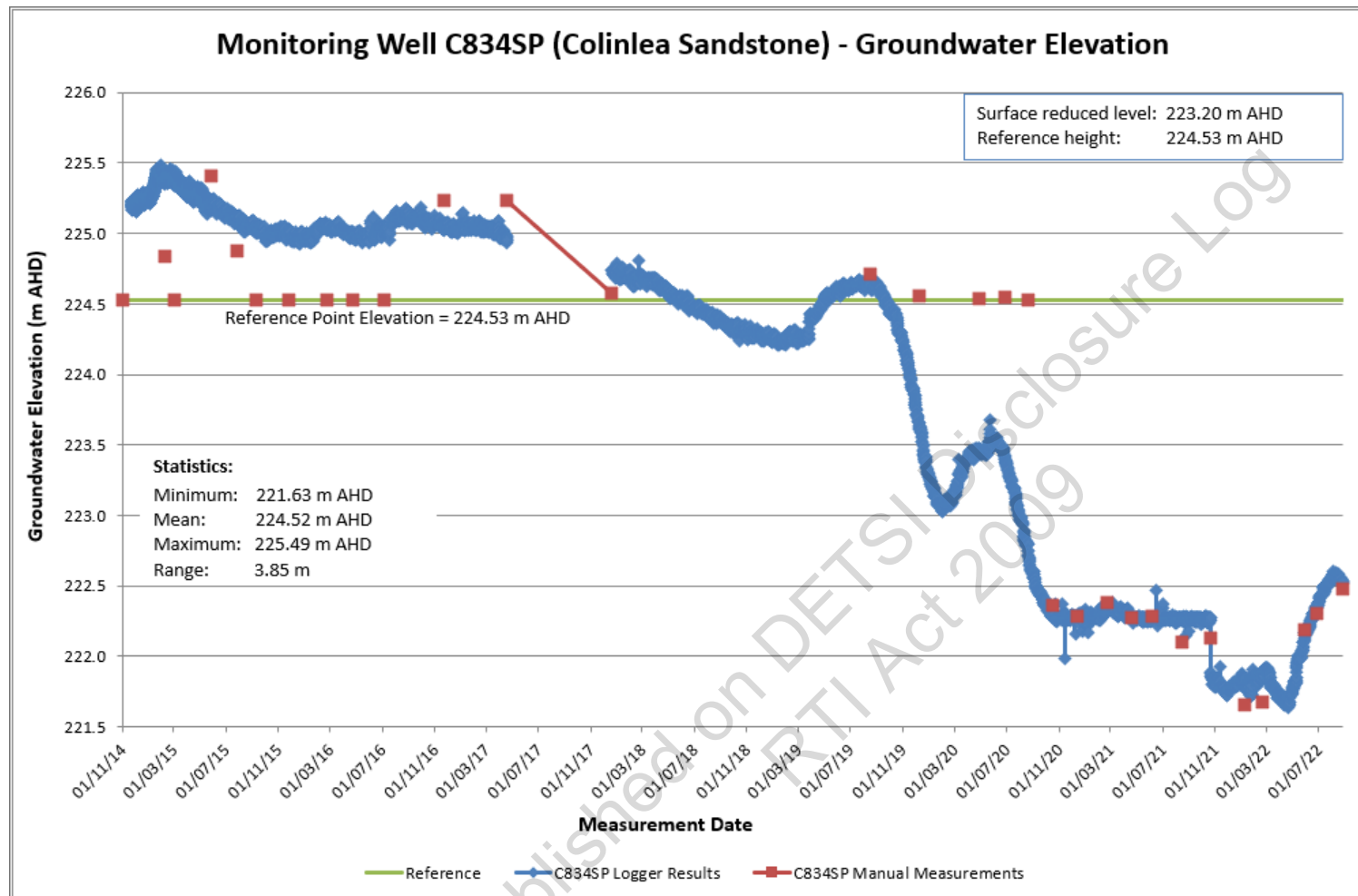


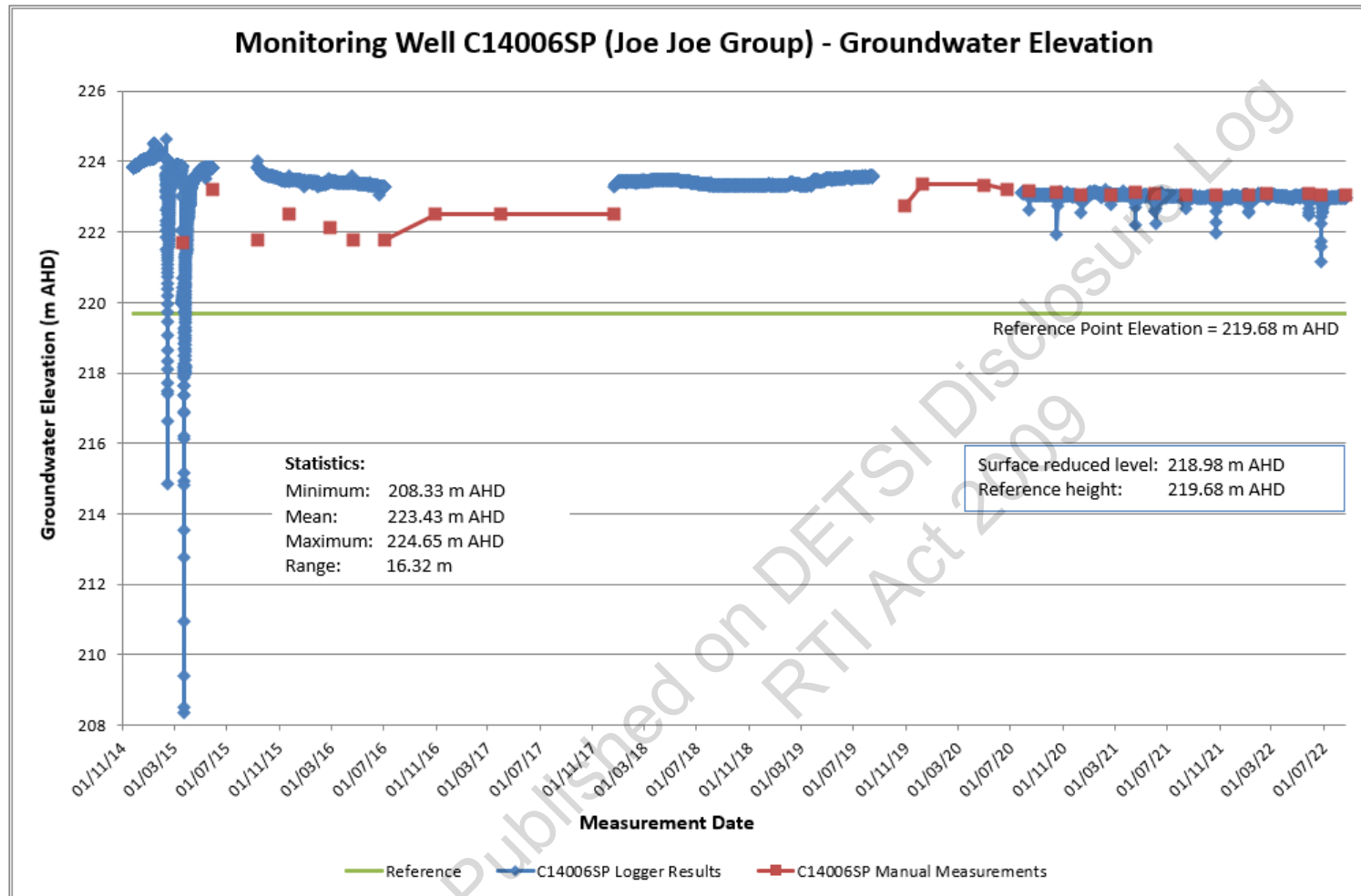


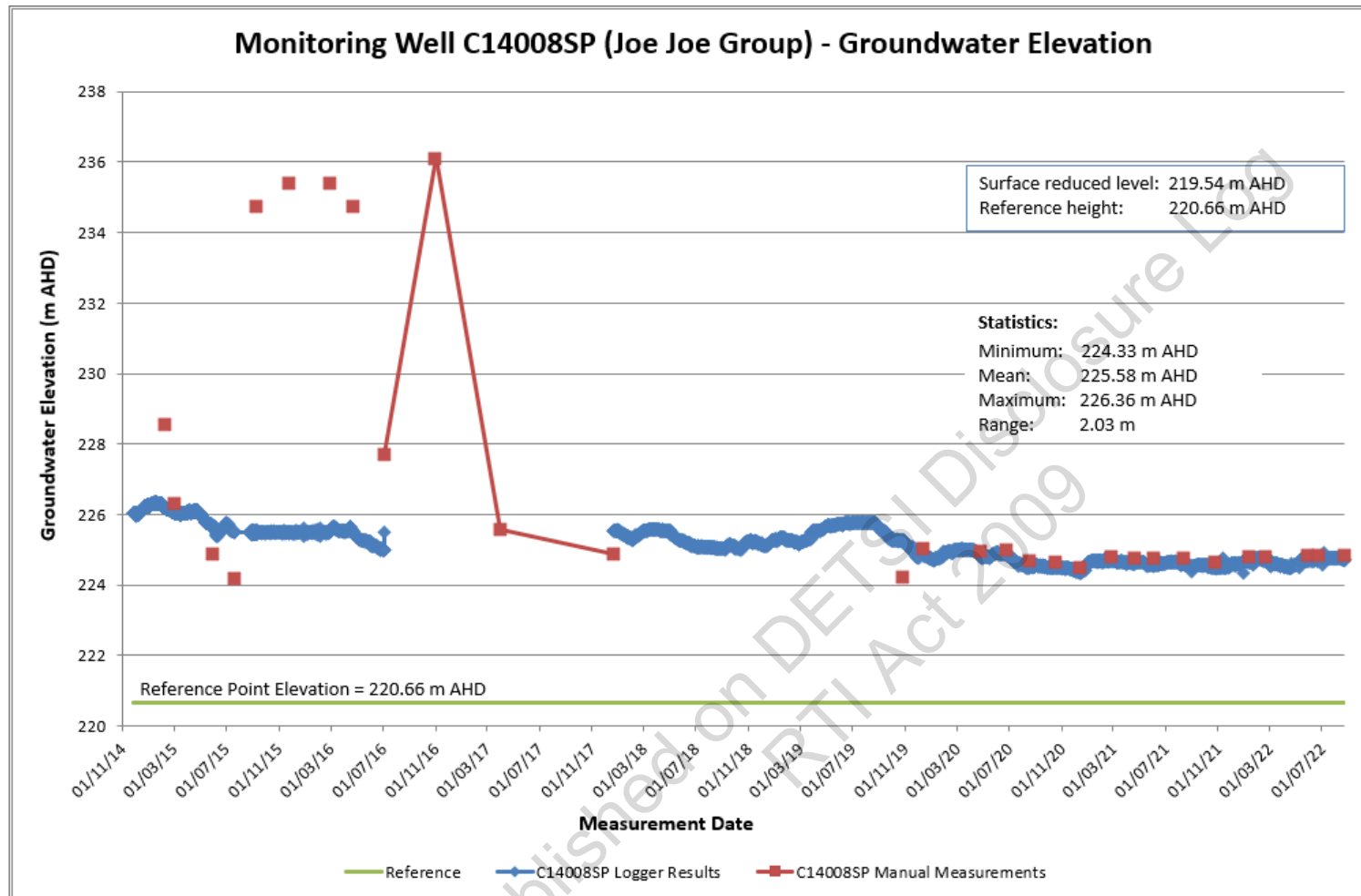


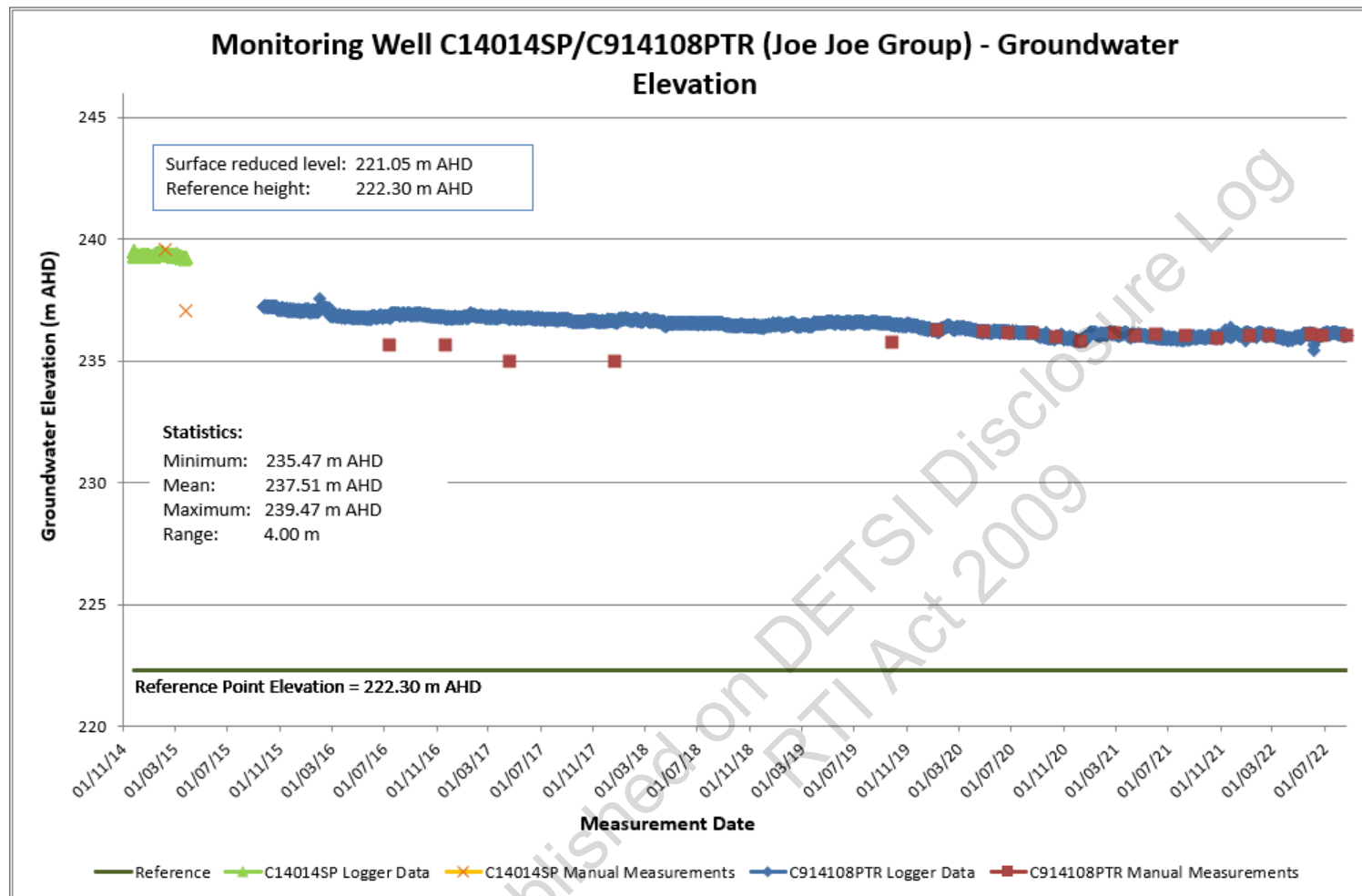


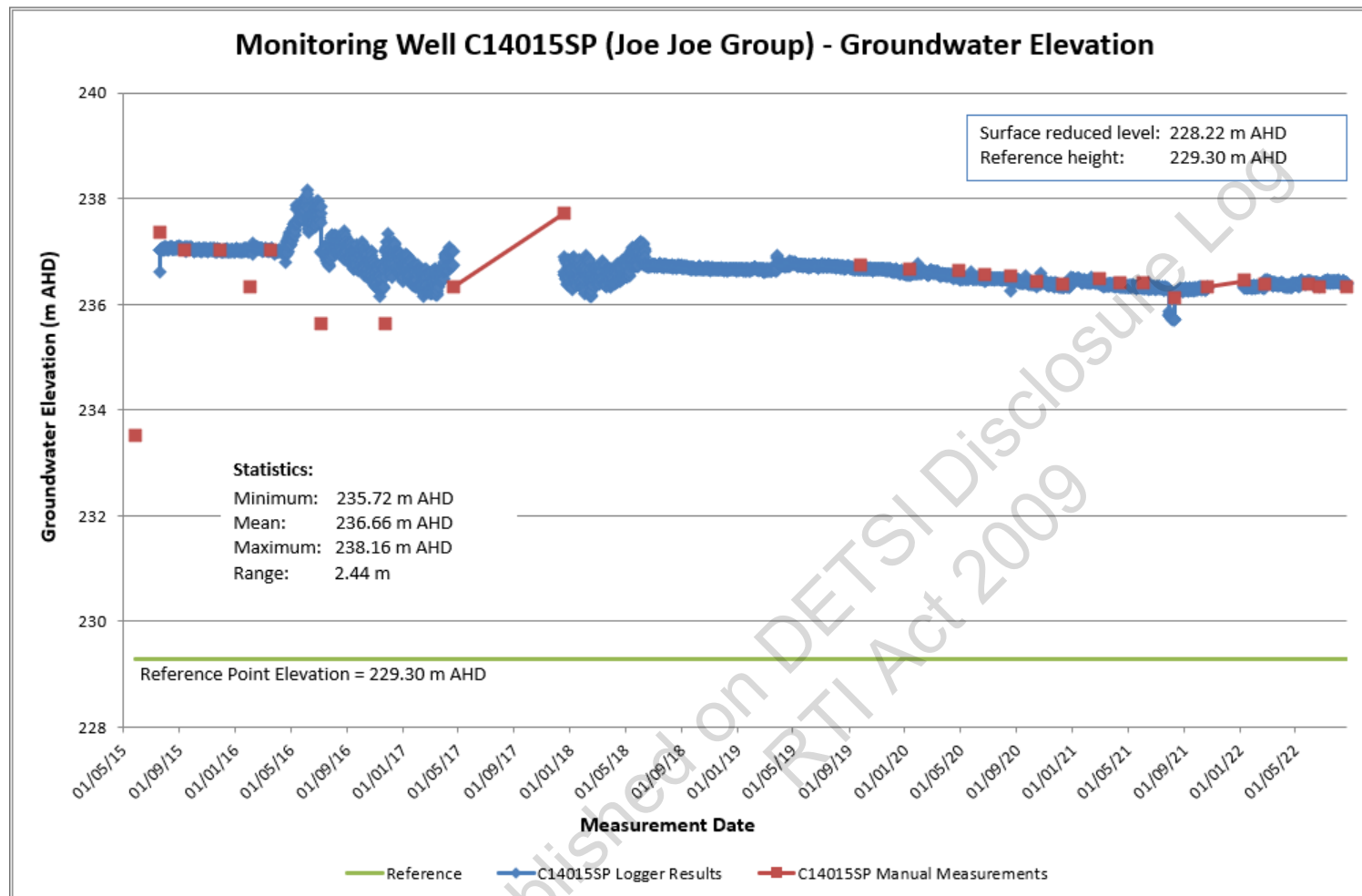


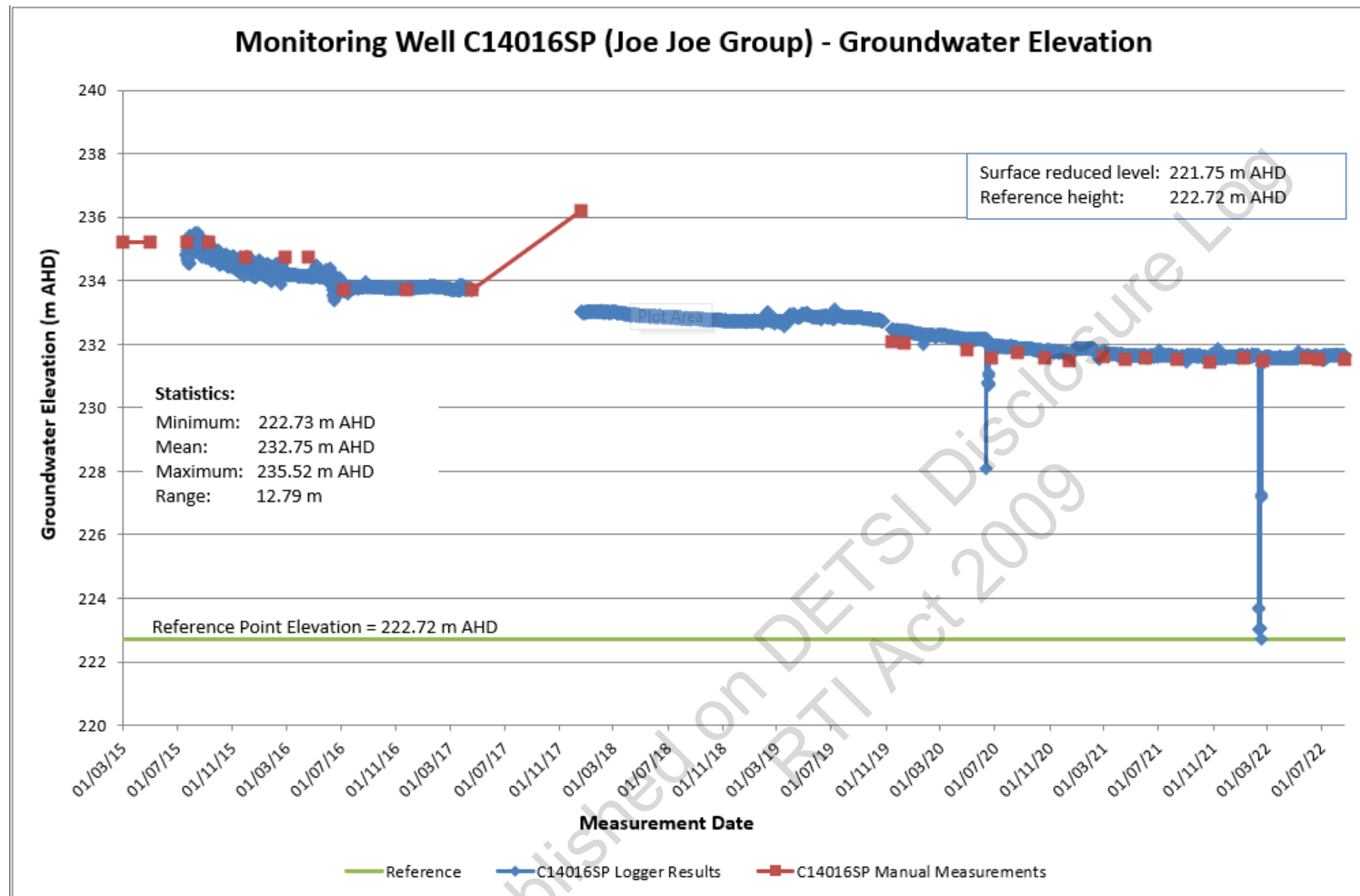


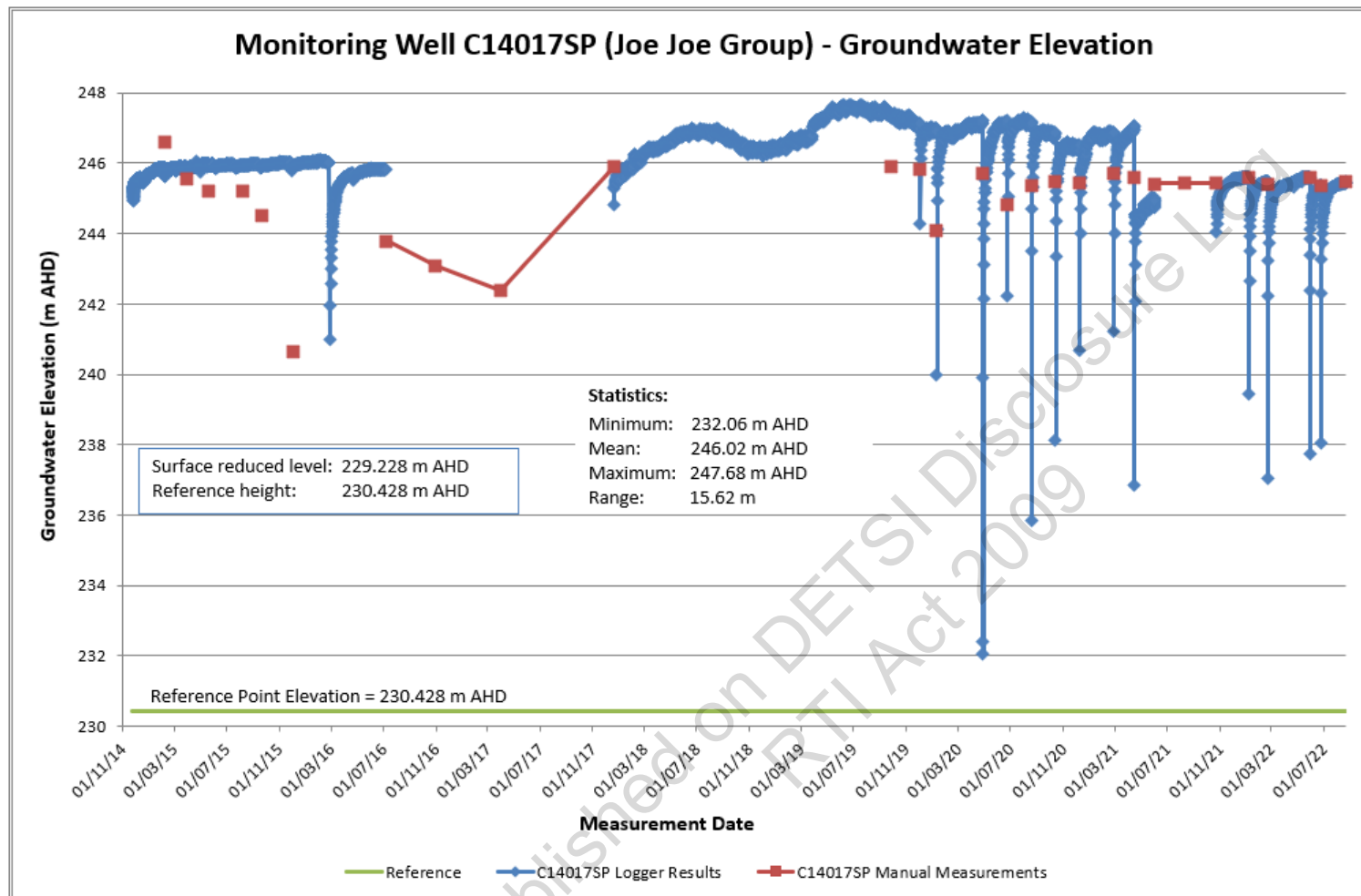


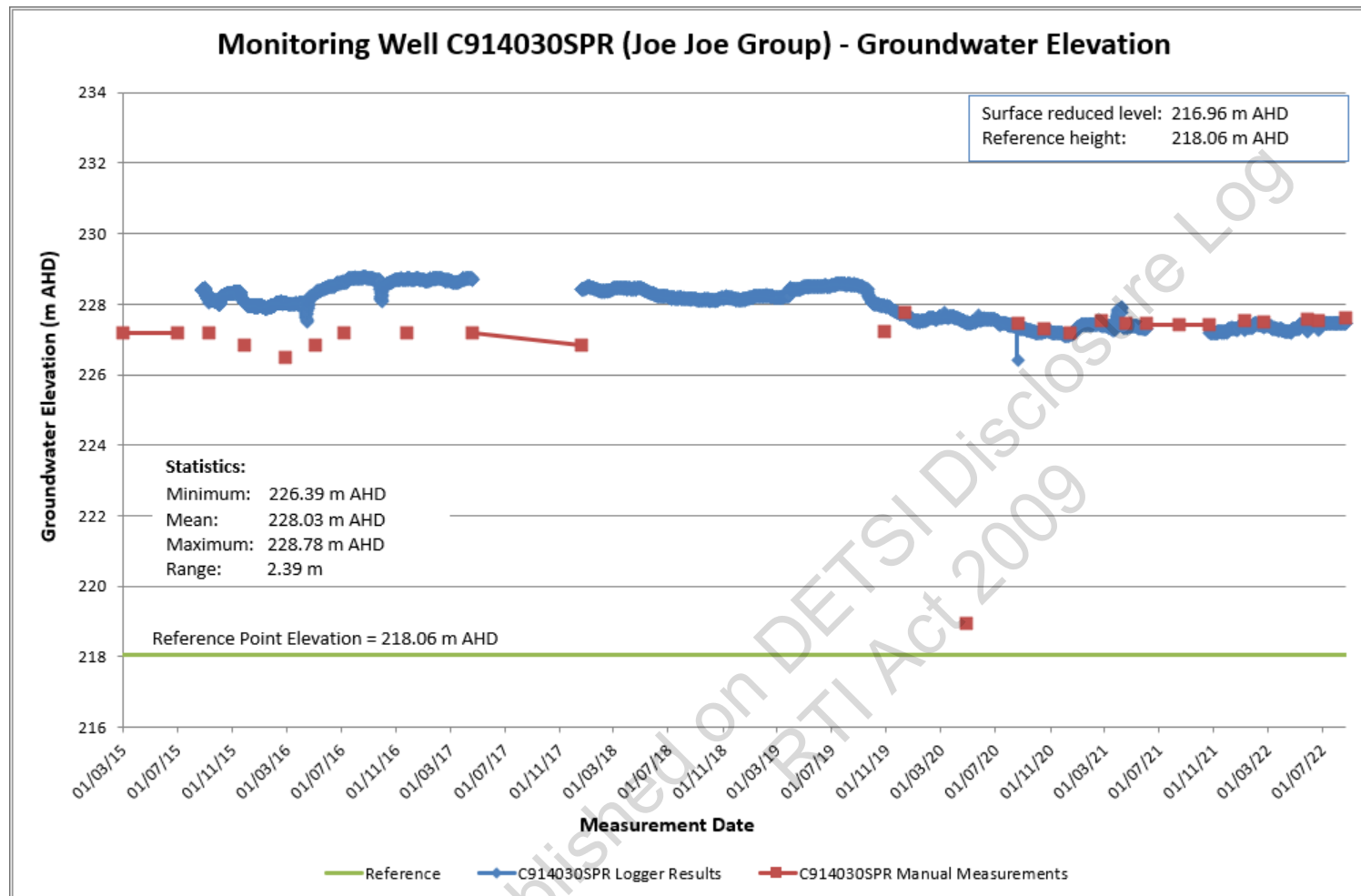


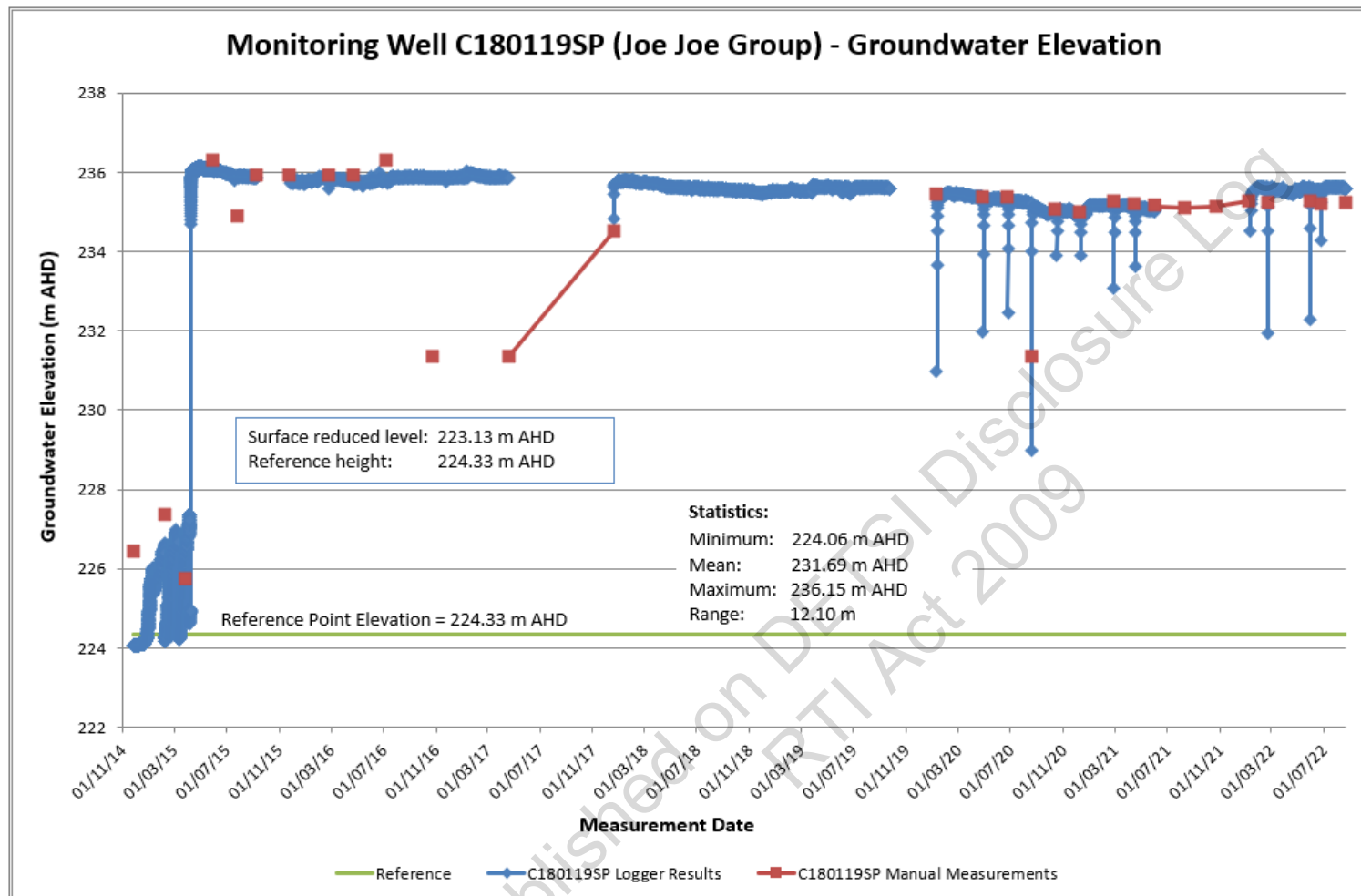


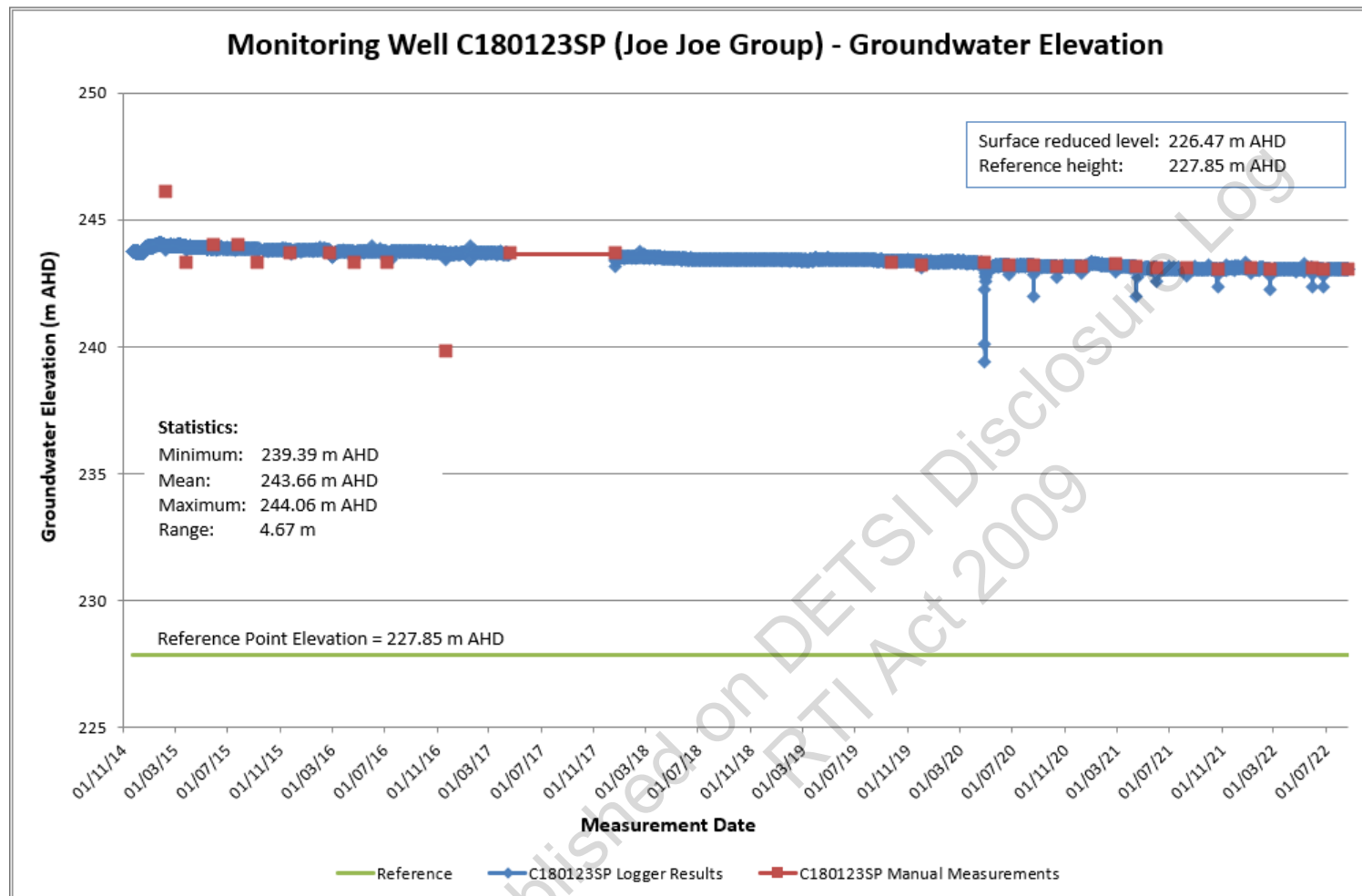


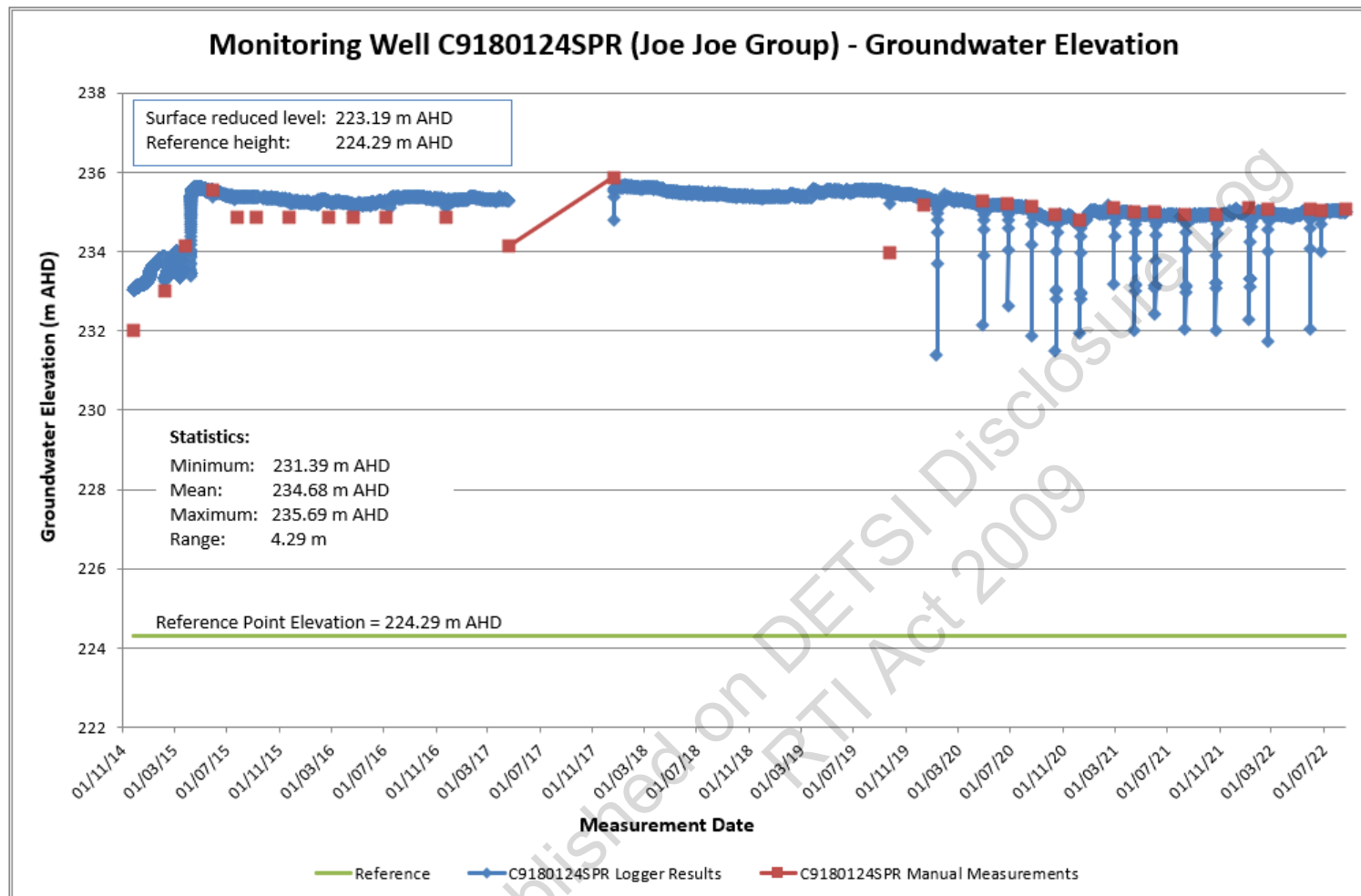


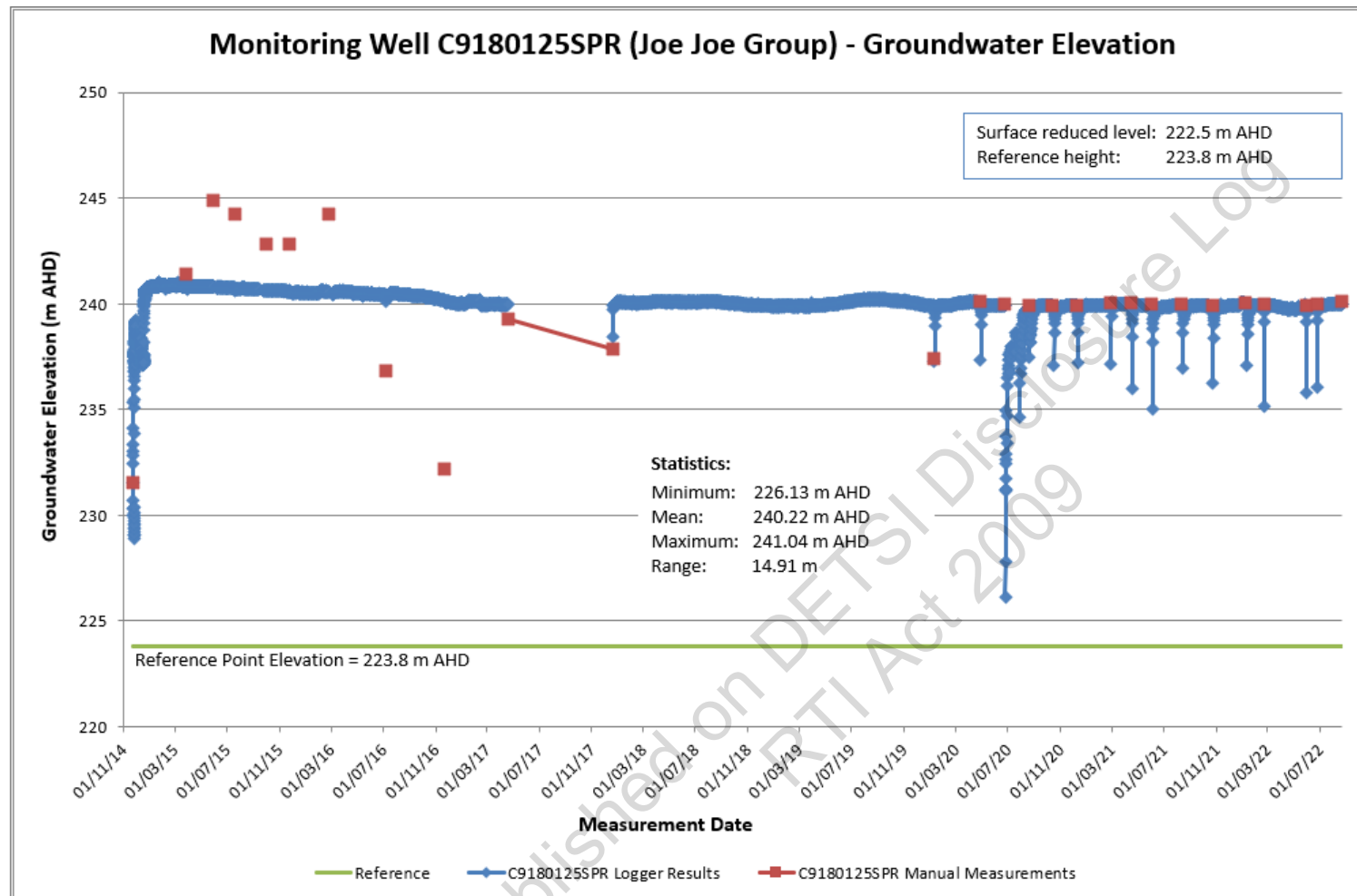












Appendix E

Revised contaminant limits

E.1 Alluvium

Table E.1 Revised alluvium contaminant limits

Analyte	C027P1	C029P1	C14027SP	C14028SP	C19001SP	HD03B
pH (field)	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0
EC (µS/cm)	7,400	34,308	51,076	45,800	27,039	922
TDS (mg/L)	4,438	21,208	39,728	33,040	16,386	607
Sulphate (mg/L)	547	1,100	2,228	2,000	890	14
Aluminium (µg/L)	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	17,975	1,356	4,418	1,929	60	1,565
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.26	0.66	0.26	0.11	0.75	0.21
Boron (µg/L)	857	5,700	3,142	3,458	2,196	198
Cobalt (µg/L)	17.4	12.9	94.0	25.4	1.4	1.4
Copper (µg/L)	184.9	145.2	173.1	88.9	3.0	8.7
Nickel (µg/L)	35.8	29.0	51.7	21.4	26.2	11.0
Zinc (µg/L)	105.8	323.5	347.0	192.7	11.9	22.8
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.2 Tertiary sediments

Table E.2 Revised Tertiary sediments contaminant limits

Analyte	C025P2	C029P2	C558P1	C9845SPR	C9180121 SPR	C18004SP	C18005SP	C18006SP	C18009SP
pH (field)	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.7 – 9.0	5.4 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0
EC (µS/cm)	15,000	12,900	10,040	2,000	3,938	40,882	53,479	61,573	26,076
TDS (mg/L)	9,000	7,735	6,729	1,262	2,556	37,765	48,460	54,458	24,192
Sulphate (mg/L)	467	320	278	67	100	815	2,522	3,046	976
Aluminium (µg/L)	55	55	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34	34	38.5
Selenium (µg/L)	11	11	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	20,298	1,631	888	50	608	130	208	812	80
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.39	0.19	0.10	0.43	0.10	0.10	0.48	0.10	0.10
Boron (µg/L)	1,737	1,300	890	370	370	1,518	5,122	6,024	1,368
Cobalt (µg/L)	1.4	1.4	5.0	1.4	1.4	1.4	17	14	1.4
Copper (µg/L)	62.9	29.9	1,069	223.7	1.4	1.4	206	1.4	1.4
Nickel (µg/L)	24.4	11.0	75.7	21.6	11.0	42.8	55	26.6	11
Zinc (µg/L)	42.3	1,123	189.8	156.9	11,136	8	369	8	75.9
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.3 Clematis Sandstone

Table E.3 Revised Clematis Sandstone contaminant limits

Analyte	C14011S P	C14012S P	C14013S P	C14021S P	C14033S P	HD02	HD03A	C18001S P	C18002S P	C19002S P
pH (field)	4.8 – 9.0	5.9 – 9.0	4.7 – 9.0	5.5 – 9.0	4.9 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	4.6 – 9.0
EC (µS/cm)	326	506	419	703	472	640	761	673	381	351.4
TDS (mg/L)	199	298	258	424	290	420	491	385	252	202
Sulphate (mg/L)	7	7	12	24	5	6	12	10.8	1	27.5
Aluminium (µg/L)	55	55	55	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	21	65	17	15	13	1,764	696	1,733	5	5
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.76	0.7	0.73	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.10	0.14	0.10	0.10	0.10	0.22	0.12	0.10	0.19	0.10
Boron (µg/L)	118	130	128	181	98	128	150	138	79	119
Cobalt (µg/L)	2.0	1.4	5.0	1.4	2.0	2.9	1.4	1.4	1.4	1.4
Copper (µg/L)	20.6	1.4	16	18.6	36.9	1.4	1.4	1.4	1.4	6.0
Nickel (µg/L)	11	11	12.6	11	11	11	11	11	11	11
Zinc (µg/L)	118.6	22	162.1	92.2	164.3	31.5	87.2	171.2	5	5
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.4 Dunda Beds

Table E.4 Revised Dunda Beds contaminant limits

Analyte	C022P1	C027P2	C14023SP	C180117SP	C19007SP	C19011SP	C19015SP
pH (field)	4.8 – 9.0	5.4 – 9.0	6.0 – 9.0	5.1 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0
EC (µS/cm)	384	959	752	395	1,418	804	714
TDS (mg/L)	226	913	445	238	824	541	414
Sulphate (mg/L)	17	28	3	21	30	1	1
Aluminium (µg/L)	608	135	55	67.1	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	44.9	34	34
Selenium (µg/L)	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	5	9,565	5	1,900	5	5	5
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.10	0.18	0.10	0.11	0.10	0.10	0.10
Boron (µg/L)	157	235	109	93	80	25	100
Cobalt (µg/L)	57.7	2.9	1.4	1.4	1.4	1.4	1.4
Copper (µg/L)	178.1	2.9	1.4	120.8	1.4	1.4	1.4
Nickel (µg/L)	11	11	11	50	11	11	11
Zinc (µg/L)	84.4	101.7	8	176.8	8	8	8
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.5 Rewan Formation

Table E.5 Revised Rewan Formation contaminant limits

Analyte	C008P1	C035P1	C555P1	C556P1	C9553P1R	C9838SPR	C919016SPR
pH (field)	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	4.9 – 9.0	5.4 – 9.0	4.6 – 9.0	6.0 – 9.0
EC (µS/cm)	22,986	4,210	861	291	558	460	838
TDS (mg/L)	17,060	2,896	555	233	356	278	507
Sulphate (mg/L)	281	64	1	13	61	9	27
Aluminium (µg/L)	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	3,737	397	1,954	117	4,010	27	5
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.37	0.74	0.10	0.46	0.50	0.10	0.10
Boron (µg/L)	1,743	812	287	127	138	150	58
Cobalt (µg/L)	15.4	1.9	2.0	6.0	1.4	1.9	1.4
Copper (µg/L)	58.9	1.4	1.4	59.2	91.4	17.8	1.4
Nickel (µg/L)	63.0	11.9	11	11	11	11	11
Zinc (µg/L)	112.5	126.0	33.8	267.2	74.2	118.9	36.9
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.6 Bandanna Formation

Table E.6 Revised Bandanna Formation contaminant limits

Analyte	C008P2	C014P2	C032P2	C035P2	C19027SP	C018P2	C847SP
pH (field)	6.0 – 9.0	6.0 – 11.7	6.0 – 9.1	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.21 – 9.0
EC (µS/cm)	3,310	1,966	1,533	1,559	1,790	1,759	365
TDS (mg/L)	1,920	1,098	923	1,157	1,019	1,028	264
Sulphate (mg/L)	98	47	3	20	27.9	8	8
Aluminium (µg/L)	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	130	356	318	2,080	5	558	5
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.17	0.29	0.60	0.06	0.10	0.10	0.10
Boron (µg/L)	307	406	385	289	540	589	130
Cobalt (µg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Copper (µg/L)	1.4	1.4	1.4	1.4	1.4	1.4	12.9
Nickel (µg/L)	11	30.4	11	11	11	11	11
Zinc (µg/L)	148.6	8.0	28.7	38.9	8.0	15.9	78.6
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.7 Colinlea Sandstone

Table E.7 Revised Colinlea Sandstone contaminant limits

Analyte	C006P3R	C011P3	C018P3	C024P3	C034P3	C833SP	C848SP	C975SP	C19029SP
pH (field)	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.7 – 9.0	6.0 – 11.3	6.0 – 9.0	5.3 – 9.0	tbd
EC (µS/cm)	1,281	1,028	1,064	1,719	2,295	1,385	3,000	616	tbd
TDS (mg/L)	764	644	686	1,145	1,260	838	1,876	396	tbd
Sulphate (mg/L)	9	1	16	23	45	11	21.8	28	tbd
Aluminium (µg/L)	55	55	55	55	55	55	55	55	tbd
Arsenic (µg/L)	13	13	13	13.7	13	13	13	13	tbd
Molybdenum (µg/L)	34	34	34	34	34	34	34	34	tbd
Selenium (µg/L)	11	11	11	11	11	11	11	11	tbd
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	tbd
Iron (µg/L)	433	794	922	20,514	3,343	65	1,965	99	tbd
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	tbd
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	tbd
Total Phosphorus (mg/L)	0.10	0.12	0.11	0.28	0.10	0.10	0.10	0.10	tbd
Boron (µg/L)	180	510	400	380	260	200	218	199	tbd
Cobalt (µg/L)	1.4	1.4	1.4	5.0	1.4	1.4	1.4	1.4	tbd
Copper (µg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	tbd
Nickel (µg/L)	11	11	11	74.5	11	11	11	11	tbd
Zinc (µg/L)	42.3	26.2	124.7	122.8	360.2	118.2	48.5	238.5	tbd
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	tbd
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	tbd

Notes: Contaminant limits for C19029SP to be determined when sufficient results are available.

E.8 Joe Joe Group

Table E.8 Revised Joe Joe Group contaminant limits

Analyte	C012P1	C012P2	C14003SP	C14006SP	C14008SP	C14015SP	C14017SP
pH (field)	5.5 – 9.0	6.0 – 9.0	4.8 – 9.0	6.0 – 9.0	5.3 – 9.0	6.0 – 9.0	6.0 – 9.0
EC (µS/cm)	2,097	2,689	53,905	8,700	709	2,680	7,000
TDS (mg/L)	1,359	1,786	49,764	5,372	427	1,600	4,200
Sulphate (mg/L)	59	55	2,881	247	15	70	130
Aluminium (µg/L)	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	165	1,519	19,491	8,200	4,507	634	596
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.31	0.10	0.10	0.10	0.10	0.22	0.10
Boron (µg/L)	477	540	4,362	547	136	430	830
Cobalt (µg/L)	1.4	1.4	38.8	1.4	11	5.9	3.0
Copper (µg/L)	1.4	58.6	924.9	1.4	1.4	1.4	1.4
Nickel (µg/L)	11.6	17.6	35.4	11	14	11	11
Zinc (µg/L)	179.8	33.3	208.5	390.5	229.6	150.8	641.1
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

Table E.9 **Revised Joe Joe Group contaminant limits**

Analyte	C14032SP	C180119SP	C180123SP	C914001SPR	C914030SPR	C9180124SPR	C9180125SPR
pH (field)	5.4 – 9.0	5.8 – 9.0	6.0 – 9.0	5.7 – 9.0	5.6 – 9.0	5.2 – 9.0	6.0 – 9.0
EC (µS/cm)	2,188	782	908	21,874	616	510	1,023
TDS (mg/L)	1,257	785	579	15,237	353	321	653
Sulphate (mg/L)	36	9	29	1,600	12	7	26
Aluminium (µg/L)	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	2,228	2,923	405	10,769	834	158	212
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.10	0.18	0.10	0.10	0.10	0.10	0.10
Boron (µg/L)	180	179	398	2,100	129	108	310
Cobalt (µg/L)	1.4	1.4	1.4	1.4	8.9	2.0	1.4
Copper (µg/L)	1.4	1.4	1.4	1.4	1.4	4.9	3.9
Nickel (µg/L)	11	18.4	11	22.1	13.9	17	11
Zinc (µg/L)	398.1	11,644	8.0	302.4	318.6	788.4	509.5
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

Appendix F

DES comments on draft GMMP review report

	Section	Review GMMP finding	DES recommendation	Response	Additional comment and relevant section of final GMMP review report
1.0	3.2.1 Groundwater Monitoring Locations	Three sites have been selected for additional Colinlea Sandstone (two bores) and Bandanna Formation (one bore) monitoring bores.	<p>This proposal is supported and it is considered that the additional sites are critical.</p> <p>However, it is considered that even with these additional monitoring bores there will still be deficiencies in the proposed network monitoring these formations. This issue and the proposed additional locations are discussed as follows:</p> <p>Colinlea Sandstone In order to better understand the propagation of drawdown from the mine towards the Doongmabulla Springs there should also be a Colinlea Sandstone monitoring bore on the western lease boundary in a location that won't be mined out. There should also be a standpipe bore in the area of C19031VWP as given the unreliability of the existing VWP bores there can be no guarantee that data from this VWP is representative of the Colinlea Sandstone.</p> <p>Bandanna Formation Similarly, there should be a Bandanna Formation monitoring bore on the western lease boundary in a location that won't be mined out.</p> <p>Colinlea Sandstone and Bandanna Formation</p>	<p>Additional monitoring bore locations will be added (see figure at the end of this response)</p> <p>There is a bore installed in bandanna formation (C19018SP) at this location. C19031 SP (VWP) is recording the pore pressure in Colinlea sandstone.</p> <p>See additional monitoring bore location map.</p>	<p>Figure 3.1 of the report has also been updated with the additional bore locations.</p> <p>Figure 3.1 of the report has also been updated with the additional bore locations.</p>

			<p>There is a proposal in section 3.2.1 to drill additional Colinlea Sandstone and Bandanna Formation monitoring bores south of the lease in the direction of Mellaluka Springs. This is supported but the proposal to treat this as a low priority, and delay until mining progresses south and impacts are noted in C19003SP and C19004SP, is not supported.</p> <p>Given the issues with local landholder use potentially impacting water levels in this area and the challenges in unpacking which stress is causing impact, the sooner baseline data is available from the proposed Colinlea Sandstone and Bandanna Formation bores in this area, the better.</p> <p>There are also concerns in both the Colinlea Sandstone and Bandanna Formation that there are sizeable gaps in the network in critical areas in the southern part of the lease area.</p> <p>In the Bandanna Formation there is a gap between C9839SPR (at 0.34 m/yr (table 6.6) almost considered impacted) and C034P1 which is some 5.6 km south of C9839SPR. Tracking this impact south will therefore soon become difficult.</p> <p>In the Colinlea Sandstone there is a gap between C840SP (most southerly monitoring bore considered impacted 0.47 m/yr</p>	<p>The existing bores in Bandanna formation are deemed to be sufficient to track the impacts to south side as there is one more bore C847SP further to the edge of ML in southside. The existing bores in Colinlea SSt formation are deemed to be sufficient to track the impacts to south side as there is one more bore C848SP further to the edge of ML in southside.</p>	
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			<p>(table 6.7)) and C034P3 which is some 5.8 km south of C840SP. Tracking this impact south will therefore also soon become difficult.</p> <p>Additionally, figure 3.1 shows Bandanna bore 823SP as an existing monitoring bore but it was mined out recently. This figure needs to be amended to provide an accurate understanding of the existing monitoring bores.</p>	The figure will be amended	Figure 3.1 of the report has also been updated and bore C823SP removed.
2.0	3.2.2 Groundwater quality trigger levels	<p>In this section the review states: <i>The contaminant limits in the GMMP should be updated using the same dataset as was used to develop the updated trigger values for consistency.</i></p>	It is recommended that the GMMP has consistent terminology with the environmental authority.	Contaminant limits will be updated in GMMP with additional data.	
3.0	3.2.3 Groundwater level thresholds	<p>This section discusses reassessment of groundwater level thresholds where logger cable lengths have been remeasured in some artesian bores and adjustments made to historical logger data. This work is supported.</p>	<p>However, there are other artesian bores where there still appear to be differences between the manually measured water level elevations and the logger data. A list of these bores has been provided below. How are these bores going to be investigated to determine the cause of this variation?</p> <p>Clematis Sandstone C18001SP C19014SP HD03A Dunda Beds C19011SP C19015SP Rewan Formation C19016SP Joe Joe C14017SP</p>	<p>The manually measured water level are consistent with logger data for bores C18001SP, C19014SP and HD03A (Clematis Sandstone), bores C19011SP and C19015SP (Dunda Beds), and bore C19016SP (Rewan Formation) (refer to figure at the end of report). The data for bore C14017SP (Joe-Joe) will be reviewed</p>	<p>Section 3.2.3 of the final GMMP review report has been updated. Water level thresholds have been updated in Table A.1, Appendix A based on an expanded baseline dataset for each bore. VWPs have been removed as water level threshold bores based on the low reliability of the VWP data. An additional five monitoring bores are recommended as water level threshold bores.</p>

4.0	3.3 Review of the validity of the groundwater monitoring program against the revised model predictions required under Condition E9	The heading in this section appears to be linked as much to E7(d) as it is to E9. It is recommended that E7(d) also be referenced. Noting that in Table 2.1 when discussing E7(d) reference is made to section 3.3 as to where the requirement is addressed. Otherwise, the wording in this section indicates that the review of the numerical groundwater model is to be completed by 10 October 2022 and a model review report issued before 10 January 2023.	There is no discussion as to when Bravus would be providing a review of the validity of the groundwater monitoring program against the revised model predictions. This GMMP review must identify when this will occur.	The validity of monitoring program will be updated after the modelling results are available	As per Section 3.3 of the final GMMP report, it is recommended that review of the validity of the groundwater monitoring program be undertaken separately following DES's review of the groundwater modelling report.
5.0	GMMP Commitment 2 - Augment the existing groundwater monitoring network over time to enable ongoing groundwater impact evaluations	The GMMP Review indicates that following recent drilling to augment the network, the status of this commitment is compliant.	However, previous concerns raised in reference to section 3.2.1 and the issue of adequate monitoring bores in the Bandanna Formation and Colinlea Sandstone, also apply here and should be included/discussed here. The low reliability of the groundwater data coming from the VWPs identified by both DES and the 2022 annual groundwater monitoring report must be discussed here and addressed as to the impacts this has on the reliability of the longer-term network and how the issue might be addressed.	Proposed monitoring bores are discussed at point #1 above	
6.0	GMMP Commitment 3 - Maintain and decommissioning of bores, according to industry standards, to ensure the	The GMMP Review considers that servicing of monitoring bores and equipment and decommissioning practices	However, there is concern that the data coming from the VWPs is not representative of the aquifers.	VWP data will be used for trend assessments only and will not be used for water level thresholds	

	management of groundwater resources and the collection of representative groundwater monitoring data	employed, result in the status of this commitment being compliant.	The issue being that DES does not consider that the VWP's are being maintained to collect representative groundwater monitoring data. This issue must be discussed and addressed.		
7.0	GMMP Commitment 5 - Detail all automatic water level loggers (model, setting, and setting information), including the depth of installation within the artesian bore headworks	The GMMP Review considers the work carried out to measure logger position and cable lengths in a number of artesian bores has resulted in the status of this commitment being met. It is agreed that the work done to this point has resulted in much better correlation between logger data and manual readings in many of these bores.	However, as discussed in response to section 3.2.3 there may still be some artesian bores where cable lengths may still be causing a discrepancy. These issues must be investigated.	Cable lengths for all artesian bores is measured and hydrographs are updated.	Section 3.4.5 of the final GMMP review report has been updated as cable length adjustments have now been corrected in the updated water level thresholds provided in Table A.1, Appendix A and hydrographs in Appendix B.
8.0	GMMP Commitment 8 - Monitor the recently installed (2018) shallow seepage groundwater monitoring bores, prior to construction of mine affected water and waste storage facilities	The review report identifies the six bores and states that water quality data has been collected for all six bores but then says that two have been dry since they were drilled.	This should be reworded to say water quality has been collected from four only because the other two are dry.	The report will be amended with correct number of bores.	Section 3.4.8 of the final GMMP review report has been updated.
9.0	GMMP10 – Boundary Bores - Install five additional bores on the eastern boundary of mining lease, as recommended by DES, to develop additional baseline data for the alluvium and Tertiary sediments in this area so as to allow for the assessment of any possible migration of contaminants to the east of the mine lease	The review states: Status: This commitment has been met. Bravus installed five boundary bores (C19019SP, C19020SP, C19021SP, C19022SP and C19023SP) (see Table 3.3) to develop additional baseline data for the alluvium and Tertiary sediments in this area. Monitoring of these bores will allow for the assessment of any possible migration of	However, it is noted that four of the five bores are dry. Provide a discussion and the implications of this.	Bores were installed to base of Tertiary or alluvium. Three bores (C19020SP, C19021SP and C19023SP) have been dry since installation. C19019SP was dry up to Feb 22 and has standing water since then. C19022 has always contained water. The fact that some bores are dry indicates that there is no groundwater present within alluvium or	

		contaminants to the east of the mine lease.		Tertiary sediments at those locations. Bores are suitably located to detect any seepage from mine water/waste storage facilities should that occur.	
10.0	GMMP 14 - Additional bores monitoring the Dunda Beds, Rewan Formation, and Permian Betts Creek Beds (which includes the Bandanna Formation and Colinlea Sandstone) will be installed within one year of commencement of mining operations at three locations co-located as far as practicable within 500 m of existing Clematis Sandstone monitoring points as follows: HD02, HD03A, and C14011SP including one bore within the vicinity of the Doongmabulla Springs Complex	The review states: Status: This commitment has been met. <i>Installation of these additional bores was completed in 2020. Bore details are provided in Table 3.3.</i>	This does not appear to have been achieved as there are no Permian bores at two of the sites. Please review the status and discuss. HD02 area (RN158092) C19014SP (Clematis) (190276) C19015SP (Dunda) (192078) C919016SPR (Rewan) (190277) C19018SP (Bandanna) (190229) C19031PT (VWP) (Colinlea) (190605) HD03A area (RN158036) C19010SP (Clematis) (190199) C19011SP (Dunda) (190279) C19012SP (Rewan Shallow) (190280) C919013SPR (Rewan Deep) (190607) C14011SP area (RN158883) C19007SP (Dunda) (190275) C19008SP (Shallow Rewan) (190274) C19009SP (Deep Rewan) (190198)	The commitment provided in GMMP Chapter-6 has got the list of approved additional monitoring bores (Table -63). Braus installed all the bores provided in GMMP>	
11.0	GMMP Commitment 16 - For all new bores, to be drilled after the compilation of the initial GMMP, a minimum of 12 datasets over 24 months, will be collected prior to developing groundwater level thresholds and water	The review report states that water quality triggers for new bores will be developed in consultation with DES when at least eight water quality results have been collected for each bore.	This appears to contradict the commitment which states 12 datasets. This should be reviewed and explained. This commitment also appears to contradict commitment 18 where it	Page 18 of DES (2021) 'Using Monitoring data to assess groundwater quality and potential environmental impacts' states that percentile estimates based on eight	

	<p>quality triggers for discussion with DES for inclusion in future iterations of the GMMP</p> <p>All new bores will be assessed against the water quality triggers developed for each hydrostratigraphic unit until (and if required) bore specific triggers are developed</p> <p>All new bores will be installed as soon as possible so as to compile additional groundwater data to inform the conceptual model and the refinement of the model as required in Condition E4a and E6</p> <p>Any consideration of revising the groundwater level thresholds, based on new data acquired, must assess the potential impacts of the revised groundwater level thresholds on GDEs.</p>		<p>appears to indicate that a minimum of 8 measurements can be used to develop water quality triggers.</p> <p>DES recommends 12 datasets.</p>	<p>samples can be used to derive site-specific triggers. Table 51 of the GMMP also states that 85th percentiles can be calculated with at least eight results greater than the LOR.</p> <p>Feedback provided to Bravus by DES during water quality trigger review during 2021 "It is suggested that a condition be included in the EA to provide values after 8 samples have been collected"</p> <p>The response to GMMP commitment 16 refers to the minimum requirement of eight samples as per Table 51 and advice received by DES.</p>	
12.0	<p>GMMP Commitment 19 - Assess groundwater, surface water, and springs using isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation</p>	<p>The review states: Status: Compliant. <i>Bravus commenced assessment of groundwater, surface water, and springs using major elements, trace elements and isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation in</i></p>	<p>There was significant discussion of this issue at the draft conceptualisation report stage in early 2022 between DES and Bravus. There was concern by DES that there is no indication as to which springs were sampled. As previously advised DES is concerned that the varying water quality across the springs is not</p>	<p>This is noted. Bravus will provide an update of the isotope results separately which will include assessment of individual spear points.</p>	

		<p>2018/2019 and again in February 2021. Results of the isotope tracers are included in EMM (2021b) and were discussed in the previous GMMP review (EMM 2021a). No additional studies have since been undertaken.</p>	<p>being adequately compared to that in the spears and that in the bores in the various aquifers. It was considered that a more detailed approach looking at one spring at a time would provide more useful results ensuring the source of spring groups can be confirmed. Bravus responded to this with some additional information, but this will need to go in the updated conceptualisation report. There needs to be discussion as to how this has been dealt with in the updated conceptualisation report.</p>		
13.0	<p>GMMP Commitment 23 - Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E5. The GMMP will be reviewed by a suitably qualified person with a report on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following</p>	<p>The review considers the status of this commitment to be compliant.</p>	<p>However, as with the response to commitment 3 there are issues with the reliability of the data from the VWP's that are not dealt with in the response to this commitment.</p> <p>The assessment in the annual groundwater monitoring report of the water level data from the VWP's being of low reliability should be included in discussions.</p>	<p>VWP bores showing consistent and reliable data are included in the monitoring network. These VWP bores data is not used to develop any groundwater level thresholds. The VWP data will be used for comparison of water level trends and any future responses to de-pressurisation</p>	
14.0	<p>GMMP Commitment 24 - The results of research plans, inclusive of the GAB Springs Research Plan and Rewan Formation Connectivity Research Plan, will be incorporated into the next</p>	<p>The GMMP review considers the status of this commitment to be compliant as information from the completed research plans has been used to develop a revised hydrogeological understanding</p>	<p>However, following the DES review of the draft conceptualisation report in April 2022, DES requested copies of all available research plan reports. No additional research plan reports</p>	<p>Bravus will provide copies of research plan reports.</p>	

	iterations of the numerical model review and GMMP (within two years of box cut and every five years after that)	which has then been used to develop the updated groundwater model.	have been provided to DES since that time. When will this occur. Provide copies of all relevant results and research plans inclusive of GAB Springs Research Plan and Rewan Formation Connectivity Research Plan to DES.		
15.0	GMMP Commitment 25 - Two existing surface water flow monitoring stations CAR04 and CAR01 will be serviced to make them operational. An additional two stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence, will be installed. These surface water monitoring locations will allow for identification of impacts on the Carmichael River and associated GDEs	The GMMP review considers the status of this commitment to be compliant.	However, there is some confusion with the reference to the additional stream flow gauging station between the Doongmabulla springs and the western edge of the mining lease. In the response to this GMMP commitment it is called Doongmabulla station. However, in section 3.4.42 it seems to be referred to as Moray West. There needs to be clarification and consistency.	The new gauging station is installed between Doongmabulla springs (not Doongmabulla station) and western edge of ML and is refereed as Moray west gauging station.	Section 3.4.25 of the final GMMP review report and figures 3.3 and 3.4 have been updated to reflect correct name of the Moray West gauging station.
16.0	GMMP Commitment 26 - Adani commits to incorporate the following in the groundwater model re-run: (Not copied in full here).	The review report states: Status: Compliant. In accordance with EA Condition E9, EMM is currently undertaking a review of the numerical groundwater model to be completed by 10 October 2022, with the model review report to be issued before 10 January 2023. The issues raised in GMMP commitment #26 will be addressed in the model review report.	The report notes the status as compliant however DES cannot accept that status until the model report has been reviewed and approved.	Ok Noted. The commitments were included in the updated conceptualisation report. The modelling results will be provided with Numerical Groundwater model report.	Section 3.4.26 of final GMMP review report has been updated to note that commitment 26 is pending DES review of updated groundwater model.

17.0	<p>GMMP Commitment 29 - The GMMP review will be conducted by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data</p> <p>The next iteration of the GMMP (after 2 years of commencement of box cut excavation) will provide piper plots of the major ions for all hydrostratigraphic units included in the EA Conditions (Condition E3a), representative DSC springs, and the Carmichael River surface water</p> <p><u>Contaminant triggers and limits</u> will be updated when additional statistically sufficient pre-operational hydrochemistry data are collected. It is noted that several monitoring bores do not currently have the required number of analyses to calculate baseline trigger values and are using generic triggers derived from the ANZECC guidelines or average of bore specific data. Additional hydrochemistry results, allowing for the revision of trigger values, will be conducted according to the approach detailed in Section 5.4.</p>	<p>The GMMP review report considers the status of this commitment to be compliant.</p>	<p>It is noted that the EA no longer refers to contaminant triggers or limits. It uses the term water quality trigger levels. It would appear that a recommendation of the GMMP review should be to update the wording in this commitment to be consistent with EA wording.</p> <p>Additionally in the review in response to this commitment it states: <i>It is recommended that contaminant limits be updated using the same dataset that was used to derive the updated trigger levels. These updated contaminant limits are presented in Appendix F and should be included in the next iteration of the GMMP.</i> Appendix F should be reviewed. If appropriate the heading in Appendix F may need changing from revised contaminant limits to water quality trigger levels.</p>	<p>Contaminant levels will be reviewed and updated in the next GMMP revision.</p> <p>Water quality triggers and contaminant limits are two separate values - the groundwater quality trigger levels (which appear in the EA) and the contaminant limits, which were derived and shown only in the GMMP. The contaminant limits were developed in the GMMP on the recommendation of DES. These values represent the 99th percentile values of the baseline dataset and are to be considered when assessing for potential environmental harm. Currently, they form part of the Stage 1 investigations undertaken when groundwater quality trigger levels are exceeded for two consecutive monitoring events. Contaminant limits did not appear in the previous EA and appear in the GMMP only as a tool for assessing environmental harm.</p>	
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	During GMMP review and groundwater model re-run consideration of potential impacts to relevant GDE's will be included when considering revision of trigger values.				
18.0	GMMP Commitment 30 – Investigate all groundwater-based complaints and maintain a complaint register. The register will be made available to the regulating authority upon request.	The response here is: Status: Compliant. <i>Bravus will maintain a compliant register for the life of the project and will be made available to the regulating authority upon request.</i>	However, it should also be clarified if any complaints have yet been received.	No complaints were received on groundwater till date.	Section 3.4.30 of the final GMMP review report has been updated.
19.0	GMMP Commitment 36 – Should groundwater monitoring indicate exceedance of any or all of the groundwater level thresholds and / or water quality trigger levels then DES will be notified via WaTERS and an investigation will be instigated and the investigation report will be made available to the administering authority within the time specified in EA conditions E10 and E12 for groundwater quality trigger exceedances and E13 and E14 for groundwater threshold level exceedances respectively.	The GMMP review considers this commitment to be compliant.	However, it would seem that these EA conditions referenced in this commitment are no longer accurate (perhaps because of a change to the EA). This report should therefore recommend a change to the wording in this commitment in line with the current EA. At the moment it does not.	The commitment will be updated based on the wording in the current EA.	
20.0	GMMP Commitment 38 – Should any or all the groundwater level impact thresholds be realised, through the assessment of groundwater monitoring data and comparison to model	The GMMP review considers this commitment compliant.	Perhaps the wording of this commitment should be reviewed. What does 'groundwater level impact thresholds realised' mean.	The wording of this commitment will be amended in the GMMP revision to be consistent with EA conditions.	

	<p>predictions, then an appropriately qualified person will complete an investigation into the potential for environmental harm (MSES and MNES) and will provide a written report to the regulator as per the conditions. In the event of exceedances of threshold levels on MNES Adani will take the following actions:</p>		<p>Does it mean that thresholds have been exceeded and mining found to be the cause? If so, should there be a recommendation to amend the wording to make the intent clearer.</p>		
21.0	<p>GMMP Commitment 40 - Conduct regular groundwater monitoring bore assessments and maintenance (where required) as well as ensuring dry or damaged bores (as a result of mining activities) are decommissioned according to the latest editions of the Minimum Construction Requirements for Water Bores in Australia, 4th Edition (NUDLC, 2020) and the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017).</p>	<p>The report at the moment states: Status: Compliant. Regular groundwater monitoring bore assessments and maintenance will be carried out by the qualified personnel deployed by the monitoring contractor. Bravus has followed the bore construction standards as mentioned above while constructing additional bores.</p>	<p>However, the review must provide detail about how Bravus is carrying out regular groundwater monitoring bore assessments and maintenance.</p>	<p>The details of bore maintenance summary will be included in the annual groundwater report.</p>	<p>Section 3.4.40 of the final GMMP review report has been updated to include bore maintenance summary in annual monitoring report.</p>
22.0	<p>GMMP Commitment 41 - As the proposed threshold values are reliant on predictions from the numerical groundwater model, to be updated within two years of the box cut excavation then every five years subsequently, Adani will compare the actual measured groundwater level data to predicted drawdown to assess the rate of change. In</p>	<p>The response in the review report is: Status: Observed groundwater level data collected to date has been used to calibrate the updated groundwater model which is currently being developed. <u>Discrepancies between actual and predicted drawdown in monitoring bores to date is a</u></p>	<p>The point being made here is not clear. It would have been thought that in the current model update there would also be a focus on the stresses occurring during mining. The wording should be clarified here.</p>	<p>Noted. Current predictions assumed commencement of mining as the 'zero' time step rather than dewatering which commenced 1 year before box-cut, therefore comparisons between predicted drawdown and observed drawdowns to date have been assumed to be preliminary.</p>	

	<p>the instance the drawdown rate of the actual data is steeper/ faster than the predicted rate, an investigation will be commenced into the cause of the drawdown rate change.</p>	<p><i>focus for transient recalibration efforts to actual pre-mining dewatering stresses. Groundwater drawdown predictions will be updated as part of the updated groundwater model. These updated predictions will be compared against observed water levels during future reporting to assess the rate of change. Investigations will be undertaken in cases where it is found that the actual drawdown exceeds the drawdown predicted by the groundwater model.</i></p>		<p>Predicted versus observed drawdowns are provided in Section 9 of the 2022 Annual Groundwater Review Report.</p>	
23.0	<p>GMMP Commitment - Springs, GDE and Baseflow Commitments</p>	<p>A commitment within this section is: Adani will investigate drilling into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information if required under relevant research programs. The response in the report is: Status: Compliant. <i>Bravus installed an additional monitoring bore (C19031SP-VWP) into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information required under relevant research programs.</i></p>	<p>It is agreed/ considered that the drilling of C19031VWP and C19018SP (Bandanna standpipe monitoring bore) and C19842C (deep bore providing lithology down to the Colinlea) have partially addressed this commitment.</p> <p>However, there are concerns about the quality of water level data available from C19031VWP and it is noted that commitment 14 to drill monitoring bores into the Permian Betts Creek Beds (Bandanna and Colinlea) at three identified locations adjacent the Doongmabulla Springs, has only partially been met.</p> <p>These issues should be addressed in this response.</p>	<p>Commitment #14 has been fulfilled as per list of bores provided in table 63 of GMMP. Additional monitoring bores will be installed between the ML and DSC (refer to figures provided at the end of this review)</p>	<p>Figure 3.1 of the final GMMP review report has also been updated with the additional bore locations.</p>

24.0	DES Recommendation 2 - Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report	The response to this issue states: <i>Bi-monthly reporting and investigations of water quality trigger exceedances with comparison to changing groundwater levels has been conducted according to EA conditions E12 and E15, under the guidance of the GMMP. A thorough annual review (EMM, 2022b) has also been undertaken according to EA conditions E18 and E19 which review these trends. The trigger exceedances investigations have indicated that variations in water quality are likely to be natural, rather than as a result of site activities.</i>	E15 relates to groundwater level thresholds. Please review the response to this recommendation.	Noted. Water quality reporting requirements are detailed in EA conditions E12, E13 and E14. GMMP Review Report will be updated accordingly.	Section 3.5.2 of the final GMMP review report has been updated to reference the correct EA conditions.
25.0	DES Recommendation 5 - The GMMP review report should provide piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).	The review response states: <i>Piper plots of major ions for all hydrostratigraphic units were included in the previous GMMP review which was submitted to DES in June 2021 (EMM 2021a). Updated piper plots for each hydrostratigraphic unit are included in the bi-monthly water quality exceedance reports. A discussion of isotope tracer results collected as part of the GAB Springs Research Plan are included in EMM (2021b). <u>These isotope tracer results have been used to revise the updated conceptualisation report which has previously</u></i>	The underlined response is true, but this was a draft which DES has made comment on. It should be stated in here that an updated version will be provided as part of the model review report prior to 10 Jan 2023. There remain concerns about whether enough information is provided on the individual springs.	The conceptualisation report will be provided to DES. Bravus will provide an update of the isotope results which will include assessment of individual spear points.	

		<i>been submitted to DES (EMM 2022a).</i>			
26.0	DES Recommendation 6 - Detail isotope tracer studies used to characterise the groundwater dependent ecosystems		DES has the same concern here as stated in regard to DES recommendation 5.	Refer to response above point #25	
27.0	Section 4 GMMP review recommendations	The review states: <i>An additional monitoring bore within Colinlea Sandstone between C19026SP and C19031VWP to track future propagation of dewatering impacts in the Colinlea Sandstone between mining and the DSC. It is recommended that this bore be installed adjacent to existing Clematis Sandstone bore C14012SP/C14013SP.</i>	This location is supported, but problems remain. There should also be a Colinlea monitoring bore on the western lease boundary in a location that won't be mined out. There should also be a standpipe bore in the area of C19031VWP given the unreliability of the VWP bores, there can be no guarantee that data from this VWP is representative of the Colinlea.	Additional monitoring bores will be installed between the ML and DSC (refer to figures provided at the end of this review)	Figure 3.1 of the final GMMP review report has also been updated with the additional bore locations.
28.0		The review also states: <i>An additional monitoring bore with Bandanna Formation between C008P2 and C19018SP to track future propagation of dewatering impacts in the Bandanna Formation between mining and the DSC. It is recommended that this bore be installed adjacent to existing Clematis Sandstone bore C14012SP/C14013SP.</i>	This location is supported but there should also be a Bandanna monitoring bore on the western lease boundary in a location that won't be mined out.	Additional monitoring bores will be installed between the ML and DSC (refer to figures provided at the end of this review)	Figure 3.1 of the final GMMP review report has also been updated with the additional bore locations.
29.0		The review states: <i>Additional monitoring bores within Bandanna Formation and Colinlea Sandstone in the</i>	Some additional information on timing would be helpful. Given the issues with local landholder use potentially impacting water levels	Refer to response at point#1 above	

		<p><i>vicinity of Mellaluka Springs to allow for detection of dewatering impacts near Mellaluka Springs and to improve the understanding of any connection between the Colinlea Sandstone and the Tertiary sediments and Joe Joe Formation. Installation of additional bores between the mining lease and Mellaluka Springs is considered low priority and could be delayed until mining progresses south and impacts are noted in C19003SP and C19004SP.</i></p>	<p>in this area and the challenges in the unpacking of what stress is causing impact, the sooner baseline data is available from the proposed Colinlea and Bandanna bores, the better.</p> <p>Additionally, the additional drilling of monitoring bores that is still required under commitment 14 should be discussed.</p>		
30.0		<p><u>Groundwater Level Thresholds</u> The review states: <i>Reassess baseline average groundwater level elevations and natural fluctuations for each bore incorporating all representative logger data (where available) before commencement of dewatering. Consider further extending baseline period for monitoring bores which have not been impacted by dewatering to date. Currently, only groundwater level data collected up to 2017 is considered in the baseline dataset. Extending the baseline period will allow for better representation of natural climatic variations in water level.</i></p>	<p>In relation to the underlined sentence, it would be helpful to have the predicted existing impacts from the model to compare with the manual assessments already carried out to gain confirmation of which areas are clearly unaffected by mining at this time.</p> <p>There should also be discussion of the low reliability of the water level data from the VWP's and the suitability of these bores to be used as groundwater level threshold bores.</p>	<p>Noted. This will be undertaken as part of the GMMP update.</p> <p>Data from VWP's will not be used to develop groundwater level thresholds.</p>	<p>Updated water level thresholds are included in Table A.1, Appendix A of the final GMMP review report.</p> <p>Section 4 of the final GMMP review report has also been updated to recommend use of the updated water level thresholds and monitoring bores.</p> <p>Section 4 of the final GMMP review report has also been updated to recommend a review of the validity of the groundwater monitoring program against the revised model predictions. It is recommended that this be undertaken following DES's review of the groundwater modelling report and results.</p>

31.0		Groundwater quality triggers The review states: <i>The contaminant limits in the GMMP should be updated using the same dataset as was used to develop the updated trigger values for consistency.</i>	Refer to water quality trigger value as per EA wording	Contaminant limits will be updated in the next GMMP revision	
Review of Annual Monitoring Report – June 2022					
This review focuses specifically on groundwater level monitoring and presentation of metered water use data from the dewatering bores.					
Section		Comments			
<u>Section 4 Mine Construction and dewatering</u>		Metered water take – there is only a graph showing combined monthly water use from all 27 bores. DES requires a spreadsheet showing monthly water take from each bore, identified by number. There should also be a map showing the locations of these bores by number. Given that some work has gone into identifying what take is from what geologic unit there should also be a table showing which geologic unit each bore is taking water from.		Monthly water take data is provided as an attached spreadsheet. Figure showing dewatering bore locations is proved below.	
<u>Review of Section 6 tables</u>		The process of reviewing the water level data in the monitoring bores and VWPs is similar to what occurred in the draft conceptualisation report and is considered a useful exercise to analyse the data and better understand likely dewatering impacts at this point in time. Some comments on the process are provided as follows: In each table, each bore is ranked as having a high, medium or low water level trend reliability. Information is provided in section 6.1 as to what constitutes these various rankings but there are no comments in the tables against the individual bores to provide understanding as to why the data from one bore might be high and another medium. This would be useful particularly in the high and medium categories.		As per Section 6.1, a high confidence was assigned to bores which had a near-continuous time series record for pre-dewatering and during-dewatering, and a medium confidence where there were some gaps in the monitoring record but where the gap did not compromise the overall integrity of the trend (ie could identify the overlying background trend). It is recognised that this assignment is	

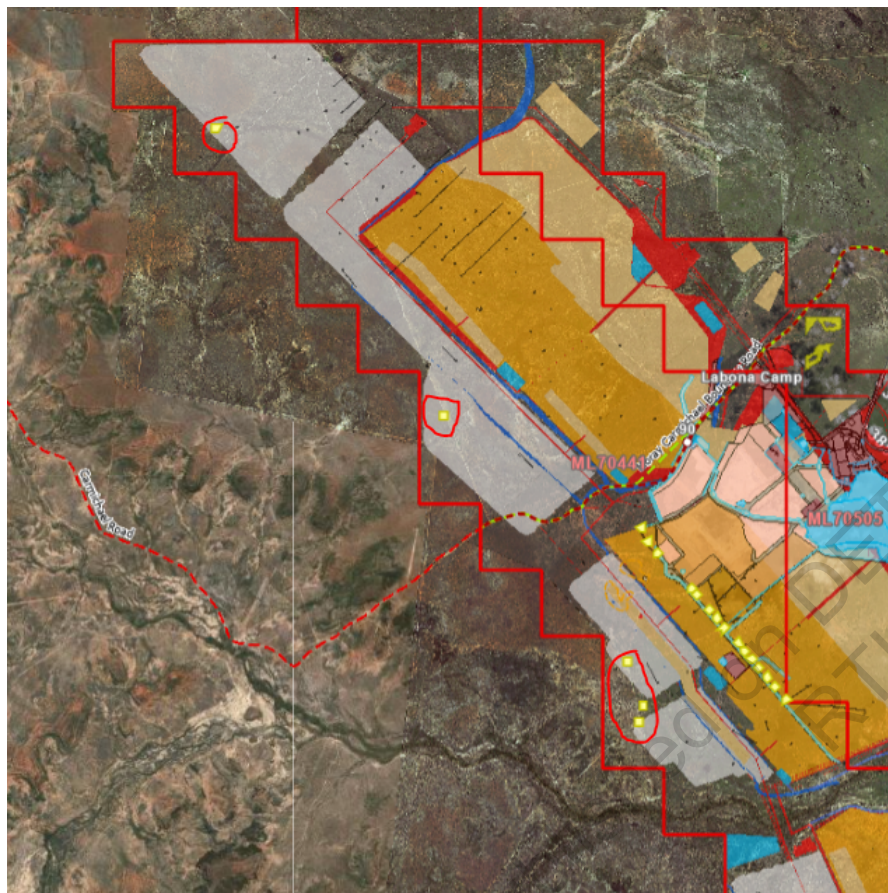
			<p>somewhat subjective, also taking into account comparison between manual measurements and logger data.</p> <p>The main takeaway is that both high and medium confidence bores have been deemed suitable to assess groundwater trends.</p>	
	VWPs - General	<p>The water level trend reliability in all the VWPs is treated as low. That assessment is supported. However, the data from most of the VWPs are then used to determine if the probe is impacted by dewatering. Perhaps there should be a footnote that is linked to the VWP assessments of dewatering impact in the tables which says something like, 'given the low reliability of the water level trend, to be used as a guide only'.</p> <p>Where VWPs indicate a difference between pre and during dewatering water level decline of greater than 0.4 m/yr they are investigated further given the low reliability of their water level trend. This approach is supported, although the practice of using data from one low reliability VWP to determine if data from another VWP is likely to be correct, is not supported.</p>	Noted	
	<p>Table 6.8 Joe Joe – C14017SP</p> <p>The report states: <i>Most of the bores show subtle positive linear correlation to climate. Although, C14017SP shows a decreasing trend greater than the threshold of 0.4 m (Figure 6.23), this is unlikely to be related to dewatering as the bore is located approximately 33 km from the closest dewatering bore.</i></p>	<p>It is agreed that this water level decline is unlikely to be caused by the dewatering. However, the assessment could be further supported by adding that the nearest Colinlea Sandstone or Bandanna Formation monitoring bore, identified as being impacted by dewatering, is 27 km north of C14017SP (C840SP).</p>	Noted	

	<p>Section 8 States; <i>Water level thresholds have been established for 50 monitoring bores and five VWPs. Threshold values are summarised in Table E3 of the EA, and Table 45 of the GMMP (AECOM 2020).</i></p>	<p>This is a quote from AECOM 2020 and therefore is no longer accurate when referencing the table in the latest version of the EA. Water level thresholds are actually now in Table E4 of the EA. This should be explained.</p>	<p>Agreed, water level thresholds are detailed in Table E4 of the EA. However, water level threshold values remain consistent between the GMMP (AECOM 2020) and the amended EA.</p> <p>Also, we note that the number of water level threshold bores was wrongly referenced in the monitoring report. There are 43 monitoring bores and 5 VWPs which have water level thresholds, not 50 monitoring bores.</p> <p>Water level thresholds for VWPs should be removed due to low reliability of the VWP data.</p>	
	<p>Table 8.1 <i>'Recent adjustment of logger cable lengths indicates that water levels in C14006SP have never actually exceeded the threshold values for this bore.'</i></p>	<p>It appears that the sentence in italics has been cut and pasted from one section of the table to a number of others without changing the bore number. Needs reviewing and adjusting.</p>	<p>Noted.</p>	
	<p>Section 9</p>	<p>It is acknowledged that the latest modelling, yet to be completed, will likely provide a better evaluation tool for future annual reporting comparisons. However, for this comparison in this annual report there should be more discussion as to how the SEIS assumptions about mine dewatering/ mining operations compare with what has actually occurred to allow a better understanding of the potential limitations of the process used to present the modelled versus observed drawdown</p>	<p>As per response to #22 above, SEIS predictions assumed commencement of mining as the 'zero' time step rather than dewatering which commenced 1 year before box-cut, therefore comparisons between predicted drawdown and observed drawdowns to date have been assumed</p>	

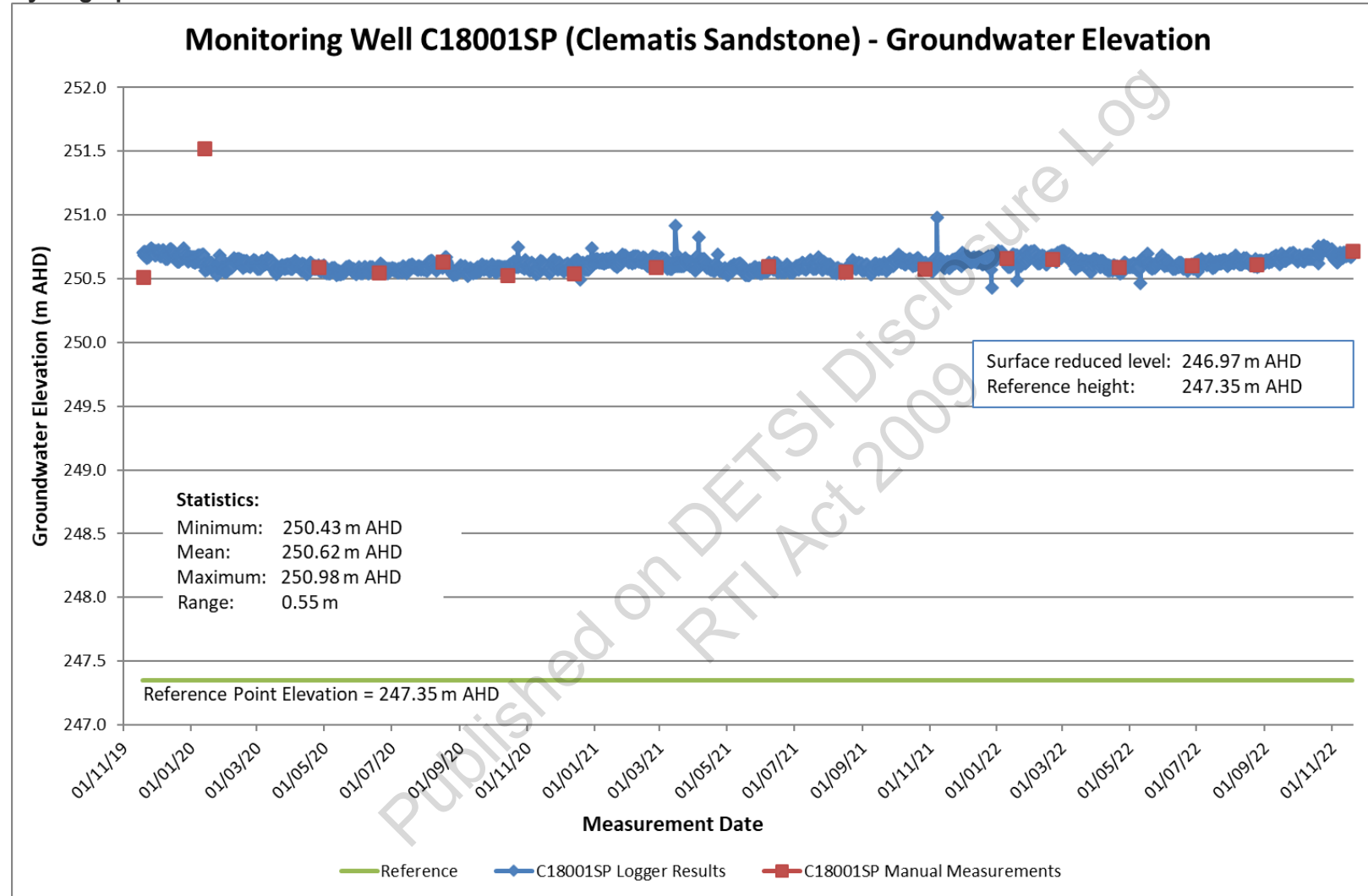
			to be preliminary. Also SEIS predictions do not take account of dewatering bores which have caused excess drawdown in some bores (ie C006P1, C827SP).	
	<p>Section 10 Recommendations <i>Updates to the groundwater model in 2022 should recalibrate to the transient pre-mining dewatering stresses to improve confidence in the modelled versus observed drawdowns at locations where trend analysis has revealed actual dewatering impacts occurring. Specifically, this includes bores C827SP, C180112SP, C833SP, C834SP and C840SP in the Colinlea Sandstone and C832SP in the Bandanna Formation.</i></p>	<p>The statement in italics seems to be missing some monitoring bore numbers when discussing which bores are impacted. The summary in section 6.13 looks to have the numbers right, perhaps refer to that.</p> <p>The detailed work presented in section 6 of this report demonstrates a number of things. Firstly, it notes that the water level trend reliability in the VWPs is low. DES would agree with this assessment. It is considered that given this assessment there should be a recommendation as to how this issue will be dealt with in those critical areas where there are no monitoring bores (or only VWPs).</p> <p>In particular, how will impacts in the target formations (Colinlea Sandstone and Bandanna Formation) be monitored. As DES has previously raised, the area to the west of the dewatering bores, between the dewatering bores and the important Doongmabulla Springs, has poor to non-existent monitoring bore coverage in the target formations.</p> <p>Figure 6.17 demonstrates reasonable coverage (albeit with some gaps) of monitoring bores in the Bandanna Formation to the north of the dewatering bores (if C19027SP is considered).</p> <p>To the south there is also reasonable coverage of monitoring bores in the Bandanna although there is a gap between C9839SPR (at 0.34 m/yr almost considered impacted) and C034P1 which is some 5.6 km south of C9839SPR. Tracking this impact south will therefore soon become difficult.</p> <p>To the west there are no monitoring bores west of C008P2. It is noted that C19018SP has recently been drilled adjacent the Doongmabulla Springs but there is a 10 km gap between C008P2 and C19018SP where there are no Bandanna monitoring bores.</p>	<p>Noted.</p> <p>Additional monitoring bores will be installed between the ML and DSC (refer to figures provided at the end of this review)</p> <p>Refer to response at point #1 above</p> <p>Additional monitoring bores will be installed between the ML and DSC (refer to</p>	

		<p>In the Colinlea Sandstone, Figure 6.21 demonstrates reasonable coverage to the south of the dewatering bores although there is a gap between C840SP (most southerly monitoring bore considered impacted) and C034P3 which is some 5.8 km south of C840SP. Tracking this impact south will therefore also soon become difficult.</p> <p>Figure 6.21 also demonstrates the lack of Colinlea Sandstone monitoring bores adjacent the northern dewatering bores and immediately north of the dewatering bores. C19026SP and C006P3R are adjacent the southern dewatering bores. The closest monitoring bore north of these two monitoring bores shown on Figure 6.21 is C011P3 some 11 km to the north-west.</p> <p>Figure 6.21 also demonstrates that there are no monitoring bores in the Colinlea Sandstone west of the dewatering bores. Therefore, the work in section 6 is unable to comment on how far west the impacts of dewatering have propagated.</p> <p>Given that EA condition E18 requires this report to provide recommendations on changes to the GMMP, it is considered essential that the findings of the water level review in this report are used to provide recommendations to the GMMP about the limitations of the monitoring network as discussed above.</p>	<p>figures provided at the end of this review) Refer to response at point #1 above</p> <p>Refer to response at point #1 above</p> <p>Noted. Additional monitoring bores will be installed between the ML and DSC (refer to figures provided at the end of this review).</p> <p>Recommendations on changes to GMMP are provided in Section 10 of the Annual Monitoring Report. Additional GMMP recommendations will be provided as per the responses to the review comments.</p>	
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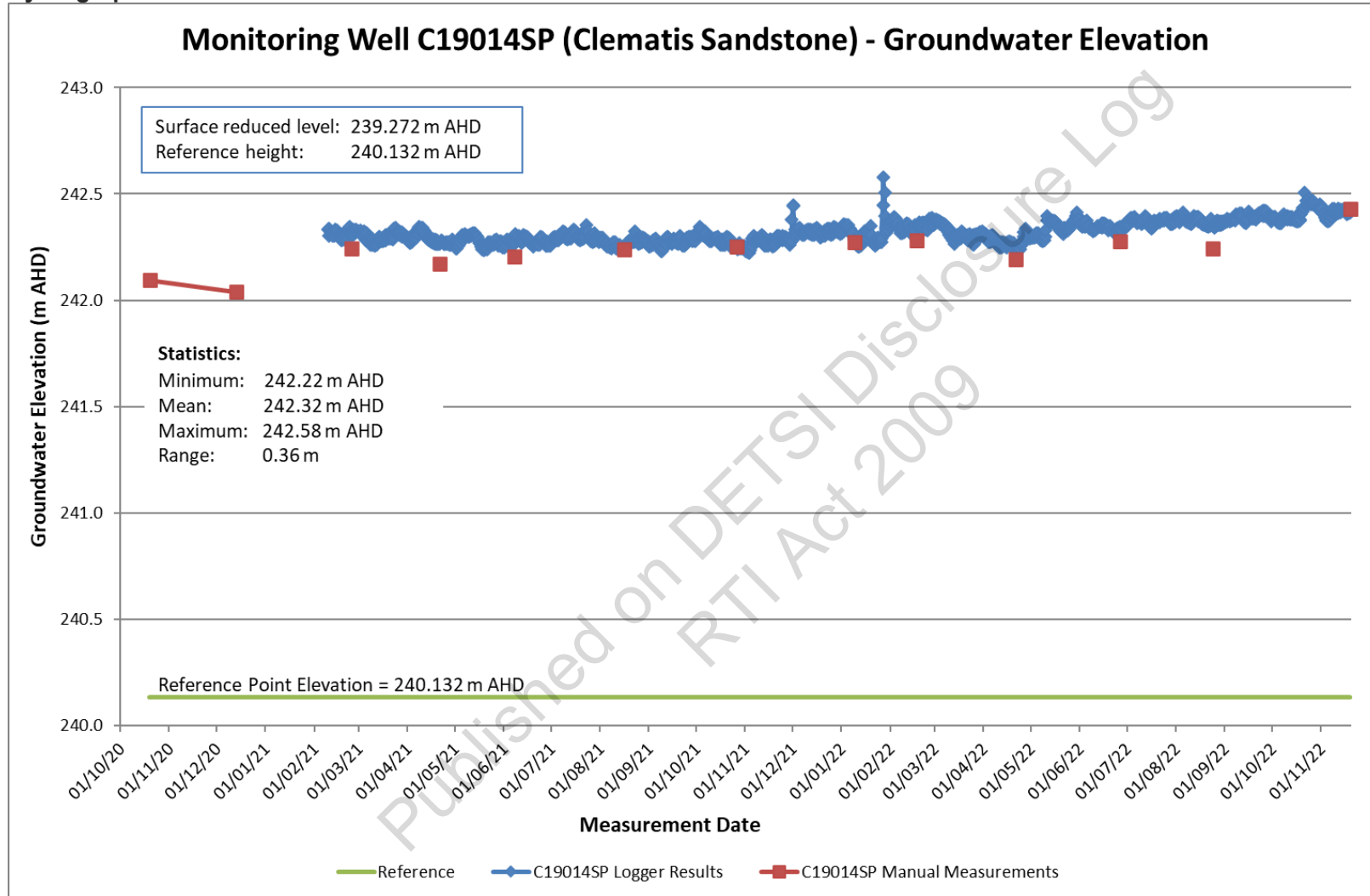
Figure for proposed monitoring additional bore locations (circled in Red) in bandanna and colinlea sandstone.



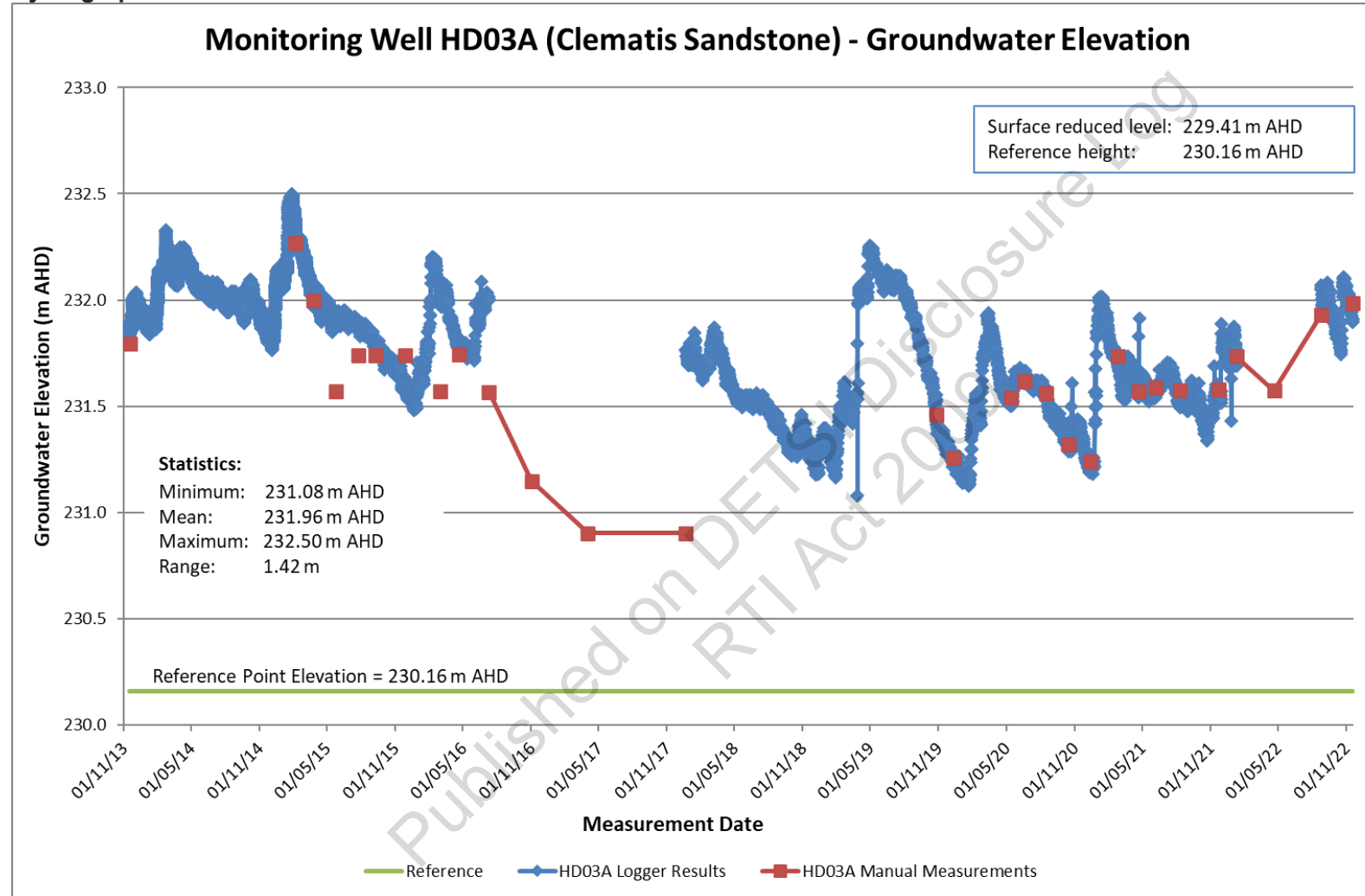
Hydrograph for C18001SP



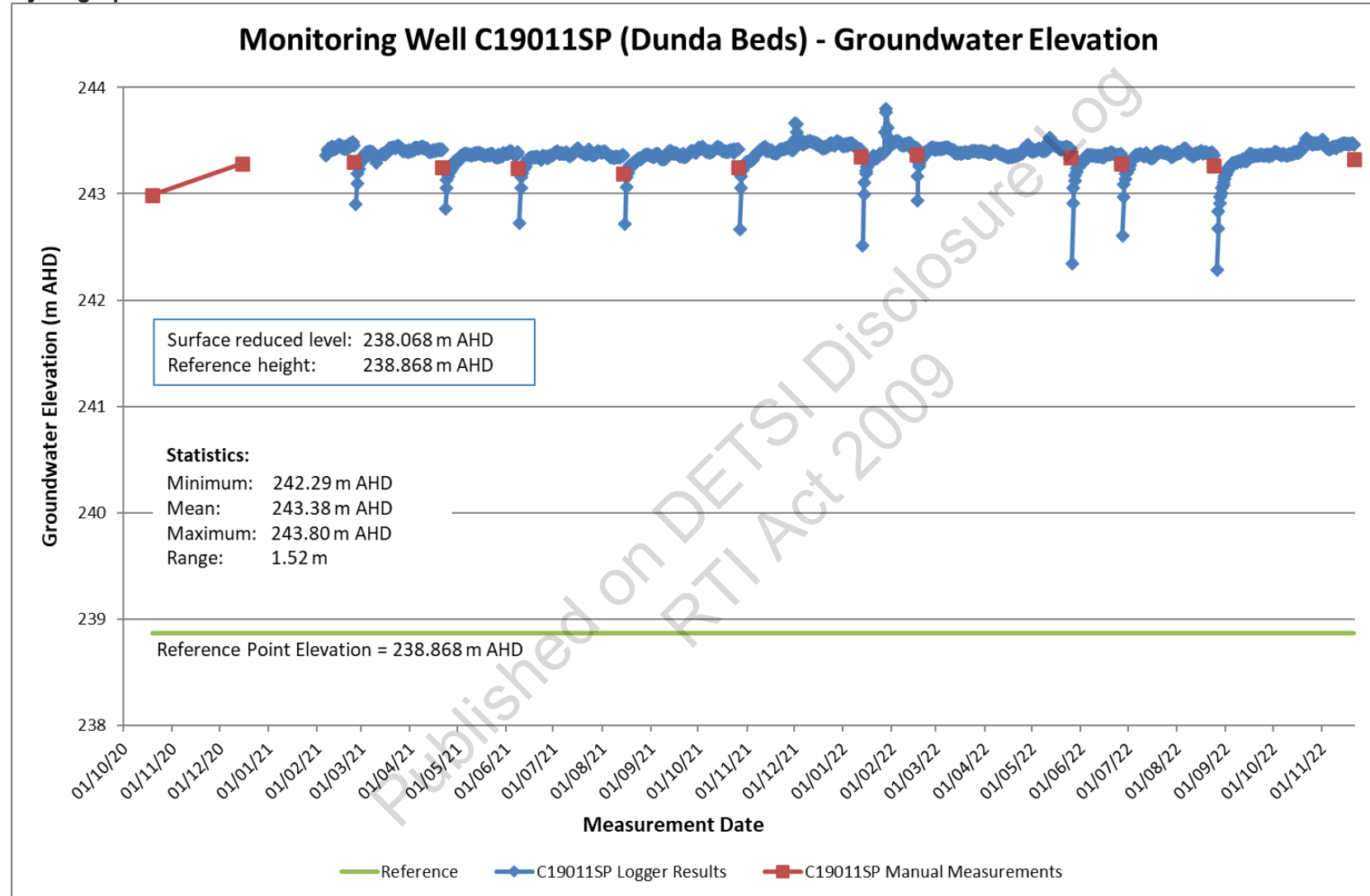
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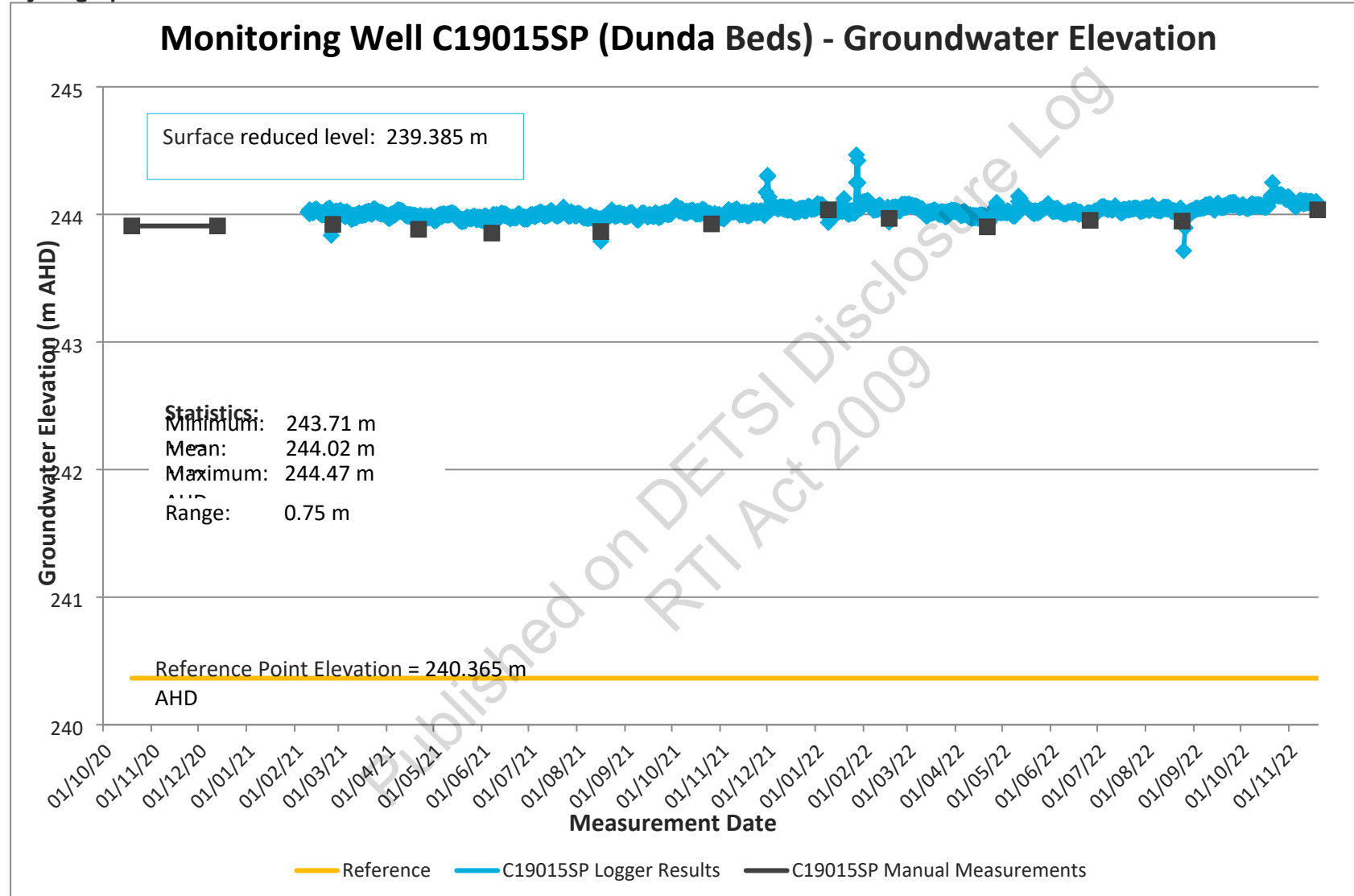
Hydrograph for HD03A



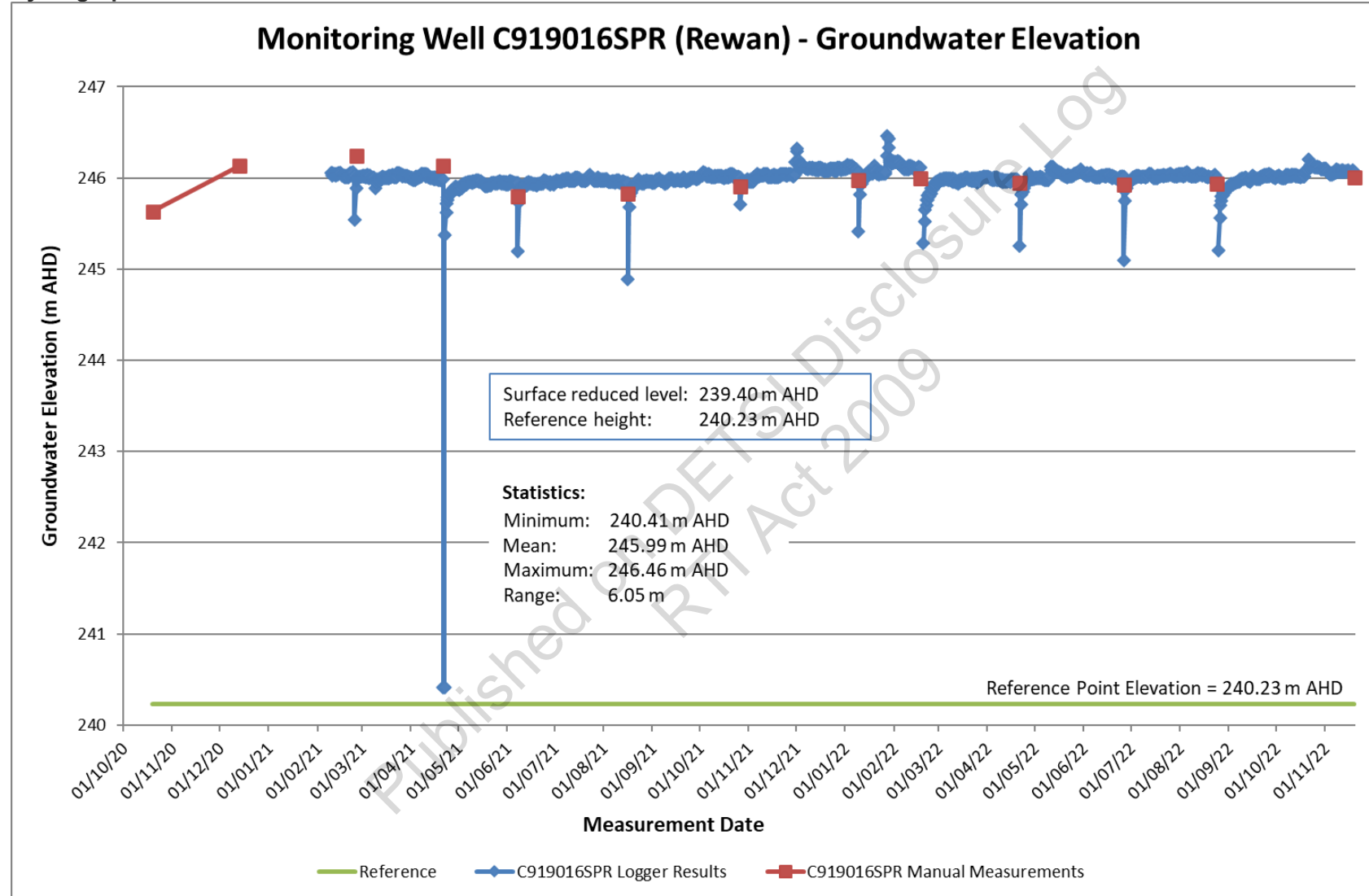
Hydrograph for C19011SP



Hydrograph for C19015SP



Hydrograph for C919015SPR





Source: Bravus (2022); DNRME (2021); ESRI (2022)

KEY

- ◆ Dewatering Bore
- Minor road
- Vehicular track



Dewatering Bore Locations

Bravus Mining & Resources

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Australia

SYDNEY

Ground floor 20 Chandos Street
St Leonards NSW 2065
T 02 9493 9500

NEWCASTLE

Level 3 175 Scott Street
Newcastle NSW 2300
T 02 4907 4800

BRISBANE

Level 1 87 Wickham Terrace
Spring Hill QLD 4000
T 07 3648 1200

CANBERRA

Suite 2.04 Level 2
15 London Circuit
Canberra City ACT 2601

ADELAIDE

Level 4 74 Pirie Street
Adelaide SA 5000
T 08 8232 2253

MELBOURNE

Suite 8.03 Level 8
454 Collins Street
Melbourne VIC 3000
T 03 9993 1900

PERTH

Suite 9.02 Level 9
109 St Georges Terrace
Perth WA 6000
T 08 6430 4800

Canada

TORONTO

2345 Young Street Suite 300
Toronto ON M4P 2E5
T 647 467 1605

VANCOUVER

60 W 6th Ave Suite 200
Vancouver BC V5Y 1K1
T 604 999 8297

Groundwater Management and Monitoring Program - Final Review Report

Carmichael Coal Mine and Rail Project

Prepared for Bravus Mining and Resources

January 2023

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1 Introduction

Bravus Mining and Resources (Bravus) has commenced development of the Carmichael Coal Mine located in the Galilee Basin, approximately 160 kilometres (km) northwest of Clermont in Central Queensland. The Carmichael Coal Mine and Rail Project was assessed by the Commonwealth and Queensland governments through an Environmental Impact Statement (EIS) process. Conditional approval of the Carmichael Coal Mine and Rail Project was granted by the Queensland Coordinator-General on 8 May 2014 and the Commonwealth Minister for the Environment on 14 October 2015 (EPBC 2010/5736). The Environmental Authority (EA) EPML01470513 for the Mining Leases (ML) 70441, 70505 and 70506 was initially granted on 2 February 2016 and further amended in September 2019, July 2020 and most recently April 2022.

A Groundwater Management and Monitoring Program (GMMP) has been prepared in accordance with EA Condition E4. Several iterations of the GMMP have been submitted for approval since 2017. The latest version of the GMMP (Version 11) was submitted and approved by the Department of Environment and Science (DES) in February 2021. The GMMP was also submitted to the Commonwealth department of Agriculture Water and Environment (DAWE) and approved (the version submitted to DAWE is referred to as GMMP Ver 11a).

As per EA Condition E5, the GMMP must be reviewed by a suitably qualified person with a draft GMMP review report provided to the administering authority by 10 October 2022. The draft GMMP review report was provided to DES on 10 October 2022 as required. DES have since reviewed the draft GMMP review report and provided comments via correspondence dated 13 December 2022.

As per EA Condition E6, a final GMMP review report must address any comments made by the administering authority and be submitted to the administering authority within three months of the draft GMMP review report submitted under condition E5. It is noted that the submission date for the final GMMP review report has been extended to 31 January 2023.

The purpose of this report is to meet the requirement of EA Condition E6 to provide a final GMMP review. A summary of responses to DES's comments and where they have been addressed within this report are provided in Appendix F.

The preparation of this report coincides with a review of the numerical groundwater model which is being used to predict groundwater drawdown for the following scenarios:

- Scenario 1: open-cut mining only. This scenario includes the simulation of the open cut pits only, with all underground mine workings excluded.
- Scenario 2: SEIS with previous fracturing assumptions. This scenario uses the updated model but assumes the same fracturing properties (fracturing height and properties multipliers) as the previous GHD 2013 SEIS model.
- Scenario 3: SEIS with updated fracturing assumptions. This scenario simulated the same mine plan as the SEIS, however the representation of fracturing properties above the longwall have been updated.

Additional information about the different modelling scenarios is included in the updated groundwater modelling report (EMM 2023).

It is noted that modelling Scenario 3 is predicting higher impacts at spring locations, especially due to underground mining, and further optimisation of the mine plan is required to limit spring impacts to less than 0.2 m. In the interim, it is recommended that drawdown predictions from model Scenario 1 (open-cut mining only) be used for the development of water level thresholds.

1.1 Suitably qualified reviewer

This review of the GMMP was undertaken by Bill Bull and Craig Vincent of EMM Consulting Pty Ltd (EMM). Craig holds the degree of Master of Science (with distinction) in Geology. Craig has 19 years of industry experience as a hydrogeologist and is a current member of the Australasian Institute of Geoscientists (AIG) and International Association of Hydrogeologists (IAH). Bill has 4 years of experience working as a hydrogeologist/geochemist with EMM.

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2 GMMP review requirements

2.1 EA requirements

Conditions E5 through to E8 of the EA states the following:

Condition E5

The GMMP must be reviewed and a draft GMMP Review Report finalised and provided to the administering authority for comment by **10 October 2022**, and every 5 years thereafter, or after every Groundwater model review undertaken as required by **Condition E9**.

Condition E6

A final GMMP Review Report must address any comments made by the administering authority and submitted to the administering authority within three months of the draft GMMP Review Report submitted under **Condition E5**.

Condition E7

The draft and final GMMP Review Reports required by **Conditions E5 and E6** must include:

- a) an assessment of the groundwater management and monitoring program against the objectives in **Condition E4**.
- b) an assessment of the GMMP against commitments in section 7 GMMP.
- c) a review of the adequacy of the monitoring locations, frequencies and groundwater quality triggers specified in **Tables E1 – Groundwater quality monitoring locations and frequency, Table E3 – Groundwater quality trigger levels and Table E4 – Groundwater level thresholds**; and
- d) a review of the validity of the groundwater monitoring program against the revised model predictions required under **Condition E9**.

Condition E8

Recommendations and certifications made within the final GMMP Review Report required by **Condition E6**, must be adopted by the environmental authority holder, and be updated within the GMMP for approval by the Administering Authority within three (3) months from the date the final GMMP Review Report is provided to the Administering Authority under **Condition E6**.

2.2 GMMP commitments

Section 7 of the GMMP outlines commitments which are required to be undertaken by Bravus. Four commitments (# 17, 23, 28 and 29) relate specifically to review of the GMMP and are detailed as follows:

17. Conduct a review of the monitoring data, using suitably qualified expert during the review of GMMP to be carried out before 1 July 2021 (or any other time frame as agreed with DES so as to align GMMP review and model re-run to happen concurrently) to update conceptualisations and conduct groundwater numerical model review based on these data.

- To allow for the correct scientific development of the GMMP it is considered (subject to agreement with DES) that the refinement and re-run of the model will occur prior to the update of the GMMP, as the model outputs and modifications can be captured in the GMMP.
- The model re-run is to occur 2 years after the commencement of the box cut and then every 5 years, the same review periods as the GMMP.

23. Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E7¹. The GMMP will be reviewed by a suitably qualified person with a report provided on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following.

28. Initial review of the approved GMMP by an appropriately qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). After the initial review, the review will be conducted every five years following, the report provided to the administering authority.

29. The GMMP review will be conducted by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data.

- The next iteration of the GMMP (after 2 years of commencement of box cut excavation) will provide piper plots of the major ions for all hydrostratigraphic units included in the EA Conditions (Condition E3a), representative DSC springs, and the Carmichael River surface water.
- Contamination triggers and limits will be updated when the additional statistically sufficient pre-operational hydrochemistry data are collected. It is noted that several monitoring bores do not currently have the required number of analyses to calculate baseline trigger values and are using generic triggers derived from the ANZECC guidelines or average of bore specific data. Additional hydrochemistry results, allowing for the revision of trigger values, will be conducted according to the approach detailed in Section 5.4 of the GMMP.
- During GMMP review and groundwater model re-run consideration of potential impacts to relevant GDEs will be included when considering revision of trigger values.”

2.3 DES recommendations

Following review of the first GMMP review report (Adani 2020), which was submitted to the Department of Environment and Science (DES) on 24 June 2020, DES provided a list of recommendations to be addressed in future GMMP review reports. The DES recommendations are provided as follows:

1. A review of monitoring data (water quality and water level) collected under the GMMP. The monitoring data should be compared to triggers, limits and thresholds after each monitoring event. The annual review should determine potential impacts and emerging trends in the data with any downward groundwater level trends compared to modelled drawdown rates. If the actual monitored rates are faster than predicted, the review report should recommend a suitable update of the triggers in the GMMP.
2. Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report.
3. The GMMP review report must provide the baseline and pre-impact water quality in a format that can be compared to future monitoring data eg time series plots.
4. The GMMP review report should include a review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality trigger and water level thresholds.

¹ Commitment #23 from the GMMP originally refers to Condition E5. Due to an amendment to the EA in April 2022, the correct reference is now Condition E7.

5. The GMMP review report should provide piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).
6. Detail isotope tracer studies used to characterise the groundwater dependent ecosystems.
7. The 2020 review report provides details of a number of new and replacement bores – 14 in total. The latitude and longitude of these bores should be provided in the review report to facilitate any necessary EA amendment to include these additional bores.
8. The location and target aquifer for all new bores should be detailed in the review report with a recommendation about any necessary EA amendments.
9. All exceedances in water quality triggers and limits should be discussed in the review report and recommendations of triggers that need to be revised should be detailed.
10. All five surface water gauging stations must be referred to in the review report for the GMMP with the data presented and interpreted.
11. The GMMP review report identifies inconsistencies in bore identification details. The review report should make recommendations about any necessary amendments to the GMMP and/or the EA.

2.4 Summary of GMMP review requirements

A summary of the various GMMP review requirements, and reference to where they have been addressed in the report are presented in Table 2.1. It is noted that several of the GMMP requirements mention that they are to be carried out before 1 July 2021, in reference to the previous GMMP review report (EMM 2021a). These requirements have been revisited in this review for completeness.

Table 2.1 Summary of GMMP review requirements and where addressed

Review requirement	Description	Relevant section of this report
EA requirement		
EA Condition E7(a)	Assessment of the groundwater management and monitoring plan against the objectives in Condition E4	Section 3.1, Table 3.1
EA Condition E7(b)	Assessment of the GMMP against commitments in section 7 of the administering authority approved GMMP	Section 3.4
EA Condition E7(c)	A review of the adequacy of the monitoring locations, frequencies and groundwater quality triggers specified in Tables E1, E3 and E4	Section 3.2
EA Condition E7(d)	A review of the validity of the groundwater monitoring program against the revised model predictions required under Condition E9	Section 3.3
GMMP commitments specific to GMMP review		
#17	Conduct a review of the monitoring data, using suitably qualified expert during the review of GMMP to be carried out before 1 July 2021.	Section 3.4.17 Section 3.5.1 (assessment of water quality and water level data)
#23	Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E7.	Section 3.2 (suitability of monitoring network) Section 3.5.1 (assessment of water quality and water level data)
#28	Initial review of the approved GMMP by an appropriately qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021.	Section 1.1 (qualifications of reviewers)
#29	The GMMP review will be conducted by 1 July 2021. The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data.	Section 3.4.29
All other GMMP commitments		
#1 to #41	Commitments #1 to #41 as outlined in the GMMP	Section 3.4.1 to Section 3.4.41
GMMP Section 7.1.1	Springs, GDES and baseflow commitments	Section 3.4.42
GMMP Section 7.1.2	Monitoring program updates	Section 3.4.43

Table 2.1 Summary of GMMP review requirements and where addressed

Review requirement	Description	Relevant section of this report
DES recommendations		
#1	Review of monitoring data (water quality and water level) collected under the GMMP. The monitoring data should be compared to triggers, limits and thresholds after each monitoring event. The annual review should determine potential impacts and emerging trends in the data with any downwards groundwater level trends compared to modelled drawdown rates. If the actual monitored rates are faster than predicted, the review report should recommend a suitable update of the triggers in the GMMP.	Section 3.5.1
#2	Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report.	Section 3.5.2
#3	The GMMP review report must provide the baseline and pre-impact water quality in a format that can be compared to future monitoring data, eg time series plots.	Section 3.5.3
#4	The GMMP review report should include a review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality trigger and water level thresholds	Section 3.5.4
#5	The GMMP review report should include piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).	Section 3.5.5
#6	Detail isotope tracer studies used to characterise the groundwater dependent ecosystems.	Section 3.5.6
#7	The 2020 review report provides details of a number of new and replacement bores – 14 in total. The latitude and longitude of these bores should be provided in the review report to facilitate any necessary EA amendment to include these additional bores.	Section 3.5.7
#8	The location and target aquifer for all new bores should be detailed in the review report with a recommendation about any necessary EA amendments.	Section 3.5.8
#9	All exceedances in water quality triggers and limits should be discussed in the review report and recommendations of triggers that need to be revised should be detailed	Section 3.5.9
#10	All five surface water gauging stations must be referred to in the review report for the GMMP with the data presented and interpreted.	Section 3.5.10
#11	The GMMP review report identifies inconsistencies in bore identification details. The review report should make recommendations about any necessary amendments to the GMMP and/or EA.	Section 3.5.11

3 GMMP review results

3.1 Assessment against objectives in EA condition E4

An assessment of the GMMP against the objectives in EA Condition E4 is summarised in Table 3.1.

Table 3.1 Assessment against objectives in EA condition E4

EA condition	Review outcome
The GMMP must be developed and implemented to meet the following objectives:	
a) Validation of the groundwater numerical model (including review of boundary and recharge conditions) to refine and confirm accuracy of groundwater impacts predicted;	<p>The GMMP has been prepared to facilitate validation of the groundwater numerical model (including review of boundary and recharge conditions) to refine and confirm accuracy of predicted groundwater impacts. The following have been included in the GMMP to meet the above requirement:</p> <ul style="list-style-type: none"> • A comprehensive groundwater monitoring network has been designed and implemented for conducting regular groundwater monitoring to collect continuous data on water levels and water quality parameters for both construction and operational phases of the Project. Groundwater data collection from monitoring bores commenced January 2020. Periodic bi-monthly groundwater monitoring commenced April 2020 and will be continuing through all phases of mining (Section 6.1 to 6.3 of GMMP). • The monitoring data collected to date is being used for updating and validating the numerical groundwater model. This includes the comparison of predicted and actual drawdowns to confirm the accuracy of the predicted groundwater impacts. • A review of boundary and recharge conditions is also being conducted as part of the groundwater model update.
b) The groundwater monitoring bore locations and purpose for each bore;	<p>Baseline groundwater monitoring bore locations and purposes are outlined in Table 26 of the GMMP (Section 3.1.2). Spearpoint bores C18010SP, C18011SP, C18012SP, C18013SP and C18014SP are detailed in Table 40 of the GMMP while seepage bores C18004SP, C18005SP, C18006SP, C18007SP, C18008SP and C18009SP are described in Table 62 of the GMMP. Bores that have been installed since the last revision of the GMMP are detailed in Table 3.3 and should be included in the next GMMP update.</p> <p>It is noted that bore C14014SP has been renamed to C914108PTR and should be updated in the GMMP.</p>
c) Groundwater level monitoring in all identified geological units present across and adjacent to the mine site to confirm existing groundwater flow patterns and monitor drawdown impacts;	<p>A comprehensive groundwater monitoring network has been designed for conducting regular groundwater monitoring of water levels and water quality in all identified geological units present across and adjacent to the mine site and included in the GMMP. This monitoring will help to confirm existing groundwater flow patterns and to monitor drawdown impacts. Baseline monitoring was undertaken between 2011 and 2017. Further monitoring commenced in January 2020 and will be continued through all phases of mining.</p>
d) Identification of groundwater drawdown level thresholds for monitoring the impacts to Groundwater Dependant Ecosystems (including spring complexes and Carmichael River alluvium);	<p>Groundwater drawdown level thresholds were developed for 48 monitoring locations and included in the GMMP for monitoring of potential impacts to Groundwater Dependant Ecosystems (including spring complexes and Carmichael River alluvium). These thresholds have since been revised based on results from the updated numerical model (updated in 2023). A summary of the revised threshold values to be incorporated into a future revision of the GMMP is presented in Table A.1, Appendix A.</p> <p>All future monitoring data will be compared against the thresholds to check for exceedances (Section 5.0 of GMMP).</p>

Table 3.1 **Assessment against objectives in EA condition E4**

EA condition	Review outcome
e) Monitoring of aquifers in the area to the south of the mining lease that may affect the Mellaluka springs;	<p>Several groundwater monitoring bores screened across the Joe Joe Group and Tertiary sediments are present in the south of the mining lease to monitor for potential impacts to the Mellaluka Springs Complex. Monitoring bores details are presented in Section 5.3.4 of GMMP.</p> <p>Groundwater levels in the Bandanna Formation and Rewan Group are also measured south of the mining lease via vibrating wire piezometer (VWP) C14200VWP.</p>
f) Identifying and refining potential impacts on groundwater levels in the Great Artesian Basin Clematis Sandstone and Dunda Beds geological units;	<p>A bore network is established to monitor the groundwater levels in the Great Artesian Basin Clematis Sandstone and Dunda Beds geological units. Further additional networks of bores have been installed during 2020. Monitoring at these new bores commenced in January 2020, and data collected will be used for identifying and refining potential impacts (see Section 5.3 and 6.2 of GMMP).</p>
g) Estimation of groundwater inflow to mine workings and surface water ingress to groundwater from flooding events using the groundwater model;	<p>Bravus has commenced monitoring of groundwater and surface water flows. Bravus has completed the servicing of existing flow gauging stations on the Carmichael River (Stations BEL01, BEL02, CAR04, CAR01 and CAR02). These flow gauging stations have been operational since September 2019 and January 2020. Bravus has also commissioned a further two flow gauging stations on Carmichael River (Stations –Moray West and Albinia stations) which have been operational since January 2021.</p> <p>The numerical groundwater model is currently undergoing review using the monitoring data plus measured mine dewatering volumes, to meet the commitment of model revision within two (2) years of the box cut excavation. The model will undergo review at least every 5 years going forward.</p> <p>Assessment of surface water-groundwater interaction has been included in the groundwater numerical model and will be refined overtime, based on groundwater and surface water monitoring data.</p>
h) Monitoring in any identified source aquifers for alternative water supplies, relevant to any approval issued under the Water Act 2000 for the project;	<p>Two additional bores have been installed for collection of groundwater data to facilitate the model refinement and to better assess the sub-E sediments below the coal seams. Monitoring has commenced at these two bores and a pumping test has been performed on one of them. Additional investigations will be carried out in future at these bores to provide information regarding the groundwater potential within the sub-E coal seam sediments, which could be used as Make-Good groundwater supplies (Section 3.5.3 and Section 6.2 of GMMP).</p>
i) Identify groundwater quality triggers for monitoring potential impacts to groundwater quality from mining activities;	<p>Bore-specific groundwater quality triggers are described in Section 5.4 of the GMMP. Groundwater quality triggers for most monitoring bores were recently updated in consultation with DES and are included in Table E3 of the amended EA (19 April 2022). These updated trigger levels should be incorporated into the next GMMP revision.</p> <p>A discussion of the adequacy of water quality triggers and suggested changes are presented in Section 3.2 of this review.</p>
j) Monitoring water level and water quality of geological units throughout all phases of mining operations including for the period post-closure and until surrender of this environmental authority;	<p>Monitoring recommendations and commitments have been compiled for all phases of mine life, including baseline, construction, operations, and post-closure (Section 6.0 of GMMP).</p>

Table 3.1 **Assessment against objectives in EA condition E4**

EA condition	Review outcome
k) Identifying monitoring bores that will be replaced due to mining activities; and	<p>The GMMP includes the commitment to augment and modify the groundwater monitoring bore network in line with the mine plan and activities. Bravus has installed an additional 15 bores for monitoring groundwater level and quality near the proposed infrastructure facilities since 2018.</p> <p>Bores identified in the GMMP for Operational Phase are based on the first five years of mining, and the Operational Monitoring network will be revised due to decommissioning of some bores (see GMMP Section 6.2). Bore C823SP has been decommissioned since the publication of the current GMMP.</p>
l) Identify, monitor and mitigate potential groundwater impacts, including groundwater level and quality, from mine dewatering and mine water and waste storage facilities (artificial recharge).	<p>Bravus has commenced monitoring for the compilation of sufficient, spatially and geological unit-wise, groundwater monitoring data to adequately assess potential impacts from mine-dewatering and mine affected water and waste storage facilities and in turn are identifying, mitigating, and monitoring impacts (see Section 6.2 of GMMP). This includes six bores installed in 2018: C18007SP and C18008SP (which have been dry), C18004SP (Weathered Tertiary), C18005SP (Weathered Tertiary), C18006SP (Weathered Tertiary) and C18009SP (Weathered Tertiary), which are monitored under the GMMP. Trigger values have been derived for the four bores with water quality measurements (ten rounds of monitoring) following the methods outlined in the GMMP ver.11 (Section 5.4). These triggers have been included in Table E3 of the April 2022 EA and should be incorporated into the next GMMP revision.</p>

3.2 Review of the adequacy of the groundwater monitoring locations, frequencies, and groundwater quality triggers specified in Table E1, E3 and E4 of the EA

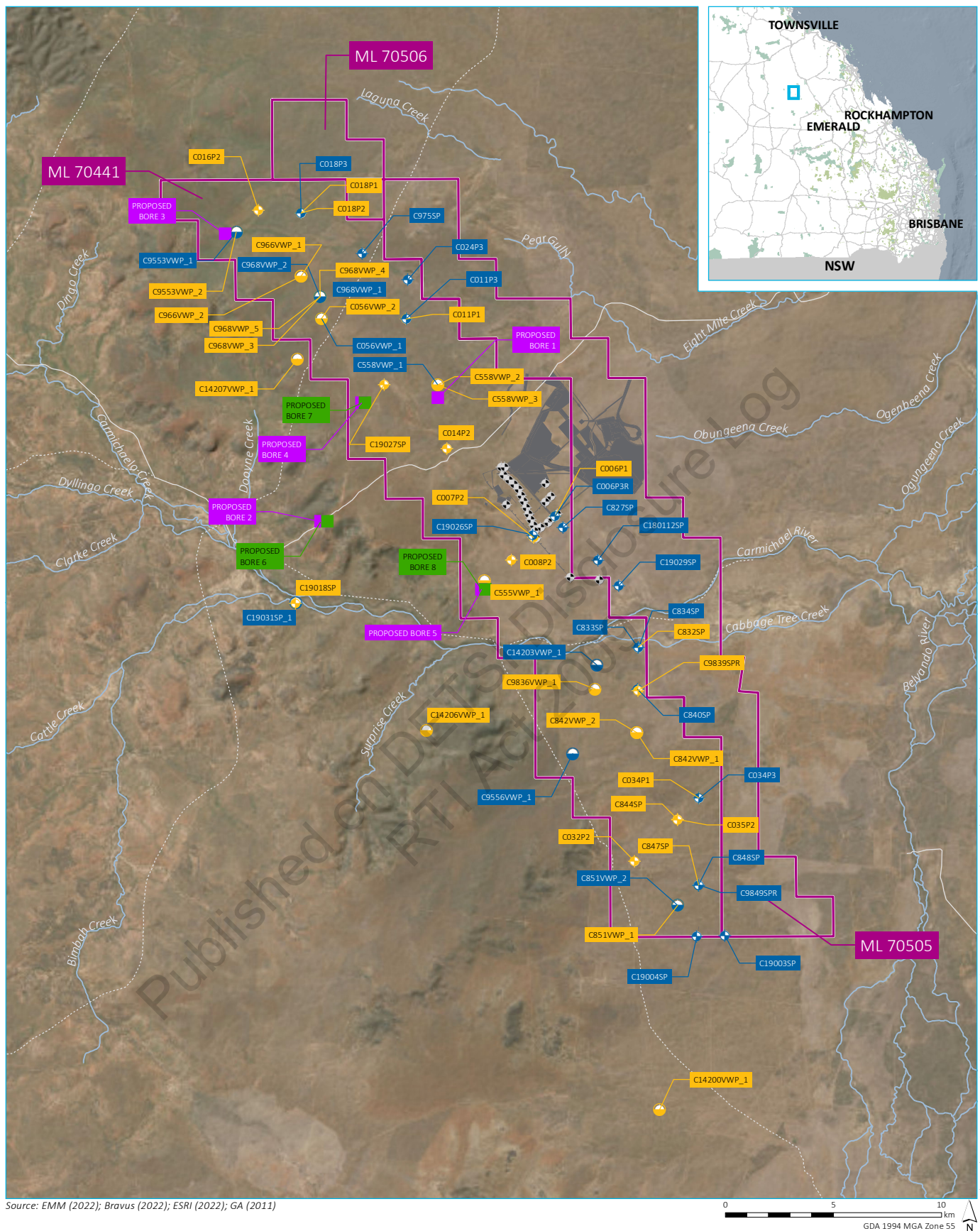
The groundwater monitoring network contains a number of monitoring locations screened within the major hydrostratigraphic units of concern to the Project and allows for both spatial and temporal variations in water level and water quality to be assessed. The bore monitoring network has been established in consultation with DES. Since publication of the GMMP, Bravus have serviced all bores and renovated some of the bores in the network, including the replacement of six blocked groundwater bores, and have commissioned additional monitoring bores.

Monitoring frequency is every two months, in accordance with the EA conditions, which require the monitoring frequency to be at least every two to three months, and provides six sets of water quality data for the groundwater bores and spring samples in one year. This is adequate to provide 12 datasets over the two years following commencement of the monitoring program (as per the GMMP) and given the logistics of laboratory analysis (including QA/QC procedures, such as holding times) is a reasonable frequency of sampling. This monitoring frequency is expected to continue until the approval of the revised GMMP (nominally May 2023) when quarterly sampling is likely to be implemented.

3.2.1 Groundwater monitoring locations

DES's review of the draft GMMP review report identified gaps in the monitoring network which should be addressed to better understand the extent and magnitude of mining/dewatering impacts and support future model updates. Eight locations were identified where additional monitoring bores should be installed to improve the adequacy of the monitoring network. The locations of the proposed additional monitoring bores are shown in Figure 3.1 and discussed below.

It is noted that an assessment of the adequacy of monitoring locations against new drawdown contours has not been undertaken to date. It is recommended that this be undertaken separately following DES's review of the groundwater modelling report.



KEY

- | | |
|--|---|
| ■ Proposed new monitoring bore - Bandanna Formation | Mining lease |
| ■ Proposed new monitoring bore - Colindale Sandstone | Mining activity |
| ● Existing monitoring bore, Bandanna Formation | — Minor road |
| ● Existing monitoring bore, Colindale Sandstone | --- Vehicular track |
| ● Existing VWP, Bandanna Formation | — Named watercourse |
| ● Existing VWP, Colindale Sandstone | ⊕ Dewatering bore |

Proposed new monitoring bore locations

Carmichael Coal Mine
GMMP Review
Figure 3.1

i Colinlea Sandstone

C011P3 is the closest Colinlea Sandstone monitoring bore to the north of the dewatering bores, at a distance of 8 km from the nearest dewatering bore. No drawdown due to dewatering has been noted in C011P3 as of the update to the hydrogeological conceptual model (EMM, 2022a). Therefore, installation of an additional monitoring bore between C19026SP and C011P3 in the Colinlea Sandstone is proposed to better delineate the magnitude and extent of drawdown impacts to the north of the dewatering bores. It is recommended that the new monitoring bore (Proposed Bore 1) be installed adjacent to existing site C558VWP (Figure 3.1). C558VWP has one sensor installed across the Colinlea Sandstone and two sensors across the Bandanna Formation. The new monitoring bore will allow comparison of trends between the bore and the existing VWP sensor installed across the Colinlea Sandstone.

Similarly, there is a lack of monitoring bores to the west of the dewatering bores, between C19026SP and C19031VWP (near DSC), to properly delineate drawdown impacts occurring in this area. Therefore, it is also proposed that a monitoring bore be installed in this area to track the propagation of dewatering impacts to the west of the dewatering bores. A bore in this area would also be able to support the west to east groundwater flow conceptualised between the DSC and the site within the Colinlea Sandstone. It is recommended that the new monitoring bore (Proposed Bore 2) be installed adjacent to existing Clematis Sandstone bores C14012SP/C14013SP (Figure 3.1).

Following DES's review of the draft GMMP review report, an additional three Colinlea Sandstone monitoring bores (Proposed Bore 3, 4 and 5) will also be installed on the western boundary of the mining lease to help delineate drawdown impacts (Figure 3.1).

ii Bandanna Formation

As was observed in the Colinlea Sandstone, there is a lack of monitoring bores within the Bandanna Formation to the west of the dewatering bores, between C008P2 and C19018SP (near DSC). Therefore, it is proposed that a monitoring bore is installed in this area to assess dewatering impacts between the mine and the DSC and address knowledge gaps of where drawdown in the Bandanna Formation is currently occurring. It is recommended that the new monitoring bore (Proposed Bore 6) be installed adjacent to existing Clematis Sandstone bores C14012SP/C14013SP (Figure 3.1).

Following DES's review of the draft GMMP review report, an additional two Bandanna Formation monitoring bores (Proposed Bore 7 and 8) will also be installed on the western boundary of the mining lease to help delineate drawdown impacts (Figure 3.1).

iii Bandanna Formation/Colinlea Sandstone – Mellaluka Springs

There are no monitoring bores in the Bandanna Formation or Colinlea Sandstone to the south of the mine, between the mining lease and the Mellaluka Springs. Installation of monitoring bores in this area would allow for a better understanding of any connection between the Bandanna Formation and Colinlea Sandstone with the Tertiary sediments and Joe Joe Formation. These bores would also allow for the propagation of any dewatering/mining impacts to the south towards the Mellaluka Springs to be better monitored.

Bores C19003SP and C19004SP are screened within the Colinlea Sandstone and are located on the southern border of the mining lease, approximately 10 km from the Mellaluka Springs. These bores would act as an early warning of any groundwater impacts propagating towards the Mellaluka Springs and therefore installation of additional bores between the mining lease and Mellaluka Springs could be delayed until mining progresses south and impacts are noted in C19003SP and C19004SP.

3.2.2 Groundwater quality trigger levels

Groundwater quality triggers for most bores and the process for determining which exceedances require investigation were updated in April 2022, with the changes included in the April 2022 update to the EA. These changes should be reflected in the next revision of the GMMP.

The water quality analysis of each sampling round is compared to the bore-specific and hydrostratigraphic unit-specific trigger values (as outlined in Table E1 and Table E3 of the EA). Trigger exceedances are reported if they occur in two consecutive monitoring events for a given water quality parameter and monitoring location. These trigger exceedances must be reported to the administering authority via WaTERS within 10 days of receipt of the assessment of analytical results. An investigation into the potential cause of the exceedances must be commenced within 14 days of becoming aware of the exceedances, and the investigation must be completed within 3 months of commencement. Appendix C shows the latest round of water quality trigger exceedances following the June 2022 field sampling.

Appendix C shows that even after updating the trigger values and investigation methodology in April 2022, exceedance investigations were triggered in 47 of the 69 monitoring bores (78 exceedances across 14 parameters). Exceedances were observed in most hydrogeological units and were unlikely to be related to mining activities due to the spatial distribution of the bores compared to the mine disturbance footprint and/or lack of dewatering impacts within bores. Investigations into trigger exceedances have repeatedly concluded that the exceedances are the result of a combination of the following:

- Natural fluctuations.
- Water level variations.
- Slow stabilisation following bore installation/bore renovations.
- Geochemical processes including oxidation of iron trigger by the introduction of dissolved oxygen during sampling or from increased rainfall recharge.
- Changing climatic conditions from a sustained period of below average rainfall to a more recent period of about average rainfall conditions, but with significant recent rainfall events.

It is recommended that water quality triggers be reassessed within two years and updated for those monitoring bores which have not been impacted by mining activities. This will allow for natural fluctuations in water quality to be better captured in the development of the trigger levels.

Sixteen bores are noted in Table E1 of the EA as not yet having been assigned triggers due to a lack of baseline data. Table 3.2 outlines these bores as well as the number of results available for each bore following the June 2022 groundwater monitoring event. It is noted that bores C19022SP and C19018SP now have more than eight results available, which is the minimum amount specified in Section 5.4.3.2.4 of the GMMP for the development of trigger levels. Trigger levels should be derived for these bores and included in the next revision of the GMMP.

The following is also noted regarding the groundwater quality triggers:

- The contaminant limits in the GMMP should be updated using the same dataset as was used to develop the updated trigger values for consistency.
- Table E2 of the EA should be updated to reflect that electrical conductivity triggers are assessed using laboratory results, not field results as currently indicated.
- Table E2 should include total dissolved solids as a trigger level parameter to be consistent with Table E3 of the EA.

Table 3.2 Bores pending trigger development

Bore	Number of results available (following June 2022 monitoring)
C19022SP	13
C19018SP	10
C19012SP	6
C19010SP	6
C19014SP	6
C19008SP	6
C919013SPR	6
C19017SP	5
C19019SP	2
C19021SP*	0
C19023SP*	0
C19024SP*	0
C19025SP*	0
C18007SP*	0
C18008SP*	0
C19020SP*	0

Note: Bores marked with '*' do not have any results available because they are dry

3.2.3 Groundwater level thresholds

Groundwater level thresholds have been exceeded in several bores since commencement of monitoring, as discussed in the bi-monthly exceedance reports submitted to DES. Investigations have concluded that exceedances of groundwater level thresholds to date are not attributable to mining activities but related to one or more of the following:

- Water levels in replacement bores being compared against water level thresholds developed from older bores which have naturally different water level elevations.
- Amendment of cable lengths (and thus historical water level elevations) in artesian bores.
- Natural water level declines due to prolonged below average rainfall conditions.
- Nearby landholder use.
- Depressurisation and slow recovery following sampling and/or bore renovations.

Groundwater level thresholds have been updated based on the latest modelling predictions and these are shown in Table A.1, Appendix A. Water level thresholds were calculated using the same methodology as presented in Section 5.3.3.1 of the GMMP. The following was also undertaken as part of the water level threshold updating process:

- Baseline average groundwater level elevations and natural fluctuations for each bore were reassessed to incorporate all representative logger data (where available) before commencement of dewatering. Previously, only groundwater level data collected up to 2017 was considered to represent baseline conditions. Hydrographs showing updated baseline datasets are provided in Appendix B.
- For replacement bores installed after commencement of dewatering (ie C19001SP, C19002SP, C19010SP and C19028SP) baseline average groundwater levels and natural fluctuations were calculated from all groundwater level data collected to date. It is noted that none of these bores show any evidence of dewatering impacts to date nor are they predicted to be impacted by mining activities to date.
- Baseline average groundwater levels and natural fluctuations have been corrected for cable length adjustments in artesian bores.
- VWP's have been deemed unsuitable as water level threshold bores and therefore water level thresholds were not reassessed for VWP's.
- The existing five VWP water level threshold locations have been replaced with the following five water level threshold bores:
 - C19010SP and C19014SP installed within Clematis Sandstone.
 - C19008SP and C919016SPR installed within Rewan Formation.
 - C19018SP installed within the AB Seam of the Bandanna Formation.
- It is noted that water level thresholds have only been assigned to C19008SP and C19010SP as these are the only new bores which have greater than two years of monitoring data. Water level thresholds for C19014SP, C919016SPR and C19018SP will be assessed when at least two years of baseline data has been collected from each bore.

The updated groundwater level thresholds for Scenario 1 (open-cut only) and Scenario 3 (SEIS with updated fracturing assumptions) are shown in Table A.1, Appendix A.

It is noted that modelling Scenario 3 is predicting higher impacts at spring locations, especially due to underground mining, and further optimisation of the mine plan is required to limit spring impacts to less than 0.2 m. In the interim, it is recommended that drawdown predictions from model Scenario 1 (open-cut mining only) be used for the development of water level thresholds and incorporated into the next iteration of the GMMP and updated in the EA. Water level thresholds for Scenario 3 will need to be updated after further optimisation of the groundwater model.

3.3 Review of the validity of the groundwater monitoring program against the revised model predictions required under Condition E9

As part of Condition E7(d) of the EA, a review of the validity of the groundwater monitoring program against the revised model predictions is required.

It is recommended that review of the validity of the groundwater monitoring program be undertaken separately following DES's review of the groundwater modelling report.

3.4 Assessment of GMMP commitments

Section 7.0 of the approved GMMP lists a total of 41 commitments with respect to groundwater monitoring, installation of additional bores, provision of supply of periodic reports, publishing of monitoring data, undertaking

of investigations should water level or water quality trigger levels be exceeded, review of the groundwater monitoring program and groundwater numerical model.

An update on the status of each of the commitments in Section 7.0 of the approved GMMP are discussed below.

3.4.1 GMMP commitment #1

1. **Implement this GMMP, which details the location and frequency of groundwater monitoring activities, as well as trigger levels and response actions**

Status: Compliant. Bi-monthly monitoring of groundwater levels and water quality commenced in April 2020 for monitoring locations specified in the GMMP. Following each bi-monthly monitoring event, groundwater levels are compared to water level thresholds and water quality results compared to water quality triggers. Exceedances of water level thresholds and water quality triggers are submitted to DES following each monitoring event.

3.4.2 GMMP commitment #2

2. **Augment the existing groundwater monitoring network over time to enable ongoing groundwater impact evaluations**

Status: Compliant. Augmentation of the groundwater monitoring network for impact evaluations has been undertaken. Bravus has installed 14 additional monitoring bores between the western ML boundary and the Doongmabulla Springs and an additional 15 monitoring bores within the mining lease consisting of 9 new bores and 6 replacement bores (see Table 3.3). All bores have been installed by appropriately licenced drilling contractors in accordance with Minimum Construction Requirements for Water Bores in Australia, 4th Edition (NUDLC, 2020) and the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017).

3.4.3 GMMP commitment #3

3. **Maintain and decommission of bores, according to industry standards, to ensure the management of groundwater resources and the collection of representative groundwater monitoring data.**

Status: Compliant. Servicing of all monitoring bores was undertaken during September-January 2020. Bore servicing included redevelopment (where necessary), upgrading of headworks and servicing of installed groundwater monitoring equipment. Decommissioning of monitoring bores is done in accordance with Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017).

3.4.4 GMMP commitment #4

4. **Utilise digital pressure gauges to obtain more accurate pressure readings at all of the artesian monitoring bores during every groundwater monitoring event.**

Status: Compliant. All artesian monitoring bores have now been equipped with ports for measurement with digital pressure gauge to enable more accurate pressure readings to be undertaken.

3.4.5 GMMP commitment #5

5. **Detail all automatic water level loggers (model, setting, and setting information), including the depth of installation within the artesian bore headworks.**

Status: Compliant. All water level logger settings (model, setting, setting information) are updated in the spreadsheet used for downloading data.

3.4.6 GMMP commitment #6

6. Compile all automated water level logger data in a standard format for all monitoring bores, such that the data provided is easier to assess and interpret. The format is, in accordance to approval conditions, to be supplied in a format specified by the administering authority. The information will include, as a minimum:

- Manual and logger download data
- Correction for barometric pressure (non-vented loggers)
- Logger set-up details, depth of installation and measurements as depth-to-water
- Logger reset or replacement details
- Logger type and accuracy
- Agreed column naming convention

Status: Compliant. All automatic logger settings have been updated to be in a standard format used for downloading data with details such as logger model, setting information for barometer pressure correction, other measurement details like temperature and depth of installation and measurements as depth-to-water.

3.4.7 GMMP commitment #7

7. Groundwater level data from bores in Bandanna Formation (C018P2, C032P2, C034P1 and C823SP), Colinslea Sandstone (C833SP and C834SP) and Joe Joe group (C14006SP, C14008SP, C14014SP (C914108PT), C14015SP, C14016SP, C14017SP, C914030SPR, C180119SP, C180123SP, C9180124SPR, and C9180125SPR) will be reviewed and updated in 2 years based on a review of data (logger data validation with future manual readings and datum measurements).

Status: Compliant. Bravus has commenced groundwater monitoring as per the monitoring network detailed in Table 62 of the GMMP. These groundwater bores have been monitored since January 2020. Hydrographs containing data up to August 2022 for the bores listed in GMMP commitment #7 are presented in Appendix D. These hydrographs show a good correlation between manual readings and logger data over the past two years.

3.4.8 GMMP commitment #8

Seepage /Infrastructure Bores

8. Monitor the recently installed (2018) shallow seepage groundwater monitoring bores, prior to construction of mine affected water and waste storage facilities.

Status: Compliant. Water quality data for four seepage monitoring bores (C18004SP, C18005SP, C18006SP and C18009SP) has been collected since 2018 and will be continued to be collected into the future during routine bi-

monthly water quality monitoring². It is noted that two seepage monitoring bores (C18007SP and C18008SP) have been dry since installation.

3.4.9 GMMP commitment #9

9. **Install additional monitoring bores located up and down gradient of surface infrastructure considered potential sources of contamination (e.g. mine infrastructure, waste dumps, and tailings areas) before construction of such facilities within 3 months of finalisation of the location of the facilities**

Status: Compliant. Two additional shallow monitoring bores (C19024SP and C19025SP) (see Table 3.3) have been drilled up and down gradient of the explosive storage area which will be used to store Ammonium Nitrate Fuel Oil (ANFO). Monitoring of water levels and water quality has commenced at these locations. Furthermore, Bravus will install additional monitoring bores located up and down gradient of surface infrastructure considered potential sources of contamination (eg mine infrastructure, waste dumps, and tailings areas) within 3 months of finalisation of the location of the facilities.

