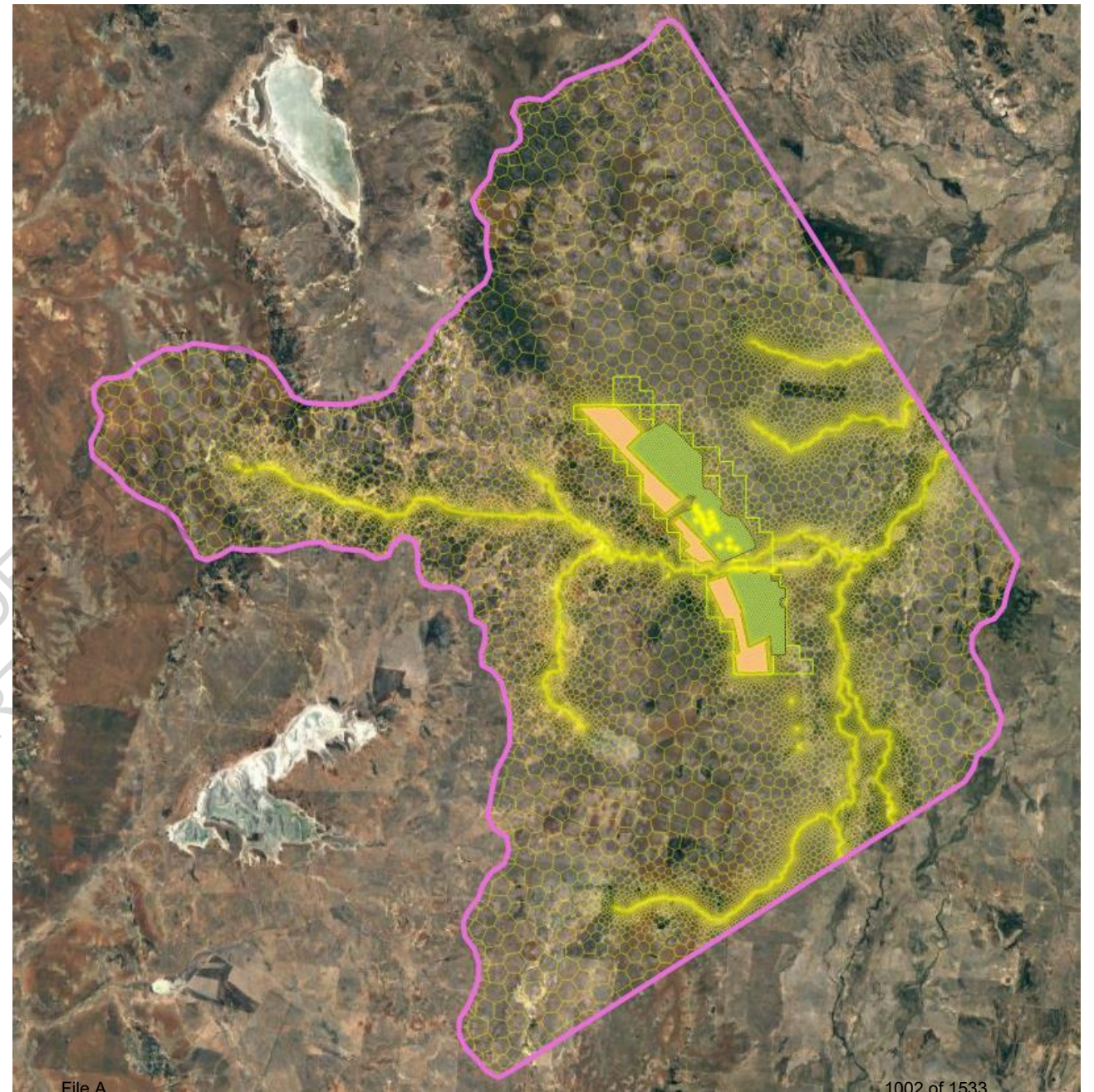


Model design overview

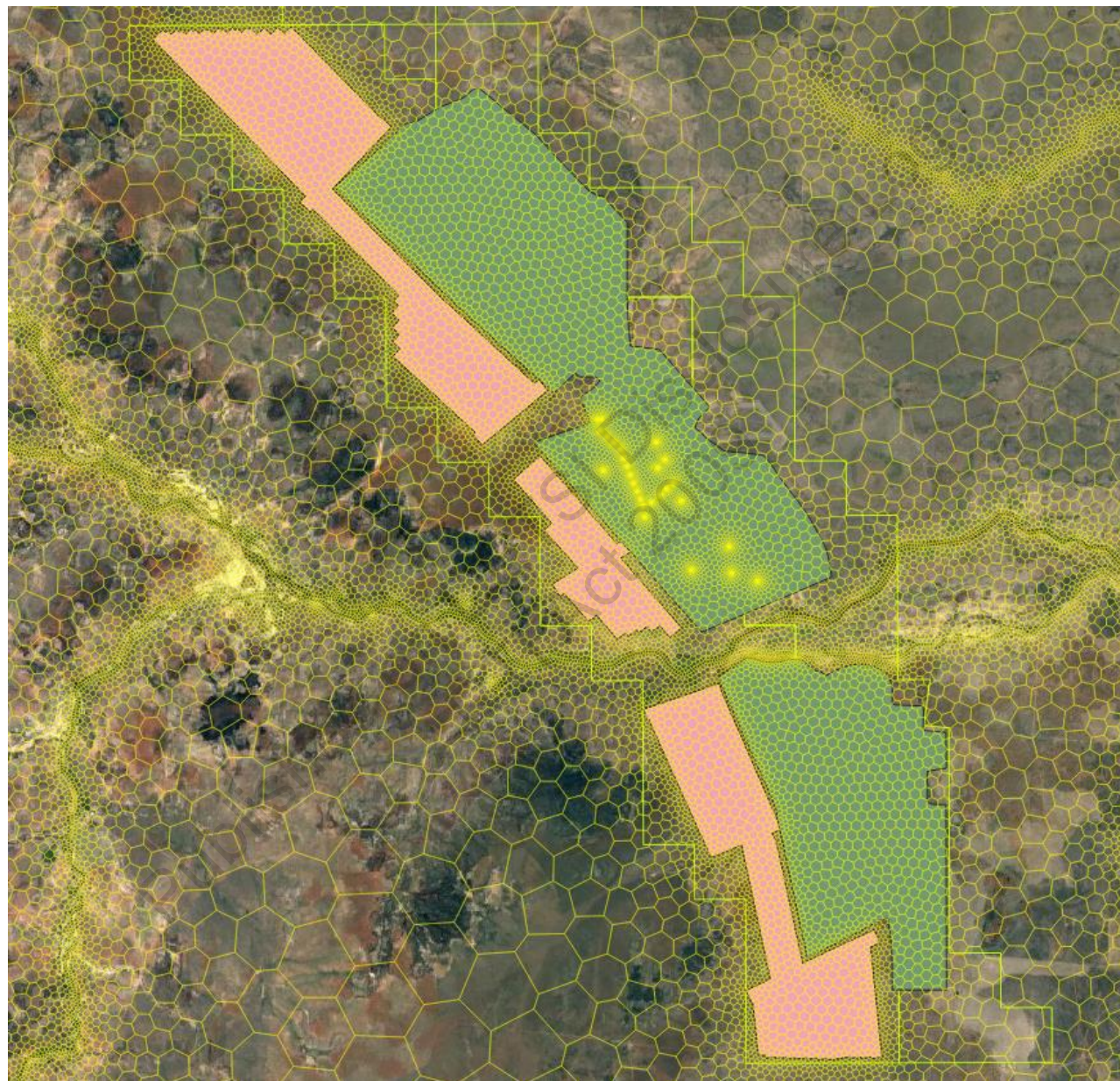
- MODFLOW-USG Transport v1.10
- Maintain domain from SEIS groundwater model
- Unstructured Voronoi polygon mesh; 34,624 nodes per layer
 - Refinement for major creeks, mapped springs, open cut and underground mine area, and dewatering bores
- 14 HSUs, one per model layer, with Rewan Formation split across 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

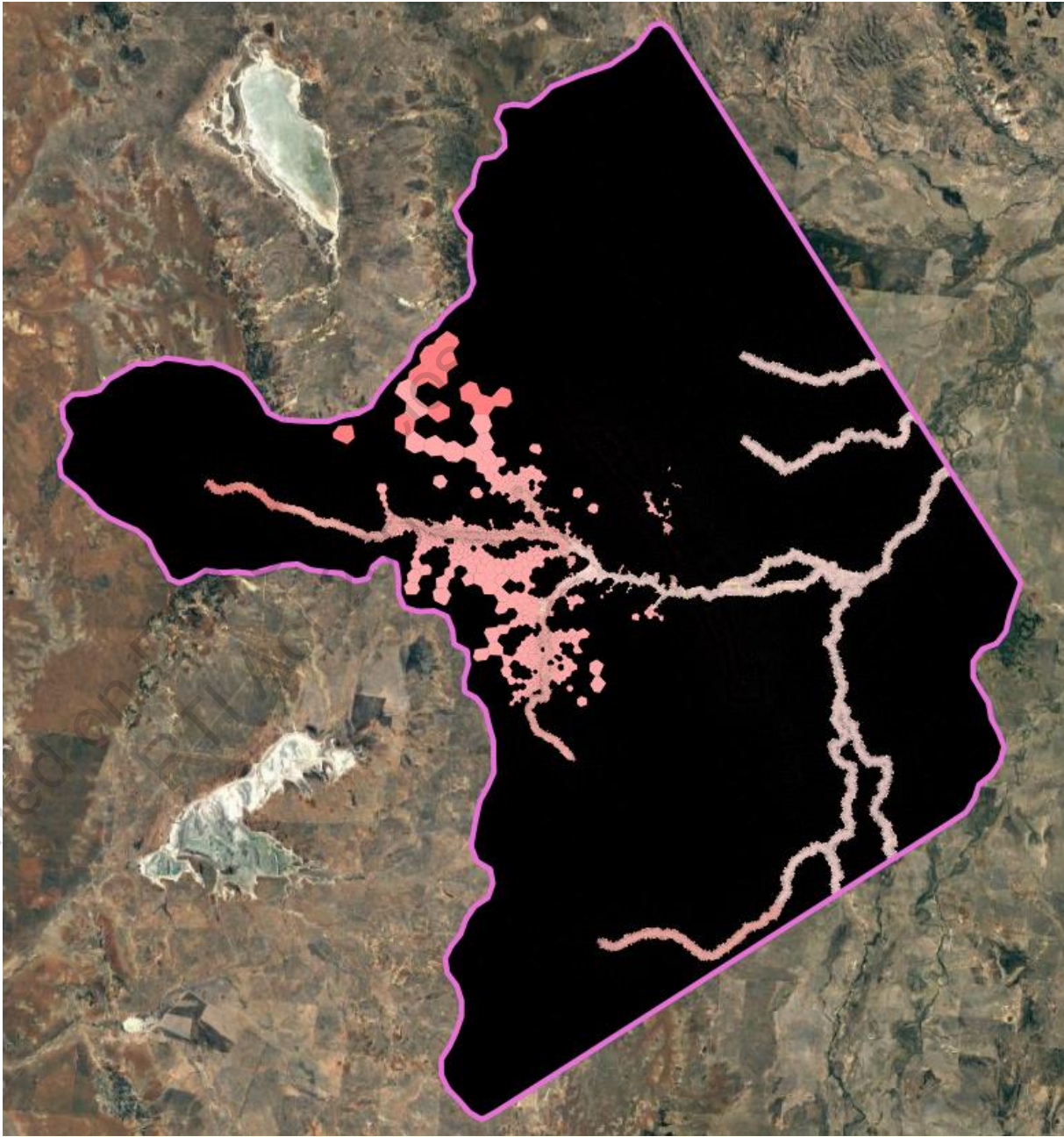
Model layer	HSU
1	Quaternary alluvium
2	Weathering zone
3	Tertiary and non-alluvial Quaternary deposits
4	Moolayember Formation
5	Clematis Sandstone / Warang Sandstone
6	Dunda Beds
7	Rewan Formation (upper)
8	Rewan Formation (lower)
9	Bandanna Formation
10	Bandanna Formation (AB Seam coal)
11	Bandanna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

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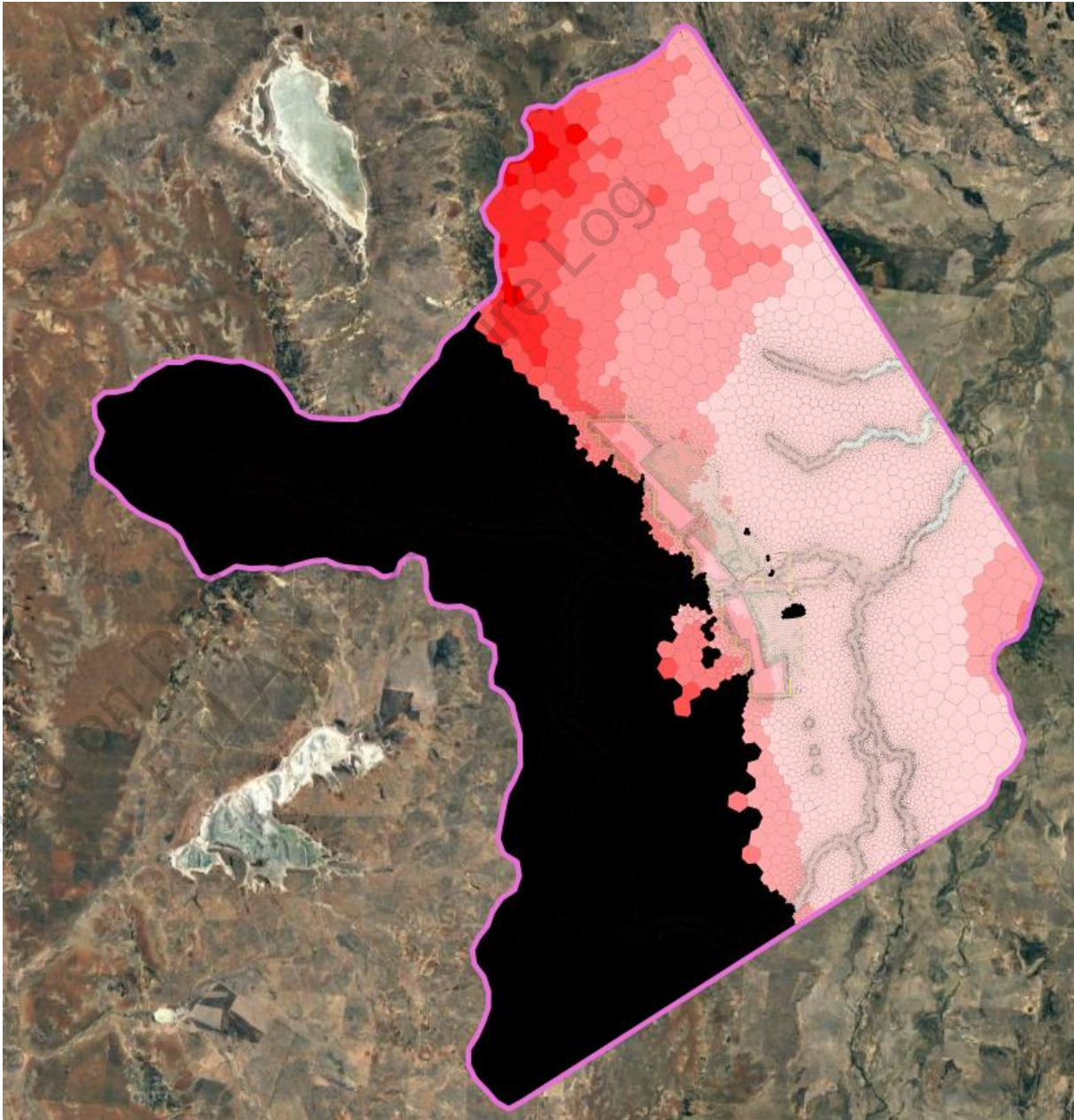
File A

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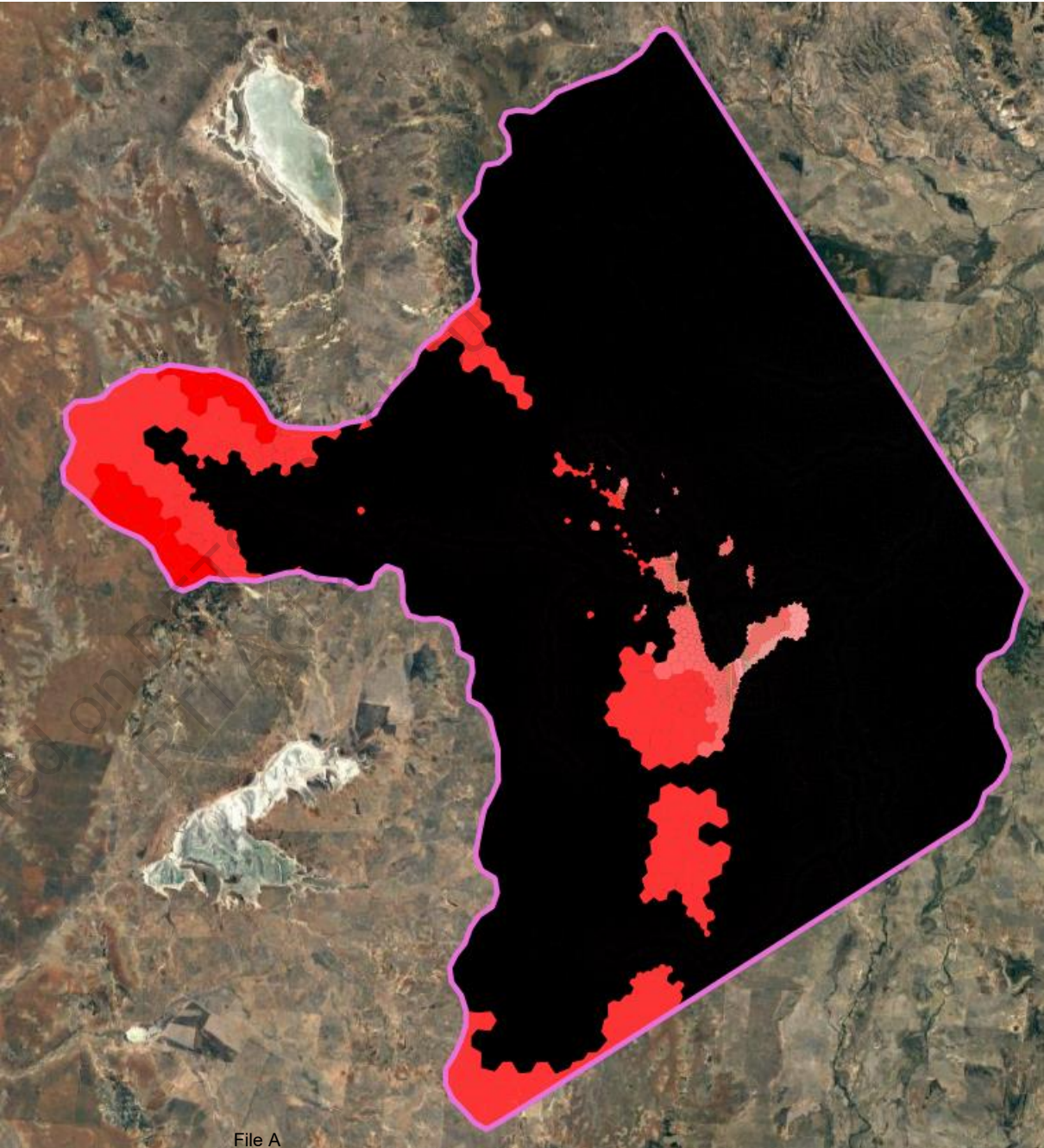
Alluvium top (mAHD)



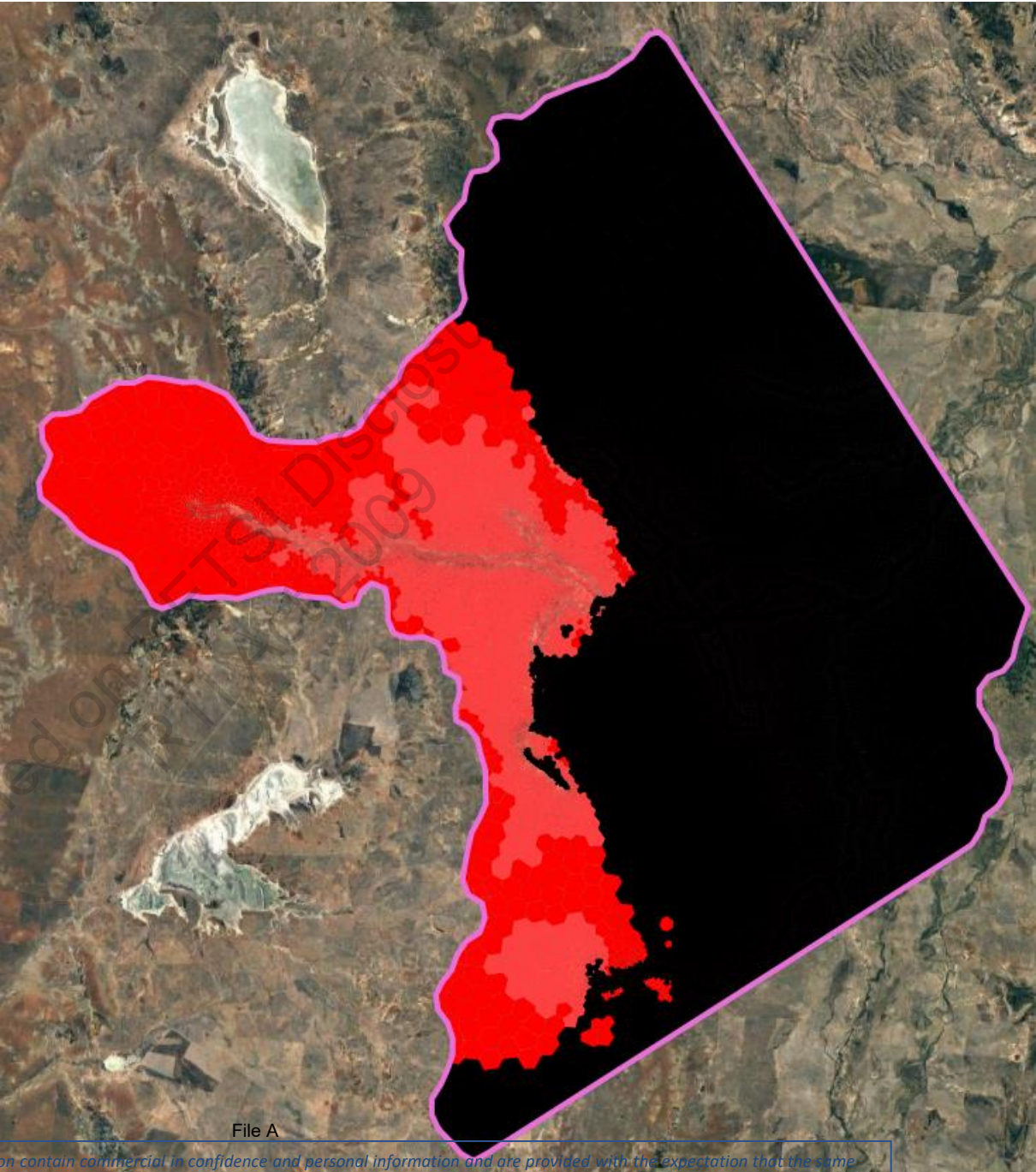
Weathering zone top (mAHD)



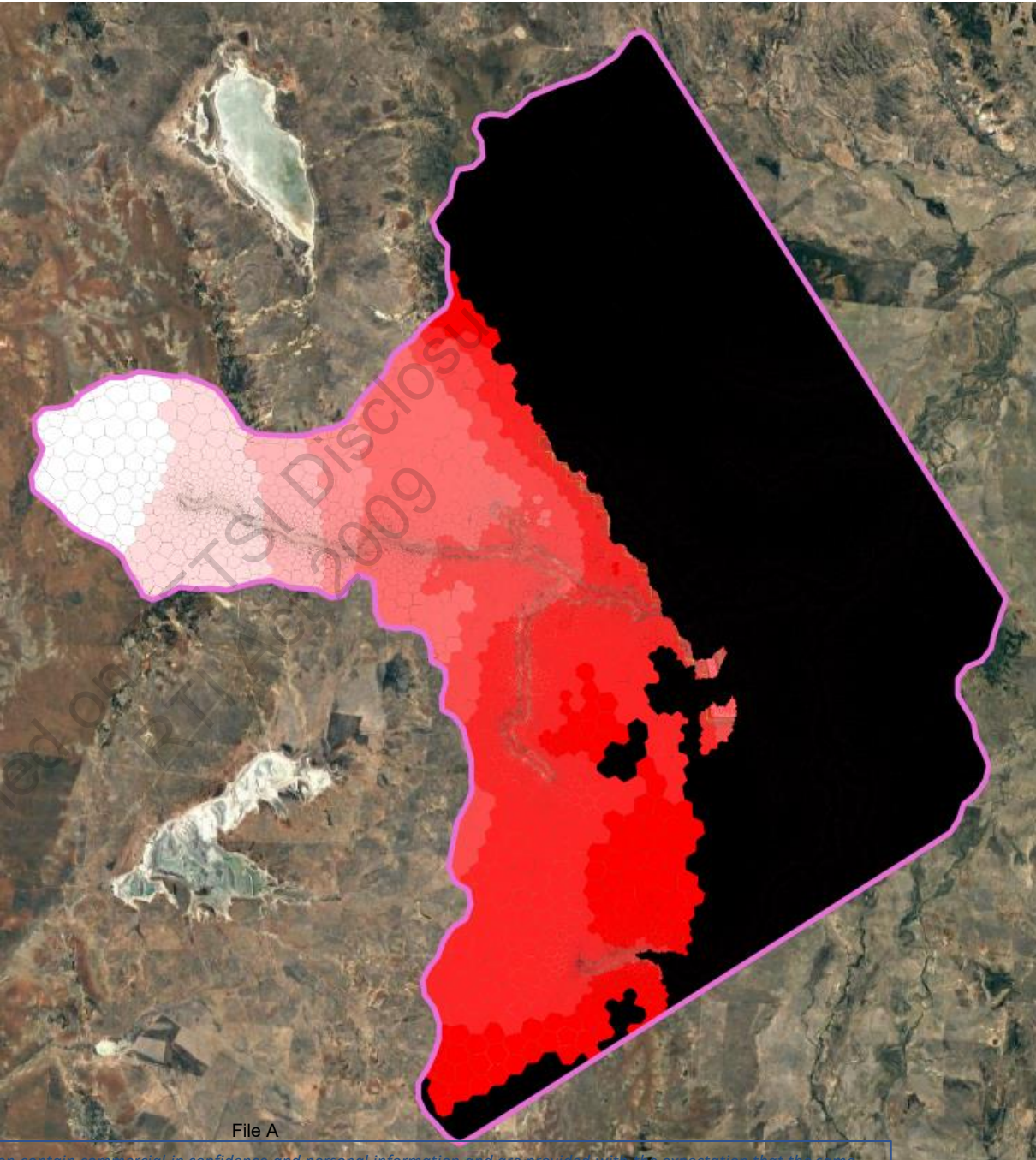
Tertiary top (mAHD)



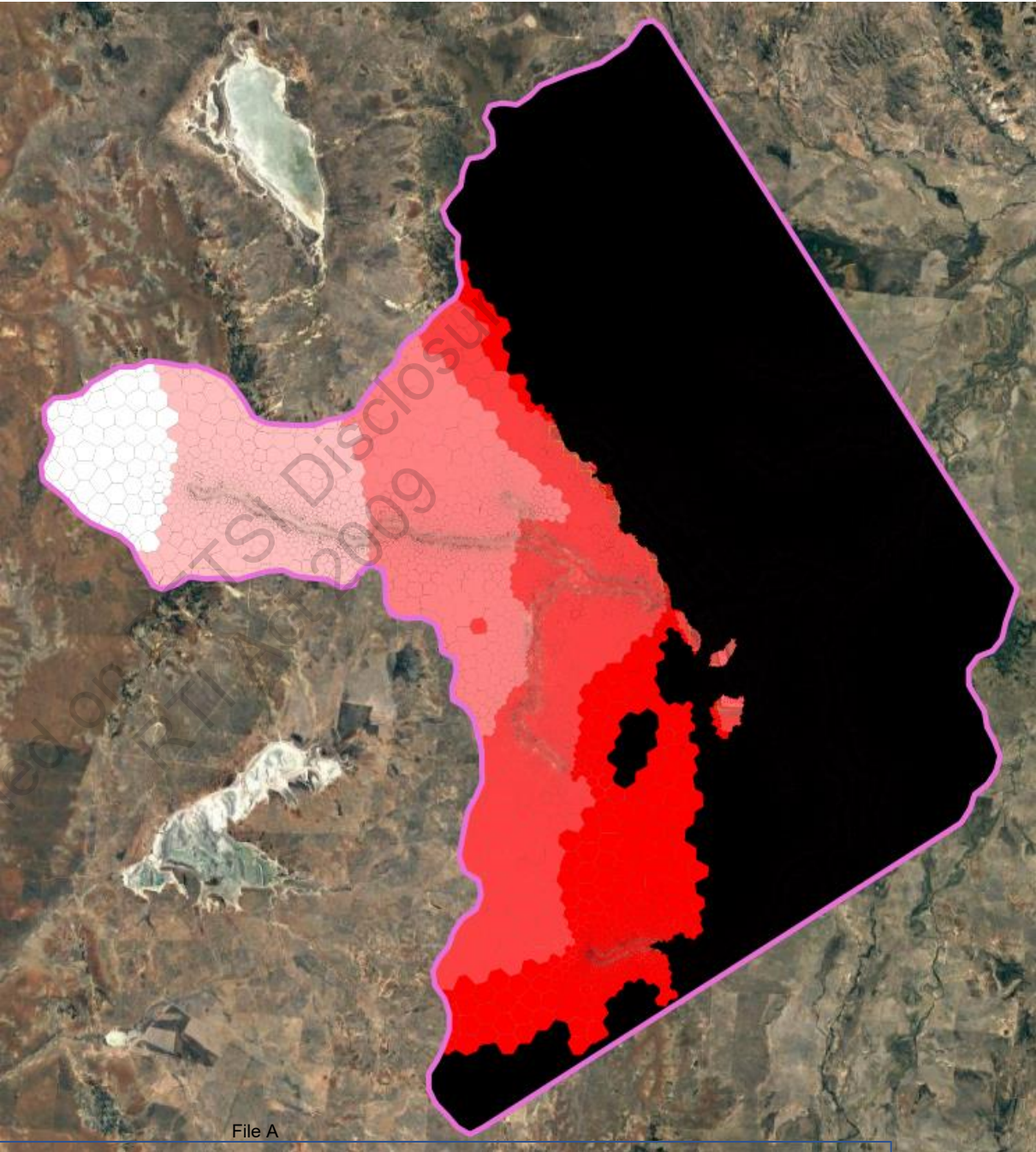
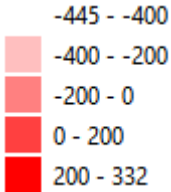
Moolayember top (mAHD)



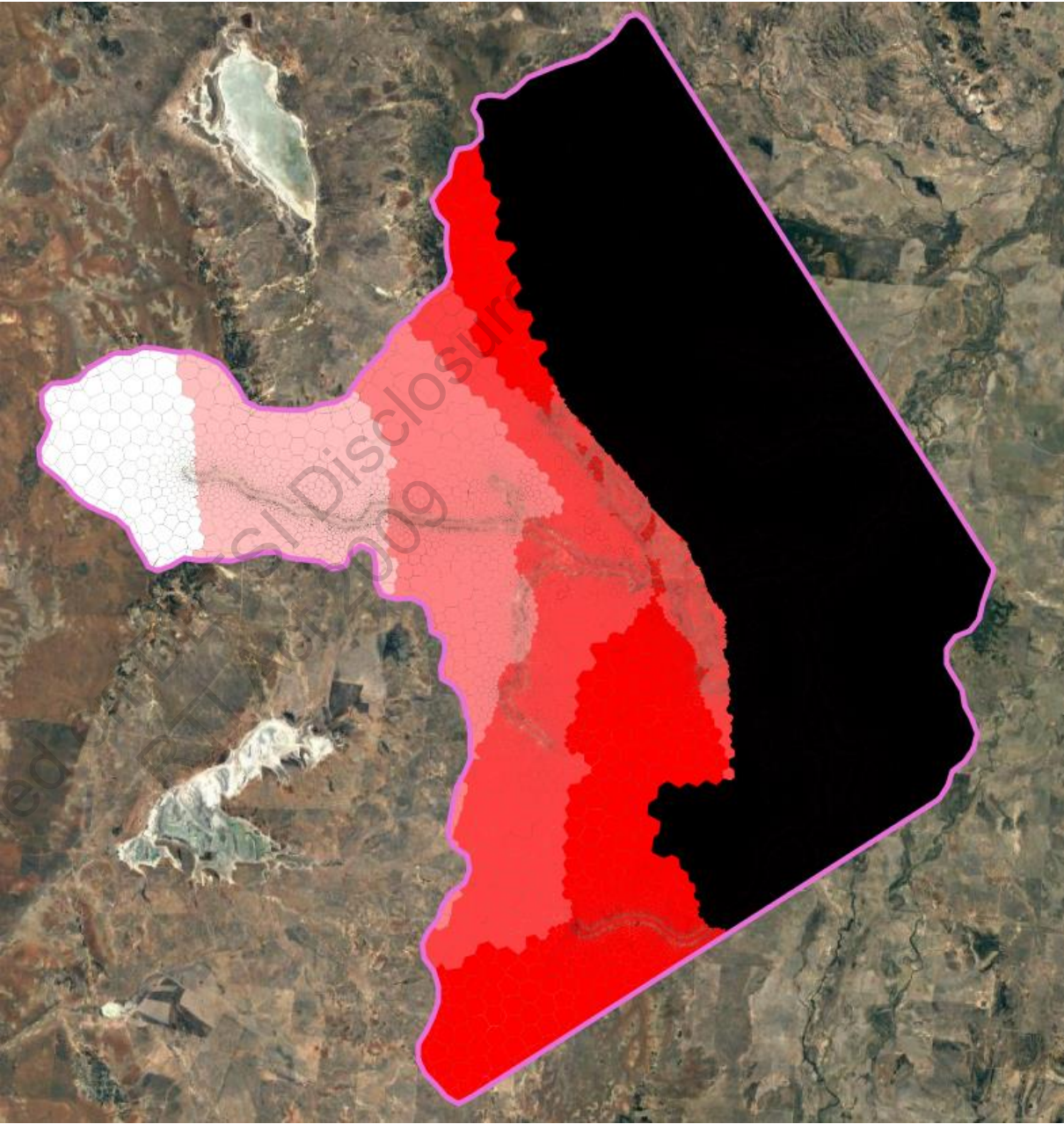
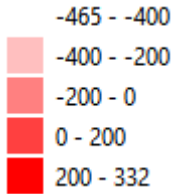
Clematis top (mAHD)



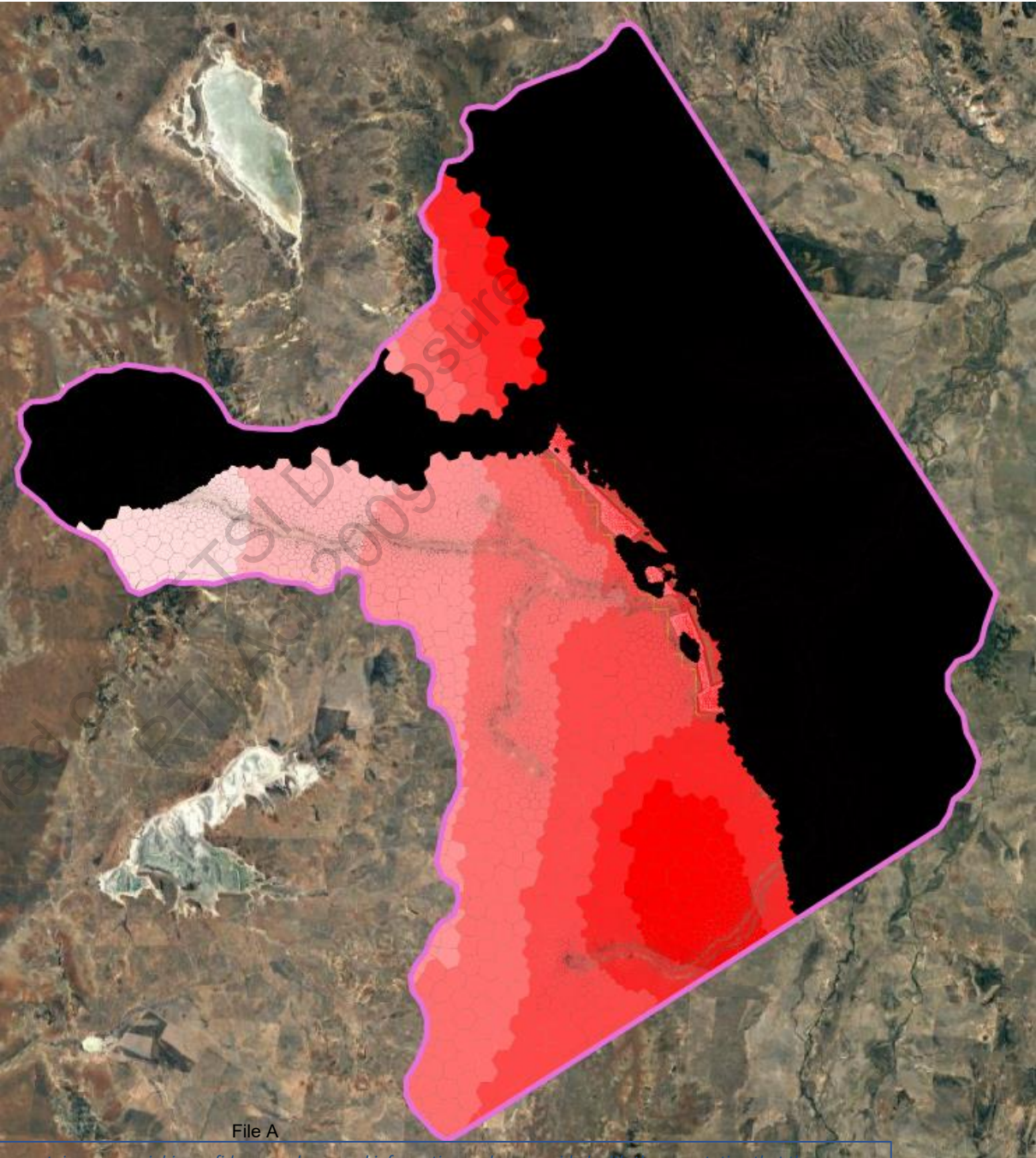
Dunda top (mAHD)



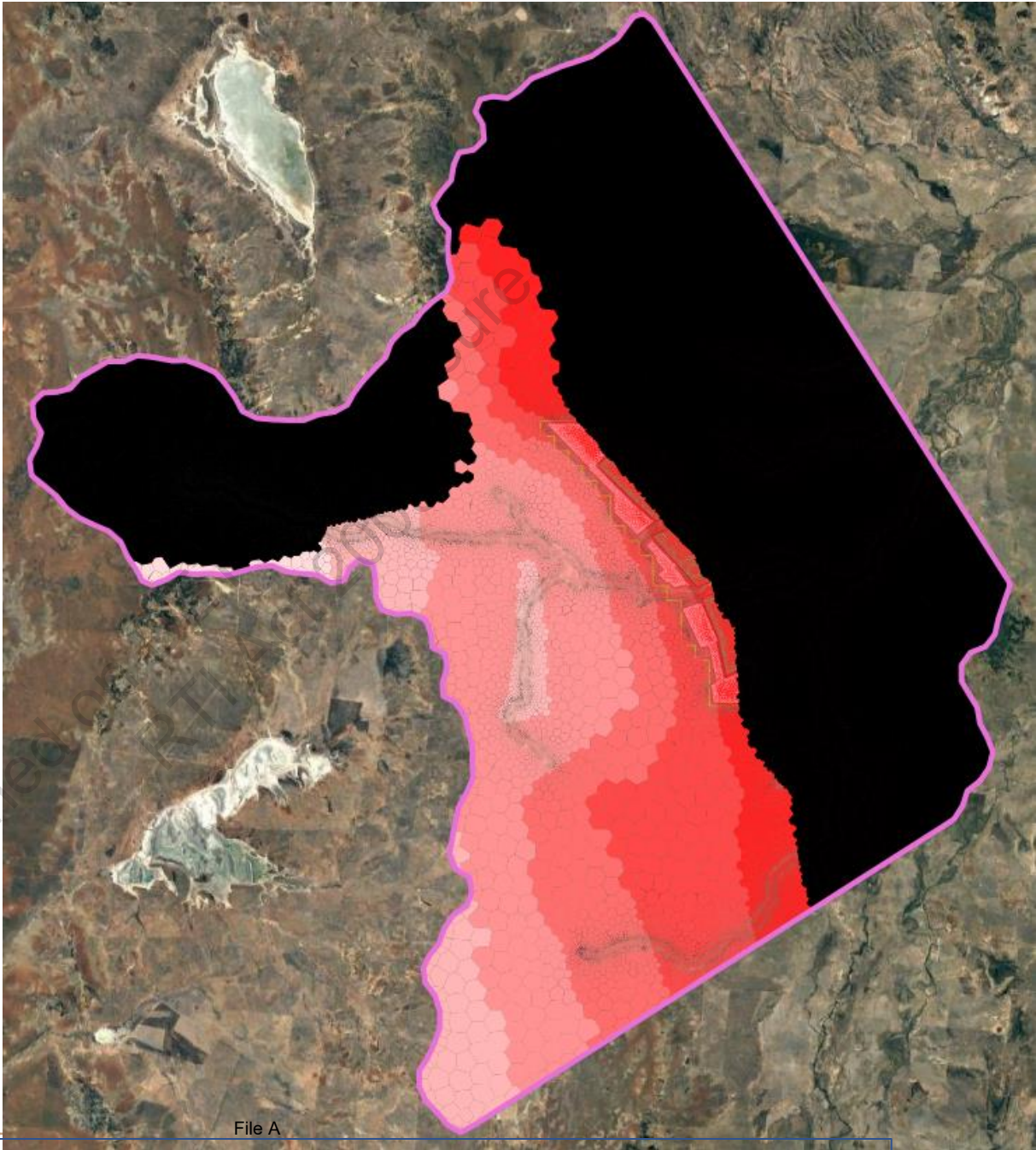
Rewan top (mAHD)



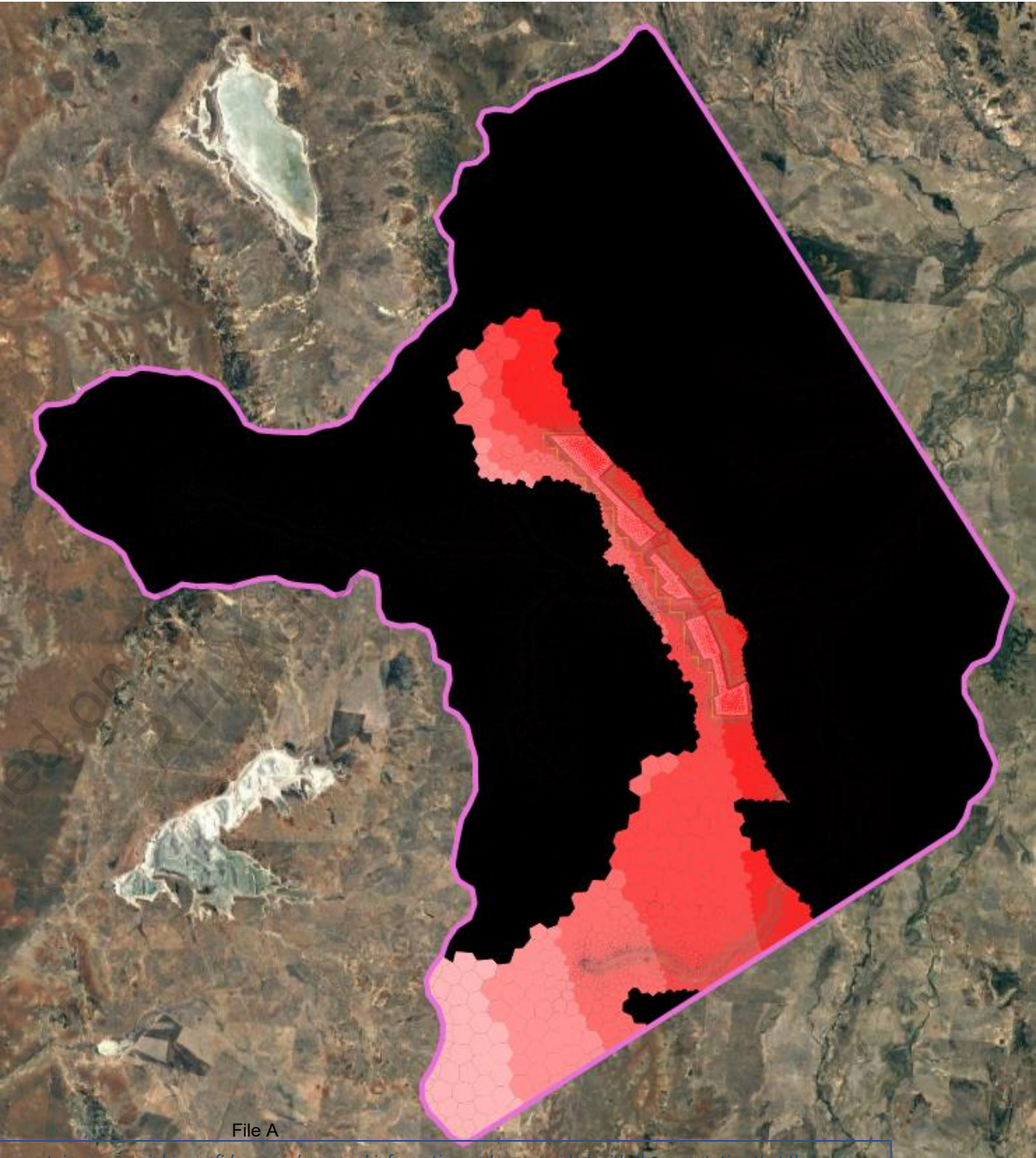
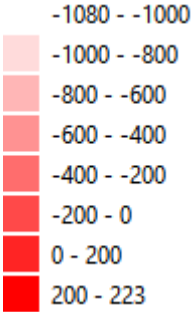
Bandanna top (mAHD)



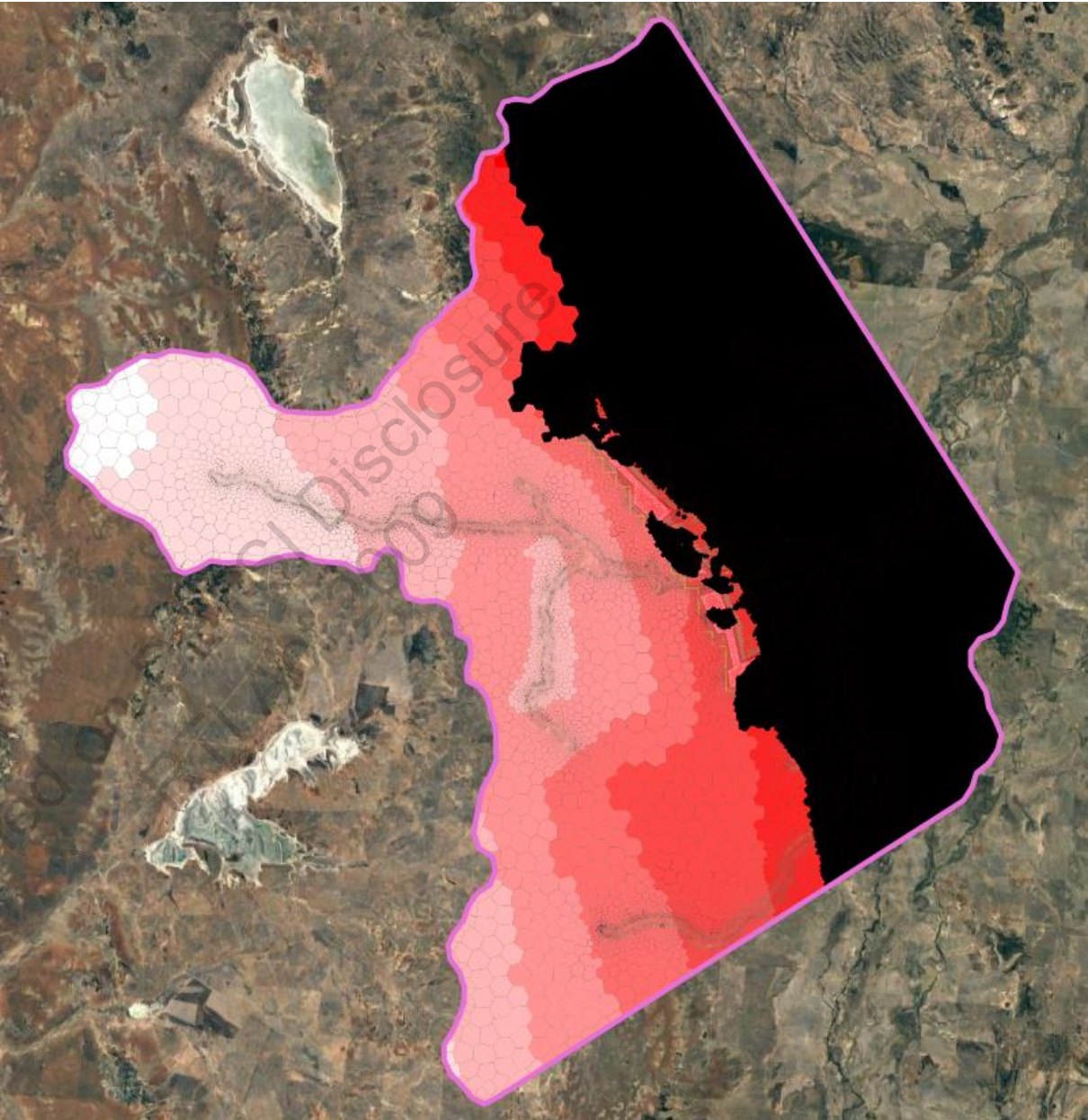
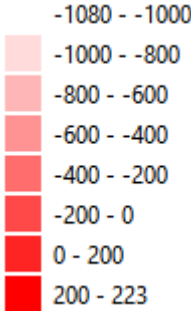
AB Coal top (mAHD)



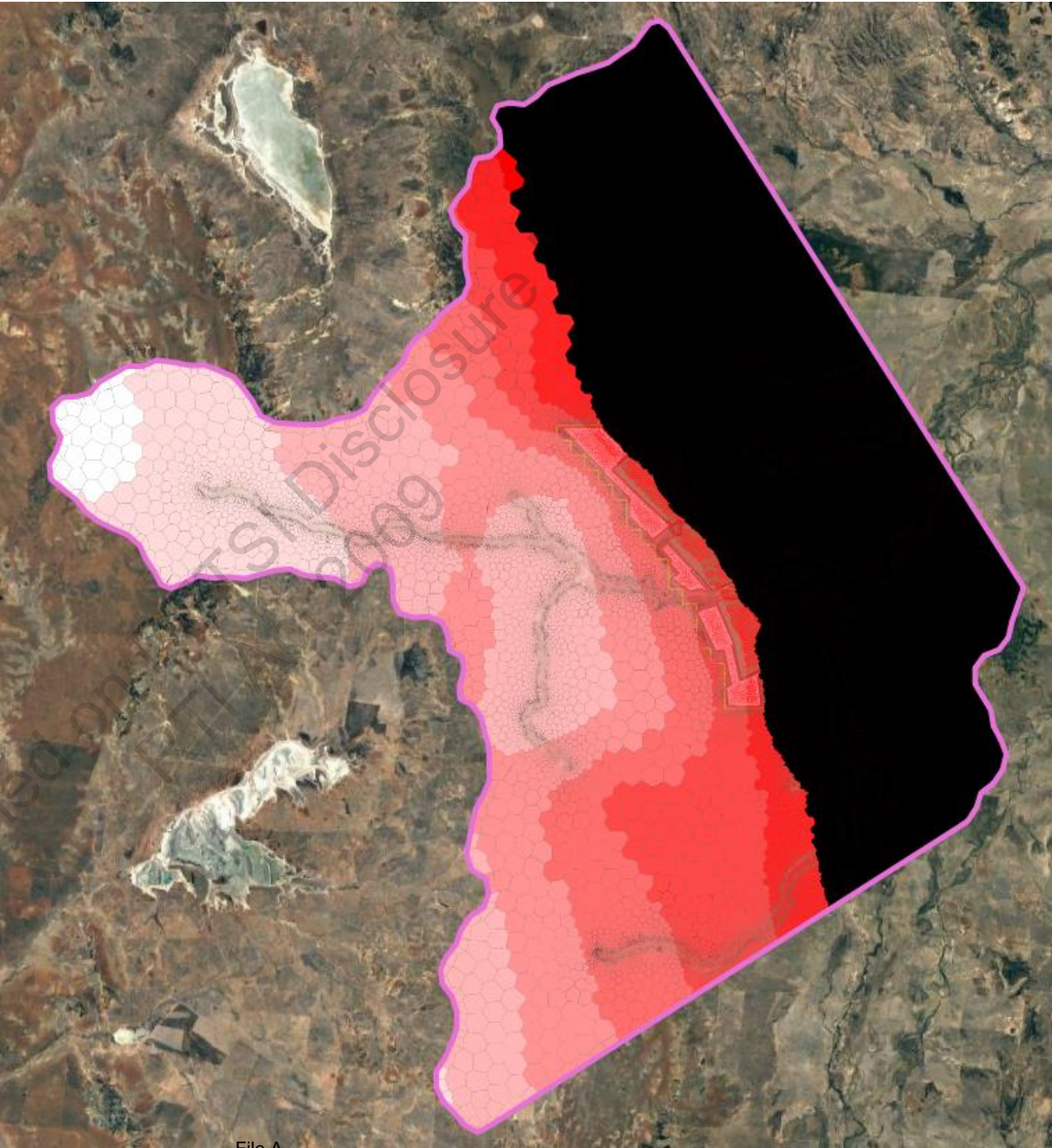
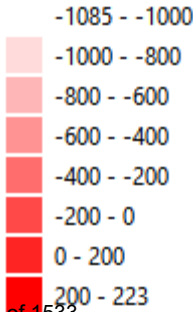
Bandanna (interburden) top (mAHD)



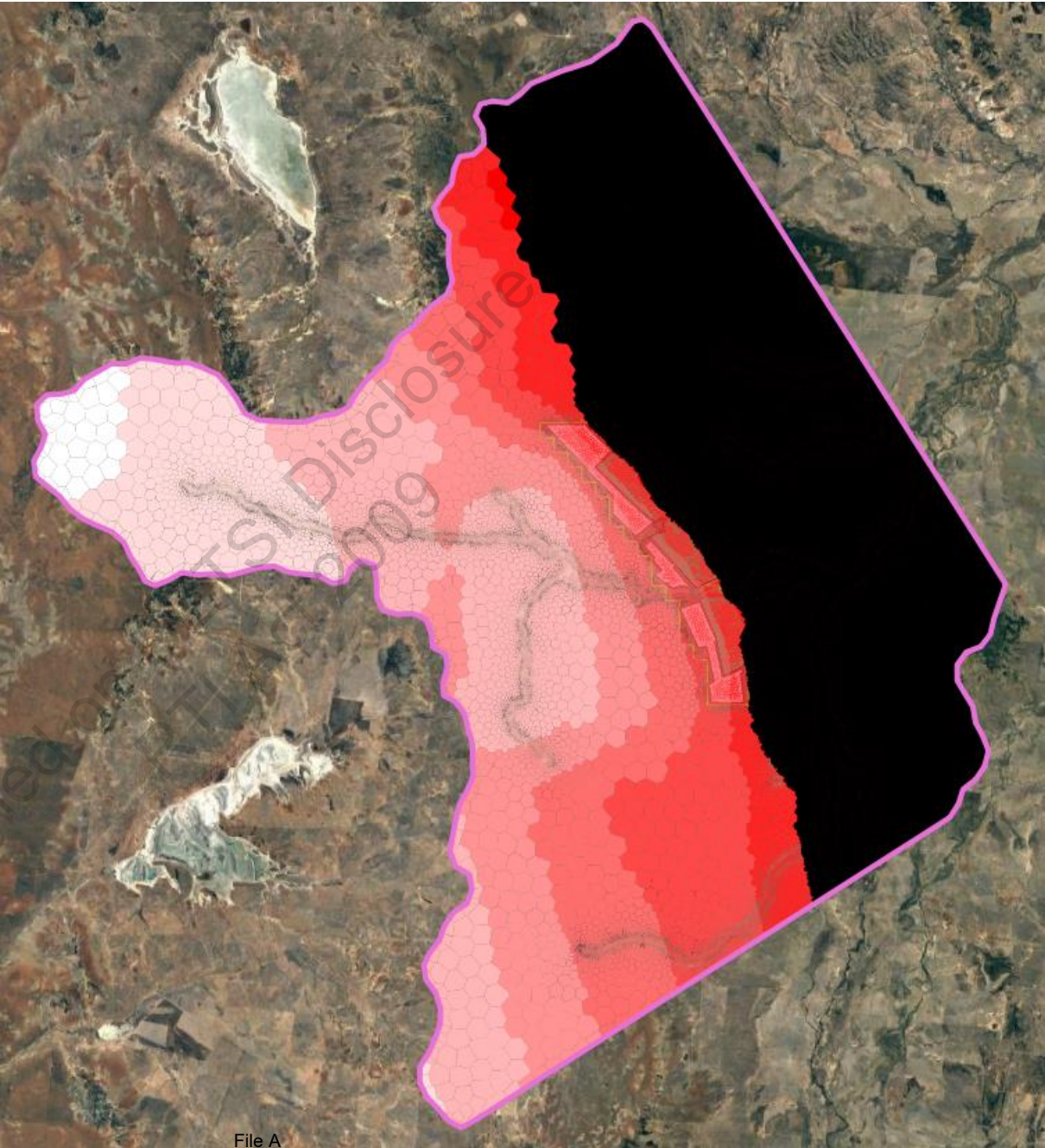
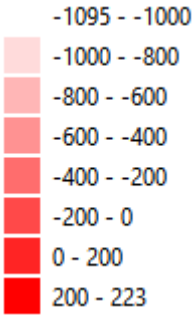
Colinlea top (mAHD)



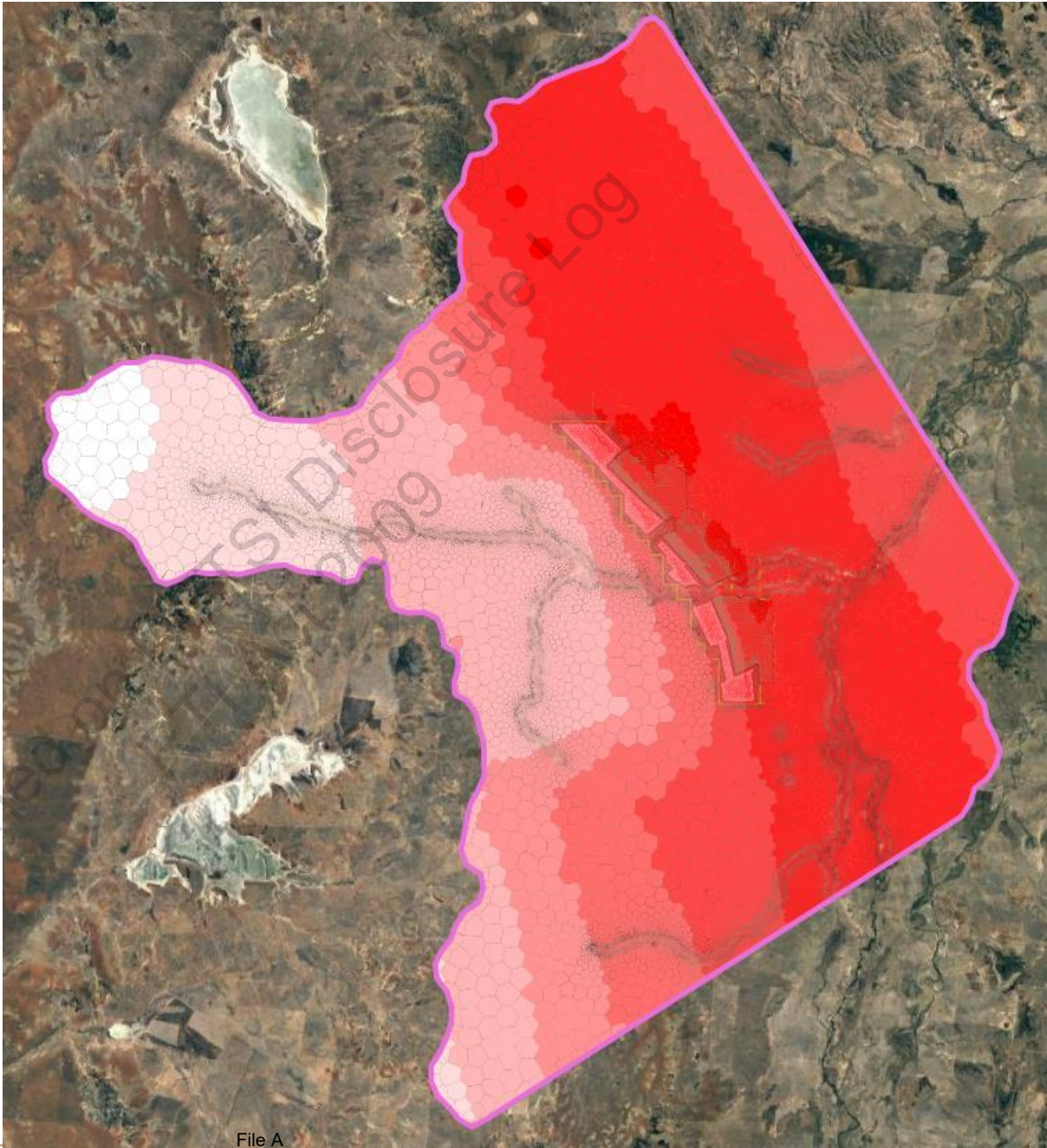
D Coal top (mAHD)



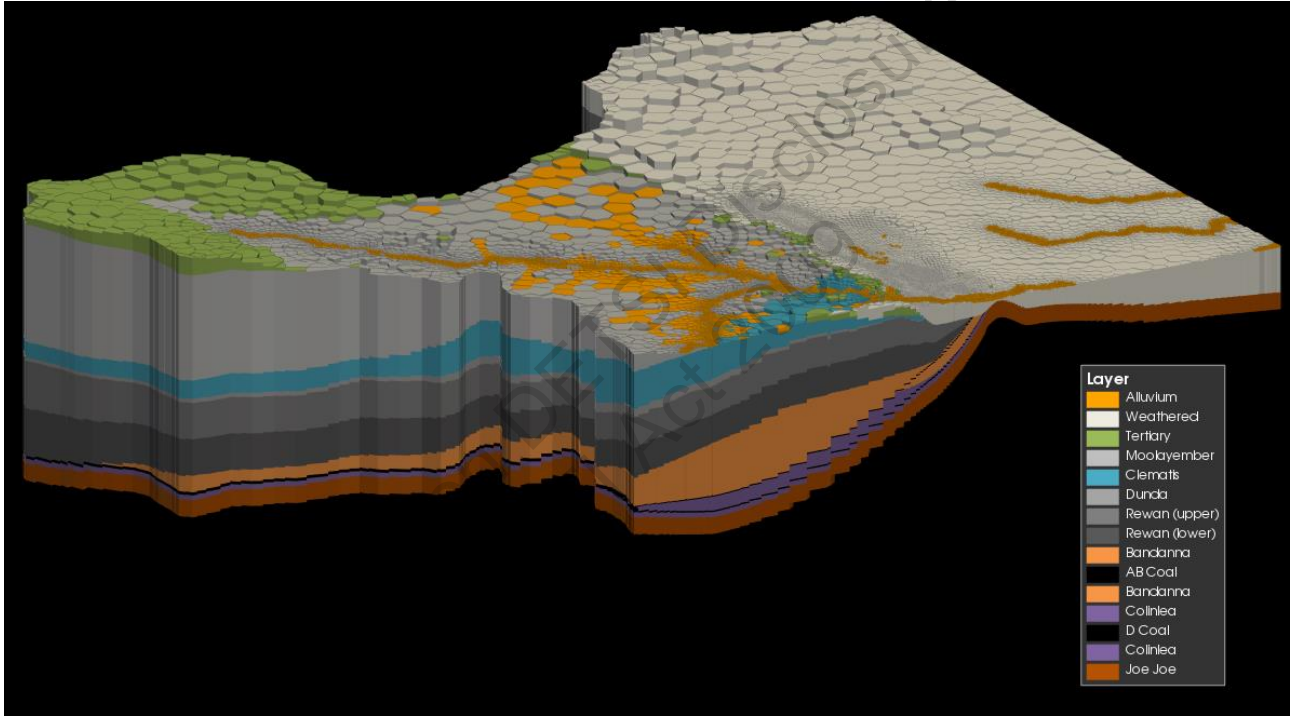
Colinlea (underburden) top (mAHD)