3.4.10 GMMP commitment #10

Boundary Bores

10. **Install five additional bores on the eastern boundary of mining lease, as recommended by DES, to develop additional baseline data for the alluvium and Tertiary sediments in this area so as to allow for the assessment of any possible migration of contaminants to the east of the mine lease**

Status: This commitment has been met. Bravus installed five boundary bores (C19019SP, C19020SP, C19021SP, C19022SP and C19023SP) (see Table 3.3) to develop additional baseline data for the alluvium and Tertiary sediments in this area. Monitoring of these bores will allow for the assessment of any possible migration of contaminants to the east of the mine lease.

3.4.11 GMMP commitment #11

Replacement Bores

11. **Alluvium bore C025P1, regularly recognised to be dry, will be replaced with a new alluvium bore located within deeper alluvium adjacent to the Carmichael River. A bore specific groundwater level threshold will be derived for this bore over time, the groundwater level threshold for existing bore C025P1 will be used in the interim.**

Status: This commitment has been met. A replacement bore (C19001SP) (see Table 3.3) for C025P1 has been installed within deeper alluvium sediments at the same location. Water level and quality data is being collected from C19001SP and will continue to be collected bi-monthly to update groundwater level threshold. As per commitment #5 above, water levels in C19001SP always exceed the threshold value which was calculated from the average water level and natural fluctuations in C025P1. It is recommended that C19001SP be assessed against the updated threshold value presented in Table A.1, Appendix A which is based on all data collected from C19001SP post-installation. This threshold value should be re-evaluated during the next update of the GMMP.

² Interim contaminant limits have been included in Appendix E of this review report.

3.4.12 GMMP commitment #12

12. A new monitoring bore will be installed into Clematis Sandstone at current location of C180118SP as this bore is currently blocked

Status: This commitment has been met. C180118SP which is blocked has been replaced with a new bore (C19002SP) (see Table 3.3). Water level and quality data is being collected from the new bore and will continue to be collected bi-monthly. As per commitment #5 above, water levels in C19002SP are naturally lower in elevation than C180118SP. It is recommended that C19002SP be assessed against the updated threshold value presented in Table A.1, Appendix A which is based on data collected from C19002SP. This threshold value should be re-evaluated during the next update of the GMMP.

3.4.13 GMMP commitment #13

13. Drilling of the replacement bores at C025P1 and C180118SP plus the five additional bores (Figure 30) within the first year of commencement of mining operations

Status: This commitment has been met. Bores C025P1 and C180118SP have been replaced with C19001SP and C19002SP, respectively. Five additional bores have also been installed (Table 3.3).

3.4.14 GMMP commitment #14

Nested Bores

14. Additional bores monitoring the Dunda Beds, Rewan Formation, and Permian Betts Creek Beds (which includes the Bandanna Formation and Colinlea Sandstone) will be installed within one year of commencement of mining operations at three locations co-located as far as practicable within 500 m of existing Clematis Sandstone monitoring points as follows: HD02, HD03A, and C14011SP including one bore within the vicinity of the Doongmabulla Springs Complex.

Status: This commitment has been met. Installation of these additional bores was completed in 2020. Bore details are provided in Table 3.3.

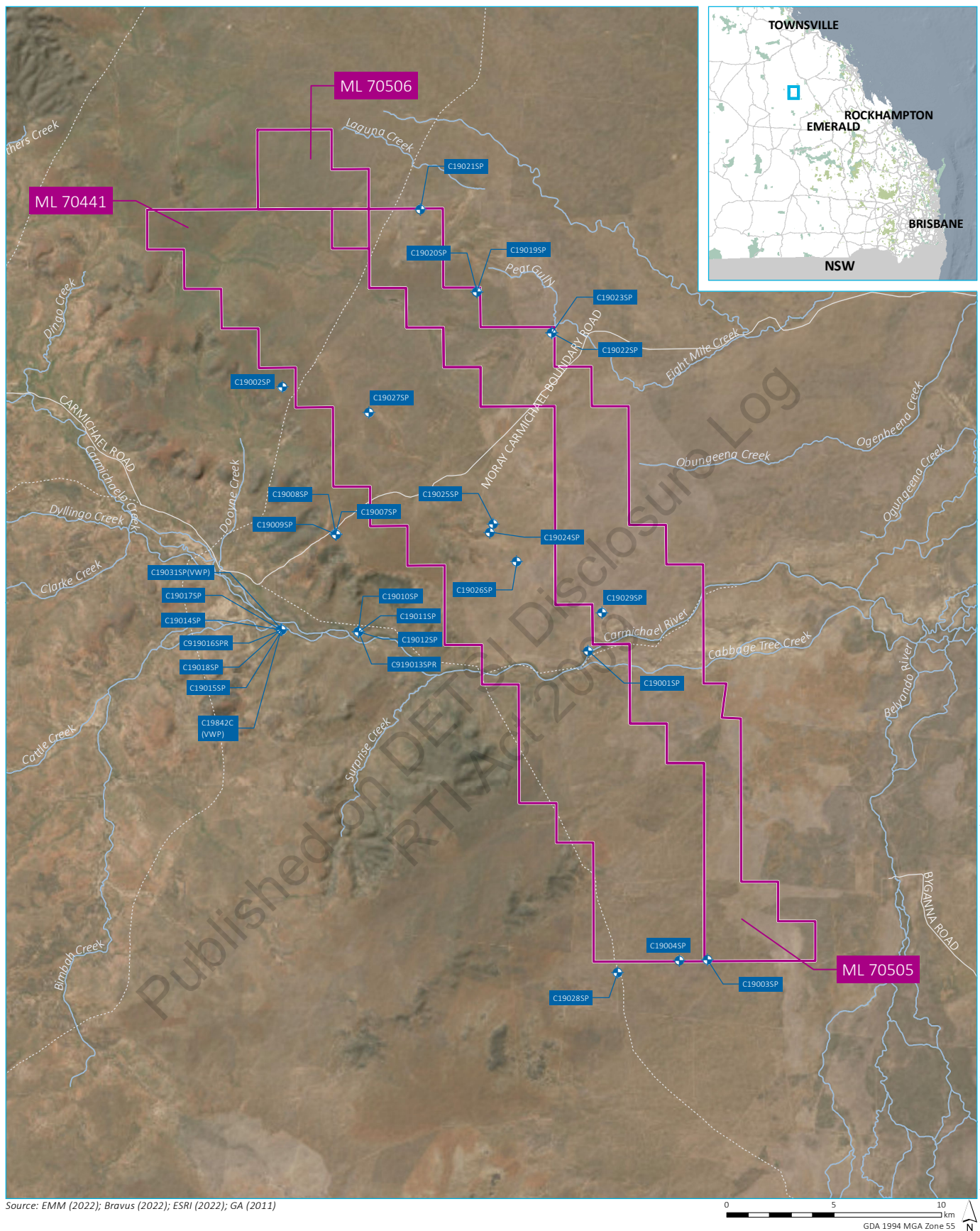
Table 3.3 **New groundwater monitoring bores 2019-2020**

	Bore ID	Easting ¹	Northing ¹	Surface RL (mAHD) ²	Depth (mBGL) ³	Screen Interval (mBGL) ³	Formation	Remarks
1	C19007SP	426268	7561274	310.28	240	222.7 - 234.7	Dunda beds	Outside & west of ML
2	C19008SP	426268	7561277	310.18	288	271-283	Rewan formation	Outside & west of ML
3	C19009SP	426286	7561268	310.15	517	504-516	Rewan formation	Outside & west of ML
4	C19010SP	427323	7556734	238.41	100	82-94	Clematis SSt	Outside & west of ML
5	C19011SP	427337	7556725	238.07	177	162-174	Dunda beds	Outside & west of ML
6	C19012SP	427331	7556730	238.4	228	212-224	Rewan formation	Outside & west of ML
7	C919013SPR	427346	7556721	238.1	440	428-440	Rewan formation	Outside & west of ML
8	C19014SP	423766	7556814	239.58	120	95.9-107.9	Clematis SSt	Outside & west of ML
9	C19015SP	423768	7556827	239.39	183	168-180	Dunda beds	Outside & west of ML
10	C19017SP	423736	7556825	239.62	463	450.8-462	Rewan formation	Outside & west of ML
11	C19018SP	423737	7556834	239.28	493	481-493	Bandanna formation	Outside & west of ML
12	C19842C (VWP)	423736	7556821	239.77	648	330	Rewan formation	Outside & west of ML
13	C919016SPR	423767	7556821	239.4	256	238-250	Rewan formation	Outside & west of ML
14	C19031SP(VWP)	423753	7556845	238.92	620	605	Colinlea SSt	Outside & west of ML
15	C19019SP	432845	7572555	255.35	15	8-14	Alluvium	Boundary bores East of ML
16	C19020SP	432847	7572550	255.15	50	43-49	Weathered Tertiary	Boundary bores East of ML
17	C19021SP	430226	7576369	264.61	15	8-14	Alluvium	Boundary bores East of ML
18	C19022SP	436340	7570625	225.23	50	43-49	Weathered Tertiary	Boundary bores East of ML
19	C19023SP	436338	7570630	225.15	15	8-14	Alluvium	Boundary bores East of ML

Table 3.3 **New groundwater monitoring bores 2019-2020**

	Bore ID	Easting ¹	Northing ¹	Surface RL (mAHD) ²	Depth (mBGL) ³	Screen Interval (mBGL) ³	Formation	Remarks
20	C19024SP	433447	7561376	253.59	15	8-14	Alluvium	Infrastructure bore
21	C19025SP	433612	7561775	247.49	15	8-14	Alluvium	Infrastructure bore
22	C19003SP	443571	7541484	229.8	226	148-160	Colinlea SSt	Sub-E Colinlea Bores
23	C19004SP	442278	7541451	238.43	264	228-240	Colinlea SSt	Sub-E Colinlea Bores
24	C19026SP	434698	7559985	238.44	260	252-259	Colinlea SSt	Replacement bore (C007P3)
25	C19027SP	427832	7566929	262.37	263	252-262	Colinlea SSt	Replacement bore(C020P2)
26	C19028SP	439400	7540894	260.68	53	40-50	Rewan formation	Replacement bore(C180116SP)
28	C19029SP	438684	7557636	224.74	71	63-69	Colinlea SSt	Replacement bore(C180114SP)
27	C19001SP	438025	7555853	227.06	18	11-17	Alluvium	Replacement bore(C027P1)
29	C19002SP	423799	7568106	305.33	125	117-123	Clematis SSt	Replacement bore(C180118SP)

Notes: ¹ GDA94 Zone 55, ² mAHD = metres Australian Height Datum, ³ mBGL = metres below Ground Level



KEY

- New monitoring bores
- Mining lease
- Minor road
- Vehicular track
- Named watercourse

New groundwater monitoring bores
(2019-2020)

Carmichael Coal Mine
GMMP Review
Figure 3.2

3.4.15 GMMP commitment #15

15. Undertake groundwater monitoring and sampling via a suitably qualified and experienced professional in accordance with recognised procedures and guidelines

Status: Compliant. Bi-monthly water quality sampling is undertaken by suitably qualified personnel from C&R Consultants. Personnel from C&R meet 'suitably qualified personnel' as defined in the EA. Bravus has also engaged suitably qualified contractors to service monitoring bores. All groundwater quality samples are sent to NATA accredited laboratories for analysis.

3.4.16 GMMP commitment #16

16. For all new bores, to be drilled after the compilation of the initial GMMP, a minimum of 12 datasets over 24 months, will be collected prior to developing groundwater level thresholds and water quality triggers for discussion with DES for inclusion in future iterations of the GMMP

- All new bores will be assessed against the water quality triggers developed for each hydrostratigraphic unit until (and if required) bore specific triggers are developed
- All new bores will be installed as soon as possible so as to compile additional groundwater data to inform the conceptual model and the refinement of the model as required in Condition E4a and E6
- Any consideration of revising the groundwater level thresholds, based on new data acquired, must assess the potential impacts of the revised groundwater level thresholds on GDEs.

Status: Compliant. Bravus has commenced monitoring of all new bores installed after compilation of the initial GMMP. The groundwater data collected from these additional bores will be used to inform the groundwater conceptual model and the refinement of the numerical model as required in EA condition E4a and E9. Water quality triggers for new bores will be developed in consultation with DES when at least eight water quality results have been collected for each bore.

The GMMP will need to be updated to include the revised groundwater level thresholds for Scenario 1 (open-cut mining only) which are presented in Table A.1, Appendix A.

3.4.17 GMMP commitment #17

17. Conduct a review of the monitoring data, using suitably qualified expert during the review of GMMP to be carried out before 1 July 2021 (or any other time frame as agreed with DES so as to align GMMP review and model re-run to happen concurrently) to update conceptualisations and conduct groundwater numerical model review based on these data)

- To allow for the correct scientific development of the GMMP it is considered (subject to agreement with DES) that the refinement and re-run of the model will occur prior to the update of the GMMP, as the model outputs and modifications can be captured in the GMMP
- The model re-run is to occur 2 years after the commencement of the box cut and then every 5 years, the same review periods as the GMMP

Status: Compliant. Monitoring data has been reviewed and the hydrogeological conceptualisation has been updated by (EMM, 2022a) as part of the numerical model revision which is ongoing and to be completed by 31 January 2023.

3.4.18 GMMP commitment #18

18. Hydrochemistry results will be reviewed after each groundwater monitoring event to assess for exceedances (water quality triggers and groundwater level thresholds) and track any emerging trends through the compilation of (water quality and groundwater level) time series plots

- **For bores where bore specific water quality triggers have not been developed, average values have been used in the interim until a minimum of 8 measurements have been recorded. These interim triggers will be revised and presented in future iterations of the GMMP**

Status: Compliant. The hydrochemistry and water level results are reviewed after each bi-monthly monitoring event and exceedances of trigger levels and thresholds were assessed as per EA conditions and are reported to the administering authority. To date, hydrochemistry and water level data has been reviewed and exceedances reporting during 15 bi-monthly monitoring events between January 2020 and June 2022. A summary of water quality exceedances during the monitoring events is presented in Appendix C and is summarised in Section 3.5.1. Water quality triggers for most monitoring bores were recently updated in consultation with DES. Water quality triggers for newly installed bores will be developed in consultation with DES once sufficient data has been collected and included in future GMMP iterations.

3.4.19 GMMP commitment #19

19. Assess groundwater, surface water, and springs using isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation

Status: Compliant. Bravus commenced assessment of groundwater, surface water, and springs using major elements, trace elements and isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation in 2018/2019 and again in February 2021. Results of the isotope tracers are included in EMM (2021b) and were discussed in the previous GMMP review (EMM 2021a). No additional studies have since been undertaken.

3.4.20 GMMP commitment #20

20. Non-mining influence on water quality (if exceedances occur which cannot be correlated to mining activities) will be assessed through the consideration of:

- **Groundwater levels, depth-to-water, and groundwater gradient changes**
- **Identification of land-use changes upgradient of monitoring bores**
- **Regular meetings / discussions with neighbouring landholders to identify activities that may influence groundwater quality**
- **Increasing the water quality analytical suite (assess possible sources)**
- **Water quality “fingerprinting” using major ion chemistry (Scholler Plots, etc.)**

Status: Compliant. Review of bi-monthly water level and water quality data to date has concluded that exceedances of water levels and water quality are currently not related to mining activities. Exceedances can be attributed to a combination of processes as summarised in Section 3.2.2. If exceedances during future monitoring are assessed to be due to mining activities, Bravus will undertake an investigation in consideration of the above requirements. Exceedance reporting is outlined in Section 3.5.1.

3.4.21 GMMP commitment #21

21. Potential groundwater impacts from mine water and waste storage need to be assessed and potential mitigation measures adopted if potential for environmental harm is identified. These mitigation measures include:

- Identification and removal of source
- Seepage capture schemes, suitable to prevent possible plume migration offsite
- Pump and treat schemes to manage possible contaminant plumes
- Augmentation of the groundwater monitoring network to validate remediation

Status: Compliant. For future compliance. If the investigation completed under Section 4.0 of the GMMP and EA condition E12 confirms that groundwater quality impacts exceeded the trigger values, and impacts are as a result of seepage of mine water and waste storage, further detailed investigation will be completed as per EA condition E13, and appropriate mitigating measures will be selected and implemented as per EA condition E14.

3.4.22 GMMP commitment #22

22. If groundwater level impacts are predicted to be beyond those allowed in the project approvals, mitigation activities with regards to water availability at the GDEs may include:

- Limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining
- Freezing mine development at current levels until the completion of investigations and assessments which conclude that further development will not exceed approved impacts
- In case the investigation(s) carried out under EA conditions E10 to E14 determines that further mine development would exceed approved impacts to MSES, then the bio-diversity offset strategy will be updated and offsets will be provided

Status: Compliant. For future compliance. If the investigation completed under Section 4.0 of the GMMP and EA condition E15 confirms that groundwater level impacts exceeded the threshold values for GDEs, and impacts are a result of mining operations, further detailed investigation will be completed as per EA condition E16, and appropriate mitigating measures will be selected and implemented.

3.4.23 GMMP commitment #23

23. Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E5. The GMMP will be reviewed by a suitably qualified person with a report on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following.

Status: Compliant. Since approval of the GMMP, the EA has been amended to include an additional condition for submission of an annual groundwater monitoring report (Condition E18). The annual groundwater monitoring report is required to include an assessment of groundwater level and water quality data. The latest annual groundwater monitoring report was submitted to DES during June 2022. An assessment of the suitability of the monitoring network is included in Section 3.2 above.

3.4.24 GMMP commitment #24

- 24. The results of research plans, inclusive of the GAB Springs Research Plan and Rewan Formation Connectivity Research Plan, will be incorporated into the next iterations of the numerical model review and GMMP (within two years of box cut and every five years after that)**

Status: Results and new datasets completed as part of the GAB Springs Research Plan, Rewan Formation Connectivity Research Plan and ongoing monitoring were used to develop a revised hydrogeological understanding of the Carmichael Coal Mine and surrounding area (EMM 2022a). The revised conceptual understanding has been used to develop the updated groundwater model. The GMMP will be updated to include a summary of the revised conceptualisation.

3.4.25 GMMP commitment #25

- 25. Two existing surface water flow monitoring stations CAR04 and CAR01 will be serviced to make them operational. An additional two stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence, will be installed. These surface water monitoring locations will allow for identification of impacts on the Carmichael River and associated GDEs**

Status: Compliant. Two existing surface flow gauging stations CAR01 and CAR04 have been serviced and are now operational. A third streamflow gauging station CAR02 is also serviced and brought into operation. Bravus has completed installation of two additional stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease (Moray West), the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence (Albinia). Two additional stream flow gauging stations were also installed on Belyando River (BEL01 and BEL02) downstream and upstream side respectively of confluence with the Carmichael River.

Hourly flow rates and daily rainfall are shown in Figure 3.3 for CAR01, CAR02, CAR04, Moray West and Albinia flow gauging stations. The response of these gauging stations to rainfall events during January, April and May 2022 are shown in Figure 3.4.

Hourly flow rates and daily rainfall are shown in Figure 3.5 for BEL01 and BEL02 flow gauging stations. The response of these gauging stations to rainfall events during January, April and May 2022 are shown in Figure 3.6.

Overall, all flow gauging stations show a good response to rainfall events.

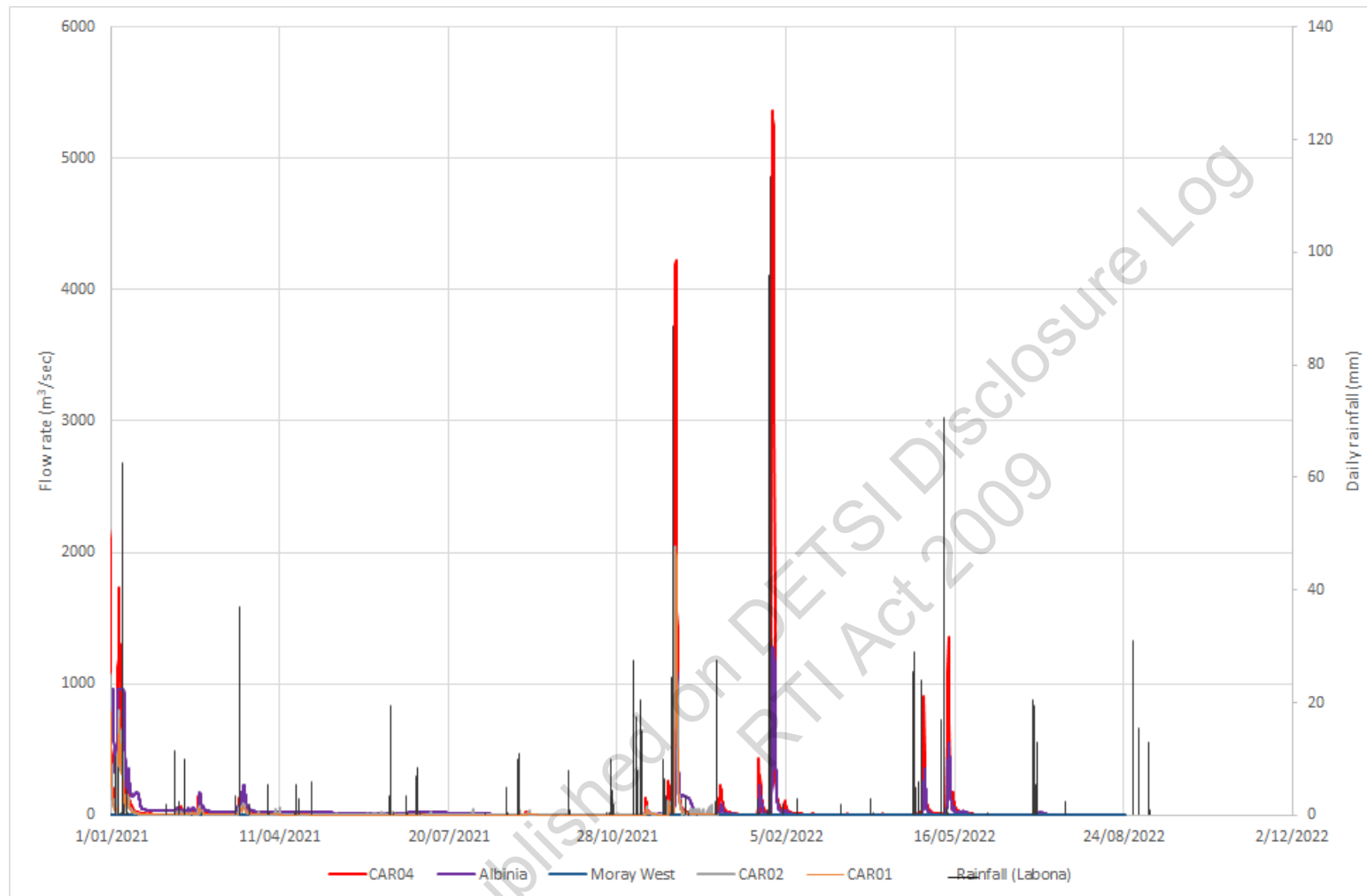


Figure 3.3 Rainfall and flow rates for gauging stations CAR01, CAR02, CAR04, Moray West and Albinia – All data

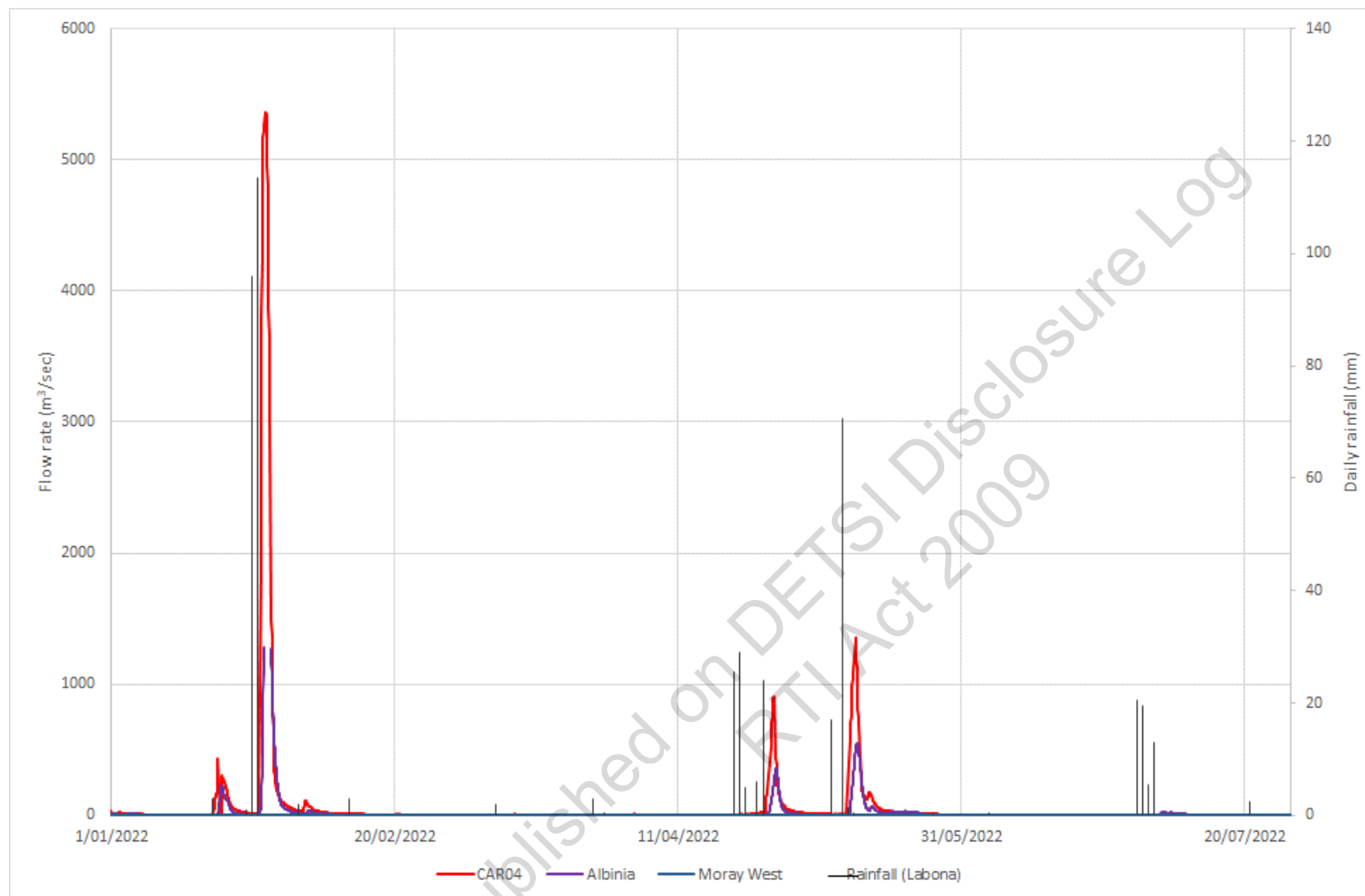


Figure 3.4 Flow rate response to rainfall during January, April and May 2022 – CAR04, Moray West and Albinia flow gauging stations

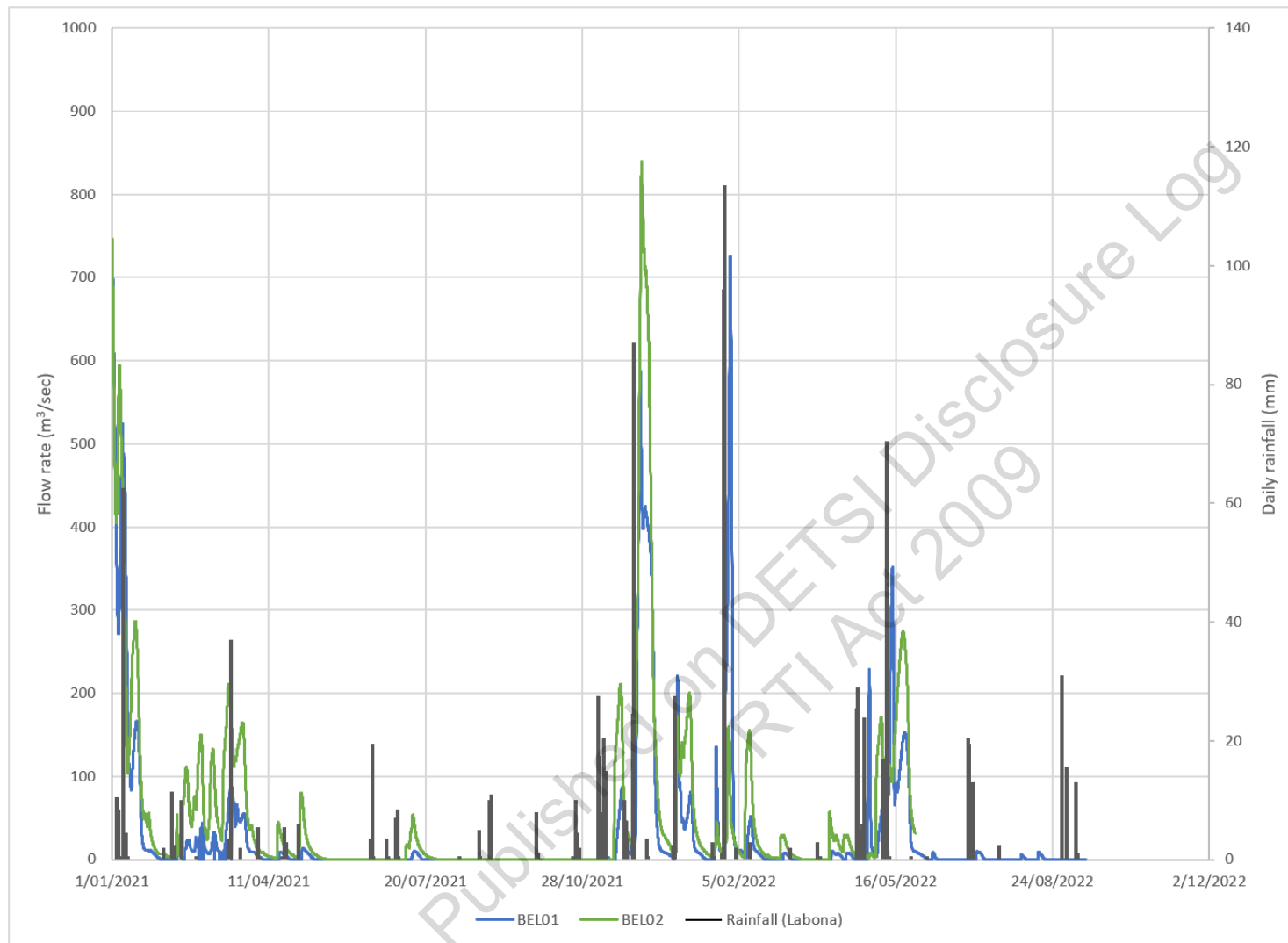


Figure 3.5 Rainfall and flow rates for gauging stations BEL01 and BEL02 – All data

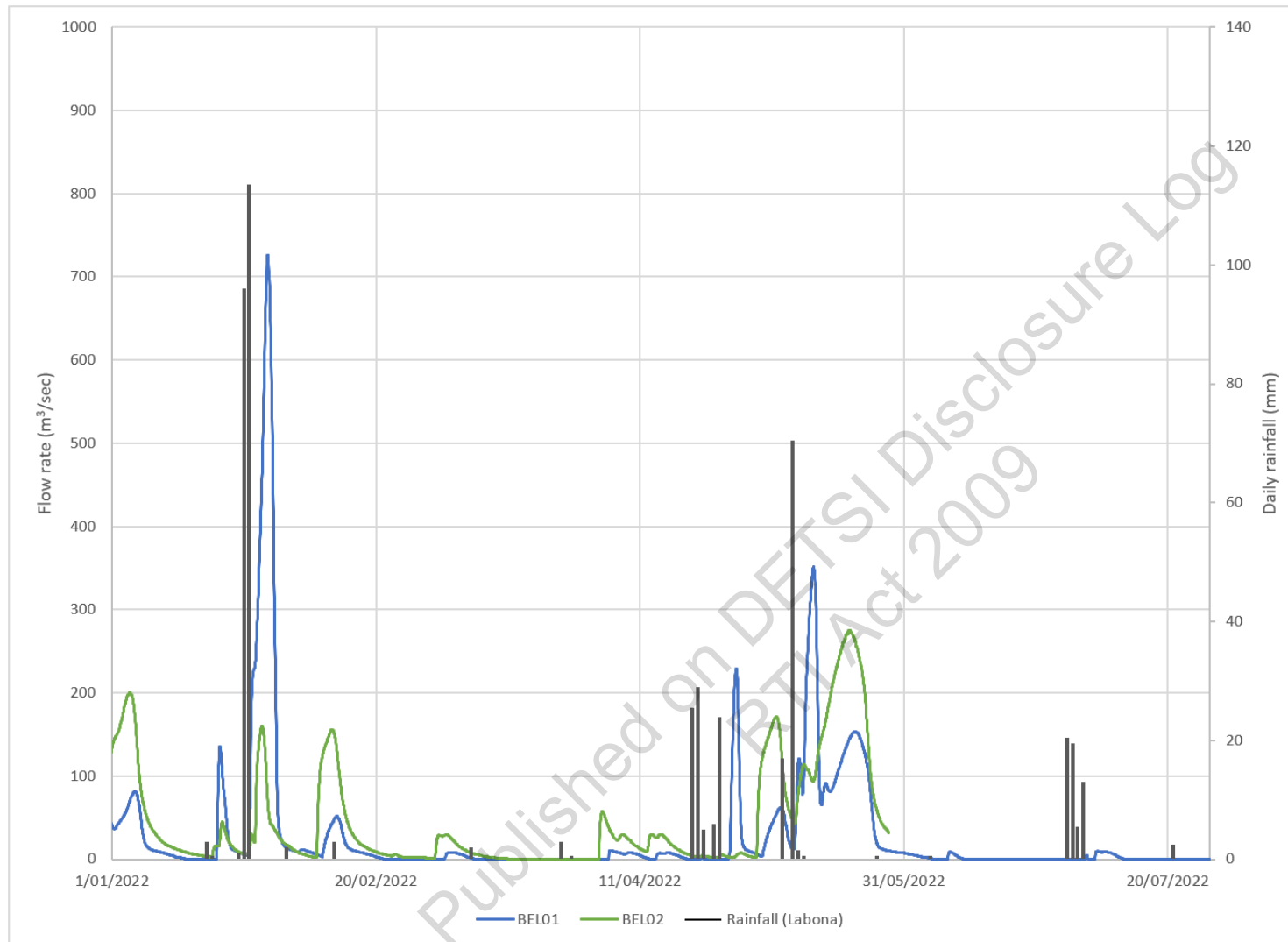


Figure 3.6 Flow rate response to rainfall during January, April and May 2022 – BEL01 and BEL02 flow gauging stations

3.4.26 GMMP commitment #26

26. Adani commits to incorporate the following in the groundwater model re-run:

- Review of the previous model conceptualisation (as per Condition E6a and commitment 16) including consideration of hydrochemistry (commitment 18)
- Incorporate available groundwater level and chemistry data from existing and new bores
- Hydrochemistry analysis from groundwater and spring samples
- Inputs from the RFCRP and GABSRP
- Review of groundwater modelling network and locations for ongoing optimisation
- Revision of groundwater drawdown rates for continuing appropriateness
- Revision of early warning triggers for continuing appropriateness
- Inclusion of updated and clearly defined bore reference levels. The review will also include how changes (if any) affect historical model calibration performance
- Transient calibration of the groundwater model, incorporating available bore water level data and surface water flows for the Carmichael River
- Review of evapotranspiration (ET) to assess its influence on model predictions relating to the DSC and the Carmichael River GDEs
- Update of the groundwater model to incorporate additional information obtained since the SEIS, including update of the geological and hydrogeological conceptualisation based on drilling works since the SEIS and groundwater level data from additional nested bores that will be installed near the DSC
- Analysis of rock properties and hydrostratigraphy from the cores of new nested bores to assess and quantify hydraulic properties within and between hydrogeological units
- Incorporate GA airborne electromagnetic survey data (if available during the next iteration of the GMMP)
- Updated sensitivity analysis
- Uncertainty analysis based on recent literature, (e.g. Middlemis and Peters, 2018, Uncertainty Analysis – Guidance for groundwater modelling within a risk management framework)"
- Systematic consideration of the sources of uncertainty as they pertain to each source aquifer and modelling limitations and document this consideration
- Inclusion of all relevant parameters in a range of modelled scenarios that encompass the identified uncertainties
- Adani will undertake ongoing stream flow gauging, as per Section 2.3.8, and the data will be used as one of the calibration parameters

- Future model updates will be compliant with the recognised modelling guidelines, "Australia Groundwater Modelling Guidelines (Barnett et al. 2012)"
- Model update will use locally appropriate parameterisations including the selection of the appropriate model scale dependent parameters such as hydraulic conductivity
- Sensitivity analysis undertaken for model updates, including an analysis of the sensitivity of the model to parameter changes due to underground mining.

The modelling review will include:

- An independent review and update of the groundwater conceptual model
- An independent review of the numerical groundwater model
- An independent review of the water balance calculations.

The recommendations of the reviews as required in Condition E7, will be, incorporated in the revised / updated GMMP document including a table of changes made in response to the independent reviews.

Status: TBD. Pending DES review of updated groundwater model.

3.4.27 GMMP commitment #27

27. At the second model re-run (7 years after commencement of box cut), Adani will specifically review both the following:

- Hydrogeological conceptualisation arising from model review and hydrochemistry analysis, consistent with and refined from the first model re-run (2 years after commencement of box cut); and
- Seismic information pertaining to the impacts of underground mining. This mining activity is not scheduled to commence until year 10, and a number of precursors are required before it commences.

If this review determines that additional seismic studies are required to determine the source aquifers of the Doongmabulla Springs Complex, these activities will be completed and that information included into revised modelling. Underground mining will not commence until these actions are completed and only if predicted impacts are consistent with approved impacts. Likewise, if the hydrogeological conceptualisation differs from that of the approved project, approval must be sought prior to relevant impact causing activities, if predicted impacts also differ from those approved.

Further, if any groundwater model re-run, or bore monitoring results, determine:

- Unauthorised impacts may or have occurred to the Doongmabulla Springs Complex from commencement of dewatering operations into the long term post closure; or
- The unlikely scenario that the Permian age hydrostratigraphic units are additional sources to the Doongmabulla Springs Complex

The following mitigation measures and corrective actions will be put in place:

- Limiting thickness of extraction of coal seams and reviewing extraction of multiple coal seams for the underground longwall mining in order to minimise drawdown impacts to Doongmabulla Springs Complex

- Freezing mine development at current levels until the completion of investigations and assessments which demonstrate and conclude that further development will not exceed approved impacts
- Assess the water balance / budgets and evaluate losses at the Doongmabulla Springs Complex, in the context of the Permian age hydrostratigraphic units being a possible additional source of groundwater.

Status: For future compliance.

3.4.28 GMMP commitment #28

28. Initial review of the approved GMMP by an appropriately qualified person with a report provided on the outcome of the review to the administering authority by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). After the initial review, the review will be conducted every five years following, the report provided to the administering authority.

Status: Compliant. The initial GMMP review report is submitted to DES in July 2021. This report is prepared to meet this commitment, and EA condition E5, to review the GMMP within two years of commencement of the first box cut excavation (ie 10 October 2022).

3.4.29 GMMP commitment #29

29. The GMMP review will be conducted by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data
- The next iteration of the GMMP (after 2 years of commencement of box cut excavation) will provide piper plots of the major ions for all hydrostratigraphic units included in the EA Conditions (Condition E3a), representative DSC springs, and the Carmichael River surface water
 - Contaminant triggers and limits will be updated when additional statistically sufficient pre-operational hydrochemistry data are collected. It is noted that several monitoring bores do not currently have the required number of analyses to calculate baseline trigger values and are using generic triggers derived from the ANZECC guidelines or average of bore specific data. Additional hydrochemistry results, allowing for the revision of trigger values, will be conducted according to the approach detailed in Section 5.4.
 - During GMMP review and groundwater model re-run consideration of potential impacts to relevant GDE's will be included when considering revision of trigger values.

Status: Compliant. Piper plots were included in the previous GMMP review report submitted in June 2021 and are also included in the bi-monthly exceedance reports. Water quality triggers were recently updated in consultation with DES and included in Table E3 of the amended EA. Water quality triggers for newly installed monitoring bores will be developed in consultation with DES once sufficient samples are collected (minimum eight samples required).

It is recommended that contaminant limits be updated using the same dataset that was used to derive the updated trigger levels. These updated contaminant limits are presented in Appendix E and should be included in the next iteration of the GMMP.

3.4.30 GMMP commitment #30

- 30. Investigate all groundwater-based complaints and maintain a complaint register. The register will be made available to the regulating authority upon request.**

Status: Compliant. No groundwater-based complaints have been received to date. Bravus will continue to maintain a compliant register for the life of the project and will be made available to the regulating authority upon request.

3.4.31 GMMP commitment #31

- 31. Implement make-good agreements with land holders affected by groundwater drawdown**

Status: For future compliance, if impacts as documented in make-good agreements are realised all make good measures as per signed agreement with land holders will be implemented.

3.4.32 GMMP commitment #32

- 32. Monitoring results will be publicly available on the Adani website (www.bravus.com.au) for the life of the CCP; the groundwater monitoring dashboard on the website will be operational within three months of approval of the GMMP. The data will be uploaded as per Section 4.8.**

Status: Compliant. All monitoring results are made publicly available on the Bravus website. Currently groundwater data collected up to August 2022 is available on the website. All future monitoring data will be made available on the website in accordance with this commitment.

General commitments regarding the groundwater monitoring include the following:

3.4.33 GMMP commitment #33

- 33. Sampling will be undertaken in accordance with the current edition of DES's Water Quality Sampling Manual, or subsequent updated versions.**

Status: Compliant. All monitoring is being undertaken in accordance with the current edition of DES's Water Quality Sampling Manual. Monitoring is undertaken by suitably qualified personnel from C&R Consulting.

3.4.34 GMMP commitment #34

- 34. Groundwater level and groundwater quality results will be maintained for the life of the project and annual data will be compiled in an annual monitoring report. The monitoring data collected annually will be submitted, by 1 July, to the administering authority via WaTERS.**

Status: Compliant. Bravus will maintain the groundwater level and groundwater quality results for the life of the project. An annual monitoring report for the period 1 July 2021 to 30 June 2022 was prepared for Bravus in June 2022 (EMM, 2022b), and the data collected was submitted to the administering authority via WaTERS by 1 July 2022.

3.4.35 GMMP commitment #35

- 35. Notification to the regulating authority within one month of receiving water quality analysis results, should any parameters tested exceed agreed trigger levels. This commitment is included in #36 below.**

Status: Compliant. See #36 below.

3.4.36 GMMP commitment #36

36. Should groundwater monitoring indicate exceedance of any or all of the groundwater level thresholds and / or water quality trigger levels then DES will be notified via WaTERS and an investigation will be instigated and the investigation report will be made available to the administering authority within the time specified in EA conditions E10 and E12 for groundwater quality trigger exceedances and E13 and E14 for groundwater threshold level exceedances respectively.

Status: Compliant. Reporting of water level and water quality exceedances have been notified via WaTERS and submitted to the administering authority within the specified time for the bi-monthly monitoring events which have been undertaken to date. The investigations to assess the cause of exceedances are completed within the specified time for all bi-monthly monitoring events and reports have been submitted to the administering authorities and via WaTERS. Bravus commits to meet the time frames specified for notifying the exceedances and submission of investigation reports in during future monitoring.

It is noted that the EA conditions in this commitment are no longer accurate based on changes to condition numbering within the latest EA which was amended 19 April 2022.

3.4.37 GMMP commitment #37

37. Adani, in the event of a confirmed exceedance of a groundwater drawdown threshold level or water quality trigger, attributable to mining activities will:
- Review the mine plan, including the sequencing of mining.
 - Update the model predictions and revise the threshold levels. As per Section 4.7.1.2, any consideration of revising the groundwater threshold levels must assess the potential impacts of the revised groundwater threshold levels on GDEs.
 - Identify potential impacts to GDEs associated with drawdown levels and implement appropriate corrective action processes as outlined in the GDEMP.

Status: Compliant. To date, exceedances of water level thresholds and water quality triggers have not been attributed to mining activities (see Section 3.5.1). In future, Bravus will meet the requirement of this commitment should any groundwater level threshold or groundwater quality trigger are exceeded so as to determine the cause of exceedance including that as a result of mining operations.

3.4.38 GMMP commitment #38

38. Should any or all the groundwater level Impact thresholds be realised, through the assessment of groundwater monitoring data and comparison to model predictions, then an appropriately qualified person will complete an investigation into the potential for environmental harm (MSES and MNES) and will provide a written report to the regulator as per the conditions. In the event of exceedances of threshold levels on MNES Adani will take the following actions:
- Update/revise the numerical groundwater model with the monitoring results.
 - Review of the mine plan including the sequencing of mining.
 - Update the predictions using the revised model to check if the revised predicted drawdown within the DSC are within the approved limits of drawdown impacts (i.e. the interim thresholds).

Status: For future compliance.

3.4.39 GMMP commitment #39

39. For completeness, the groundwater monitoring data, factual and interpretative reports (including any possible investigations as a result of triggers / thresholds) will be provided to the Commonwealth regulators as well as the State regulators.

- **All corrective actions and mitigation measures, derived based on possible investigations as a result of triggers / thresholds, will be consistent with the GDEMP.**

Status: Compliant. All groundwater monitoring collected during bi-monthly sampling, factual interpretative reports and investigation reports are provided to the Commonwealth regulators as well as the State regulators. Any recommendations resulting from the investigations completed due to triggers / thresholds exceedances including corrective actions and mitigation measures, will also be assessed to be consistent with the GDEMP requirements.

3.4.40 GMMP commitment #40

40. Conduct regular groundwater monitoring bore assessments and maintenance (where required) as well as ensuring dry or damaged bores (as a result of mining activities) are decommissioned according to the latest editions of the Minimum Construction Requirements for Water Bores in Australia, 4th Edition (NUDLC, 2020) and the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017).

Status: Compliant. Regular groundwater monitoring bore assessments and maintenance will be carried out by the qualified personnel deployed by the monitoring contractor. Bravus has followed the bore construction standards as mentioned above while constructing additional bores.

Details of bore maintenance will be included in the annual groundwater monitoring report required under Condition E18 of the EA.

3.4.41 GMMP commitment #41

41. As the proposed threshold values are reliant on predictions from the numerical groundwater model, to be updated within two years of the box cut excavation then every five years subsequently, Adani will compare the actual measured groundwater level data to predicted drawdown to assess the rate of change. In the instance the drawdown rate of the actual data is steeper/ faster than the predicted rate, an investigation will be commenced into the cause of the drawdown rate change.

Status: Observed groundwater level data collected to date has been used to calibrate the updated groundwater model which is currently being developed. Discrepancies between actual and predicted drawdown in monitoring bores to date is a focus for transient recalibration efforts to actual pre-mining dewatering stresses. Groundwater drawdown predictions will be updated as part of the updated groundwater model. These updated predictions will be compared against observed water levels during future reporting to assess the rate of change. Investigations will be undertaken in cases where it is found that the actual drawdown exceeds the drawdown predicted by the groundwater model.

Predicted drawdown (SEIS model) versus observed drawdown are provided in Section 9 of the 2022 Annual Groundwater Monitoring Report.

3.4.42 GMMP commitment –Springs, GDE and Baseflow Commitments

The status of summary of Springs, GDE and Baseflow commitments relevant for this review period is provide below.

- **Adani are committed to utilising bore C027P2 as an early warning trigger for the Carmichael River. Monitoring of the Dunda Beds and Rewan Formation as potential contributors to the Doongmabulla Spring Complex (DSC) will be undertaken to enable spatially comparable data to be collected.**

Status: Compliant. Bore C027P2 is being continuously monitored to assess for potential induced flow from Dunda Beds into coal seams. Bravus is carrying out regular groundwater monitoring in a network of bores installed between the mining lease area and Doongmabulla Springs covering Dunda beds and Rewan formations to enable collection of spatially comparable data.

- **The reporting will include any revised predictive modelling and comments regarding potential impacts on the sensitive ecosystems.**

Status: A report summarising the updated groundwater model is required to be submitted to DES before 31 January 2023. This report will include commentary on potential impacts to GDEs.

- **The GMMP will closely interlink to the GDEMP developed by Adani specifically the Doongmabulla Spring Complex, Mellaluka Spring Complex, Carmichael River baseflow and GDEs, and Waxy Cabbage Palm tree communities sub-plans. Data collected from the GMMP will assist in the monitoring of the ecological health at these GDEs and will allow for the identification of potential stress and consequently requirements for mitigation and management measures as outlined in the sub-plans.**

Status: Compliant. Groundwater monitoring data collected under the GMMP is being made available for GDEMP for monitoring of the ecological health at these GDEs.

- **Adani will investigate drilling into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information if required under relevant research programs.**

Status: Compliant. Bravus installed additional monitoring bores C19031SP-VWP, C19018SP and C19842C into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information required under relevant research programs. An additional eight monitoring bores will be installed within Permian units between the mining lease and Doongmabulla Springs as discussed in Section 3.2.1 and shown in Figure 3.1.

- **Adani will also install two additional stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence.**

Status: Compliant. Bravus completed installation of two additional flow gauging stations Moray west and Albinia station flow gauges. For additional information refer to Section 3.4.25.

3.4.43 GMMP commitment –Monitoring program updates

- **To develop the optimum groundwater monitoring plan Adani proposes a phased approach, which will allow for the correct scientific development of the program and allow for variation over time to suit the site/mining phases.**

Status: Compliant. An optimum groundwater monitoring program is developed under GMMP and implemented to suit to the current stage of construction and operational phases of the project.

- **Any revised GMMP will be submitted for approval with the administering authority, prior to the implementation of the next phase of mining/**

Status: Compliant. Bravus submitted updated GMMP (ver 11 and ver 11a) to DES and DAWE respectively, and both departments approved the same.

3.5 Assessment of DES recommendations

A letter was received from DES dated 12 October 2020 requesting that future GMMP review reports address a number of items as per sections 3.5.1 to 3.5.11 below. Assessment of the DES recommendations for the GMMP review report are provided below.

3.5.1 DES recommendation #1

1. **A review of monitoring data (water quality and water level) collected under the GMMP. The monitoring data should be compared to triggers, limits and thresholds after each monitoring event. The annual review should determine potential impacts and emerging trends in the data with any downward groundwater level trends compared to modelled drawdown rates. If the actual monitored rates are faster than predicted, the review report should recommend a suitable update of the triggers in the GMMP.**

The amended EA has since been updated to include Condition E18 to submit an annual groundwater monitoring report which must include the following:

- Summary of groundwater monitoring activity undertaken during the year.
- An assessment of water quality data and water level data for long-term trends with time series graphs of all data for all groundwater bores.
- A summary of investigation of exceedances of groundwater quality triggers and groundwater level thresholds carried out under this schedule.
- Month wise dewatering volumes during the year.
- An assessment of any differences between the impacted groundwater level predicted and the actual impacts for the corresponding period.
- A summary of all recommended changes to the GMMP.

The latest annual groundwater monitoring report was submitted to DES during June 2022.

3.5.2 DES recommendation #2

2. **Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report.**

Bi-monthly reporting and investigations of water quality trigger exceedances with comparison to changing groundwater levels has been conducted according to EA conditions E12, E13 and E14, under the guidance of the GMMP. A thorough annual review (EMM, 2022b) has also been undertaken according to EA conditions E18 and E19 which review these trends. The trigger exceedances investigations have indicated that variations in water quality are likely to be natural, rather than as a result of site activities.

3.5.3 DES recommendation #3

3. **The GMMP review report must provide the baseline and pre-impact water quality in a format that can be compared to future monitoring data eg time series plots.**

Time series plots of all results for all analytes and all monitoring bores have been included in the latest annual groundwater monitoring report (comparing the baseline and pre-impact water quality) which was submitted to DES during June 2022.

3.5.4 DES recommendation #4

- 4. The GMMP review report should include a review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality trigger and water level thresholds.**

A review of the adequacy of groundwater monitoring locations, frequencies, groundwater quality triggers and water level thresholds is discussed in Section 3.2.

3.5.5 DES recommendation #5

- 5. The GMMP review report should provide piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).**

Piper plots of major ions for all hydrostratigraphic units were included in the previous GMMP review which was submitted to DES in June 2021 (EMM 2021a). Updated piper plots for each hydrostratigraphic unit are included in the bi-monthly water quality exceedance reports.

A discussion of isotope tracer results collected as part of the GAB Springs Research Plan are included in EMM (2021b). These isotope tracer results have been used to revise the updated conceptualisation report which has previously been submitted to DES (EMM 2022a).

3.5.6 DES recommendation #6

- 6. Detail isotope tracer studies used to characterise the groundwater dependent ecosystems.**

Results of isotope tracer studies are discussed in EMM (2021b) and included in the previous GMMP review which was submitted to DES in June 2022 (EMM 2021a). No additional isotope studies or investigations have been undertaken since the previous GMMP review was submitted.

3.5.7 DES recommendation #7

- 7. The 2020 review report provides details of a number of new and replacement bores – 14 in total. The latitude and longitude of these bores should be provided in the review report to facilitate any necessary EA amendment to include these additional bores.**

Coordinates for the 14 replacement bores are provided in Table 3.3 above. Any new bores installed since these have been captured in Table E1 (Appendix 5) of the EA, including details such as latitude, longitude and target aquifer.

3.5.8 DES recommendation #8

- 8. The location and target aquifer for all new bores should be detailed in the review report with a recommendation about any necessary EA amendments.**

The locations of all new bores are shown in Figure 3.2 and target aquifer and bore details provided in Table 3.3. The monitoring bores listed in the EA (Table E1 in Appendix 5) will be updated with all new monitoring bores.

3.5.9 DES recommendation #9

9. All exceedances in water quality triggers and limits should be discussed in the review report and recommendations of triggers that need to be revised should be detailed.

Water quality triggers are discussed in Section 3.2.2 and water level thresholds in Section 3.2.3.

3.5.10 DES recommendation #10

10. All five surface water gauging stations must be referred to in the review report for the GMMP with the data presented and interpreted.

Data for surface water gauging stations are discussed in Section 3.4.25.

3.5.11 DES recommendation #11

11. The GMMP review report identifies inconsistencies in bore identification details. The review report should make recommendations about any necessary amendments to the GMMP and/or the EA.

The groundwater monitoring network presented in Table 62 of GMMP has been updated. Changes to the monitoring network have been incorporated in Table E1 Appendix 5 of the latest EA amendment.

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4 GMMP review recommendations

Additional Monitoring Bores

Following advice from DES, it is recommended that the following additional monitoring bores be drilled to monitor for water level fluctuations:

- An additional monitoring bore within Colinlea Sandstone to be installed between C19026SP and C011P3 to better delineate the magnitude and extent of drawdown impacts to the northwest of the dewatering bores. It is recommended that this bore be installed adjacent to existing site C558VWP.
- An additional monitoring bore within Colinlea Sandstone between C19026SP and C19031VWP to track future propagation of dewatering impacts in the Colinlea Sandstone between mining and the DSC. It is recommended that this bore be installed adjacent to existing Clematis Sandstone bore C14012SP/C14013SP.
- Three further additional monitoring bores within Colinlea Sandstone on the western boundary of the mining lease to track future propagation of dewatering impacts.
- An additional monitoring bore within Bandanna Formation between C008P2 and C19018SP to track future propagation of dewatering impacts in the Bandanna Formation between mining and the DSC. It is recommended that this bore be installed adjacent to existing Clematis Sandstone bore C14012SP/C14013SP.
- An additional two monitoring bores within Bandanna Formation on the western boundary of the mining lease to track future propagation of dewatering impacts.
- Additional monitoring bores within Bandanna Formation and Colinlea Sandstone in the vicinity of Mellaluka Springs to allow for detection of dewatering impacts near Mellaluka Springs and to improve the understanding of any connection between the Colinlea Sandstone and the Tertiary sediments and Joe Joe Formation. Installation of additional bores between the mining lease and Mellaluka Springs is considered low priority and could be delayed until mining progresses south and impacts are noted in C19003SP and C19004SP.

Groundwater level thresholds

To improve the assessment of groundwater level thresholds, it is recommended that the updated water level thresholds for Scenario 1 (open-cut only mining) shown in Table A.1, Appendix A be used from now on. These groundwater level thresholds have been updated based on the latest modelling predictions and reassessment of baseline datasets as discussed in Section 3.2.3.

Groundwater level thresholds for monitoring bores with less than two years of data should be reassessed for baseline average groundwater level elevations and natural fluctuations when at least two years of baseline data has been collected.

Groundwater quality triggers

The following updates are also noted regarding the groundwater quality triggers:

- The contaminant limits in the GMMP should be updated using the same dataset as was used to develop the updated trigger values for consistency.

- Monitoring bores C19022SP and C19018SP now have more than eight results which is the minimum amount required for development of trigger levels. It is recommended that trigger levels are derived for these bores and included in the next revision of the GMMP.
- Table E2 of the EA should be updated to reflect that electrical conductivity triggers are assessed using laboratory results, not field results as currently indicated.
- Table E2 should include total dissolved solids as a trigger level parameter to be consistent with Table E3 of the EA.
- It is recommended that water quality triggers be reassessed within two years and updated for those monitoring bores which have not been impacted by mining activities. This will allow for natural fluctuations in water quality to be better captured in the development of the trigger levels.

Review of the validity of the groundwater monitoring program against the revised model predictions

It is recommended that review of the validity of the groundwater monitoring program be undertaken separately following DES's review of the groundwater modelling report and results.

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5 References

Adani (2020). Carmichael Coal Mine and Rail Project Groundwater Management and Monitoring Program – Review Report. Prepared 24/06/2020.

EMM (2021a). Groundwater Management and Monitoring Program/Plan – Review Report. Prepared for Bravus Mining and Resources.

EMM (2021b). Carmichael Coal Mine Great Artesian Basin Springs Research Plan.

EMM (2022a). Carmichael Coal Mine Great Artesian Basin Springs Research Plan: RP1.6 Hydrogeological conceptualisation review and updated groundwater model.

EMM (2022b). 2022 Annual Groundwater Monitoring Report – Carmichael Coal Mine. Prepared for Bravus Mining and Resources.

EMM (2023). Carmichael Coal Mine: RP1.6 Hydrogeological conceptualisation and updated groundwater modelling, Report No.2: Numerical groundwater flow model report.

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Appendix A

Updated groundwater level thresholds

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
Carmichael River Location								
C027P1	Scenario 1	Alluvium	0.02	222.35	6.13	Prediction plus ½ NF	3.09	219.26
	Scenario 3		0.28				3.34	219.01
HD03B	Scenario 1	Alluvium	0.05	225.35	1.67	Prediction plus ½ NF	0.88	224.47
	Scenario 3		0.25				1.08	224.27
C027P2	Scenario 1	Dunda Beds	0.85	226.94	2.85	Prediction plus ½ NF	2.28	224.66
	Scenario 3		19.98			½ NF + 90% of prediction	19.41	207.53
C029P1	Scenario 1	Alluvium	0.09	214.48	1.29	Prediction plus ½ NF	0.74	213.74
	Scenario 3		0.83				1.48	213.00
C029P2	Scenario 1	Tertiary sediments	19.35	220.01	3.71	½ NF + 90% of prediction	19.27	200.74
	Scenario 3		23.88				23.35	196.66
C19001SP	Scenario 1	Alluvium	0.00	215.04	0.35	Prediction plus ½ NF	0.18	214.87
	Scenario 3		0.00				0.18	214.86
C025P2	Scenario 1	Tertiary sediments	29.63	217.59	1.20	½ NF + 90% of prediction	27.26	190.33
	Scenario 3		23.54				21.78	195.81
C14028SP	Scenario 1	Alluvium	30.88	205.49	0.38	½ NF + 90% of prediction	27.98	177.51
	Scenario 3		20.73				18.84	186.65
C14027SP	Scenario 1	Alluvium	0.00	203.62	0.22	Prediction plus ½ NF	0.11	203.51
	Scenario 3		0.05				0.16	203.46

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
C14006SP	Scenario 1	Joe Joe Group	52.11	223.42	0.94	½ NF + 90% of prediction	47.37	176.05
	Scenario 3		47.08				42.84	180.58
Great Artesian Basin to West of Mine Lease								
C19002SP	Scenario 1	Clematis Sandstone	0.19	248.90	0.31	Prediction plus ½ NF	0.35	248.55
	Scenario 3		1.66			½ NF + 75% of prediction	1.40	247.50
C14033SP	Scenario 1	Clematis Sandstone	0.10	250.59	0.29	Prediction plus ½ NF	0.24	250.35
	Scenario 3		0.93			½ NF + 75% of prediction	0.84	249.75
C14011SP	Scenario 1	Clematis Sandstone	0.18	242.81	0.26	Prediction plus ½ NF	0.31	242.50
	Scenario 3		1.04			½ NF + 75% of prediction	0.91	241.90
C14012SP	Scenario 1	Clematis Sandstone	0.10	242.60	0.26	Prediction plus ½ NF	0.23	242.37
	Scenario 3		0.65			½ NF + 75% of prediction	0.61	241.99
C14013SP	Scenario 1	Clematis Sandstone	0.10	242.42	0.41	Prediction plus ½ NF	0.30	242.12
	Scenario 3		0.65			½ NF + 75% of prediction	0.69	241.73
HD02	Scenario 1	Clematis Sandstone	0.05	234.31	2.54	Prediction plus ½ NF	1.32	232.99
	Scenario 3		0.27			1.54	232.77	
HD03A	Scenario 1	Clematis Sandstone	0.05	231.82	1.42	Prediction plus ½ NF	0.76	231.06
	Scenario 3		0.27			0.98	230.84	
C14021SP	Scenario 1	Clematis Sandstone	0.57	246.16	0.62	Prediction plus ½ NF	0.88	245.28
	Scenario 3		0.74			½ NF + 75% of prediction	0.87	245.29

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
C022P1	Scenario 1	Dunda Beds	10.57	246.57	0.44	½ NF + 90% of prediction	9.73	236.84
	Scenario 3		172.87				155.80	90.77
C027P2	Scenario 1	Dunda Beds	0.85	226.94	2.85	Prediction plus ½ NF	2.28	224.66
	Scenario 3		19.98			½ NF + 90% of prediction	19.41	207.53
C14023SP	Scenario 1	Dunda Beds	0.71	247.22	0.50	½ NF + 75% of prediction	0.78	246.44
	Scenario 3		0.76				0.82	246.40
C180117SP	Scenario 1	Dunda Beds	2.95	250.87	0.46	½ NF + 75% of prediction	2.44	248.43
	Scenario 3		15.25			½ NF + 90% of prediction	13.95	236.92
C9553P1R	Scenario 1	Rewan Formation	2.90	252.27	0.18	½ NF + 75% of prediction	2.27	250.00
	Scenario 3		118.27			½ NF + 90% of prediction	106.53	145.74
C556P1	Scenario 1	Rewan Formation	3.48	234.66	0.97	½ NF + 75% of prediction	3.10	231.56
	Scenario 3		137.90			½ NF + 90% of prediction	124.60	110.06
C555P1	Scenario 1	Rewan Formation	2.18	230.05	0.50	½ NF + 75% of prediction	1.89	228.16
	Scenario 3		89.23			½ NF + 90% of prediction	80.56	149.49
Doongmabulla to West of Mine Lease								
HD02	Scenario 1	Clematis Sandstone	0.05	234.31	2.54	Prediction plus ½ NF	1.32	232.99
	Scenario 3		0.27				1.54	232.77
HD03A	Scenario 1	Clematis Sandstone	0.05	231.82	1.42	Prediction plus ½ NF	0.76	231.06
	Scenario 3		0.27				0.98	230.84

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
C14013SP	Scenario 1	Clematis Sandstone	0.10	242.42	0.41	Prediction plus ½ NF	0.30	242.12
	Scenario 3		0.65			½ NF + 75% of prediction	0.69	241.73
C022P1	Scenario 1	Dunda Beds	10.57	246.57	0.44	½ NF + 90% of prediction	9.73	236.84
	Scenario 3		172.87				155.80	90.77
C14012SP	Scenario 1	Clematis Sandstone	0.10	242.60	0.26	Prediction plus ½ NF	0.23	242.37
	Scenario 3		0.65			½ NF + 75% of prediction	0.61	241.99
C14021SP	Scenario 1	Clematis Sandstone	0.57	246.16	0.62	Prediction plus ½ NF	0.88	245.28
	Scenario 3		0.74			½ NF + 75% of prediction	0.87	245.29
C848SP	Scenario 1	D Seam	115.97	231.60	0.98	½ NF + 90% of prediction	104.86	126.74
	Scenario 3		163.60				147.73	83.87
C19010SP	Scenario 1	Clematis Sandstone	0.05	238.59	0.68	Prediction plus ½ NF	0.39	238.20
	Scenario 3		0.30				0.64	237.95
C19014SP	Scenario 1	Clematis Sandstone	0.05	TBD	TBD	Prediction plus ½ NF	TBD	TBD
	Scenario 3		0.27				TBD	TBD
C19008SP	Scenario 1	Rewan Formation	3.35	245.25	0.27	½ NF + 75% of prediction	2.64	242.61
	Scenario 3		20.11			½ NF + 90% of prediction	18.24	227.01
C919016SPR	Scenario 1	Rewan Formation	4.38	TBD	TBD	Prediction plus ½ NF	TBD	TBD
	Scenario 3		8.34				TBD	TBD
C19018SP	Scenario 1	AB Seam	50.92	TBD	TBD	Prediction plus ½ NF	TBD	TBD

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
Scenario 3			189.43				TBD	TBD
Mellaluka Springs to the southeast of Mine Lease								
C180120SP	Scenario 1	Tertiary/Joe Joe Group	61.91	239.57	2.53	½ NF + 90% of prediction	56.99	182.58
	Scenario 3		85.41				78.13	161.44
C180122SP	Scenario 1	Tertiary/Joe Joe Group	78.87	233.05	0.75	½ NF + 90% of prediction	71.36	161.69
	Scenario 3		92.93				84.01	149.04
C180119SP	Scenario 1	Joe Joe Group	78.87	235.73	1.26	½ NF + 90% of prediction	71.61	164.12
	Scenario 3		92.93				84.27	151.46
C180123SP	Scenario 1	Joe Joe Group	53.02	243.66	0.90	½ NF + 90% of prediction	48.17	195.49
	Scenario 3		74.43				67.44	176.22
C9180124SPR	Scenario 1	Joe Joe Group	78.87	235.40	0.88	½ NF + 90% of prediction	71.42	163.98
	Scenario 3		92.93				84.08	151.32
C9180125SPR	Scenario 1	Joe Joe Group	61.91	240.30	2.61	½ NF + 90% of prediction	57.03	183.27
	Scenario 3		85.41				78.17	162.13
Sentinel Bores								
C14016SP	Scenario 1	Joe Joe Group	105.63	233.52	2.97	½ NF + 90% of prediction	96.55	136.97
	Scenario 3		128.28				116.94	116.58
C9845SPR	Scenario 1	Tertiary sediments	4.68	234.86	0.35	½ NF + 75% of prediction	3.69	231.17
	Scenario 3		30.93			½ NF + 90% of prediction	28.01	206.85

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
C14029SP	Scenario 1	Tertiary/Joe Joe Group	110.48	227.74	0.74	½ NF + 90% of prediction	99.80	127.94
	Scenario 3		103.59				93.60	134.14
C14003SP	Scenario 1	Joe Joe Group	29.39	209.37	0.27	½ NF + 90% of prediction	26.58	182.79
	Scenario 3		25.78				23.34	186.03
C14030SP/ C914030SPR	Scenario 1	Joe Joe Group	110.48	228.36	1.29	½ NF + 90% of prediction	100.08	128.28
	Scenario 3		103.59				93.87	134.49
C14015SP	Scenario 1	Joe Joe Group	81.36	236.84	0.54	½ NF + 90% of prediction	73.49	163.35
	Scenario 3		106.38				96.01	140.83
C016P2	Scenario 1	AB Seam	34.51	248.52	0.34	½ NF + 90% of prediction	31.23	217.29
	Scenario 3		166.32				149.86	98.66
C14004SP	Scenario 1	Joe Joe Group	29.39	209.44	0.52	½ NF + 90% of prediction	26.71	182.73
	Scenario 3		25.78				23.46	185.98
C14008SP	Scenario 1	Joe Joe Group	89.91	225.50	1.38	½ NF + 90% of prediction	81.61	143.89
	Scenario 3		78.66				71.48	154.02
C19028SP	Scenario 1	Rewan Formation	28.87	238.93	0.22	½ NF + 90% of prediction	26.09	212.84
	Scenario 3		51.96				46.87	192.06
C14024SP	Scenario 1	Clematis Sandstone/Rewan Group	1.43	262.69	0.16	½ NF + 75% of prediction	1.15	261.54
	Scenario 3		1.04				0.86	261.83
C14020SP	Scenario 1	Moolayember	0.06	252.45	0.31	Prediction plus ½ NF	0.22	252.23

Table A.1 **Summary of updated groundwater level thresholds**

Bore ID	Modelling scenario	Geology	Maximum predicted drawdown (m)	Average baseline groundwater level (mAHD)	Natural Fluctuation (NF) over baseline period (m)	Groundwater level threshold criteria	Groundwater level threshold (m)	Groundwater level threshold (mAHD)
	Scenario 3	Formation	0.56			½ NF + 75% of prediction	0.58	251.87

Notes: 1. Updated modelling Scenario 1 = open-cut mining only.

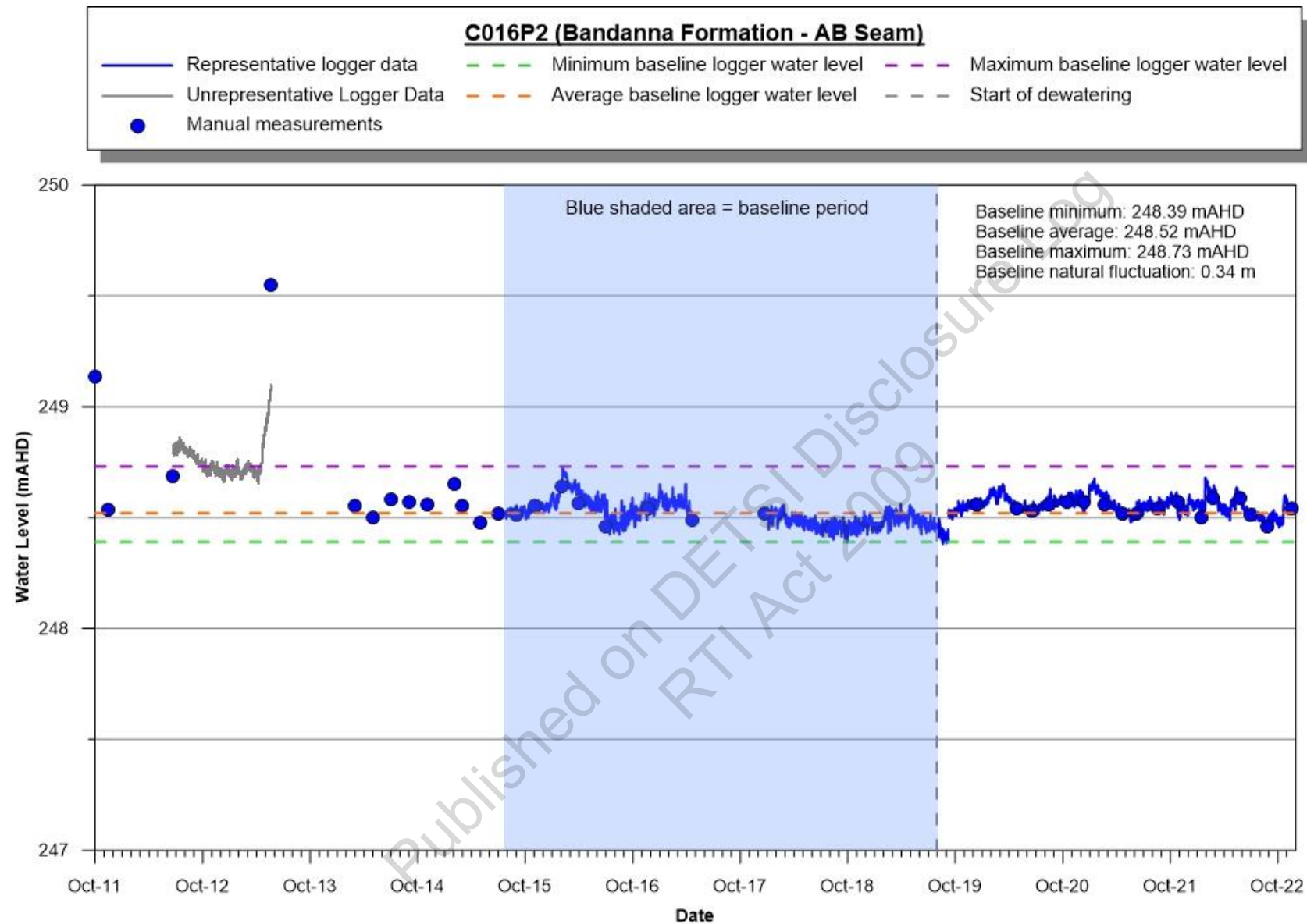
2. Updated modelling Scenario 3 = SEIS with updated fracturing assumptions.

3. TBD = water level threshold to be developed when minimum of two years data is available.

4. Water level thresholds for Scenario 3 to be updated pending results of further groundwater model optimisation.

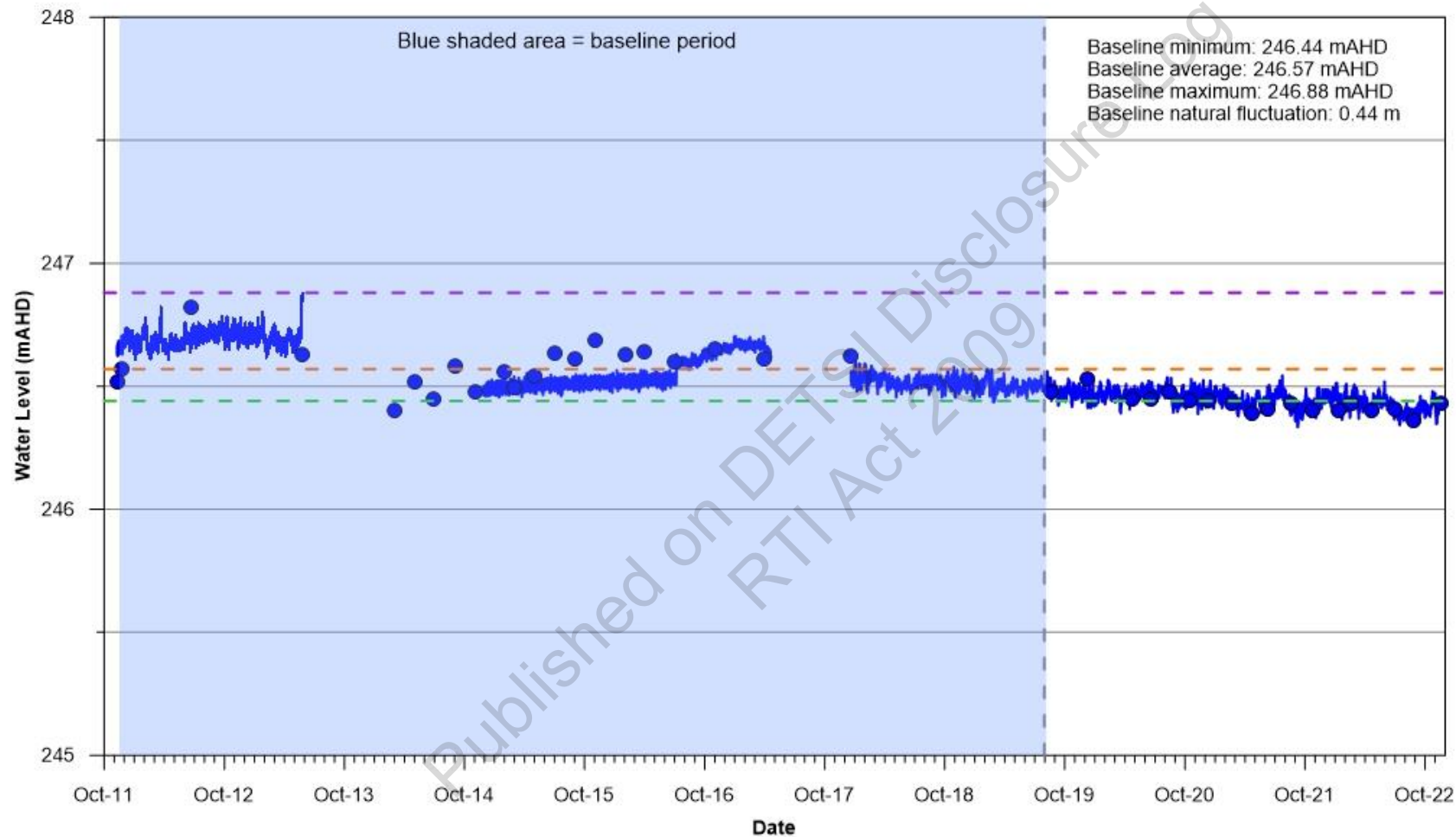
Appendix B

Hydrographs showing updated baseline datasets



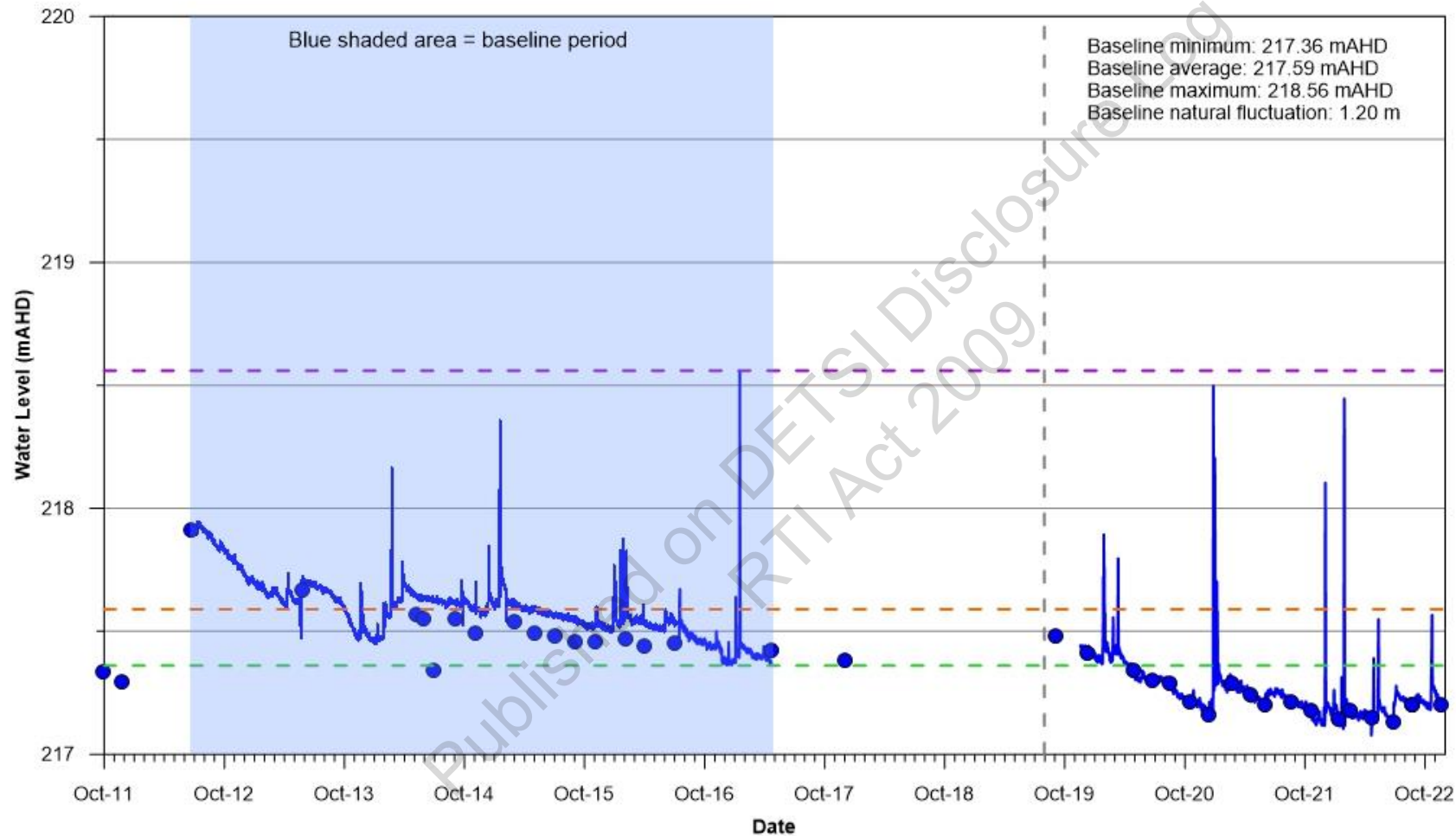
C022P1 (Dunda Beds)

- Representative logger data
- Manual measurements
- - - Minimum baseline logger water level
- - - Average baseline logger water level
- - - Maximum baseline logger water level
- - - Start of dewatering



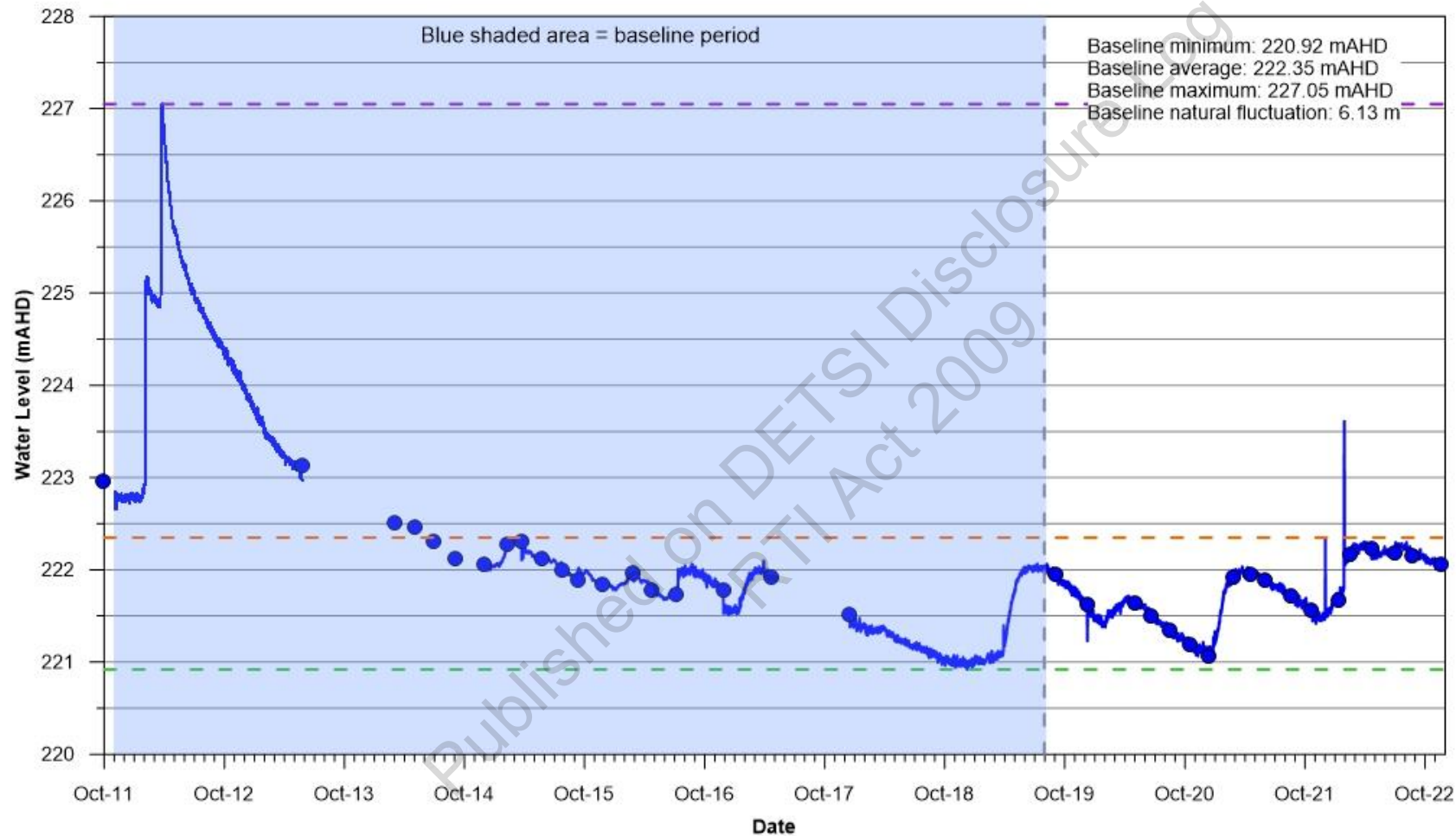
C025P2 (Tertiary sediments)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



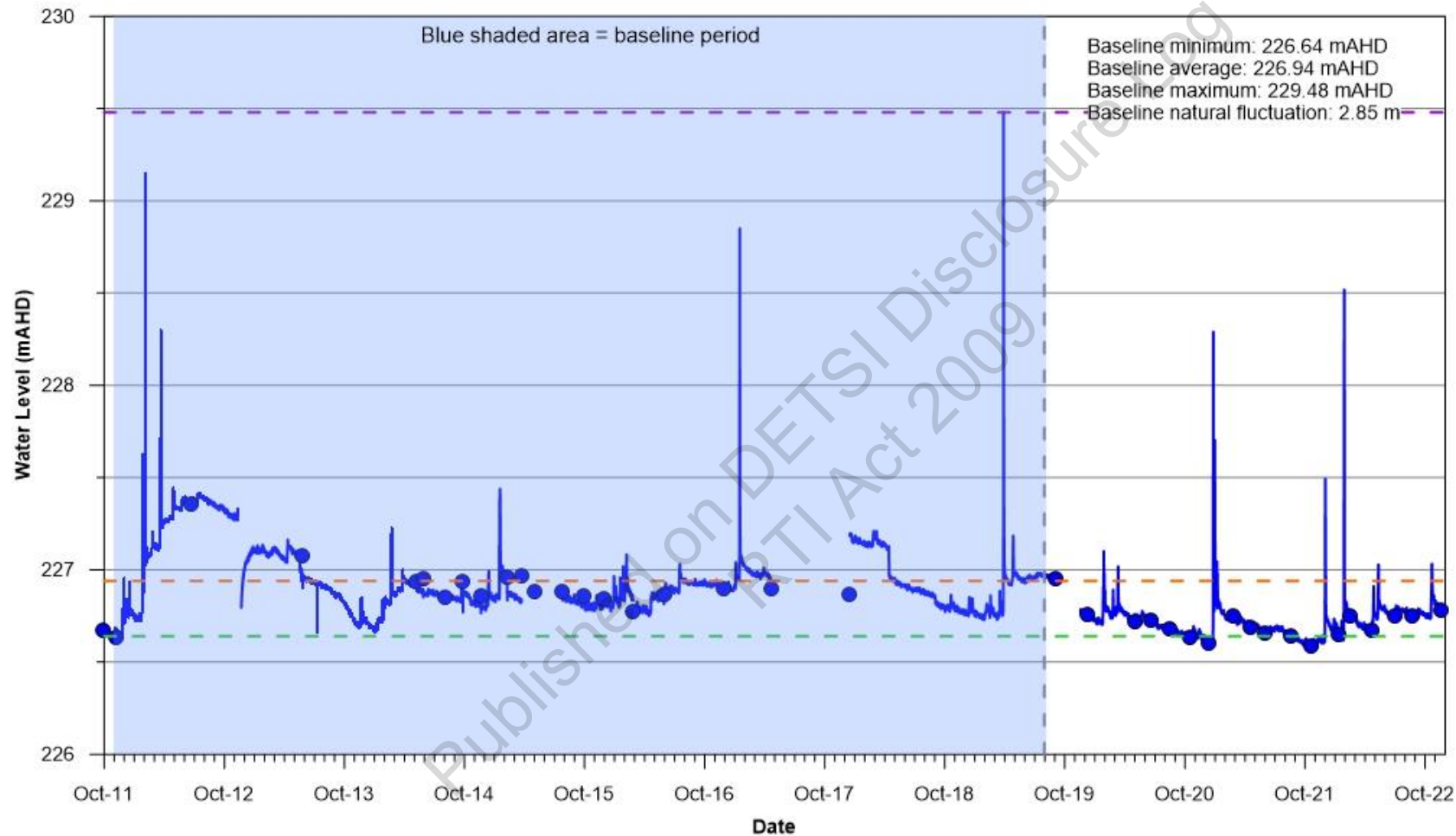
C027P1 (Alluvium)

- Representative logger data
- Manual measurements
- - - Minimum baseline logger water level
- - - Average baseline logger water level
- - - Maximum baseline logger water level
- - - Start of dewatering



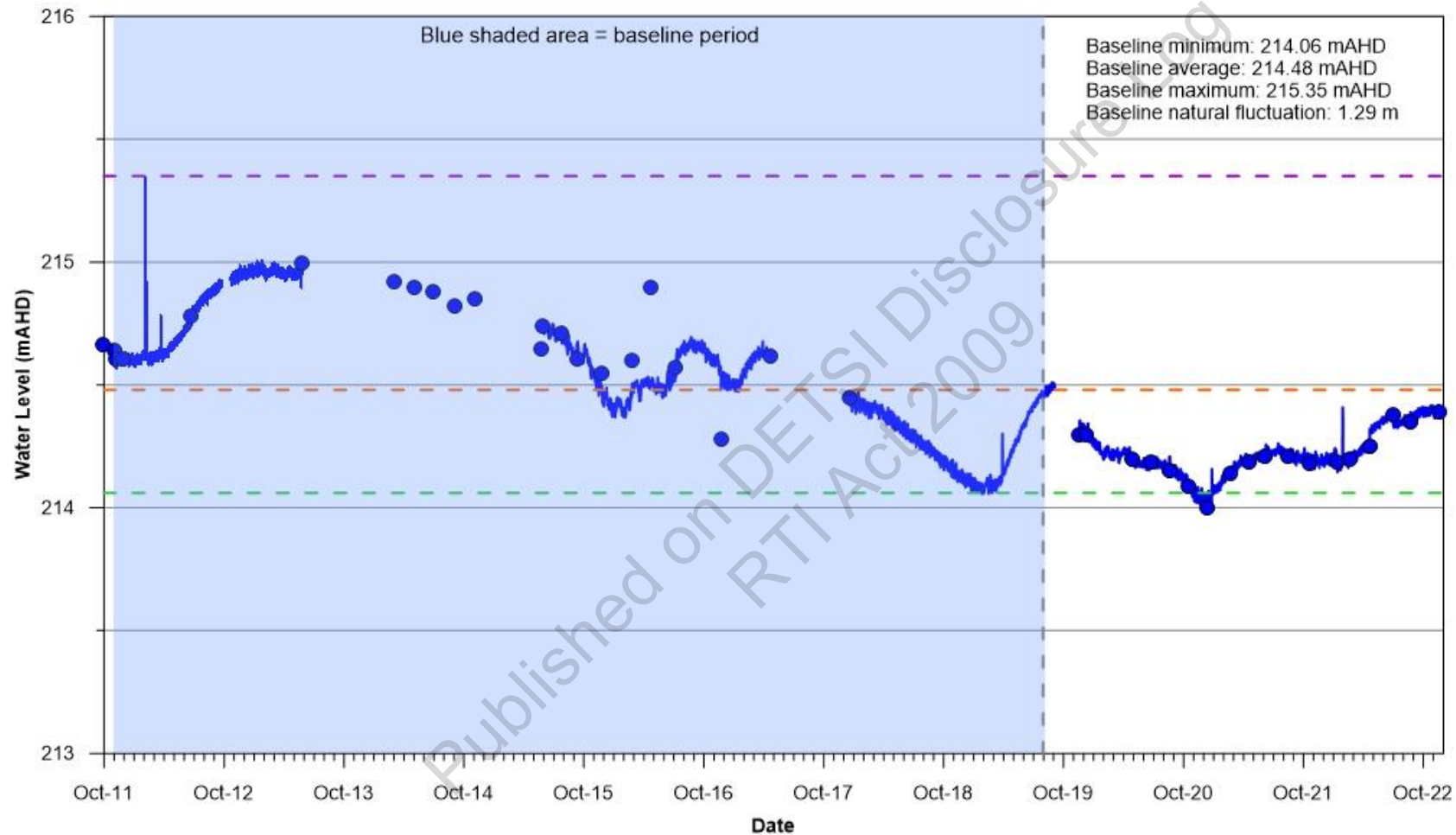
C027P2 (Dunda Beds)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- Average baseline logger water level
- Start of dewatering



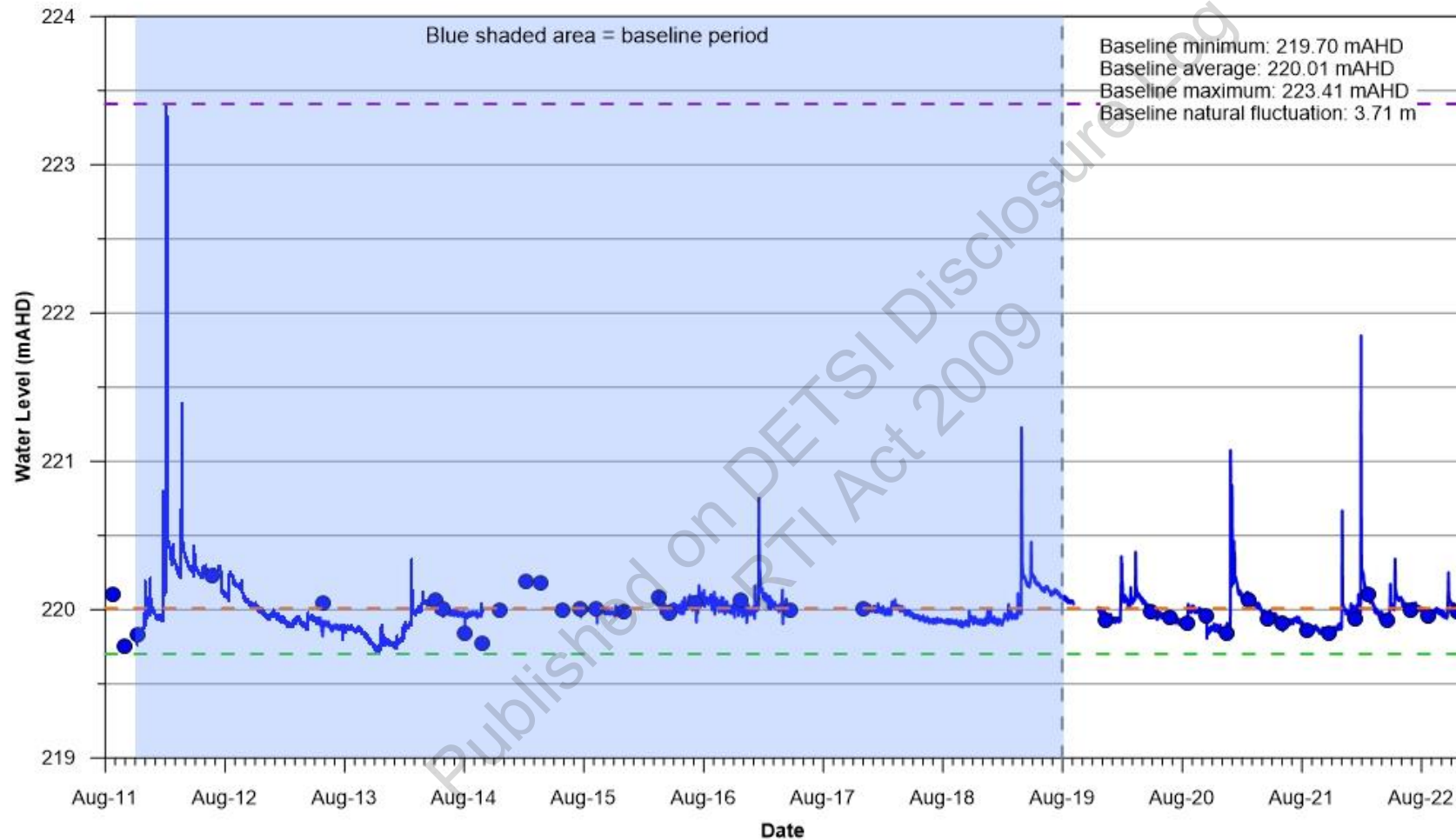
C029P1 (Alluvium)

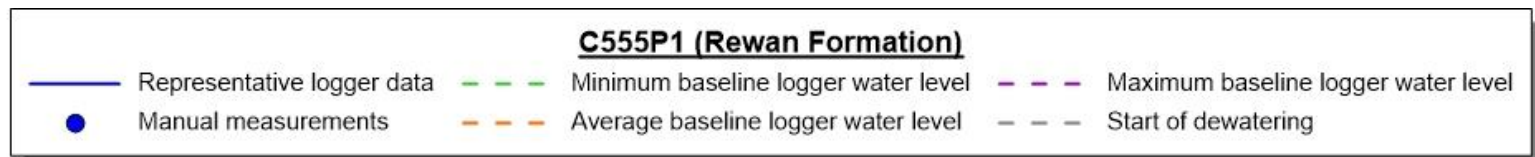
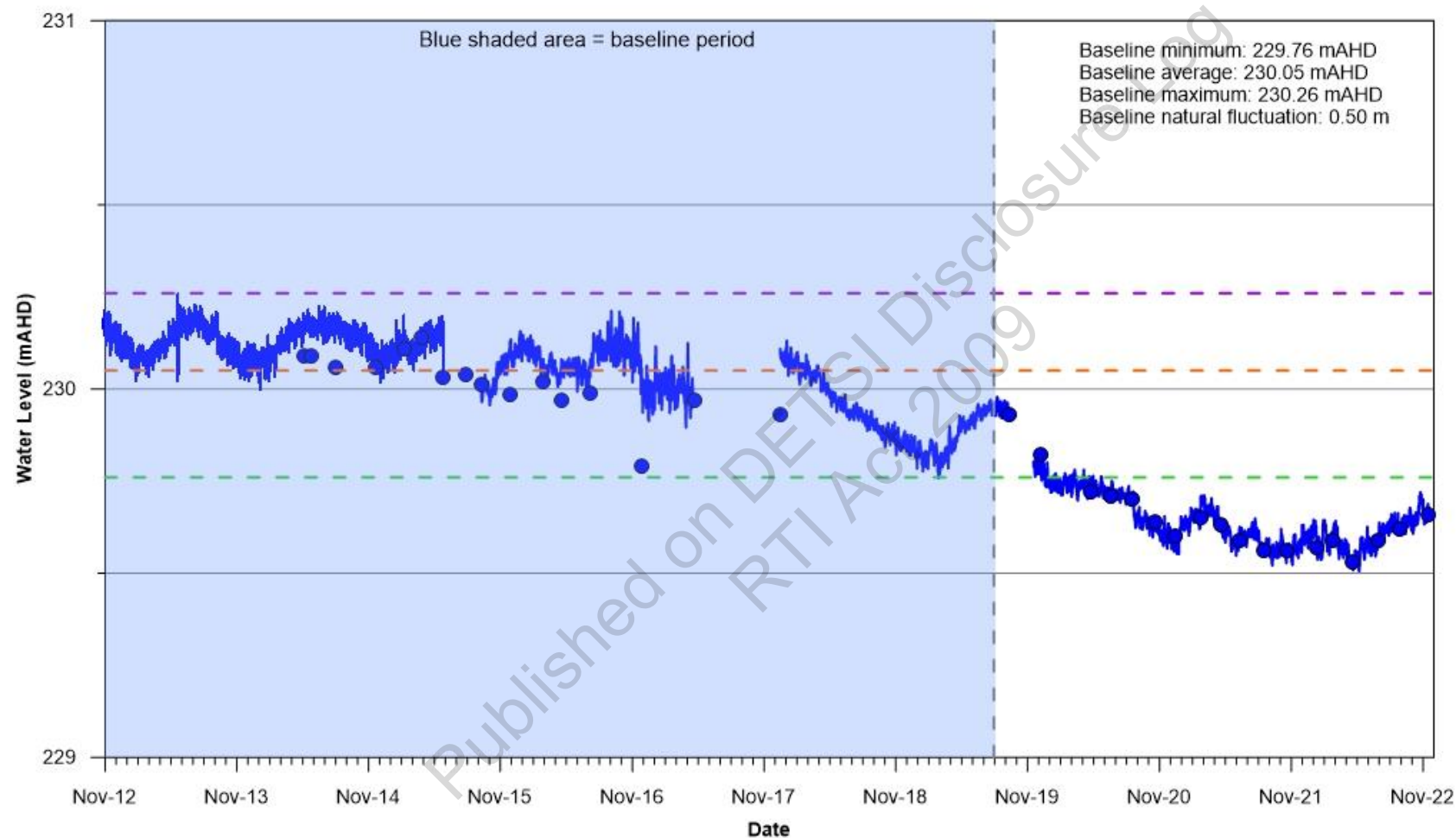
- Representative logger data
- Manual measurements
- - - Minimum baseline logger water level
- - - Average baseline logger water level
- - - Maximum baseline logger water level
- - - Start of dewatering

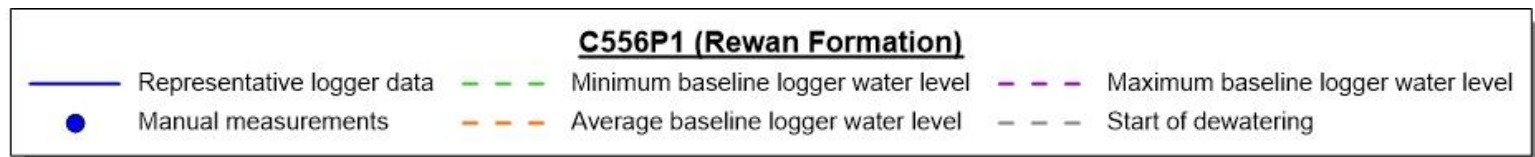
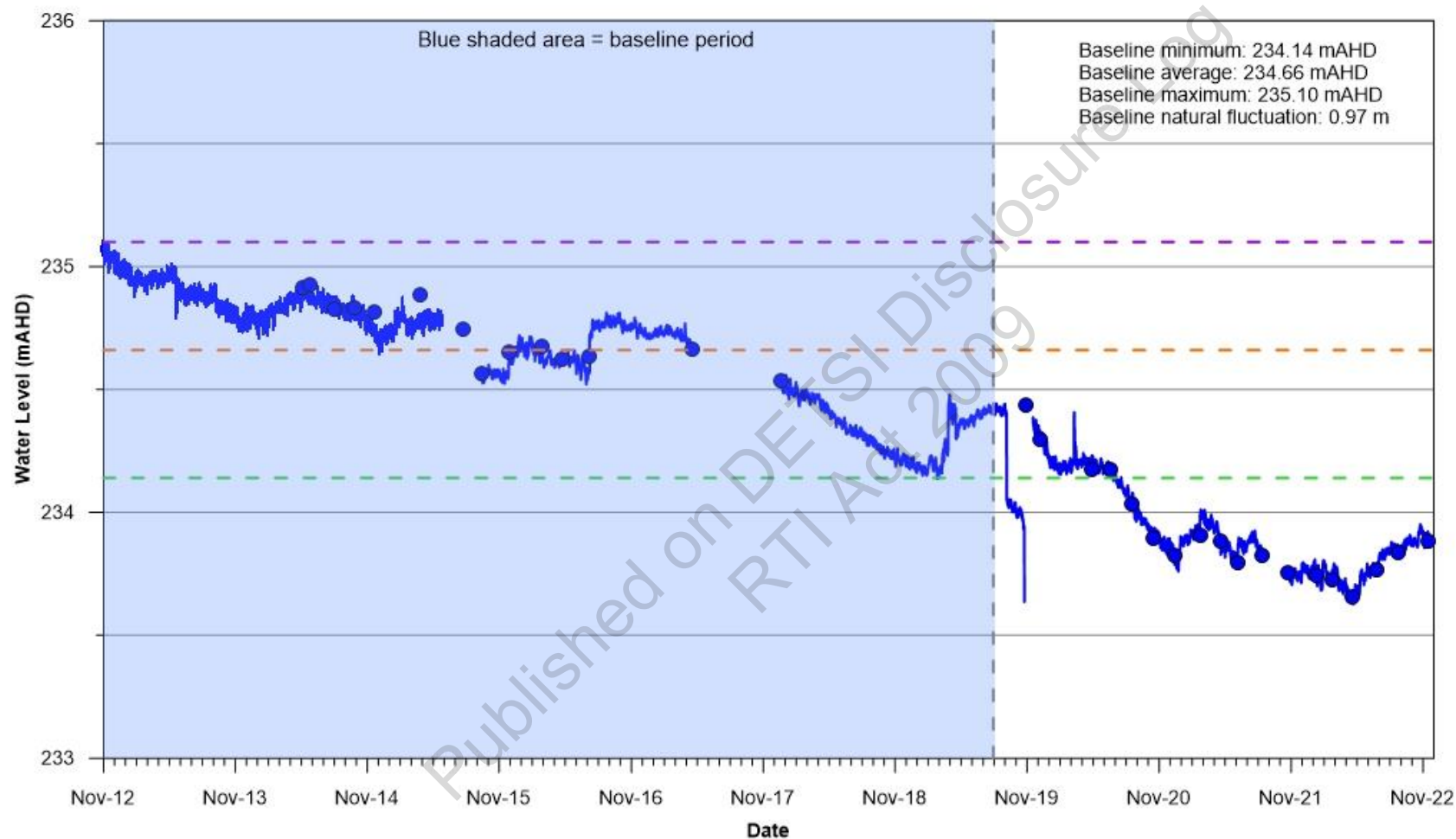


C029P2 (Tertiary sediments)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level
- Start of dewatering

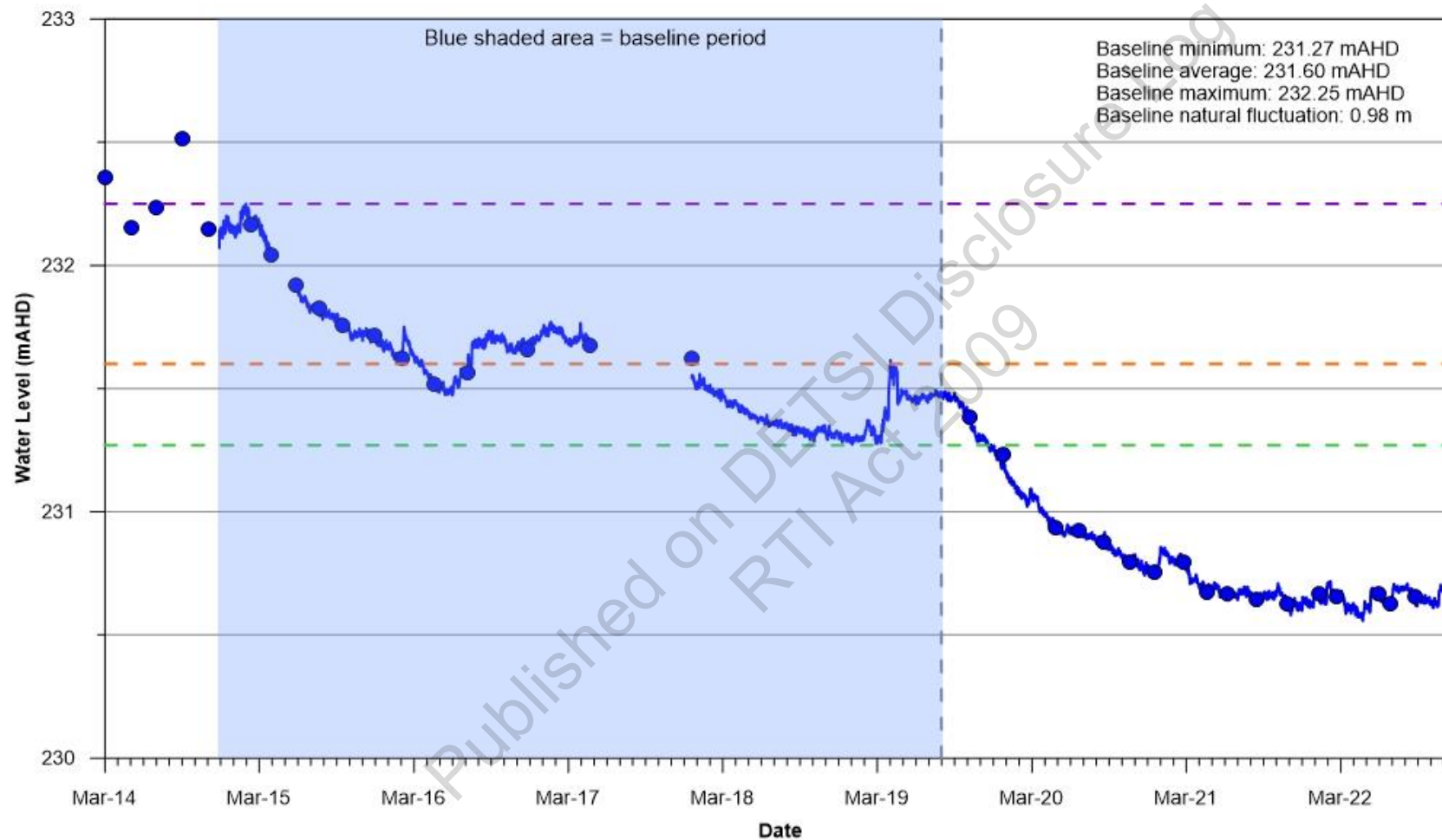


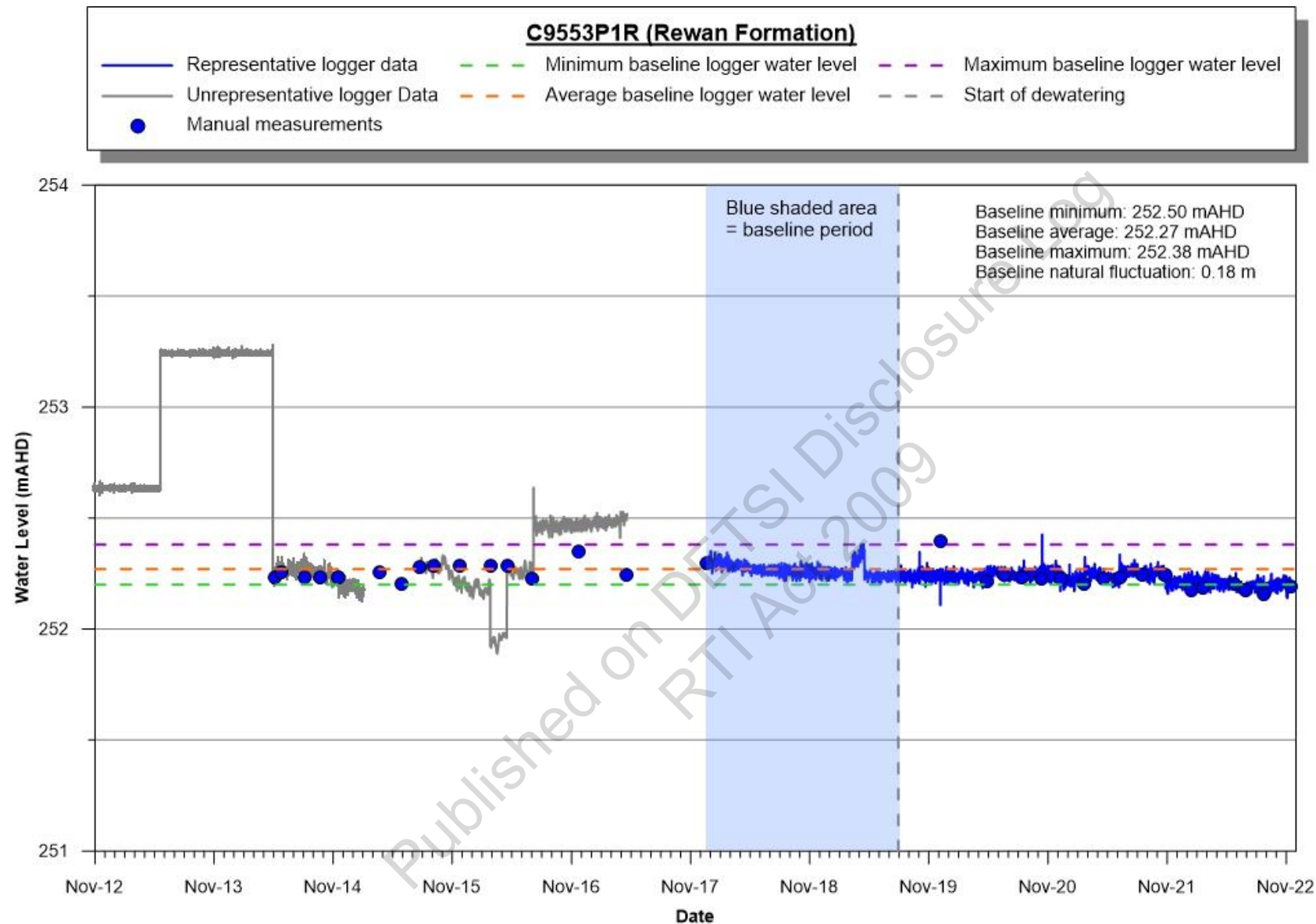




C848SP (Colinlea Formation - D Seam)

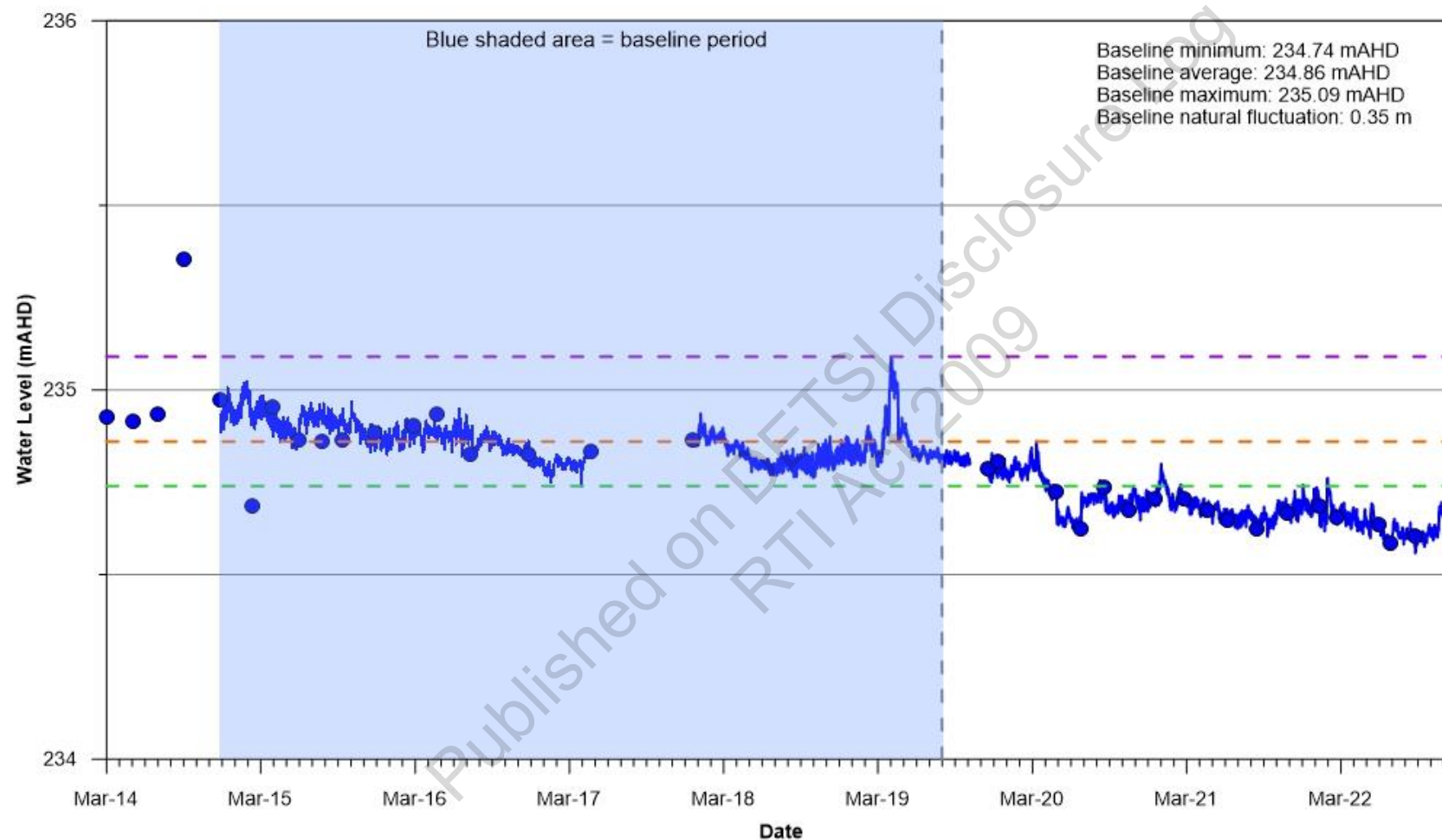
- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering





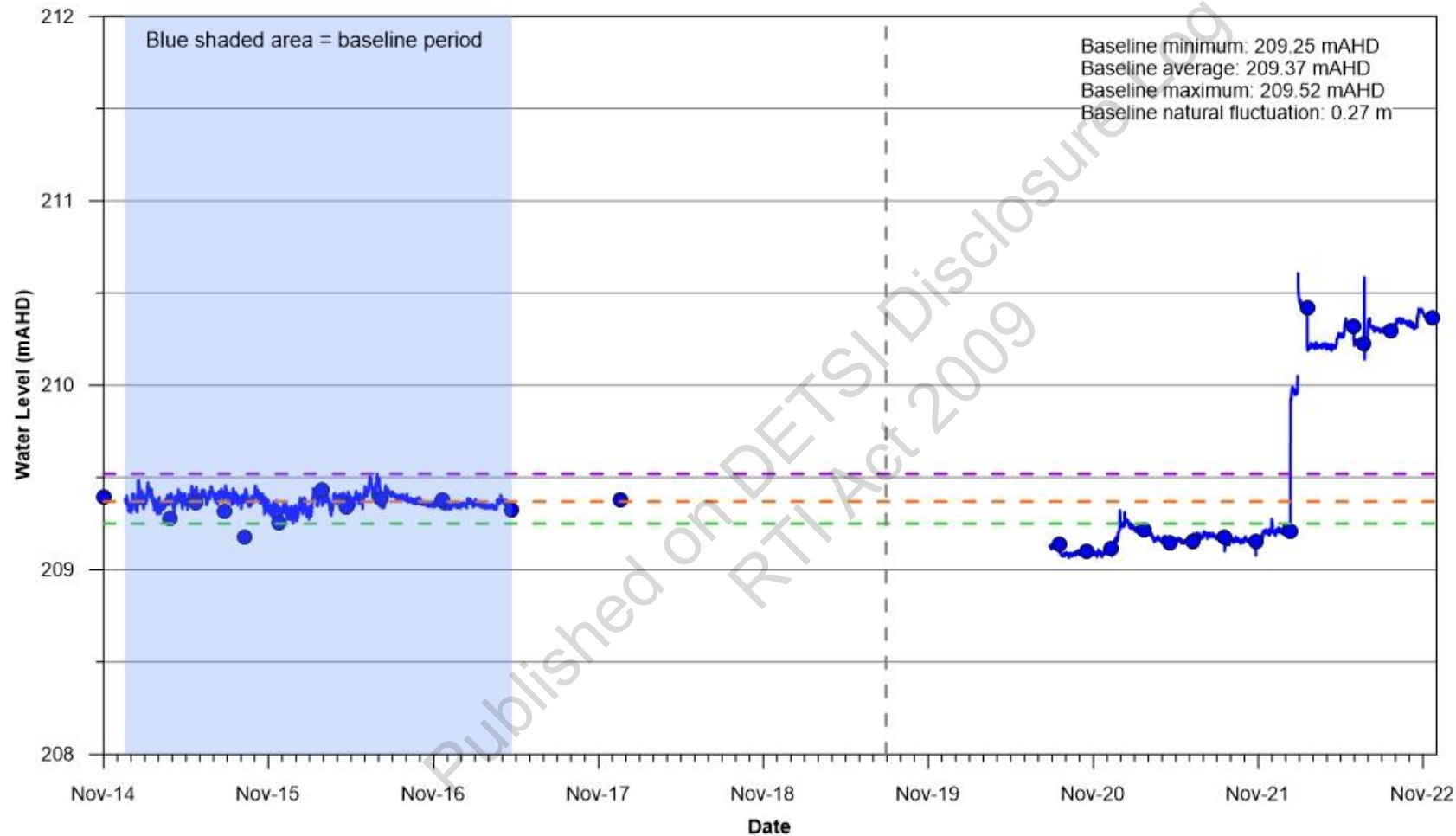
C9845SPR (Tertiary sediments)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- Average baseline logger water level
- Start of dewatering



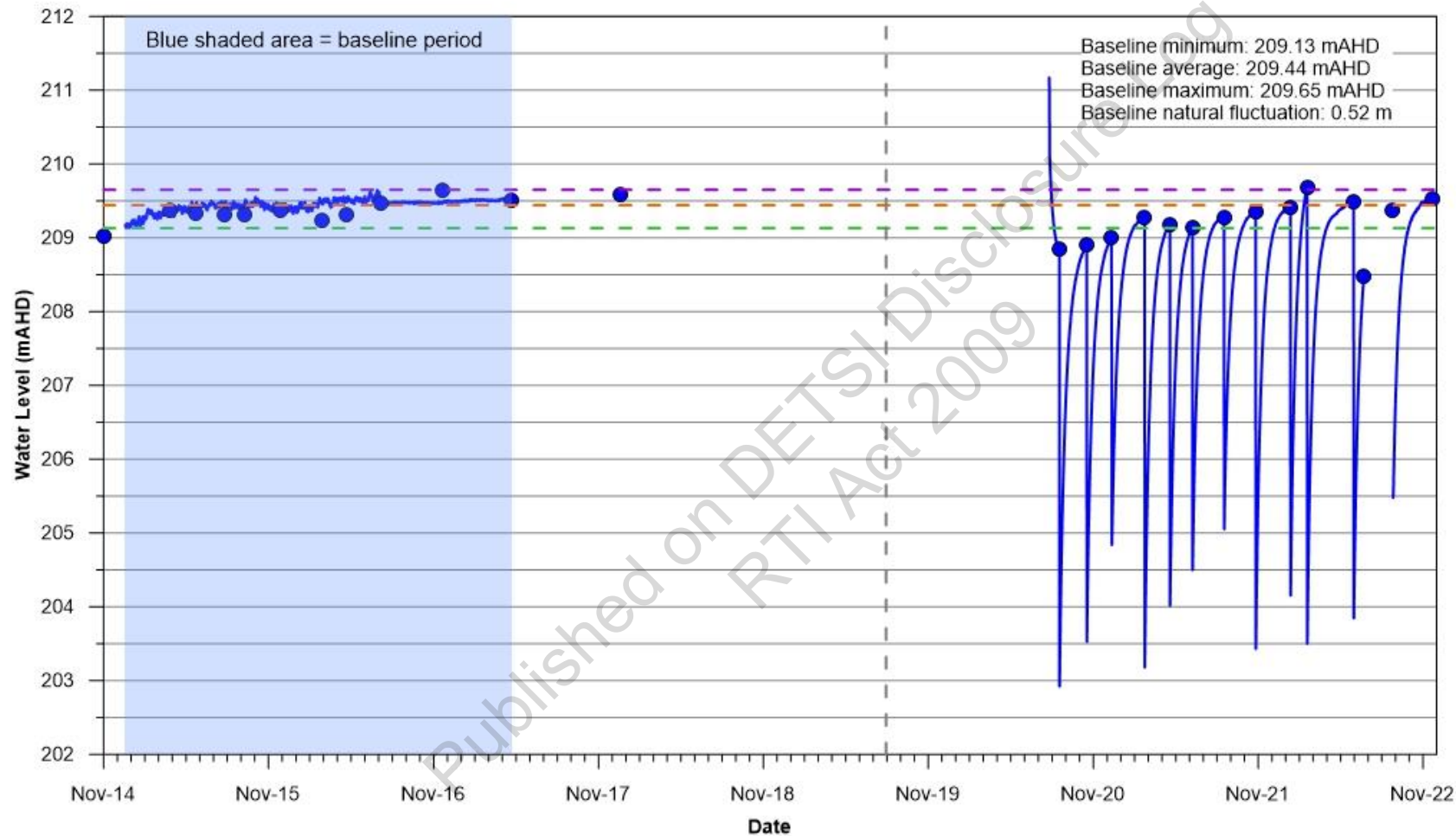
C14003SP (Joe Joe Group)

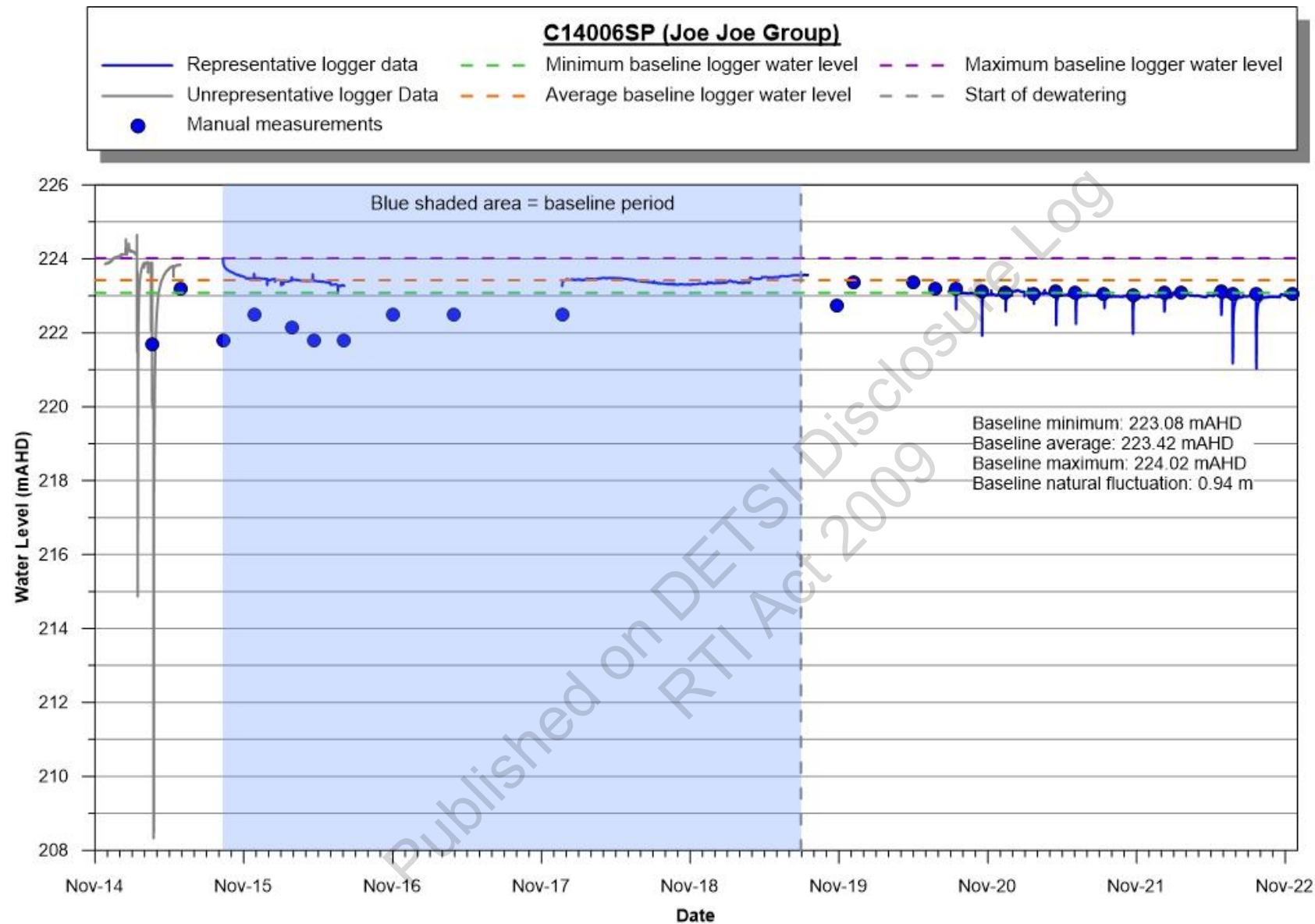
- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



C14004SP (Joe Joe Group)

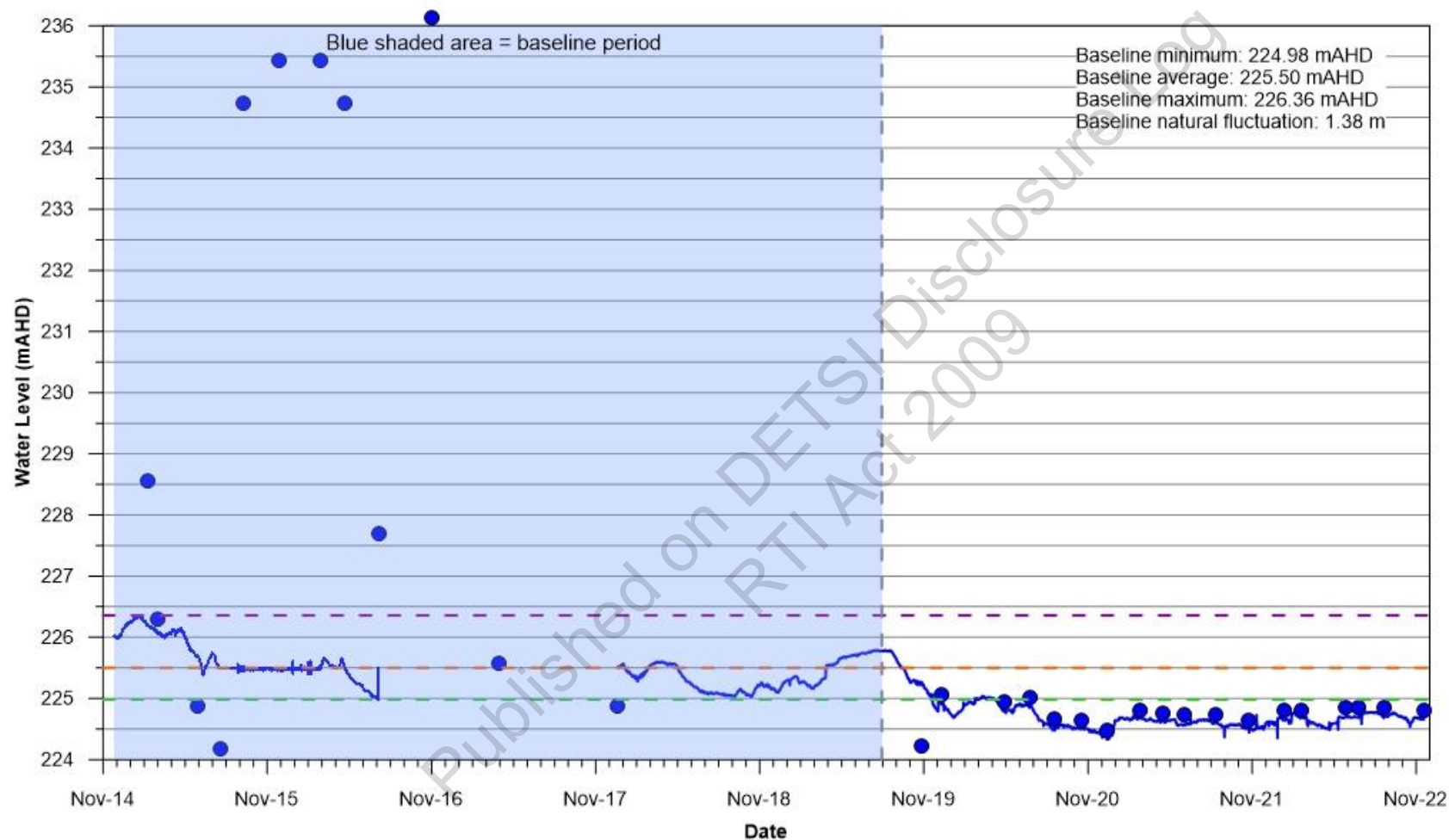
- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering





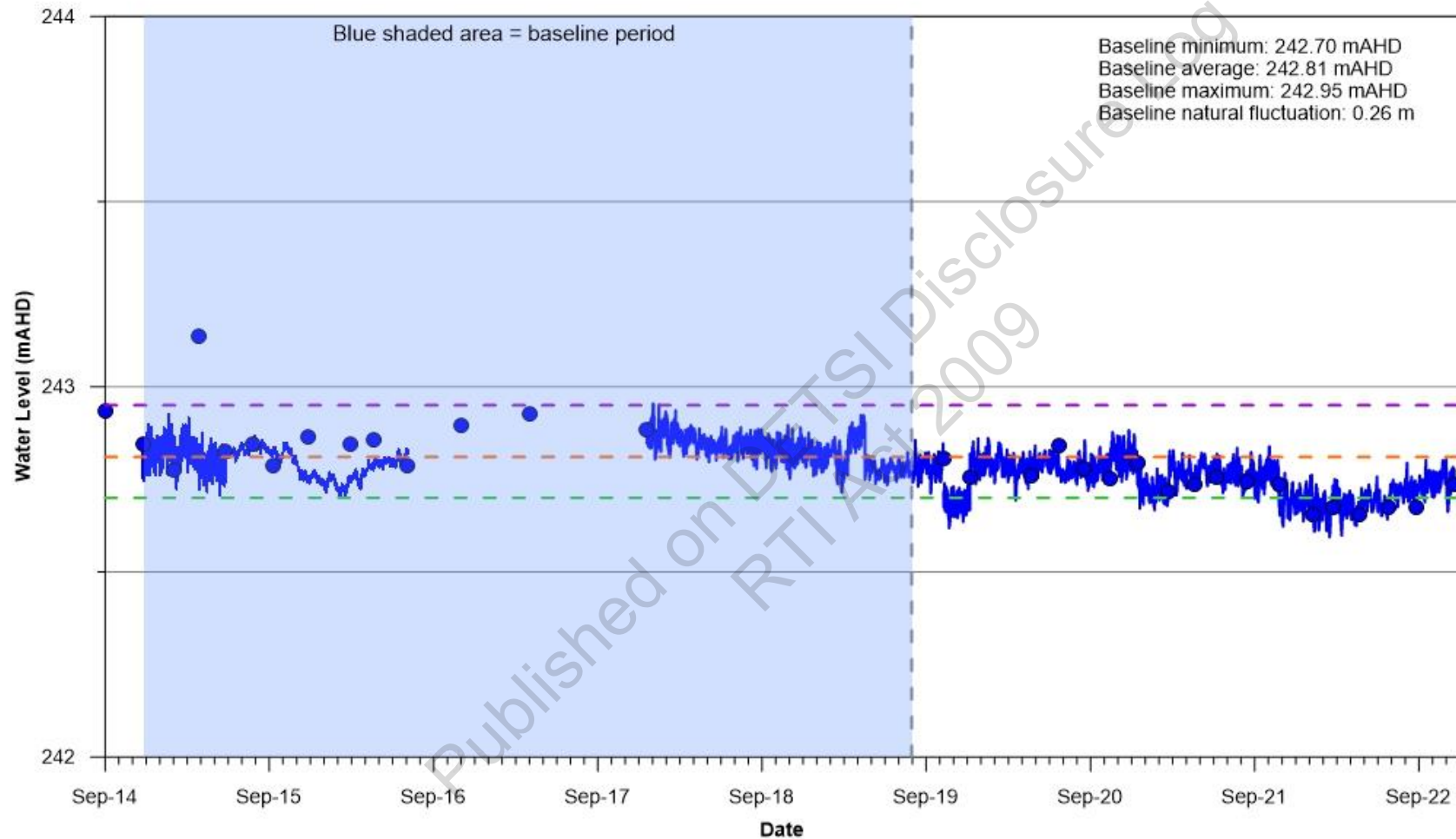
C14008SP (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



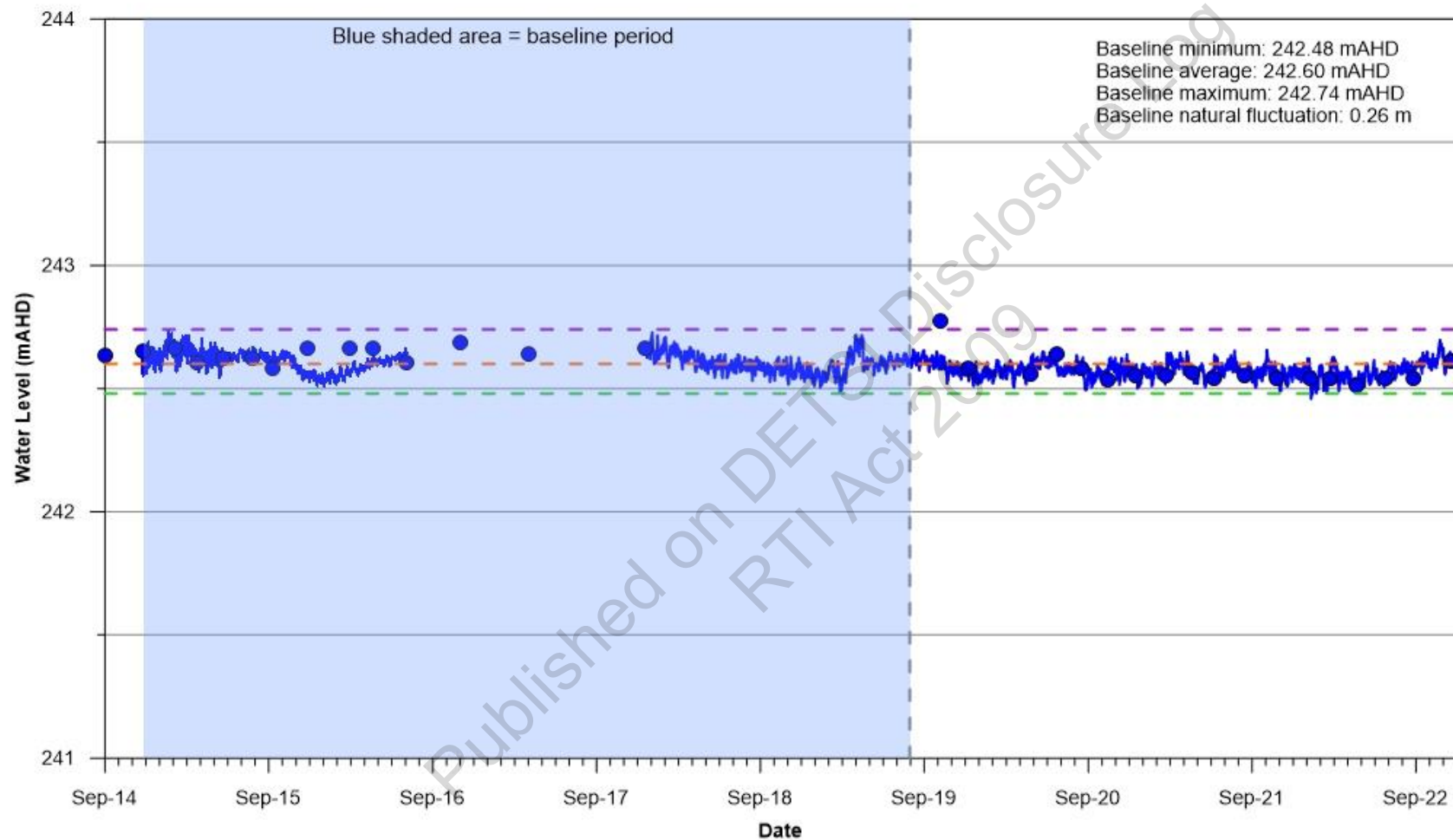
C14011SP (Clematis)

- Representative logger data
- Manual measurements
- - - Minimum baseline logger water level
- - - Average baseline logger water level
- - - Maximum baseline logger water level
- - - Start of dewatering



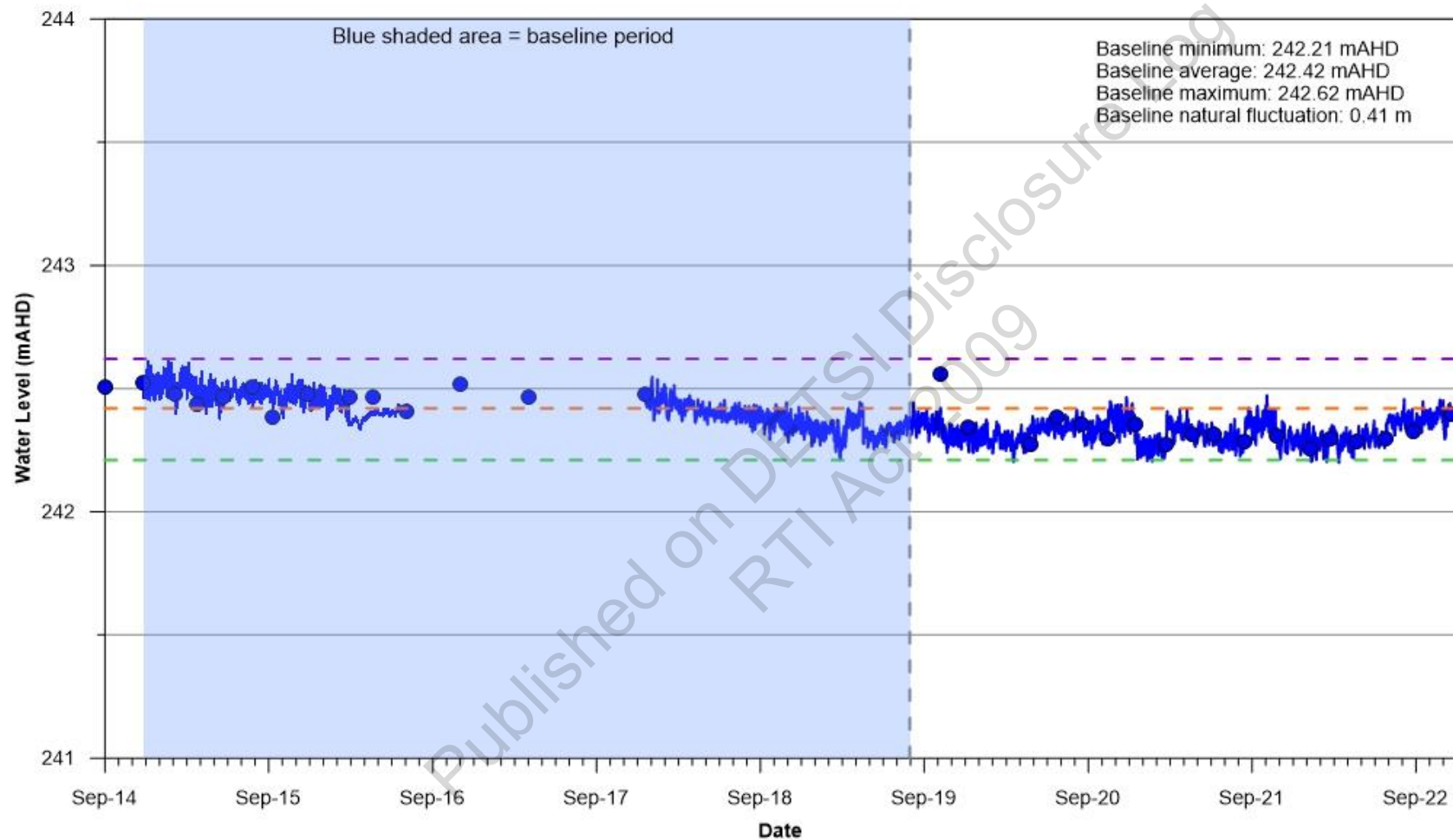
C14012SP (Clematis)

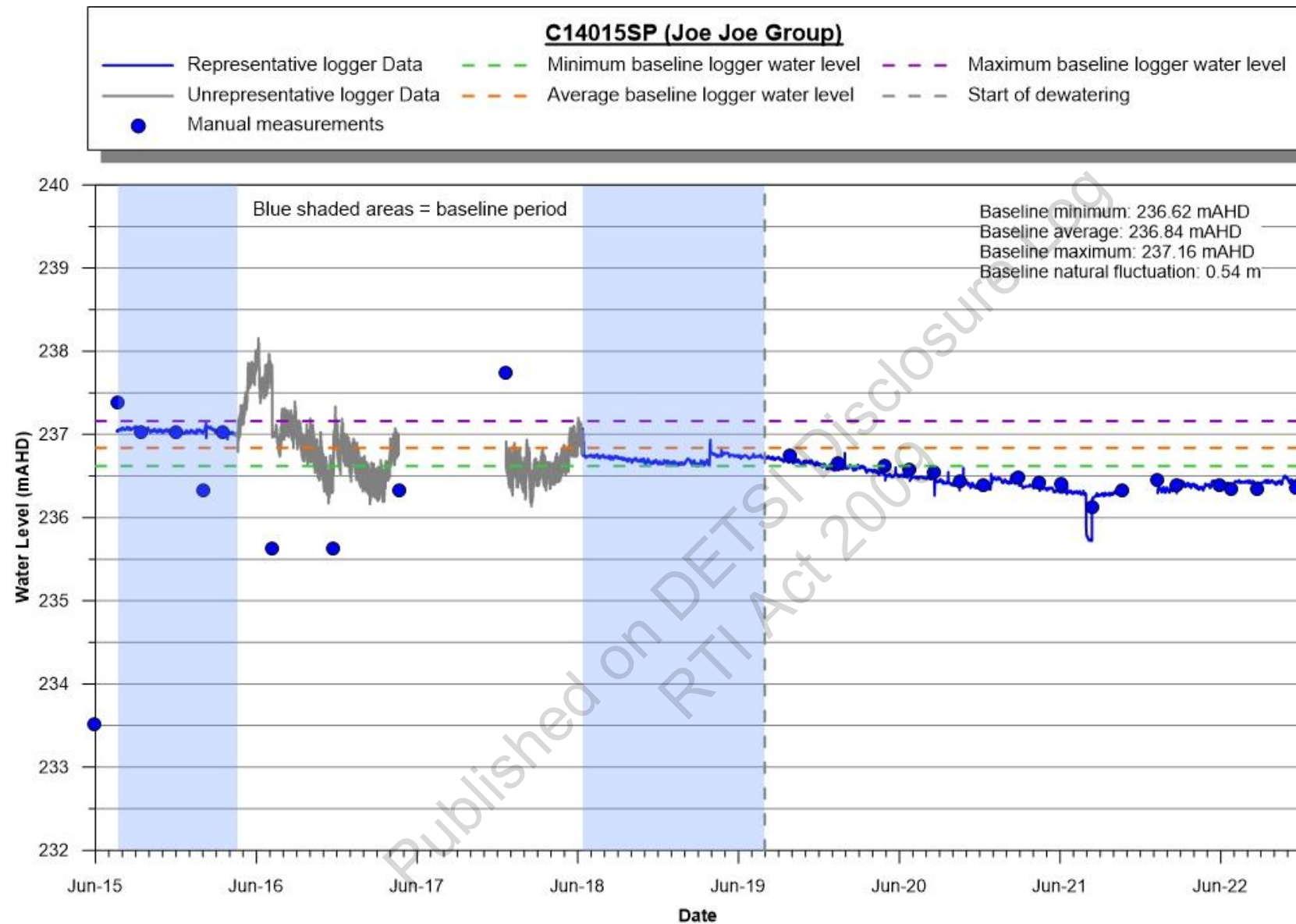
- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- Average baseline logger water level
- Start of dewatering



C14013SP (Clematis)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- Average baseline logger water level
- Start of dewatering





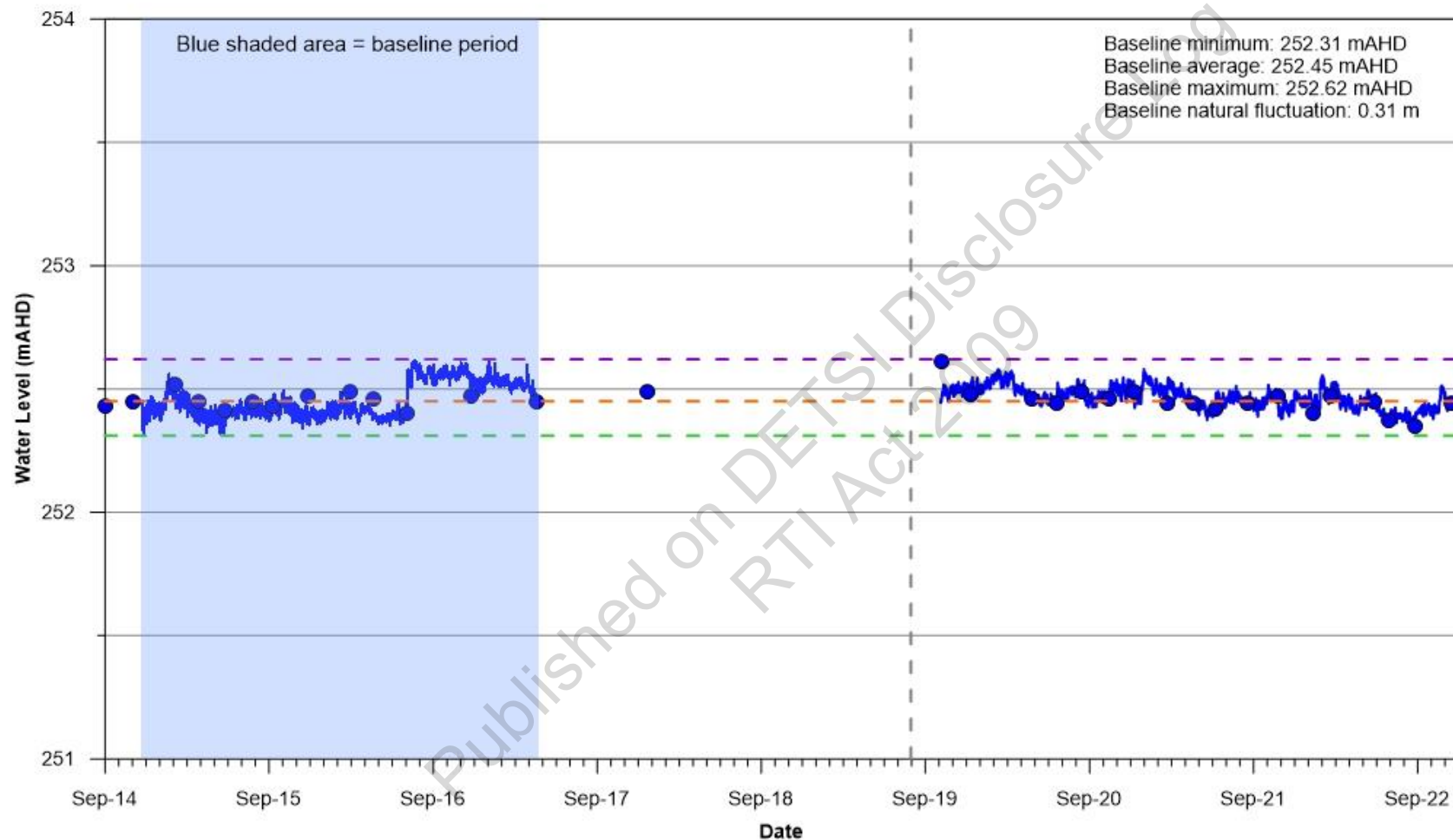
C14016SP (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



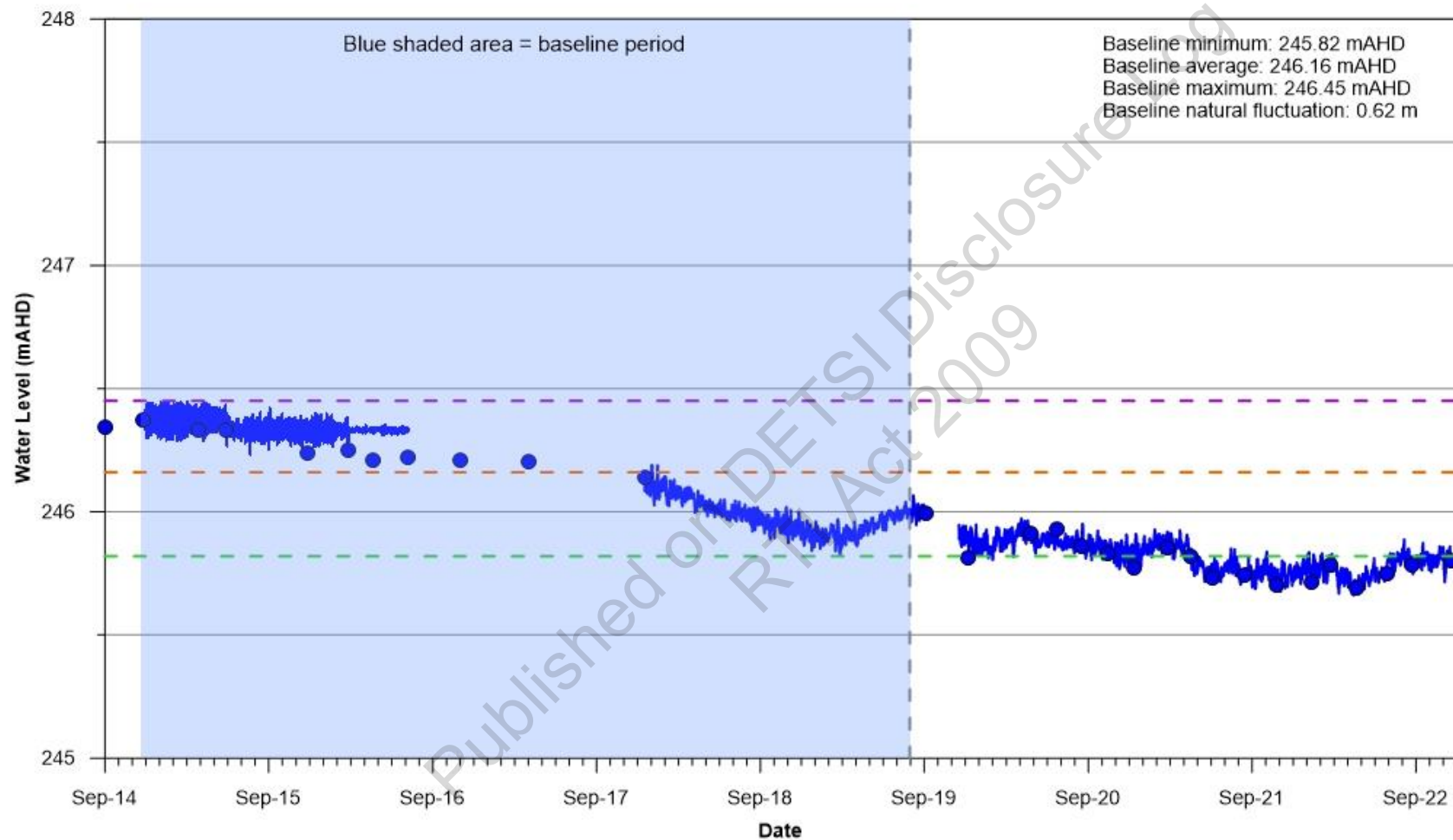
C14020SP (Moolayember)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level
- Start of dewatering



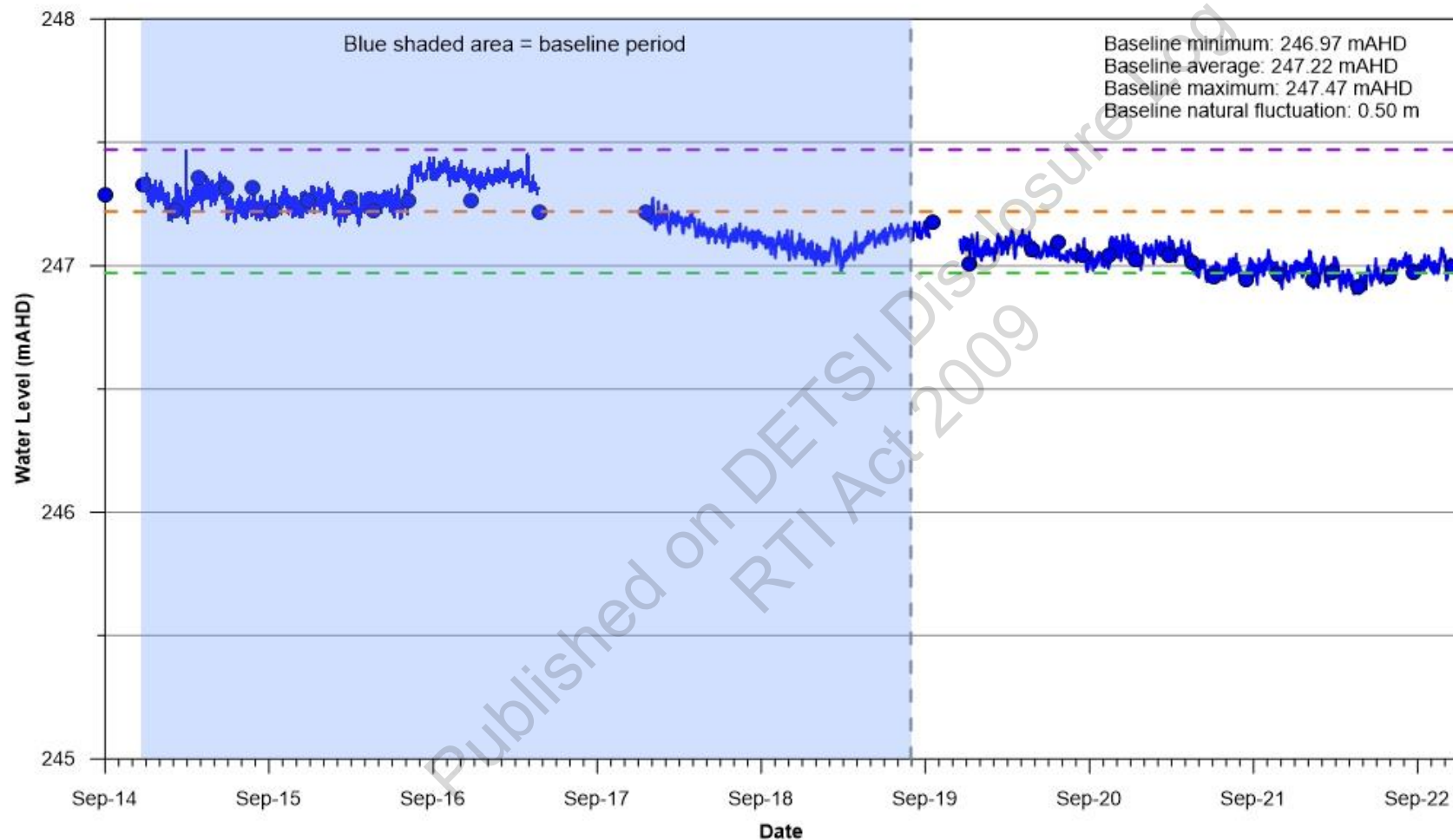
C14021SP (Clematis)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