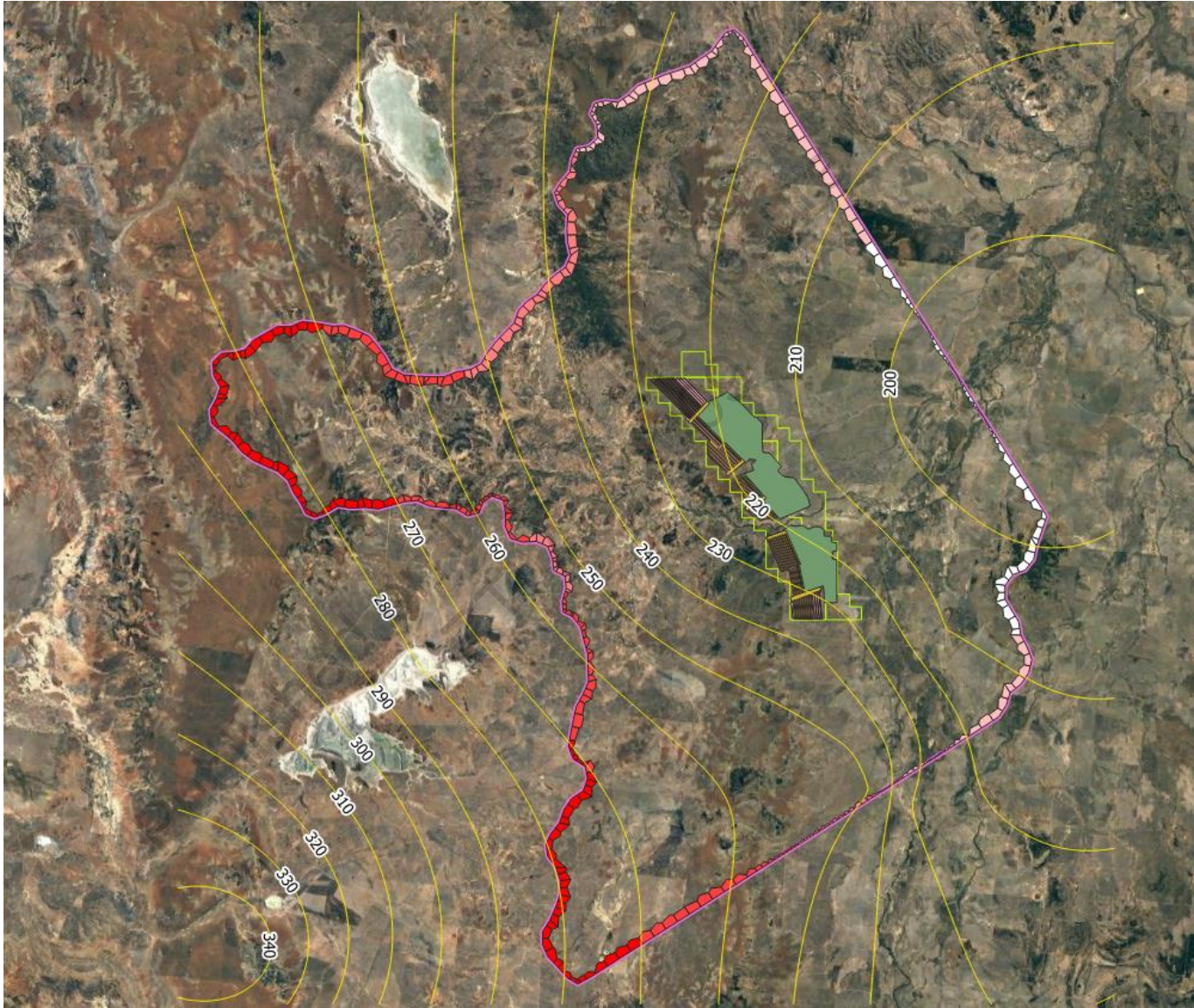
Joe Joe top (mAHD)



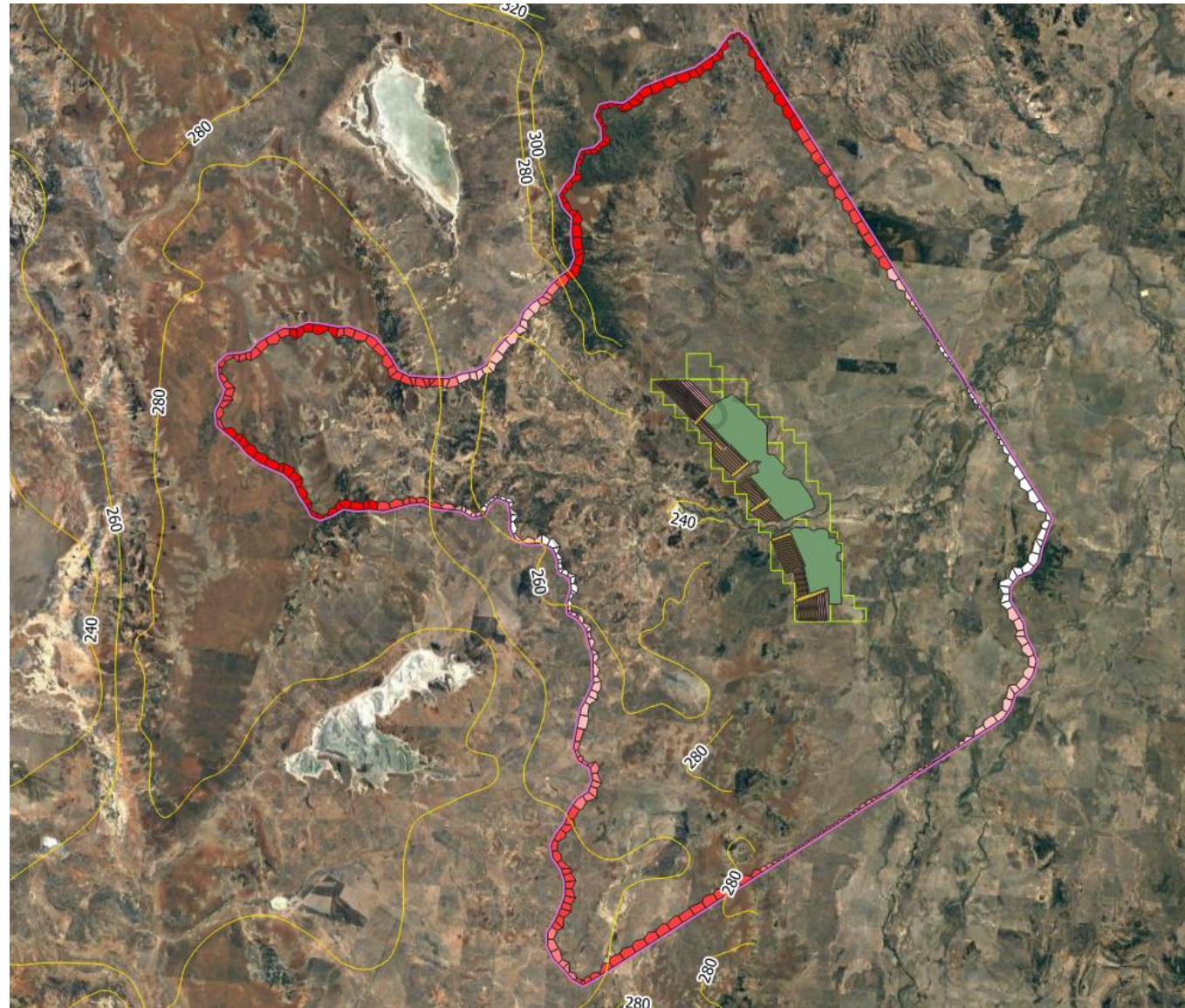
Cross section (west-east)



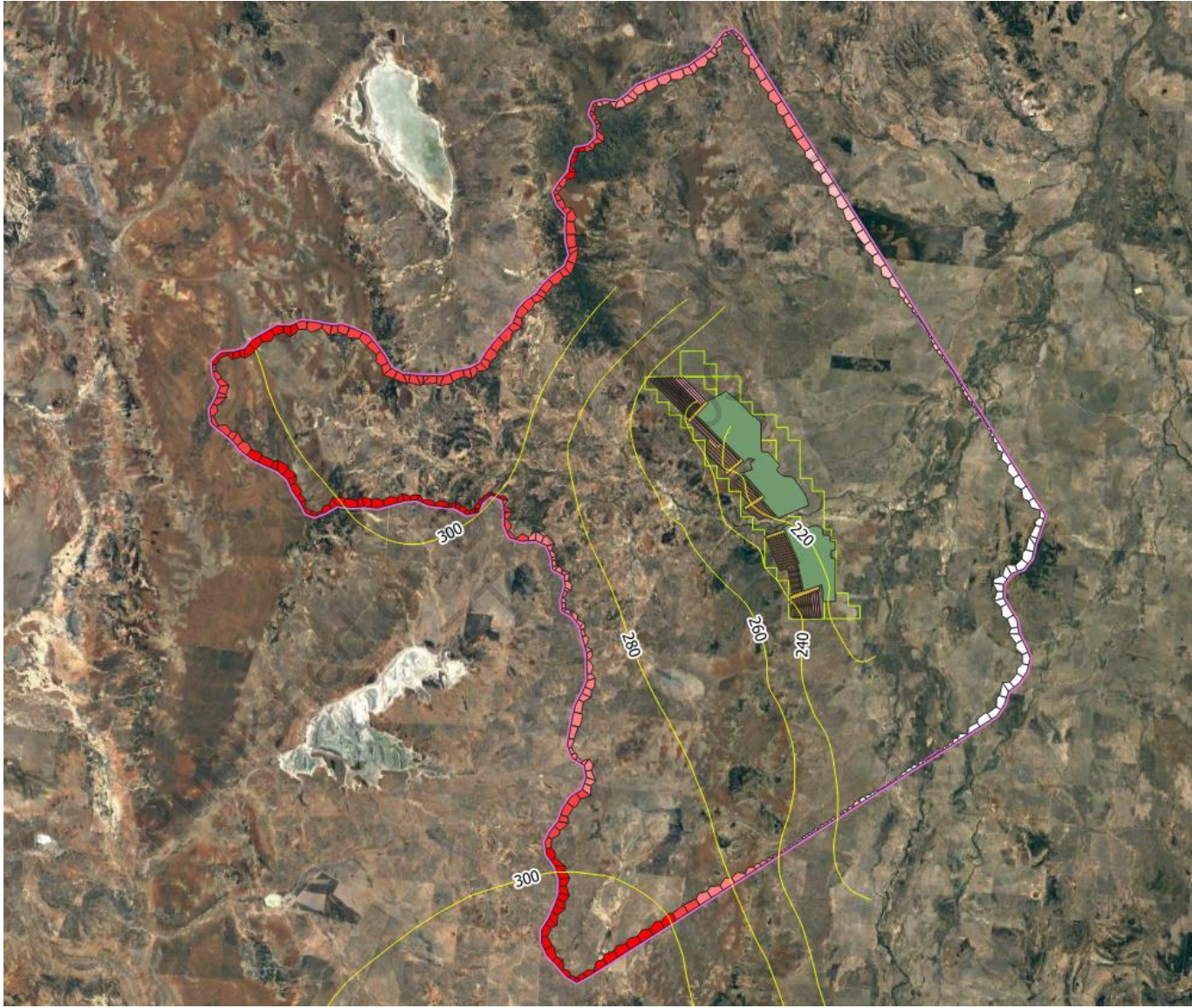
Surficial regional boundaries



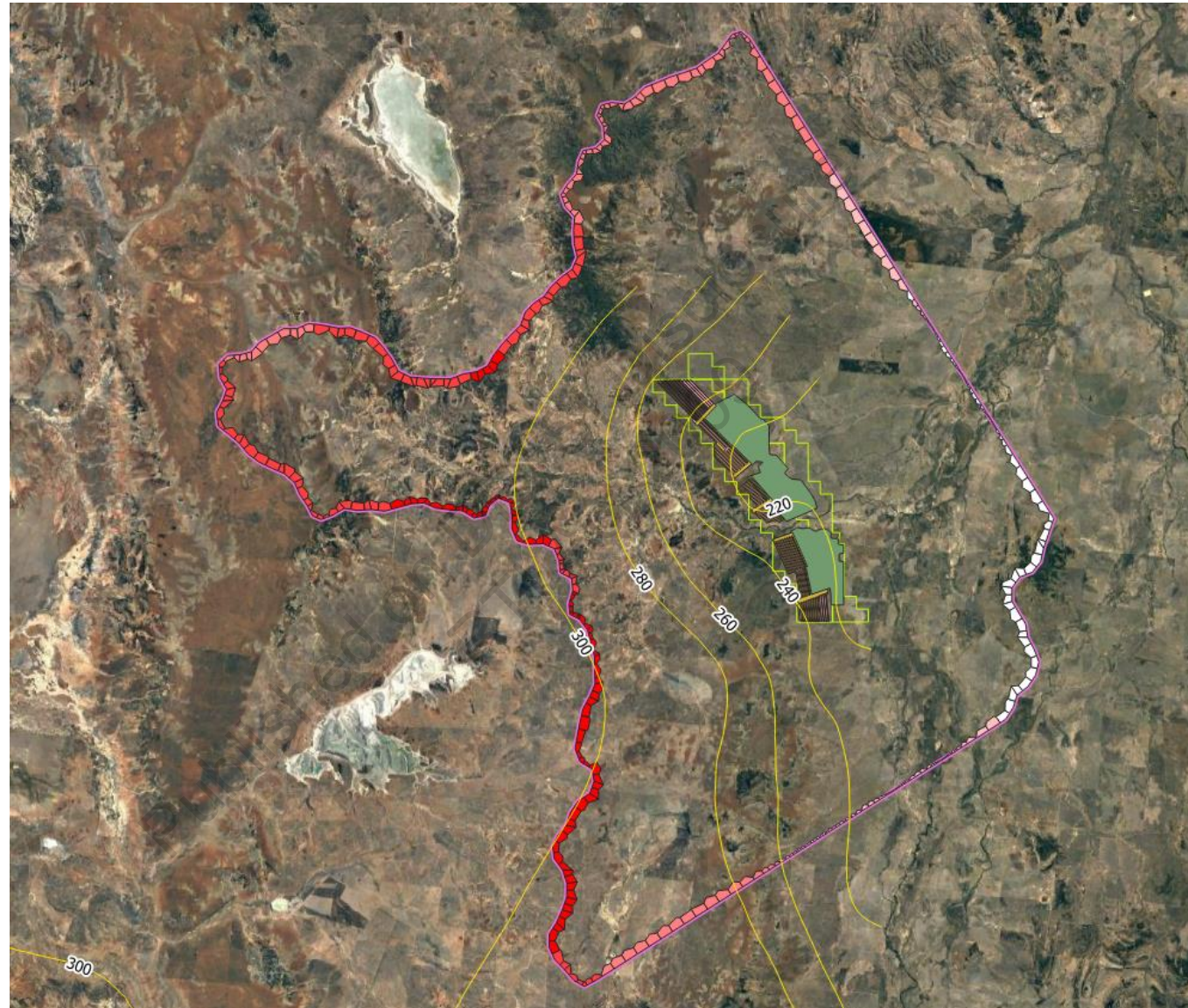
Clematis regional boundaries



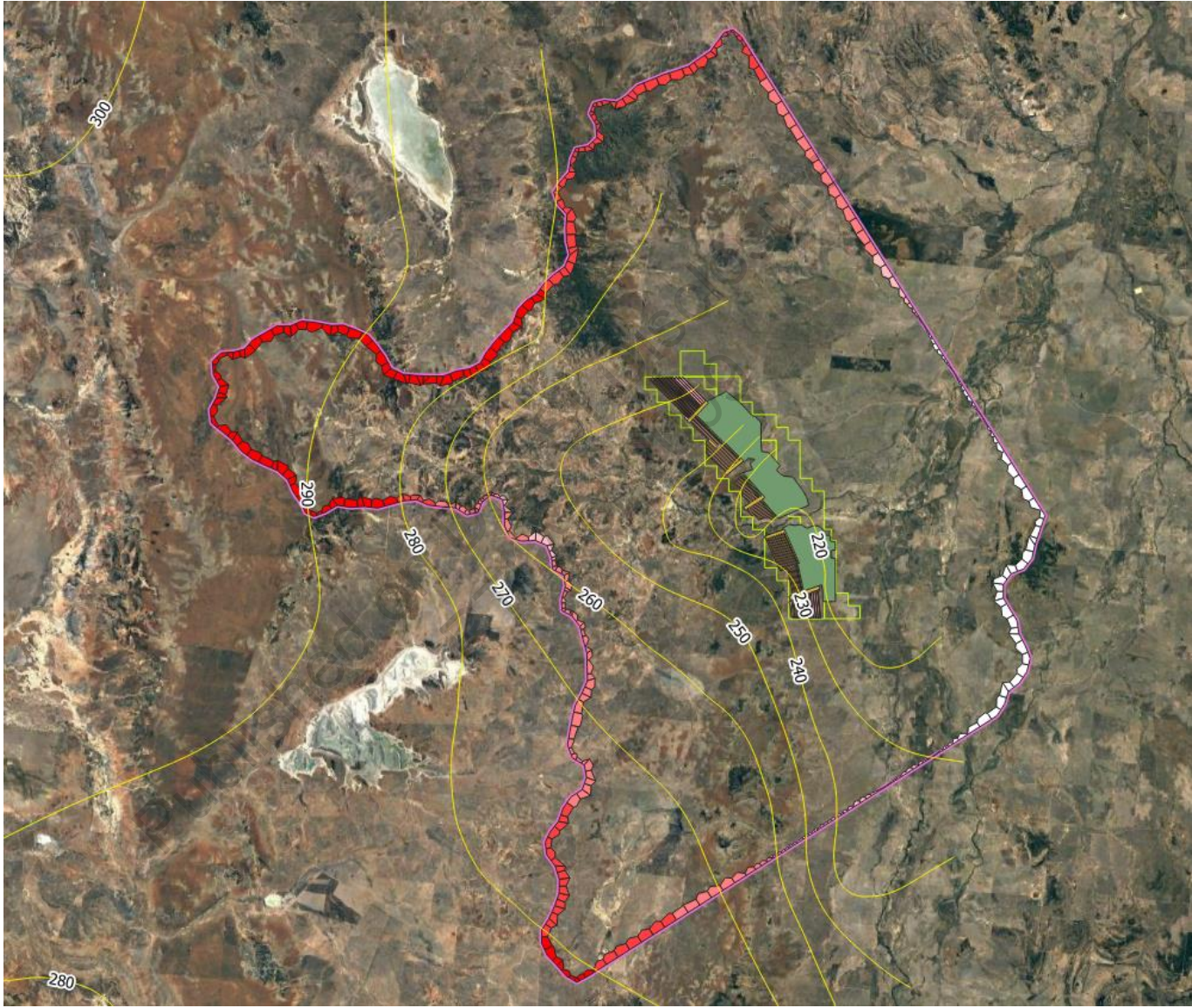
Bandanna regional boundaries



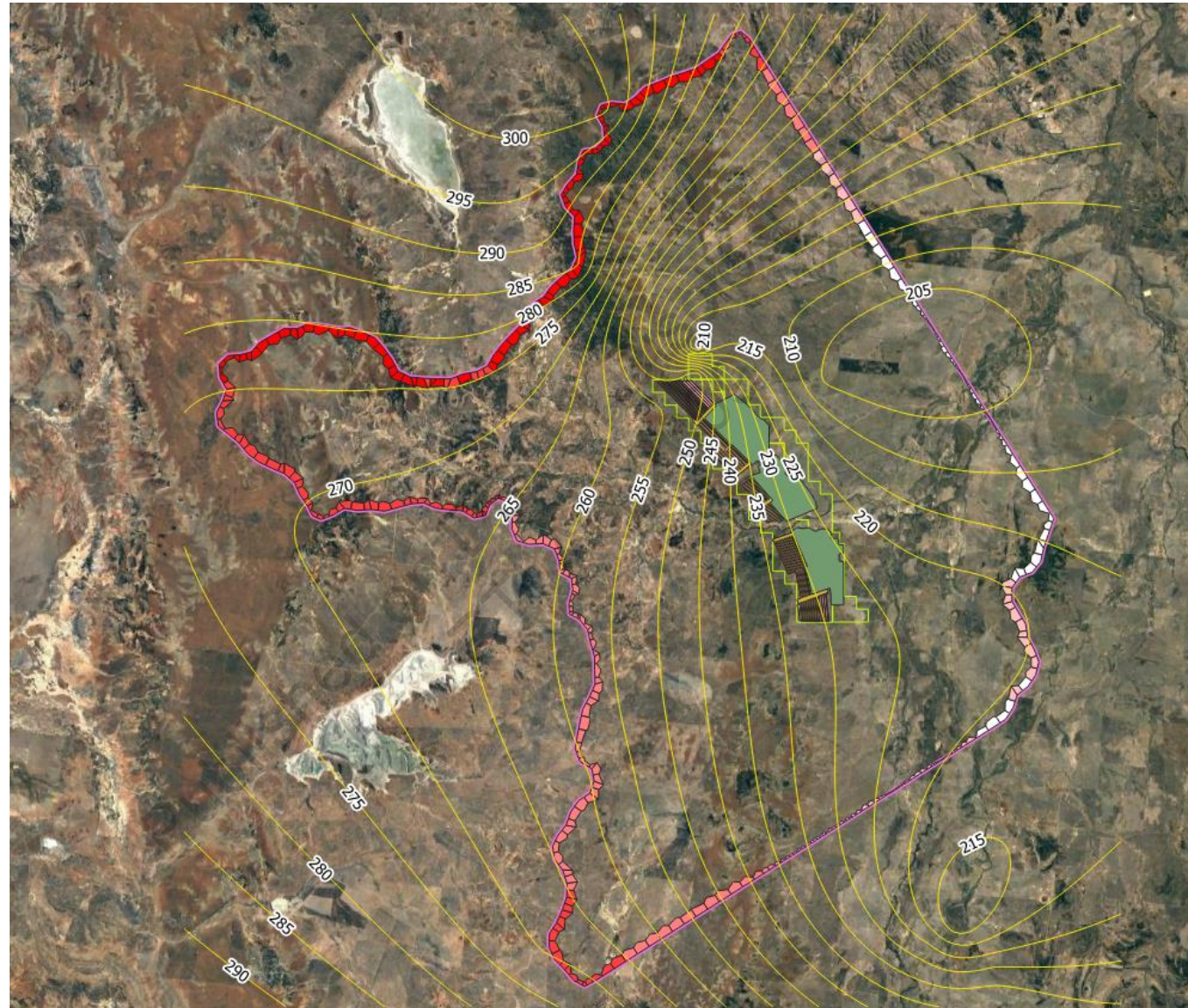
Coal seam regional boundaries



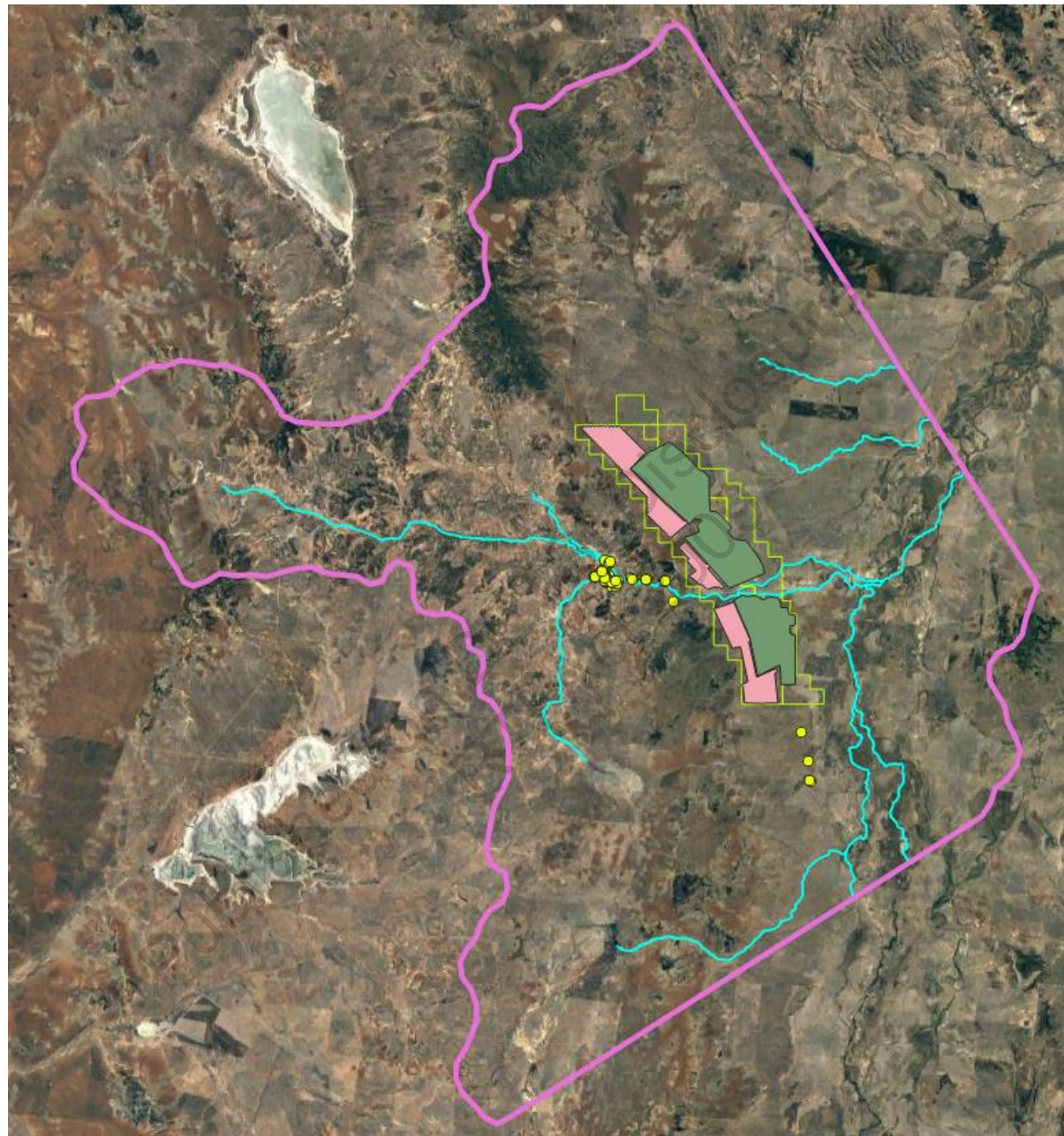
Colinlea regional boundaries



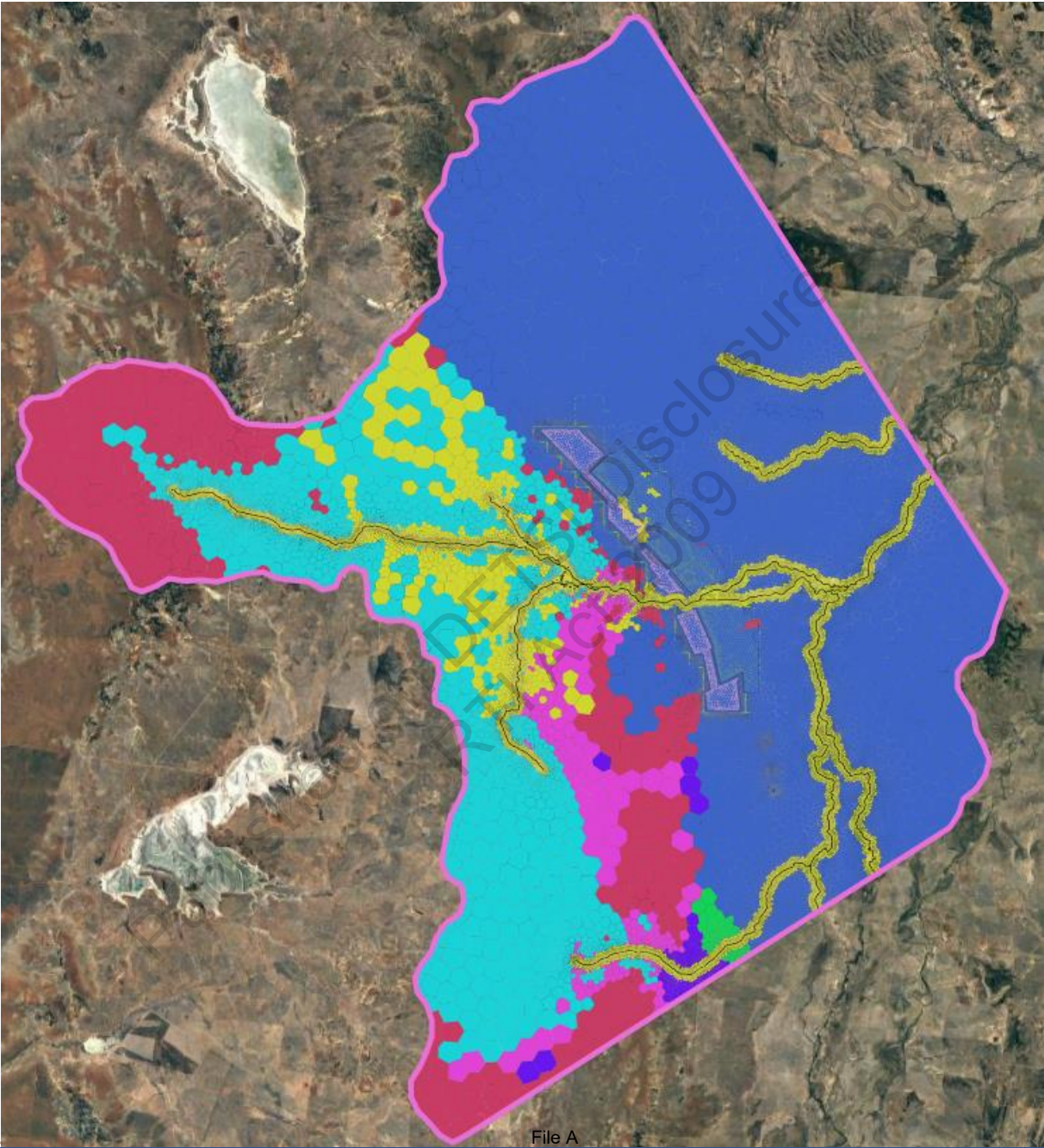
Joe Joe regional boundaries



Surface water



Recharge



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

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MINING & RESOURCES

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

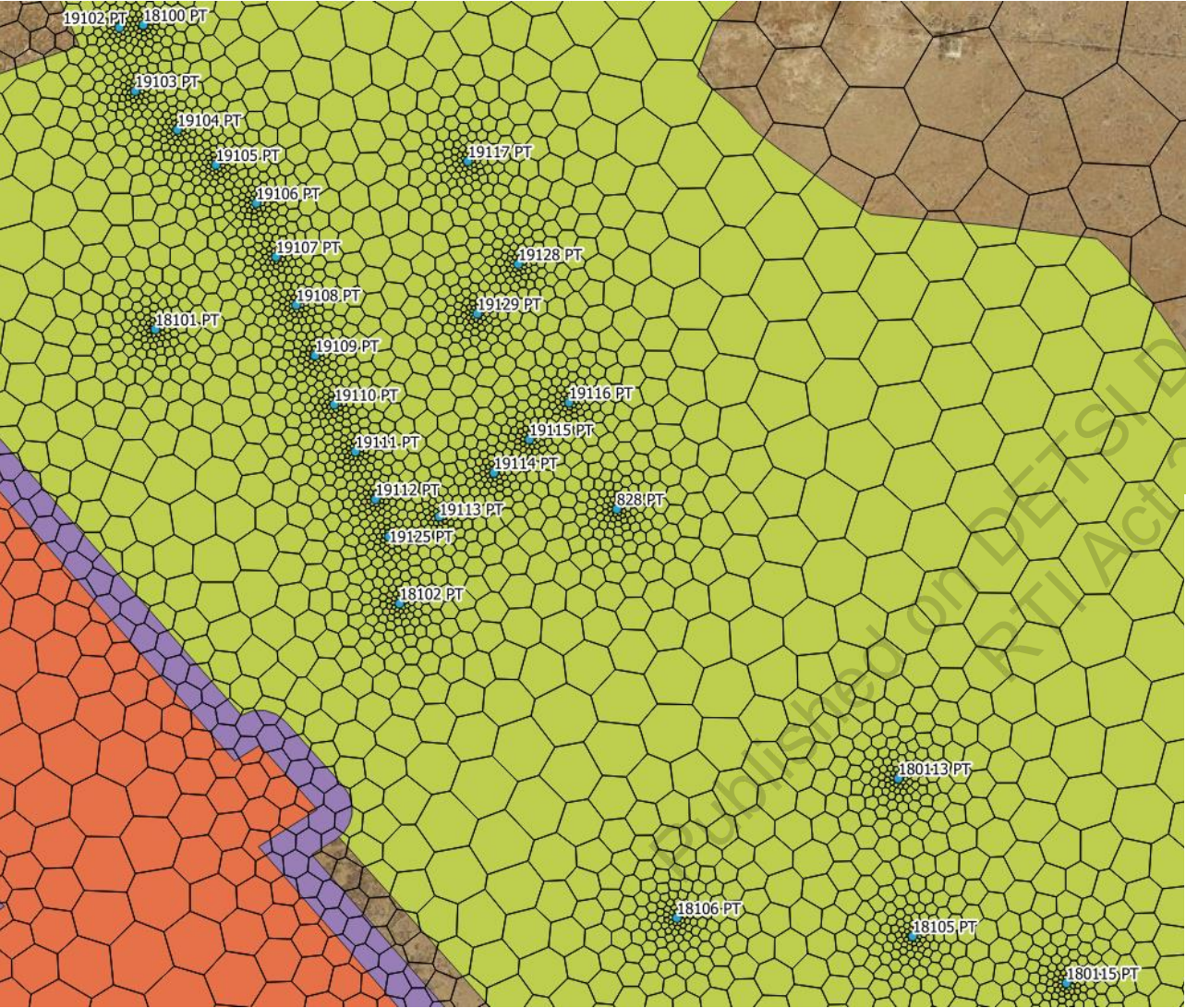
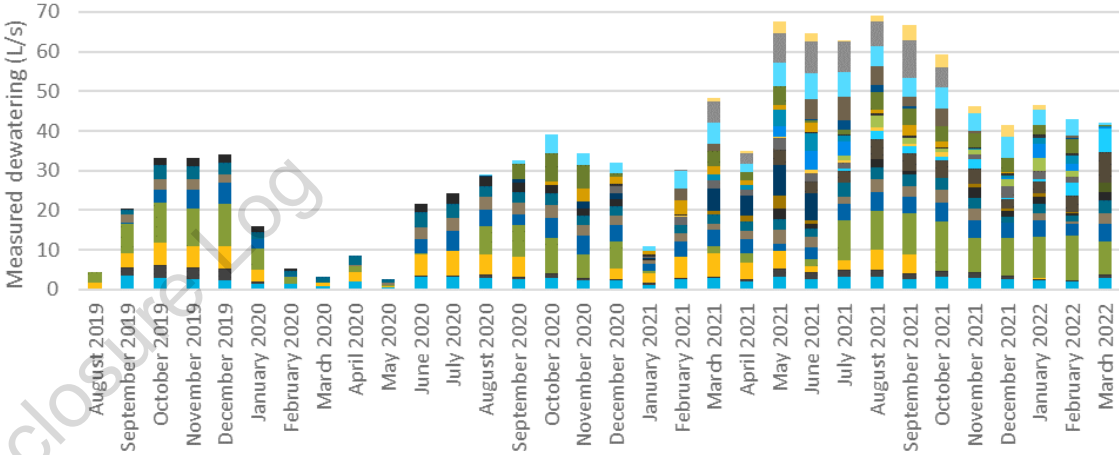
Modelled watercourses

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

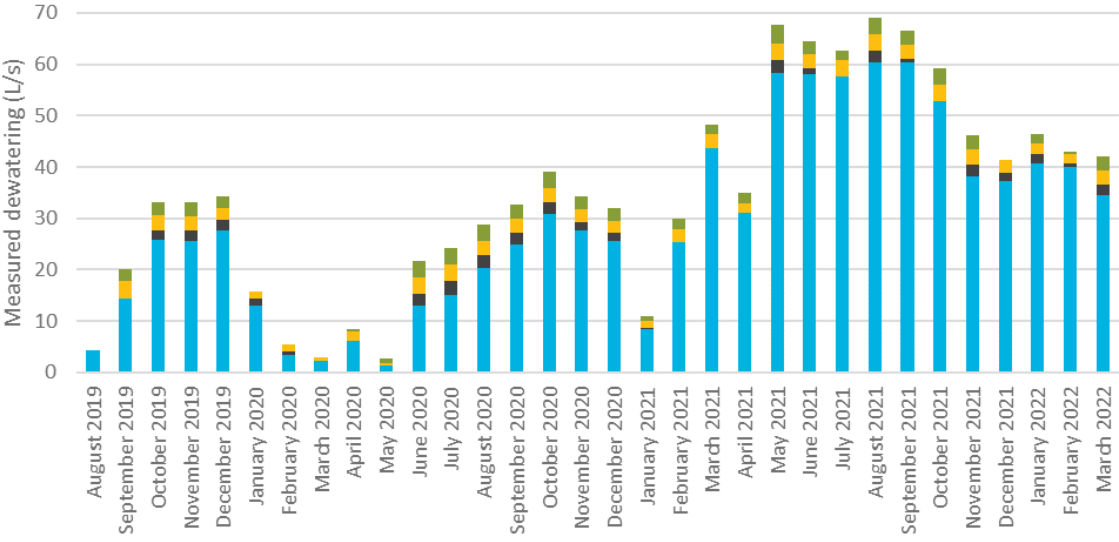
Modelled recharge and evapotranspiration

- 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



- 828 PT
- 18100 PT
- 18101 PT
- 18102 PT
- 18106 PT
- 180113 PT
- 18105 PT
- 180115 PT
- 19125 PT
- 19113 PT
- 19114 PT
- 19115 PT
- 19116 PT
- 19129 PT
- 19128 PT
- 19112 PT
- 19111 PT
- 19110 PT
- 19109 PT
- 19102 PT
- 19103 PT
- 19104 PT
- 19105 PT
- 19106 PT
- 19107 PT
- 19108 PT
- 19117 PT



- Full permian sequence
- D Seam
- D Seam and underlying Colinlea Sandstone
- Colinlea Sandstone underlying D Seam

History-matching detailed process

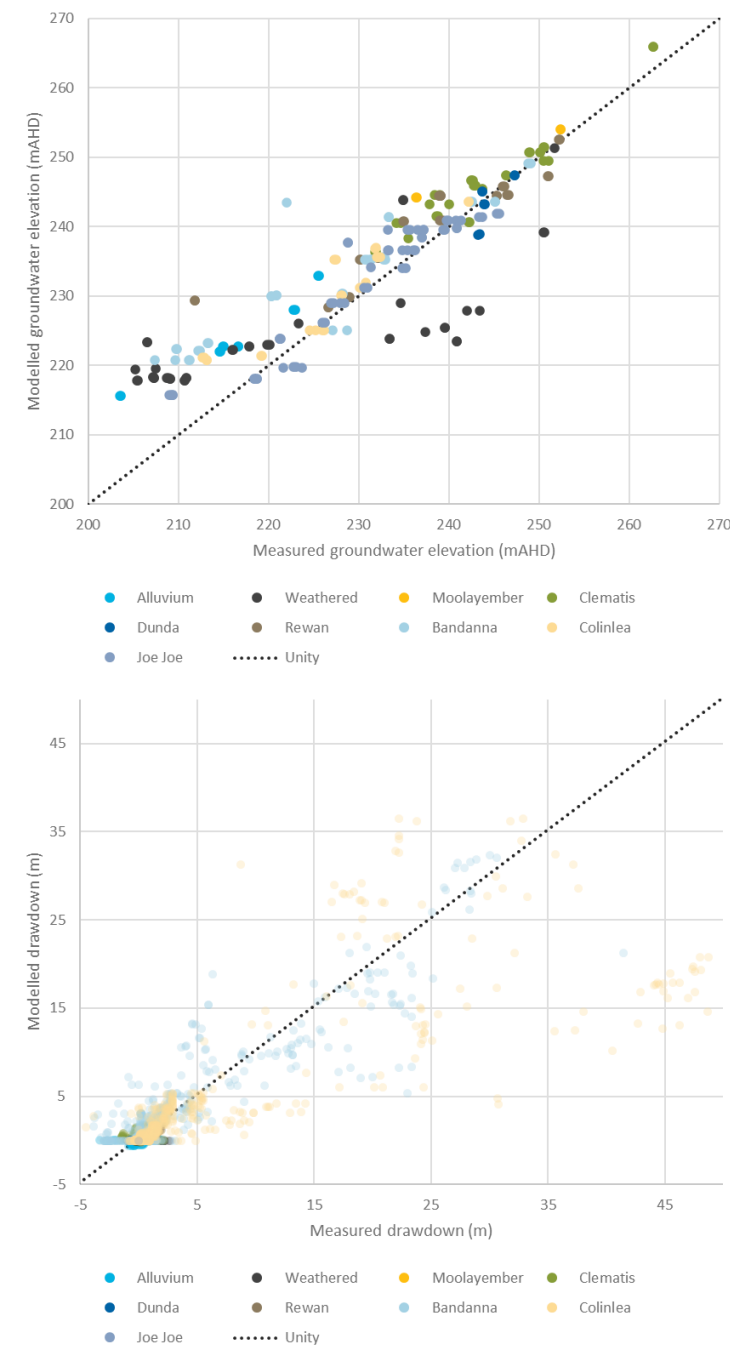
- Set up model with expected hydraulic properties based on hydrogeological conceptual model
- Define measured groundwater level data and estimates of spring flux as targets
 - Group targets by HSU, using first transient measurement as a 'head' target, and the remainder as 'head-change' targets
- Run 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

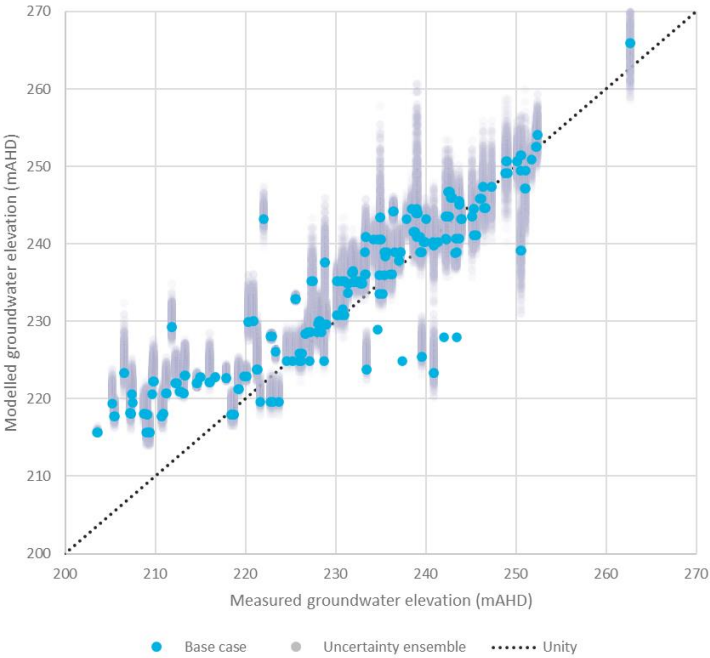
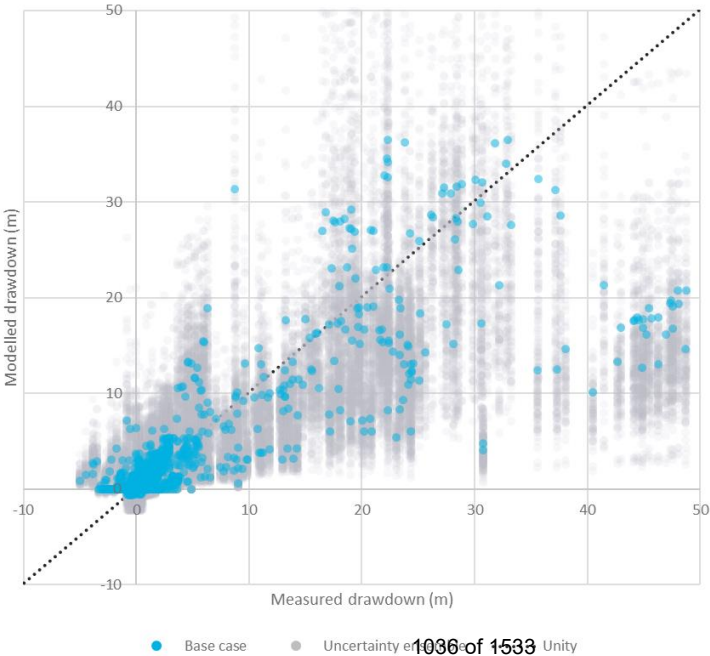
- History-matching undertaken on weighted head and head-change targets
- Performance reported against **unweighted head values**
- **SRMS 6.7%**
- Mean residual -3.6 m
- Mean absolute residual 4.8 m
- Minimum residual -39.4 m
- Maximum residual 17.5 m
- Number of observations 11,441
- Range of observations 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



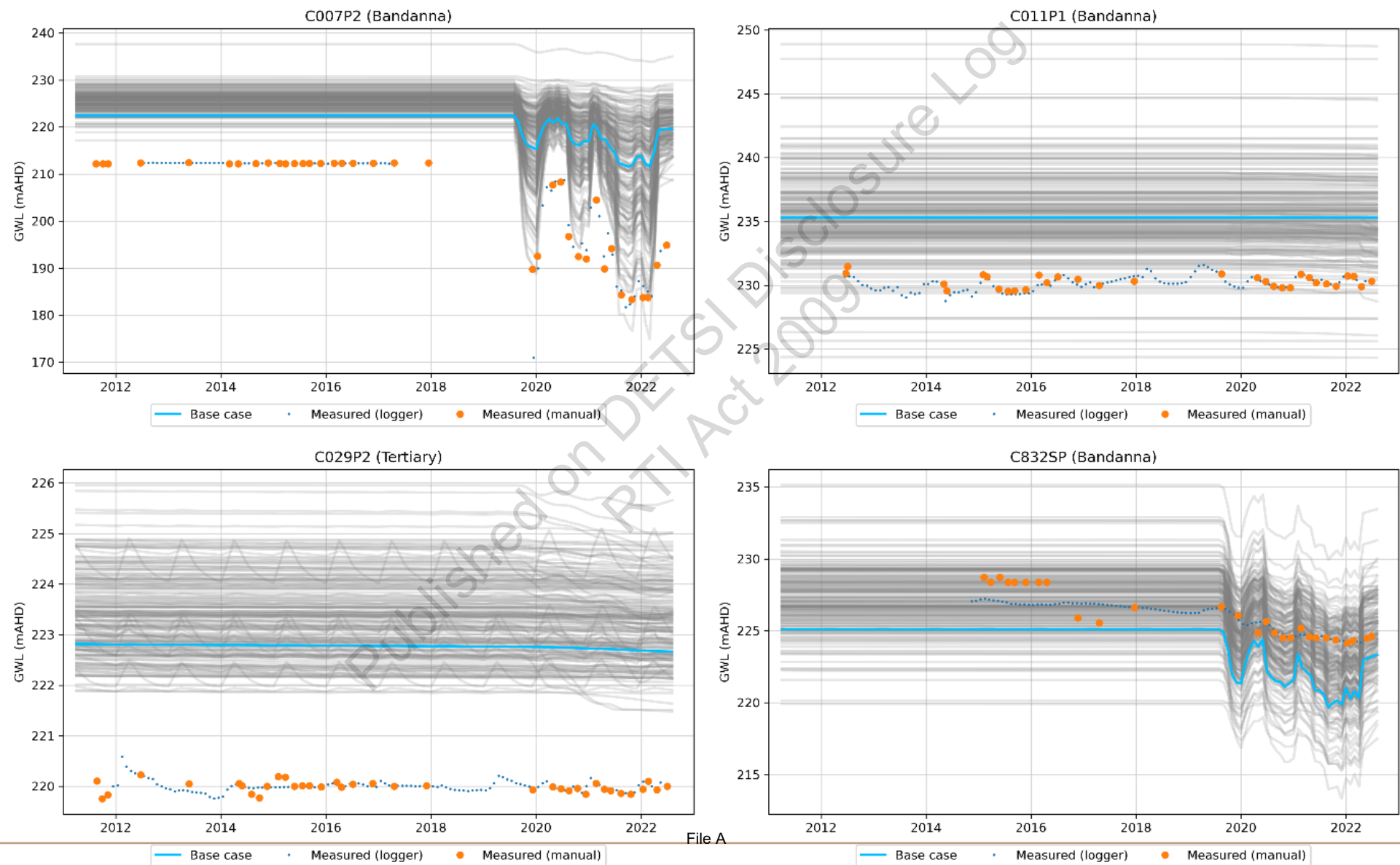
History-matching performance: ensemble

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

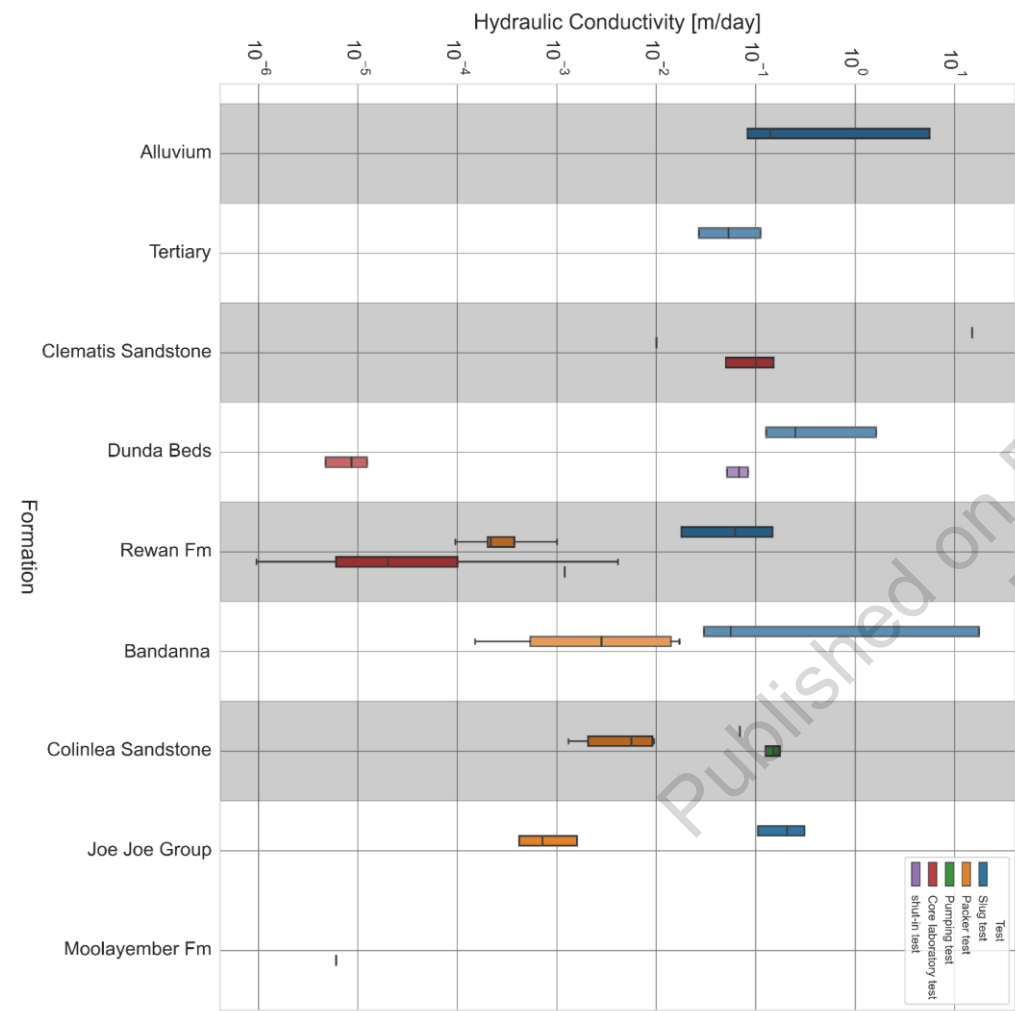


History-matching: example hydrographs

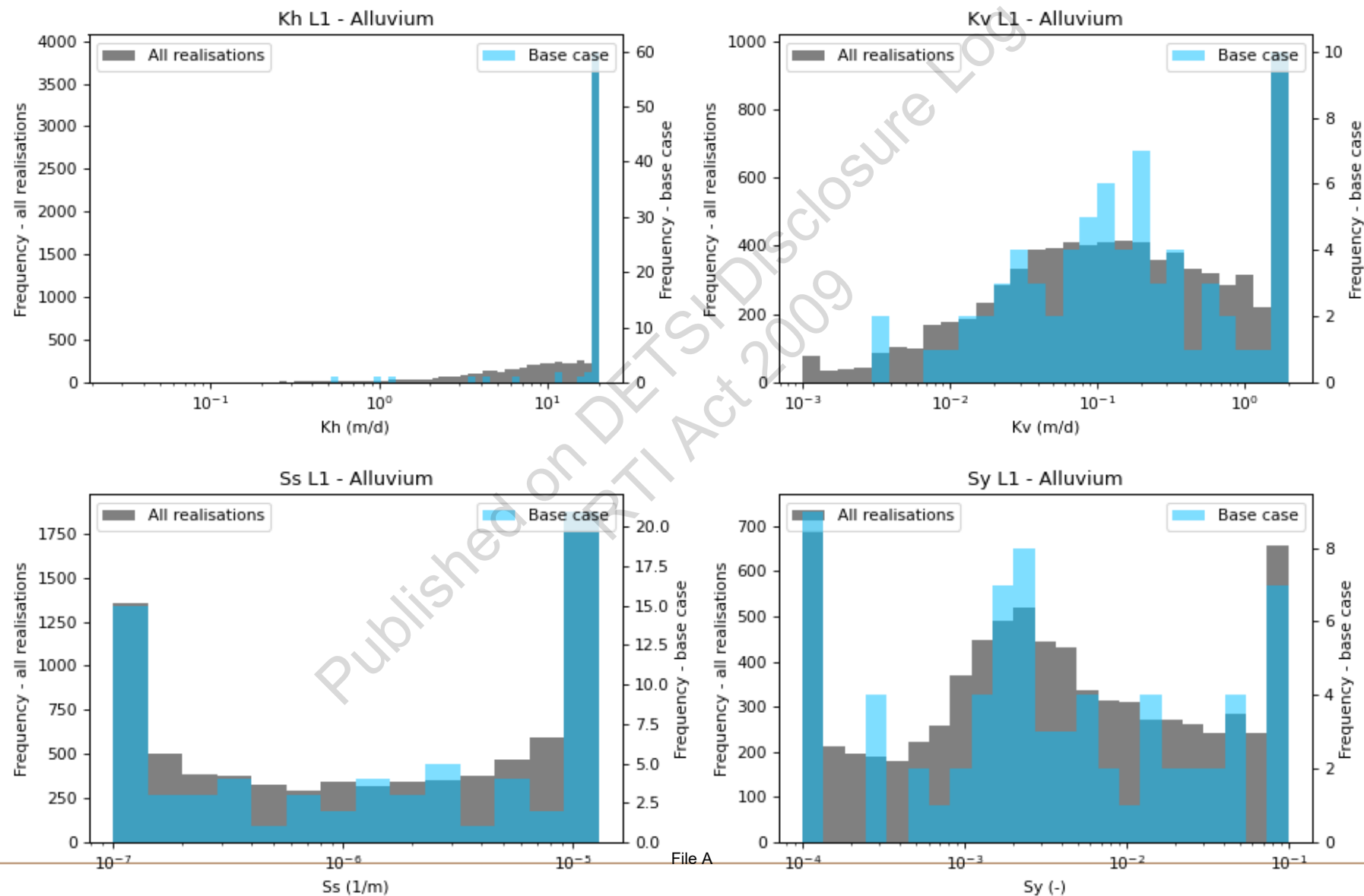


Parameterisation

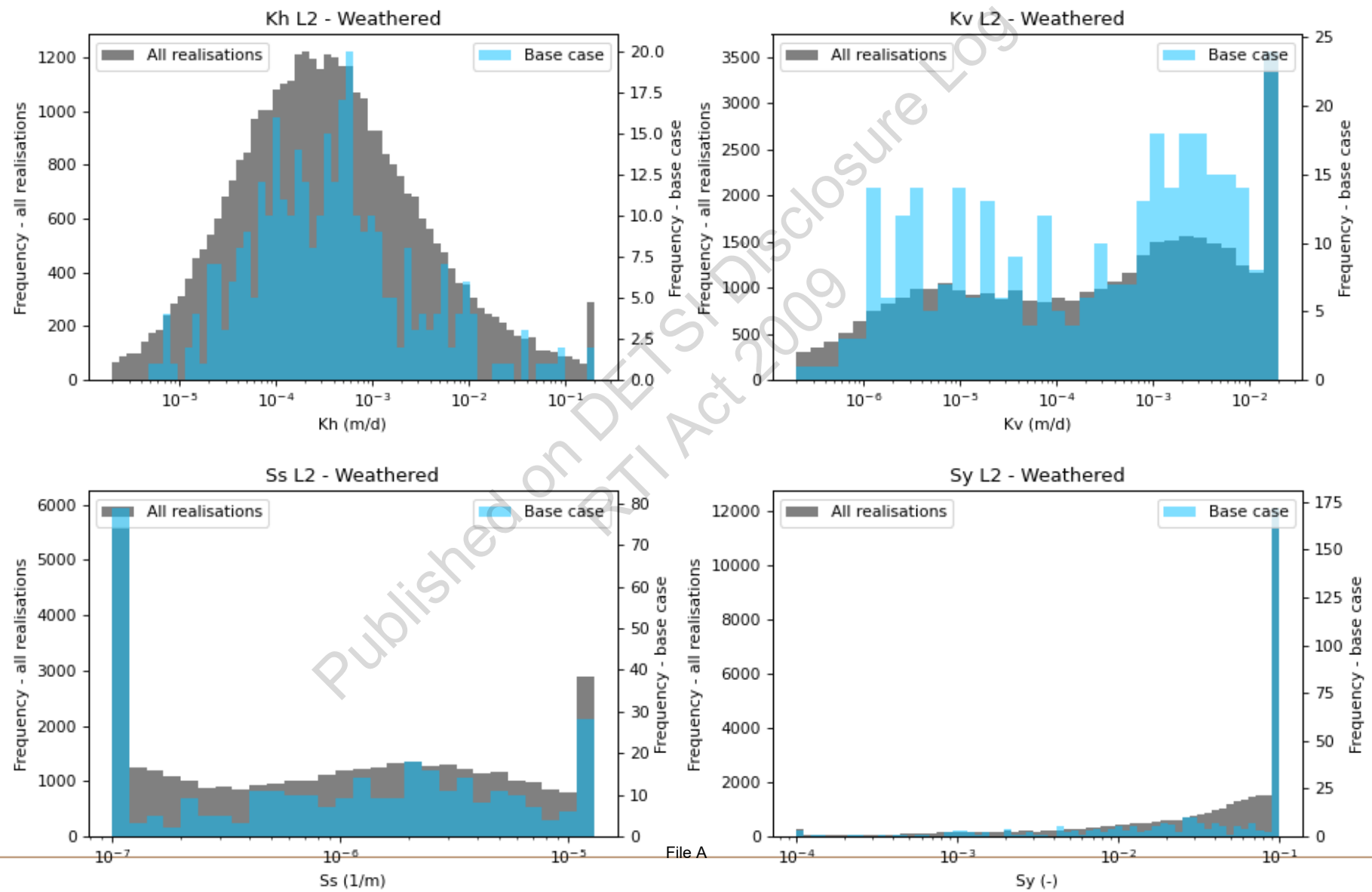
Interpreted hydraulic conductivity



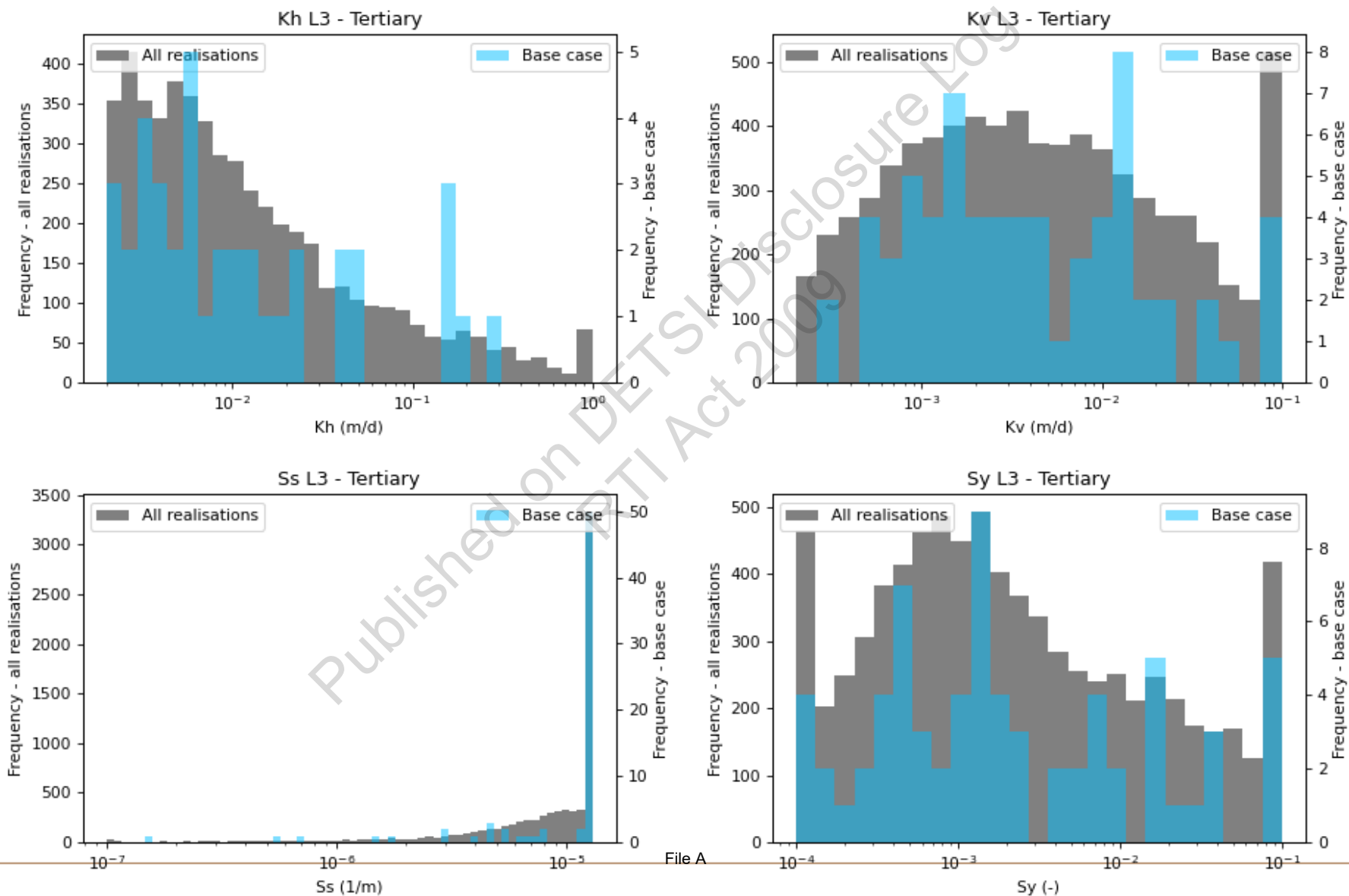
Parameterisation – L1 Alluvium



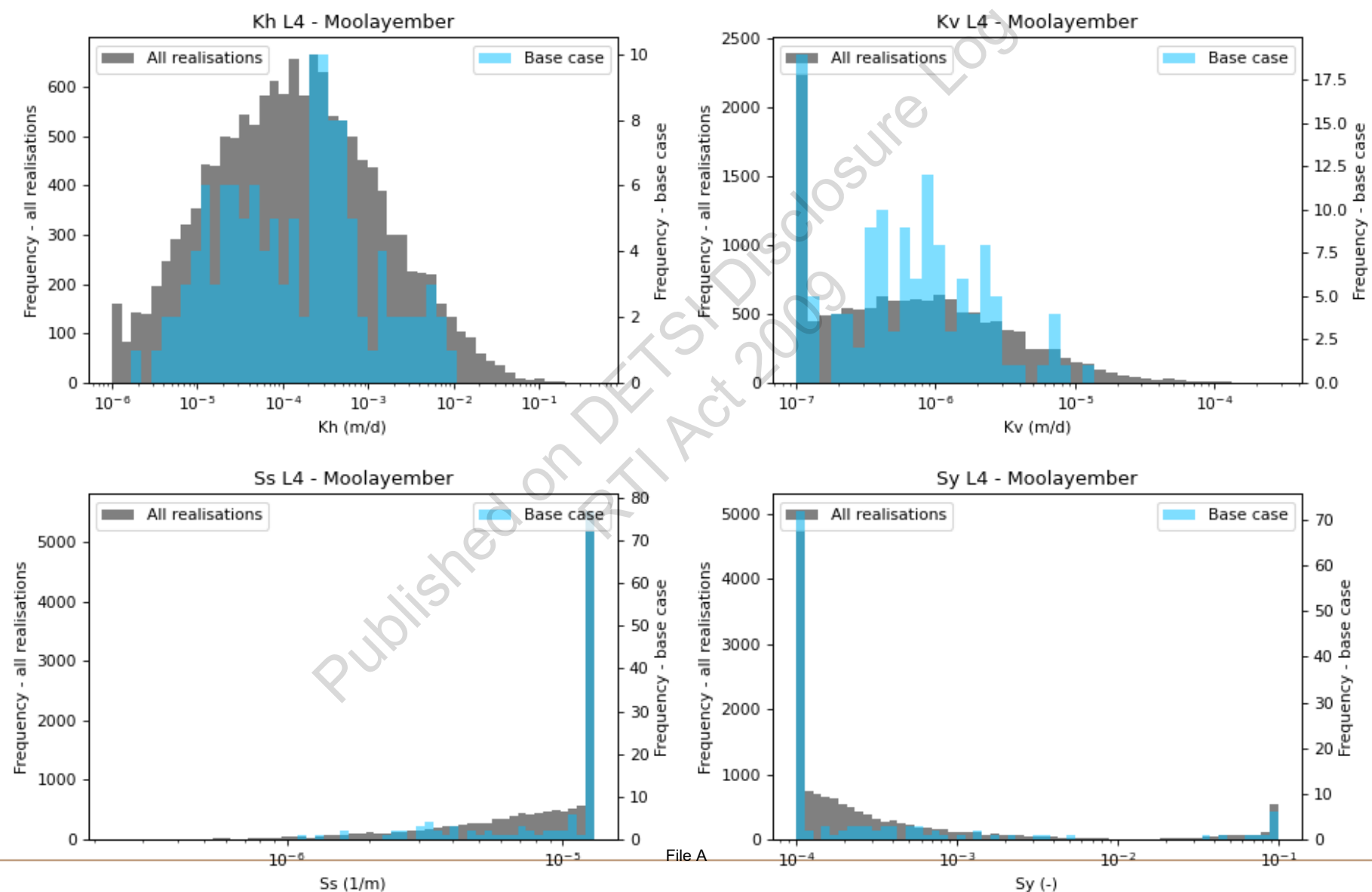
Parameterisation – L2 Weathered



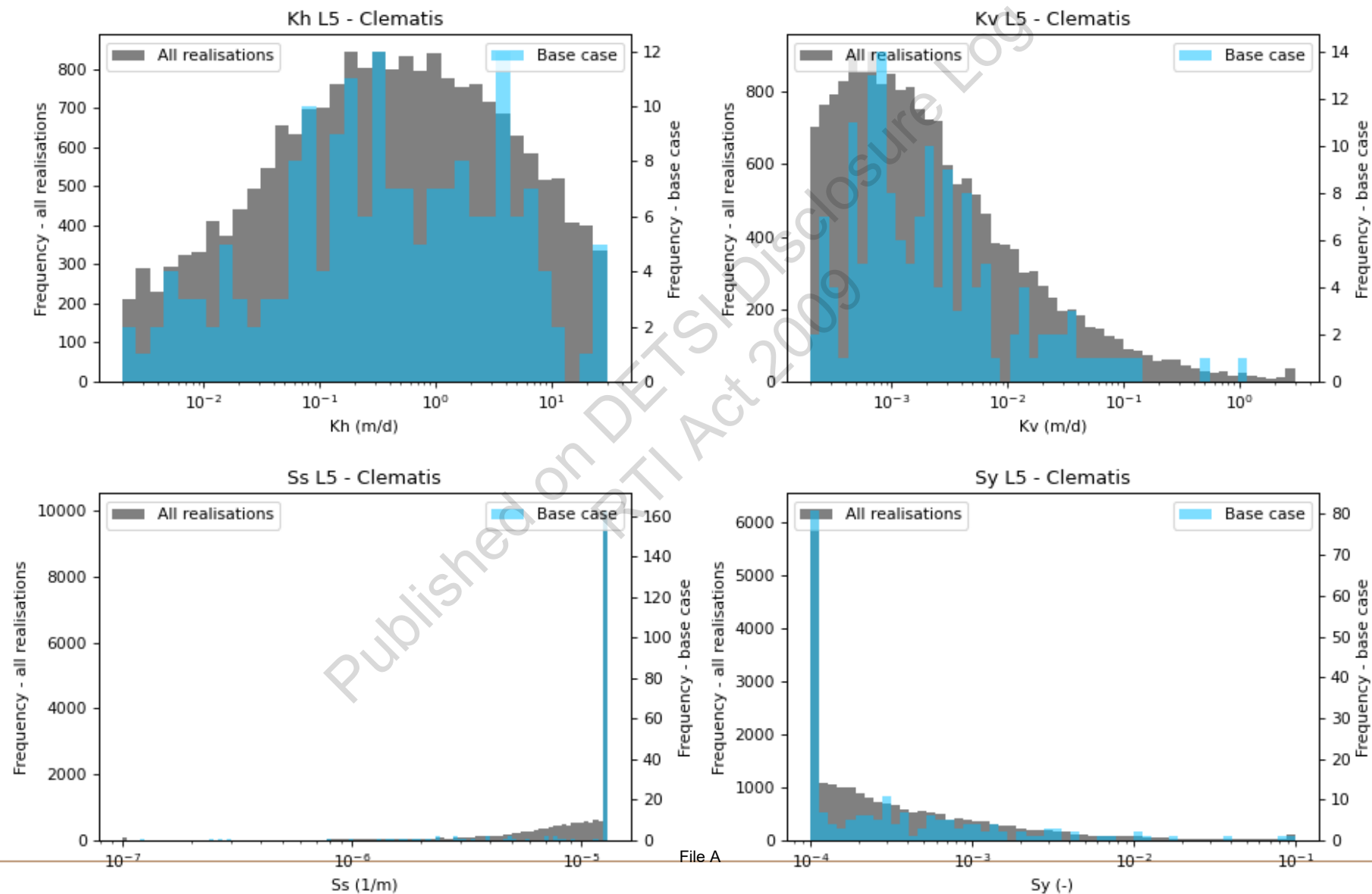
Parameterisation – L3 Tertiary



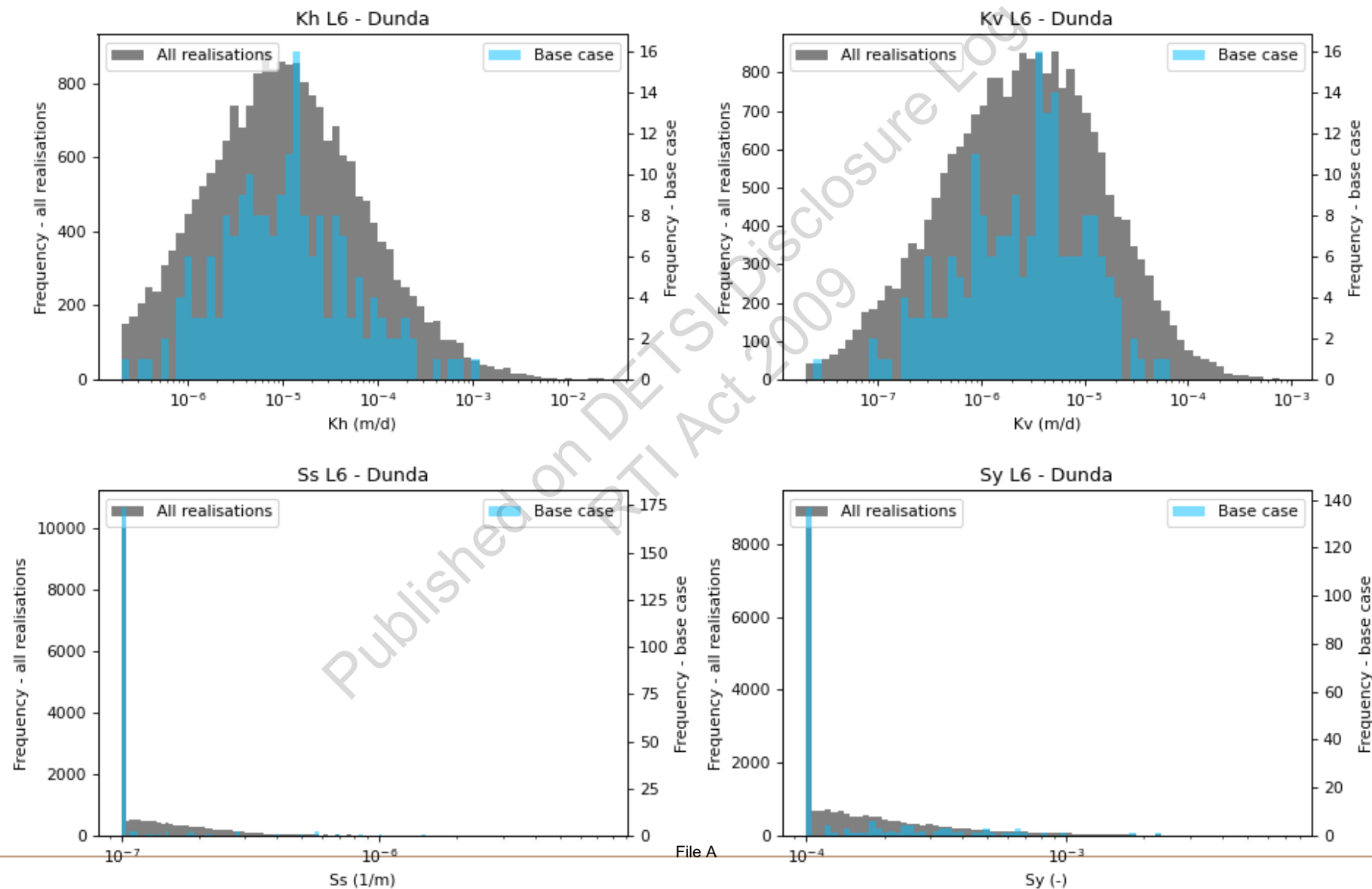
Parameterisation – L4 Moolayember



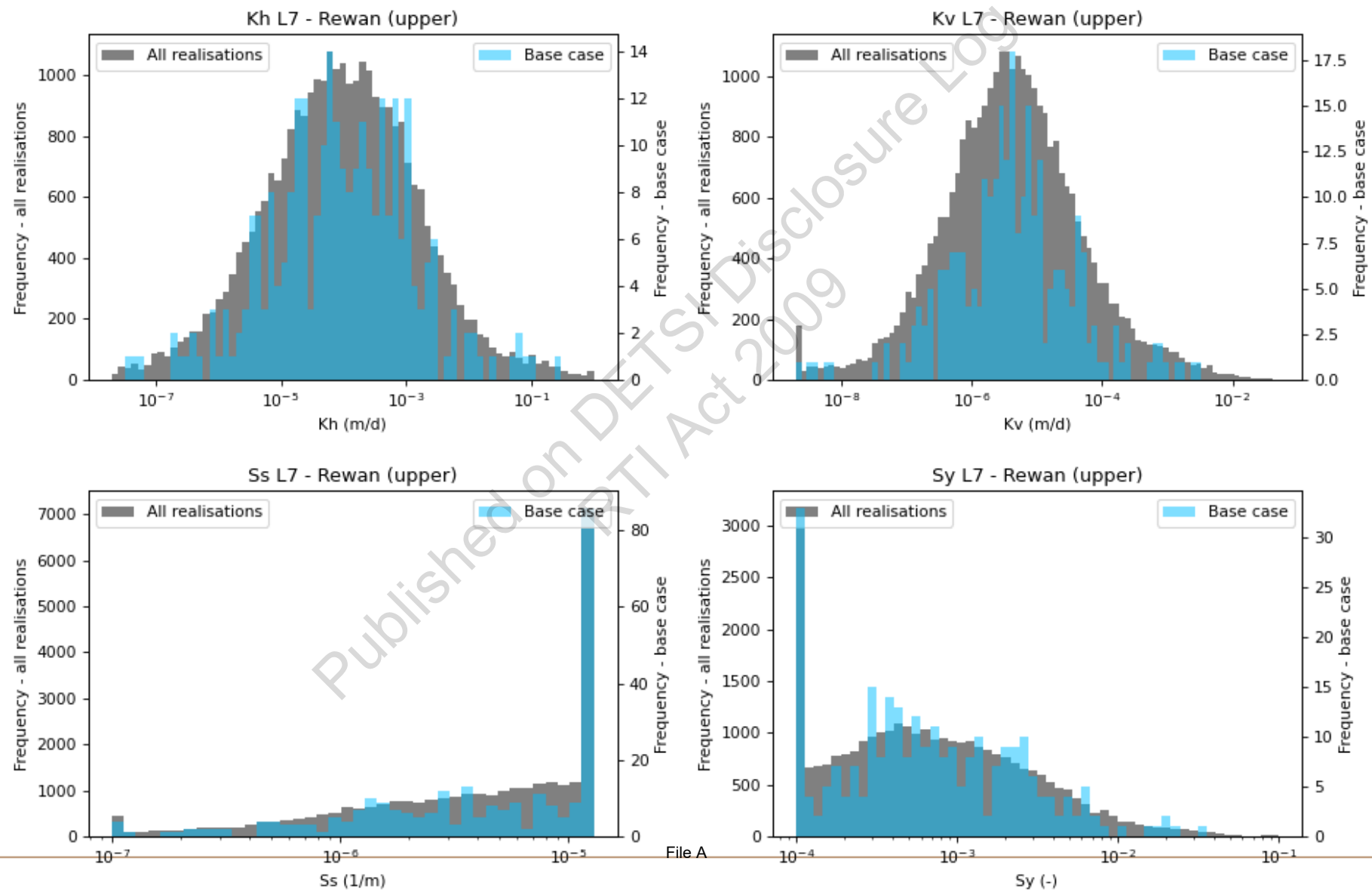
Parameterisation – L5 Clematis



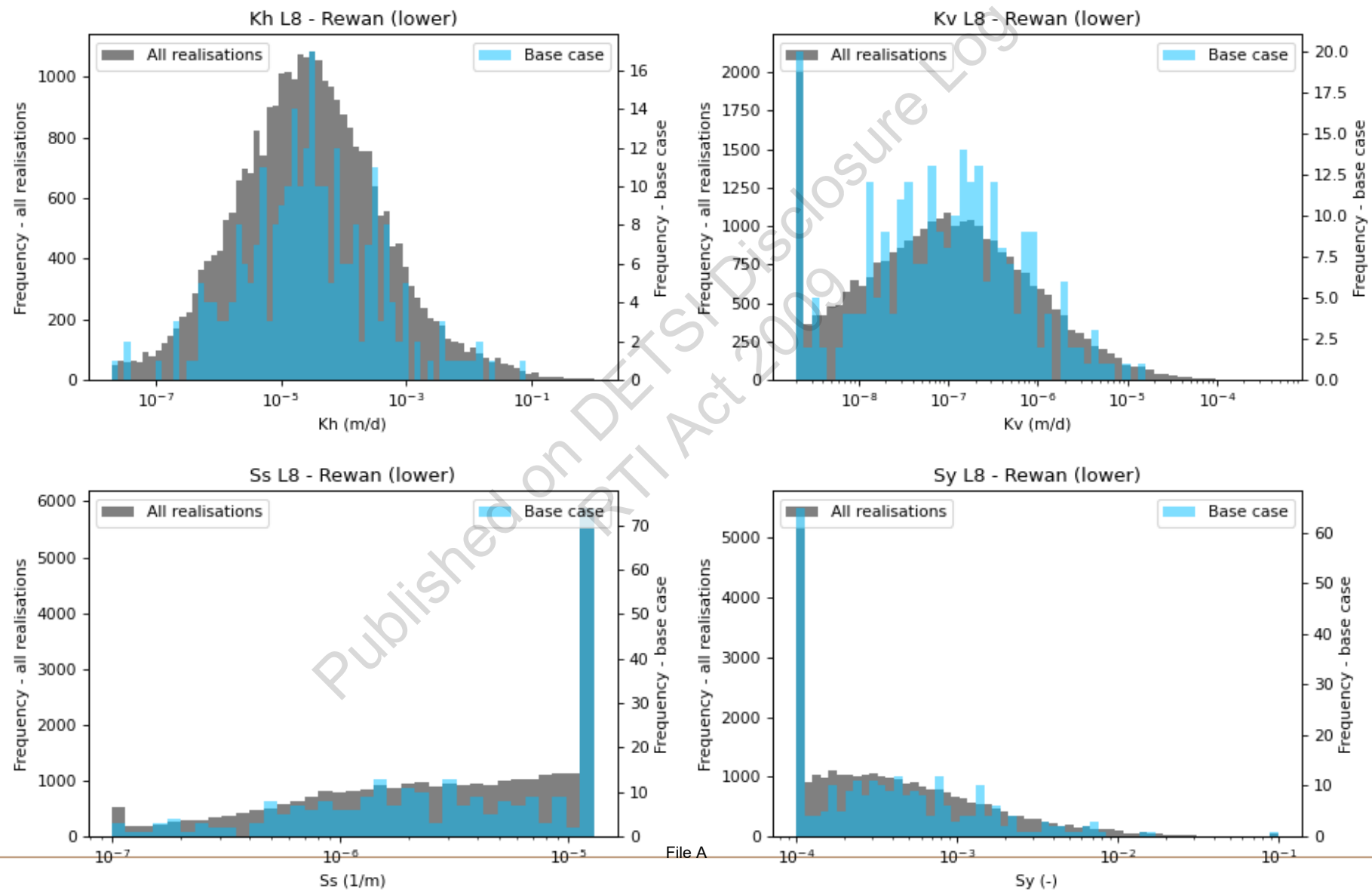
Parameterisation – L6 Dunda



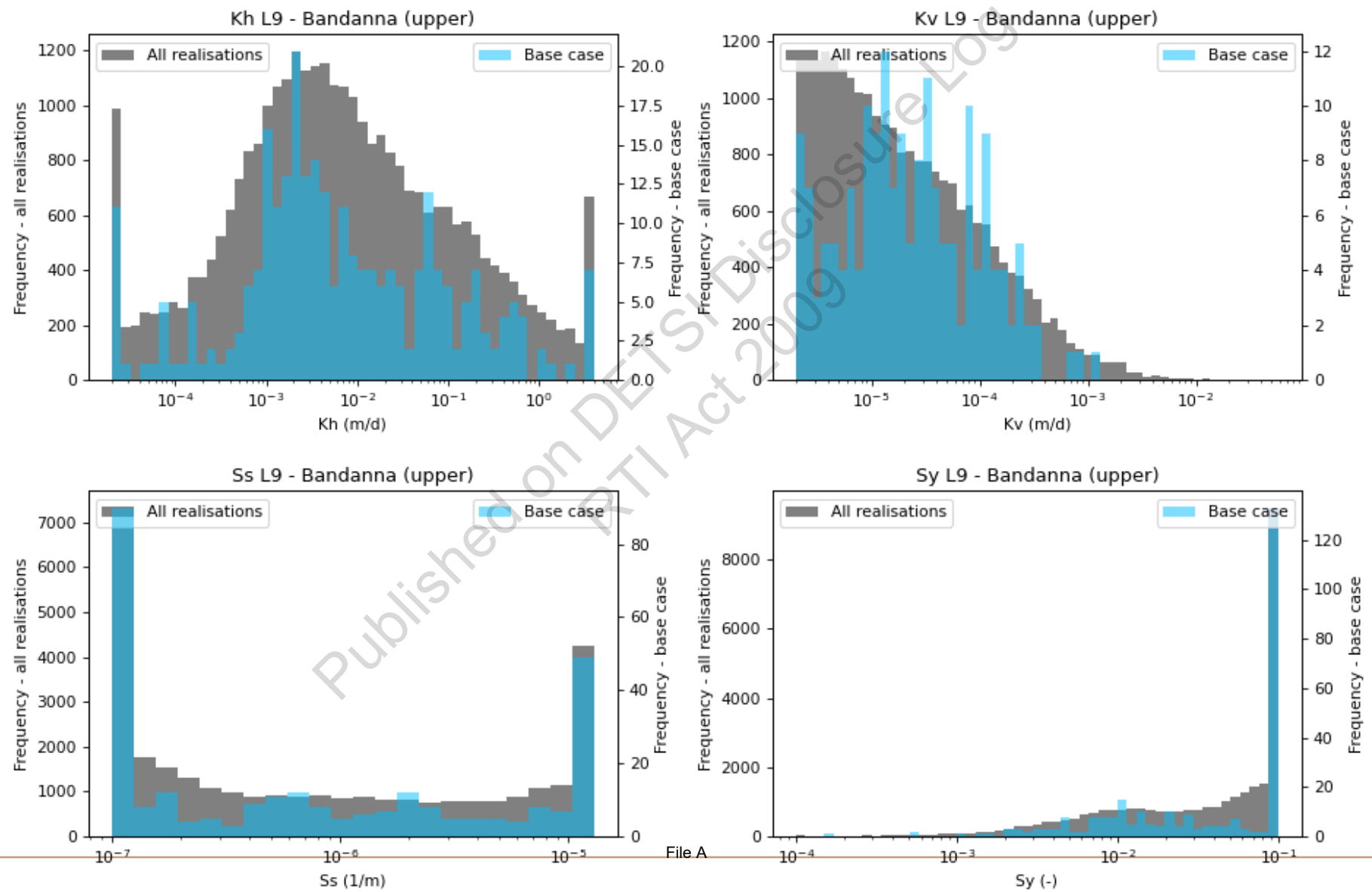
Parameterisation – L7 Rewan (upper)



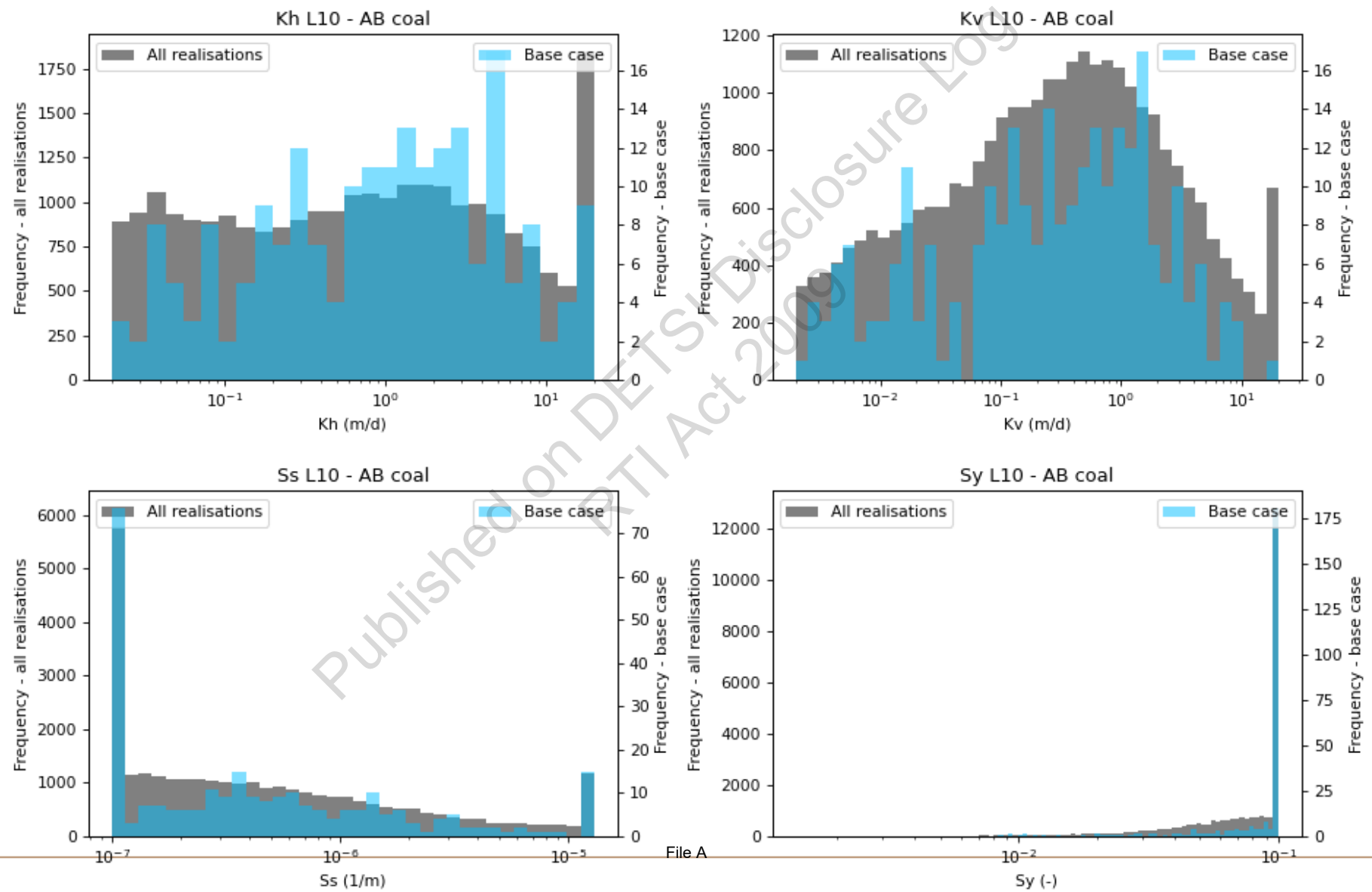
Parameterisation – L8 Rewan (lower)



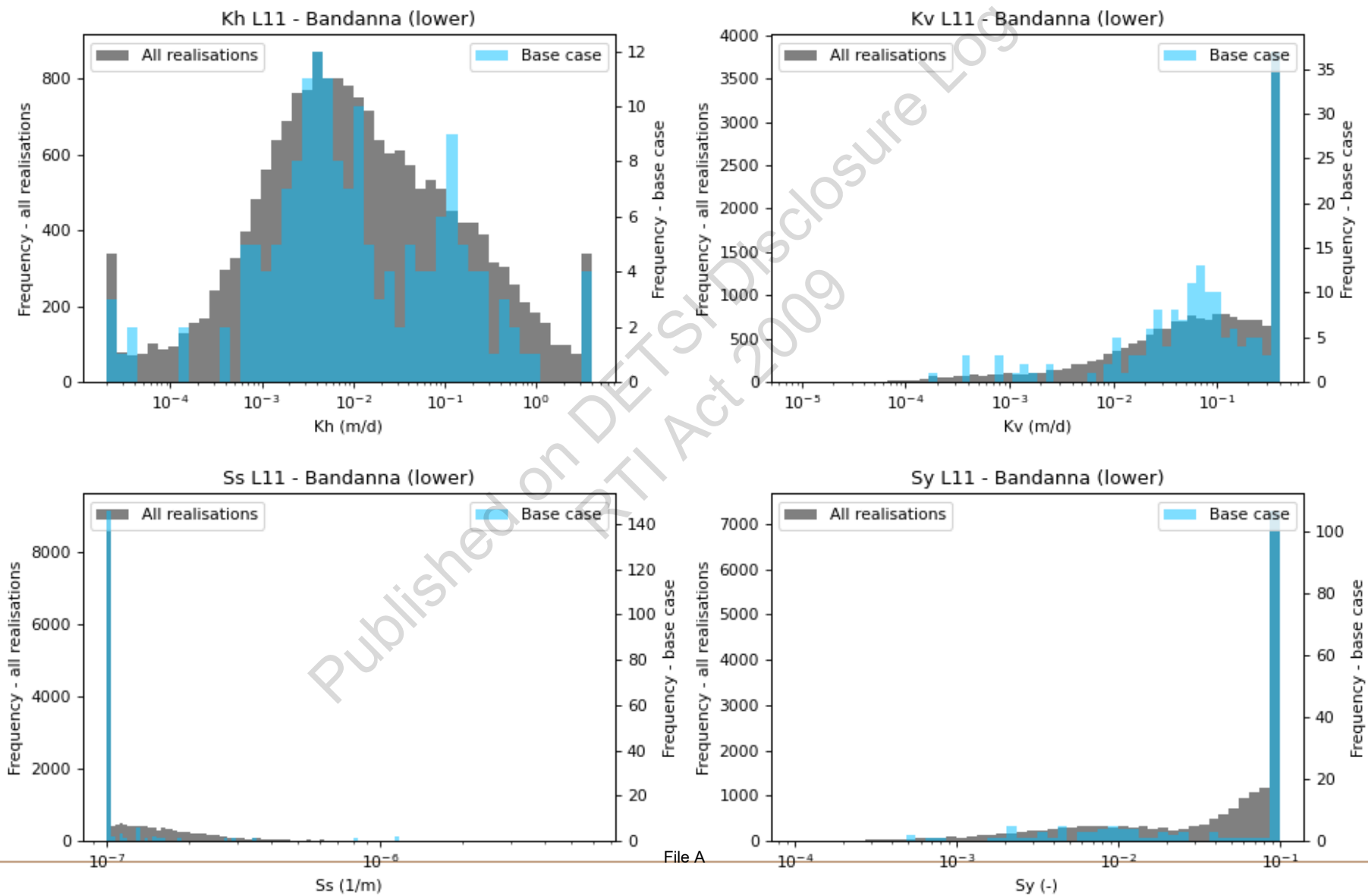
Parameterisation – L9 Bandanna (upper)



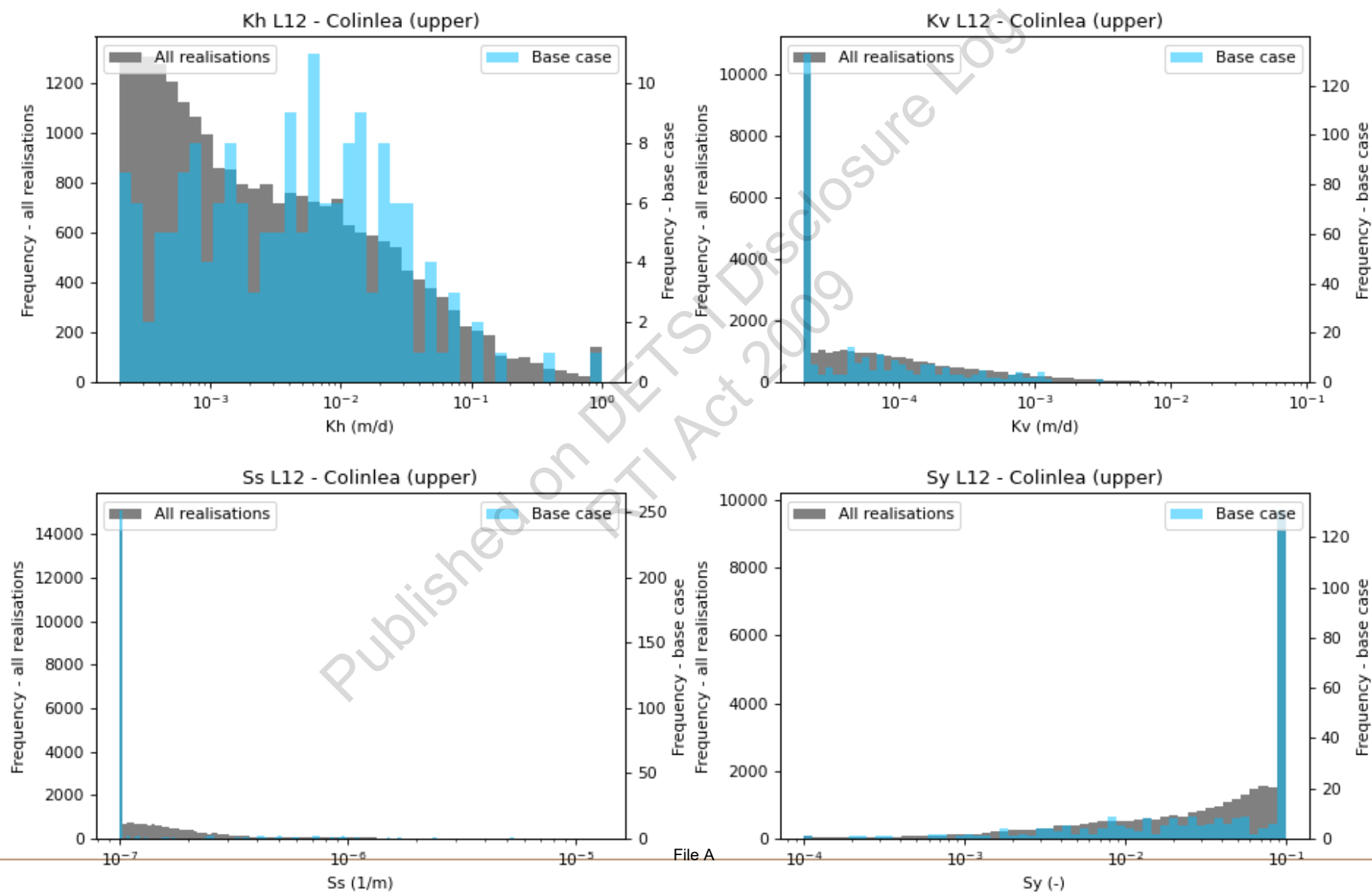
Parameterisation – L10 AB Coal



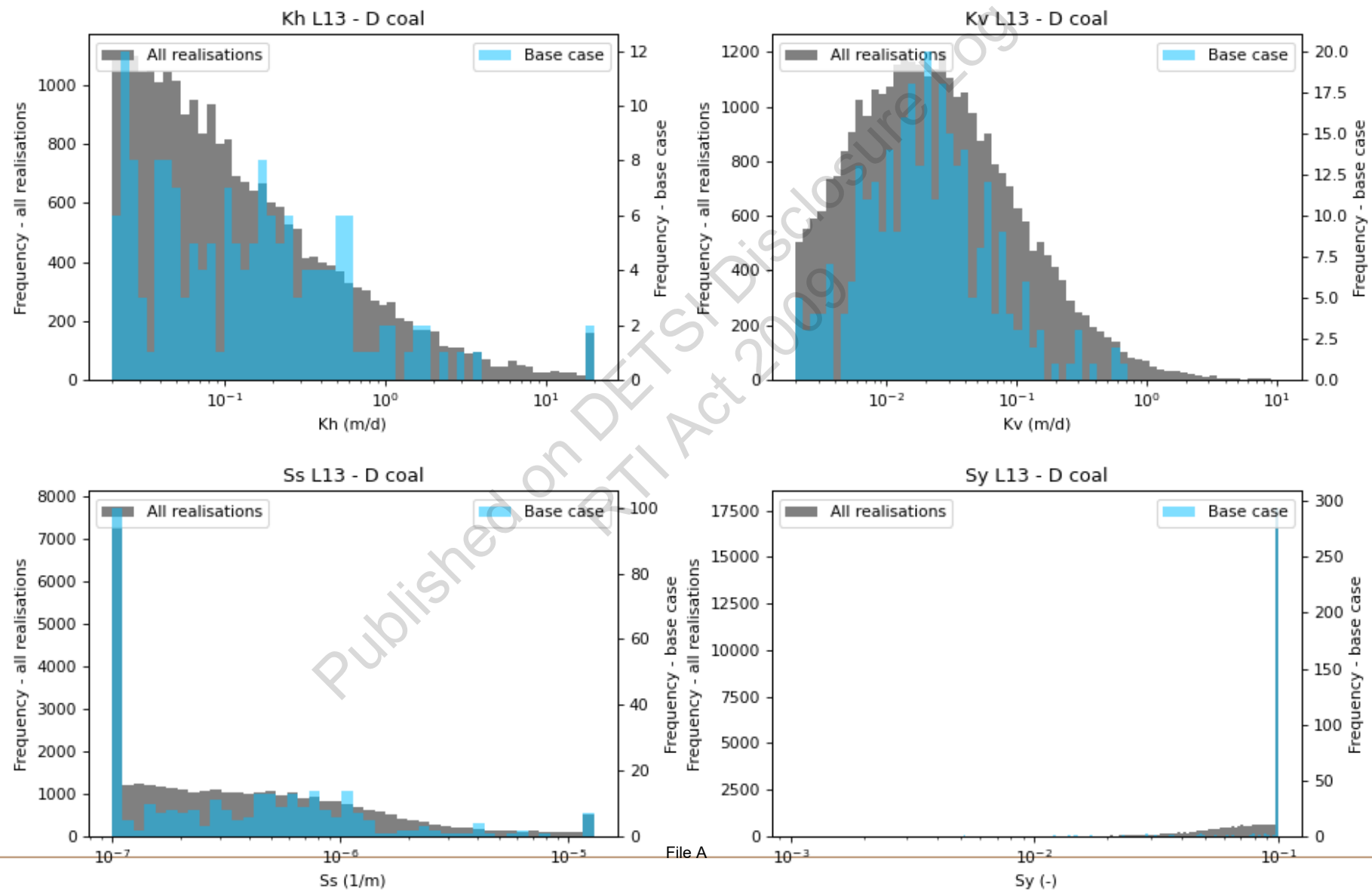
Parameterisation – L11 Bandanna (lower)



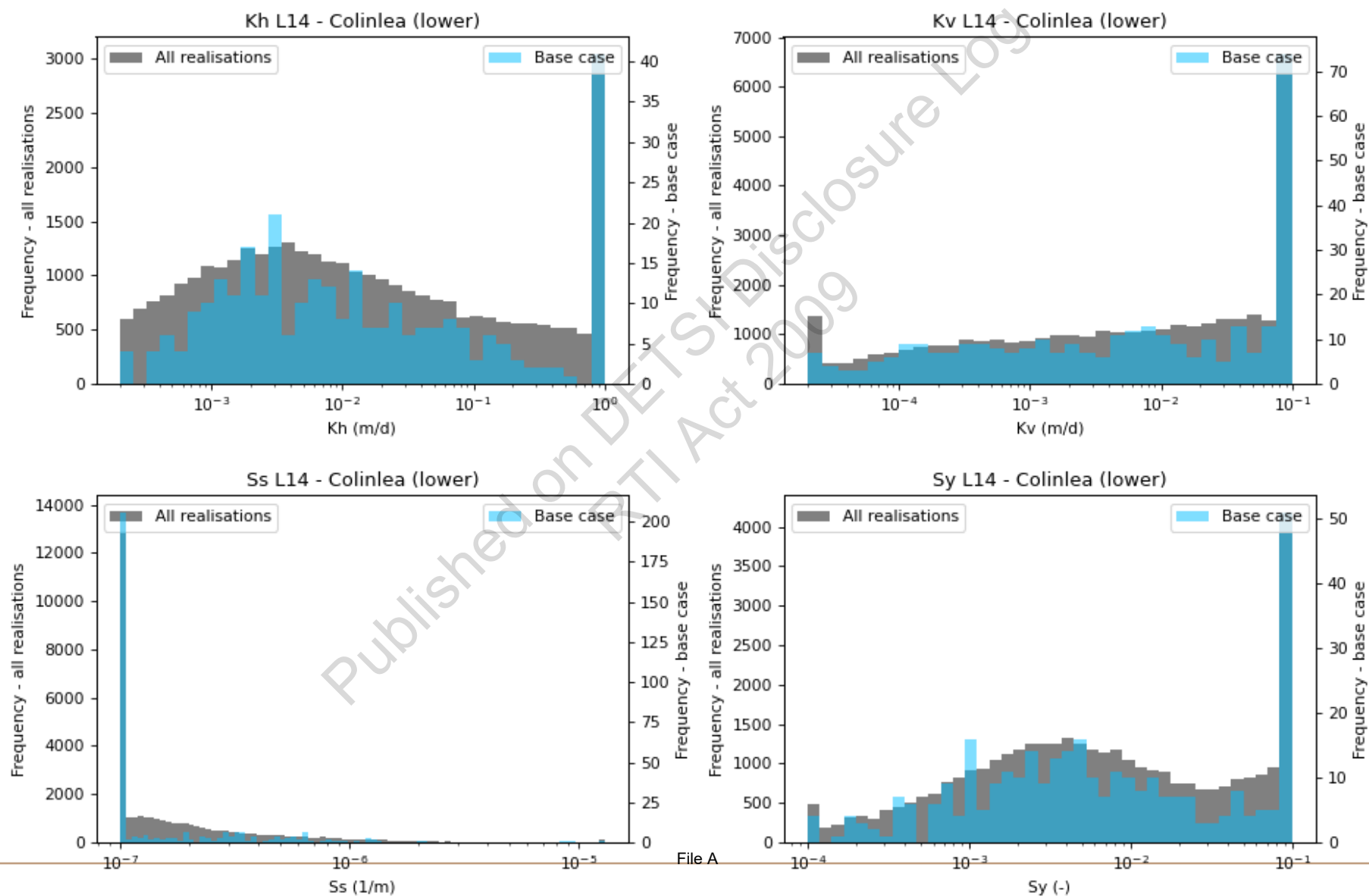
Parameterisation – L12 Colinlea (upper)



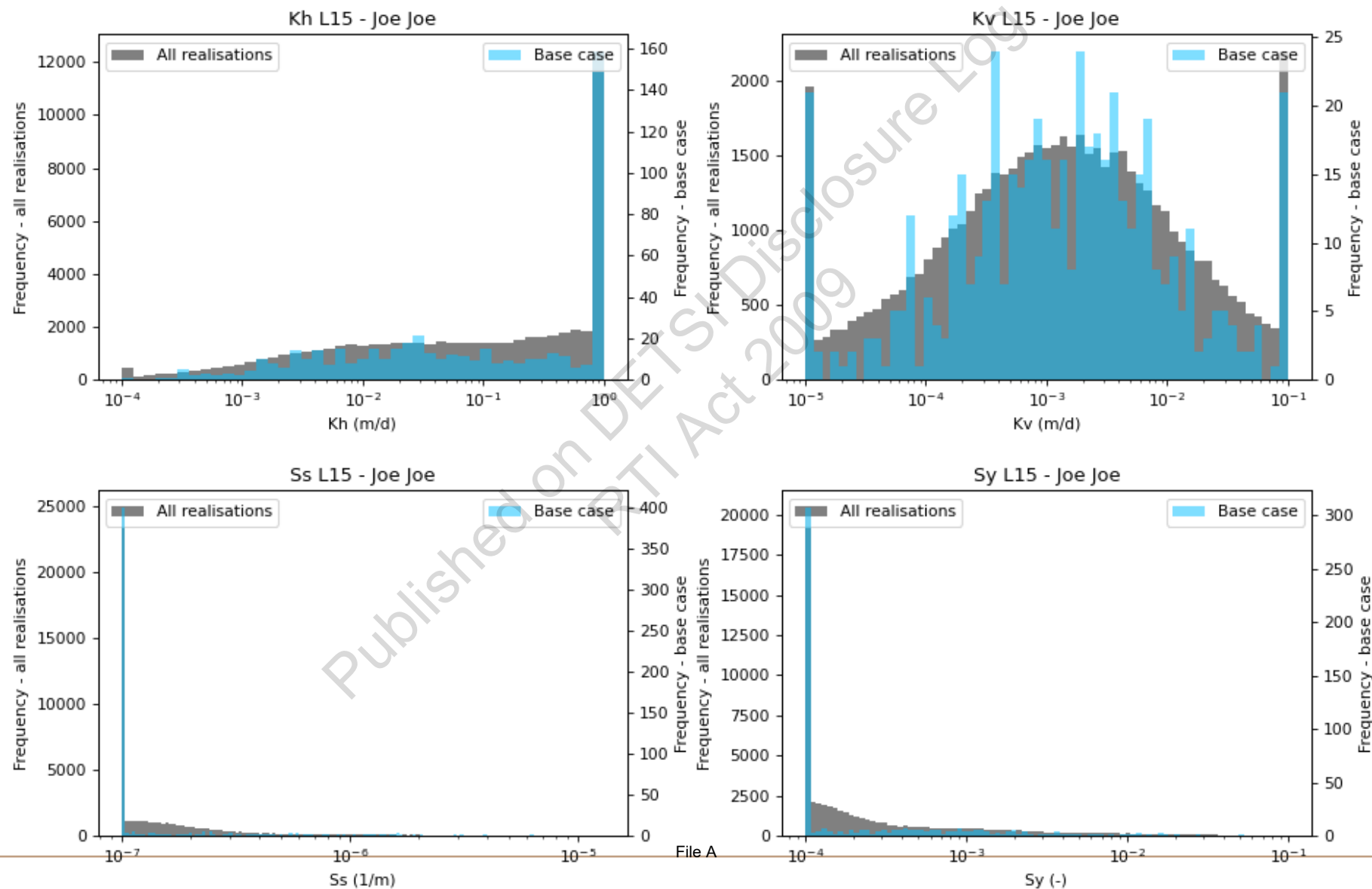
Parameterisation – L13 D Coal



Parameterisation – L14 Colinlea (lower)

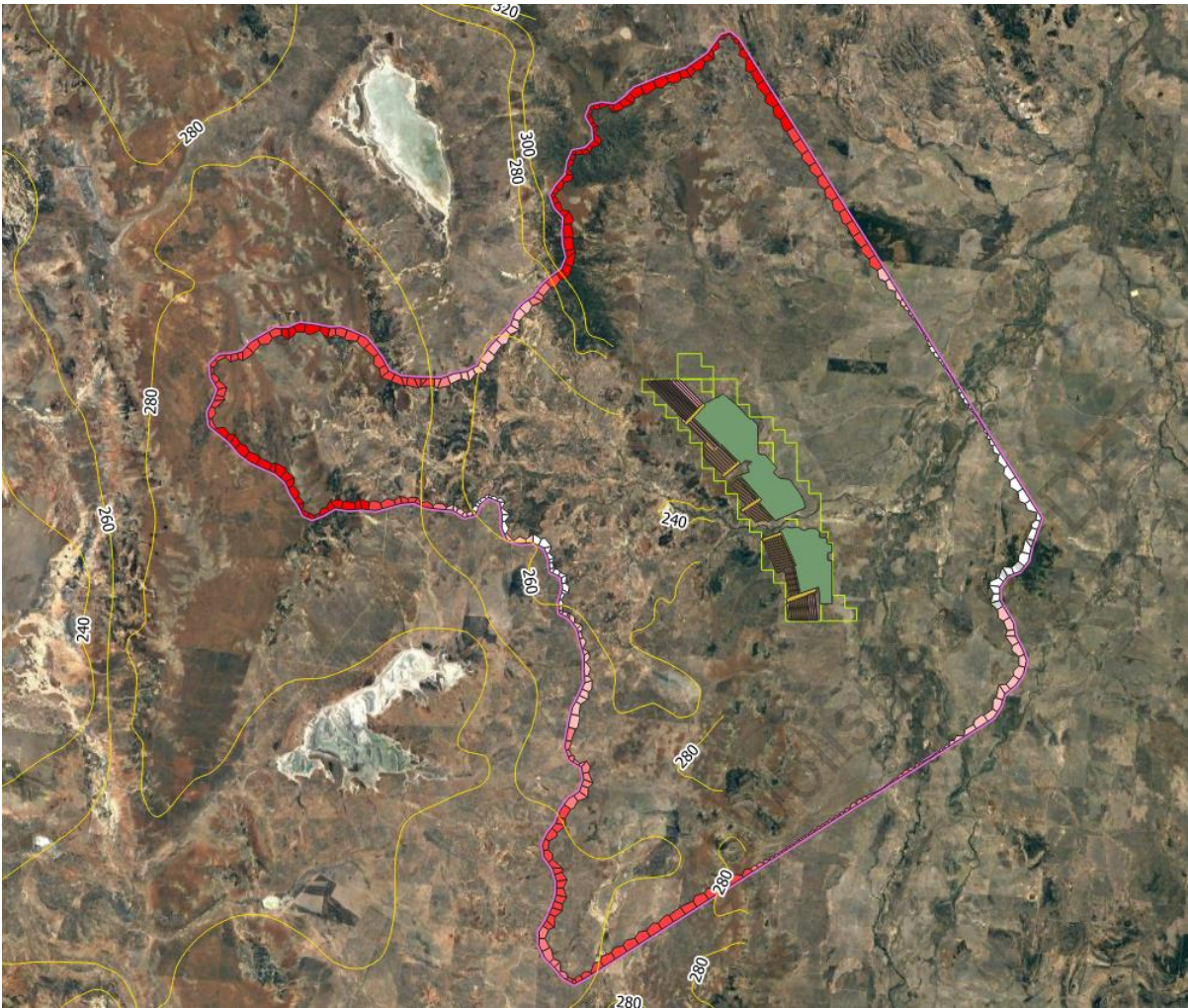


Parameterisation – L15 Joe Joe

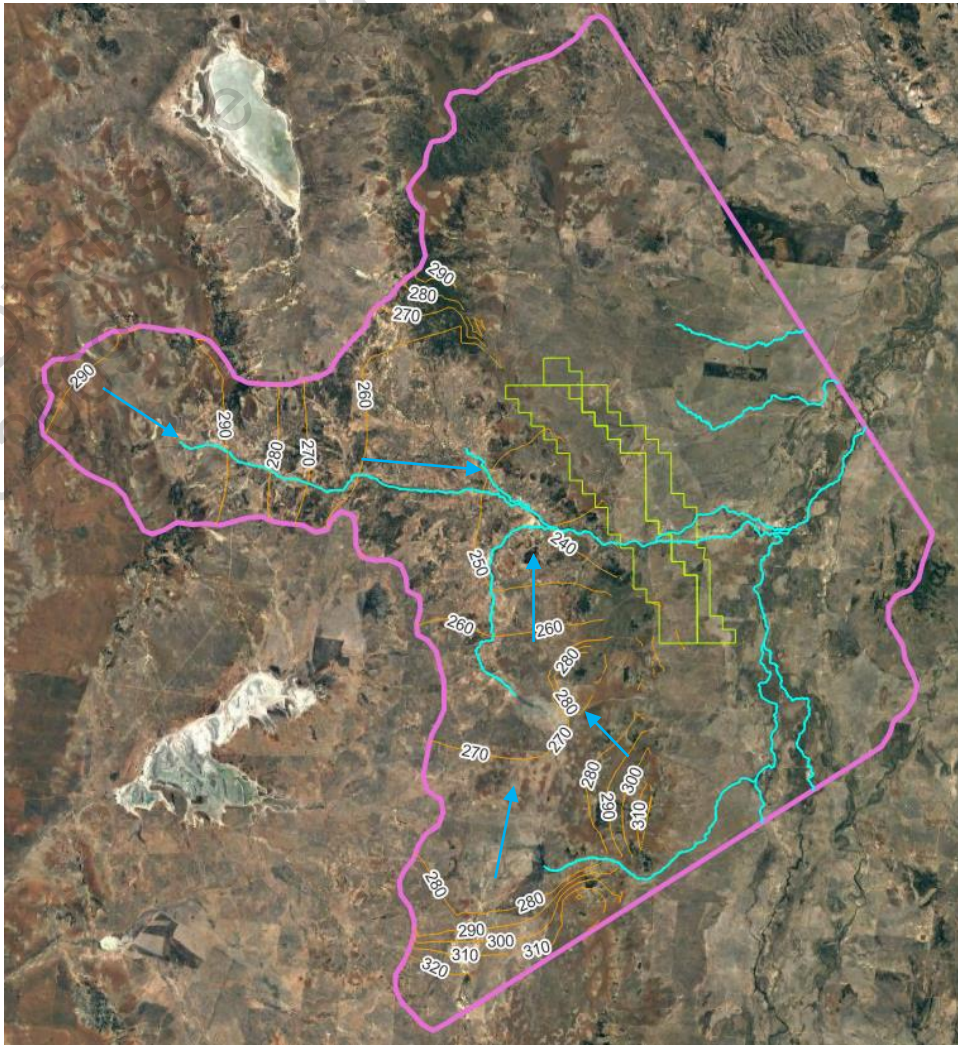


Steady state potentiometric surface – Clematis Sandstone

Interpreted

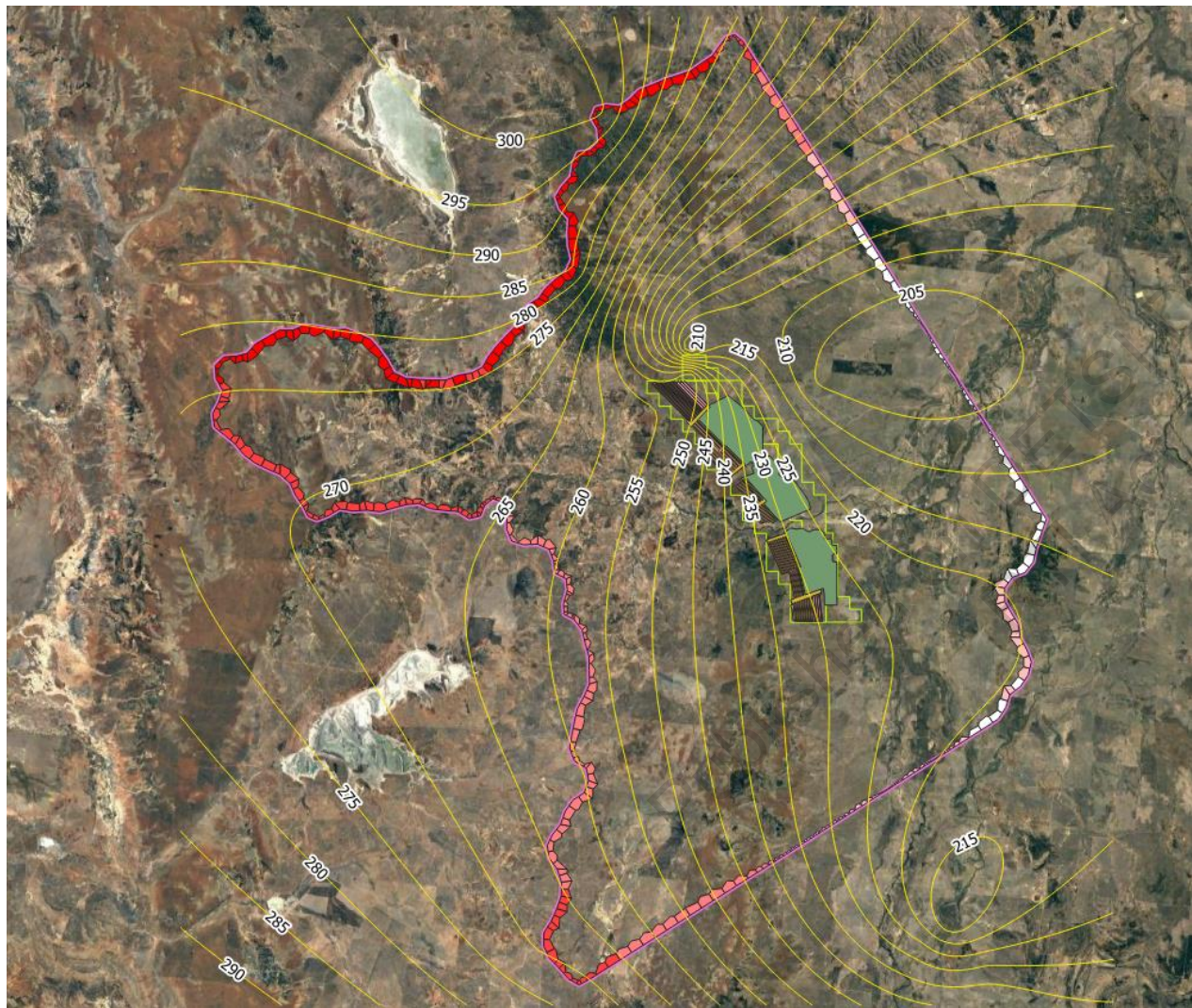


Modelled



Steady state potentiometric surface – Joe Joe Group

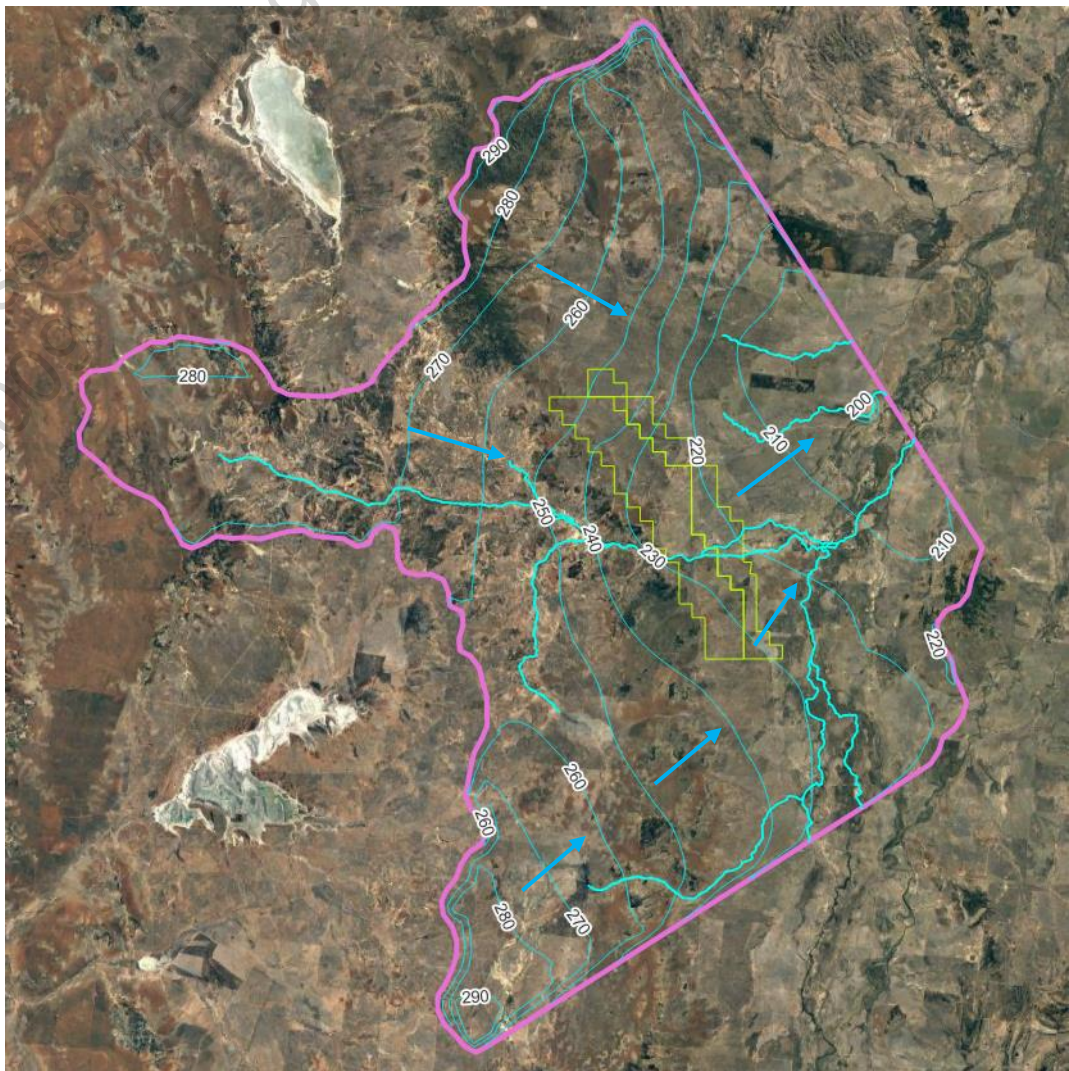
Interpreted



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File A

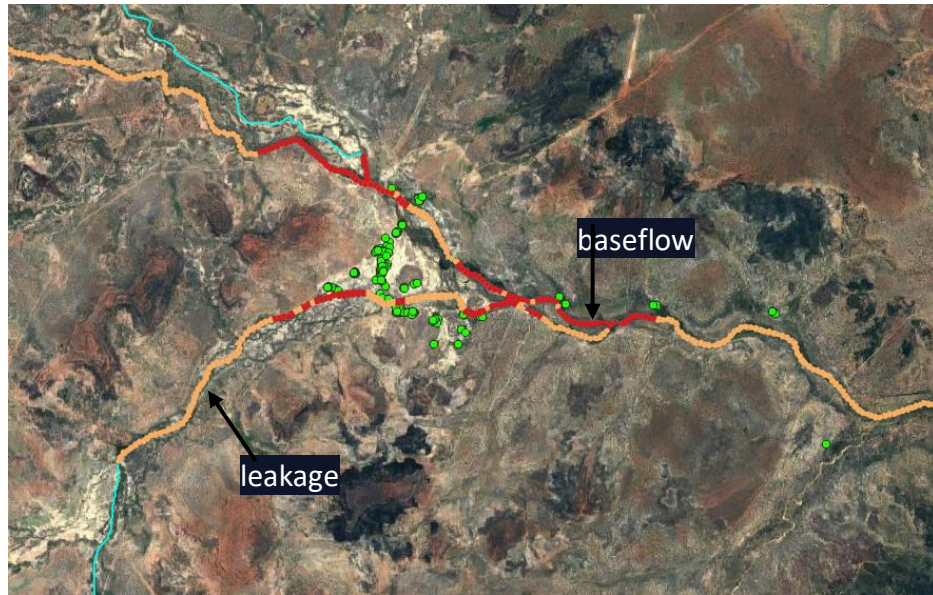
Modelled



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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%

BRAVUS

MINING & RESOURCES

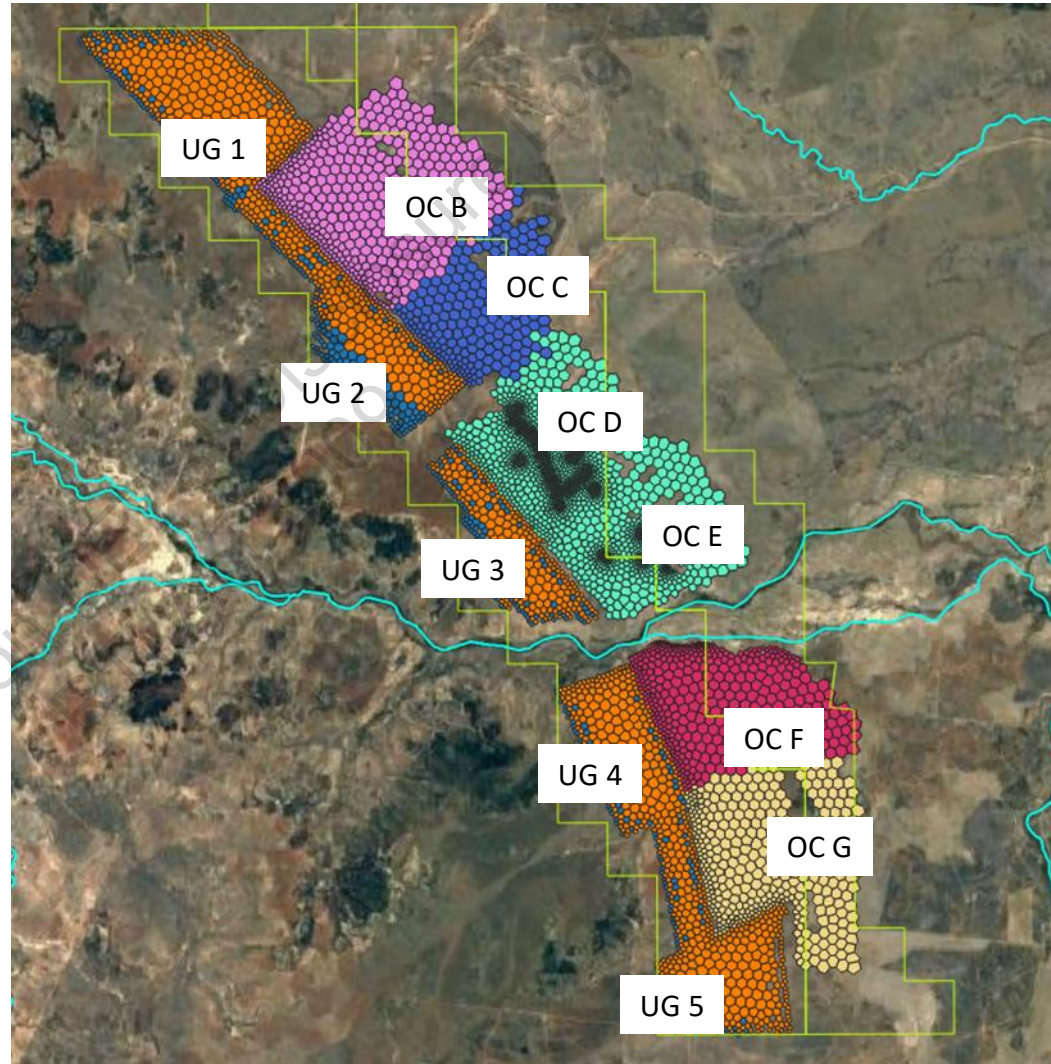
Predictive scenarios

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

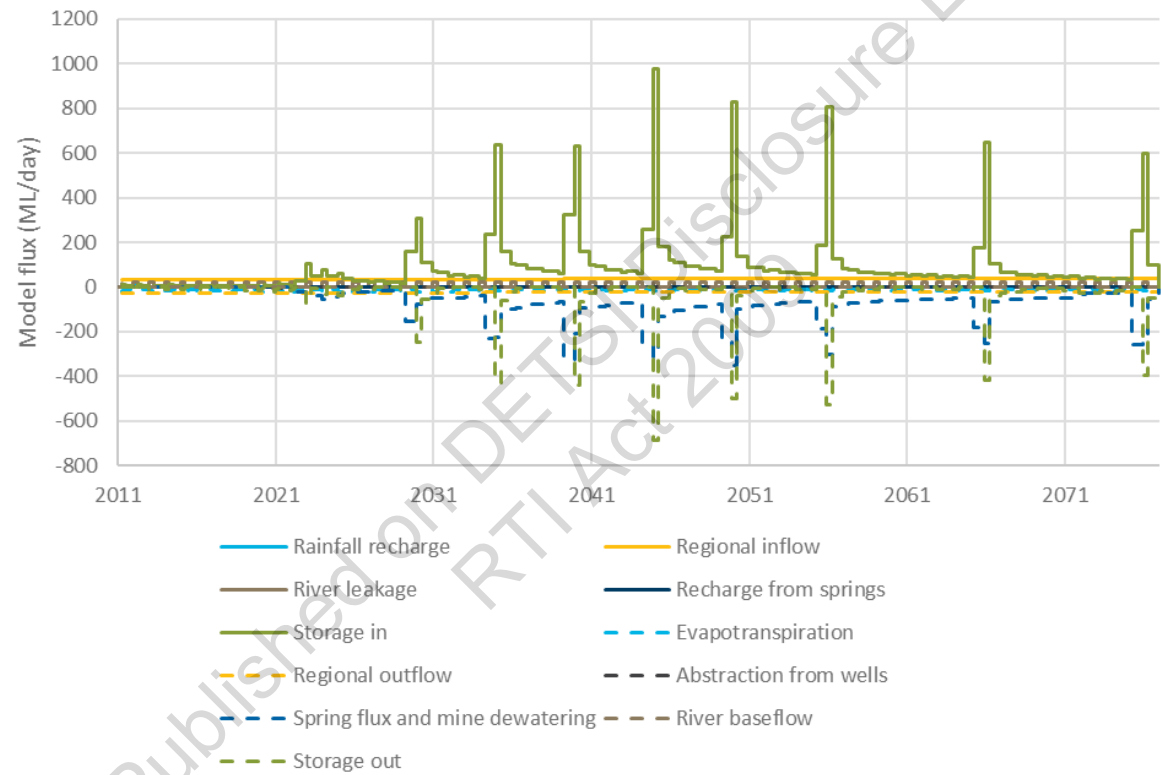
- OC: open cut
- SEIS: open cut and underground