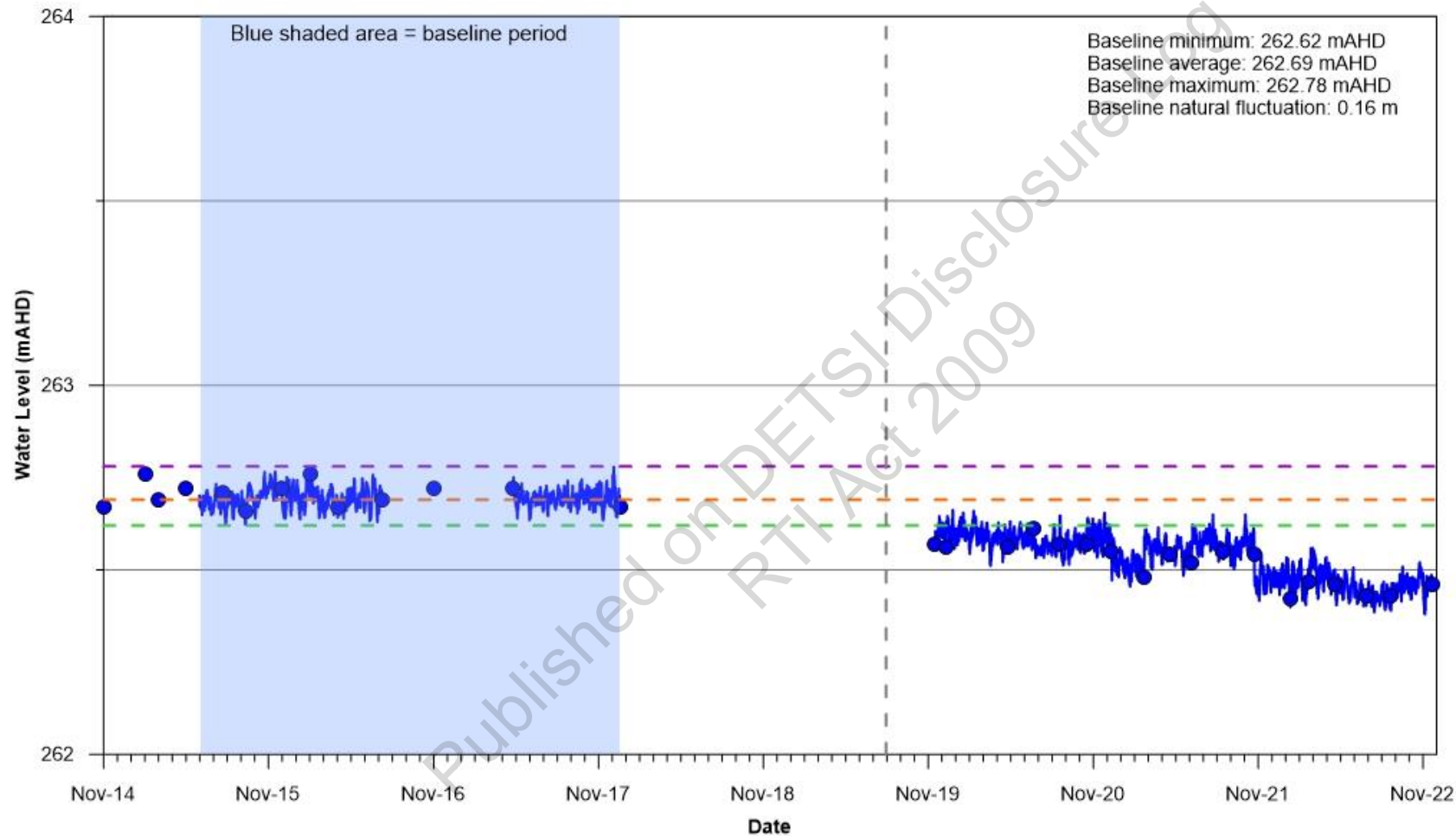
C14023SP (Dunda Beds)

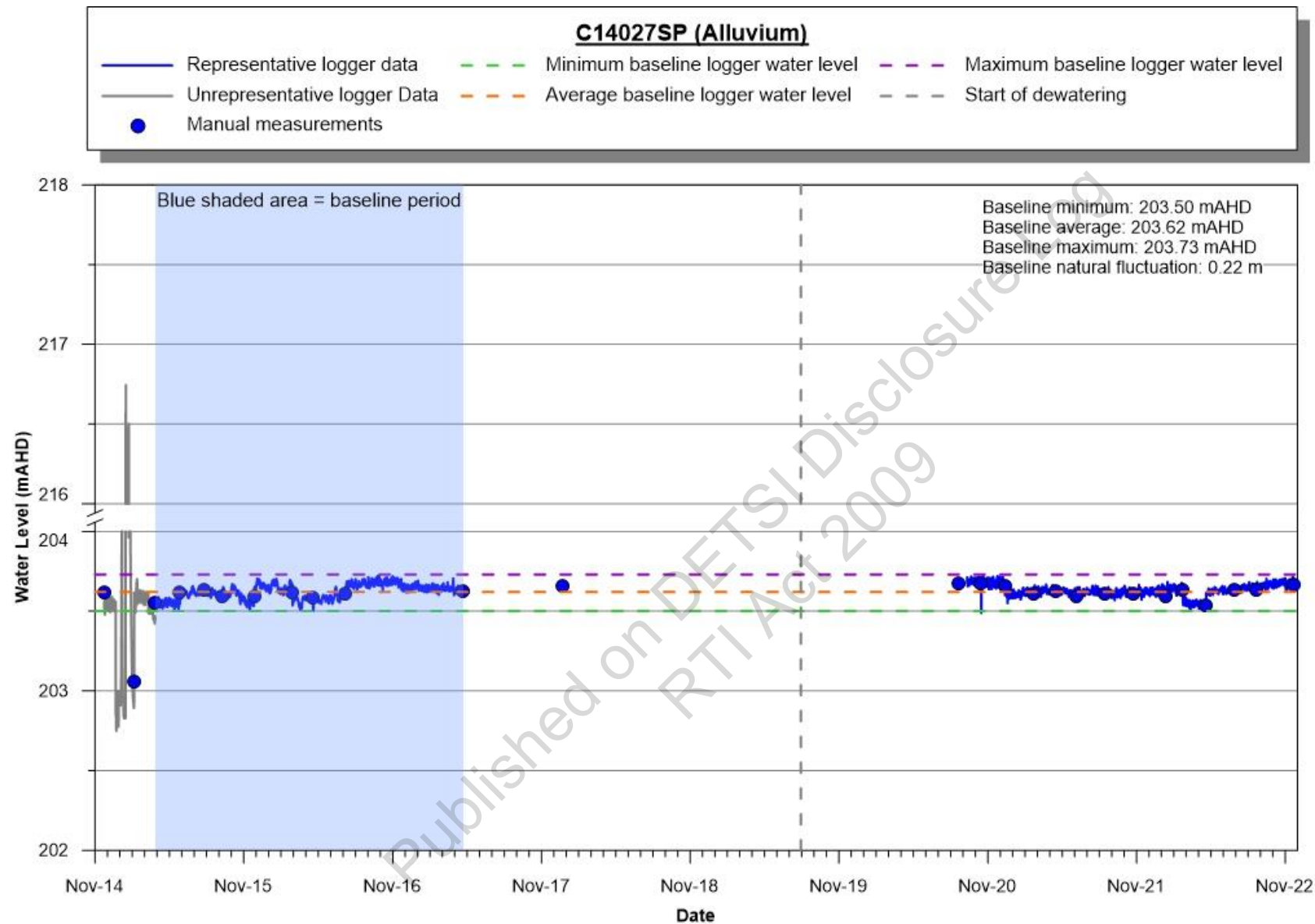
- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



C14024SP (Clematis/Rewan Group)

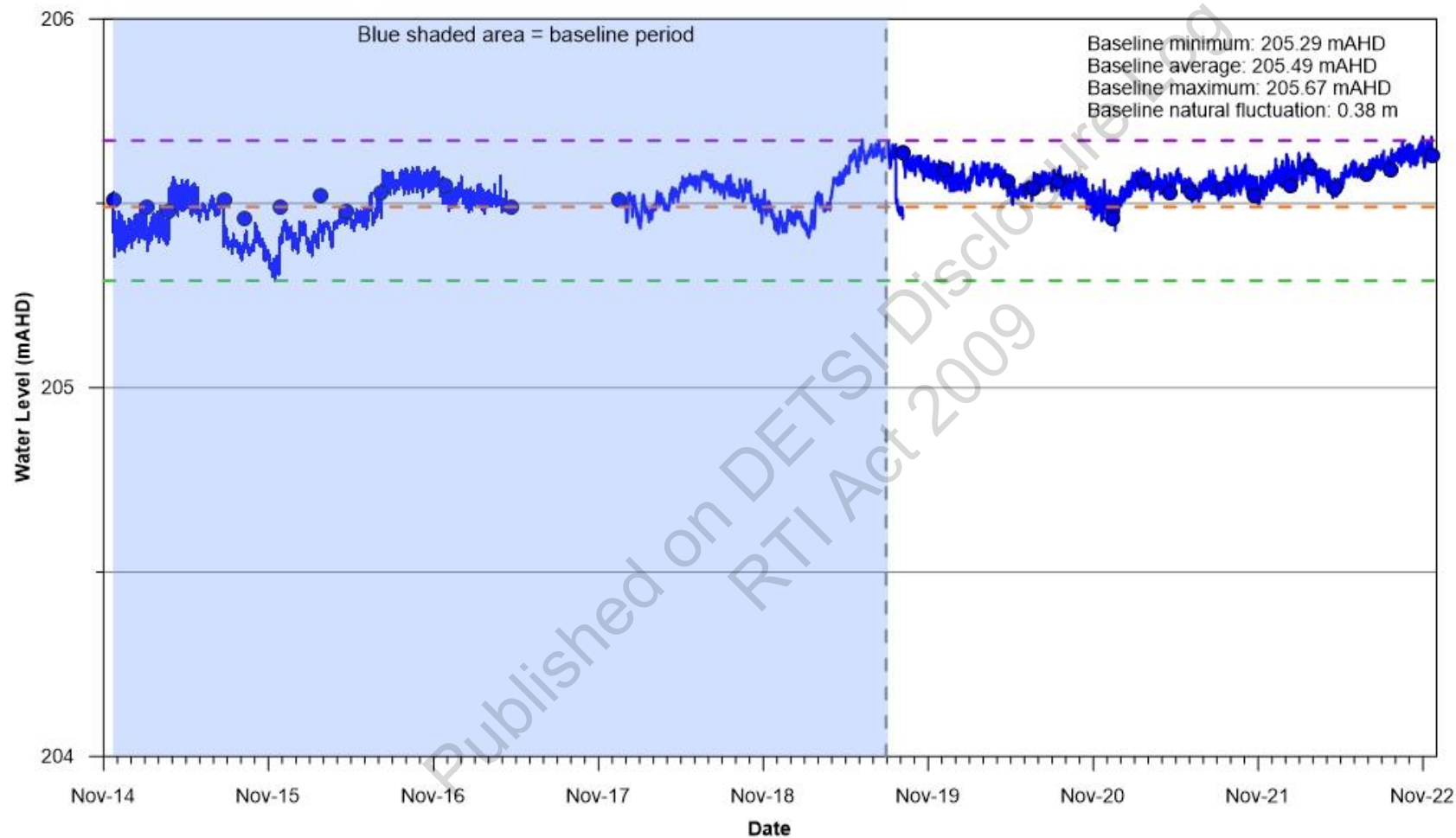
- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level
- Start of dewatering





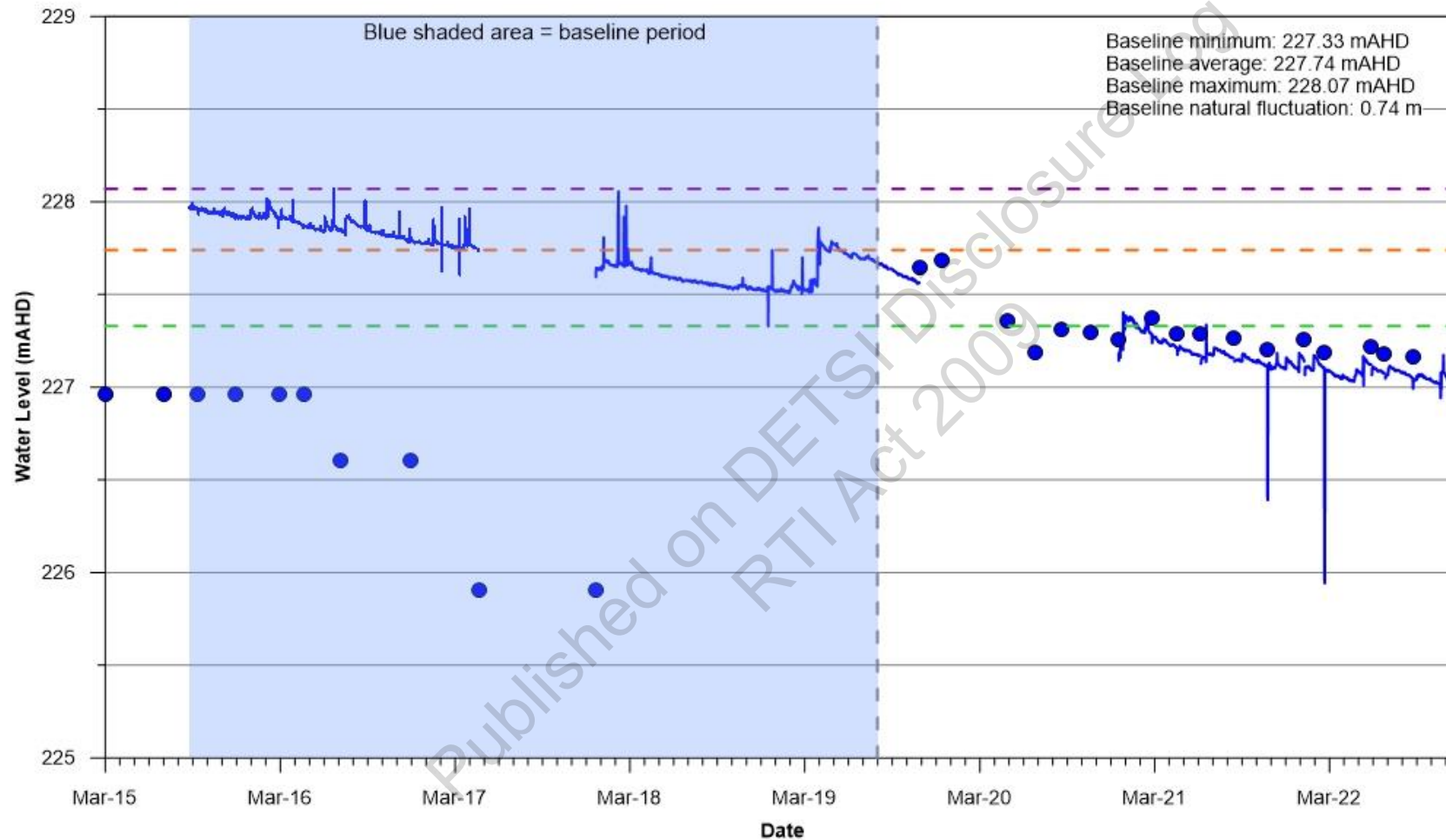
C14028SP (Alluvium)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



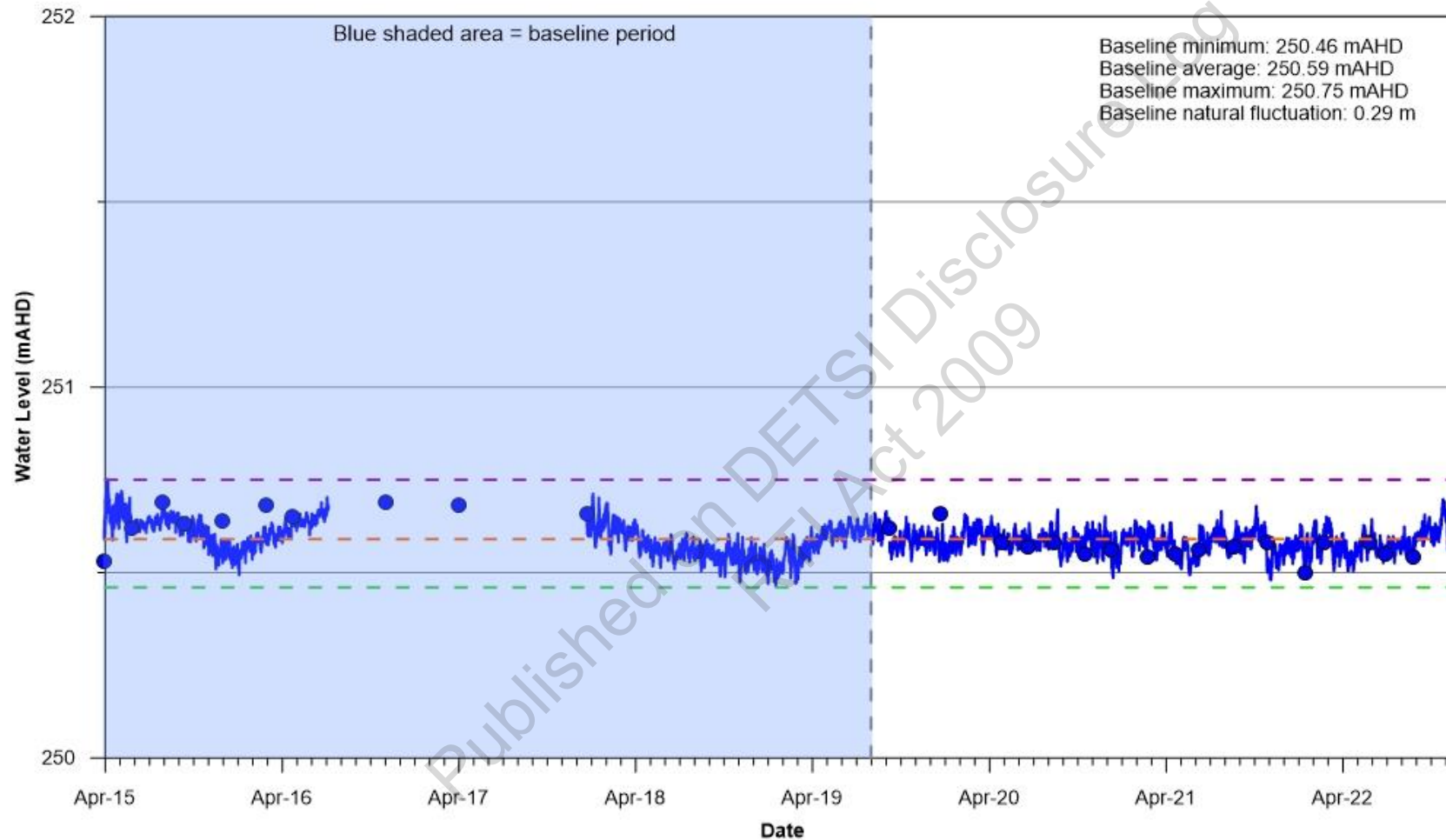
C14029SP (Tertiary sediments/Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



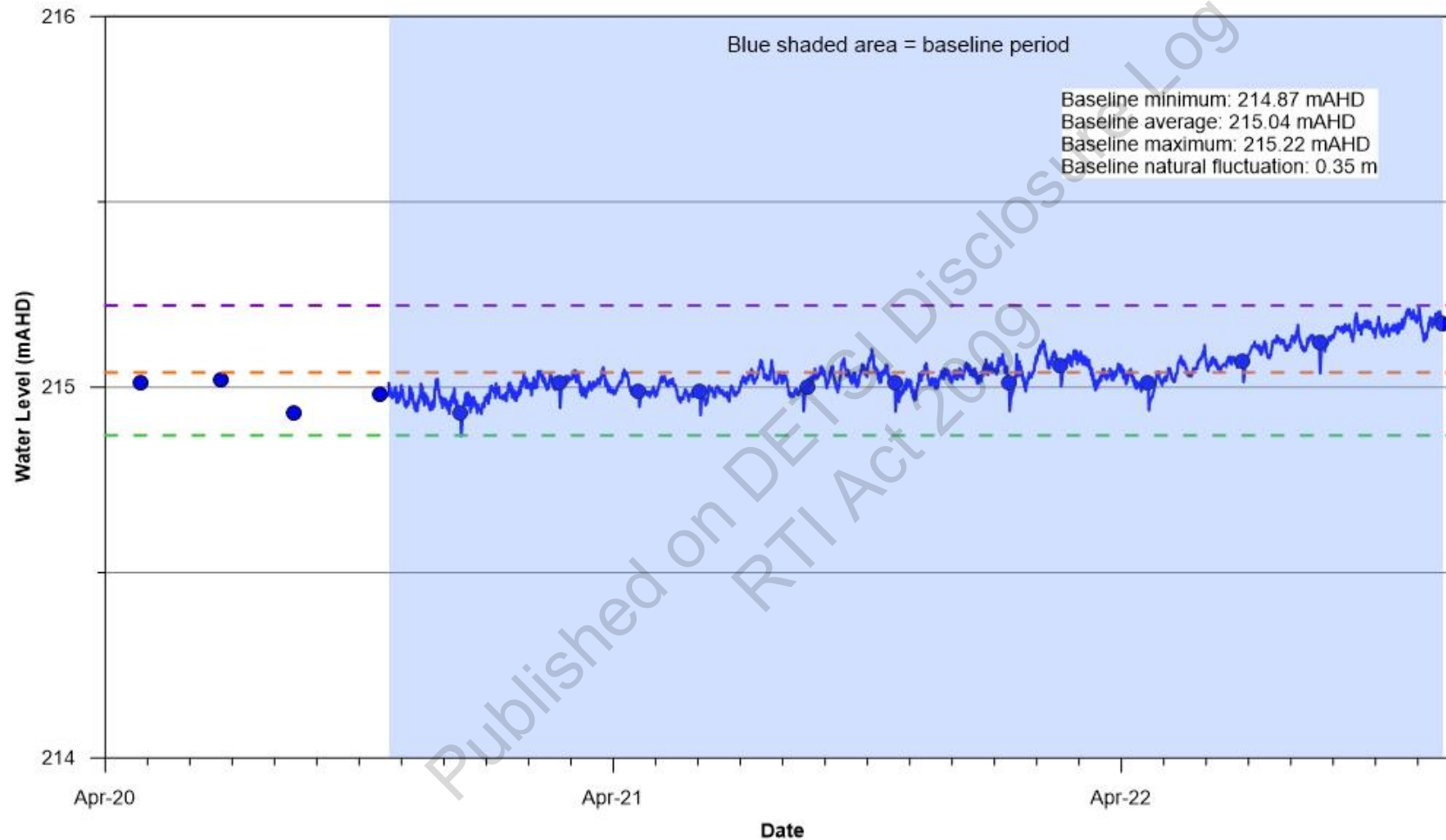
C14033SP (Clematis)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level
- Start of dewatering



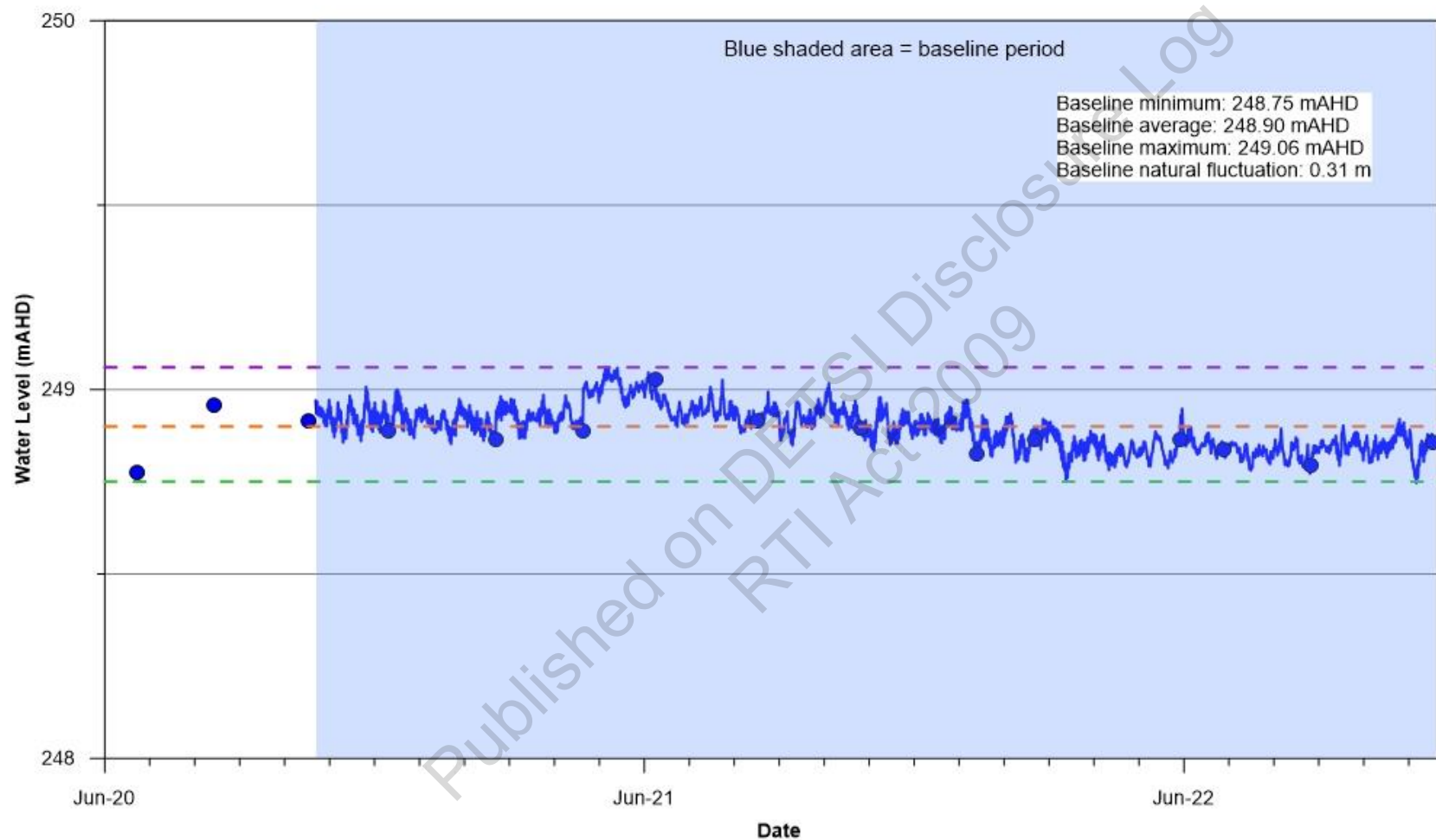
C19001SP (Alluvium)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level



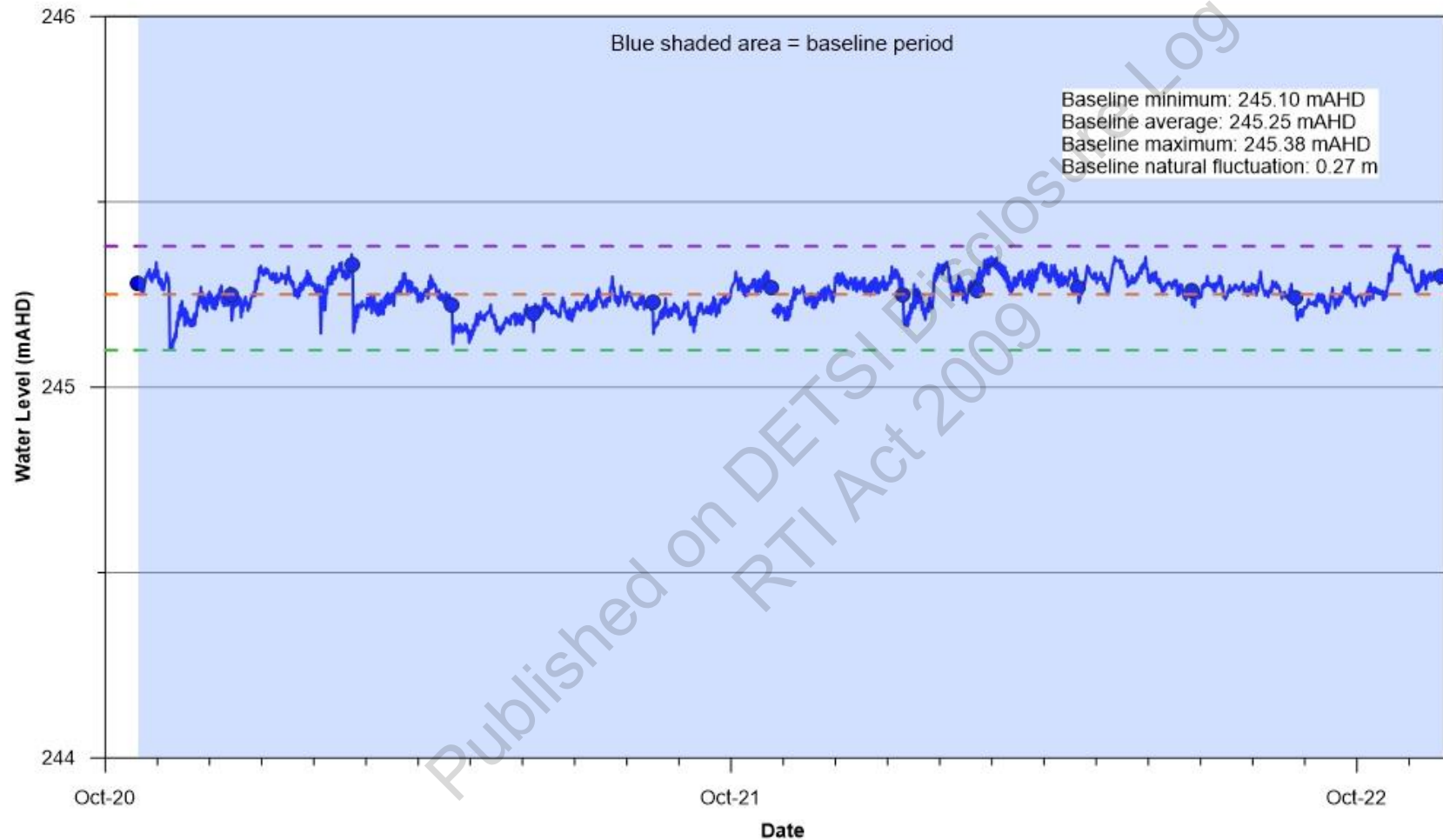
C19002SP (Clematis)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level



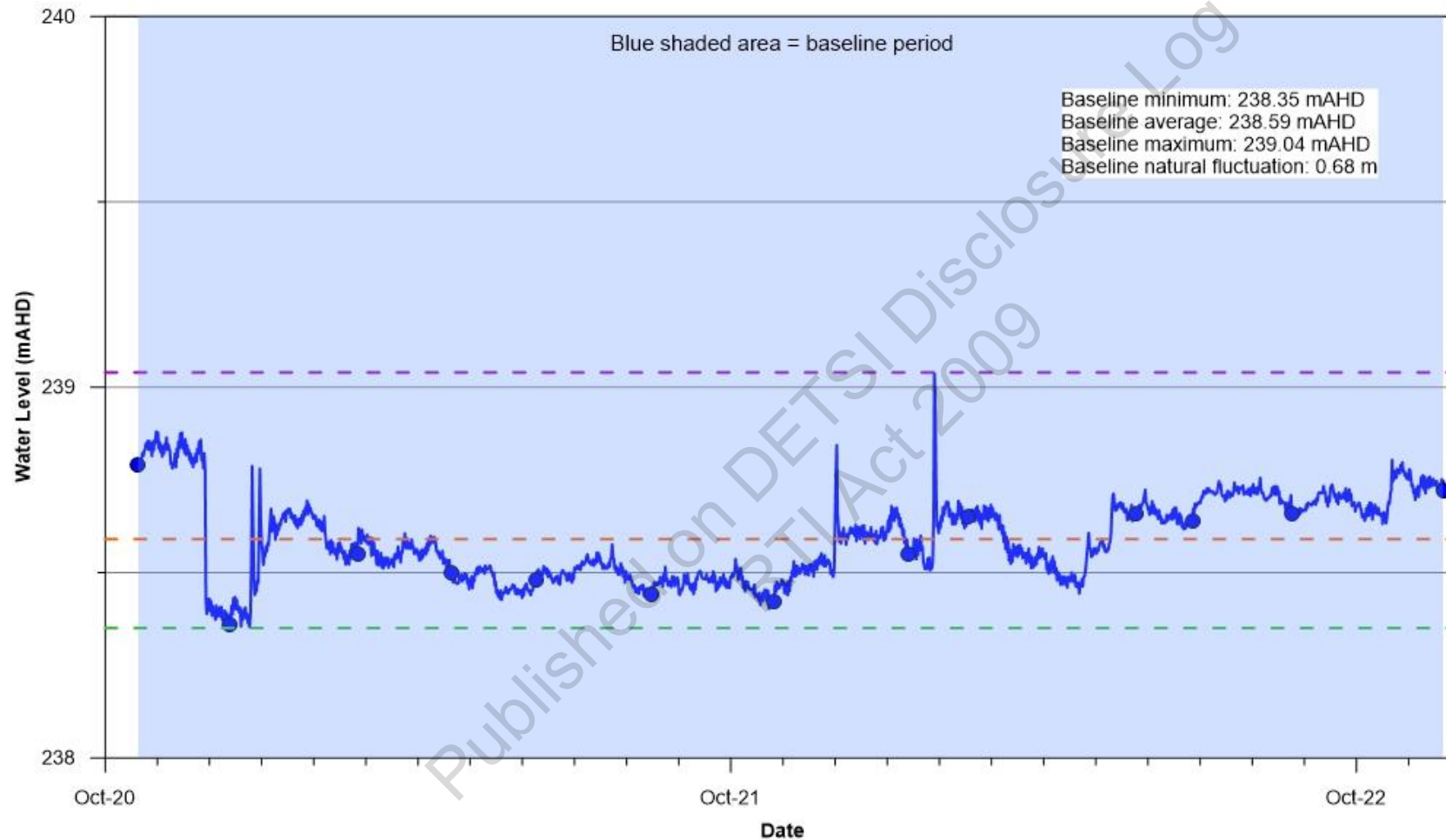
C19008SP (Rewan Formation)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level



C19010SP (Clematis)

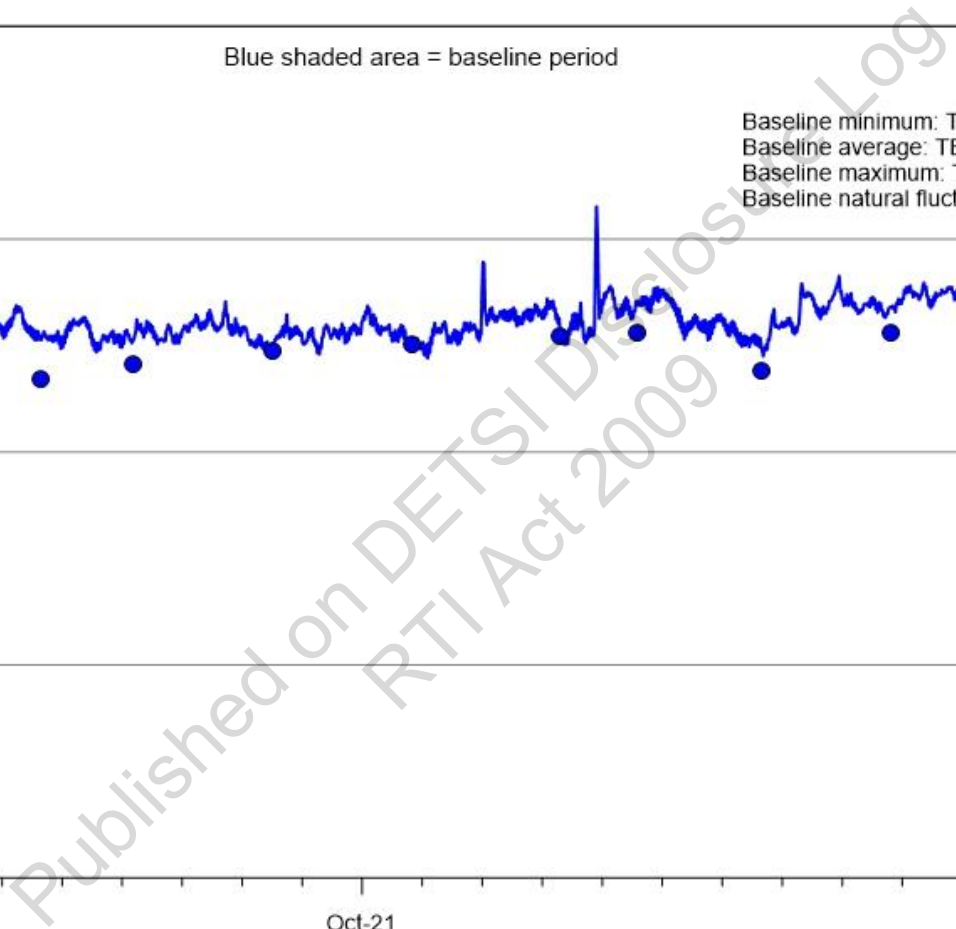
- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level



C19014SP (Clematis)

— Representative logger data ● Manual measurements

Manual measurements



C19018SP (Bandanna Formation)

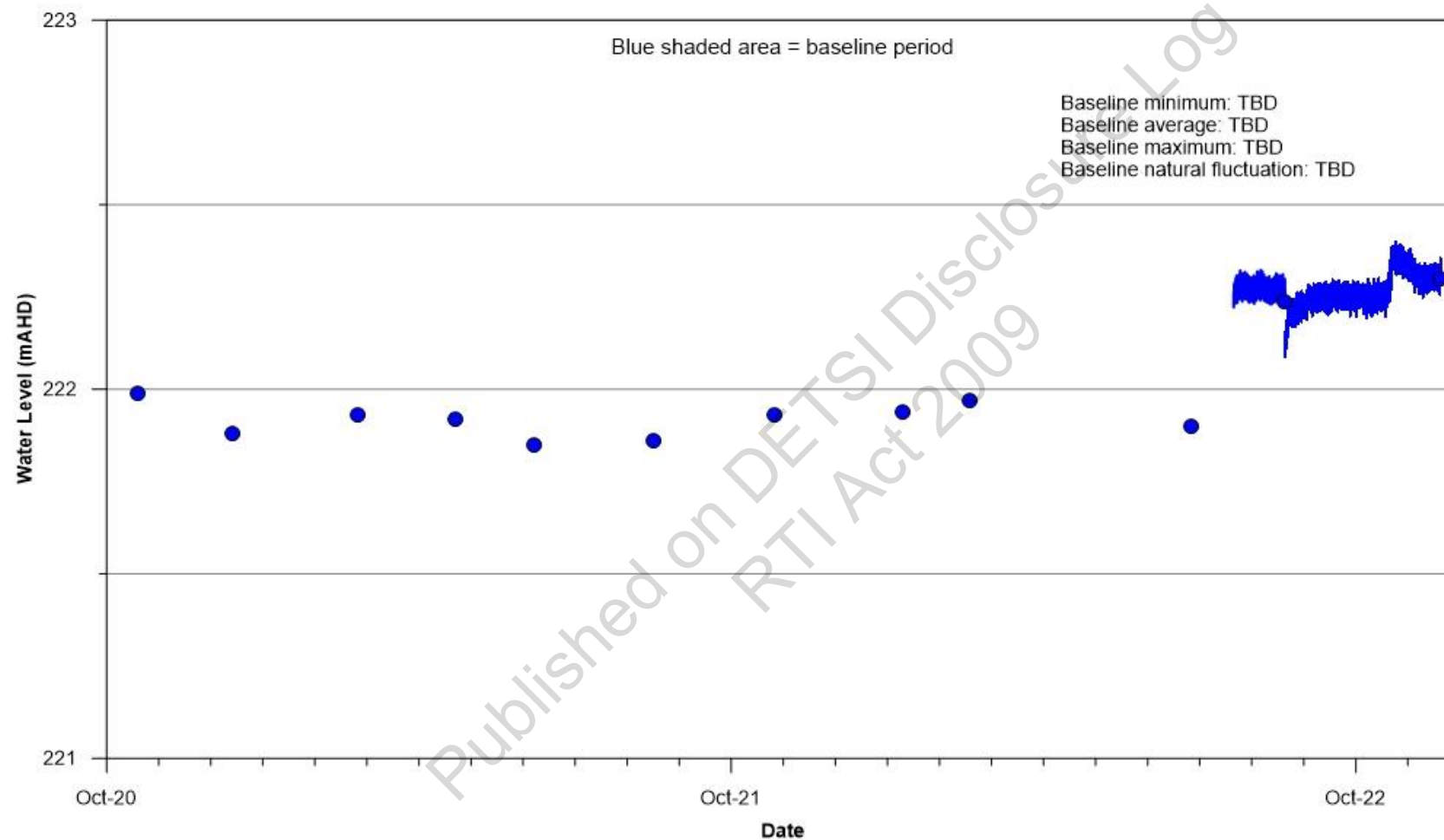
— Representative logger data ● Manual measurements

C19018SP (Bandanna Formation)

— Representative logger data ● Manual measurements

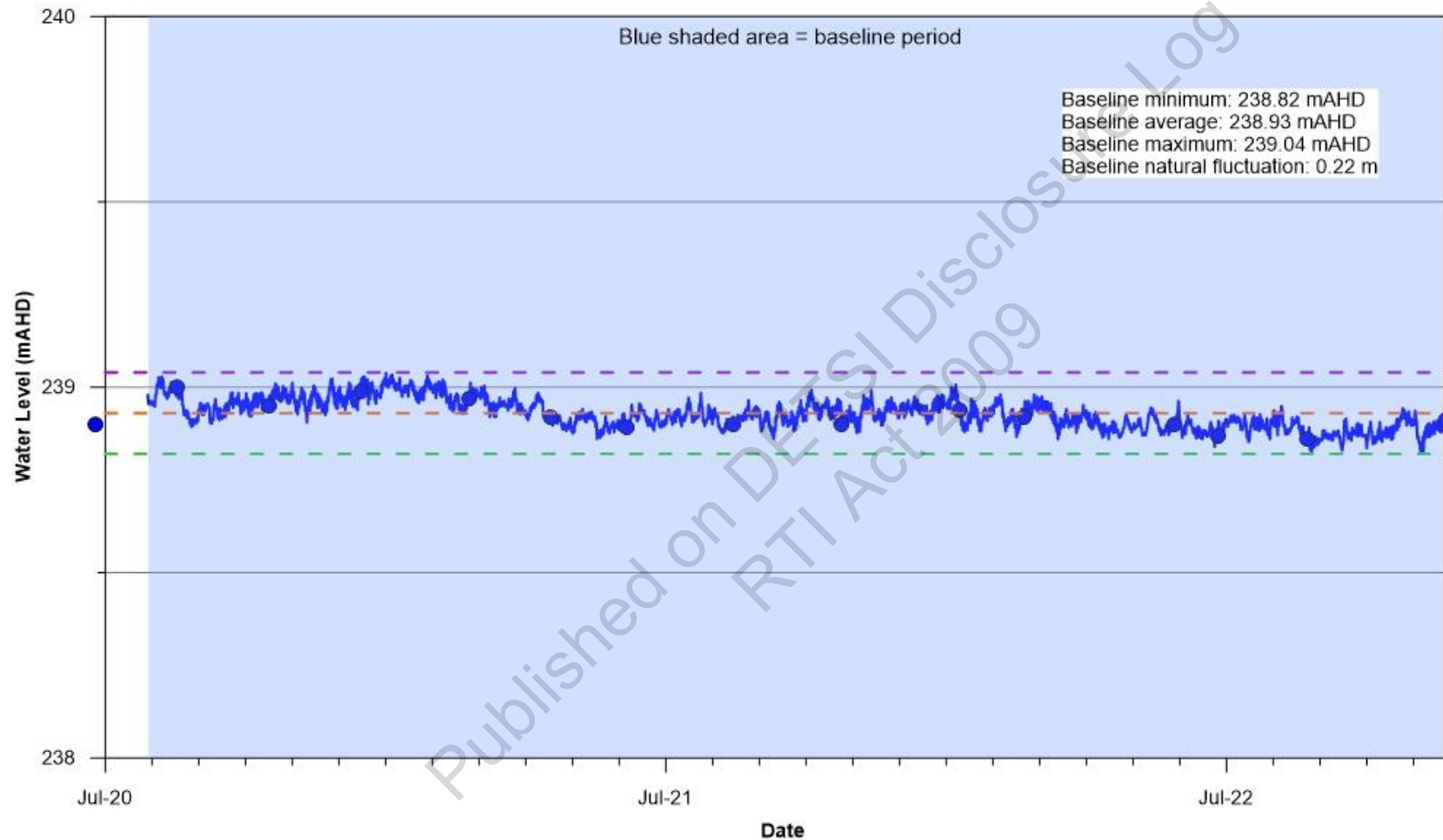
C19018SP (Bandanna Formation)

— Representative logger data ● Manual measurements



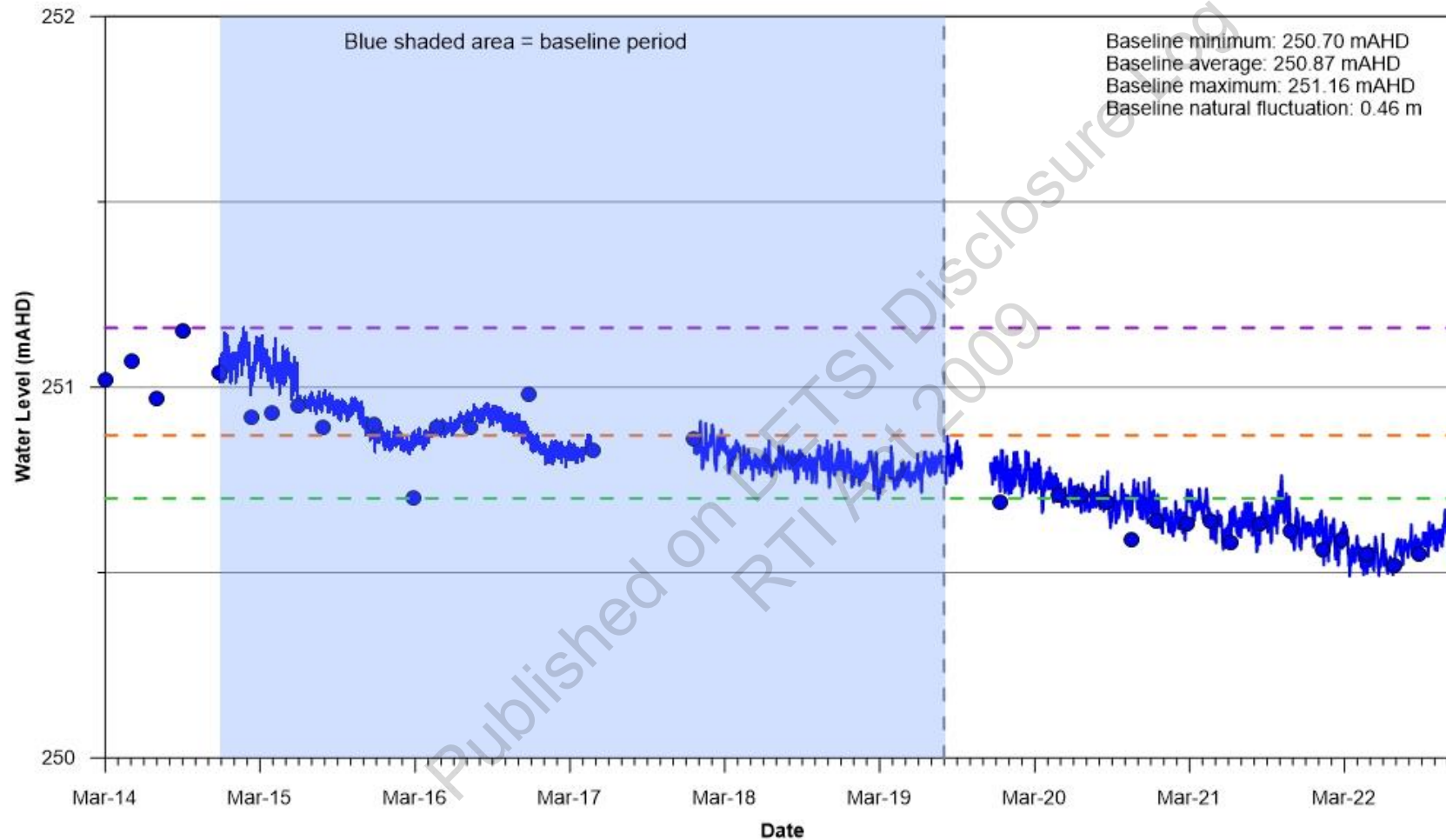
C19028SP (Rewan Formation)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level



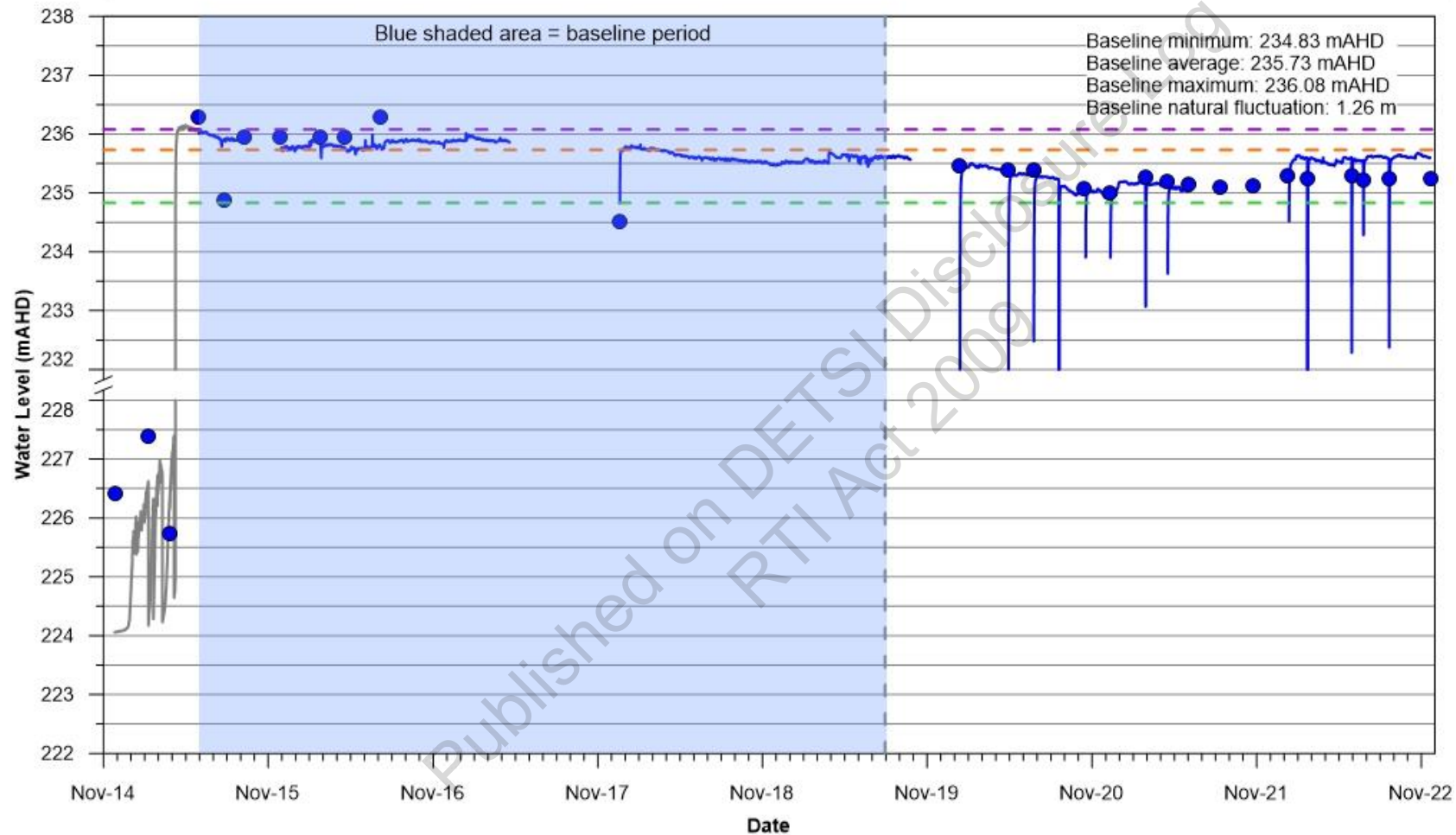
C180117SP (Dunda Beds)

- Representative logger data
- Manual measurements
- Minimum baseline logger water level
- Average baseline logger water level
- Maximum baseline logger water level
- Start of dewatering



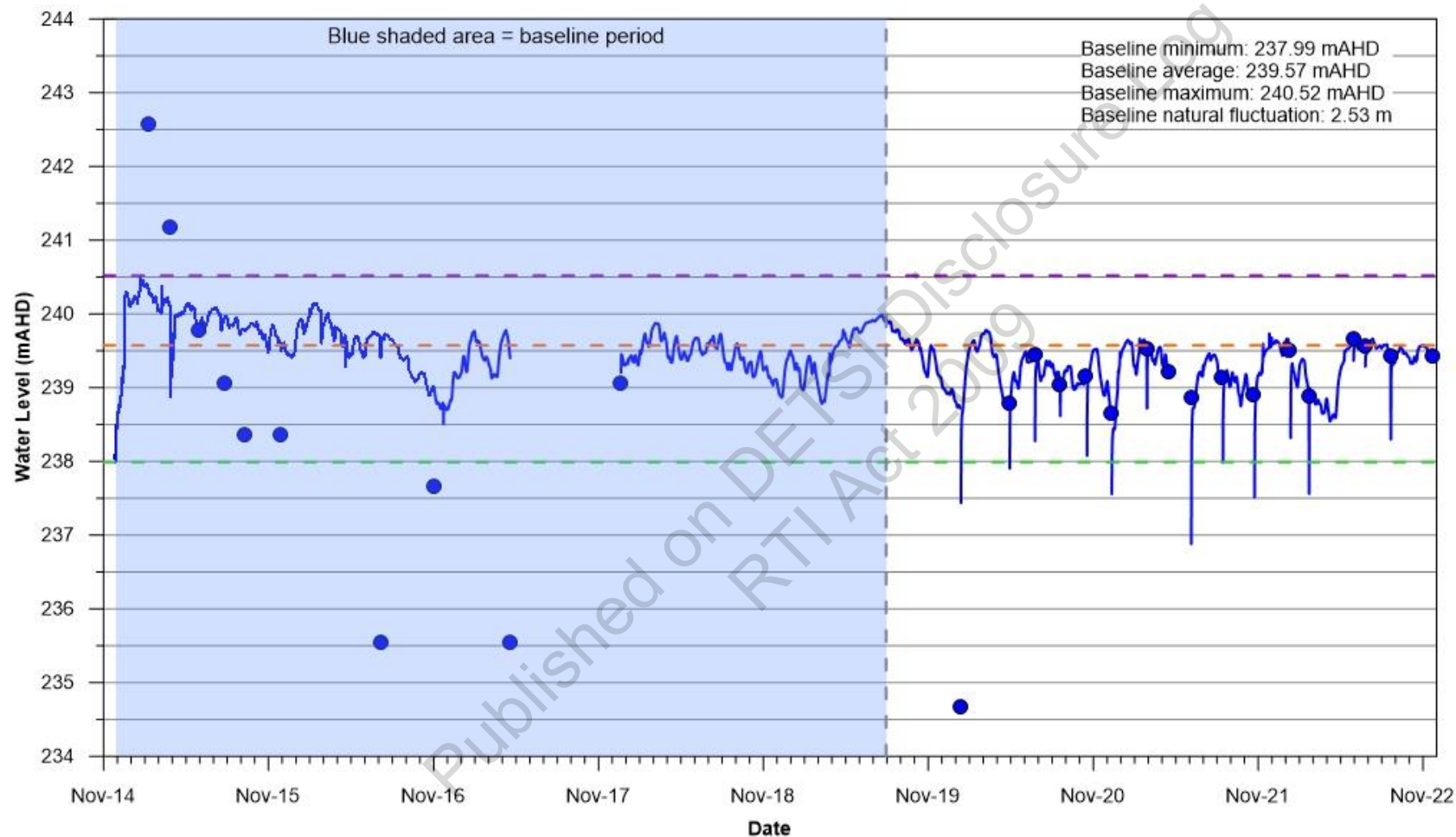
C180119SP (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Unrepresentative logger data - - - Average baseline logger water level - - - Start of dewatering
- Manual measurements



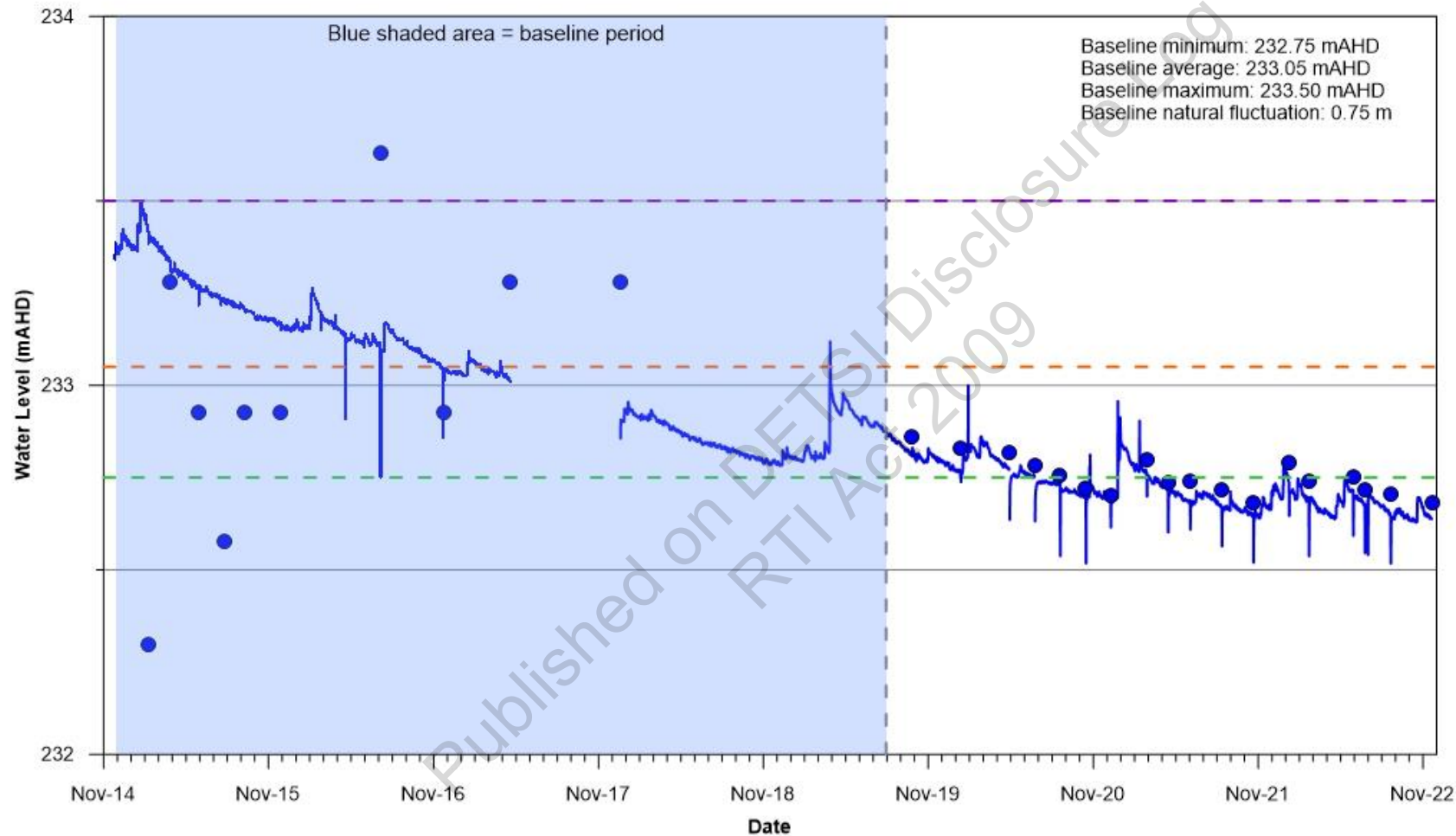
C180120SP (Tertiary sediments/Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



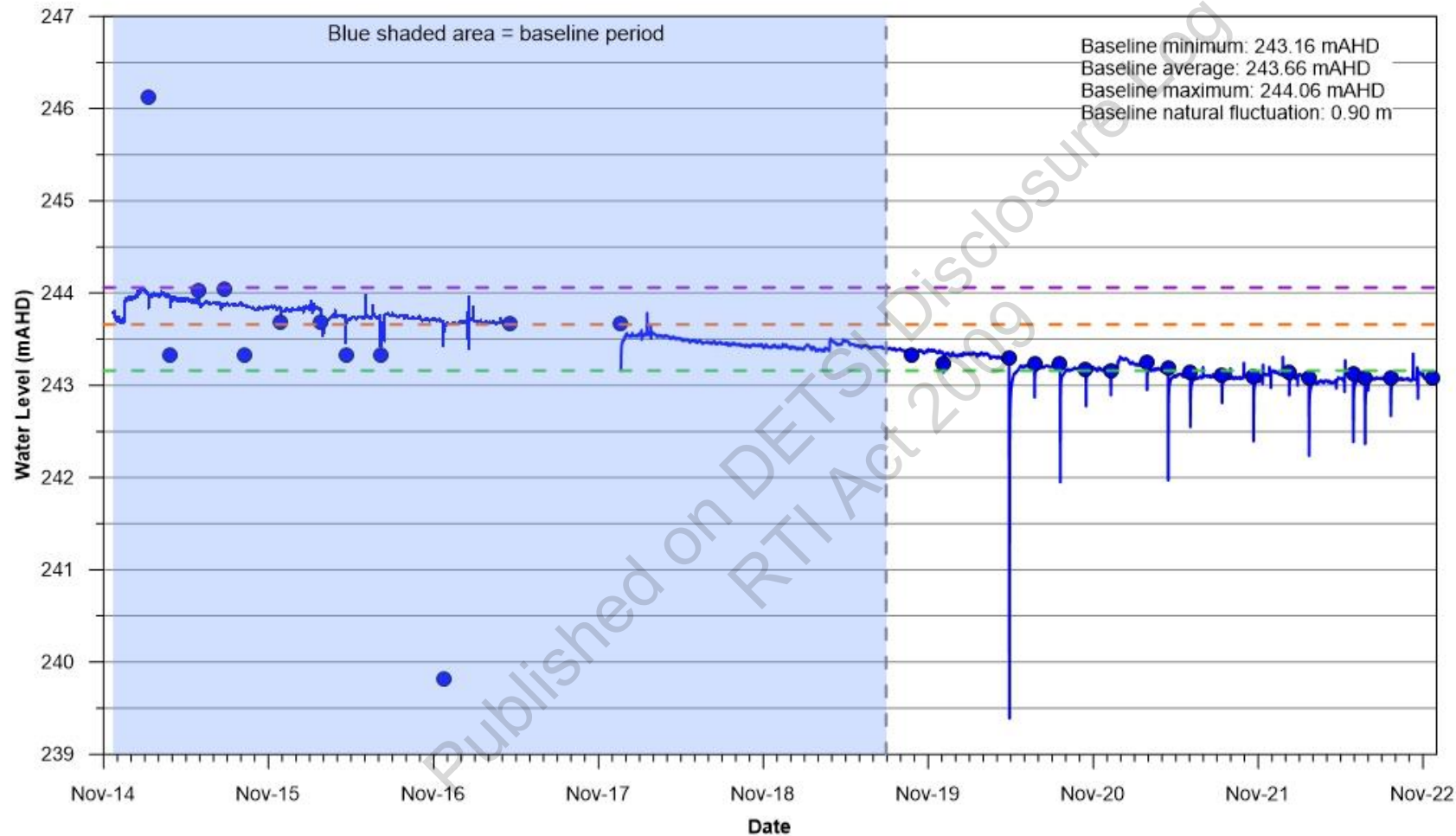
C180122SP (Tertiary sediments/Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



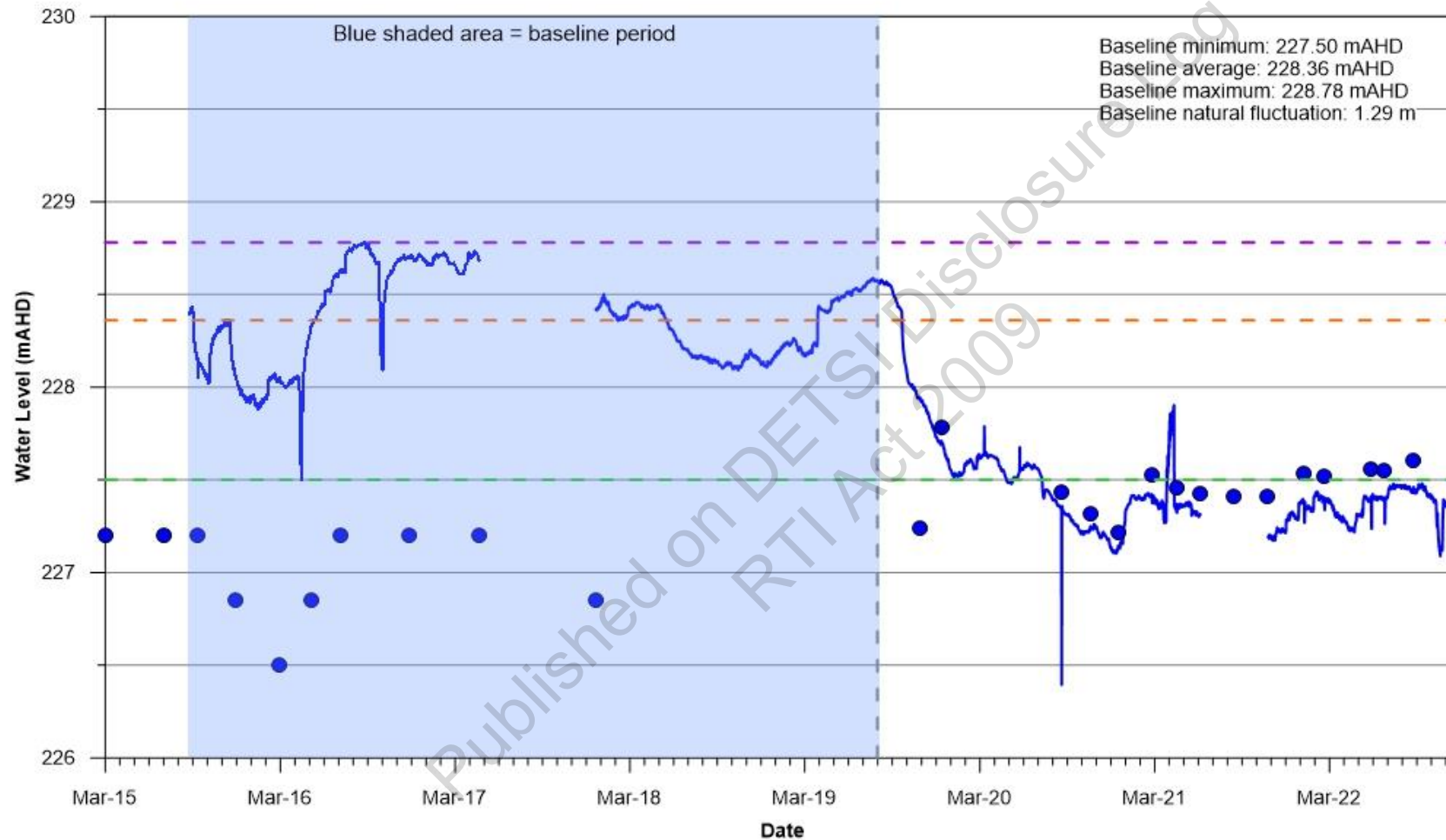
C180123SP (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



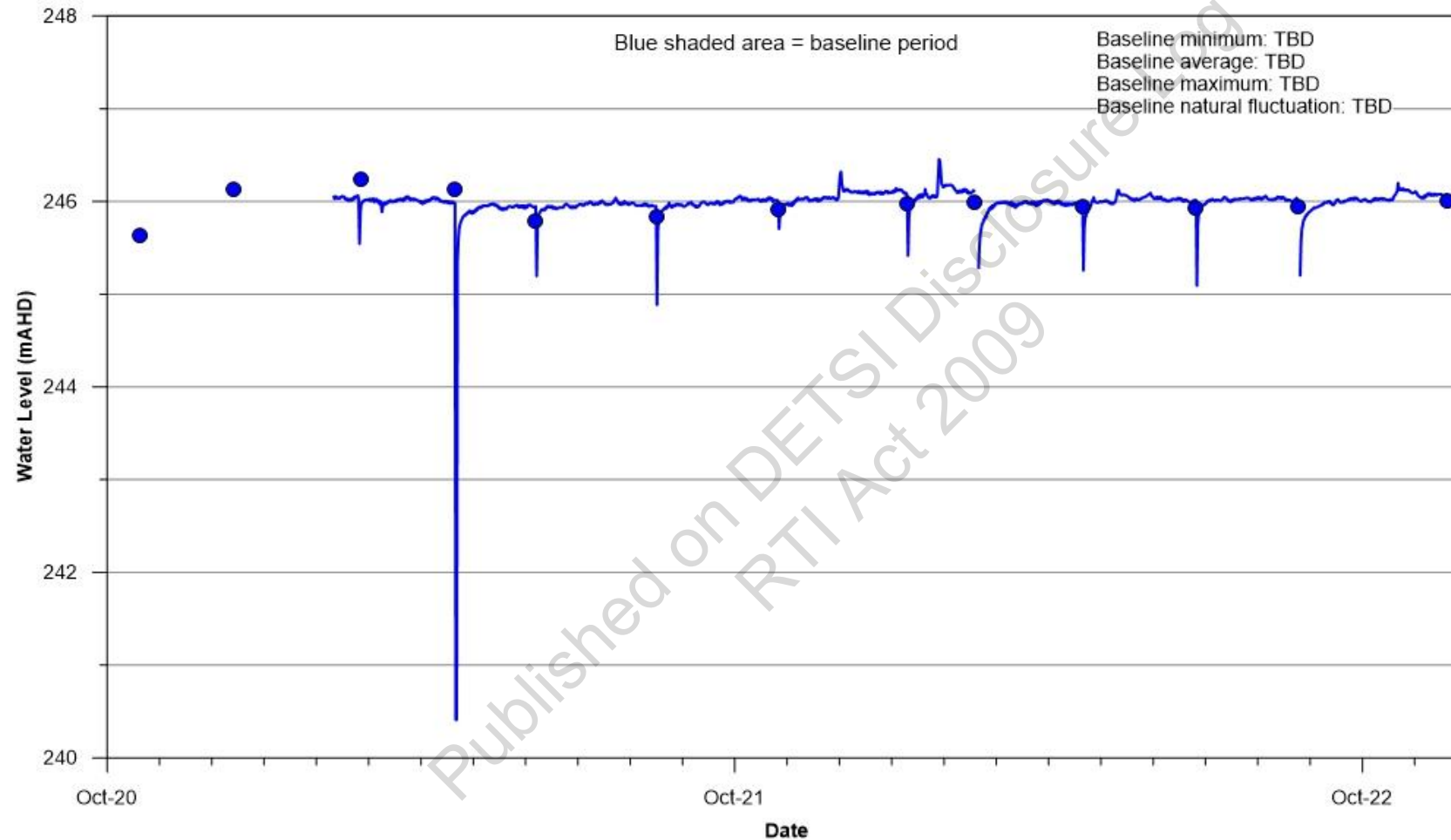
C914030SPR (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



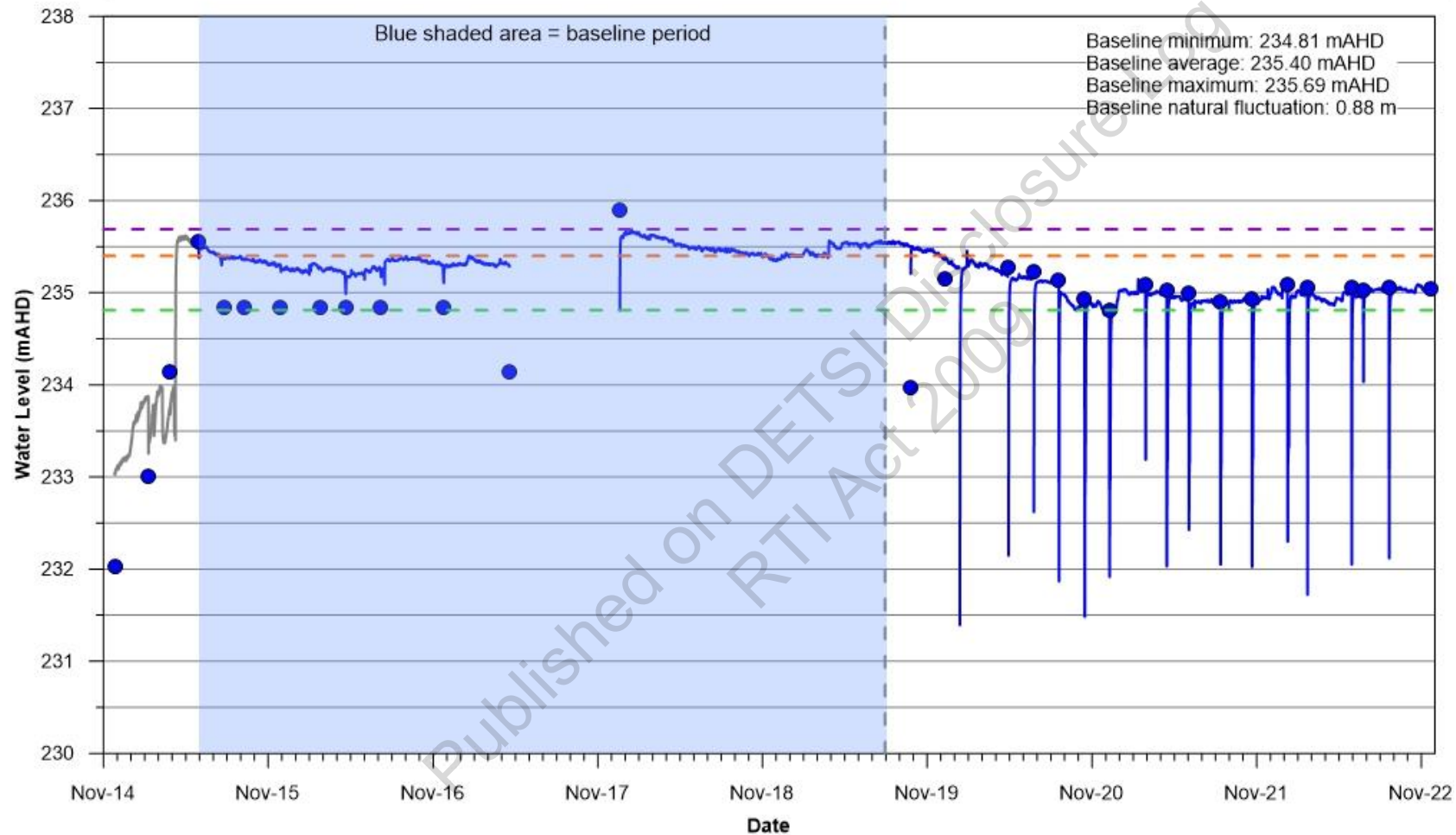
C919016SPR (Rewan Formation)

— Representative logger data ● Manual measurements



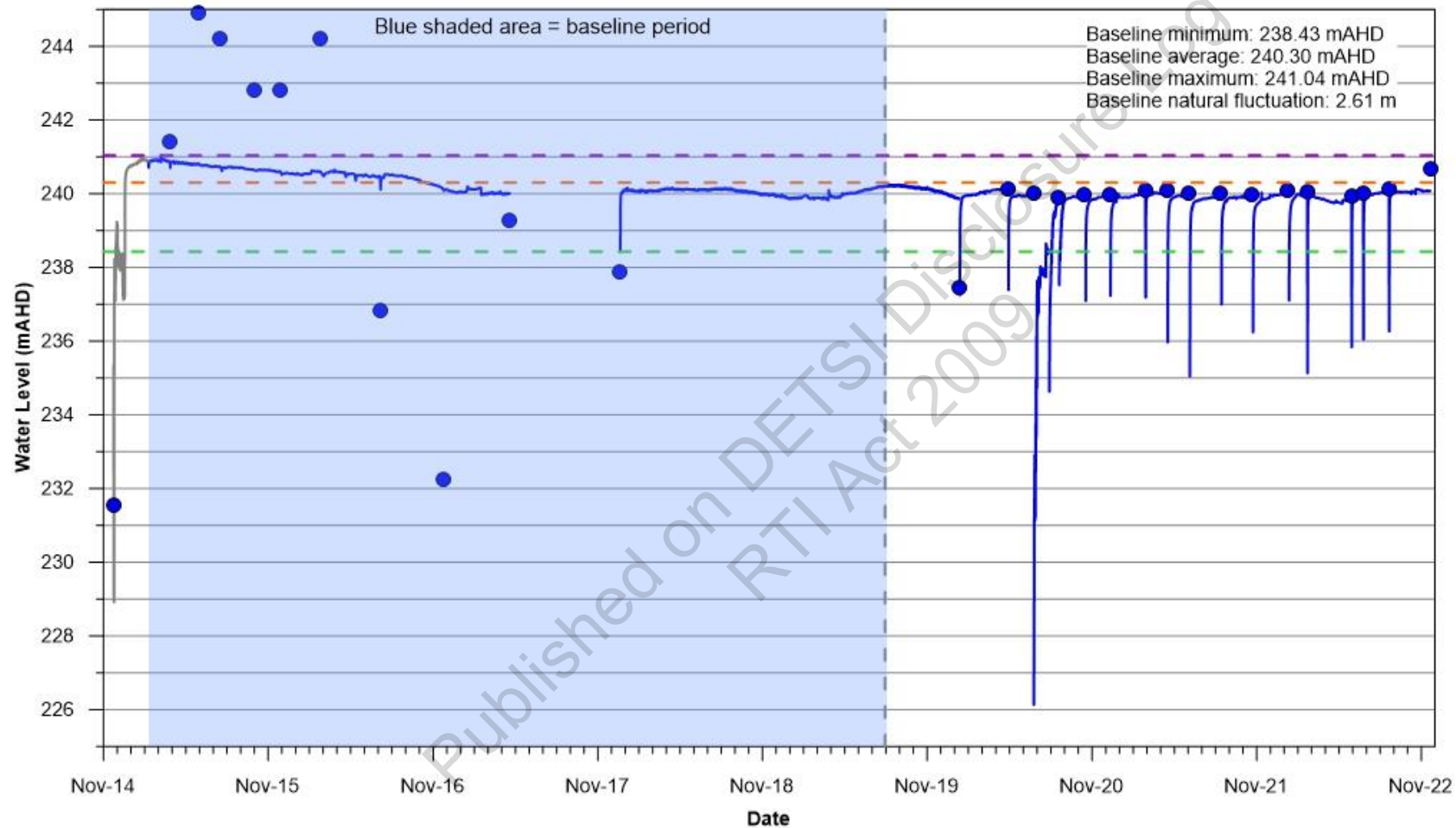
C9180124SPR (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Unrepresentative logger data - - - Average baseline logger water level - - - Start of dewatering
- Manual measurements



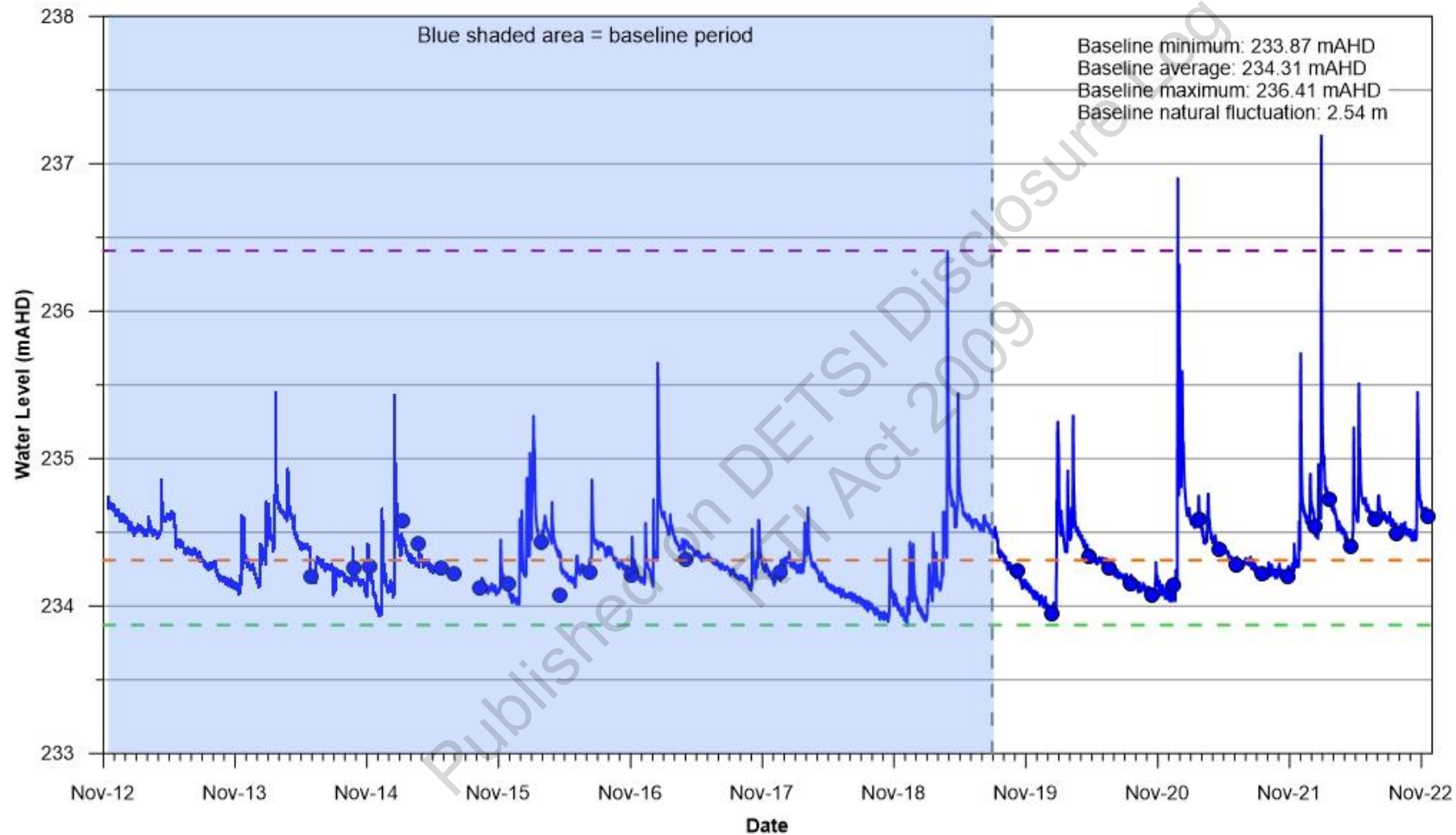
C9180125SPR (Joe Joe Group)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Unrepresentative logger data - - - Average baseline logger water level - - - Start of dewatering
- Manual measurements



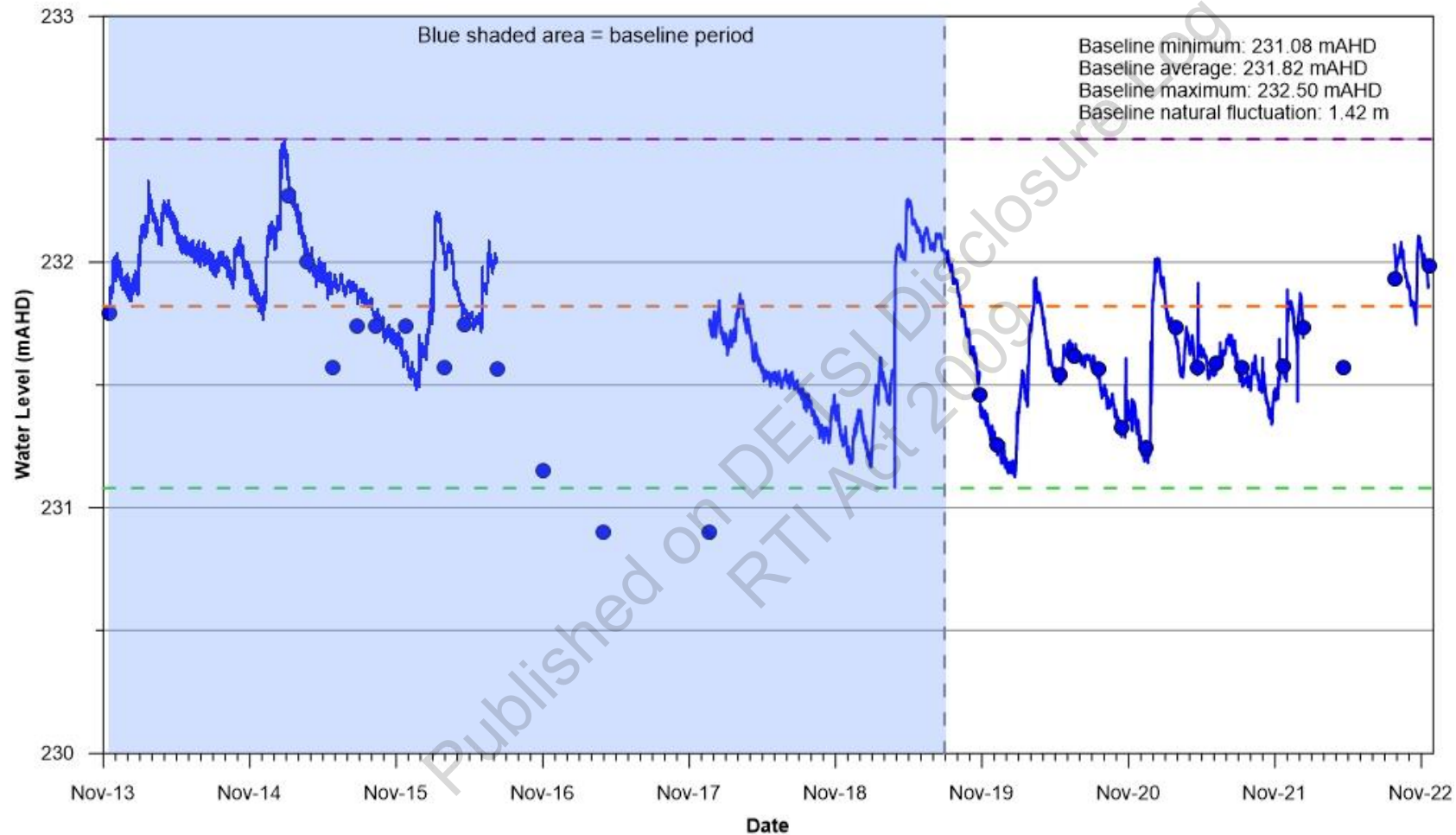
HD02 (Clematis)

- Representative logger data
- Manual measurements
- - - Minimum baseline logger water level
- - - Average baseline logger water level
- - - Maximum baseline logger water level
- - - Start of dewatering



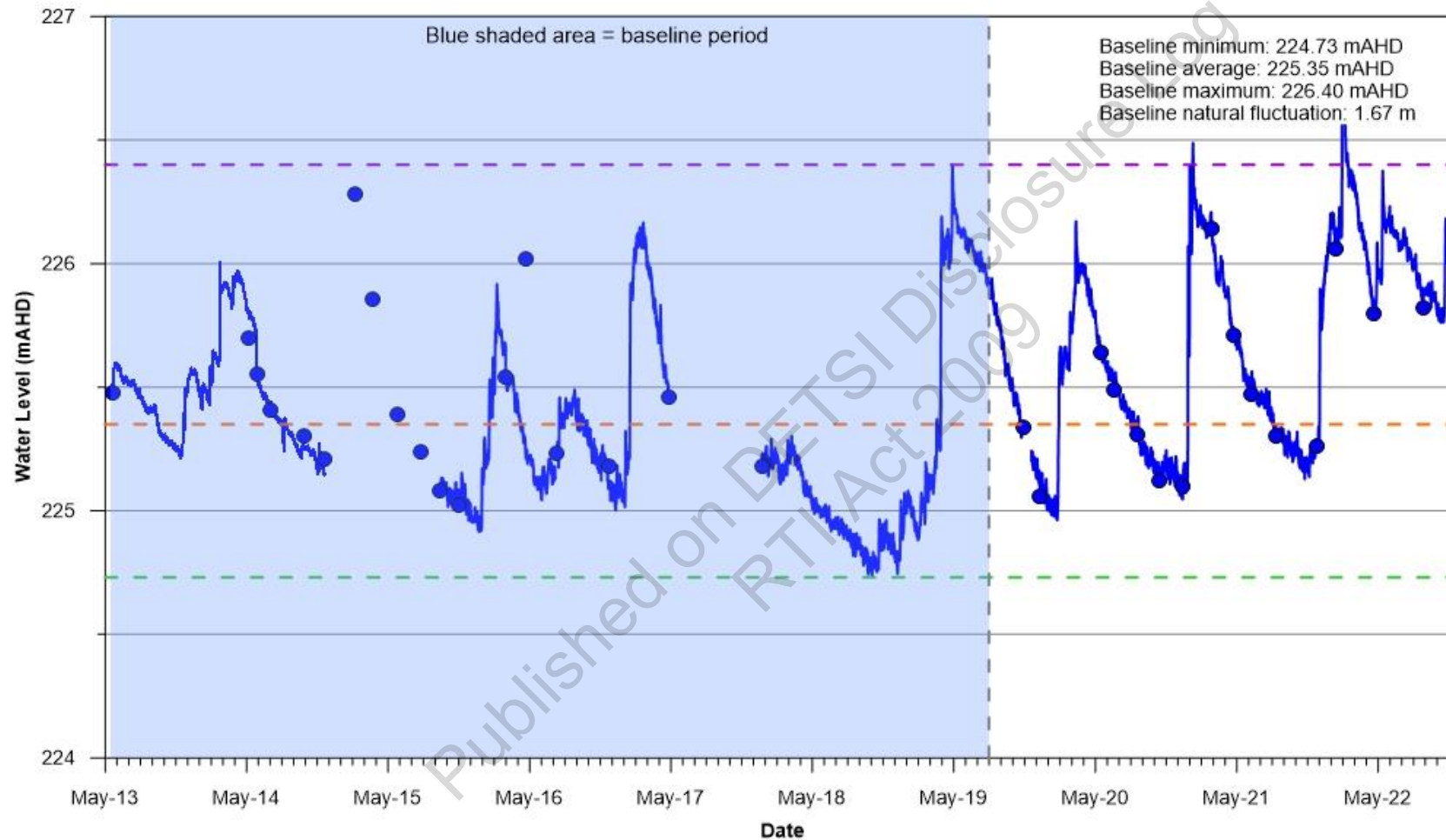
HD03A (Clematis)

- Representative logger data
- Minimum baseline logger water level
- Maximum baseline logger water level
- Manual measurements
- - - Average baseline logger water level
- - - Start of dewatering



HD03B (Alluvium)

- Representative logger data - - - Minimum baseline logger water level - - - Maximum baseline logger water level
- Manual measurements - - - Average baseline logger water level - - - Start of dewatering



Appendix C

Water quality trigger level exceedances

Table C.1 Water quality trigger exceedances – June 2022 monitoring round

Aquifer	Monitoring Bore	Parameter	Units	Trigger Level	February 2022	April /May 2022	June 2022	During dewatering Mann-Kendall trend	Bore has water level dewatering impact?	Proximity to mine disturbance footprint <2 km
Alluvium	C027P1	Arsenic	µg/L	13	4	14	13	No trend	No	No
		>C10-C40	µg/L	100	<100	120	170	No trend		
	C14027SP	Electrical Conductivity	µS/cm	50740	48500	54300	52000	Increasing	No	No
		Sulphate	mg/L	2200	2200	2290	2200	No trend		
	C14028SP	Electrical Conductivity	µS/cm	45000	44800	47500	46200	No trend	No	No
	C19001SP	Boron	µg/L	2133	2450	2350	2290	Increasing	No	Yes
		Electrical Conductivity	µS/cm	24880	27800	29100	28000	Increasing		
		Sulphate	mg/L	820	896	852	853	Increasing		
		Iron	µg/L	60	60	70	130	Increasing		
		Total dissolved solids	mg/L	16170	17500	17400	16300	Increasing		
Bandanna Formation	C008P2	Boron	µg/L	266	280	290	280	No trend	Yes	Yes
	C032P2	Boron	µg/L	370	360	410	400	Increasing	No	No
	C035P2	Boron	µg/L	261	260	320	310	Increasing	No	No
	C19027SP	Aluminium	µg/L	55	80	80	120	No trend	No	No
		pH (field)	pH units	6.0 – 9.0	10.70	10.57	10.80	Increasing		
	C847SP	Electrical Conductivity	µS/cm	358	351	387	361	Increasing	No	No
		Boron	µg/L	110	100	130	140	Increasing		
Clematis Sandstone	C14011SP	Cobalt	µg/L	2	2	2	2	No trend	No	No
	C14012SP	Boron	µg/L	120	160	120	140	No trend	No	No

Table C.1 Water quality trigger exceedances – June 2022 monitoring round

Aquifer	Monitoring Bore	Parameter	Units	Trigger Level	February 2022	April /May 2022	June 2022	During dewatering Mann-Kendall trend	Bore has water level dewatering impact?	Proximity to mine disturbance footprint <2 km
Colinlea Sandstone	C14013SP	Electrical Conductivity	µS/cm	490	512	501	495	Increasing	No	No
		Boron	µg/L	120	150	130	140	Increasing		
		Cobalt	µg/L	4	4	4	4	No trend		
		Electrical Conductivity	µS/cm	410	415	419	424	Increasing		
	C14021SP	Boron	µg/L	130	130	160	160	Increasing	No	No
	C14033SP	Cobalt	µg/L	2	2	2	2	Increasing	No	No
		Electrical Conductivity	µS/cm	377	381	394	388	No trend		
	C18001SP	Electrical Conductivity	µS/cm	667	670	680	681	Increasing	No	No
		Boron	µg/L	120	110	150	140	No trend		
		Total Dissolved Solids	mg/L	379	334	384	400	No trend		
	C18002SP	Electrical Conductivity	µS/cm	380	382	384	383	Increasing	No	No
		Boron	µg/L	65	60	70	70	No trend		
	HD02	Iron	µg/L	1297	5530	2660	1590	Increasing	No	No
	C006P3R	Boron	µg/L	160	210	a	170	Increasing	Yes	Yes
		Electrical Conductivity	µS/cm	1030	1260	a	1320	Increasing		
		Total dissolved solids	mg/L	631	720	a	708	No trend		
Colinlea Sandstone	C011P3	Boron	µg/L	450	500	470	470	Increasing	No	No
	C034P3	Iron	µg/L	2796	2690	2860	2940	No trend	No	No
	C19029SP	Iron	µg/L	165	280	260	350	No trend	Yes	Yes

Table C.1 Water quality trigger exceedances – June 2022 monitoring round

Aquifer	Monitoring Bore	Parameter	Units	Trigger Level	February 2022	April /May 2022	June 2022	During dewatering Mann-Kendall trend	Bore has water level dewatering impact?	Proximity to mine disturbance footprint <2 km
Dunda Beds	C848SP	Boron	µg/L	190	180	200	230	Increasing	No	No
	C022P1	Boron	µg/L	130	120	130	150	No trend	No	No
	C027P2	Boron	µg/L	210	180	240	230	Increasing	No	No
	C14023SP	Electrical Conductivity	µS/cm	748	714	759	757	Increasing	No	No
	C180117SP	Iron	µg/L	1498	2100	1710	2280	Increasing	No	No
	C19015SP	Boron	µg/L	100	100	100	110	No trend	No	No
		Electrical Conductivity	µS/cm	712	697	726	712	No trend		
		Total Dissolved Solids	mg/L	398	390	413	400	No trend		
Joe Joe Group	C14003SP	C6-C10	µg/L	20	<20	150	180	Increasing	No	No
		Electrical Conductivity	µS/cm	53230	51900	53800	54200	No trend		
		Total dissolved solids	mg/L	43245	45800	43400	50700	No trend		
	C14006SP	Boron	µg/L	502	440	550	510	No trend	No	No
	C14008SP	Boron	µg/L	112	90	120	120	Increasing	No	No
		Cobalt	µg/L	10	10	11	10	No trend		
		Nickel	µg/L	11	13	14	12	No trend		
	C14015SP	Iron	µg/L	580	630	710	640	No trend	No	No
	C14017SP	Iron	µg/L	540	670	650	620	Increasing	No	No
	C14032SP	Boron	µg/L	170	220	210	200	No trend	No	No
		Cobalt	µg/L	1.4	3	3	3	No trend		

Table C.1 Water quality trigger exceedances – June 2022 monitoring round

Aquifer	Monitoring Bore	Parameter	Units	Trigger Level	February 2022	April /May 2022	June 2022	During dewatering Mann-Kendall trend	Bore has water level dewatering impact?	Proximity to mine disturbance footprint <2 km
Rewan	C180119SP	Iron	µg/L	1370	3750	7410	5090	No trend	No	No
		Zinc	µg/L	2000	3740	6440	5250	No trend		
	C180123SP	Boron	µg/L	356	430	400	430	No trend	No	No
	C914001SPR	Electrical Conductivity	µS/cm	21300	17900	22600	21900	No trend	No	No
	C914030SPR	Nickel	µg/L	11	12	12	12	No trend	No	No
		Boron	µg/L	92	120	100	110	No trend		
	C9180124SPR	Iron	µg/L	110	210	340	5230	Increasing	No	No
		Electrical Conductivity	µS/cm	473	469	482	493	No trend		
Tertiary	C035P1	Boron	µg/L	710	690	750	720	No trend	No	No
	C556P1	Cobalt	µg/L	5	6	5	5	No trend	No	No
	C029P2	Iron	µg/L	1440	1520	1610	1590	No trend	No	Yes
		Electrical Conductivity	µS/cm	53150	51900	54200	53400	Increasing		
		Iron	µg/L	170	100	170	240	Increasing		
		Nickel	µg/L	37	20	56	64	No trend		
	C18006SP	Iron	µg/L	674	850	a	840	Increasing	No	Yes
	C18009SP	Boron	µg/L	1328	1510	1340	1690	Increasing	No	Yes
	C558P1	Boron	µg/L	840	850	960	850	No trend	No	No
	C9180121SPR	Iron	µg/L	344	550	780	360	No trend	No	No
	C9845SPR	Electrical Conductivity	µS/cm	2000	1960	2010	2010	Increasing	No	No

Table C.1 Water quality trigger exceedances – June 2022 monitoring round

Aquifer	Monitoring Bore	Parameter	Units	Trigger Level	February 2022	April /May 2022	June 2022	During dewatering Mann-Kendall trend	Bore has water level dewatering impact?	Proximity to mine disturbance footprint <2 km
		Boron	µg/L	240	230	280	270	Increasing		
		Nitrate	mg/L	0.1	0.11	0.12	0.1	Decreasing		

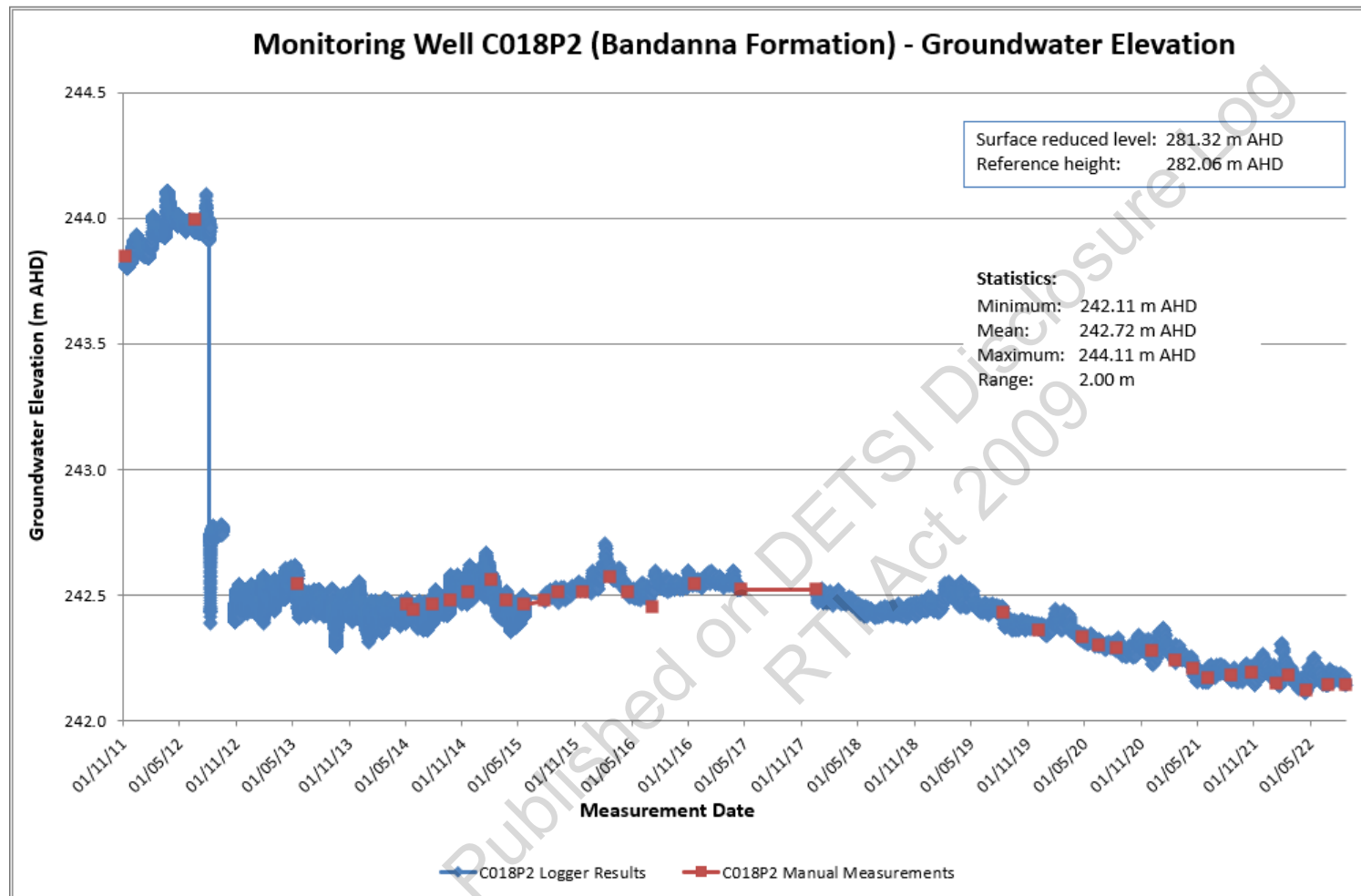
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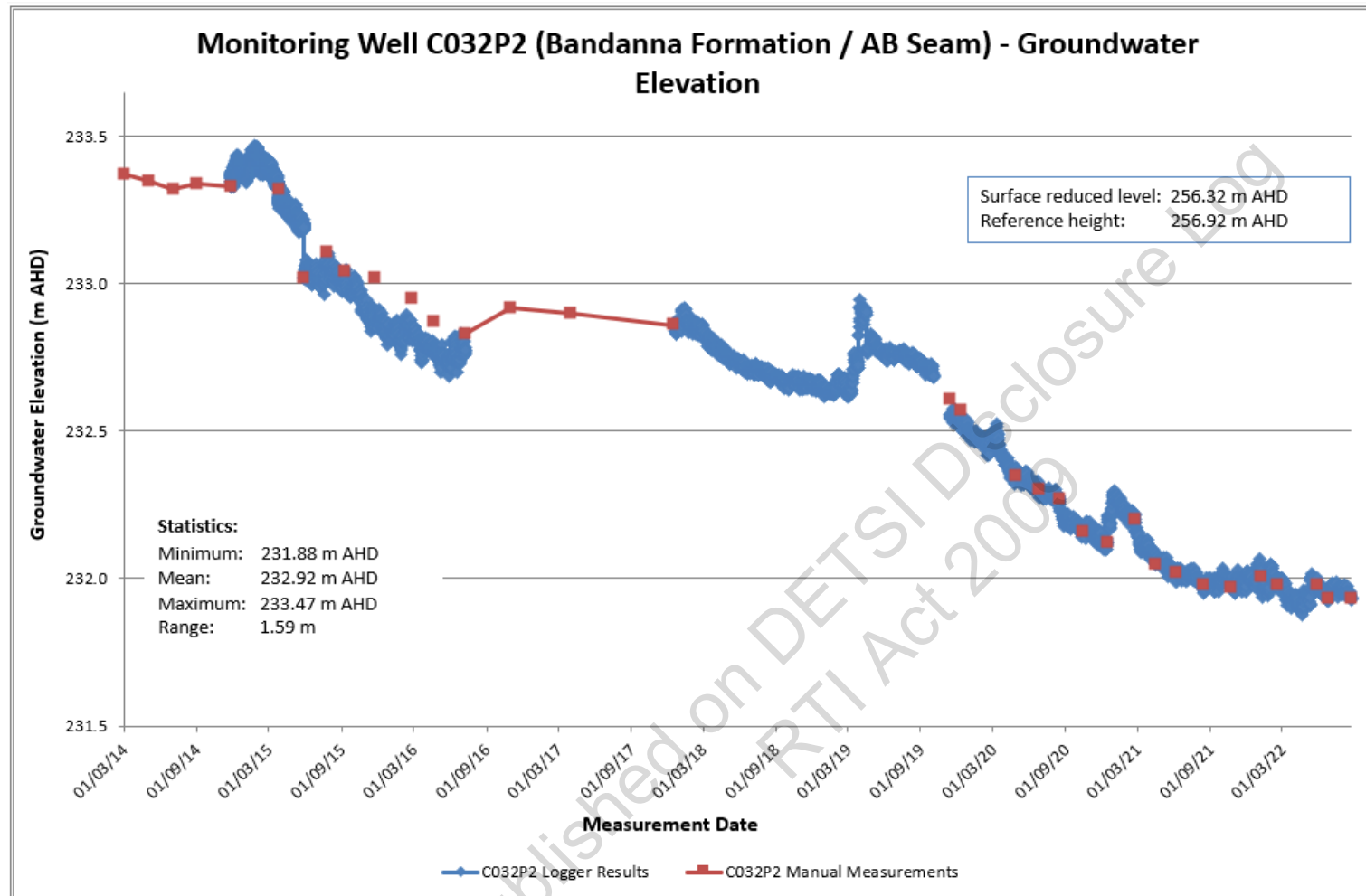
- Values highlighted in red have either reached or exceeded the trigger values.
- <LOR = value reported at less than the laboratory limit of reporting (LOR).
 - a = sample unable to be collected due to impeded access to the bore following rainfall.
- Yellow highlighted cells indicate two consecutive results reach or exceed trigger level and therefore Step 1 investigation is required.
- Monitoring bores with green shading show increasing parameter trend together with water level dewatering impact and/or located within 2 km of mine disturbance, thus requiring a detailed assessment.

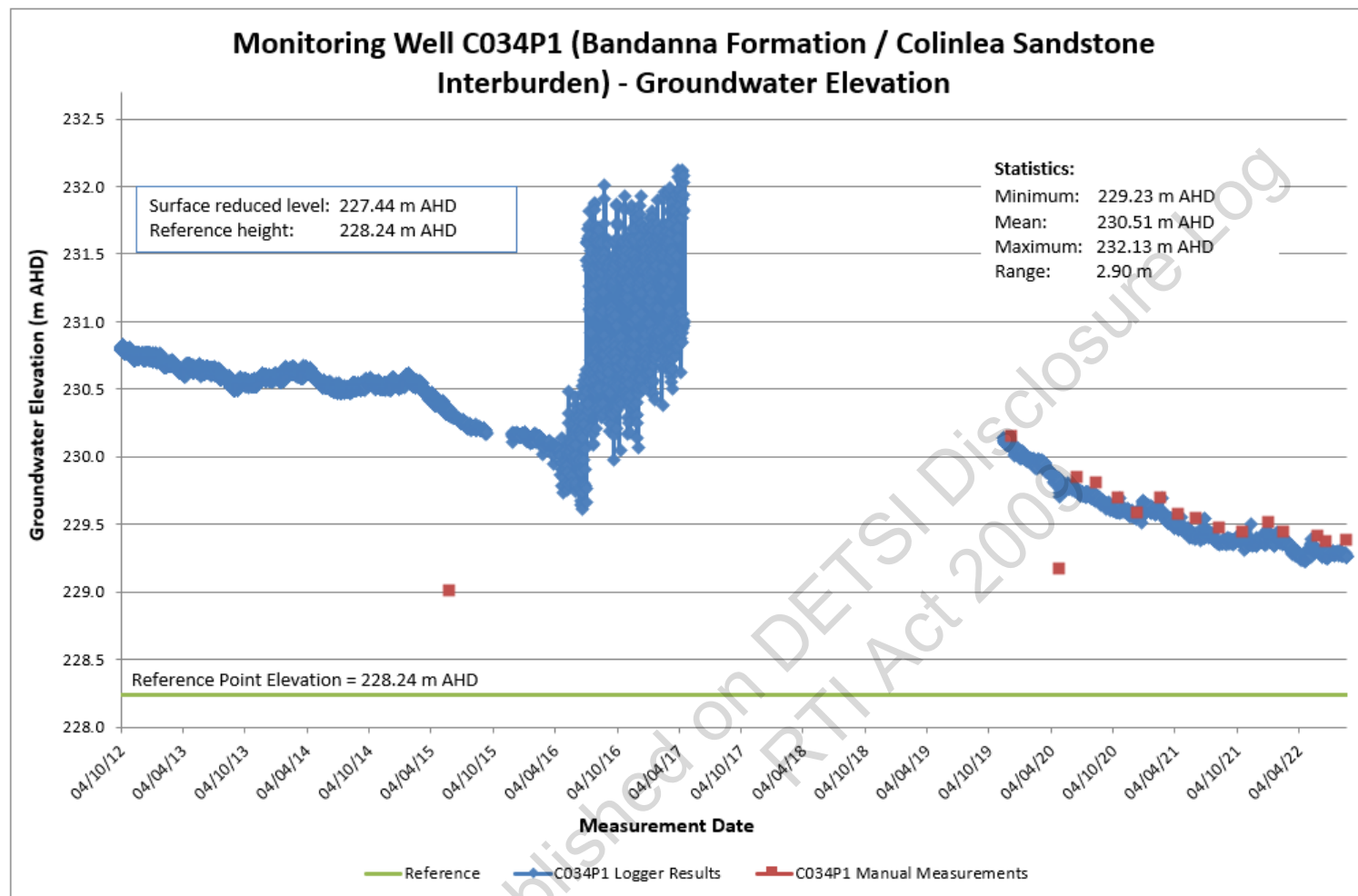
Appendix D

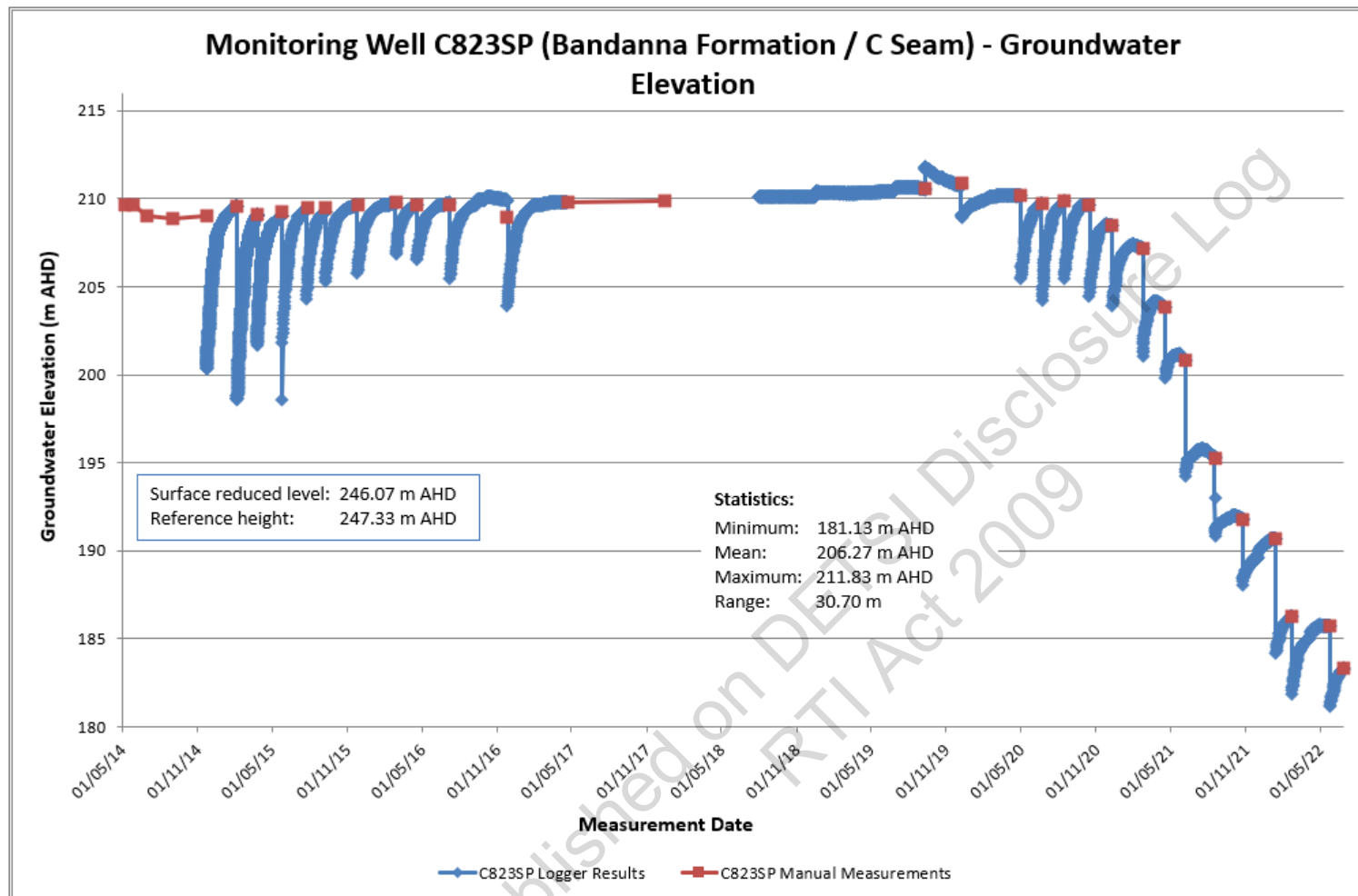
Logger data validation hydrographs

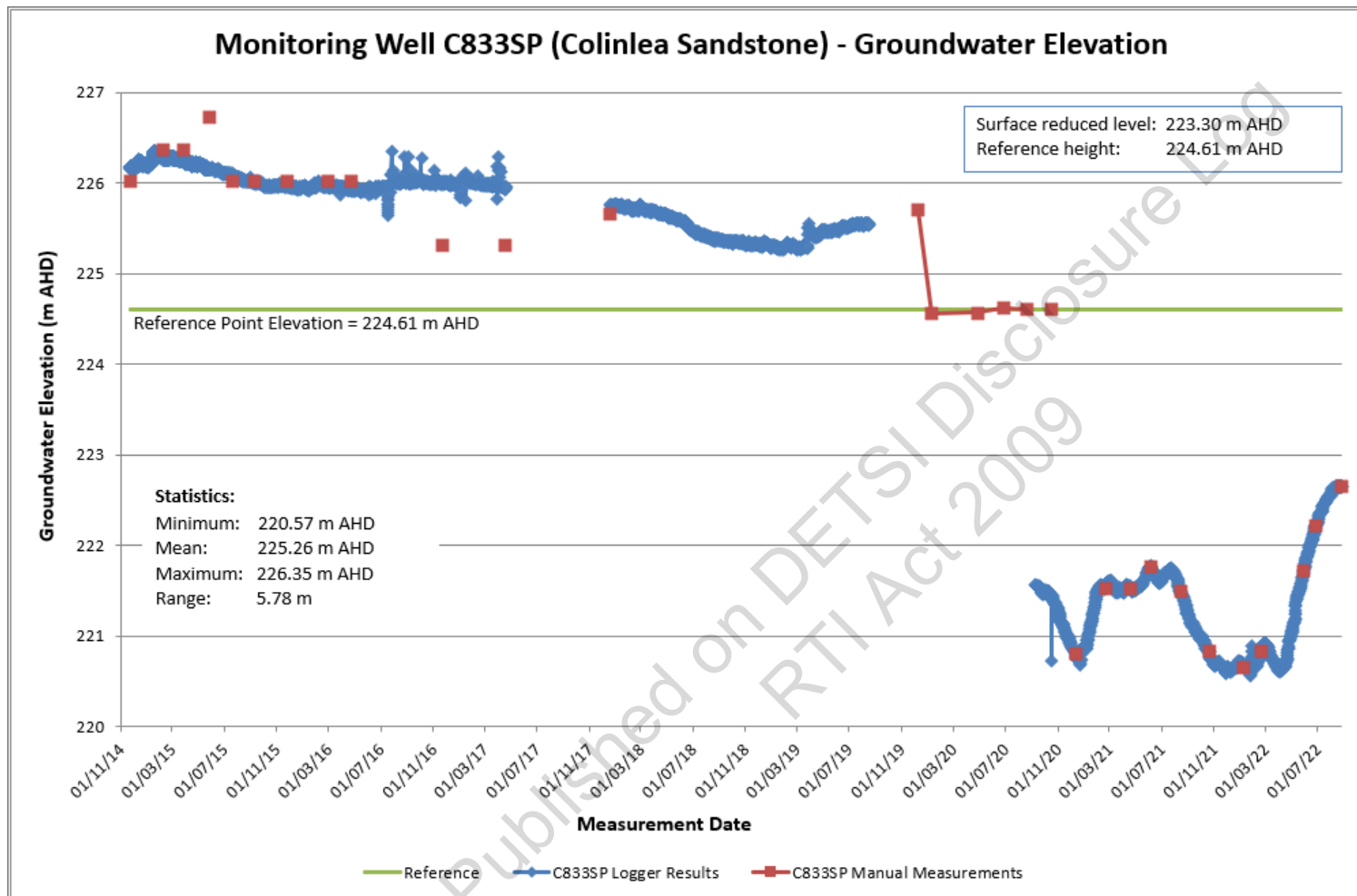
D.1 Bandanna Formation

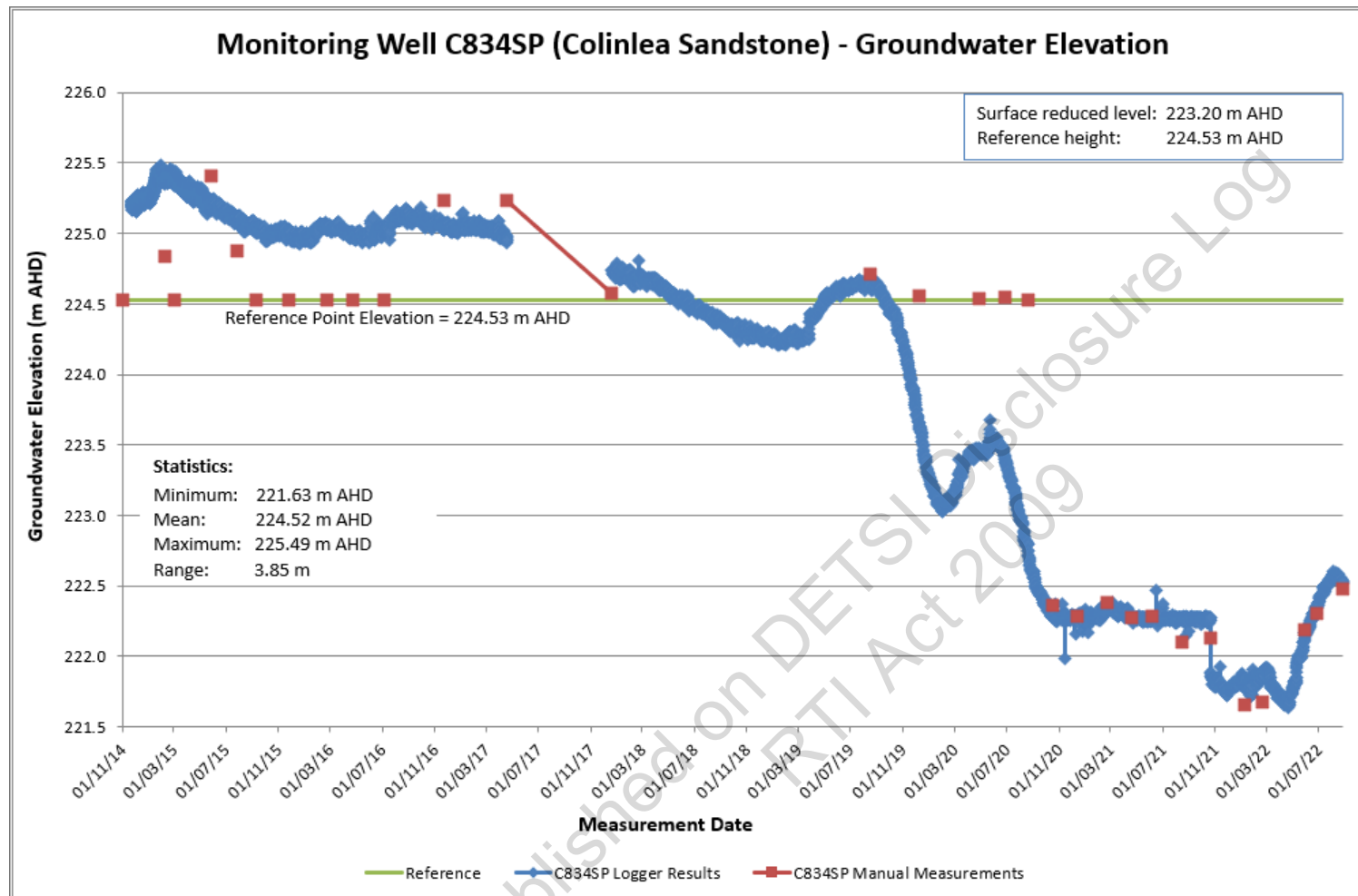


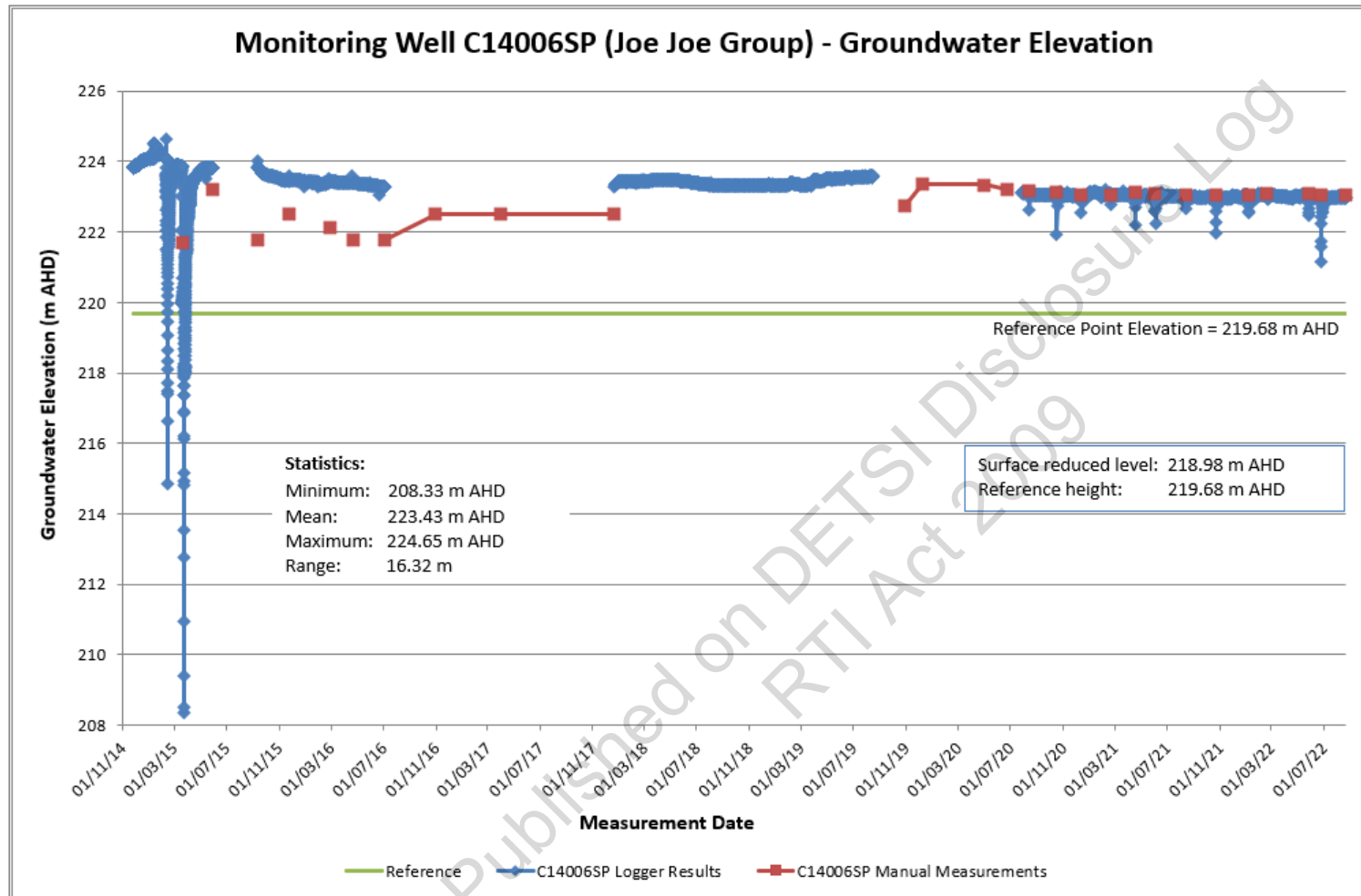


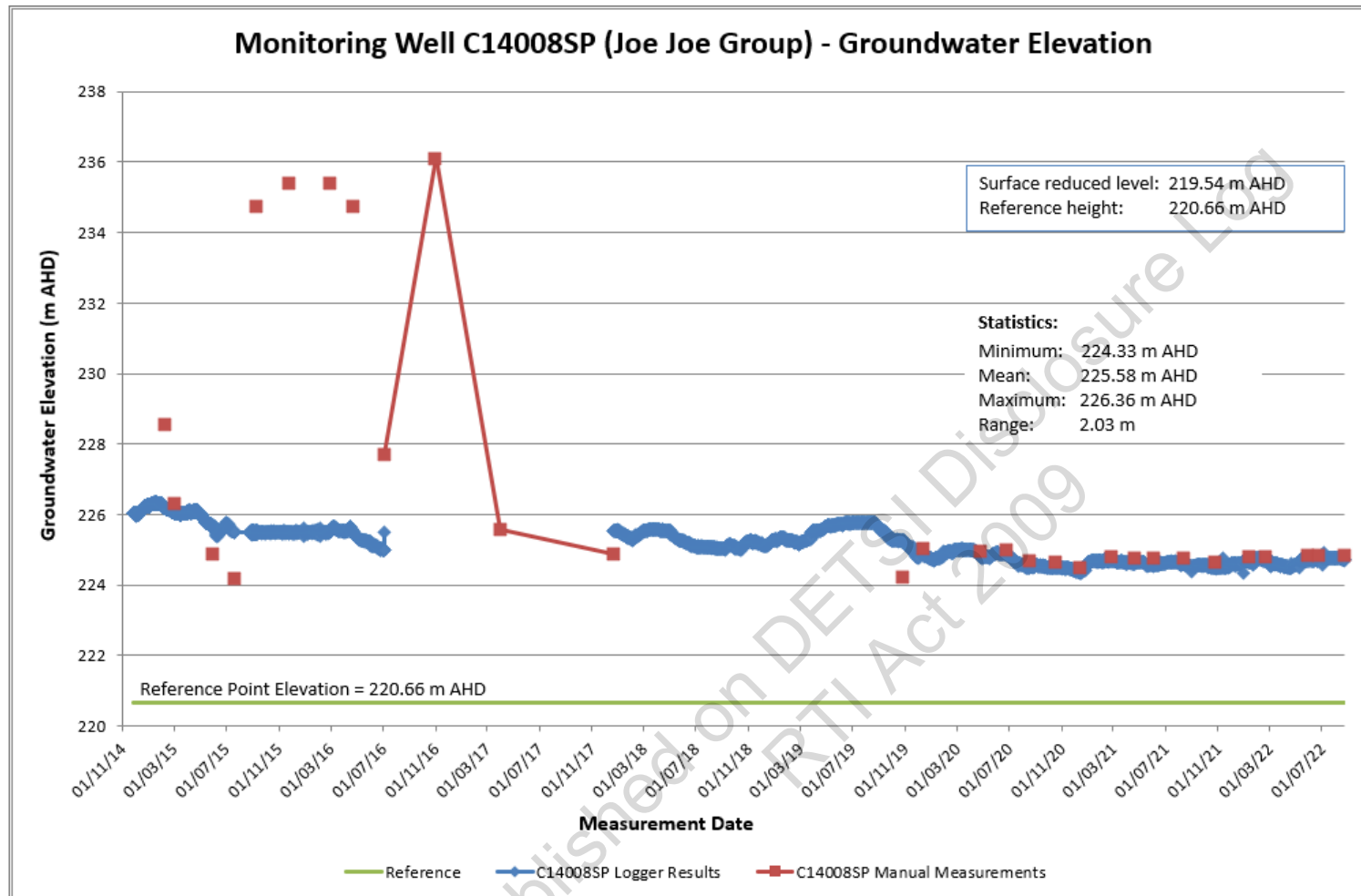


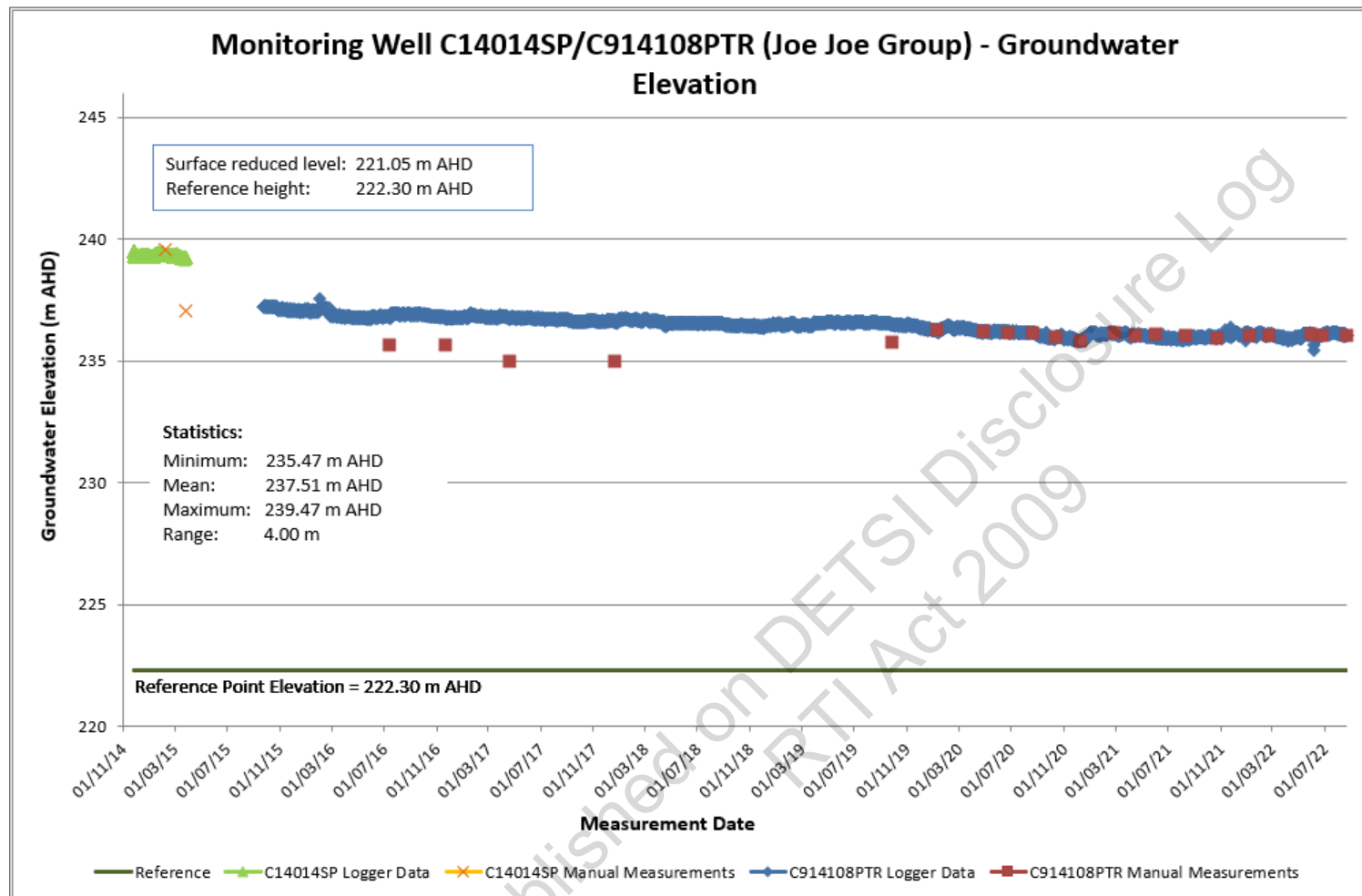


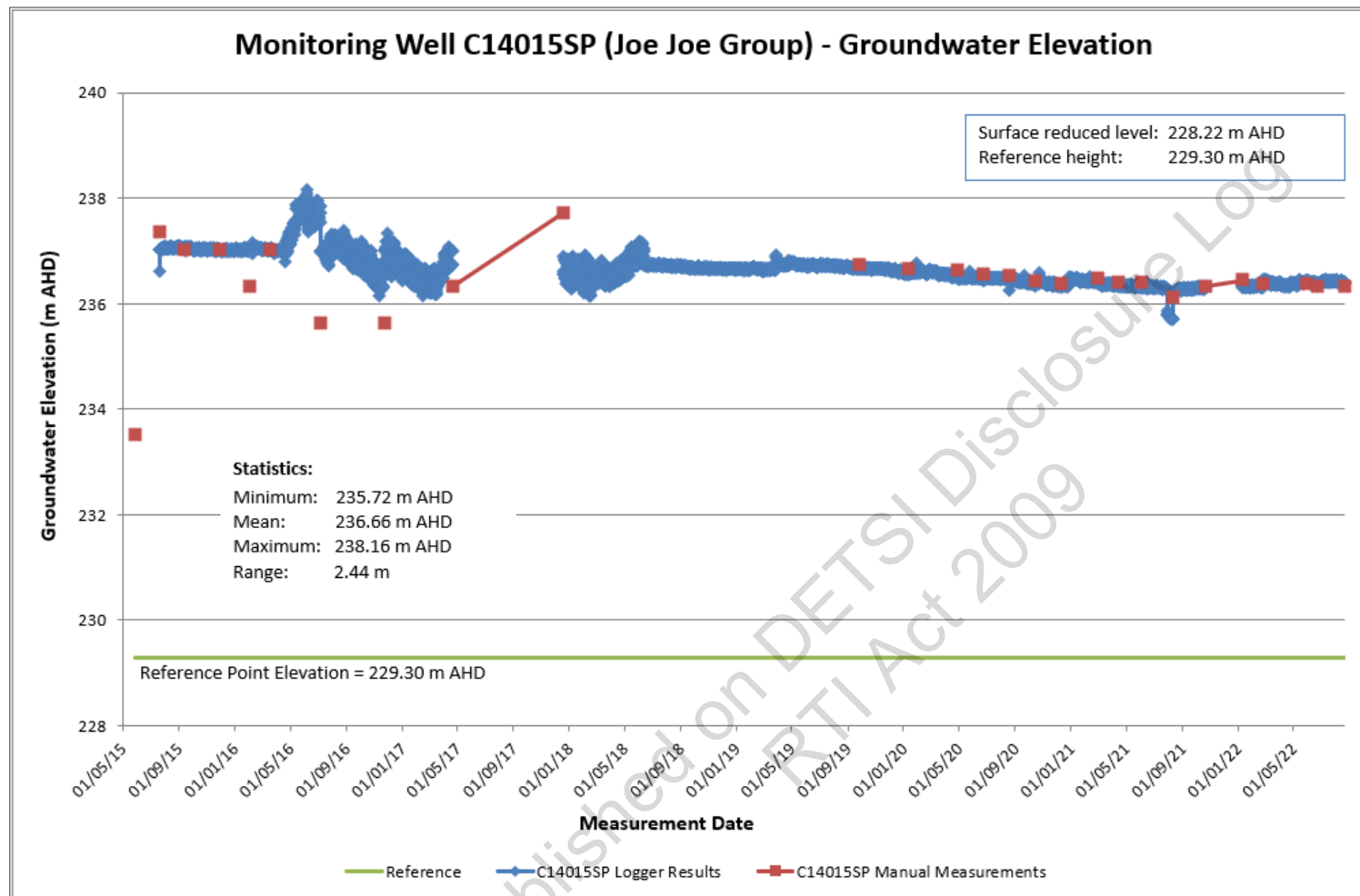


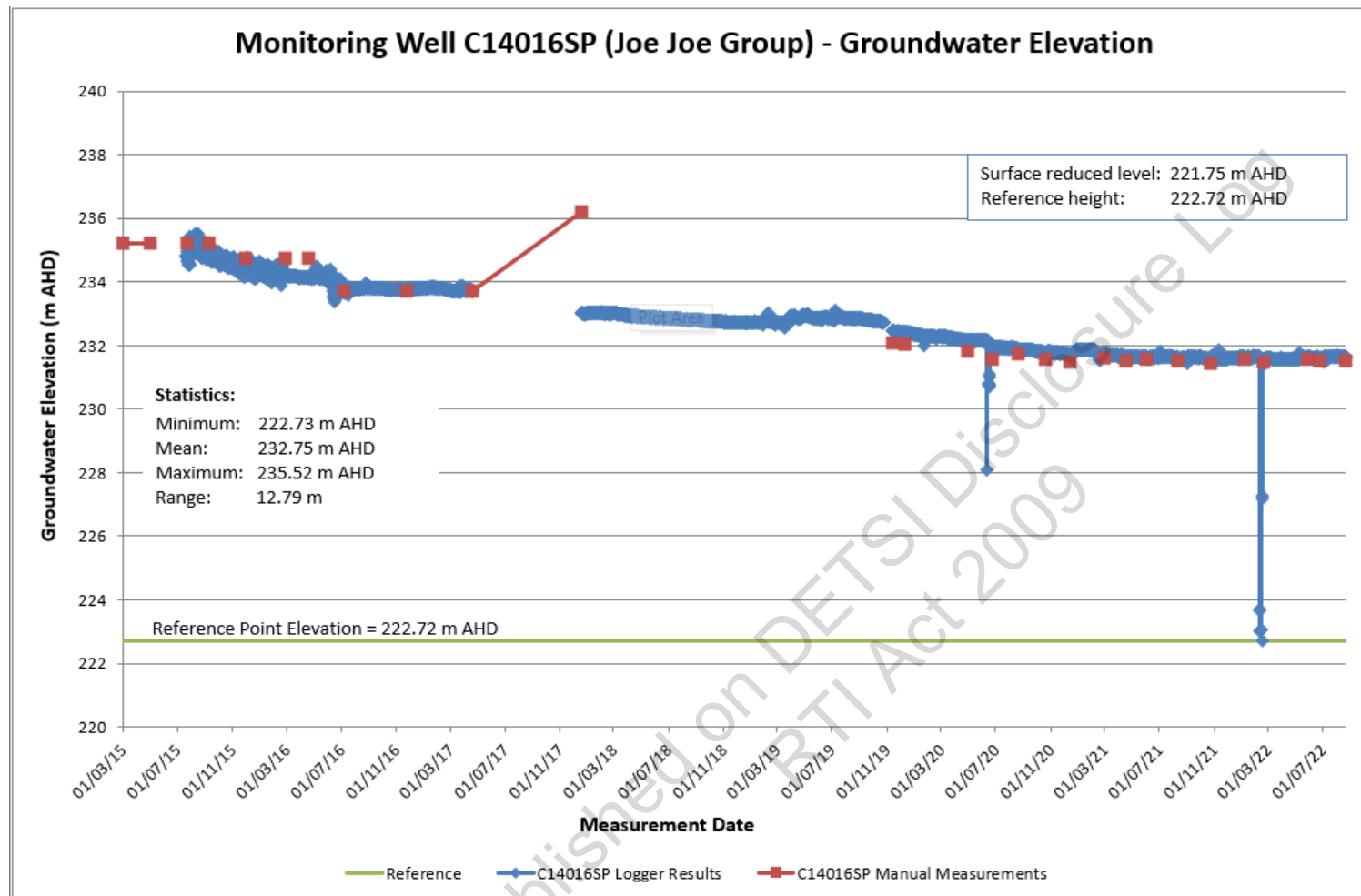


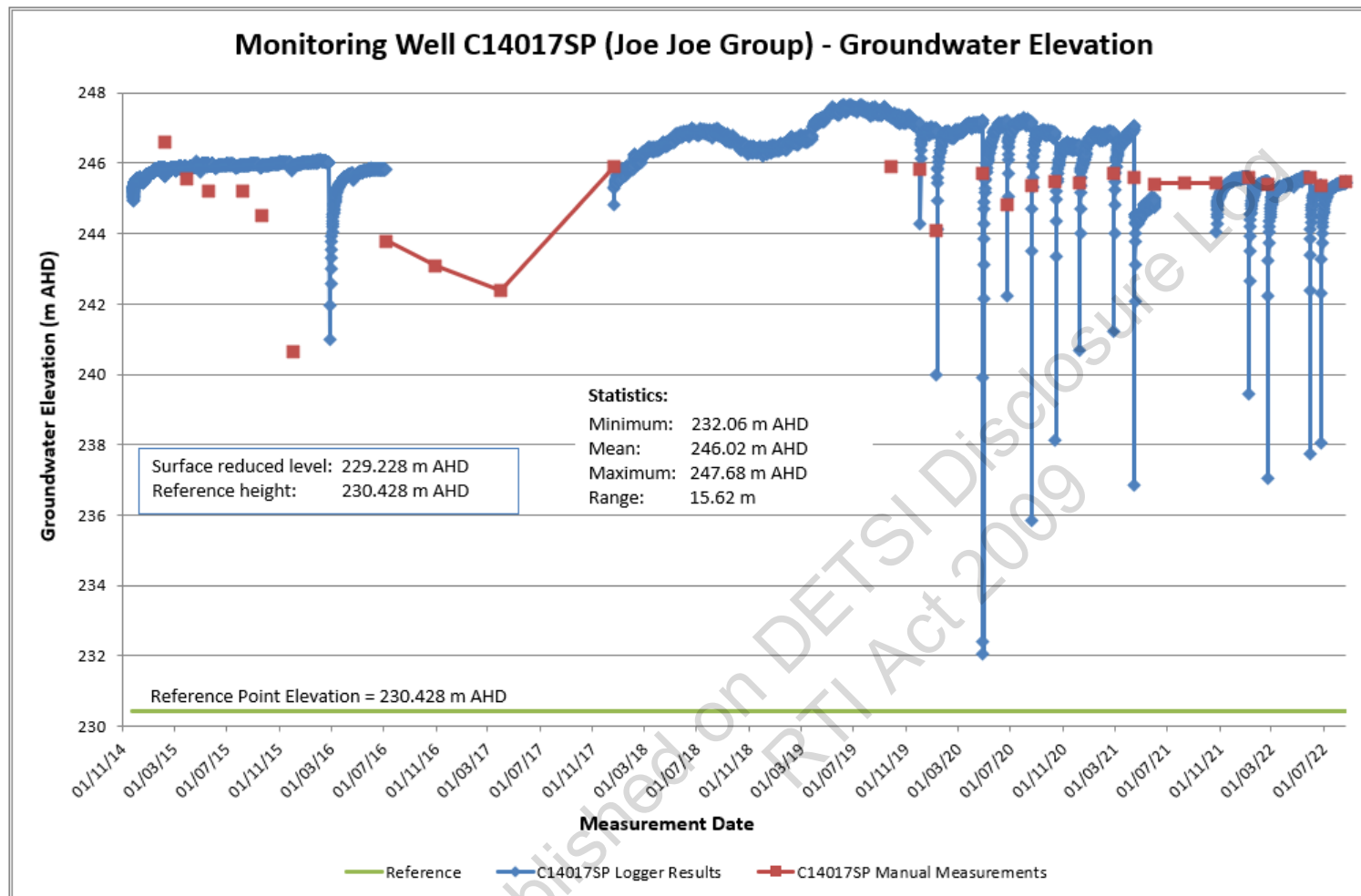


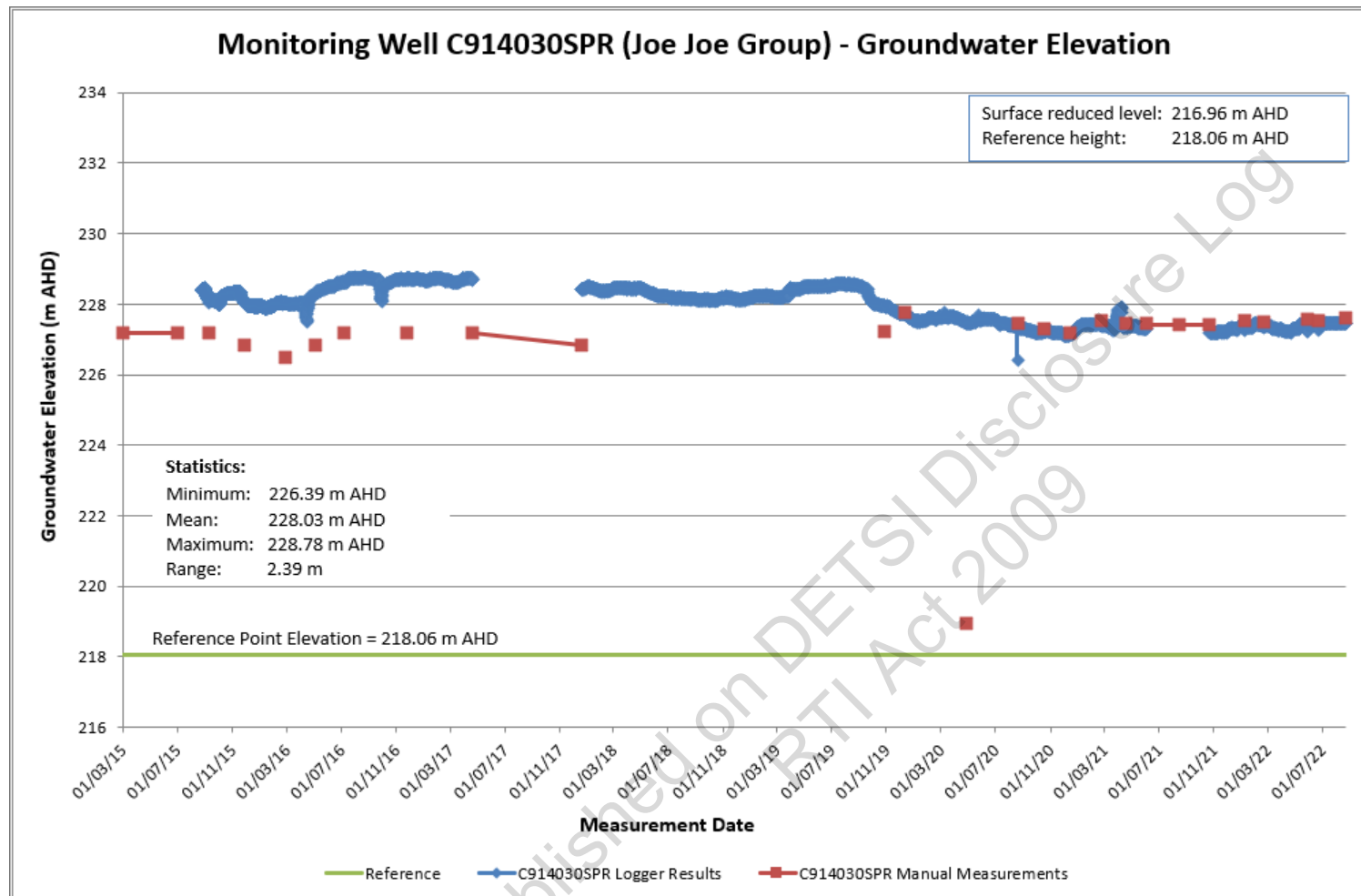


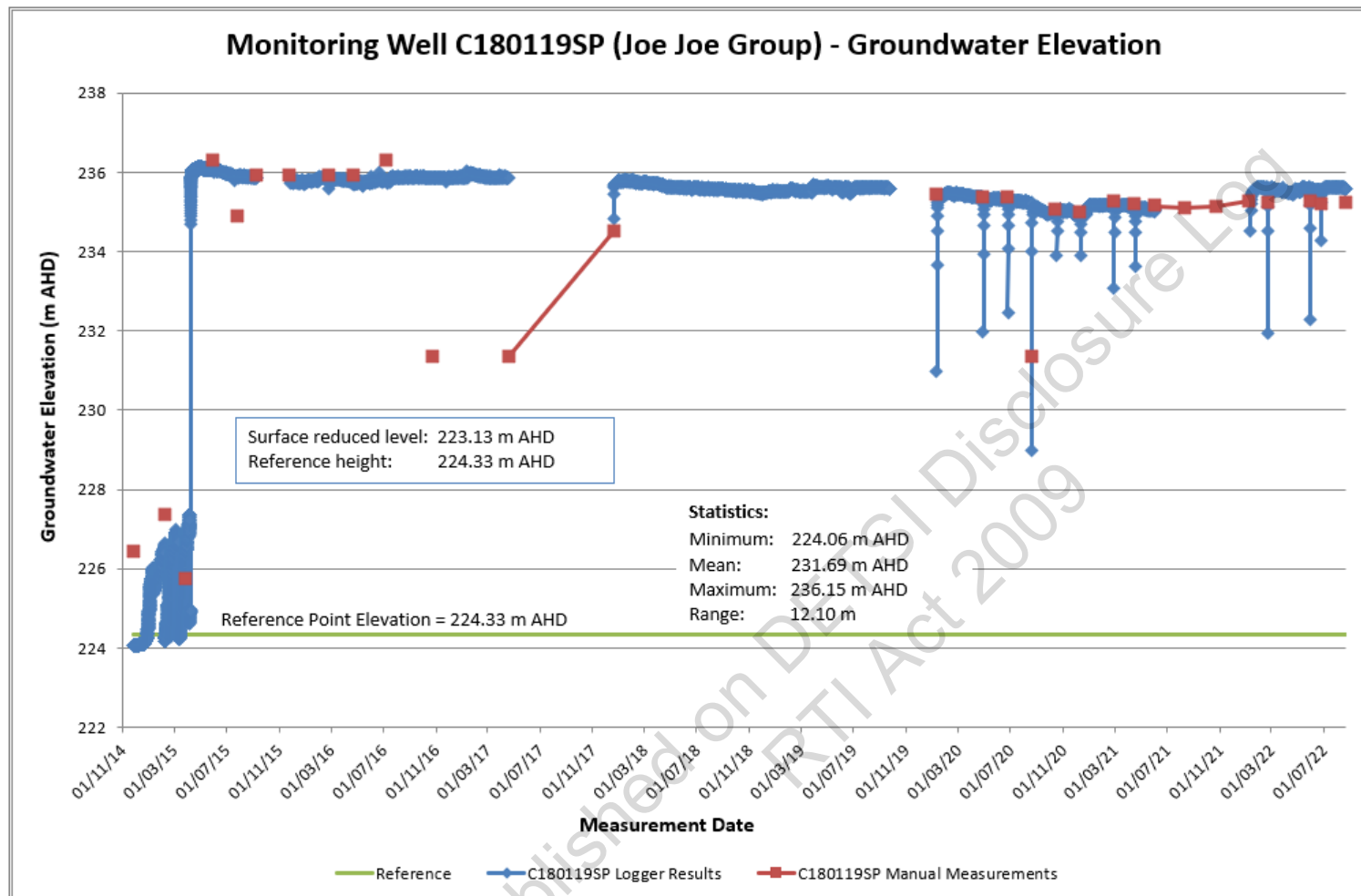


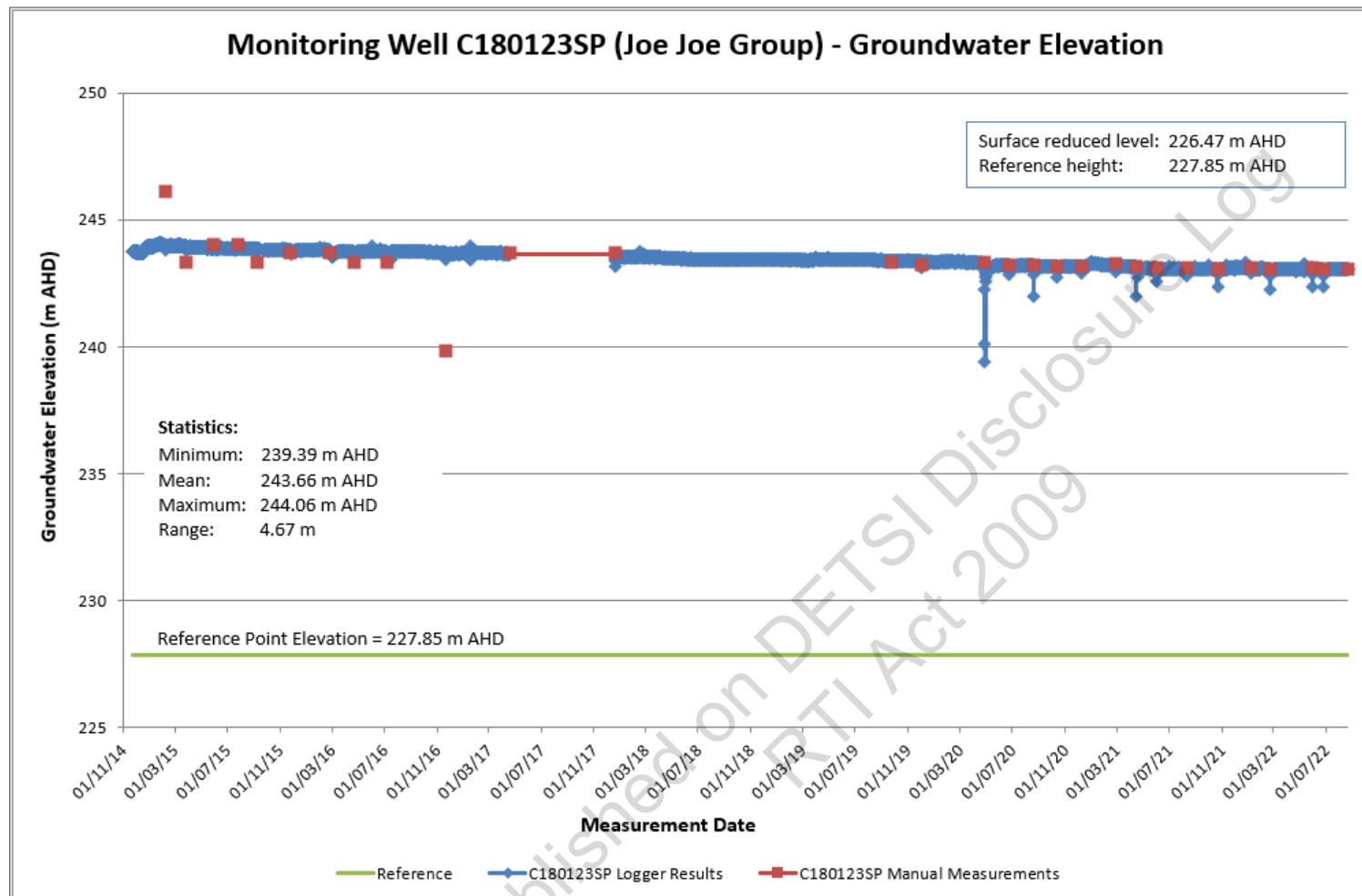


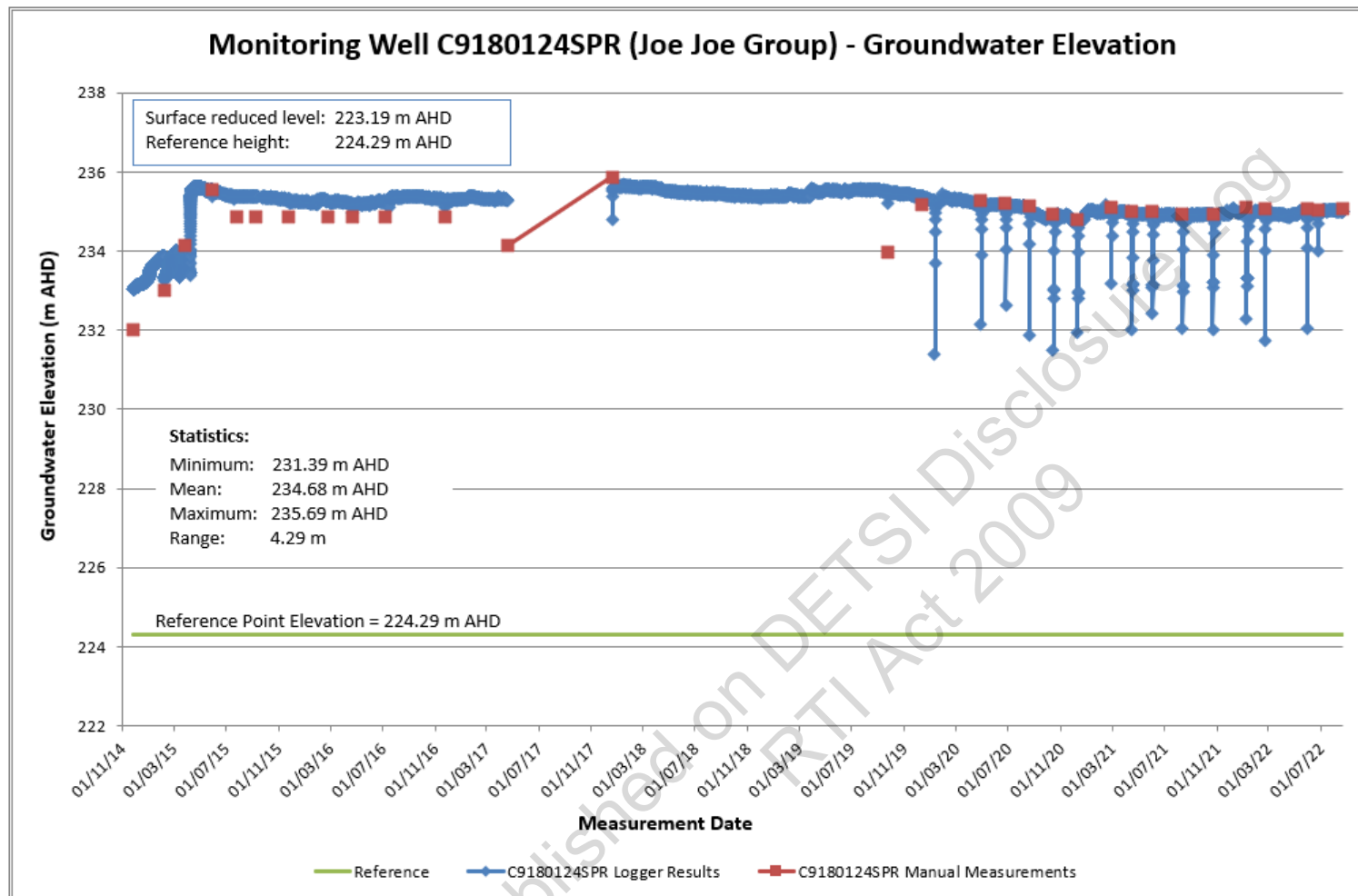


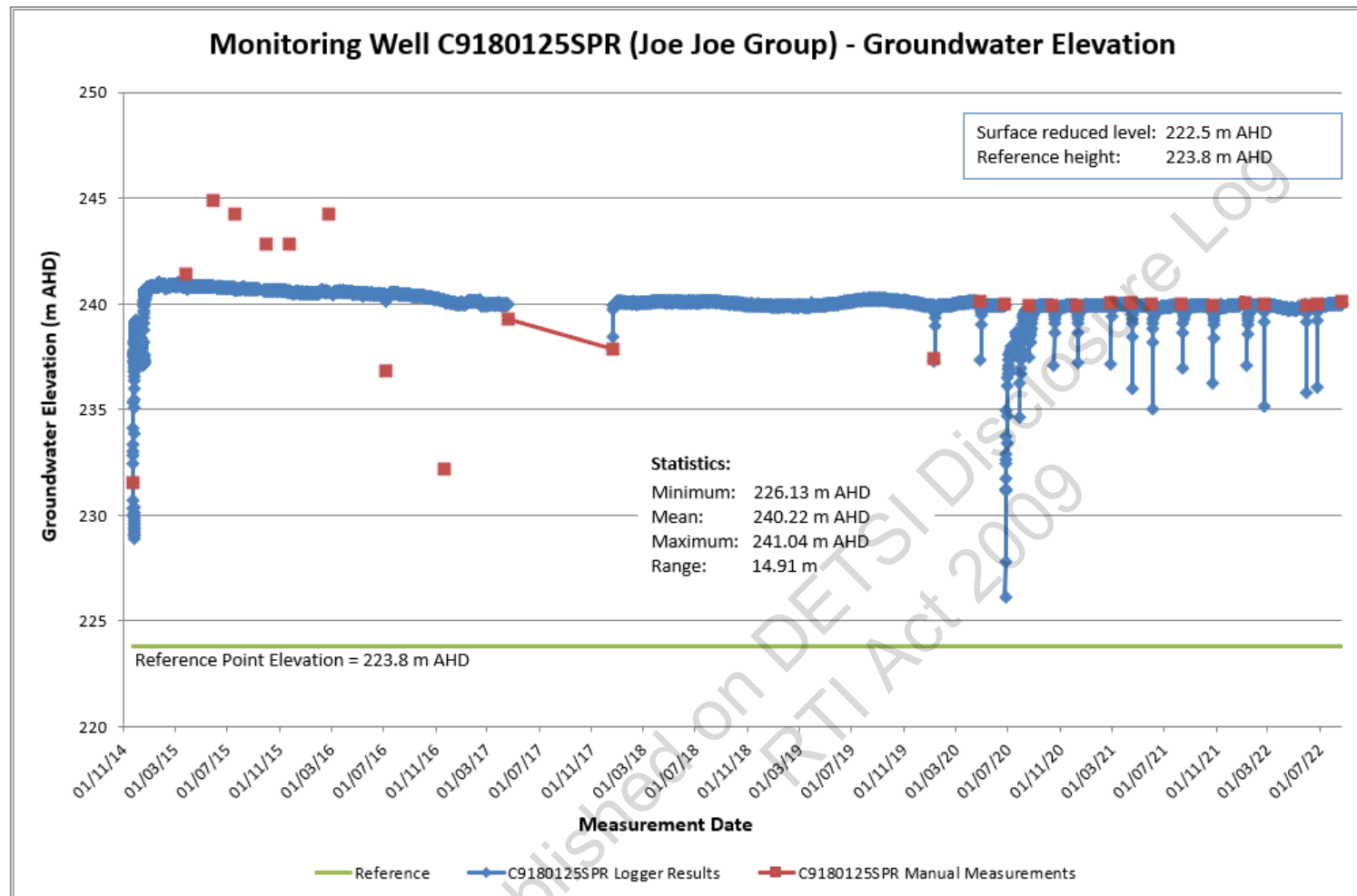












Appendix E

Revised contaminant limits

E.1 Alluvium

Table E.1 Revised alluvium contaminant limits

Analyte	C027P1	C029P1	C14027SP	C14028SP	C19001SP	HD03B
pH (field)	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0
EC (µS/cm)	7,400	34,308	51,076	45,800	27,039	922
TDS (mg/L)	4,438	21,208	39,728	33,040	16,386	607
Sulphate (mg/L)	547	1,100	2,228	2,000	890	14
Aluminium (µg/L)	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	17,975	1,356	4,418	1,929	60	1,565
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.26	0.66	0.26	0.11	0.75	0.21
Boron (µg/L)	857	5,700	3,142	3,458	2,196	198
Cobalt (µg/L)	17.4	12.9	94.0	25.4	1.4	1.4
Copper (µg/L)	184.9	145.2	173.1	88.9	3.0	8.7
Nickel (µg/L)	35.8	29.0	51.7	21.4	26.2	11.0
Zinc (µg/L)	105.8	323.5	347.0	192.7	11.9	22.8
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.2 Tertiary sediments

Table E.2 Revised Tertiary sediments contaminant limits

Analyte	C025P2	C029P2	C558P1	C9845SPR	C9180121 SPR	C18004SP	C18005SP	C18006SP	C18009SP
pH (field)	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.7 – 9.0	5.4 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0
EC (µS/cm)	15,000	12,900	10,040	2,000	3,938	40,882	53,479	61,573	26,076
TDS (mg/L)	9,000	7,735	6,729	1,262	2,556	37,765	48,460	54,458	24,192
Sulphate (mg/L)	467	320	278	67	100	815	2,522	3,046	976
Aluminium (µg/L)	55	55	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34	34	38.5
Selenium (µg/L)	11	11	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	20,298	1,631	888	50	608	130	208	812	80
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.39	0.19	0.10	0.43	0.10	0.10	0.48	0.10	0.10
Boron (µg/L)	1,737	1,300	890	370	370	1,518	5,122	6,024	1,368
Cobalt (µg/L)	1.4	1.4	5.0	1.4	1.4	1.4	17	14	1.4
Copper (µg/L)	62.9	29.9	1,069	223.7	1.4	1.4	206	1.4	1.4
Nickel (µg/L)	24.4	11.0	75.7	21.6	11.0	42.8	55	26.6	11
Zinc (µg/L)	42.3	1,123	189.8	156.9	11,136	8	369	8	75.9
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.3 Clematis Sandstone

Table E.3 Revised Clematis Sandstone contaminant limits

Analyte	C14011S P	C14012S P	C14013S P	C14021S P	C14033S P	HD02	HD03A	C18001S P	C18002S P	C19002S P
pH (field)	4.8 – 9.0	5.9 – 9.0	4.7 – 9.0	5.5 – 9.0	4.9 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	4.6 – 9.0
EC (µS/cm)	326	506	419	703	472	640	761	673	381	351.4
TDS (mg/L)	199	298	258	424	290	420	491	385	252	202
Sulphate (mg/L)	7	7	12	24	5	6	12	10.8	1	27.5
Aluminium (µg/L)	55	55	55	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	21	65	17	15	13	1,764	696	1,733	5	5
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.76	0.7	0.73	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.10	0.14	0.10	0.10	0.10	0.22	0.12	0.10	0.19	0.10
Boron (µg/L)	118	130	128	181	98	128	150	138	79	119
Cobalt (µg/L)	2.0	1.4	5.0	1.4	2.0	2.9	1.4	1.4	1.4	1.4
Copper (µg/L)	20.6	1.4	16	18.6	36.9	1.4	1.4	1.4	1.4	6.0
Nickel (µg/L)	11	11	12.6	11	11	11	11	11	11	11
Zinc (µg/L)	118.6	22	162.1	92.2	164.3	31.5	87.2	171.2	5	5
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.4 Dunda Beds

Table E.4 Revised Dunda Beds contaminant limits

Analyte	C022P1	C027P2	C14023SP	C180117SP	C19007SP	C19011SP	C19015SP
pH (field)	4.8 – 9.0	5.4 – 9.0	6.0 – 9.0	5.1 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0
EC (µS/cm)	384	959	752	395	1,418	804	714
TDS (mg/L)	226	913	445	238	824	541	414
Sulphate (mg/L)	17	28	3	21	30	1	1
Aluminium (µg/L)	608	135	55	67.1	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	44.9	34	34
Selenium (µg/L)	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	5	9,565	5	1,900	5	5	5
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.10	0.18	0.10	0.11	0.10	0.10	0.10
Boron (µg/L)	157	235	109	93	80	25	100
Cobalt (µg/L)	57.7	2.9	1.4	1.4	1.4	1.4	1.4
Copper (µg/L)	178.1	2.9	1.4	120.8	1.4	1.4	1.4
Nickel (µg/L)	11	11	11	50	11	11	11
Zinc (µg/L)	84.4	101.7	8	176.8	8	8	8
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.5 Rewan Formation

Table E.5 Revised Rewan Formation contaminant limits

Analyte	C008P1	C035P1	C555P1	C556P1	C9553P1R	C9838SPR	C919016SPR
pH (field)	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	4.9 – 9.0	5.4 – 9.0	4.6 – 9.0	6.0 – 9.0
EC (µS/cm)	22,986	4,210	861	291	558	460	838
TDS (mg/L)	17,060	2,896	555	233	356	278	507
Sulphate (mg/L)	281	64	1	13	61	9	27
Aluminium (µg/L)	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	3,737	397	1,954	117	4,010	27	5
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.37	0.74	0.10	0.46	0.50	0.10	0.10
Boron (µg/L)	1,743	812	287	127	138	150	58
Cobalt (µg/L)	15.4	1.9	2.0	6.0	1.4	1.9	1.4
Copper (µg/L)	58.9	1.4	1.4	59.2	91.4	17.8	1.4
Nickel (µg/L)	63.0	11.9	11	11	11	11	11
Zinc (µg/L)	112.5	126.0	33.8	267.2	74.2	118.9	36.9
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.6 Bandanna Formation

Table E.6 Revised Bandanna Formation contaminant limits

Analyte	C008P2	C014P2	C032P2	C035P2	C19027SP	C018P2	C847SP
pH (field)	6.0 – 9.0	6.0 – 11.7	6.0 – 9.1	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.21 – 9.0
EC (µS/cm)	3,310	1,966	1,533	1,559	1,790	1,759	365
TDS (mg/L)	1,920	1,098	923	1,157	1,019	1,028	264
Sulphate (mg/L)	98	47	3	20	27.9	8	8
Aluminium (µg/L)	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	130	356	318	2,080	5	558	5
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.17	0.29	0.60	0.06	0.10	0.10	0.10
Boron (µg/L)	307	406	385	289	540	589	130
Cobalt (µg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Copper (µg/L)	1.4	1.4	1.4	1.4	1.4	1.4	12.9
Nickel (µg/L)	11	30.4	11	11	11	11	11
Zinc (µg/L)	148.6	8.0	28.7	38.9	8.0	15.9	78.6
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

E.7 Colinlea Sandstone

Table E.7 Revised Colinlea Sandstone contaminant limits

Analyte	C006P3R	C011P3	C018P3	C024P3	C034P3	C833SP	C848SP	C975SP	C19029SP
pH (field)	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.7 – 9.0	6.0 – 11.3	6.0 – 9.0	5.3 – 9.0	tbd
EC (µS/cm)	1,281	1,028	1,064	1,719	2,295	1,385	3,000	616	tbd
TDS (mg/L)	764	644	686	1,145	1,260	838	1,876	396	tbd
Sulphate (mg/L)	9	1	16	23	45	11	21.8	28	tbd
Aluminium (µg/L)	55	55	55	55	55	55	55	55	tbd
Arsenic (µg/L)	13	13	13	13.7	13	13	13	13	tbd
Molybdenum (µg/L)	34	34	34	34	34	34	34	34	tbd
Selenium (µg/L)	11	11	11	11	11	11	11	11	tbd
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	tbd
Iron (µg/L)	433	794	922	20,514	3,343	65	1,965	99	tbd
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	tbd
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	tbd
Total Phosphorus (mg/L)	0.10	0.12	0.11	0.28	0.10	0.10	0.10	0.10	tbd
Boron (µg/L)	180	510	400	380	260	200	218	199	tbd
Cobalt (µg/L)	1.4	1.4	1.4	5.0	1.4	1.4	1.4	1.4	tbd
Copper (µg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	tbd
Nickel (µg/L)	11	11	11	74.5	11	11	11	11	tbd
Zinc (µg/L)	42.3	26.2	124.7	122.8	360.2	118.2	48.5	238.5	tbd
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	tbd
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	tbd

Notes: Contaminant limits for C19029SP to be determined when sufficient results are available.