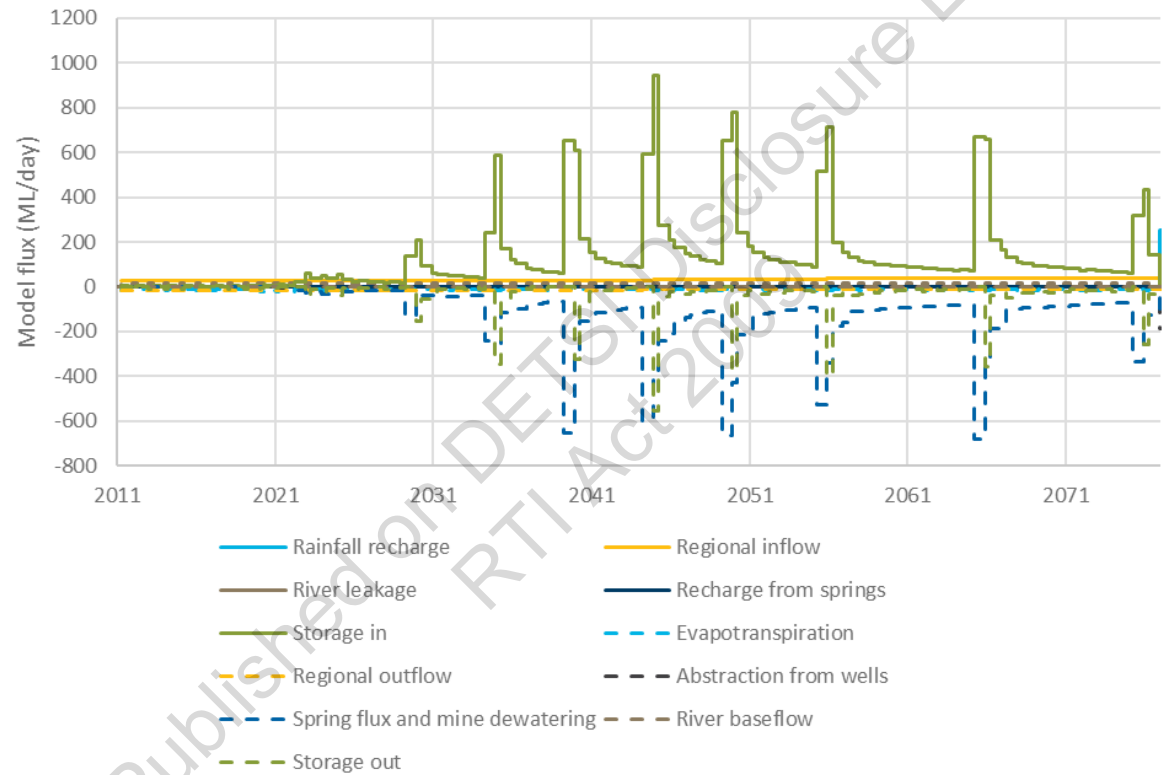
Modelled mine plan (as per SEIS)

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					

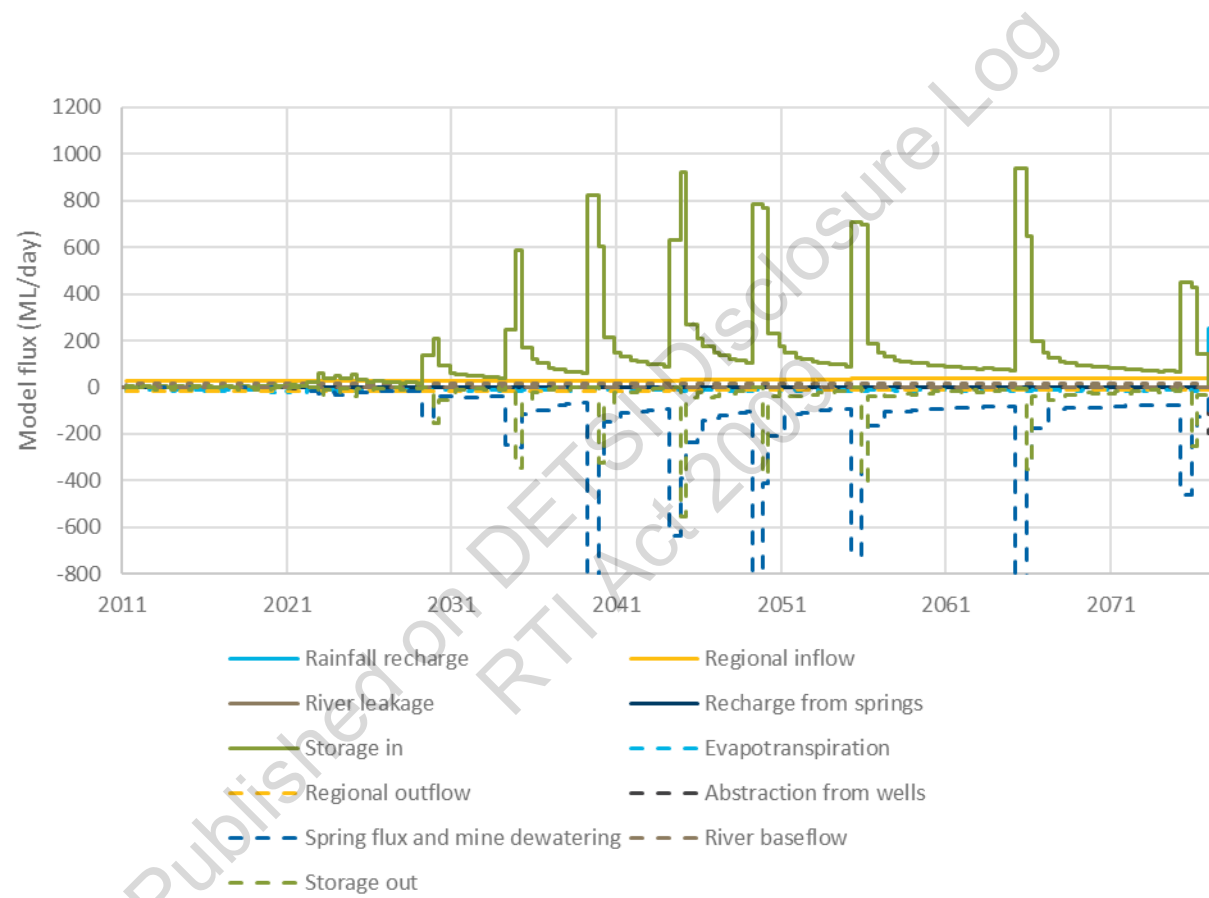
Modelled water balance: OC



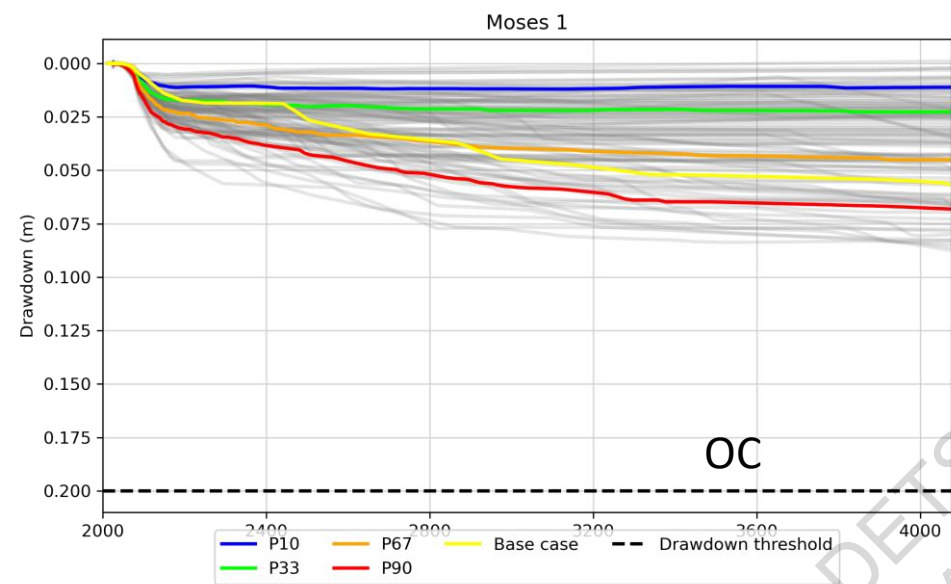
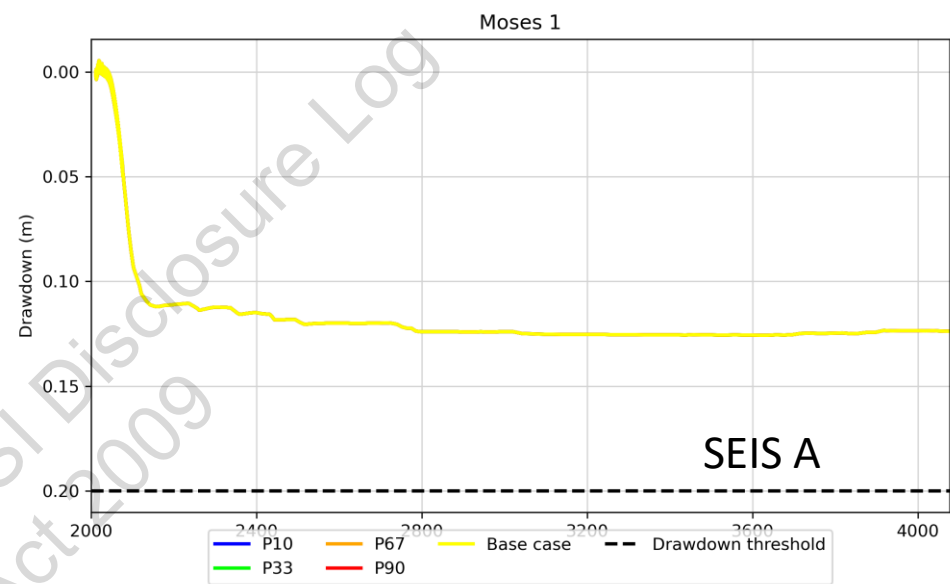
Modelled water balance: SEIS A



Modelled water balance: SEIS B



Modelled hydrographs



Modelled drawdown (m) at springs

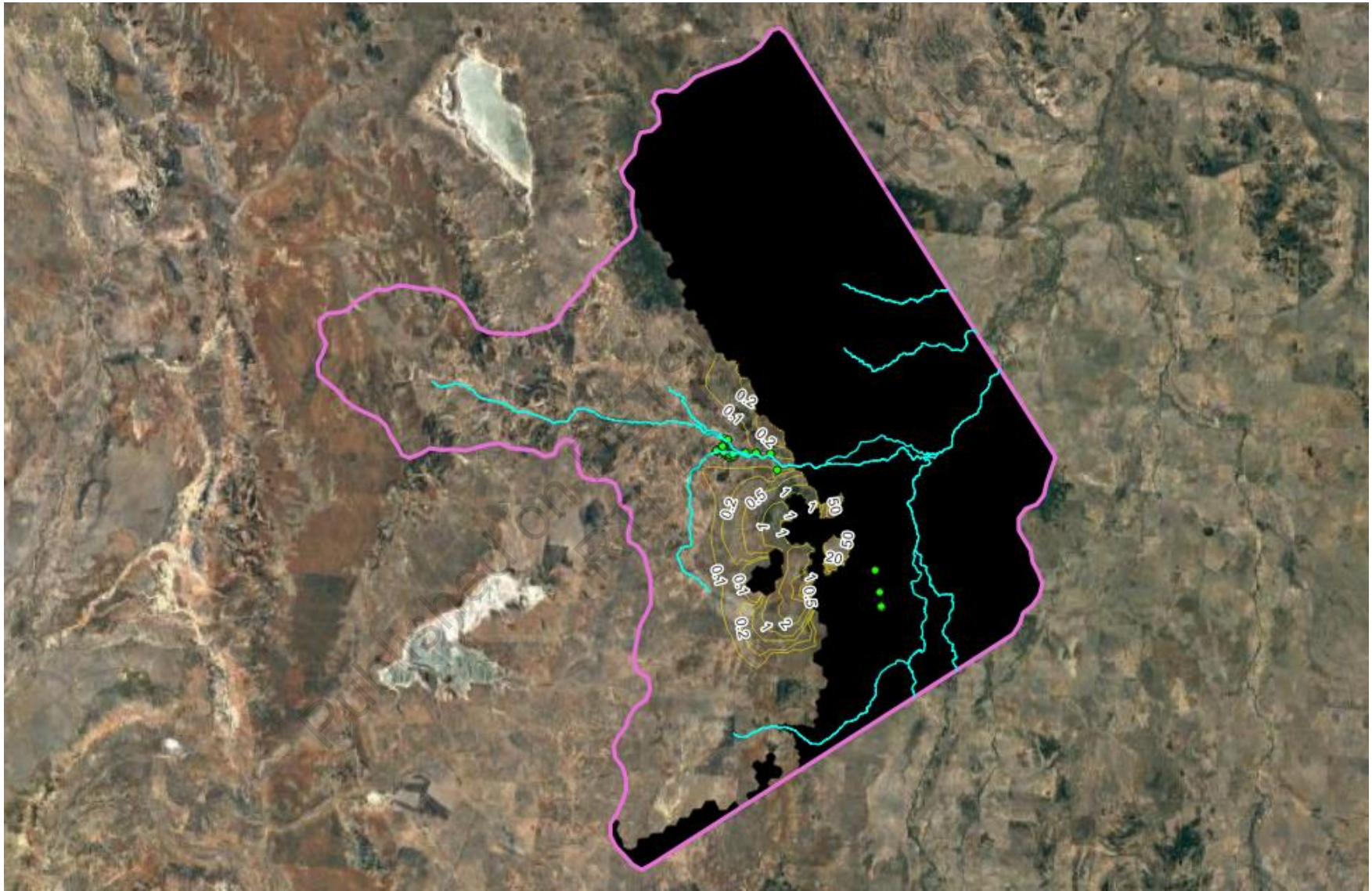
Spring	GHD (2013)	OC	SEIS A	SEIS B
Moses 4	<0.05	0.05	0.12	0.31
Moses 3	<0.05	0.05	0.12	0.31
Moses 2	0.08	0.05	0.12	0.31
Little Moses 1	<0.05	0.05	0.08	0.24
Moses 1	0.06	0.06	0.13	0.32
Moses 7	0.09	0.05	0.12	0.31
Moses 10	0.08	0.05	0.12	0.31
Moses 15	0.07	0.05	0.12	0.31
Moses 20	0.12	0.06	0.12	0.31
Moses 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

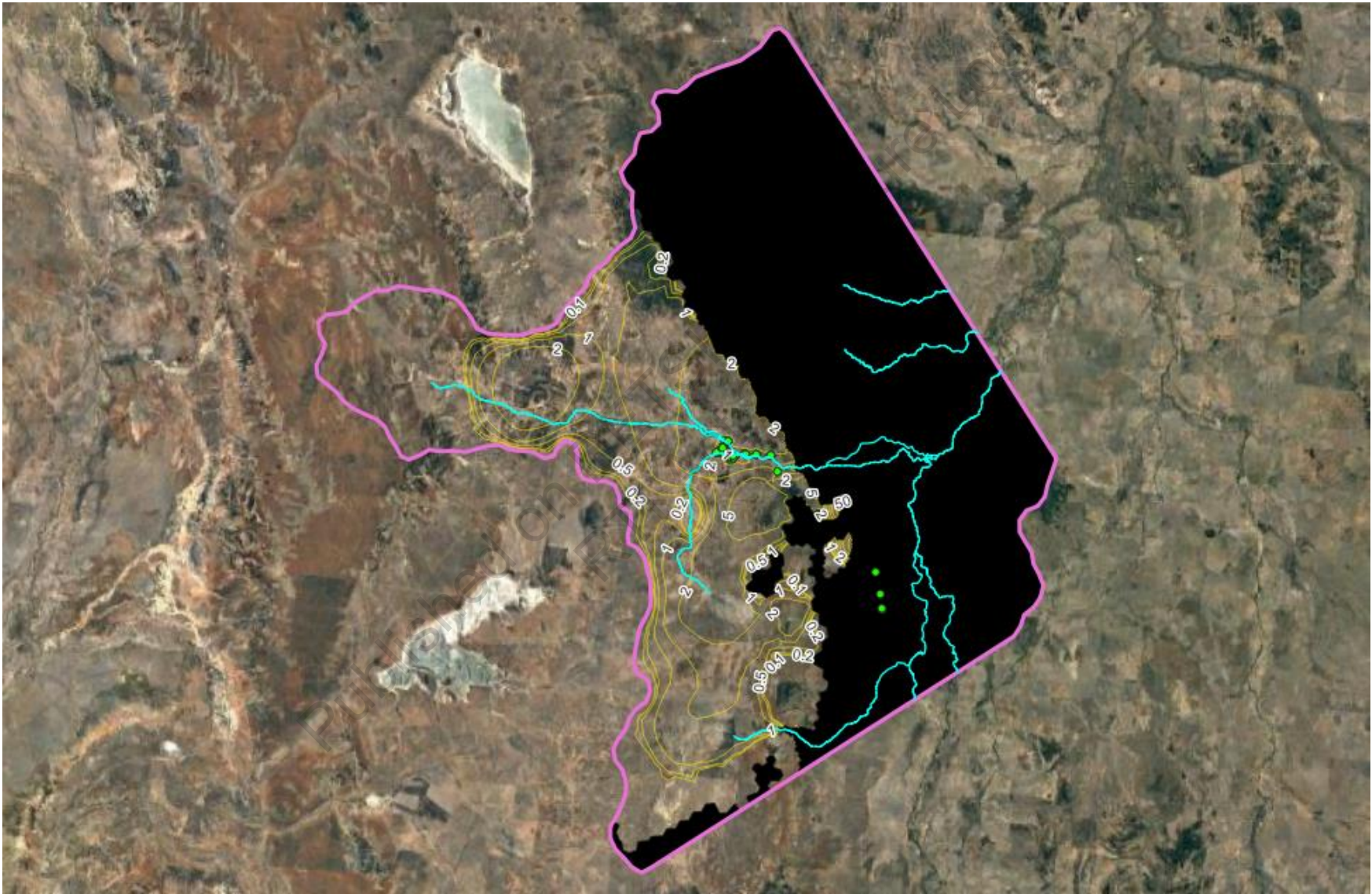
Spring	OC
Moses 4	0%
Moses 3	0%
Moses 2	0%
Little Moses 1	0%
Moses 1	0%
Moses 7	0%
Moses 10	0%
Moses 15	0%
Moses 20	0%
Moses 26	0%
Joshua Spring	0%

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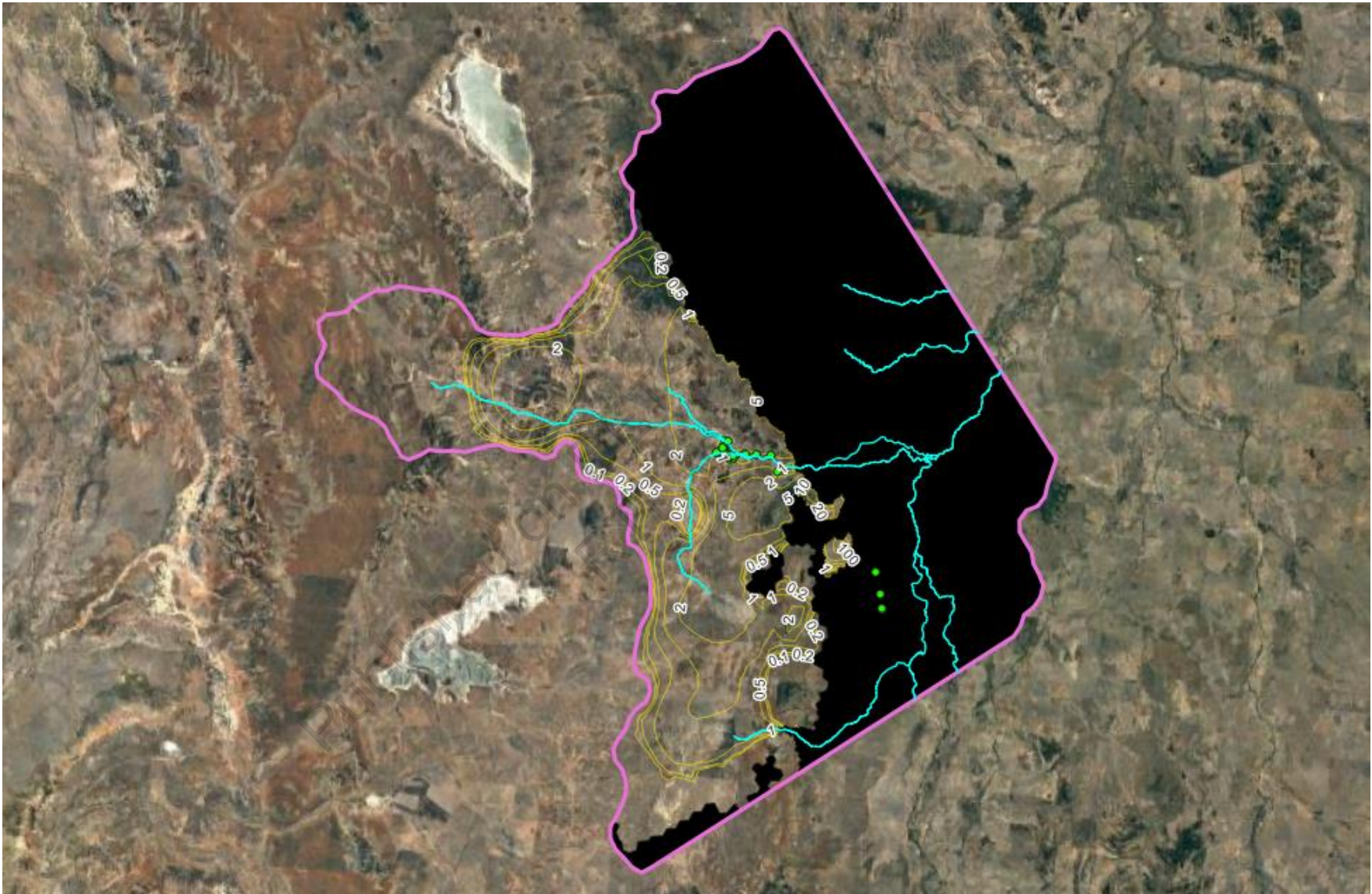
Modelled base case drawdown in Clematis: OC



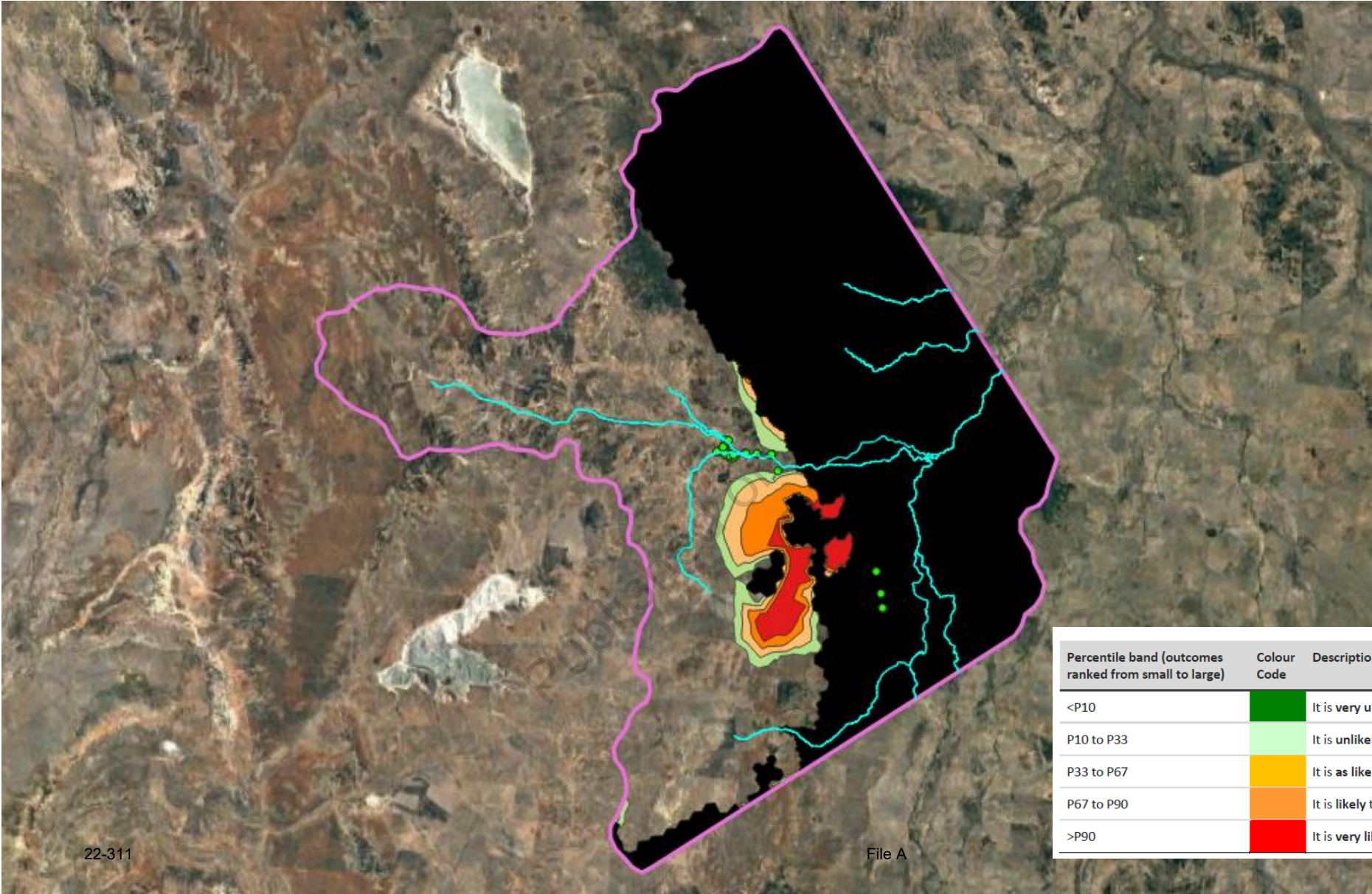
Modelled base case drawdown in Clematis: SEIS A



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

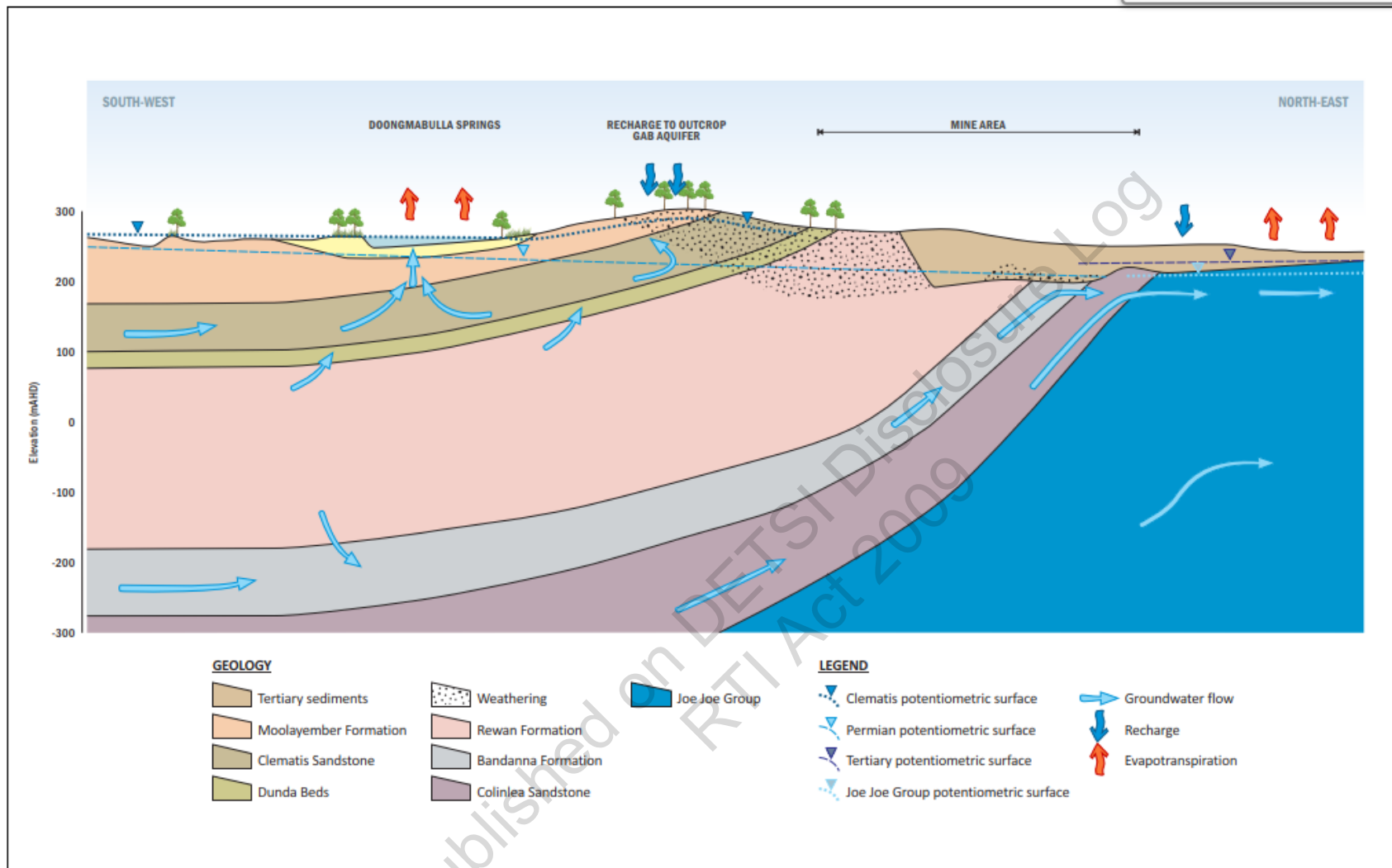
Feature of conceptual model	Summary of key knowledge
Local groundwater flow	<p>Local groundwater flow characteristics differ based on hydrostratigraphic unit (HSU), with the main points summarised as follows:</p> <ul style="list-style-type: none"> • Alluvium: Flow mimics topography and flows west to 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.



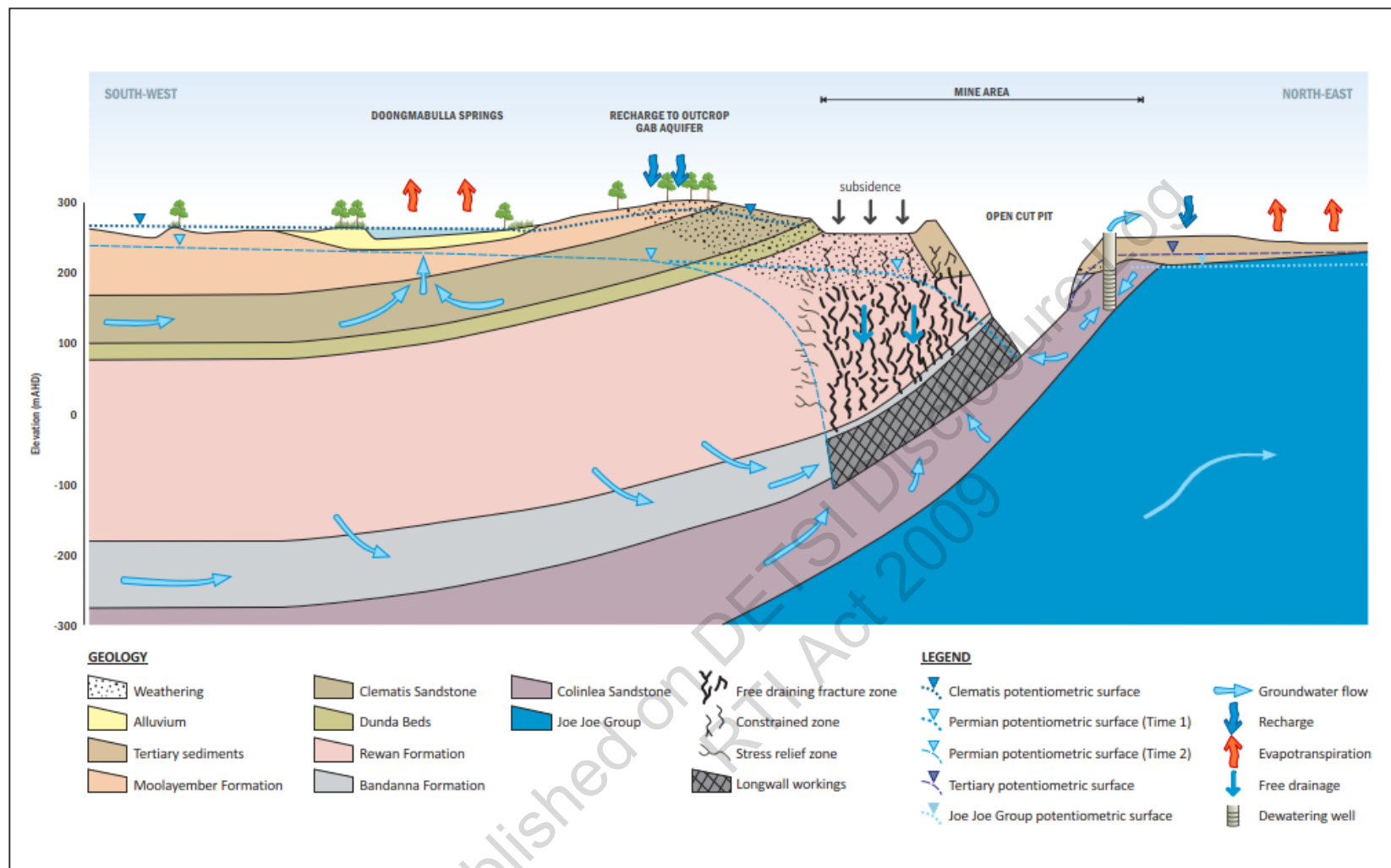
Pre-mining hydrogeological conceptual model

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

Bravus Mining & Resources

Figure 12.2

Figure 2.2 Mining hydrogeological conceptual model

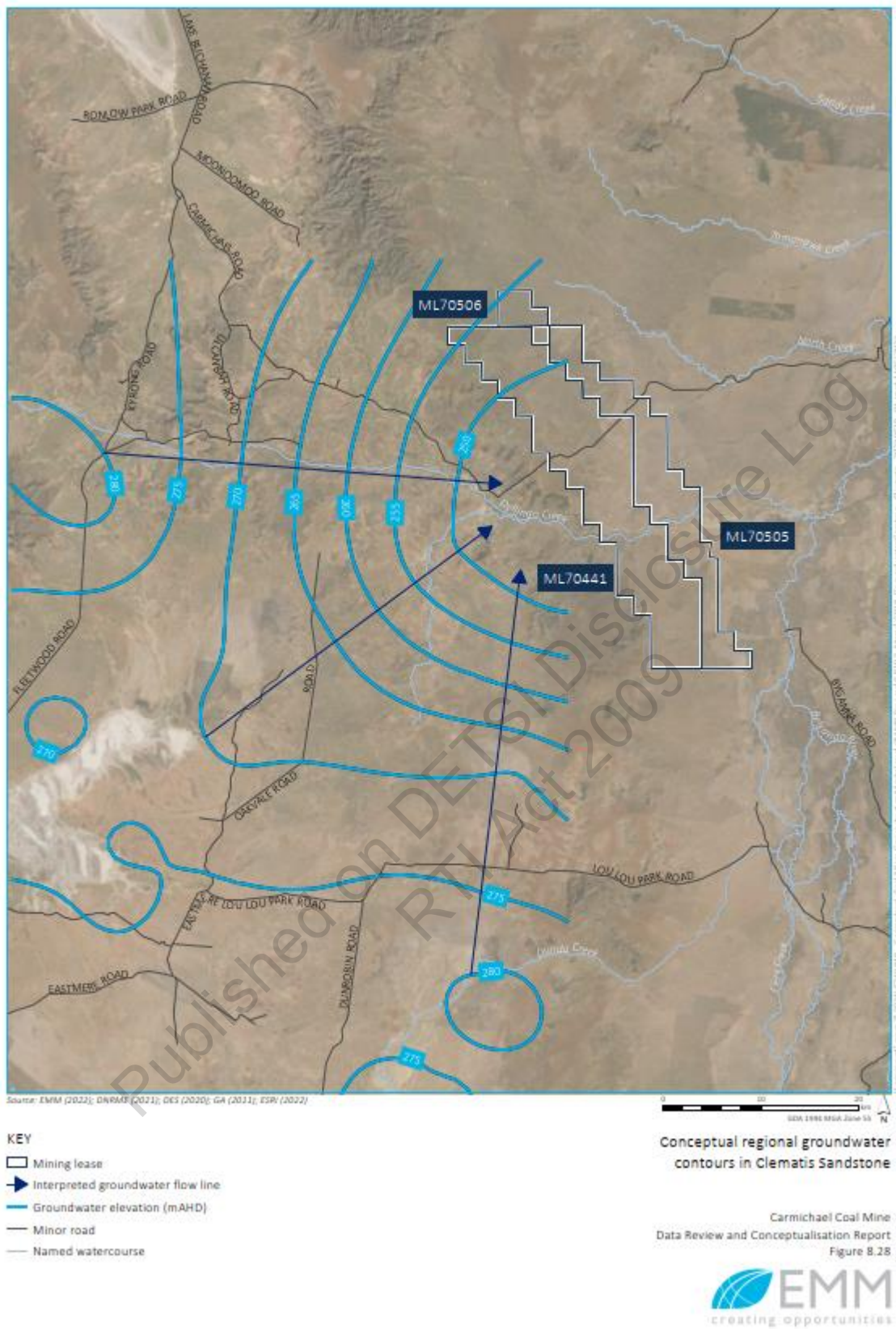


Figure 2.3 Conceptual regional groundwater contours in Clematis Sandstone

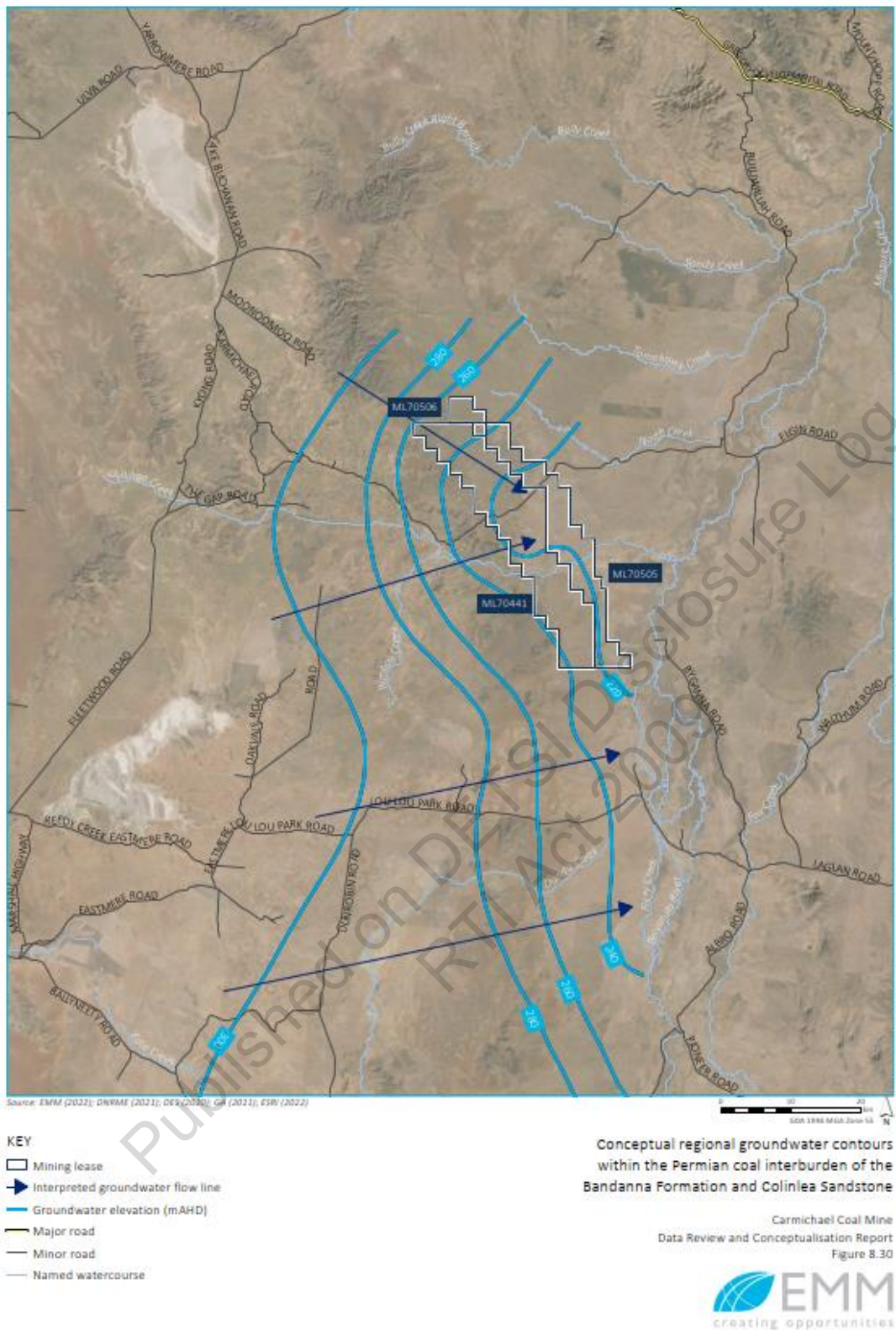
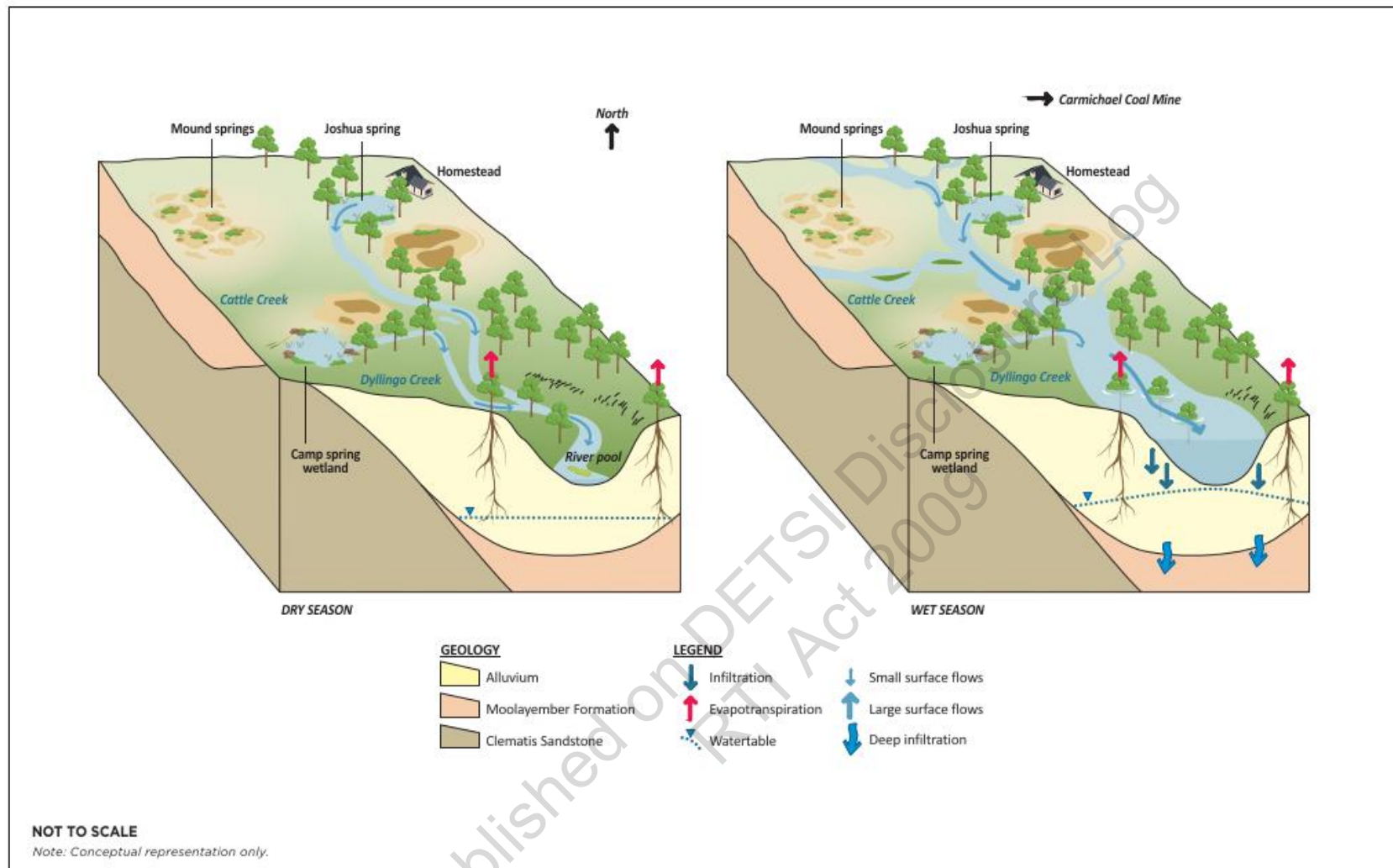


Figure 2.4 Conceptual regional groundwater contours within the Permian coal interburden of the Bandanna Formation and Colinlea Sandstone



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.

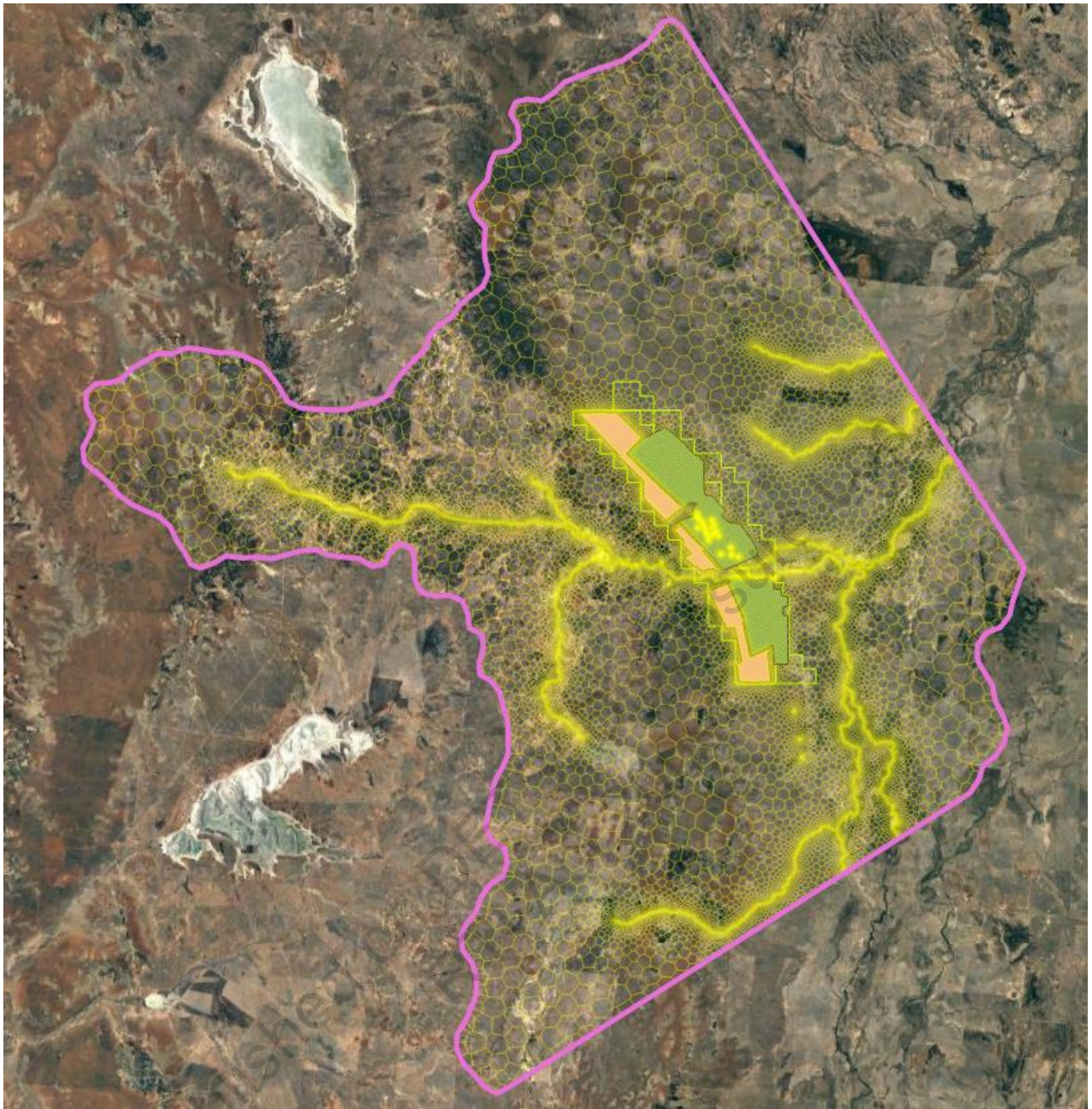


Figure 3.1 Model domain and Voronoi mesh

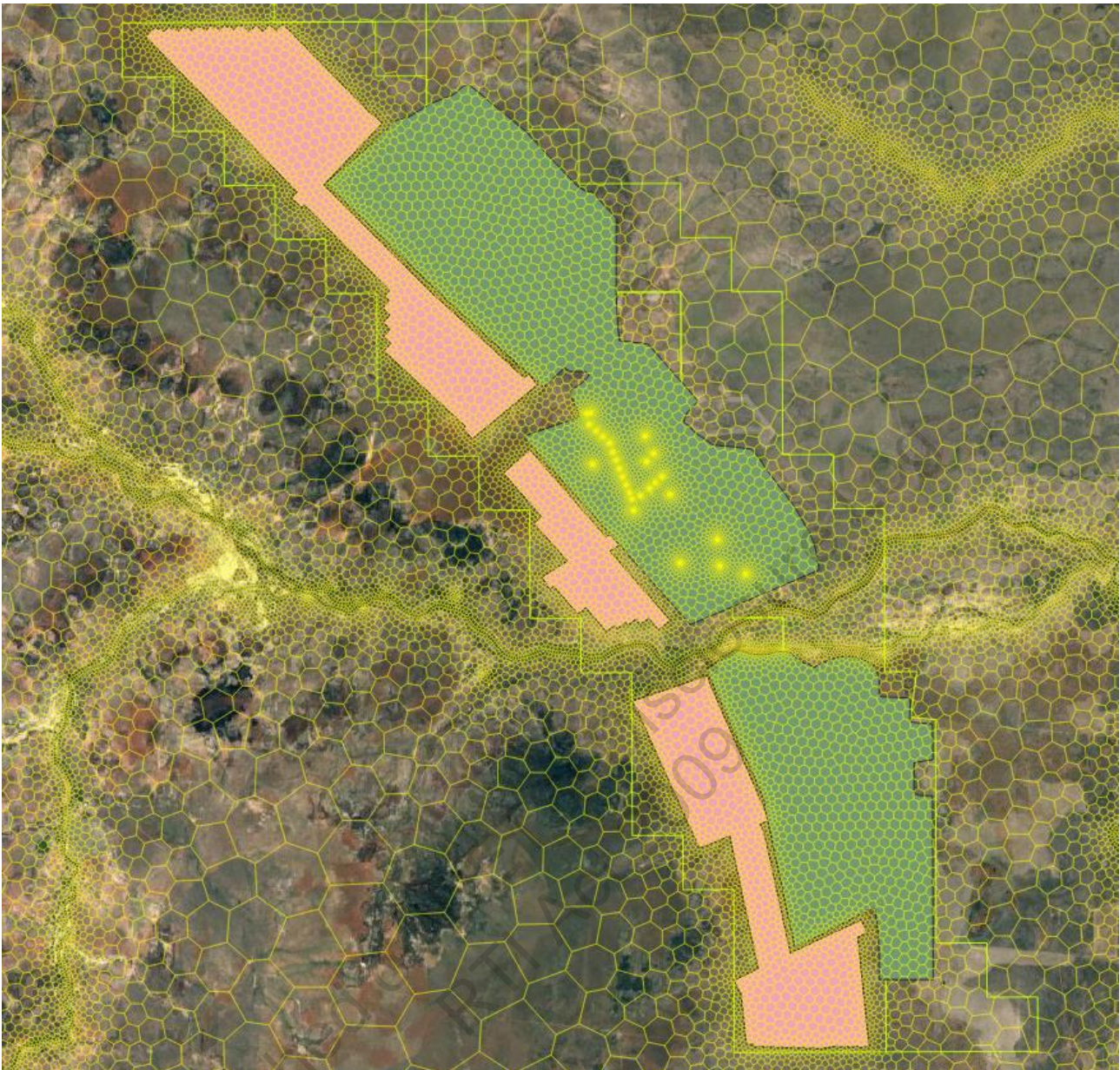


Figure 3.2

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.

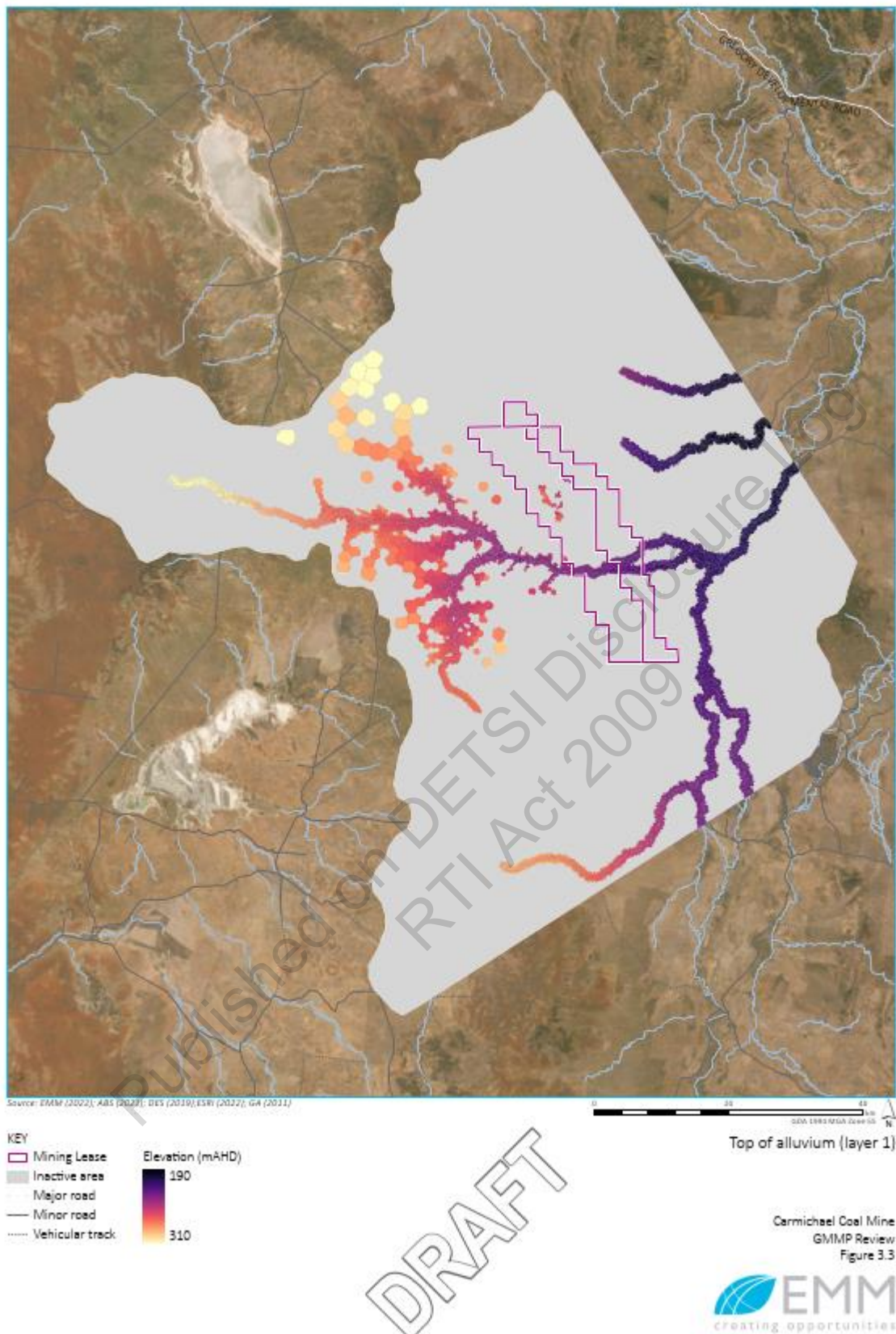


Figure 3.3 **Top of alluvium (layer 1)**

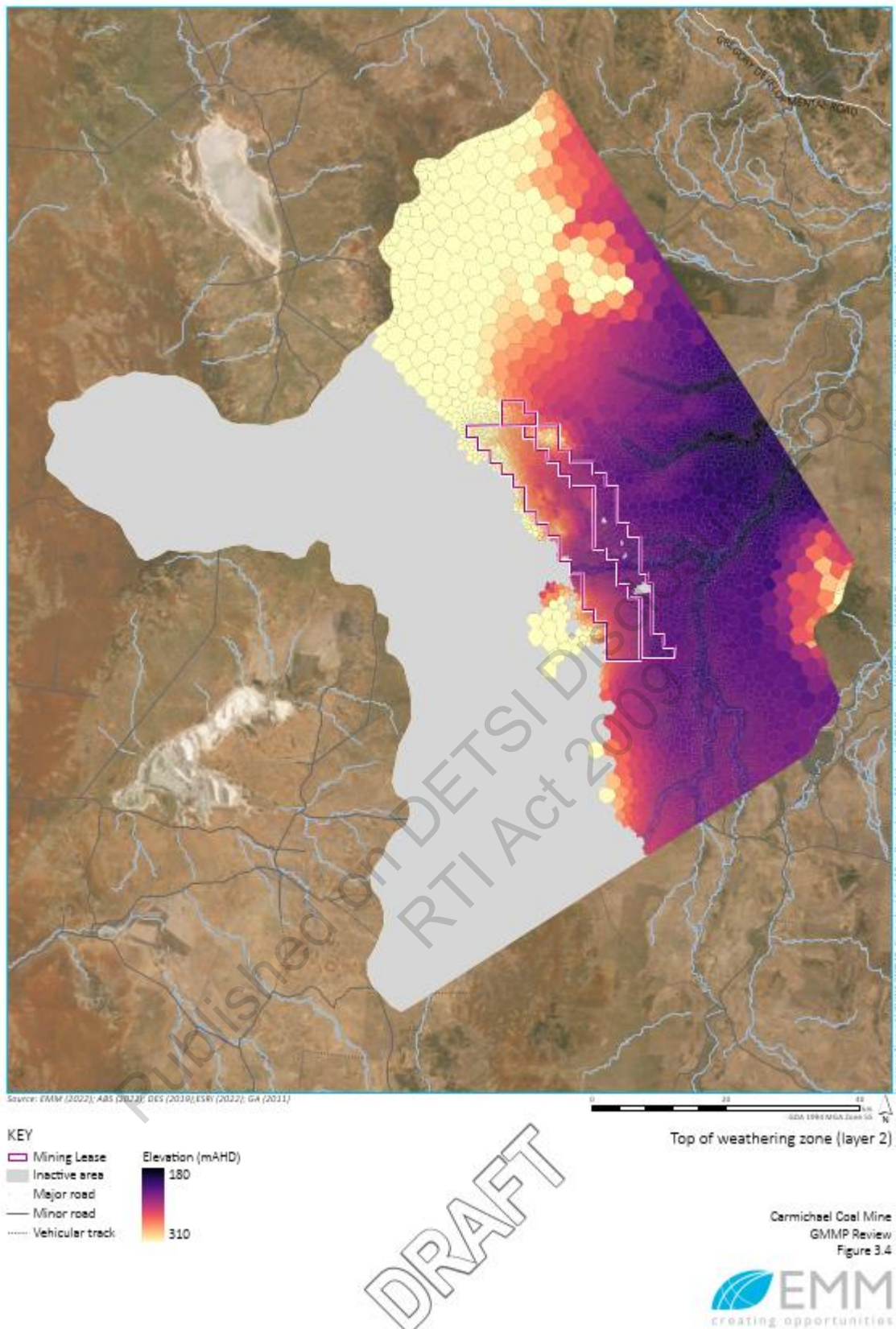


Figure 3.4 Top of weathering zone (layer 2)

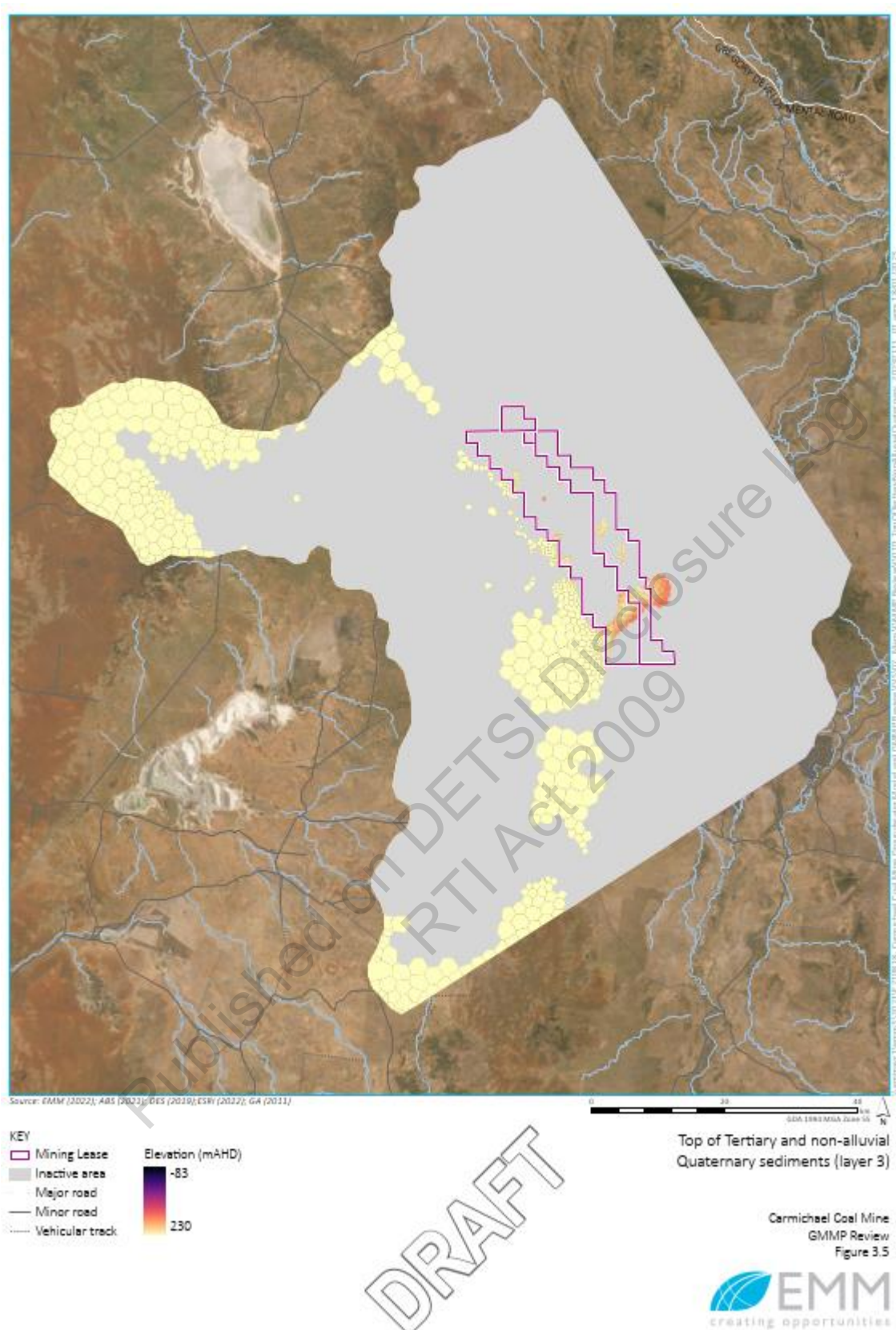


Figure 3.5 Top of Tertiary and non-alluvial Quaternary sediments (layer 3)