E.8 Joe Joe Group

Table E.8 Revised Joe Joe Group contaminant limits

Analyte	C012P1	C012P2	C14003SP	C14006SP	C14008SP	C14015SP	C14017SP
pH (field)	5.5 – 9.0	6.0 – 9.0	4.8 – 9.0	6.0 – 9.0	5.3 – 9.0	6.0 – 9.0	6.0 – 9.0
EC (µS/cm)	2,097	2,689	53,905	8,700	709	2,680	7,000
TDS (mg/L)	1,359	1,786	49,764	5,372	427	1,600	4,200
Sulphate (mg/L)	59	55	2,881	247	15	70	130
Aluminium (µg/L)	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	165	1,519	19,491	8,200	4,507	634	596
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.31	0.10	0.10	0.10	0.10	0.22	0.10
Boron (µg/L)	477	540	4,362	547	136	430	830
Cobalt (µg/L)	1.4	1.4	38.8	1.4	11	5.9	3.0
Copper (µg/L)	1.4	58.6	924.9	1.4	1.4	1.4	1.4
Nickel (µg/L)	11.6	17.6	35.4	11	14	11	11
Zinc (µg/L)	179.8	33.3	208.5	390.5	229.6	150.8	641.1
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

Table E.9 **Revised Joe Joe Group contaminant limits**

Analyte	C14032SP	C180119SP	C180123SP	C914001SPR	C914030SPR	C9180124SPR	C9180125SPR
pH (field)	5.4 – 9.0	5.8 – 9.0	6.0 – 9.0	5.7 – 9.0	5.6 – 9.0	5.2 – 9.0	6.0 – 9.0
EC (µS/cm)	2,188	782	908	21,874	616	510	1,023
TDS (mg/L)	1,257	785	579	15,237	353	321	653
Sulphate (mg/L)	36	9	29	1,600	12	7	26
Aluminium (µg/L)	55	55	55	55	55	55	55
Arsenic (µg/L)	13	13	13	13	13	13	13
Molybdenum (µg/L)	34	34	34	34	34	34	34
Selenium (µg/L)	11	11	11	11	11	11	11
Silver (µg/L)	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Iron (µg/L)	2,228	2,923	405	10,769	834	158	212
Mercury (µg/L)	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nitrate as N (mg/L)	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus (mg/L)	0.10	0.18	0.10	0.10	0.10	0.10	0.10
Boron (µg/L)	180	179	398	2,100	129	108	310
Cobalt (µg/L)	1.4	1.4	1.4	1.4	8.9	2.0	1.4
Copper (µg/L)	1.4	1.4	1.4	1.4	1.4	4.9	3.9
Nickel (µg/L)	11	18.4	11	22.1	13.9	17	11
Zinc (µg/L)	398.1	11,644	8.0	302.4	318.6	788.4	509.5
TRH C6-C10 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR
TRH >C10-C40 (µg/L)	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR	>LOR

Appendix F

DES comments on draft GMMP review report

	Section	Review GMMP finding	DES recommendation	Response	Additional comment and relevant section of final GMMP review report
1.0	3.2.1 Groundwater Monitoring Locations	Three sites have been selected for additional Colinlea Sandstone (two bores) and Bandanna Formation (one bore) monitoring bores.	<p>This proposal is supported and it is considered that the additional sites are critical.</p> <p>However, it is considered that even with these additional monitoring bores there will still be deficiencies in the proposed network monitoring these formations. This issue and the proposed additional locations are discussed as follows:</p> <p>Colinlea Sandstone In order to better understand the propagation of drawdown from the mine towards the Doongmabulla Springs there should also be a Colinlea Sandstone monitoring bore on the western lease boundary in a location that won't be mined out. There should also be a standpipe bore in the area of C19031VWP as given the unreliability of the existing VWP bores there can be no guarantee that data from this VWP is representative of the Colinlea Sandstone.</p> <p>Bandanna Formation Similarly, there should be a Bandanna Formation monitoring bore on the western lease boundary in a location that won't be mined out.</p> <p>Colinlea Sandstone and Bandanna Formation</p>	<p>Additional monitoring bore locations will be added (see figure at the end of this response)</p> <p>There is a bore installed in bandanna formation (C19018SP) at this location. C19031 SP (VWP) is recording the pore pressure in Colinlea sandstone.</p> <p>See additional monitoring bore location map.</p>	<p>Figure 3.1 of the report has also been updated with the additional bore locations.</p> <p>Figure 3.1 of the report has also been updated with the additional bore locations.</p>

			<p>There is a proposal in section 3.2.1 to drill additional Colinlea Sandstone and Bandanna Formation monitoring bores south of the lease in the direction of Mellaluka Springs. This is supported but the proposal to treat this as a low priority, and delay until mining progresses south and impacts are noted in C19003SP and C19004SP, is not supported.</p> <p>Given the issues with local landholder use potentially impacting water levels in this area and the challenges in unpacking which stress is causing impact, the sooner baseline data is available from the proposed Colinlea Sandstone and Bandanna Formation bores in this area, the better.</p> <p>There are also concerns in both the Colinlea Sandstone and Bandanna Formation that there are sizeable gaps in the network in critical areas in the southern part of the lease area.</p> <p>In the Bandanna Formation there is a gap between C9839SPR (at 0.34 m/yr (table 6.6) almost considered impacted) and C034P1 which is some 5.6 km south of C9839SPR. Tracking this impact south will therefore soon become difficult.</p> <p>In the Colinlea Sandstone there is a gap between C840SP (most southerly monitoring bore considered impacted 0.47 m/yr</p>	<p>The existing bores in Bandanna formation are deemed to be sufficient to track the impacts to south side as there is one more bore C847SP further to the edge of ML in southside. The existing bores in Colinlea SSt formation are deemed to be sufficient to track the impacts to south side as there is one more bore C848SP further to the edge of ML in southside.</p>	
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			<p>(table 6.7)) and C034P3 which is some 5.8 km south of C840SP. Tracking this impact south will therefore also soon become difficult.</p> <p>Additionally, figure 3.1 shows Bandanna bore 823SP as an existing monitoring bore but it was mined out recently. This figure needs to be amended to provide an accurate understanding of the existing monitoring bores.</p>	The figure will be amended	Figure 3.1 of the report has also been updated and bore C823SP removed.
2.0	3.2.2 Groundwater quality trigger levels	<p>In this section the review states: <i>The contaminant limits in the GMMP should be updated using the same dataset as was used to develop the updated trigger values for consistency.</i></p>	It is recommended that the GMMP has consistent terminology with the environmental authority.	Contaminant limits will be updated in GMMP with additional data.	
3.0	3.2.3 Groundwater level thresholds	<p>This section discusses reassessment of groundwater level thresholds where logger cable lengths have been remeasured in some artesian bores and adjustments made to historical logger data. This work is supported.</p>	<p>However, there are other artesian bores where there still appear to be differences between the manually measured water level elevations and the logger data. A list of these bores has been provided below. How are these bores going to be investigated to determine the cause of this variation?</p> <p>Clematis Sandstone C18001SP C19014SP HD03A Dunda Beds C19011SP C19015SP Rewan Formation C19016SP Joe Joe C14017SP</p>	<p>The manually measured water level are consistent with logger data for bores C18001SP, C19014SP and HD03A (Clematis Sandstone), bores C19011SP and C19015SP (Dunda Beds), and bore C19016SP (Rewan Formation) (refer to figure at the end of report). The data for bore C14017SP (Joe-Joe) will be reviewed</p>	<p>Section 3.2.3 of the final GMMP review report has been updated. Water level thresholds have been updated in Table A.1, Appendix A based on an expanded baseline dataset for each bore. VWPs have been removed as water level threshold bores based on the low reliability of the VWP data. An additional five monitoring bores are recommended as water level threshold bores.</p>

4.0	3.3 Review of the validity of the groundwater monitoring program against the revised model predictions required under Condition E9	The heading in this section appears to be linked as much to E7(d) as it is to E9. It is recommended that E7(d) also be referenced. Noting that in Table 2.1 when discussing E7(d) reference is made to section 3.3 as to where the requirement is addressed. Otherwise, the wording in this section indicates that the review of the numerical groundwater model is to be completed by 10 October 2022 and a model review report issued before 10 January 2023.	There is no discussion as to when Bravus would be providing a review of the validity of the groundwater monitoring program against the revised model predictions. This GMMP review must identify when this will occur.	The validity of monitoring program will be updated after the modelling results are available	As per Section 3.3 of the final GMMP report, it is recommended that review of the validity of the groundwater monitoring program be undertaken separately following DES's review of the groundwater modelling report.
5.0	GMMP Commitment 2 - Augment the existing groundwater monitoring network over time to enable ongoing groundwater impact evaluations	The GMMP Review indicates that following recent drilling to augment the network, the status of this commitment is compliant.	However, previous concerns raised in reference to section 3.2.1 and the issue of adequate monitoring bores in the Bandanna Formation and Colinlea Sandstone, also apply here and should be included/discussed here. The low reliability of the groundwater data coming from the VWPs identified by both DES and the 2022 annual groundwater monitoring report must be discussed here and addressed as to the impacts this has on the reliability of the longer-term network and how the issue might be addressed.	Proposed monitoring bores are discussed at point #1 above	
6.0	GMMP Commitment 3 - Maintain and decommissioning of bores, according to industry standards, to ensure the	The GMMP Review considers that servicing of monitoring bores and equipment and decommissioning practices	However, there is concern that the data coming from the VWPs is not representative of the aquifers.	VWP data will be used for trend assessments only and will not be used for water level thresholds	

	management of groundwater resources and the collection of representative groundwater monitoring data	employed, result in the status of this commitment being compliant.	The issue being that DES does not consider that the VWP's are being maintained to collect representative groundwater monitoring data. This issue must be discussed and addressed.		
7.0	GMMP Commitment 5 - Detail all automatic water level loggers (model, setting, and setting information), including the depth of installation within the artesian bore headworks	The GMMP Review considers the work carried out to measure logger position and cable lengths in a number of artesian bores has resulted in the status of this commitment being met. It is agreed that the work done to this point has resulted in much better correlation between logger data and manual readings in many of these bores.	However, as discussed in response to section 3.2.3 there may still be some artesian bores where cable lengths may still be causing a discrepancy. These issues must be investigated.	Cable lengths for all artesian bores is measured and hydrographs are updated.	Section 3.4.5 of the final GMMP review report has been updated as cable length adjustments have now been corrected in the updated water level thresholds provided in Table A.1, Appendix A and hydrographs in Appendix B.
8.0	GMMP Commitment 8 - Monitor the recently installed (2018) shallow seepage groundwater monitoring bores, prior to construction of mine affected water and waste storage facilities	The review report identifies the six bores and states that water quality data has been collected for all six bores but then says that two have been dry since they were drilled.	This should be reworded to say water quality has been collected from four only because the other two are dry.	The report will be amended with correct number of bores.	Section 3.4.8 of the final GMMP review report has been updated.
9.0	GMMP10 – Boundary Bores - Install five additional bores on the eastern boundary of mining lease, as recommended by DES, to develop additional baseline data for the alluvium and Tertiary sediments in this area so as to allow for the assessment of any possible migration of contaminants to the east of the mine lease	The review states: Status: This commitment has been met. Bravus installed five boundary bores (C19019SP, C19020SP, C19021SP, C19022SP and C19023SP) (see Table 3.3) to develop additional baseline data for the alluvium and Tertiary sediments in this area. Monitoring of these bores will allow for the assessment of any possible migration of	However, it is noted that four of the five bores are dry. Provide a discussion and the implications of this.	Bores were installed to base of Tertiary or alluvium. Three bores (C19020SP, C19021SP and C19023SP) have been dry since installation. C19019SP was dry up to Feb 22 and has standing water since then. C19022 has always contained water. The fact that some bores are dry indicates that there is no groundwater present within alluvium or	

		contaminants to the east of the mine lease.		Tertiary sediments at those locations. Bores are suitably located to detect any seepage from mine water/waste storage facilities should that occur.	
10.0	GMMP 14 - Additional bores monitoring the Dunda Beds, Rewan Formation, and Permian Betts Creek Beds (which includes the Bandanna Formation and Colinlea Sandstone) will be installed within one year of commencement of mining operations at three locations co-located as far as practicable within 500 m of existing Clematis Sandstone monitoring points as follows: HD02, HD03A, and C14011SP including one bore within the vicinity of the Doongmabulla Springs Complex	The review states: Status: This commitment has been met. Installation of these additional bores was completed in 2020. Bore details are provided in Table 3.3.	This does not appear to have been achieved as there are no Permian bores at two of the sites. Please review the status and discuss. HD02 area (RN158092) C19014SP (Clematis) (190276) C19015SP (Dunda) (192078) C919016SPR (Rewan) (190277) C19018SP (Bandanna) (190229) C19031PT (VWP) (Colinlea) (190605) HD03A area (RN158036) C19010SP (Clematis) (190199) C19011SP (Dunda) (190279) C19012SP (Rewan Shallow) (190280) C919013SPR (Rewan Deep) (190607) C14011SP area (RN158883) C19007SP (Dunda) (190275) C19008SP (Shallow Rewan) (190274) C19009SP (Deep Rewan) (190198)	The commitment provided in GMMP Chapter-6 has got the list of approved additional monitoring bores (Table -63). Braus installed all the bores provided in GMMP>	
11.0	GMMP Commitment 16 - For all new bores, to be drilled after the compilation of the initial GMMP, a minimum of 12 datasets over 24 months, will be collected prior to developing groundwater level thresholds and water	The review report states that water quality triggers for new bores will be developed in consultation with DES when at least eight water quality results have been collected for each bore.	This appears to contradict the commitment which states 12 datasets. This should be reviewed and explained. This commitment also appears to contradict commitment 18 where it	Page 18 of DES (2021) 'Using Monitoring data to assess groundwater quality and potential environmental impacts' states that percentile estimates based on eight	

	<p>quality triggers for discussion with DES for inclusion in future iterations of the GMMP</p> <p>All new bores will be assessed against the water quality triggers developed for each hydrostratigraphic unit until (and if required) bore specific triggers are developed</p> <p>All new bores will be installed as soon as possible so as to compile additional groundwater data to inform the conceptual model and the refinement of the model as required in Condition E4a and E6</p> <p>Any consideration of revising the groundwater level thresholds, based on new data acquired, must assess the potential impacts of the revised groundwater level thresholds on GDEs.</p>		<p>appears to indicate that a minimum of 8 measurements can be used to develop water quality triggers.</p> <p>DES recommends 12 datasets.</p>	<p>samples can be used to derive site-specific triggers. Table 51 of the GMMP also states that 85th percentiles can be calculated with at least eight results greater than the LOR.</p> <p>Feedback provided to Bravus by DES during water quality trigger review during 2021 "It is suggested that a condition be included in the EA to provide values after 8 samples have been collected"</p> <p>The response to GMMP commitment 16 refers to the minimum requirement of eight samples as per Table 51 and advice received by DES.</p>	
12.0	<p>GMMP Commitment 19 - Assess groundwater, surface water, and springs using isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation</p>	<p>The review states: Status: Compliant. <i>Bravus commenced assessment of groundwater, surface water, and springs using major elements, trace elements and isotope tracers to aid in the assessment of water quality results and groundwater conceptualisation in</i></p>	<p>There was significant discussion of this issue at the draft conceptualisation report stage in early 2022 between DES and Bravus. There was concern by DES that there is no indication as to which springs were sampled. As previously advised DES is concerned that the varying water quality across the springs is not</p>	<p>This is noted. Bravus will provide an update of the isotope results separately which will include assessment of individual spear points.</p>	

		<p>2018/2019 and again in February 2021. Results of the isotope tracers are included in EMM (2021b) and were discussed in the previous GMMP review (EMM 2021a). No additional studies have since been undertaken.</p>	<p>being adequately compared to that in the spears and that in the bores in the various aquifers. It was considered that a more detailed approach looking at one spring at a time would provide more useful results ensuring the source of spring groups can be confirmed. Bravus responded to this with some additional information, but this will need to go in the updated conceptualisation report. There needs to be discussion as to how this has been dealt with in the updated conceptualisation report.</p>		
13.0	<p>GMMP Commitment 23 - Include in the review of the GMMP an assessment of groundwater level and water quality data, and the suitability of the monitoring network, as per Condition E5. The GMMP will be reviewed by a suitably qualified person with a report on the outcome of the review to the administering authority by 1st July 2021. After the initial review, the review must be completed within three months of the second anniversary date of commencing box cut excavation and every 5 years following</p>	<p>The review considers the status of this commitment to be compliant.</p>	<p>However, as with the response to commitment 3 there are issues with the reliability of the data from the VWP's that are not dealt with in the response to this commitment.</p> <p>The assessment in the annual groundwater monitoring report of the water level data from the VWP's being of low reliability should be included in discussions.</p>	<p>VWP bores showing consistent and reliable data are included in the monitoring network. These VWP bores data is not used to develop any groundwater level thresholds. The VWP data will be used for comparison of water level trends and any future responses to de-pressurisation</p>	
14.0	<p>GMMP Commitment 24 - The results of research plans, inclusive of the GAB Springs Research Plan and Rewan Formation Connectivity Research Plan, will be incorporated into the next</p>	<p>The GMMP review considers the status of this commitment to be compliant as information from the completed research plans has been used to develop a revised hydrogeological understanding</p>	<p>However, following the DES review of the draft conceptualisation report in April 2022, DES requested copies of all available research plan reports. No additional research plan reports</p>	<p>Bravus will provide copies of research plan reports.</p>	

	iterations of the numerical model review and GMMP (within two years of box cut and every five years after that)	which has then been used to develop the updated groundwater model.	have been provided to DES since that time. When will this occur. Provide copies of all relevant results and research plans inclusive of GAB Springs Research Plan and Rewan Formation Connectivity Research Plan to DES.		
15.0	GMMP Commitment 25 - Two existing surface water flow monitoring stations CAR04 and CAR01 will be serviced to make them operational. An additional two stream flow gauging stations, one between the Doongmabulla Springs and the western edge of the mining lease, the other downstream of the eastern edge of the mining lease and upstream of the Belyando River confluence, will be installed. These surface water monitoring locations will allow for identification of impacts on the Carmichael River and associated GDEs	The GMMP review considers the status of this commitment to be compliant.	However, there is some confusion with the reference to the additional stream flow gauging station between the Doongmabulla springs and the western edge of the mining lease. In the response to this GMMP commitment it is called Doongmabulla station. However, in section 3.4.42 it seems to be referred to as Moray West. There needs to be clarification and consistency.	The new gauging station is installed between Doongmabulla springs (not Doongmabulla station) and western edge of ML and is refereed as Moray west gauging station.	Section 3.4.25 of the final GMMP review report and figures 3.3 and 3.4 have been updated to reflect correct name of the Moray West gauging station.
16.0	GMMP Commitment 26 - Adani commits to incorporate the following in the groundwater model re-run: (Not copied in full here).	The review report states: Status: Compliant. In accordance with EA Condition E9, EMM is currently undertaking a review of the numerical groundwater model to be completed by 10 October 2022, with the model review report to be issued before 10 January 2023. The issues raised in GMMP commitment #26 will be addressed in the model review report.	The report notes the status as compliant however DES cannot accept that status until the model report has been reviewed and approved.	Ok Noted. The commitments were included in the updated conceptualisation report. The modelling results will be provided with Numerical Groundwater model report.	Section 3.4.26 of final GMMP review report has been updated to note that commitment 26 is pending DES review of updated groundwater model.

17.0	<p>GMMP Commitment 29 - The GMMP review will be conducted by 1 July 2021 (or any other time frame as agreed with DES so as to align the GMMP review and model re-run to happen concurrently). The revised GMMP will include statistical analysis of hydrochemistry and groundwater quality data</p> <p>The next iteration of the GMMP (after 2 years of commencement of box cut excavation) will provide piper plots of the major ions for all hydrostratigraphic units included in the EA Conditions (Condition E3a), representative DSC springs, and the Carmichael River surface water</p> <p><u>Contaminant triggers and limits</u> will be updated when additional statistically sufficient pre-operational hydrochemistry data are collected. It is noted that several monitoring bores do not currently have the required number of analyses to calculate baseline trigger values and are using generic triggers derived from the ANZECC guidelines or average of bore specific data. Additional hydrochemistry results, allowing for the revision of trigger values, will be conducted according to the approach detailed in Section 5.4.</p>	<p>The GMMP review report considers the status of this commitment to be compliant.</p>	<p>It is noted that the EA no longer refers to contaminant triggers or limits. It uses the term water quality trigger levels. It would appear that a recommendation of the GMMP review should be to update the wording in this commitment to be consistent with EA wording.</p> <p>Additionally in the review in response to this commitment it states: <i>It is recommended that contaminant limits be updated using the same dataset that was used to derive the updated trigger levels. These updated contaminant limits are presented in Appendix F and should be included in the next iteration of the GMMP.</i> Appendix F should be reviewed. If appropriate the heading in Appendix F may need changing from revised contaminant limits to water quality trigger levels.</p>	<p>Contaminant levels will be reviewed and updated in the next GMMP revision.</p> <p>Water quality triggers and contaminant limits are two separate values - the groundwater quality trigger levels (which appear in the EA) and the contaminant limits, which were derived and shown only in the GMMP. The contaminant limits were developed in the GMMP on the recommendation of DES. These values represent the 99th percentile values of the baseline dataset and are to be considered when assessing for potential environmental harm. Currently, they form part of the Stage 1 investigations undertaken when groundwater quality trigger levels are exceeded for two consecutive monitoring events. Contaminant limits did not appear in the previous EA and appear in the GMMP only as a tool for assessing environmental harm.</p>	
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	During GMMP review and groundwater model re-run consideration of potential impacts to relevant GDE's will be included when considering revision of trigger values.				
18.0	GMMP Commitment 30 – Investigate all groundwater-based complaints and maintain a complaint register. The register will be made available to the regulating authority upon request.	The response here is: Status: Compliant. <i>Bravus will maintain a compliant register for the life of the project and will be made available to the regulating authority upon request.</i>	However, it should also be clarified if any complaints have yet been received.	No complaints were received on groundwater till date.	Section 3.4.30 of the final GMMP review report has been updated.
19.0	GMMP Commitment 36 – Should groundwater monitoring indicate exceedance of any or all of the groundwater level thresholds and / or water quality trigger levels then DES will be notified via WaTERS and an investigation will be instigated and the investigation report will be made available to the administering authority within the time specified in EA conditions E10 and E12 for groundwater quality trigger exceedances and E13 and E14 for groundwater threshold level exceedances respectively.	The GMMP review considers this commitment to be compliant.	However, it would seem that these EA conditions referenced in this commitment are no longer accurate (perhaps because of a change to the EA). This report should therefore recommend a change to the wording in this commitment in line with the current EA. At the moment it does not.	The commitment will be updated based on the wording in the current EA.	
20.0	GMMP Commitment 38 – Should any or all the groundwater level impact thresholds be realised, through the assessment of groundwater monitoring data and comparison to model	The GMMP review considers this commitment compliant.	Perhaps the wording of this commitment should be reviewed. What does 'groundwater level impact thresholds realised' mean.	The wording of this commitment will be amended in the GMMP revision to be consistent with EA conditions.	

	<p>predictions, then an appropriately qualified person will complete an investigation into the potential for environmental harm (MSES and MNES) and will provide a written report to the regulator as per the conditions. In the event of exceedances of threshold levels on MNES Adani will take the following actions:</p>		<p>Does it mean that thresholds have been exceeded and mining found to be the cause? If so, should there be a recommendation to amend the wording to make the intent clearer.</p>		
21.0	<p>GMMP Commitment 40 - Conduct regular groundwater monitoring bore assessments and maintenance (where required) as well as ensuring dry or damaged bores (as a result of mining activities) are decommissioned according to the latest editions of the Minimum Construction Requirements for Water Bores in Australia, 4th Edition (NUDLC, 2020) and the Minimum Standards for the Construction and Reconditioning of Water Bores that Intersect the Sediments of Artesian Basins in Queensland (DNRME, 2017).</p>	<p>The report at the moment states: Status: Compliant. Regular groundwater monitoring bore assessments and maintenance will be carried out by the qualified personnel deployed by the monitoring contractor. Bravus has followed the bore construction standards as mentioned above while constructing additional bores.</p>	<p>However, the review must provide detail about how Bravus is carrying out regular groundwater monitoring bore assessments and maintenance.</p>	<p>The details of bore maintenance summary will be included in the annual groundwater report.</p>	<p>Section 3.4.40 of the final GMMP review report has been updated to include bore maintenance summary in annual monitoring report.</p>
22.0	<p>GMMP Commitment 41 - As the proposed threshold values are reliant on predictions from the numerical groundwater model, to be updated within two years of the box cut excavation then every five years subsequently, Adani will compare the actual measured groundwater level data to predicted drawdown to assess the rate of change. In</p>	<p>The response in the review report is: Status: Observed groundwater level data collected to date has been used to calibrate the updated groundwater model which is currently being developed. <u>Discrepancies between actual and predicted drawdown in monitoring bores to date is a</u></p>	<p>The point being made here is not clear. It would have been thought that in the current model update there would also be a focus on the stresses occurring during mining. The wording should be clarified here.</p>	<p>Noted. Current predictions assumed commencement of mining as the 'zero' time step rather than dewatering which commenced 1 year before box-cut, therefore comparisons between predicted drawdown and observed drawdowns to date have been assumed to be preliminary.</p>	

	<p>the instance the drawdown rate of the actual data is steeper/ faster than the predicted rate, an investigation will be commenced into the cause of the drawdown rate change.</p>	<p><i>focus for transient recalibration efforts to actual pre-mining dewatering stresses. Groundwater drawdown predictions will be updated as part of the updated groundwater model. These updated predictions will be compared against observed water levels during future reporting to assess the rate of change. Investigations will be undertaken in cases where it is found that the actual drawdown exceeds the drawdown predicted by the groundwater model.</i></p>		<p>Predicted versus observed drawdowns are provided in Section 9 of the 2022 Annual Groundwater Review Report.</p>	
23.0	<p>GMMP Commitment - Springs, GDE and Baseflow Commitments</p>	<p>A commitment within this section is: Adani will investigate drilling into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information if required under relevant research programs. The response in the report is: Status: Compliant. <i>Bravus installed an additional monitoring bore (C19031SP-VWP) into deeper Permian age units for the purpose of acquiring data for monitoring purposes and to capture information required under relevant research programs.</i></p>	<p>It is agreed/ considered that the drilling of C19031VWP and C19018SP (Bandanna standpipe monitoring bore) and C19842C (deep bore providing lithology down to the Colinlea) have partially addressed this commitment.</p> <p>However, there are concerns about the quality of water level data available from C19031VWP and it is noted that commitment 14 to drill monitoring bores into the Permian Betts Creek Beds (Bandanna and Colinlea) at three identified locations adjacent the Doongmabulla Springs, has only partially been met.</p> <p>These issues should be addressed in this response.</p>	<p>Commitment #14 has been fulfilled as per list of bores provided in table 63 of GMMP. Additional monitoring bores will be installed between the ML and DSC (refer to figures provided at the end of this review)</p>	<p>Figure 3.1 of the final GMMP review report has also been updated with the additional bore locations.</p>

24.0	DES Recommendation 2 - Increasing trends in groundwater quality may provide early warning of triggers being approached and should be discussed in the GMMP review report	The response to this issue states: <i>Bi-monthly reporting and investigations of water quality trigger exceedances with comparison to changing groundwater levels has been conducted according to EA conditions E12 and E15, under the guidance of the GMMP. A thorough annual review (EMM, 2022b) has also been undertaken according to EA conditions E18 and E19 which review these trends. The trigger exceedances investigations have indicated that variations in water quality are likely to be natural, rather than as a result of site activities.</i>	E15 relates to groundwater level thresholds. Please review the response to this recommendation.	Noted. Water quality reporting requirements are detailed in EA conditions E12, E13 and E14. GMMP Review Report will be updated accordingly.	Section 3.5.2 of the final GMMP review report has been updated to reference the correct EA conditions.
25.0	DES Recommendation 5 - The GMMP review report should provide piper plots of major ions for all hydrostratigraphic units and recommendations about revisions to the conceptual model (including isotope tracer results).	The review response states: <i>Piper plots of major ions for all hydrostratigraphic units were included in the previous GMMP review which was submitted to DES in June 2021 (EMM 2021a). Updated piper plots for each hydrostratigraphic unit are included in the bi-monthly water quality exceedance reports. A discussion of isotope tracer results collected as part of the GAB Springs Research Plan are included in EMM (2021b). <u>These isotope tracer results have been used to revise the updated conceptualisation report which has previously</u></i>	The underlined response is true, but this was a draft which DES has made comment on. It should be stated in here that an updated version will be provided as part of the model review report prior to 10 Jan 2023. There remain concerns about whether enough information is provided on the individual springs.	The conceptualisation report will be provided to DES. Bravus will provide an update of the isotope results which will include assessment of individual spear points.	

		<i>been submitted to DES (EMM 2022a).</i>			
26.0	DES Recommendation 6 - Detail isotope tracer studies used to characterise the groundwater dependent ecosystems		DES has the same concern here as stated in regard to DES recommendation 5.	Refer to response above point #25	
27.0	Section 4 GMMP review recommendations	The review states: <i>An additional monitoring bore within Colinlea Sandstone between C19026SP and C19031VWP to track future propagation of dewatering impacts in the Colinlea Sandstone between mining and the DSC. It is recommended that this bore be installed adjacent to existing Clematis Sandstone bore C14012SP/C14013SP.</i>	This location is supported, but problems remain. There should also be a Colinlea monitoring bore on the western lease boundary in a location that won't be mined out. There should also be a standpipe bore in the area of C19031VWP given the unreliability of the VWP bores, there can be no guarantee that data from this VWP is representative of the Colinlea.	Additional monitoring bores will be installed between the ML and DSC (refer to figures provided at the end of this review)	Figure 3.1 of the final GMMP review report has also been updated with the additional bore locations.
28.0		The review also states: <i>An additional monitoring bore with Bandanna Formation between C008P2 and C19018SP to track future propagation of dewatering impacts in the Bandanna Formation between mining and the DSC. It is recommended that this bore be installed adjacent to existing Clematis Sandstone bore C14012SP/C14013SP.</i>	This location is supported but there should also be a Bandanna monitoring bore on the western lease boundary in a location that won't be mined out.	Additional monitoring bores will be installed between the ML and DSC (refer to figures provided at the end of this review)	Figure 3.1 of the final GMMP review report has also been updated with the additional bore locations.
29.0		The review states: <i>Additional monitoring bores within Bandanna Formation and Colinlea Sandstone in the</i>	Some additional information on timing would be helpful. Given the issues with local landholder use potentially impacting water levels	Refer to response at point#1 above	

		<p><i>vicinity of Mellaluka Springs to allow for detection of dewatering impacts near Mellaluka Springs and to improve the understanding of any connection between the Colinlea Sandstone and the Tertiary sediments and Joe Joe Formation. Installation of additional bores between the mining lease and Mellaluka Springs is considered low priority and could be delayed until mining progresses south and impacts are noted in C19003SP and C19004SP.</i></p>	<p>in this area and the challenges in the unpacking of what stress is causing impact, the sooner baseline data is available from the proposed Colinlea and Bandanna bores, the better.</p> <p>Additionally, the additional drilling of monitoring bores that is still required under commitment 14 should be discussed.</p>		
30.0		<p><u>Groundwater Level Thresholds</u> The review states: <i>Reassess baseline average groundwater level elevations and natural fluctuations for each bore incorporating all representative logger data (where available) before commencement of dewatering. Consider further extending baseline period for monitoring bores which have not been impacted by dewatering to date. Currently, only groundwater level data collected up to 2017 is considered in the baseline dataset. Extending the baseline period will allow for better representation of natural climatic variations in water level.</i></p>	<p>In relation to the underlined sentence, it would be helpful to have the predicted existing impacts from the model to compare with the manual assessments already carried out to gain confirmation of which areas are clearly unaffected by mining at this time.</p> <p>There should also be discussion of the low reliability of the water level data from the VWP's and the suitability of these bores to be used as groundwater level threshold bores.</p>	<p>Noted. This will be undertaken as part of the GMMP update.</p> <p>Data from VWP's will not be used to develop groundwater level thresholds.</p>	<p>Updated water level thresholds are included in Table A.1, Appendix A of the final GMMP review report.</p> <p>Section 4 of the final GMMP review report has also been updated to recommend use of the updated water level thresholds and monitoring bores.</p> <p>Section 4 of the final GMMP review report has also been updated to recommend a review of the validity of the groundwater monitoring program against the revised model predictions. It is recommended that this be undertaken following DES's review of the groundwater modelling report and results.</p>

31.0		<p><u>Groundwater quality triggers</u></p> <p>The review states: <i>The contaminant limits in the GMMP should be updated using the same dataset as was used to develop the updated trigger values for consistency.</i></p>	Refer to water quality trigger value as per EA wording	Contaminant limits will be updated in the next GMMP revision	
Review of Annual Monitoring Report – June 2022					
This review focuses specifically on groundwater level monitoring and presentation of metered water use data from the dewatering bores.					
Section		Comments			
<u>Section 4 Mine Construction and dewatering</u>		<p>Metered water take – there is only a graph showing combined monthly water use from all 27 bores. DES requires a spreadsheet showing monthly water take from each bore, identified by number. There should also be a map showing the locations of these bores by number. Given that some work has gone into identifying what take is from what geologic unit there should also be a table showing which geologic unit each bore is taking water from.</p>		<p>Monthly water take data is provided as an attached spreadsheet.</p> <p>Figure showing dewatering bore locations is proved below.</p>	
<u>Review of Section 6 tables</u>		<p>The process of reviewing the water level data in the monitoring bores and VWPs is similar to what occurred in the draft conceptualisation report and is considered a useful exercise to analyse the data and better understand likely dewatering impacts at this point in time.</p> <p>Some comments on the process are provided as follows:</p> <p>In each table, each bore is ranked as having a high, medium or low water level trend reliability. Information is provided in section 6.1 as to what constitutes these various rankings but there are no comments in the tables against the individual bores to provide understanding as to why the data from one bore might be high and another medium. This would be useful particularly in the high and medium categories.</p>		<p>As per Section 6.1, a high confidence was assigned to bores which had a near-continuous time series record for pre-dewatering and during-dewatering, and a medium confidence where there were some gaps in the monitoring record but where the gap did not compromise the overall integrity of the trend (ie could identify the overlying background trend). It is recognised that this assignment is</p>	

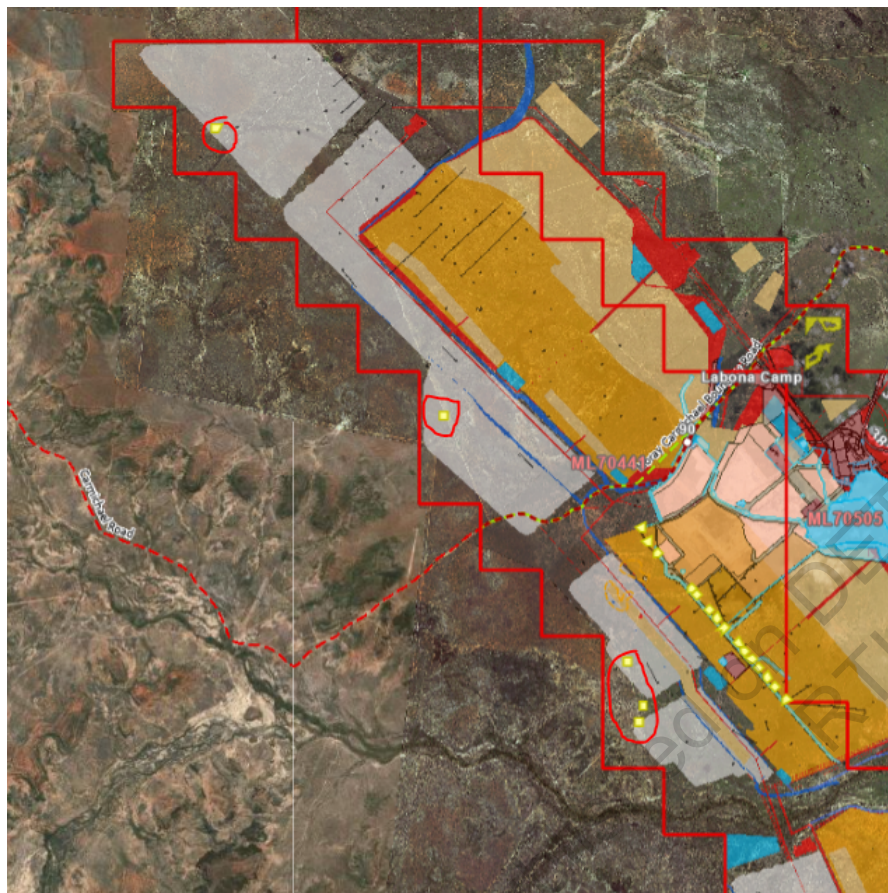
			<p>somewhat subjective, also taking into account comparison between manual measurements and logger data.</p> <p>The main takeaway is that both high and medium confidence bores have been deemed suitable to assess groundwater trends.</p>	
	VWPs - General	<p>The water level trend reliability in all the VWPs is treated as low. That assessment is supported. However, the data from most of the VWPs are then used to determine if the probe is impacted by dewatering. Perhaps there should be a footnote that is linked to the VWP assessments of dewatering impact in the tables which says something like, 'given the low reliability of the water level trend, to be used as a guide only'.</p> <p>Where VWPs indicate a difference between pre and during dewatering water level decline of greater than 0.4 m/yr they are investigated further given the low reliability of their water level trend. This approach is supported, although the practice of using data from one low reliability VWP to determine if data from another VWP is likely to be correct, is not supported.</p>	Noted	
	<p>Table 6.8 Joe Joe – C14017SP</p> <p>The report states: <i>Most of the bores show subtle positive linear correlation to climate. Although, C14017SP shows a decreasing trend greater than the threshold of 0.4 m (Figure 6.23), this is unlikely to be related to dewatering as the bore is located approximately 33 km from the closest dewatering bore.</i></p>	<p>It is agreed that this water level decline is unlikely to be caused by the dewatering. However, the assessment could be further supported by adding that the nearest Colinlea Sandstone or Bandanna Formation monitoring bore, identified as being impacted by dewatering, is 27 km north of C14017SP (C840SP).</p>	Noted	

	<p>Section 8 States; <i>Water level thresholds have been established for 50 monitoring bores and five VWP's. Threshold values are summarised in Table E3 of the EA, and Table 45 of the GMMP (AECOM 2020).</i></p>	<p>This is a quote from AECOM 2020 and therefore is no longer accurate when referencing the table in the latest version of the EA. Water level thresholds are actually now in Table E4 of the EA. This should be explained.</p>	<p>Agreed, water level thresholds are detailed in Table E4 of the EA. However, water level threshold values remain consistent between the GMMP (AECOM 2020) and the amended EA.</p> <p>Also, we note that the number of water level threshold bores was wrongly referenced in the monitoring report. There are 43 monitoring bores and 5 VWPs which have water level thresholds, not 50 monitoring bores.</p> <p>Water level thresholds for VWPs should be removed due to low reliability of the VWP data.</p>	
	<p>Table 8.1 <i>'Recent adjustment of logger cable lengths indicates that water levels in C14006SP have never actually exceeded the threshold values for this bore.'</i></p>	<p>It appears that the sentence in italics has been cut and pasted from one section of the table to a number of others without changing the bore number. Needs reviewing and adjusting.</p>	<p>Noted.</p>	
	<p>Section 9</p>	<p>It is acknowledged that the latest modelling, yet to be completed, will likely provide a better evaluation tool for future annual reporting comparisons. However, for this comparison in this annual report there should be more discussion as to how the SEIS assumptions about mine dewatering/ mining operations compare with what has actually occurred to allow a better understanding of the potential limitations of the process used to present the modelled versus observed drawdown</p>	<p>As per response to #22 above, SEIS predictions assumed commencement of mining as the 'zero' time step rather than dewatering which commenced 1 year before box-cut, therefore comparisons between predicted drawdown and observed drawdowns to date have been assumed</p>	

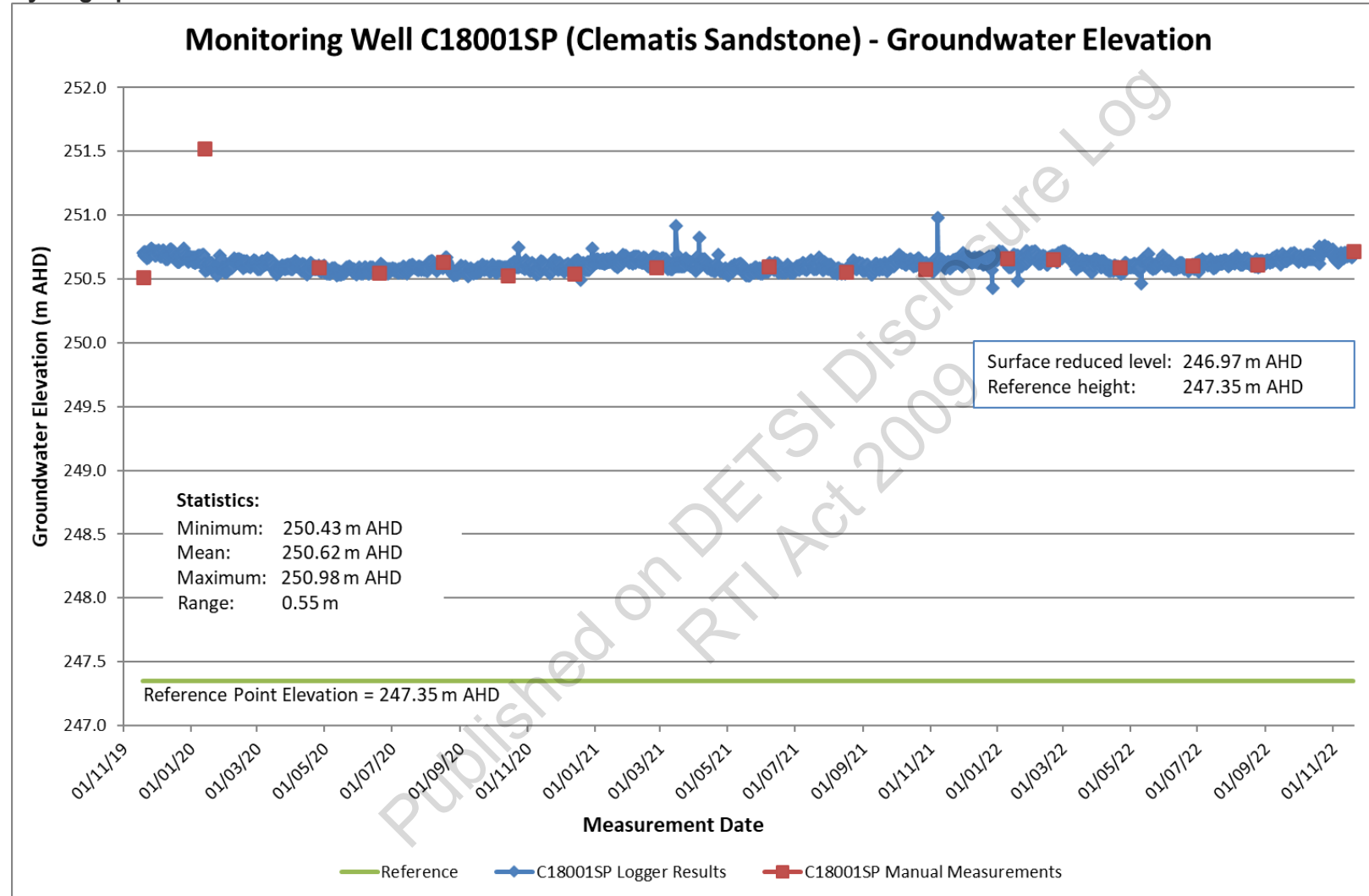
			to be preliminary. Also SEIS predictions do not take account of dewatering bores which have caused excess drawdown in some bores (ie C006P1, C827SP).	
	<p>Section 10 Recommendations <i>Updates to the groundwater model in 2022 should recalibrate to the transient pre-mining dewatering stresses to improve confidence in the modelled versus observed drawdowns at locations where trend analysis has revealed actual dewatering impacts occurring. Specifically, this includes bores C827SP, C180112SP, C833SP, C834SP and C840SP in the Colinlea Sandstone and C832SP in the Bandanna Formation.</i></p>	<p>The statement in italics seems to be missing some monitoring bore numbers when discussing which bores are impacted. The summary in section 6.13 looks to have the numbers right, perhaps refer to that.</p> <p>The detailed work presented in section 6 of this report demonstrates a number of things. Firstly, it notes that the water level trend reliability in the VWP is low. DES would agree with this assessment. It is considered that given this assessment there should be a recommendation as to how this issue will be dealt with in those critical areas where there are no monitoring bores (or only VWPs).</p> <p>In particular, how will impacts in the target formations (Colinlea Sandstone and Bandanna Formation) be monitored. As DES has previously raised, the area to the west of the dewatering bores, between the dewatering bores and the important Doongmabulla Springs, has poor to non-existent monitoring bore coverage in the target formations.</p> <p>Figure 6.17 demonstrates reasonable coverage (albeit with some gaps) of monitoring bores in the Bandanna Formation to the north of the dewatering bores (if C19027SP is considered).</p> <p>To the south there is also reasonable coverage of monitoring bores in the Bandanna although there is a gap between C9839SPR (at 0.34 m/yr almost considered impacted) and C034P1 which is some 5.6 km south of C9839SPR. Tracking this impact south will therefore soon become difficult.</p> <p>To the west there are no monitoring bores west of C008P2. It is noted that C19018SP has recently been drilled adjacent the Doongmabulla Springs but there is a 10 km gap between C008P2 and C19018SP where there are no Bandanna monitoring bores.</p>	<p>Noted.</p> <p>Additional monitoring bores will be installed between the ML and DSC (refer to figures provided at the end of this review)</p> <p>Refer to response at point #1 above</p> <p>Additional monitoring bores will be installed between the ML and DSC (refer to</p>	

		<p>In the Colinlea Sandstone, Figure 6.21 demonstrates reasonable coverage to the south of the dewatering bores although there is a gap between C840SP (most southerly monitoring bore considered impacted) and C034P3 which is some 5.8 km south of C840SP. Tracking this impact south will therefore also soon become difficult.</p> <p>Figure 6.21 also demonstrates the lack of Colinlea Sandstone monitoring bores adjacent the northern dewatering bores and immediately north of the dewatering bores. C19026SP and C006P3R are adjacent the southern dewatering bores. The closest monitoring bore north of these two monitoring bores shown on Figure 6.21 is C011P3 some 11 km to the north-west.</p> <p>Figure 6.21 also demonstrates that there are no monitoring bores in the Colinlea Sandstone west of the dewatering bores. Therefore, the work in section 6 is unable to comment on how far west the impacts of dewatering have propagated.</p> <p>Given that EA condition E18 requires this report to provide recommendations on changes to the GMMP, it is considered essential that the findings of the water level review in this report are used to provide recommendations to the GMMP about the limitations of the monitoring network as discussed above.</p>	<p>figures provided at the end of this review) Refer to response at point #1 above</p> <p>Refer to response at point #1 above</p> <p>Noted. Additional monitoring bores will be installed between the ML and DSC (refer to figures provided at the end of this review).</p> <p>Recommendations on changes to GMMP are provided in Section 10 of the Annual Monitoring Report. Additional GMMP recommendations will be provided as per the responses to the review comments.</p>	
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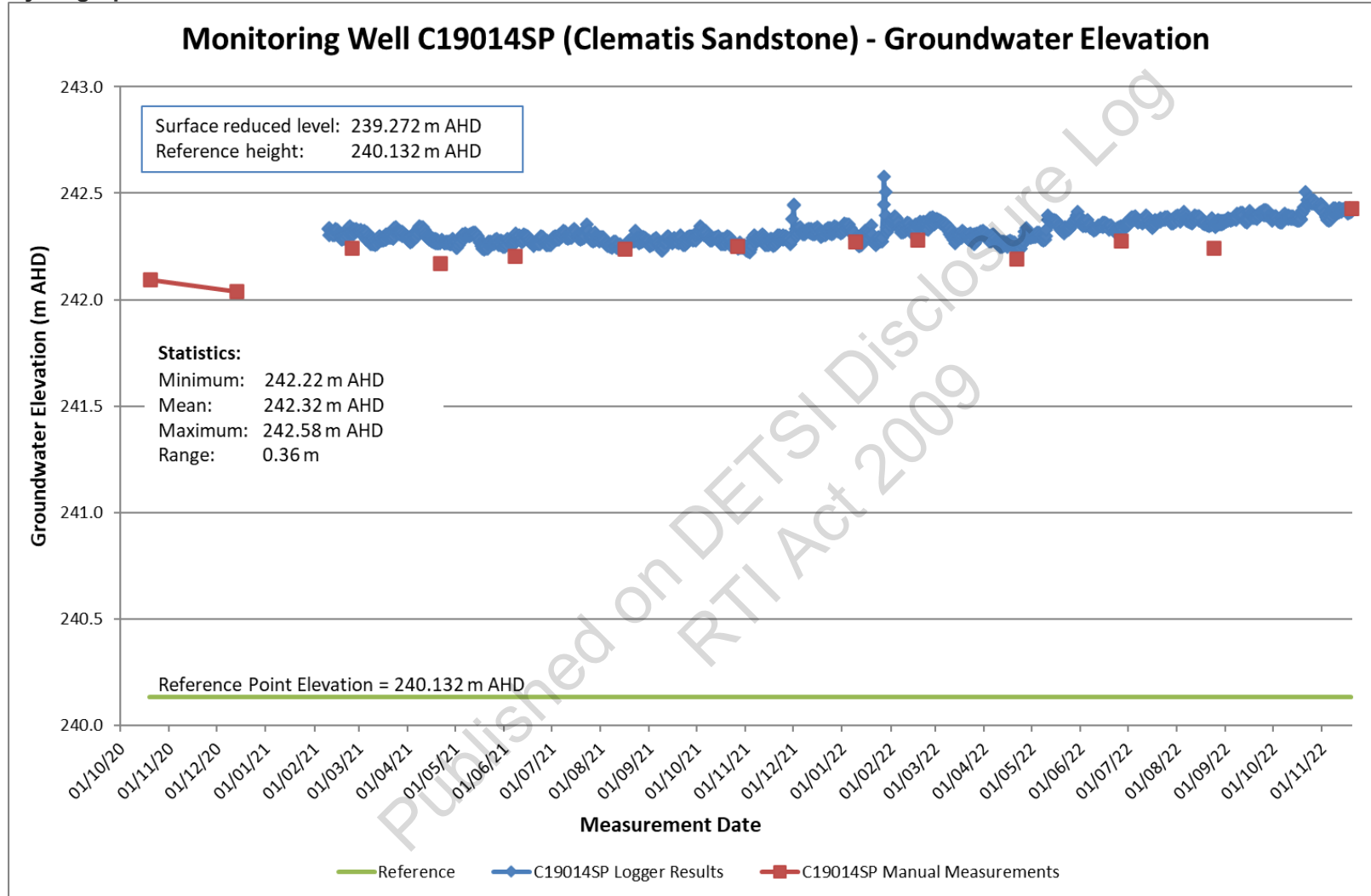
Figure for proposed monitoring additional bore locations (circled in Red) in bandanna and colinlea sandstone.



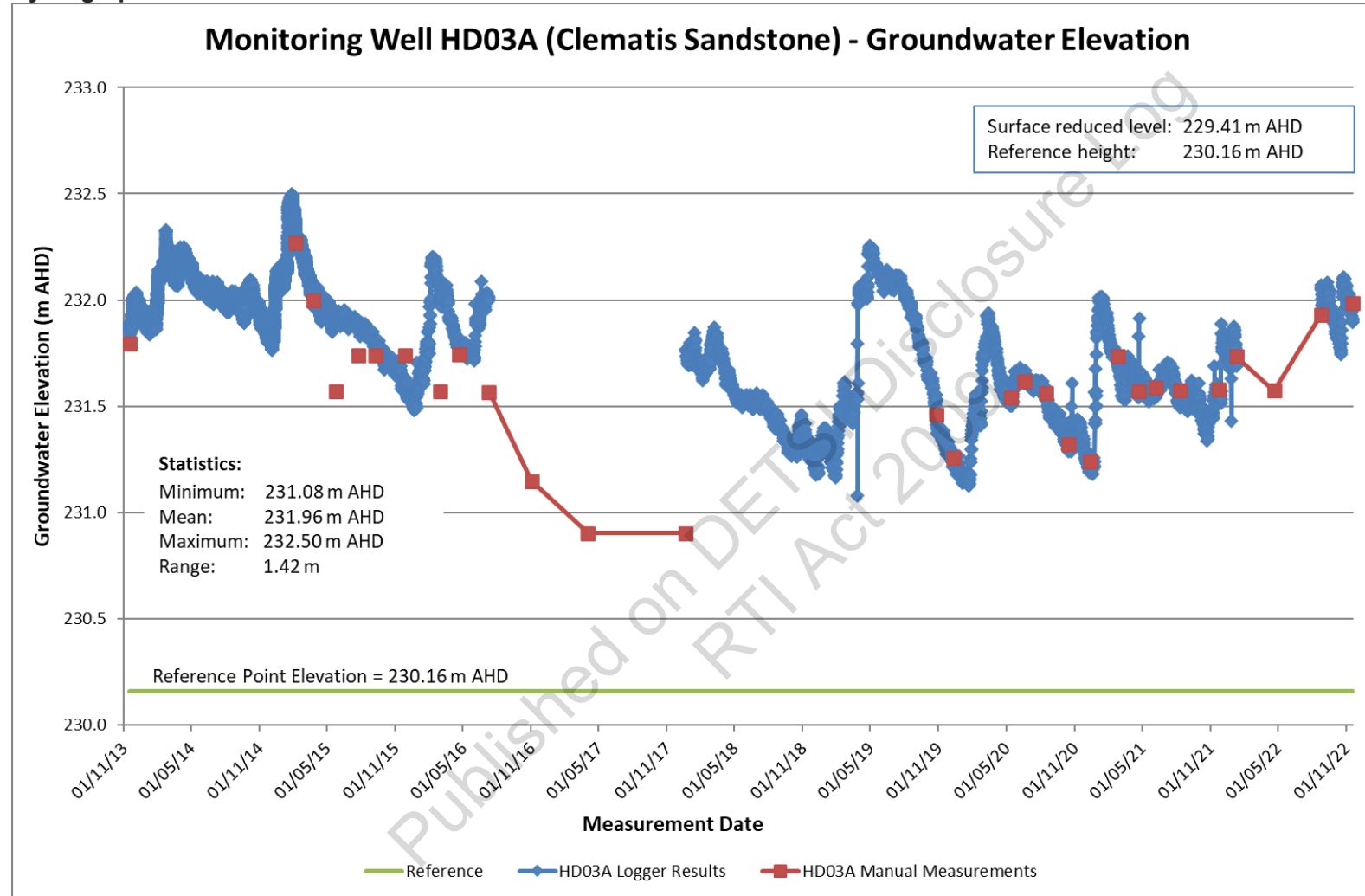
Hydrograph for C18001SP



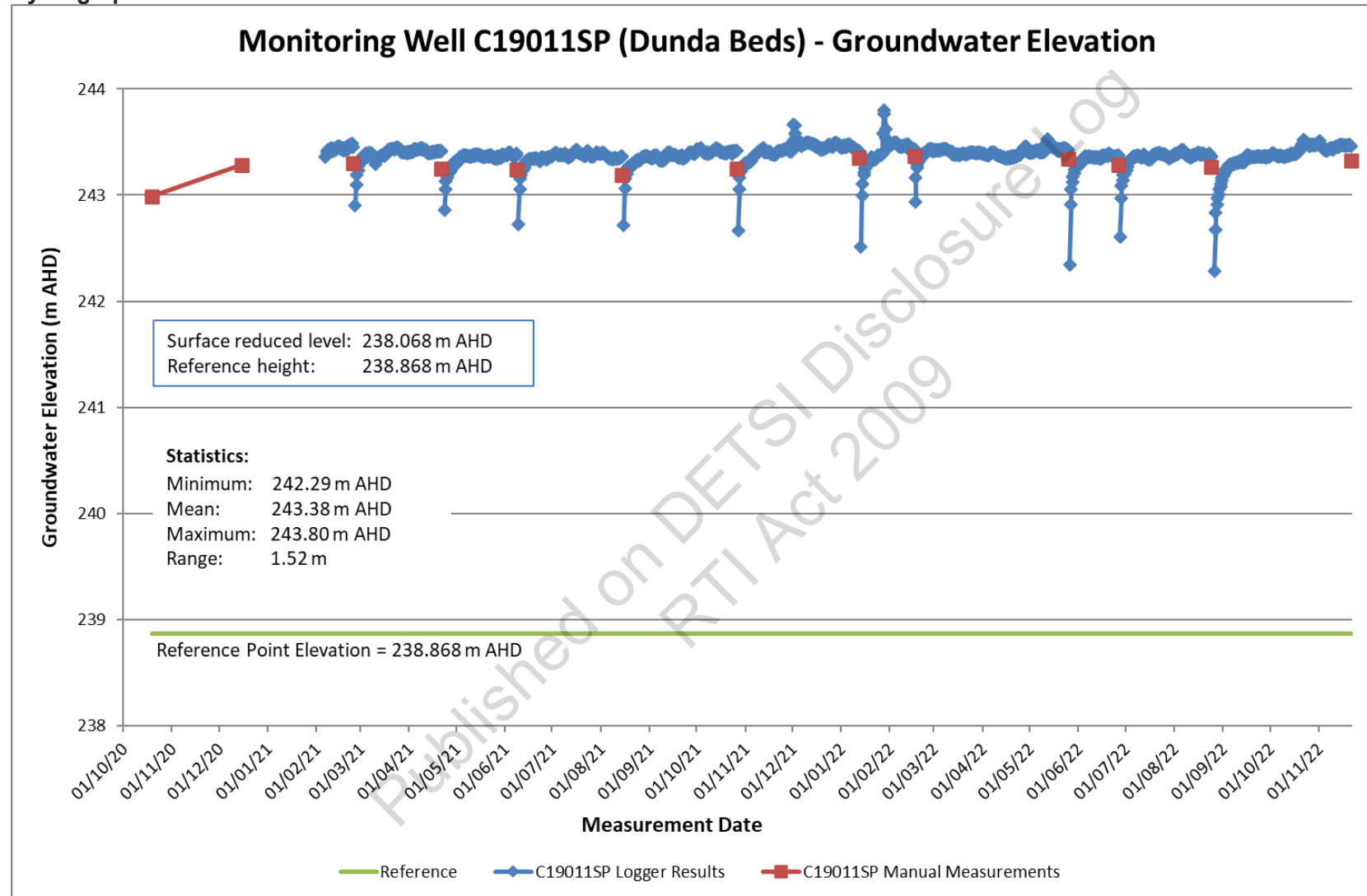
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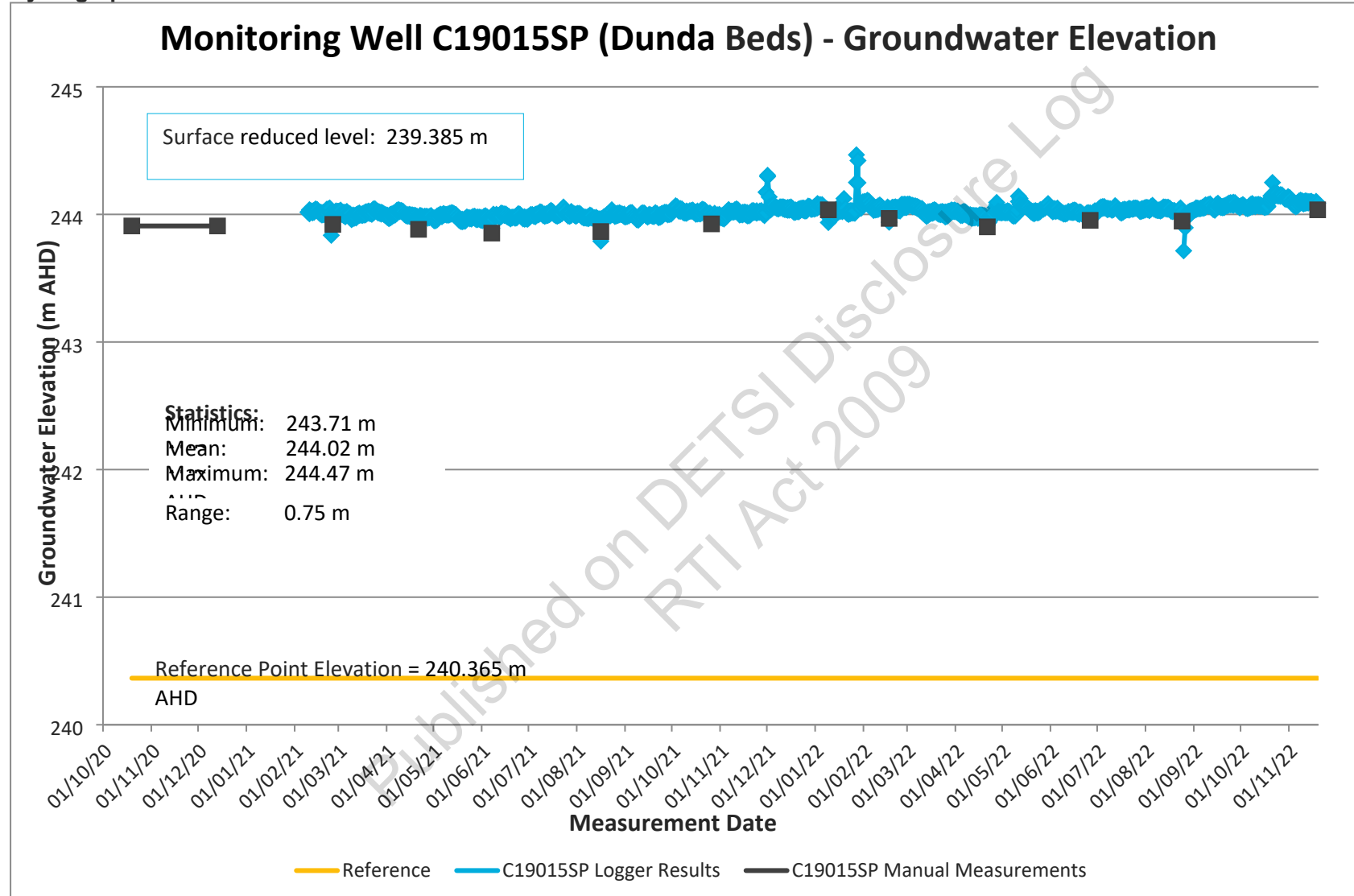
Hydrograph for HD03A



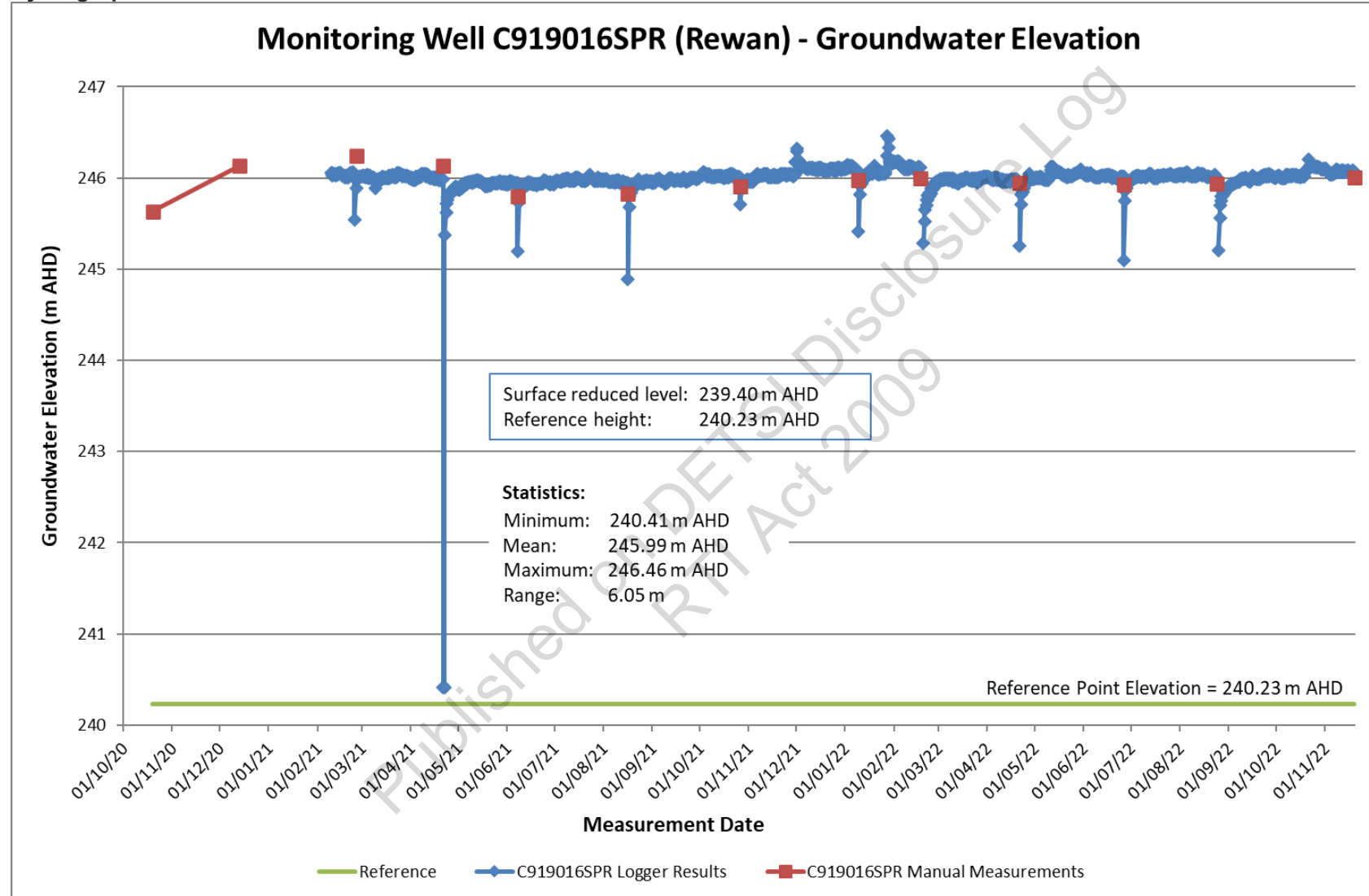
Hydrograph for C19011SP



Hydrograph for C19015SP



Hydrograph for C919015SPR





Source: Bravus (2022); DNRME (2021); ESRI (2022)

KEY

- ◆ Dewatering Bore
- Minor road
- Vehicular track



Dewatering Bore Locations

Bravus Mining & Resources

V:\2020\20201150 - Adani Groundwater Support\GIS\02_Maps\Dewatering Bores.mxd 6/01/2023

Australia

SYDNEY

Ground floor 20 Chandos Street
St Leonards NSW 2065
T 02 9493 9500

NEWCASTLE

Level 3 175 Scott Street
Newcastle NSW 2300
T 02 4907 4800

BRISBANE

Level 1 87 Wickham Terrace
Spring Hill QLD 4000
T 07 3648 1200

CANBERRA

Suite 2.04 Level 2
15 London Circuit
Canberra City ACT 2601

ADELAIDE

Level 4 74 Pirie Street
Adelaide SA 5000
T 08 8232 2253

MELBOURNE

Suite 8.03 Level 8
454 Collins Street
Melbourne VIC 3000
T 03 9993 1900

PERTH

Suite 9.02 Level 9
109 St Georges Terrace
Perth WA 6000
T 08 6430 4800

Canada

TORONTO

2345 Young Street Suite 300
Toronto ON M4P 2E5
T 647 467 1605

VANCOUVER

60 W 6th Ave Suite 200
Vancouver BC V5Y 1K1
T 604 999 8297



MINING & RESOURCES

Carmichael Coal Mine Project

Groundwater Model Review - Progress Meeting - 4

Tuesday 10 January 2023

BRAVUS

MINING & RESOURCES

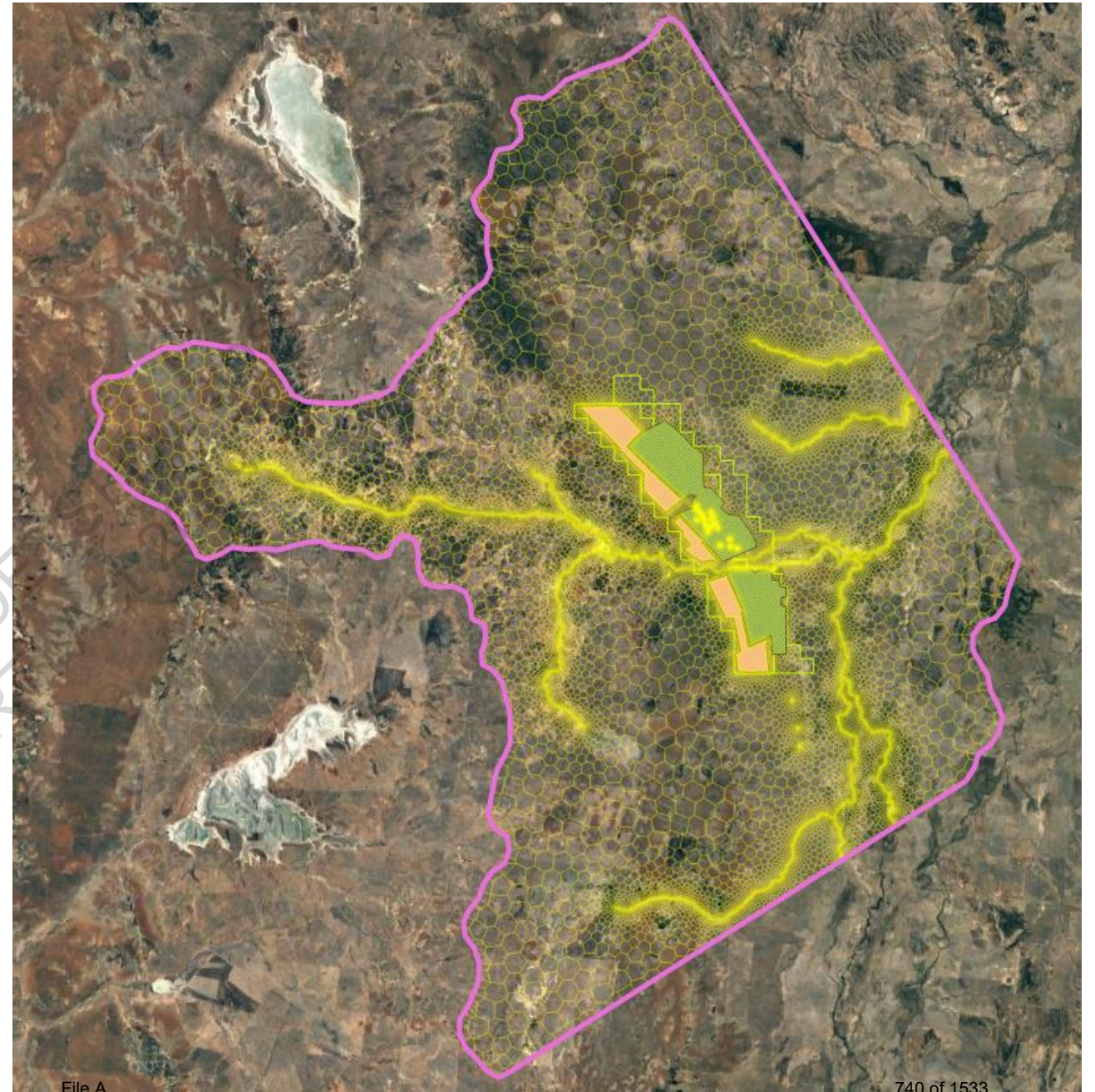
Model design information

Model design overview

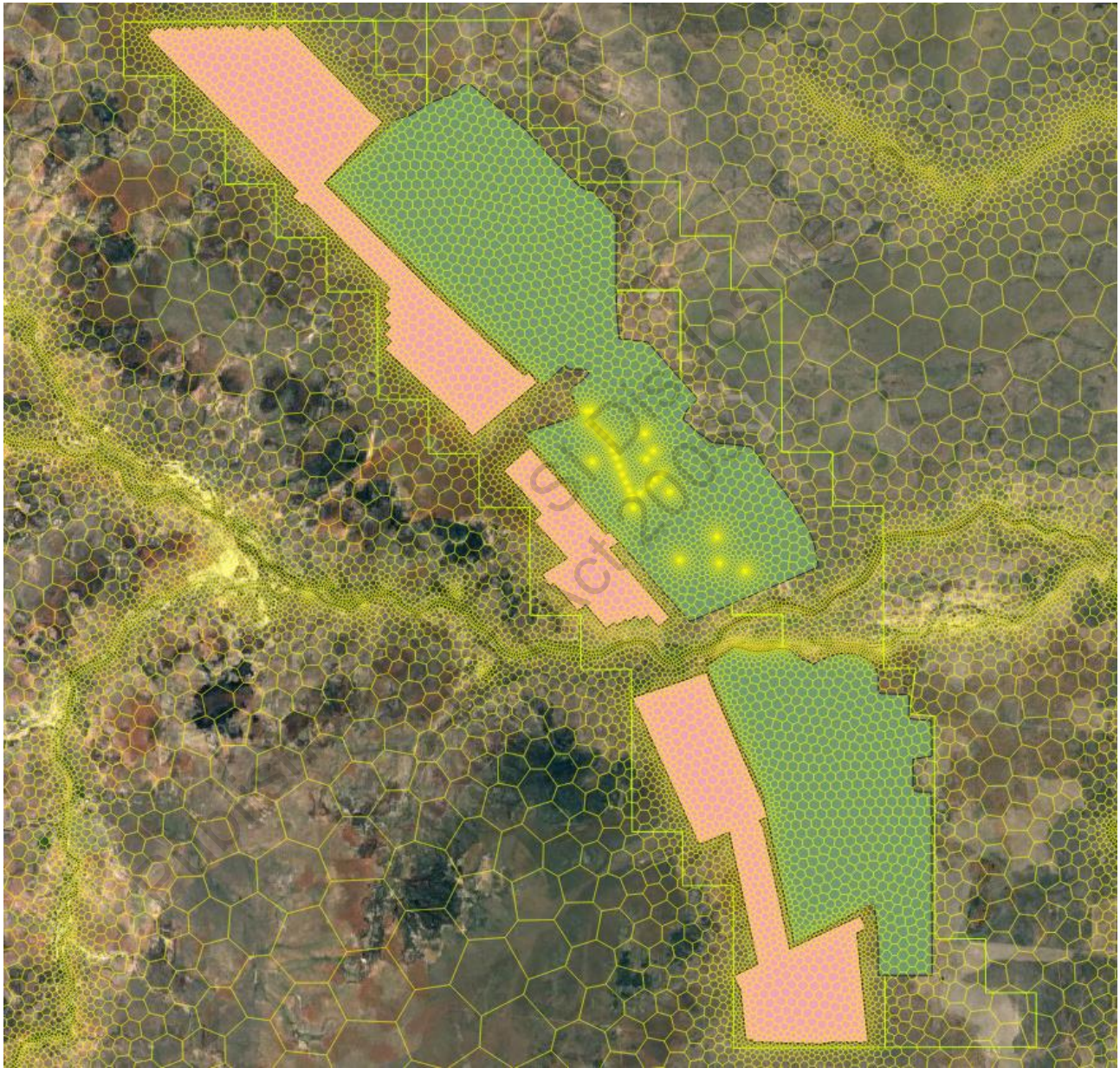
- MODFLOW-USG Transport v1.10
- Maintain domain from SEIS groundwater model
- Unstructured Voronoi polygon mesh; 34,624 nodes per layer
 - Refinement for major creeks, mapped springs, open cut and underground mine area, and dewatering bores
- 14 HSUs, one per model layer, with Rewan Formation split across two model layers
- Model layers developed based on further work by Titus Murray, extrapolated to merge with Bioregional Assessment HSU layers towards edges of the model domain
- Model layers pinched out where HSU conceptualised to not exist
 - 519,360 total nodes; 233,967 active nodes
- Regional head boundary conditions based on Bioregional Assessment head contours
- Major watercourses simulated with flow in wet season only; behave as drains otherwise
- Springs simulated by drain boundary conditions in source aquifer (DSC = Clematis, Mellaluka = Joe Joe), with drain return to alluvium at DSC
- Recharge defined as a percentage of measured rainfall, variable per outcropping HSU
- Potential evapotranspiration constant across model domain, with enhanced extinction depth for deeper-rooted vegetation aligned with riverine corridors
- Transient history-matching employs quarterly stress periods prior to mining activities; monthly thereafter
- Predictions employ seasonal stress periods, incorporating mine dewatering and hydraulic conductivity enhancement associated with fracturing above longwall panels

Mesh

- Variable node spacing variable in line with stresses, monitoring and areas of interest with regard to the modelling objectives:
 - production bores: 20 m;
 - open cut mining: 500 m;
 - underground mining: 500 m;
 - buffer zone around underground mining to account for horizontal stress relief: 200 m;
 - major creeks: 150 m;
 - Doongmabulla Springs: 200 m; and
 - other mapped springs: 100 m



Mesh



Model layers

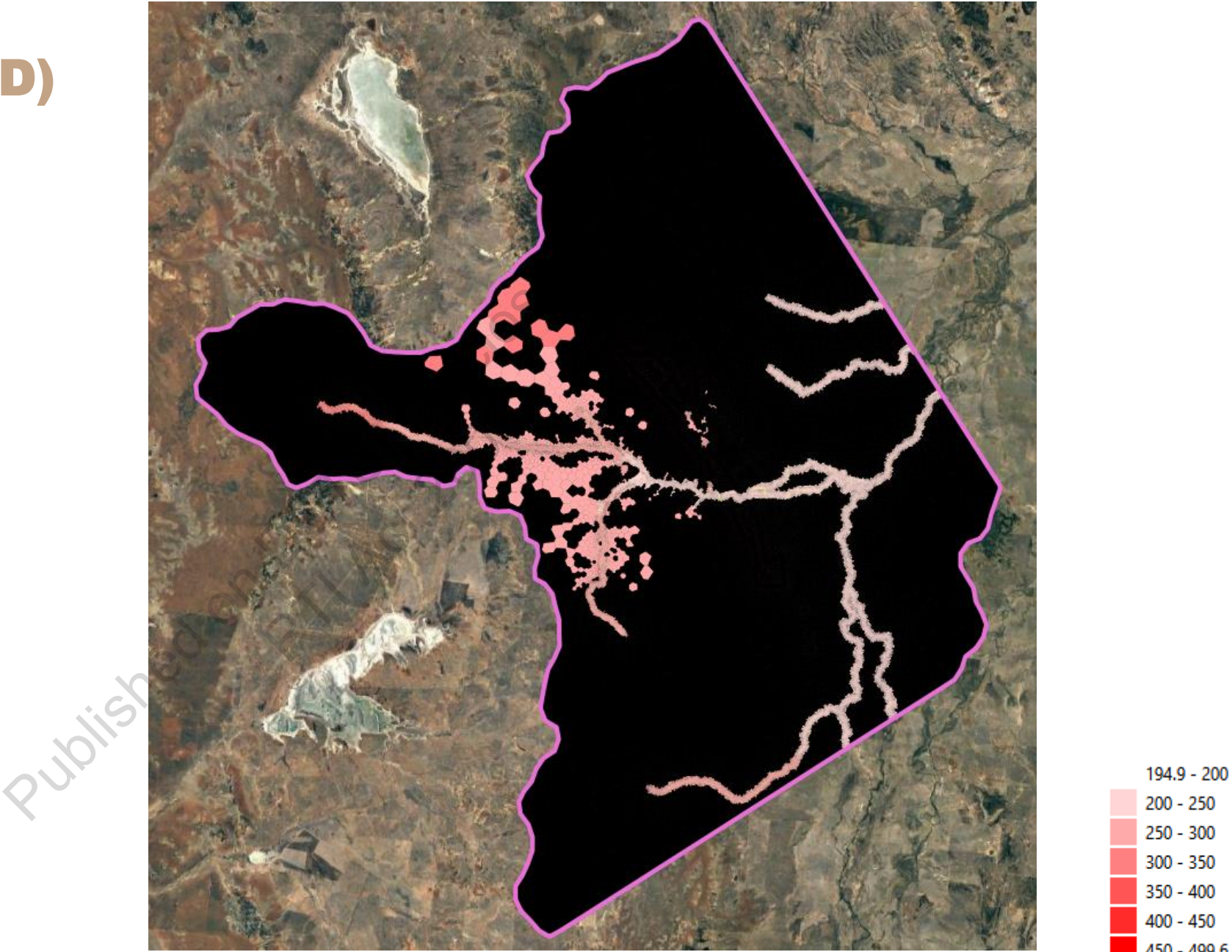
Model layer	HSU
1	Quaternary alluvium
2	Weathering zone
3	Tertiary and non-alluvial Quaternary deposits
4	Moolayember Formation
5	Clematis Sandstone / Warang Sandstone
6	Dunda Beds
7	Rewan Formation (upper)
8	Rewan Formation (lower)
9	Bandanna Formation
10	Bandanna Formation (AB Seam coal)
11	Bandanna Formation
12	Colinlea Sandstone
13	Colinlea Sandstone (D Seam coal)
14	Colinlea Sandstone
15	Joe Joe Group

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File A

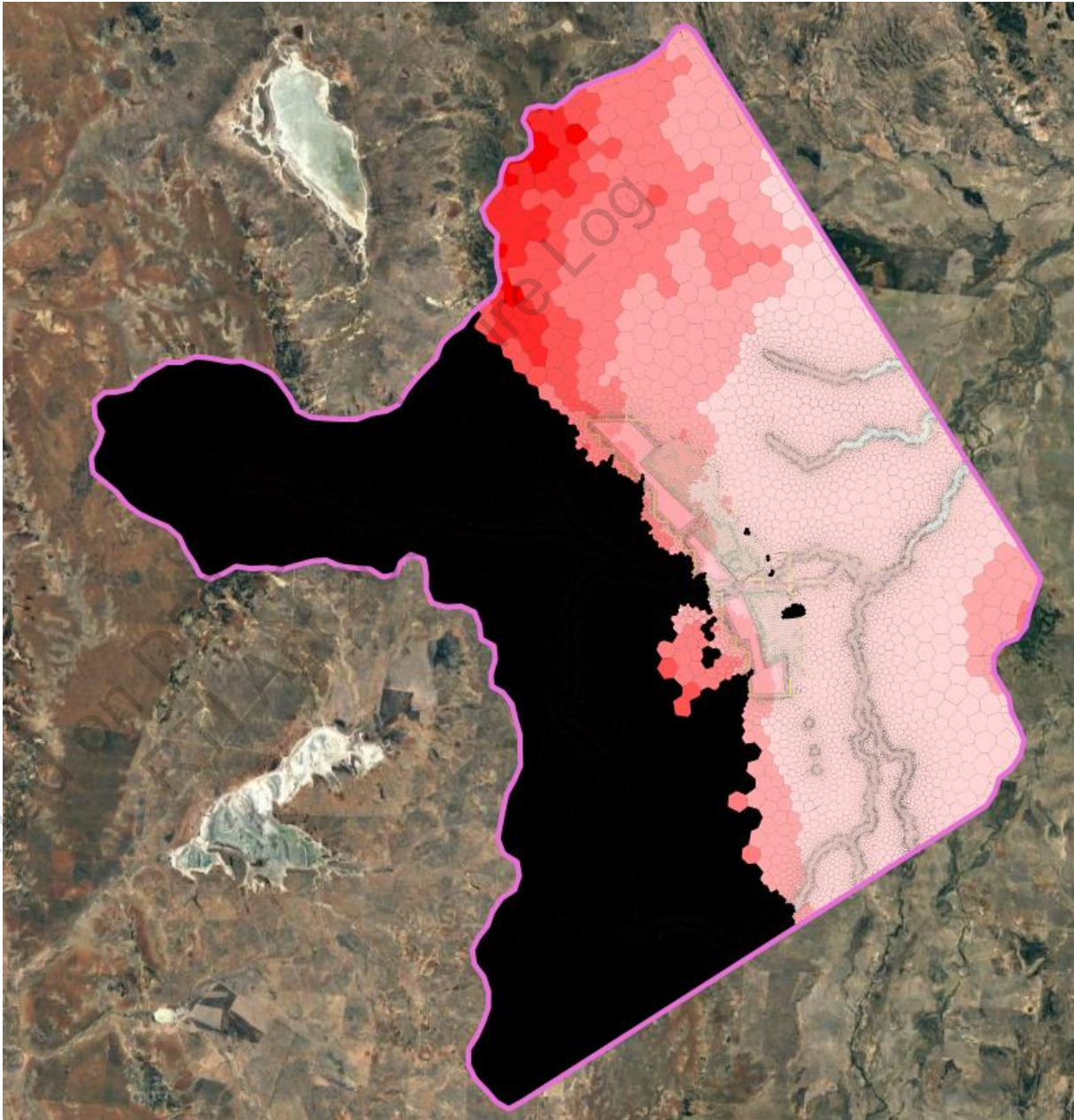
742 of 1533

Alluvium top (mAHD)

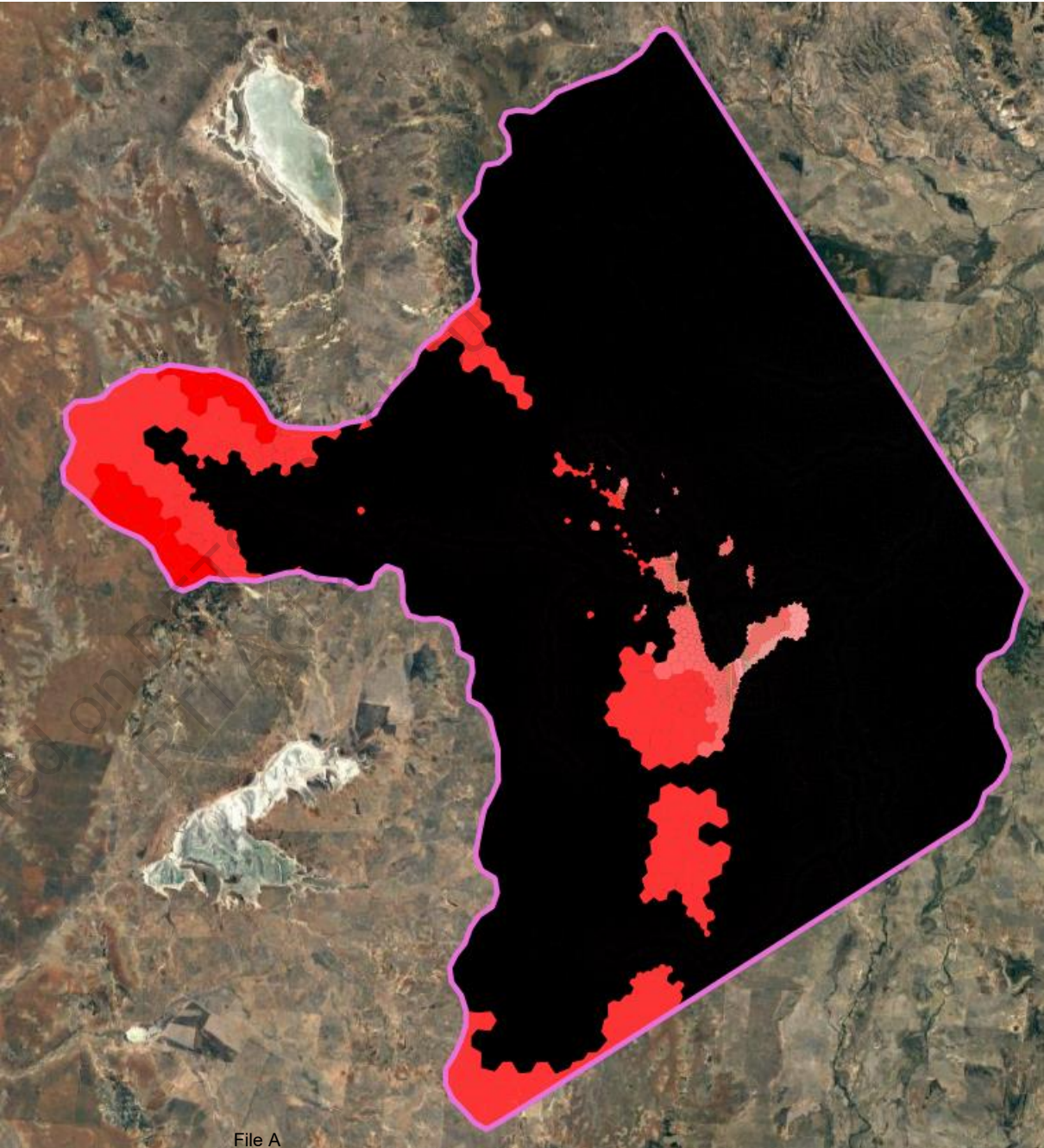


Published on 2023-01-31

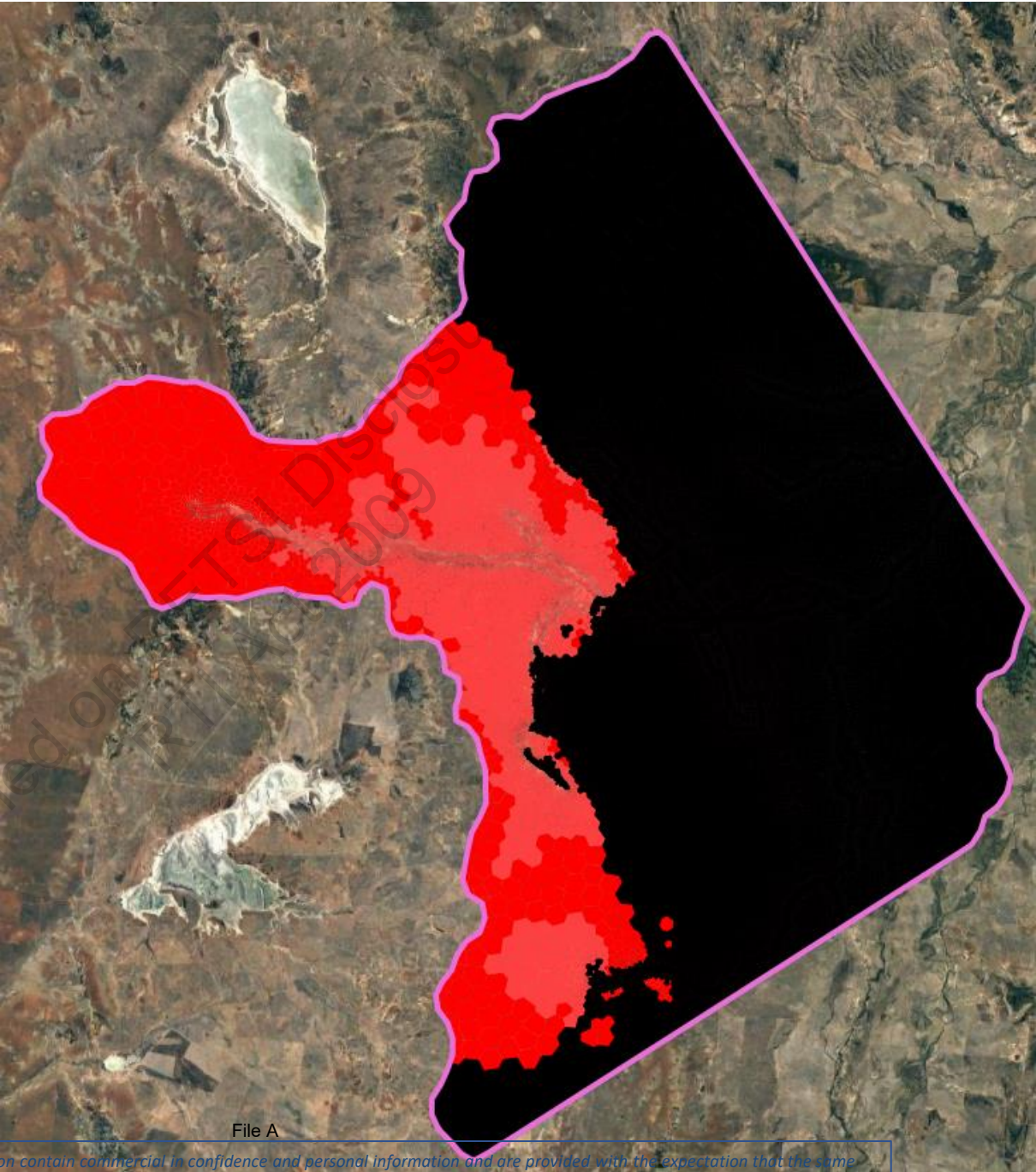
Weathering zone top (mAHD)



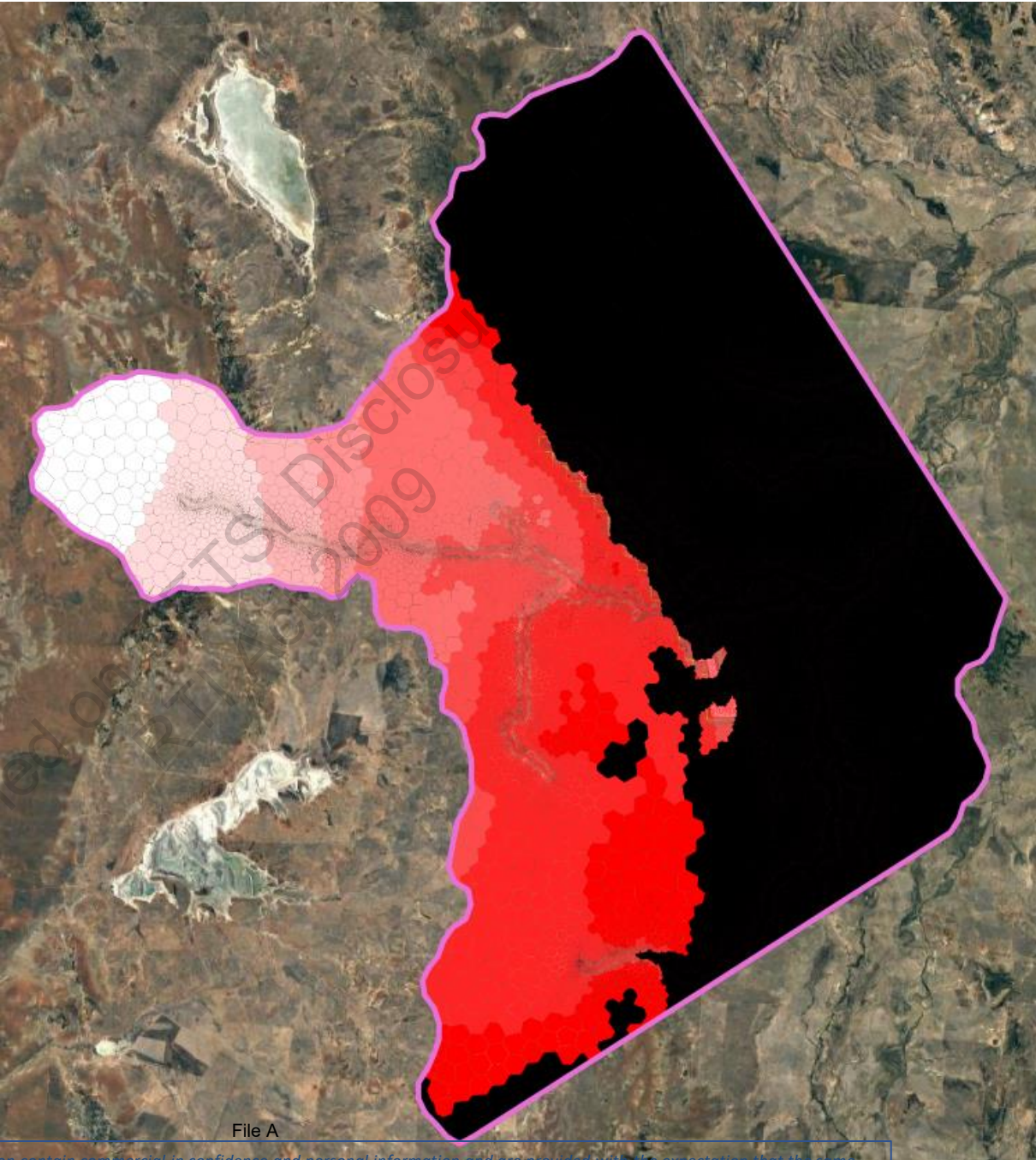
Tertiary top (mAHD)



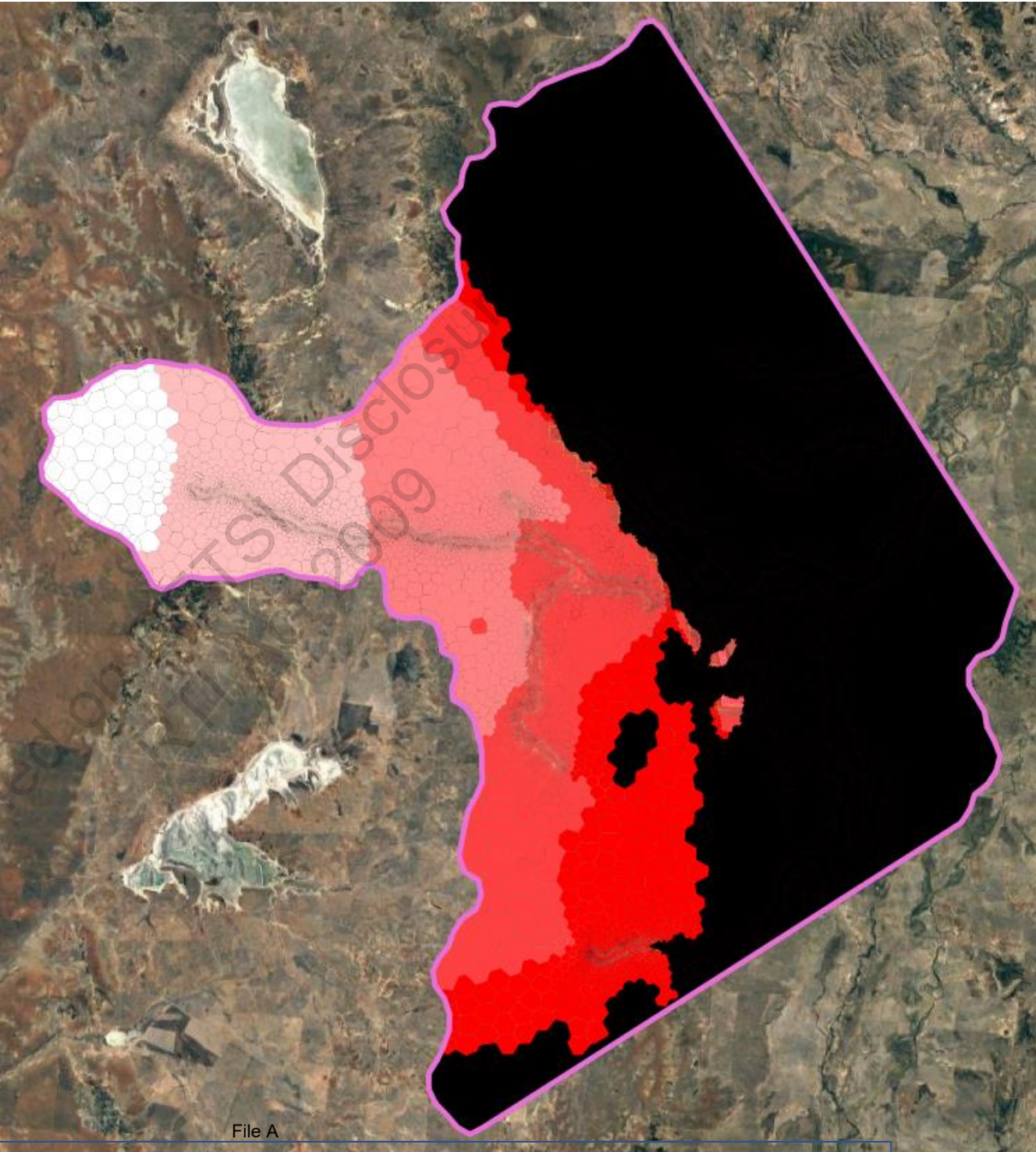
Moolayember top (mAHD)



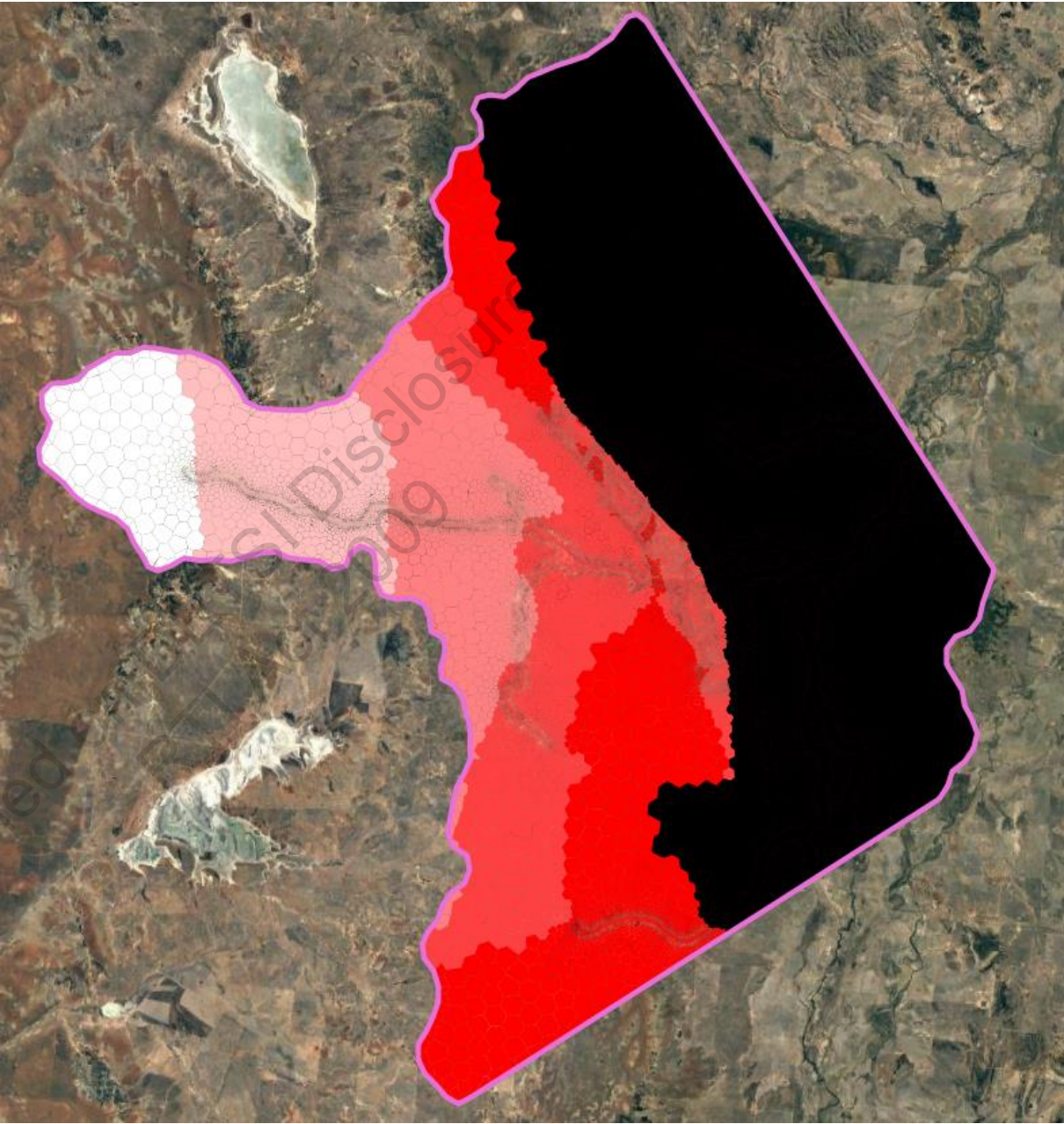
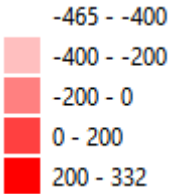
Clematis top (mAHD)



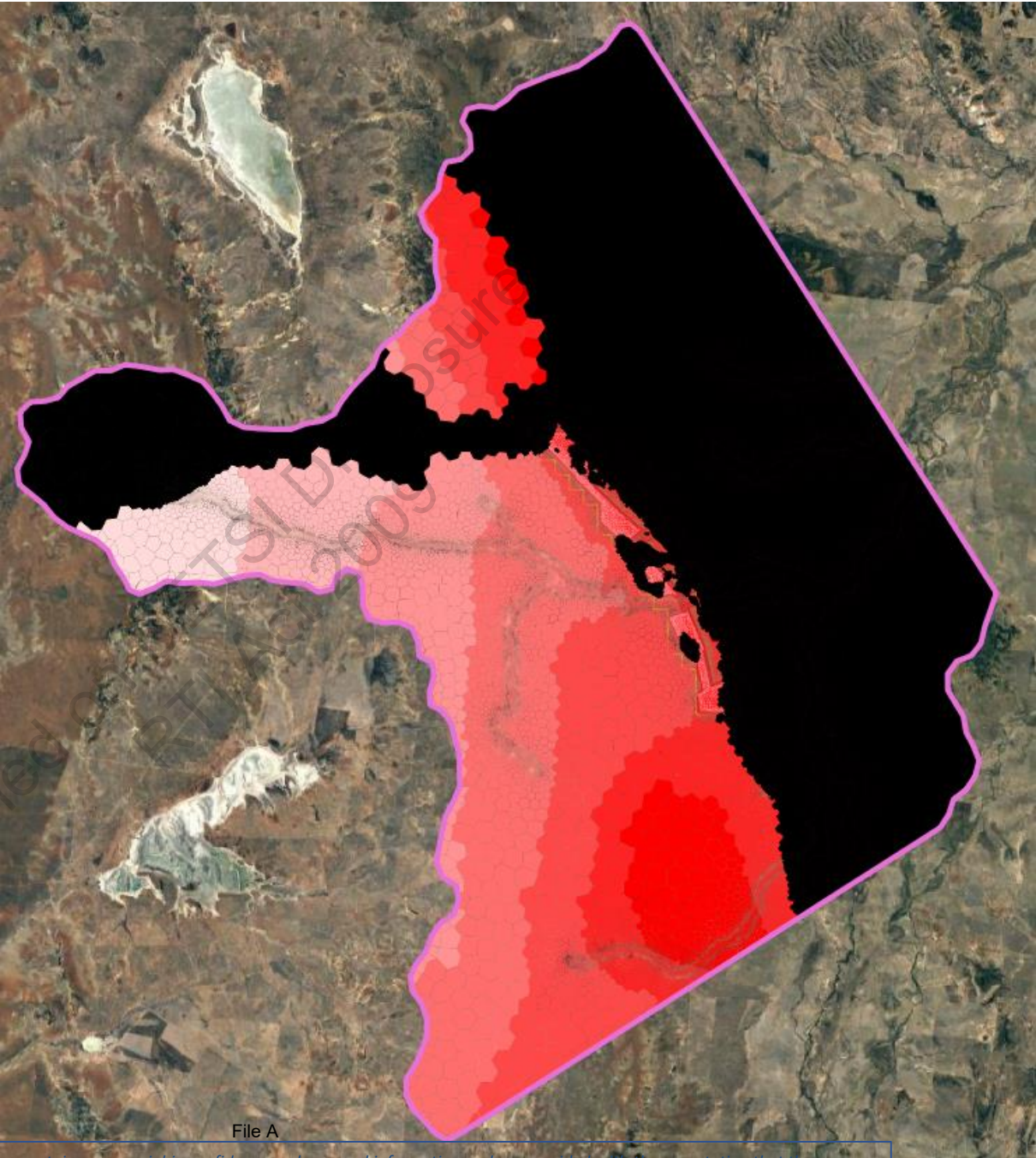
Dunda top (mAHD)



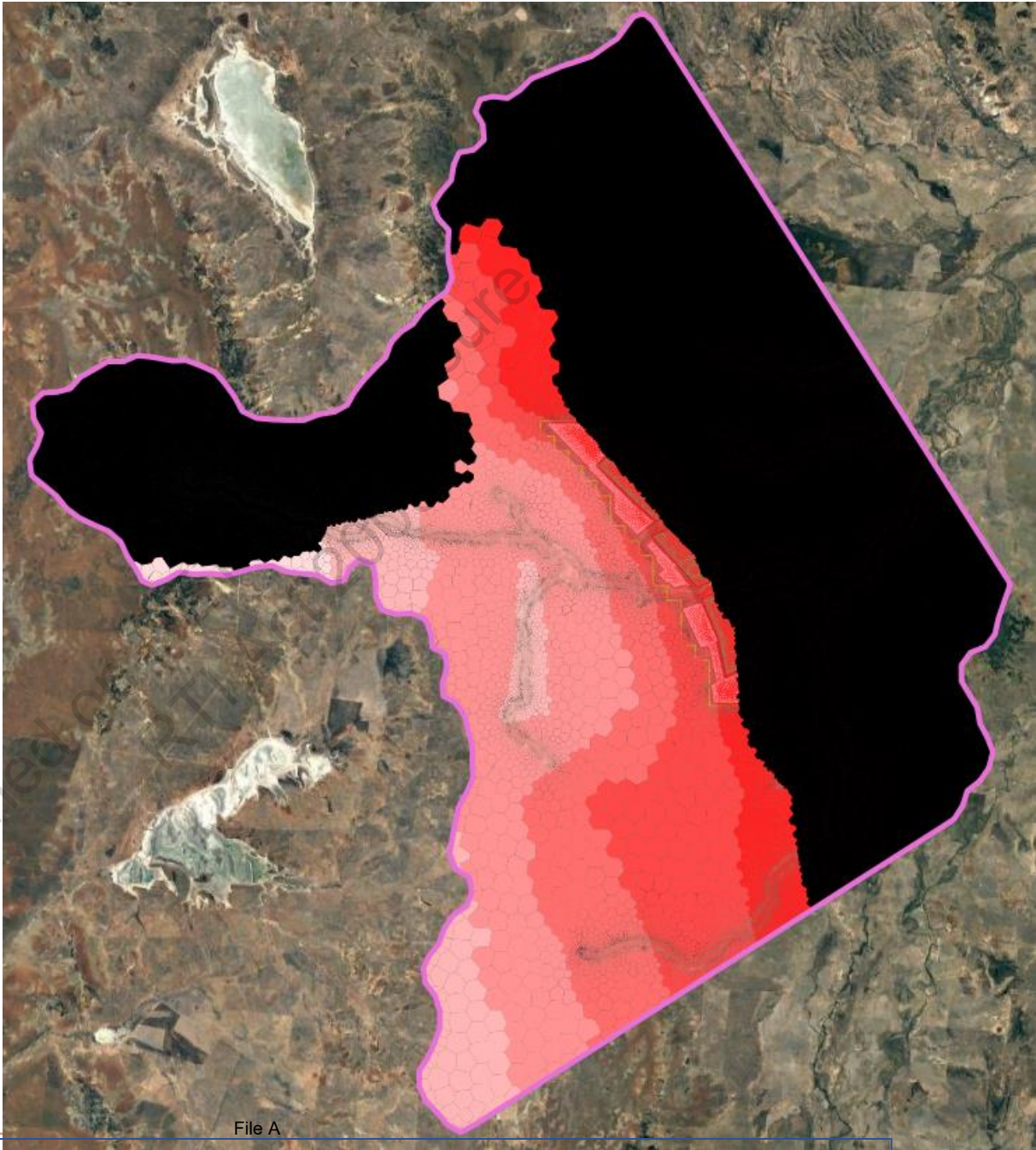
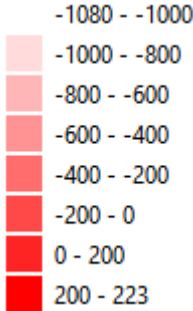
Rewan top (mAHD)



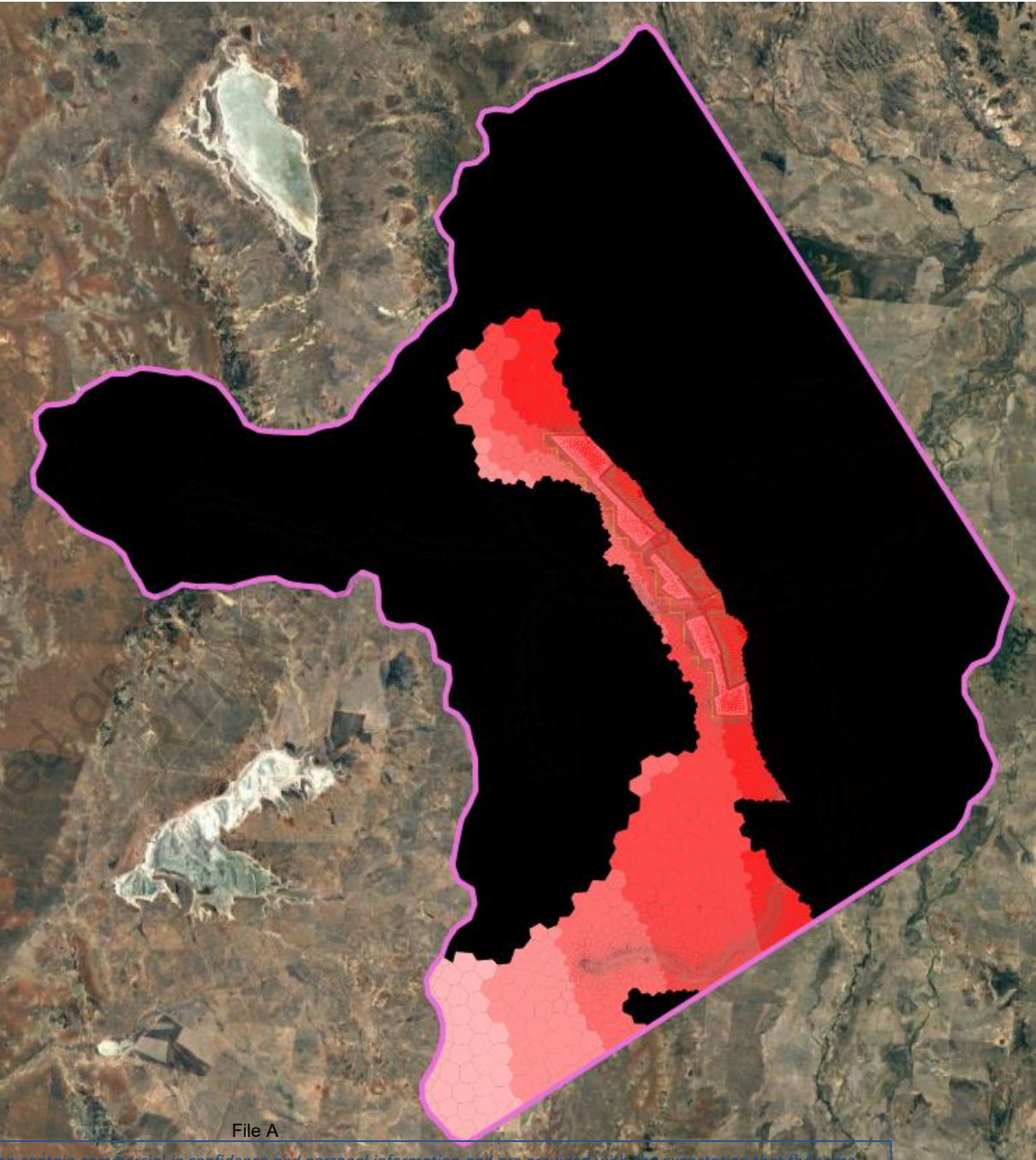
Bandanna top (mAHD)



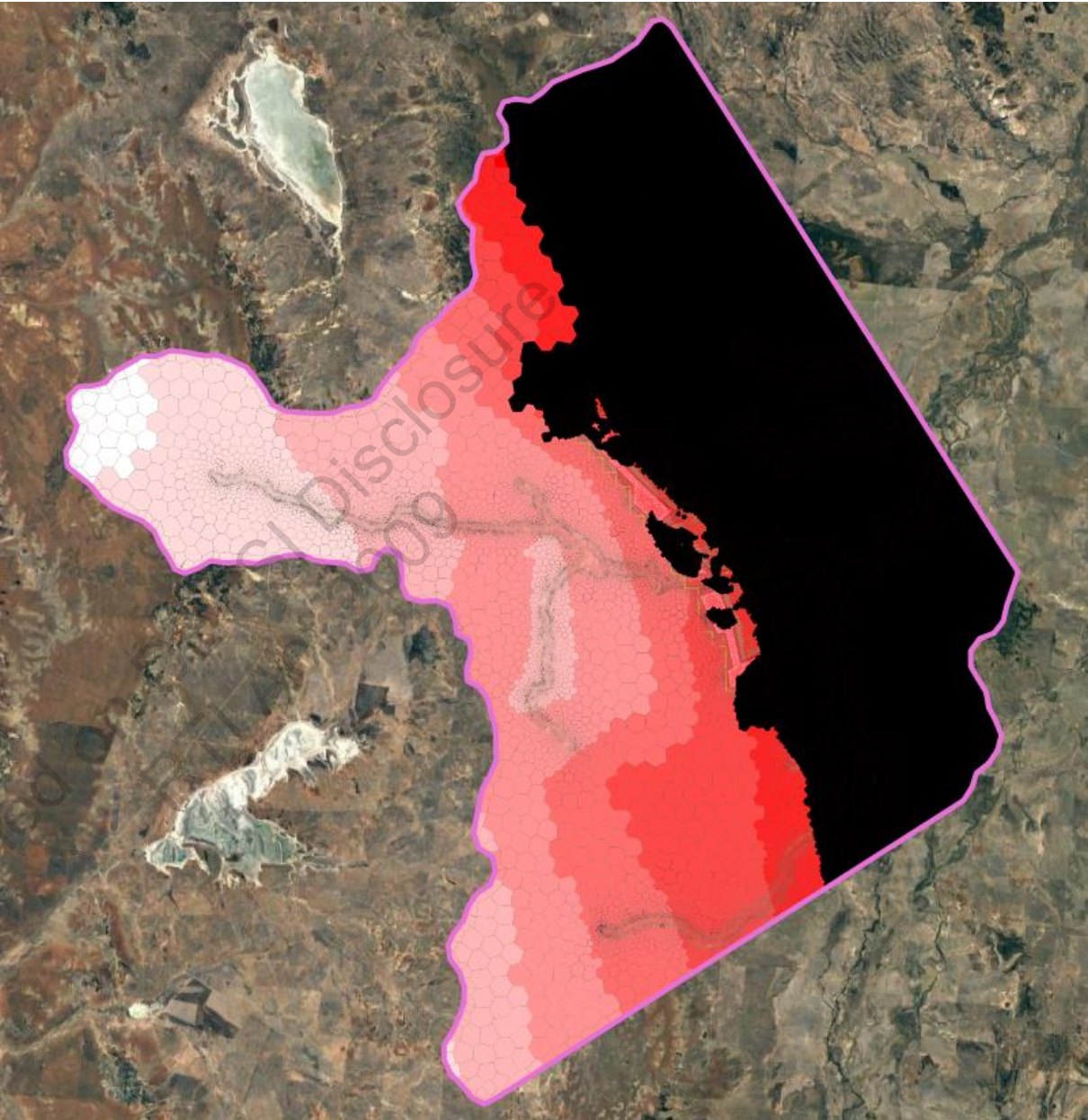
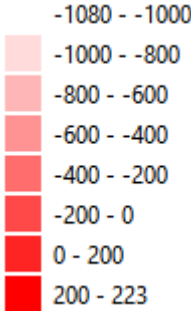
AB Coal top (mAHD)



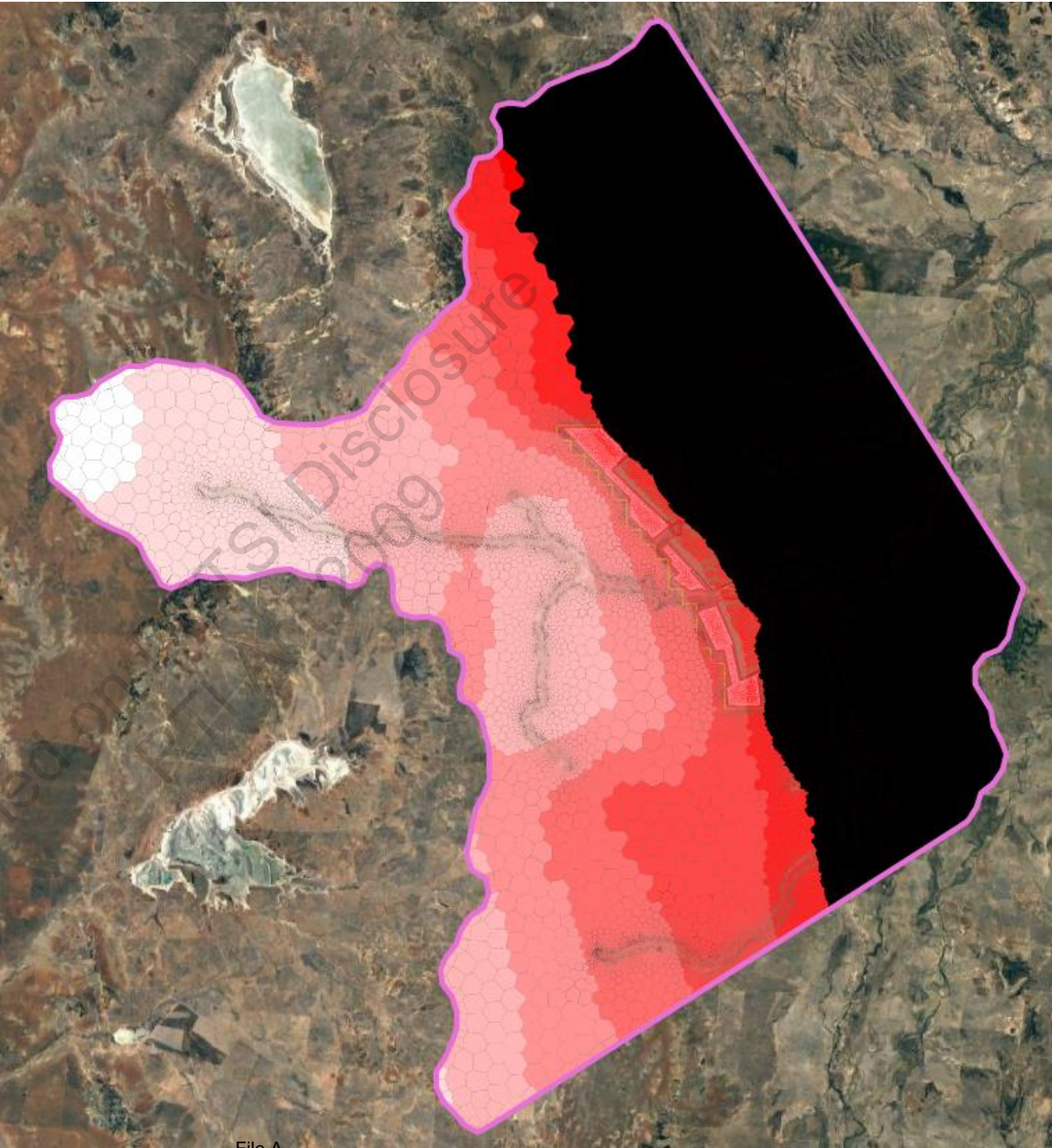
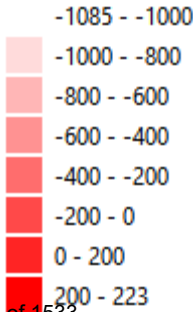
Bandanna (interburden) top (mAHD)



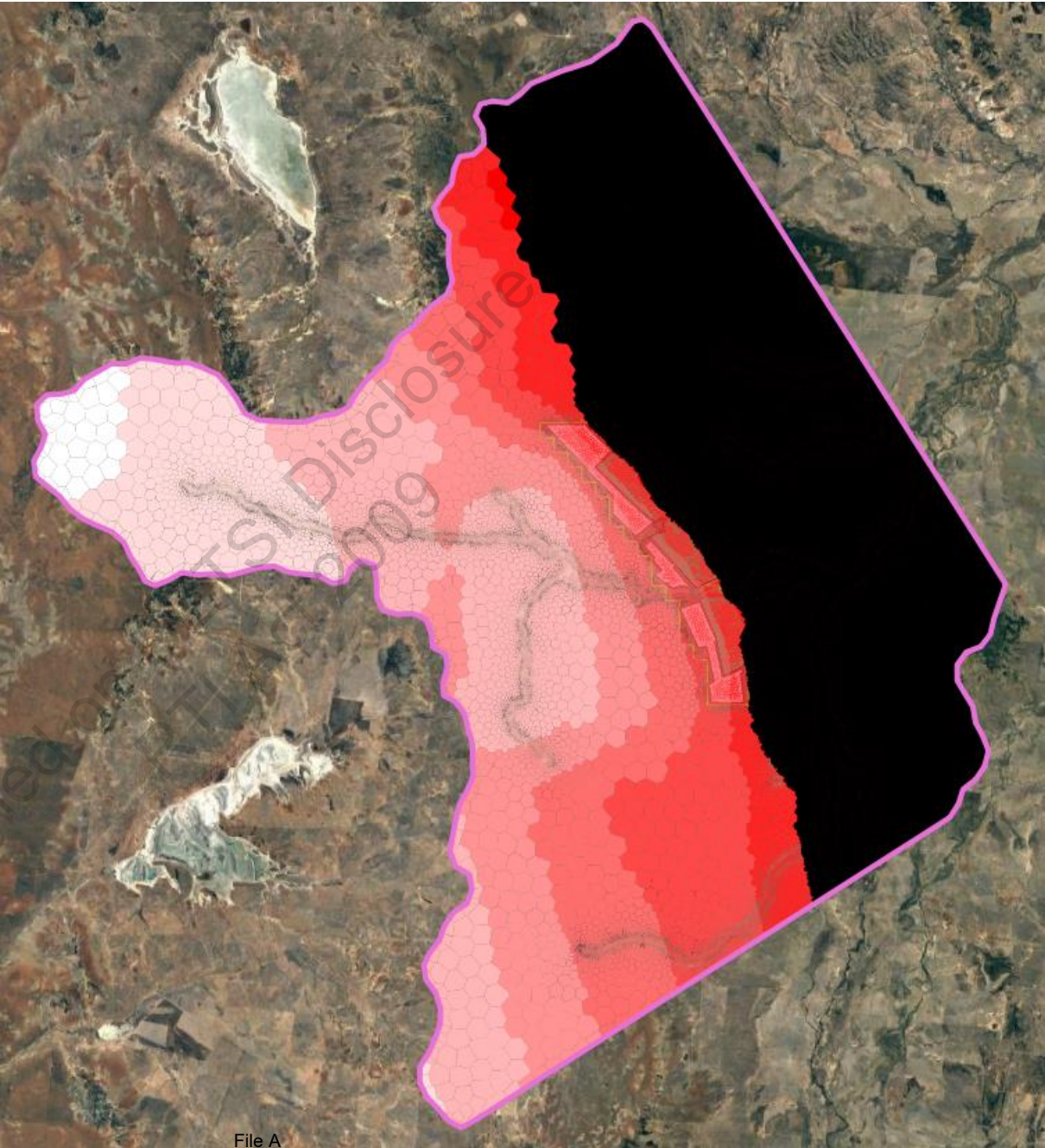
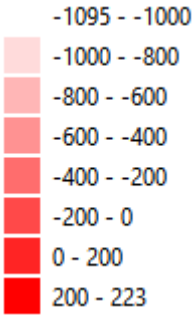
Colinlea top (mAHD)



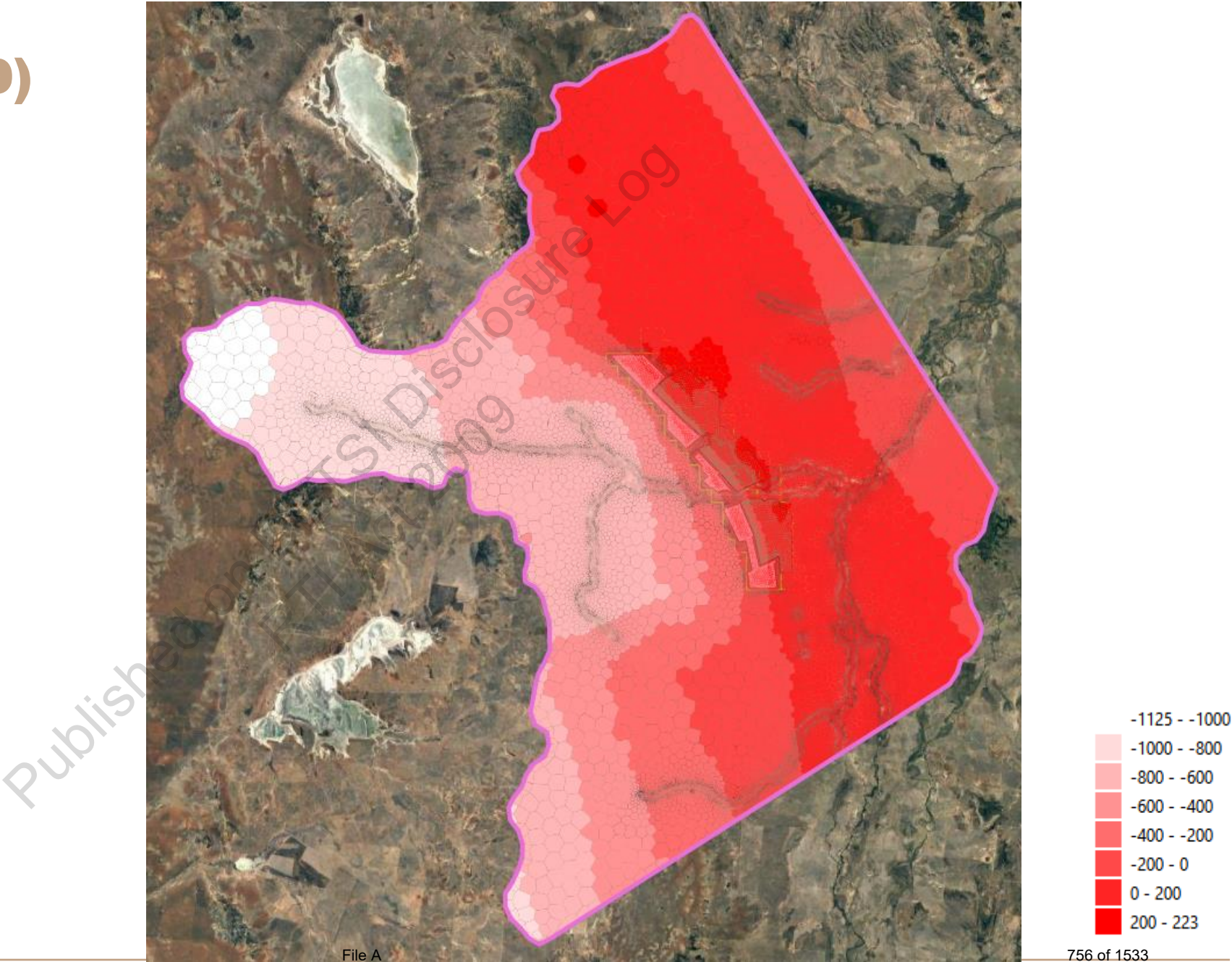
D Coal top (mAHD)



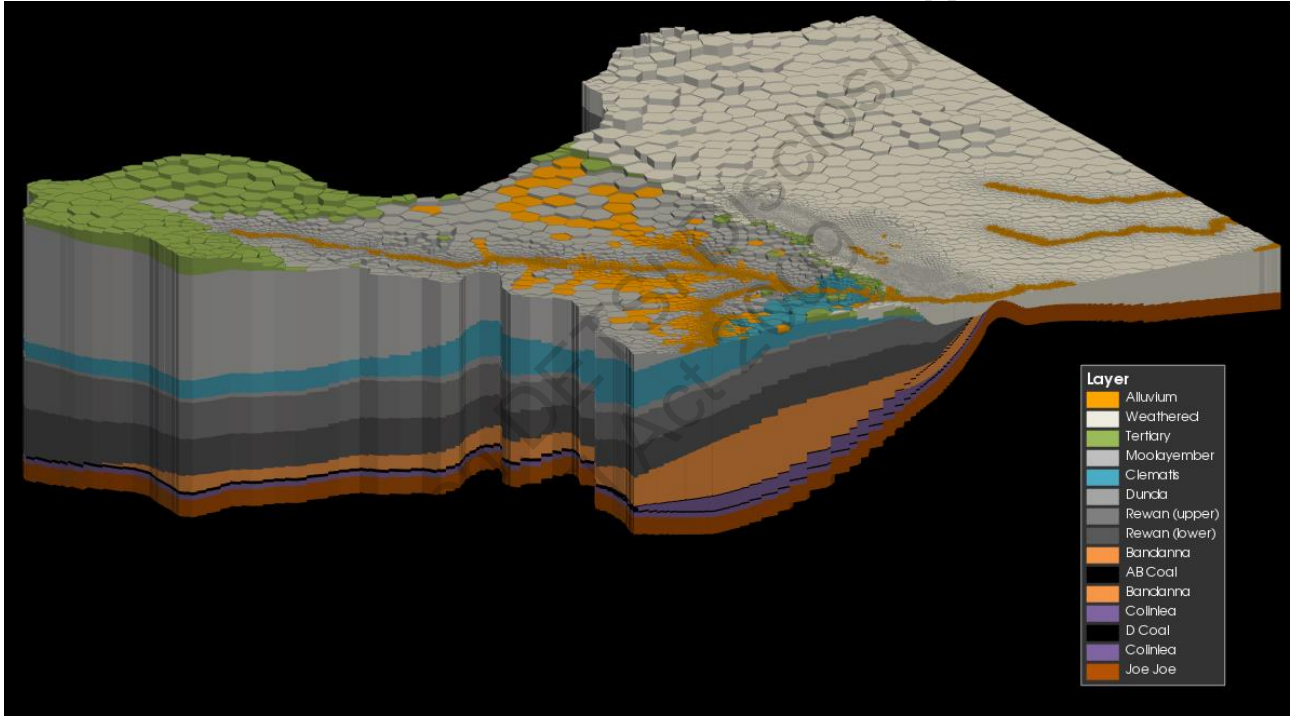
Colinlea (underburden) top (mAHD)



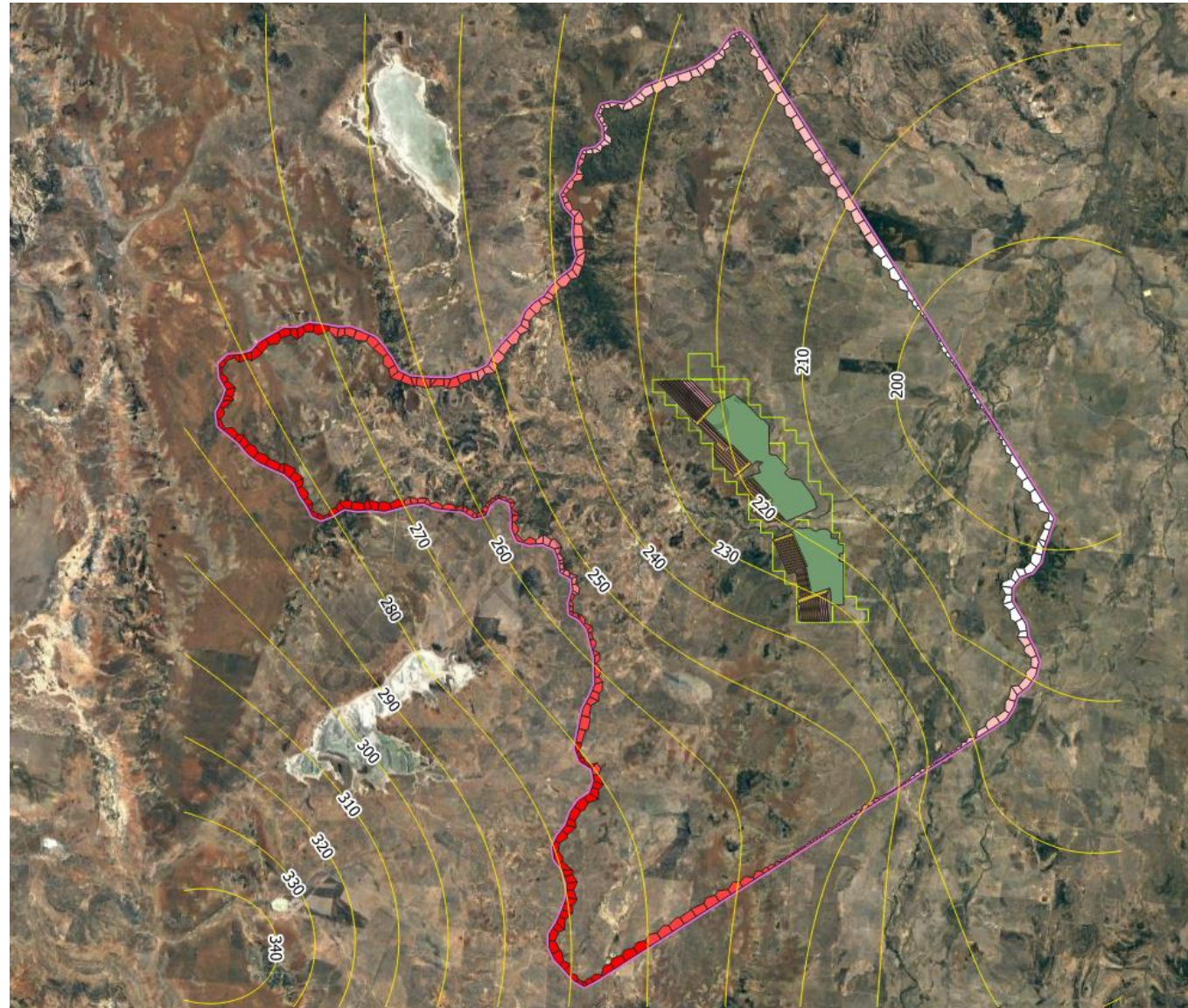
Joe Joe top (mAHD)



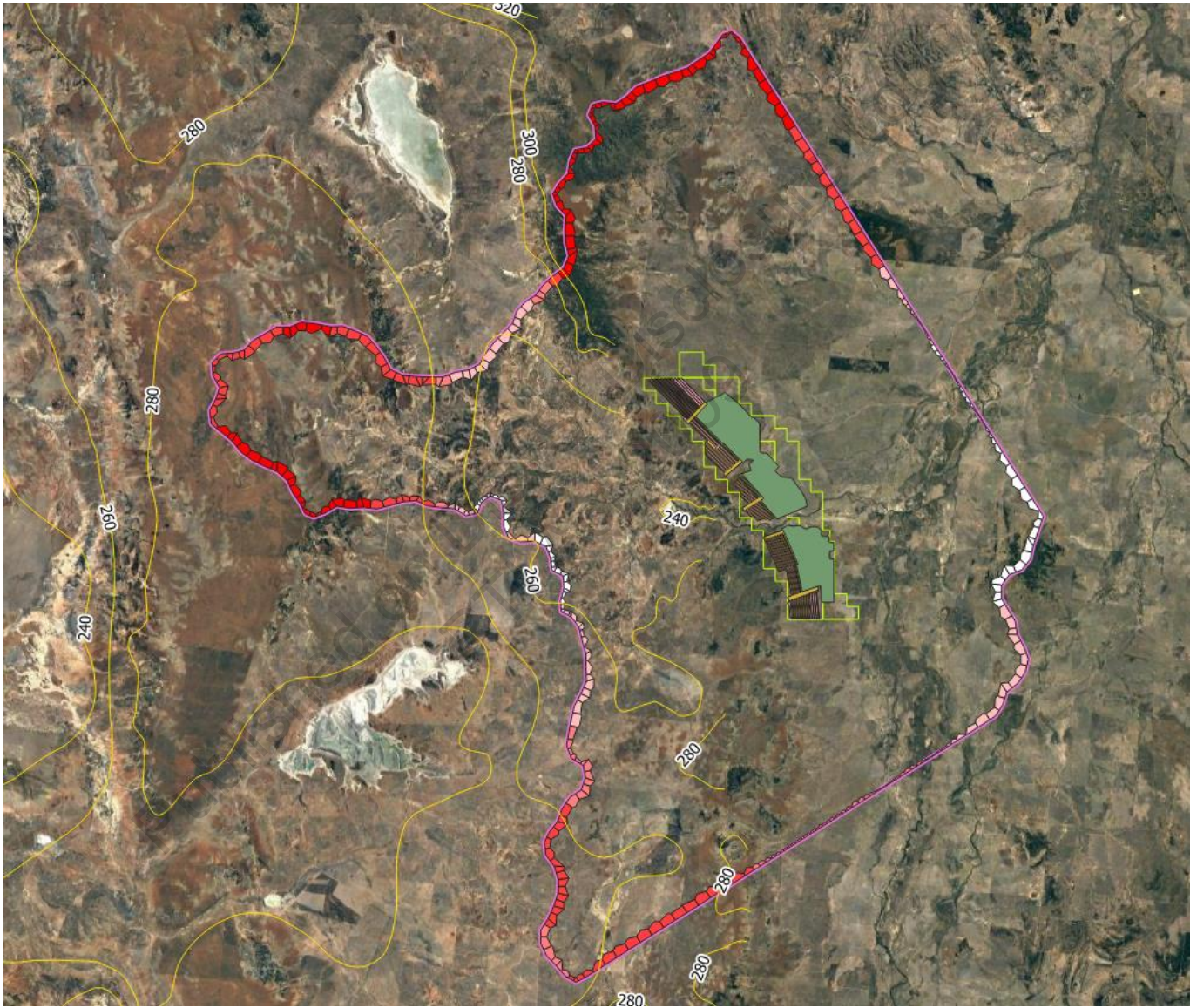
Cross section (west-east)