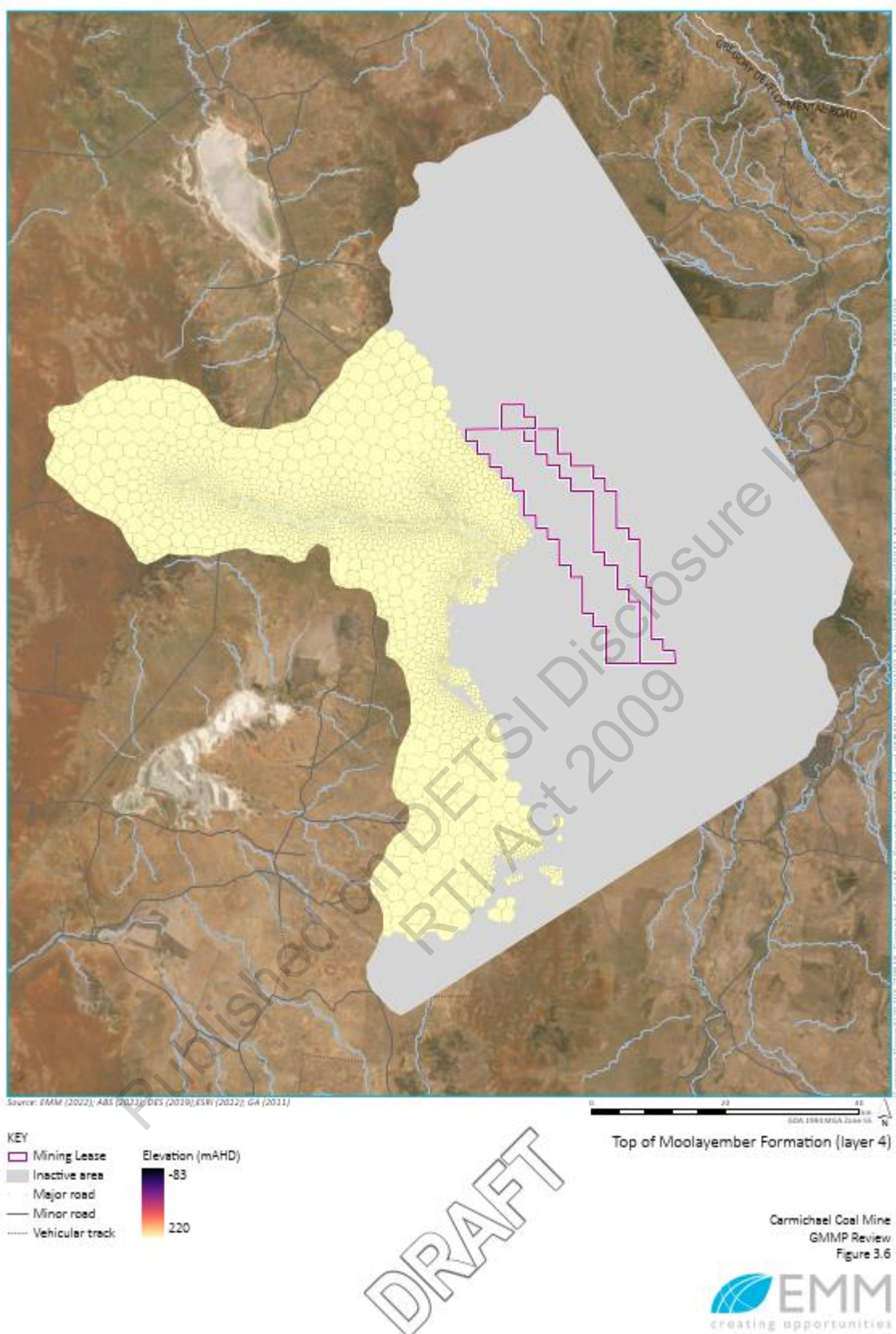


Figure 3.6 Top of Moolayember Formation (layer 4)

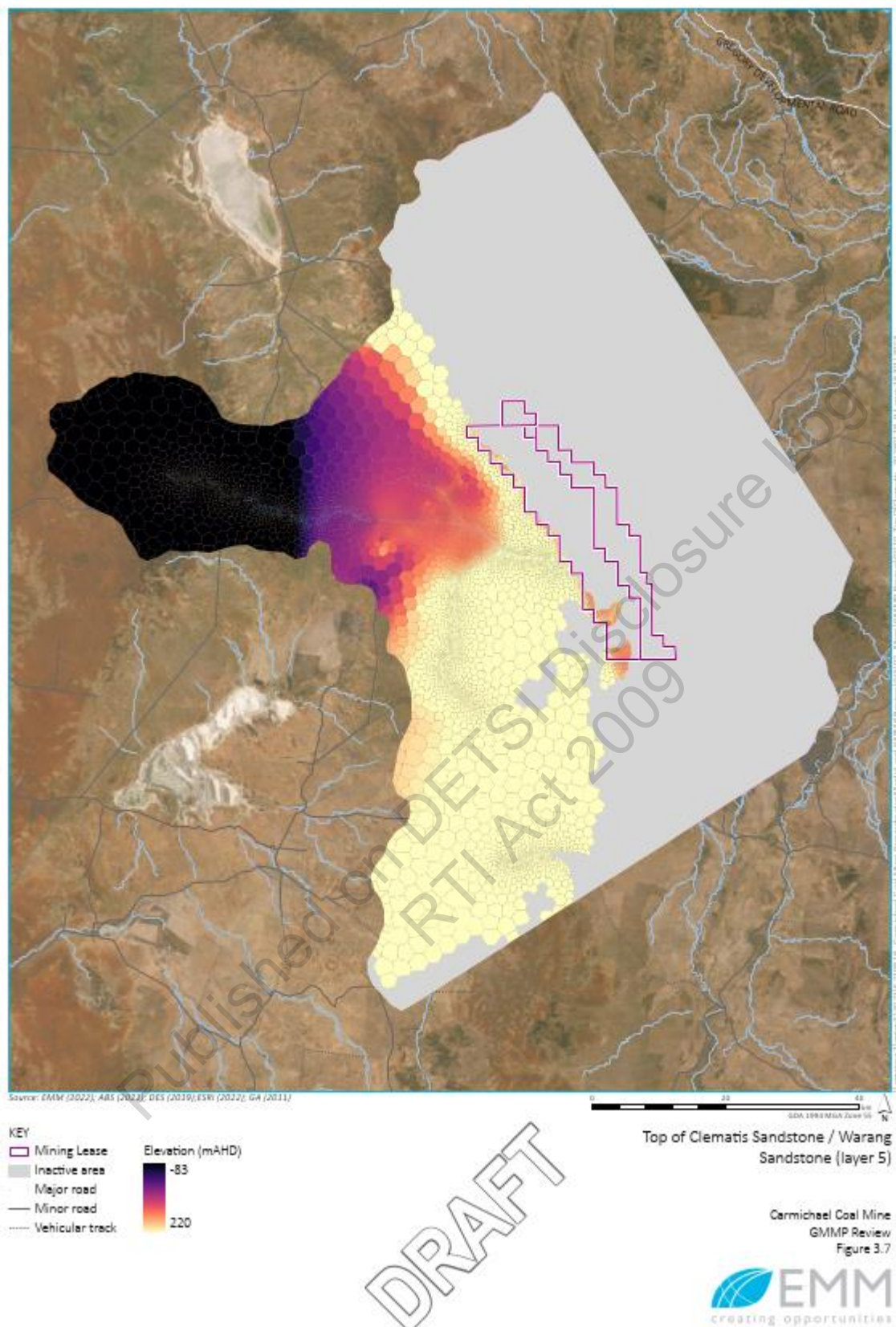


Figure 3.7 Top of Clematis Sandstone / Warang Sandstone (layer 5)

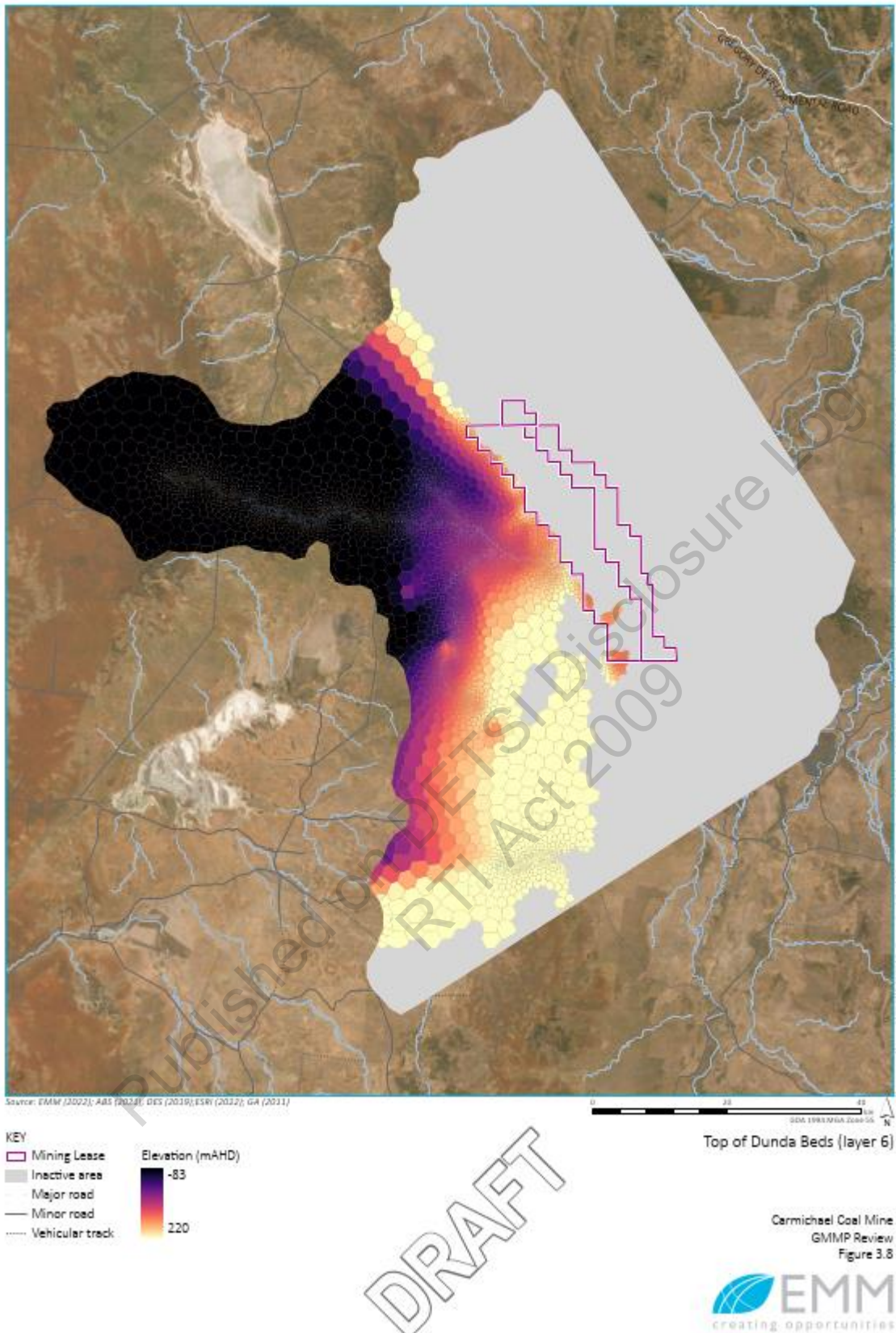


Figure 3.8 **Top of Dunda Beds (layer 6)**

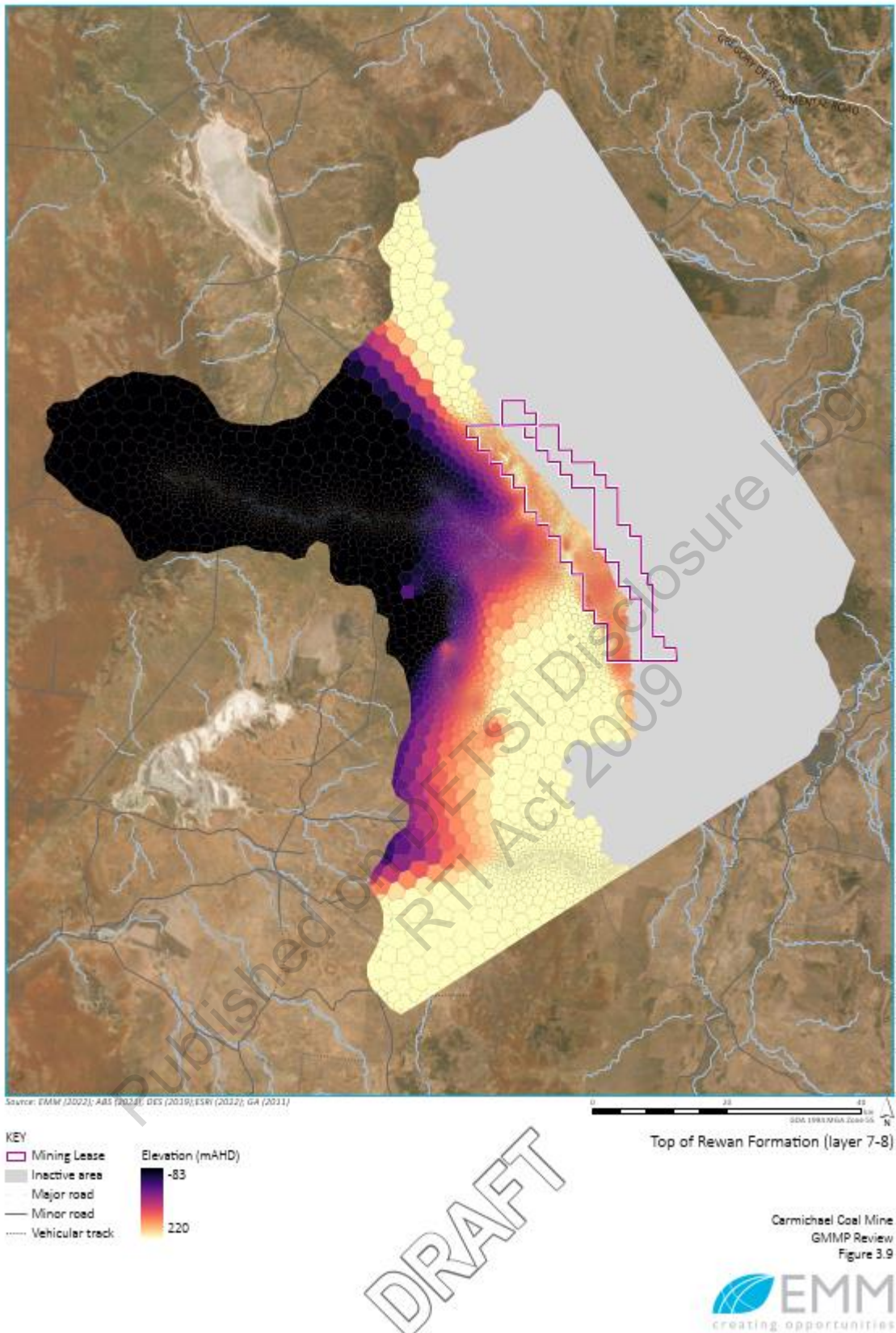


Figure 3.9 Top of Rewan Formation (layer 7-8)

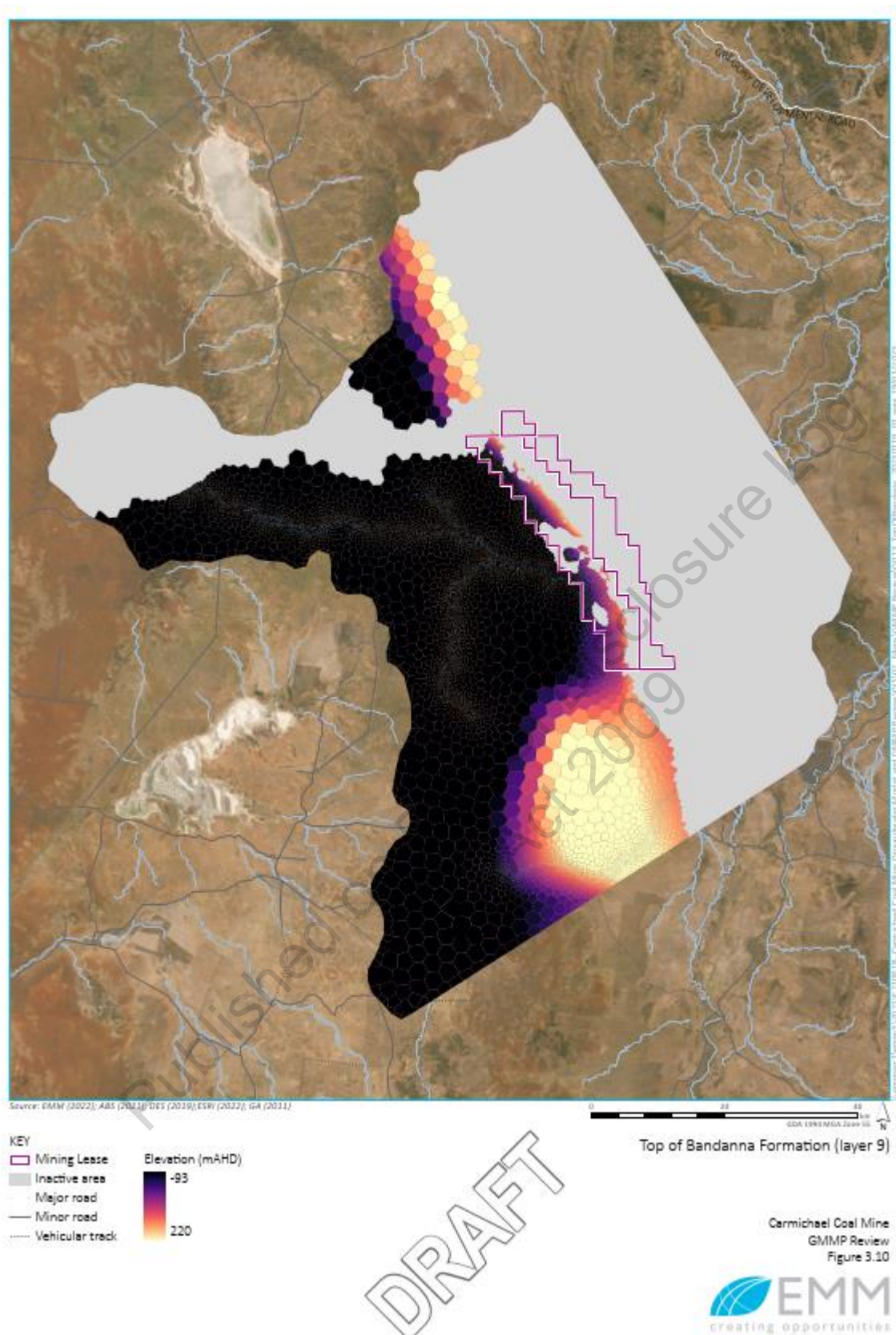


Figure 3.10 Top of Bandanna Formation (layer 9)

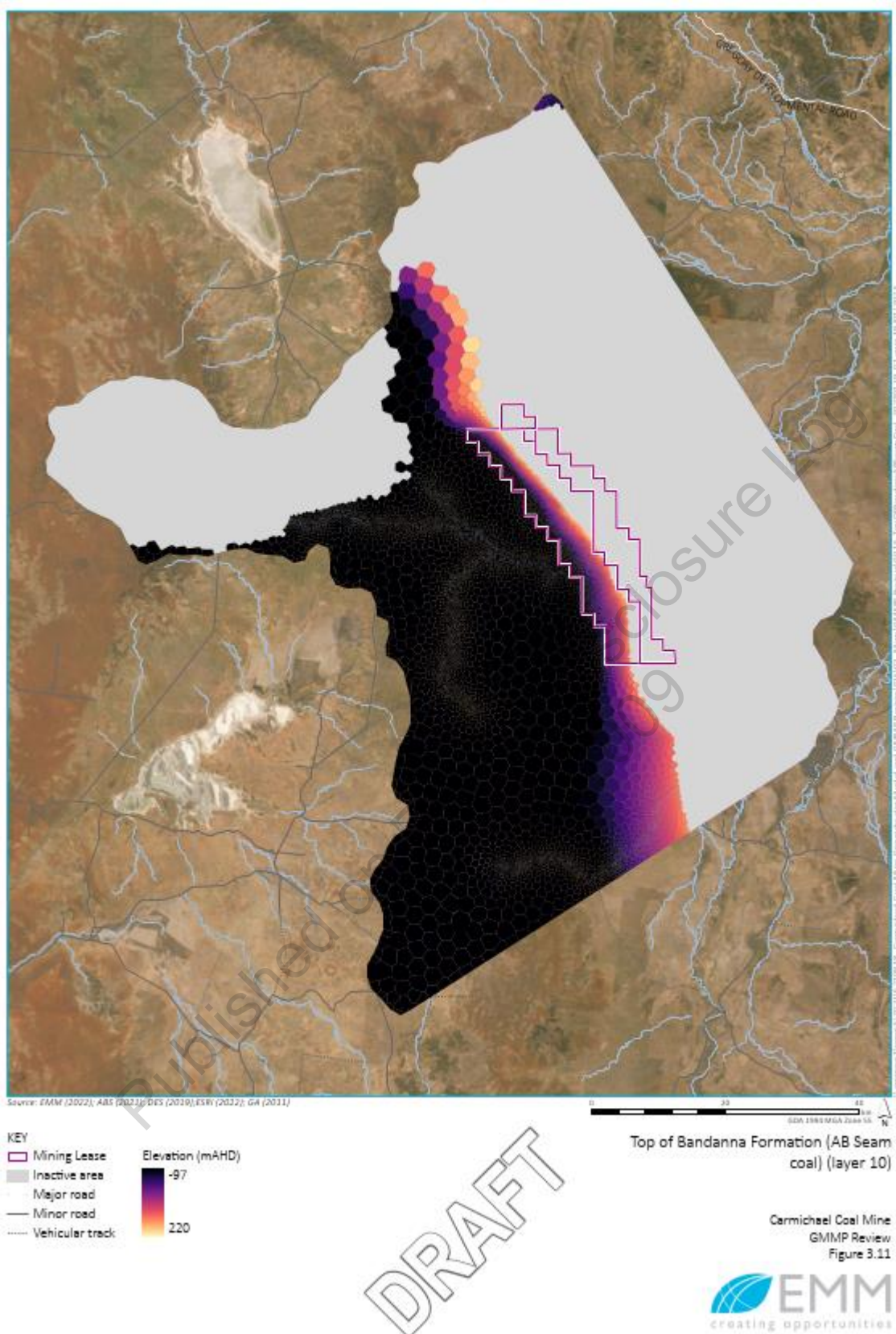


Figure 3.11 Top of Bandanna Formation (AB Seam coal) (layer 10)

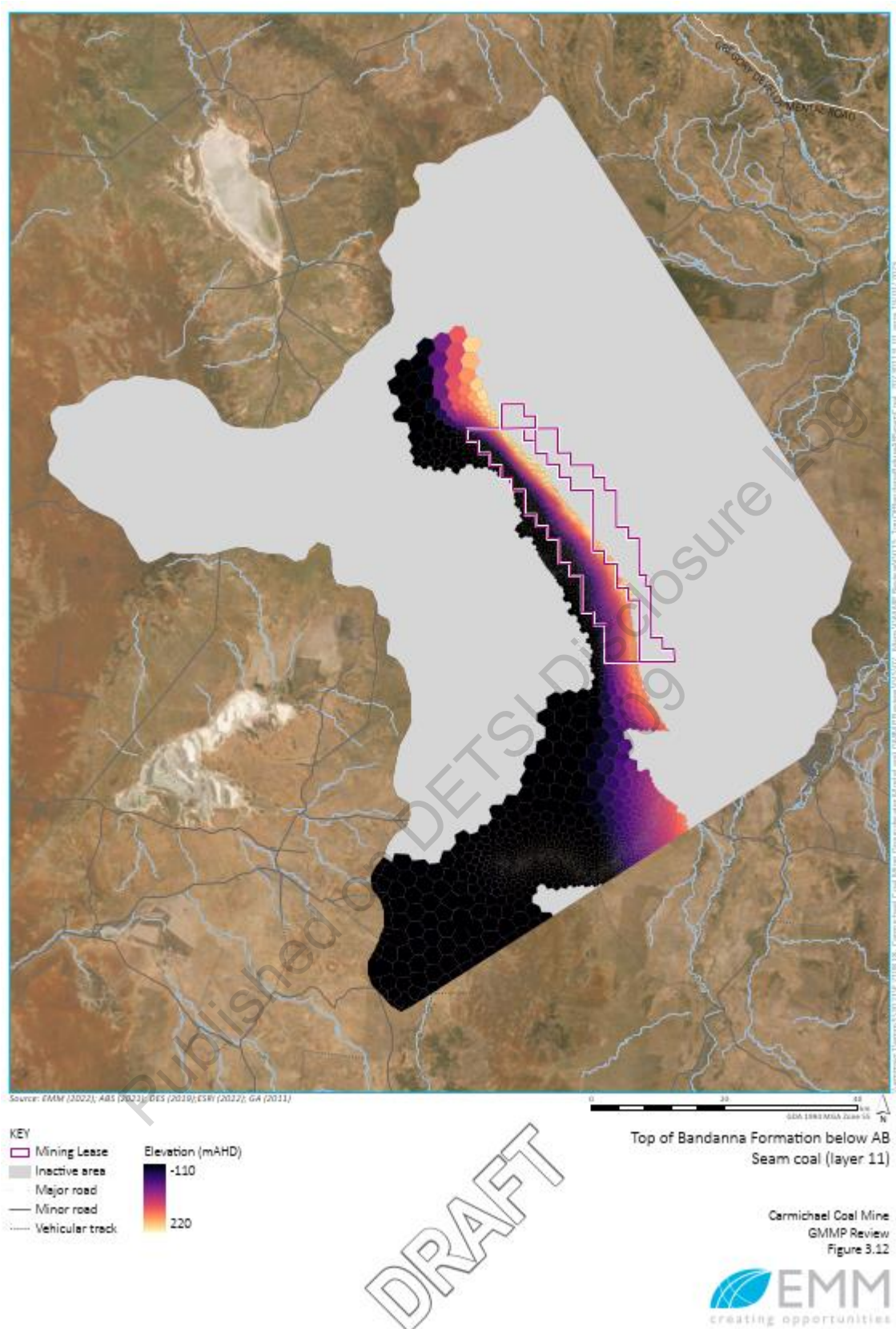


Figure 3.12 Top of Bandanna Formation below AB Seam coal (layer 11)

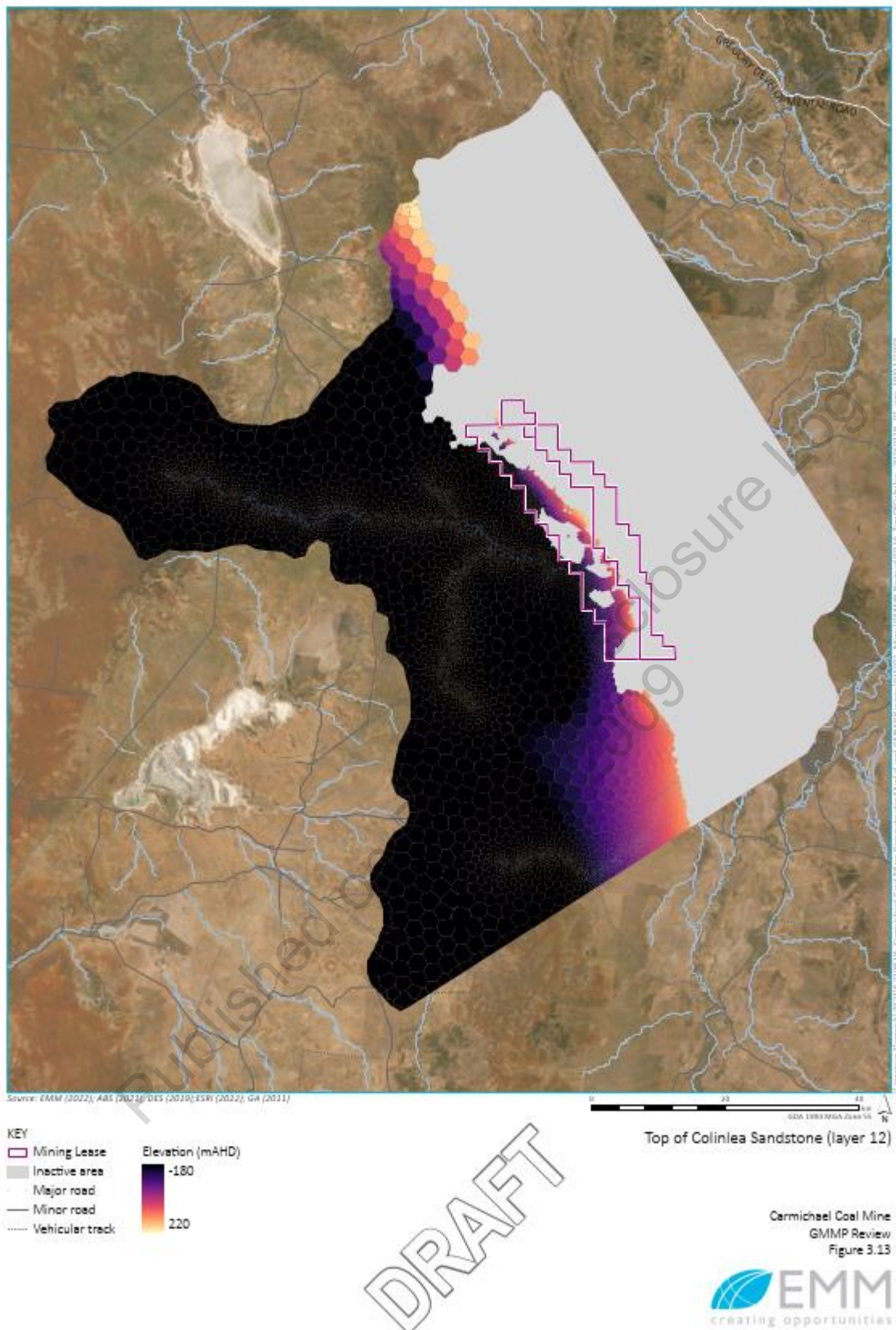


Figure 3.13 Top of Colinlea Sandstone (layer 12)

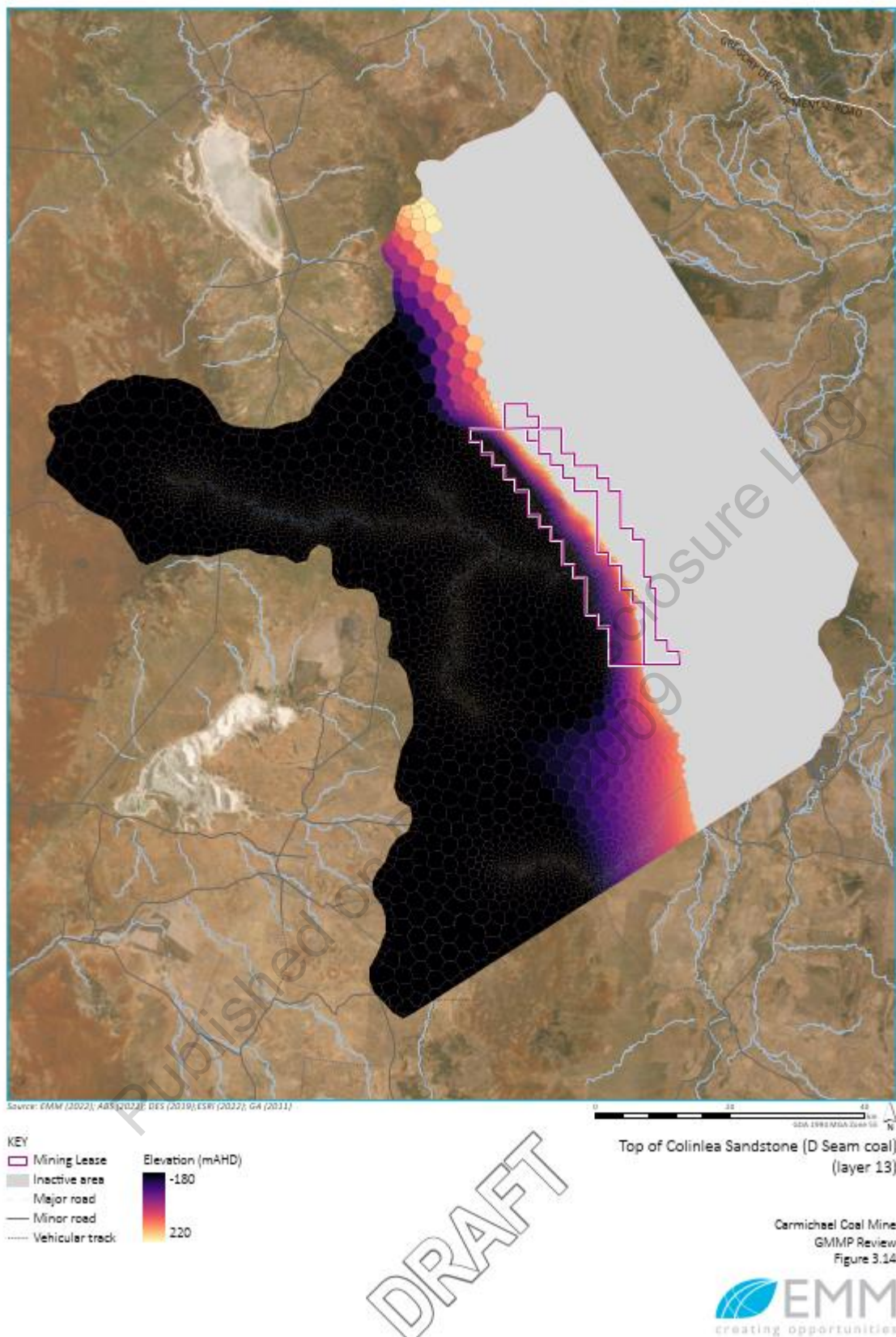


Figure 3.14 Top of Colinlea Sandstone (D Seam coal) (layer 13)

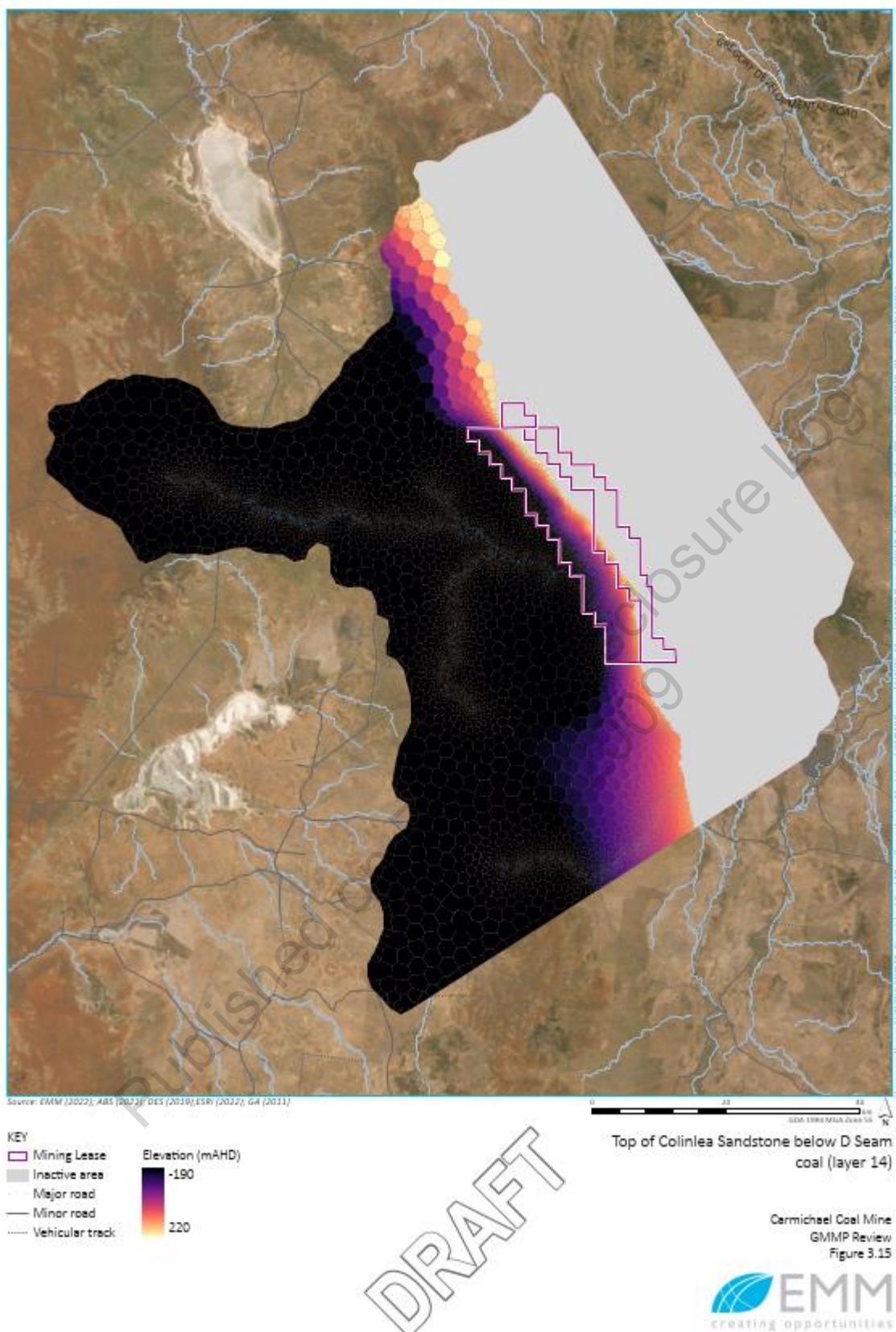


Figure 3.15 Top of Colinlea Sandstone below D Seam coal (layer 14)

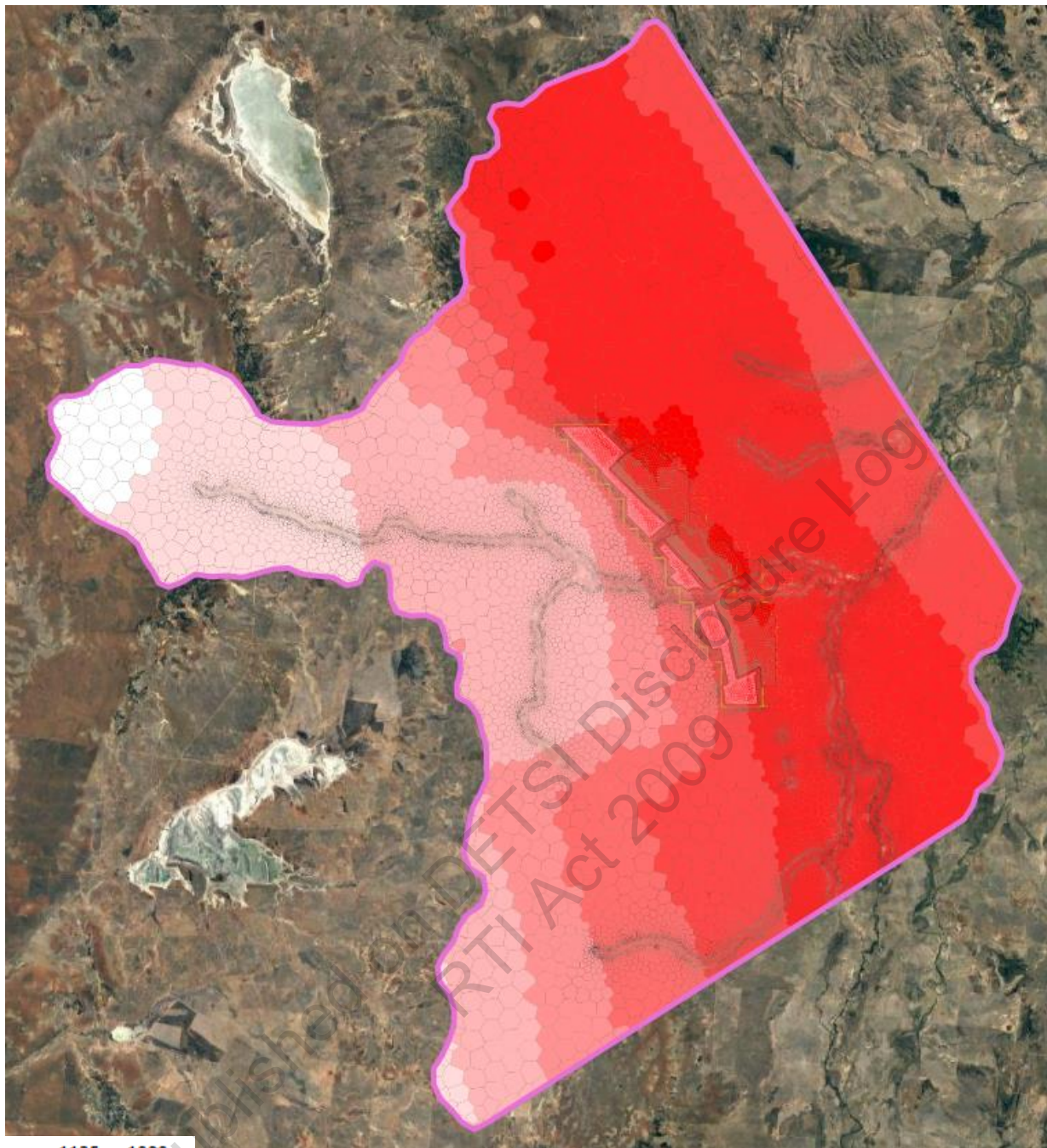
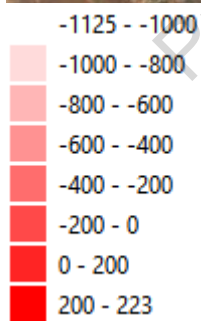


Figure 3.16 Top of Joe Joe Group (layer 15)

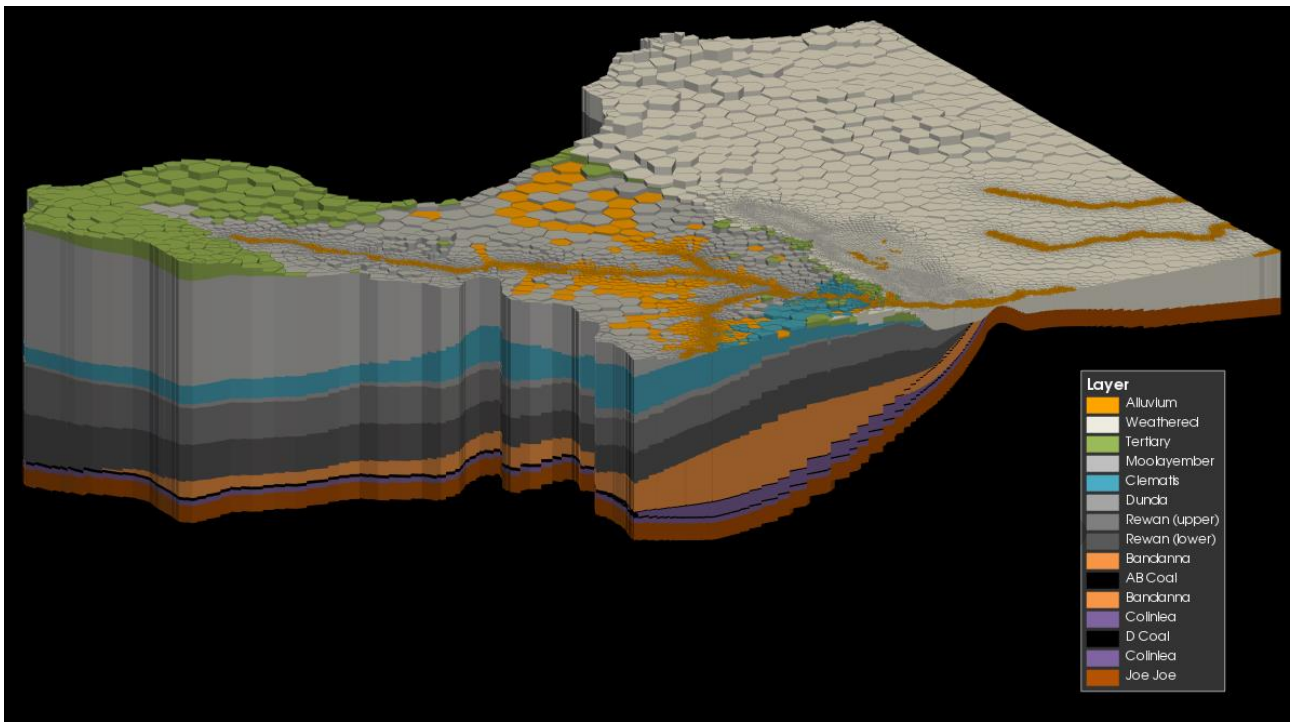


Figure 3.17 3-D visualisation of modelled HSUs

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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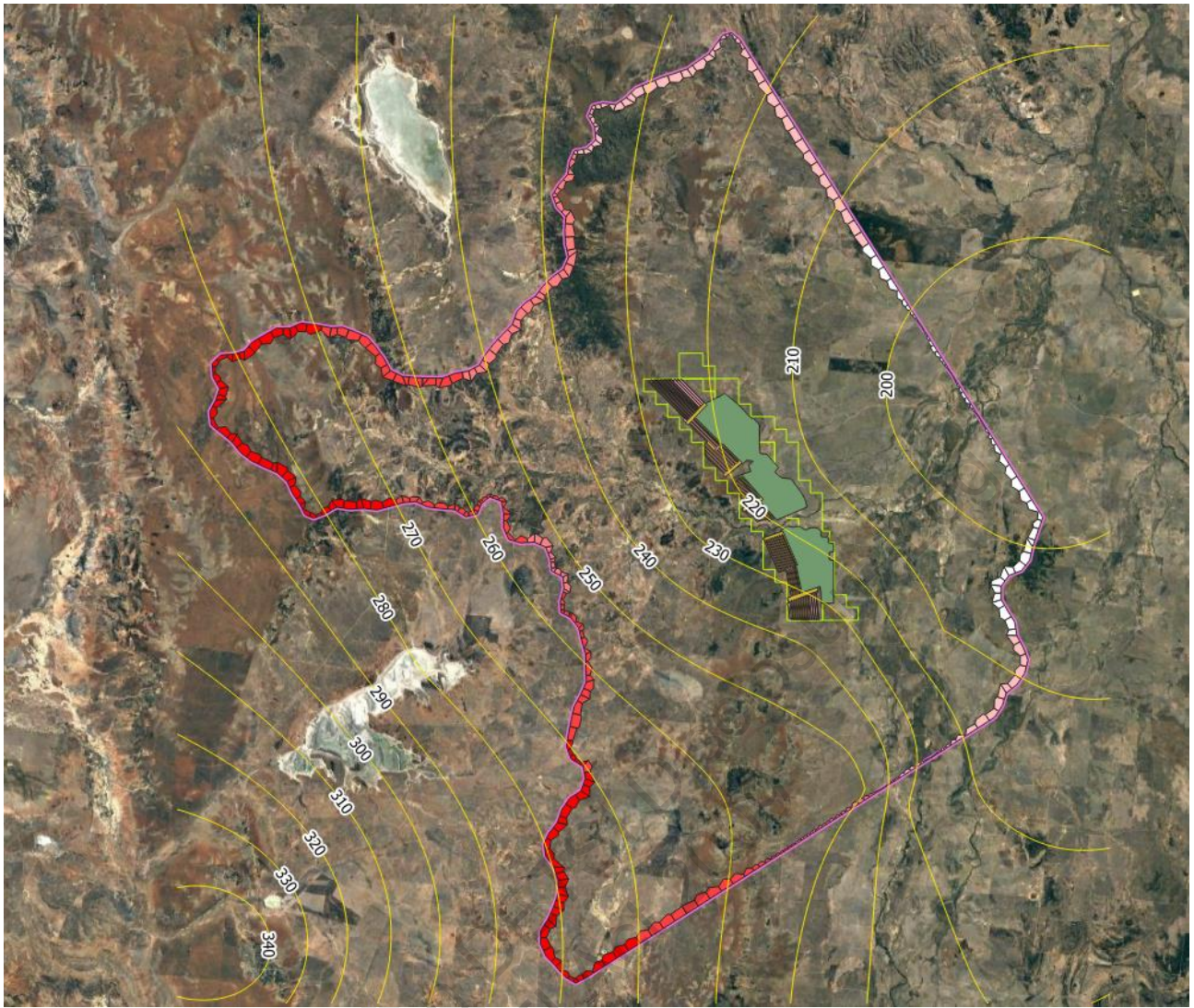


Figure 3.18 **Modelled regional boundary conditions in surficial layers**

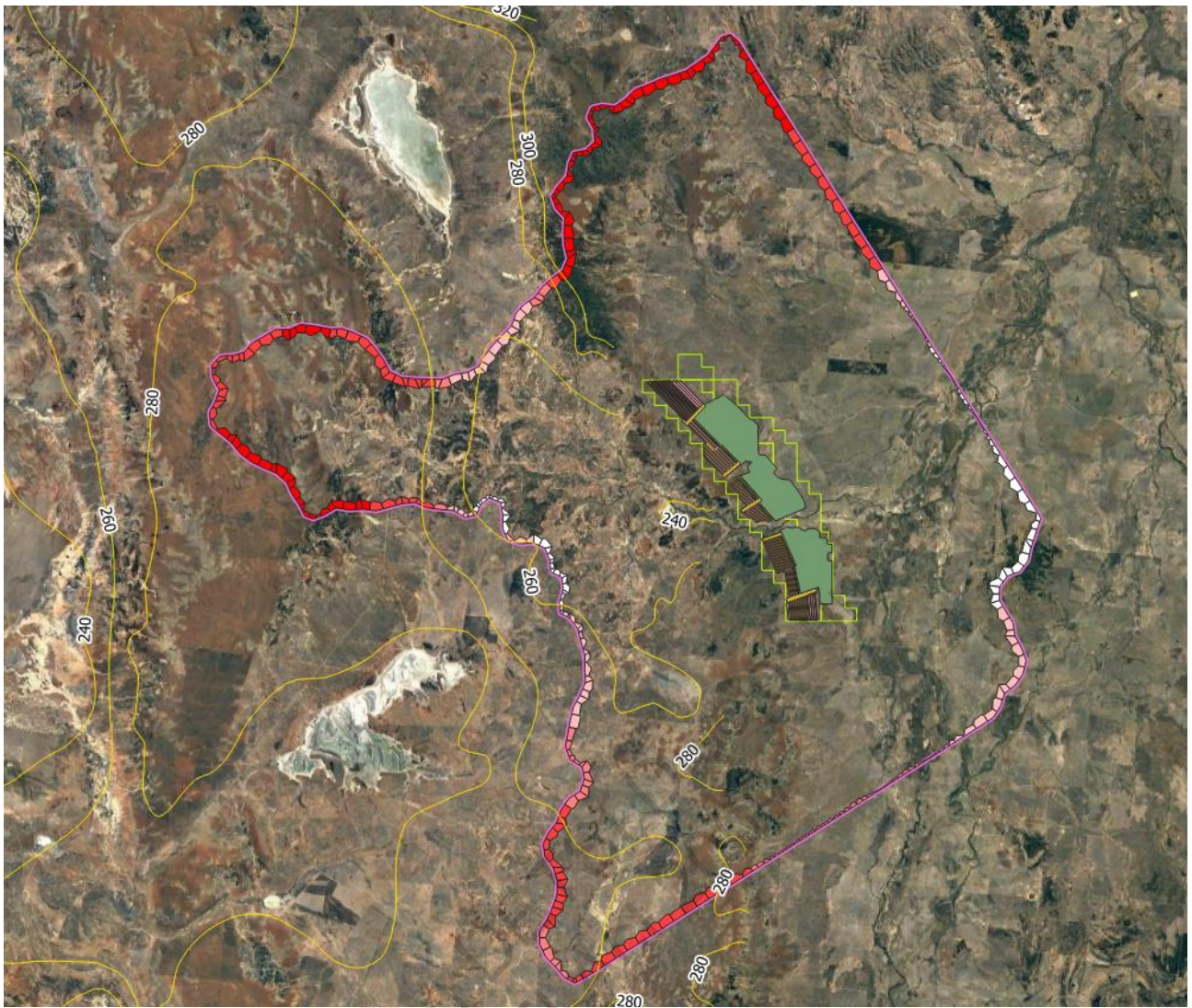


Figure 3.19 **Modelled regional boundary conditions in Clematis Sandstone**

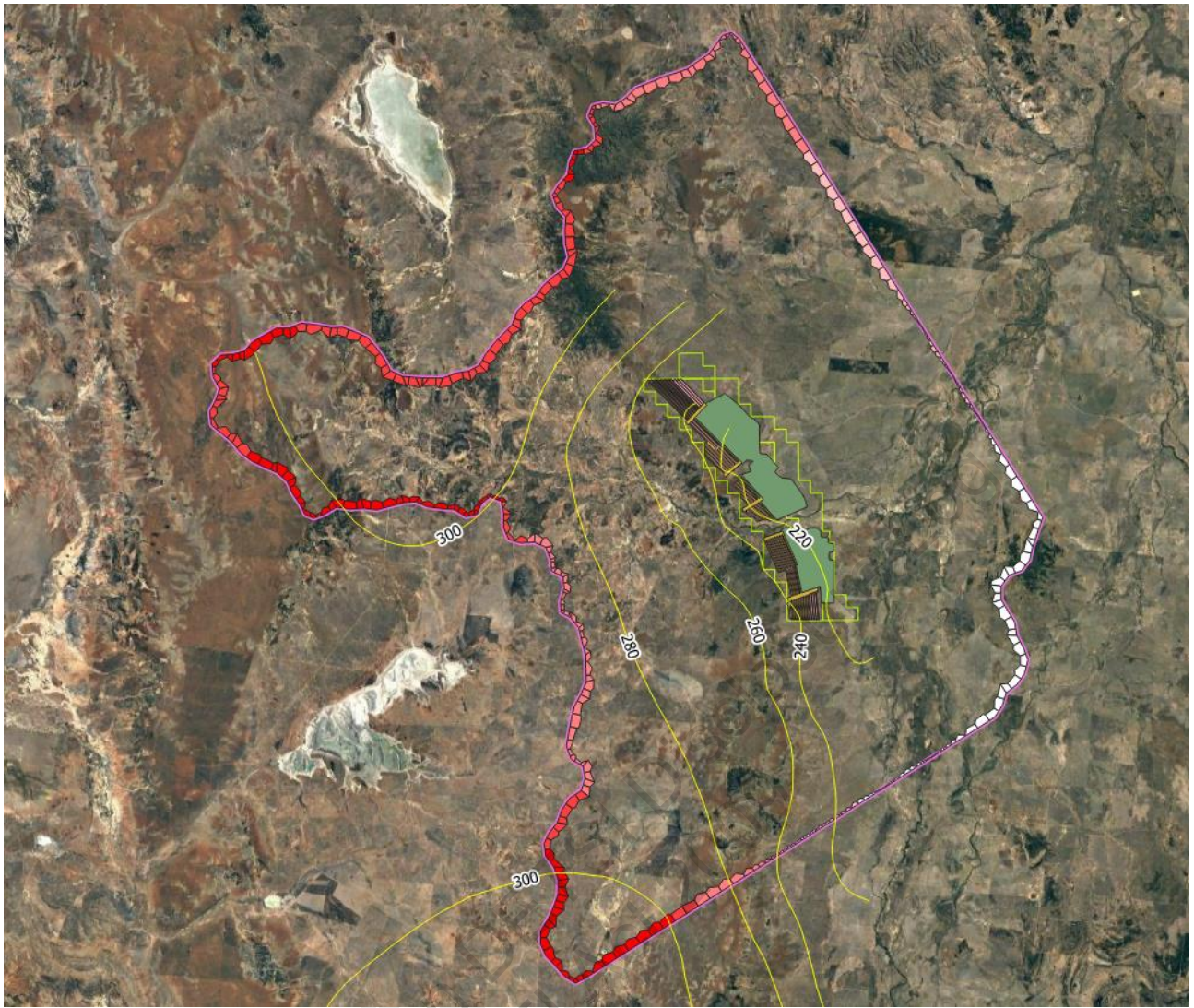


Figure 3.20 Modelled regional boundary conditions in Bandanna Formation (coal seam overburden) and AB Coal

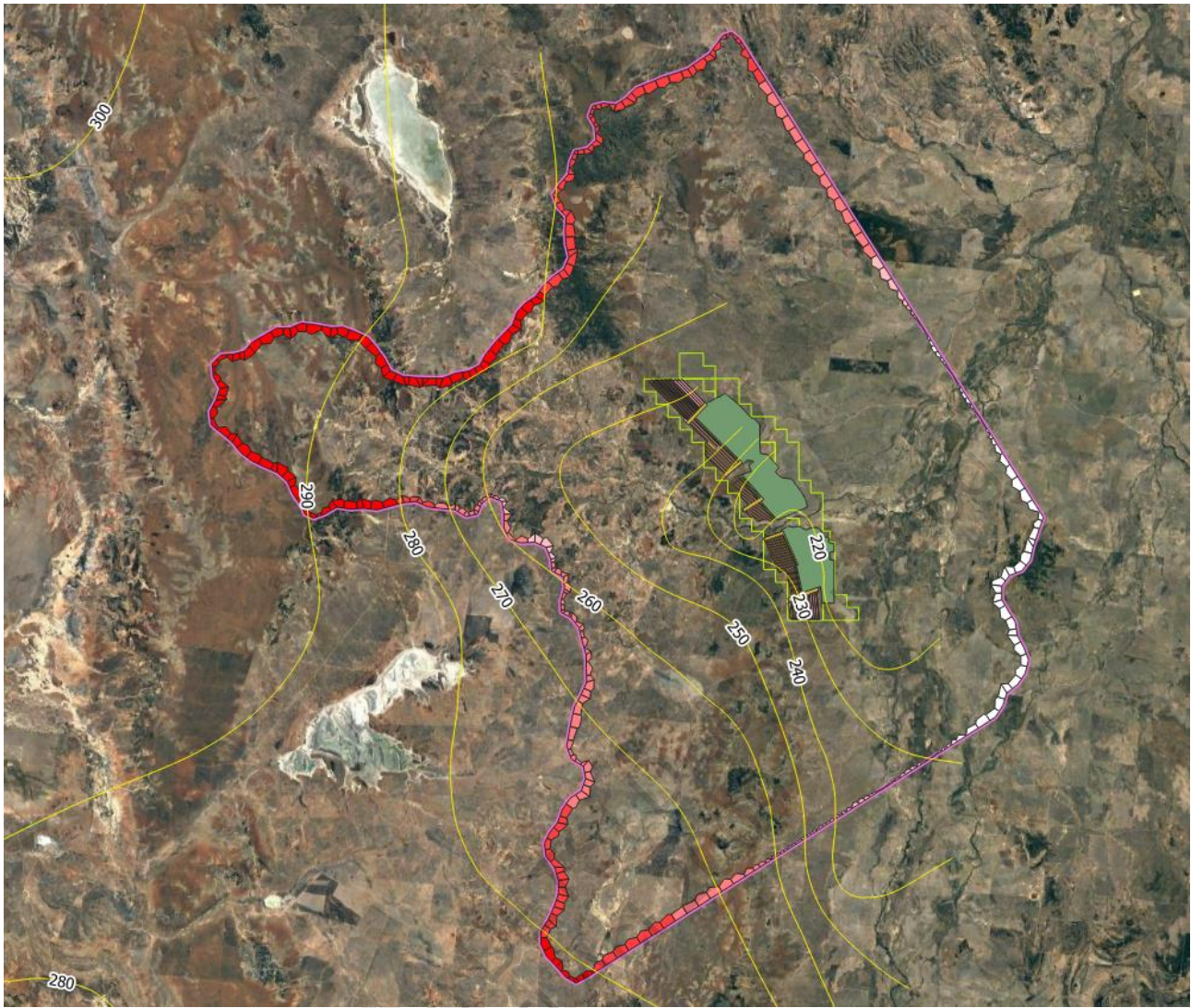


Figure 3.21 Modelled regional boundary conditions in D Coal and Colinlea Sandstone (coal seam underburden)

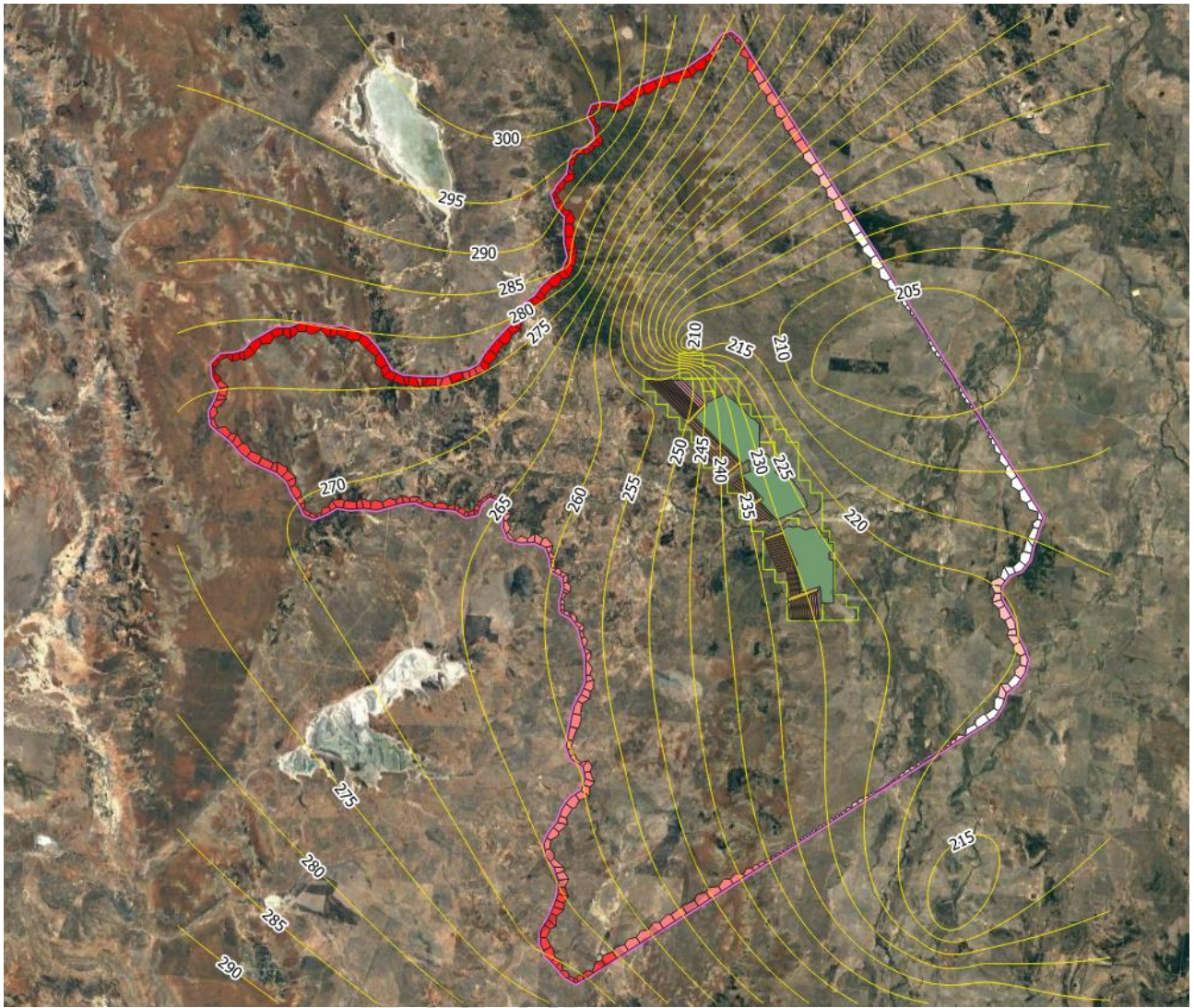


Figure 3.22 **Modelled regional boundary conditions in Joe Joe Group**

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).

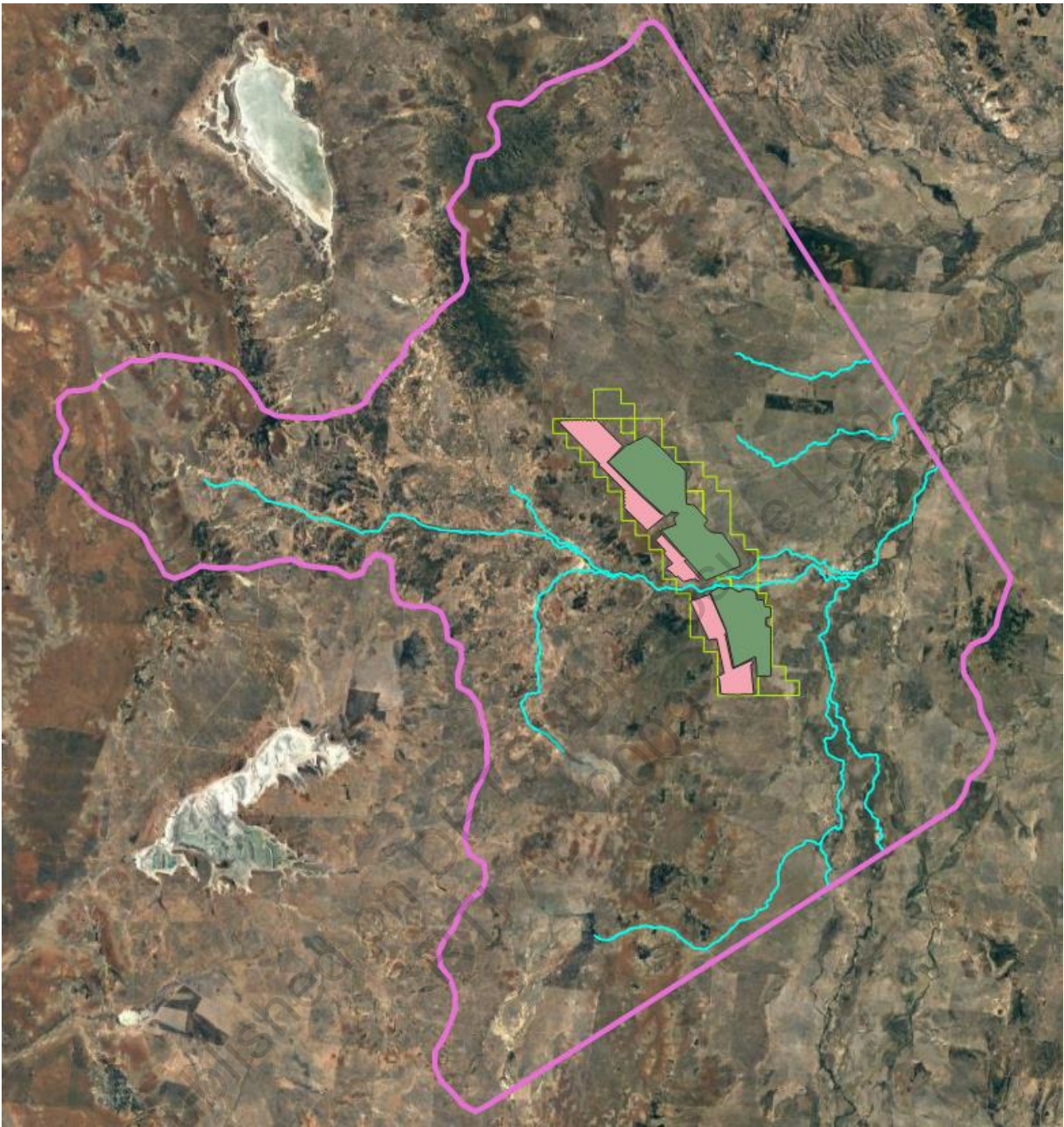


Figure 3.23 Modelled major watercourses

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.

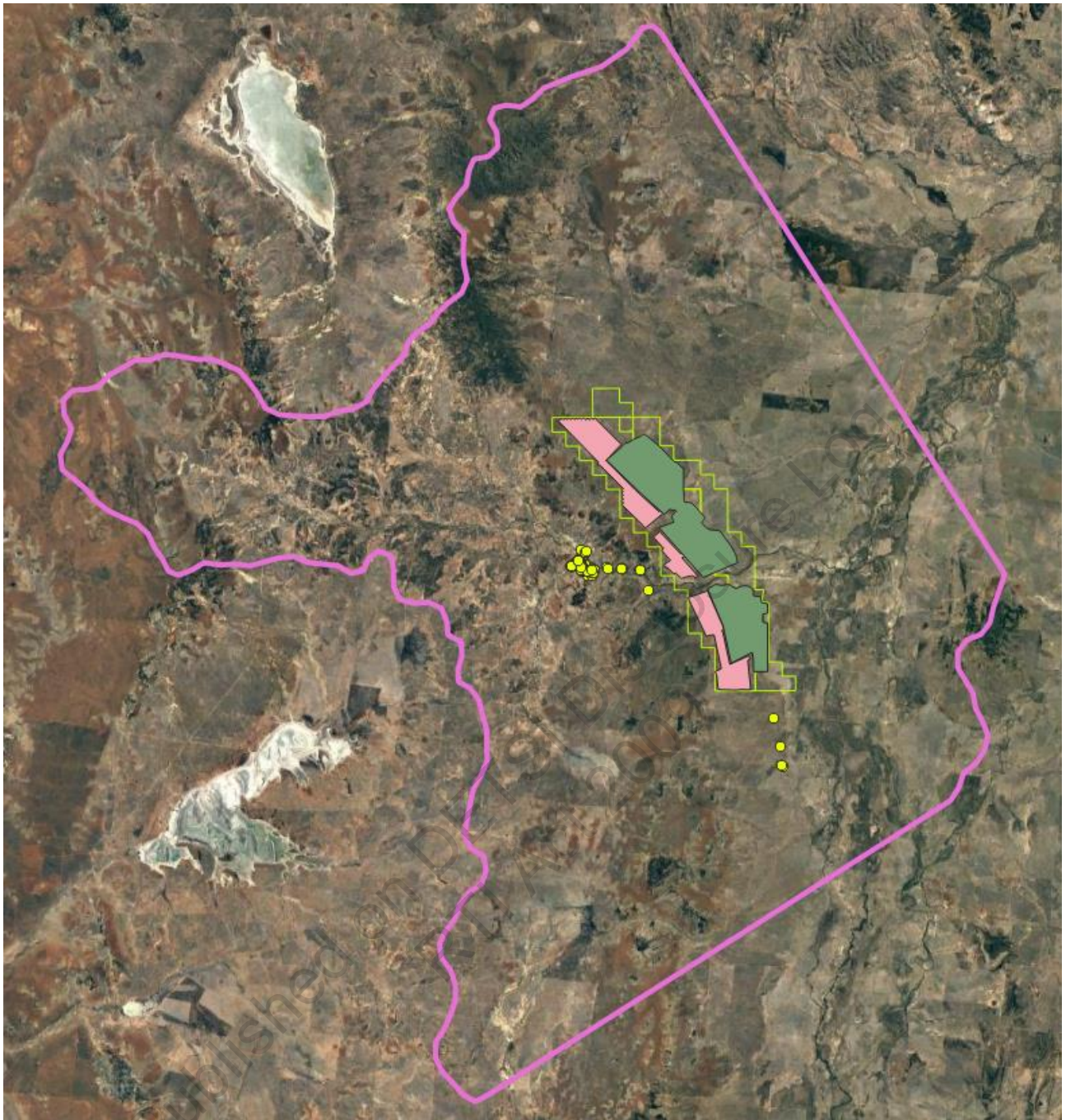


Figure 3.24 Modelled springs

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.

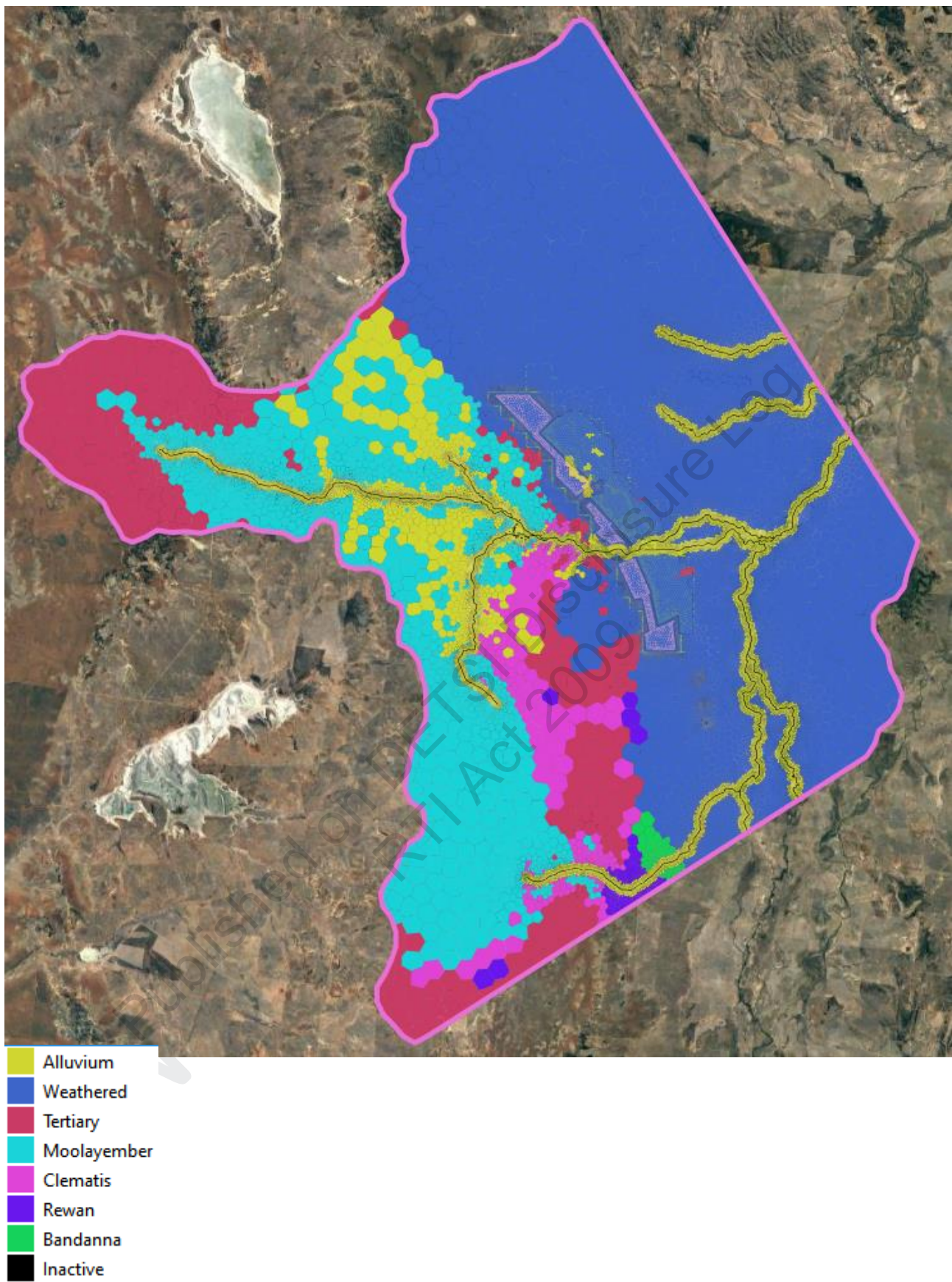


Figure 3.25 Modelled recharge zones based on outcropping HSU

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.

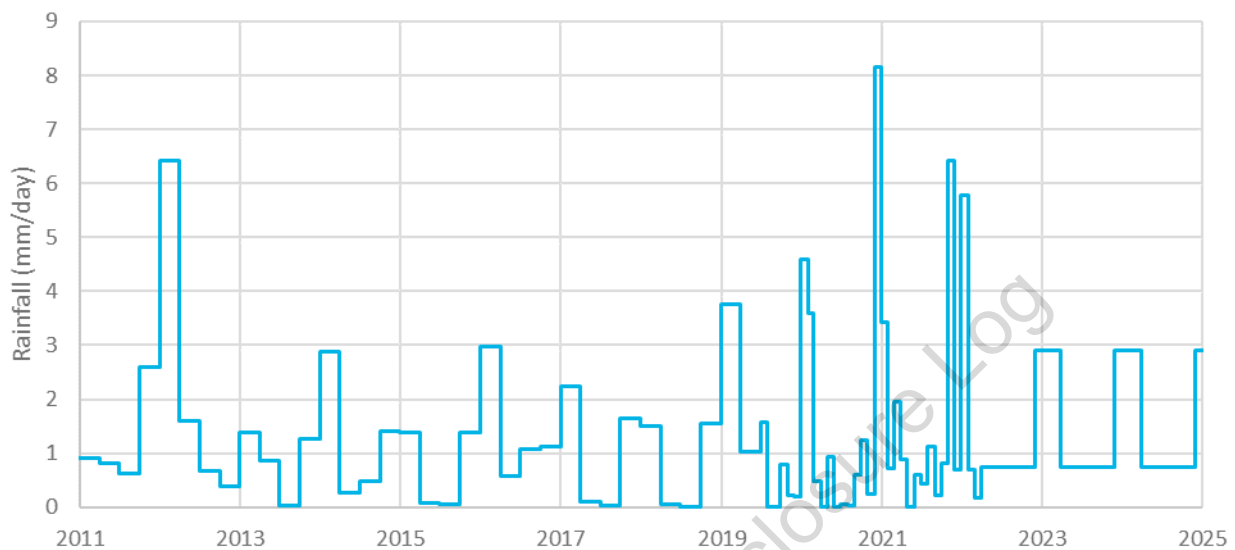


Figure 3.26 Time series of rainfall discretised by model stress periods

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.

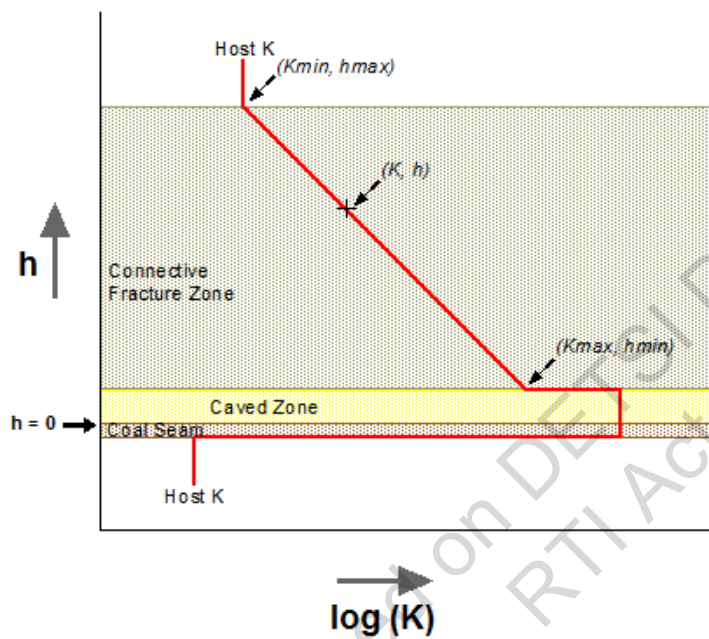


Figure 3.27 Ramp function parameters

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.

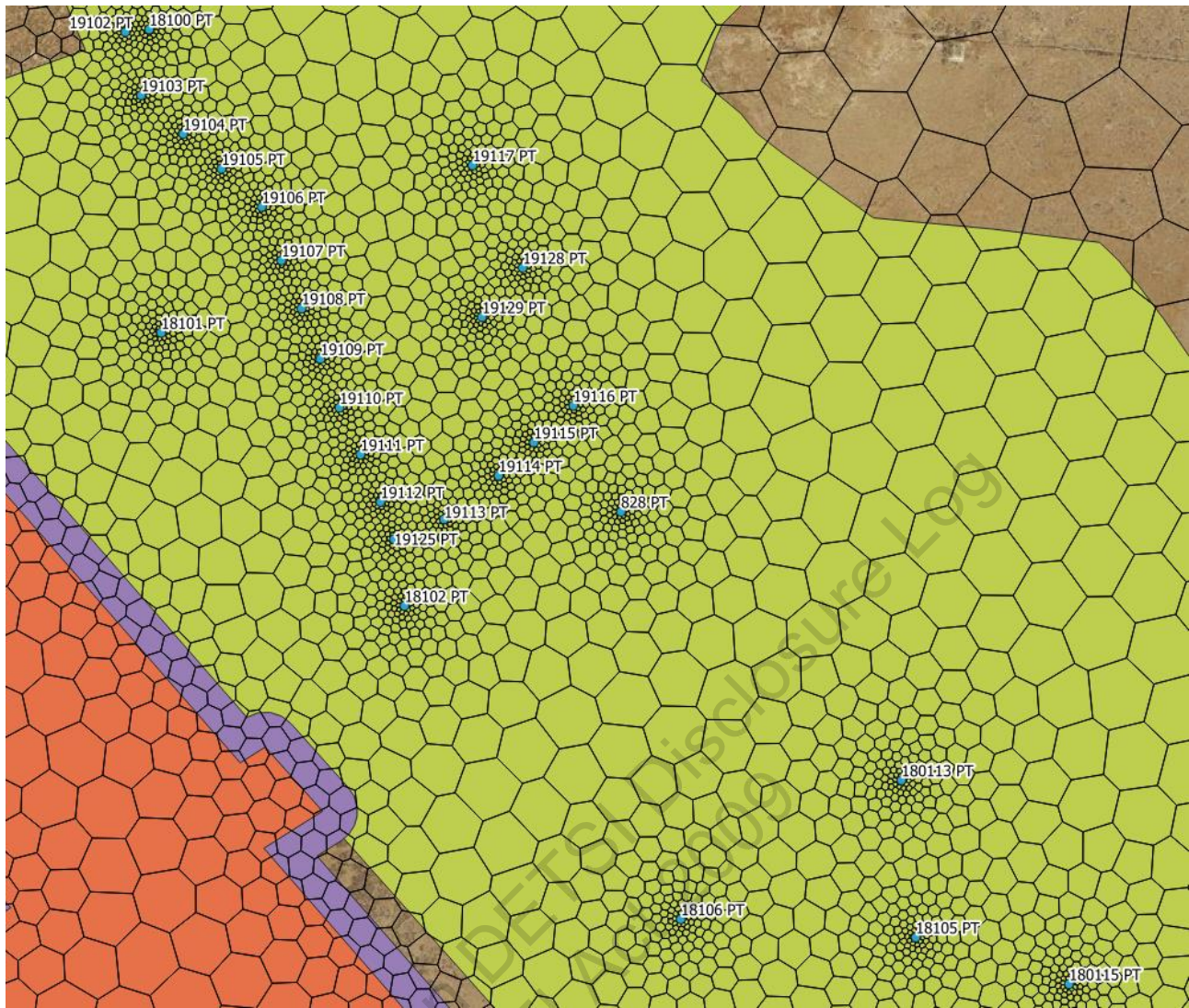


Figure 3.28 **Modelled production bores**

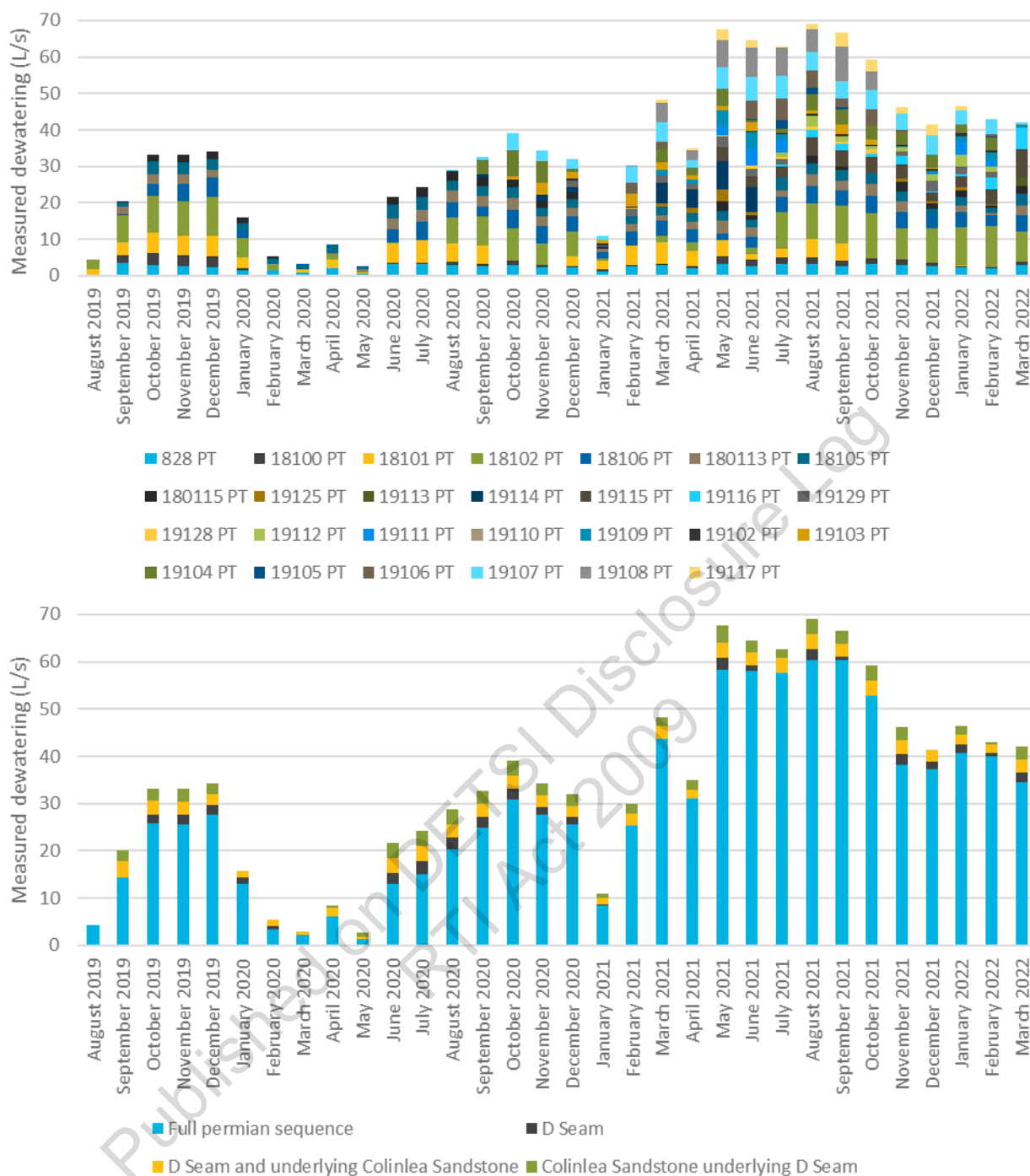


Figure 3.29 Measured production bore dewatering rates

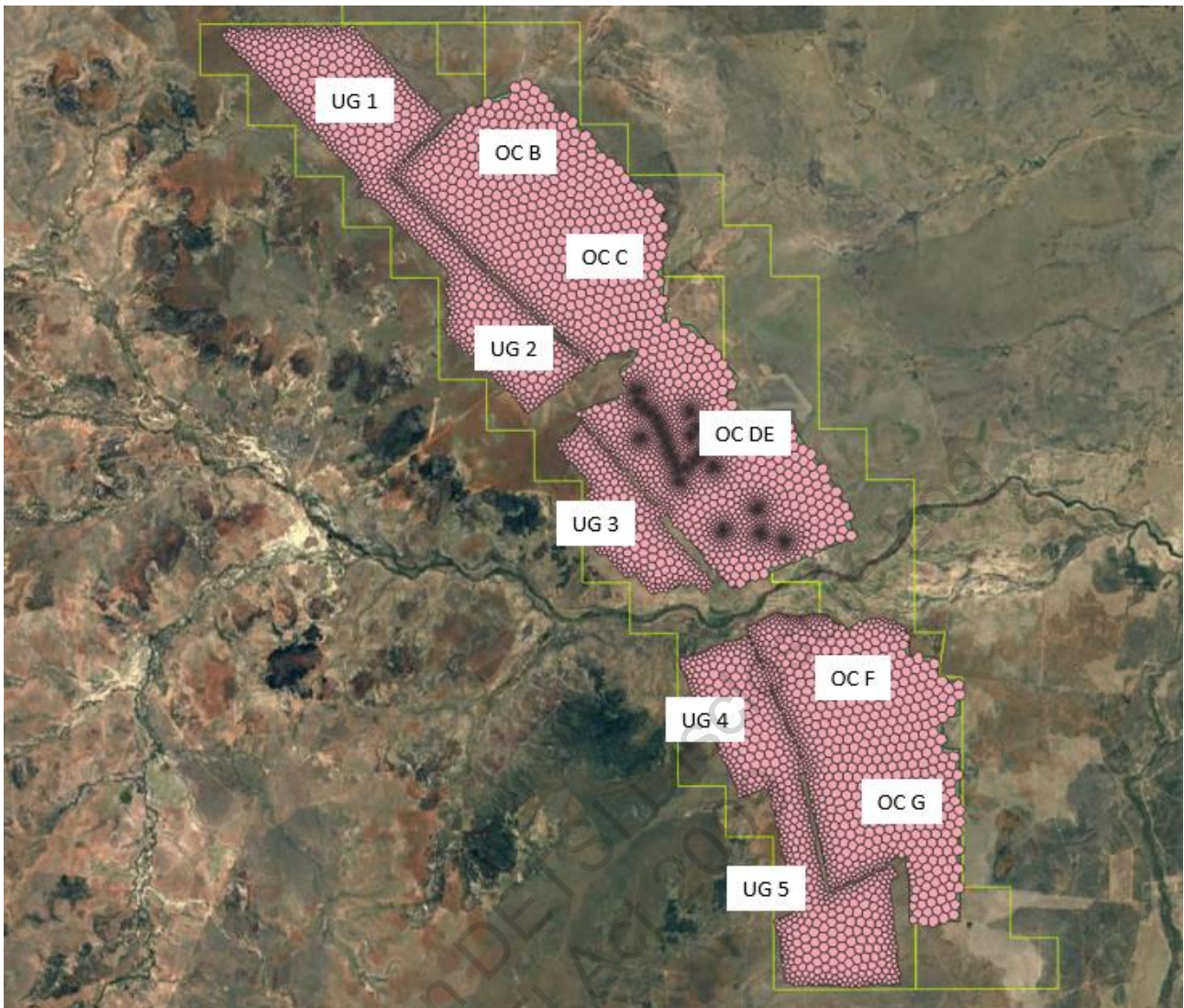


Figure 3.30 Modelled drain boundary conditions at the end of mining

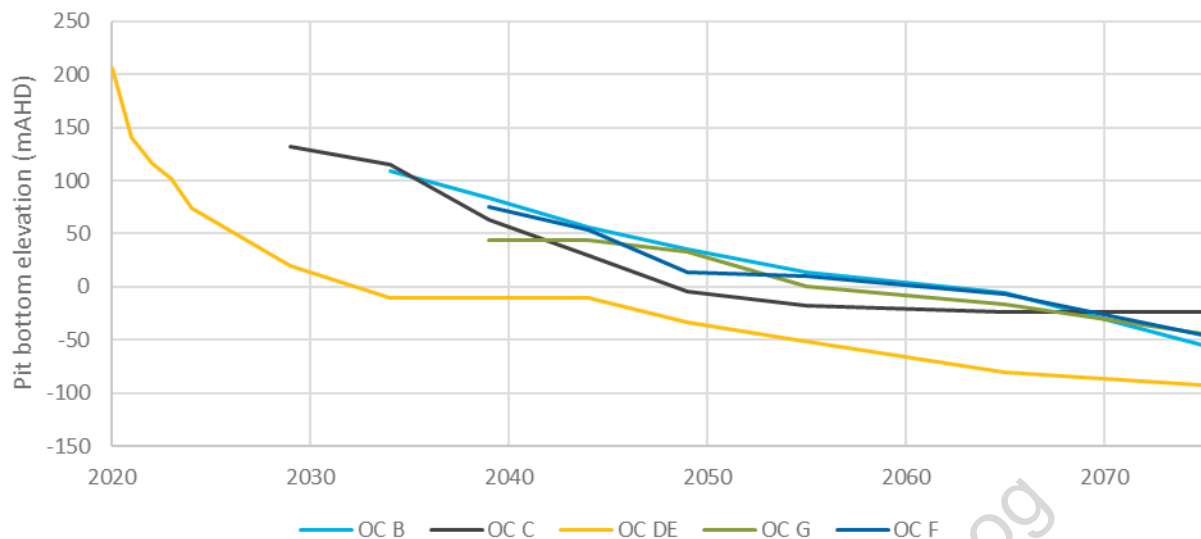


Figure 3.31 Open cut pit bottom elevations

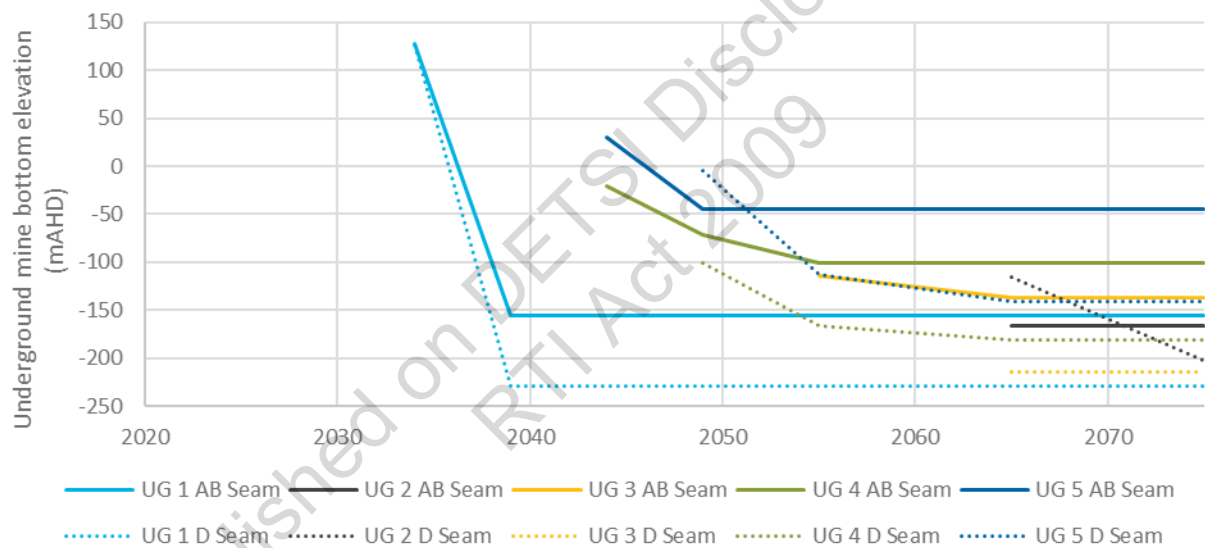


Figure 3.32 Underground mine bottom elevations

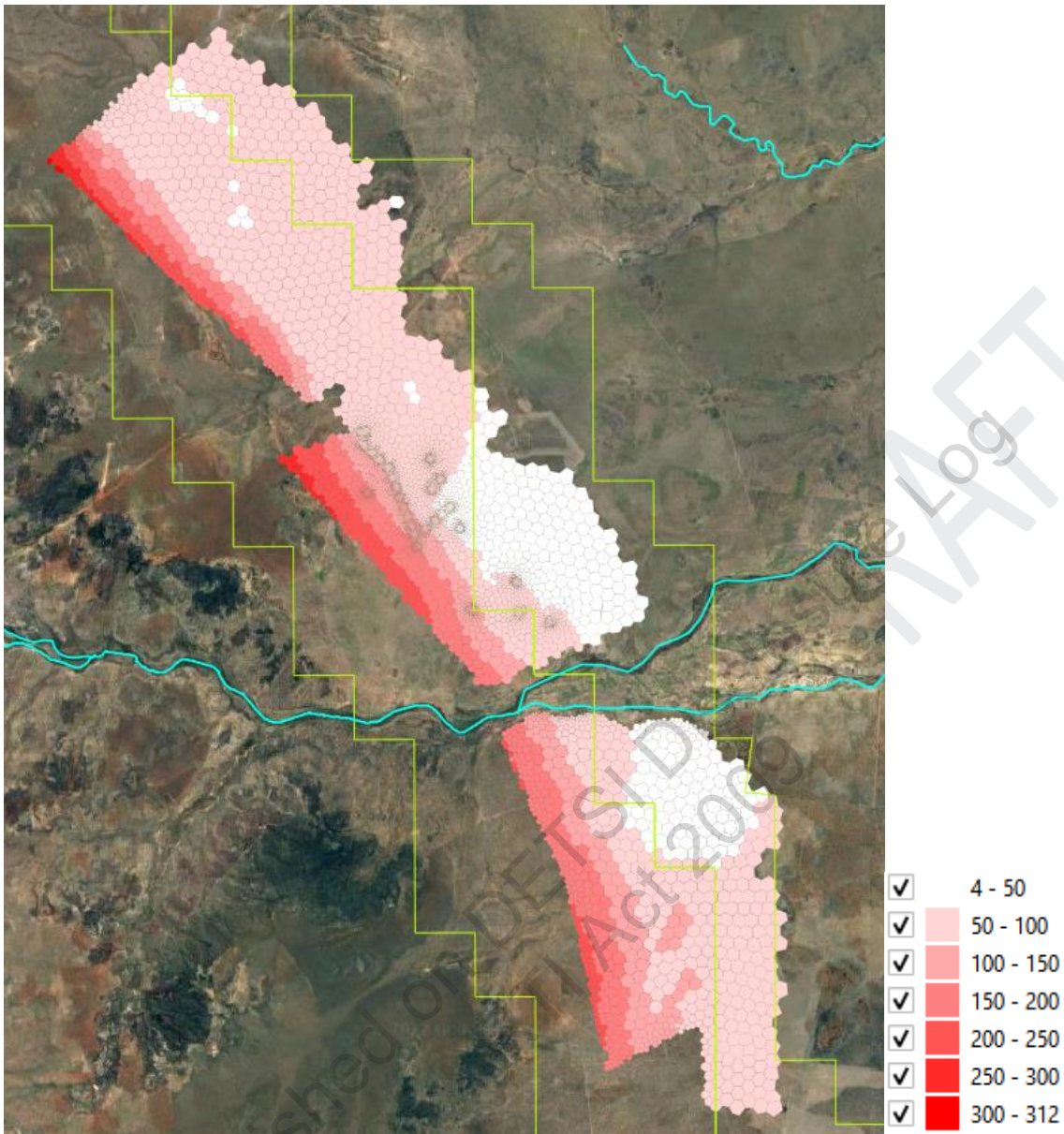


Figure 3.33 Modelled post-mining pit void depth

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).

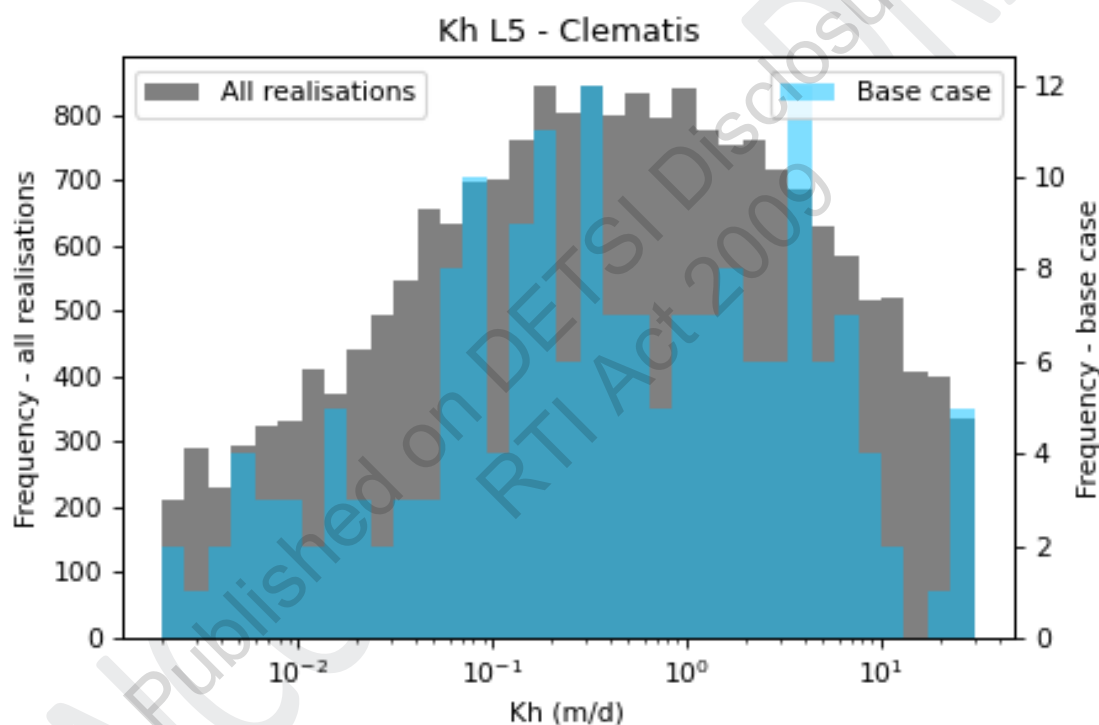


Figure 4.2 Horizontal hydraulic conductivity pilot point parameter frequency distribution for Clematis Sandstone across base realisation and uncertainty ensemble

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.

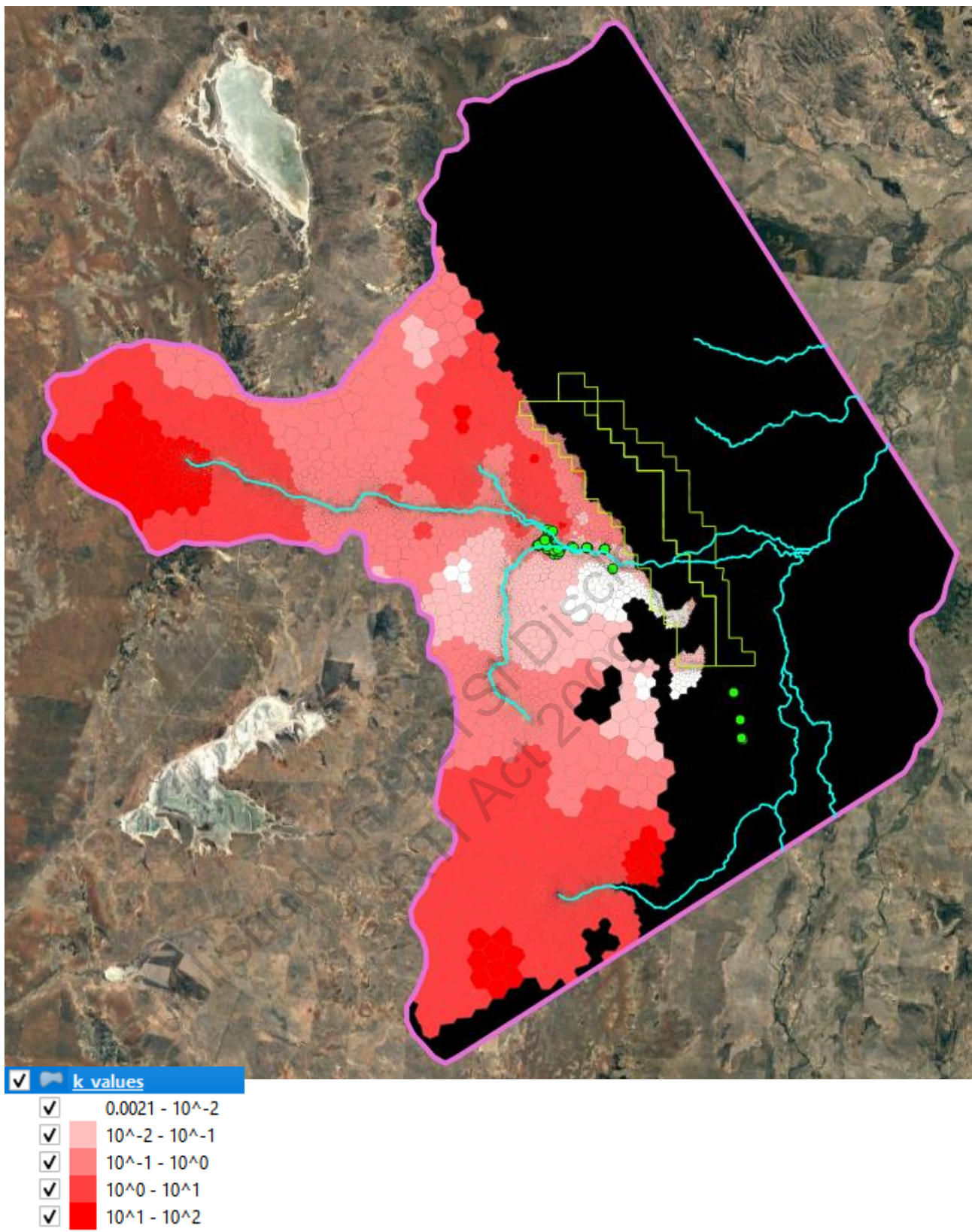


Figure 4.3 Base realisation modelled horizontal hydraulic conductivity in Clematis Sandstone

b Layers 7 and 8: Rewan Formation

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.

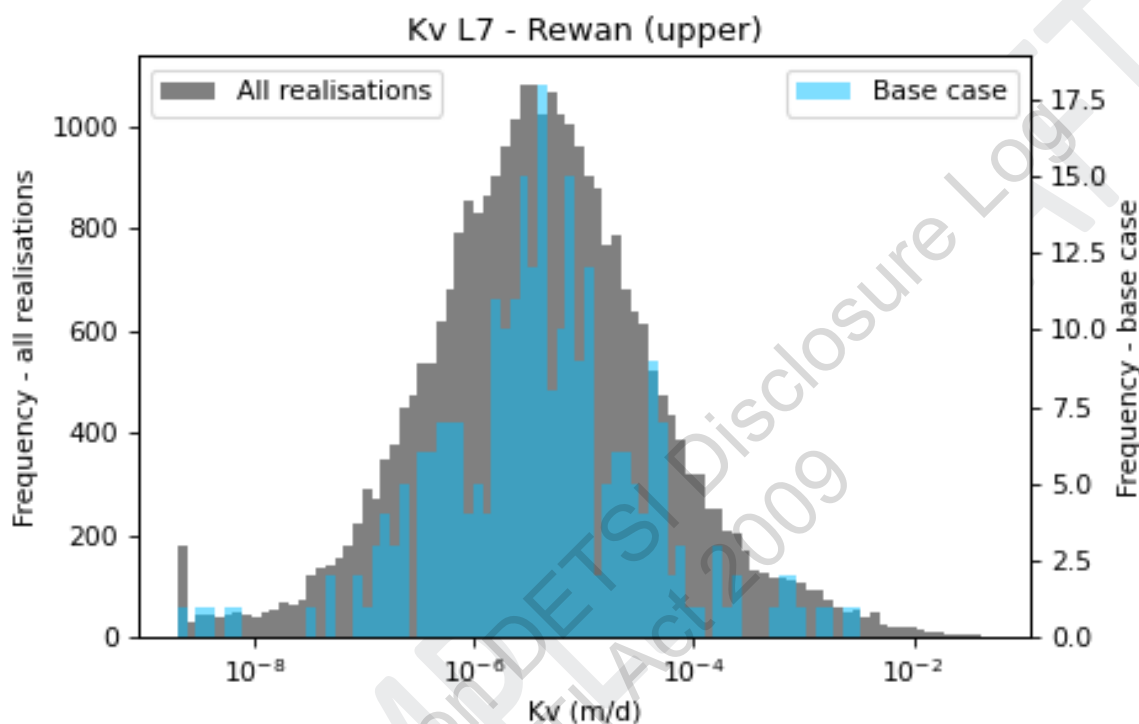


Figure 4.4 Vertical hydraulic conductivity pilot point parameter frequency distribution for upper Rewan Formation across base realisation and uncertainty ensemble

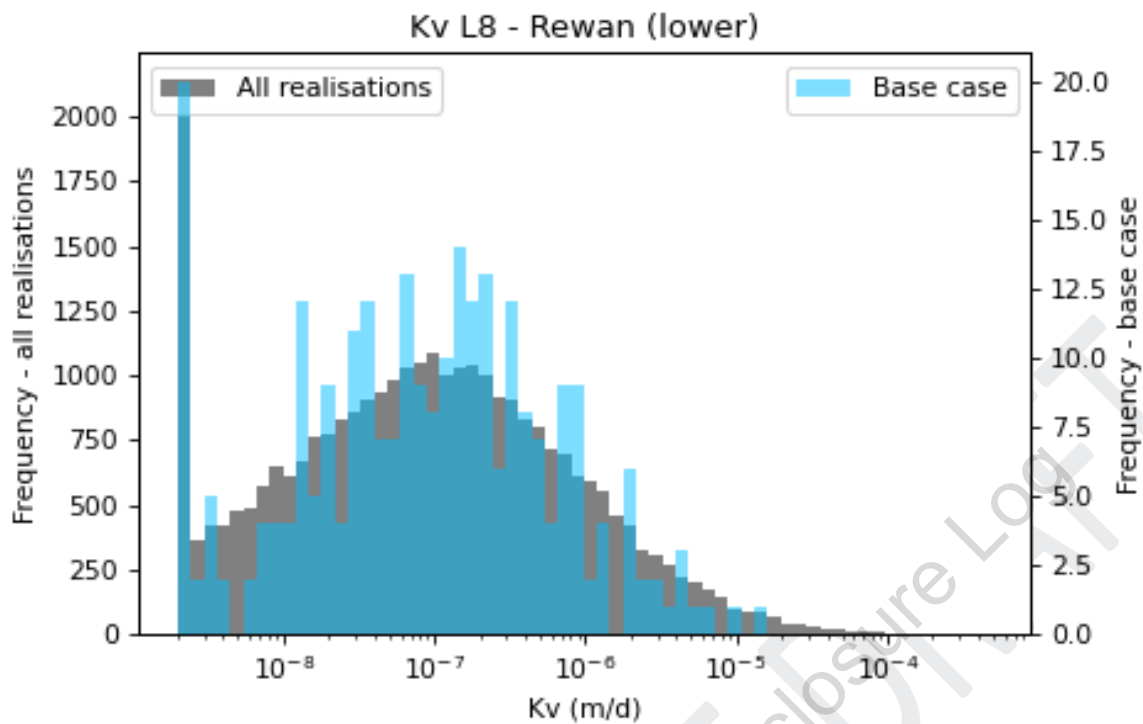


Figure 4.5 Vertical hydraulic conductivity pilot point parameter frequency distribution for lower Rewan Formation across base realisation and uncertainty ensemble

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.

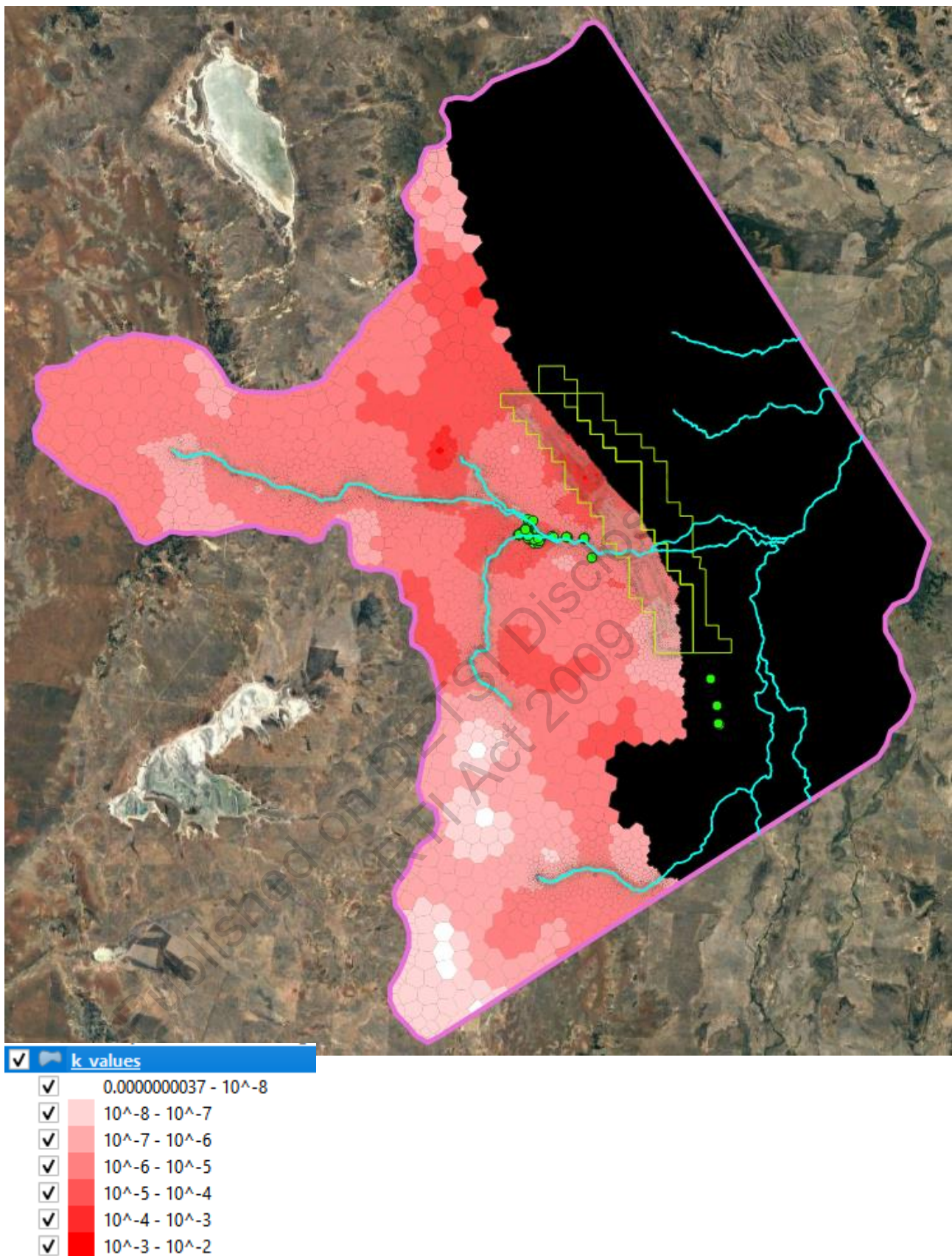


Figure 4.6 Base realisation modelled vertical hydraulic conductivity in upper Rewan Formation

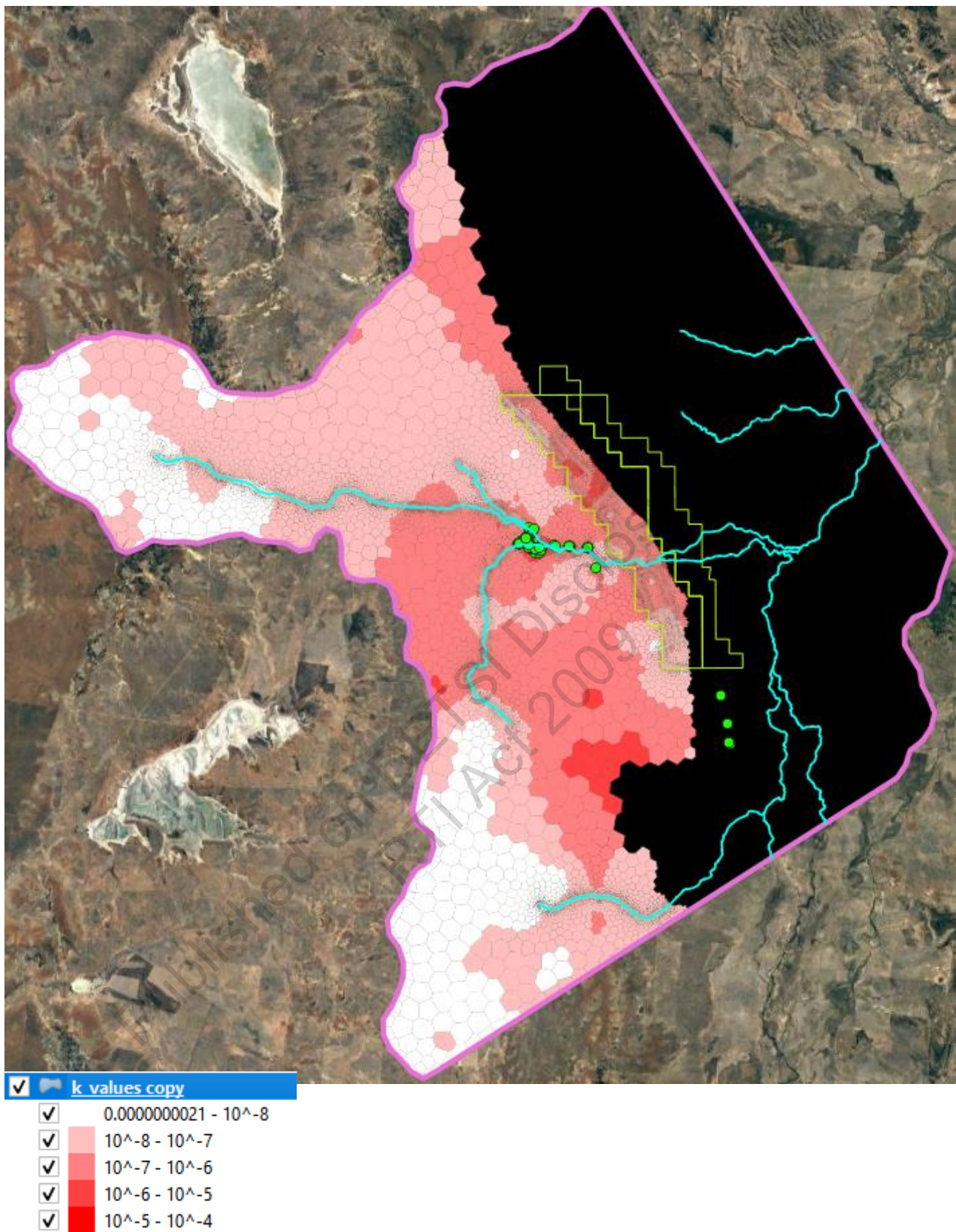


Figure 4.7 Base realisation modelled vertical hydraulic conductivity in lower Rewan Formation

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.

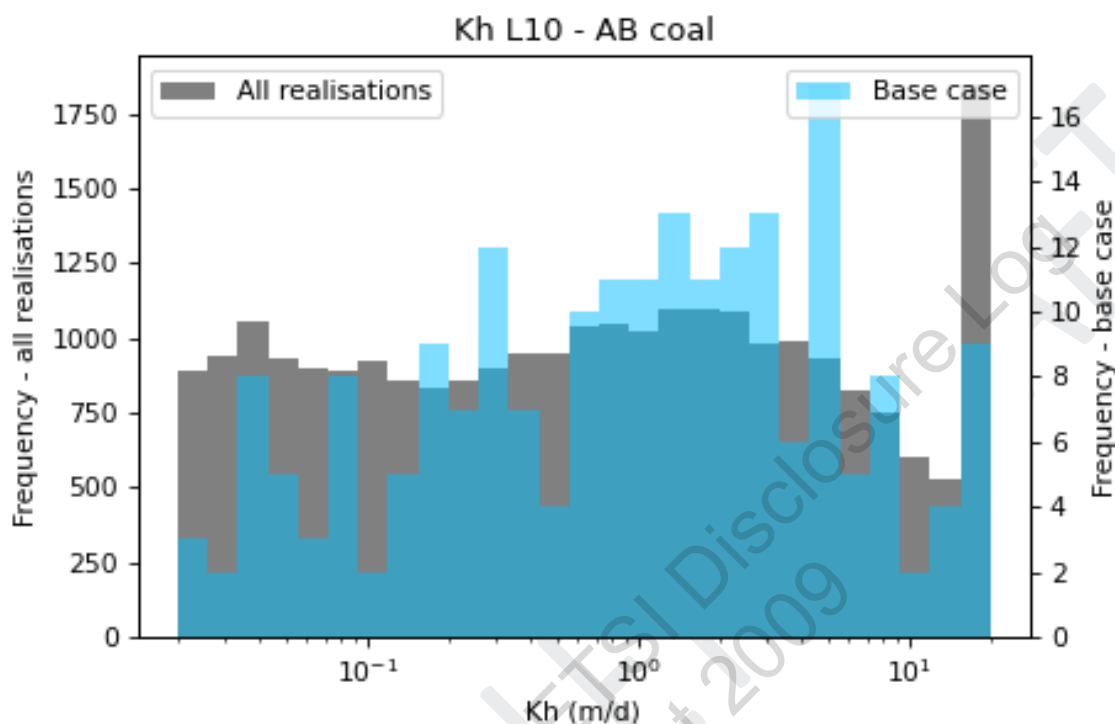


Figure 4.8 Horizontal hydraulic conductivity pilot point parameter frequency distribution for AB Coal across base realisation and uncertainty ensemble

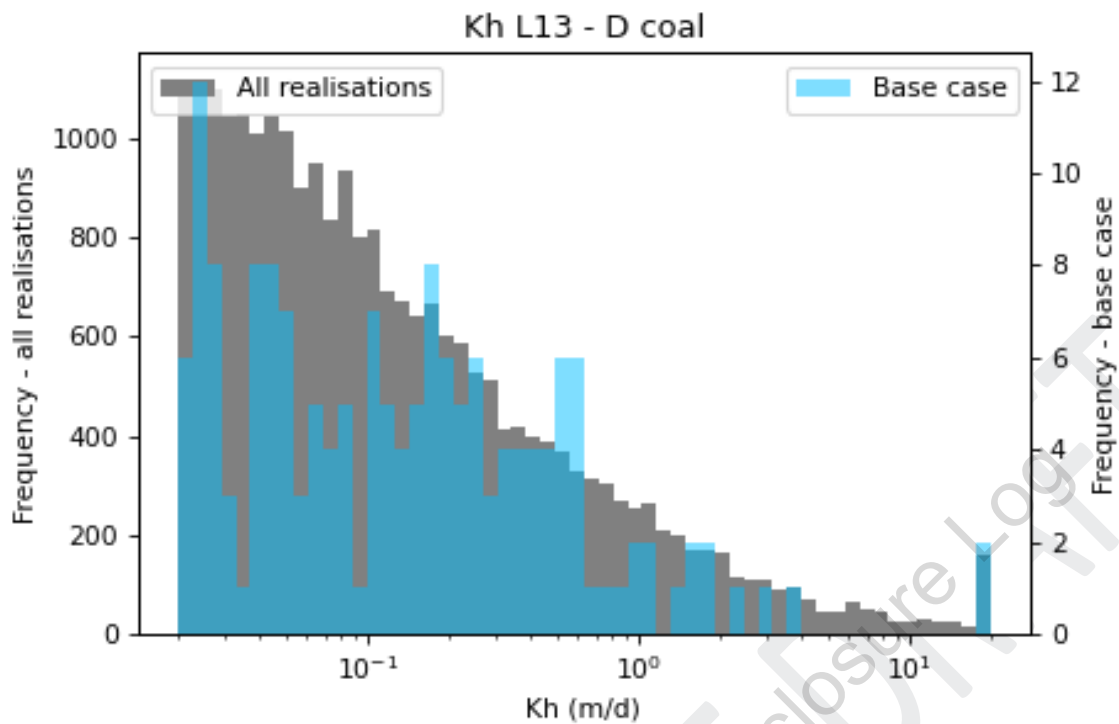


Figure 4.9 Horizontal hydraulic conductivity pilot point parameter frequency distribution for D Coal across base realisation and uncertainty ensemble

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.