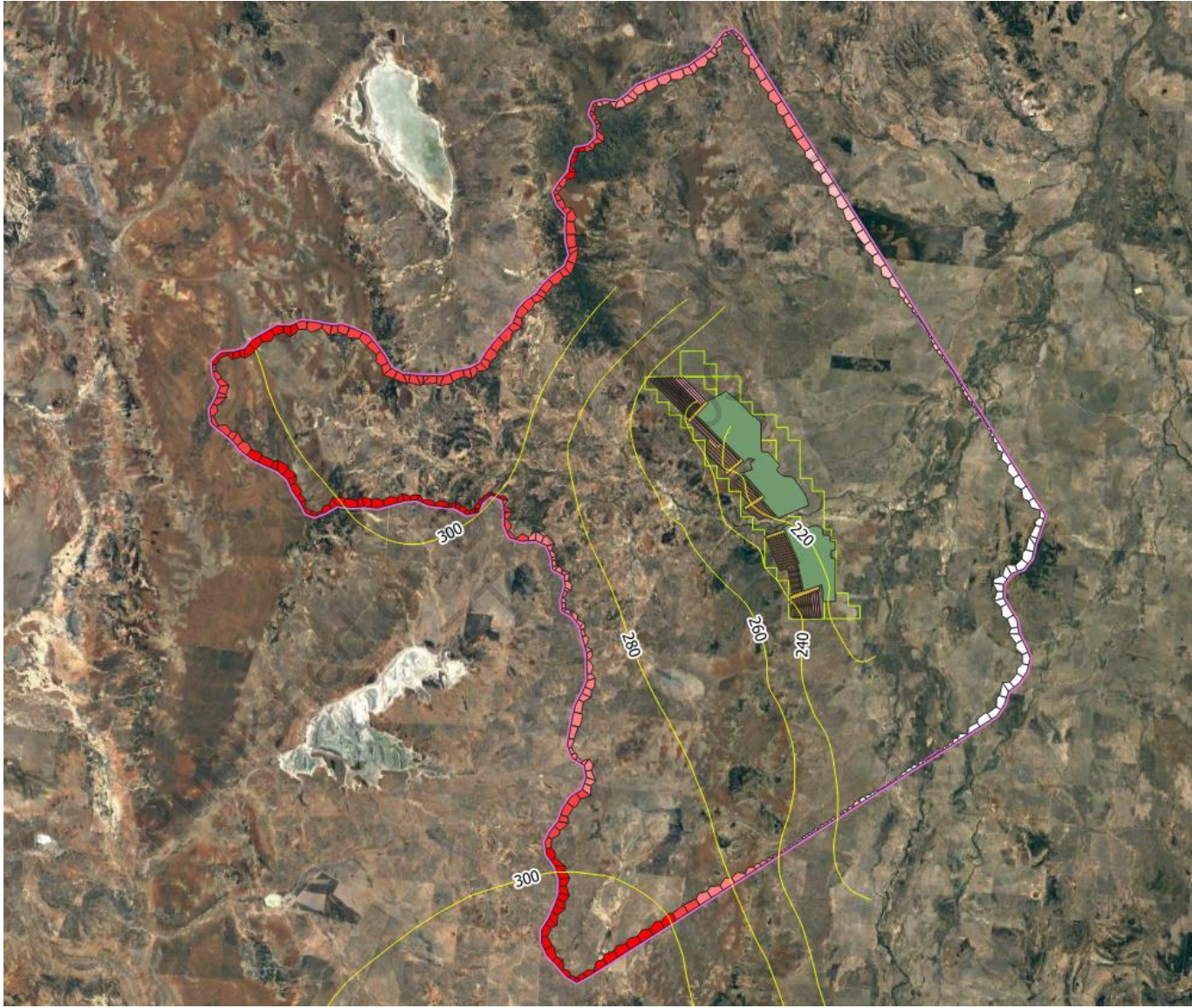
Surficial regional boundaries



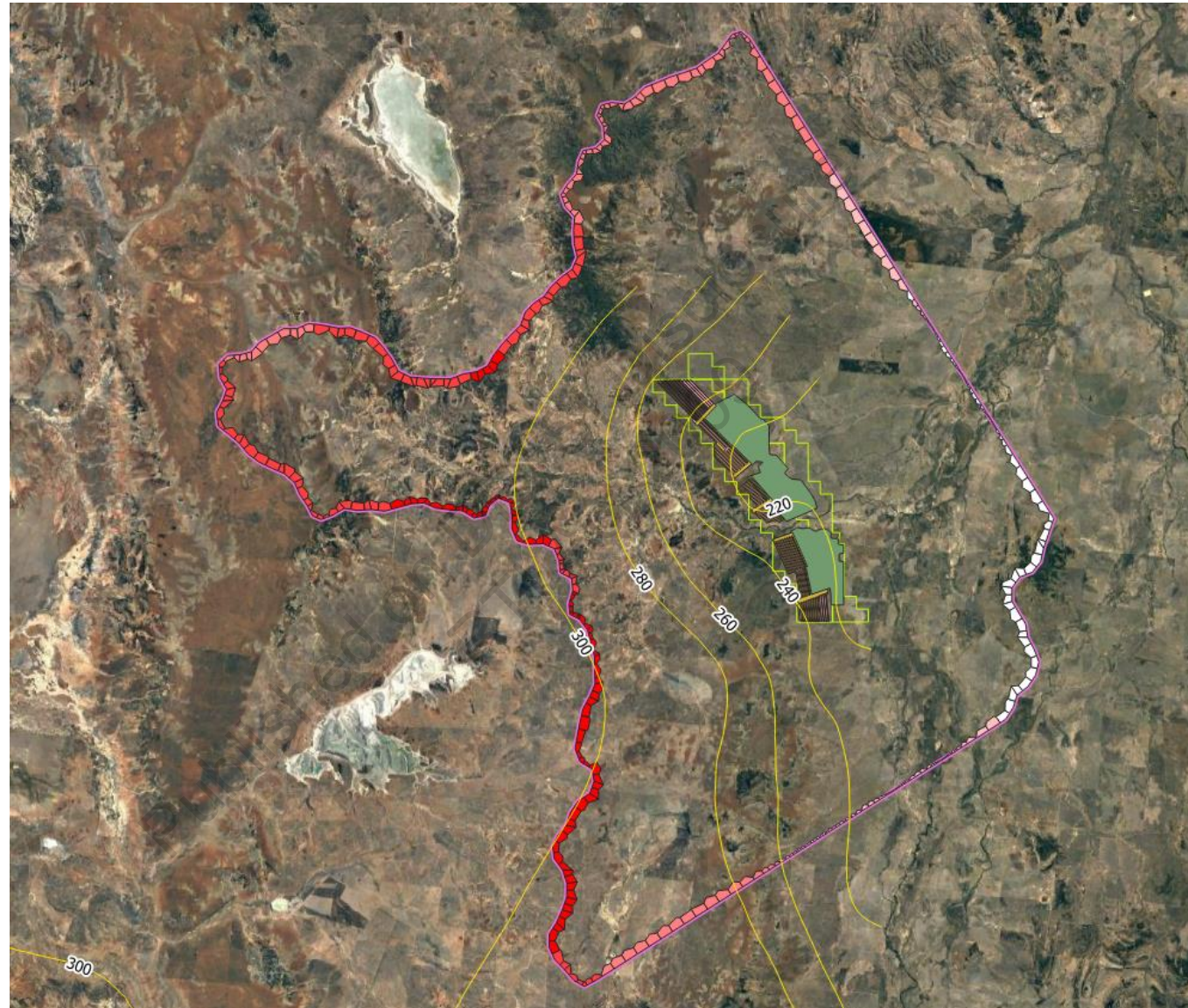
Clematis regional boundaries



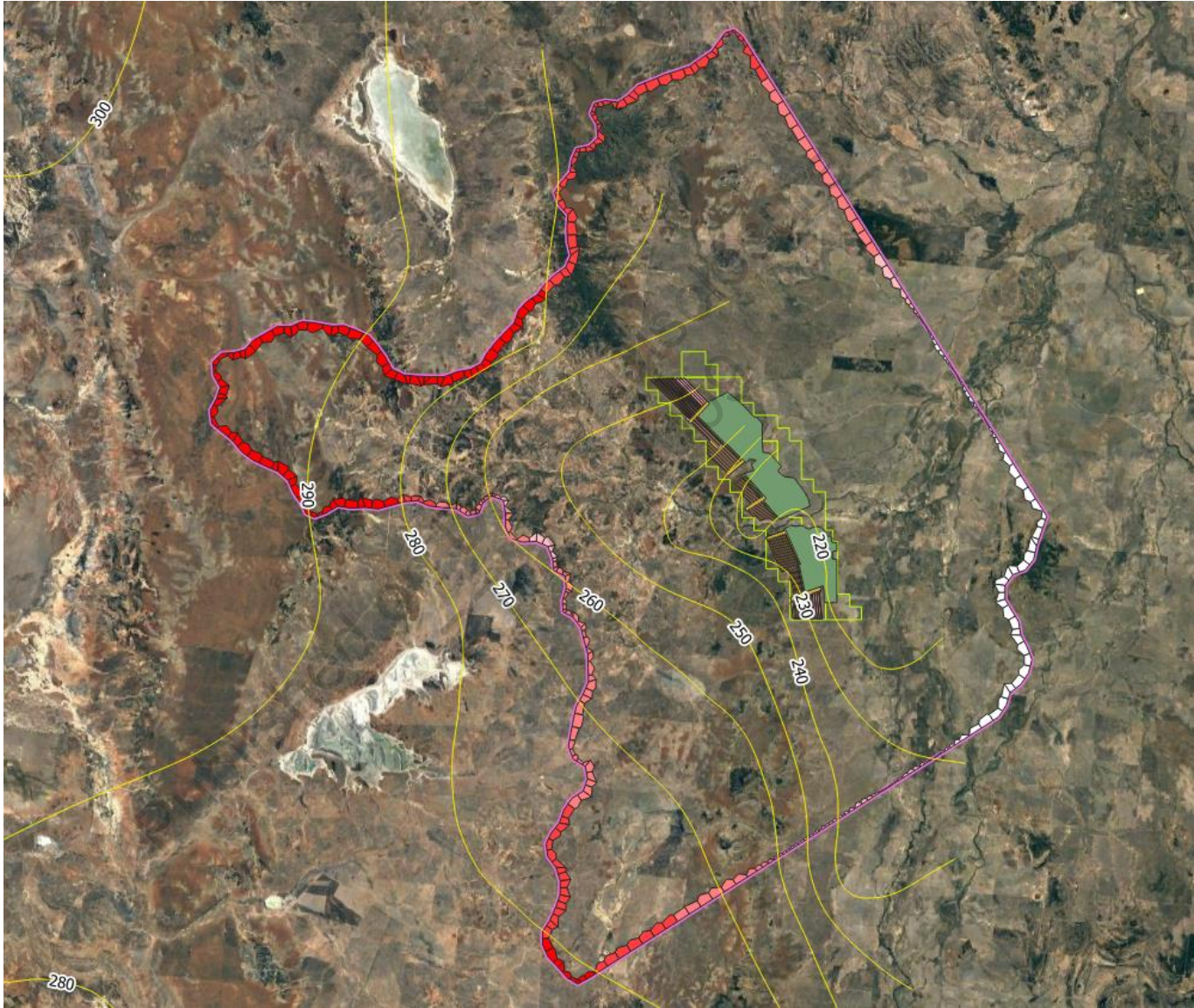
Bandanna regional boundaries



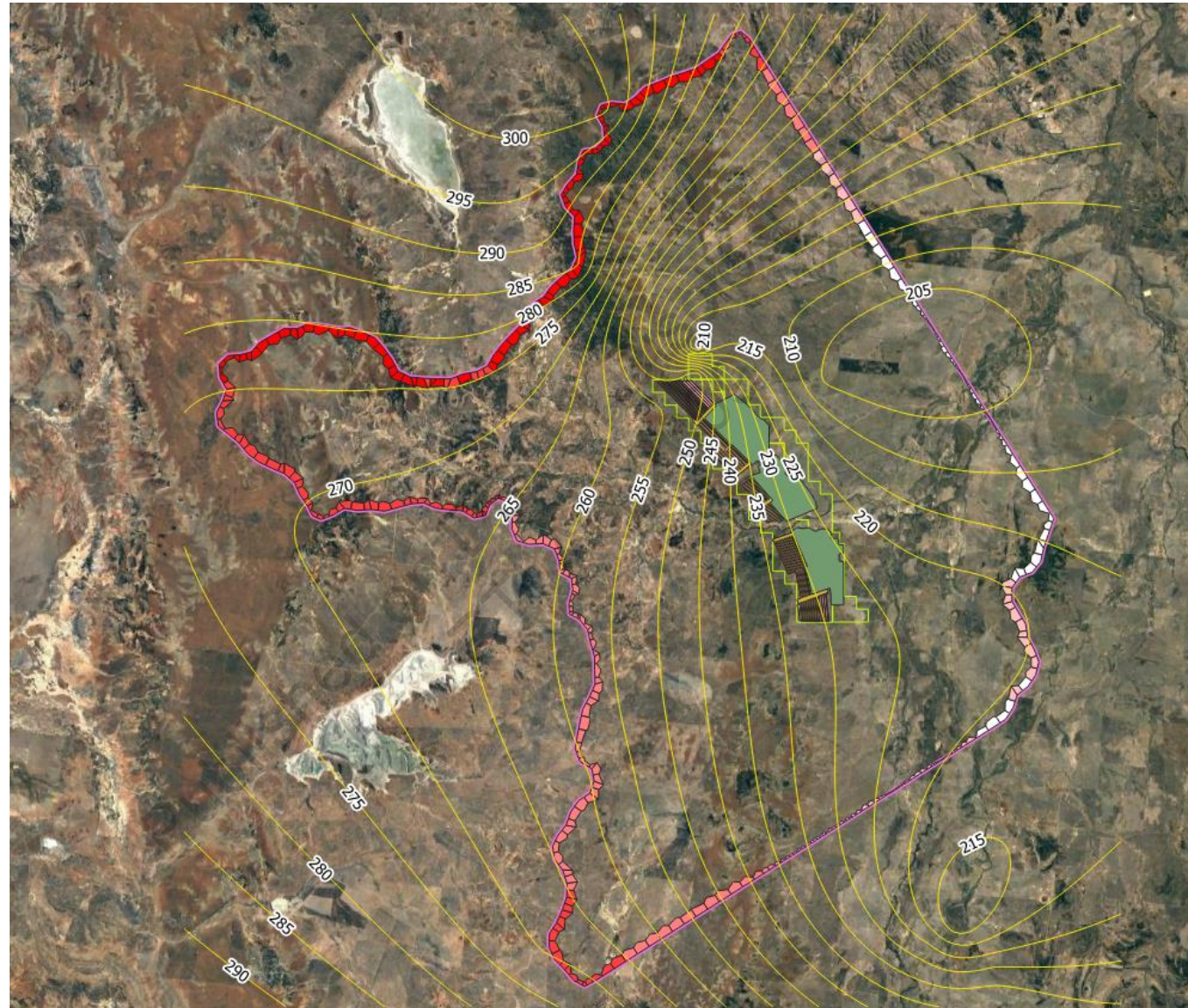
Coal seam regional boundaries



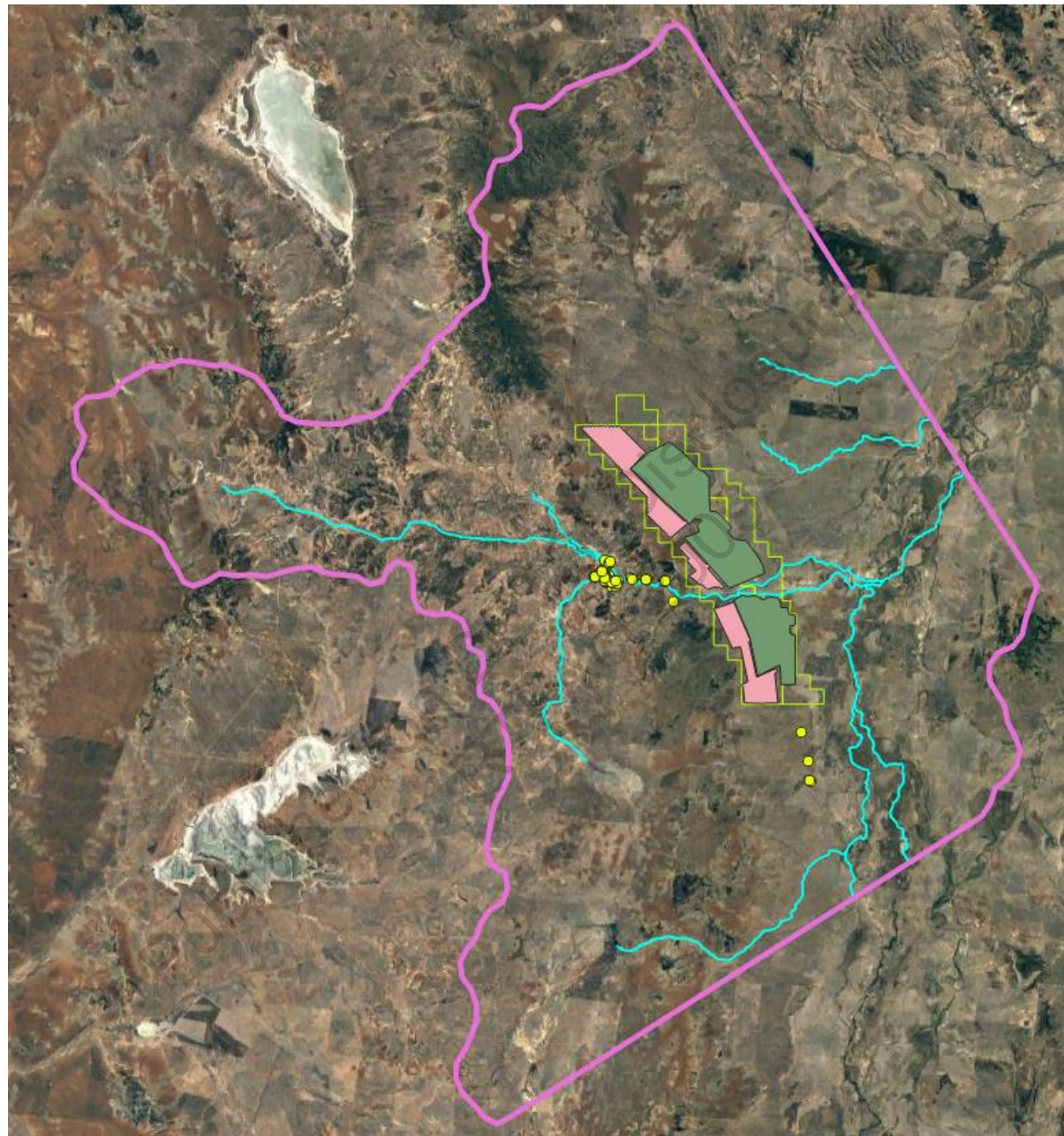
Colinlea regional boundaries



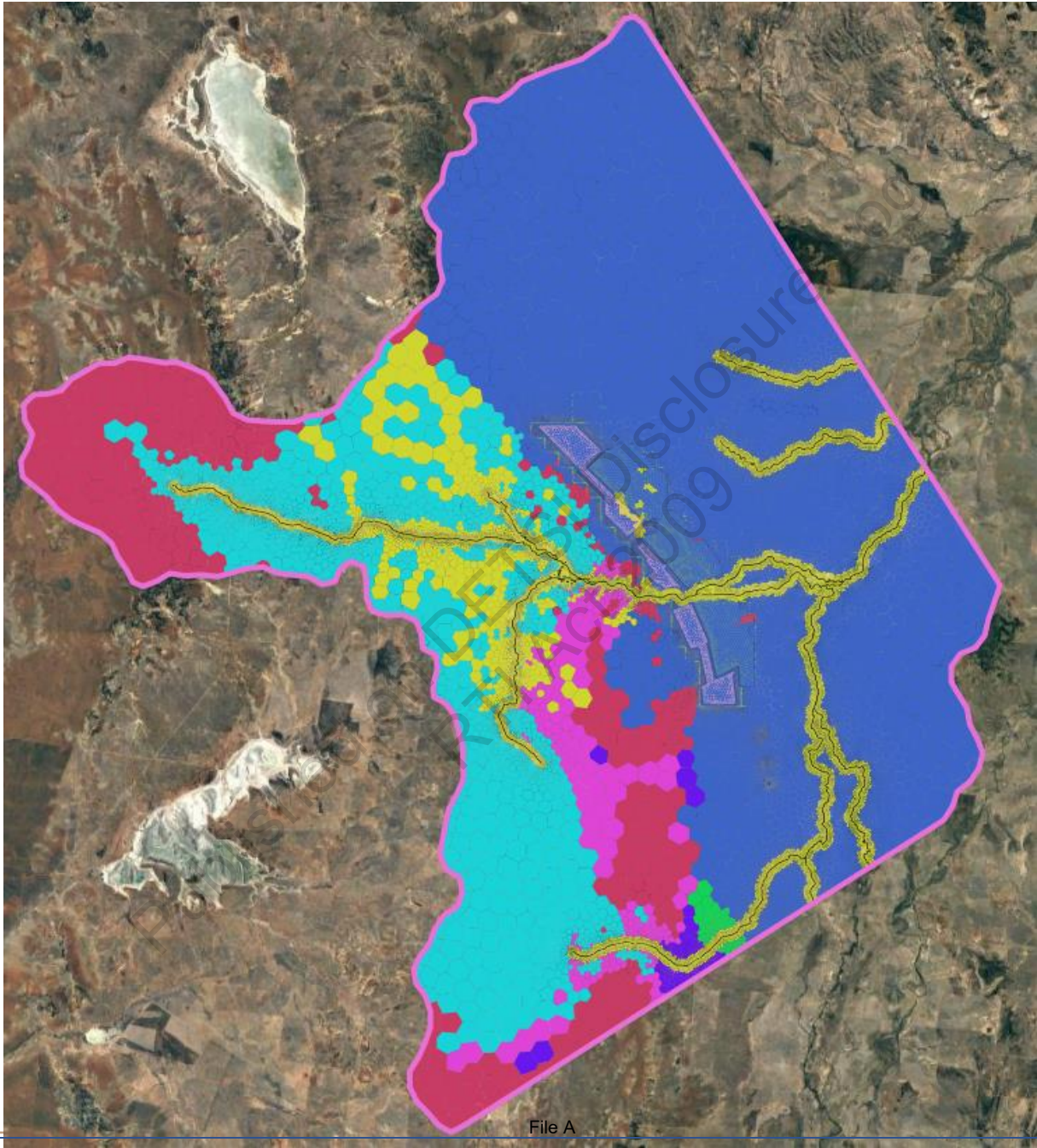
Joe Joe regional boundaries



Surface water



Recharge



- Alluvium
- Weathered
- Tertiary
- Moolayember
- Clematis
- Rewan
- Bandanna
- Inactive

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History-matching

History-matching stresses

- Environmental stresses:
 - Regional throughflow
 - Watercourses, leaking to groundwater system during wet season
 - Doongmabulla/Mellaluka springs
 - Recharge to outcropping HSUs, set as a proportion of measured rainfall
 - Evapotranspiration
- Mining stresses:
 - Dewatering bores, active from August 2019, with monthly abstraction rates

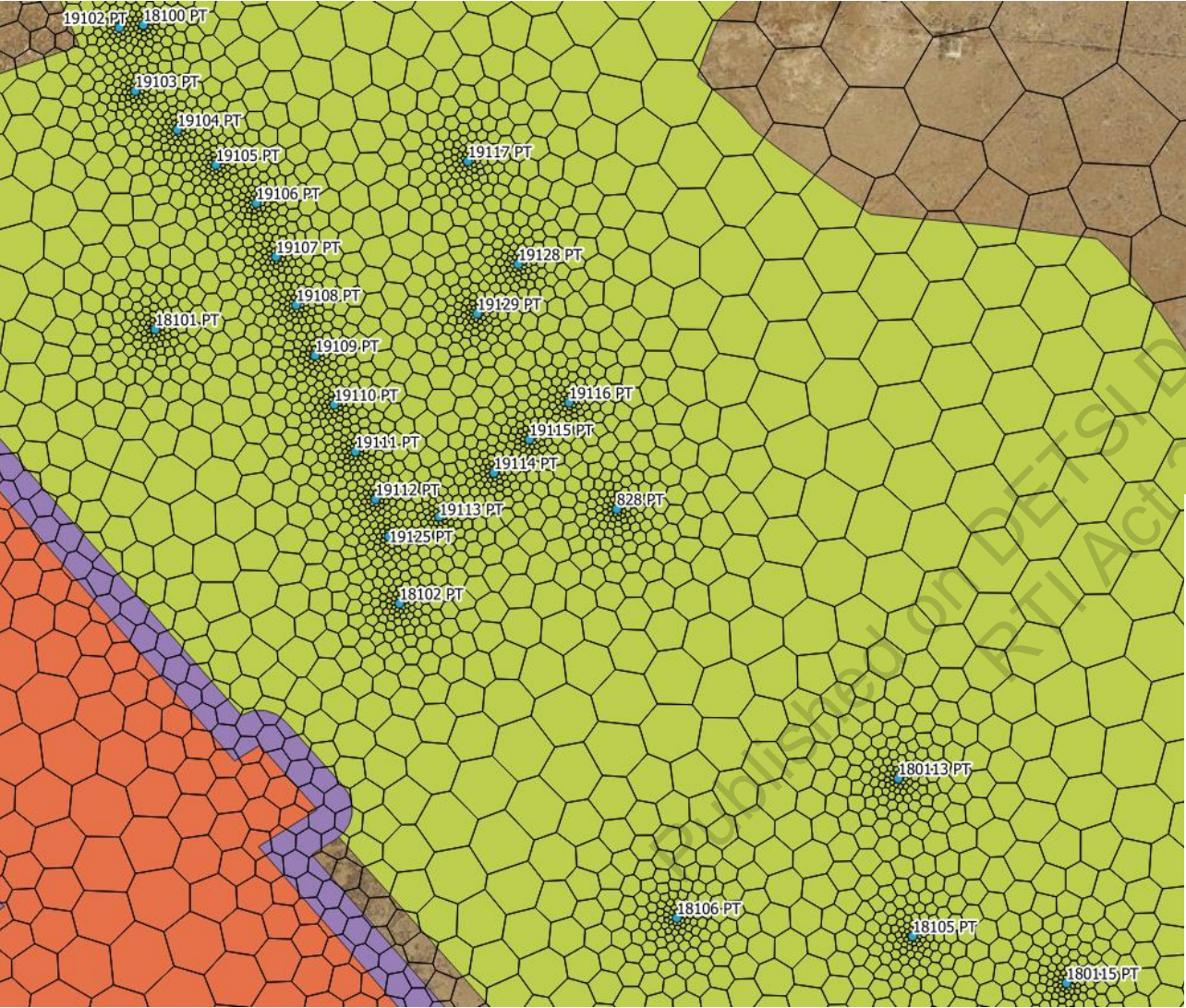
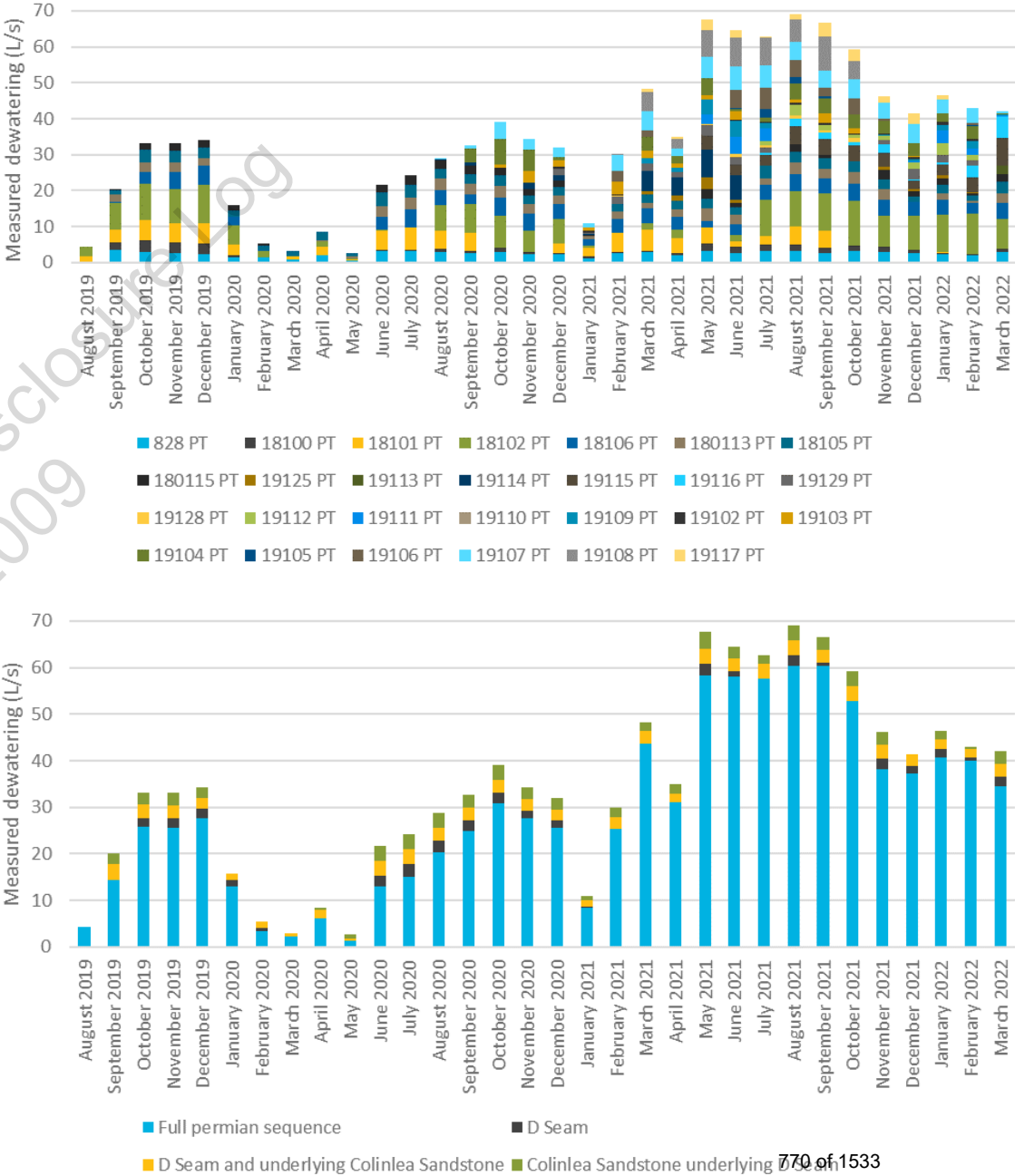
Modelled watercourses

Watercourse	Depth in steady state stress period (m)	Wet season depth (m)	Dry season depth (m)
Belyando River	1.18	1.78	0
Belyando western breakout	0.59	0.89	0
Bimbah Creek	0	0	0
Carmichael River	0.30	0.70	0
Cattle Creek	0.15	0.35	0
Dunda Creek	0	0	0
Dyllingo Creek	0.15	0.35	0
Dyllingo northern breakout	0	0	0
North Creek	0	0	0
Tomahawk Creek	0	0	0

Modelled recharge and evapotranspiration

- Recharge calculated per stress period based on measured rainfall data at Ulcanbah station, with a PEST-estimated multiplier applied per outcropping HSU resulting in the following annual average recharge rates:
 - Quaternary alluvium: 0.009 mm/year (plus recharge from watercourse leakage and springs discharging to surface)
 - Weathering zone: 0.002 mm/year
 - Tertiary and non-alluvial Quaternary deposits: 0.083 mm/year
 - Moolayember Formation: 0.003 mm/year
 - Clematis Sandstone / Warang Sandstone: 0.194 mm/year
 - Rewan Formation: 0.001 mm/year
 - Bandanna Formation: 0.001 mm/year
- Evapotranspiration applied per stress period with a maximum rate equal to pan evaporation, with an extinction depth of 1.4 m regionally and 6 m in highly vegetated riverine areas

Modelled production bores



History-matching detailed process

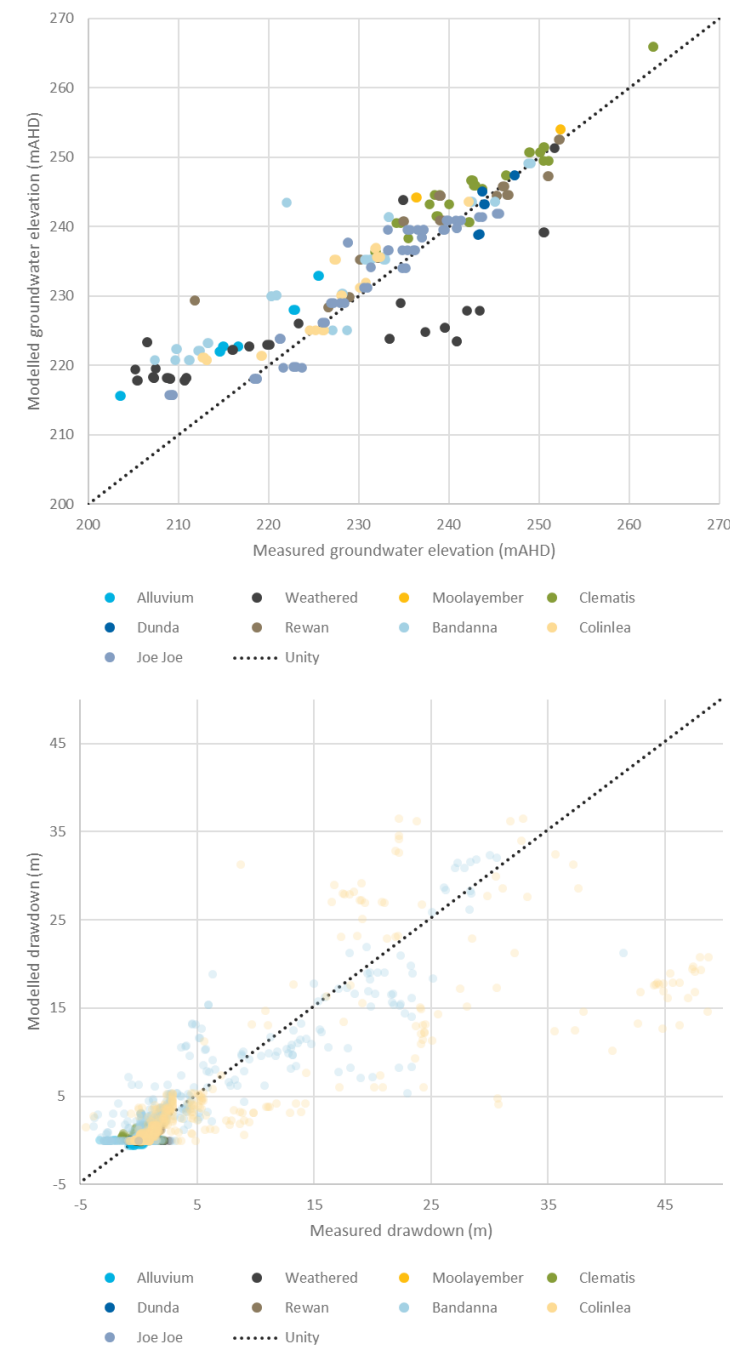
- Set up model with expected hydraulic properties based on hydrogeological conceptual model
- Define measured groundwater level data and estimates of spring flux as targets
 - Group targets by HSU, using first transient measurement as a 'head' target, and the remainder as 'head-change' targets
- Run model to calculate starting objective function
- Re-weight targets such that each target group (head and head-change per HSU, spring flux) contributes an equal amount to the starting objective function
- Run PEST on parameter zones, giving homogeneous values as a starting point for **highly parameterised** history-matching
- Set up **pilot points (>30,000)** with parameter bounds based on conceptualisation with additional range (up to an order of magnitude) to account for smaller scale heterogeneities
- Re-weight targets as per point 4 above, for new starting point
- Run **PESTPP-IES for 10 iterations**, with 500 realisations
- Review model parameters against conceptualisation, and make adjustments accordingly (e.g. limit anisotropy ratio)
- Run model with updated parameters to ensure performance against targets is not substantially degraded
- Run **PESTPP-IES for 1 more iteration**; further improving history-matching performance and developing a suite of parameter values that can be used for predictive uncertainty analysis

Further effort in history-matching

- Unsatisfied with history-matching performance of uncertainty ensemble, run **PESTPP-IES for 13 more iterations** with primarily unweighted targets (all target weights = 1 except for two drawdown groups and flux, which were assigned lower weights to bring the contribution to objective function more in line with other groups)
- Still unhappy with history-matching performance of uncertainty ensemble, **re-weight targets again** such that each group contributes an equal amount to the objective function, then multiply weights of initial head targets by $\text{SQRT}(2)$ to double the contribution of these groups
- Run **PESTPP-IES for 7 iterations**, increasing the number of realisations to 500, and use resultant parameter ensemble for base case
- Following review by Noel Merrick, re-develop parameter ensemble centered on base realization, with tighter Gaussian distribution where one standard deviation is equal to one order of magnitude ($\sigma = 0.5$) for predictive uncertainty analysis

History-matching performance: base case

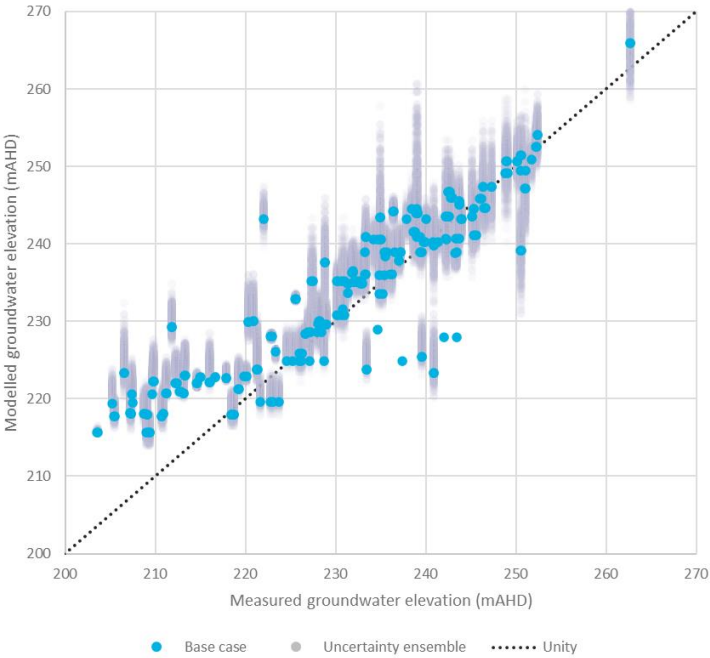
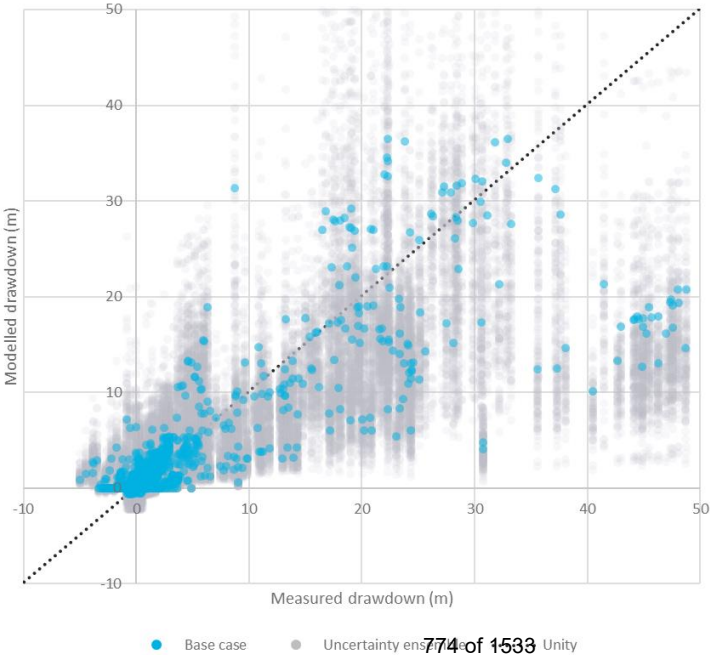
- History-matching undertaken on weighted head and head-change targets
- Performance reported against **unweighted head values**
- **SRMS 6.7%**
- Mean residual -3.6 m
- Mean absolute residual 4.8 m
- Minimum residual -39.4 m
- Maximum residual 17.5 m
- Number of observations 11,441
- Range of observations 93.5 m
- Flux targets:
- Joshua Spring
 - Estimated flux 1 ML/d
 - Modelled flux 0.91 ML/d
- Other DSC fluxes
 - Estimated flux 0.4 ML/d
 - Modelled flux 0.57 ML/d



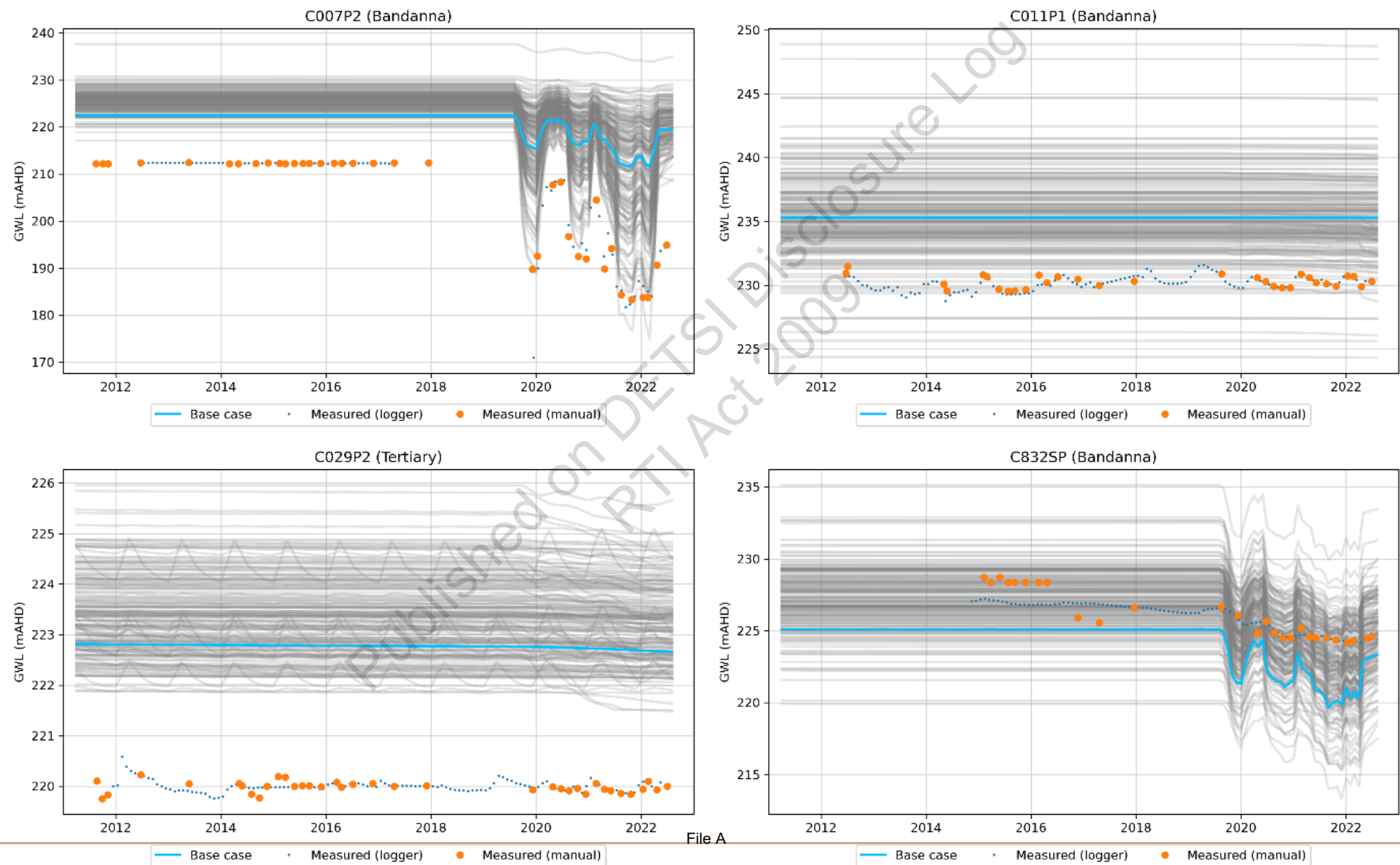
History-matching performance: ensemble

SRMS error	Initial head	Transient head-change	Transient head
Base realisation	10.9%	3.4%	6.7%
Maximum	14.1%	4.7%	8.9%
90 th percentile	13.0%	3.8%	8.2%
Median	12.1%	3.3%	7.5%
10 th percentile	11.4%	2.9%	7.0%
Minimum	10.5%	2.5%	6.3%

- Performance acceptance criteria adopted for predictive ensemble:
 - Initial hydraulic head SRMS 12.5%
 - Transient head-change SRMS 3.5%
 - Transient head SRMS 8.0%
- 500 parameter realisations
- 164 non-convergences
- 231 rejected on performance
- **105**/500 realisations accepted

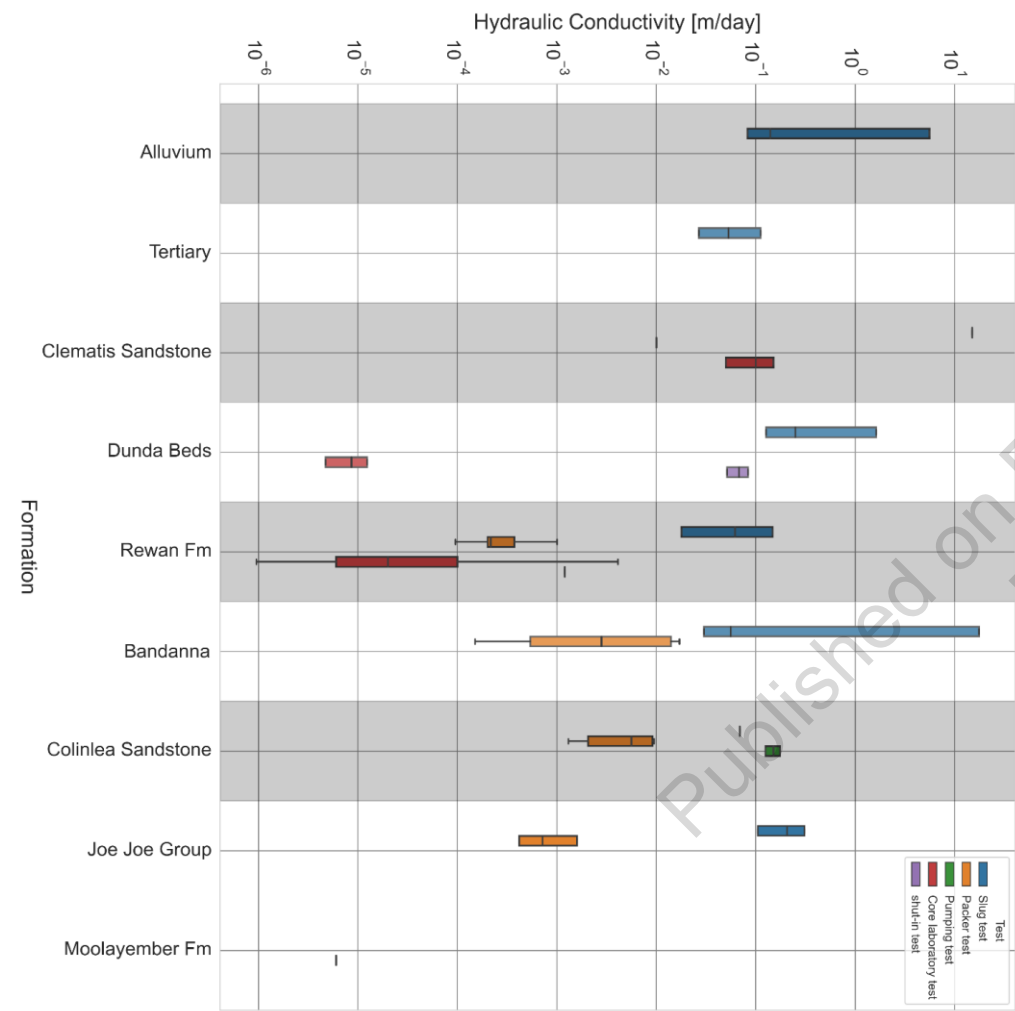


History-matching: example hydrographs

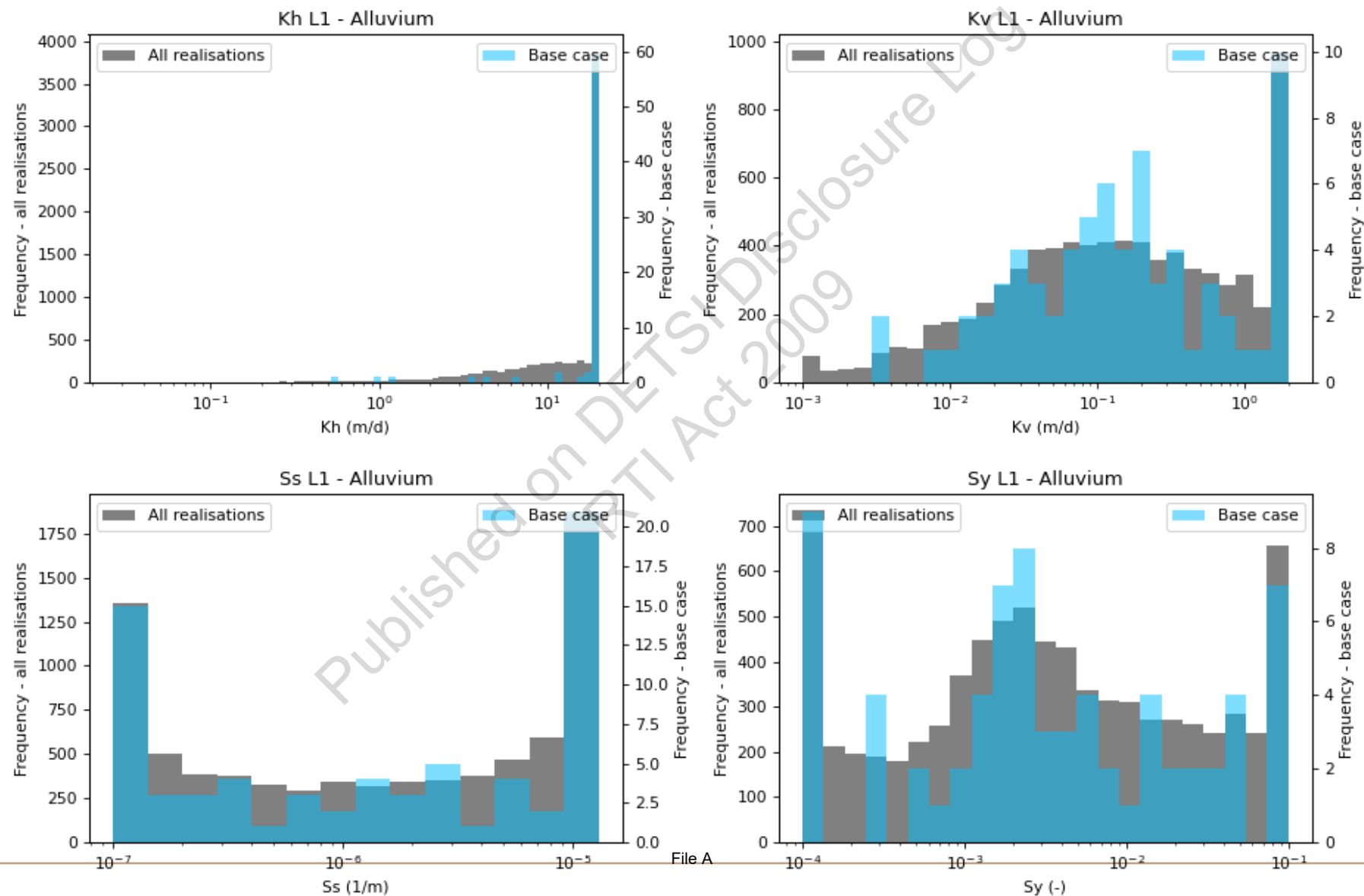


Parameterisation

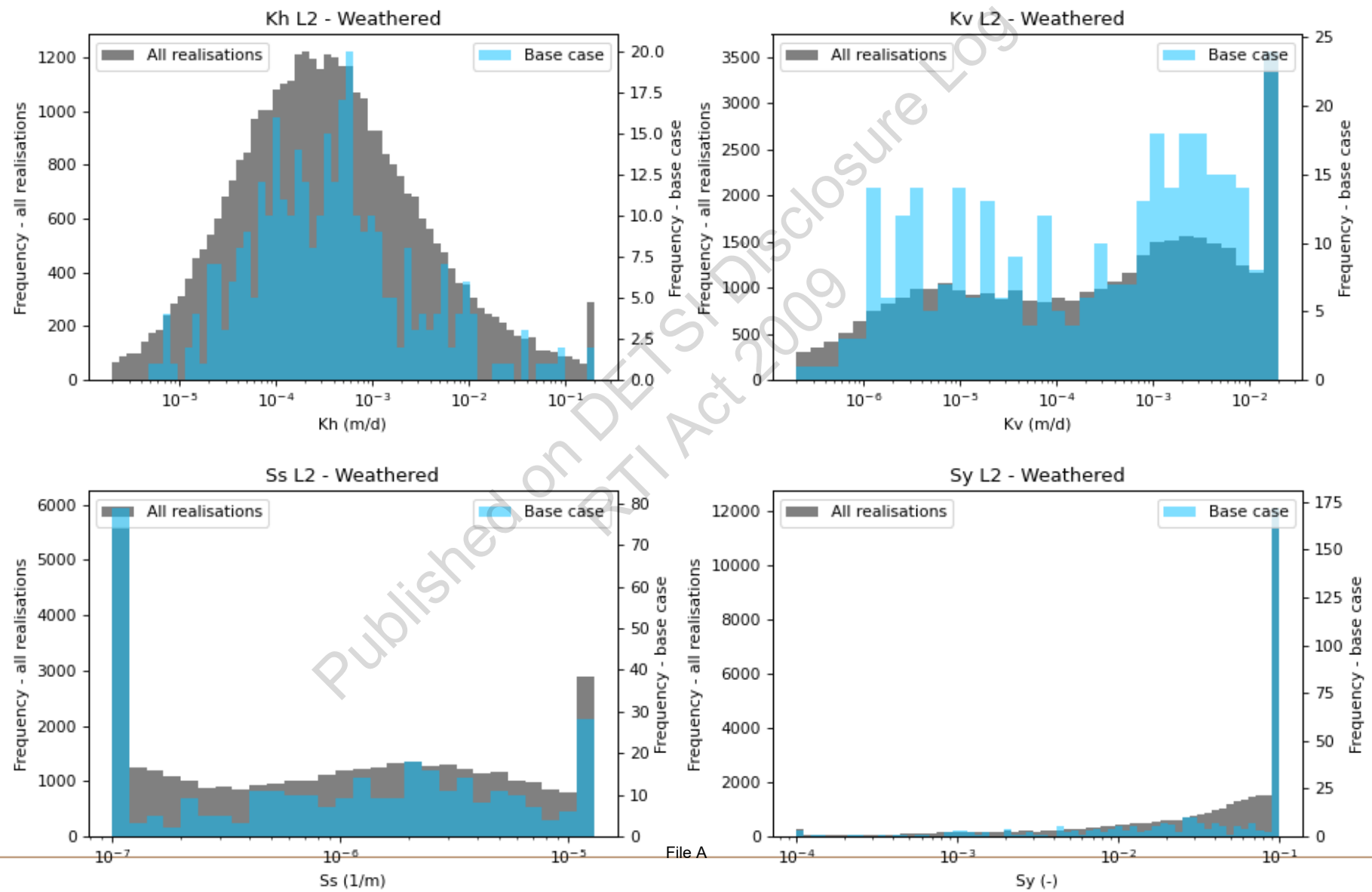
Interpreted hydraulic conductivity



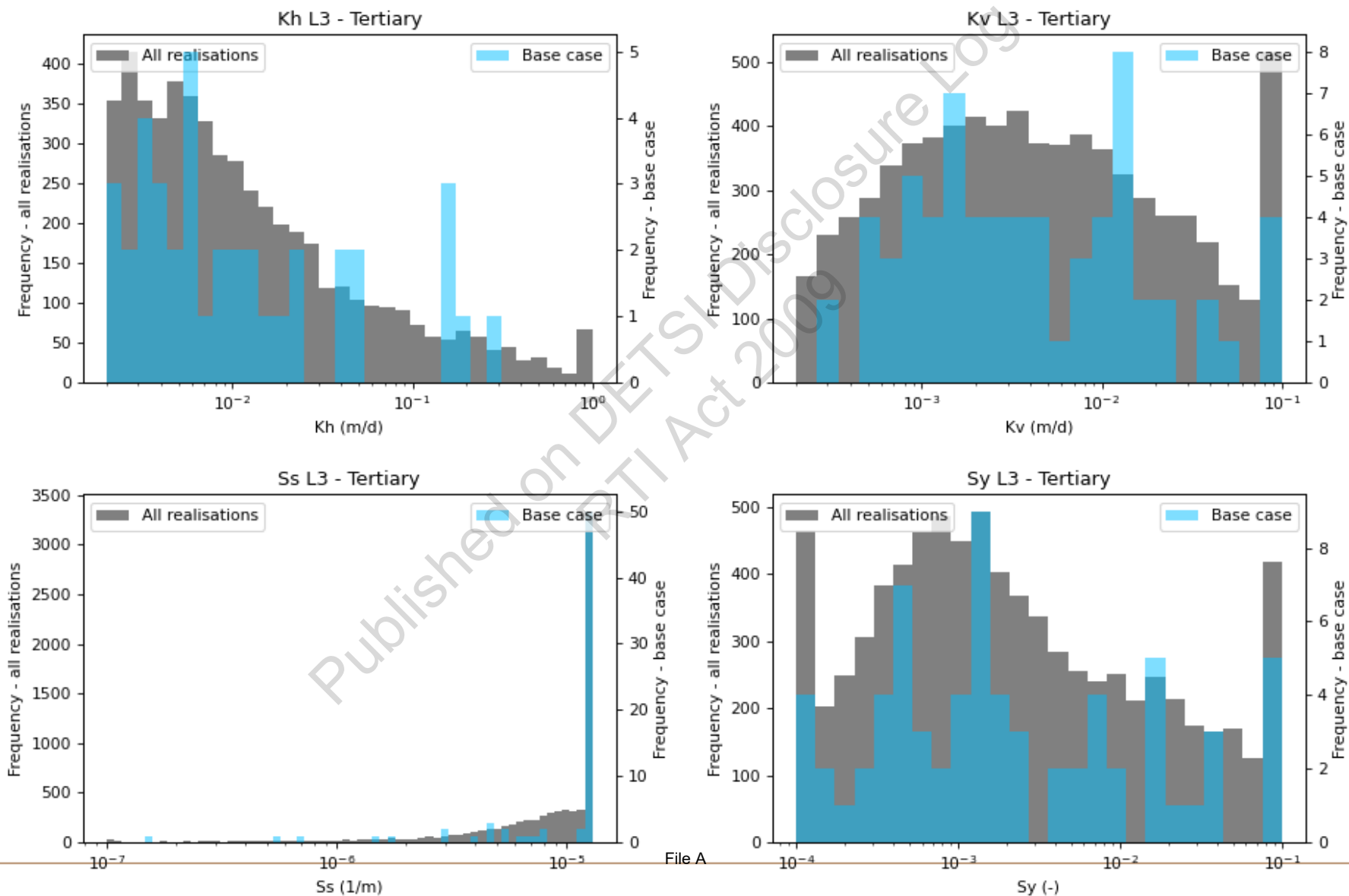
Parameterisation – L1 Alluvium



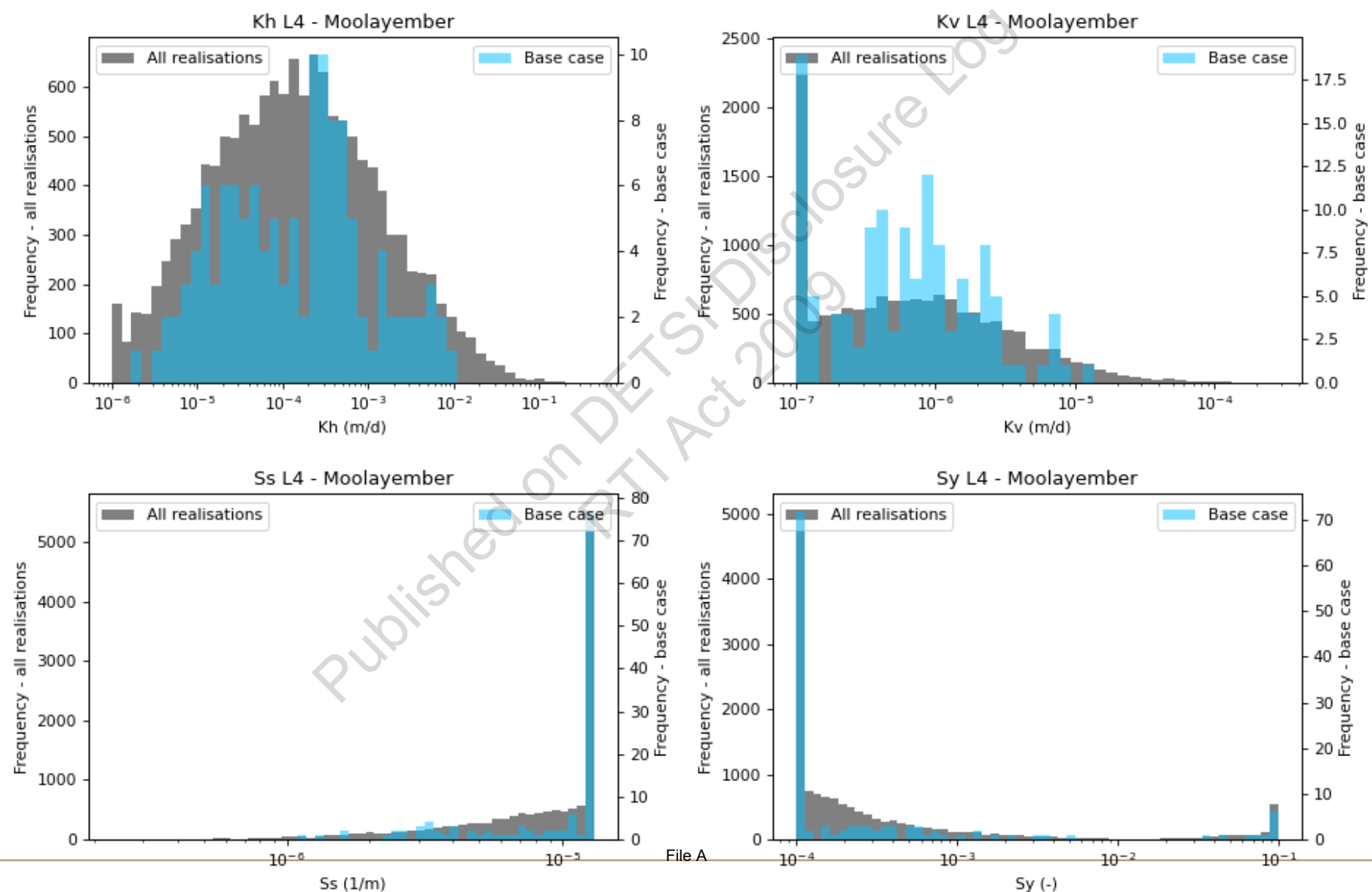
Parameterisation – L2 Weathered



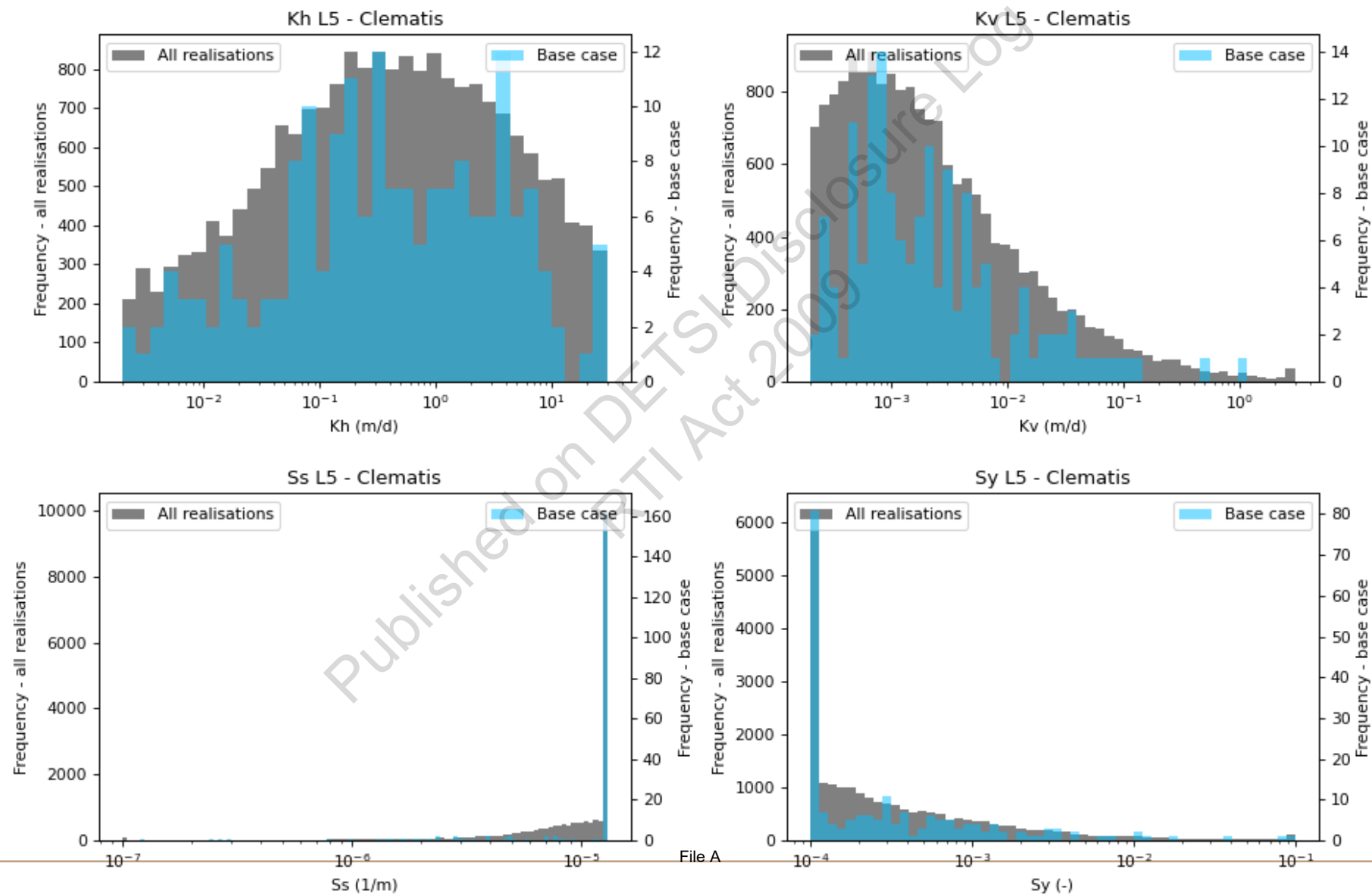
Parameterisation – L3 Tertiary



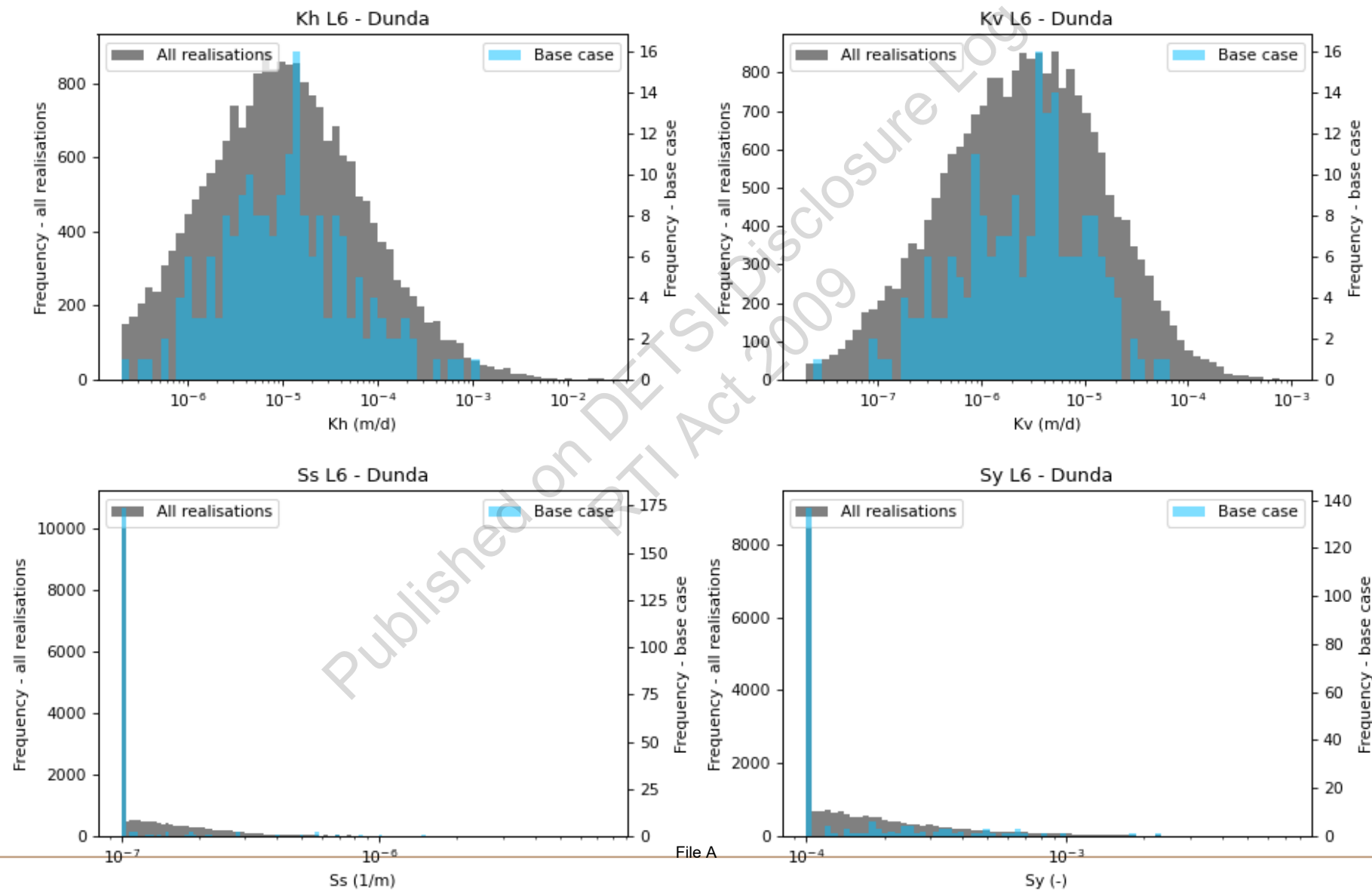
Parameterisation – L4 Moolayember



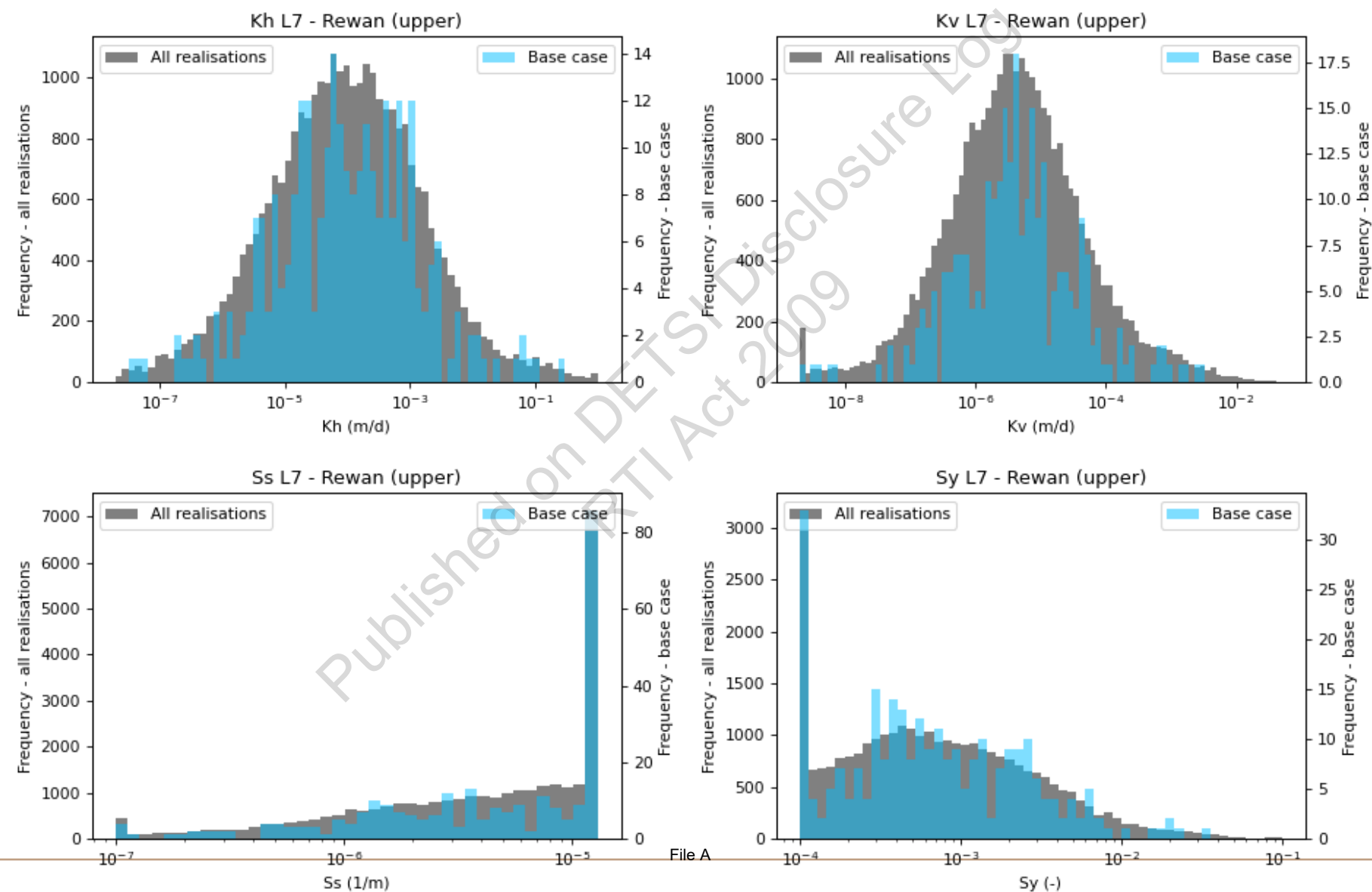
Parameterisation – L5 Clematis



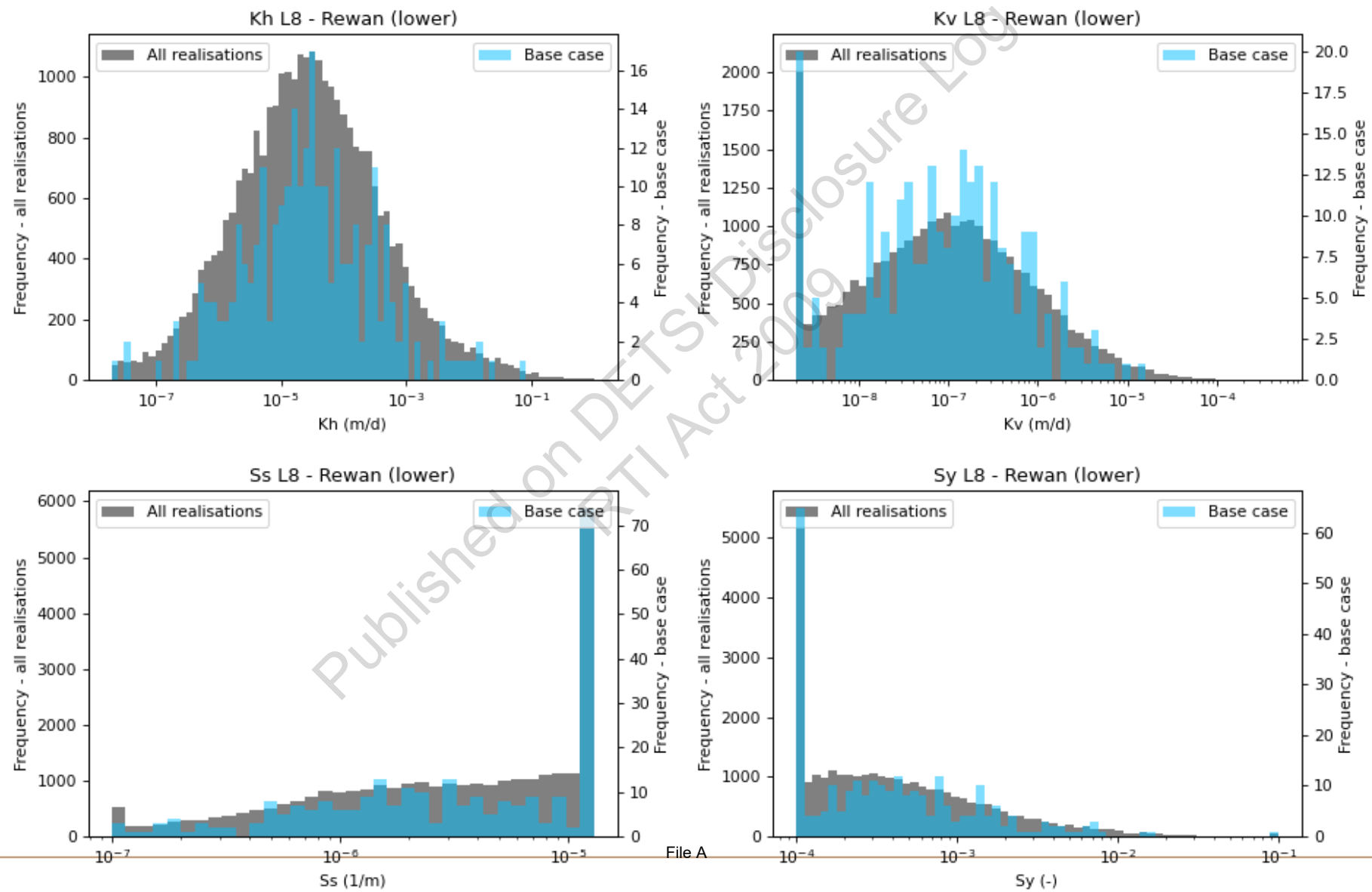
Parameterisation – L6 Dunda



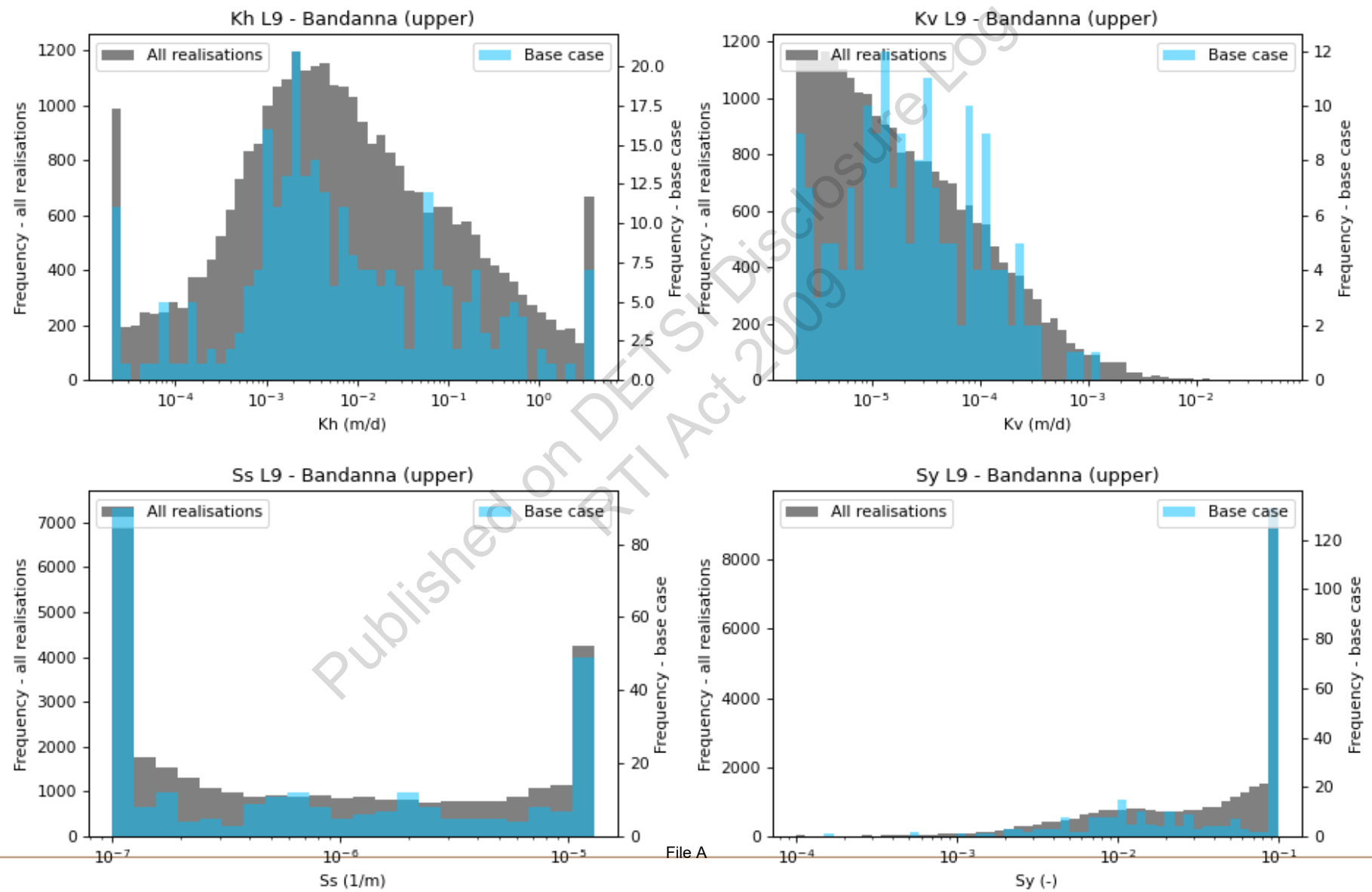
Parameterisation – L7 Rewan (upper)



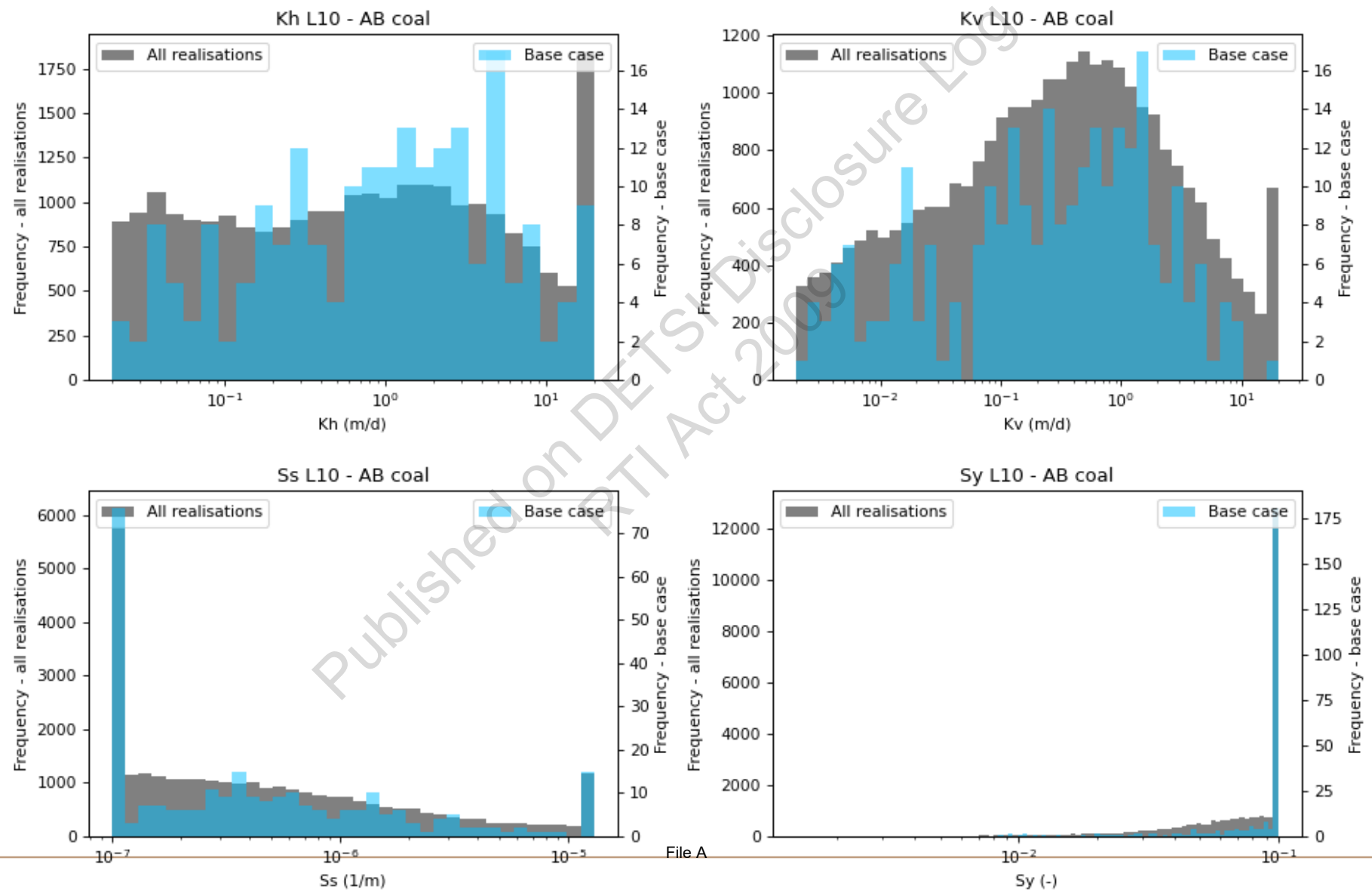
Parameterisation – L8 Rewan (lower)



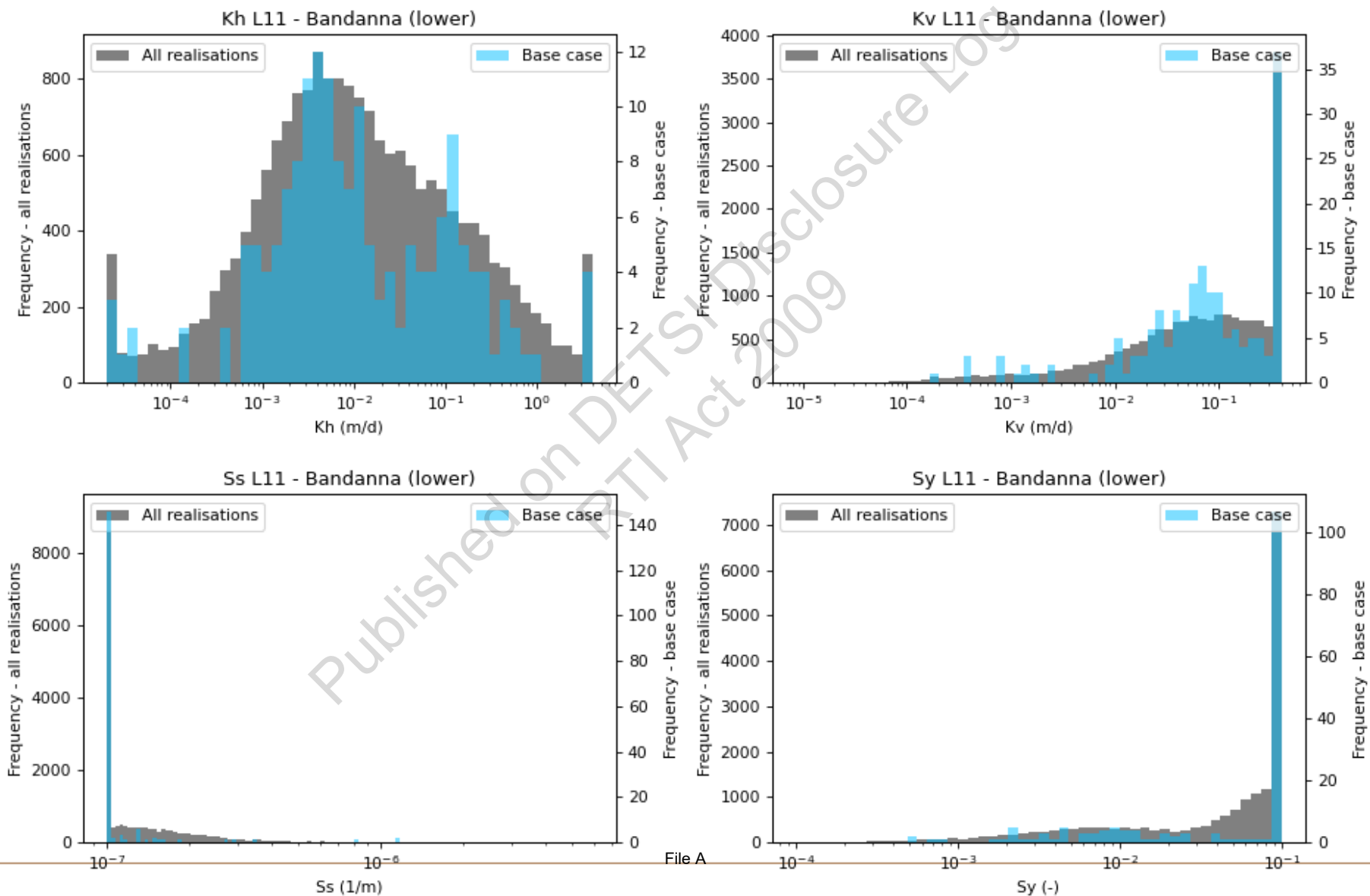
Parameterisation – L9 Bandanna (upper)



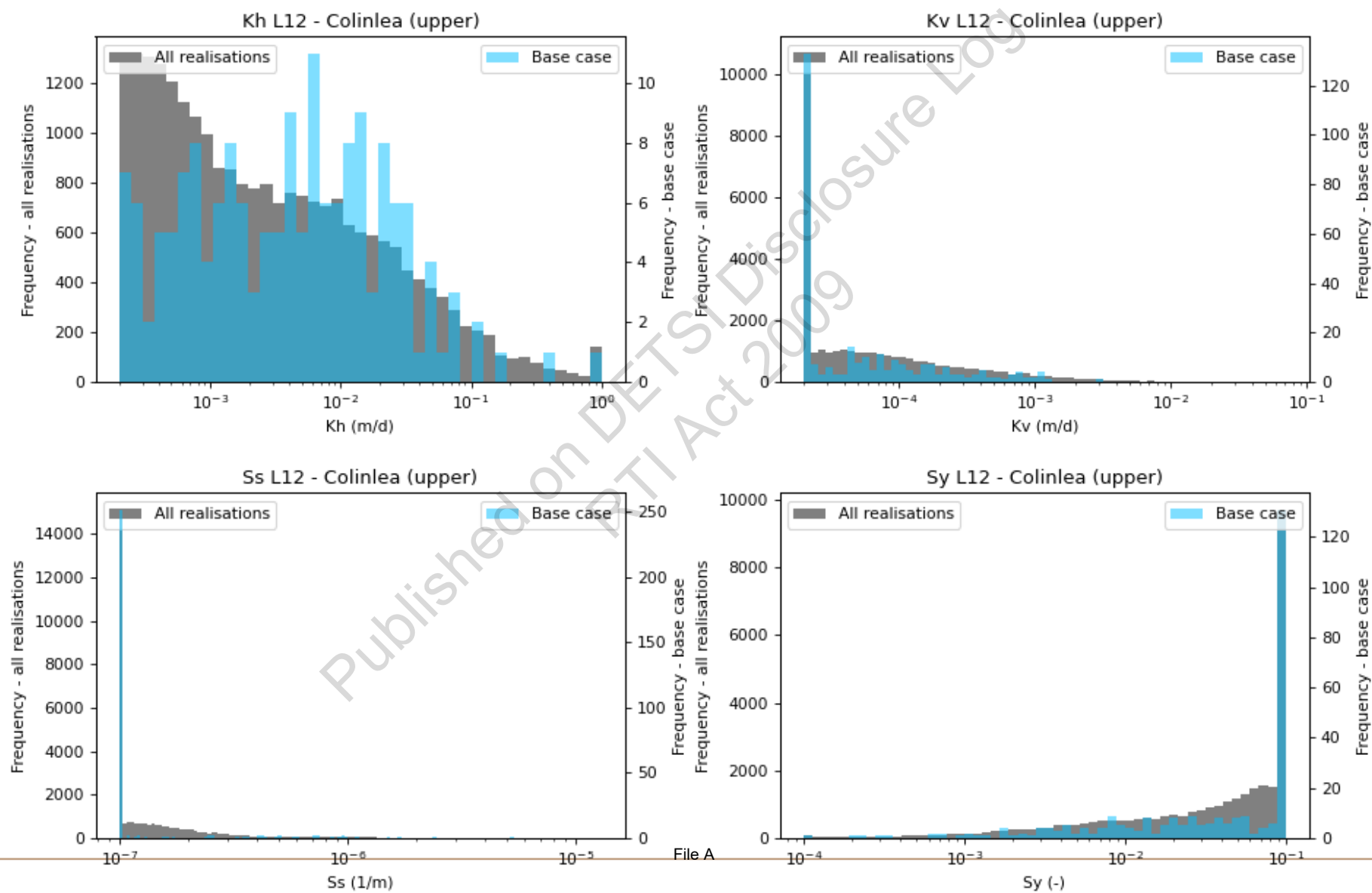
Parameterisation – L10 AB Coal



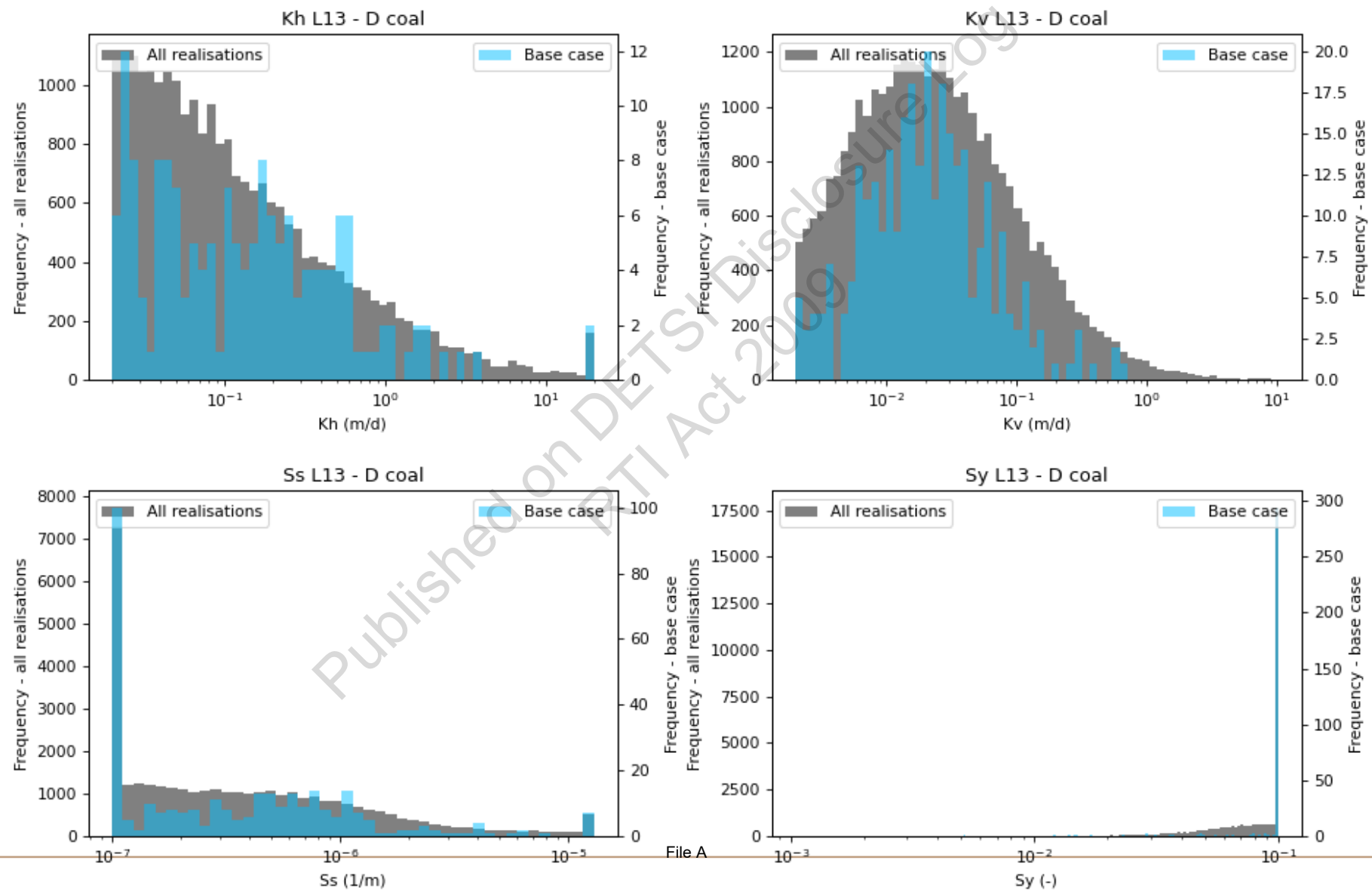
Parameterisation – L11 Bandanna (lower)



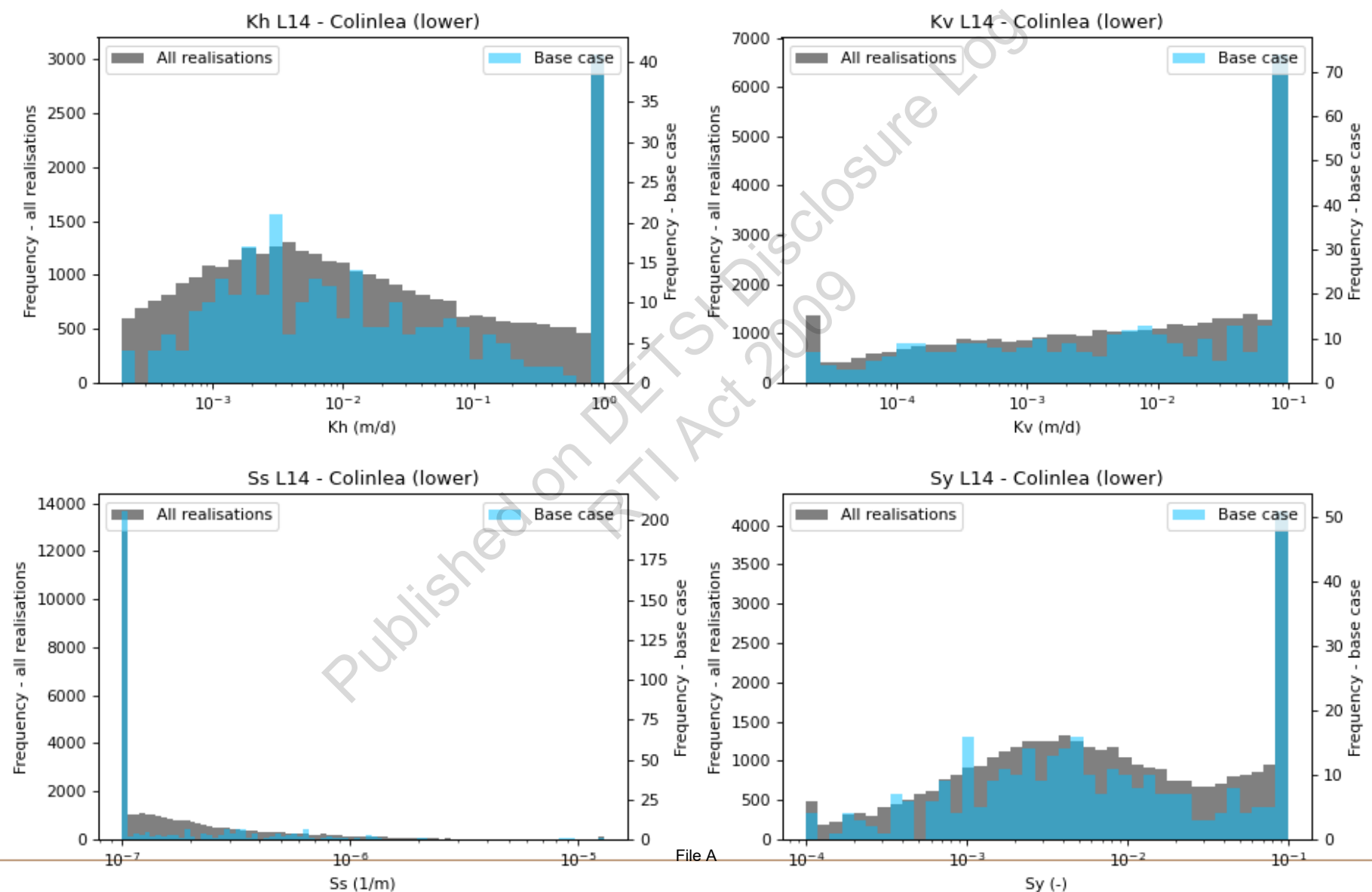
Parameterisation – L12 Colinlea (upper)



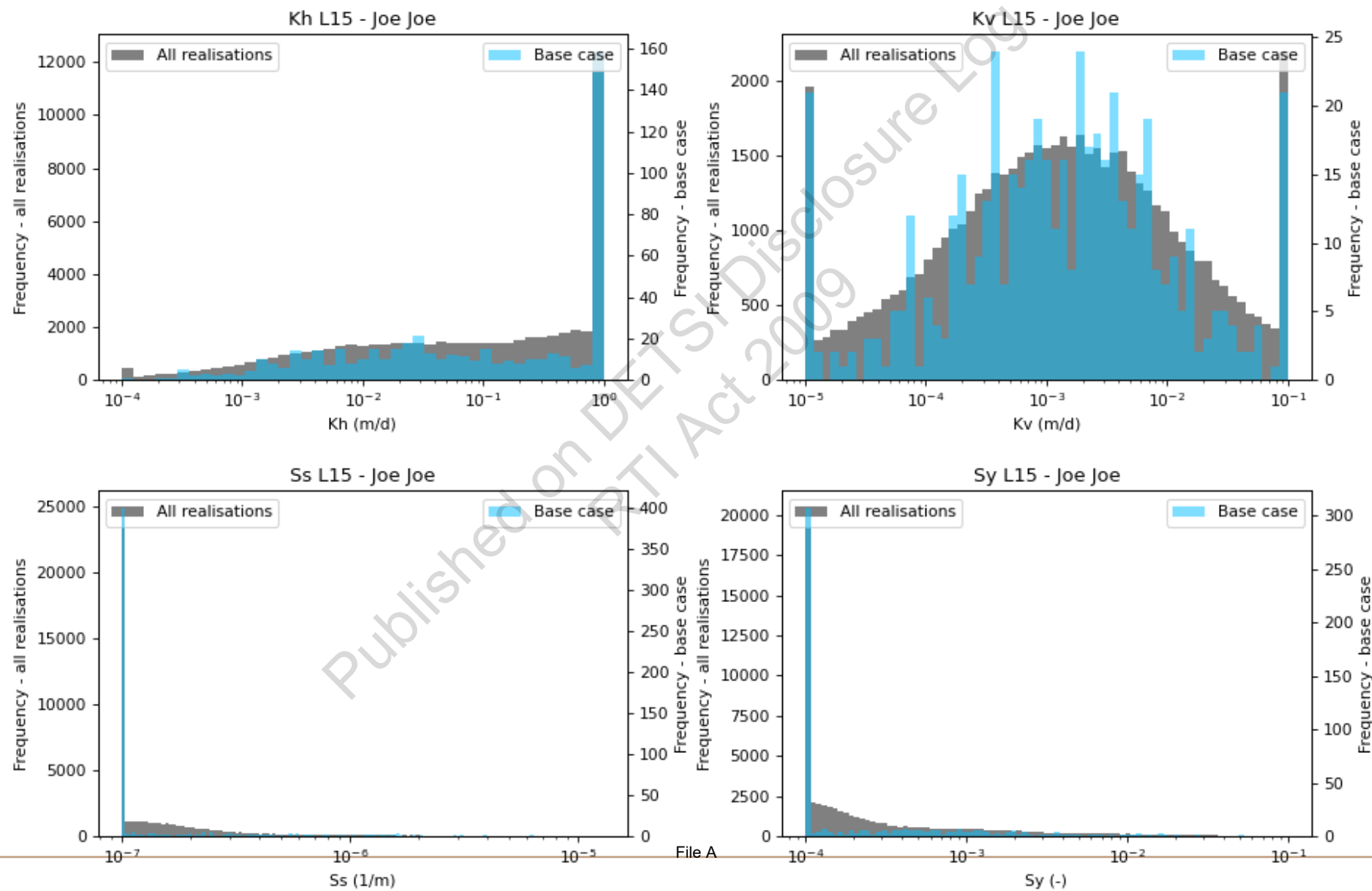
Parameterisation – L13 D Coal



Parameterisation – L14 Colinlea (lower)

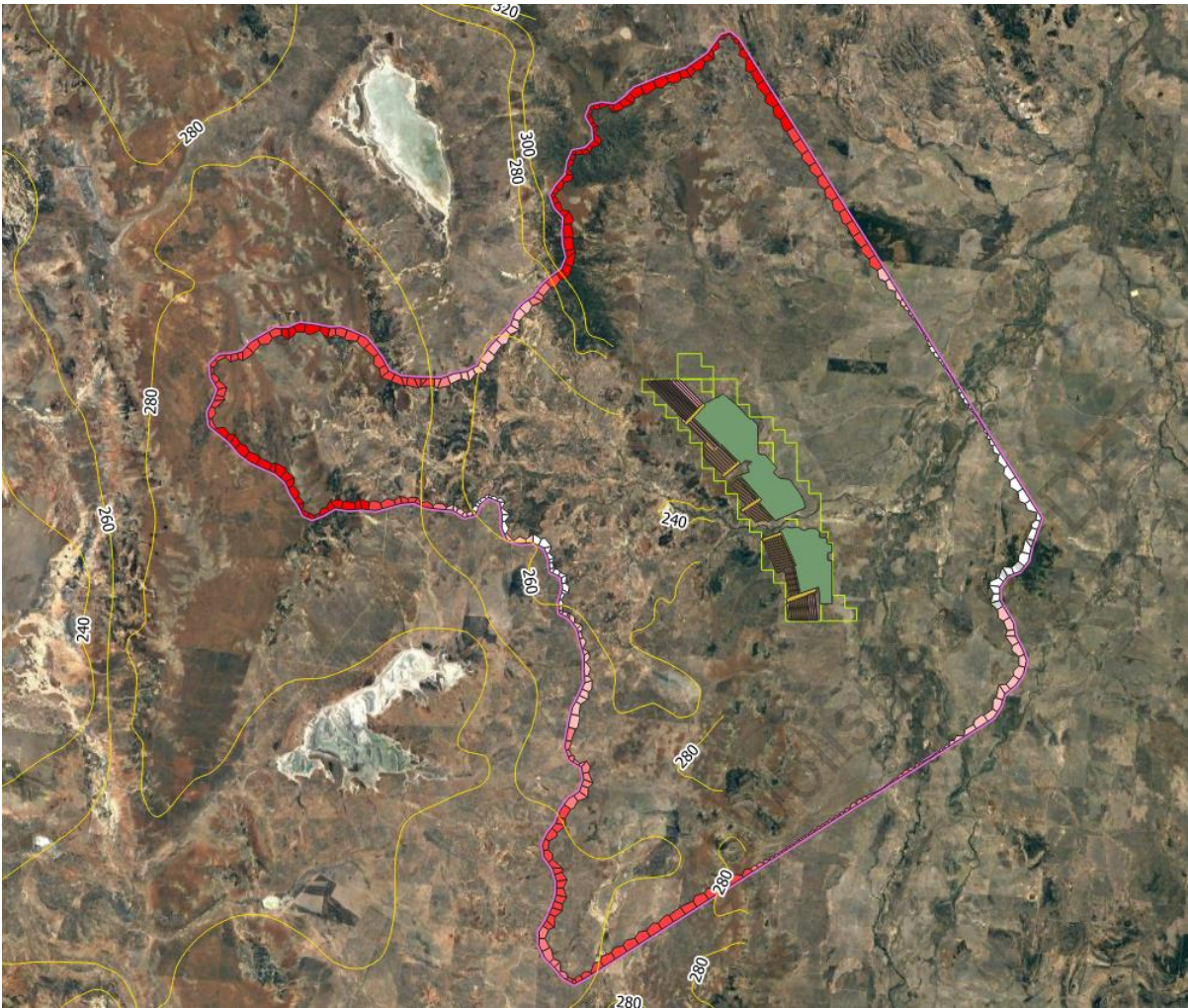


Parameterisation – L15 Joe Joe

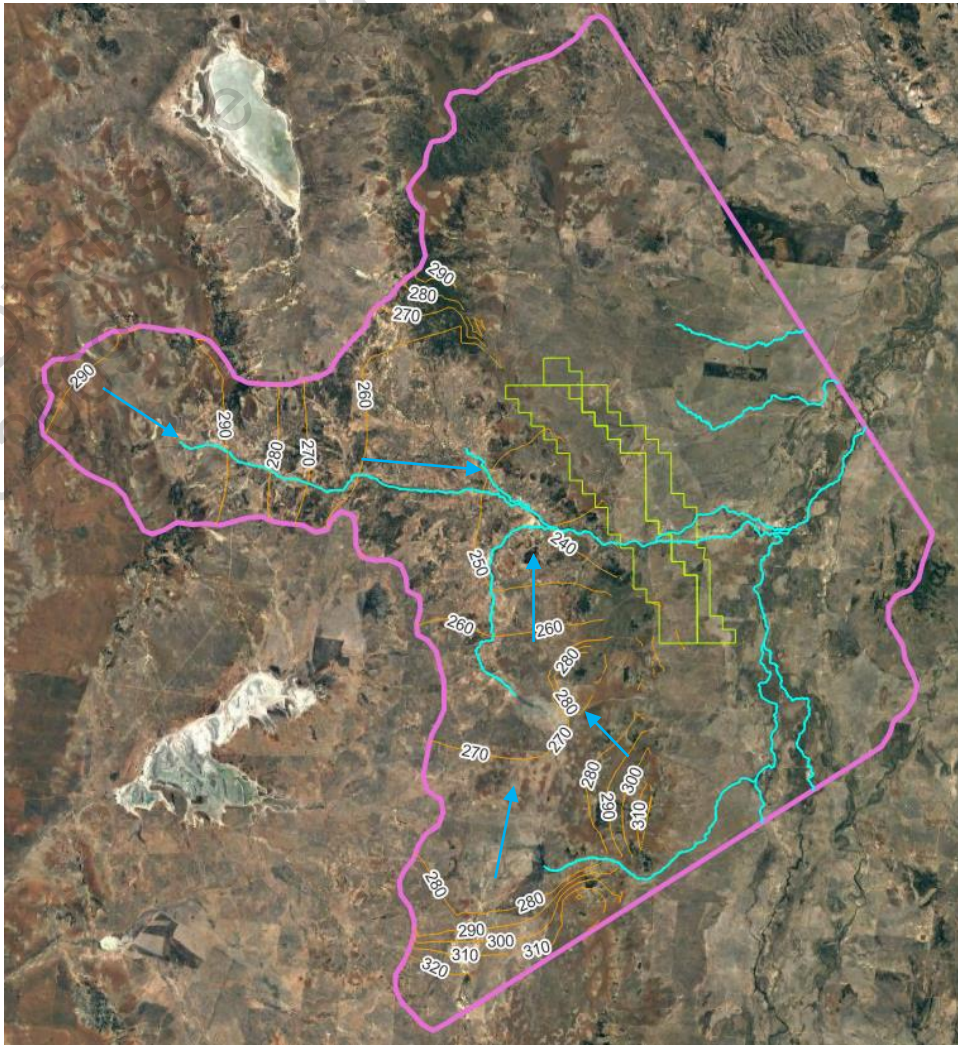


Steady state potentiometric surface – Clematis Sandstone

Interpreted

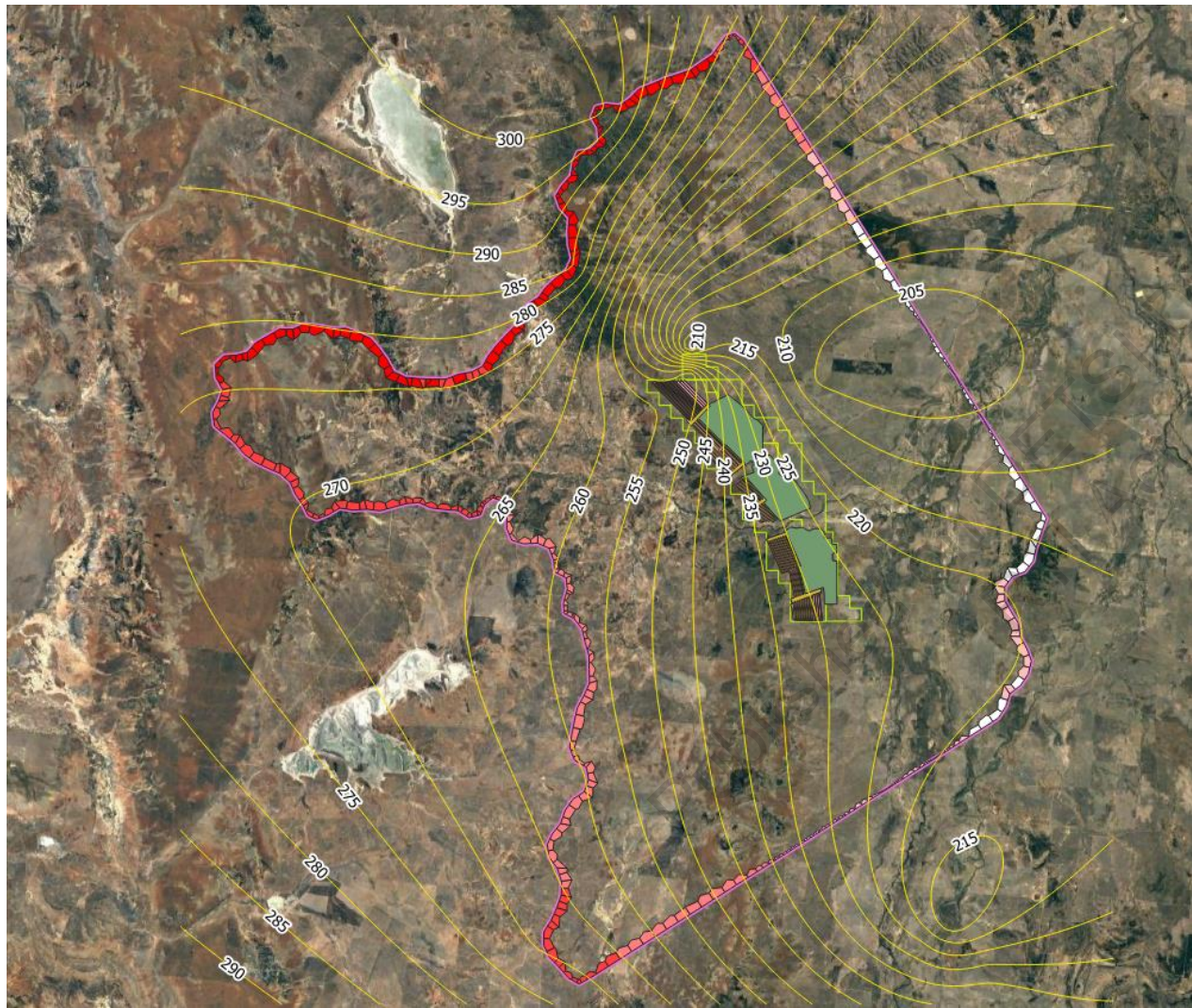


Modelled



Steady state potentiometric surface – Joe Joe Group

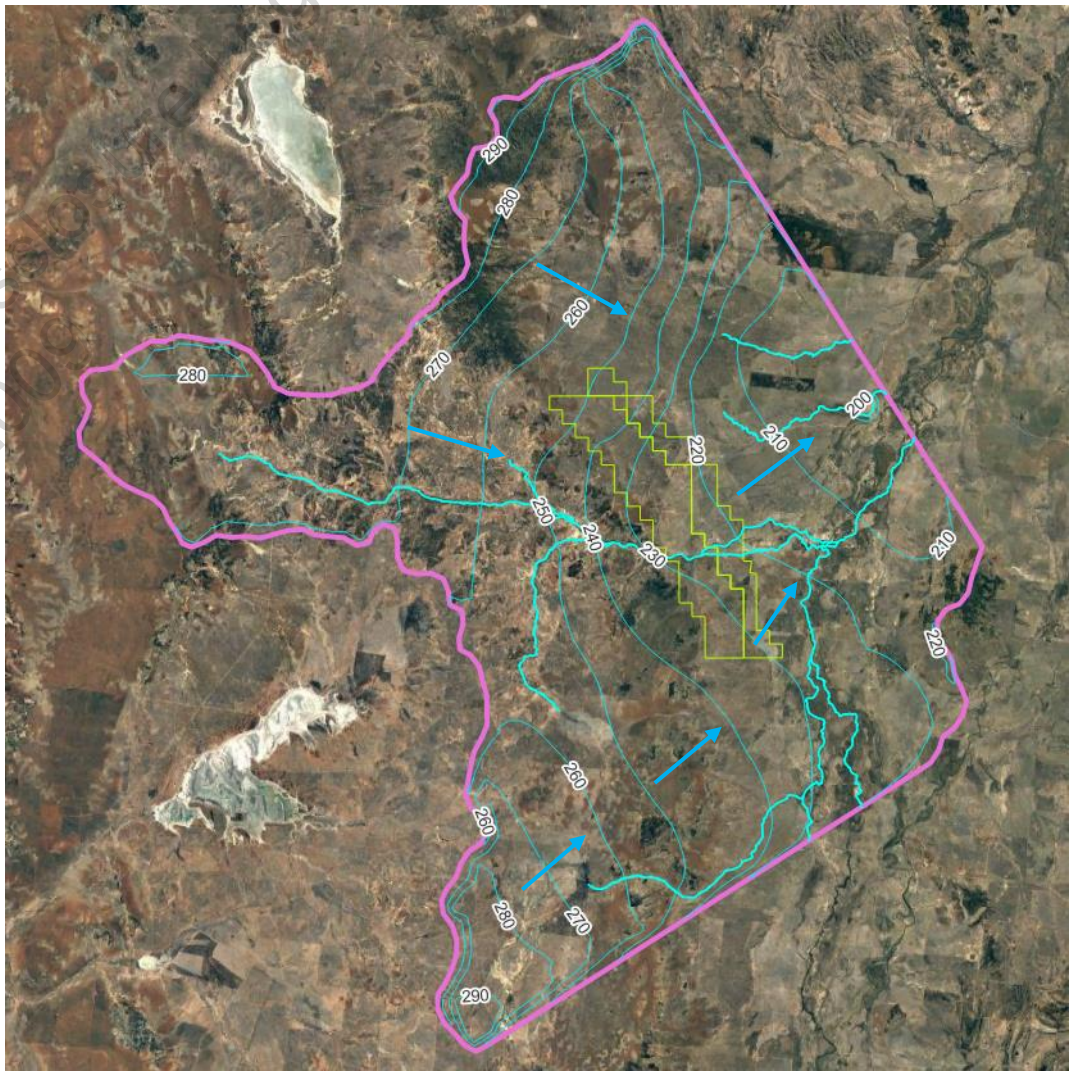
Interpreted



22-311

File A

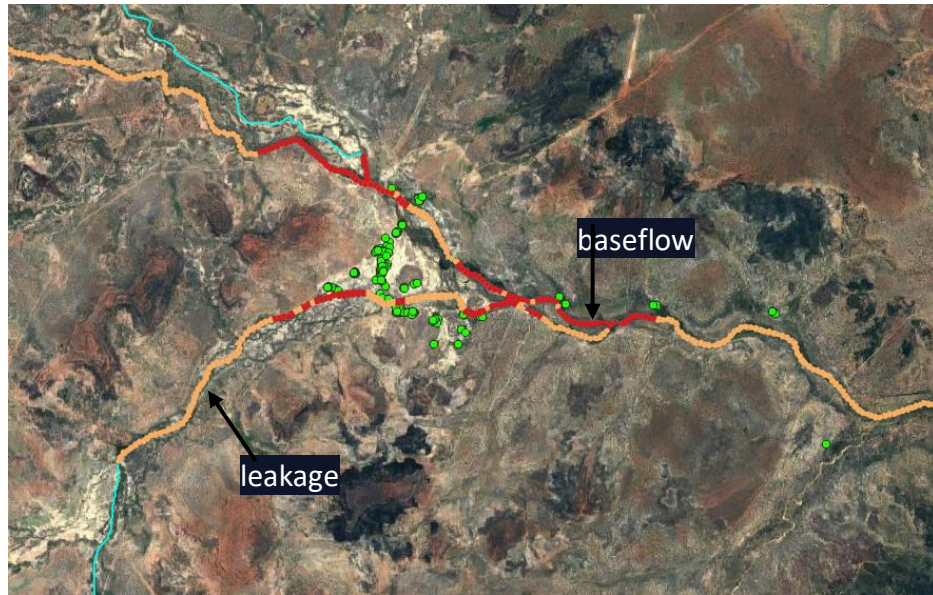
Modelled



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Surface water - groundwater interaction

End of wet season



End of dry season



- Upstream areas recharge groundwater system in the wet season
- Directly downstream of DSC, the Carmichael River is a gaining system all year round due to shallow groundwater levels and perhaps spring discharge
- Further downstream, Carmichael River becomes a losing system during the wet season and contributes no recharge during the dry season.
- The surface water system is mainly a losing system within the model domain

Steady state modelled water balance: base case

Modelled steady state water balance		
	Inflow (ML/d)	Outflow (ML/d)
Regional throughflow	33.83	25.60
Rainfall-derived recharge	0.69	-
Evapotranspiration	-	21.72
River baseflow/leakage	14.70	1.89
Spring discharge	1.19	1.17
Storage	-	-
TOTAL	50.40	50.40
IN-OUT		0.00
Mass balance error		0.01%

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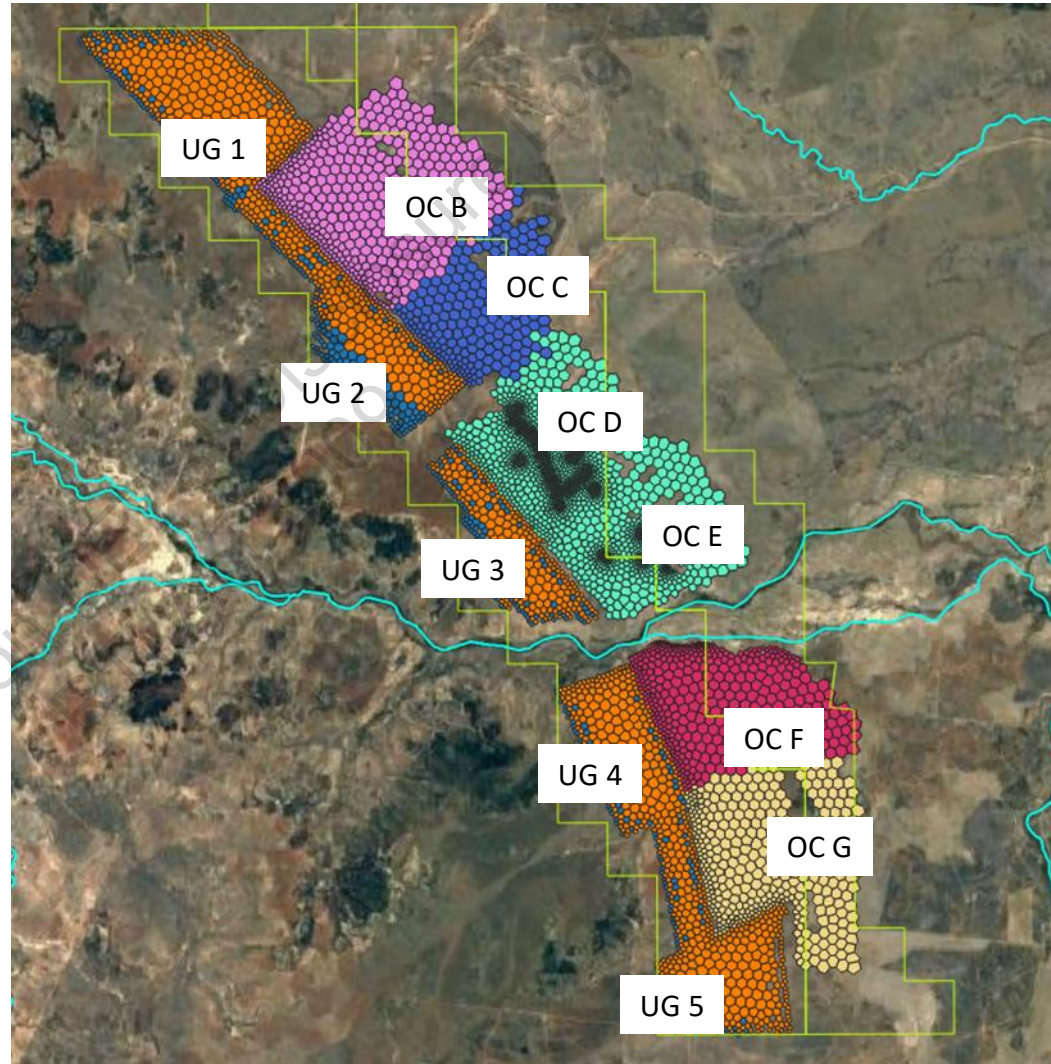
Predictive scenarios

Predictive scenarios

- OC: open cut mine only; no underground mining
- SEIS A: mine plan and fracturing as per SEIS (2013); full underground mine footprint
- SEIS B: mine plan as per SEIS (2013), fracturing geometry, relief zone and properties from Rewan research program
- Predictive scenarios include:
 - Drain boundary conditions representing mine plan, with stage at base of mine and high conductance to ensure full dewatering
 - Time-varying material properties above underground mine panels
 - SEIS A: horizontal and vertical hydraulic conductivity increased by a factor of 50 for first 75 m, then factor of 10 for remaining 75 m, no fracturing above Rewan. SEIS (2013) used a constant height of fracturing of 160 m above longwall panels.
 - SEIS B: horizontal and vertical hydraulic conductivity increased within 250 m above coal seam; log hydraulic conductivity reduction with height (ramp function, Merrick 2017)
 - Time-varying material properties in open cut mine model cells above AB Coal seam
 - Horizontal and vertical hydraulic conductivity increased to 1,000 m/d
 - Specific yield increased to 100%
 - Time-varying material properties in open cut mine model cells below AB Coal seam (backfill)
 - Horizontal and vertical hydraulic conductivity increased to 0.5 m/d
 - Post-mining recovery:
 - 2,000-year post-mining stress period
 - All dewatering deactivated but open cut pit, backfill and fracturing properties remain active

Modelled mine plan

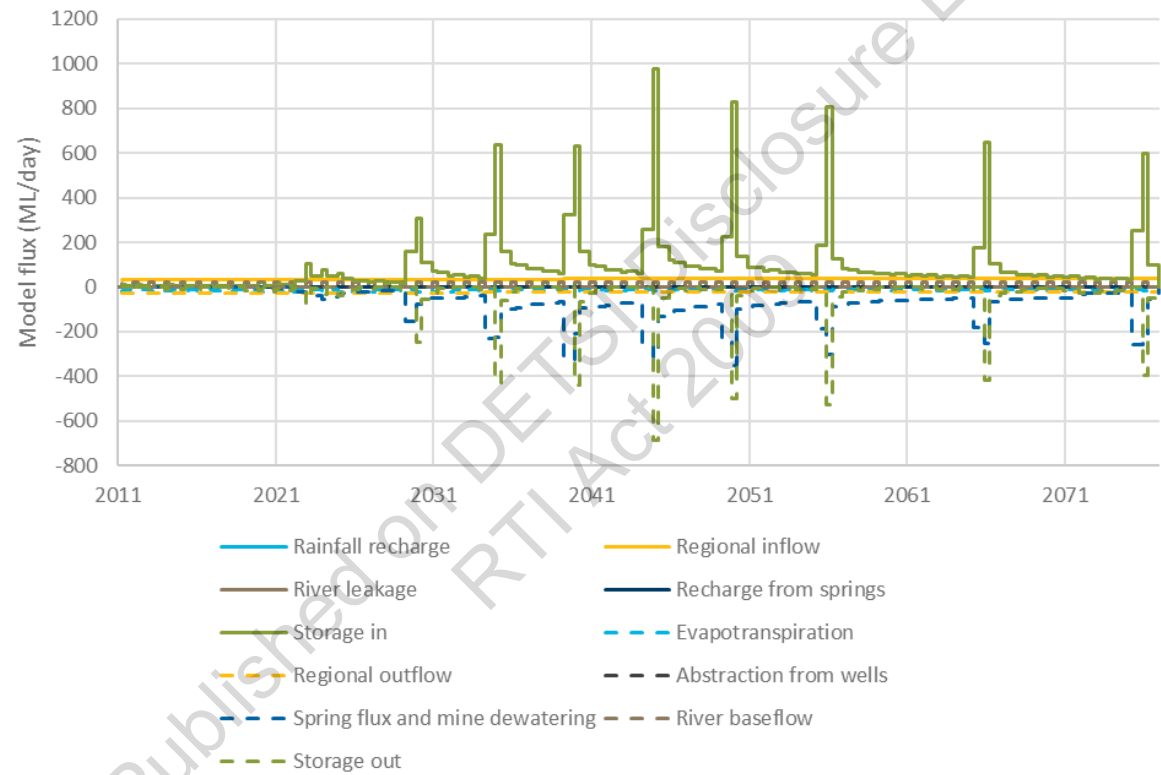
- OC: open cut
- SEIS: open cut and underground



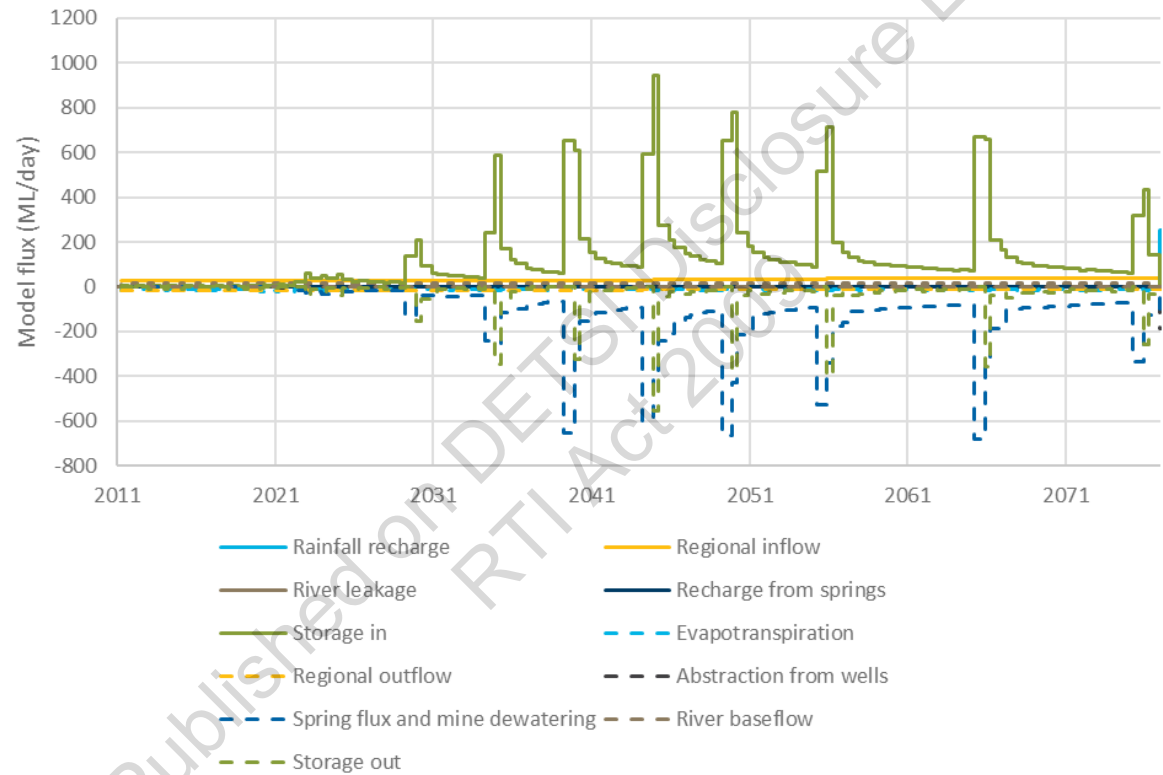
Modelled mine plan (as per SEIS)

Year	OC B	OC C	OC DE	OC F	OC G	UG 1	UG 2	UG 3	UG 4	UG 5
2020			Active							
2021			Active							
2022			Active							
2023			Active							
2024			Active							
2029		Active	Active							
2034	Active	Active	Active			Active				
2039	Active	Active	Active	Active	Active					
2044	Active	Active	Active	Active	Active				Active	Active
2049	Active	Active	Active	Active	Active					
2055	Active	Active	Active	Active	Active			Active		
2065	Active	Active	Active	Active	Active		Active			
2075	Active			Active	Active					

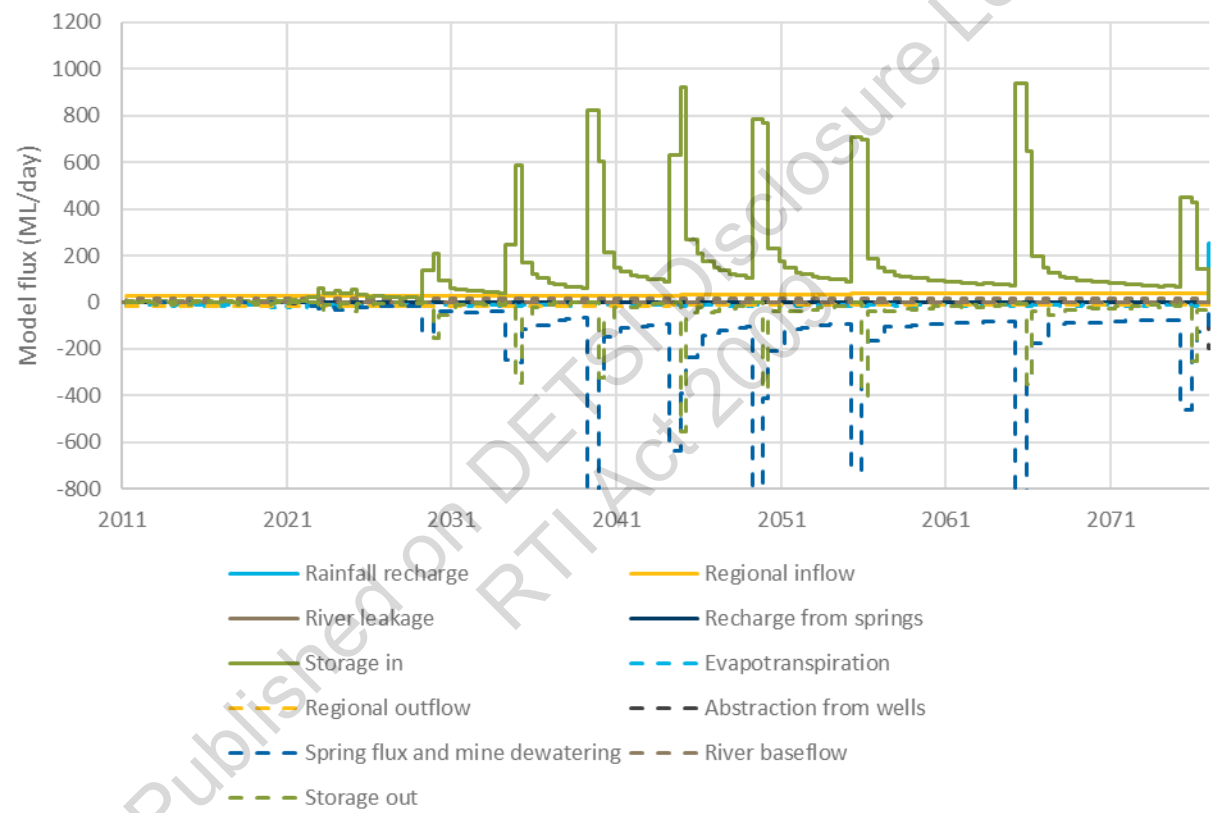
Modelled water balance: OC



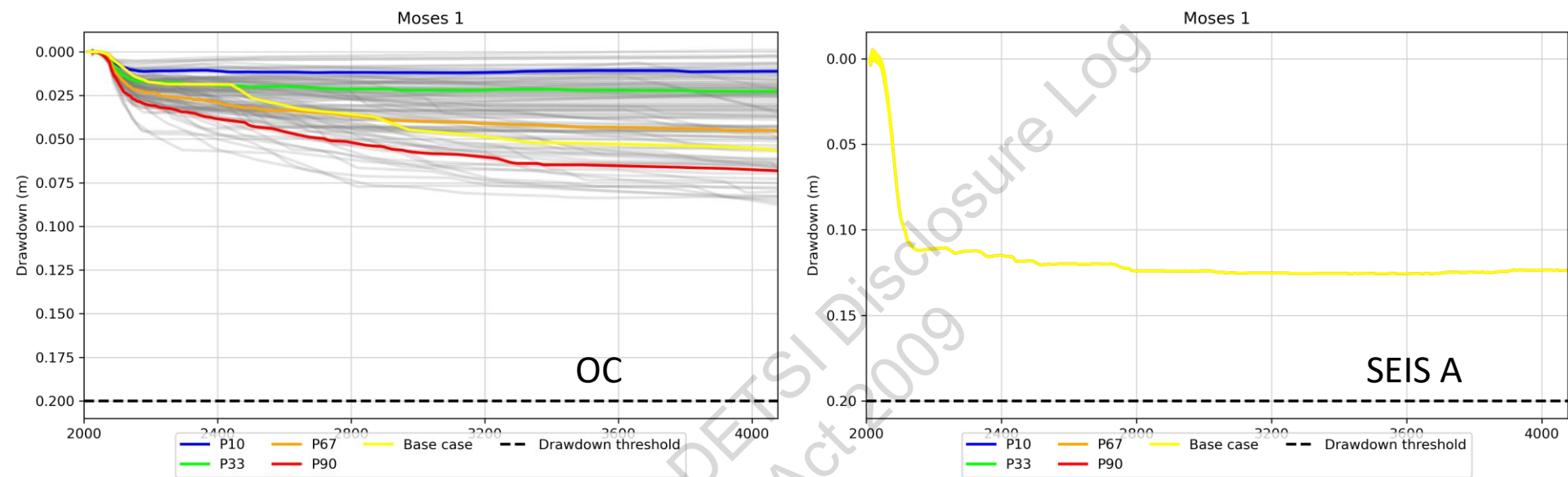
Modelled water balance: SEIS A



Modelled water balance: SEIS B



Modelled hydrographs



Modelled drawdown (m) at springs

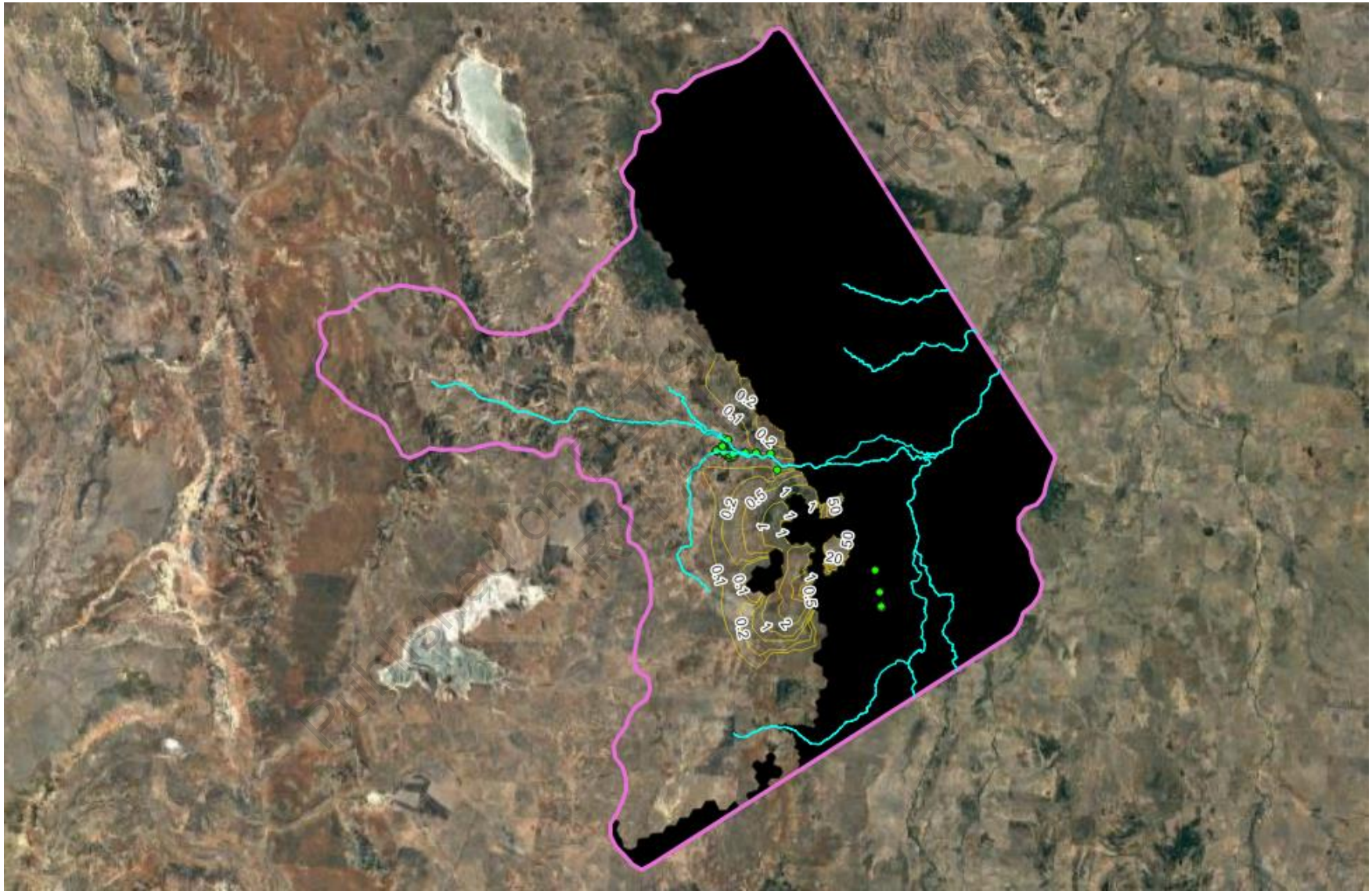
Spring	GHD (2013)	OC	SEIS A	SEIS B
Moses 4	<0.05	0.05	0.12	0.31
Moses 3	<0.05	0.05	0.12	0.31
Moses 2	0.08	0.05	0.12	0.31
Little Moses 1	<0.05	0.05	0.08	0.24
Moses 1	0.06	0.06	0.13	0.32
Moses 7	0.09	0.05	0.12	0.31
Moses 10	0.08	0.05	0.12	0.31
Moses 15	0.07	0.05	0.12	0.31
Moses 20	0.12	0.06	0.12	0.31
Moses 26	0.12	0.06	0.12	0.31
Joshua Spring	0.19	0.02	0.03	0.13
Mellaluka 1	<0.05 – 1.03	>10	>10	>10
Mellaluka 2	<0.05 – 1.14	>10	>10	>10
Storys	<0.05 – 2.34	>10	>10	>10
Lignum	0.06 – 8.22	>10	>10	>10

Proportion of runs exceeding 0.2 m drawdown at DSC for open cut only scenario

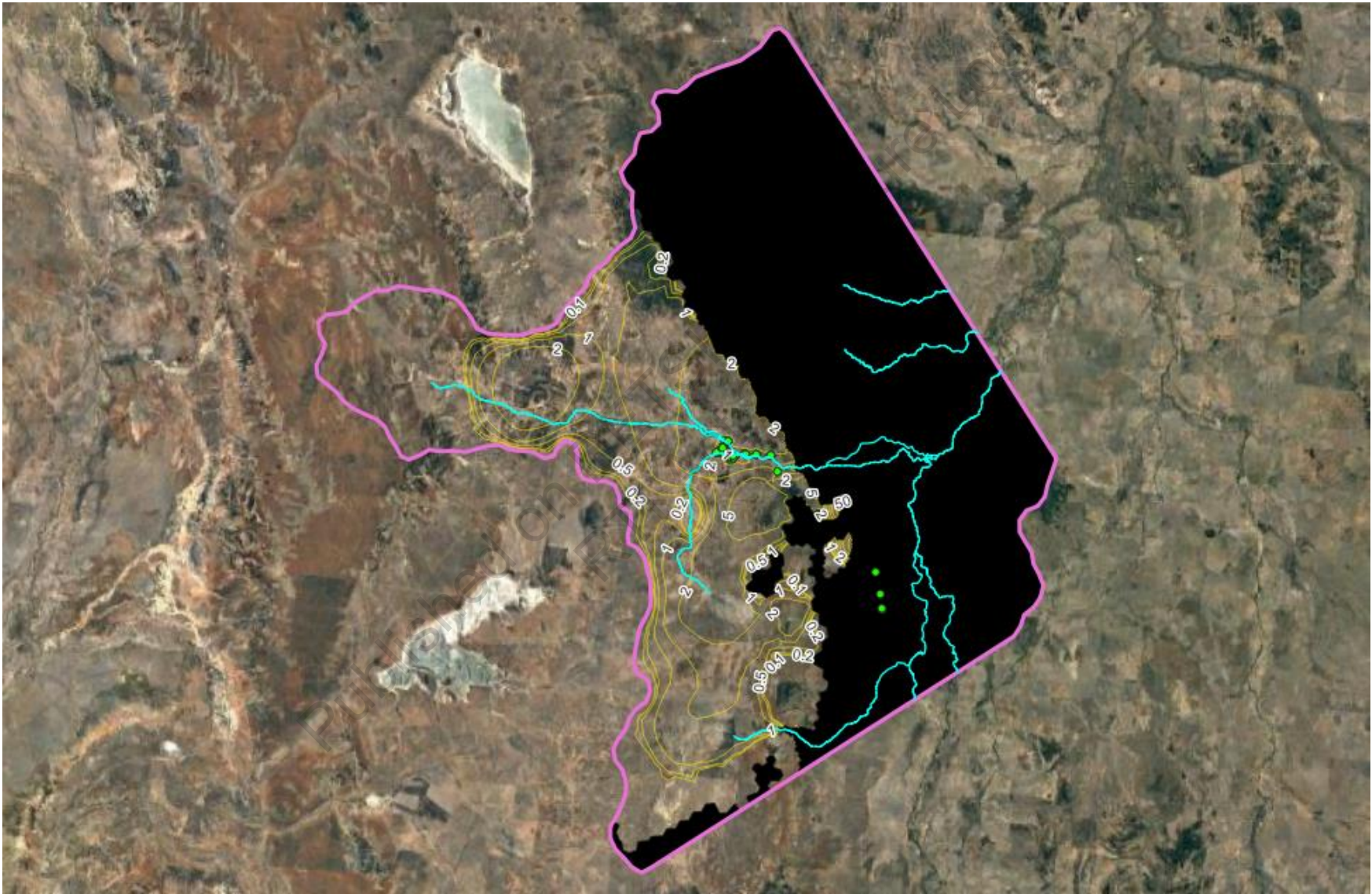
Spring	OC
Moses 4	0%
Moses 3	0%
Moses 2	0%
Little Moses 1	0%
Moses 1	0%
Moses 7	0%
Moses 10	0%
Moses 15	0%
Moses 20	0%
Moses 26	0%
Joshua Spring	0%

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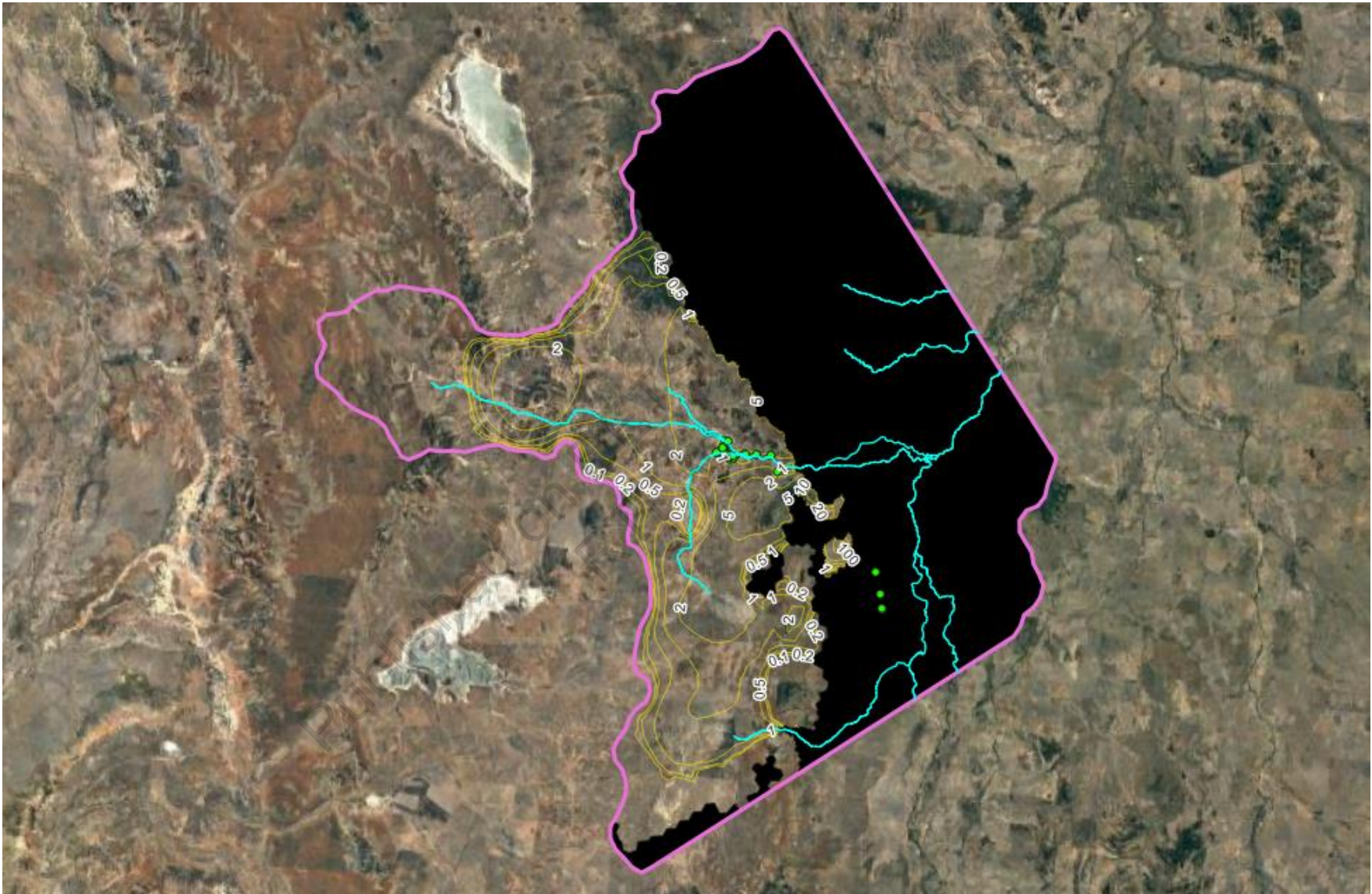
Modelled base case drawdown in Clematis: OC



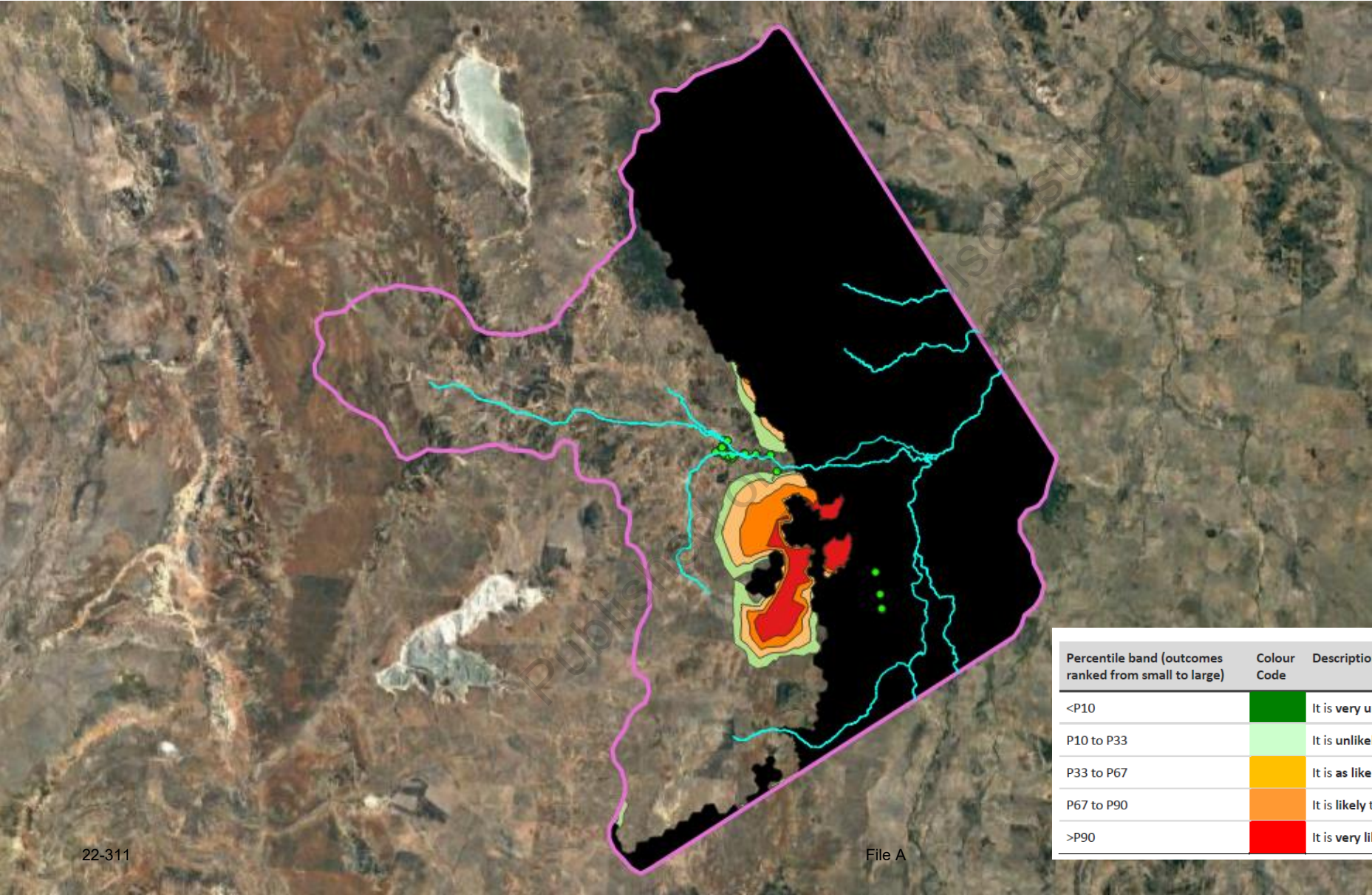
Modelled base case drawdown in Clematis: SEIS A



Modelled base case drawdown in Clematis: SEIS B



Likelihood of 0.2 m drawdown exceedance in Clematis: OC



- Presented drawdown is maximum regardless of timing
- Results presentation aligns with IESC 2018 explanatory note (Middlemis & Peeters)

Percentile band (outcomes ranked from small to large)	Colour Code	Description of likelihood
<P10	Dark Green	It is very unlikely that the drawdown/mounding exceeds the threshold
P10 to P33	Light Green	It is unlikely the drawdown/mounding exceeds the threshold
P33 to P67	Yellow	It is as likely as not the drawdown/mounding exceeds the threshold
P67 to P90	Orange	It is likely the drawdown/mounding exceeds the threshold
>P90	Red	It is very likely the drawdown/mounding exceeds the threshold

Summary

- Model updated to meet Environmental Authority (EA) Condition E9, while addressing past review criticisms of the SEIS.
- Model rebuilt aligned with updated conceptualisation and datasets including geological model, groundwater pressures, groundwater drawdown and mine dewatering bore rates. Knowledge from Rewan Research and GAB Spring Research packages (i.e. spring conceptualisation and discharge volumes) incorporated.
- As noted by T Murray (2022), tying in the local Rewan Research model to the Bioregional assessment model highlighted some very significant mismatches and worrying errors. Murray recommended that a full review of the broader Bio-regional assessment model is warranted.*
- Model history-matching and predictive uncertainty analysis used pilot points and PESTPP-IES with 500 parameter realisations developed.
- Results predict that the open cut (OC) only scenario will not breach the DSC drawdown threshold of 0.2 m for the base case or majority of ensemble of realisations.
- Although the OC basecase and the majority of realisations do not breach DSC drawdown thresholds, significant modelled drawdown emanates from the OC F and G pits. This is caused by the assumption that Clematis Sandstone exists in this region.*

Summary

- Modelling of the SEIS mine plan using the previous model fracturing assumptions (Scenario A) associated with underground mining, results in base case drawdowns that do not breach the DSC 0.2 m drawdown threshold. These are comparable to the SEIS (2013) model results.
- Modelling of the SEIS mine plan using updated fracturing and relief zone assumptions (Scenario B), results in base case drawdowns that do breach the 0.2 m drawdown threshold, but only in the order of 5-10 cm.

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Recommendations

- The groundwater system is complex, with vertical hydraulic gradients evident within the Clematis Sandstone. Further refinement to model layering within this unit may be required in future.
- Drawdown in the Clematis is exacerbated in the southern area of the mine, largely due to the interpreted/assumed geological layering. Further drilling is recommended to confirm the geology in this area (outcrop/subcrop, thickness and extent).
- Based on drilling outcomes, further Clematis, Bandanna and/or Colinlea monitoring bores may be required in the southern region to monitor drawdown impacts, which potentially could emanate from OC F and G pits. This is in addition to previously recommended bores to be installed in the western portion of the mining lease, east of the DSC.*
- The model tends to simulate hydraulic heads higher than measured in regional discharge areas (i.e. heads <220 mAHD). Further investigation into this may be warranted to identify whether this is a regional throughflow process or whether groundwater may be discharging at greater rates within the model domain (e.g. greater evapotranspiration).
- A large amount of uncertainty remains associated with fracturing above and relief zone around, underground mining areas. Predictions appear to be sensitive to how these are simulated but, to date, there are no site data available to inform how the local system behaves. Updated knowledge, where available, should be used within the next 5-year model review with accompanied future predictive uncertainty analysis.

Recommendations

- Due to the current uncertainty associated with fracturing above and relief zone around, underground mining areas, it recommended that GMMP develops groundwater drawdown thresholds that are associated with the OC mining scenario only, at this stage.*
- Future GAB Spring Research studies will concentrate on ecological water requirements (EWRs) of springs. Future modelling should include updated EWRs and associated thresholds.

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Discussion



Carmichael Coal Mine: RP1.6 Hydrogeological conceptualisation and updated groundwater modelling

Report No.2: Numerical groundwater flow model report

Prepared for Bravus Mining and Resources

January 2023

Executive Summary

Click here to begin typing. For headings in the Executive Summary please use Summary Heading 1-5 styles. These styles are located under the More Styles button on the EMM ribbon. This ensures correct structure of your TOC.

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1 Introduction

1.1 Project background

Bravus Mining and Resources (Bravus) has commenced development of the Carmichael Coal Mine (CCM) located in the Galilee Basin, approximately 160 kilometres (km) northwest of Clermont in Central Queensland. The Carmichael Coal Mine and Rail Project was assessed by the Commonwealth and Queensland governments through an Environmental Impact Statement (EIS) process. Conditional approval of the Carmichael Coal Mine and Rail Project was granted by the Queensland Coordinator-General on 8 May 2014 and the Commonwealth Minister for the Environment on 14 October 2015 (EPBC 2010/5736). The Environmental Authority (EA) EPML01470513 for the Mining Leases (ML) 70441, 70505 and 70506 was initially granted on 2 February 2016 and further amended in September 2019, July 2020 and most recently April 2022.

A numerical groundwater model has been developed in accordance with EA **Condition E9**. The condition requires the previous SEIS groundwater model first developed in 2013 to support the initial approvals, to be reviewed and updated where appropriate, allowing the GMMP to be updated in accordance with **Condition E4** and **Condition E5**. This update includes but not limited to: groundwater monitoring data, predicted mine dewatering volumes, predicted groundwater drawdown and impacts to the Groundwater Dependant Ecosystems (including spring complexes and Carmichael River alluvium).

Condition E9 specifically requires the groundwater model to be updated to include a transient calibration and include additional model layers for aquifers below the D seam of the Colinlea Sandstone, and in accordance with the GMMP. Specific requirements for E9 are outlined in 1.6.

In accordance with **Condition E9 requirement j)** and **Condition E10**, Australasian Groundwater and Environmental (AGE) Consultants has been engaged as the independent peer reviewer.

1.2 Previous modelling

Summarise previous modelling – versions, by whom ...

1.3 Modelling objectives

The objectives of the updated groundwater modelling are to:

- meet the specific requirements outlined by EA **Condition E9**;
- incorporate updated knowledge and conceptualisation of the groundwater system, including addressing past review comments;
- simulate the approved CCM groundwater-affecting activities, including mine development and dewatering operations and compare to the original SEIS model results;
- predict groundwater volumes intercepted as a result of mining activities;
- predict the extent and magnitude of groundwater drawdown induced by mining activities, particularly at key receptors;
- assess the predictive uncertainty related to impacts associate with mine dewatering and the resulting predicted groundwater drawdown; and
- predict the long-term state of the groundwater system post mining.

1.4 Modelling guidelines

The model design, history-matching, predictions and predictive uncertainty analysis have been developed consistent with current guidelines including:

- Barnett et al. (2012), Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra; and
- Middlemis & Peeters (2018), Information guidelines explanatory note: Uncertainty analysis – guidance for groundwater modelling within a risk management framework.

In addition, the modelling approach is aligned with the philosophies explored during the Groundwater Modelling Decision Support Initiative (GMDSI), an industry-funded project focused on improving the role groundwater modelling plays in environmental management and decision making.

1.5 Report structure

The structure of the report has been developed to logically step through the modelling process, and is structured as follows:

- Section 2 - A summary of the hydrogeological conceptualisation, recently updated by EMM and presented in detail within the Hydrogeological Conceptualisation Report (EMM 2022a);
- Section 3 - The model design outlining the approach to represent the conceptual model in a quantitative and numerical framework, while meeting the modelling objectives;
- Section 4 - History matching, which includes an approach to determining the basecase realisation along with a suite of alternative realisations;
- Section 5 - Basecase prediction and predictive uncertainty analysis- add more detail in final report;
- Section 6 - Approach to addressing past model review criticism- add more detail in final report; and
- Section 7 – Summary and recommendations- add more detail in final report.

Figure 1.1 Carmichael coal mine location map

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1.6 Specific Regulatory Requirements

The Environmental Authority (EA) EPML01470513 for the Mining Leases (ML) 70441, 70505 and 70506 was initially granted on 2 February 2016 and further amended in September 2019, July 2020 and most recently April 2022. As stated in the latest EA Permit, Condition E9 requires the numerical groundwater model in the reports titled “Carmichael Coal Mine and Rail Project SEIS: Report for Mine Hydrogeology Report (13 November 2013)” and “Carmichael Coal Mine and Rail Project SEIS: Mine Hydrogeology Report Addendum (24 October 2013)” must be reviewed to incorporate groundwater monitoring data and measured mine dewatering volumes from the GMMP in conditions E4 and E5.