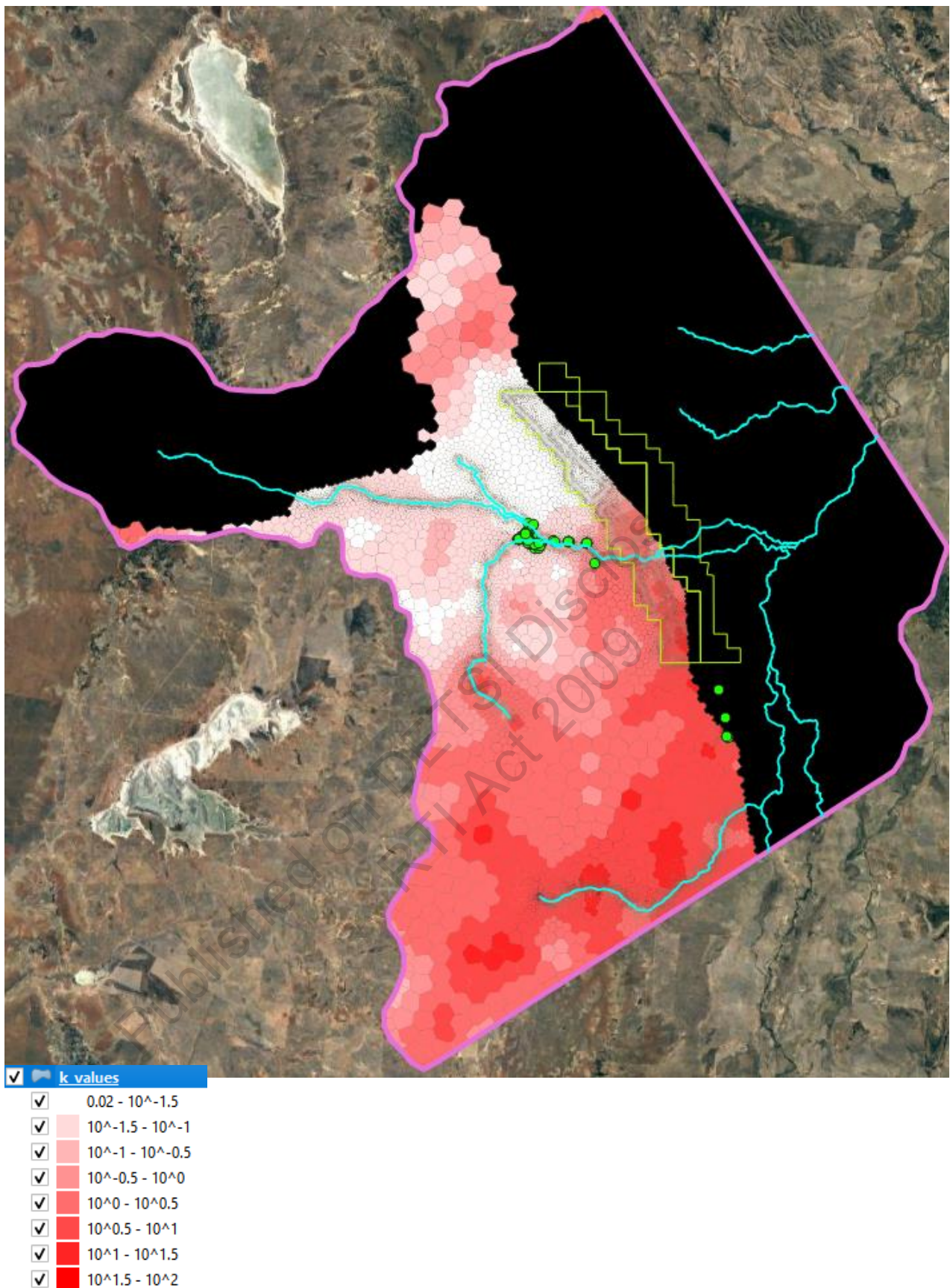


Figure 4.10 Base realisation modelled horizontal hydraulic conductivity in AB Coal seam

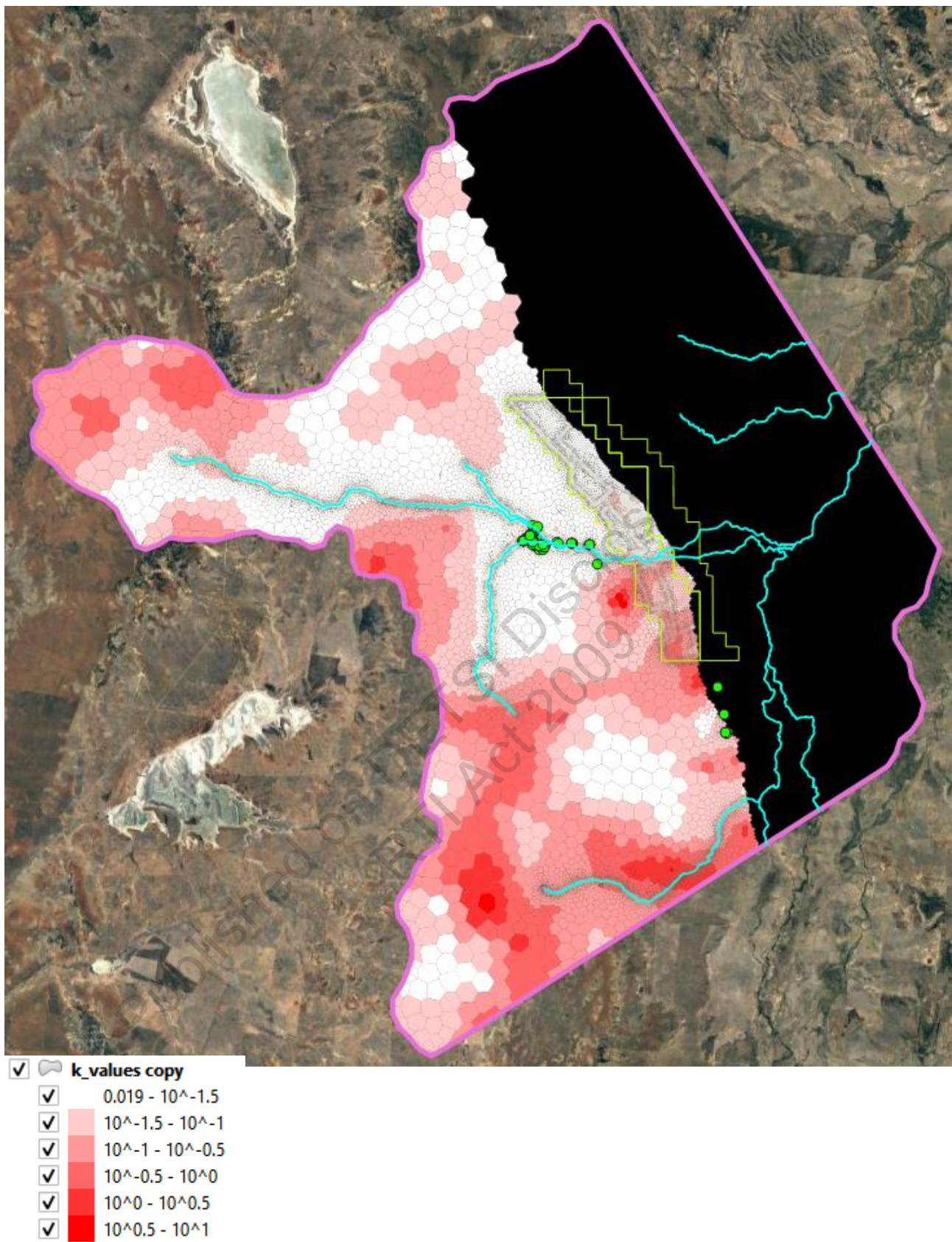


Figure 4.11 Base realisation modelled horizontal hydraulic conductivity in D Coal seam

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

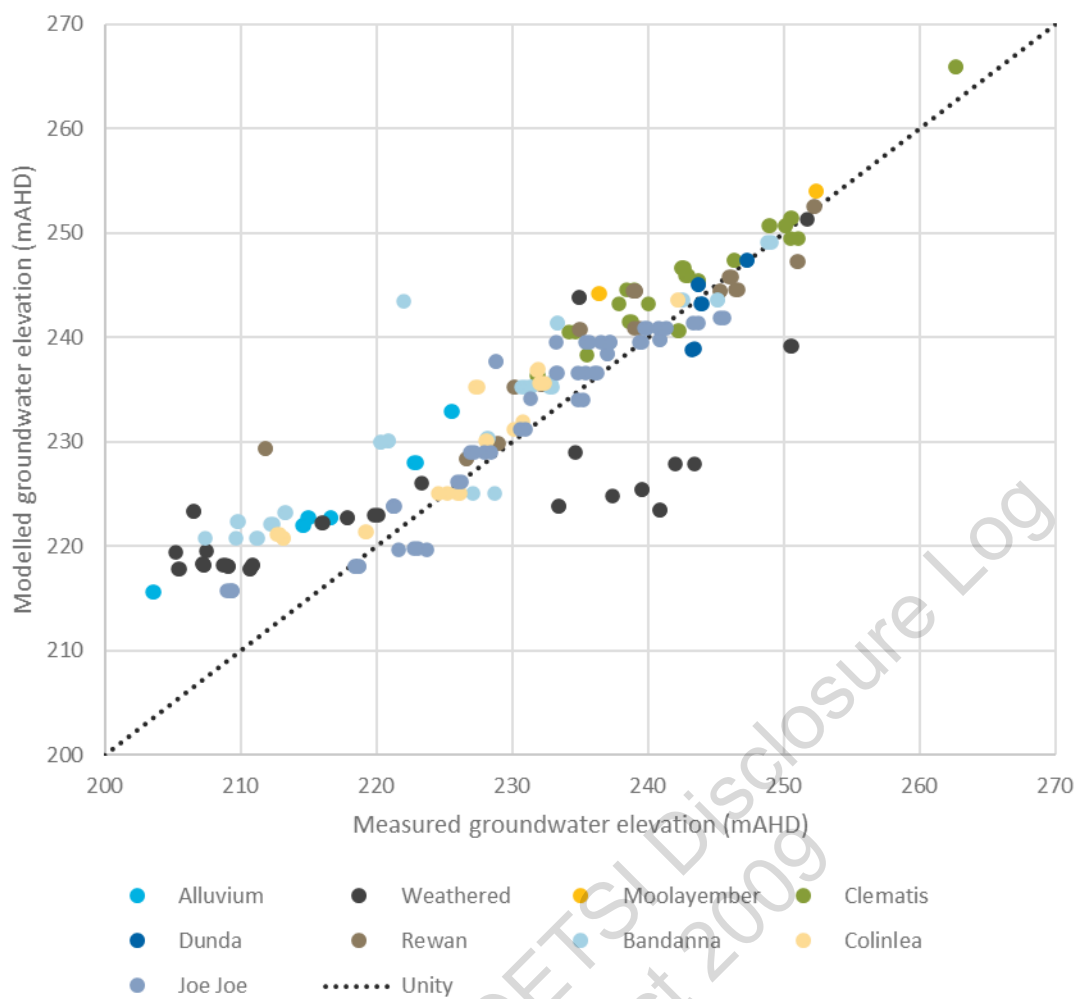


Figure 4.12 Modelled vs measured scatter plot for initial hydraulic head measurements for base realisation grouped by HSU

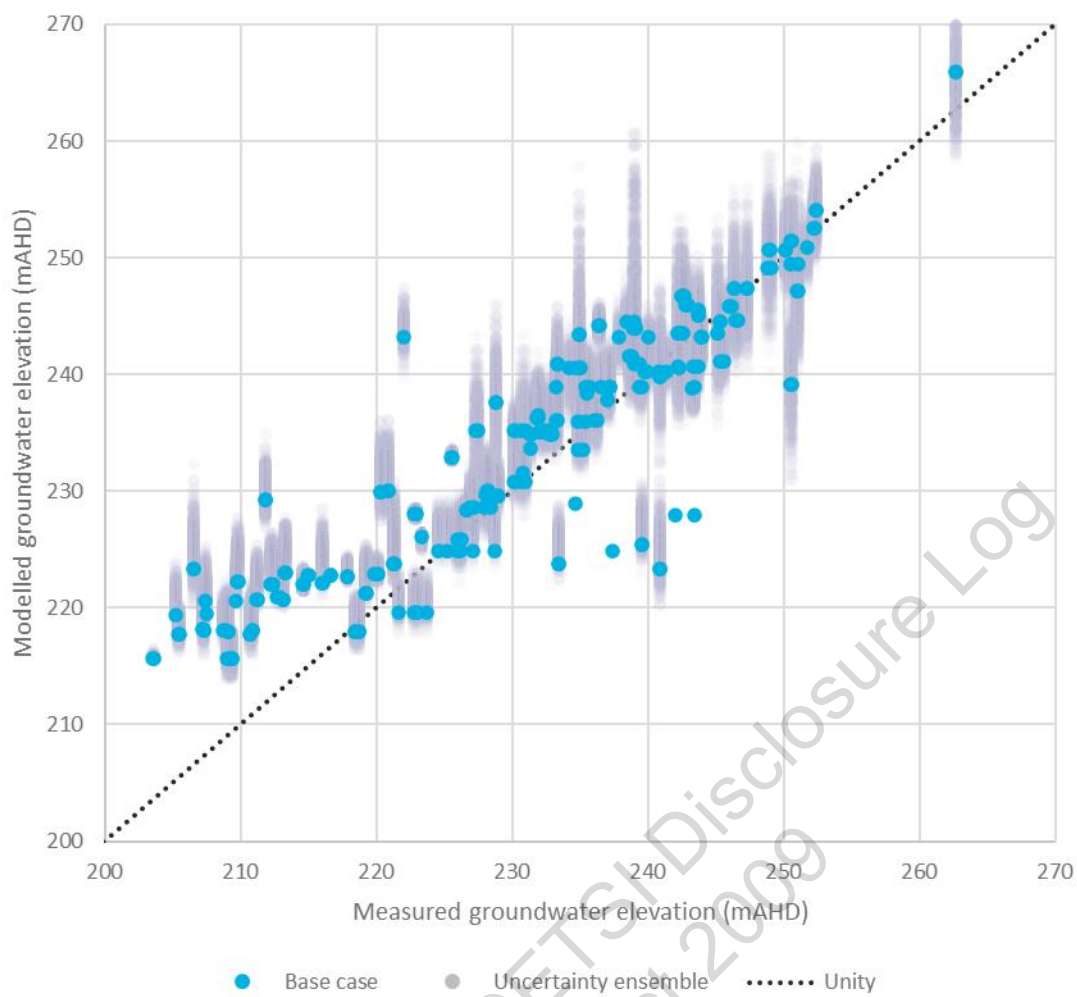


Figure 4.13 Modelled vs measured scatter plot for initial hydraulic head measurements for base realisation and uncertainty suite

ii Modelled groundwater contours

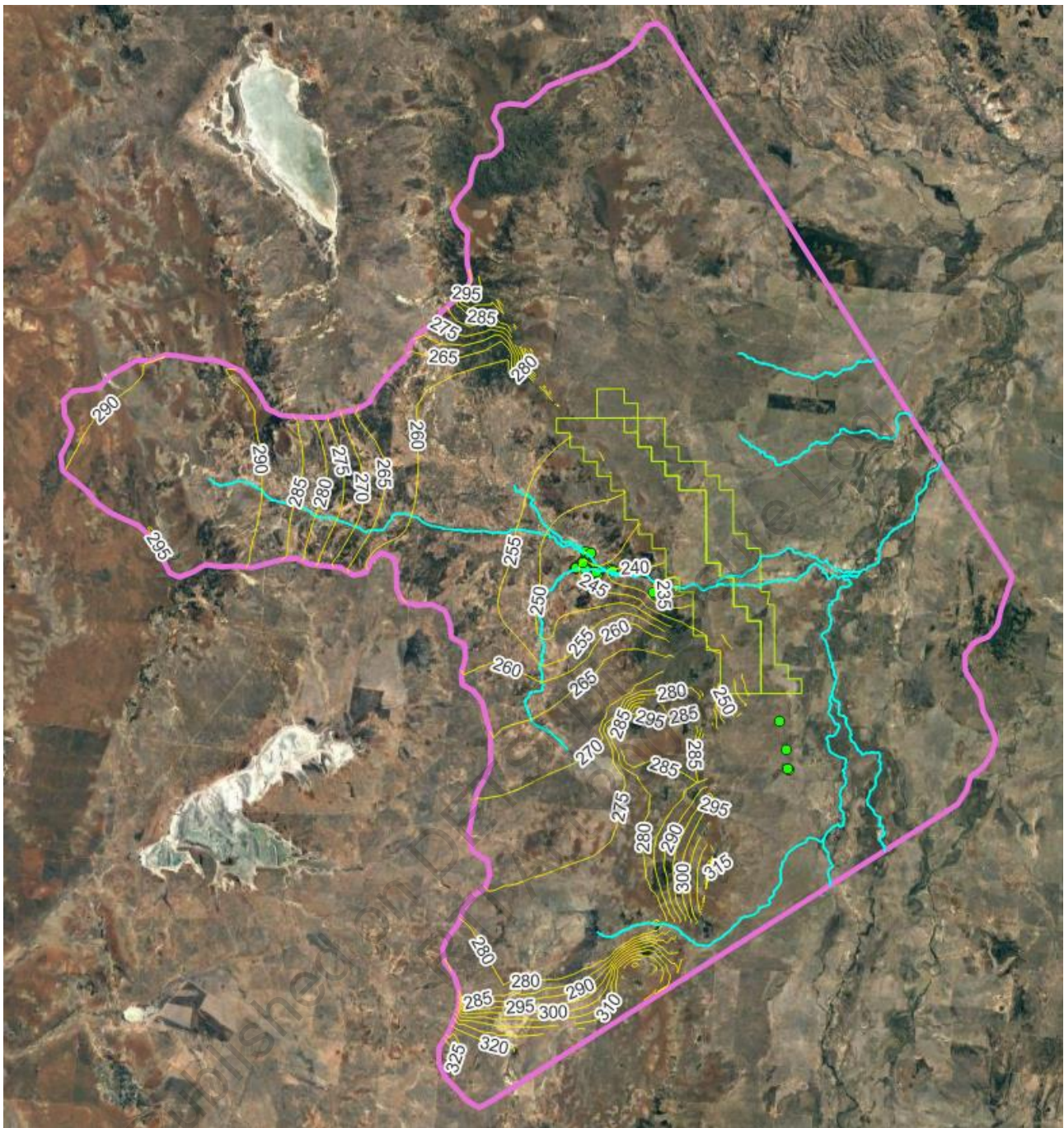


Figure 4.14 Modelled steady-state groundwater level contours in Clematis Sandstone

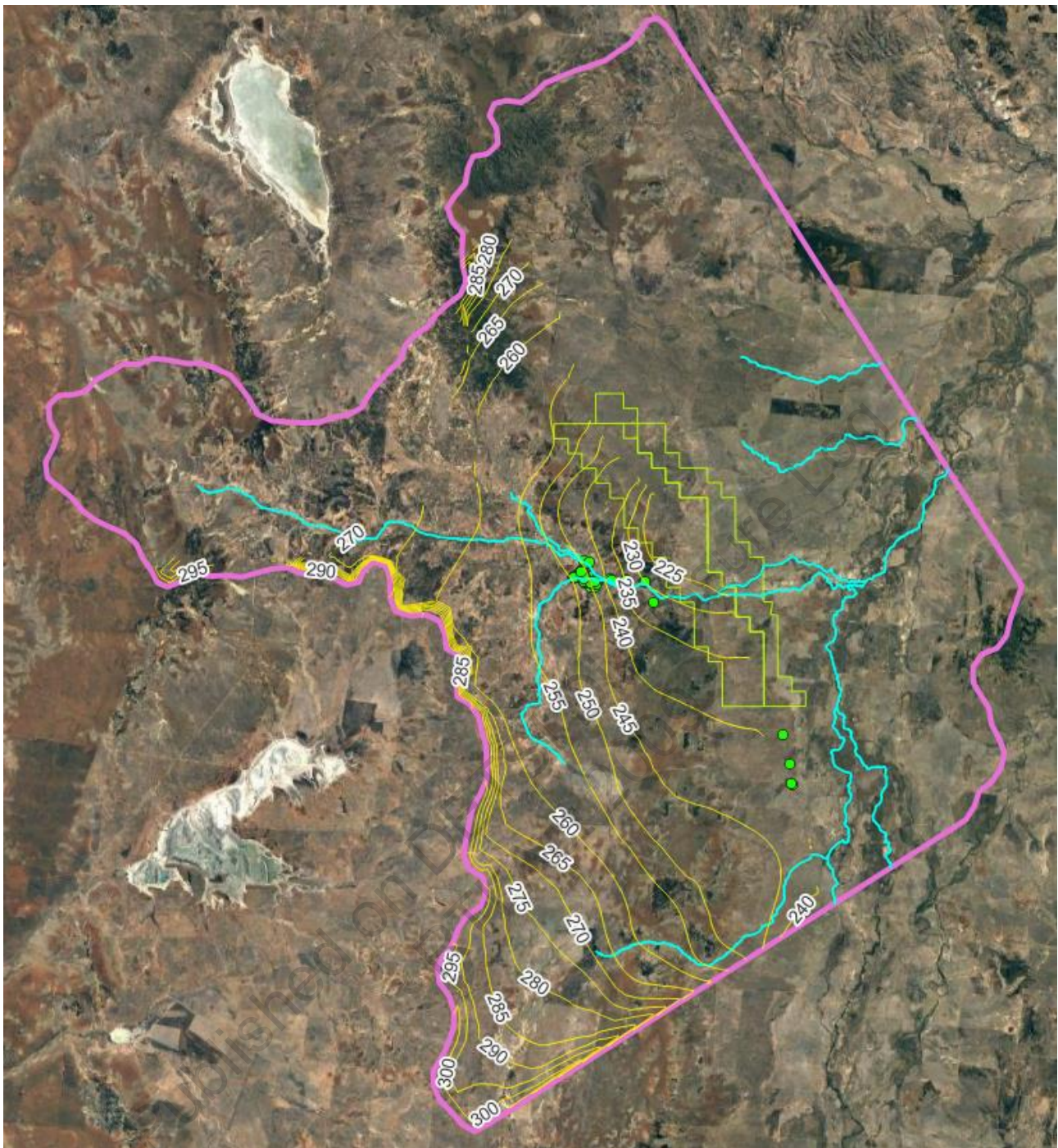


Figure 4.15 Modelled steady-state groundwater level contours in AB Coal

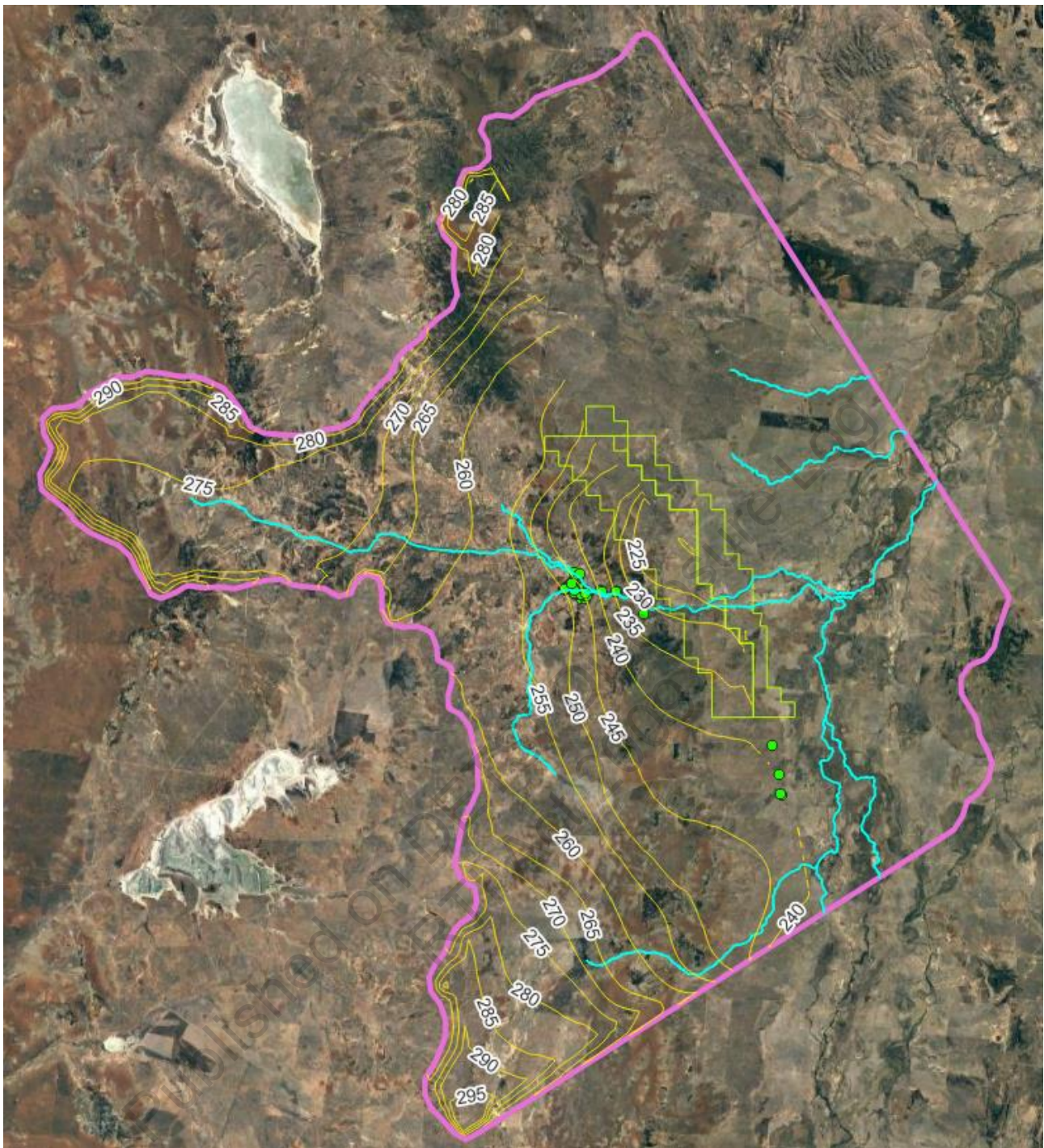


Figure 4.16 Modelled steady-state groundwater level contours in D Coal

iii Modelled hydrographs

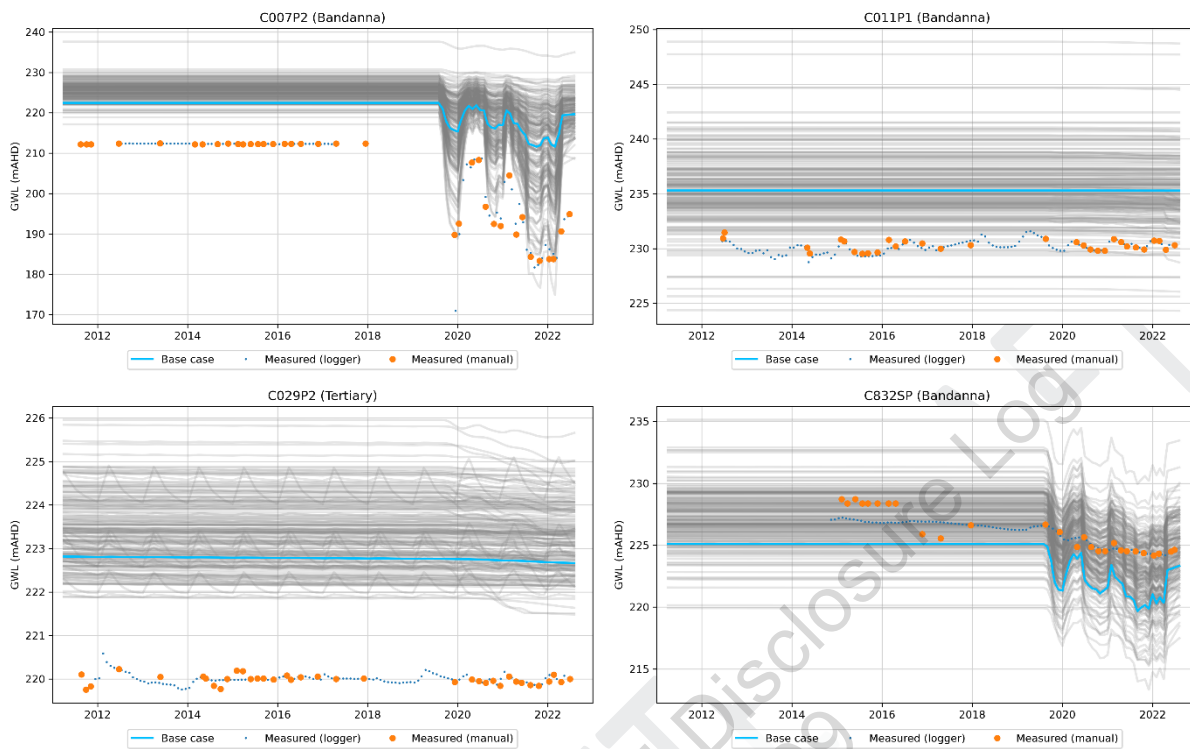


Figure 4.17 Selected history-matching hydrographs

4.2.3 Drawdown

i Scatter plot

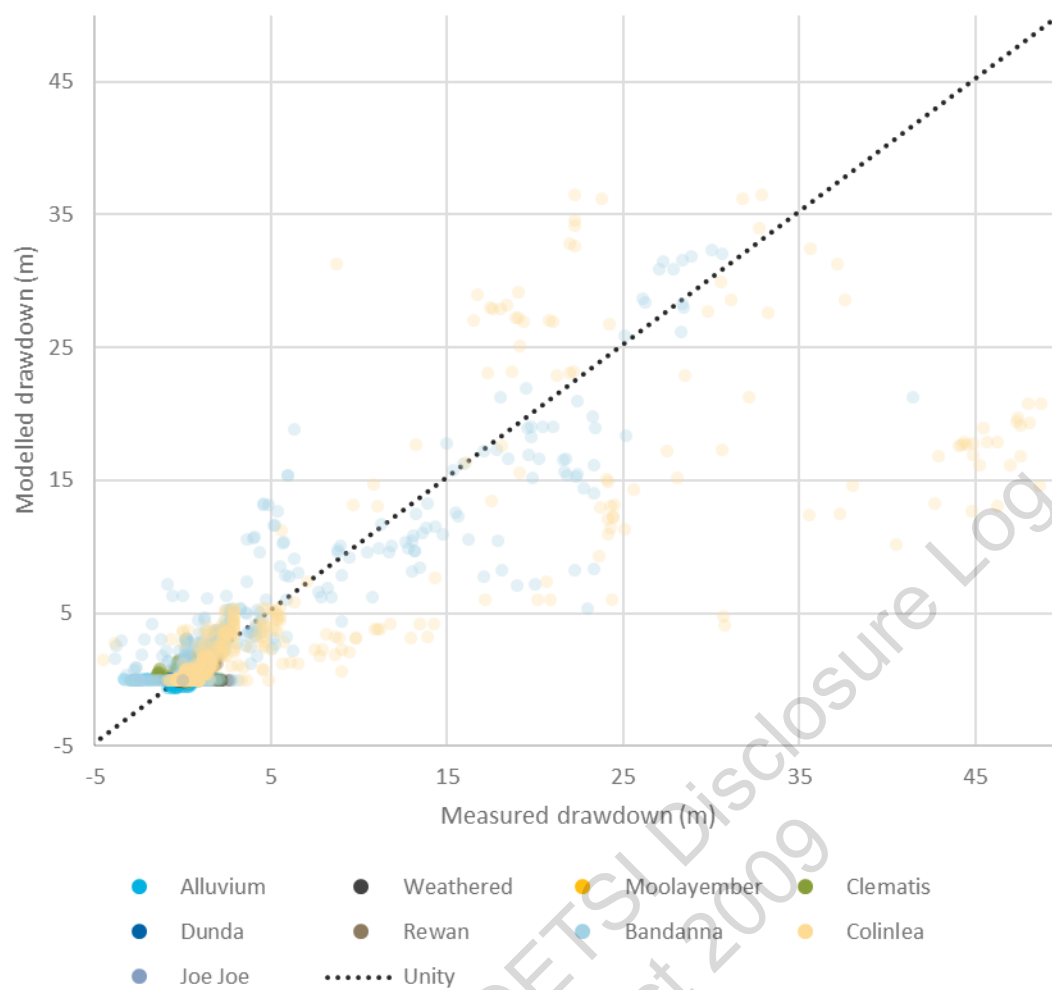


Figure 4.18 Modelled vs measured scatter plot of head-change for base realisation grouped by HSU

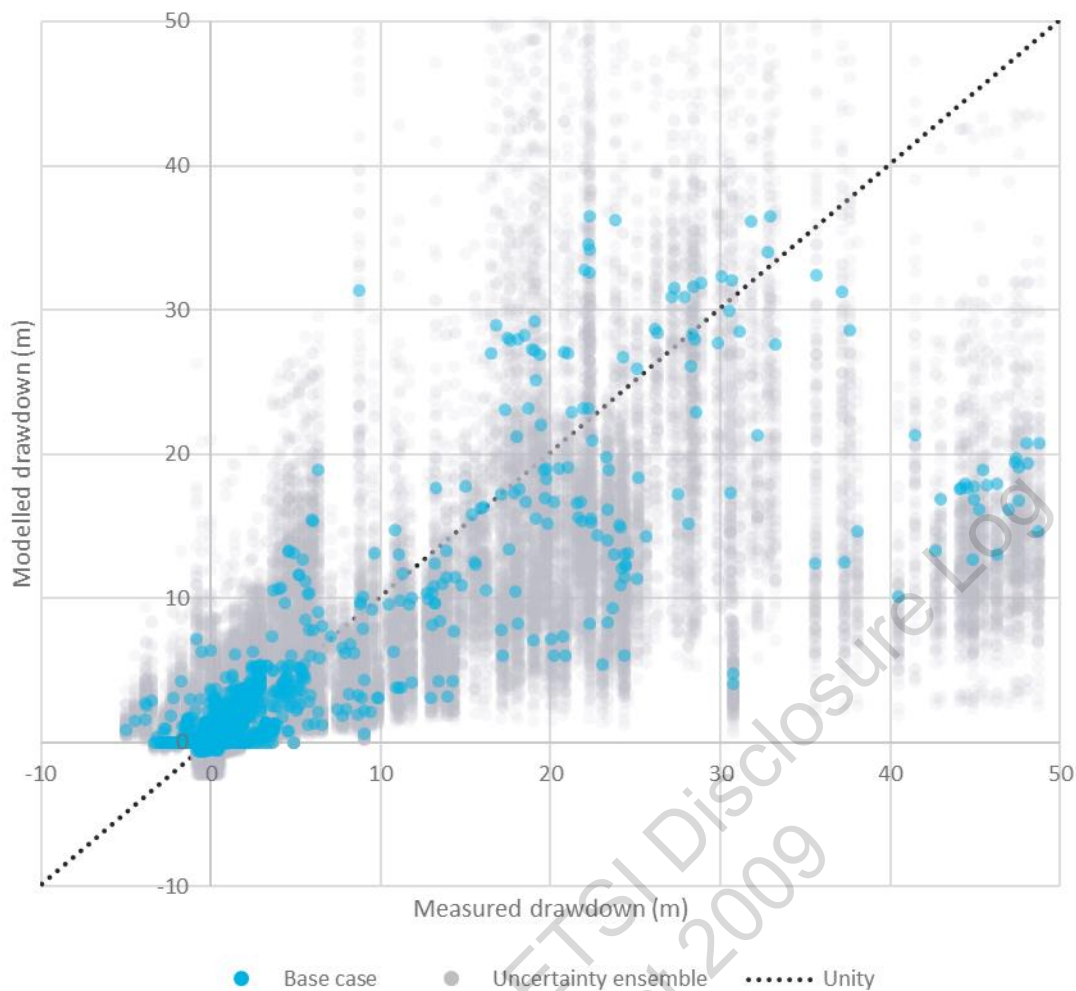


Figure 4.19 Modelled vs measured scatter plot of head change for base realisation and uncertainty suite

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/ivers.



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%

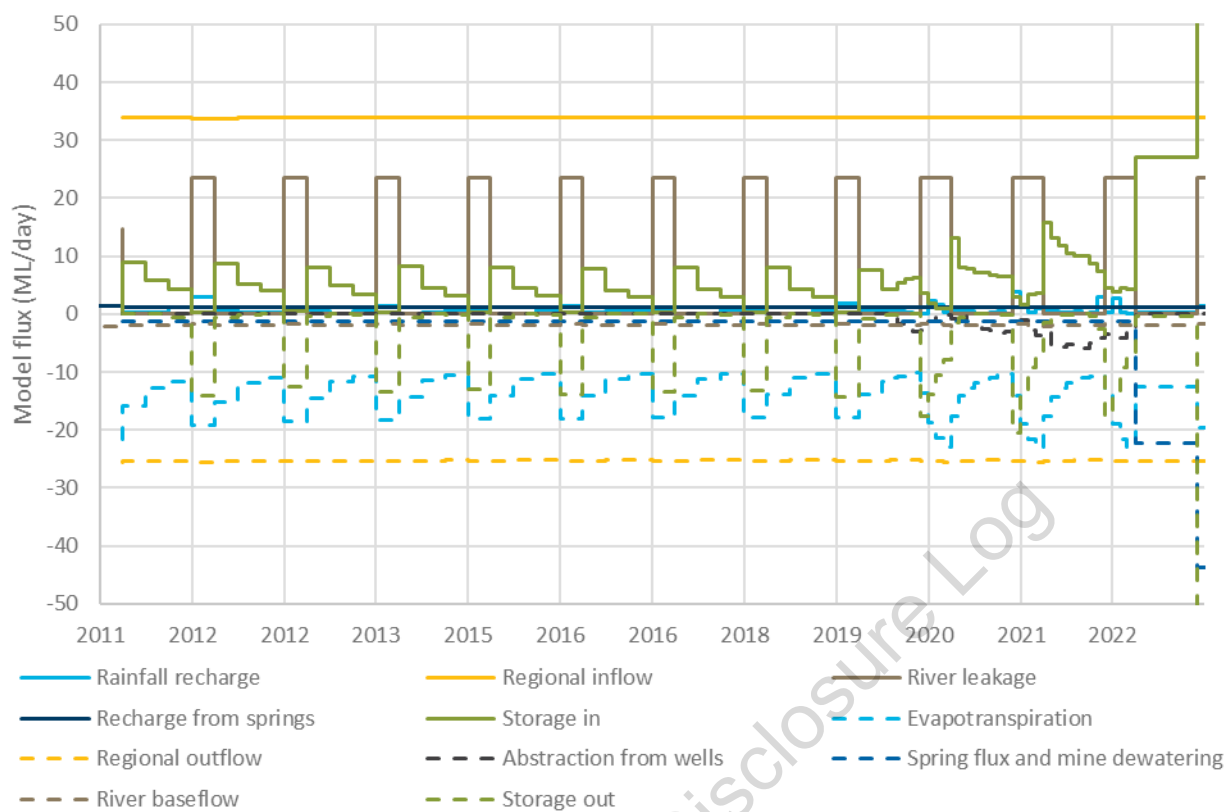


Figure 4.22 Model water balance for the history-matching period

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	41,466	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.

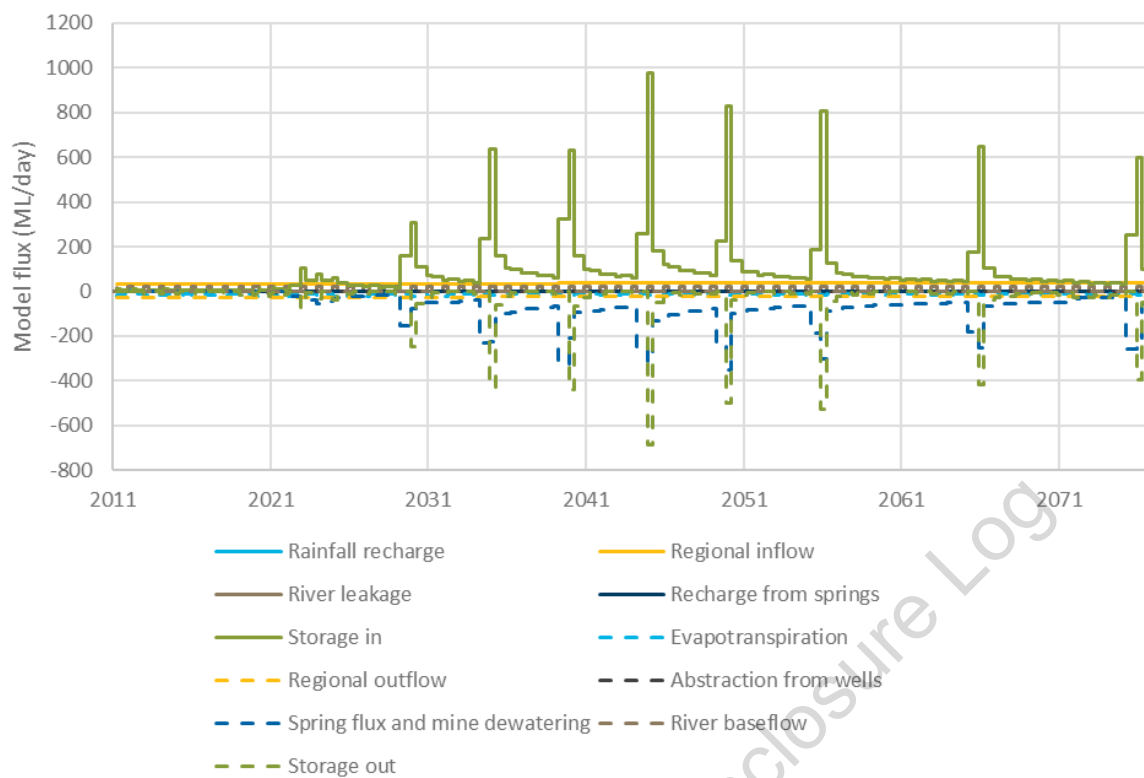


Figure 5.1 Scenario 1 modelled water balance

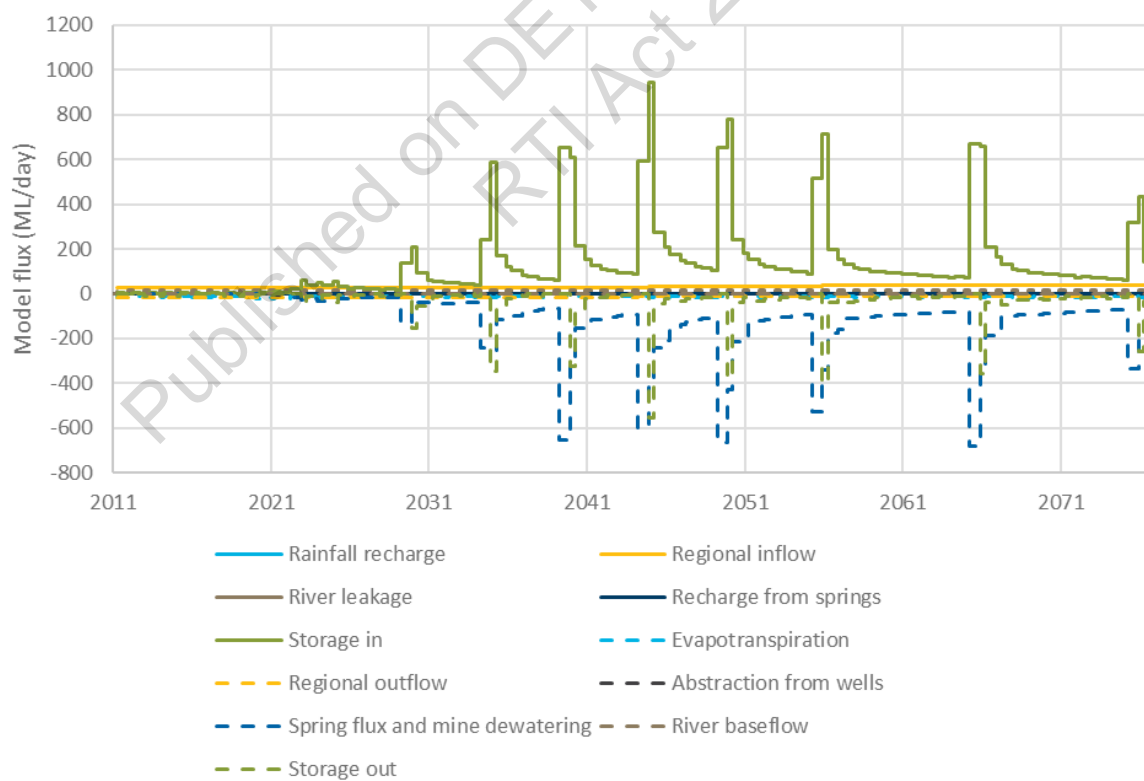


Figure 5.2 Scenario 2 modelled water balance

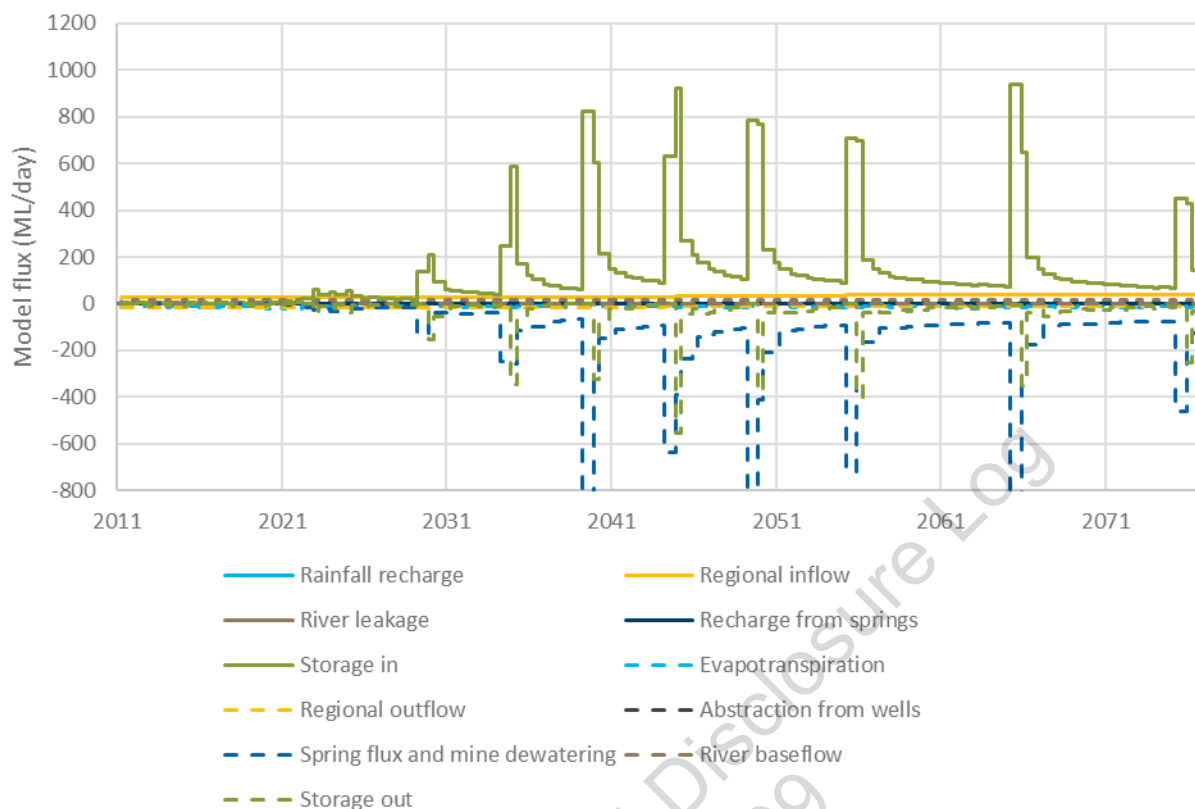


Figure 5.3 Scenario 3 modelled water balance

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).

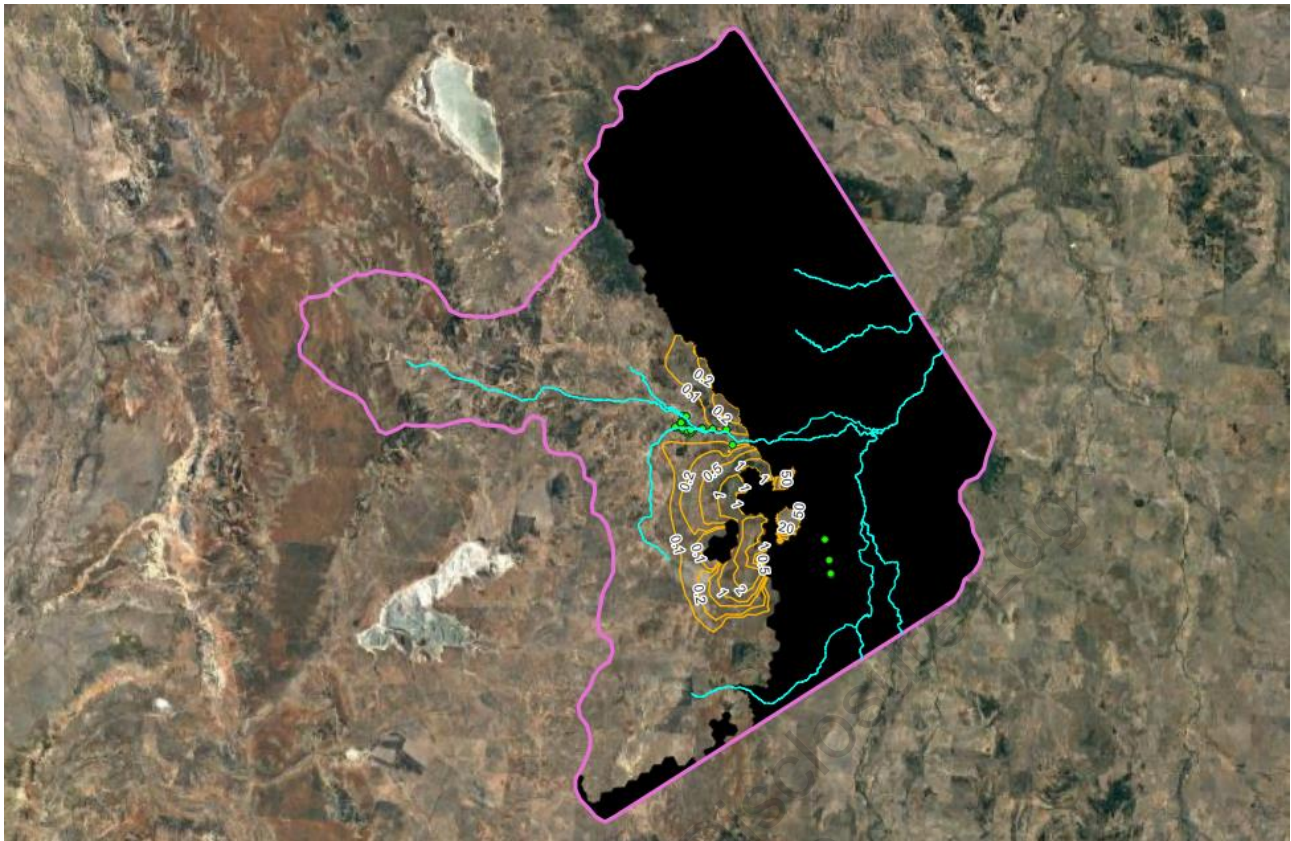


Figure 5.4 Scenario 1 modelled maximum drawdown in Clematis Sandstone

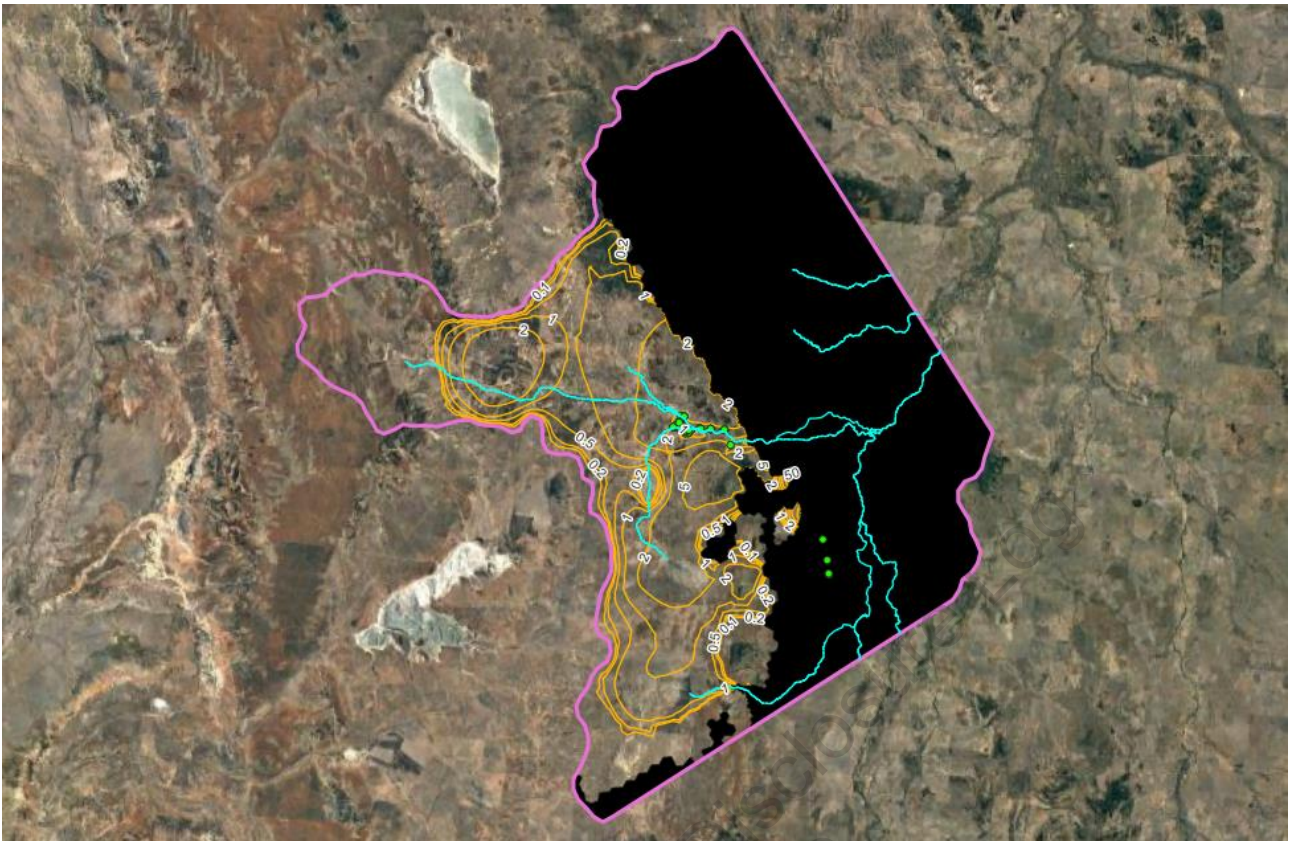


Figure 5.5 Scenario 2 modelled maximum drawdown in Clematis Sandstone

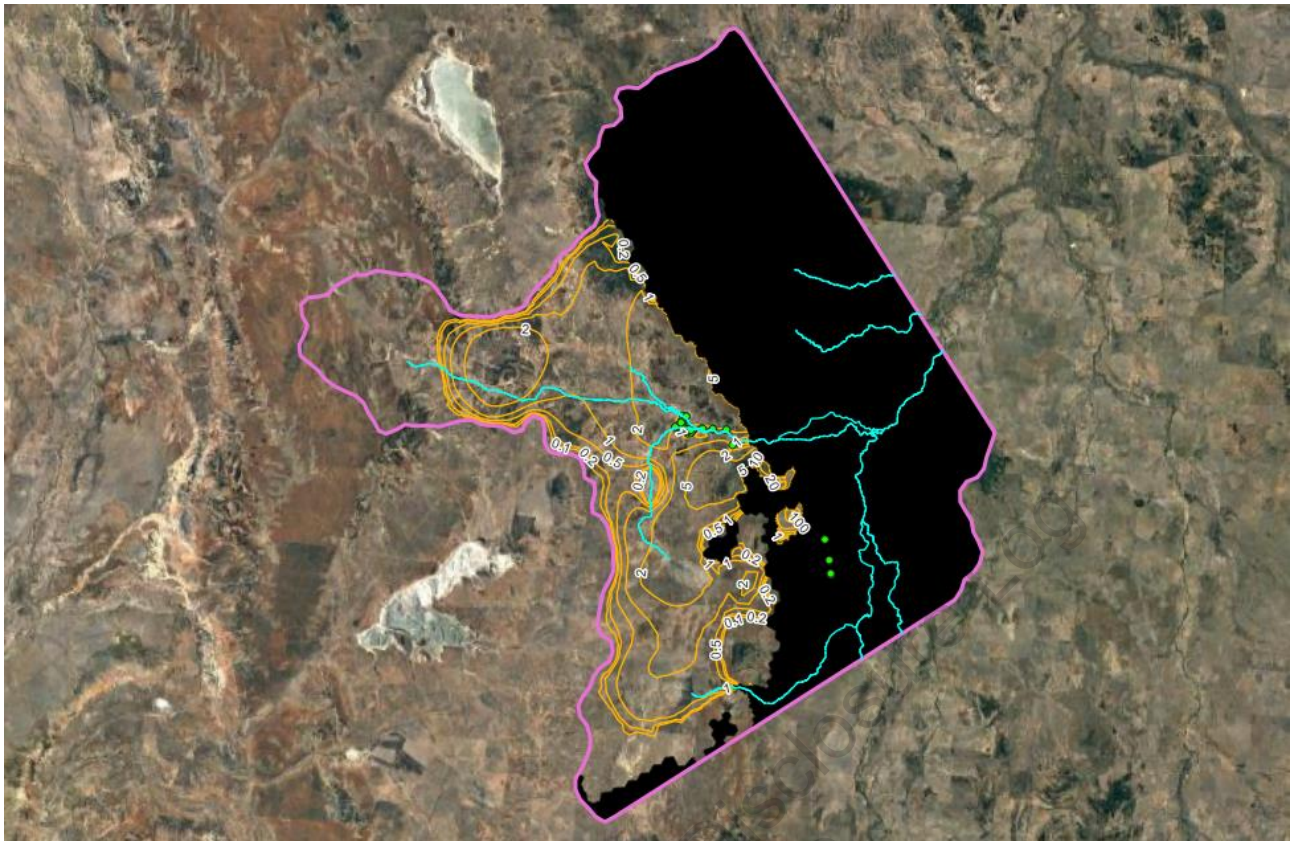


Figure 5.6 Scenario 3 modelled maximum drawdown in Clematis Sandstone

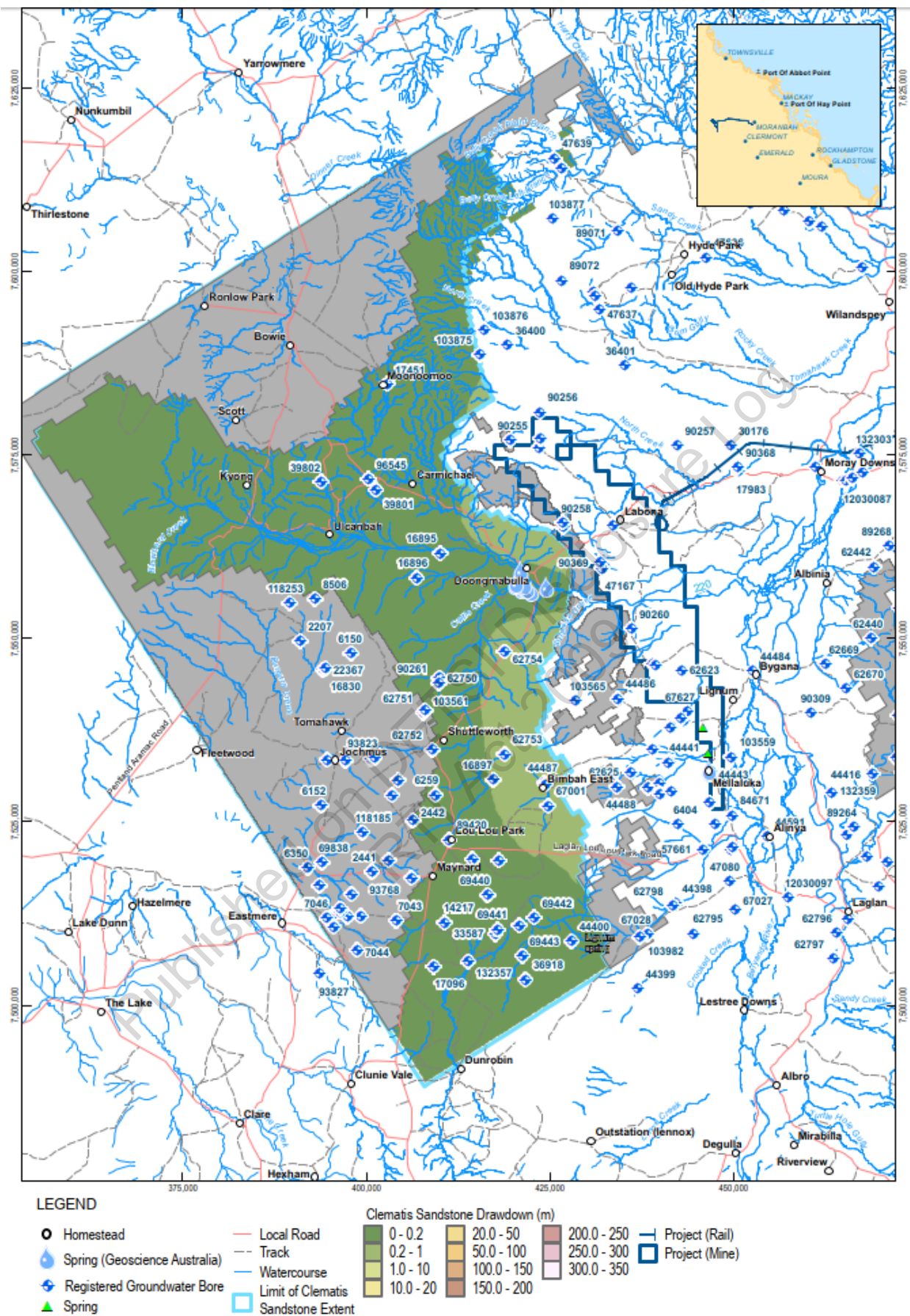
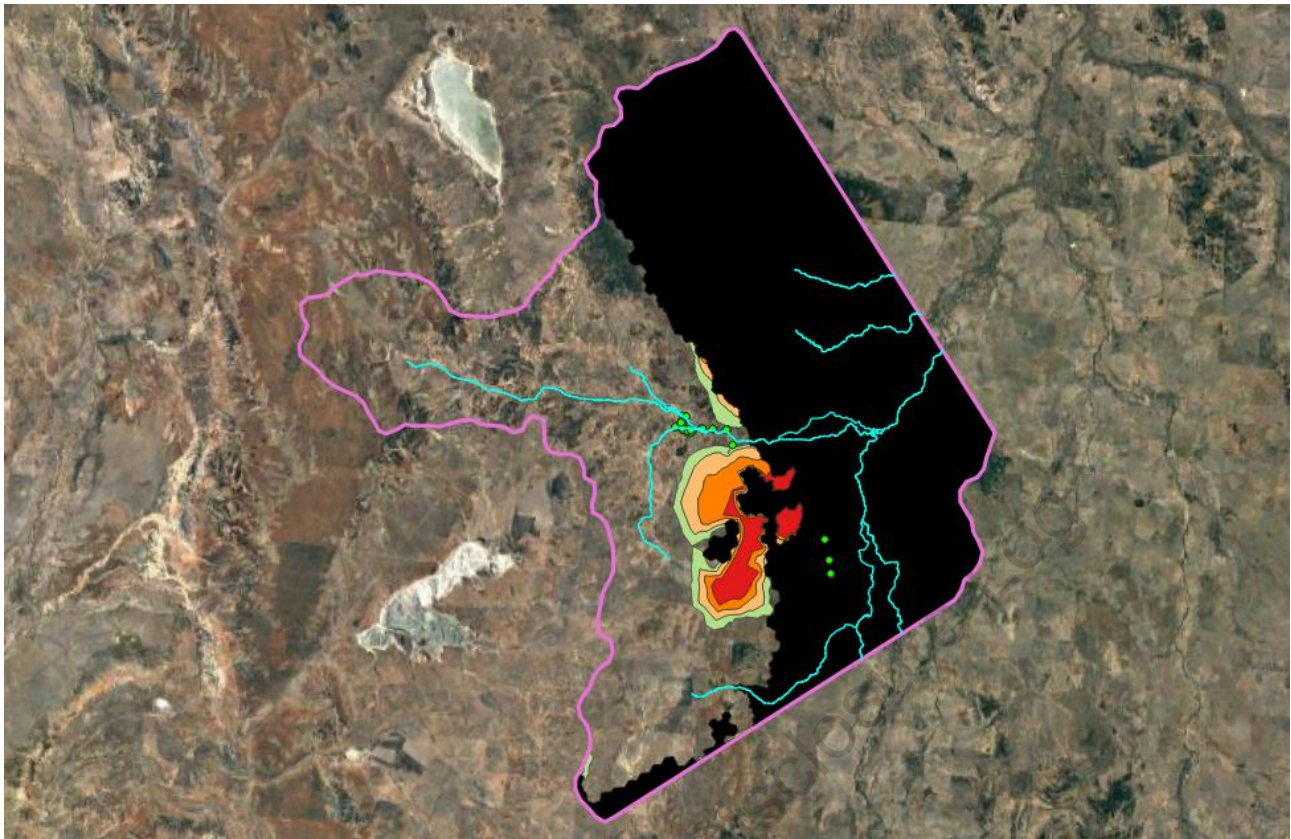


Figure 5.7 2013 SEIS modelled 'long term post closure' drawdown in Clematis Sandstone



Percentile band (outcomes ranked from small to large)	Colour Code	Description of likelihood
<P10	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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Figure 5.11 Scenario 3 modelled maximum drawdown in AB coal seams

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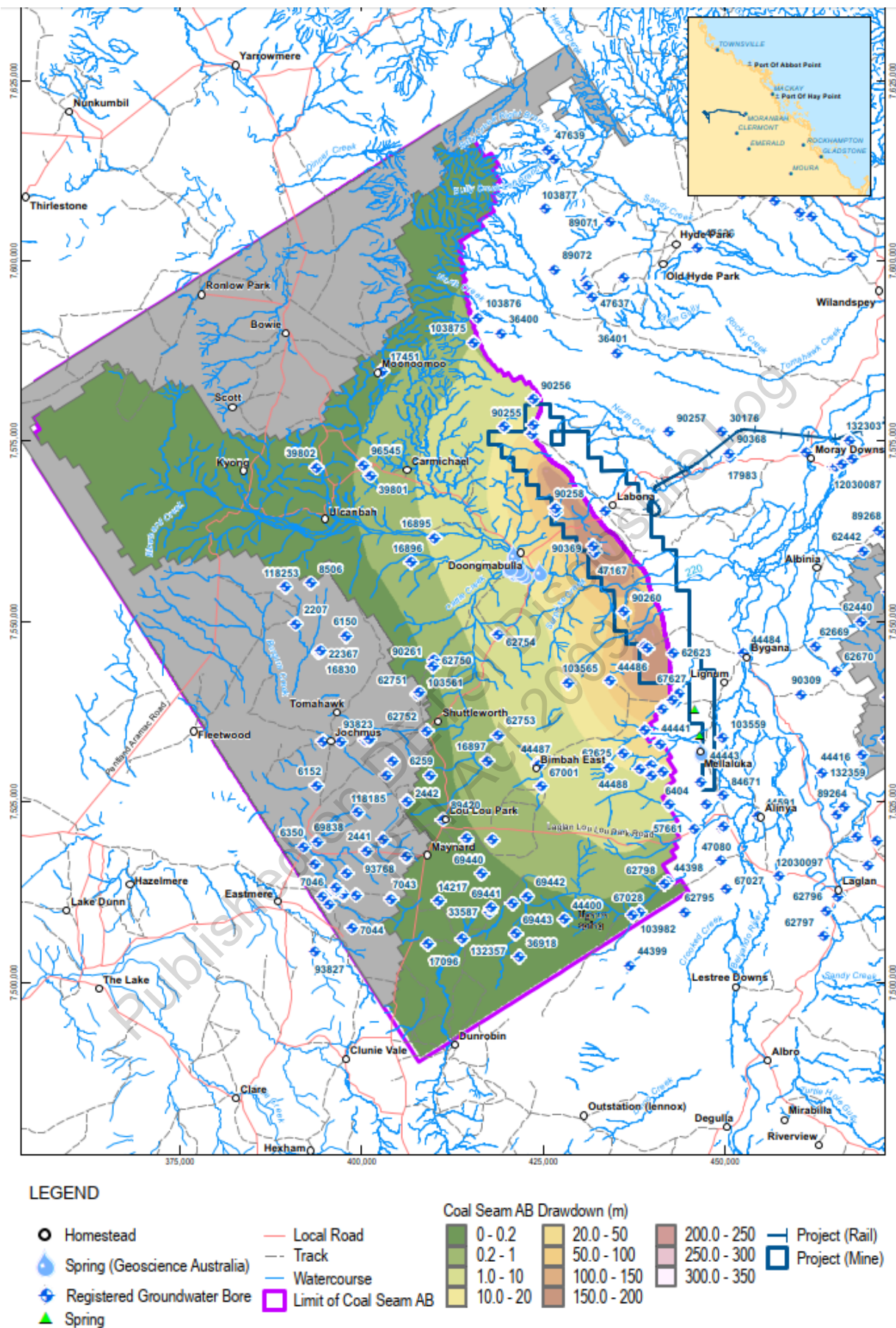


Figure 5.12 2013 SEIS modelled 'long term post closure' drawdown in AB coal seams