The model review must provide a revised numerical groundwater model which is based on a transient calibration and includes additional model layers for aquifers below the D seam of the Colinlea Sandstone, and in accordance with the GMMP. Condition E9 states that the revised model must include the following, with the location of the condition met shown in brackets within this report:

- a) a review of the hydrogeological conceptualisation used in the previous model (Section xx);
- b) an update of the predicted impacts (Section xx);
- c) a revised water balance model (Section xx);
- d) a review of assumptions used in the previous model (Section xx);
- e) predictions of changes in groundwater levels for a range of scenarios (Section xx);
- f) any changes made since the previous model review, including data changes (Section xx);
- g) a justification for the refined model and the outputs of the refined model (Section xx);
- h) an evaluation of the accuracy of the predicted changes in groundwater levels, groundwater flow rates to surface water and recommended actions to improve the accuracy of the model predictions (Section xx); and
- i) an independent peer review and certification that the environmental authority holder has undertaken the review in accordance with all commitments in the GMMP (Appendix x).

In addition to the requirement of meeting Condition E9, a response to past review criticisms has also been undertaken and this is detailed in Section xx.

2 Conceptual hydrogeological model

A review of the existing and updated hydrogeological conceptual model (HCM) has been documented in detail in EMM (2022a). A HCM is a descriptive representation of a specific groundwater system that incorporates knowledge and interpretation of the geological, hydrological, and hydrogeological conditions in the study area. The HCM summarises the hydrogeological understanding of key processes such as recharge and discharge, and the influence of any boundaries or stresses that may have impact on the flow system. The inherently complex groundwater system is simplified in a way that describes the main features and processes controlling groundwater flow.

To provide context for this report, a summary of the HCM is presented in a tabulated format in Table 2.1. The HCM is presented graphically for the pre-mining and during-mining phases in Figure 2.1 and Figure 2.2, respectively. Figure 2.3 and Figure 2.4 show regional interpreted groundwater contours and flow direction for key hydrogeological units, and Figure 2.5 presents an updated conceptualisation related to surface water, groundwater and spring interaction which are discussed in Table 2.1.

Table 2.1 Summary of the conceptual hydrogeological model developed for the CCM

Feature of conceptual model	Summary of key knowledge
Hydrogeological framework	<p>The main stratigraphic units of relevance to the CCM include, from top to bottom:</p> <ul style="list-style-type: none"> • Quaternary alluvium and Tertiary sediments: confined and unconfined aquifers, notably adjacent to the Carmichael River. • Triassic Moolayember Formation: an unconfined aquitard. • Triassic Clematis Sandstone: an aquifer, unconfined in the east and confined in the west. • Triassic Dunda Beds: a confined aquitard. • Triassic Rewan Formation: a confined aquitard. • Permian Bandanna Formation: alternating confined aquifers (interburden and coal seams). • Permian Colinlea Sandstone: alternating confined aquifers (interburden and coal seams). • Early Permian Joe Joe Group: considered the geological basement in this region. <p>In addition, a distinct weathering profile, which crosscuts Permian and Triassic sediments, exists above the “fresh” Triassic sediments. The base of the weathering shows a distinct thickening towards the scarp and is likely to impede vertical recharge from rainfall, where it exists.</p>
Faults and structures	<ul style="list-style-type: none"> • There is an absence of significant regional faults in the area. • There are only four minor faults interpreted within the coal strata, with previous SEIS assessments estimating vertical throws of between 20 m and 40 m. These faults are generally oriented in an east-west direction. • As part of the Rewan Formation Connectivity Research Plan (RFCRP), studies have shown very little evidence of faulting at least in the Rewan Formation and above. Juxtaposition analysis suggest faults would have throws less than 25 m and maybe as small as 10 m. • There are artesian pressures in the Clematis Sandstone, Dunda Beds and upper Rewan Formation up-gradient of Surprise Creek. There may be a flow barrier (weathering or lineament) in that area restricting outflow from the Clematis Sandstone. • A synform had been proposed during the SEIS phase, with a northeast to southwest fold axis that passes broadly through the centre of the site. The synform affects the Betts Creek Beds and Rewan Formation and the fold axis tends to align with a regional potentiometric ‘low’. • Two alternative conceptualisations have been recently proposed by EMM (EMM 2022a) as an alternative to the synform: local faulting or a permeable Joe Joe Group acting as an underdrain. The local fault (or higher permeable zone) is conceptualised to cut across the Bandanna, Colinlea and Joe Joe Group mainly within the lease area.
Regional groundwater flow system	<ul style="list-style-type: none"> • Regionally, there is a general south to north flow system that diverges at a groundwater divide along the intermontane valley of the Great Dividing Range (GDR). • To the east of the GDR, groundwater tends to flow “up-dip” and converges towards the Mining Leases, for formations above the Rewan Formation. Figure 2.3 shows the interpreted regional groundwater contours for the Clematis Sandstone based on recent data obtained from QLD Globe portal. <p>Groundwater beneath the Clematis Sandstone under pre-mining conditions is observed to flow southeast to the north of the Carmichael River and flow northeast to the south of the Carmichael River. Regional interpreted groundwater contours and flow direction within the Permian coal interburden of the deeper Bandanna Formation and Colinlea Sandstone are shown in Figure 2.4.</p>

Table 2.1 Summary of the conceptual hydrogeological model developed for the CCM

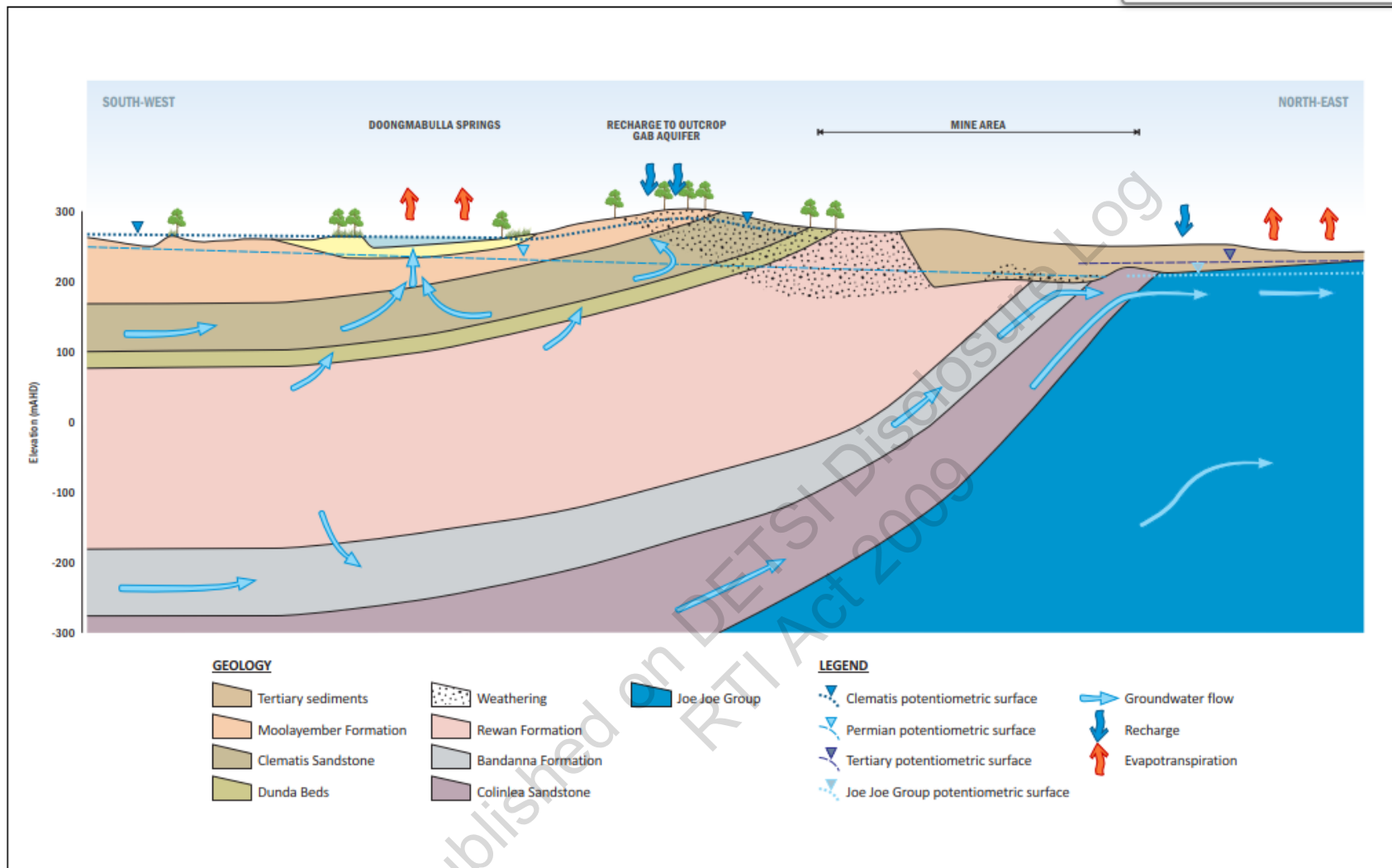
Feature of conceptual model	Summary of key knowledge
Local groundwater flow	<p>Local groundwater flow characteristics differ based on hydrostratigraphic unit (HSU), with the main points summarised as follows:</p> <ul style="list-style-type: none"> • Alluvium: Flow mimics topography and flows west to east along the Carmichael River floodplain. • Tertiary sediments: Flows from south to north. • Clematis Sandstone: Flow converges on the Doongmabulla Springs Complex (DSC), indicating discharge to DSC, baseflow to Carmichael River and evapotranspiration. • Dunda Beds: Flow converges on bore C027P2, near the centre of the mining lease. • Rewan Formation: Flow converges towards bore C008P1, again near the centre of the mining lease. • Bandanna Formation (AB Seam): Groundwater flow converges towards bore C014P2, with flow directions exacerbated by extraction from the mine dewatering bores. • Colinlea Sandstone: Groundwater flow converges towards bore C006P3R and is likely influenced by the local faulting/high permeable zone previously proposed. • Joe Joe Group: Groundwater flow converges on C14003SP and C14004SP and is influenced by the local faulting/highly permeable zone. Flow affected locally by discharge to the Mellaluka Spring Complex (MSC) and pumping from landholder bores.
Recharge and discharge mechanisms	<p>The recharge and discharge mechanisms of each stratigraphic unit can be summarised as follows:</p> <p><u>Recharge</u></p> <ul style="list-style-type: none"> • The alluvium is recharged via surface water infiltration, rainfall infiltration, vertical leakage from underlying units and spring discharge. • Tertiary sediments are recharged via surface water infiltration, rainfall infiltration in outcropping areas and vertical leakage from other units. • The Moolayember Formation and Dunda Beds are recharged via rainfall infiltration into outcropping areas and as well as vertical leakage from other units. • The Clematis Sandstone and Rewan Formation are only recharged through rainfall in outcropping areas. • The Bandanna Formation, Colinlea Sandstone and Joe Joe Group are recharged only through vertical leakage from other units. • Regional groundwater flows towards the local aquifers from the west. <p><u>Discharge</u></p> <ul style="list-style-type: none"> • Alluvium can discharge through baseflow to surface water, post wet season. • All stratigraphic units can discharge via vertical leakage to other units or throughflow. • Alluvium, Tertiary sediments, Moolayember Formation, Clematis Sandstone and Dunda Beds can discharge through evapotranspiration where the depth to water table is shallow. • Spring discharge occurs from the Clematis Sandstone. • Uncontrolled discharge to poorly constructed bores can occur in the Tertiary sediments and Clematis Sandstone. • The Dunda Beds and Clematis Sandstone outcrop along the western boundary of the CCM area. • The Rewan Formation, Bandanna Formation, Colinlea Sandstone and Joe Joe Group subcrop within the CCM area.

Table 2.1 Summary of the conceptual hydrogeological model developed for the CCM

Feature of conceptual model	Summary of key knowledge
Groundwater stresses	<ul style="list-style-type: none"> Open cut mining will occur, facilitated by perimeter production bores to remove groundwater and allow for dry mining. Drawdown will mainly be associated with targeted Permian coal measures and host materials (Bandanna Formation and Colinlea Sandstone). Extraction from the Bandanna Formation and Colinlea Sandstone has occurred from August 2019 onwards through dewatering bores. No dewatering impacts are noted or expected in the alluvium, Tertiary, Clematis Sandstone and Dunda Beds, indicating that the Rewan Formation aquitard is hydraulically isolating the upper units. Longwall mine panels will develop to the west of the open cut pits, which will target the deeper coal seams. A free draining zone may exist above the longwall panels where groundwater can seep directly from the overlying Rewan Formation. The mine is likely to reach equilibrium over several decades and perhaps beyond a millennia post-mining, with the system acting as a long-term sink and groundwater flow being directed towards the final voids and underground workings.
Aquifer properties	<p>Prior SEIS modelling and aquifer testing work has determined the following horizontal hydraulic conductivity value ranges for each of the HSUs:</p> <ul style="list-style-type: none"> Alluvium: 3×10^{-2} – 11 m/d Tertiary sediments: 2×10^{-4} – 1.7×10^{-1} m/d Moolayember Formation: 5×10^{-2} m/d Clematis Sandstone: 1×10^{-2} – 15 m/d Dunda Beds: 2×10^{-3} – 3 m/d Rewan Formation: 1×10^{-4} – 0.29 m/d Bandanna Formation: 1×10^{-4} – 35 m/d Colinlea Sandstone: 1×10^{-4} – 2×10^{-1} m/d Joe Joe Group: 2×10^{-4} – 4.1×10^{-1} m/d As part of the recent RFCRP, the median horizontal hydraulic conductivity of the Rewan Formation was determined to be 2.4×10^{-4} m/d with specific storage values ranging between 3.7×10^{-7} to 6.6×10^{-6} m⁻¹
Groundwater-surface water interactions	<ul style="list-style-type: none"> Groundwater discharges at the DSC and MSC within the study area. Springs may supply 15-20% of the water used by floodplain vegetation downstream of the springs. Rainfall runoff causes ephemeral creeks and rivers to flow periodically, with the greatest flows during the wet season. Approximately 1% of surface water flows, recharge the alluvial aquifer adjacent to and beneath the waterway, which contributes to sustaining floodplain vegetation through the dry season. Waterways in the vicinity of the mine are ephemeral and lose water to groundwater, with little to no baseflow occurring. During the dry season, Dyllingo Creek and Carmichael River rarely flow due to low rainfall, but during the wet season, rainfall can result in streamflow events with water depths of up to 10 m. During these events, water infiltrates through the floodplain and recharges the alluvial aquifer. Figure 2.5 illustrates the conceptual model related to surface water/groundwater/spring interactions west of the CCM.

Table 2.1 Summary of the conceptual hydrogeological model developed for the CCM

Feature of conceptual model	Summary of key knowledge
Groundwater dependent ecosystems	<ul style="list-style-type: none"> The DSC is located approximately 8 km west of the CCM, at the confluence of Bimbah/Cattle Creek, Dyllingo Creek, Carmichael Creek and Carmichael River. The MSC is located to the south of the CCM. Water discharged from the springs typically supports vegetation at the spring location. At some locations, the entire discharge volume is lost to evapotranspiration, while at other locations, wetlands are formed due to larger discharge volumes. Isotope testing strongly suggests that the water from the DSC is more likely to be sourced from groundwater originating in the underlying Triassic Clematis Sandstone rather than from deeper groundwater sources such as the Permian Bandanna Formation, Colinlea Sandstone or the Joe Joe group. The MSC is located at the east of the Colinlea Sandstone subcrop. Springs are formed via local weak points through the Tertiary sediments.
Climate	<ul style="list-style-type: none"> Annual rainfall in the area is approximately 540 mm (BoM Ulcanbah station 036050; 1937-2021). The majority of rainfall occurs from December to March, with January and February being the wettest months. Potential evapotranspiration is approximately 50 mm per month greater than the average rainfall in January to August, and 100 mm per month greater in September to December. Alluvium, Tertiary, Clematis Sandstone and Dunda Beds hydrographs have a strong correlation with climate, suggesting rainfall recharge and creek flow seepage is an important contributor to the dynamics of the groundwater system. A long-term below average rainfall trend occurring from 2013 onwards may have contributed to a decline in groundwater levels over time, prior to mine commencement.



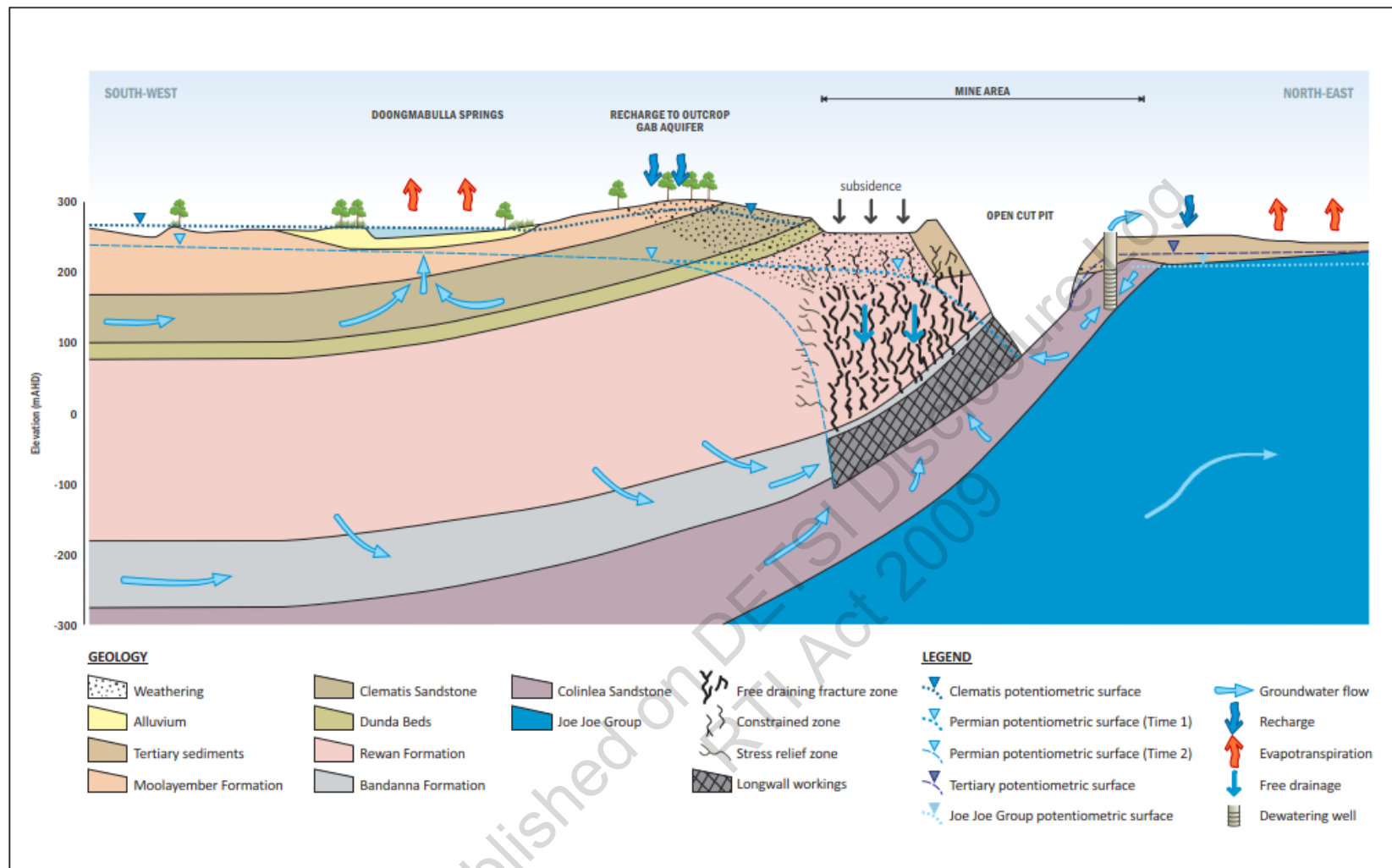
Pre-mining hydrogeological conceptual model

Carmichael Coal Mine: RP1.6 Hydrogeological conceptualisation review and updated groundwater modelling

Bravus Mining & Resources

Figure 12.1

Figure 2.1 Pre-mining hydrogeological conceptual model



Mining hydrogeological conceptual model

Carmichael Coal Mine: RP1.6 Hydrogeological conceptualisation review and updated groundwater modelling

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Figure 12.2

Figure 2.2 Mining hydrogeological conceptual model

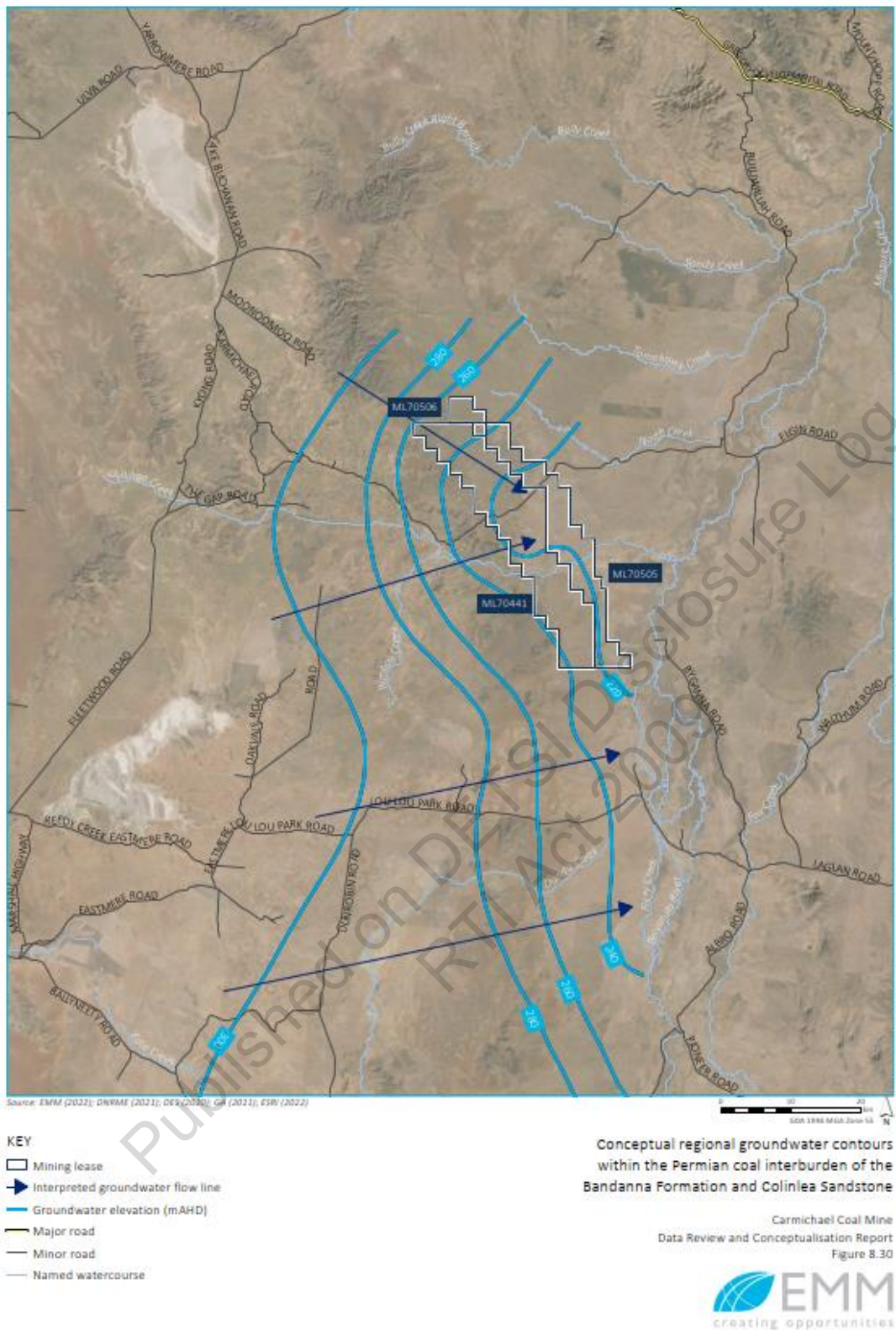
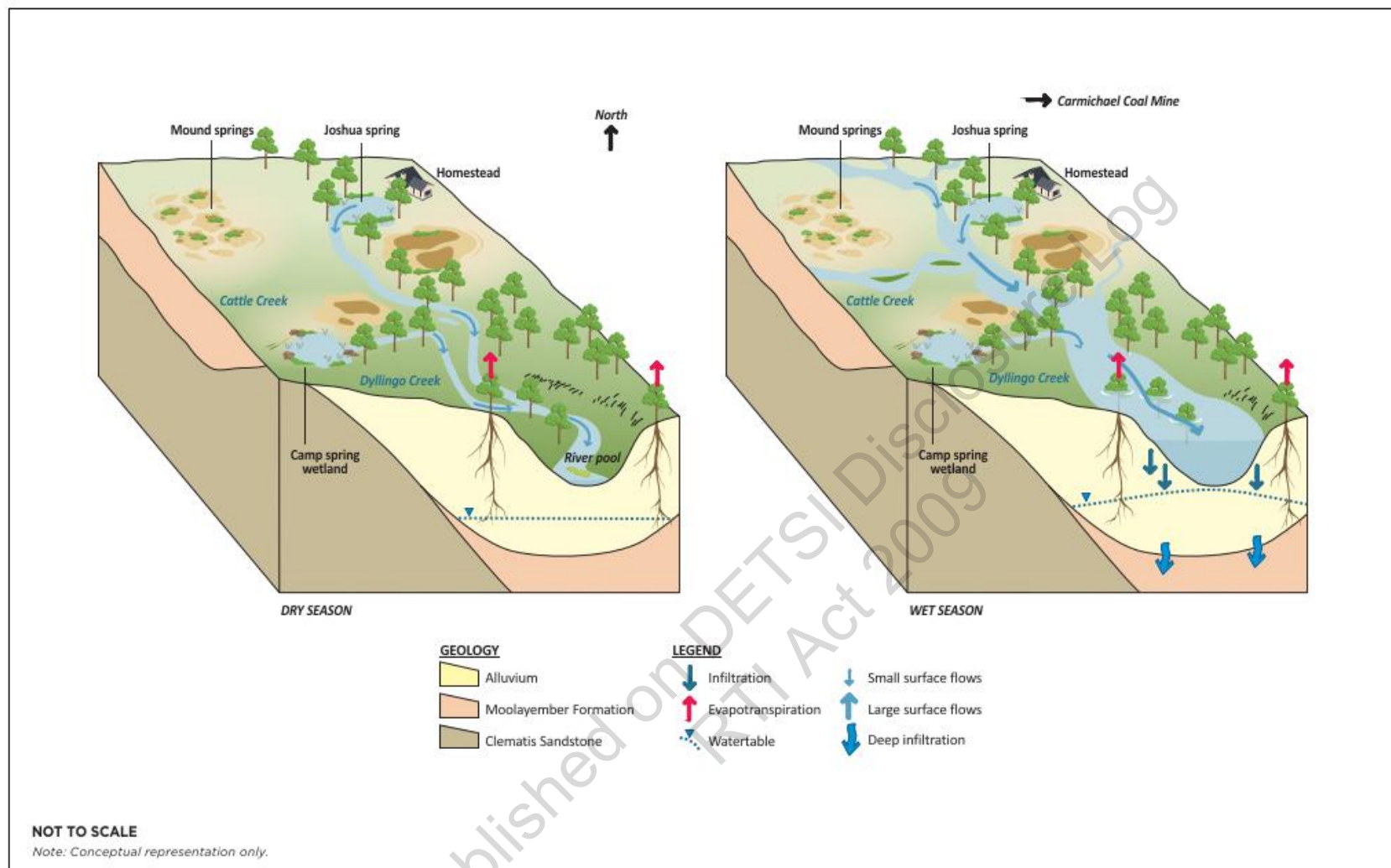


Figure 2.4 Conceptual regional groundwater contours within the Permian coal interburden of the Bandanna Formation and Colinlea Sandstone



Surface water/groundwater interaction conceptual model

Carmichael Coal Mine: RP1.6 Hydrogeological conceptualisation review and updated groundwater modelling

Bravus Mining & Resources

Figure 12.3

Figure 2.5 Surface water/groundwater interaction conceptual model

3 Model design

In response to review comments on the existing numerical groundwater flow model, the updated hydrogeological conceptual model, advances in modelling software, and modern regulatory expectations with regard to predictive uncertainty analysis, a new model has been developed rather than just updating the existing modelling framework.

3.1 Equivalent porous medium

The model was designed using an equivalent porous medium (EPM) approach for each HSU. This approach is commonly used in regional groundwater modelling of fractured rock hydrogeological environments. The EPM method assigns bulk hydraulic properties for rock matrix and associated fracture networks as if they were a single porosity medium such as a granular aquifer (Anderson and Woessner 1991). This approach was adopted for the following reasons:

- in order to simulate regional-scale groundwater impacts a simplified modelling approach was needed; and
- dual porosity and discrete fracture network models require significant detail on fracture/joint orientations, spacings and apertures, which were not available for the geology in the model domain.

It is noted that the EPM approach is appropriate for a regional groundwater model, though potentially at the expense of small-scale prediction accuracy by not capturing the detail of local fracture network properties.

3.2 Software

The numerical groundwater flow model was developed using MODFLOW-USG version 1.10 (Panday et al 2013, Panday 2022). This modelling code contains additional capabilities over previous releases of MODFLOW, utilising a control volume finite difference formulation in which a model cell can be connected to an arbitrary number of other cells. The formulation allows for the development of an unstructured, highly refined model mesh over areas of interest without influencing the regional mesh refinement. In addition, MODFLOW-USG contains an optional Newton-Raphson formulation which improves model stability for processes involving the drying and rewetting of model cells, and this functionality is used.

The Groundwater Vistas 8 (ESI 2021) graphical user interface (GUI) was used to build and run the model, and to conduct some components of post-processing of simulation results. Python scripts were also used for automation of model data pre- and post-processing.

3.3 Domain and spatial discretisation

GHD (2012) developed the existing numerical model domain as a rotated finite difference grid with active area based on the extent of surface water catchments, measuring approximately 93 km east-west by 108 km north-south (along the axes rotated with the grid). To aid comparison of predictions from previous evolutions of modelling of the CCM with those from the new CCM2.0 model, the domain of the existing regional numerical model was adopted, with some modifications. The domain is presented in Figure 3.1, and is adequately large enough to:

- encompass all mine-related water-affecting features, including mine excavations and groundwater monitoring locations;
- encompass all identified receptors with potential to be affected by mining activities; and
- include model boundary conditions such that regional flow directions can be simulated.

3.3.1 Mesh

An unstructured Voronoi polygon mesh is employed to discretise the model domain, developed using AlgoMesh version 2 (HydroAlgorithmics 2020) to incorporate spatial detail at relevant features. This meshing method is numerically efficient and can handle complex geometries. A Voronoi polygon cell is based on a triangle-generated mesh where normally six triangular cells can be combined into one Voronoi cell, thus significantly reducing the number of model cell elements, while providing the flexibility to represent the geometry of irregular features in the mesh. The ability to implement spatial refinement at areas of interest only (without refinement propagating across the whole domain as in older versions of MODFLOW) allows simulation of details at mine and receptor scales in a regional scale model while keeping the number of model cells relatively low. The Voronoi mesh was generated using a 'high' quality setting, resulting in 34,624 Voronoi cells per model layer.

The model mesh employs a cell spacing at model edges of 2,000 m and maximum regional cell spacing of approximately 3,500 m, reducing to smaller cells in areas of interest as follows:

- production bores: 20 m;
- open cut mining area: 500 m;
- underground mining area: 500 m;
- buffer zone around underground mining area to account for horizontal stress relief: 200 m;
- major creeks: 150 m;
- Doongmabulla springs: 200 m; and
- other mapped springs: 100 m.

In addition to the above, further refinement was induced between the edge of the open cut mining area and the southern bank of Carmichael River, to ensure spatial separation of boundary condition cells. Monitoring bores were also incorporated in mesh development to ensure that model nodes are placed at the locations of monitoring, though without cell refinement. The model mesh, presented in Figure 3.1 (regional mesh) and Figure 3.2 (local mesh at mine site), contains all pertinent hydrologic and proposed engineered water management features.

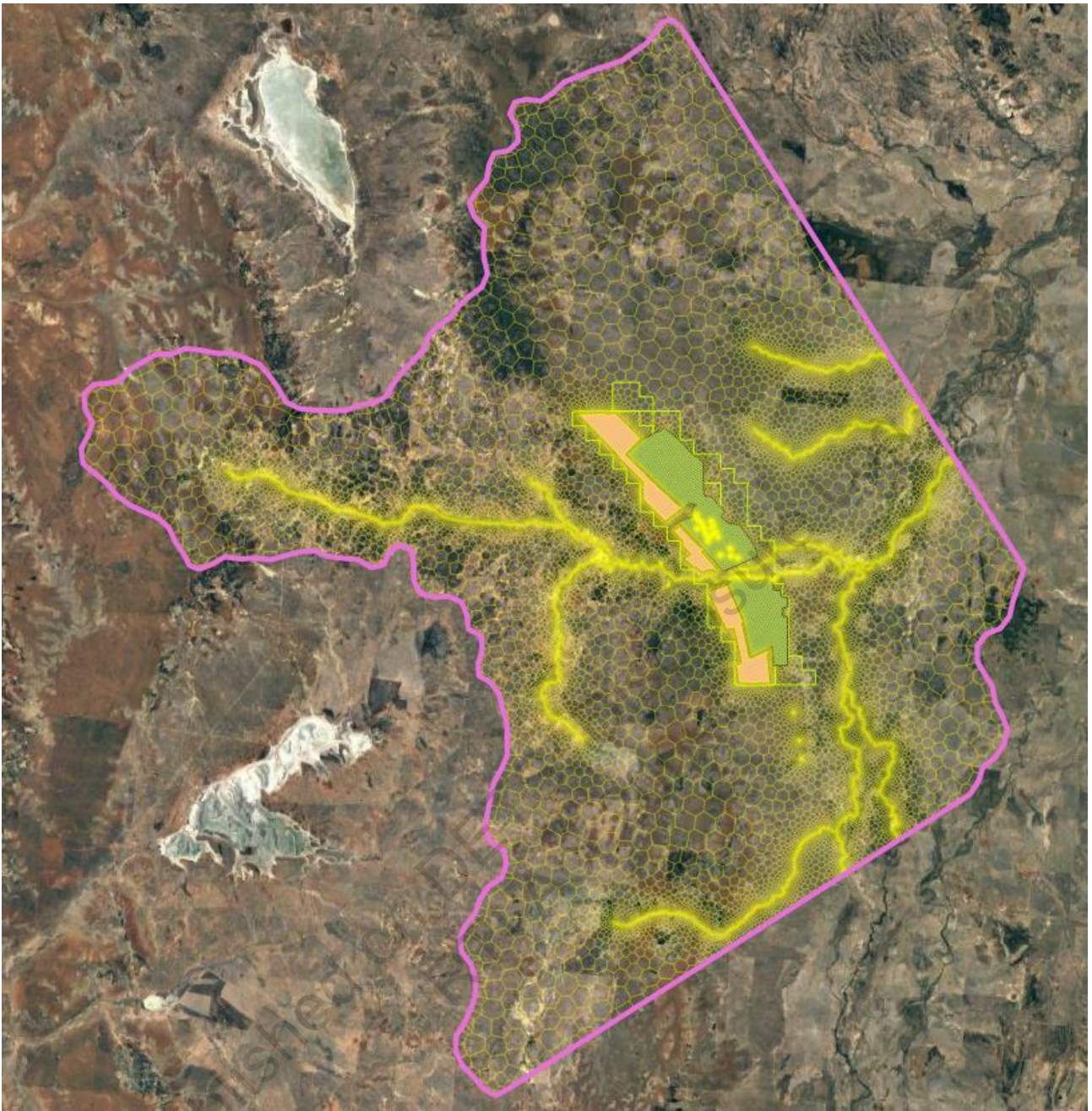


Figure 3.1 Model domain and Voronoi mesh

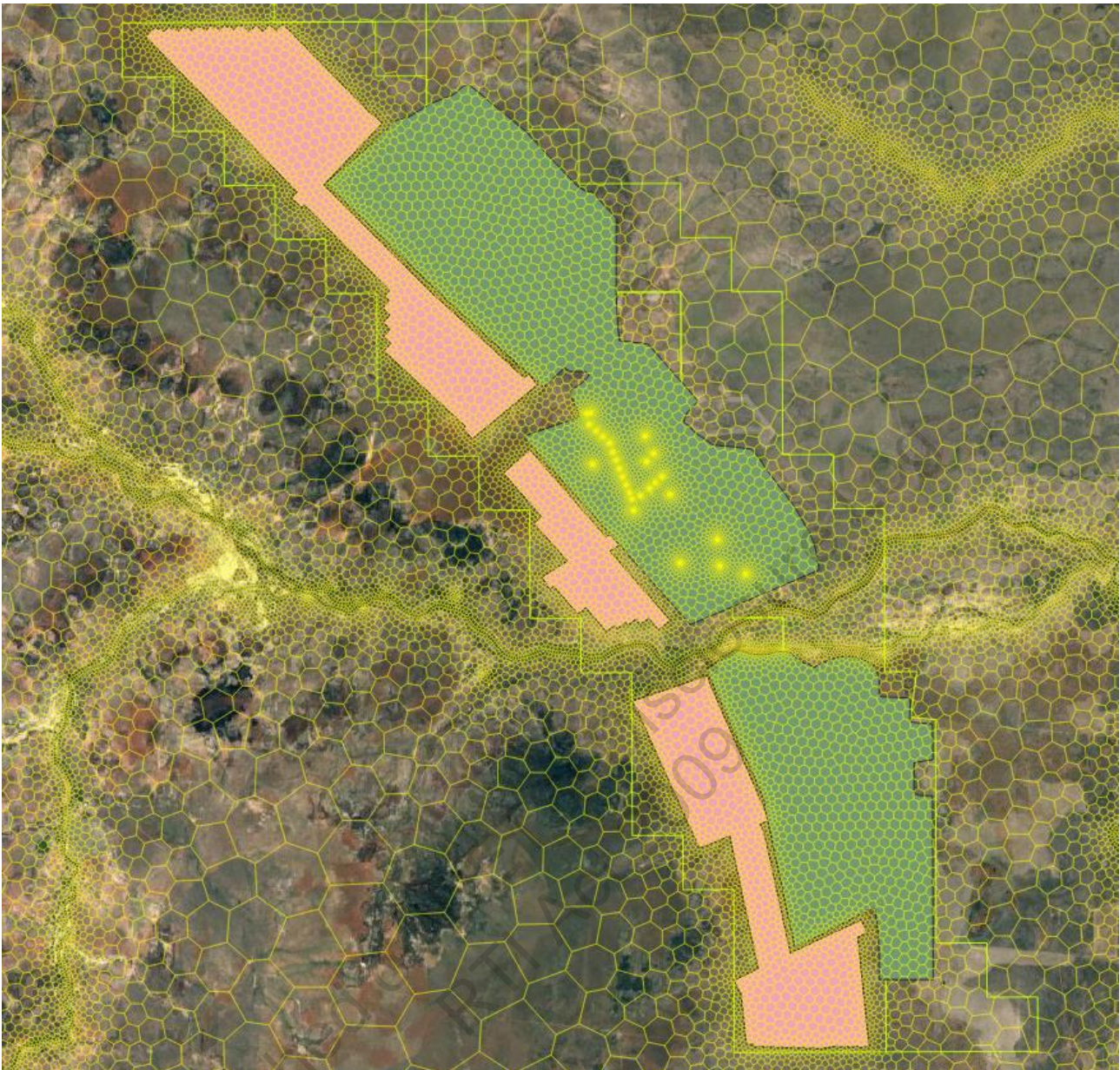


Figure 3.2 Voronoi mesh in mine area

3.3.2 Layers

The HSUs in the study area have been described in EMM (2022a) and summarised in Section 1.6. Based on the objectives listed in Section 1.1 and the conceptual hydrogeological understanding, a minimum of 14 layers were required to represent the key HSUs in the model domain.

Surfaces for the top/bottom of the key regional HSUs were developed using data from multiple sources including:

- coal seam elevation surfaces developed by Bravus;
- geological contact elevation mapping based on borehole data (logs and geophysics) from Bravus;
- updated structural geological layers developed by Titus Murray using specific lithological and structural interpretation software (Murray 2022); and
- bioregional assessment layers (Bioregional Assessment Programme 2014).

The top of the model is set at topography and the base of the model is set 100 m below the top of Joe Joe Group, sufficiently deep below the base of mining to allow for regional groundwater flow below the base of the mine. Model layers are described in Table 3.1.

Table 3.1 Model layer summary

HSU name	Groundwater model layer	Mine infrastructure / additional notes
Quaternary alluvium	Layer 1 – aquifer	
Weathering zone	Layer 2 – aquitard	
Tertiary and non-alluvial Quaternary deposits	Layer 3 – aquifer	
Moolayember Formation	Layer 4 – aquitard	Unit not present at mine
Clematis Sandstone / Warang Sandstone	Layer 5 – aquifer	
Dunda Beds	Layer 6 – aquitard	
Rewan Formation	Layer 7-8 – aquitard	Divided vertically into two model layers
Bandanna Formation	Layer 9 – aquifer	
Bandanna Formation (AB Seam coal)	Layer 10 – aquifer	Mined coal seam
Bandanna Formation	Layer 11 – aquifer	
Colinlea Sandstone	Layer 12 – aquifer	
Colinlea Sandstone (D Seam coal)	Layer 13 – aquifer	Mined coal seam
Colinlea Sandstone	Layer 14 – aquifer	
Joe Joe Group	Layer 15 – aquifer	

MODFLOW-USG enables groundwater model layers to pinch out and be deactivated. Layers are pinched out where the unit they represent is conceptualised to be absent. The Rewan Formation has been divided into two layers to allow for discretisation of hydraulic property changes with depth.

The top elevations of each model layer are presented in Figure 3.3 to Figure 3.16. Three-dimensional visualisations of the model layering at cross sections aligned perpendicular to and along the strike of the mine are presented in Figure 3.17. These show the regional HSU elevation trends and sub-cropping observed at the edge of the Galilee Basin.

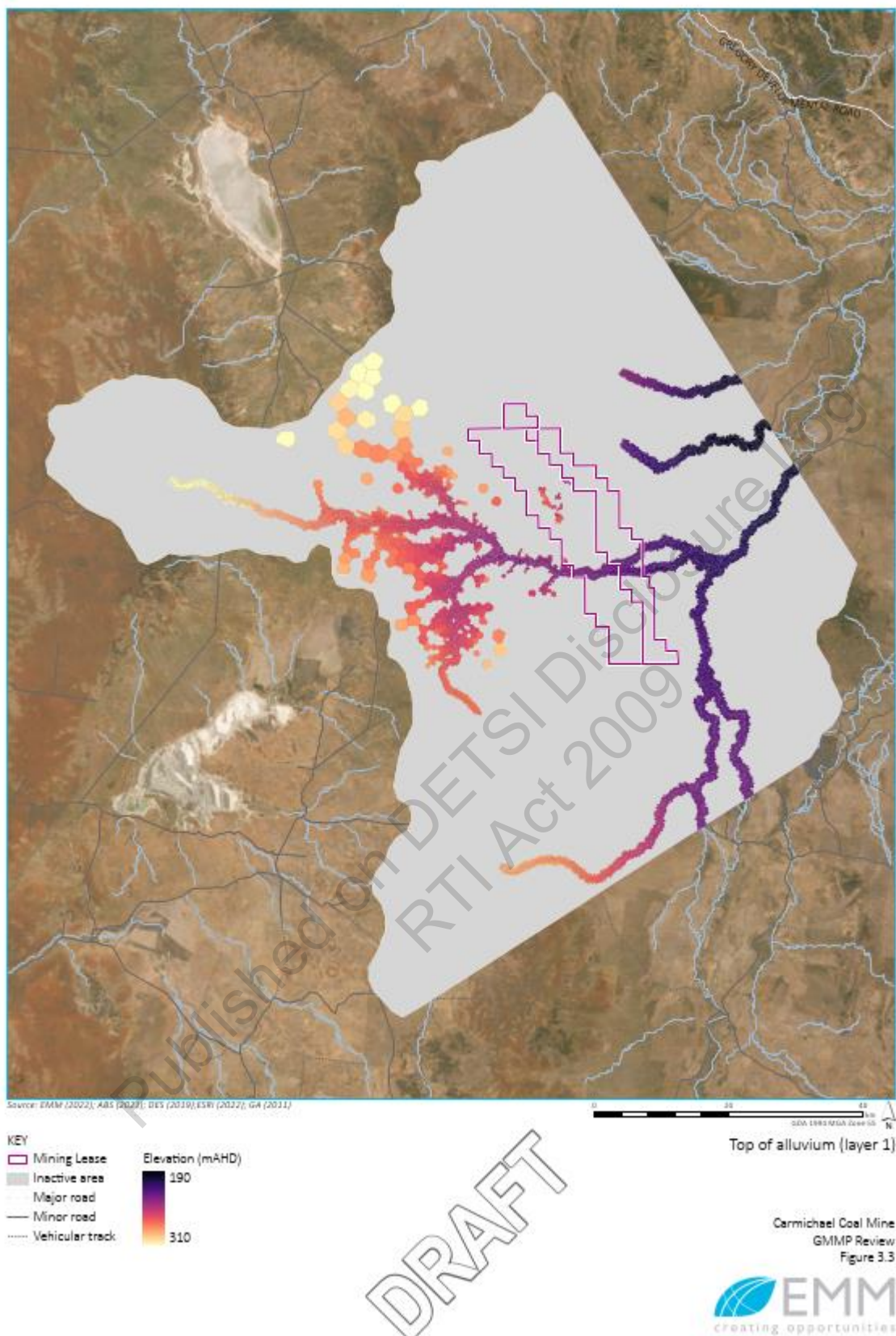


Figure 3.3 **Top of alluvium (layer 1)**

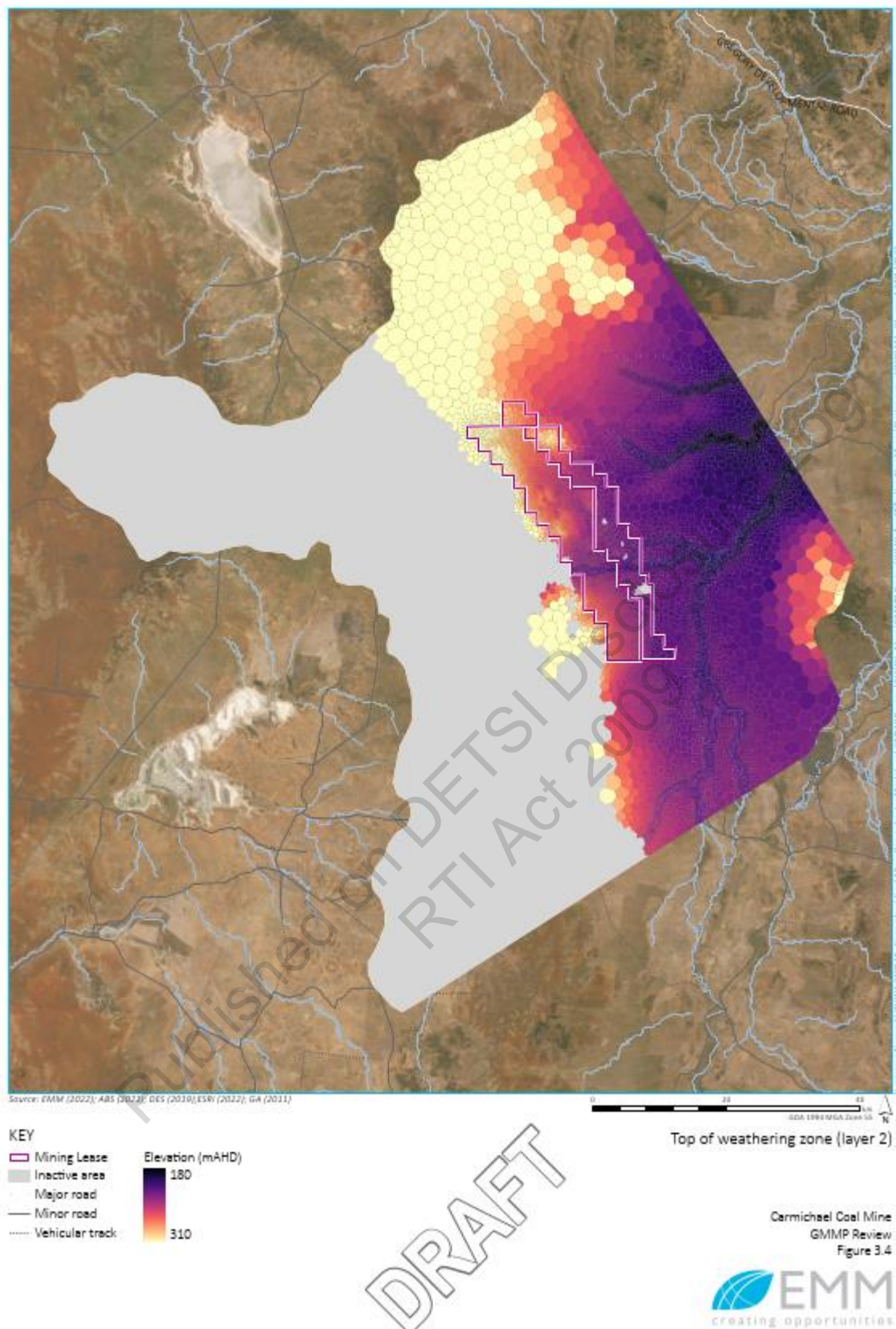


Figure 3.4 Top of weathering zone (layer 2)

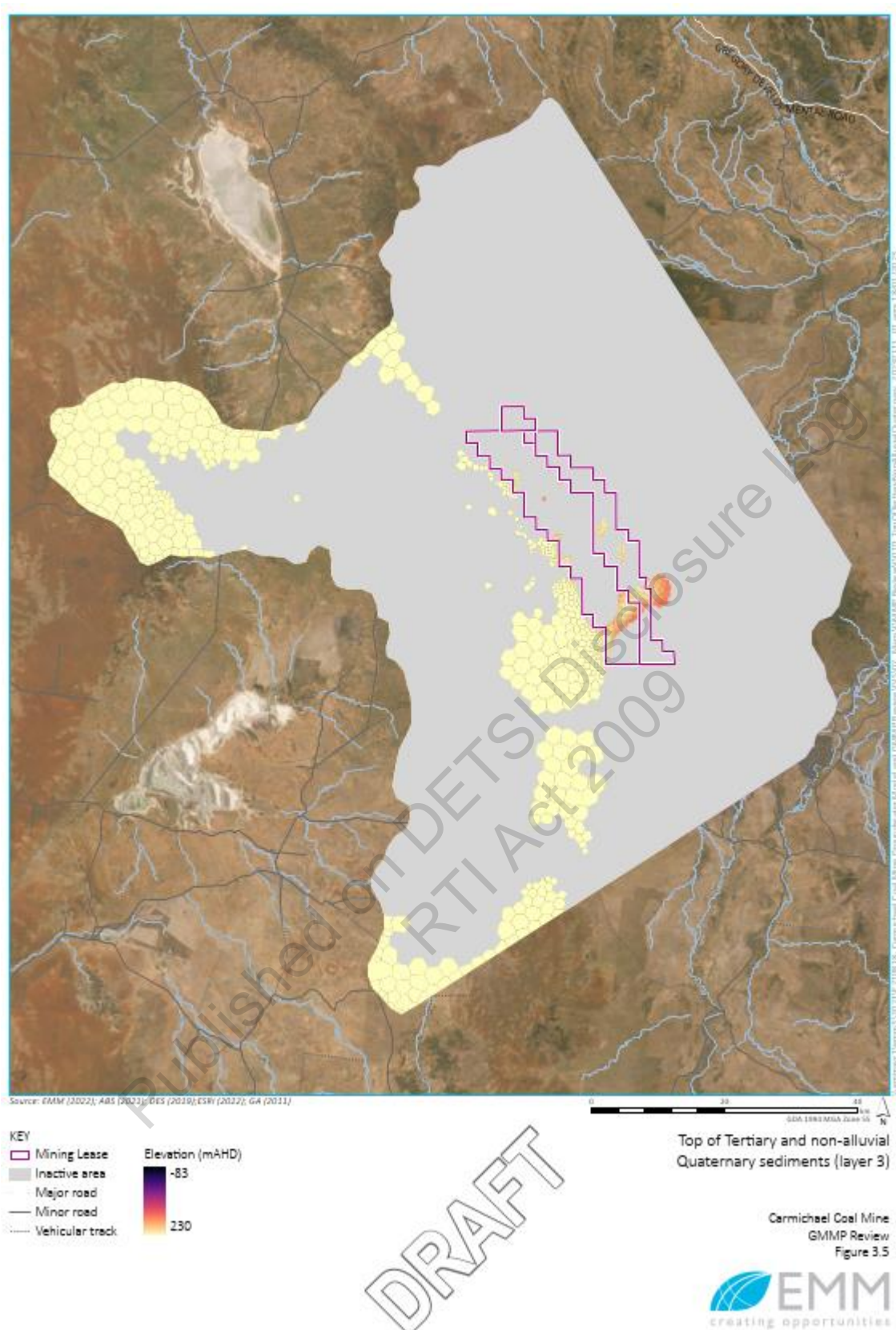


Figure 3.5 Top of Tertiary and non-alluvial Quaternary sediments (layer 3)

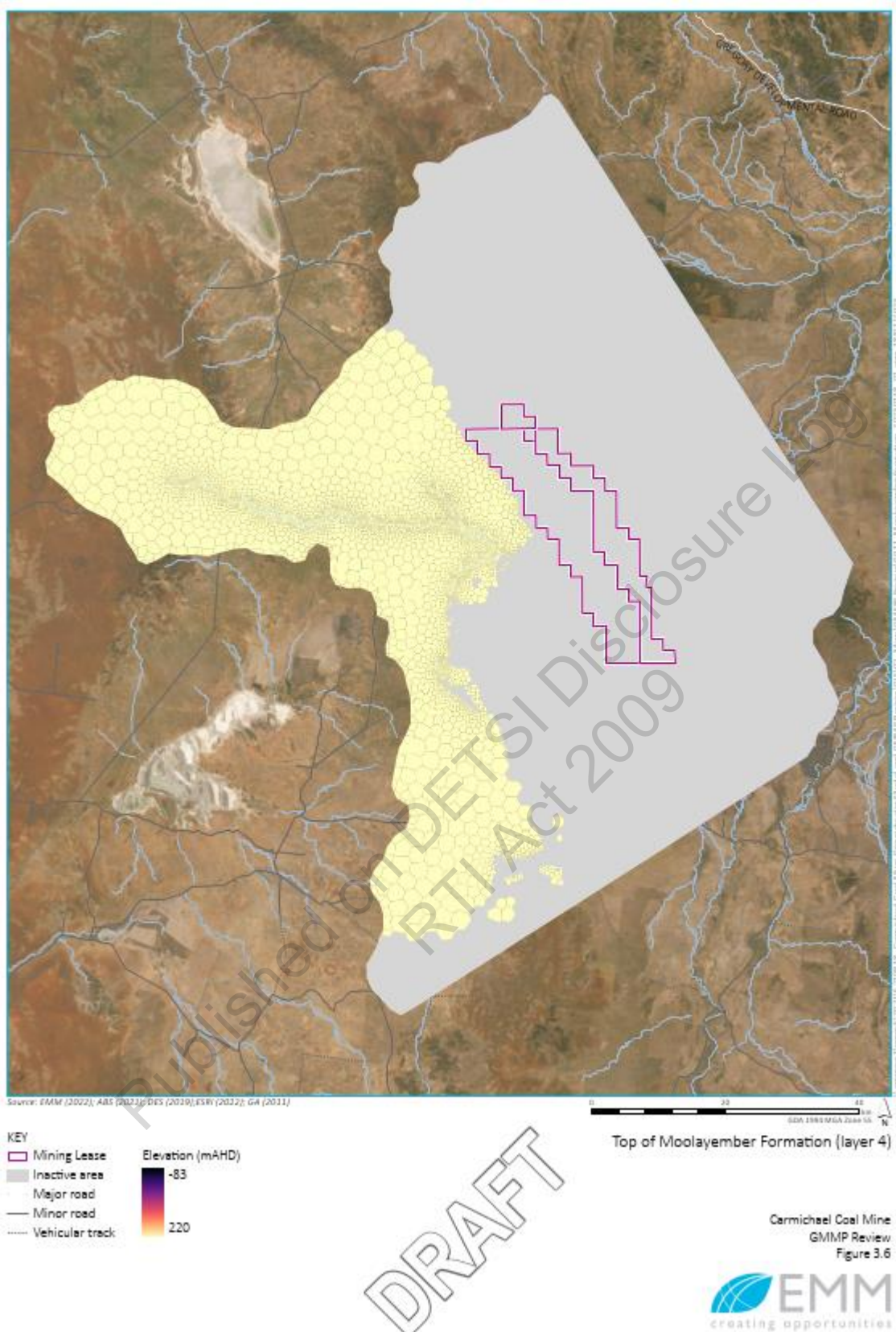


Figure 3.6 Top of Moolayember Formation (layer 4)

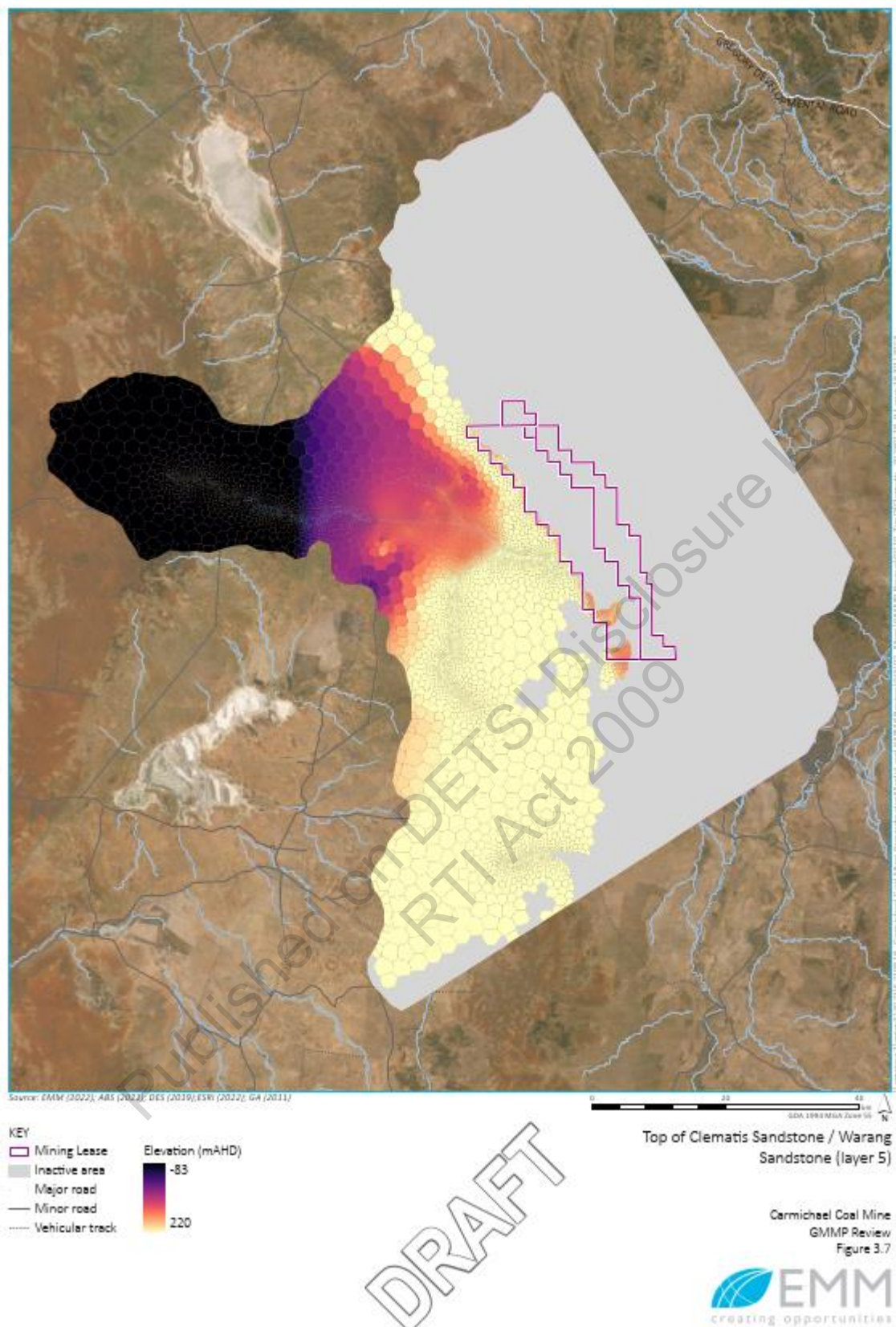


Figure 3.7 Top of Clematis Sandstone / Warang Sandstone (layer 5)

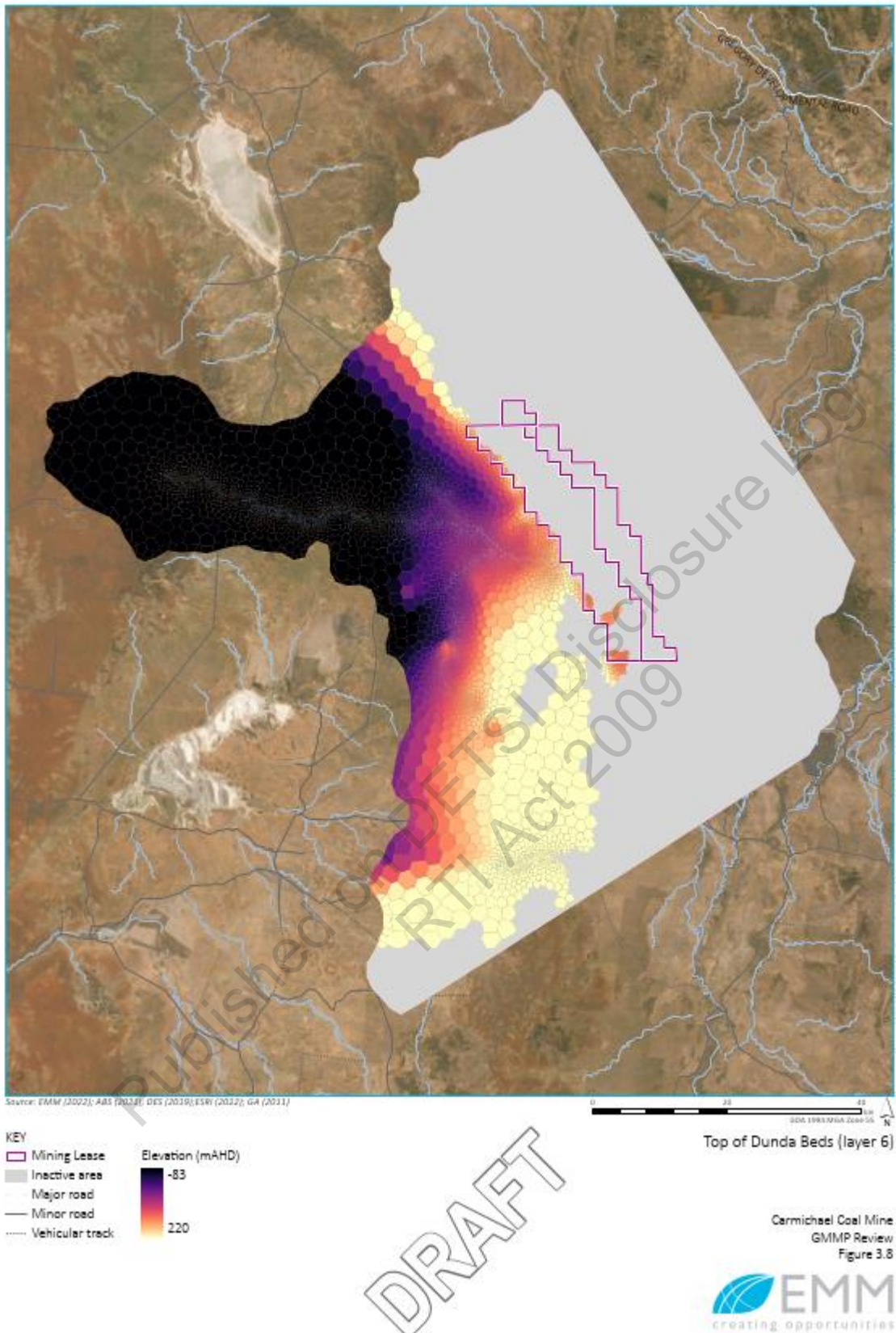


Figure 3.8 **Top of Dunda Beds (layer 6)**

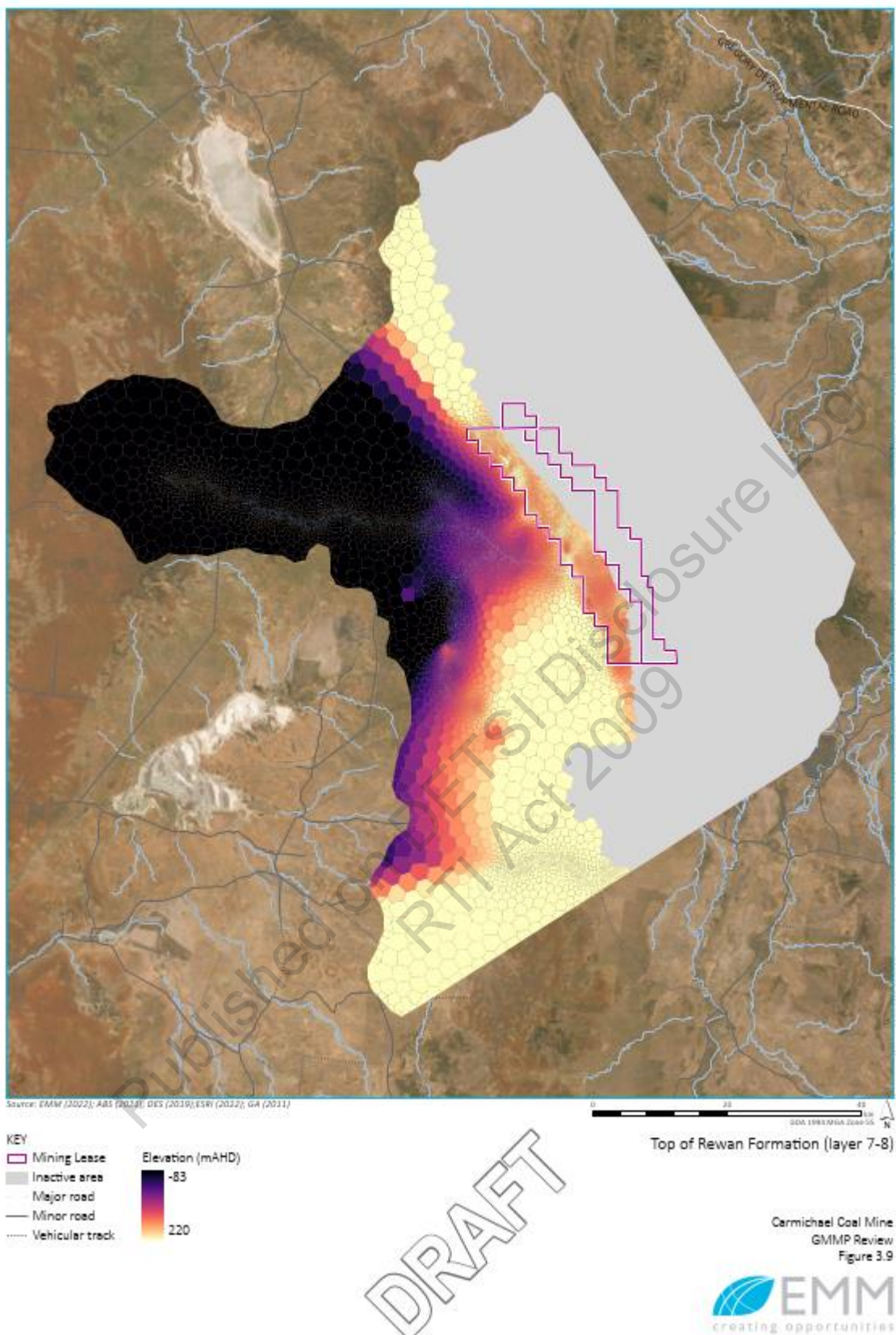


Figure 3.9 Top of Rewan Formation (layer 7-8)

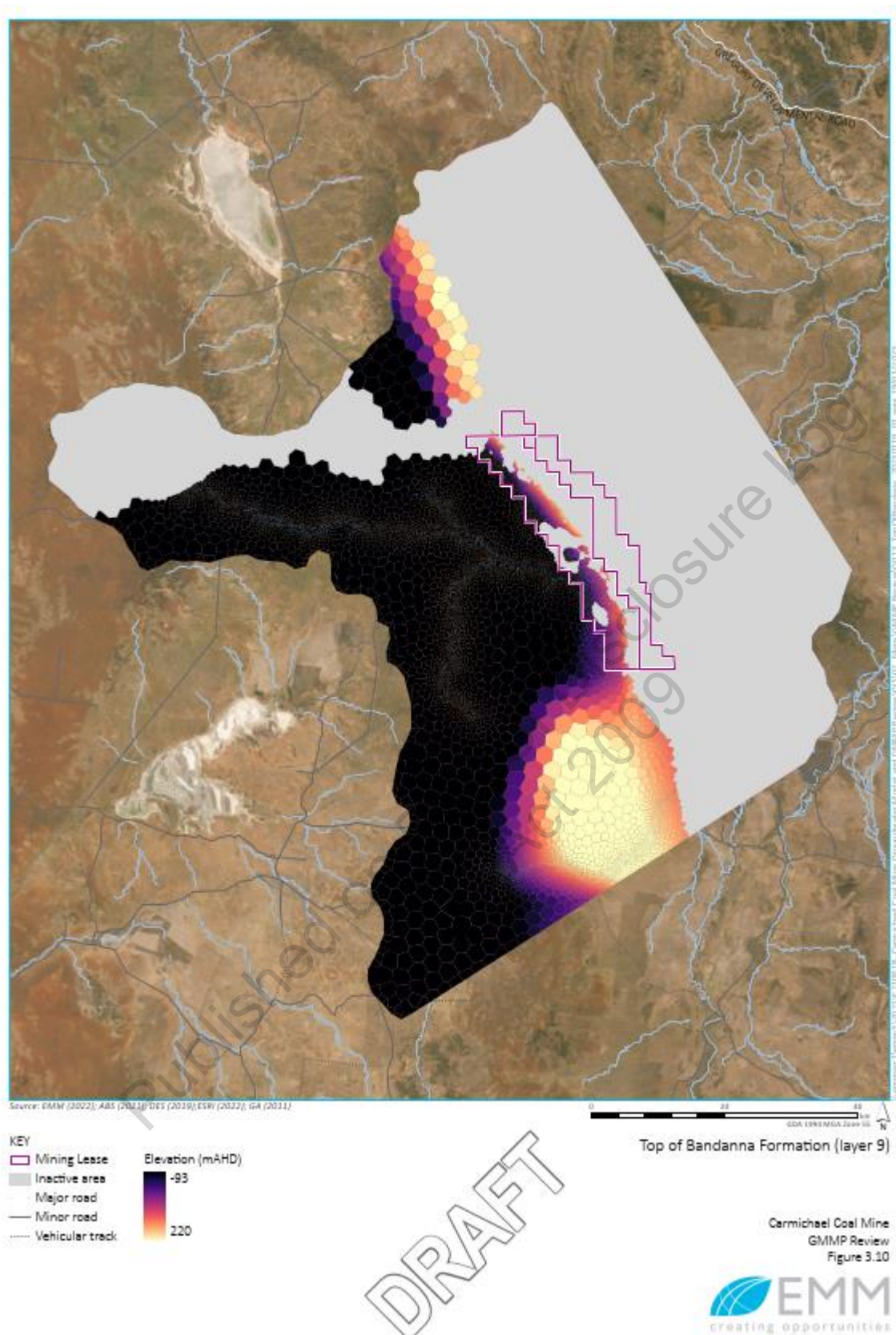


Figure 3.10 Top of Bandanna Formation (layer 9)

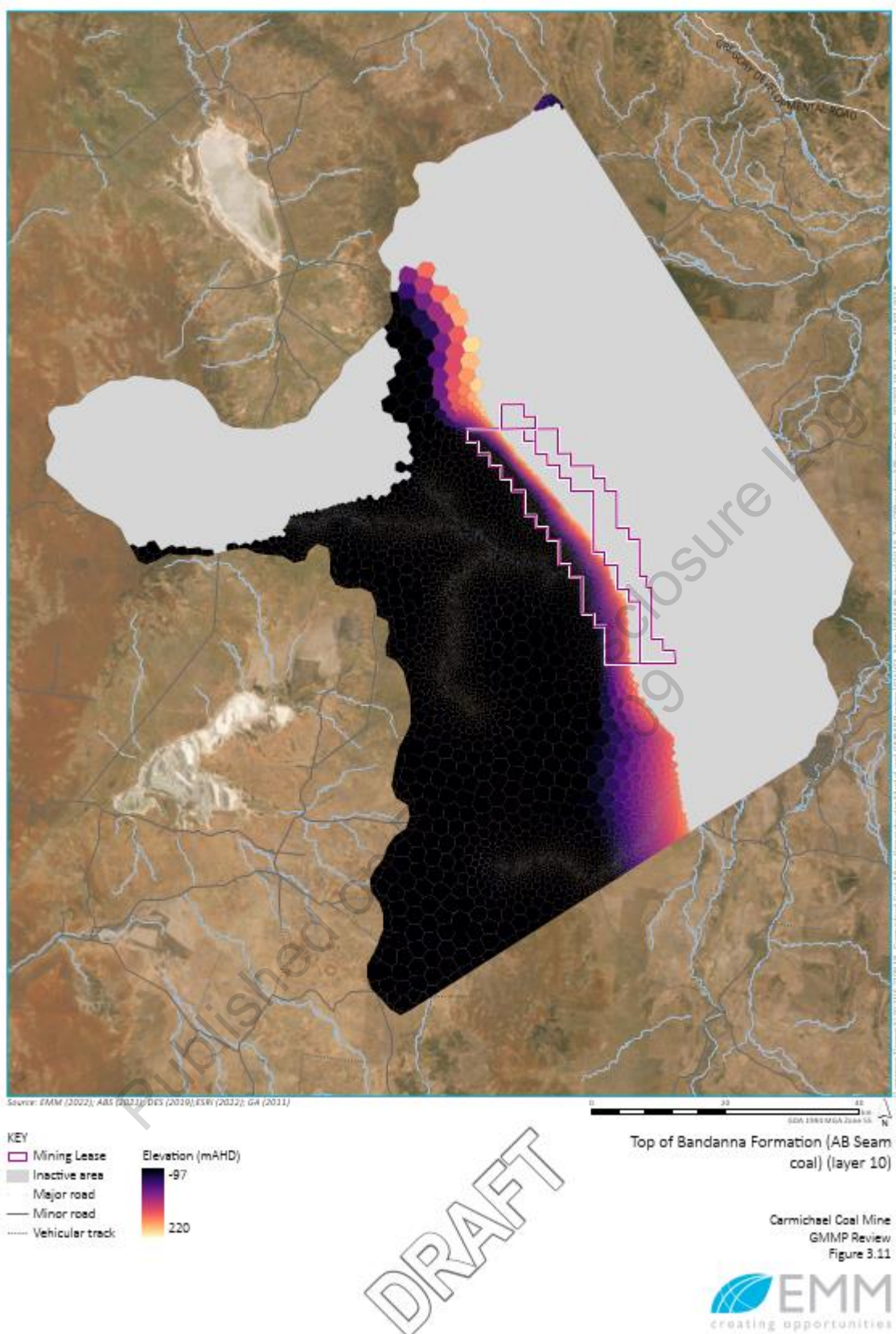


Figure 3.11 Top of Bandanna Formation (AB Seam coal) (layer 10)

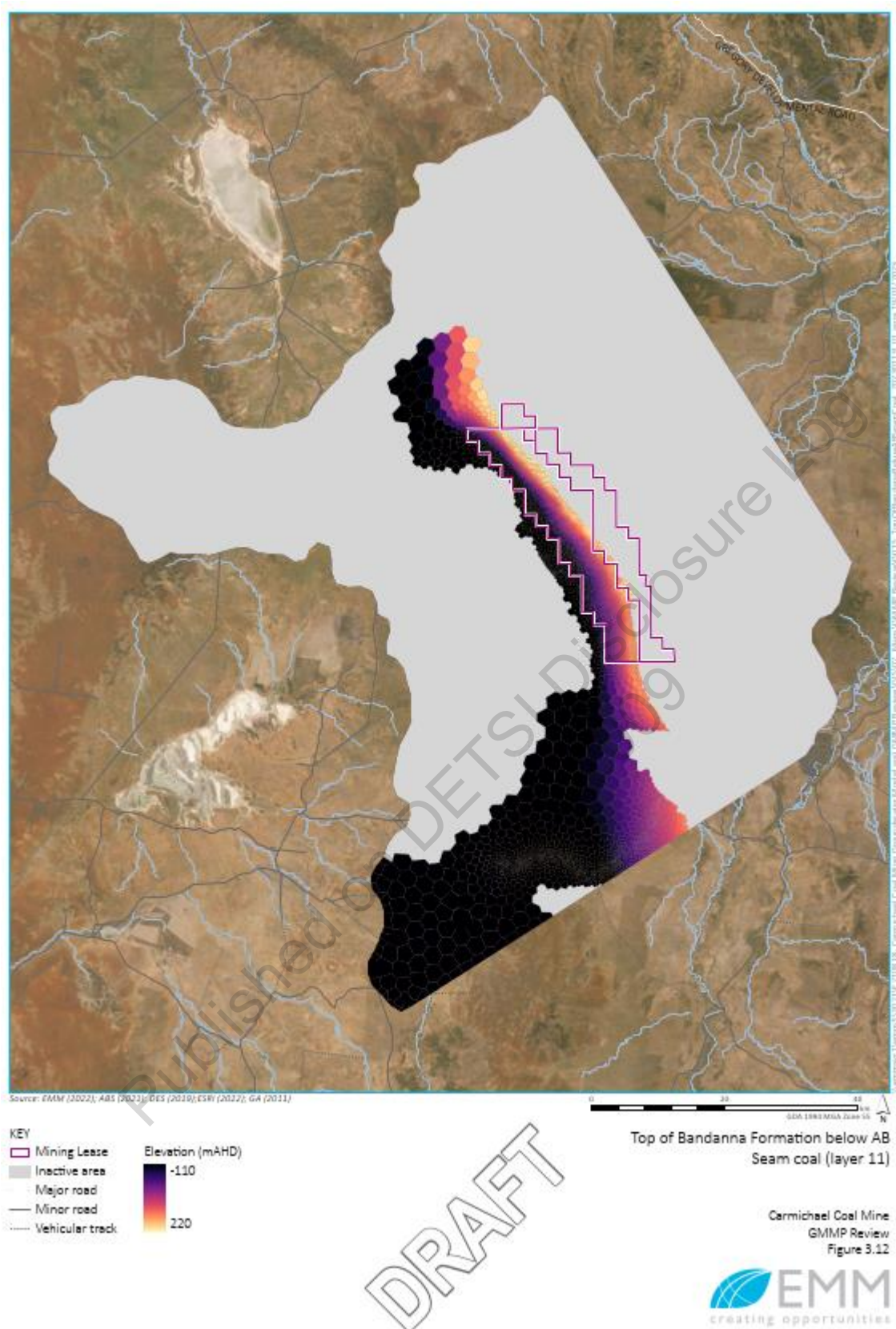


Figure 3.12 Top of Bandanna Formation below AB Seam coal (layer 11)

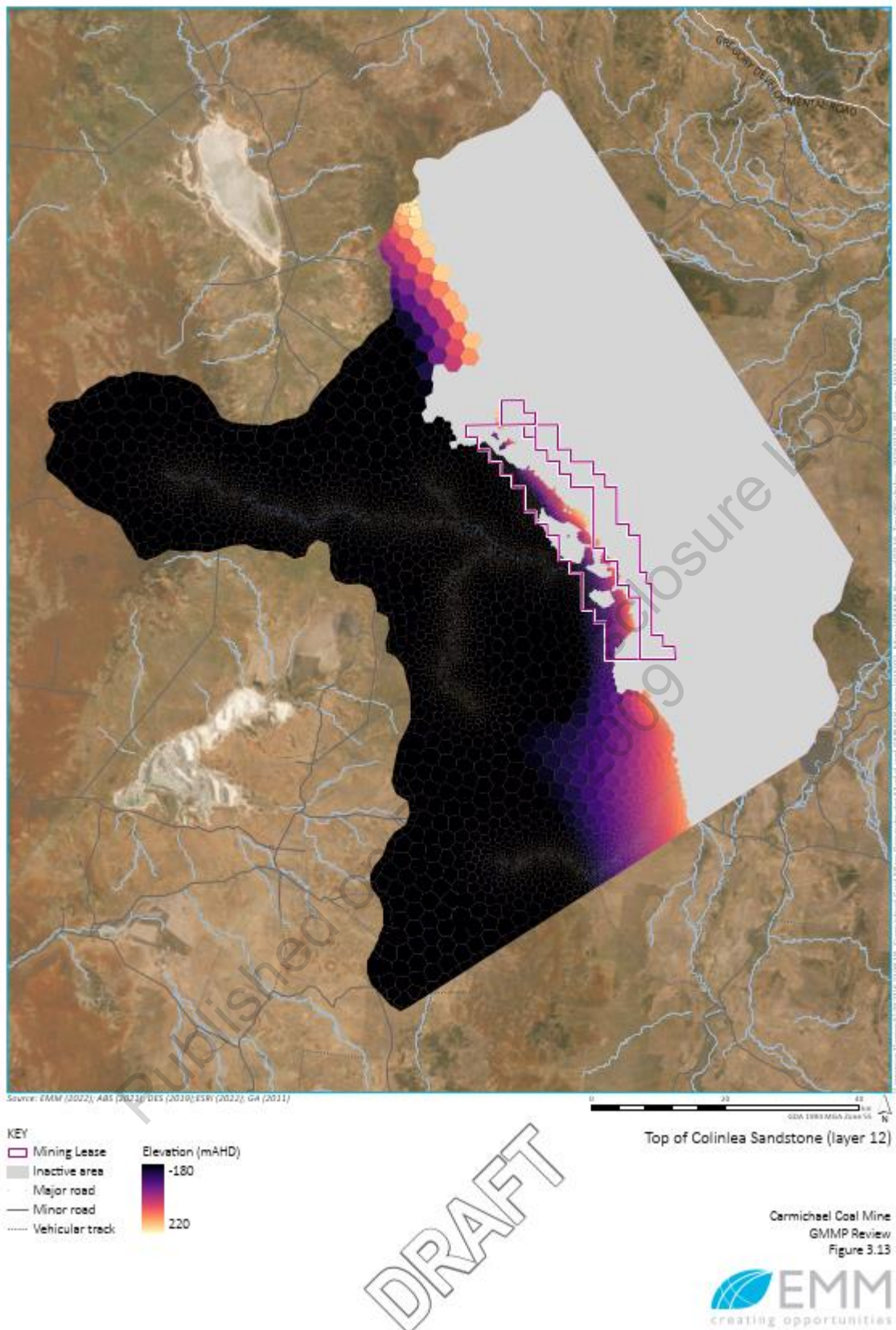


Figure 3.13 Top of Colinlea Sandstone (layer 12)

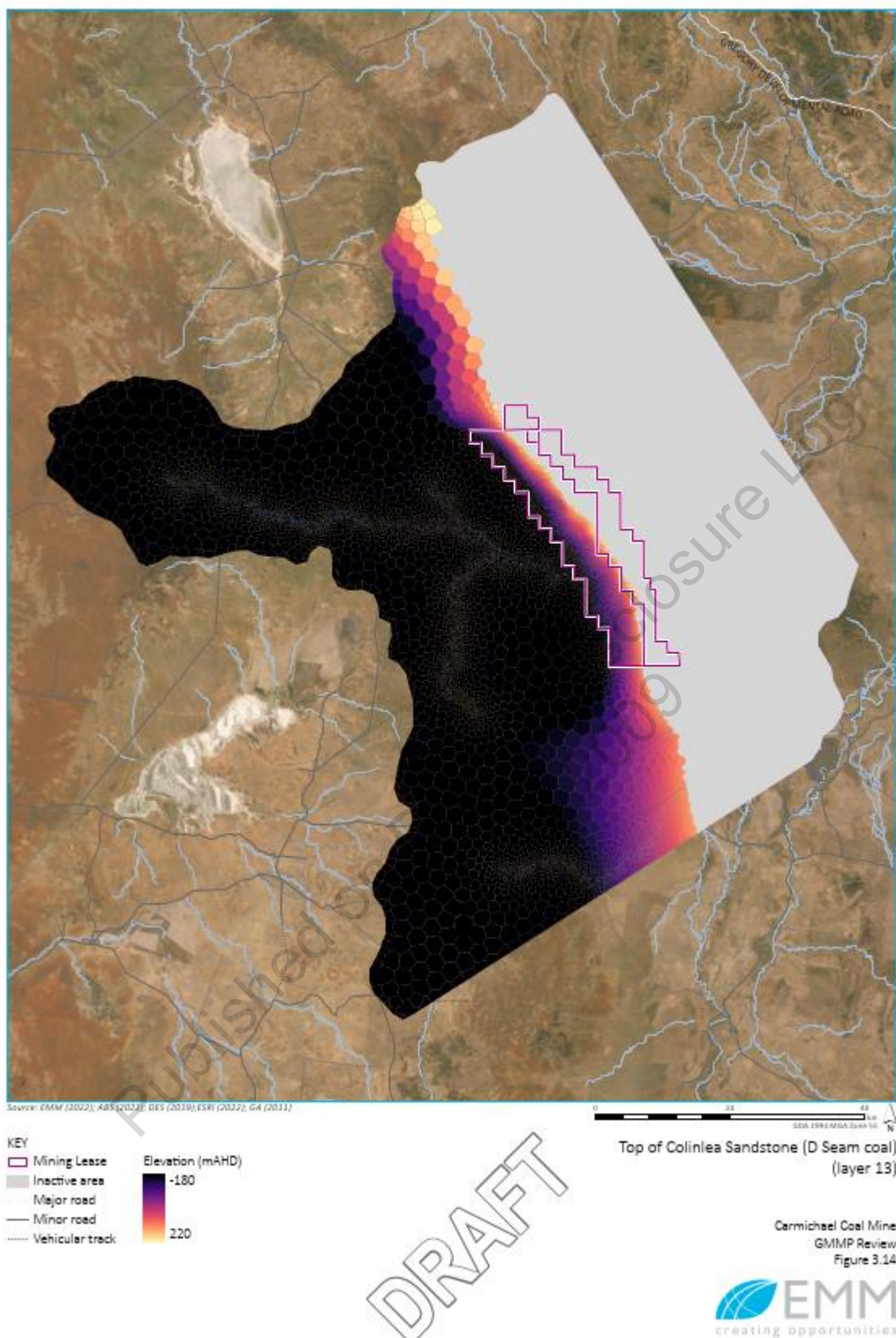


Figure 3.14 Top of Colinlea Sandstone (D Seam coal) (layer 13)

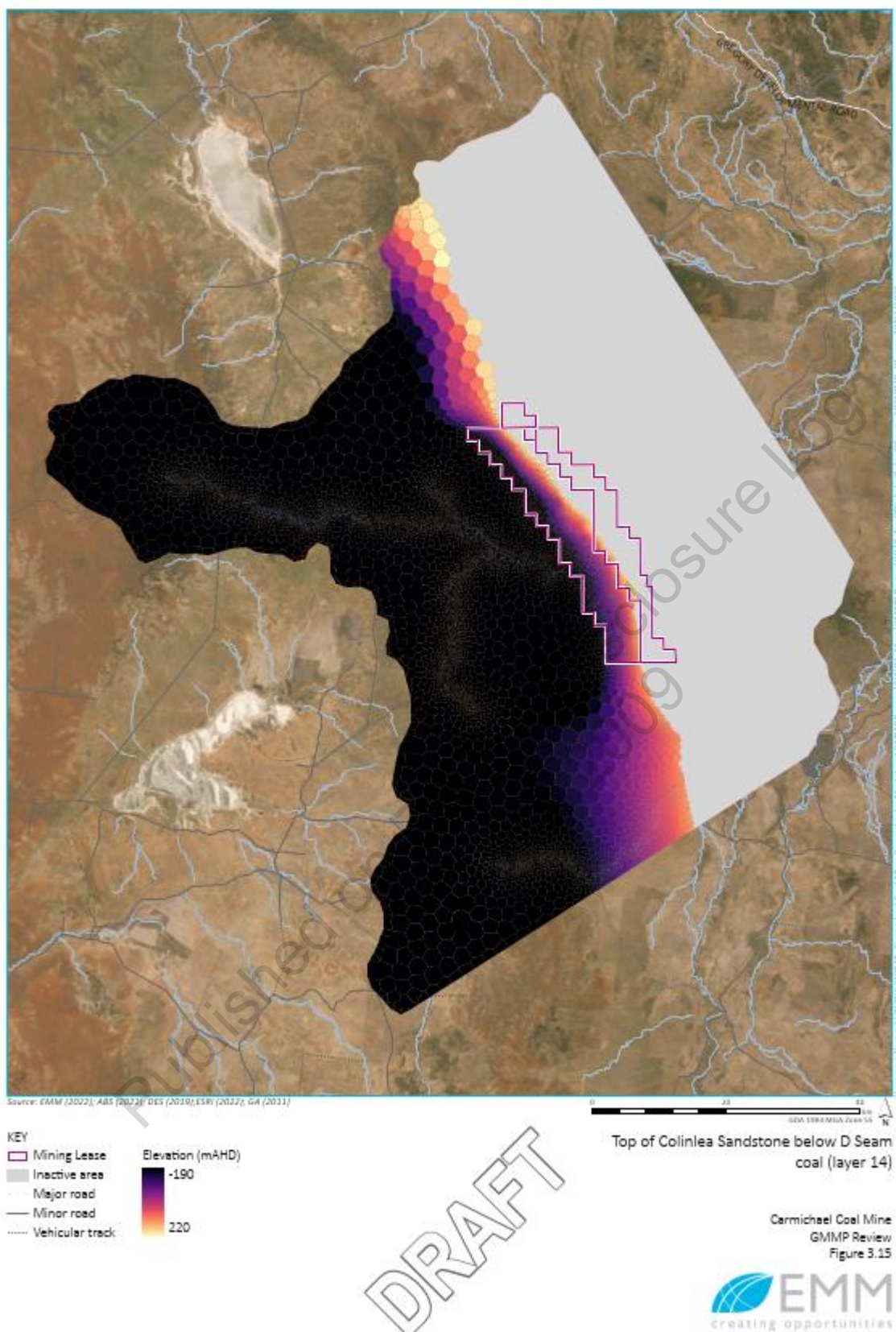


Figure 3.15 Top of Colinlea Sandstone below D Seam coal (layer 14)

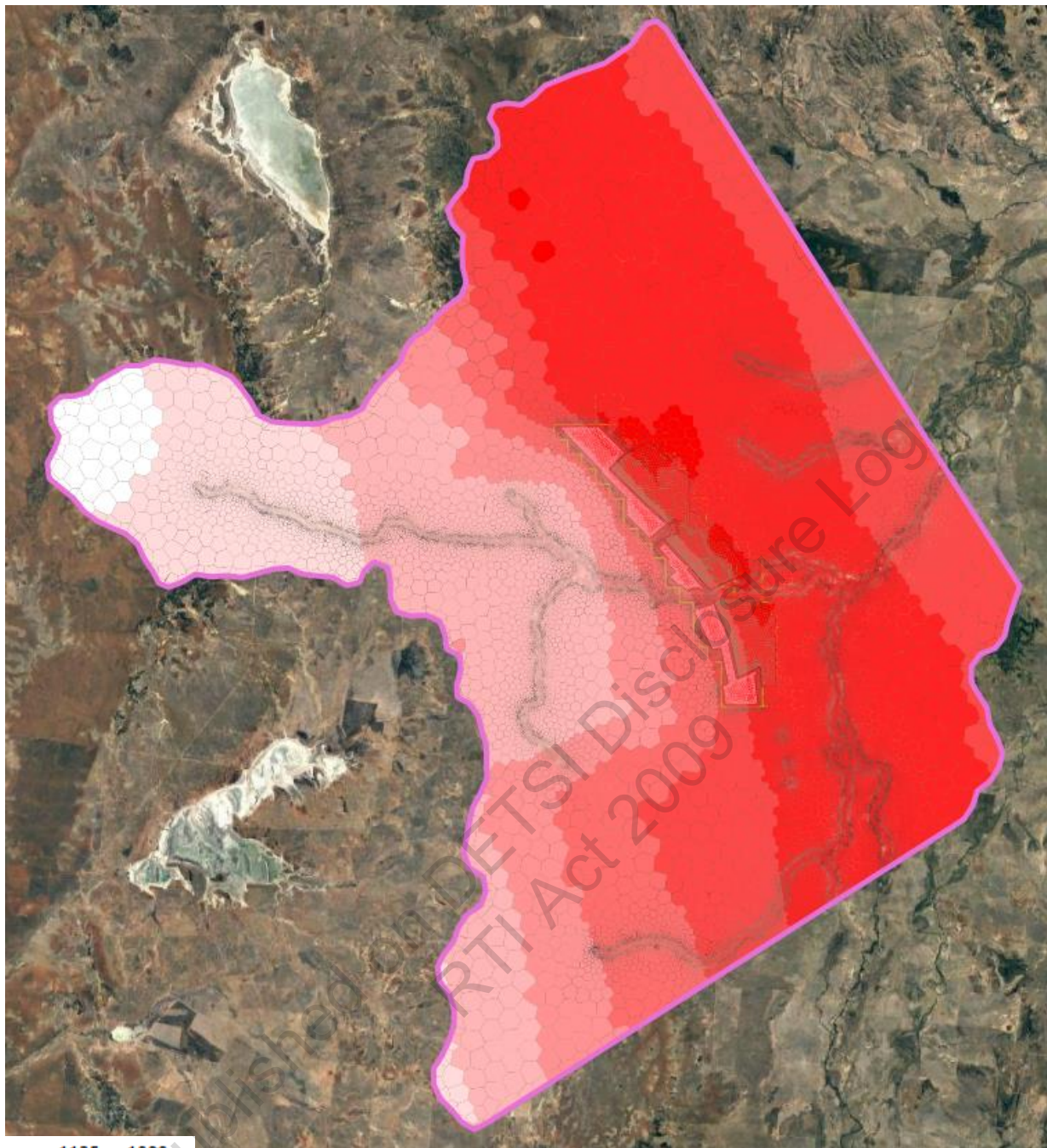
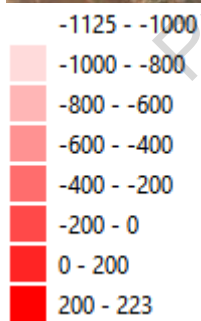


Figure 3.16 Top of Joe Joe Group (layer 15)

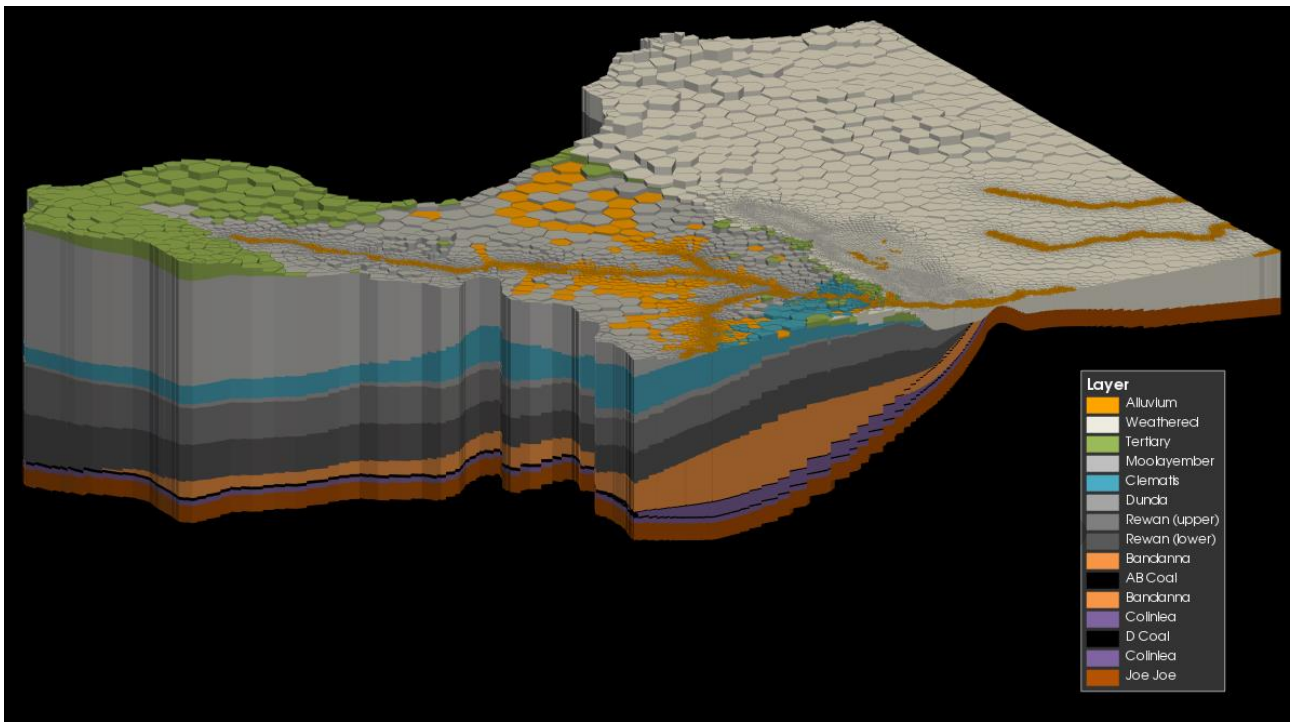


Figure 3.17 3-D visualisation of modelled HSUs

3.4 Temporal discretisation and numerical solution

The history-matching period employs two initial stress periods; one transient stress period run to pseudo-steady state for numerical stability, and one true steady state stress period to establish stable pre-mining groundwater conditions. Following the steady state stress period, 34 quarterly stress periods are employed over the history-matching period from April 2011 to August 2019, followed by 32 monthly stress periods from the commencement of mine dewatering. Starting from April 2022, the predictive mine plan is simulated with 109 part-year stress periods (8 months and 4 months respectively), representing dry and wet seasons. A subsequent final stress period simulates 2,000 years of post-mining recovery. A summary of the model stress periods is provided in Table 3.2.

The adaptive time stepping feature of MODFLOW-USG is employed to efficiently discretise stress periods into time steps such that a numerically stable solution is obtained. The SMS solver is employed to solve the differential equations with a head closure criterion (HCLOSE) of 1×10^{-2} m, using the χ MD linear method and Delta-Bar-Delta/Newton Raphson nonlinear method.

Table 3.2 Model stress periods

Stress period	Stress period duration	Description
1	100 years	Pseudo-steady state stress period run in transient mode to provide numerical stability for the following true steady state stress period
2	Steady state	Develops initial pre-mining conditions in response to modelled hydraulic parameters and boundary conditions
3 to 36	Quarterly	History-matching period, from April 2011 to August 2019 (climate stresses only)
37 to 68	Monthly	History-matching period including mine dewatering, from August 2019 to April 2022
69 to 177	Part-yearly	Predictive period simulating mining activities from April 2022 to December 2076
178	2,000 years	Predictive period simulating 1,000 years of post-mine recovery

3.5 Boundary conditions

3.5.1 Regional groundwater flow

As discussed in Section 1.6, groundwater generally flows across the model domain from the south-west towards the north-east. Constant head boundary conditions (CHD package) are applied at the model boundaries in primary aquifers (alluvium and surficial sediments, Clematis Sandstone, and deeper Permian strata) to simulate lateral groundwater flow to and from the broader groundwater system. Conceptual hydraulic head contours were taken from the Bioregional Assessment Programme (2015) for the Bandanna Formation, and Colinlea Sandstone. Groundwater contours were developed for the Clematis Sandstone in consultation with DES and using data available from QLDGlobe. Data for the shallow sediments and Joe Joe Group were sourced from Turvey et al. (2015), with representative measured steady state groundwater heads used to infer regional contours.

The modelled constant head boundaries are shown in Figure 3.18 to Figure 3.22. The hydraulic heads assigned to the constant head boundary conditions are set to the inferred elevation of the potentiometric surfaces, ranging from 190 mAHD in the eastern area of the model domain to 290 mAHD in the western and south-western corners. By assigning constant head boundary conditions around the model edge, not only at inferred locations of inflow or outflow prior to mining, the model is able to simulate changes to flows across the model boundary that may arise due to simulated mining activities, regardless of whether those locations are conceptualised as being inflow or outflow areas prior to mining. Boundary cells are inactive at locations where an HSU is pinched out; this

includes the eastern portion of the model domain for subcropping units (Clematis Sandstone, Bandanna Formation, and Colinlea Sandstone).

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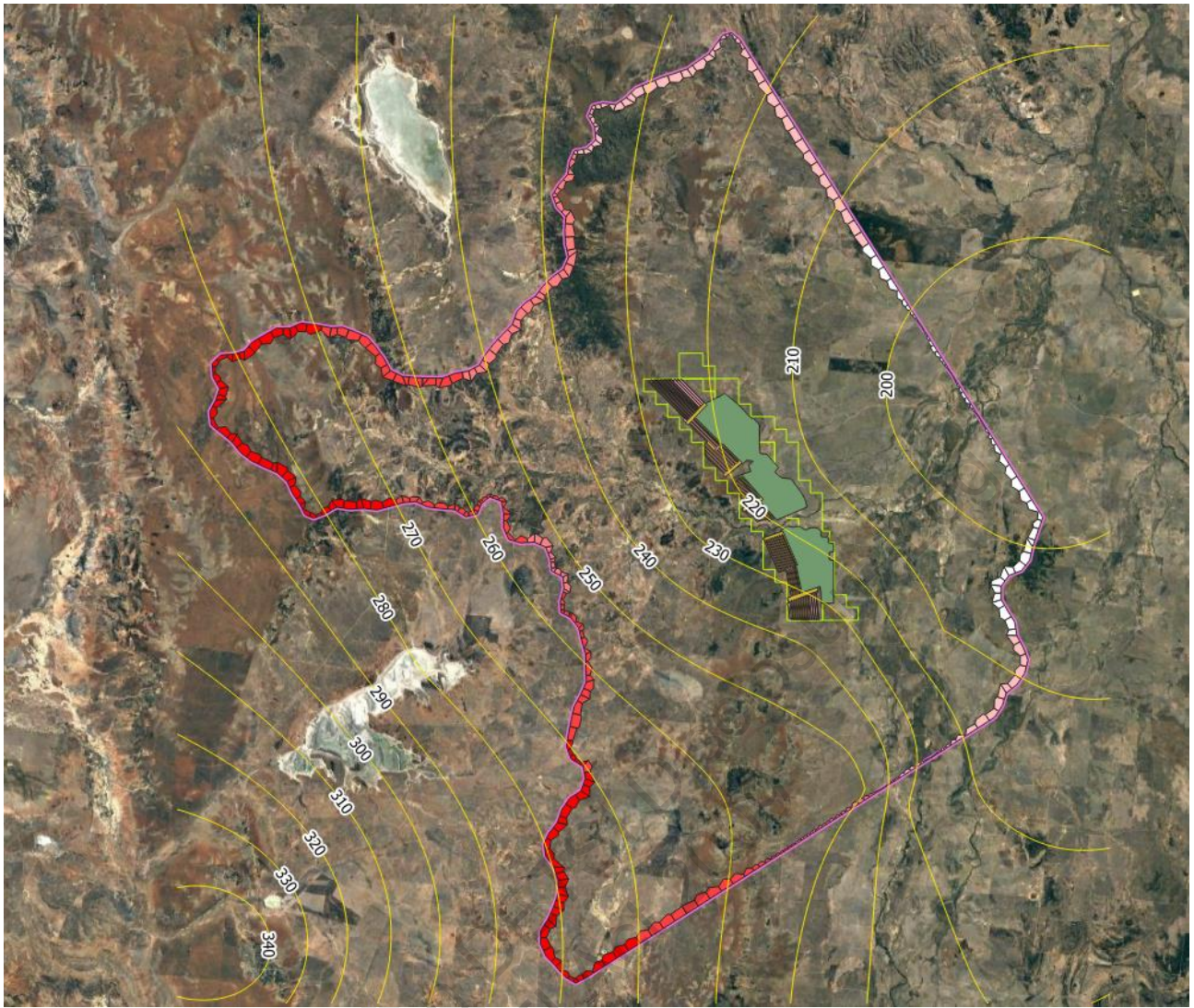


Figure 3.18 **Modelled regional boundary conditions in surficial layers**

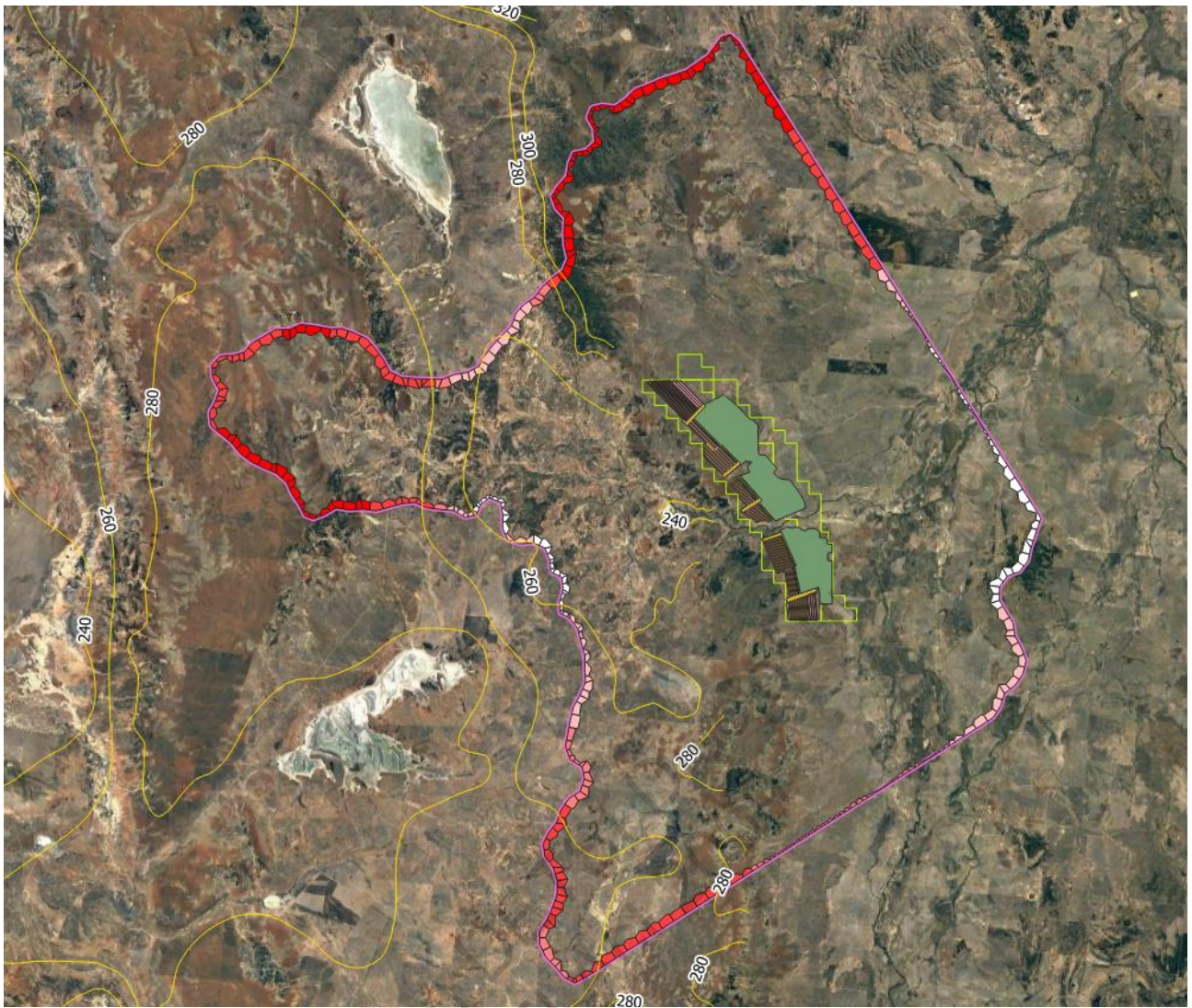


Figure 3.19 **Modelled regional boundary conditions in Clematis Sandstone**

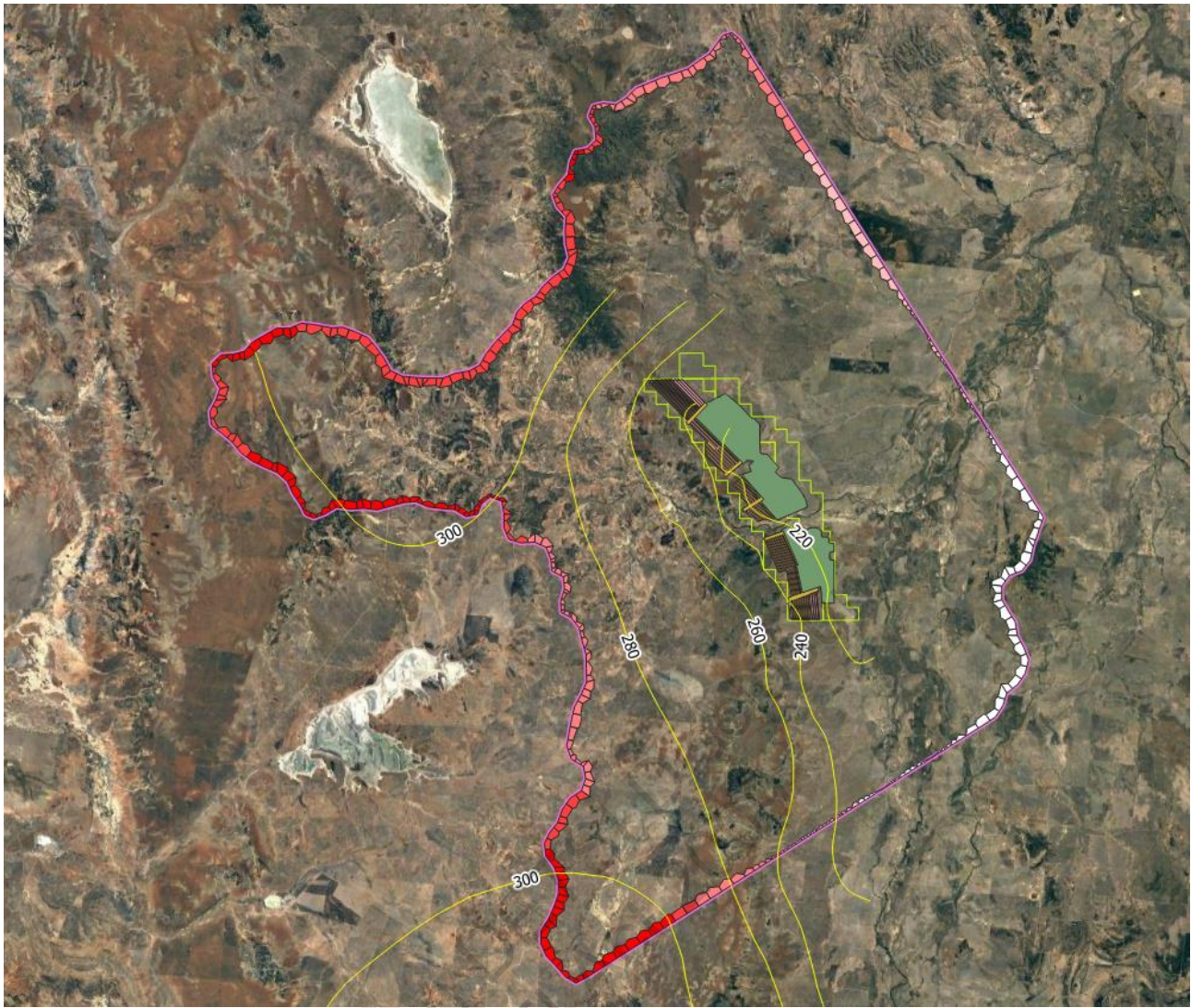


Figure 3.20 Modelled regional boundary conditions in Bandanna Formation (coal seam overburden) and AB Coal

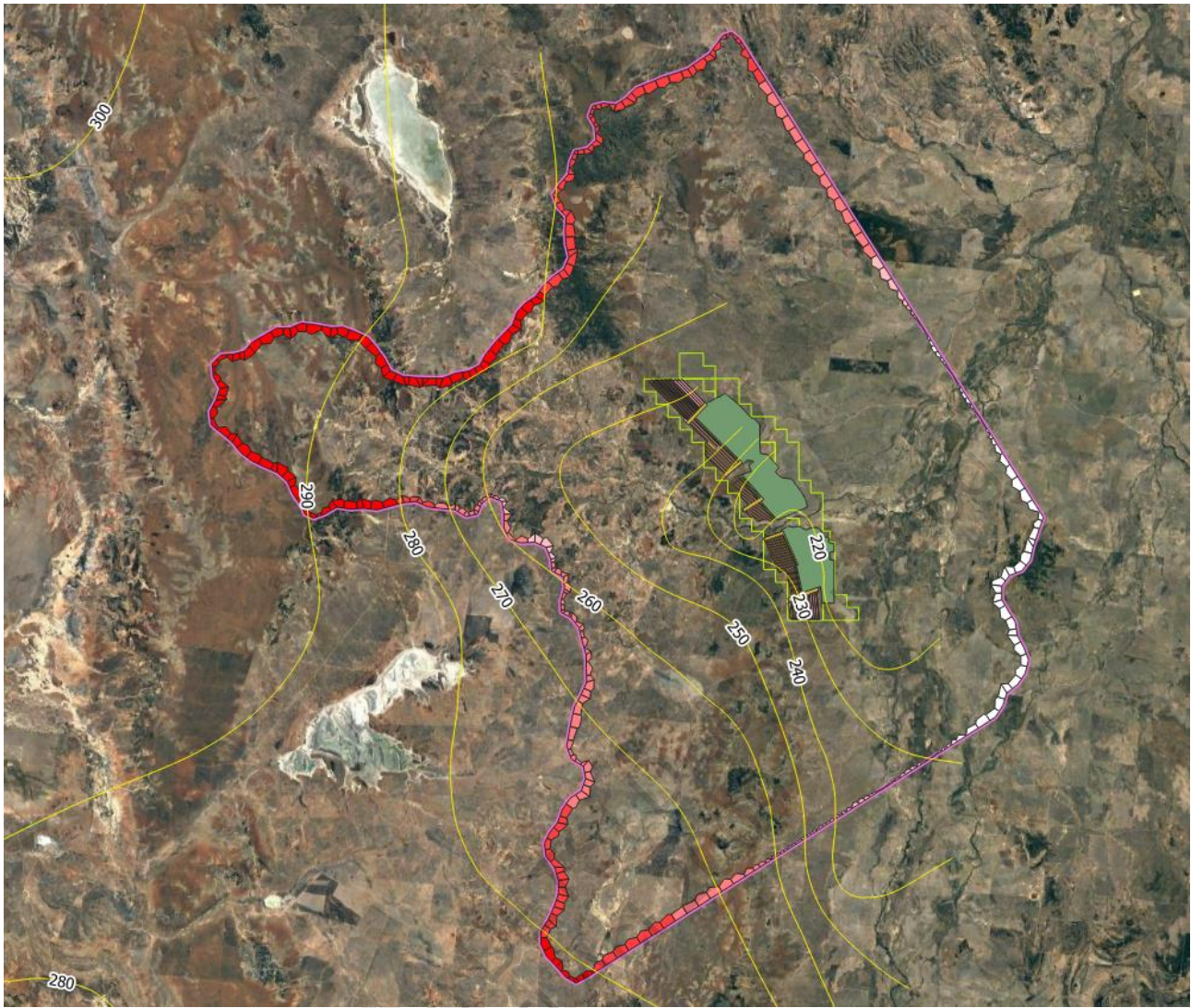


Figure 3.21 Modelled regional boundary conditions in D Coal and Colinlea Sandstone (coal seam underburden)

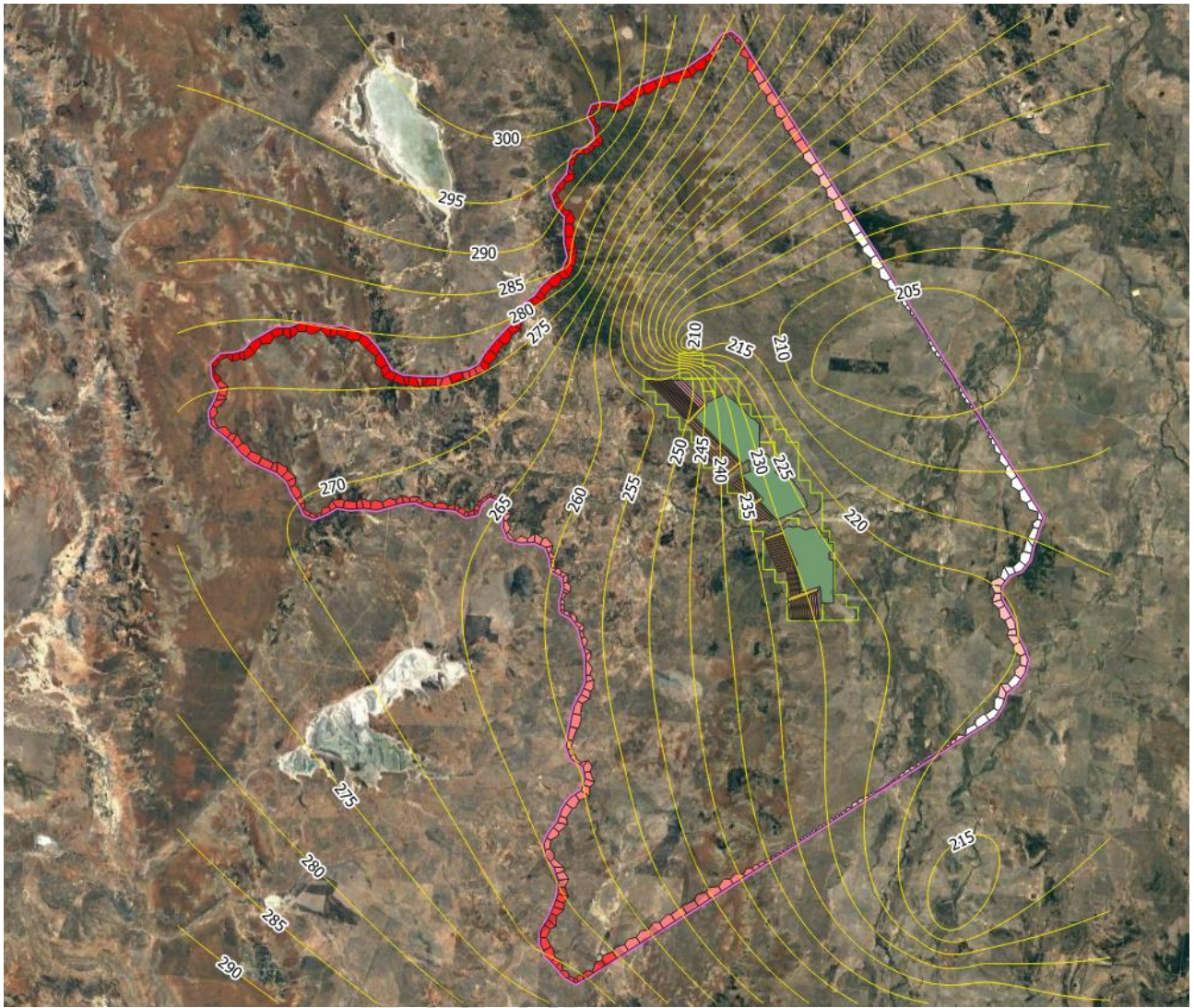


Figure 3.22 Modelled regional boundary conditions in Joe Joe Group

3.5.2 Watercourses

Major watercourses were simulated with river (RIV package) boundary conditions. The major systems identified in the model domain are as follows, and are presented in Figure 3.23:

- Belyando River (including a western breakout);
- Bimbah Creek;
- Carmichael River;
- Cattle Creek;
- Dunda Creek;
- Dyllingo Creek (including a northern breakout);
- North Creek; and
- Tomahawk Creek.

The watercourses were simulated with RIV package base set to topography, and time-varying stage above the river base. Wet season (December through March, simplified to Q1 for the history-matching period) stage elevation was set according to average measured river height, with the same values applied for each wet season (EMM 2022a). Dry season stage elevation was set to topography. The topography at each river boundary condition was extracted from the surface DEM, using zonal statistics to determine the lowest surface elevation in each river boundary condition model cell. River depths for the history-matching and prediction periods are presented in Table 3.3.

Conductance for the river boundary conditions was calculated with the following equation:

$$\text{Conductance} = \frac{\text{Hydraulic conductivity of river bed} \times \text{Cell area}}{\text{River bed thickness}}$$

Given an assumed riverbed thickness of 1 m and vertical hydraulic conductivity of 1 m/d, and a river area per cell of 1,500 m, starting riverbed conductance was applied as 1,500 m²/d. Given that the hydraulic properties of the riverbed sediments are not known, river boundary conductance was allowed to vary during the history-matching period (refer Section 4).

Setting river stage elevation equal to the river bottom during the dry season causes the boundary to behave in the same way as the drain (DRN) package; i.e. only allowing groundwater discharge at these cells. When the head in the aquifer is above the drain stage, water is removed from the boundary condition at a rate controlled by the conductance and hydraulic gradient. Conversely, discharge to the drain is zero when heads in the aquifer drop below the stage of the drain. During the wet season, water is allowed to enter and exit the model due to the river stage rising above topography, with groundwater inflow controlled by the conductance and driving head (i.e. saturated thickness of the river boundary condition).

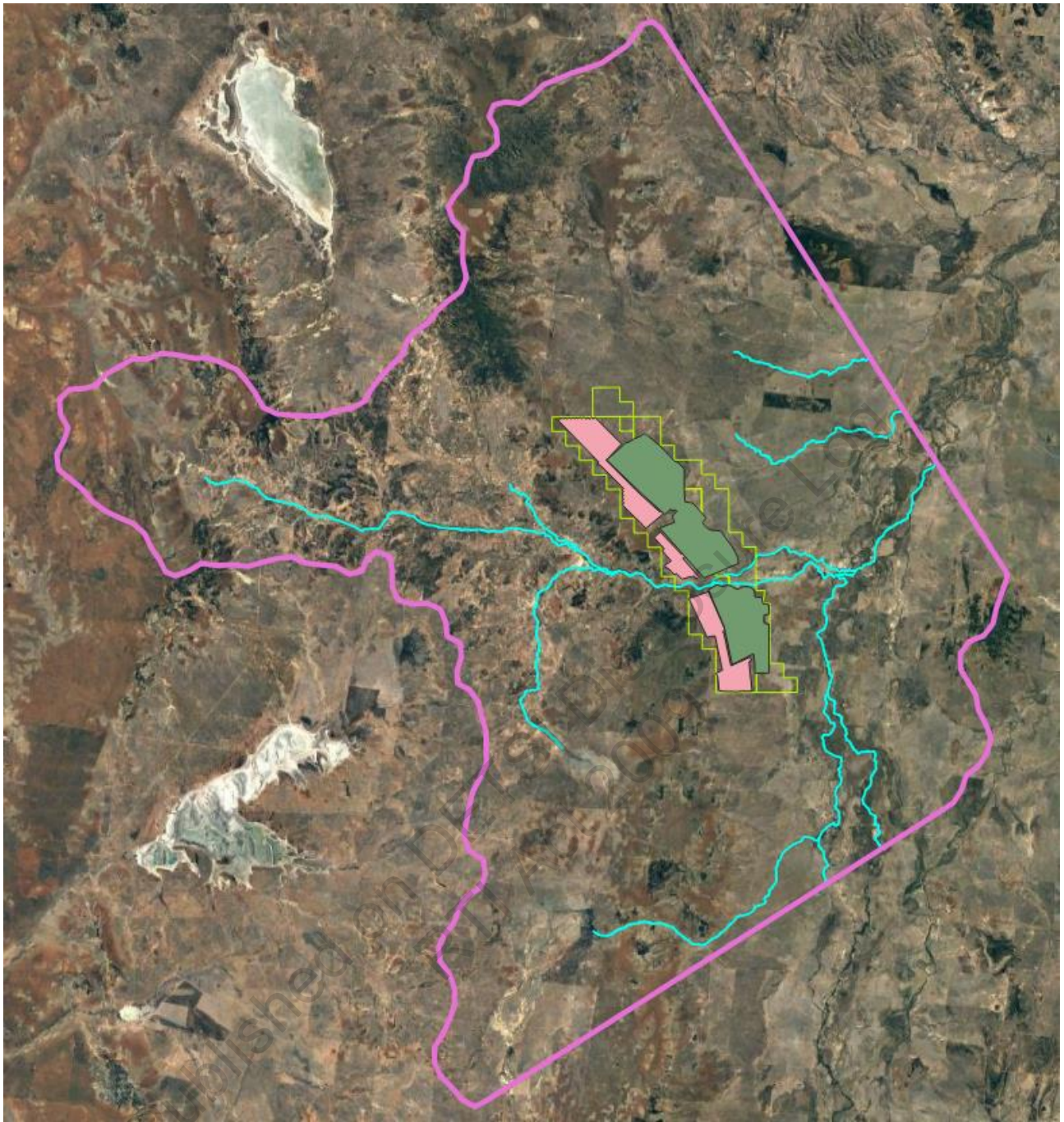


Figure 3.23 Modelled major watercourses

Table 3.3 **Modelled watercourse depths**

Watercourse ID	Depth in steady state stress period (m)	Wet season depth (m)	Dry season depth (m)
Belyando River	1.18	1.78	0
Belyando western breakout	0.59	0.89	0
Bimbah Creek	0	0	0
Carmichael River	0.30	0.70	0
Cattle Creek	0.15	0.35	0
Dunda Creek	0	0	0
Dyllingo Creek	0.15	0.35	0
Dyllingo northern breakout	0	0	0
North Creek	0	0	0
Tomahawk Creek	0	0	0

i **Doongmabulla Springs**

Springs comprising the Doongmabulla Spring Complex are simulated at mapped locations via drain (DRN) cells located within the Clematis Sandstone, consistent with the conceptualised source aquifer (EMM 2022a). The boundary stage elevations are set to the surveyed spring elevations. Boundary cell conductance was modified during the history-matching period to approximate the hydraulic separation between the Clematis Sandstone and ground surface. This in turn simplifies the model design for the spring features, removing the requirement to explicitly simulate and calibrate each spring conduit during the history-matching process.

The Doongmabulla Spring Complex is conceptualised to contain artesian springs with water sourced from the Clematis Sandstone, which discharges to surface and acts as a recharge mechanism for surficial sediments. To accommodate this, and consistent with the conceptualisation by EMM (2022a), selected drain cells were modified to drain return flow cells (DRT package), where modelled discharge via the drain cells was injected into model layer 1 at the same coordinates. Drain return flux was set equal to the drain outflow, with flux targets used to guide total drain flows.

ii **Other springs**

Other springs in the model domain include the following:

- Lignum;
- Mellaluka; and
- Storys.

Unlike the Doongmabulla Springs Complex, these springs are conceptualised as surface expression of watertable. These are simulated with the drain (DRN) package in model layer 15 (the highest active aquifer layer at these locations), with boundary stage elevations set to topography. Boundary cell conductance was modified during the history-matching process tied to springs in the DSC in lieu of flux estimates.

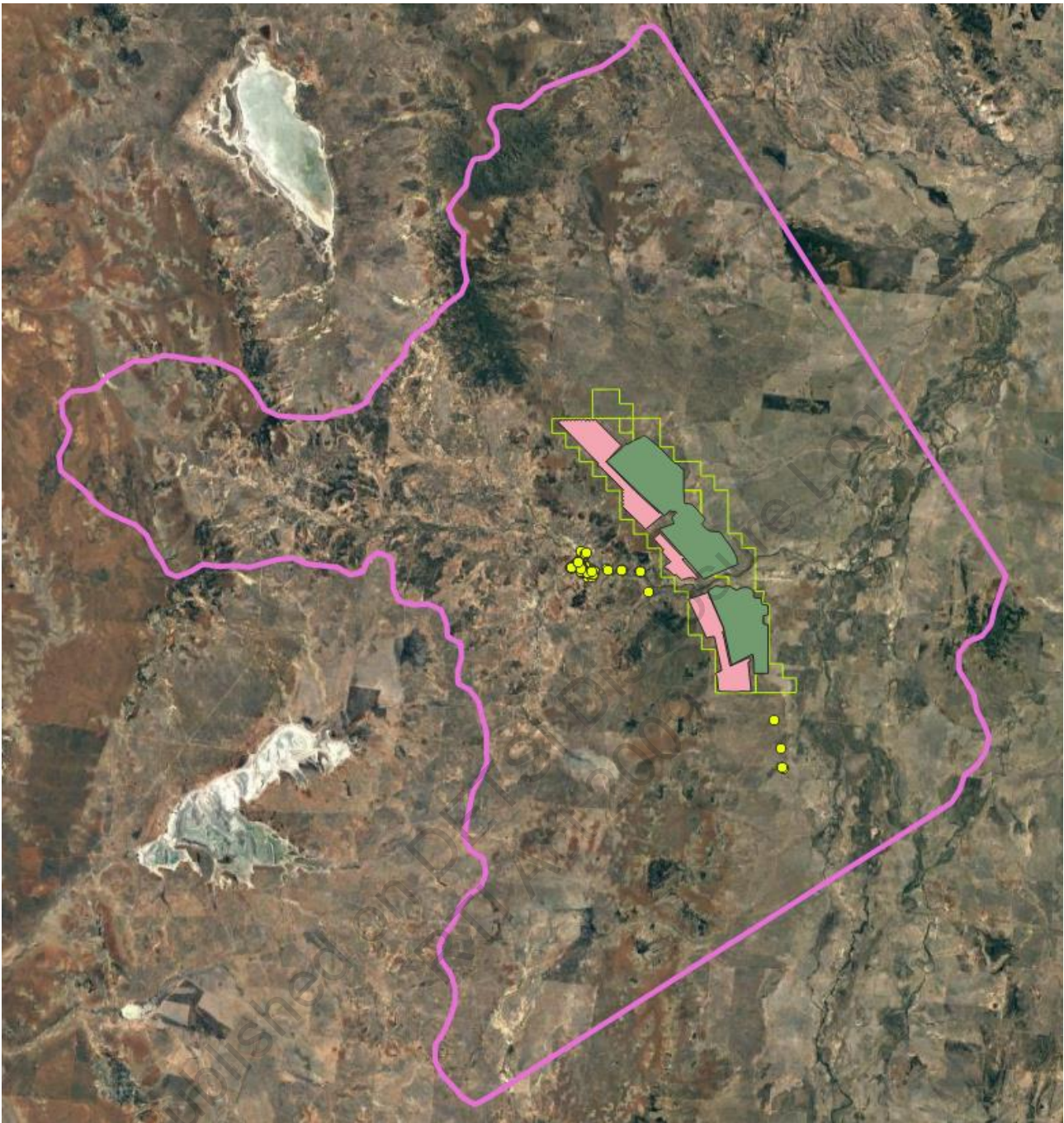


Figure 3.24 Modelled springs

3.5.3 Recharge

In accordance with the conceptual model, diffuse rainfall recharge to the watertable was modelled differently for each HSU based on its surface coverage, infiltration potential and seasonal influences. In addition, preferential recharge along flowing watercourses was also modelled implicitly for surficial alluvial deposits. The recharge package (RCH) was used to simulate these recharge processes, and the drain return flow (DRT) package was used to simulate alluvial recharge from artesian springs (discussed further in Section 3.5.2i).

Recharge was calculated per stress period based on measured data at Ulcanbah station (BoM station 036050), with a multiplier applied per outcropping HSU resulting in the following annual average rates:

- Quaternary alluvium: 0.009 mm/year;
- weathering zone: 0.002 mm/year;
- Tertiary and non-alluvial Quaternary deposits: 0.083 mm/year;
- Moolayember Formation: 0.003 mm/year;
- Clematis Sandstone / Warang Sandstone: 0.194 mm/year;
- Dunda Beds: 0.131 mm/year; and
- Rewan Formation: 0.098 mm/year.

Recharge was allowed to vary during the history-matching period, discussed further in Section 4. Modelled recharge zones are presented in Figure 3.25, aligned with outcropping HSUs.

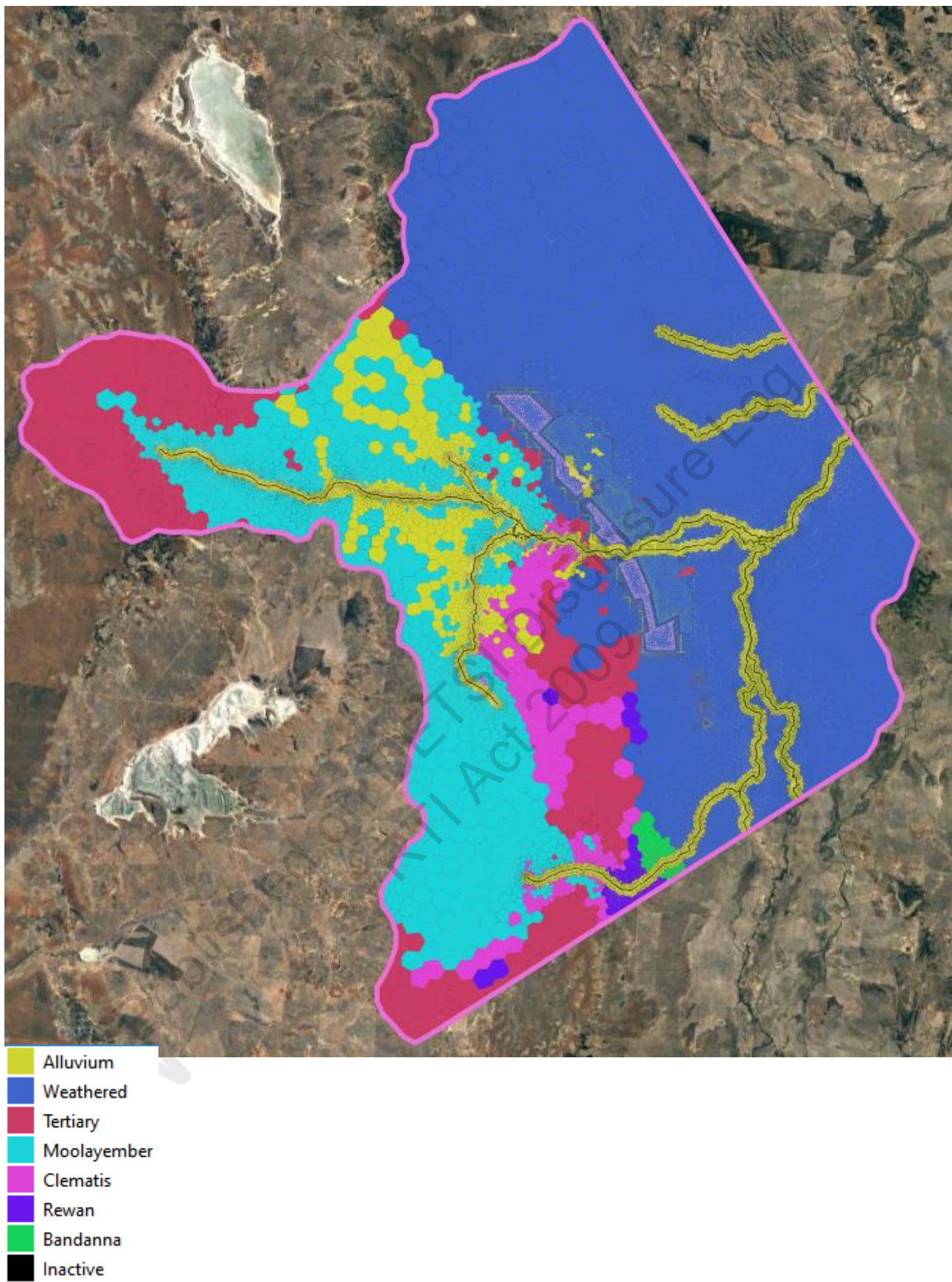


Figure 3.25 Modelled recharge zones based on outcropping HSU

History-matching stress periods incorporate actual measured rainfall. Predictive stress periods (refer Table 3.2) utilise average measured rainfall for wet/dry seasons, and the long-term stress periods utilise the average of all measured rainfall data. Rainfall data discretised by stress period duration are presented in Figure 3.26. The shorter duration of stress periods from August 2019 to April 2022 allows for more detail to be included, though the averaging over a month reduces the modelled influence of individual rainfall events.

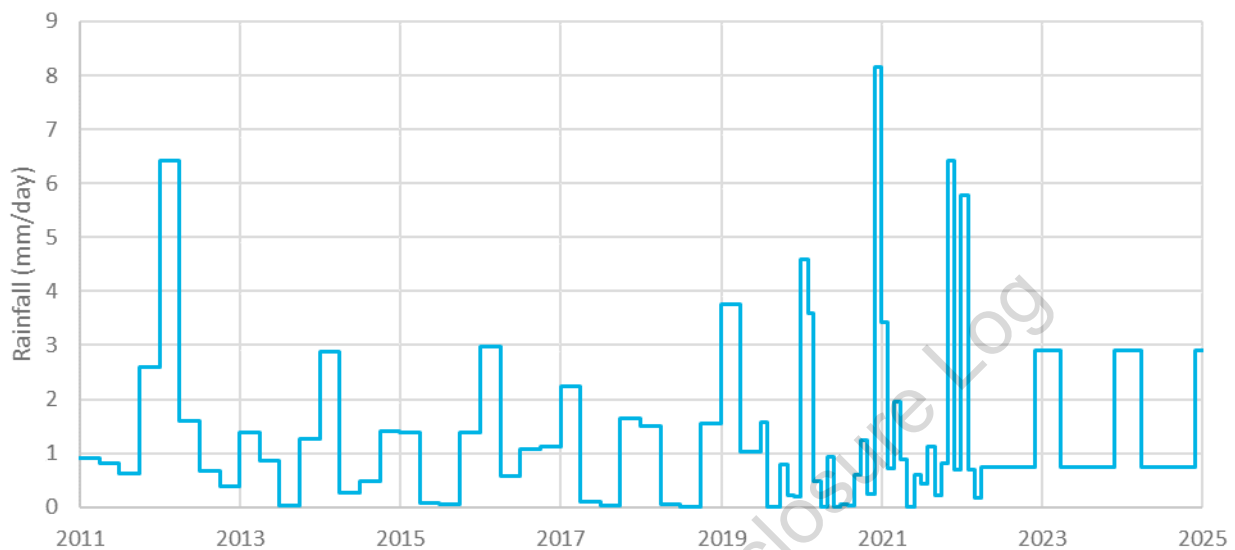


Figure 3.26 Time series of rainfall discretised by model stress periods

3.5.4 Evapotranspiration

The MODFLOW evapotranspiration (EVT) package is employed to represent evapotranspiration across the model domain. Maximum potential evapotranspiration is set per model stress period in accordance with BoM climate maps (BoM 2022), based on 30-year averaged data with equating to an average rate of 4.4 mm/day.

Based on the relatively sparse vegetation in the study area, review of aerial photography, and assessment of land use prepared by BRS (2010), an evapotranspiration extinction depth of 1.5 m has been applied for the model domain. This evapotranspiration extinction depth is consistent with Shah et al. (2007) for grass cover on sandy soil. A second evapotranspiration zone is active adjacent to surface water features to represent increased vegetation cover, with an extinction depth of 6 m. Evapotranspiration is not applied to surface water features.

3.5.5 Mining activities

One predictive scenario was developed based on planned mining developments to allow for assessment of absolute impacts. The mine plan was provided by Bravus, discretised into 13 stages and from 2020 to 2075. Detail of the mine plan is presented in Table 3.4 showing open cut pits (OC) B through F, and underground areas (UG) 1 through 5. The mine plan is similar to the plan presented in the SEIS (GHD 2013a) with some changes to staging, notably delaying commencement of the underground mine by 10 years.

Table 3.4 Summary of mine plan

Year	OC B	OC C	OC DE	OC G	OC F	UG 1	UG 2	UG 3	UG 4	UG 5
2020			Active							
2021			Active							
2022			Active							

Table 3.4 **Summary of mine plan**

Year	OC B	OC C	OC DE	OC G	OC F	UG 1	UG 2	UG 3	UG 4	UG 5
2023			Active							
2024			Active							
2029		Active	Active							
2034	Active	Active	Active			Active				
2039	Active	Active	Active	Active	Active	Active				
2044	Active	Active	Active	Active	Active	Active			Active	Active
2049	Active	Active	Active	Active	Active	Active			Active	Active
2055	Active	Active	Active	Active	Active	Active		Active	Active	Active
2065	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active
2075	Active	Active	Active	Active	Active	Active	Active	Active	Active	Active

i **Production bores**

The MODFLOW well (WEL) package is employed to simulate groundwater abstraction from mine dewatering bores. Measured groundwater abstraction for each bore is incorporated in the monthly stress periods in the history-matching period from August 2019 to March 2022 (Table 3.2). Predicted mine dewatering is simulated via drain boundary cells (refer Section ii), and as such no groundwater abstraction bores are active in the predictive period.

Modelled production bores are presented in Figure 3.28, and measured monthly abstraction rates are presented per bore and per screened HSU in Figure 3.29.

ii **Mine voids**

Groundwater removed from open cut and underground mine voids is simulated using the MODFLOW drain (DRN) package. This represents removal of any groundwater entrained in excavated material and groundwater inflows to the excavated voids. The mine progression is simulated in accordance with the provided staged mine plan (refer Appendix D) for the predictive period, with boundary cells activated at the first stress period corresponding to the numbered mine plan stage. Drain conductance is set at a suitably high value to ensure full dewatering of model cells to the assigned drain stage (1,000 m²/d). The modelled DRN cells at the end of mining are presented in Figure 3.30.

Modelled base elevations for open cut pits and underground mines are presented in Figure 3.31 and Figure 3.32 respectively.

Prediction stress periods (refer Table 3.2) present a higher temporal resolution than is available for the mine plan, to preserve the dynamic equilibrium of the groundwater system between the wet and dry seasons. Activation of mine dewatering DRN cells at the start of these seasonal stress periods results in rapid modelled dewatering and associated drawdown. This is accounted for in post-processing of the modelled water balance (Section 5.2) by averaging DRN flux across all stress periods corresponding to a single mine stage and is considered conservative in predicting drawdown impacts (Section 5.3).

iii Mining-induced property changes

Longwall panel mining of the coal seams is conceptualised to induce fracturing above mined panels and is expected to result in enhanced hydraulic conductivity. The time-varying materials (TVM) package is applied in model cells above underground mine cells, increasing hydraulic conductivity following mining. Two approaches were prepared, following GHD (2013b) and Merrick (2021), to allow for direct comparison against the existing groundwater model and updated for current estimates.

The fracturing property changes adopted by GHD (2013) include modification of hydraulic conductivity for cells within 160 m of the top of mined cells, with no fracturing above the top of the Rewan Formation. Hydraulic conductivity values are increased by a factor of 50 for cells within 75 m of the mined cells, and a factor of 10 for the remaining 75 m.

Merrick (2021) calculated fracturing heights above mine cells, with an average value of 230 m. Associated hydraulic conductivity increases are calculated using a ramp function, detailed in Merrick (2017) and presented in Figure 3.27.

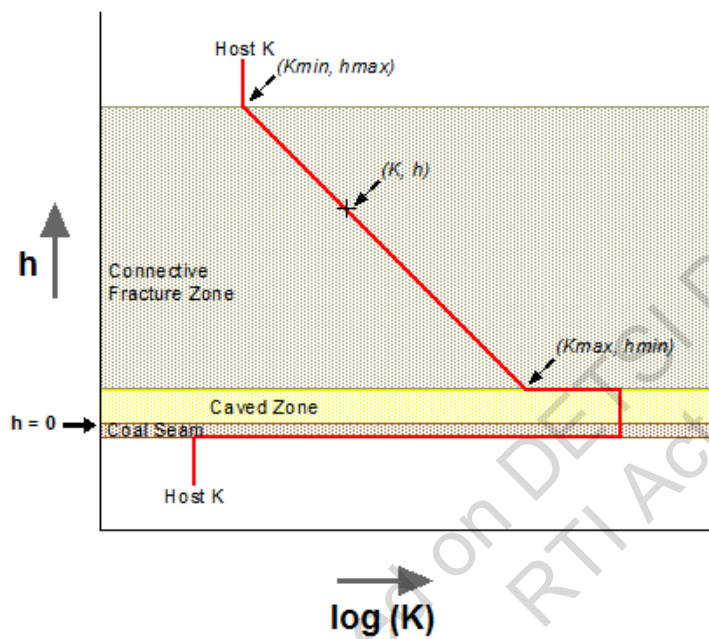


Figure 3.27 Ramp function parameters

Hydraulic conductivity in the connective fracture zone is calculated by:

$$K = 10^{\left(\log(K_{max}) - \frac{\log(K_{max}) - \log(K_{min})}{h_{max} - h_{min}}(h - h_{min})\right)}$$

Parameters for the updated model are as follows:

- $K_{max} = 5 \text{ m/d}$;
- K_{min} = background (calibrated) hydraulic conductivity;
- $h_{max} = 230 \text{ m}$; and
- $h_{min} = 0 \text{ m}$ (assuming caving to top of coal seam).

No fracturing was assigned to model layers 1 to 3 due to the assumption of self-sealing clays (alluvium, weathering, and Tertiary sediments).

At the end of mining, modelled drain cells corresponding to dewatering of mine voids are deactivated. At the cessation of mining, the open cut pit is planned to be backfilled as follows:

- Pits C, E, and F are located closer to the Carmichael River and thus are required to be backfilled to the top of the AB Coal seam
- All other pits are located further away from Carmichael River and thus are only required to be backfilled to the top of the D Coal seam.

The post-mining open cut pit depth is presented in Figure 3.33 and rehabilitation and backfill is simulated to commence at the end of mining. These pit depths and the pre-mining watertable elevation in the vicinity of the mine indicate potential for a pit lake to form. The open cut pit and associated stresses are simulated following mining using three packages:

- the time-varying materials (TVM) package is applied at model nodes within the residual open cut pit void, converting the material properties to that of a 'void' at the cessation of mining. This package assigns multiplier values to horizontal and vertical hydraulic conductivities, specific yield, and specific storage. The final values are 1,000 m/d for hydraulic conductivity, 100% for specific yield, and specific storage 1.3×10^{-5} m/d;
- the connected linear node (CLN) package is applied across the footprint of the open cut pit void, with a setup designed to mimic surface water evaporation but with greater numerical stability than the ETS package. One CLN 'well' was assigned per node, with top elevation set at pre-mining topography and bottom elevation set at the base of the backfilled pit. Abstraction was activated at each of these wells, with rate scaled by cell area such that the maximum rate of water removal is 3.1 mm/day (a 30% reduction from the pan evaporation rate of 4.4 mm/day, consistent with Fandrich (2016)). If the water level drops below the bottom of a well, no water is abstracted, mimicking evaporation; and
- recharge from rainfall (RCH) is increased over the pit footprint to 100% of rainfall (1.5 mm/d) for the post-mining period, where rainfall can directly recharge the potential pit lake surface.

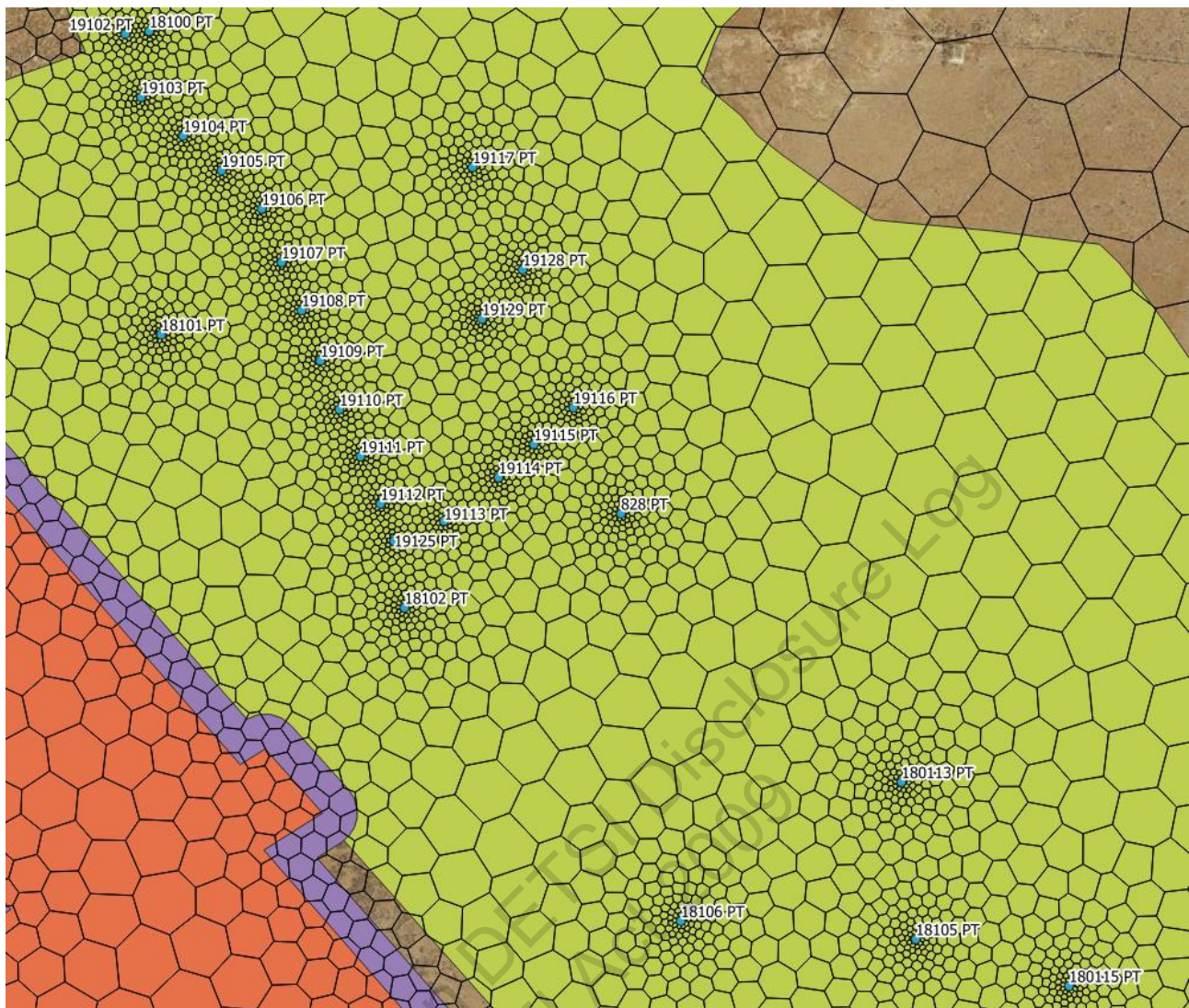


Figure 3.28 **Modelled production bores**

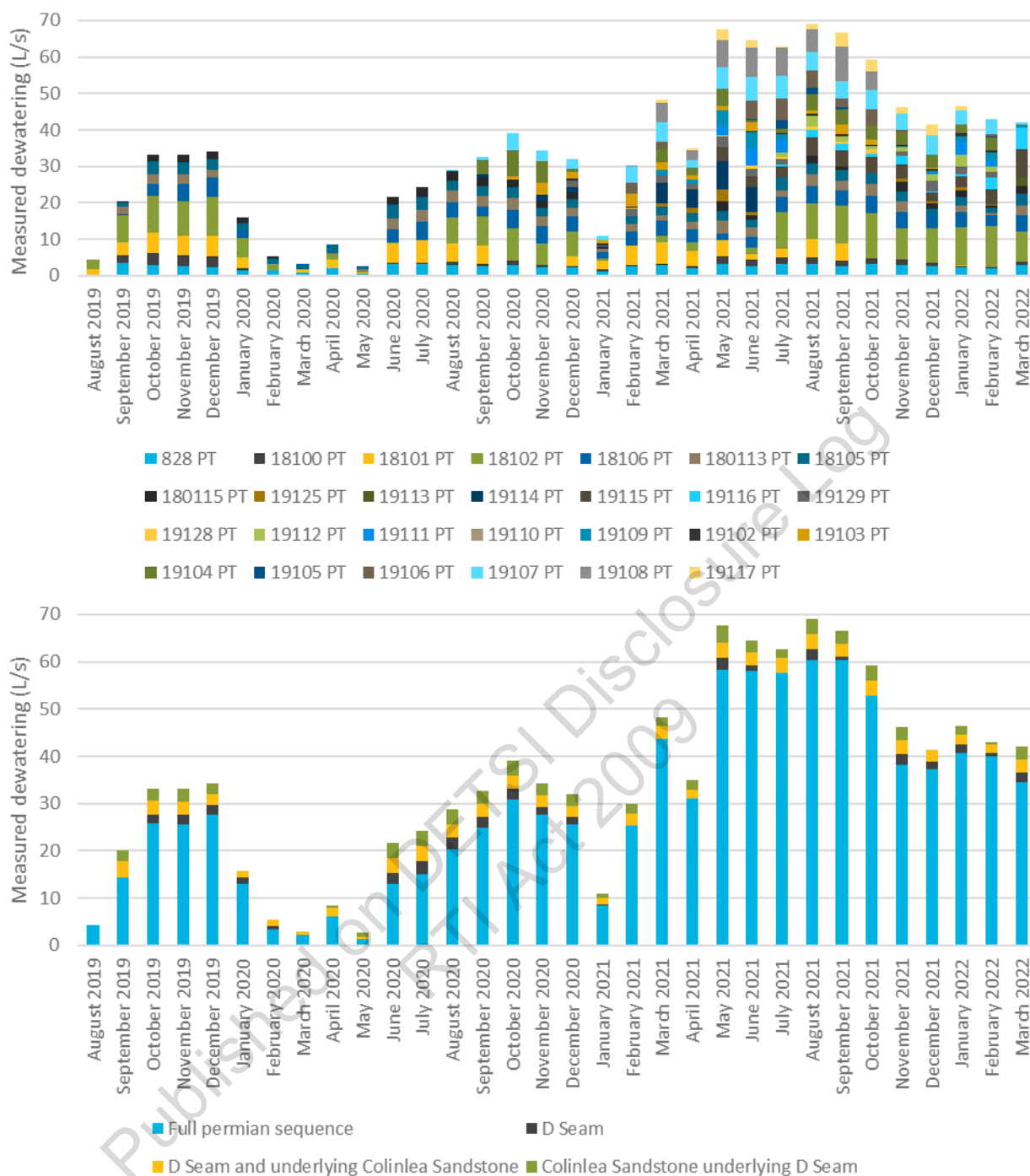


Figure 3.29 Measured production bore dewatering rates

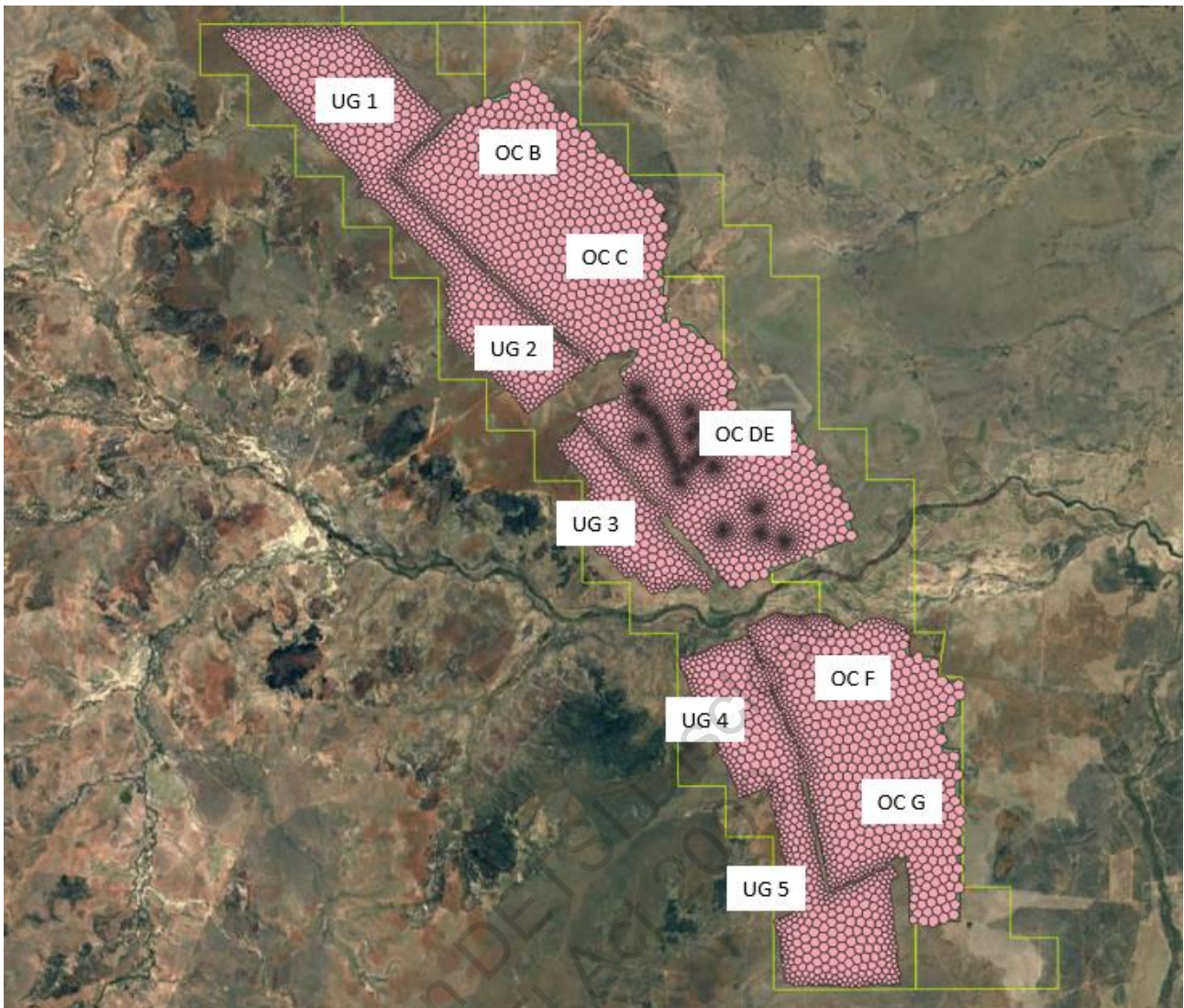


Figure 3.30 Modelled drain boundary conditions at the end of mining

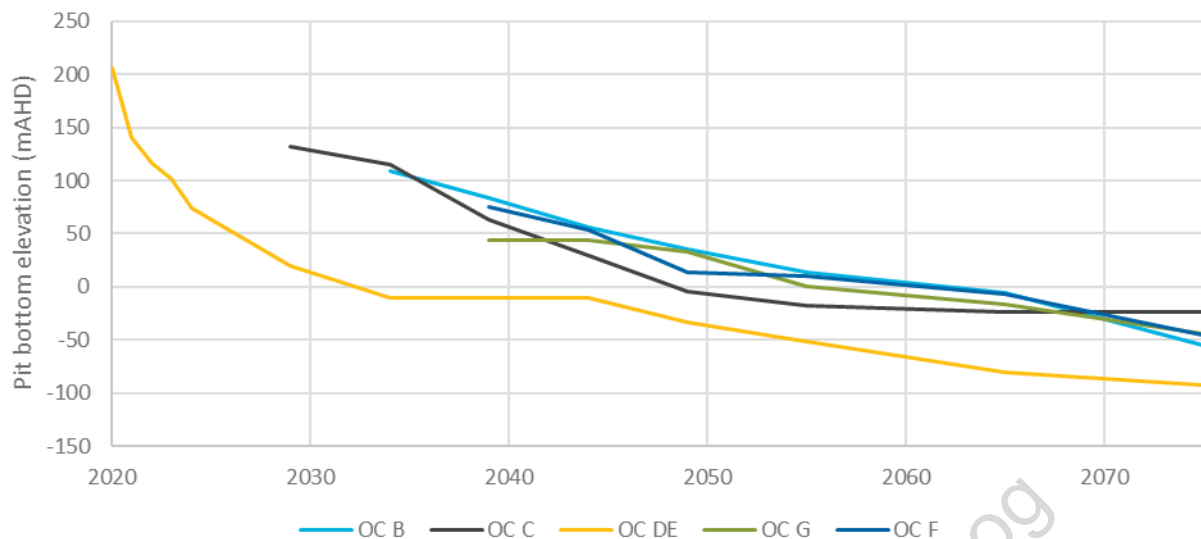


Figure 3.31 Open cut pit bottom elevations

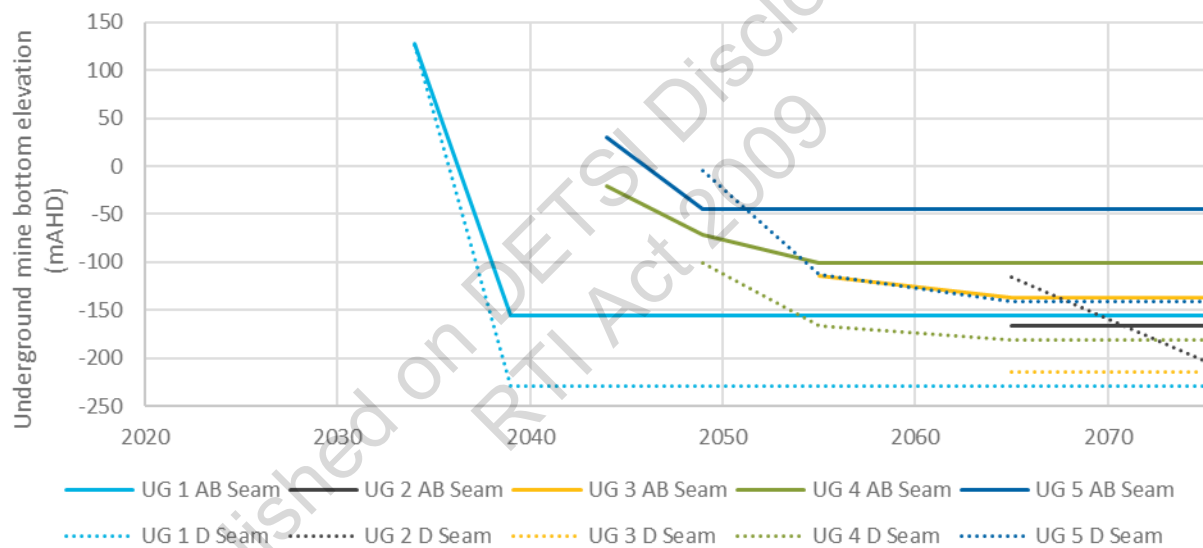


Figure 3.32 Underground mine bottom elevations

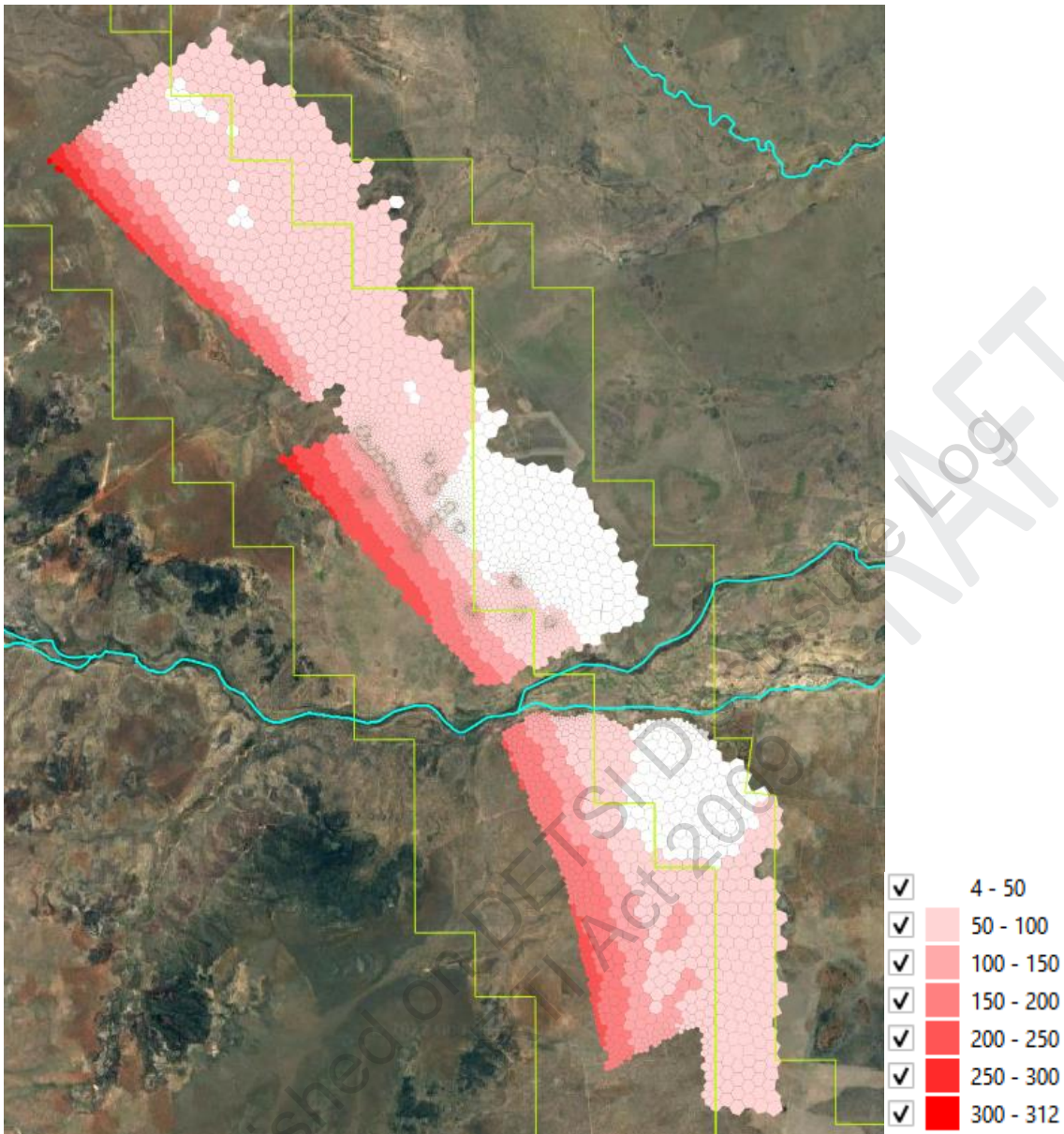


Figure 3.33 Modelled post-mining pit void depth

4 History-matching

4.1 Approach

A combination of manual and automated approaches were employed during the history-matching process using PESTPP-IES (White., 2018, White et al., 2019) This code optimises an ensemble of random model parameter realisations on an iterative basis, making an estimate of the Jacobian matrix (which is used by the traditional PEST code) using the ensemble of parameters and observations for each parameter upgrade iteration.

History-matching was undertaken using hydraulic head data from pre-mining conditions and during mining, employing bores impacted by mine dewatering. Spring flux targets were included to ensure consistency between water balance modelling and the numerical groundwater flow model.

Initially, the model was calibrated with homogeneous parameters, using a single value for each hydraulic property per HSU. This approach was aimed at providing a computationally efficient means to arrive at starting parameters that provided a model-wide fit to hydraulic head and flux data, to use as initial parameter value estimates for subsequent highly parameterised history-matching.

4.1.1 Targets

The model was history-matched using both hydraulic head and head-change targets, to obtain model parameterisation consistent with both pre-development and impacted conditions. Hydraulic head targets were used at the time of measurement, rather than steady state, as the unimpacted system is conceptualised to exist in a dynamic equilibrium associated with seasonal and climatic patterns. Automated history-matching software then attempts to match both absolute groundwater level and dynamics, both from climatic stresses and mine dewatering. Groundwater measurements were taken from manual readings and loggers; these have been separated into separate target groups. Logger data were resampled to monthly measurements to reduce the volume of target data.

Flux targets at Doongmabulla springs were defined for the steady-state stress period, as discharge estimates from water balance modelling (EMM, 2022b) do not incorporate seasonality or longer-term climatic influences. This is consistent with the conceptualisation that the Doongmabulla springs are sourced from the deeper Clematis Sandstone, and therefore exhibit less influence from climate.

A total of 11,443 history-matching targets were employed. These were subdivided into the following groups:

- 239 hydraulic head targets, grouped by HSU;
- 11,202 head-change targets, grouped by HSU; and
- 2 flux targets.

PEST operates with the goal of minimising a least-squares objective function, defined as the sum of squared weighted differences between measurements and corresponding model outputs (known as residuals). Doherty (2016) defines the objective function as:

$$\varphi = \sum (w_i r_i)^2$$

where r is the calculated residual, and w is a unitless statistical weighting.

A weighting scheme was adopted to ensure that each measurement group effectively contributed to the objective function, and likewise that monitoring locations with high volumes of data did not overly control the history-matching process. Statistical contributions to the objective function of the uncalibrated model were calculated, and weights modified such that each target group contributed the same value to the starting objective function. Each measurement within a target group therefore had the same weight applied. Weights of hydraulic head

targets were increased by a factor of $\sqrt{2}$ to double the relative computational effort towards matching absolute groundwater levels.

Measurement noise was not included in the PESTPP-IES control file.

The locations of monitoring bores used for history-matching targets are presented in Figure 4.1, categorised by HSU.

Figure 4.1 History-matching target bores and springs

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4.1.2 Stresses

Hydrogeological stresses applied during the history-matching period are detailed in Section 3.5. These are:

- seasonal rainfall-derived recharge;
- seasonal leakage from surface water features; and
- pumping via bores for mine dewatering.

As described in EMM (2022a), the groundwater monitoring dataset exhibits responses to both climatic and mining stresses, with variable magnitude of impact depending on location.

4.1.3 Parameterisation

i Pilot points

The algorithm for calculation of the Jacobian matrix via PESTPP-IES is extremely efficient when compared to other versions of PEST, and as such there is no effective limit on the number of pilot points that can be incorporated in the history-matching assessment. A triangulation algorithm was employed to place pilot points between targets (including pumping bores), and additional pilot points were placed at regular 5 km spacing. A total of 7,740 pilot points were used per hydraulic parameter (horizontal and vertical hydraulic conductivity, specific storage, specific yield), resulting in 30,960 pilot point parameters. Additional parameters for spring (Drain) conductance (Section 3.5.2i) and recharge zones (Section 3.5.3) were included, resulting in a total of 30,976 parameters.

ii Initial (prior) parameter values

PESTPP-IES requires the user to supply statistical characteristics of the prior parameter values and allowable ranges; this takes the form of either independent standard deviations around the expected (initial / mean) value per parameter, or parameter covariances where for example there may be spatial correlation between parameters (e.g. between pilot points used to interpolate parameters to the model mesh for a given layer). These characteristics are used by PESTPP-IES when drawing stochastic parameter realisations at the start of each iteration.

Parameters were not assumed to be spatially dependent (correlated), and parameter standard deviations were calculated from the log-transformed range defined in the PESTPP-IES control file, where the upper and lower bounds (as per EMM (2022a)) are taken to represent the 95% confidence interval. As mentioned above, parameters varied as part of the history-matching process include:

- all HSU hydraulic parameters (horizontal and vertical hydraulic conductivity, specific storage, specific yield);
- all spring (Drain) conductance parameters; and
- all groundwater recharge rate zone parameters.

A 500-realisation ensemble of parameter values was developed as the 'prior' parameter ensemble, and several iterations were employed using PESTPP-IES to develop a parameter field minimising the error to measurements. Following model review, a final 'posterior' ensemble of parameter realisations was developed, with a Gaussian distribution centred on base realisation pilot point values where one standard deviation is equal to one order of magnitude. This ensemble was used towards predictive uncertainty analysis (Section 5.3).

iii History-matched (posterior) parameter values

This section describes the ‘base case’ or best estimate achieved by PESTPP-IES from all 500 history-matched model realisations, along with accepted uncertainty parameter field realisations (discussed further in Section 4.2.1). These parameters include hydraulic conductivity (Kh and Kv) distributions, storage properties, as well as parameters applied to modelled boundary conditions (i.e. recharge and drain (spring) conductance). The focus here is on discussion of the key aquifer and aquitard units (Clematis, Rewan, and coal seams), with minimal reference to the properties of the other HSUs including shallower sediments and deeper Permian units.

a Layer 5: Clematis Sandstone aquifer

The Clematis Sandstone is conceptualised as the source aquifer of the Doongmabulla springs, and is a key unit for estimating spring impacts. The pilot point parameter frequency distribution for the Clematis Sandstone is presented in Figure 4.2, with frequency for the base realisation on the secondary vertical axis. This shows the variation within the unit for the base realisation, and the combined Gaussian distributions of uncertainty realisations centred on each of the base pilot point values. The majority of values lie between 0.1 and 1 m/day, which is consistent with the hydrogeological conceptual model (EMM 2022a).

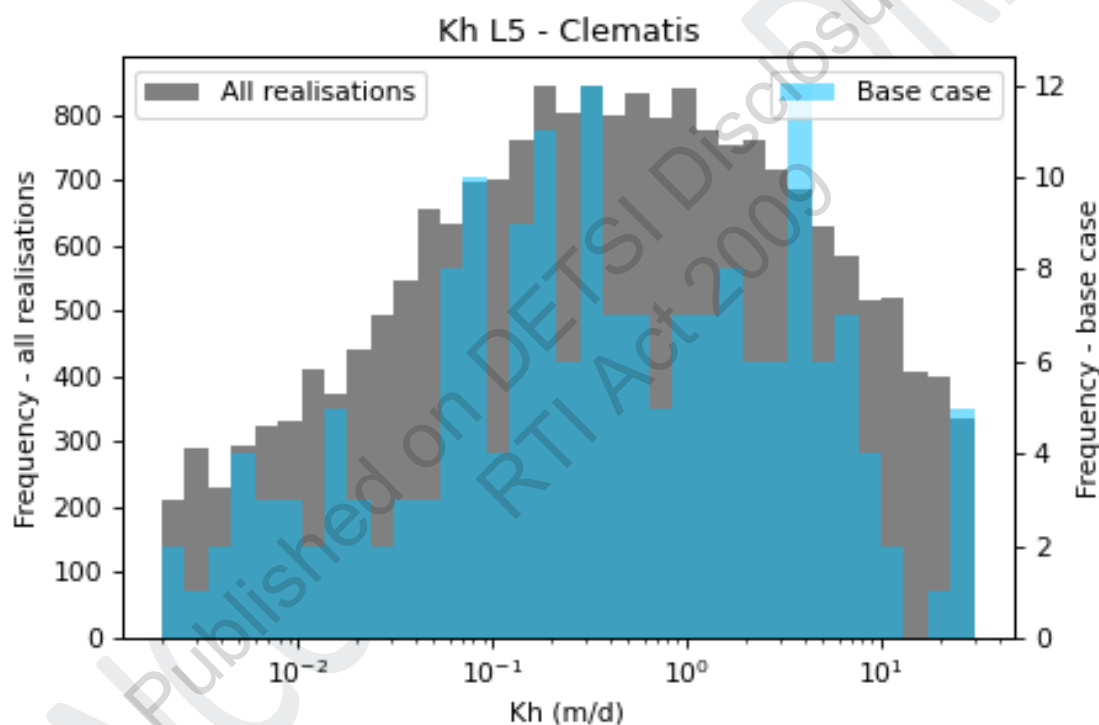


Figure 4.2 Horizontal hydraulic conductivity pilot point parameter frequency distribution for Clematis Sandstone across base realisation and uncertainty ensemble

The spatial distribution of modelled horizontal hydraulic conductivity in the Clematis Sandstone for the base realisation is presented in Figure 4.3. Hydraulic conductivity is generally higher north of the Carmichael River, with values typically higher than 0.1 m/day. The Clematis Sandstone south of the Carmichael River is simulated with lower hydraulic conductivities, below 0.1 m/day.

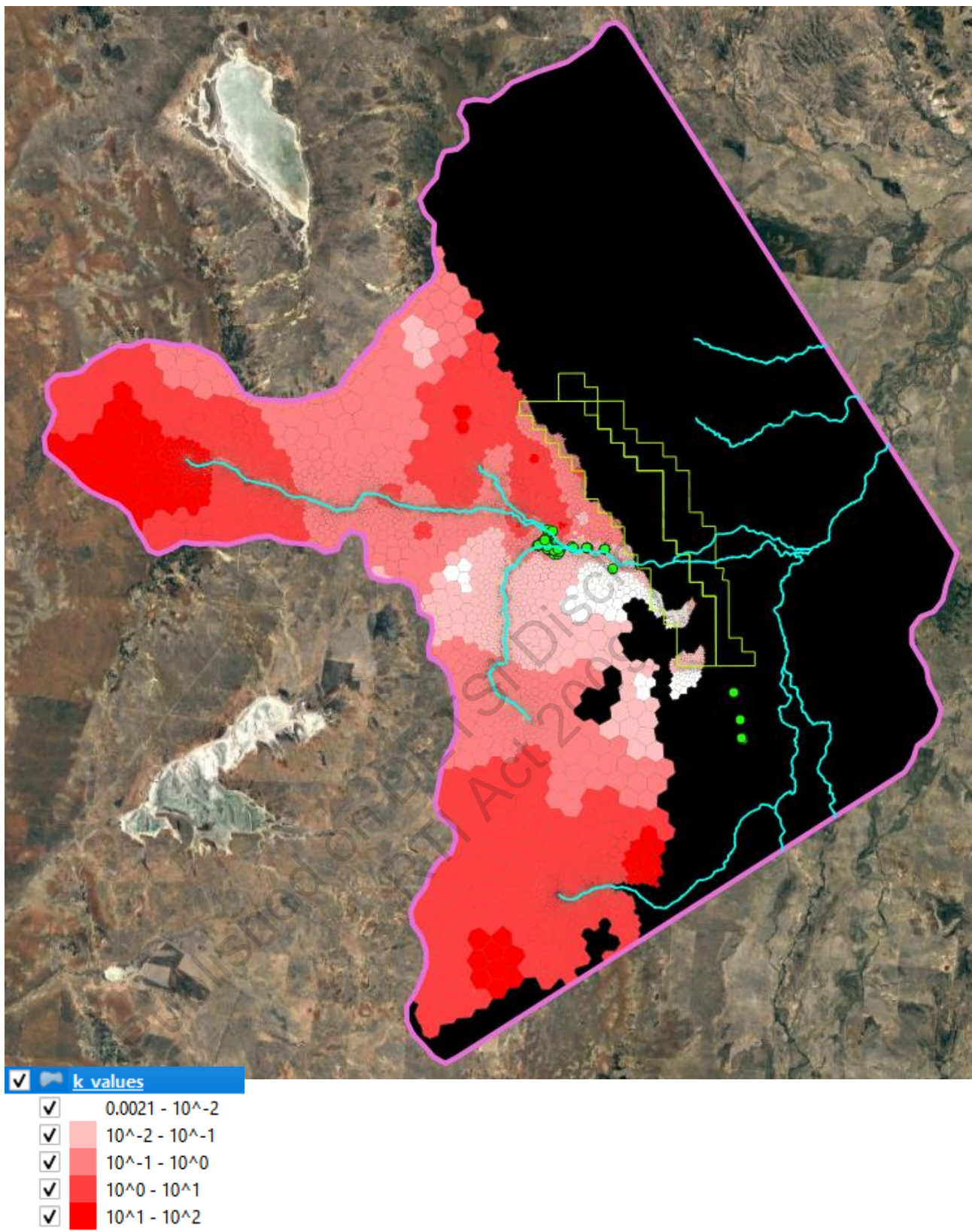


Figure 4.3 Base realisation modelled horizontal hydraulic conductivity in Clematis Sandstone

The Rewan Formation is the primary aquitard separating the Doongmabulla springs and the mined coal seams. This unit is subdivided into two model layers of equal thickness, to allow for additional discretisation of hydraulic conductivity with depth. Vertical hydraulic conductivity pilot point parameter frequency distributions for the upper and lower Rewan Formation are presented in Figure 4.4 and Figure 4.5 respectively. Typical modelled vertical hydraulic conductivity values for the Rewan Formation are between 1×10^{-6} and 1×10^{-5} m/day for the upper profile and around 1×10^{-7} m/day for the lower profile. In addition to this, a number of pilot points are at the lower bound assigned to the lower Rewan Formation; 2×10^{-9} m/day.

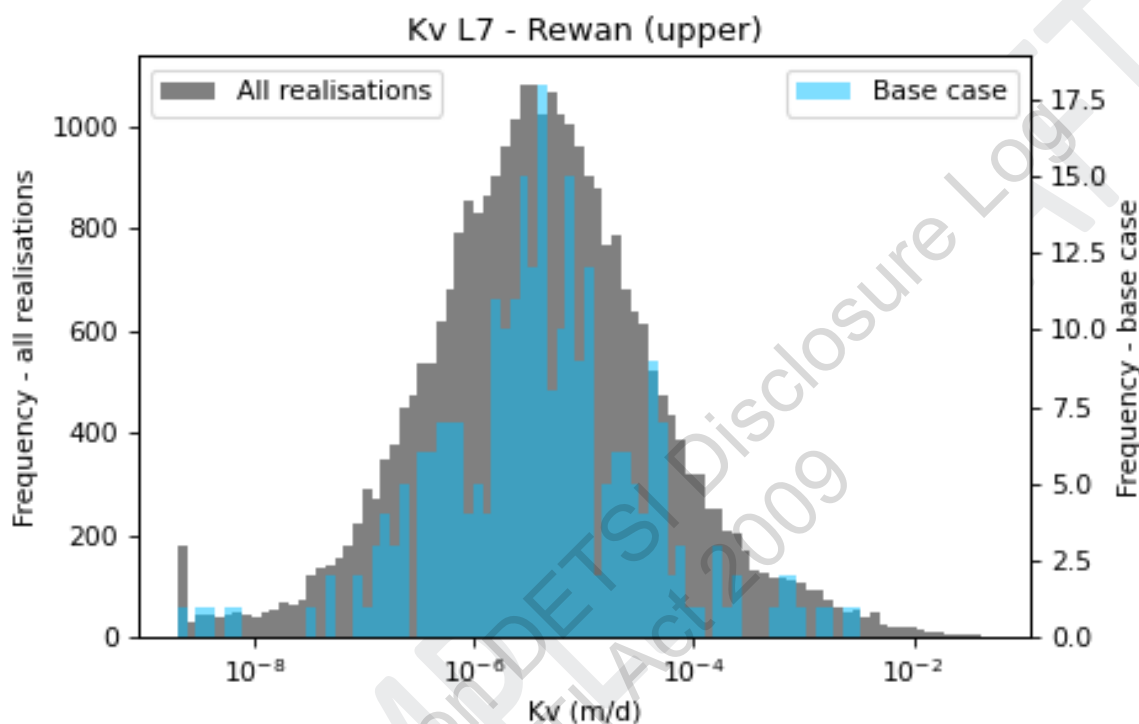


Figure 4.4 Vertical hydraulic conductivity pilot point parameter frequency distribution for upper Rewan Formation across base realisation and uncertainty ensemble

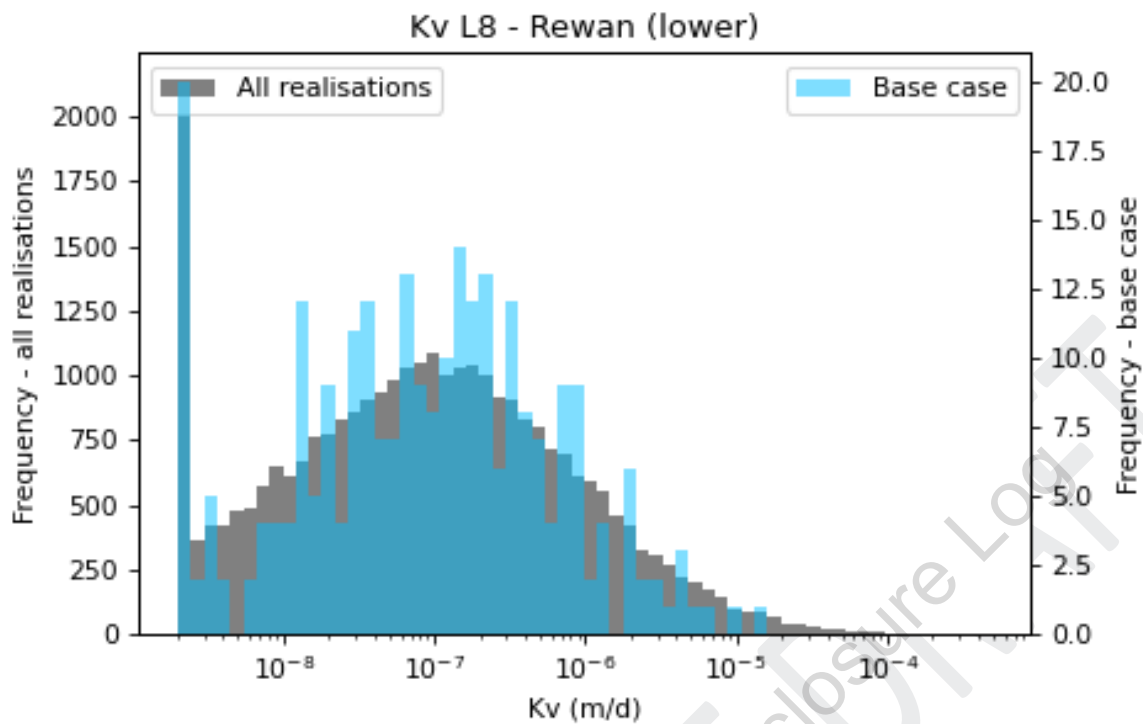


Figure 4.5 Vertical hydraulic conductivity pilot point parameter frequency distribution for lower Rewan Formation across base realisation and uncertainty ensemble

The spatial distribution of modelled vertical hydraulic conductivity in the upper and lower Rewan Formation is presented in Figure 4.6 and Figure 4.7 respectively. Similar to the Clematis Sandstone, an area of lower hydraulic conductivity is simulated south of the Carmichael River, towards the southern end of the ML, with areas of higher conductivity north of the Carmichael River.

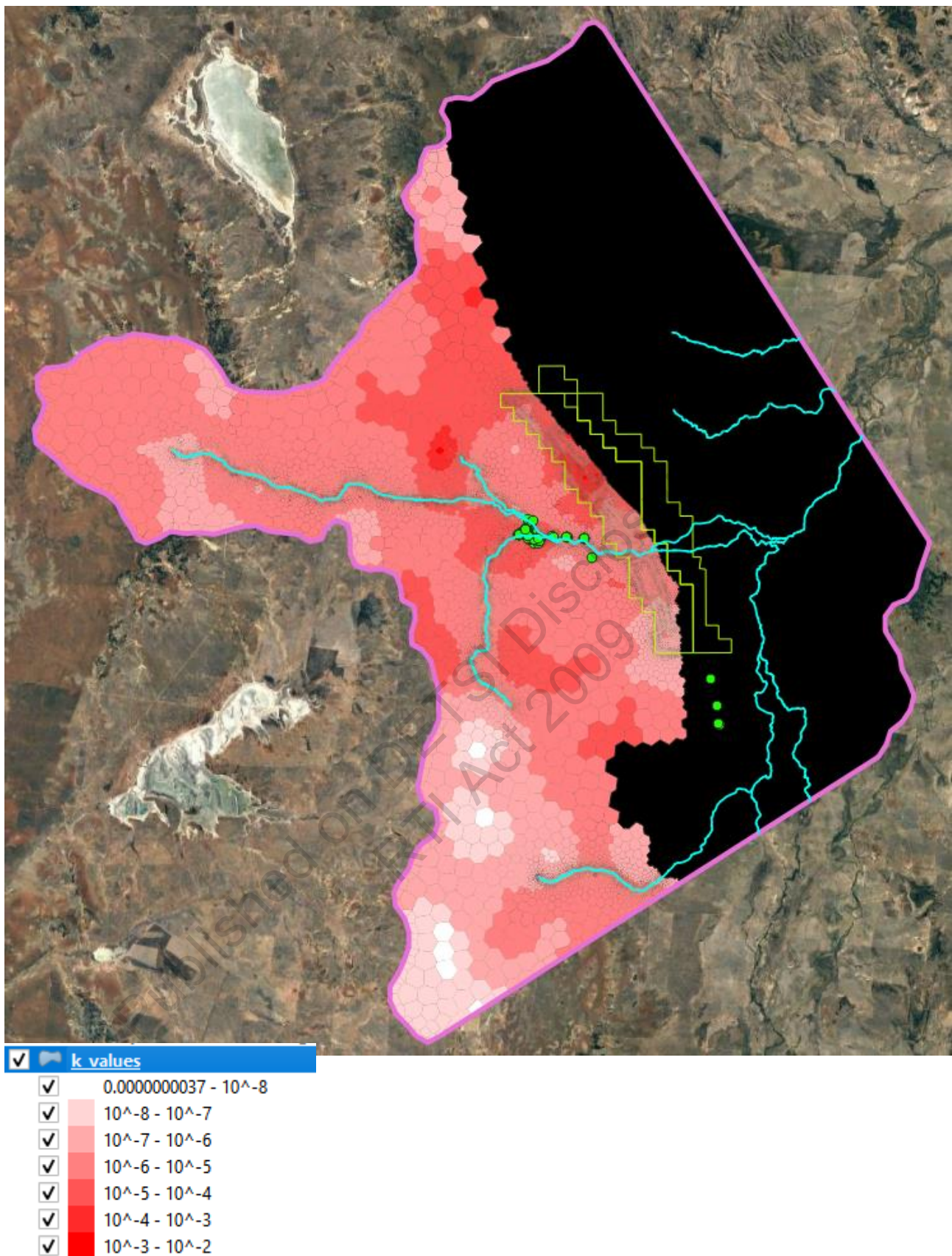


Figure 4.6 Base realisation modelled vertical hydraulic conductivity in upper Rewan Formation

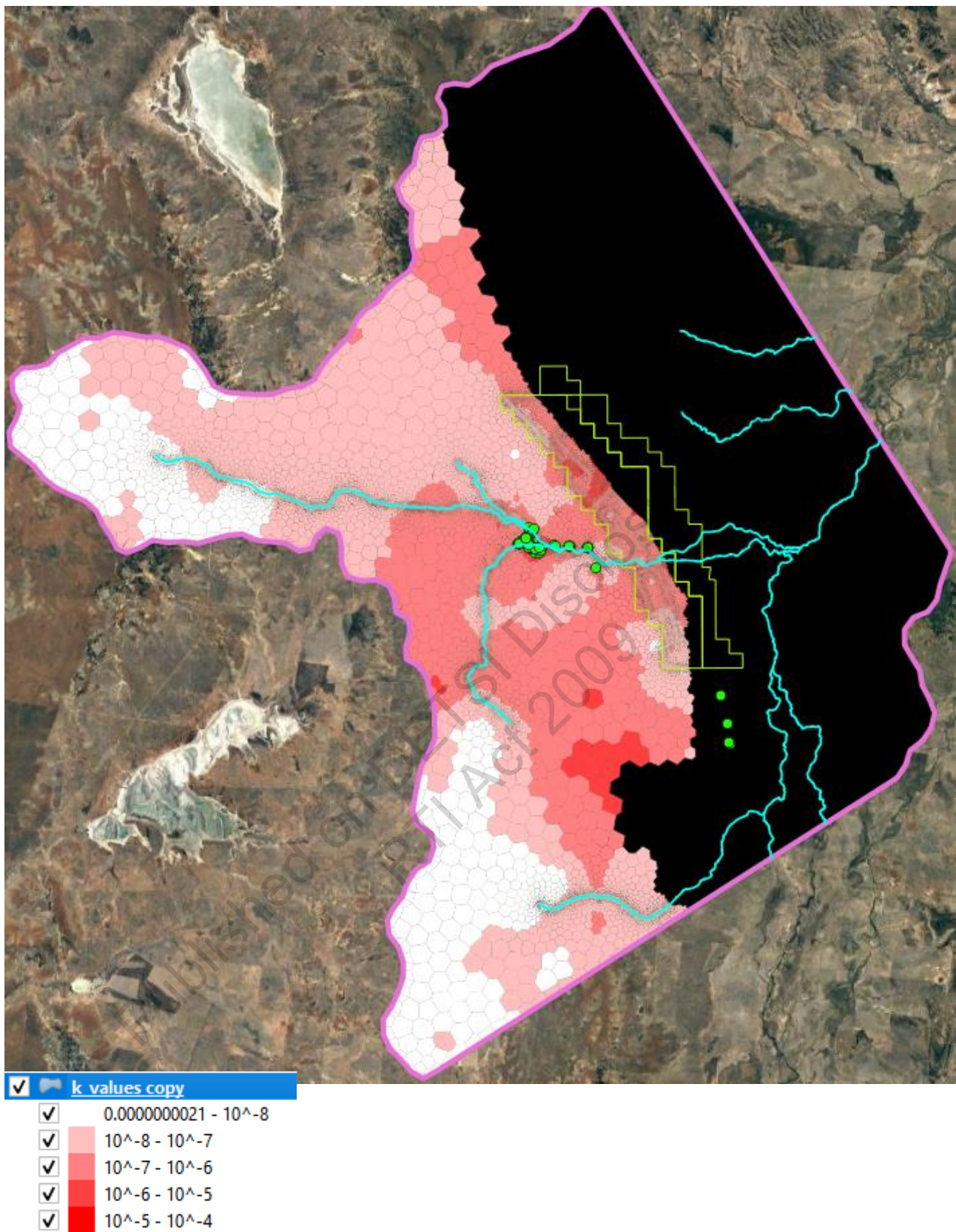


Figure 4.7 Base realisation modelled vertical hydraulic conductivity in lower Rewan Formation

Modelled horizontal hydraulic conductivity pilot point parameter frequency distributions for the AB and D coal seams are presented in Figure 4.8 and Figure 4.9 respectively. The AB seam is simulated with a relatively even distribution, with peak around 1-2 m/day. The D seam is simulated with a much lower hydraulic conductivity, with PEST tending to the lower end of conceptual bounds, 1×10^{-2} m/day.

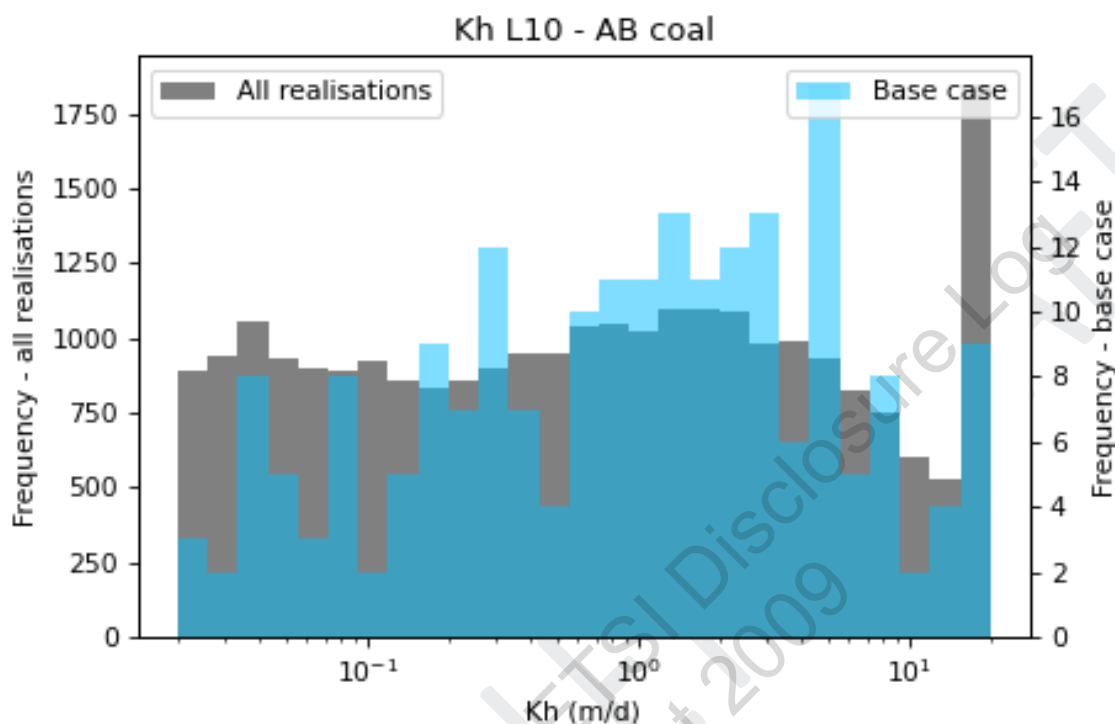


Figure 4.8 Horizontal hydraulic conductivity pilot point parameter frequency distribution for AB Coal across base realisation and uncertainty ensemble

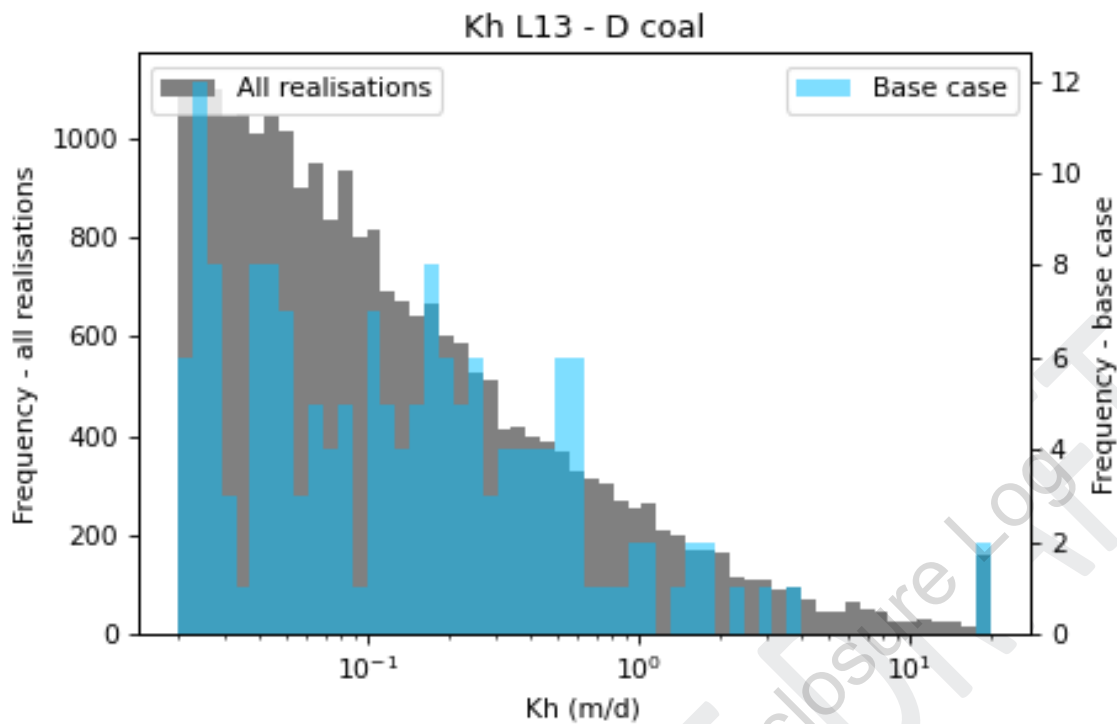


Figure 4.9 Horizontal hydraulic conductivity pilot point parameter frequency distribution for D Coal across base realisation and uncertainty ensemble

The spatial distribution of modelled horizontal hydraulic conductivity in the AB and D coal seams is presented in Figure 4.10 and Figure 4.11 respectively. Unlike shallower layers, lower hydraulic conductivity is simulated north of the Carmichael River for both layers.

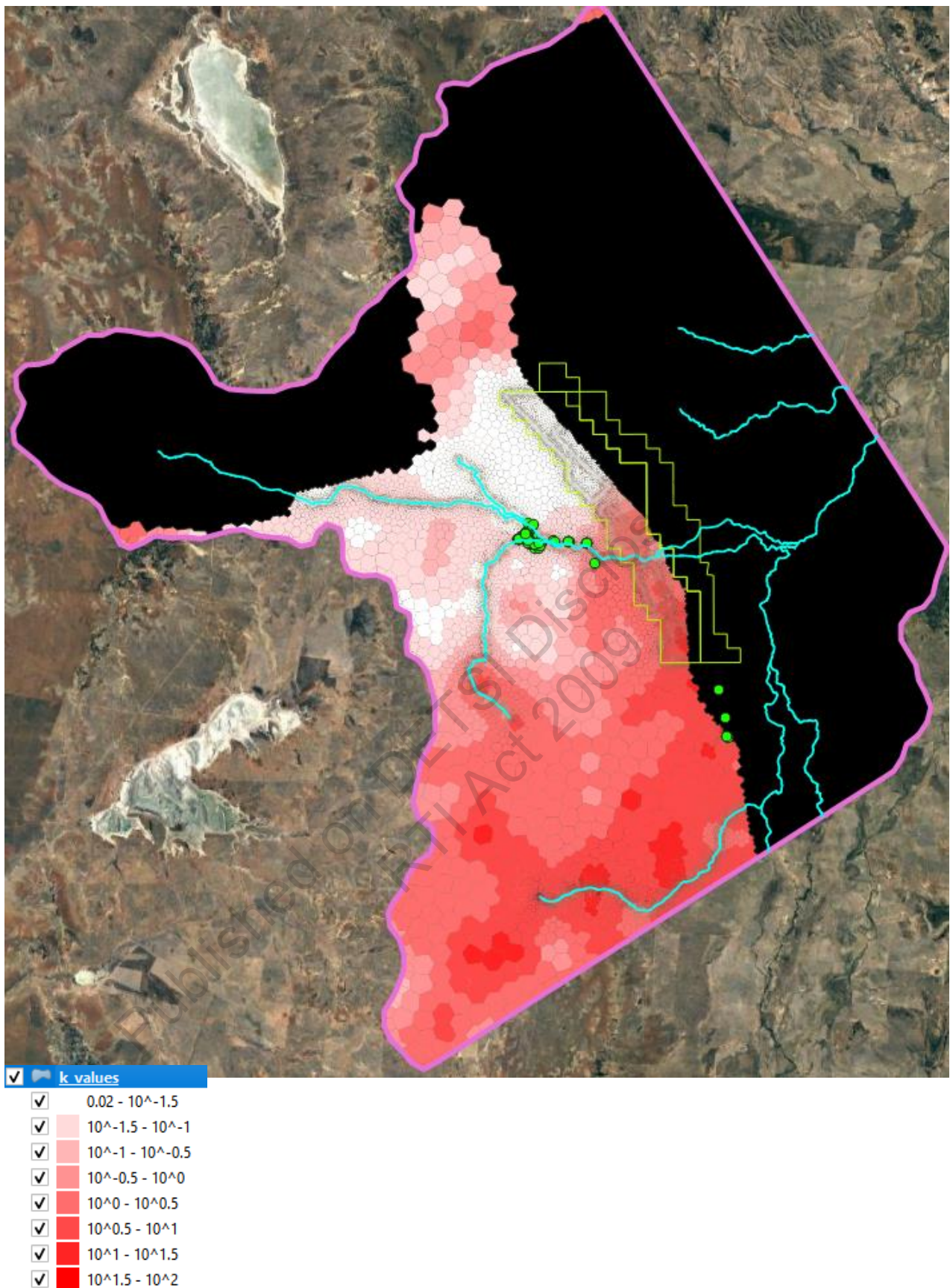


Figure 4.10 Base realisation modelled horizontal hydraulic conductivity in AB Coal seam

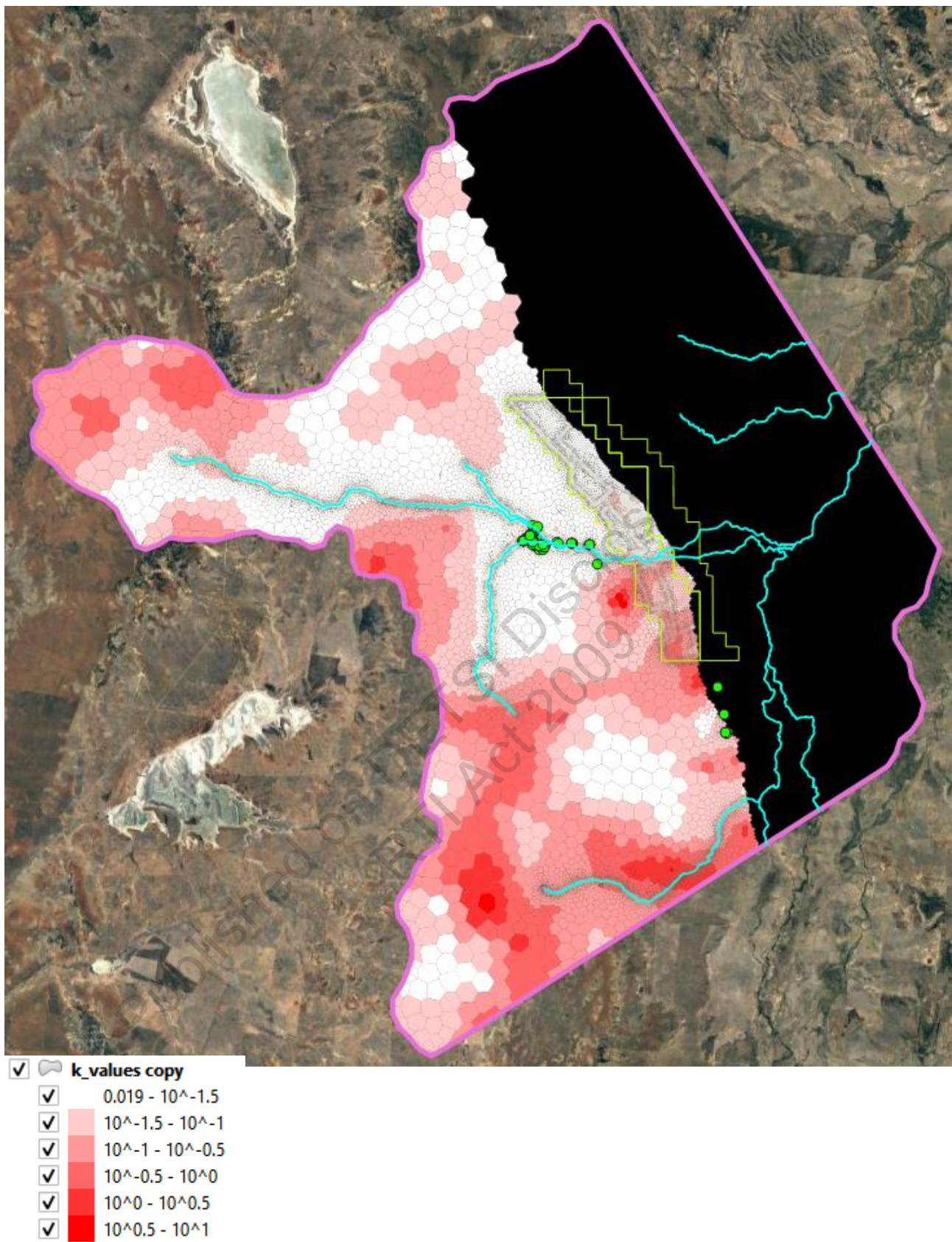


Figure 4.11 Base realisation modelled horizontal hydraulic conductivity in D Coal seam

Frequency distributions for the full suite of modifiable parameters are presented in Appendix B.

4.2 Performance

4.2.1 Statistical performance

History-match performance was statistically quantified using SRMS error for hydraulic head and drawdown, given as a percentage:

$$SRMS = \frac{100}{\Delta H} \sqrt{\frac{1}{n} \sum_{i=1}^n [W_i(z_{hi} - h_i)]^2}$$

where:

- ΔH is the range of measured hydraulic heads across the model domain;
- n is the number of measurements used in the history-match dataset;
- W_i is the statistical weighting (unitless) applied to measurement i ;
- z_{hi} is the modelled hydraulic head/drawdown at location/time i ; and
- h_i is the measured hydraulic head/drawdown at location/time i .

The SRMS error was calculated for initial head measurements, temporal head-change (drawdown), and transient head. No statistical weightings were applied to measurements. The resultant values are presented in Table 4.1.

Table 4.1 SRMS error summary for adopted basecase

History-matching mode	SRMS
Initial hydraulic head	10.9%
Transient head-change	3.4%
Transient head	6.7%

Of the 500-realisation parameter suite, 493 of the models successfully ran to completion of the history-matching period. Statistical results of the suite are presented in Table 4.2.

Table 4.2 SRMS error summary for parameter ensemble

	Initial hydraulic head	Transient head-change	Transient head
Base realisation	10.9%	3.4%	6.7%
Maximum	14.1%	4.7%	8.9%
90 th percentile	13.0%	3.8%	8.2%
Median	12.1%	3.3%	7.5%
10 th percentile	11.4%	2.9%	7.0%

Table 4.2 SRMS error summary for parameter ensemble

	Initial hydraulic head	Transient head-change	Transient head
Minimum	10.5%	2.5%	6.3%

In order to ensure suitable history-matching performance for the uncertainty ensemble, a screening filter was applied with the following cut-off values:

- initial hydraulic head SRMS: 12.5%;
- transient head-change SRMS: 3.5%; and
- transient head SRMS 8.0%.

Following this filtering, 231 parameter realisations were rejected based on poor performance against measured data.

4.2.2 Hydraulic head

i Scatter plot

A scatter plot of modelled against measured hydraulic head

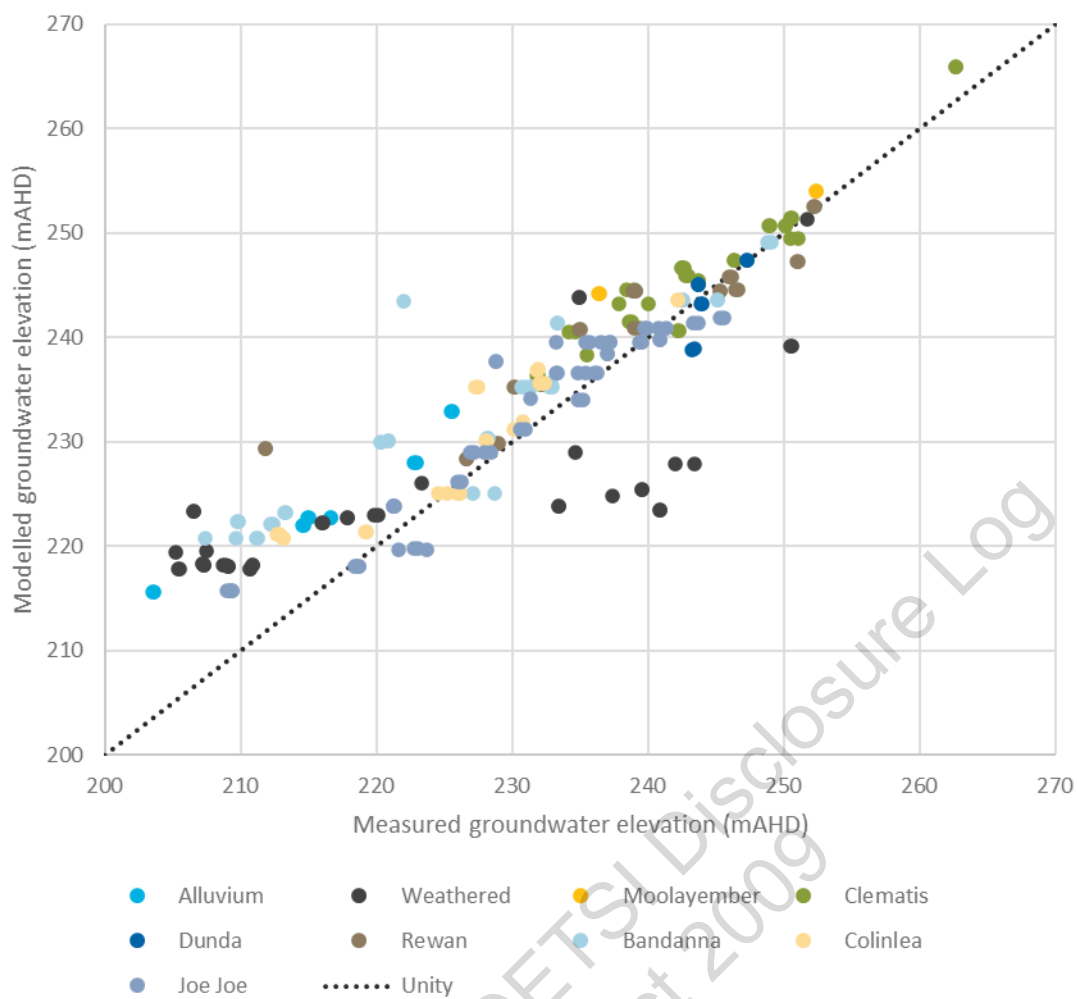


Figure 4.12 Modelled vs measured scatter plot for initial hydraulic head measurements for base realisation grouped by HSU

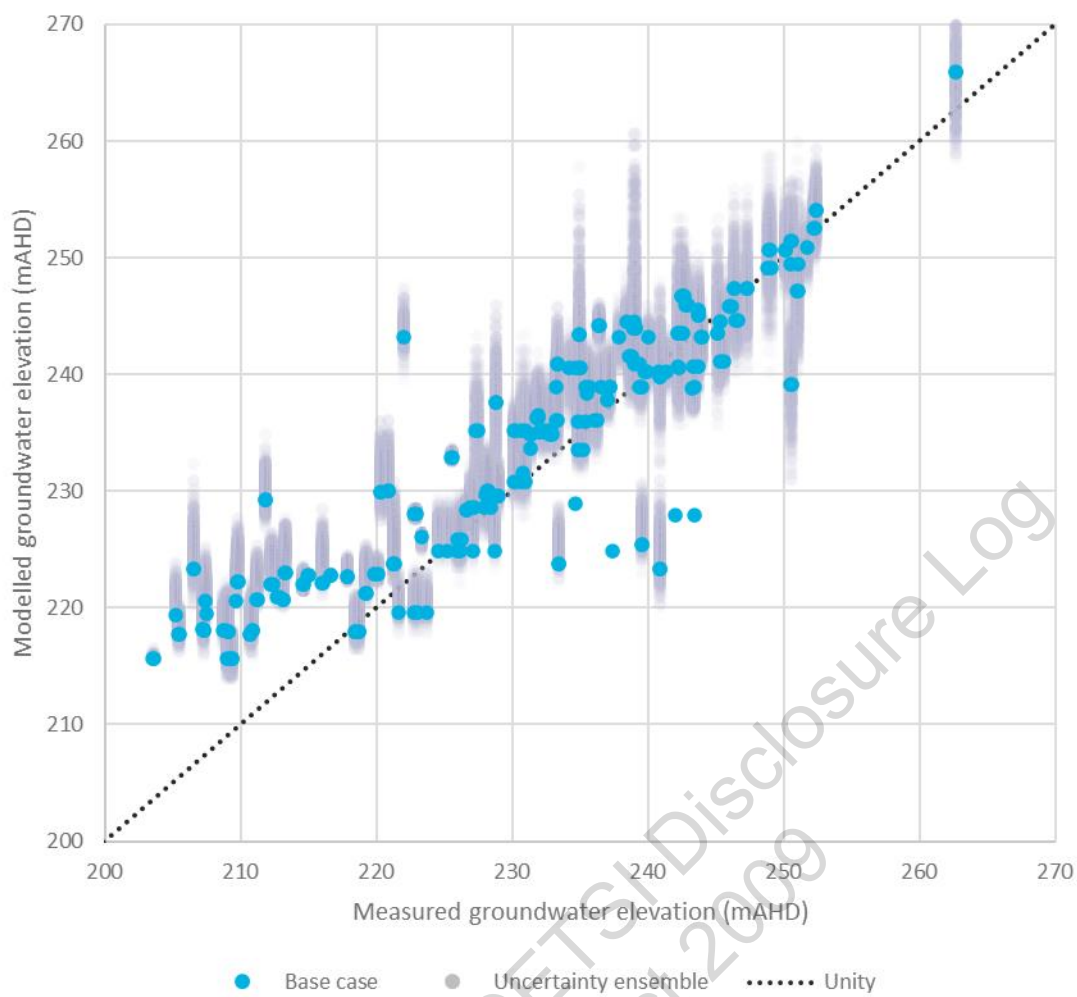


Figure 4.13 Modelled vs measured scatter plot for initial hydraulic head measurements for base realisation and uncertainty suite

ii Modelled groundwater contours

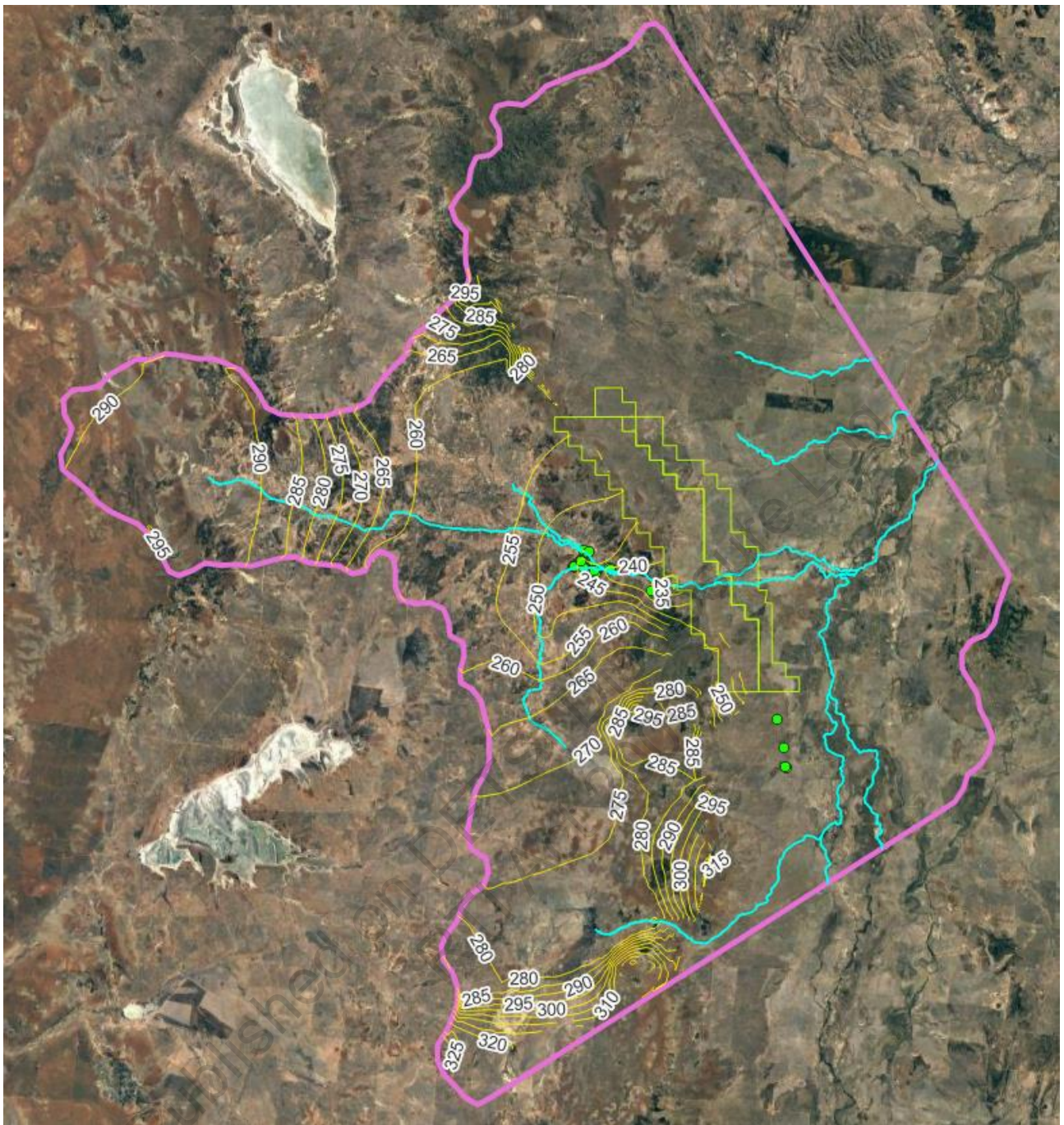


Figure 4.14 Modelled steady-state groundwater level contours in Clematis Sandstone

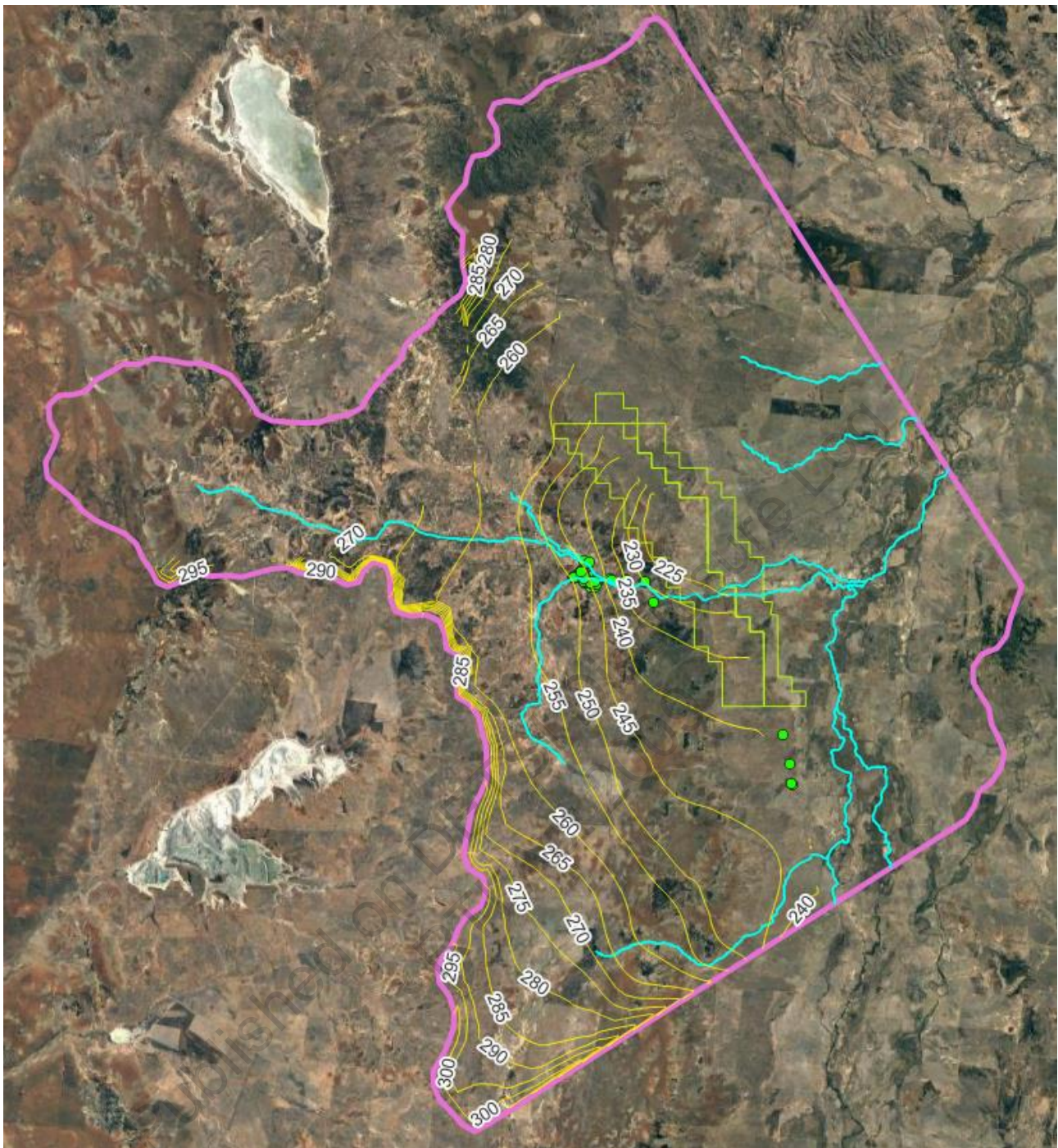


Figure 4.15 Modelled steady-state groundwater level contours in AB Coal

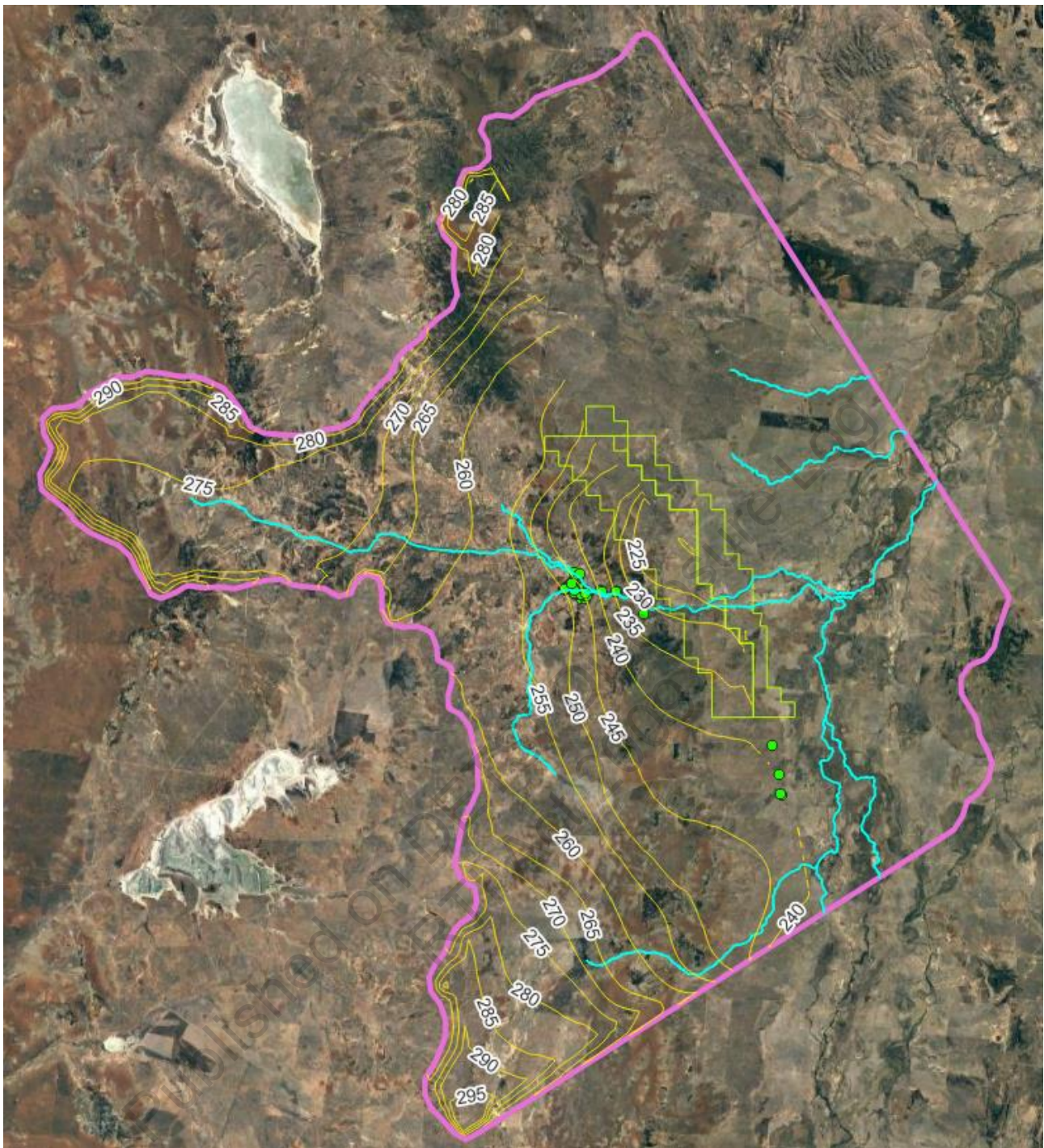


Figure 4.16 Modelled steady-state groundwater level contours in D Coal

iii Modelled hydrographs

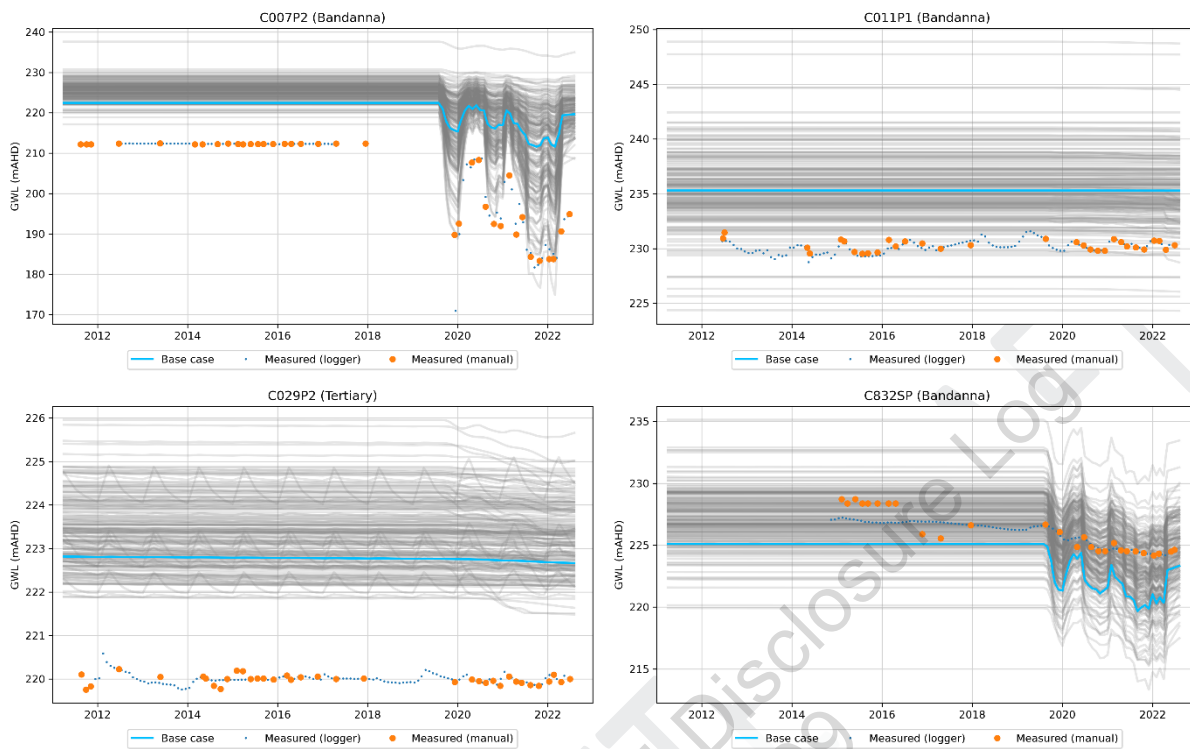


Figure 4.17 Selected history-matching hydrographs

4.2.3 Drawdown

i Scatter plot

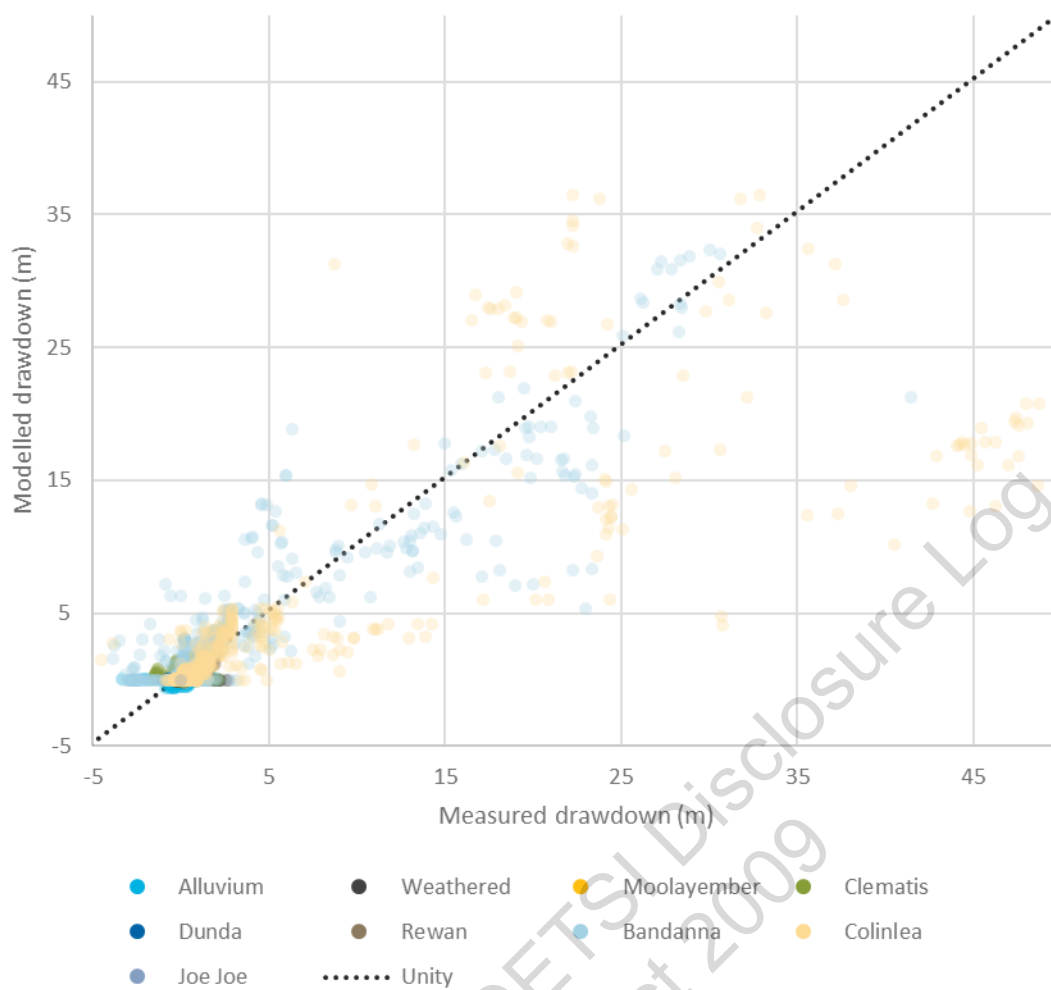


Figure 4.18 Modelled vs measured scatter plot of head-change for base realisation grouped by HSU

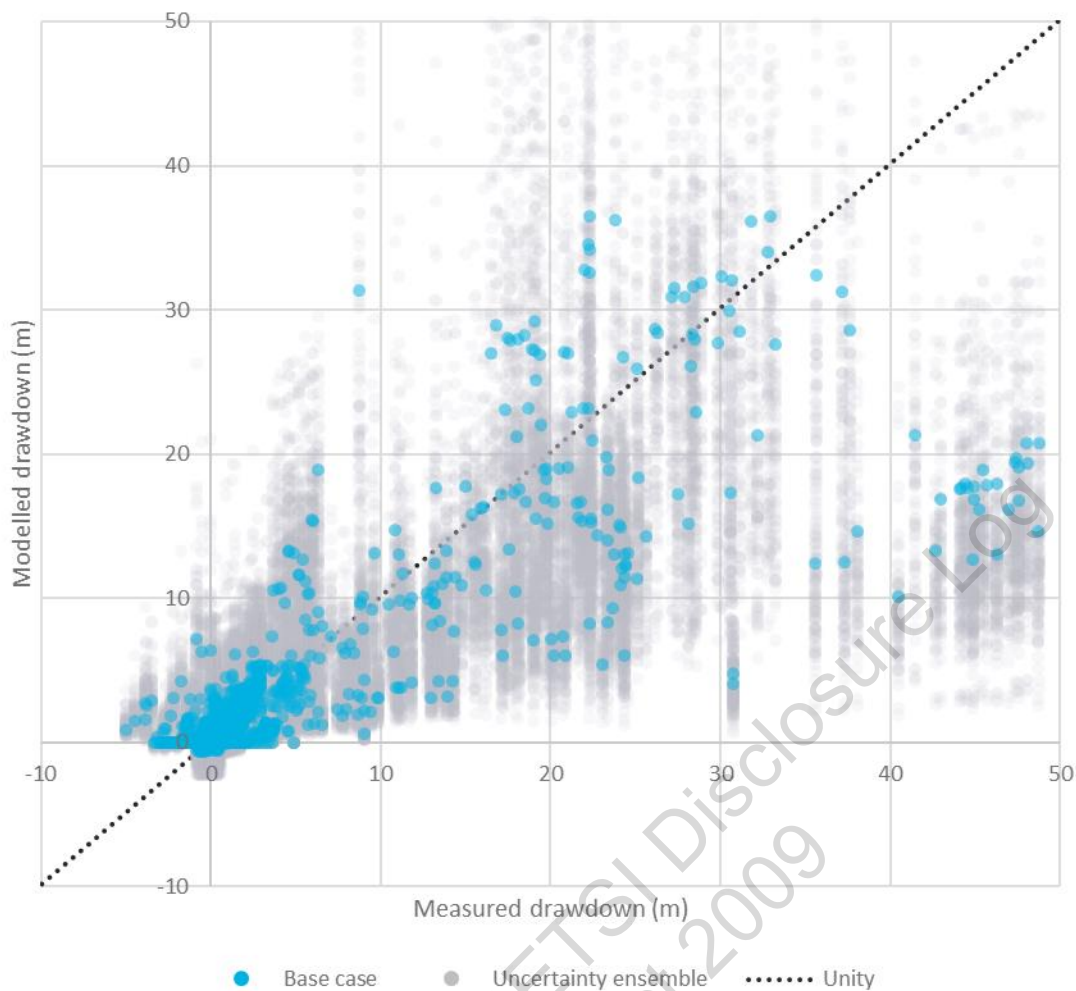


Figure 4.19 Modelled vs measured scatter plot of head change for base realisation and uncertainty suite

4.2.4 Surface water – groundwater interaction

Tom, conceptualisation and then representation of modelled surface water features and how they interact with the groundwater system, was previously severely scrutinised.

Can we produce plots of the following:

- During the wet season (pick maybe the latest?), show spatially where water leaks the most from the creek/river features and recharges the aquifer. Show as a colour flood along features
- During the dry season, are there any areas spatially that show baseflow? Show as a colour flood along features
- Show times series of flow in/out of selected creeks/rivers.



Figure 4.20 Baseflow (gaining) and seepage (losing) regions- wet season



Figure 4.21 Baseflow (gaining) and seepage (losing) regions- dry season

4.2.5 Spring flow

Table 4.3 **Modelled spring flows (kL/d)**

	Joshua Spring	Other Doongmabulla springs
Estimate (EMM 2022b)	1,000	400
Base realisation	912	565
Maximum	1,601	1,470
90 th percentile	1,198	894
Median	802	534
10 th percentile	527	295
Minimum	146	143

4.3 Water balance

Table 4.4 **Modelled steady state water balance**

	Inflow (ML/d)	Outflow (ML/d)
Regional throughflow	33.83	25.60
Rainfall-derived recharge	0.69	-
Evapotranspiration	-	21.72
River baseflow/leakage	14.70	1.89
Spring discharge	1.19	1.17
Storage	-	-
TOTAL	50.40	50.40
IN-OUT		0.00
Mass balance error		0.01%

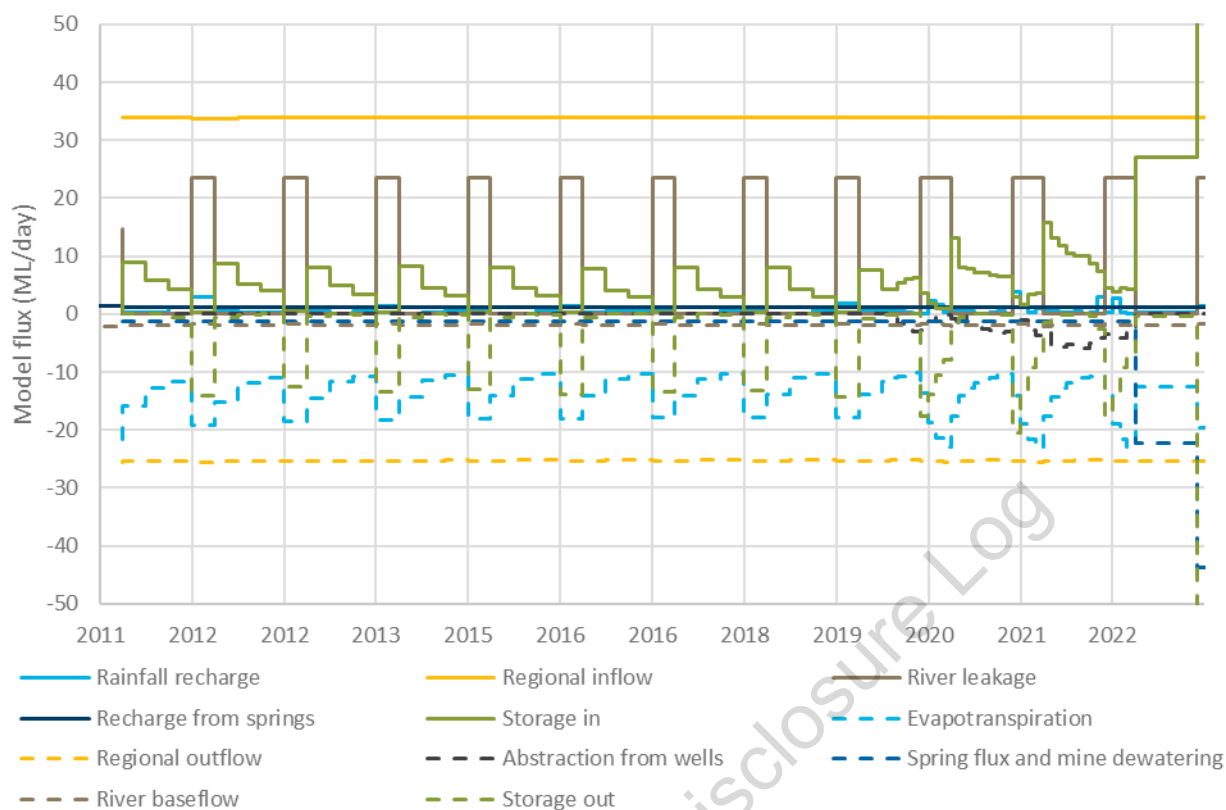


Figure 4.22 Model water balance for the history-matching period

4.4 Comparison with SEIS model

4.4.1 Model parameters

4.4.2 Calibration performance

4.4.3 Clematis heads

4.4.4 Water balance

Table 4.5 Pre- development water balance comparison

2013 SIS balance shown below:

Table 11 Calibrated steady state pre-development model – water balance

Component	SEIS model			Option 1 (2013)
	Flow IN (m ³ /d)	Flow OUT (m ³ /d)	IN – OUT (m ³ /d)	Flow IN (m ³ /d)
Recharge	2,533	0	2,533	2,940
Evapotranspiration	0	4,001	-4,001	0
Discharge from/to Adjoining Areas	44,680	41,468	3,214	84,933
Groundwater Extraction	0	152	-152	0
Carmichael River Leakage	6,662	7,084	-421	6,549
Discharge to Other Water Courses	0	1,200	-1,200	0
TOTAL	53,876	53,904	-28 (-0.05%)	94,422

5 Predictive modelling

5.1 Overview and approach

Three prediction scenarios have been developed including the following:

1. Scenario 1- Open cut only. This scenario includes the simulation of the open cut pits only, with all underground mine workings excluded.
2. Scenario 2- SEIS with previous fracturing assumptions. This scenario uses the updated model but assumes the same fracturing properties (fracturing height and properties multipliers) as the previous GHD 2013 SEIS model. For reference regarding the fracture zone approach, this scenario assumes:
 - a) a 160 m high fracturing height above the mined coal seams.
 - b) an increase in hydraulic conductivity of 2 orders of magnitude for all model cells above mined coal seams to surface.
3. Scenario 3- SEIS with updated fracturing assumptions. This scenario simulated the same mine plan as the SEIS, however the representation of fracturing properties above the longwall have been updated to include the following:
 - a) Fracturing heights were estimated previously as part of the RFCRP, with numerical geomechanical modelling predicting fractures to surface above all longwall panels. In contrast, the Ditton method with a multi-seam correction factor applied, estimated fracturing to a height of 252 m, which covers 48% of the underground mine footprint. For simplicity, this scenario assumed xxx.
 - b) the fractured properties above the longwall panels used the ramp function as outlined in Section **Error! Reference source not found.** below.
 - c) Tom, need to add text related to the increased permeability for the stress relief zone

Scenarios 1, 2 and 3 are compared directly to the 2013 SEIS model, where appropriate, to satisfy Condition E9.

At this stage, an optimised scenario, which will include a modified underground mine plan, has not been developed. The resulting effects on the groundwater system associated with the modified scenario will fall between the results presented for Scenario 1 and Scenario 3, the latter can be considered the 'bookends' of likely groundwater impacts. Therefore, the project at this stage is proposing to assess Scenario 1 as the planned operating scenario, with a commitment to update the groundwater model and associated optimised underground mine plan, prior to one year before underground mining is planned to commence, which is currently at 2037.

5.1.1 Assessing likelihood of drawdown

The maximum drawdown predicted for the Clematis Sandstone and the proportion of exceedance of the 0.2 m threshold set at spring locations are shown in Section 5.3.2. At this stage, full uncertainty analysis and thus the likelihood of drawdown assessment has only been completed for the Open cut only scenario (Scenario 1). The basecase realisations for Scenario 2 and 3 have been developed to allow a comparison to the previous SEIS model (GHD 2013).

The method follows that at each model cell, the drawdown was ranked in terms of magnitude and then the P10, P33, P66, and P90 values were calculated. Each percentile value was then interpolated using an inverse distance weighted algorithm to produce a percentile-based surface (eg one surface for each percentile threshold). A 0.2 m contour were then generated from each percentile surface to allow each of the maps to be amalgamated. This

approach is realisation independent and presents a conservative model cell-based approach to determine the maximum extents for drawdown for each likelihood threshold.

The rationale for the percentile approach to presenting predicted 500 drawdown realisations is based on Table 2 of Middlemis and Peeters (2018). Those uncertainty guidelines describe the importance of calibrated language and having a consistent and precise language to communicate impacts to decision makers.

Table 5.1 provides a summary of the combined numeric, narrative and visual approach to describe likelihood of drawdown exceeding the 0.2 m threshold, as a result of the Project. This table will provide the clarity on how to consider the likelihood bands presented in Figure 5.8 for Scenario 1.

Table 5.1 Combined numeric, narrative, and visual approach for assessing the likelihood of drawdown

Percentile band (outcomes ranked from small to large)	Colour code	
<P10		It is very unlikely that drawdown exceeds the threshold
P10 to P33		It is unlikely that drawdown exceeds the threshold
P33 to P67		It is as likely as not the drawdown exceeds the threshold
P67 to P90		It is likely that drawdown exceeds the threshold
>P90		It is very likely that drawdown exceeds the threshold

5.2 Water balance results

5.2.1 Operational phase

a Overall modelled water balance

Add text here . SEIS model did not document operational water balance.

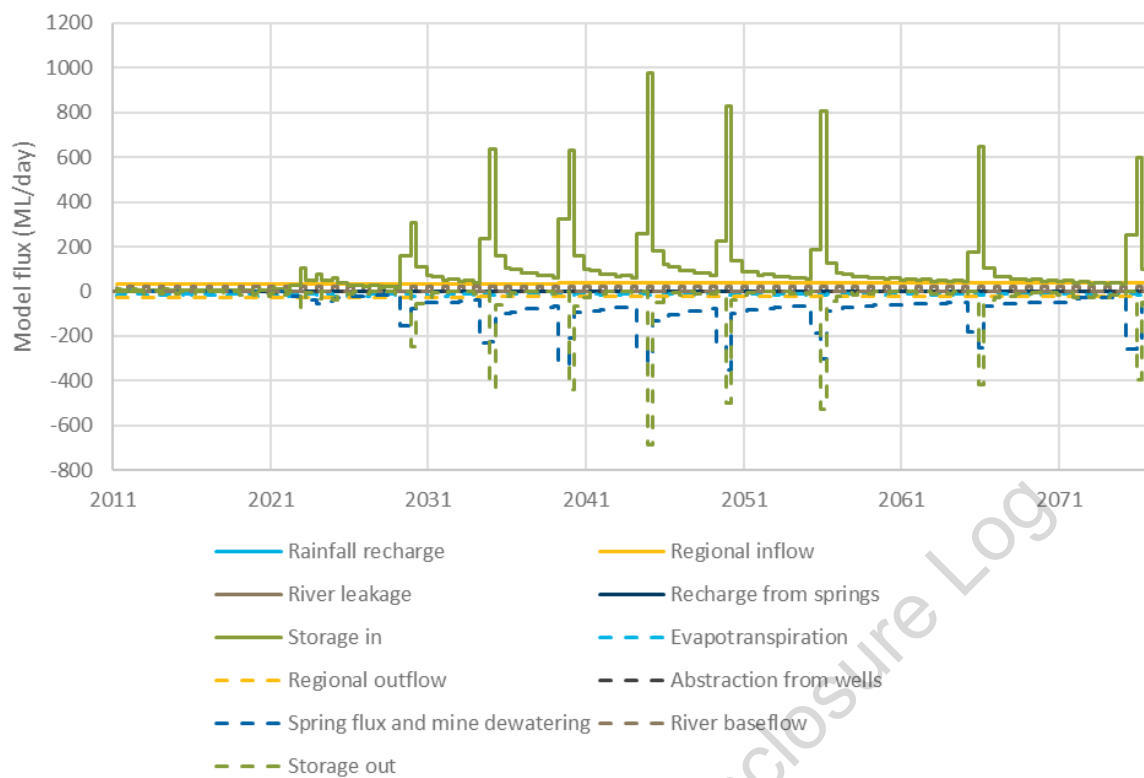


Figure 5.1 Scenario 1 modelled water balance

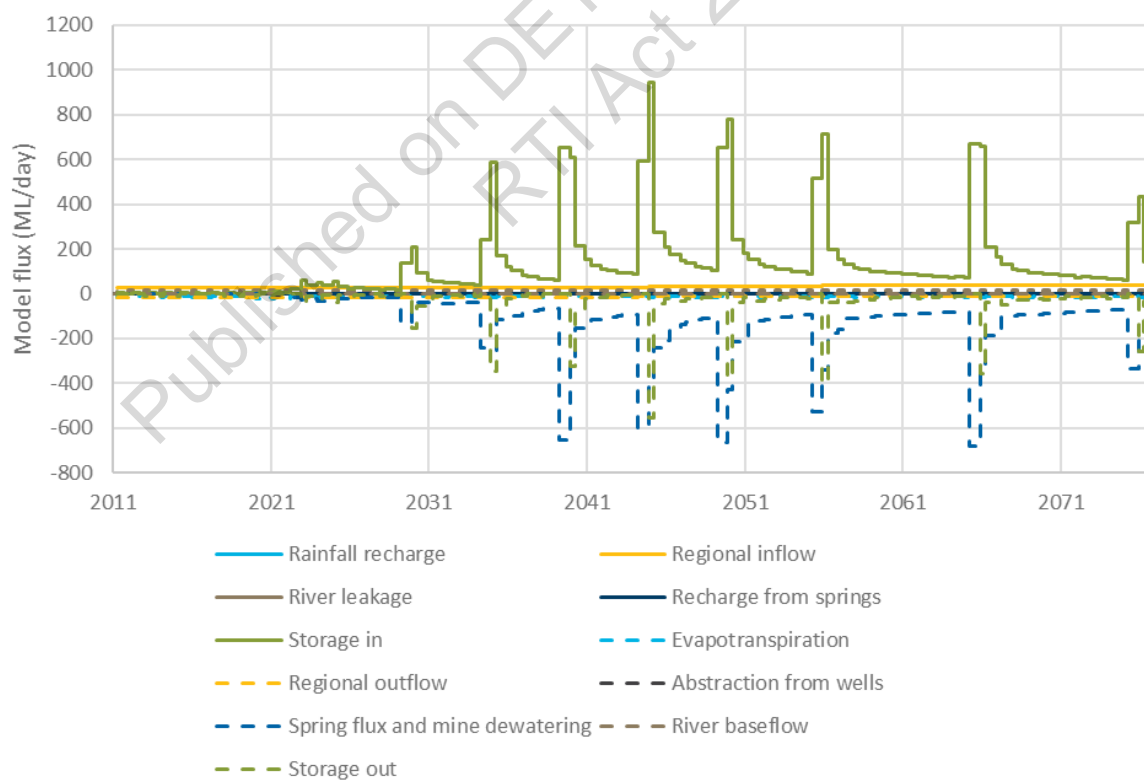


Figure 5.2 Scenario 2 modelled water balance

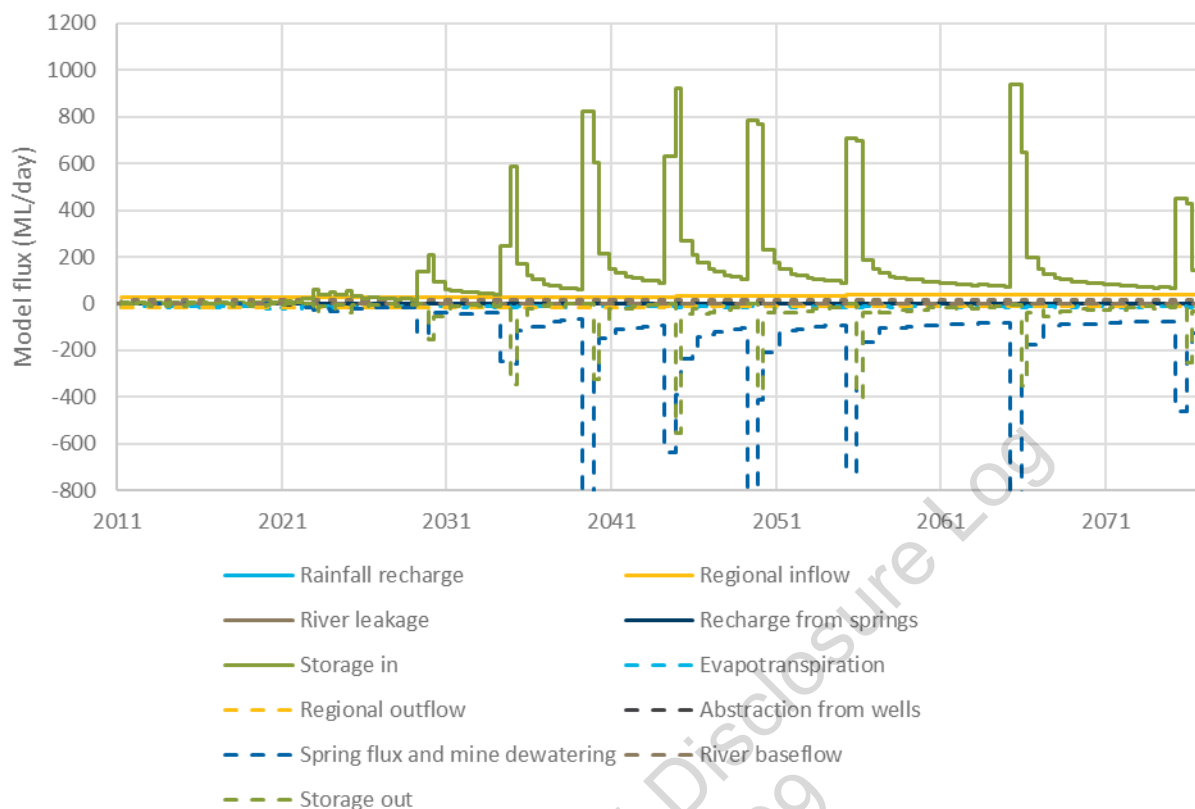


Figure 5.3 Scenario 3 modelled water balance

b Mine inflows

Add figure and text comparison to SEIS

Table 5.2 Prediction mine ingress (ML/day) for Scenario 1

Mine Year	Open cut	Underground	Total
1	0.4	0	0.4
2	0.8	0	0.8
3	3.1	0	3.1
4	29.4	0	29.4
5	43.3	0	43.3
10	63.2	0	63.2
15	113.6	0	113.6
20	121.6	0	121.6
25	134.3	0	134.3
30	108.6	0	108.6
35	78.5	0	78.5

Table 5.2 Prediction mine ingress (ML/day) for Scenario 1

Mine Year	Open cut	Underground	Total
47	60.2	0	60.2

Table 5.3 Prediction mine ingress (ML/day) for Scenario 2

Mine Year	Open cut	Underground	Total
1			0.4
2			0.7
3			2.9
4			20.5
5			26.2
10			53.5
15			118.6
20			198.4
25			226.3
30			203.8
35			136.7
47			141.4

Table 5.4 Prediction mine ingress (ML/day) for the Scenario 3

Mine Year	Open cut	Underground	Total
1			0.4
2			0.7
3			2.9
4			20.5
5			26.2
10			53.5
15			119.2
20			220.4
25			227.8
30			213.1
35			147.8

Table 5.4 Prediction mine ingress (ML/day) for the Scenario 3

Mine Year	Open cut	Underground	Total
47			156.2

Table 5.5 Prediction mine ingress (ML/day) for the 2013 SEIS model (GMMP, 2020)

Mine Year	Open cut	Underground	Total
1	4.9	0	4.9
2	7	0	7
3	11.6	0	11.6
4	10.7	0.1	10.8
5	11.7	1	12.7
10	11.2	5.3	16.5
15	10.6	15.5	26.1
20	8.5	5.8	14.3
25	7.8	7.5	15.3
30	7.8	4.6	12.4
35	7	6.4	13.4
47	6.6	0	6.6

5.2.2 Post closure phase

Compare water balance tables only

Table 5.6 Modelled water balance post closure- Scenario 1

	Inflow (ML/d)	Outflow (ML/d)
Regional throughflow	37.06	23.18
Rainfall-derived recharge	252.81	-
Evapotranspiration	-	195.23
River baseflow/leakage	14.70	1.89
Spring discharge	1.17	1.18
Storage	0.43	0.01
TOTAL	306.17	221.48
IN-OUT		84.69
Mass balance error		27.66%

Table 5.7 Modelled water balance post closure- Scenario 2

	Inflow (ML/d)	Outflow (ML/d)
Regional throughflow	29.79	13.44
Rainfall-derived recharge	252.70	-
Evapotranspiration	-	222.02
River baseflow/leakage	11.84	1.40
Spring discharge	0.78	0.79
Storage	0.01	0.03
TOTAL	295.13	237.64
IN-OUT		57.46
Mass balance error		19.47%

Table 5.8 Modelled water balance post closure- Scenario 3

	Inflow (ML/d)	Outflow (ML/d)
Regional throughflow	26.99	14.45
Rainfall-derived recharge	252.67	-
Evapotranspiration	-	261.11
River baseflow/leakage	11.84	1.39
Spring discharge	0.77	0.78
Storage	0.16	2.36
TOTAL	292.44	280.08
IN-OUT		12.35
Mass balance error		4.22%

Table 5.9 Modelled water balance post closure- 2013 SEIS model

	Inflow (ML/d)	Outflow (ML/d)
Regional throughflow	44.83	41.3
Rainfall-derived recharge	2.53	-
Evapotranspiration	-	3.34
River baseflow/leakage	6.43	6.43

Table 5.9 **Modelled water balance post closure- 2013 SEIS model**

	Inflow (ML/d)	Outflow (ML/d)
Spring discharge	-	0.65
Pumping wells	-	0.15
Flux to pit	-	2.40
Storage	0	0
TOTAL	53.79	54.29
IN-OUT		-0.49
Mass balance error		0.91%

5.3 Drawdown related effects

5.3.1 Overview

xx

5.3.2 Spatial groundwater responses

i Clematis Sandstone

Basecase drawdown and probability of exceedance (Scenario 1 only).

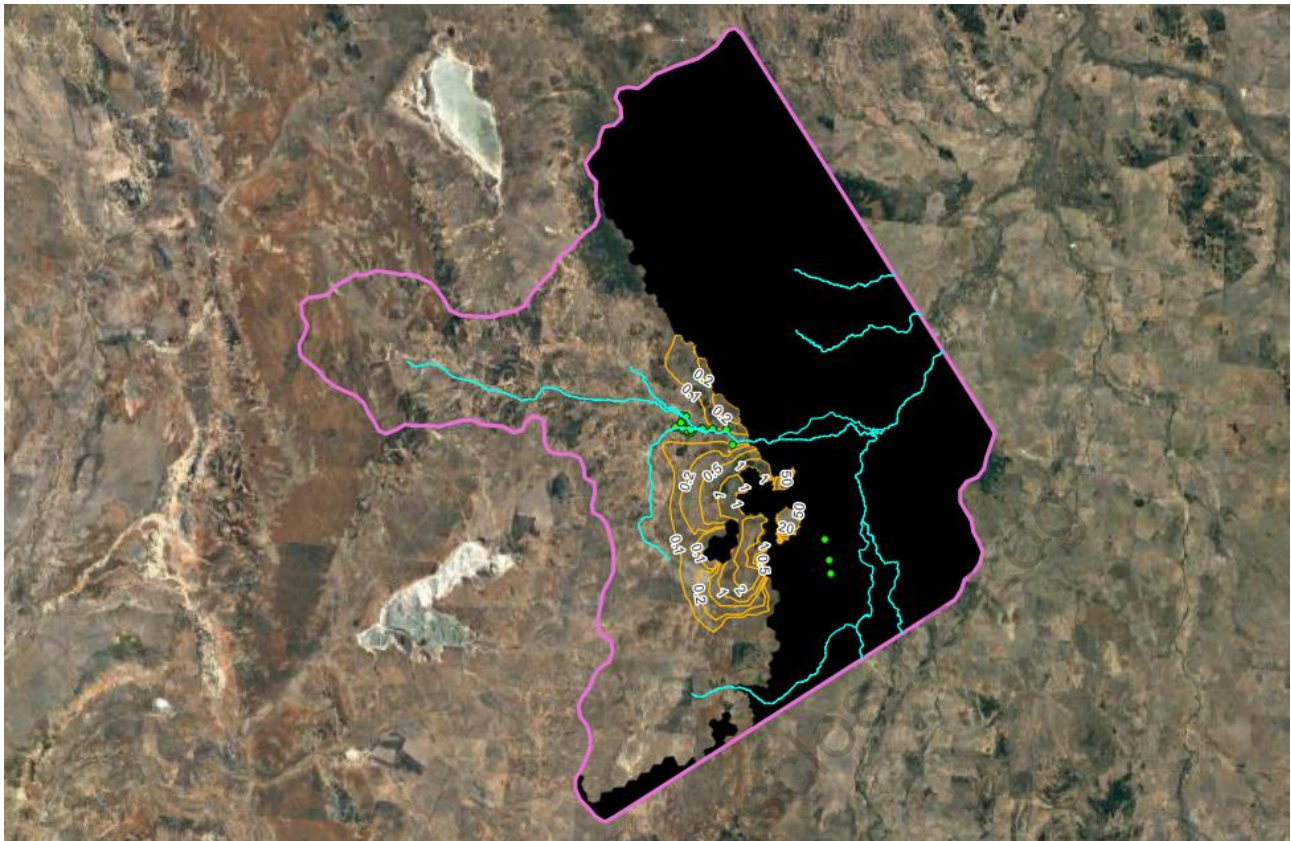


Figure 5.4 Scenario 1 modelled maximum drawdown in Clematis Sandstone

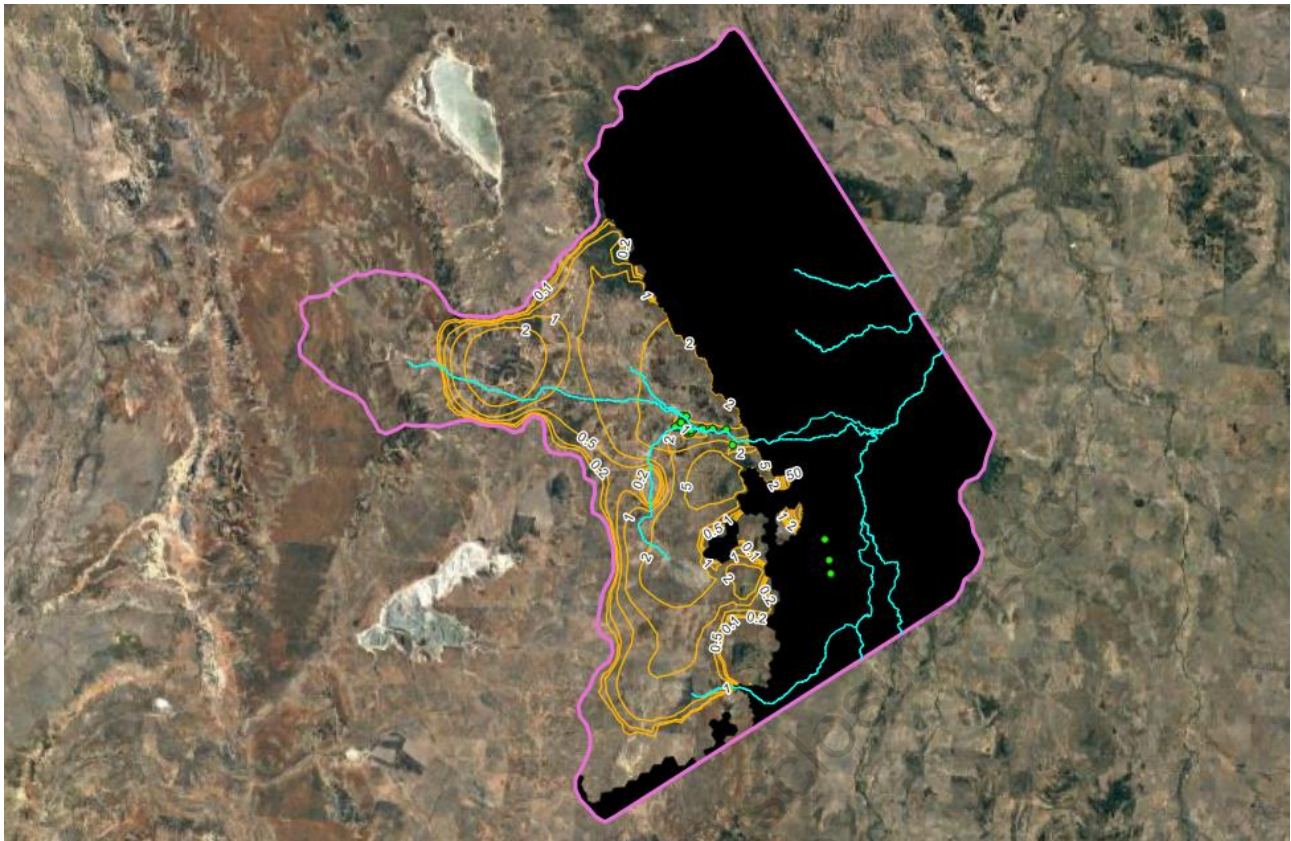


Figure 5.5 Scenario 2 modelled maximum drawdown in Clematis Sandstone

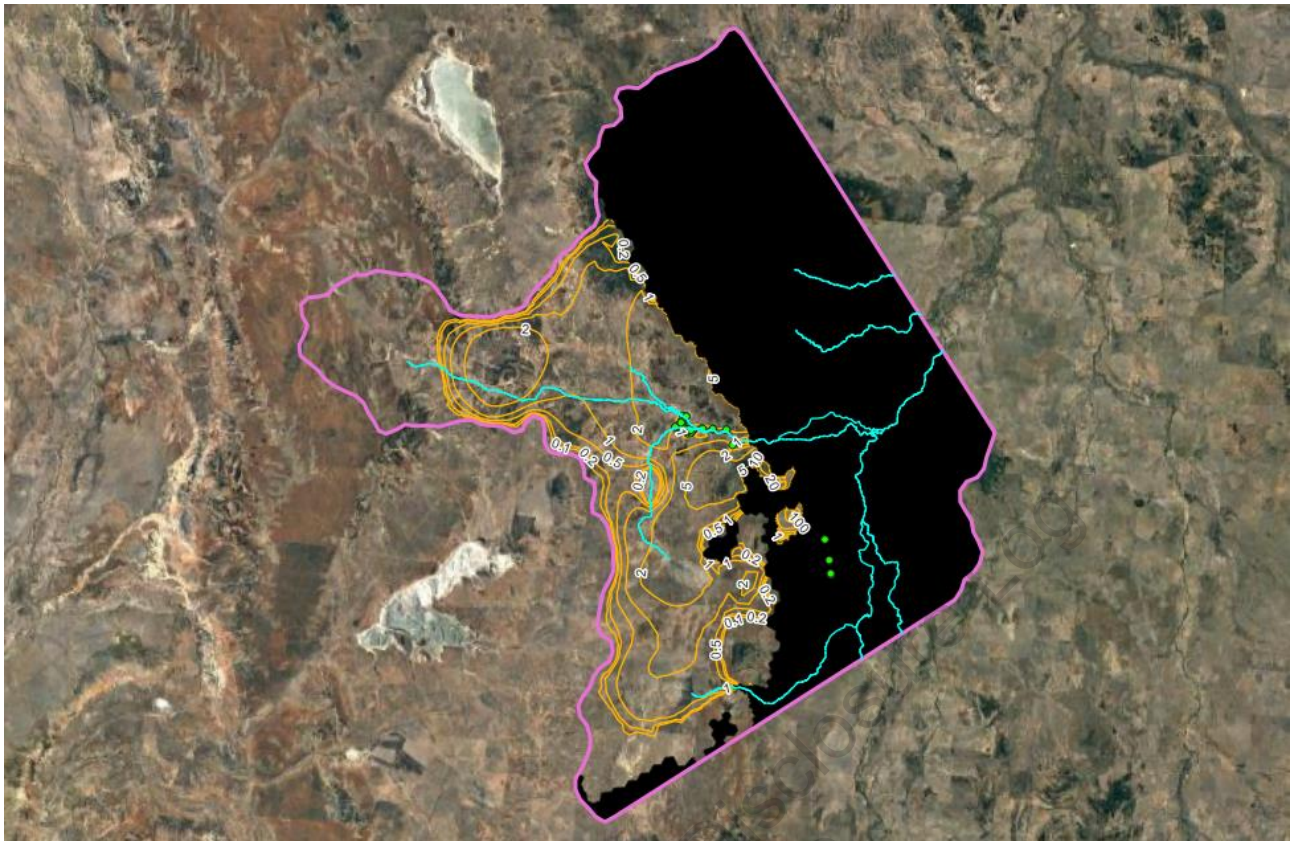


Figure 5.6 Scenario 3 modelled maximum drawdown in Clematis Sandstone

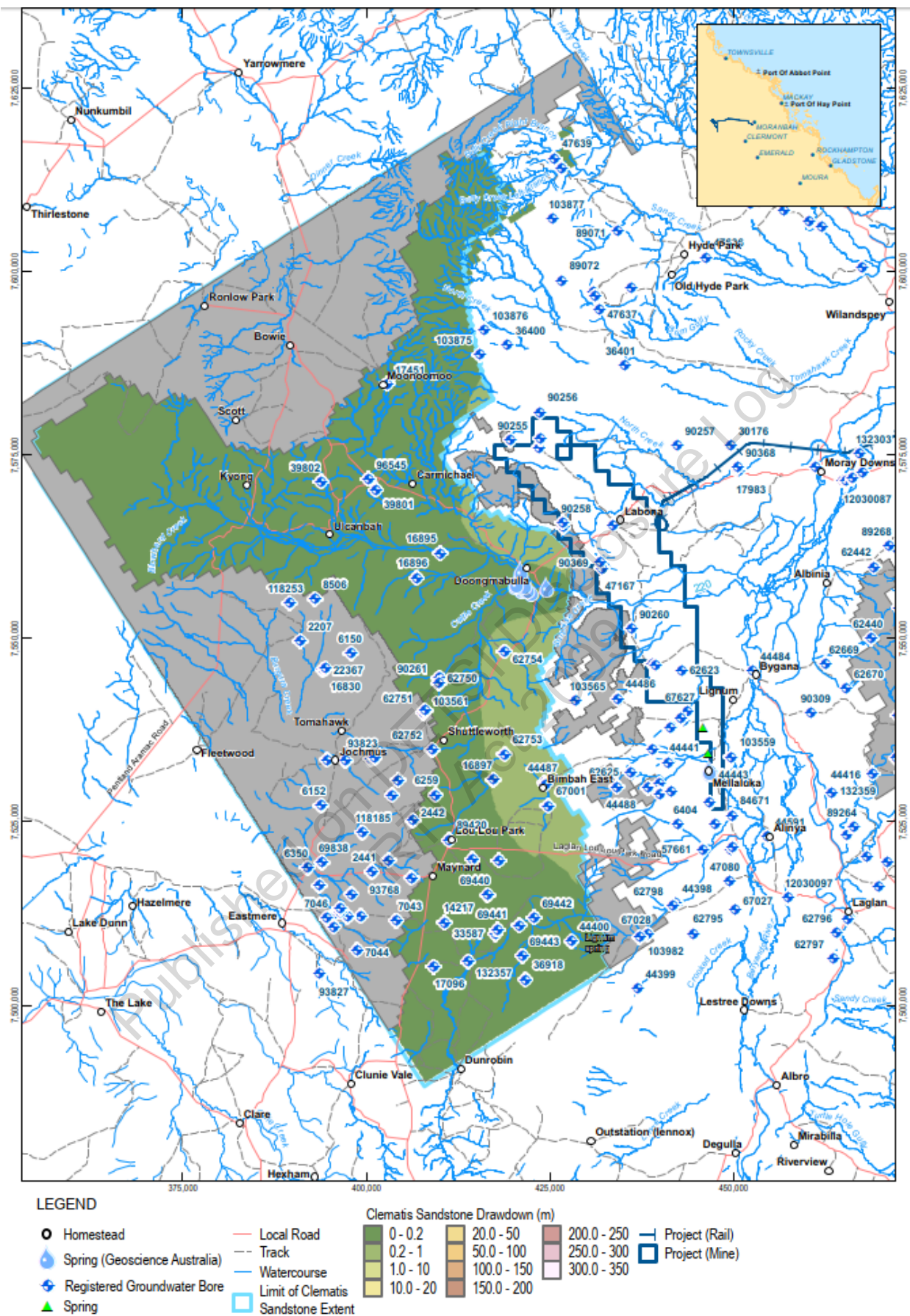
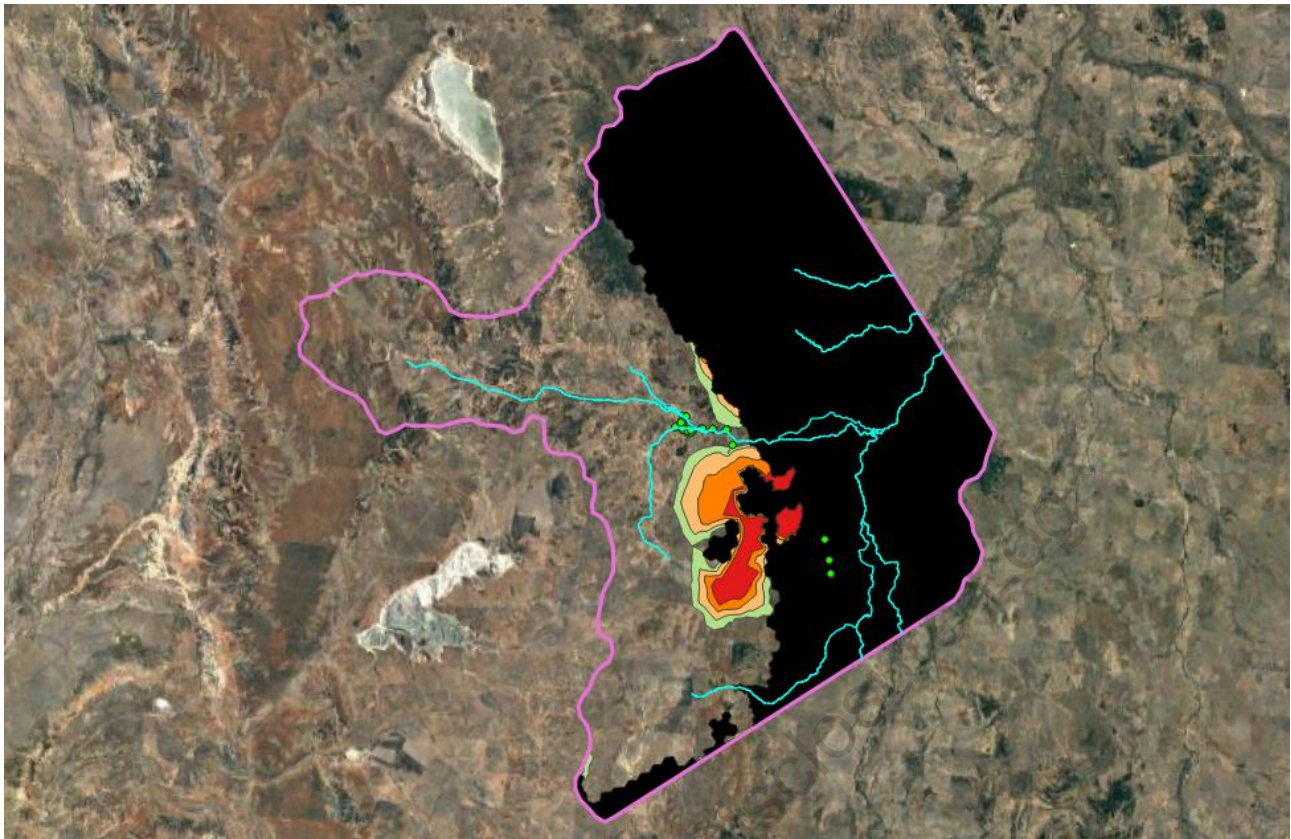


Figure 5.7 2013 SEIS modelled 'long term post closure' drawdown in Clematis Sandstone



Percentile band (outcomes ranked from small to large)	Colour Code	Description of likelihood
<P10	Dark Green	It is very unlikely that the drawdown/mounding exceeds the threshold
P10 to P33	Light Green	It is unlikely the drawdown/mounding exceeds the threshold
P33 to P67	Yellow	It is as likely as not the drawdown/mounding exceeds the threshold
P67 to P90	Orange	It is likely the drawdown/mounding exceeds the threshold
>P90	Red	It is very likely the drawdown/mounding exceeds the threshold

Figure 5.8 Scenario 1 proportion of exceedance for 0.2 m drawdown in Clematis Sandstone

Add text

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Add updated figure

Figure 5.9 Scenario 1 modelled maximum drawdown in AB coal seams

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Add updated figure

Figure 5.10 Scenario 2 modelled maximum drawdown in AB coal seams

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Add updated figure

Figure 5.11 Scenario 3 modelled maximum drawdown in AB coal seams

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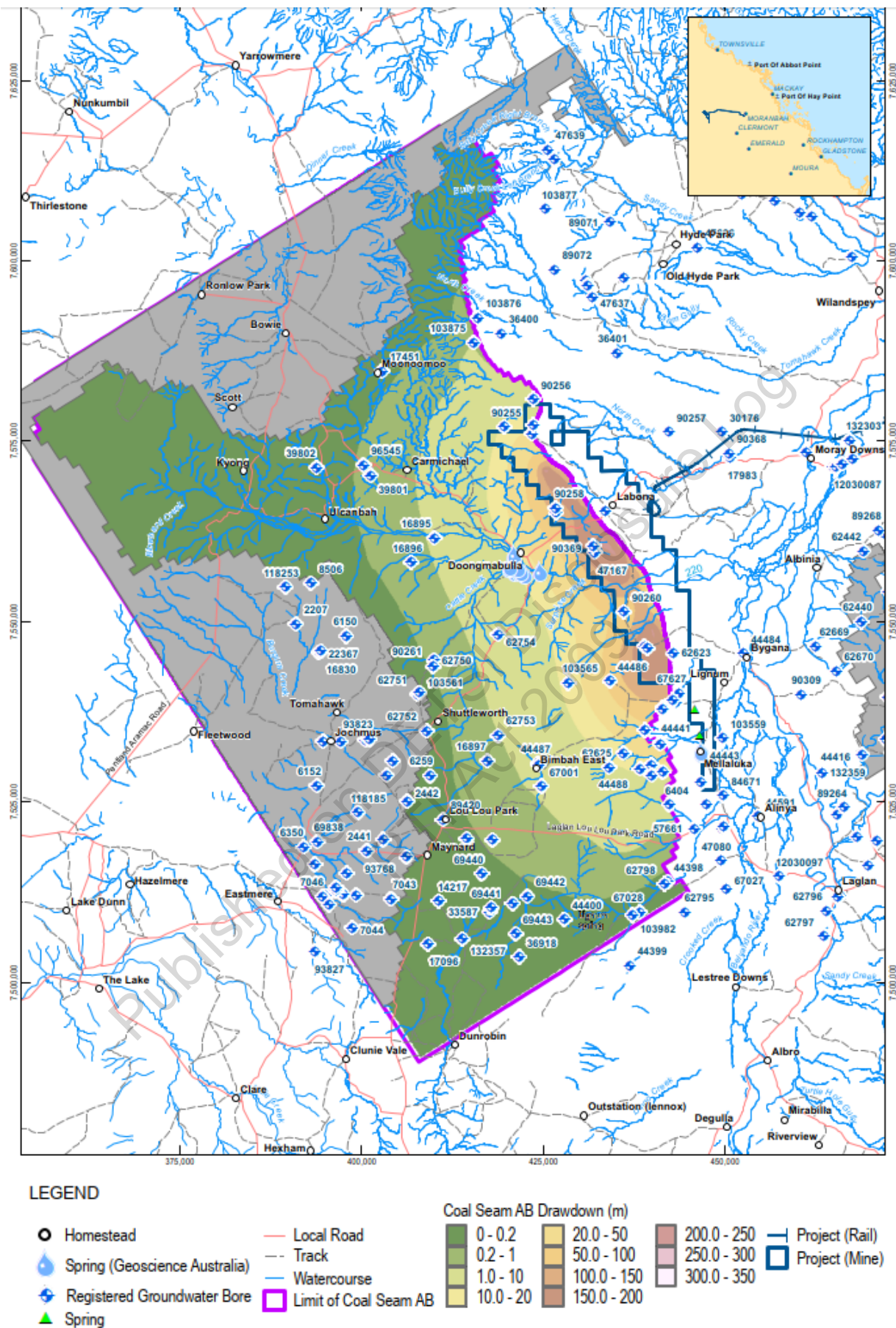


Figure 5.12 2013 SEIS modelled 'long term post closure' drawdown in AB coal seams

5.3.3 Drawdown hydrographs

Figure 5.13 All scenario base case selected modelled drawdown hydrographs

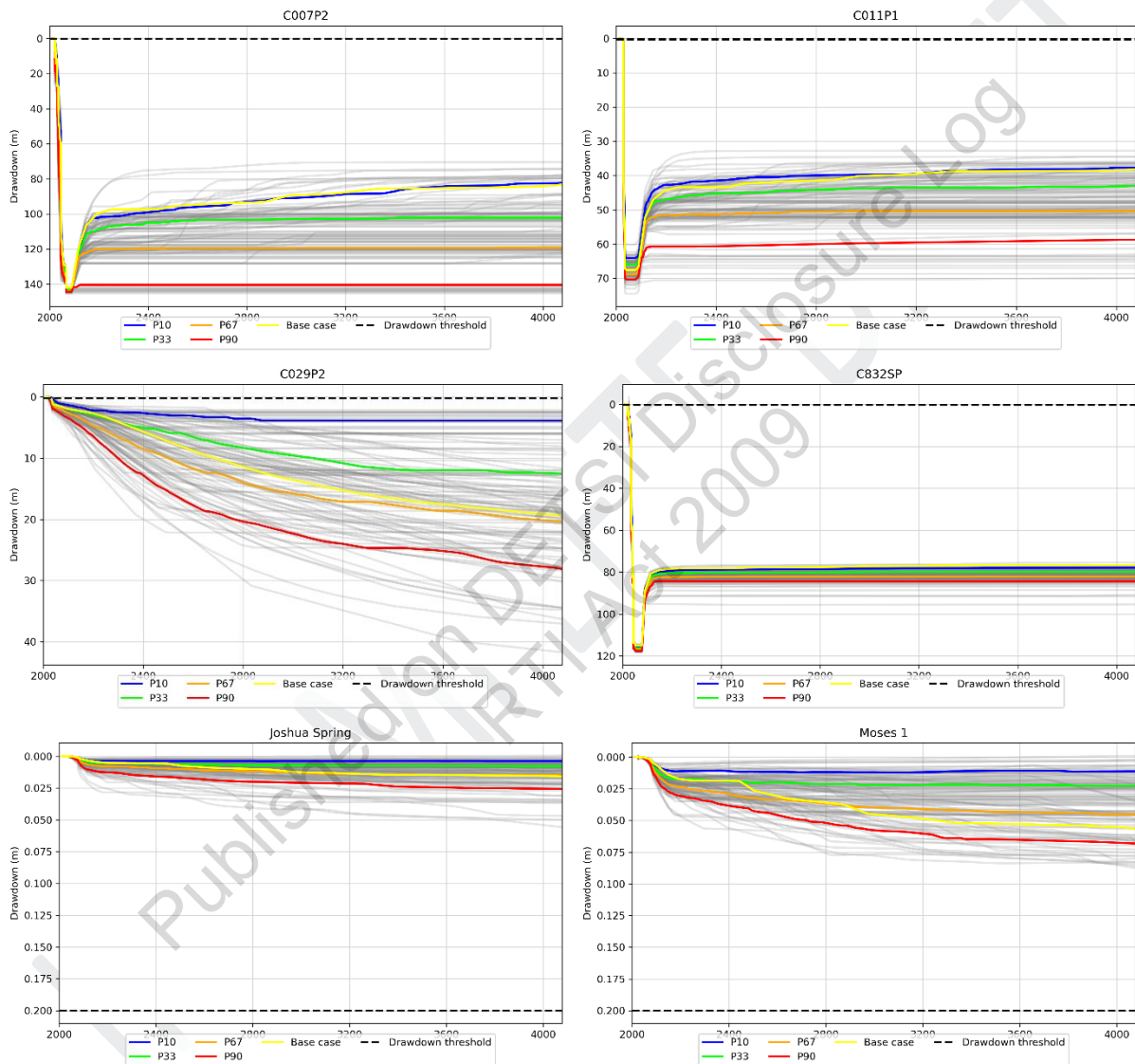


Figure 5.14 Scenario 1 selected modelled drawdown hydrographs



Figure 5.15 Scenario 2 selected modelled drawdown hydrographs

Figure 5.16 Scenario 3 selected modelled drawdown hydrographs

5.3.4 Drawdown at springs

Table 5.10 Modelled maximum drawdown at springs for the base scenarios (m)

Spring ID	Alternate ID	GHD (2013a)- operational	GHD (2013a)- post closure	Scenario 1	Scenario 2	Scenario 3
1031_Moses4	Moses 4	<0.05	<0.05	0.05	0.12	0.31

Table 5.10 **Modelled maximum drawdown at springs for the base scenarios (m)**

Spring ID	Alternate ID	GHD (2013a)- operational	GHD (2013a)- post closure	Scenario 1	Scenario 2	Scenario 3
1032_Moses3	Moses 3	<0.05	<0.05	0.05	0.12	0.31
1033_Moses2	Moses 2	0.08	0.08	0.05	0.12	0.31
1034_Littmose	Little Moses 1	<0.05	<0.05	0.05	0.08	0.24
1035_Moses1	Moses 1	0.06	0.06	0.06	0.13	0.32
1036_75E		0.09	0.09	0.05	0.12	0.31
1037_75A		0.08	0.07	0.05	0.12	0.31
1038_75D		0.07	0.07	0.05	0.12	0.31
1039_75B		0.12	0.11	0.06	0.12	0.31
1040_75C		0.12	0.11	0.06	0.12	0.31
1041_Doongma	Joshua Spring	0.19	0.16	0.02	0.03	0.13
41_(no name recorded)	Mellaluka 1	<0.05 – 1.03	1.6 – 8.39	10.90	4.70	6.17
42_(no name recorded)	Mellaluka 2	<0.05 – 1.14	2.9 – 9.07	10.95	4.67	6.20
Storie's	Storys	<0.05 – 2.34	8.2 – 13.4	18.11	12.42	13.25
Lignum	Lignum	0.06 – 8.22	14.8 – 25.6	7.30	7.17	8.66

Also should show drawdown hydrographs at selected springs (maybe 3 locations?) for base cases vs GHD SEIS model

Table 5.11 **Proportion of model realisations exceeding 0.2 m drawdown threshold for “Open cut” only scenario**

Spring ID	Alternate ID	Percentage of exceedance
1031_Moses4	Moses 4	0%
1032_Moses3	Moses 3	0%
1033_Moses2	Moses 2	0%
1034_Littmose	Little Moses 1	0%
1035_Moses1	Moses 1	0%
1036_75E		0%
1037_75A		0%
1038_75D		0%
1039_75B		0%

Table 5.11 Proportion of model realisations exceeding 0.2 m drawdown threshold for “Open cut” only scenario

Spring ID	Alternate ID	Percentage of exceedance
1040_75C		0%
1041_Doongma	Joshua Spring	0%

5.3.5 Drawdown at 3rd party bores

Just a table for comparison. Use Craig’s updated bore list.

Table 5.12 Predicted drawdown (m) at 3rd party bores for basecase scenarios

Site ID (RN)	Local bore name	Formation	Easting	Northing	GHD (2013a)- operational	GHD (2013a)- post closure	Scenario 1	Scenario 2	Scenario 3
TBA	Dexter bore	Permian Overburden/ Tertiary	445677	7540047					
103249	Desert Bore	Permian Overburden/ Tertiary	442972	7538727	8.2	85.9			
158471 or 44484 (GHD 2013)	House Bore	Tertiary/Joe -Joe formation	449378	7541377					
N/A	Tapgate bore	Tertiary/Joe -Joe formation	448517	7544827					
N/A	Shed bore	Tertiary/Joe -Joe formation	446876	7547938					
158001	Lake bore	Tertiary/Joe -Joe formation	446122	7549419					
TBA	Hut bore	Tertiary/Joe -Joe formation	449869	7550061					
44486	Desert Bore	Dunda Beds	434344	7542064	3.1	4.7			
TBA	Clayholes bore	Clematis Sandstone	424733	7536432					
44487	Bimbah House Bore	Clematis Sandstone	424155	7529828					
67626	Bimbah Irrigation bore	Clematis Sandstone	424155	7529828	0.2	0.5			

Table 5.12 Predicted drawdown (m) at 3rd party bores for basecase scenarios

Site ID (RN)	Local bore name	Formation	Easting	Northing	GHD (2013a)- operational	GHD (2013a)- post closure	Scenario 1	Scenario 2	Scenario 3
TBA	Glens Bore	Dunda beds/Clematis (TBC)	429833	7532978					
44488	Cockatoo Bore	Dunda beds	432768	7533696					
62625	Soak Bore	Dunda Beds	435979	7534079	1.1	3.7			
132959	Gidgea Bore	Joe-Joe formation	446731	7528369					
103378	Iron Bark Bore	Rewan formation / Dunda beds	441486	7528898					
103230	3 mile bore	Tertiary/Dunda Beds	441722	7532437	0.4	28.6			
103229	Desert Bore	Tertiary	442930	7538681	8.6	75.1			
132961	Middle Bore	Interburden in early permian	442929	7534861					
103231	Poison Bore	Tertiary/Dunda Beds	438212	7535068	4.5	38.8			
103559	Stories bore	Tertiary/ Joe -Joe	446437	7534364	0.8	4.5			
90212	Shellys bore	Rewan formation / Dunda beds	439949	7529980					
44443	House bore	Tertiary/ Joe -Joe	446729	7532074					
103680	Gold Lotto	Tertiary/Sand stone	446002	7556100					
158649	Satr Light	Tertiary/Sand stone	448146	7554149					

Table 5.12 Predicted drawdown (m) at 3rd party bores for basecase scenarios

Site ID (RN)	Local bore name	Formation	Easting	Northing	GHD (2013a)- operational	GHD (2013a)- post closure	Scenario 1	Scenario 2	Scenario 3
17983 (TBC)	Eight Mile Bore	Tertiary (TBC)	451231	7572656					
17981 (TBC)	10 Mile Bore	Tertiary (TBC)	423365	7575902	18.1 (Permian Sandstone, L10)	23.6			
90255 (TBC)	15 Mile bore	Tertiary (TBC)	419310	7577204	0.8 (Clematis/Dunda)	0.8			
TBA	Yambina Bore	Tertiary (TBC)	457184	7571423					
TBA	Crazy Bore	Dunda beds	414230	7576676					
TBA	Wild Bore	Dunda beds	415707	7574934					
103423	Gidgea No.1 Bore	Assumed above Clematis	446731	7528369	n/a (new bore)	n/a (new bore)			
132960	Gidgea No.2 Bore	Clematis (assumed)	446731	7528369	n/a (new bore)	n/a (new bore)			
TBA	Carmichael House Bore	Moolayember or Clematis	406312	7570944	n/a (new bore)	n/a (new bore)			
TBA	Kades Bore	Moolayember or Clematis	406128	7571872	n/a (new bore)	n/a (new bore)			
TBA	Cow Paddock Bore	Moolayember or Dunda	409855	7570961	n/a (new bore)	n/a (new bore)			
96545	Mosquito Bore	Moolayember or Clematis	400432	7571736	n/a (new bore)	n/a (new bore)			
158631	Riverlane Bore	Tertiary	451106	7541406	n/a (new bore)	n/a (new bore)			

5.3.6 Predicted baseflow assessment and comparison to 2013 SEIS model

Only show losing and gaining spatial maps in history match section. Table below should be satisfactory.

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Table 5.13 Predicted baseflow assessment

Component	All river features	Carmichael River
2013 SEIS model		
Baseflow- history match (m ³ /d)	n/a	
Baseflow- end of operation (m ³ /d)	n/a	
Baseflow- long term post closure (m ³ /d)	n/a	
Baseflow rate change (m ³ /d)- end of operation	n/a	
Baseflow percentage change (%)- end of operation	n/a	
Baseflow rate change (m ³ /d)- long term post closure	n/a	
Baseflow percentage change (%)- long term post closure	n/a	
Scenario 1		
Baseflow- history match (m ³ /d)		
Baseflow- end of operation (m ³ /d)		
Baseflow- long term post closure (m ³ /d)		
Baseflow rate change (m ³ /d)- end of operation		
Baseflow percentage change (%)- end of operation		
Baseflow rate change (m ³ /d)- long term post closure		
Baseflow percentage change (%)- long term post closure		
Scenario 2		
Baseflow- history match (m ³ /d)		
Baseflow- end of operation (m ³ /d)		
Baseflow- long term post closure (m ³ /d)		
Baseflow rate change (m ³ /d)- end of operation		
Baseflow percentage change (%)- end of operation		
Baseflow rate change (m ³ /d)- long term post closure		
Baseflow percentage change (%)- long term post closure		
Scenario 3		
Baseflow- history match (m ³ /d)		
Baseflow- end of operation (m ³ /d)		
Baseflow- long term post closure (m ³ /d)		
Baseflow rate change (m ³ /d)- end of operation		
Baseflow percentage change (%)- end of operation		
Baseflow rate change (m ³ /d)- long term post closure		

Table 5.13 Predicted baseflow assessment

Component	All river features	Carmichael River
Baseflow percentage change (%)- long term post closure		

6 Response to past model review criticisms

Following submission of the initial and supplementary EIS, the conceptual hydrogeological model and numerical groundwater flow model have been reviewed by a range of scientists. A summary of review elements has been previously compiled and documented in EMM 2022. Individual comments and recommendations are presented in Table 6.1 along with our responses following model design, history match, predictions and uncertainty analysis.

Table 6.1 Approach to address past project criticism

Author/reference	Summary of comments	Data/research/approach
URS 2013b	<p>Field data could have been better integrated into conceptual model, to determine a set of preferred values and ranges for hydraulic conductivity and storage.</p> <p>No storage calibration from steady state model – literature values used.</p> <p>Water balance with high recharge loss.</p> <p>Heterogeneous hydraulic conductivity across layers.</p> <p>Issues raised include: Cumulative percentage discrepancy, stream leakage and baseflow, model parameter variation due to longwall mining, and post closure water balance.</p> <p>Geology – the cross section indicates uniformly dipping units to the west, and noted that groundwater flow patterns across the site are contrary to the dip of the units.</p> <p>Are higher potentiometric pressures to the north and south considered for the flow in the report, are enhanced recharge, or structures considered?</p> <p>Suggested that hydraulic connection between the Permian target coal and the GAB be added, querying the potential for faults that could connect the Clematis Sandstone to the Permian unit thus impacting on the GAB.</p> <p>The recharge rates to the Galilee Basin confined Permian units are not well detailed and are incomplete, additional details are required for the confined aquifers and what rates were included across the model domain. Surficial geology has recharge rates of 0 to 44 mm/yr, while modelling used rates of 0.1 to 5mm/yr.</p> <p>It is considered that additional discussion regarding flow patterns, on and adjacent to the mine lease, is required as these flows are contrary to the dip of the geology. Consideration of different flow directions in the Galilee Basin units and GAB units, groundwater divide and groundwater low points north of the Carmichael River.</p> <p>Groundwater flow in the Clematis Sandstone needs to be included in the conceptual model, to indicate flow pattern differences in the GAB units and Galilee Basin units.</p>	<p>Hydrogeological conceptualisation has been updated to address the key issues raised by this document, including:</p> <ul style="list-style-type: none"> • Drilling and installing monitoring sites to the west of the lease area to provide geological control and to assess Triassic and Permian pressures in the vicinity of the DSC to establish source aquifer. • New geological mapping in the area to the west of the mine lease near the DSC. • New field and laboratory measurements of K and S for the Rewan, Dunda and Clematis HSUs. Detailed analysis of Kx and Kz with depth across the Rewan aquitard. Integrated K datasets have established field-based statistical ranges for each HSU. • The GAB Springs research program and Rewan connectivity research program have produced updated potentiometrics and vertical flow gradients using contemporary data. • A comprehensive hydrogeochemistry and isotopes analysis program has confirmed a Triassic source aquifer for the DSC. • A comprehensive surface water-groundwater investigation has been undertaken to inform the updated HCM and groundwater model. • This revised HCM has undertaken statistical trend analysis on over 100 monitoring locations to identify any potential dewatering impacts in each main HSU. This trend analysis provides direct feedback on how each HSU is responding to over two years of dewatering in the Permian Betts Creek Beds. • Updated nested hydrograph analysis has provided insights on the vertical hydraulic gradients across the site and helped to better understand the mechanisms for DSC discharge, the extent of artesian heads in the Clematis, Dunda Beds and upper Rewan formations, and the impacts of landholder pumping and dewatering on the Permian HSUs. • The Rewan connectivity research program has included review of field data, lithofacies interpretation, interpretation of groundwater resources, detailed analysis of hydraulic

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	<p>The Rewan Group as a unit is important for model predictions on the GAB, additional discussion on the sensitivity results should be provided.</p> <p>No source of data or assumptions on the geology outside of the mine lease.</p> <p>Model convergence criteria might be too high at 1×10^{-2} m, typically 1×10^{-3} m is used.</p> <p>Elevated water balance errors in some stress periods of the predictive model represents a genuine shortcoming of the current model.</p> <p>Does hydraulic conductivity vary with depth?</p> <p>The calibration does not show if the vertical hydraulic gradients were preserved at locations that had multi nested monitoring points.</p> <p>No transient calibration was performed, storage parameters were selected from literature values, effects from river stage changes show a change of several meters, can the steady state model be representative?</p> <p>How were SW/GW interactions assessed in the steady state model for the dry season outside of the mine lease?</p> <p>Please explain how the recharge rate was determined and provide discussion on the effective recharge.</p> <p>Please explain how a robust predictive model can be generated from the current steady state model calibrated to average head data only.</p> <p>Hydraulic conductivity distribution was used for Layers 9 to 12, rather than a uniform value used, resulting in a bull's eye value in one area. Show the distribution and comment on values.</p> <p>A low value of residual saturation was used for the unsaturated zones at 5×10^{-3}.</p> <p>Large mass balance errors were identified at some stress periods, as such the predictive model outcomes are questioned.</p> <p>Horizontal and vertical hydraulic conductivities and storage parameters were not increased for the mined coal seam (the goaf) after mining. Only the vertical hydraulic conductivity was increased for the layers above goaf. The impact of dewatering could be underestimated. Changes to the coal seam parameters is recommended.</p> <p>Water balance needs further discussion, for the post-closure modelling and for the discharge to other water courses, in addition to the error difference. Predicted baseflow impacts require further discussion as rates are different in tables and figures.</p> <p>A mine plan with schedule was not provided. For a 5 year mine plan, how was it applied, equally in yearly increments?</p> <p>No uncertainty analysis was detailed or discussed in the report, an uncertainty analysis could provide additional confidence in model predictions with</p>	<p>properties, reprocessing of seismic data, mapping and modelling of fault styles, fault juxtaposition analysis, shale gouge & fault membrane seal analysis, assessment of fault leakage potential, assessment of longwall subsidence on hydraulic properties. These studies have indicated that the Rewan aquitard is a competent aquitard at the site with no potential for natural flow pathways to hydraulically connect the Triassic and Permian formations. The study did identify the key risk for hydraulic connection is related to mine-induced longwall subsidence.</p> <p>Planned updates to groundwater flow model (GWFM):</p> <ul style="list-style-type: none"> • Sensible modelled fluxes and low water balance errors cumulatively and for discrete time intervals • Transient calibration, including flux targets for SW-GW interactions as per Section Error! Reference source not found. • Highly parameterised approach to calibration, with parameter bounds guided by (but not restricted to) field data • Hydraulic conductivity reduction with depth in accordance with Section Error! Reference source not found., nominally for Rewan Formation but also for other HSUs if supported by observed data • Presentation of modelled vertical hydraulic gradients • Detailed calibration sensitivity analysis • Time-varying material properties to include mined coal seam, not just layers above goaf • Type 3 predictive uncertainty analysis

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	<p>regards to: storage, hydraulic conductivity and storage after longwall mining, groundwater ingress, and climate change.</p> <p>Recommendations:</p> <ul style="list-style-type: none"> • Clear description of the conceptual model. • Provide a summary of model approaches, objectives and model level. • Validate the location and type of boundaries. • Calibrate the model with transient head targets, flow data, that preserve the vertical head gradients. • A review of the model mass balance as it includes negative recharge. • Improve the cumulative percentage error to be under 1%. • Discuss the flow component of the model. • Conduct a sensitivity analysis for the transient predictive model. 	
GHD 2013	This report does not contain any model criticisms or recommendations.	N/A
IESC 2013	<p>Important data gaps exist in the groundwater flow conceptualisation, especially in the deeper groundwater systems, most notably hydraulic head information. The interpretation is not considered to be consistent with expected groundwater flow for deeper formations, given regional geology and accepted regional groundwater flow directions within the GAB. insufficient data provided in the draft SEIS to substantiate the proponent's groundwater flow conceptualisation.</p> <p>The current groundwater model assumes the Rewan Formation will respond uniformly as an aquitard. More data are needed to predict the effect of potential subsidence induced fracturing in the Rewan Formation on leakage rates from the GAB to the coal seam. Information on the degree of groundwater connectivity between the coal seams and the GAB is essential to understand the potential impacts of this project.</p> <p>The source aquifer for the Mellaluka Springs Complex has not been determined, and as such it is not possible to accurately predict impacts from mining on these Springs. For both the Mellaluka and Doongmabulla Springs Complexes there is insufficient information on ecology and water chemistry. The Committee has little confidence in the capacity of the groundwater flow conceptualisation and groundwater flow model to predict the impact on these Spring Complexes.</p> <p>The proponent undertook a limited cumulative impact assessment including four other proposed projects in the region. There are, however, additional relevant proposed projects which should be included.</p>	<p>Hydrogeological conceptualisation has been updated to address the key issues raised by IESC, including:</p> <ul style="list-style-type: none"> • Drilling and installing monitoring sites to the west of the lease area to provide geological control and to assess Triassic and Permian pressures in the vicinity of the DSC to understand the deeper flow systems, the pressure gradients across the Rewan and to establish the source aquifer for the DSC. It is commonly accepted that flow moves up-dip in the Surat Basin on the northern side of the range due to discharge at the Dawson River and springs. Similarly, at the project site east of the groundwater divide, there is up-dip flow towards discharge locations at the project area. This is discussed in detail in Section 7. • Subsidence-induced fracturing was a major component of the Rewan connectivity research program. Findings from that research have informed the revised HCM in this report. • The GAB Springs Research program is leading to more defined understanding of how the DSC functions. New monitoring bores and VWP's and hydrochemical and isotopes surveys have identified that the Clematis Sandstone is the source aquifer for the springs. Nested sites at the springs and downstream of the springs have shown that the Clematis Sandstone is strongly artesian in this area and is likely restricted to the east, which is driving artesian pressure build up behind that restricted flow outlet. This is leading to pressures building up over geological time and driving discharge to those springs.

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	<p>The conceptual model would benefit from an assessment of regional faults.</p> <p>The Committee is not confident that the proponent's groundwater model will be able to accurately predict responses to perturbation of the groundwater system arising from the proposed mine.</p> <p>The Committee has significant concerns in relation to the use of no flow boundaries at most of the edges of the model domain and the truncation of the Clematis Sandstone (and other geological formations) on the western side in the numerical model. The Committee challenges the model boundaries, and the use of no flow boundaries without justification, as it might have profound effects on the model's predictions.</p> <p>The assessment of the height of the subsidence fracture zone above longwall mining was not based on local site data nor with due consideration of multi-seam mining. The connectivity of the fracture network and the relative increase in hydraulic conductivity of strata within this zone needs verification. Subsidence fracture zone height and hydraulic connectivity could have implications for the predictive results.</p> <p>The proponent's field data needs to be further integrated into the groundwater model to establish an appropriate set of values and ranges for model layers' hydraulic parameters for the Rewan Formation. The implications of an increase in the permeability of the Rewan Formation and variations to the local geology and the effects on regional groundwater processes need to be further explored.</p> <p>There remain important data gaps and modelling inaccuracies which bring into question the hydraulic conductivity values employed by the model.</p> <p>However due to uncertainty around model parameters for hydraulic conductivity and the characterisation of the Rewan Formation, conclusions on impacts to the GAB and springs need to be reconsidered.</p> <p>Revision of the groundwater model and more in-depth spring surveys to enable a more rigorous assessment of potential impacts on the Doongmabulla and Mellaluka Springs Complexes.</p> <p>The development of an appropriately scaled regional groundwater model and water balance, commensurate to the size of the development, to reduce uncertainty in regard to cumulative impacts.</p> <p>The conceptual groundwater model is not adequate nor underpinned by sufficient representative data. There is insufficient hydraulic head information, particularly in the deeper geological units.</p> <p>Due to inappropriate boundary conditions the Committee has no confidence in the results of the groundwater model. The Committee considers that the revised groundwater model is not adequate to assess the potential impacts.</p>	<ul style="list-style-type: none"> • The conceptual model has drawn on the Rewan research into fault behaviour at site and how this may influence Rewan connectivity. This includes dedicated research on reprocessing of seismic data, mapping and modelling of fault styles, fault juxtaposition analysis, shale gouge & fault membrane seal analysis, and assessment of fault leakage potential. • New field and laboratory measurements of K and S for the Rewan, Dunda and Clematis HSUs. Detailed analysis of Kx and Kz with depth across the Rewan aquitard. Integrated K datasets have established field-based statistical ranges for each HSU. <p>Planned updates to GWFM:</p> <ul style="list-style-type: none"> • Calibrated parameters to be more closely tied to field data (ie Section Error! Reference source not found.) • Additional justification on regional boundary conditions, potential sensitivity analysis on no flow boundaries • Detailed uncertainty analysis incorporating potential connectivity between the GAB and the coal seams based on RP5

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	<p>Groundwater flow in deeper aquifers would be anticipated to conform to the generally recognised regional westerly flow within the GAB from the eastern recharge zone towards the centre of the basin. The independent peer review of the groundwater model undertaken by URS also notes that the model flow direction is at odds, and is not consistent, with the regional flow direction and geology.</p> <p>The URS review of a draft version of the groundwater model recommends that the proponents validate the location and type of boundaries in the model.</p> <p>The model truncates geology on the western side of the numerical model, the no flow boundary condition employed forces the numerical model to indicate groundwater flow towards the Carmichael River based on limited available bore data.</p> <p>No-flow boundaries (particularly for the Triassic and Permian hydrogeological units) in the model need to be justified and appear to be based on the surface water catchments. As a consequence, the Committee has no confidence in the predicted groundwater flows in the Permian and Triassic Formations.</p> <p>There is uncertainty around the capacity of the Rewan Formation to act as an aquitard to limit vertical leakage between adjacent formations. Mean values of hydraulic conductivity are recommended to be used. The formation does not take into consideration any potential of faulting.</p> <p>The Committee is not confident that the proponent's groundwater model, based on the current conceptualisation will be able to accurately predict responses to perturbation of the groundwater system arising from the proposed mine.</p>	
Hydrogeologic 2014	<p>Transient calibration has not been undertaken, which is a model shortcoming that has been addressed via comprehensive sensitivity and uncertainty analysis.</p> <p>To improve the match of three bores in the southern Clematis outcrop would require increased recharge in this key area, and/or aquifer parameter changes, plus contemporaneous groundwater monitoring data for model validation, which is recommended for future investigation.</p> <p>The model stress period arrangement indicates annual increments for the first five years, which is acceptable; however, subsequent stress periods are 5-yearly to 2049, then 10-yearly to 2059, which is possibly a little coarse but not unreasonable; future modelling programs should review and/or refine this arrangement by testing model sensitivity to refined stress periods (no more than 1-2 years).</p> <p>Future model work programs are recommended to investigate refinements of the recharge to improve the match to southern Clematis water levels and to investigate the flow system in the Lake Galilee area. To improve the model matches at these three key</p>	<p>Hydrogeological conceptualisation has been updated to address the key issues raised by Hydrogeologic, including:</p> <ul style="list-style-type: none"> • Increased monitoring sites in the Clematis Sandstone west of the lease area to better understand flow dynamics in this GAB aquifer. A thorough review of long-term groundwater levels and vertical gradients has provided insights that suggest the Clematis Sandstone is artesian to the west of Surprise Creek and that a flow restriction occurs near Surprise Creek that reduced the eastern flow component of the aquifer sufficiently to raise pressures in this formation to the west. These artesian pressures then drive discharge to the springs. • Drilling and installing monitoring sites to the west of the lease area to provide geological control and to assess Triassic and Permian pressures in the vicinity of the DSC to understand the deeper flow systems, the pressure gradients across the Rewan and to establish the source aquifer for the DSC.

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	<p>Clematis bores would require increased boundary inflows from the south and/or increased rates of modelled Clematis recharge, and/or aquifer parameter changes.</p> <p>Ongoing investigations and monitoring in the area of groundwater flow from the south to north, and a significant flow to the west (and GAB) area are required to provide data for future validation of the model in terms of layer elevations and properties for aquifers/aquitards (including geochemistry and isotopes), groundwater levels and quality and surface-groundwater interactions (notably river and spring flows/levels and geochemistry).</p> <p>It is recommended that model sensitivity be explored for inactive cells immediately east of the Clematis outcrop, and that this boundary condition be tested in the next model update by applying the “dummy layer/parameter” treatment to the currently inactive cells in layers 4 and above in this central area.</p> <p>It is suggested that layer 12 of the model be split into 2 separate layers, this model refinement would be required in the future to help investigate aquifer connectivity with Mellaluka Springs, where significant drawdowns have been predicted, in conjunction with the data that will be acquired from the three monitoring boreholes recently drilled in this area.</p> <p>An involuntary model error was discovered where hydraulic parameters were different on Layer 4 in the eastern half of the model domain. Model design should aim for the implementation of parameters that warrants refinement in the future to either ensure consistent parameter values across all layers that represent specific units (or to objectively justify the parameter values applied).</p> <p>Further to the drilling on the Rewan Group, further tests be undertaken (chemical and isotope testing of pore water samples from the preserved core) to provide formation-scale aquitard parameters for input to the model.</p> <p>Future investigations should consider applying appropriate episodic recharge volumes to short periods, perhaps using data from the very wet periods of 2010-11 and 2011-12 (rather than annual averages) to validate the model.</p> <p>Further investigation of vertical head gradients is recommended during future work programs, especially once additional data is obtained in relation to the influence of the Rewan aquitard.</p> <p>Future refinements should consider; Lake Galilee recharge/discharge features, eastern outflow boundary conductance parameter consistency across all aquifers, and evaporation rate assumptions and sensitivities for post-closure pit void.</p>	<ul style="list-style-type: none"> • The conceptual model has drawn on the Rewan research into fault behaviour at site and how this may influence Rewan connectivity. This includes dedicated research on reprocessing of seismic data, mapping and modelling of fault styles, fault juxtaposition analysis, shale gouge & fault membrane seal analysis, and assessment of fault leakage potential. • New field and laboratory measurements of K and S for the Rewan, Dunda and Clematis HSUs. Detailed analysis of Kx and Kz with depth across the Rewan aquitard. Integrated K datasets have established field-based statistical ranges for each HSU. • Updated nested hydrograph analysis has provided insights on the vertical hydraulic gradients across the site and helped to better understand the mechanisms for DSC discharge, the extent of artesian heads in the Clematis, Dunda Beds and upper Rewan formations, and the impacts of landholder pumping and dewatering on the Permian HSUs. • A comprehensive surface water-groundwater investigation has been undertaken to inform the updated HCM and groundwater model. <p>Planned updates to GWFM:</p> <ul style="list-style-type: none"> • Active modelled area to be reviewed and updated if necessary • Additional vertical refinement of model layers in the area of mining • Transient calibration to groundwater heads, including trends from environmental stresses and pumping as assessed in Section Error! Reference source not found. • Calibration to be undertaken as a combination of highly parameterised and zone-based, indicated by conceptualisation and data availability • Updated recharge information as per Section Error! Reference source not found., incorporating episodic recharge rates • Updated stress period durations to more appropriately represent mine plan • Explicit simulation of post-closure pit void, including time-varying material properties, direct incident rainfall and evapotranspiration surface based on pit base elevation

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GHD 2015	<p>The model covers an active model domain of approximately 8,600 square kilometres. Consequently, there are limited data across a large geographical area, and as mentioned in the bioregional assessment for the area published by CSIRO (Evans et al, 2014), very limited hydrogeological information is available for the model region.</p> <p>It is acknowledged limited calibration and stratigraphic data is available for the area outside of the mine lease, and techniques have been adopted to interpolate discrete observations across a broad area.</p> <p>Of the 168 realisations in the sensitivity analysis, only four were characterised as having a potentially significant change in impact and an insignificant change in model calibration (ie indicative of uncertainty that will require further investigations and data to resolve. These results apply to the hydraulic conductivity of the Tertiary clay in the vicinity of the Mellaluka springs complex, where three additional bores have since been drilled).</p> <p>As the project continues to evolve, the groundwater model will continue to be updated to reflect advances in understanding of the regional hydrogeological conditions.</p> <p>Limited data are available within the western region of the model to develop comprehensive conceptualisations regarding groundwater flow conditions, a point that is documented in the bioregional assessment for the area published by CSIRO (Evans et al, 2014).</p> <p>The following recommendations are provided to guide future investigations and modelling studies, which should also consider the recommendations provided by the independent reviews completed to date:</p> <p>Update calibration targets based upon subsequent groundwater level data collected over the model domain, particularly within the GAB units to the west of the mine.</p> <ul style="list-style-type: none"> • Re-calibrate the model, including transient calibration, using operational and regional monitoring data. • Review modelled discharge to the Carmichael River against the updated stream gauging data accrued over the period since the model development. • Incorporation of the weathered zone into the model. • Review of recharge parameters, particularly in the GAB units. • Update of the model to represent any revisions in the proposed mine plan, including pit sequencing, pit geometry, proposed dewatering methods and closure methods and timing. • Split the existing model layer 12 into two layers to provide separation between the early Permian basement and the D-seams underburden. 	<p>Hydrogeological conceptualisation has been updated to address the key issues raised by GHD (2015), including:</p> <p>Drilling and installing monitoring sites to the west of the lease area to provide geological control and to assess Triassic and Permian pressures in the vicinity of the DSC to establish source aquifer, and to better constrain regional groundwater flow systems.</p> <p>Planned updates to GWFM:</p> <ul style="list-style-type: none"> • Update to GWFM based on updates to HCM, including explicit representation of weathered zone as per Section Error! Reference source not found. • Enhanced vertical discretisation in the vicinity of the mine • Transient calibration with updated targets, including surface water discharge fluxes where available • Transient recharge fluxes representing climate during history-matching period • More detail in sensitivity and uncertainty analyses

Table 6.1 **Approach to address past project criticism**

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	Thus the accuracy of the predicted river flows and impacts could be enhanced in future modelling work by calibrating river conductance values against reliable baseflow targets for the Carmichael River.	
CSIRO 2019	<p>The review found that the modelling used is not suitable to ensure the outcomes sought by the EPBC Act conditions are met.</p> <p>Comparison of the SEIS model and the two alternate re-run models shows that the location of the western model boundary has little impact on drawdown predictions. However, these re-runs were not calibrated, thus reducing confidence in the predictions that they make. A re-calibration is warranted to improve confidence in model predictions.</p> <p>The SEIS model includes the most recent calibrated parameter set developed for the Carmichael Coal Mine in 2013. Although, it must be noted that model errors increased from 4.5% RMS error reported for the SEIS model to 7.2% when compared to updated data following resurveying bore locations.</p> <p>Representation in the model of surface water flows for the Carmichael River over-predicts flows from the river into the groundwater. As a result the groundwater drawdown in the alluvium (Carmichael River GDEs) will be greater than the predicted model.</p> <p>Parameterisation of the Rewan Formation and Clematis Sandstone by the SEIS model. Calibrated hydraulic conductivity values for the Rewan Formation are very low compared with measured values, which minimises vertical water movement, and hydraulic conductivity values for the Clematis Sandstone are high, which increases the lateral transfer of water.</p> <p>The approach used to model potential impacts to the groundwater system due to mining indicates that the model will under-estimate the amount of drawdown predicted at the DSC and the Carmichael River GDE as a result of model representation of:</p> <ul style="list-style-type: none"> • The unrealistically high modelled flow in the Carmichael River. • Error in the bore heights used to calibrate the model. • Hydraulic conductivity in the Clematis Sandstone and Rewan Formation model layers. <p>Recommendations:</p> <p>Future updates of the model should also use stream flow as one of the calibration parameters;</p> <p>Guidance for uncertainty analysis should be considered in future model updates.</p> <p>Model updates should include recalibration, and clearly define bore reference levels, how they have changed over time and how these changes affect model prediction and performance.</p> <p>Recalibration should include revised bore heights to provide confidence that captured evapotranspiration</p>	<ul style="list-style-type: none"> • A comprehensive groundwater-surface water investigation has been undertaken to inform the updated HCM and groundwater model. This study has assessed both creek flows, creek interactions with groundwater, as well as spring typology and water balances. • New field and laboratory measurements of K and S for the Rewan, Dunda and Clematis HSUs. Detailed analysis of Kx and Kz with depth across the Rewan aquitard. Integrated K datasets have established field-based statistical ranges for each HSU. • Drilling and installing monitoring sites to the west of the lease area to provide geological control and to assess Triassic and Permian pressures in the vicinity of the DSC to establish source aquifer. A comprehensive hydrogeochemistry and isotopes analysis program has also independently confirmed a Triassic source aquifer for the DSC. <p>Planned updates to GWFM:</p> <ul style="list-style-type: none"> • Recalibration to all available data, including fluxes to surface water • Any changes in model bore heights to be documented • Calibration to assign parameters consistent with HCM • Sensitivity analysis to include relative composite sensitivity • Type 3 (Monte Carlo) predictive uncertainty analysis, including assessment of mining-induced hydraulic parameter changes

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	<p>is not limiting drawdown to the DSC and the Carmichael River GDE.</p> <p>Future model updates should use locally appropriate parameterisations.</p> <p>Sensitivity analysis undertaken for future model updates should seek to assess cumulative sensitivity.</p> <p>Future model updates should include analysis of the sensitivity of the model to parameter changes due to underground mining.</p> <p>To constrain the source aquifer(s) of the DSC, a more sophisticated statistical analysis of hydrochemistry data is required. This includes assessing a wider variety of groundwater and surface water analytes, as well as appropriate use of isotope hydrochemistry analysis.</p> <p>Installation of bores to monitor the groundwater system in the Dunda Beds and Rewan Formation (upper Rewan and lower Rewan) at existing monitoring points in the west of the central zone would allow an assessment of any dewatering impact propagating through the Rewan Formation (in effect, nested monitoring bores). Ideally all units from outcrop to sub-Joe Joe coal (Jericho Formation) would be monitored.</p> <p>It is strongly recommended that the monitoring program includes stream flow gauging upstream and downstream of the mine area. Additionally, an improved and re-calibrated flow-discharge relationship for each gauge would improve the accuracy of the data.</p> <p>It is not plausible and reasonable to state unequivocally that the Clematis Sandstone is the sole source aquifer for the DSC, as sufficient uncertainty surrounding hydrogeochemistry, inter-aquifer connectivity and groundwater flow (Currell et al., 2017; Lewis et al., 2018; Webb et al., 2015) exists to necessitate a precautionary approach to the conceptualisation, as ruled by Land Court of Queensland (2015).</p>	

7 Summary and recommendations

The main summary points from the updated modelling study include:

- Model updated to meet Environmental Authority (EA) Condition E9, while addressing past review criticisms of the SEIS.
- Model rebuilt aligned with updated conceptualisation and datasets including geological model, groundwater pressures, groundwater drawdown and mine dewatering bore rates. Knowledge from Rewan Research and GAB Spring Research packages (i.e. spring conceptualisation and discharge volumes) incorporated.
- As noted by T Murray (2022), tying in the local Rewan Research model to the Bioregional assessment model highlighted some very significant mismatches and worrying errors. Murray recommended that a full review of the broader Bio-regional assessment model is warranted.
- Model history-matching and predictive uncertainty analysis used pilot points and PESTPP-IES with 500 parameter realisations developed.
- Results predict that the open cut (OC) only scenario will not breach the DSC drawdown threshold of 0.2 m for the base case or majority of ensemble of realisations.
- Although the OC basecase and the majority of realisations do not breach DSC drawdown thresholds, significant modelled drawdown emanates from the OC F and G pits. This is caused by the assumption that Clematis Sandstone exists in this region.
- Modelling of the SEIS mine plan using the previous model fracturing assumptions (Scenario A) associated with underground mining, results in base case drawdowns that do not breach the DSC 0.2 m drawdown threshold. These are comparable to the SEIS (2013) model results.
- Modelling of the SEIS mine plan using updated fracturing and relief zone assumptions (Scenario B), results in base case drawdowns that do breach the 0.2 m drawdown threshold, but only in the order of 5-10 cm.

The following recommendations are made:

- The groundwater system is complex, with vertical hydraulic gradients evident within the Clematis Sandstone. Further refinement to model layering within this unit may be required in future.
- Drawdown in the Clematis is exacerbated in the southern area of the mine, largely due to the interpreted/assumed geological layering. Further drilling is recommended to confirm the geology in this area (outcrop/subcrop, thickness and extent).
- Based on drilling outcomes, further Clematis, Bandanna and/or Colinlea monitoring bores may be required in the southern region to monitor drawdown impacts, which potentially could emanate from OC F and G pits. This is in addition to previously recommended bores to be installed in the western portion of the mining lease, east of the DSC.
- The model tends to simulate hydraulic heads higher than measured in regional discharge areas (i.e. heads <220 mAHD). Further investigation into this may be warranted to identify whether this is a regional throughflow process or whether groundwater may be discharging at greater rates within the model domain (e.g. greater evapotranspiration).

- A large amount of uncertainty remains associated with fracturing above and relief zone around, underground mining areas. Predictions appear to be sensitive to how these are simulated but, to date, there are no site data available to inform how the local system behaves. Updated knowledge, where available, should be used within the next 5-year model review with accompanied future predictive uncertainty analysis.
- Due to the current uncertainty associated with fracturing above and relief zone around, underground mining areas, it recommended that GMMP develops groundwater drawdown thresholds that are associated with the OC mining scenario only, at this stage.
- Future GAB Spring Research studies will concentrate on ecological water requirements (EWRs) of springs. Future modelling should include updated EWRs and associated thresholds.

References

- Anderson MP & Woessner WM 1991, *Applied groundwater modeling*. First edition. Academic Press.
- Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A & Boronkay A 2012, *Australian groundwater modelling guidelines*. Waterlines report series number 12. National Water Commission.
- Bioregional Assessment Programme 2014, Galilee top of formation elevation v03, Bioregional Assessment Derived Dataset, accessed 12 May 2022, <http://data.bioregionalassessments.gov.au/dataset/8911f763-a618-452f-829b-58497369f8e8>.
- Bioregional Assessment Programme 2015, GAL Group 2 contour data, Bioregional Assessment Derived Dataset, accessed 18 April 2022, <https://data.gov.au/data/dataset/803b0f5c-acb8-4adf-9ae1-3cb385ed4061>.
- BRS 2010, *Land use of Australia*, version 5, 2010-11, retrieved from Australian Government Department of Agriculture, Water and the Environment, <https://www.awe.gov.au/abares/aclump>.
- BoM 2022, *Maps of average conditions*, retrieved from Bureau of Meteorology, <http://www.bom.gov.au/climate/averages/maps.shtml>.
- Doherty 2016, *PEST Model-independent parameter estimation user manual part I: PEST, SENSAN and Global Optimisers*. Sixth edition. Watermark Numerical Computing.
- EMM 2022a, Carmichael Coal Mine: RP1.6 Hydrogeological conceptualisation review and updated groundwater modelling, Report No1: Data Review and Conceptualisation Report, prepared for Bravus Mining and Resources, June 2022.
- Environmental Simulations Incorporated 2021, *Guide to using Groundwater Vistas version 8*.
- Fandrich R 2016, *Measurements and modelling of evaporation from abandoned mine pit lakes*, AusIMM Life-of-Mine 2016, Brisbane.
- GHD 2013a, Carmichael Coal Mine and Rail Project SEIS Appendix K1: Mine Hydrogeology Report, Report prepared for Adani Mining Pty Ltd.
- GHD 2013b, Carmichael Coal Mine and Rail Project SEIS Mine Hydrogeology Report Addendum, Report prepared for Adani Mining Pty Ltd, 24 October 2013.
- Merrick N 2017, Recent Advances in Groundwater Modelling for Coal Mines, Mine Subsidence Technological Society, Tenth Triennial Conference, November 2017.
- Merrick N 2021, Rewan Formation Connectivity Research Plan, Research Package 5.4: Assignment of Hydraulic Properties from Supplementary Field Work and Existing Data Sources, Report prepared for Bravus Mining and Resources Pty Ltd.
- Middlemis H & Peeters LJM 2018, *Uncertainty analysis – guidance for groundwater modelling within a risk management framework*. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia 2018.
- Murray T 2022, *unpublished raw data inferring hydrostratigraphy of the CCM area*.
- Panday S, Langevin CD, Niswonger RG, Ibaraki, Motomu & Hughes JD 2013, MODFLOW-USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p.
- Panday S 2022, USG-Transport Version 1.10.0: The Block-Centered Transport Process for MODFLOW-USG, GSI Environmental, Jun 2022, <http://www.gsi-net.com/en/software/free-software/UST-Transport.html>

Shah N, Nachabe M & Ross M 2007, Extinction depth and evapotranspiration from ground water under selected land covers, Groundwater, Volume 45, Issue 3, 2007.

Turvey C., Skorulis A., Minchin W., Merrick N. P., & Merrick D. P. 2015, Galilee Basin Hydrogeological Model, milestone 3 report for Geoscience Australia, Heritage Computing Pty Ltd trading as HydroSimulations, November 2015.

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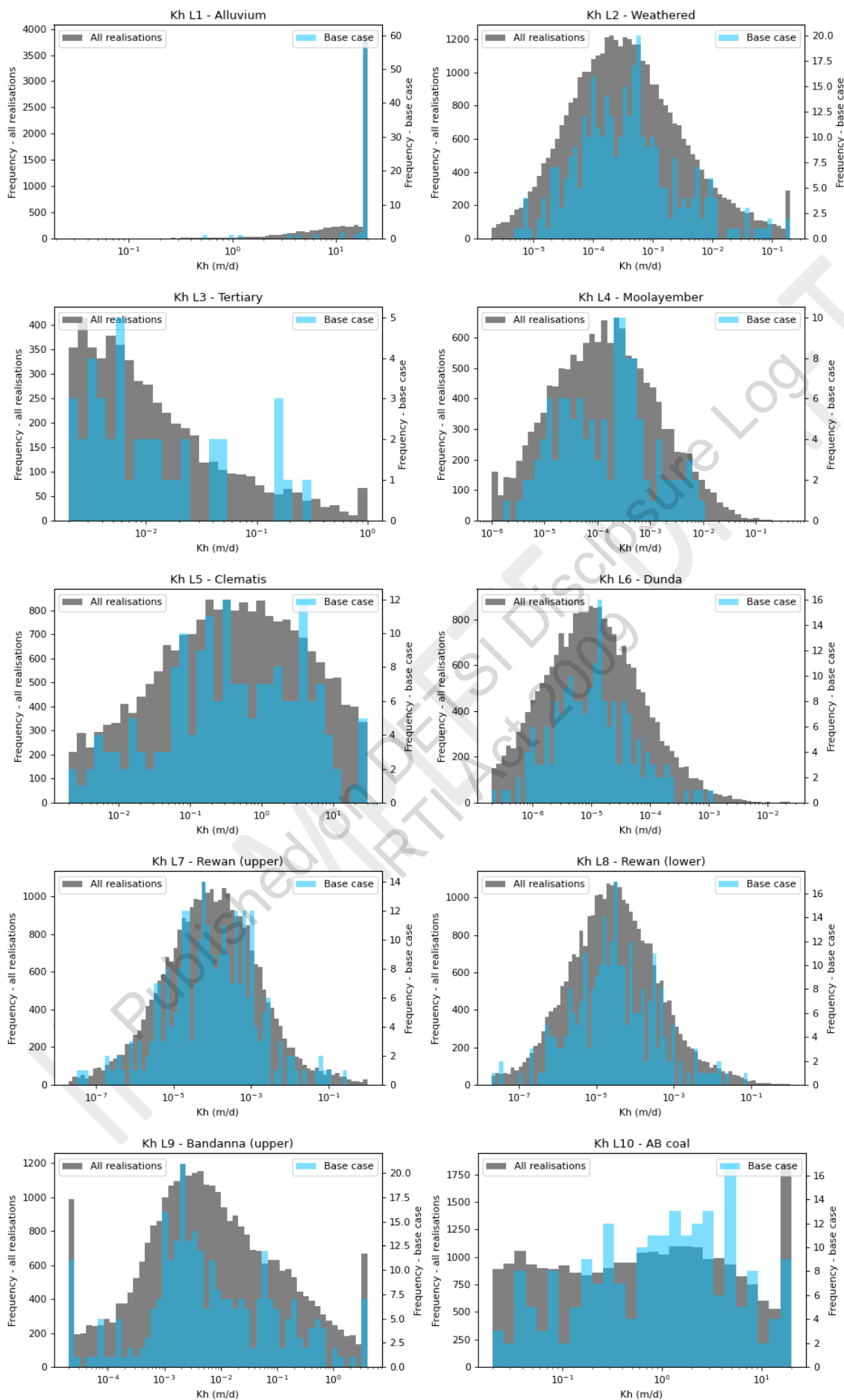
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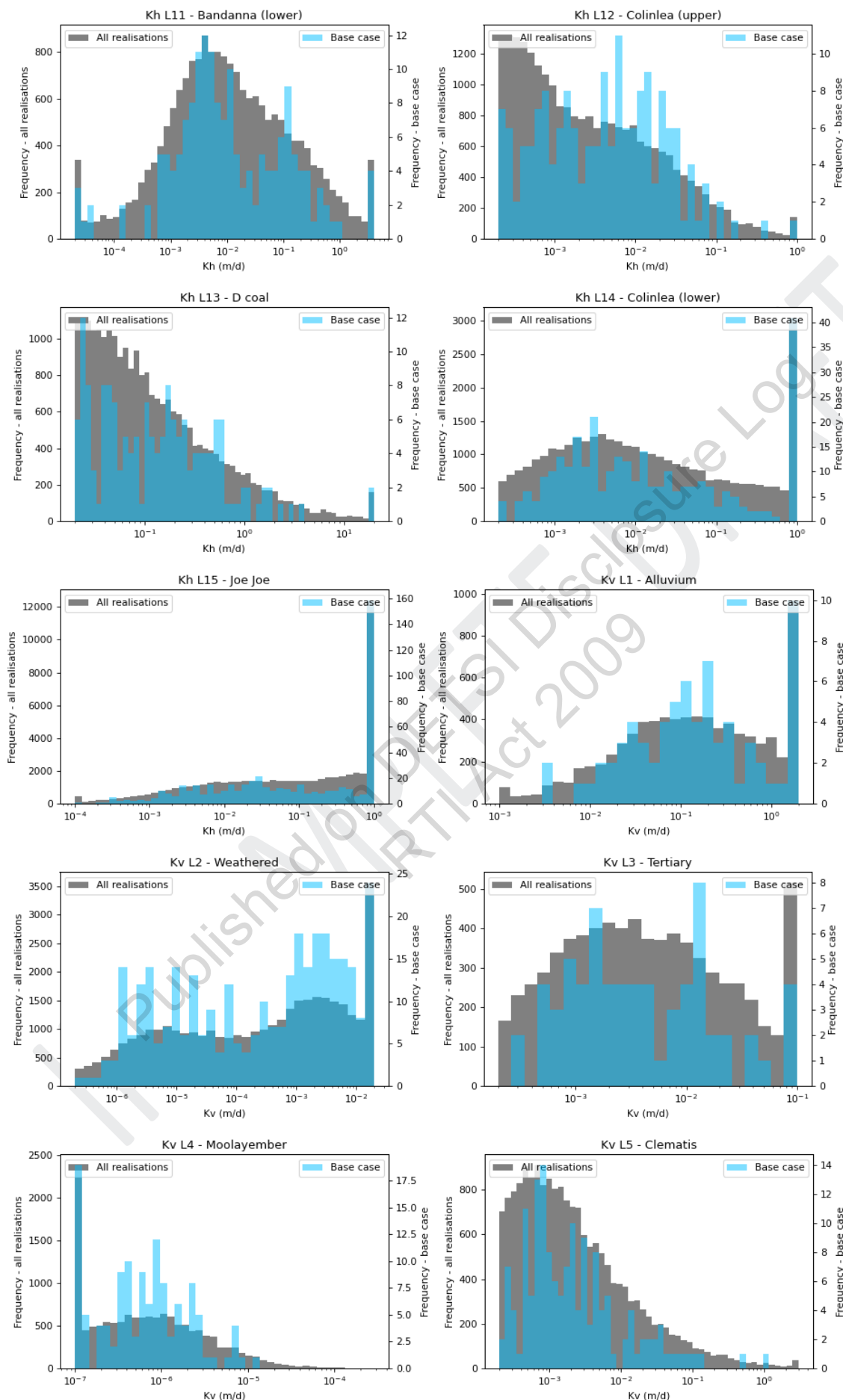
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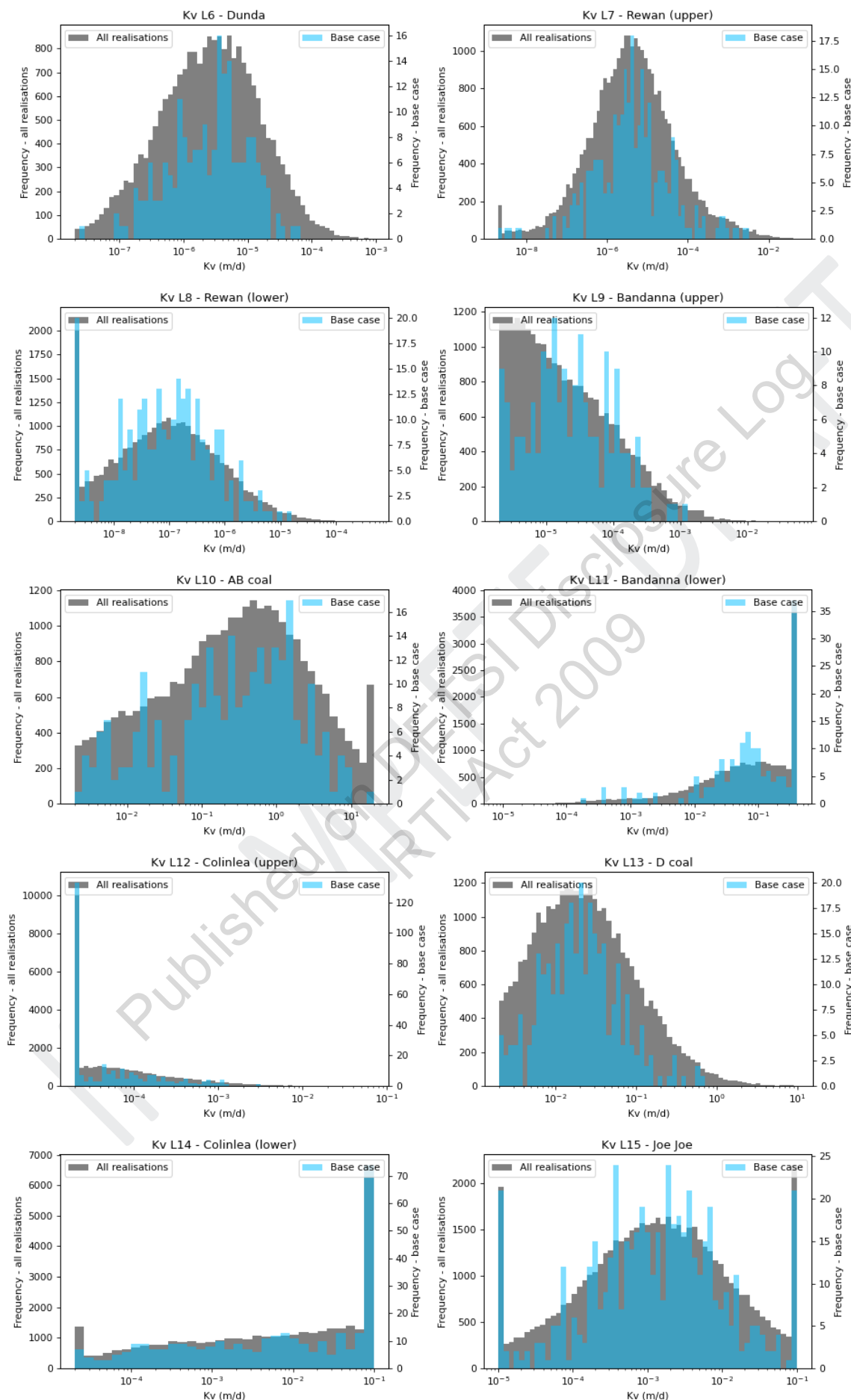
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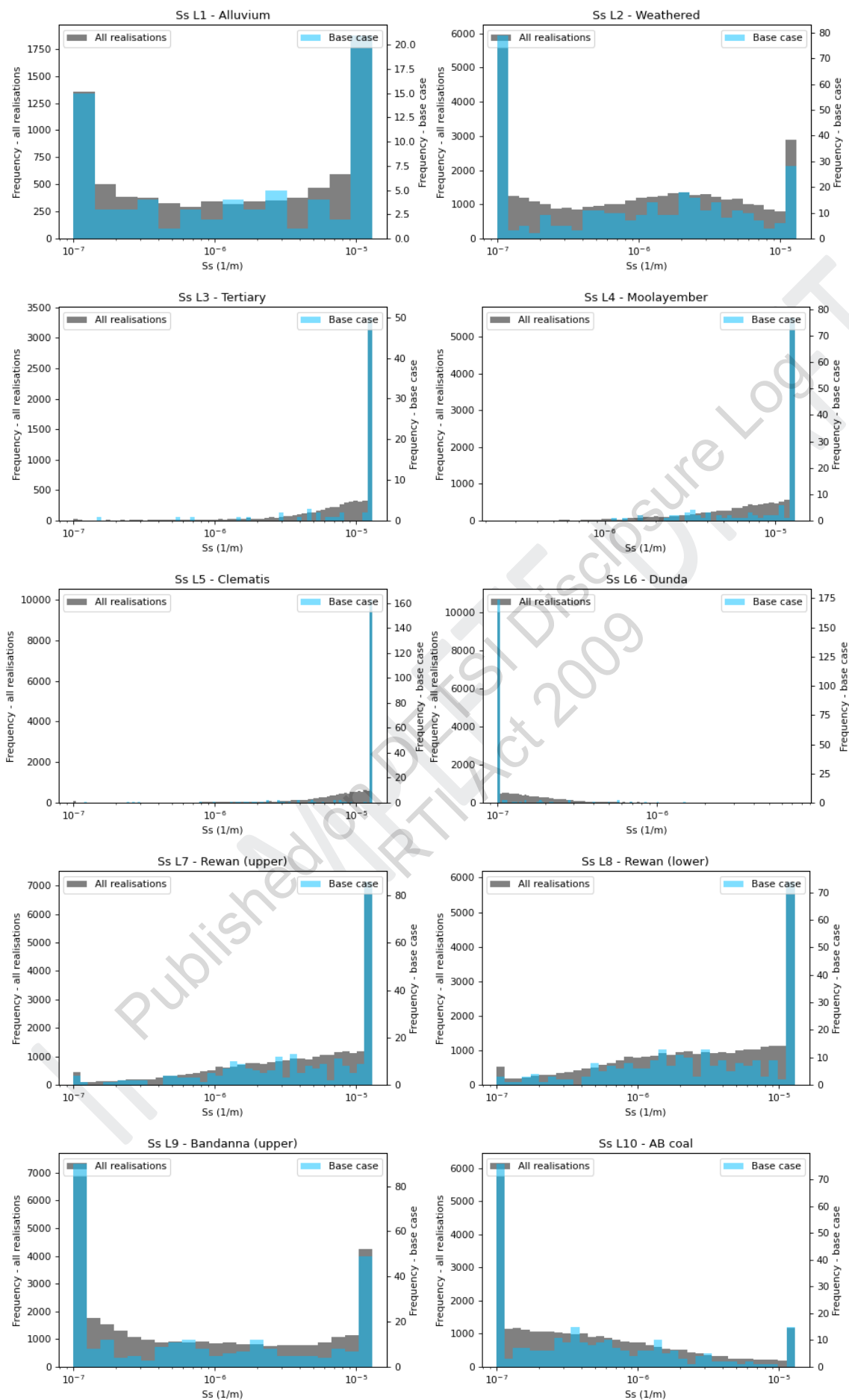
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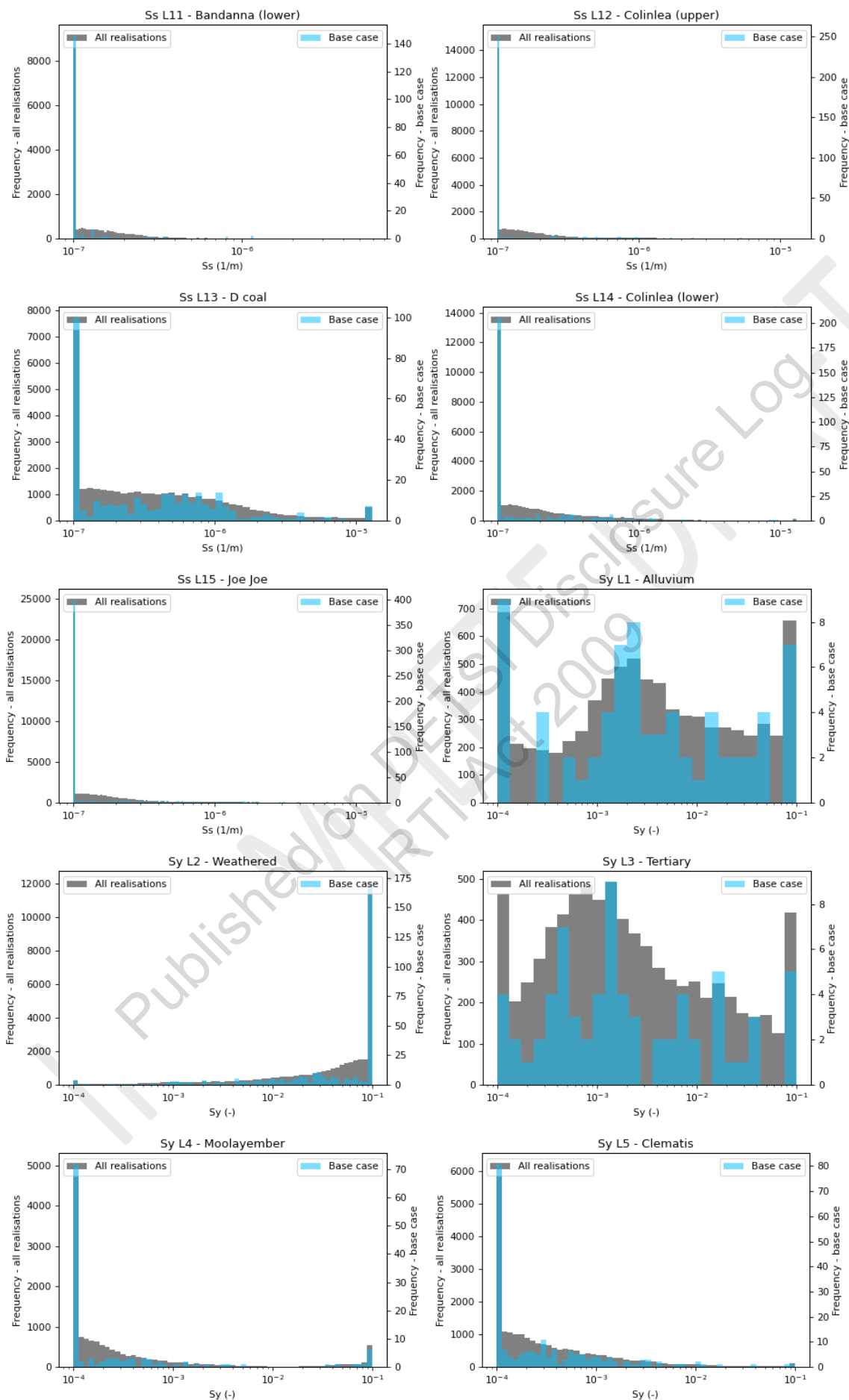
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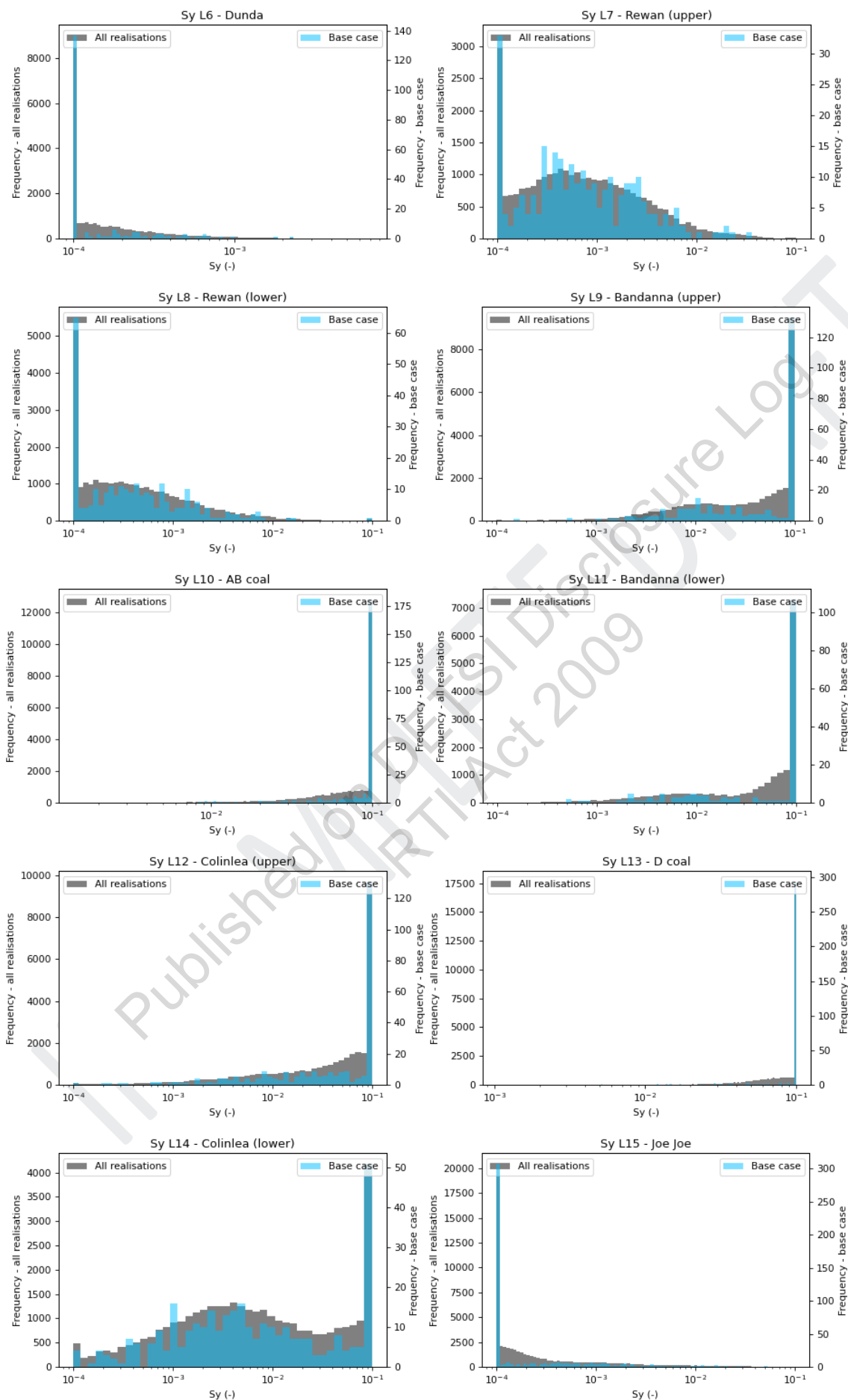


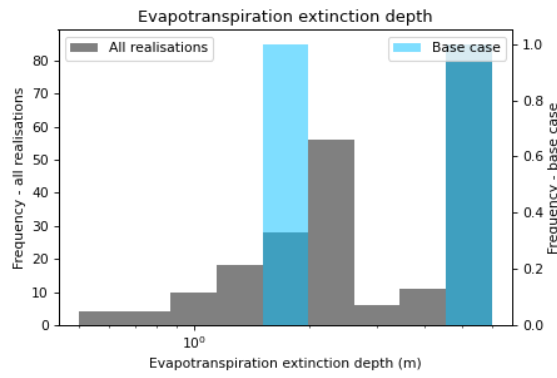
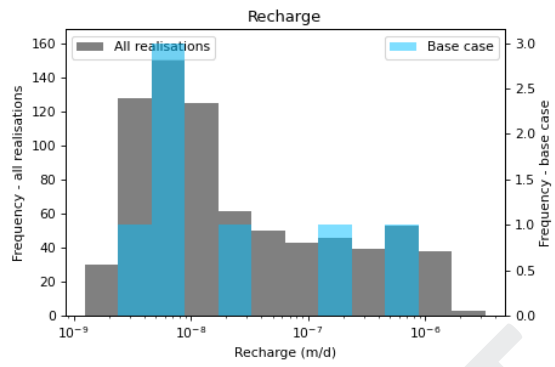
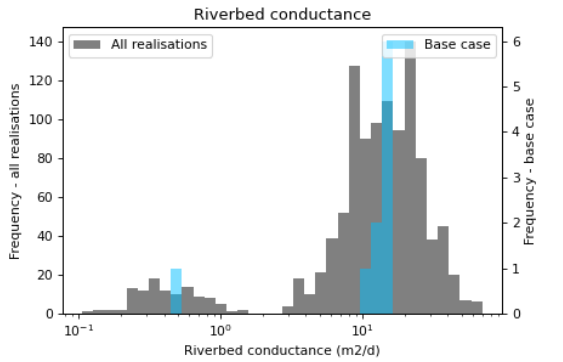
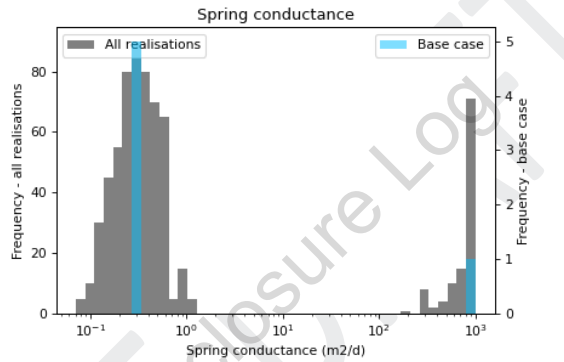






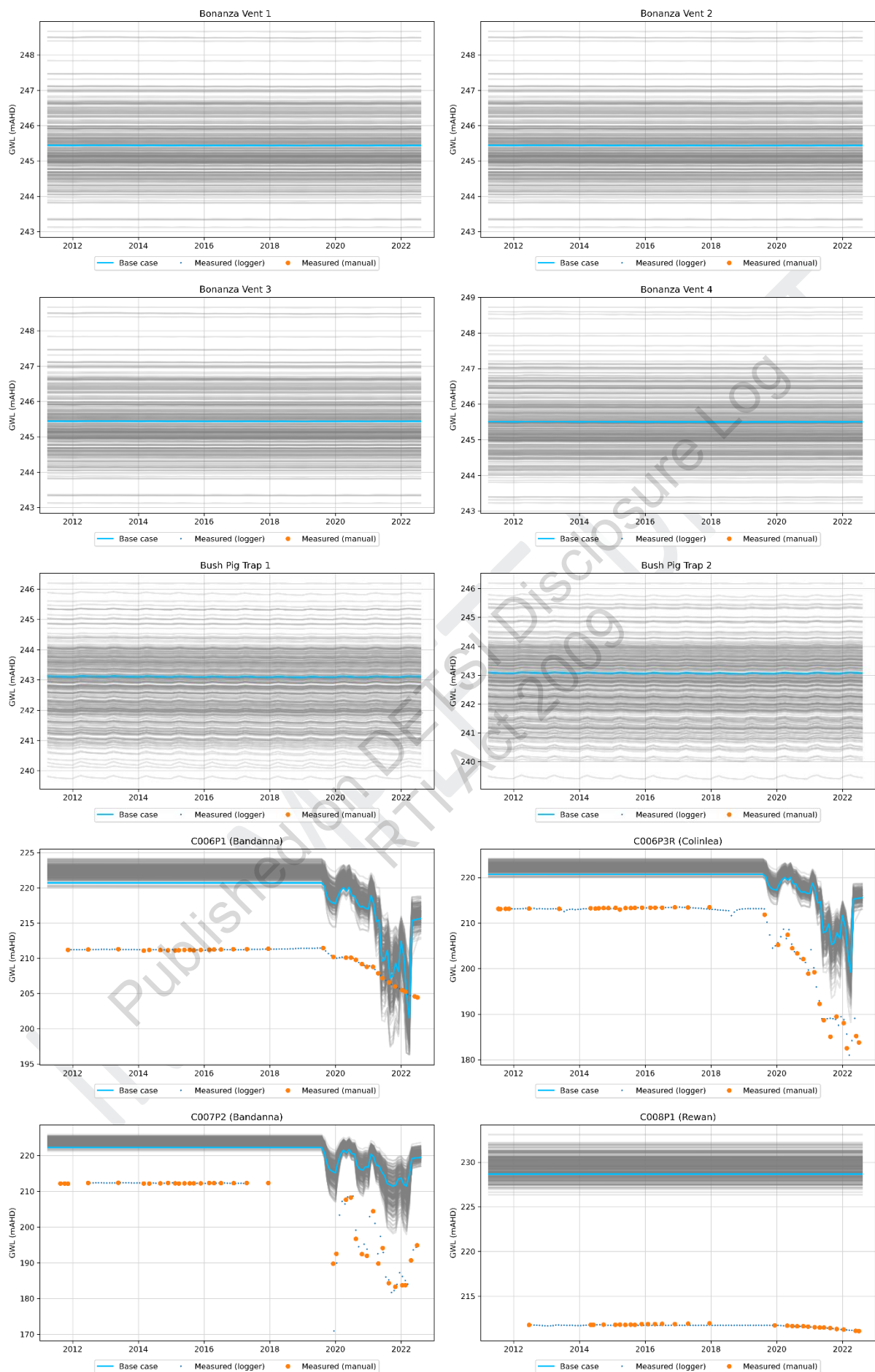


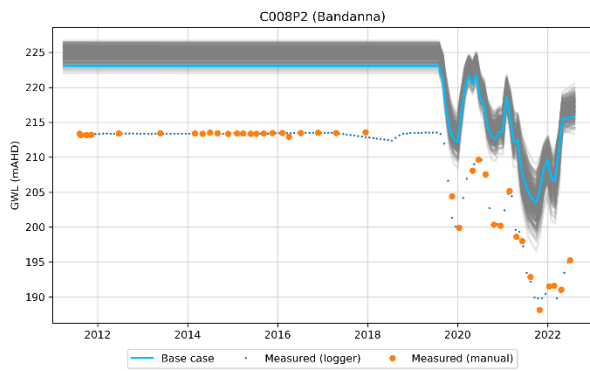
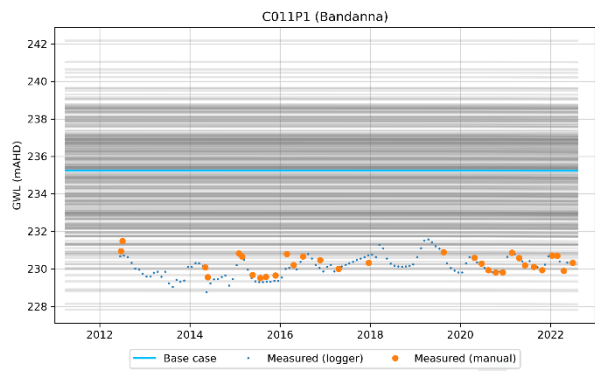
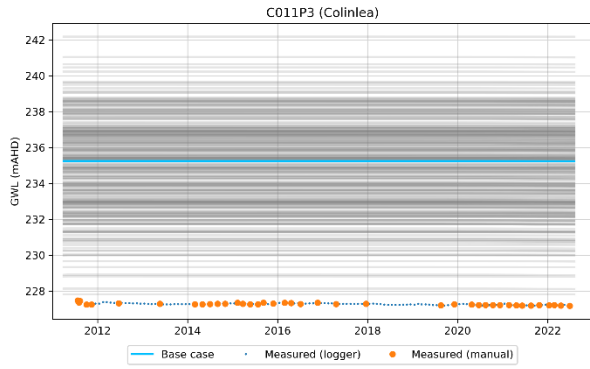
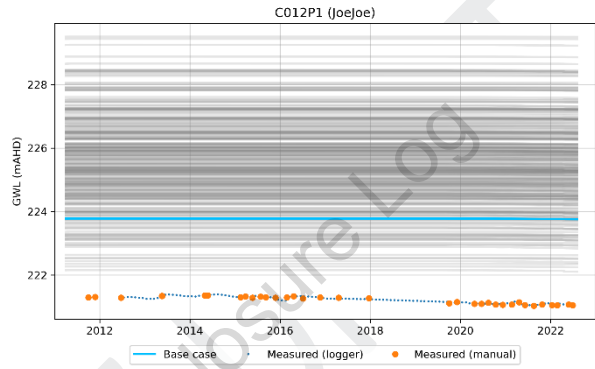
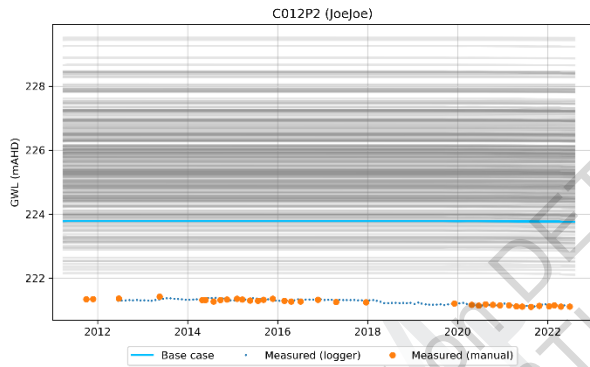
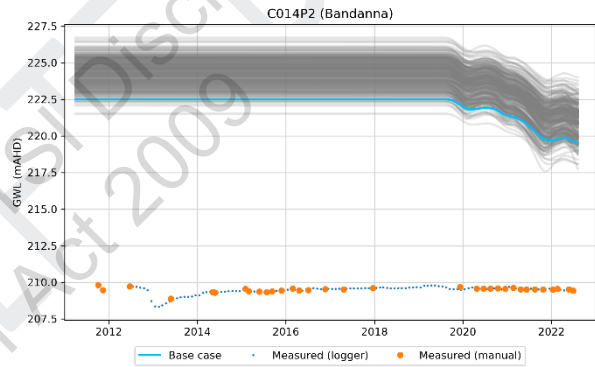
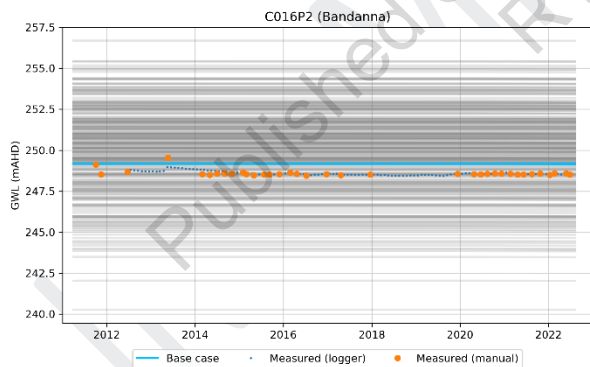
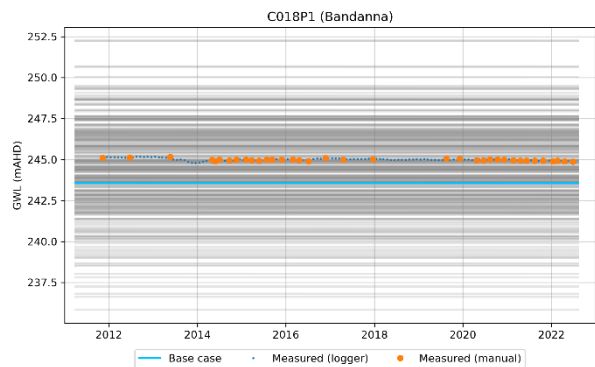
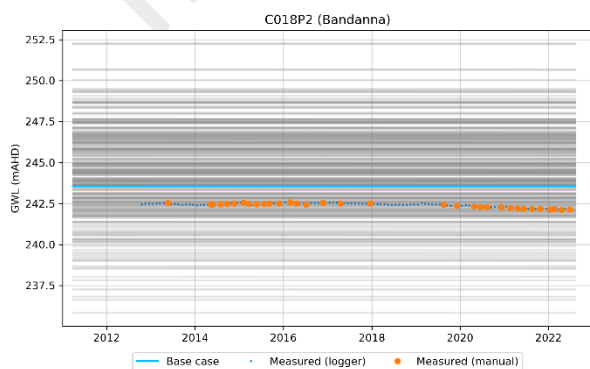
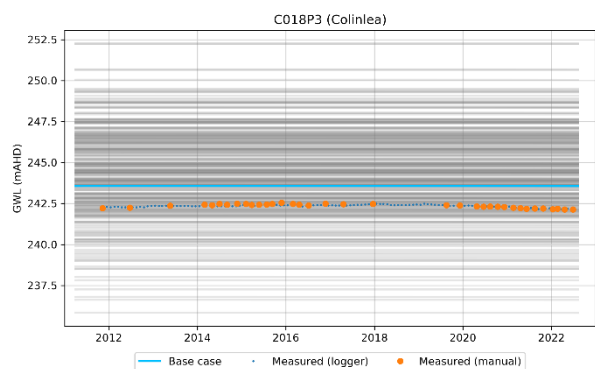




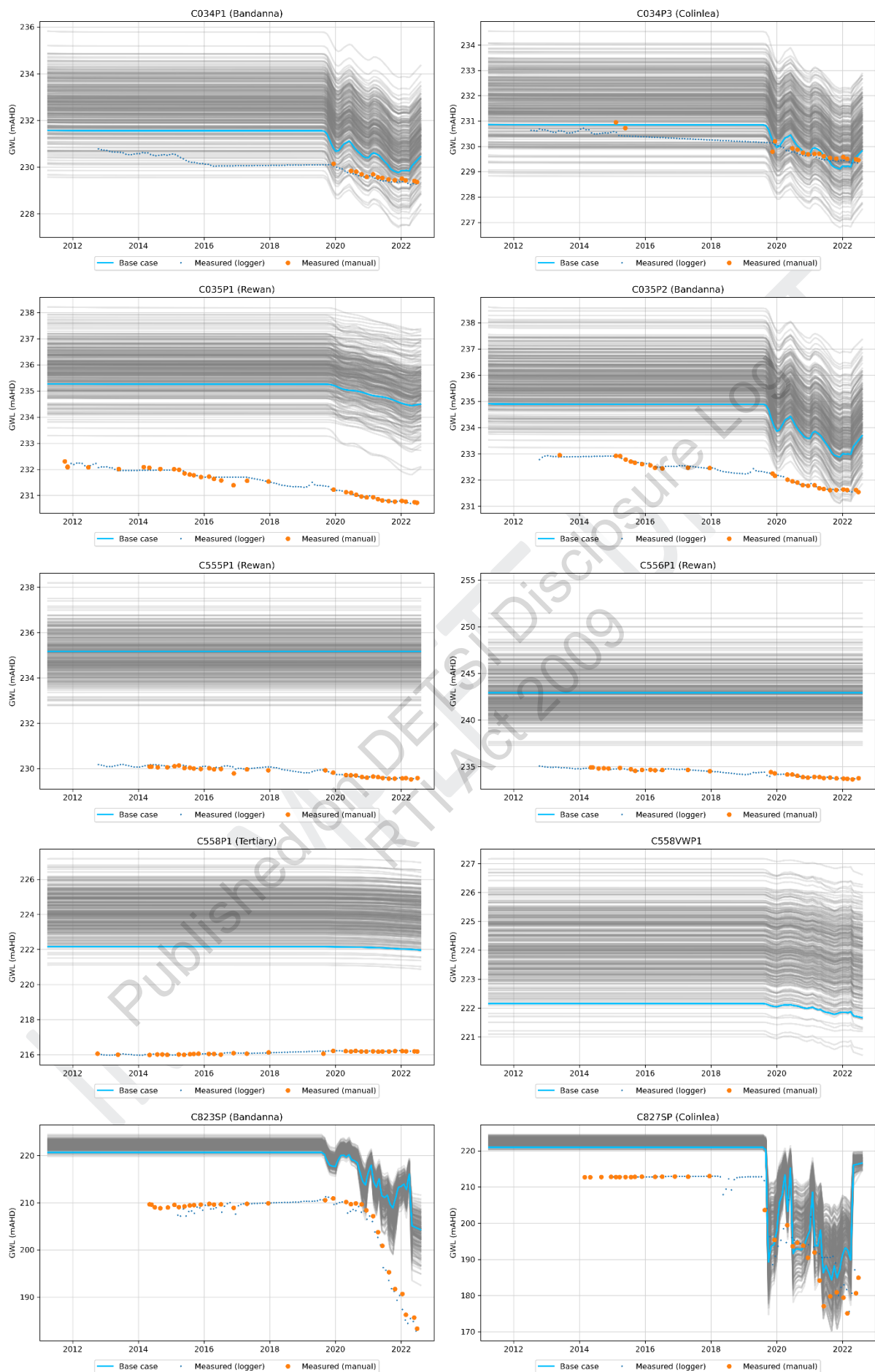
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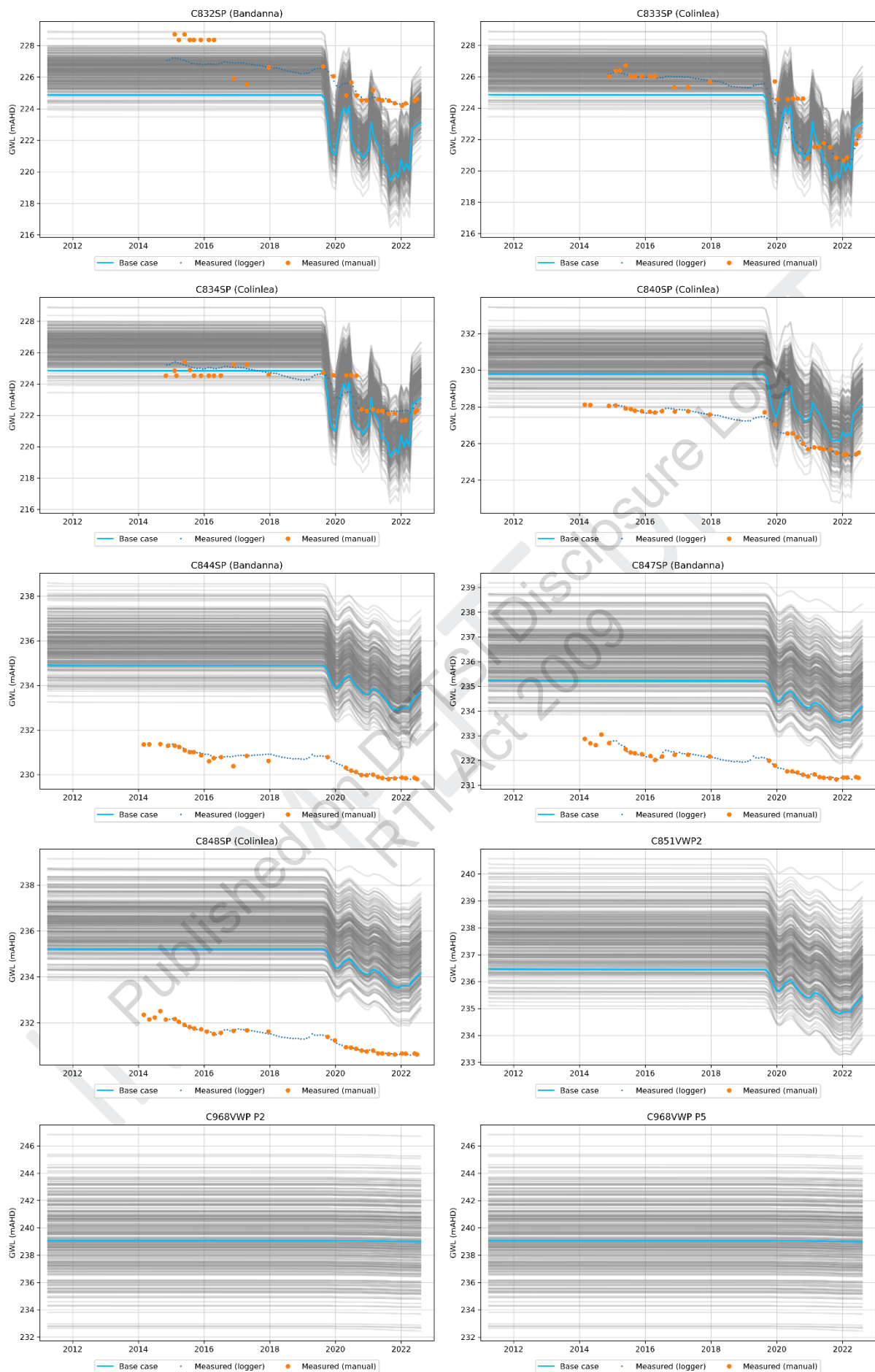
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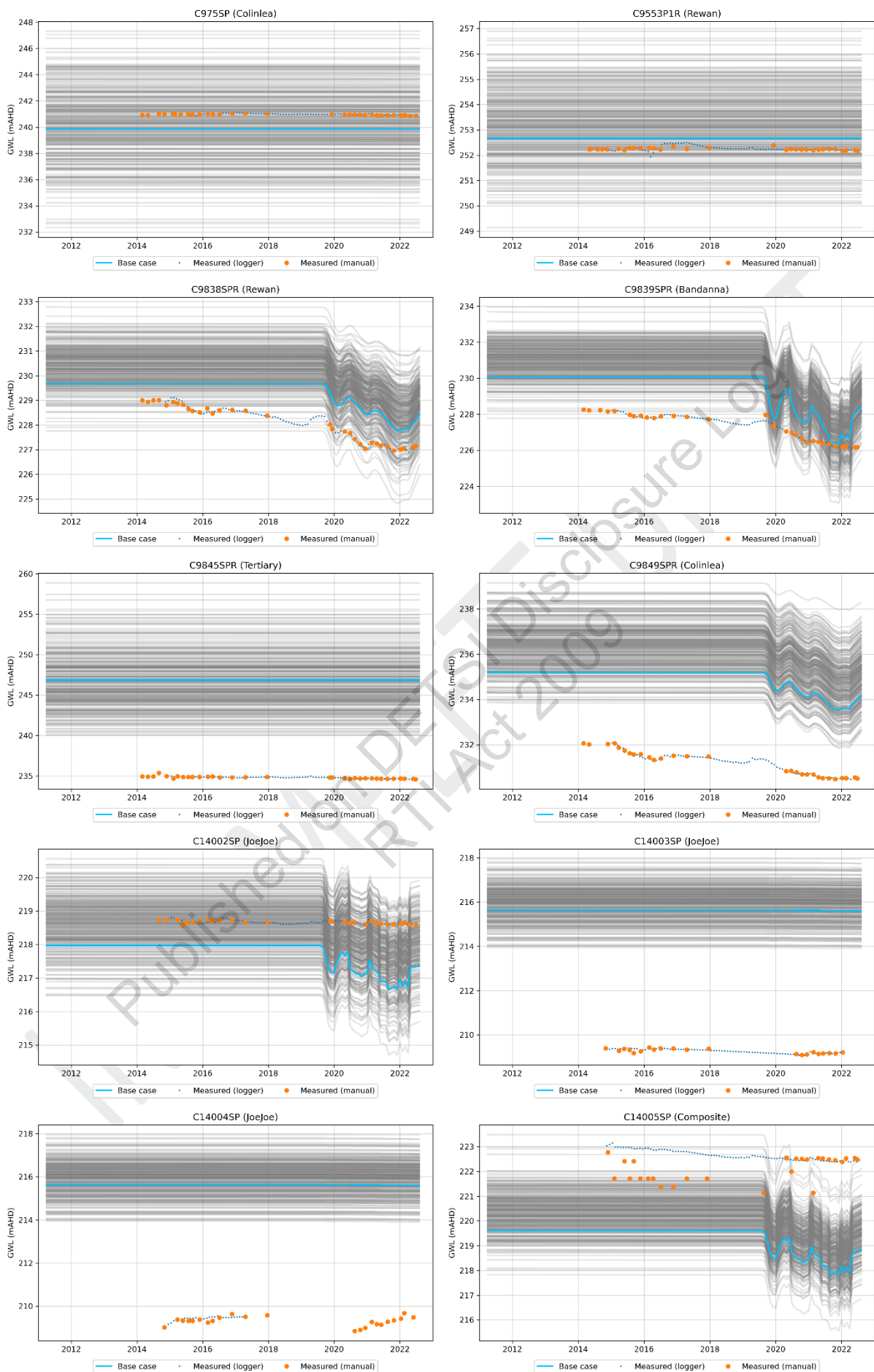


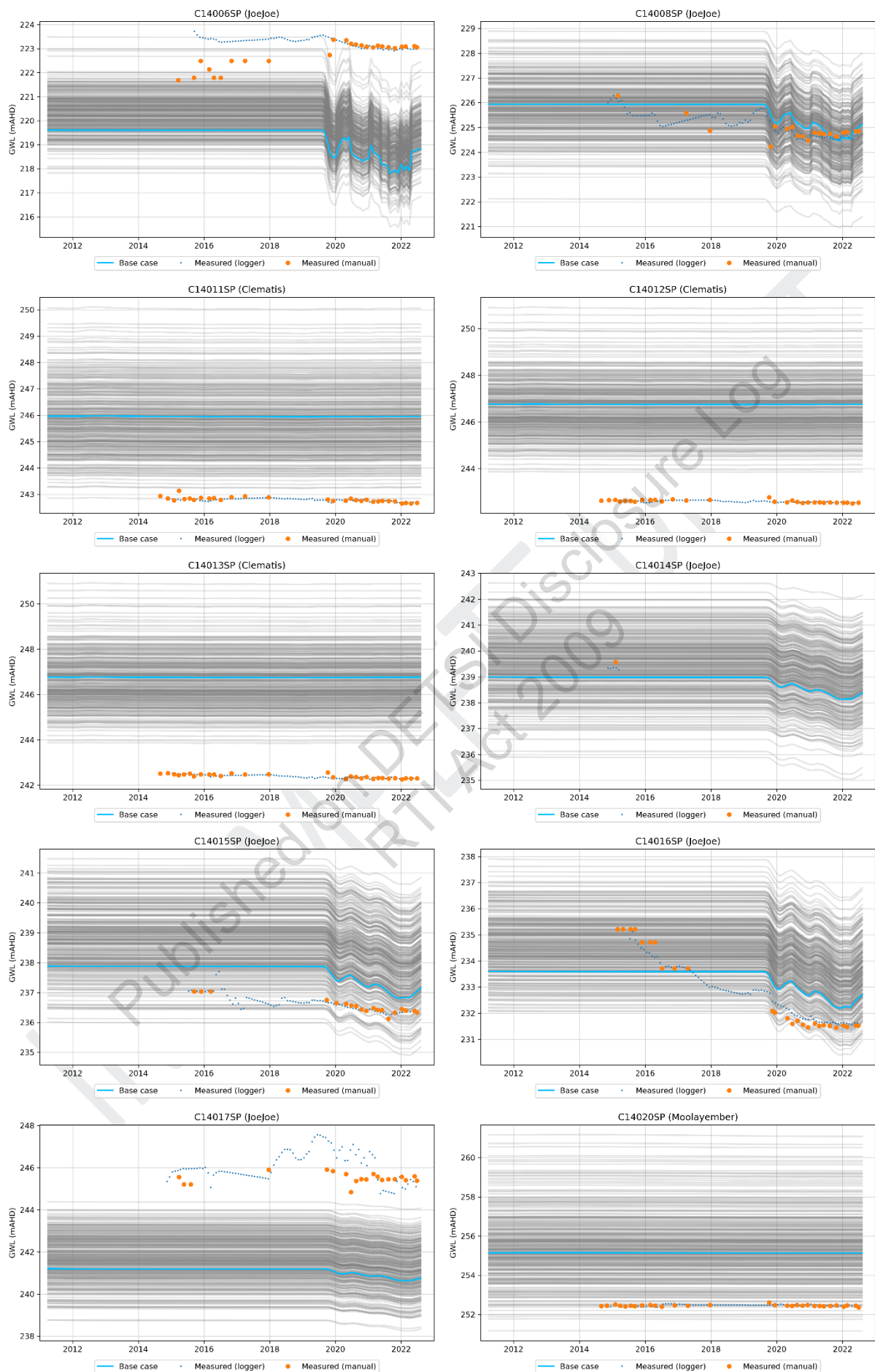


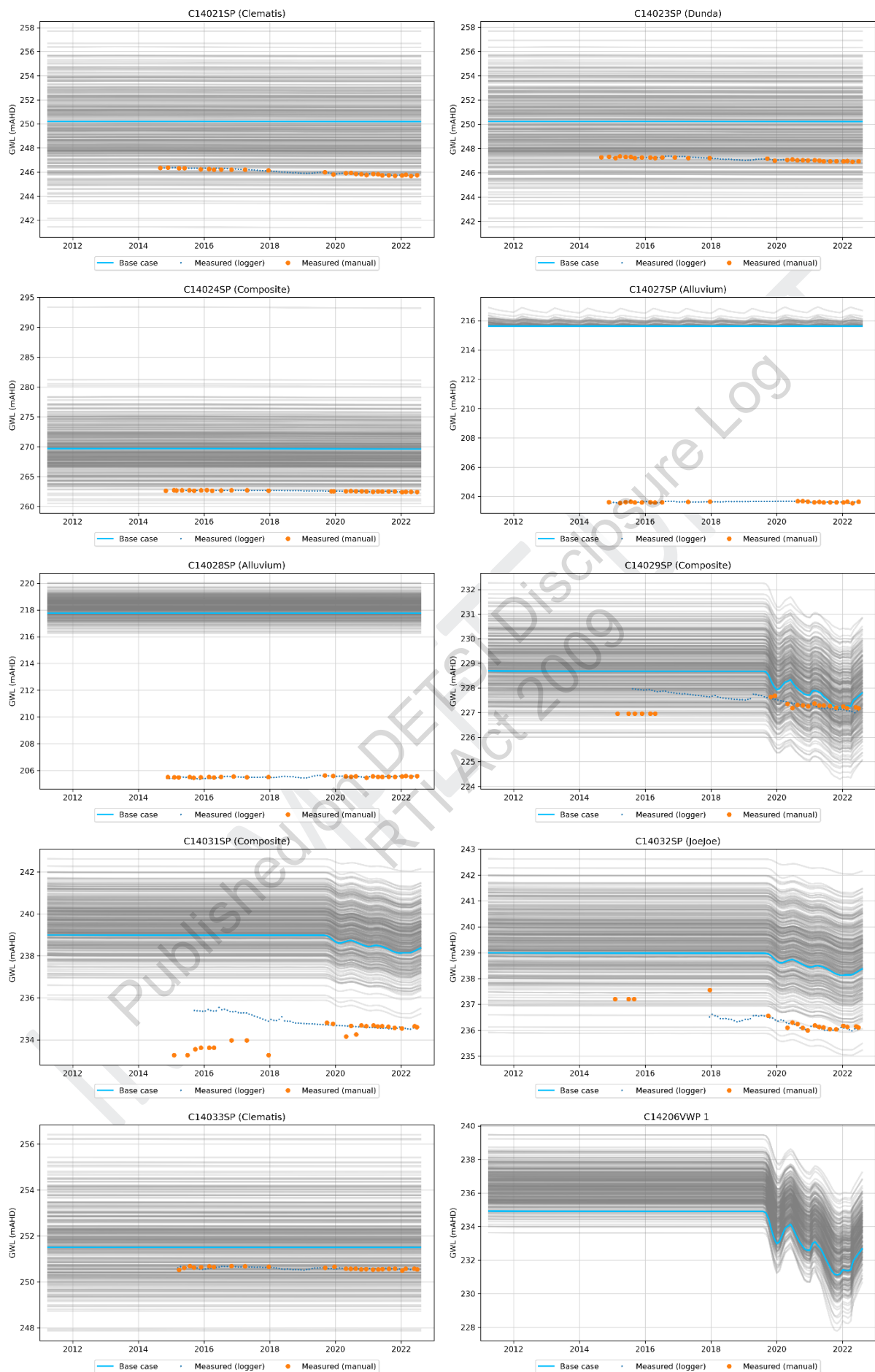


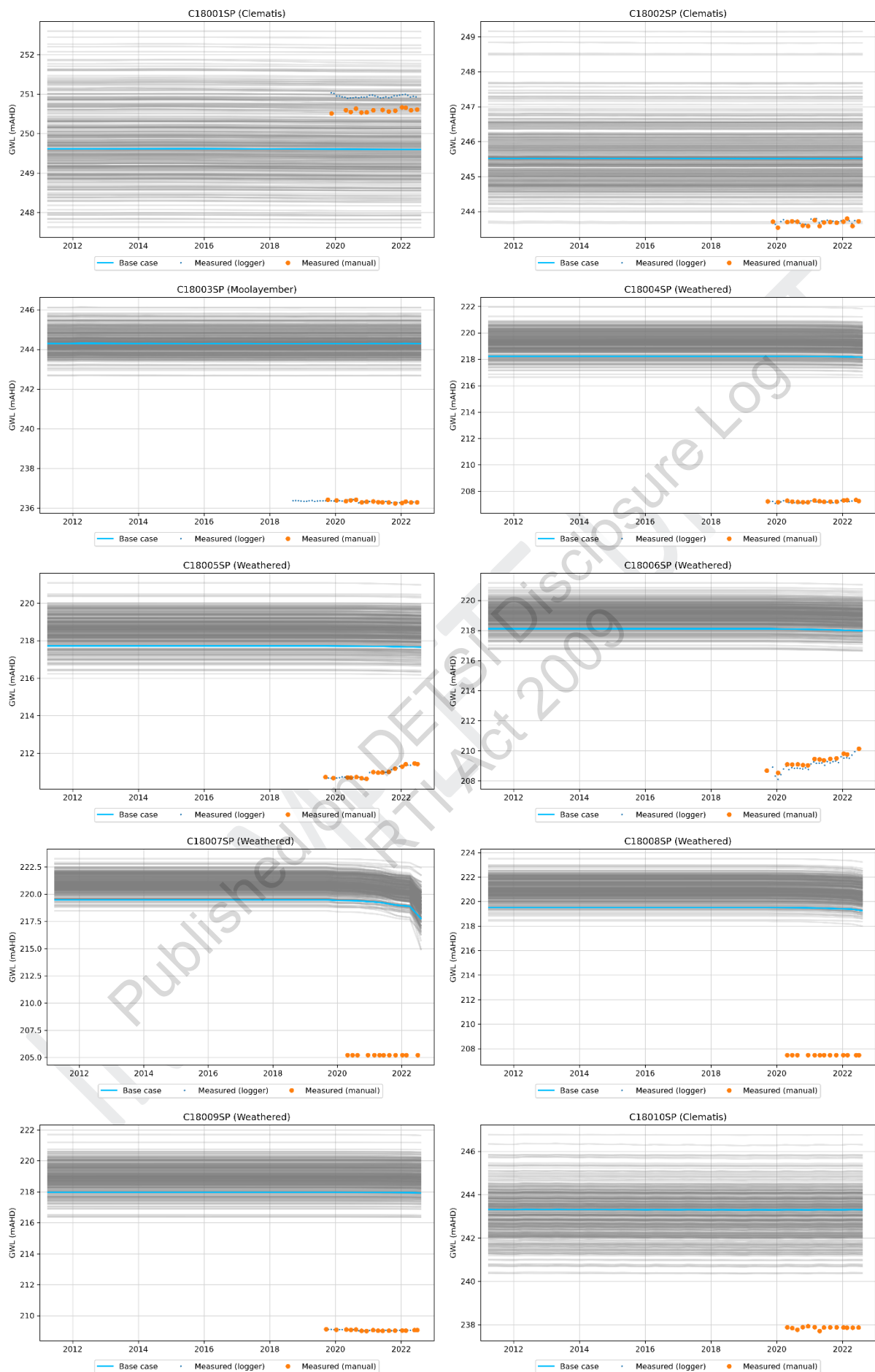


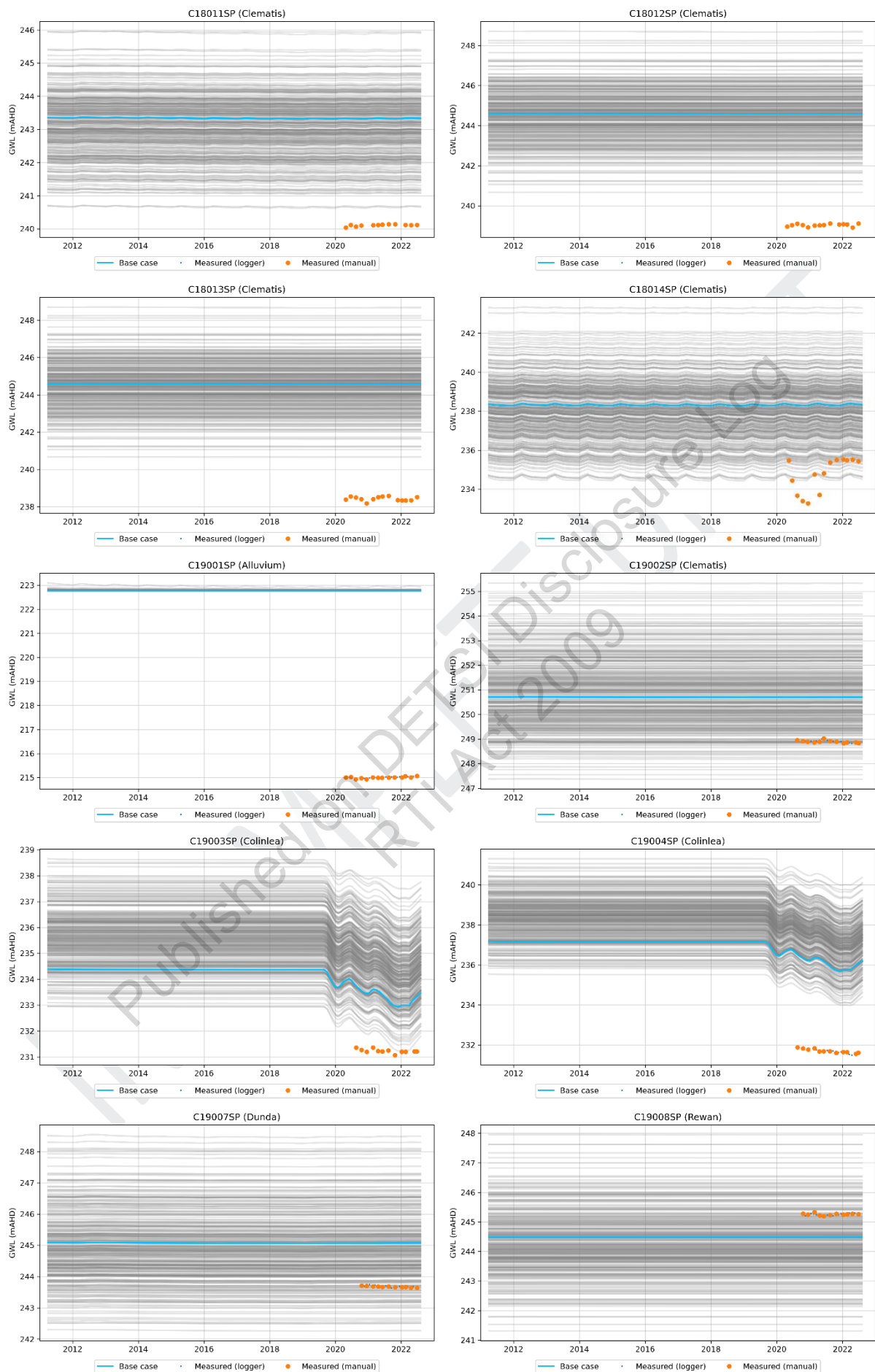


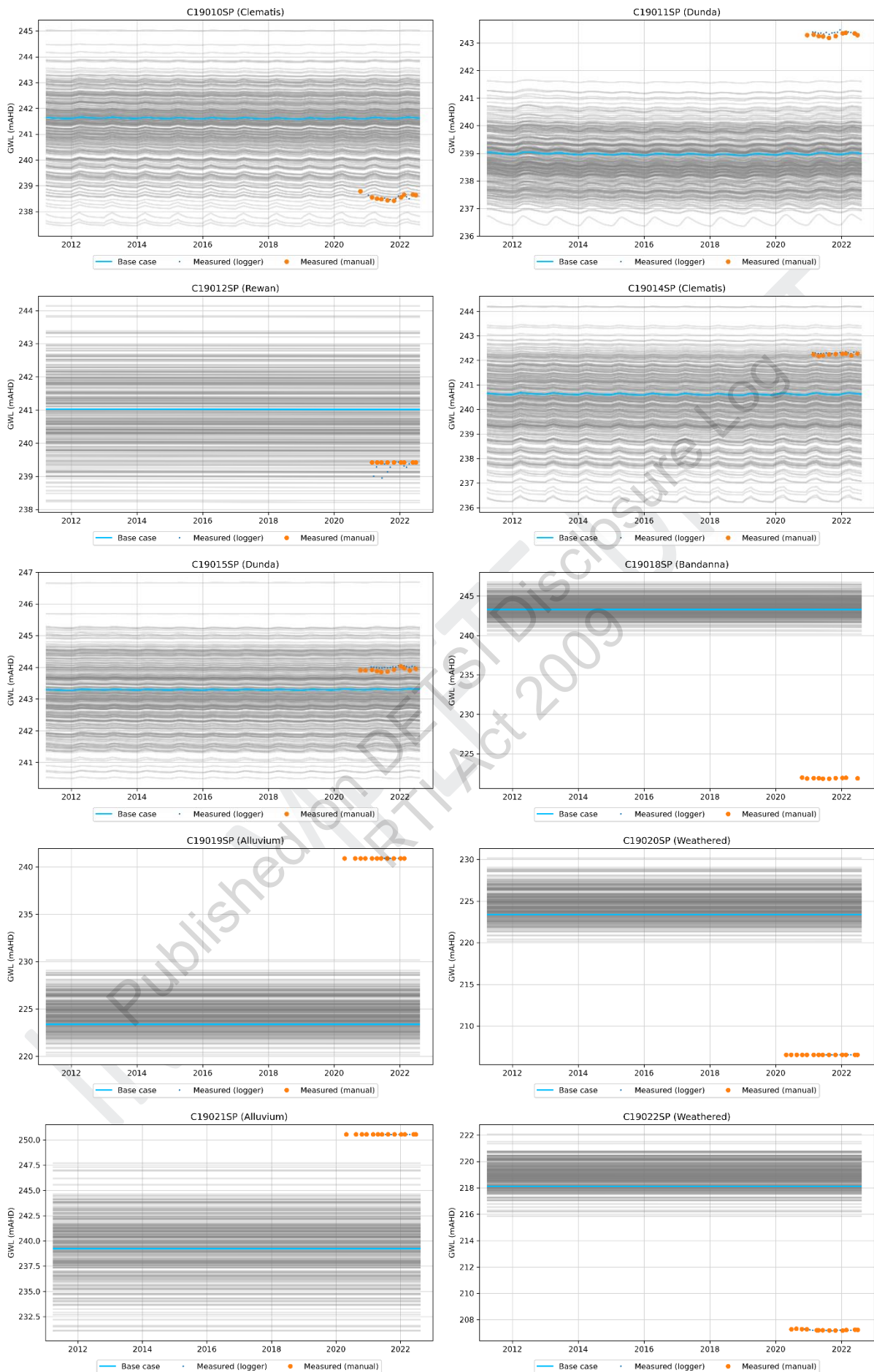


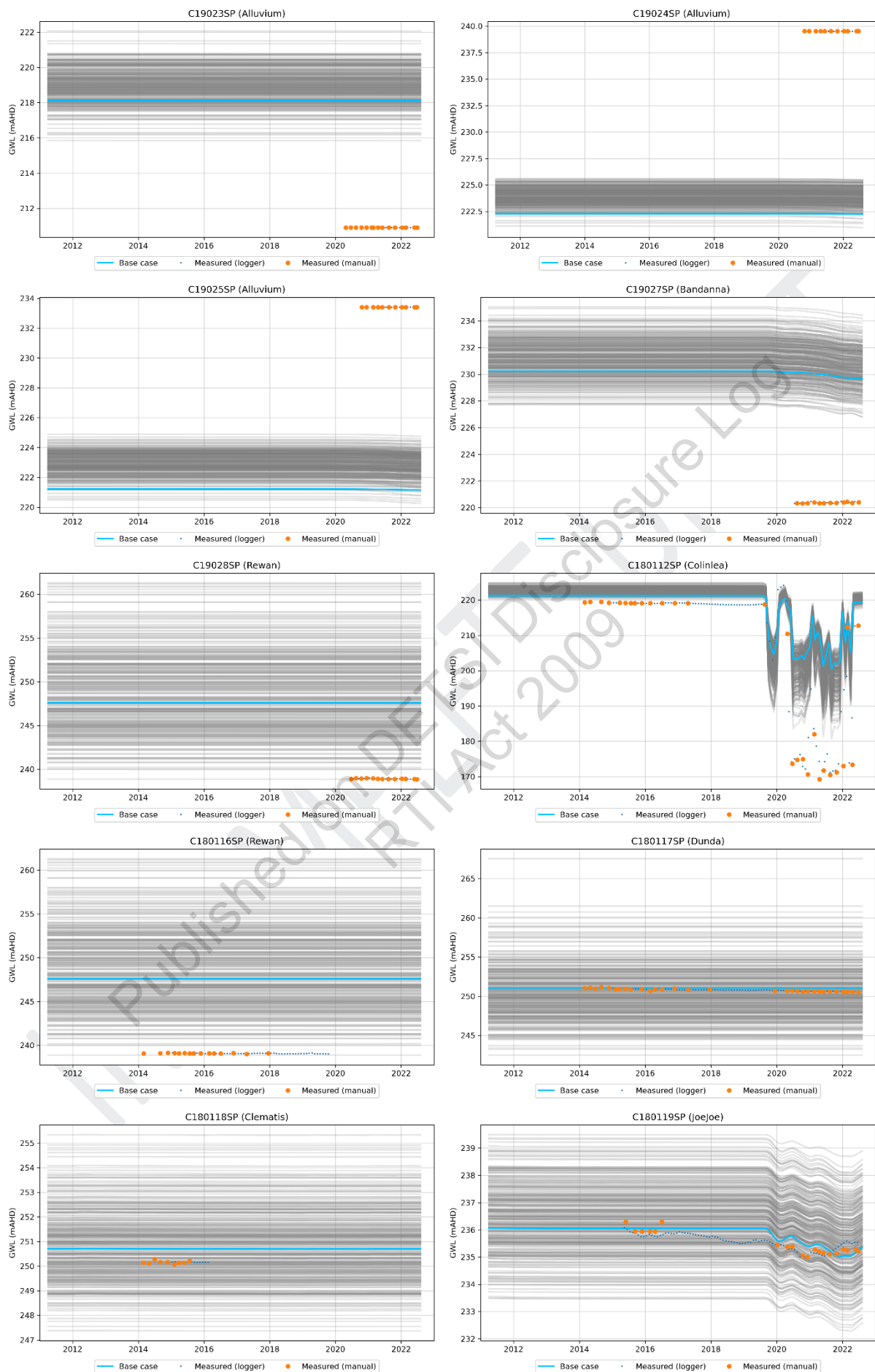


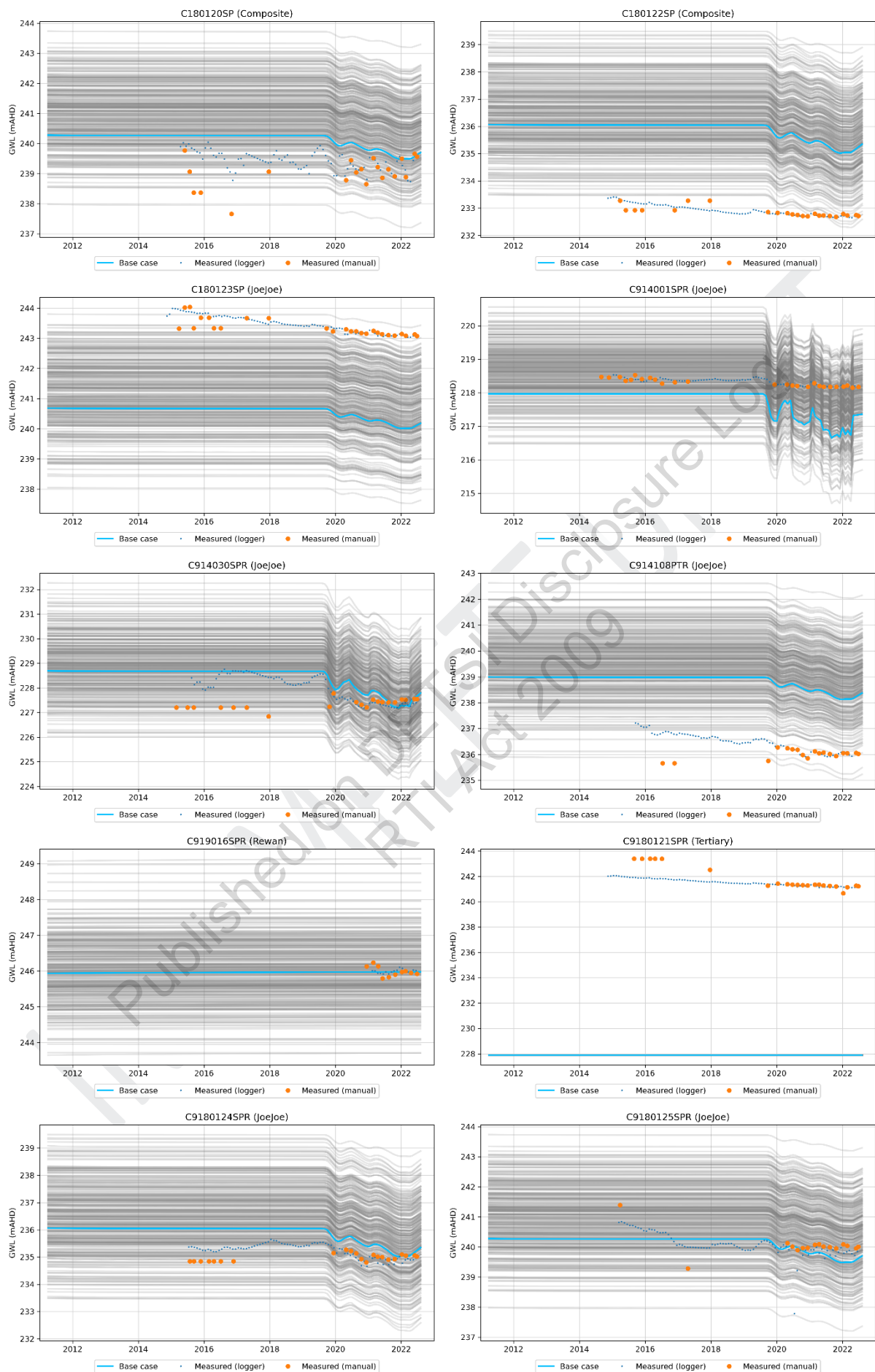


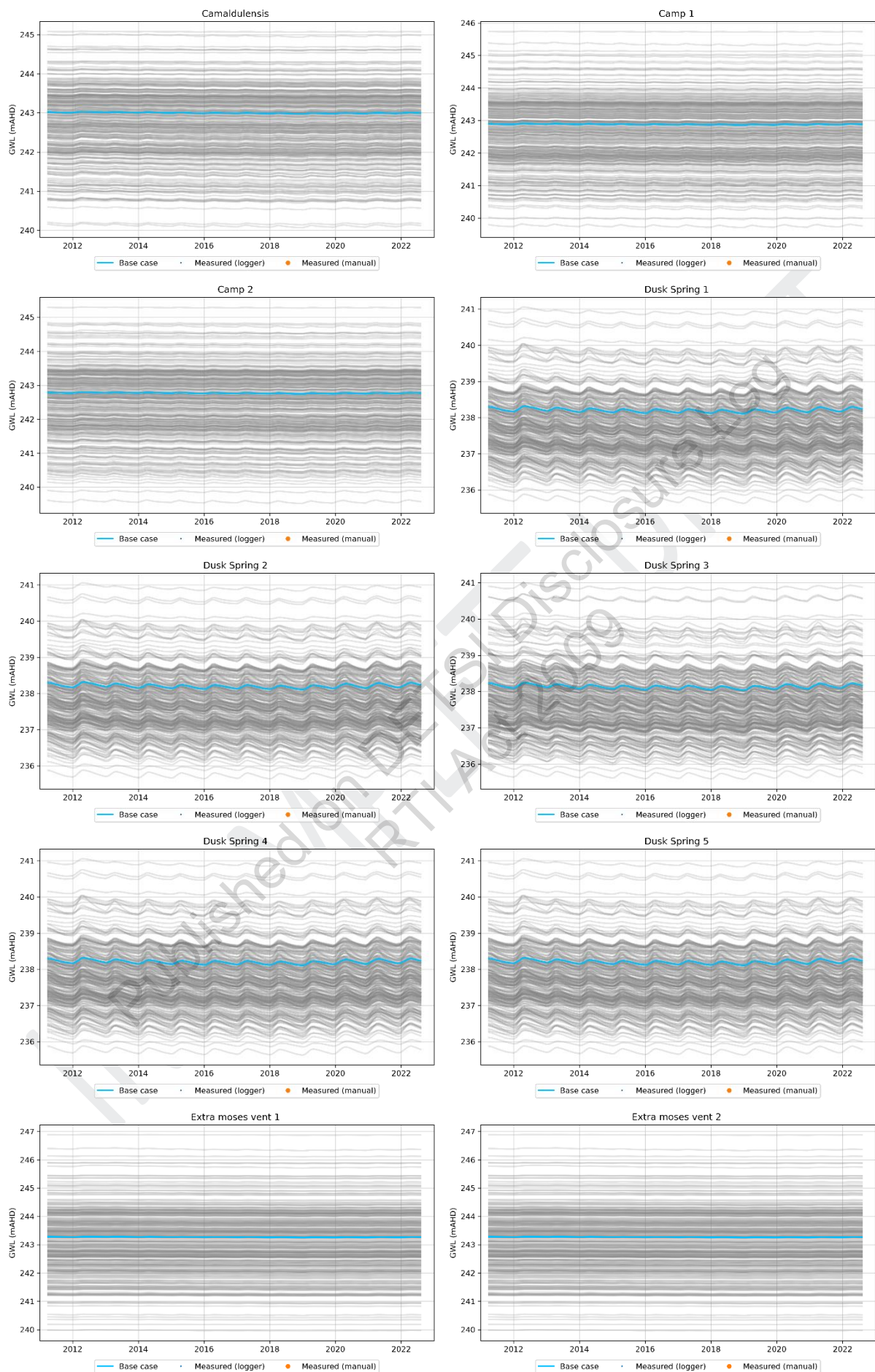


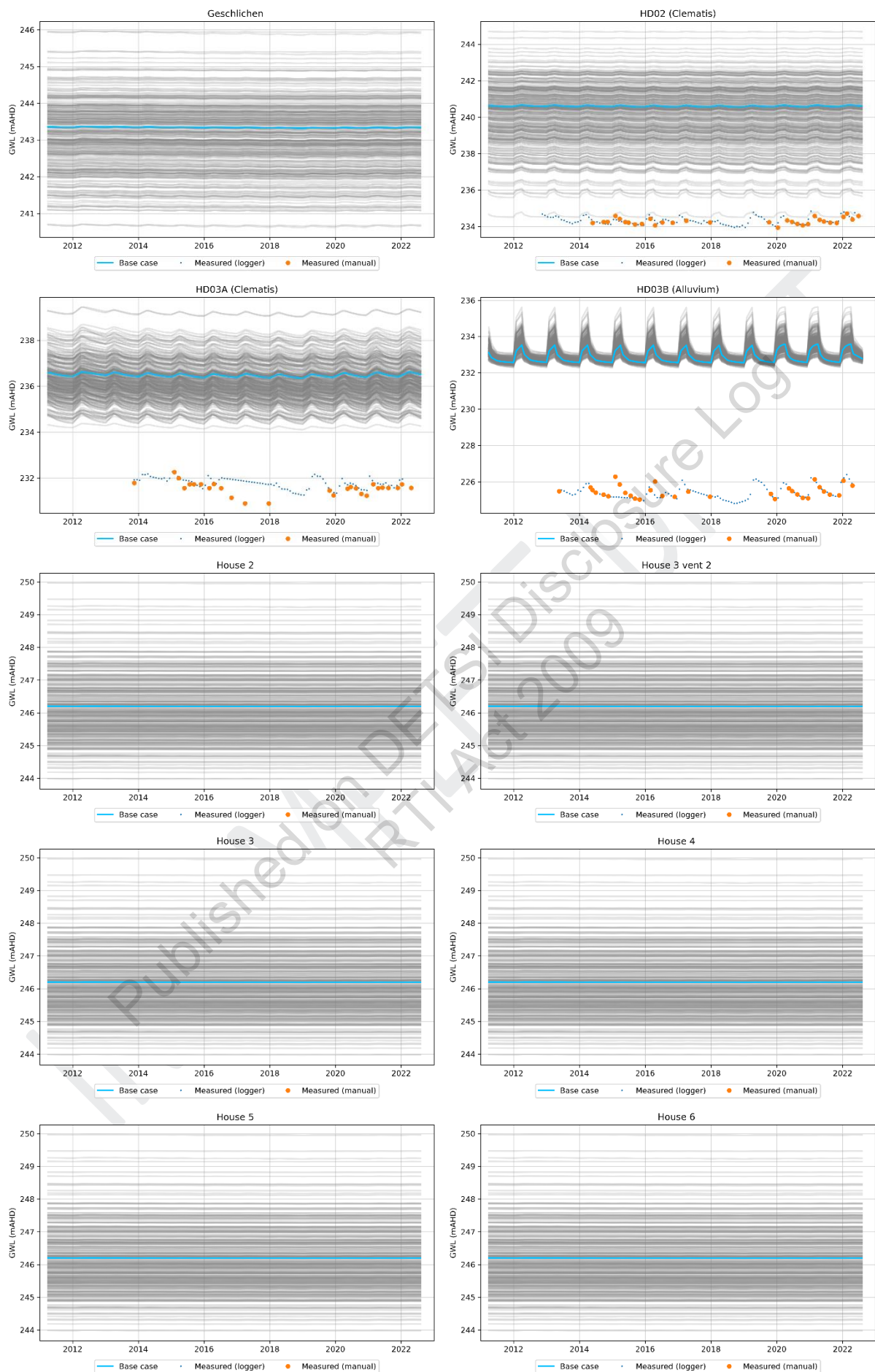


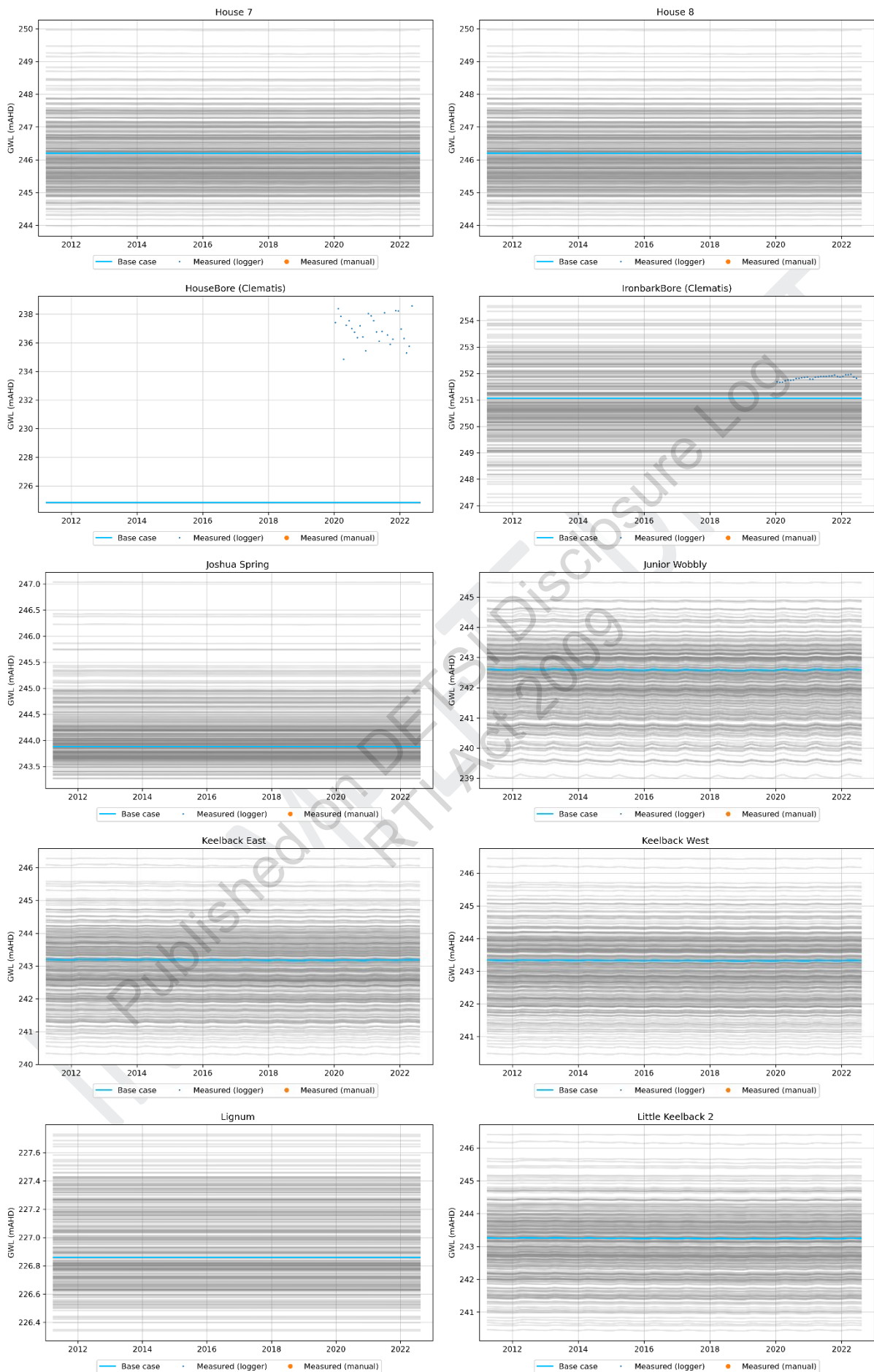


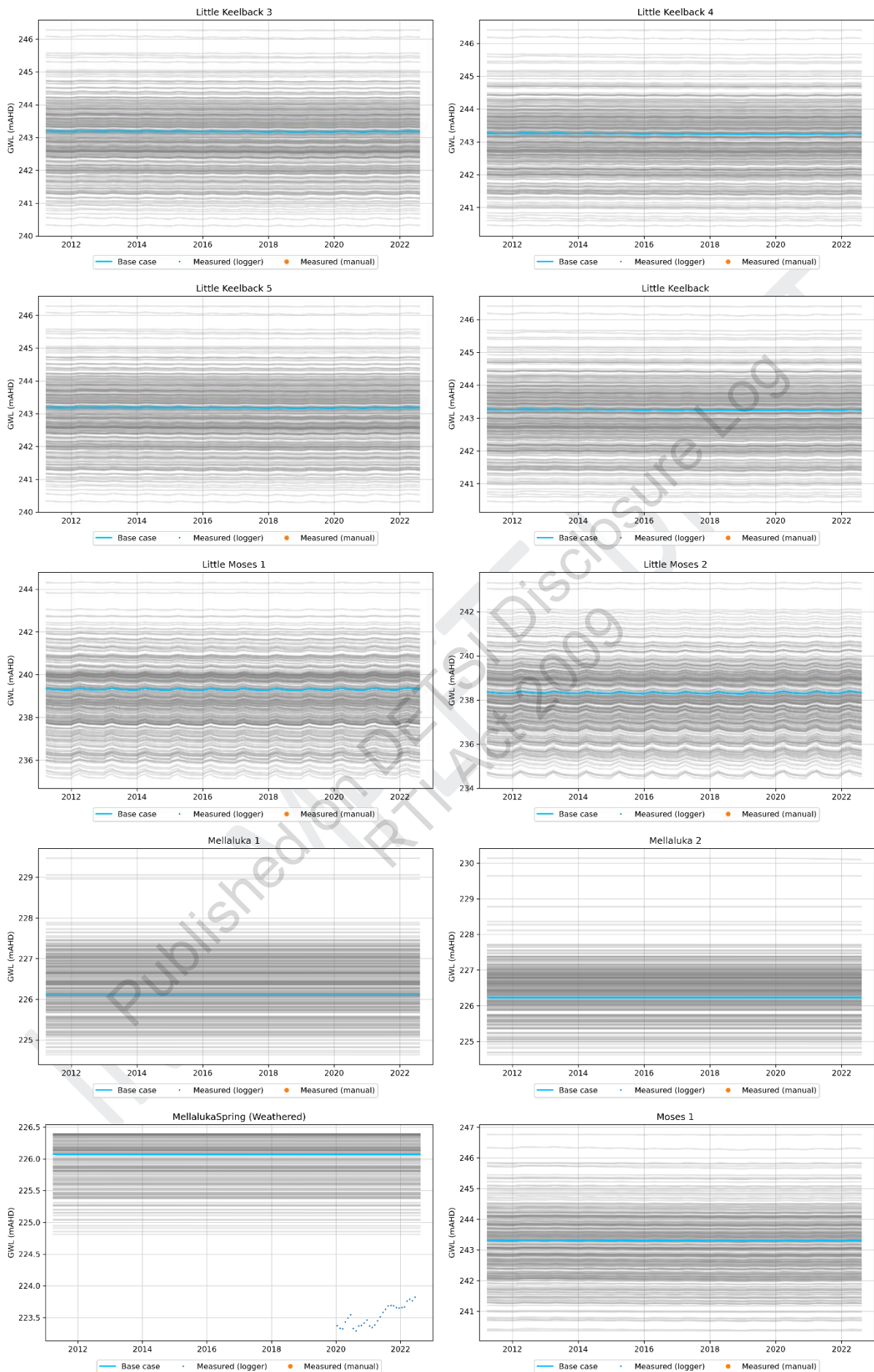


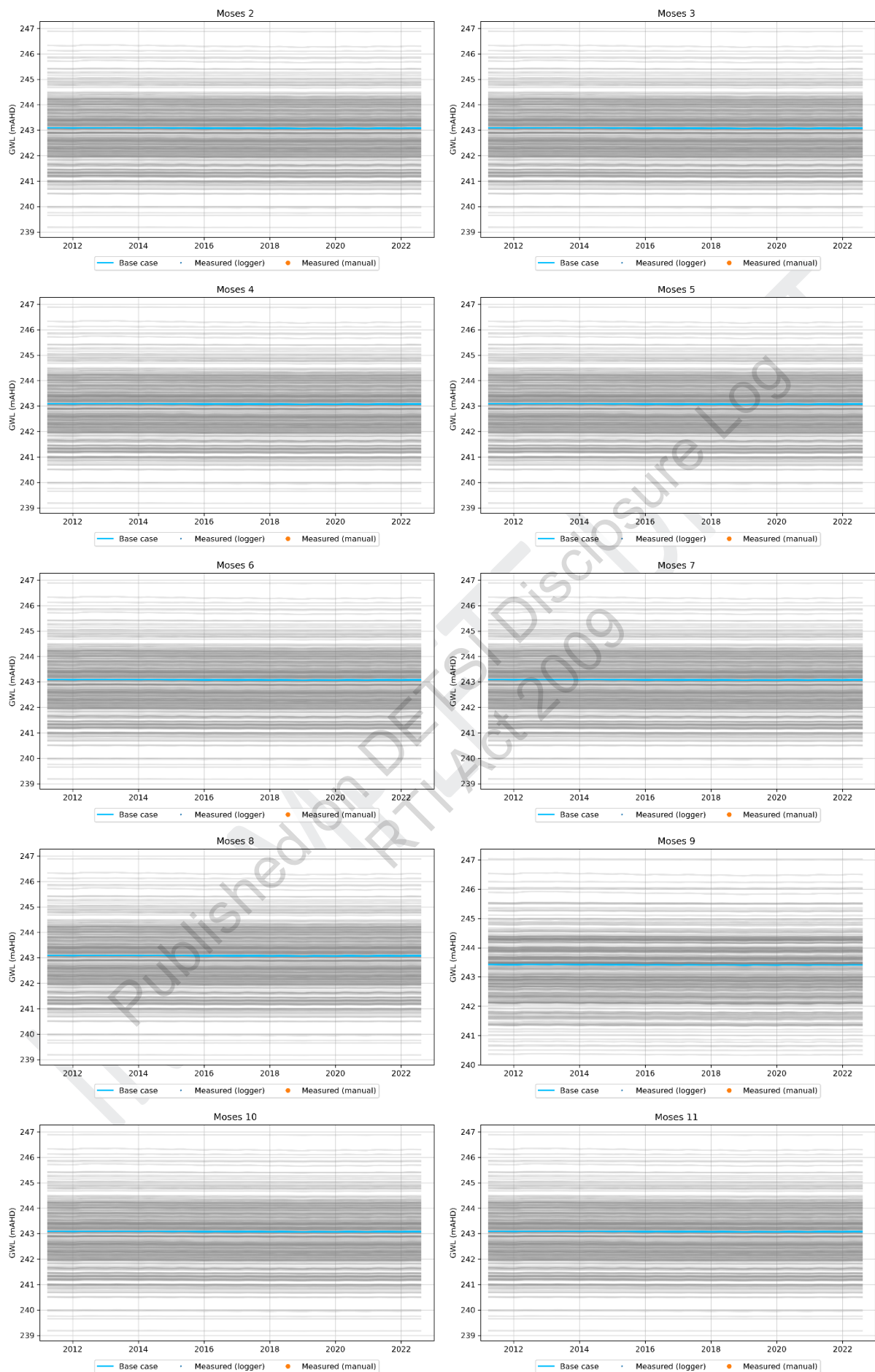


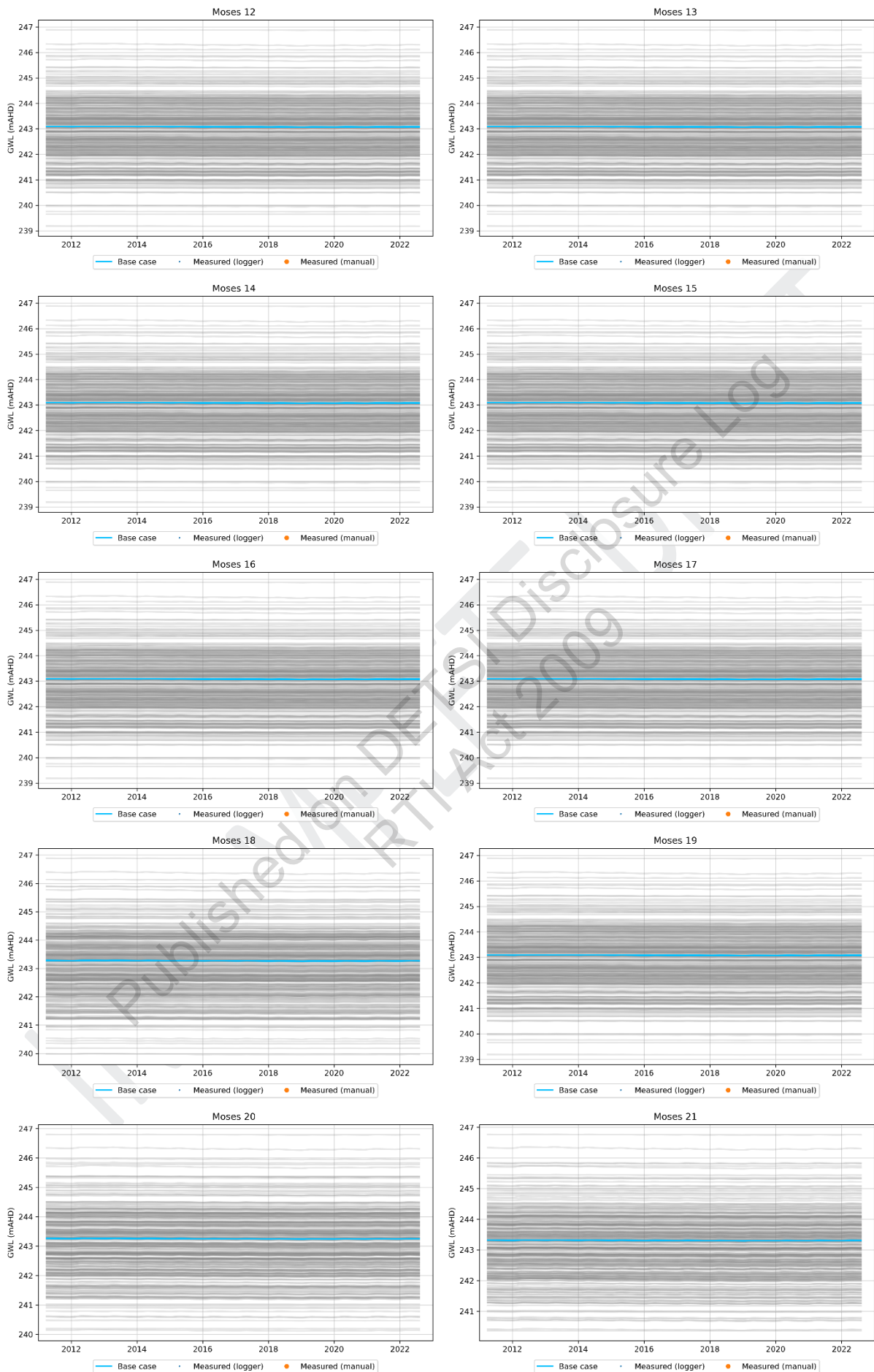


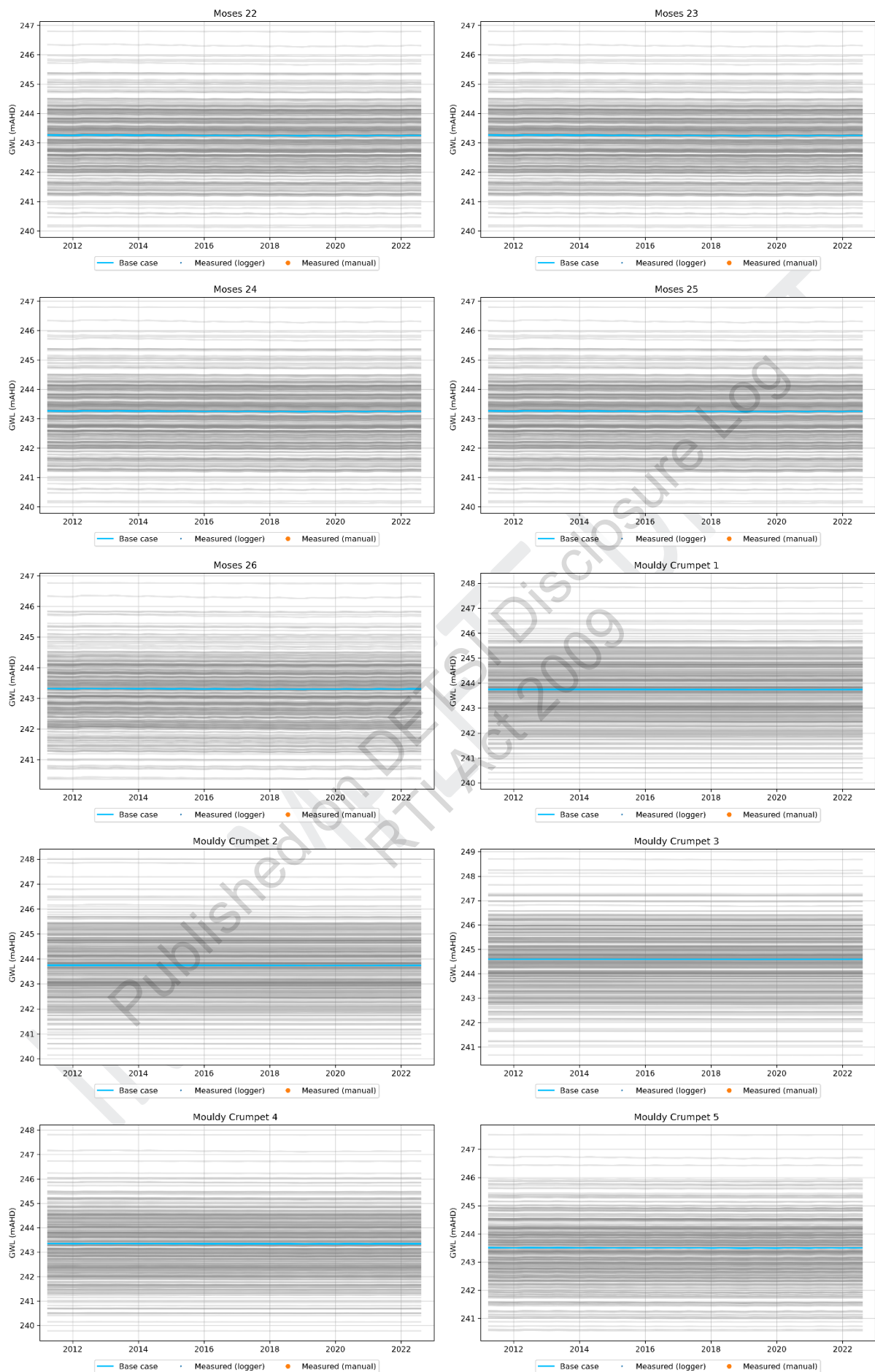


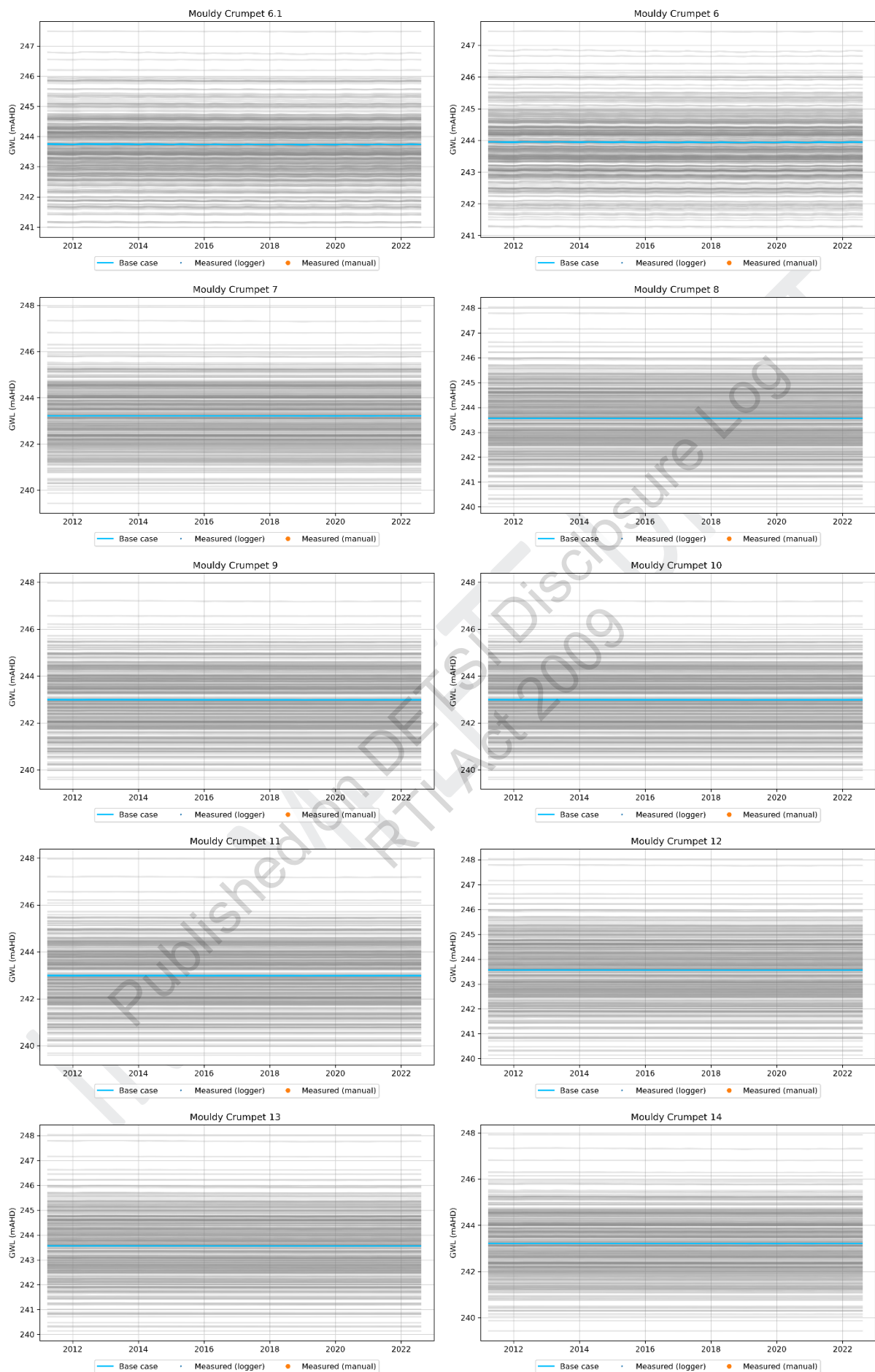


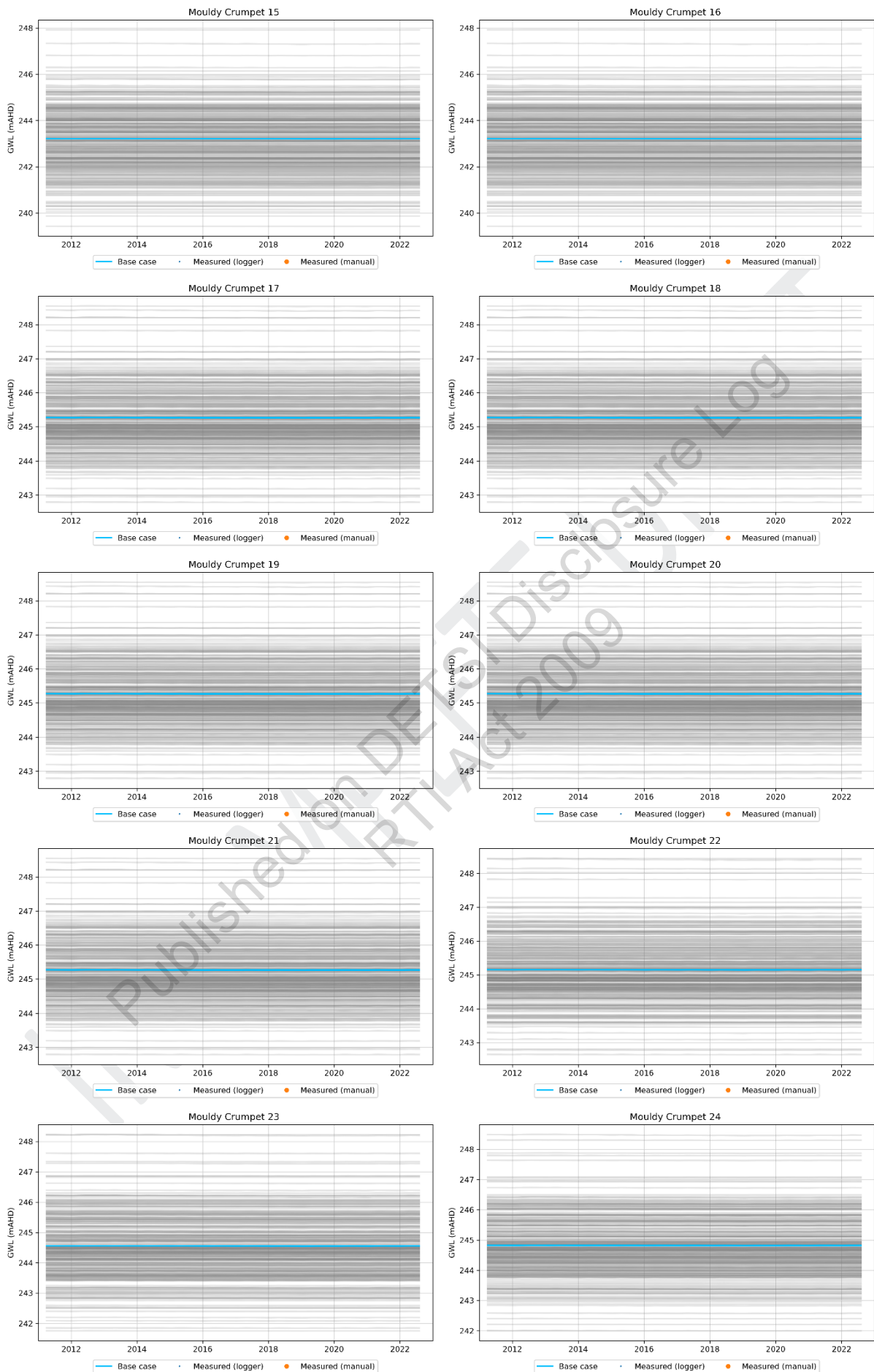


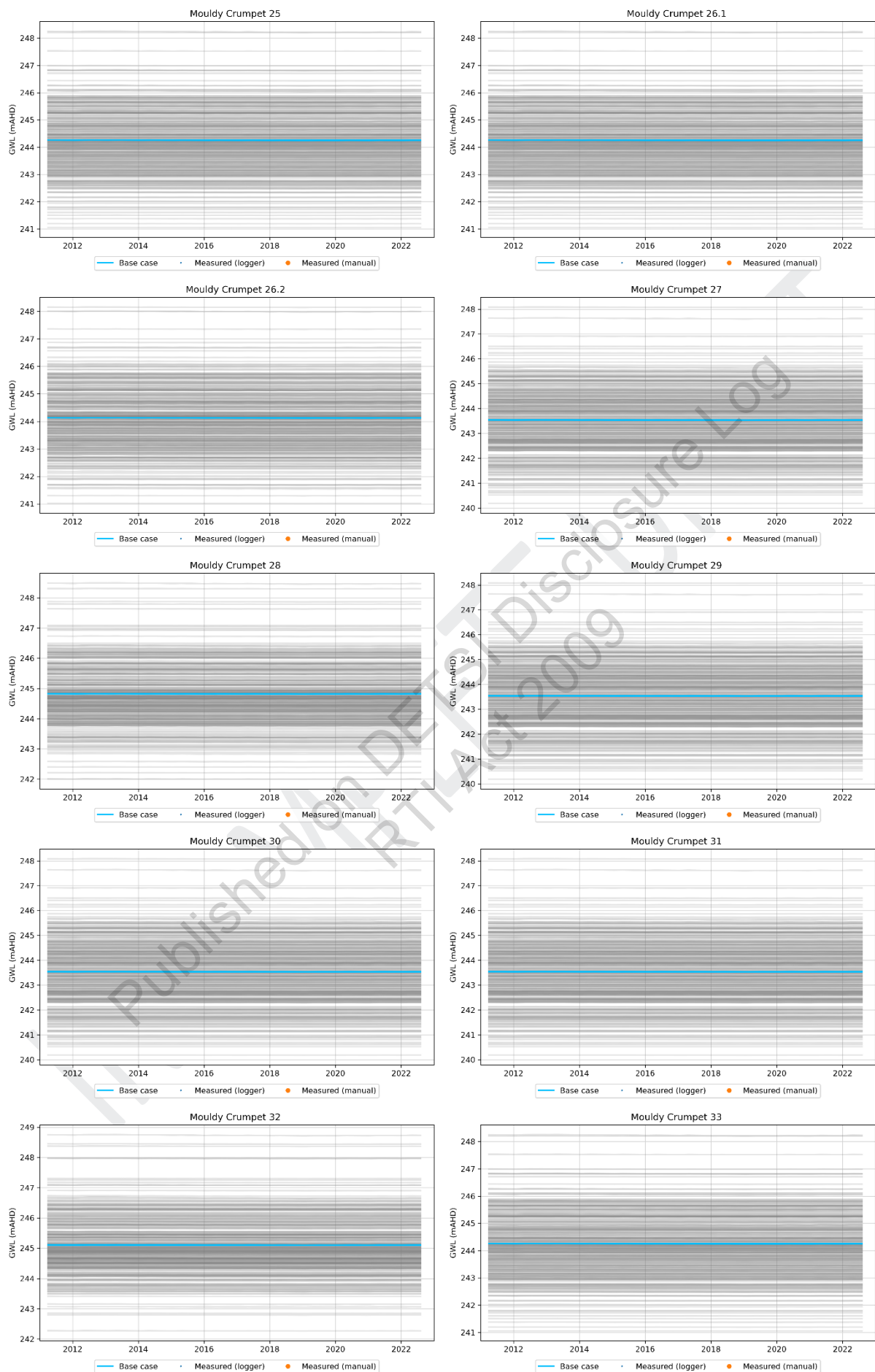


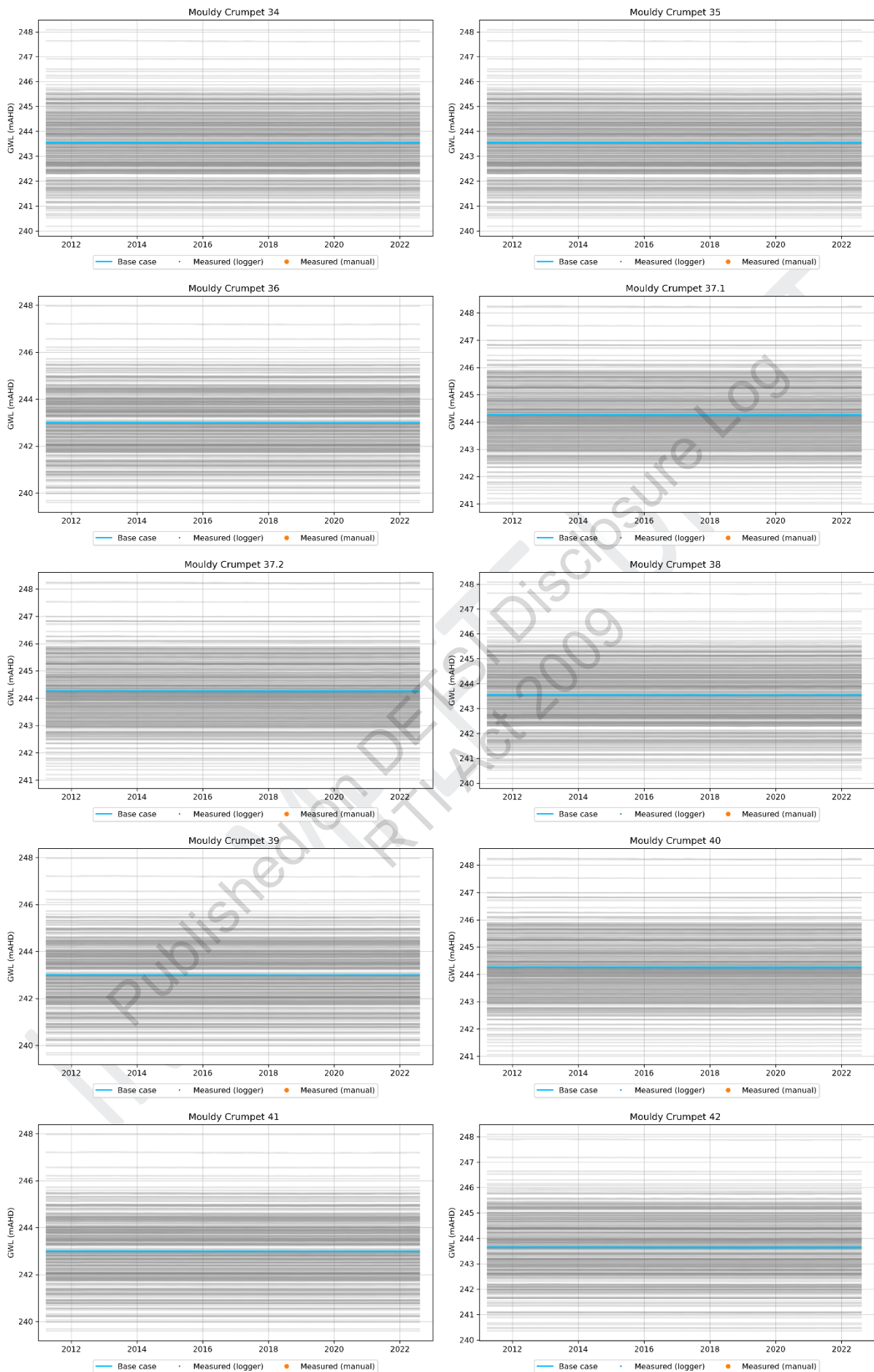


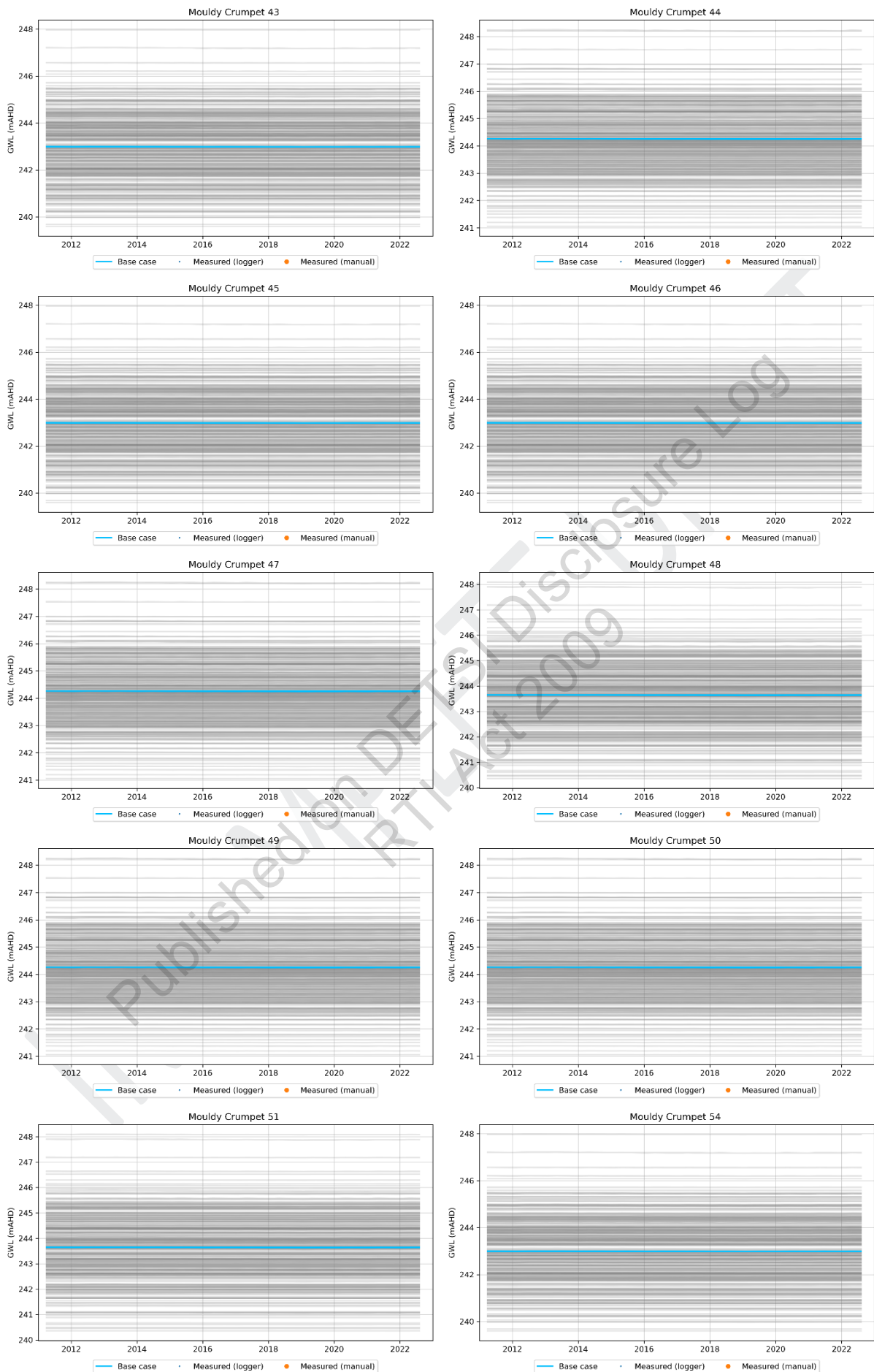


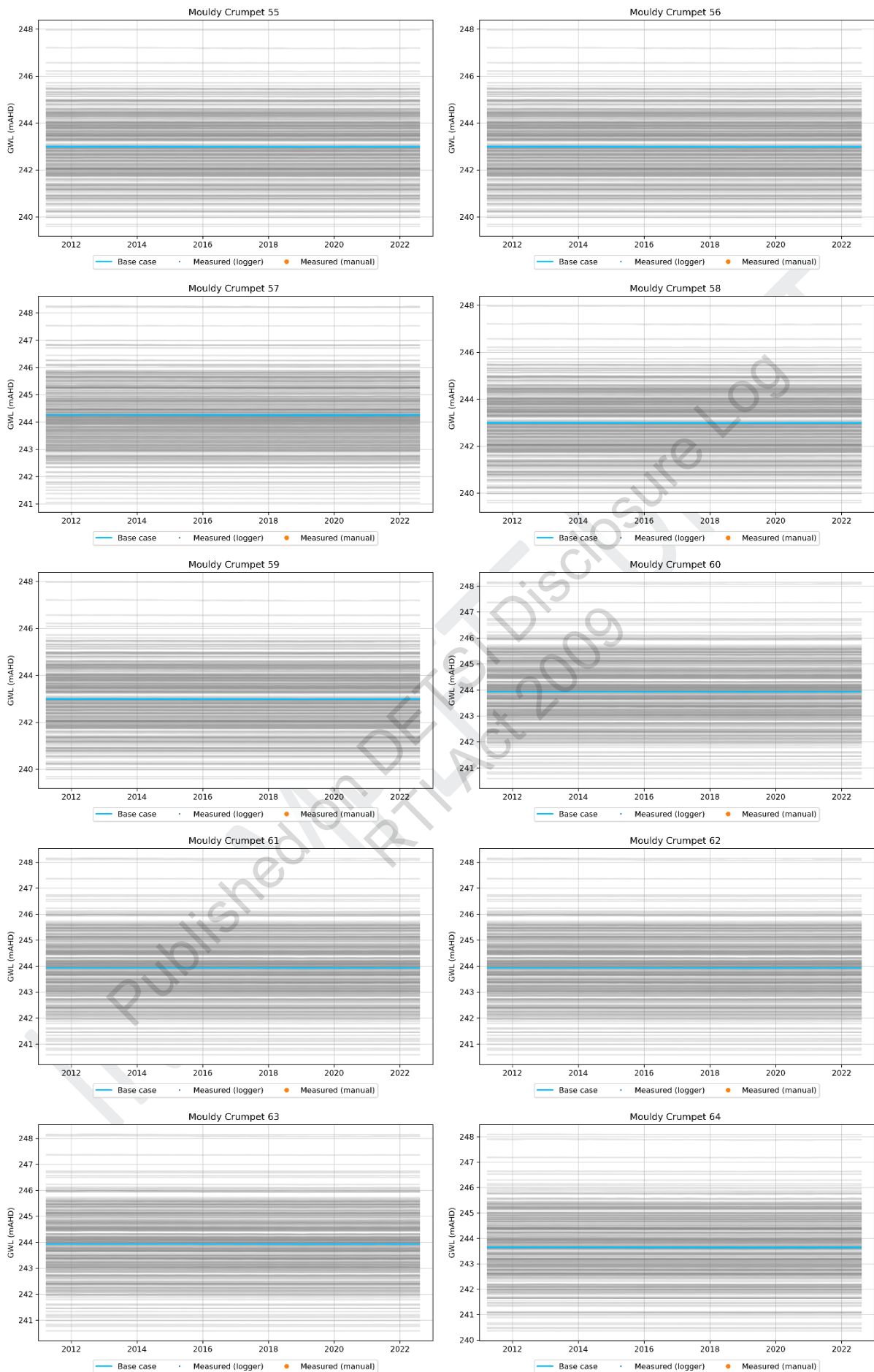


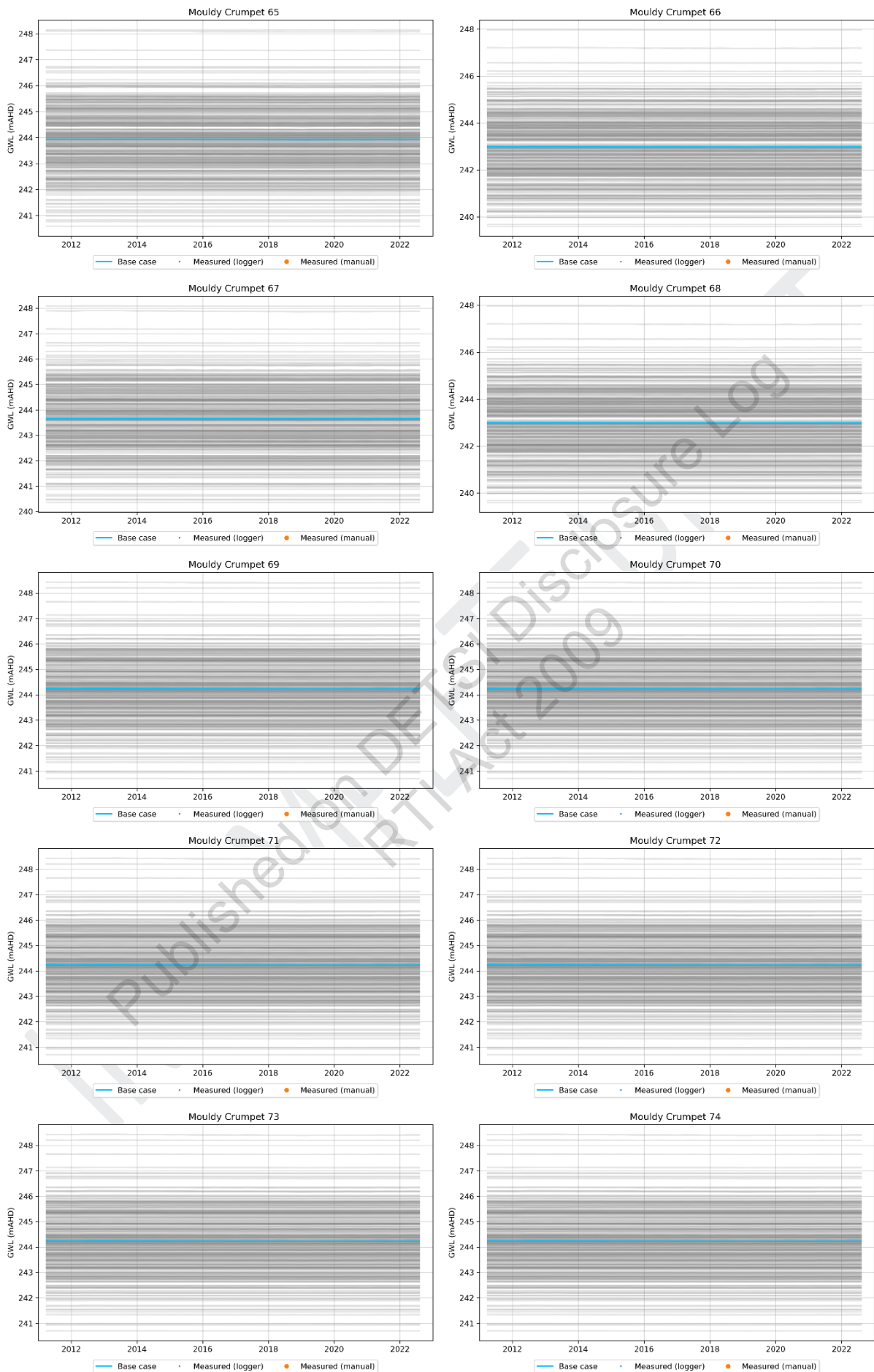


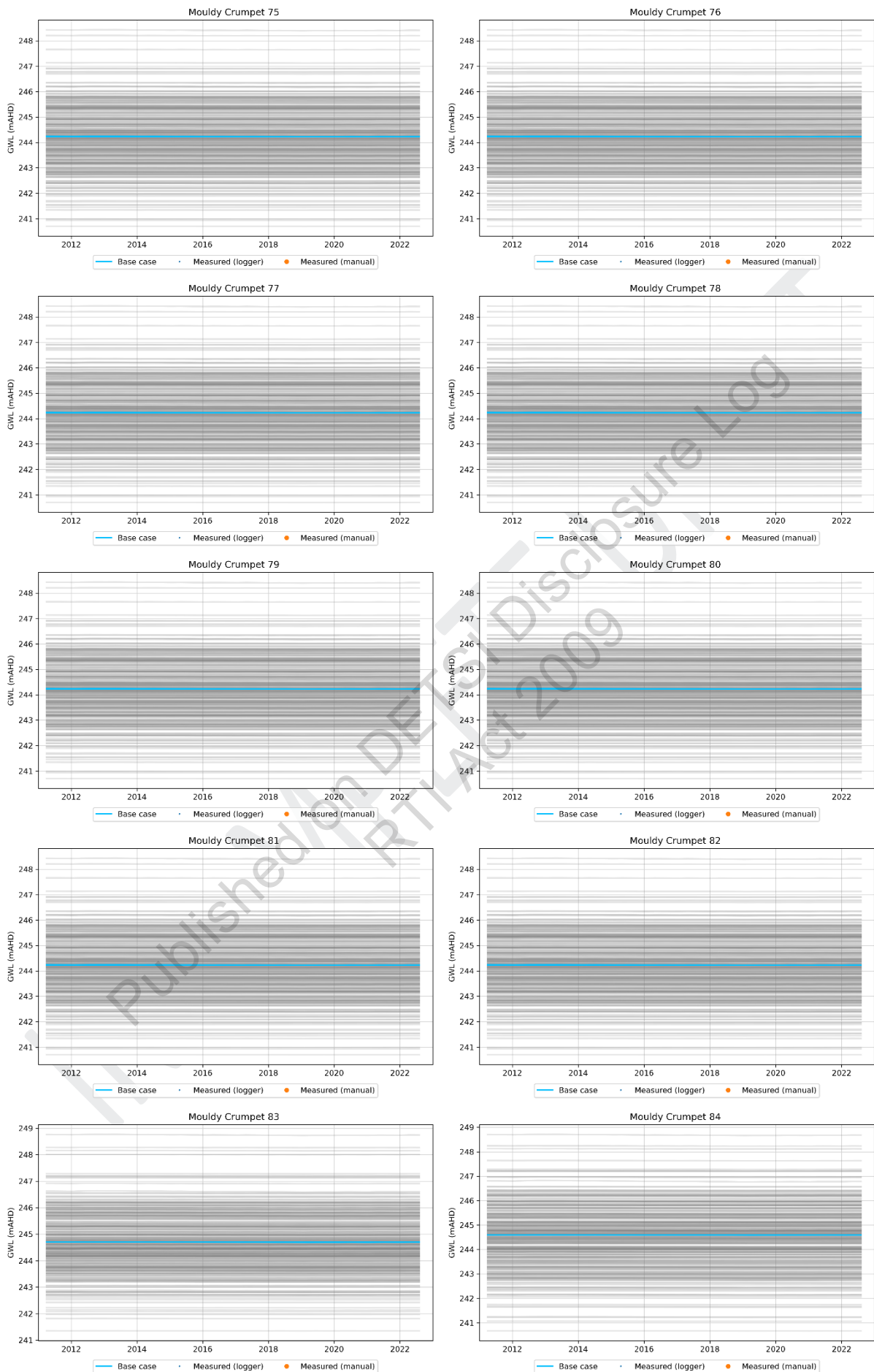


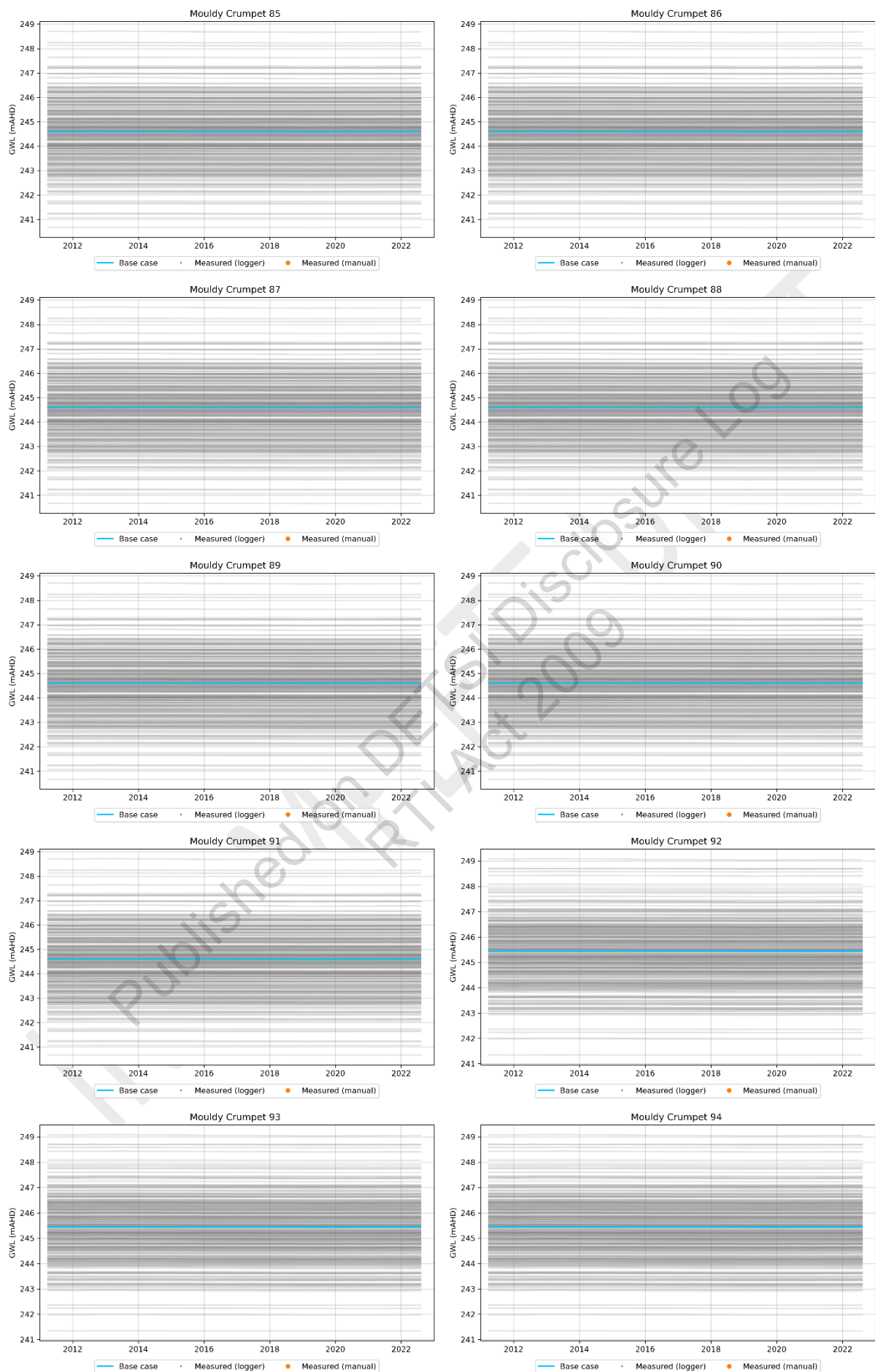


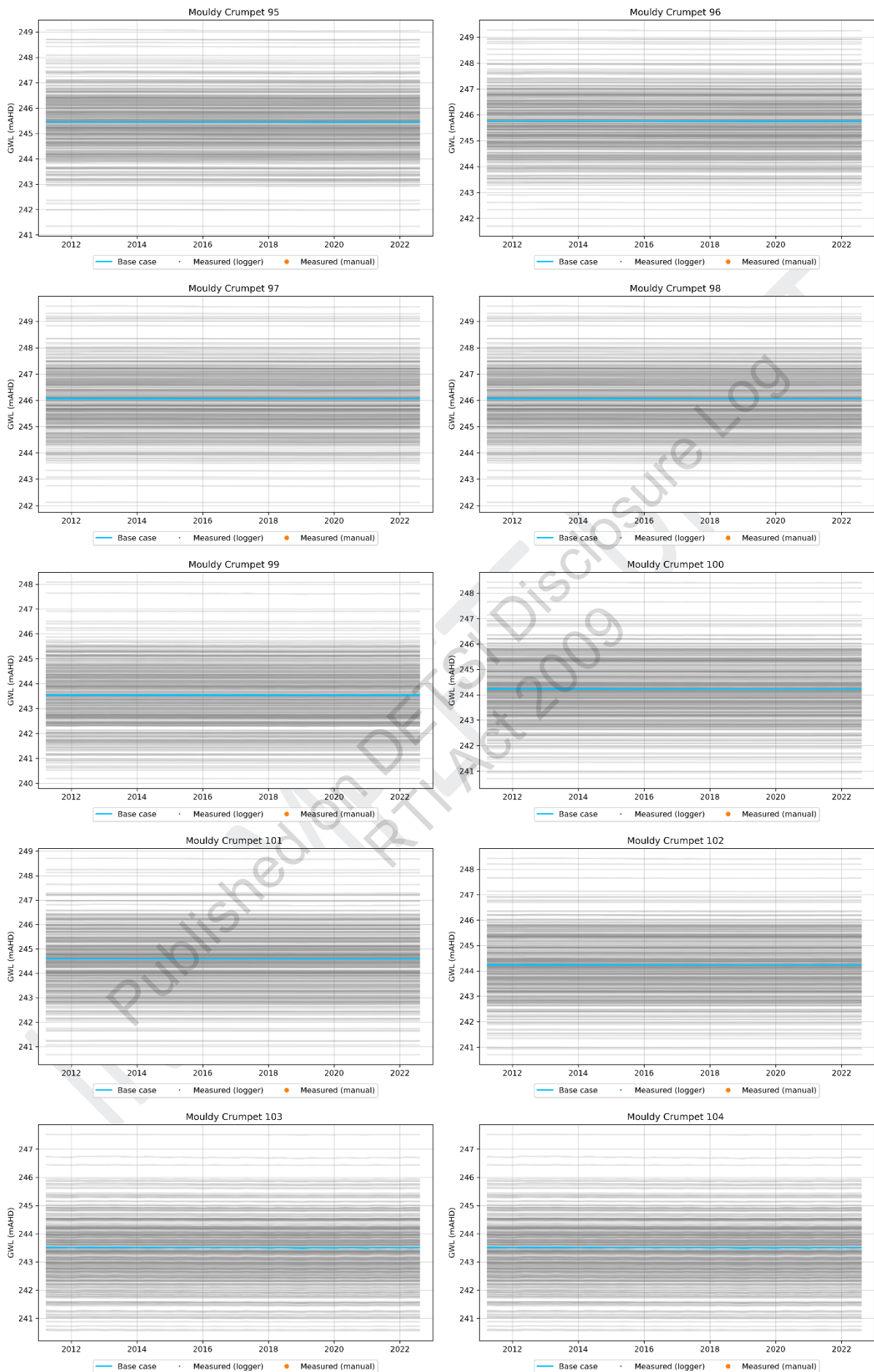


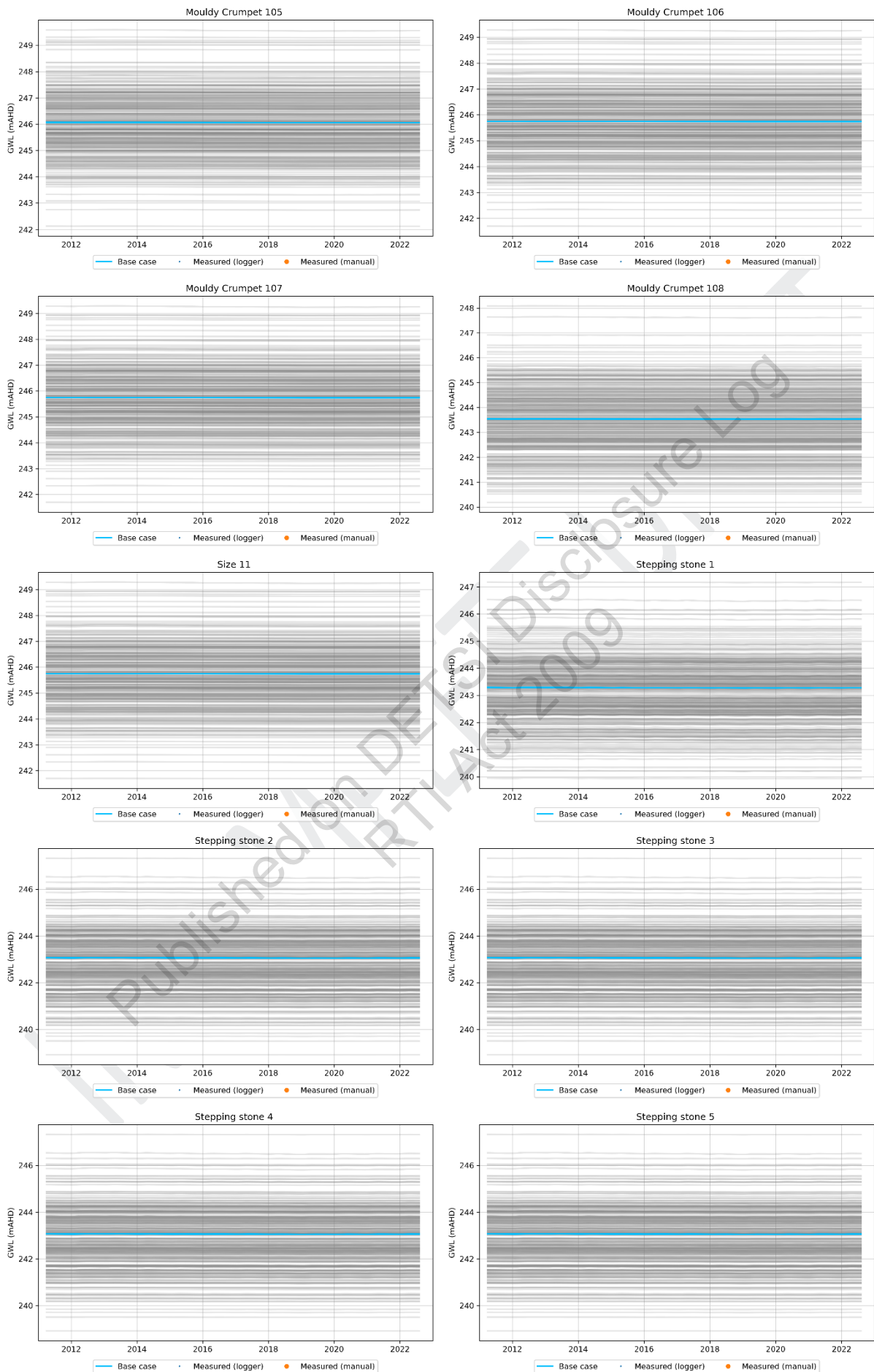


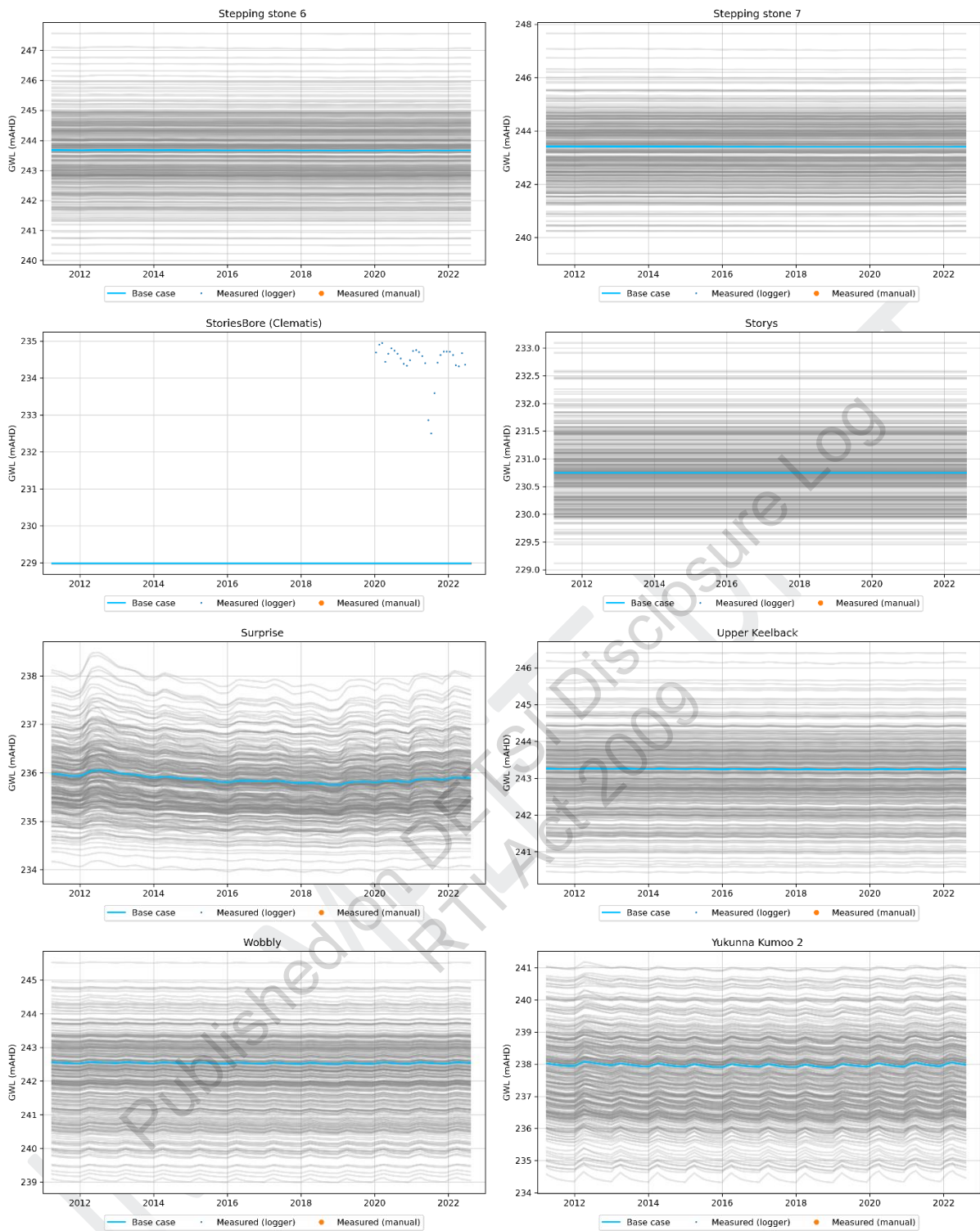


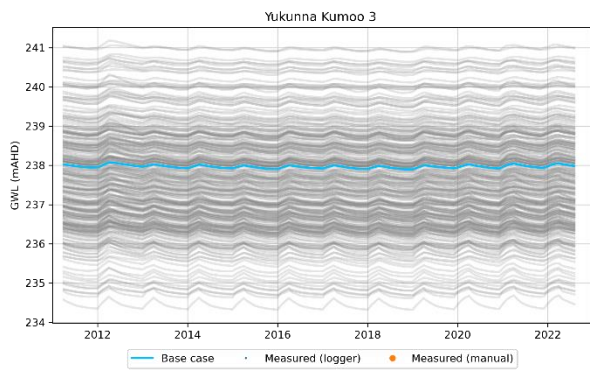
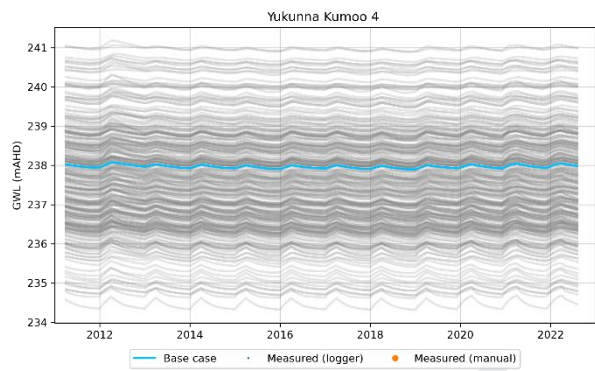
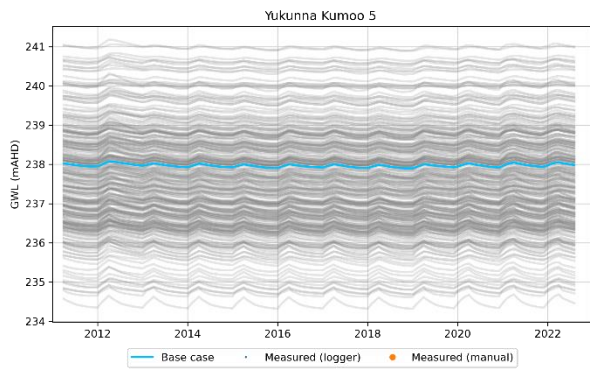
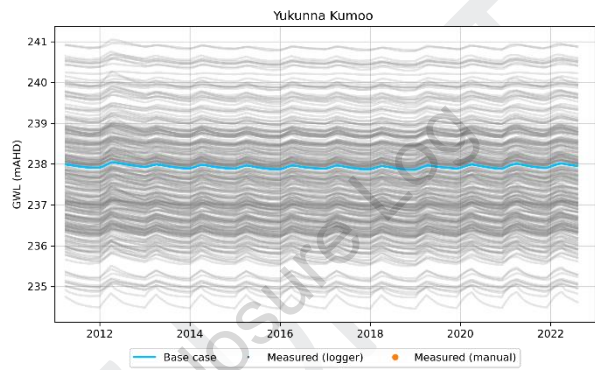












Appendix D

Hydrographs: mining

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Appendix E

Hydrographs: mining and recovery

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Appendix F

Hydrographs: predictive uncertainty drawdown

F.1 Appendix Heading

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Australia

SYDNEY

Ground floor 20 Chandos Street
St Leonards NSW 2065
T 02 9493 9500

NEWCASTLE

Level 3 175 Scott Street
Newcastle NSW 2300
T 02 4907 4800

BRISBANE

Level 1 87 Wickham Terrace
Spring Hill QLD 4000
T 07 3648 1200

CANBERRA

Level 2 Suite 2.04
15 London Circuit
Canberra City ACT 2601

ADELAIDE

Level 4 74 Pirie Street
Adelaide SA 5000
T 08 8232 2253

MELBOURNE

Suite 8.03 Level 8 454 Collins
Street
Melbourne VIC 3000
T 03 9993 1900

PERTH

Suite 9.02 Level 9 109 St
Georges Terrace
Perth WA 6000

Canada

TORONTO

2345 Young Street Suite 300
Toronto ON M4P 2E5

VANCOUVER

60 W 6th Ave Suite 200
Vancouver BC V5Y 1K1



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Carmichael Coal Mine Project

Groundwater Model Review - Progress Meeting - 4

Tuesday 10 January 2023

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Model design information