5.3.3 Drawdown hydrographs

Figure 5.13 All scenario base case selected modelled drawdown hydrographs

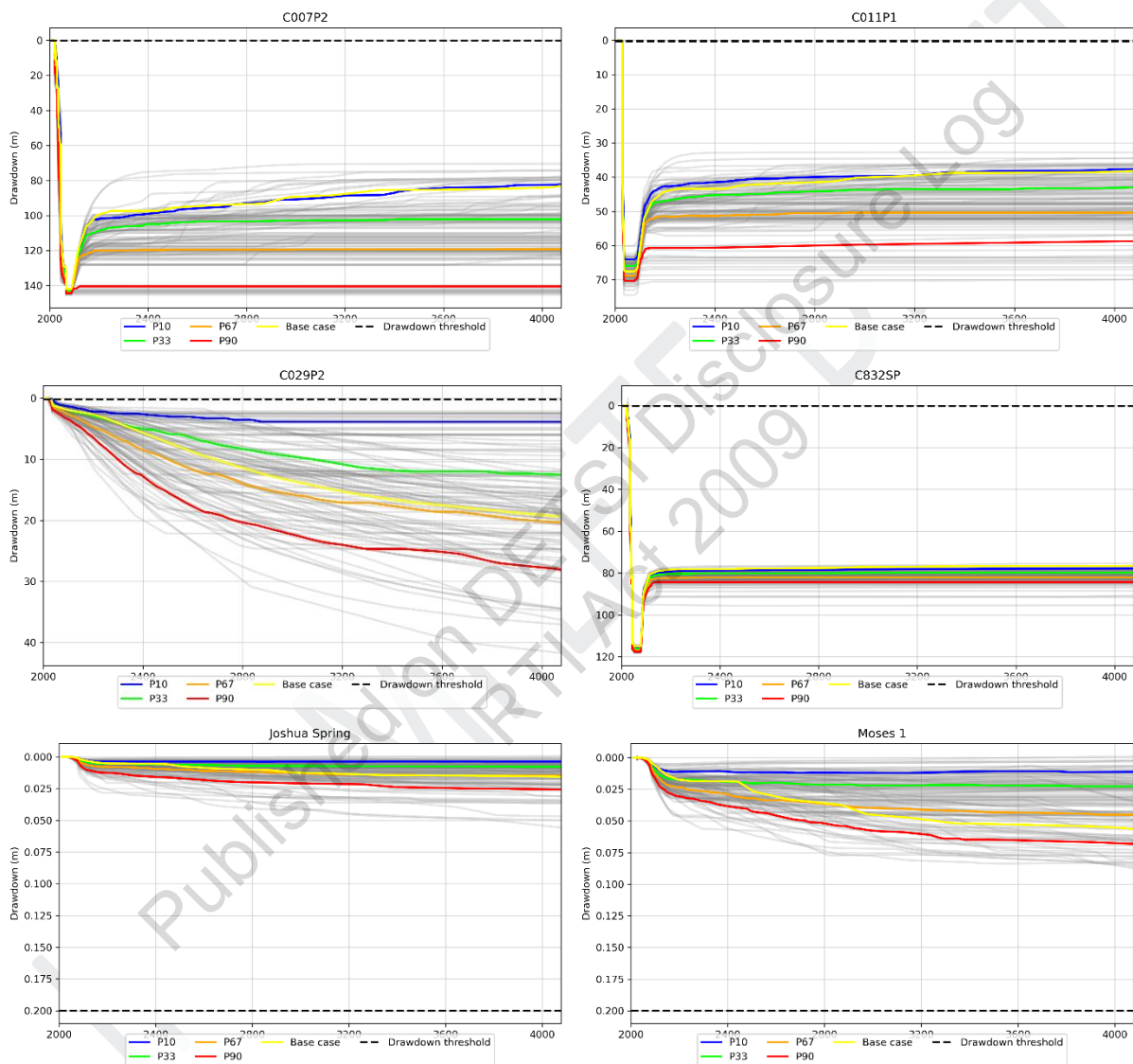


Figure 5.14 Scenario 1 selected modelled drawdown hydrographs



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		

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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

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

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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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Author/reference	Summary of comments	Data/research/approach
	<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

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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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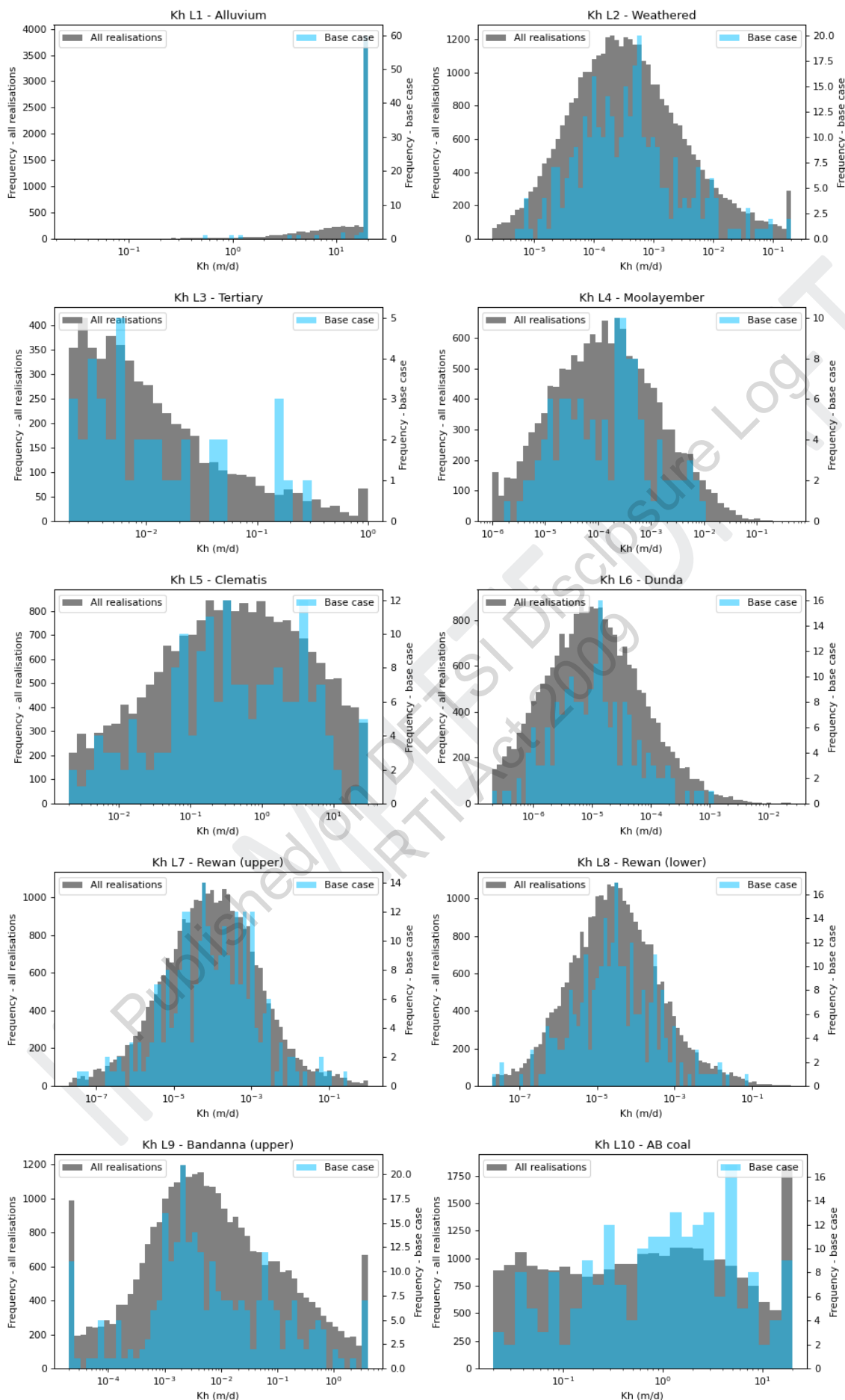
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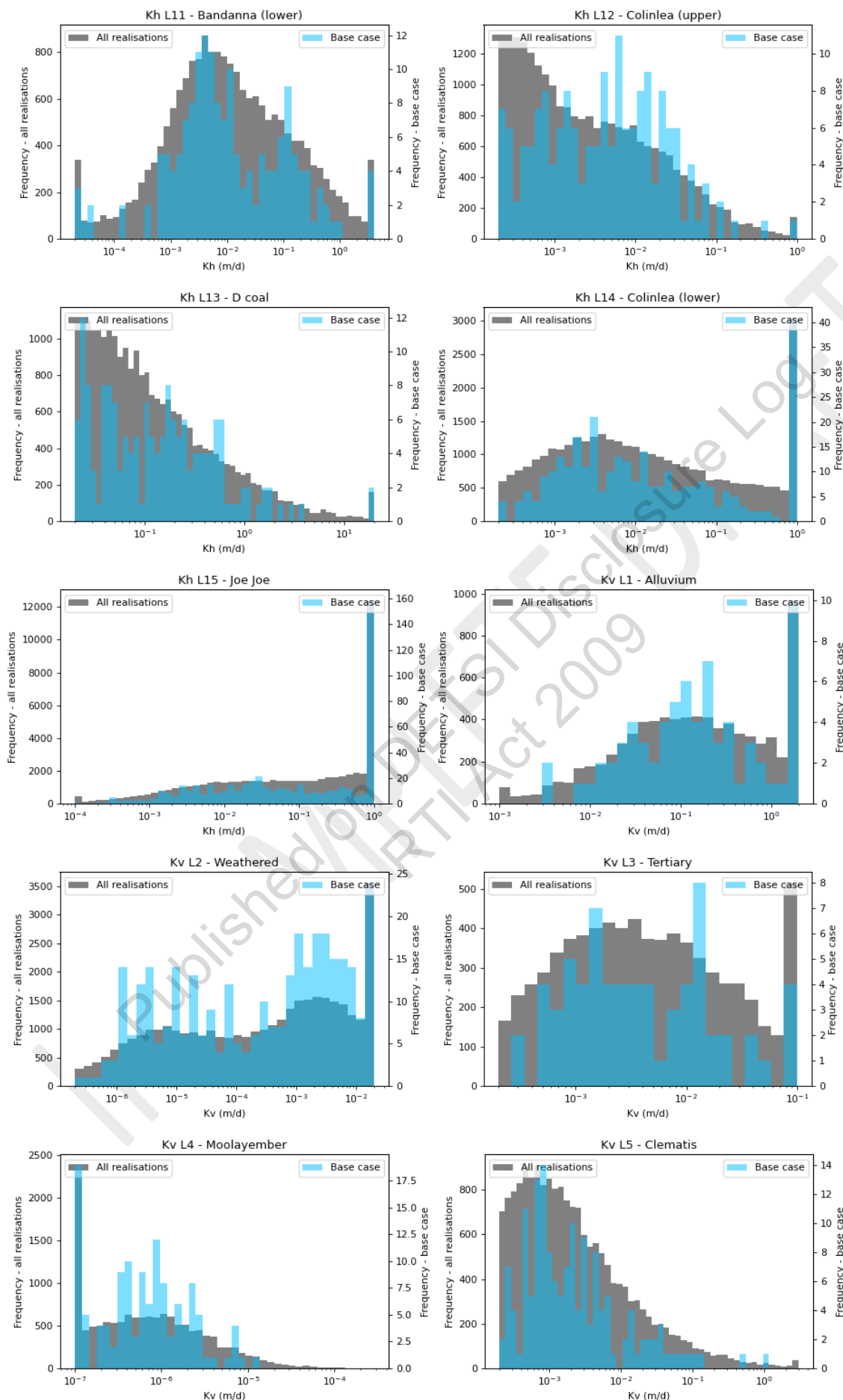
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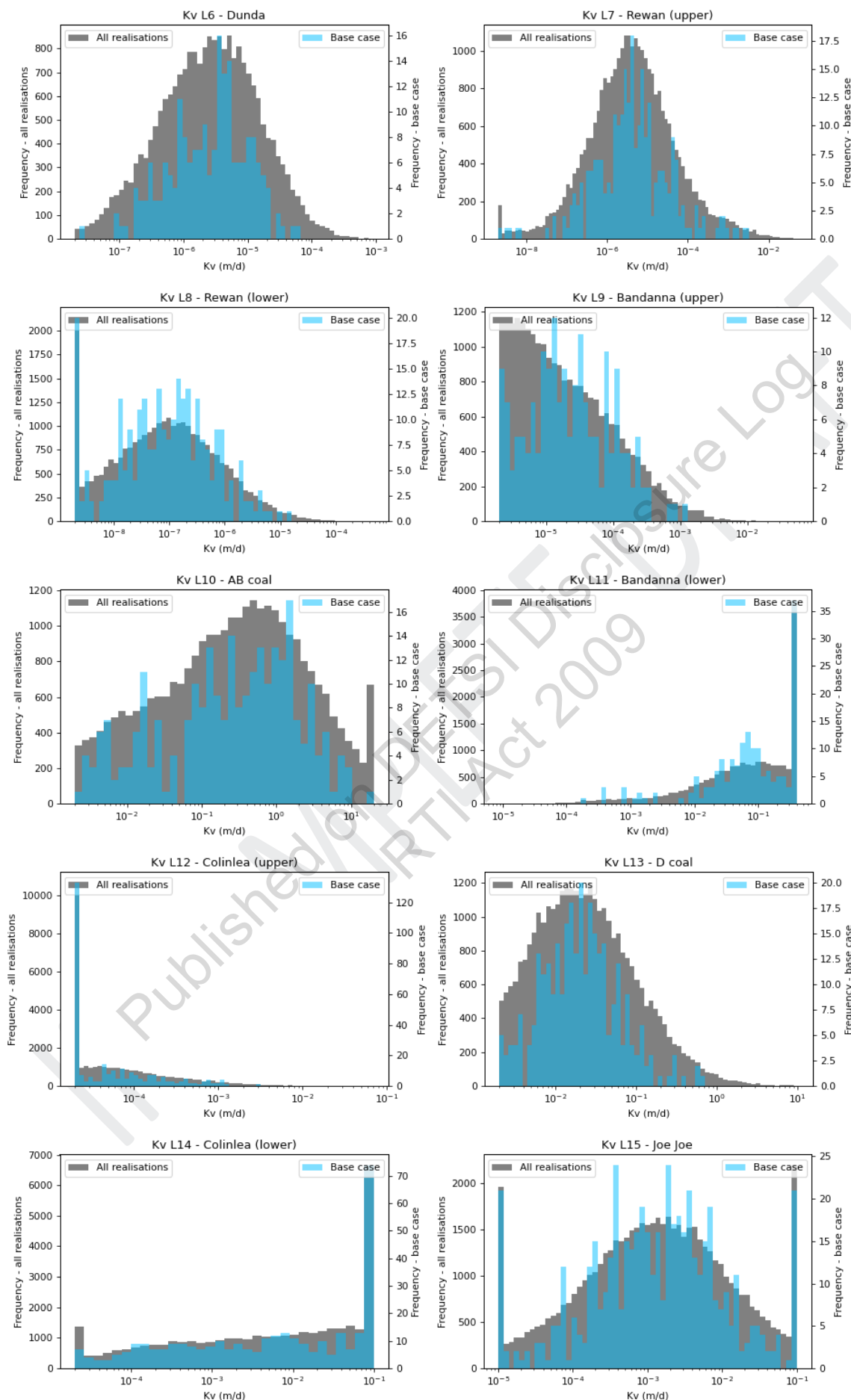
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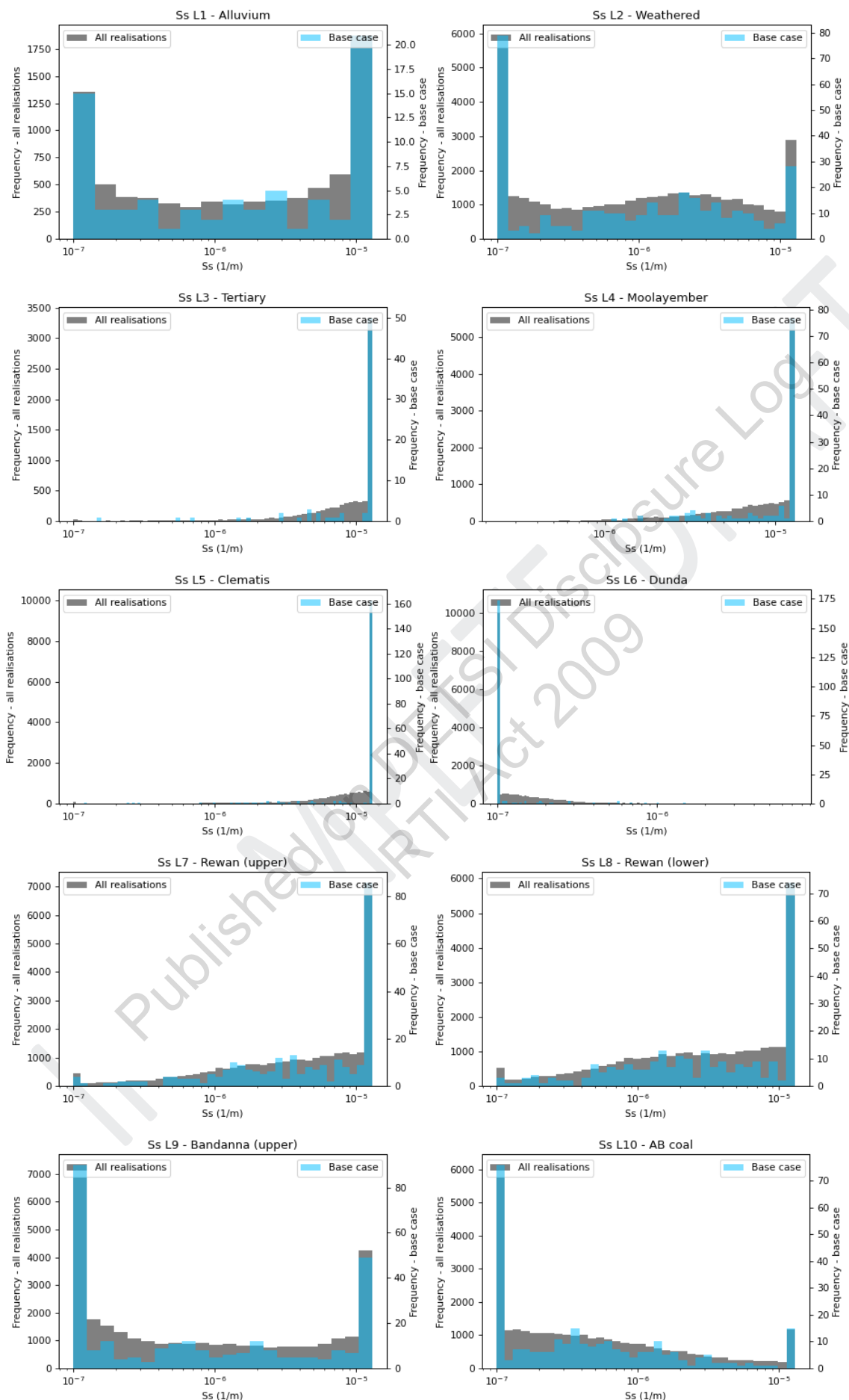
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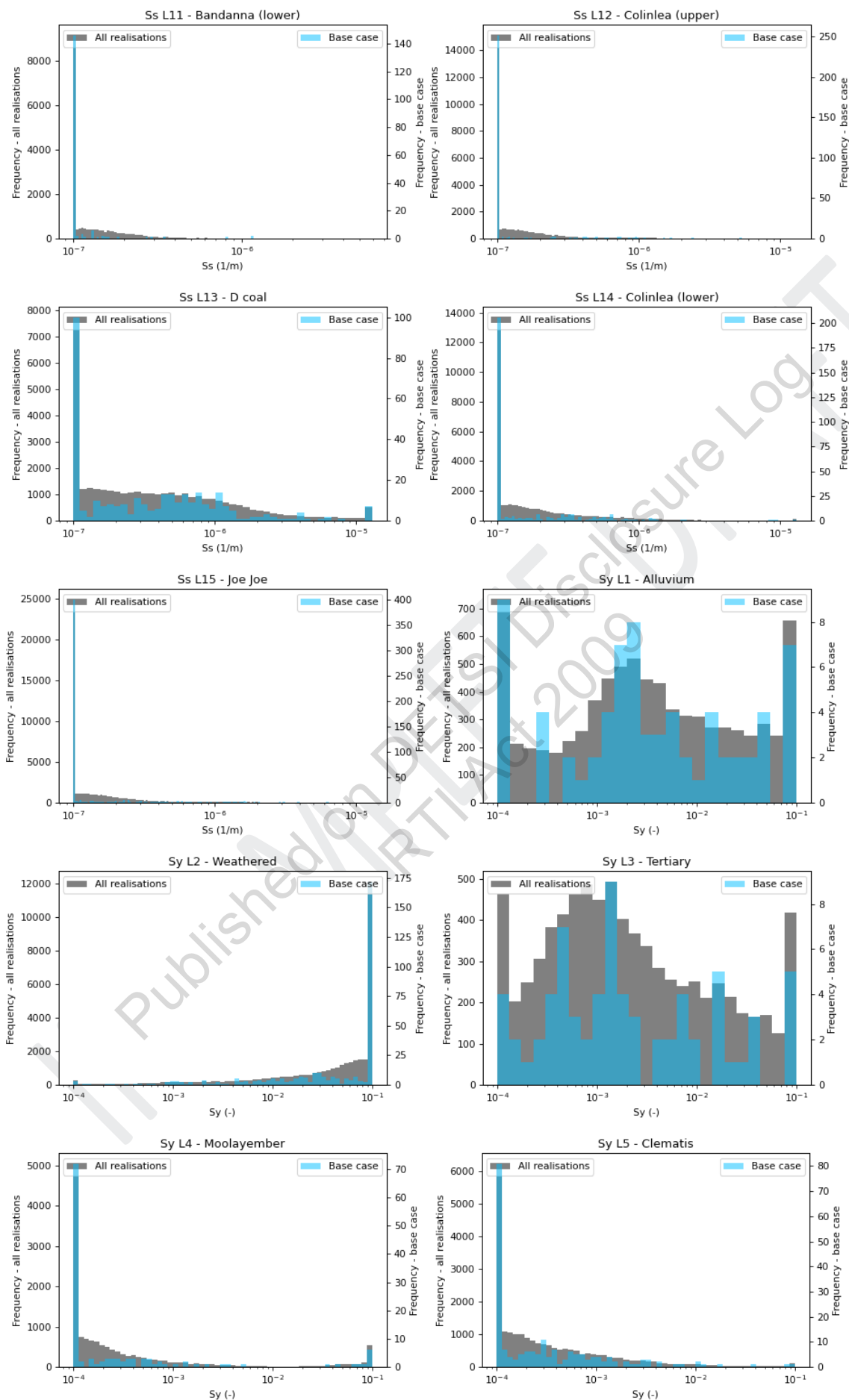
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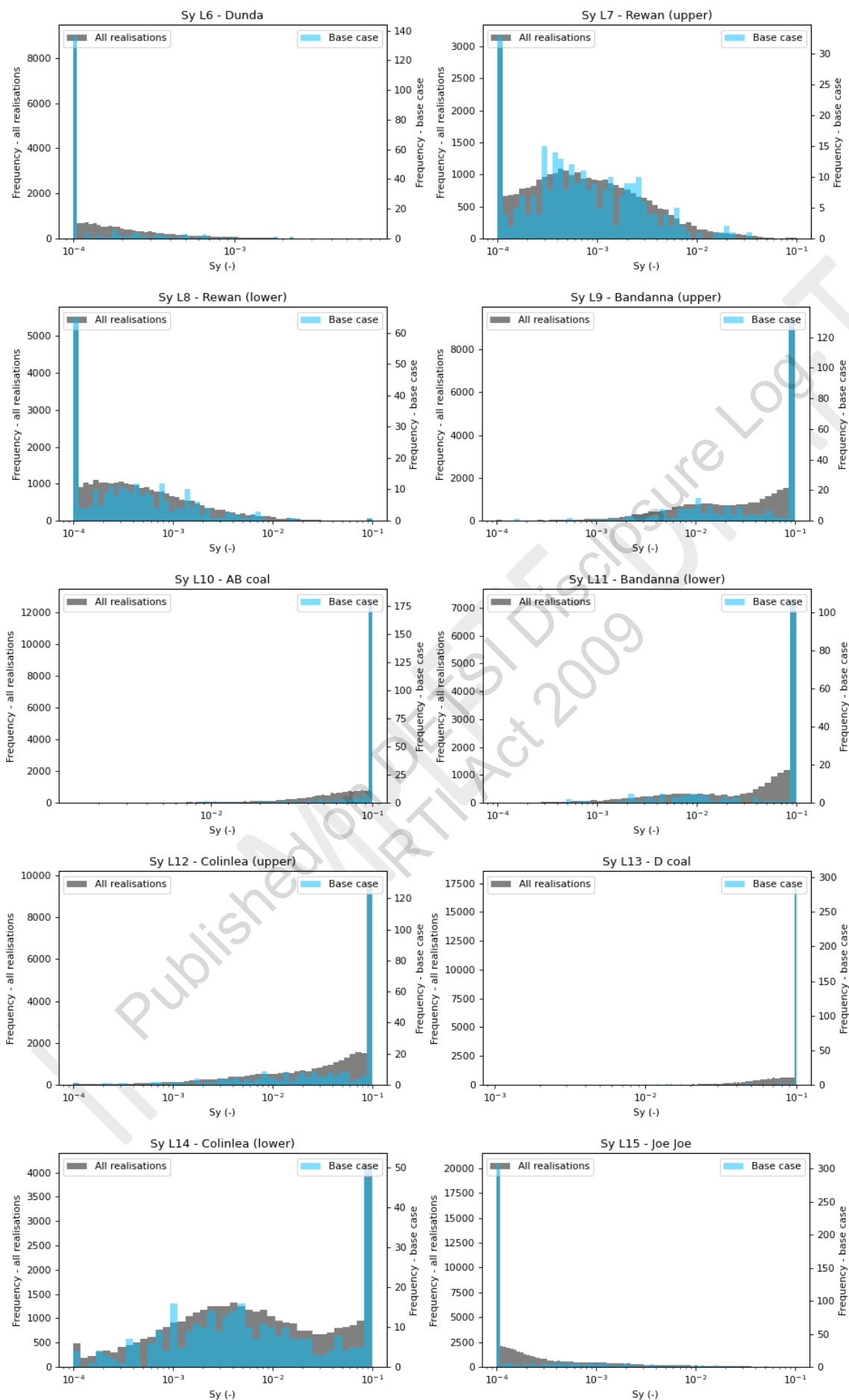


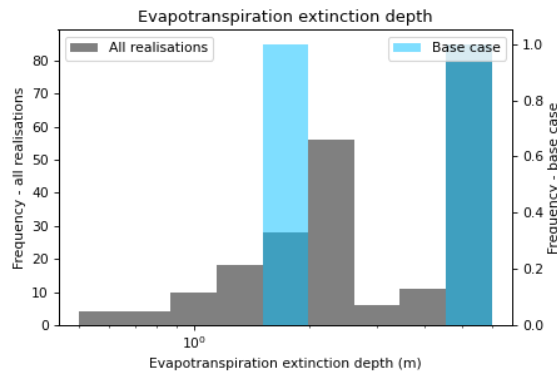
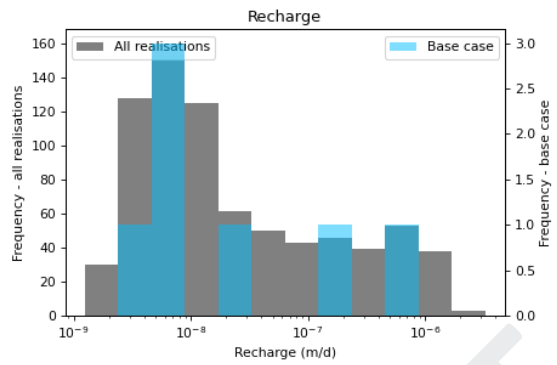
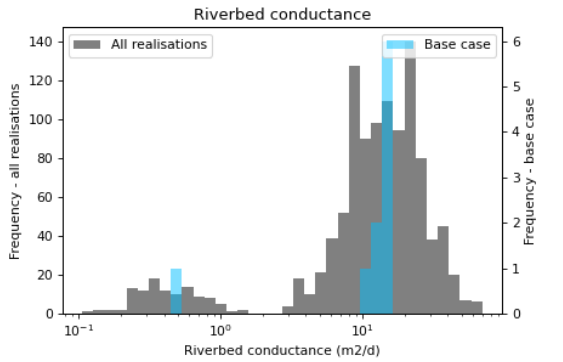
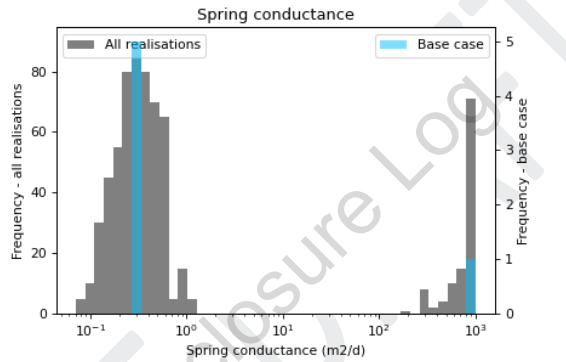






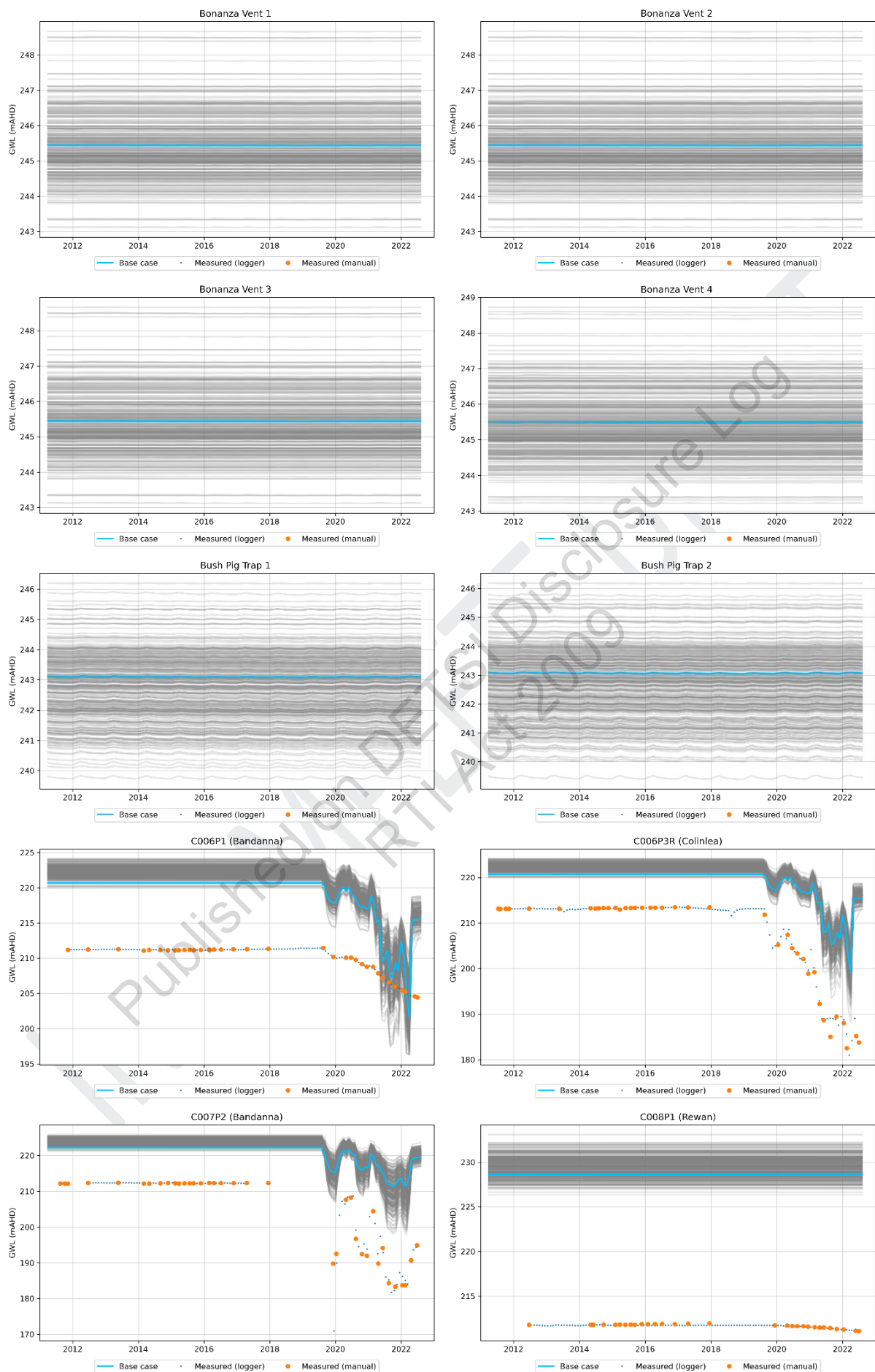


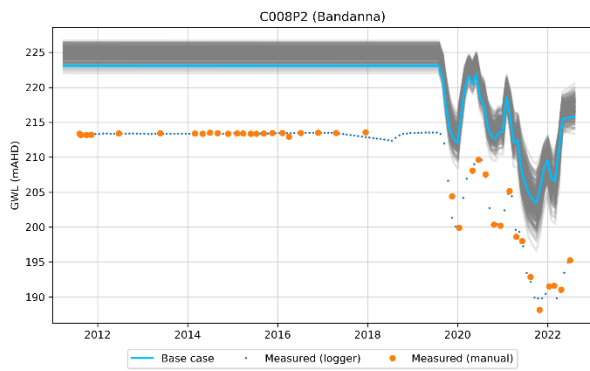
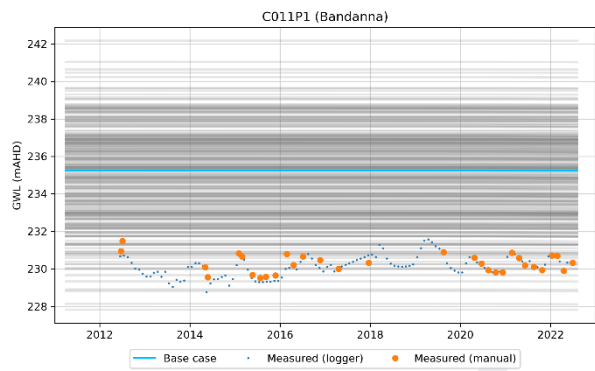
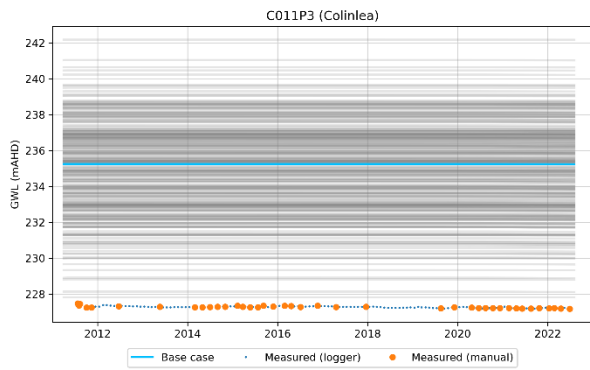
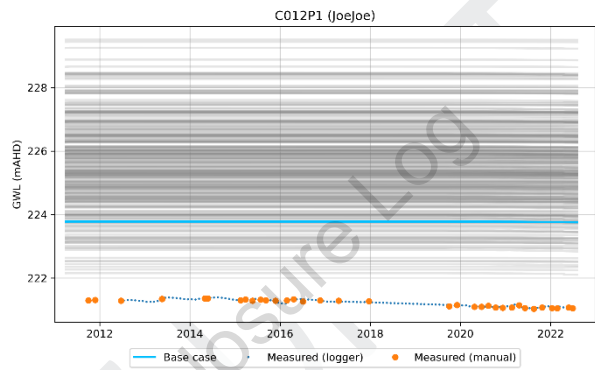
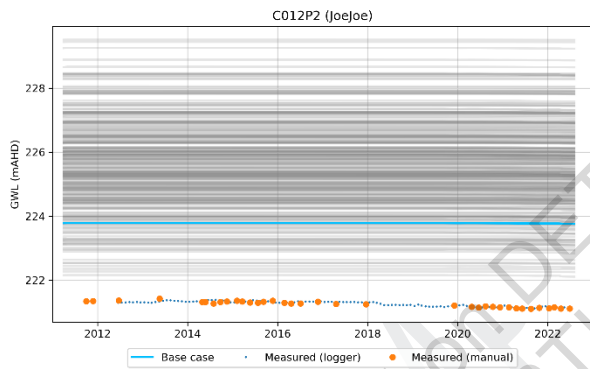
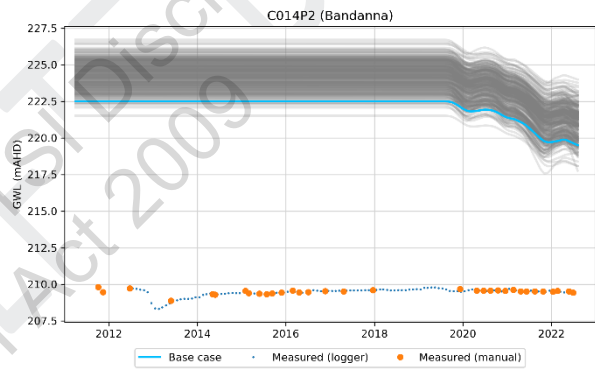
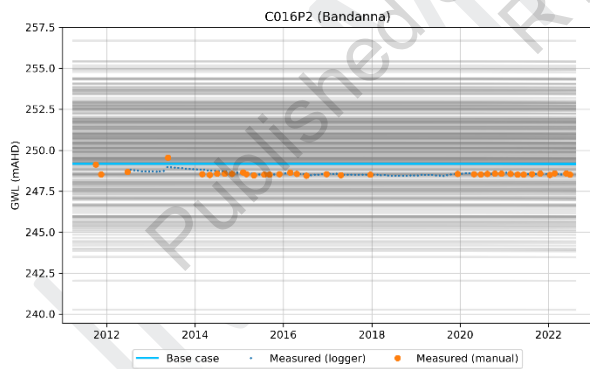
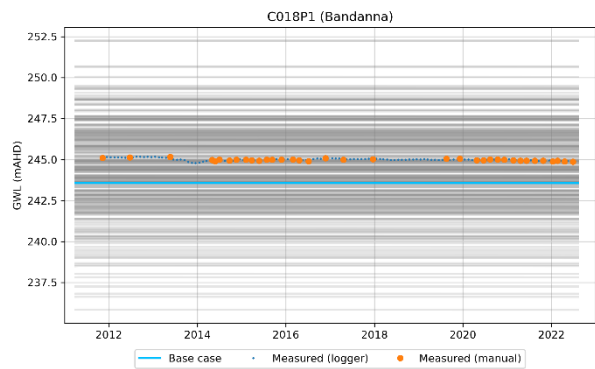
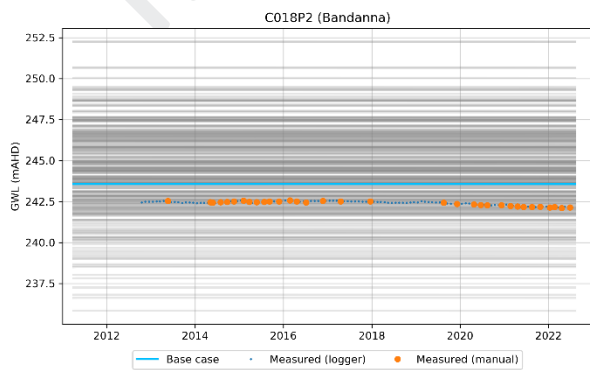
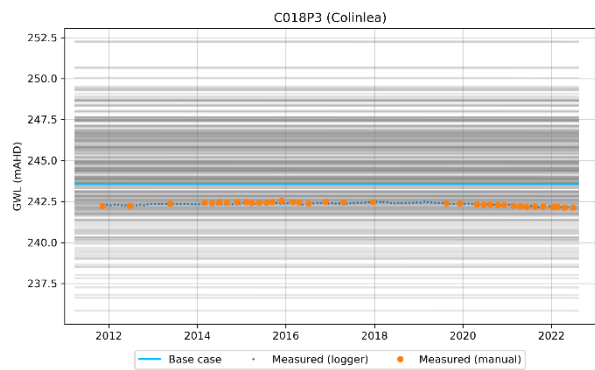




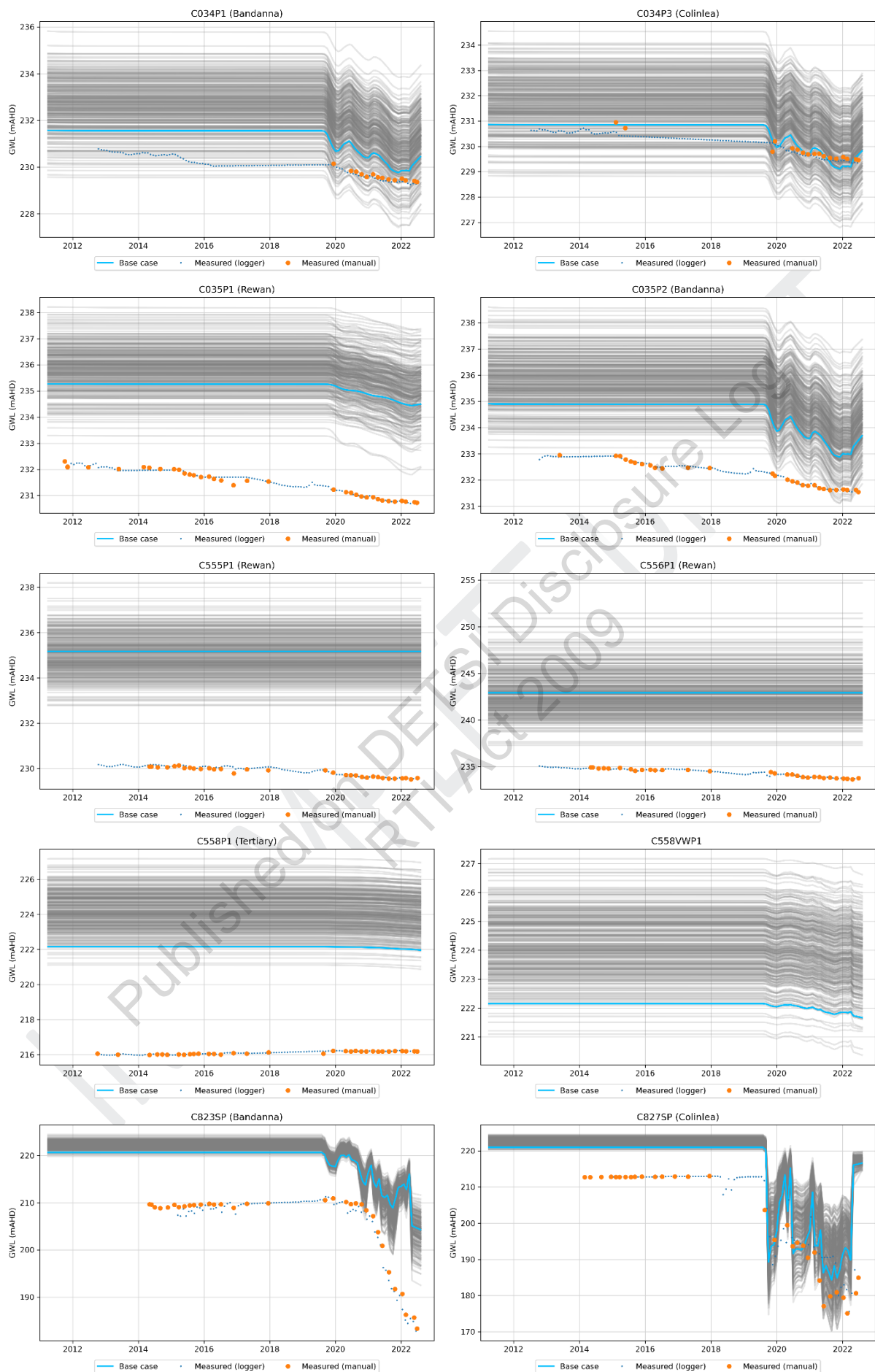
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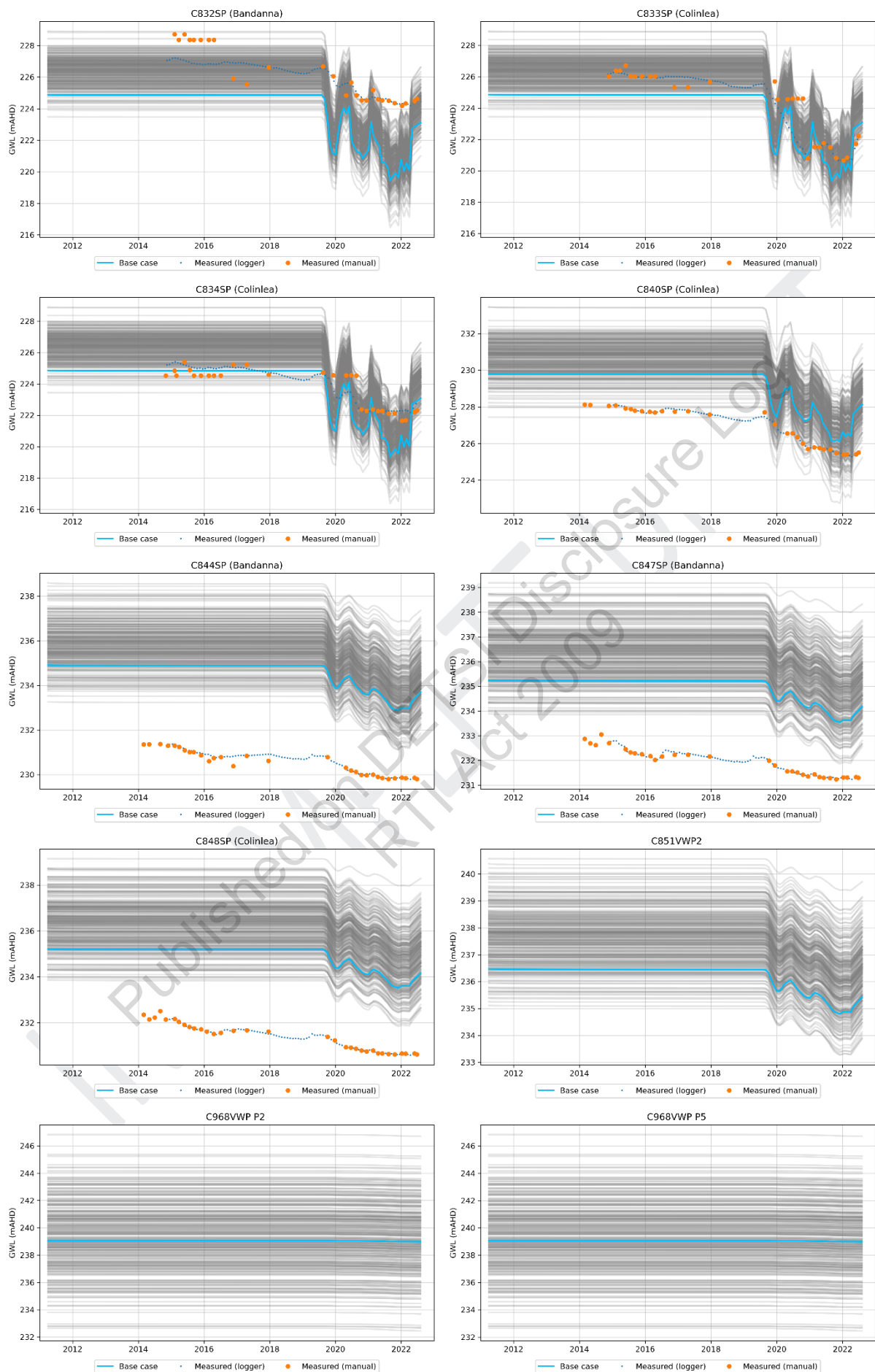
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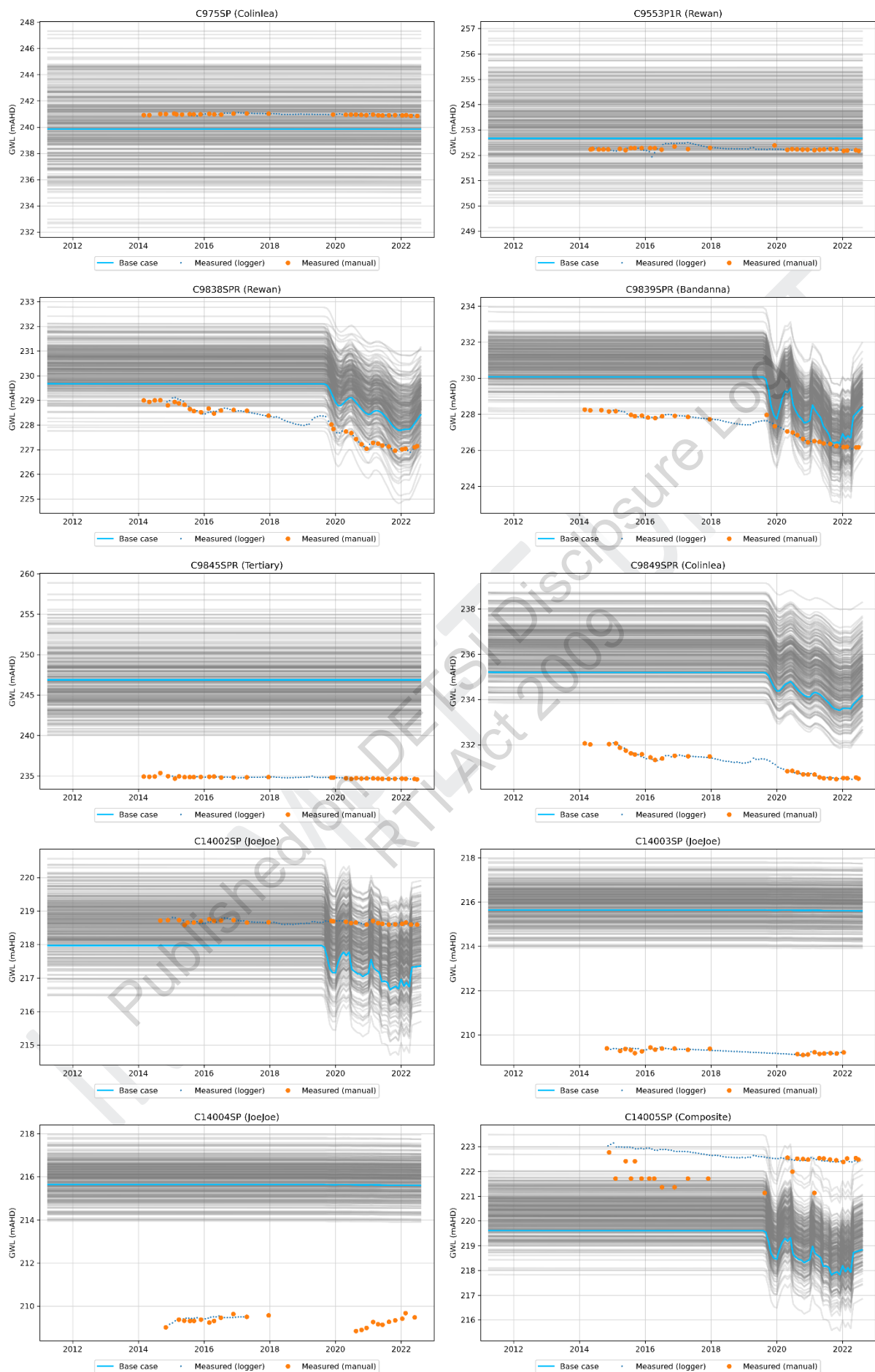


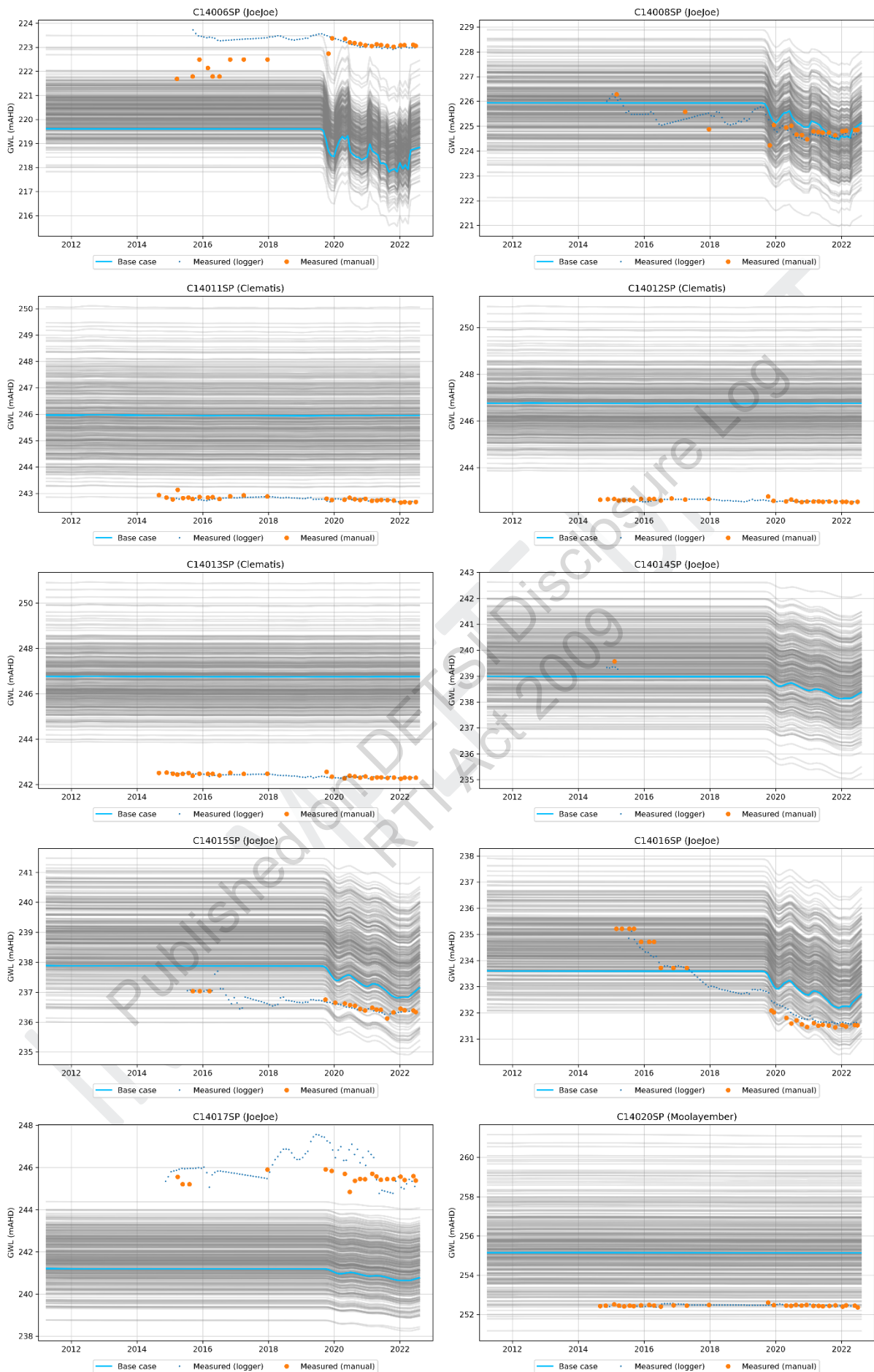


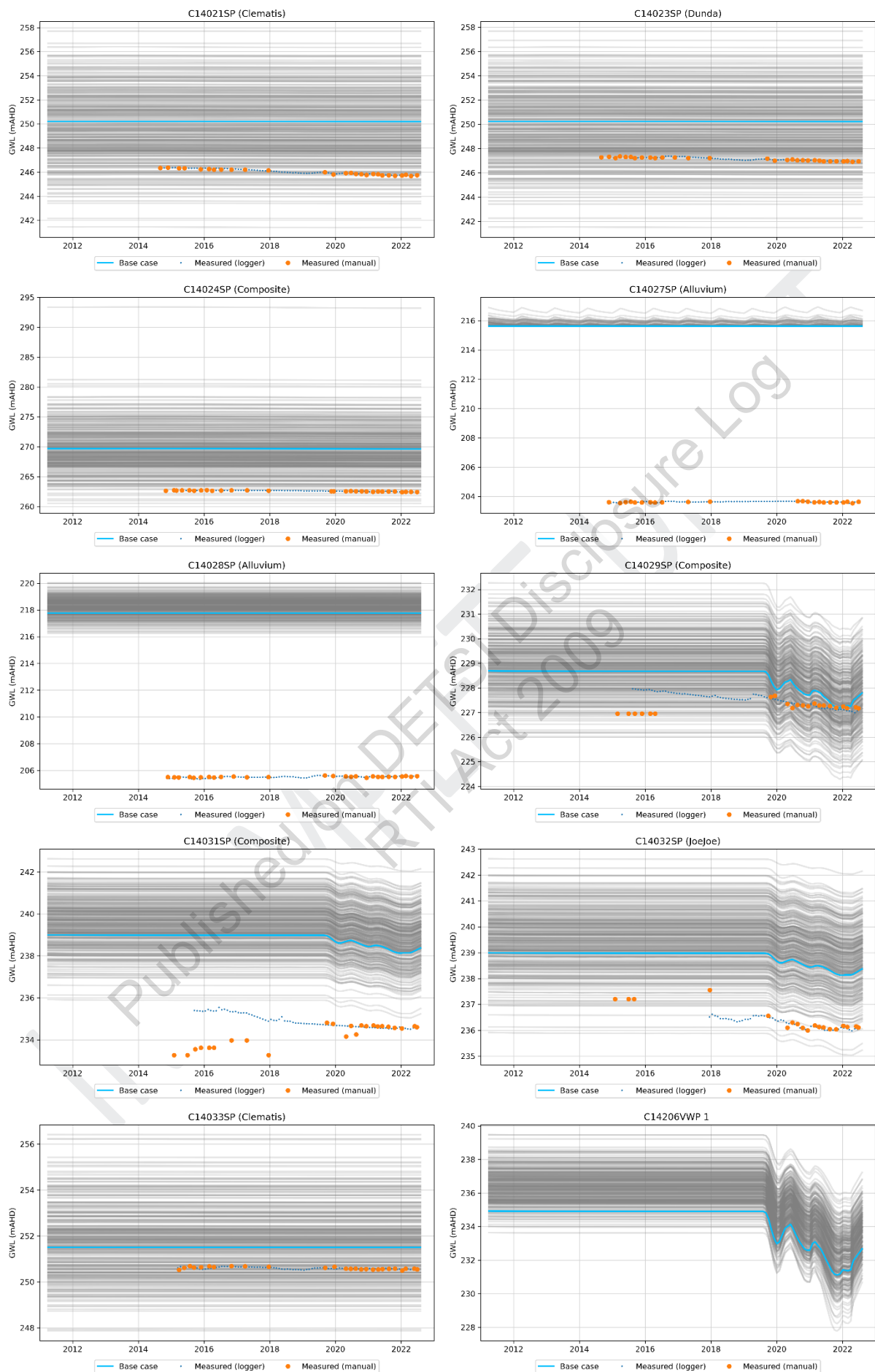


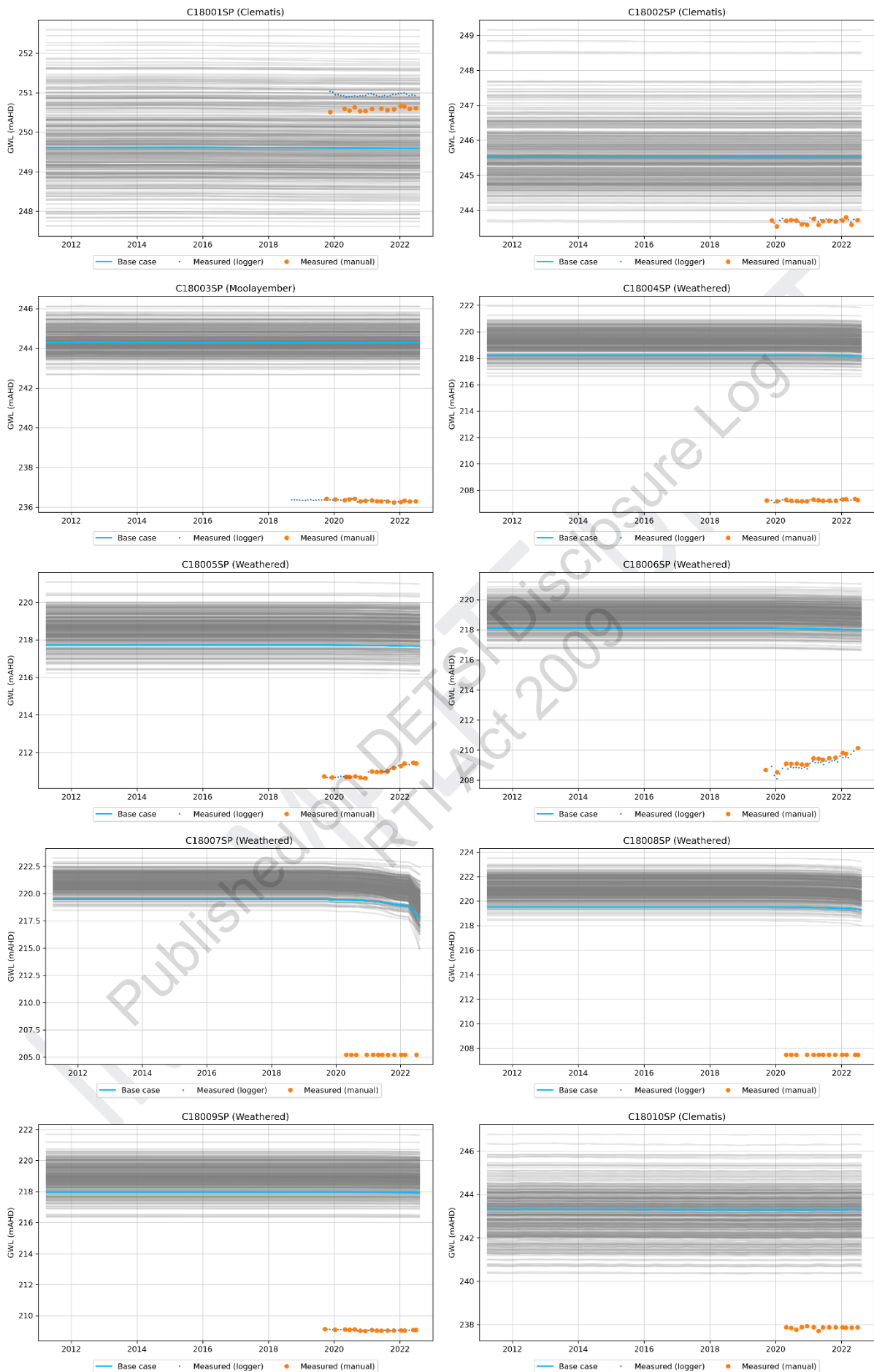


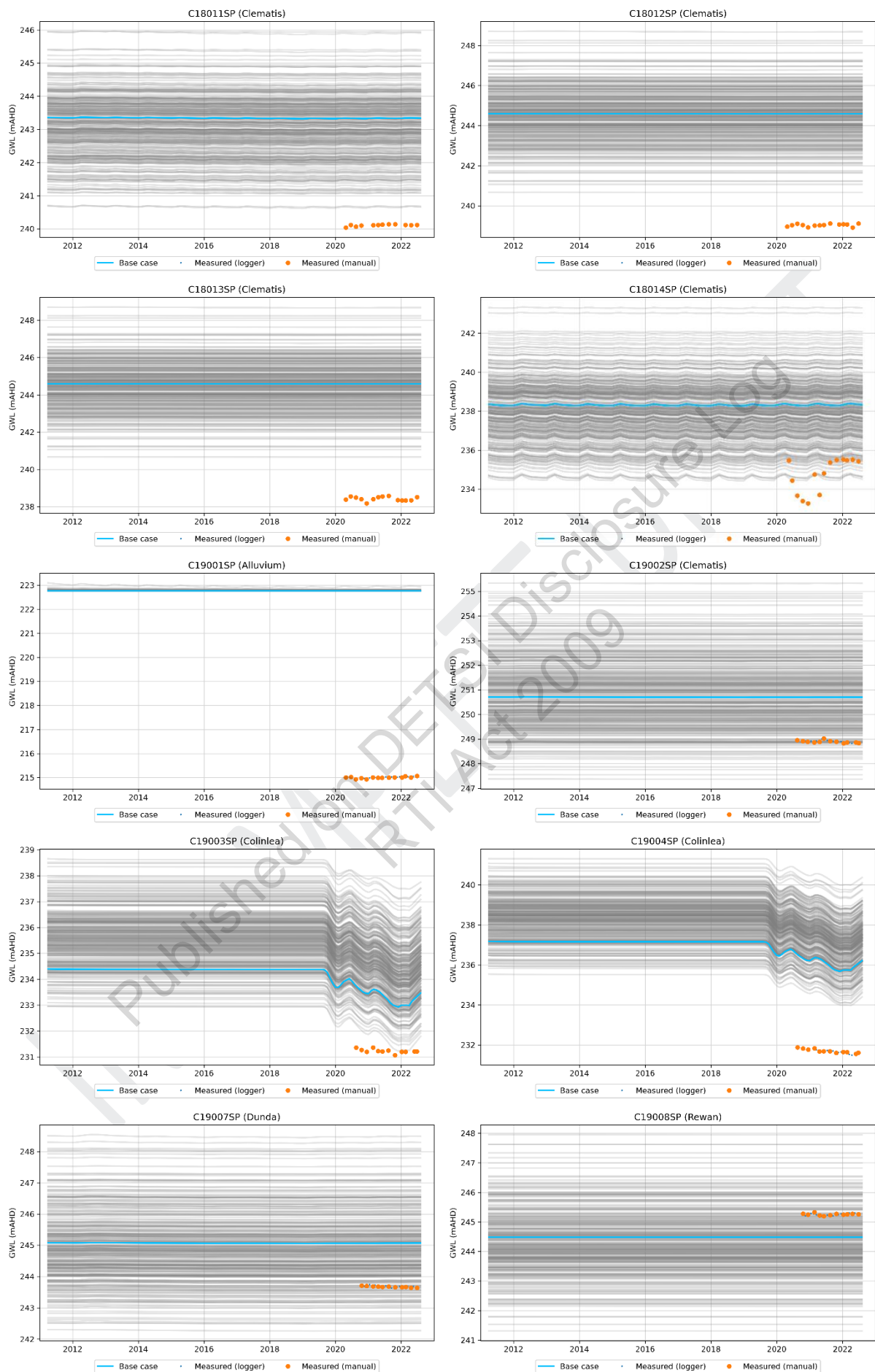


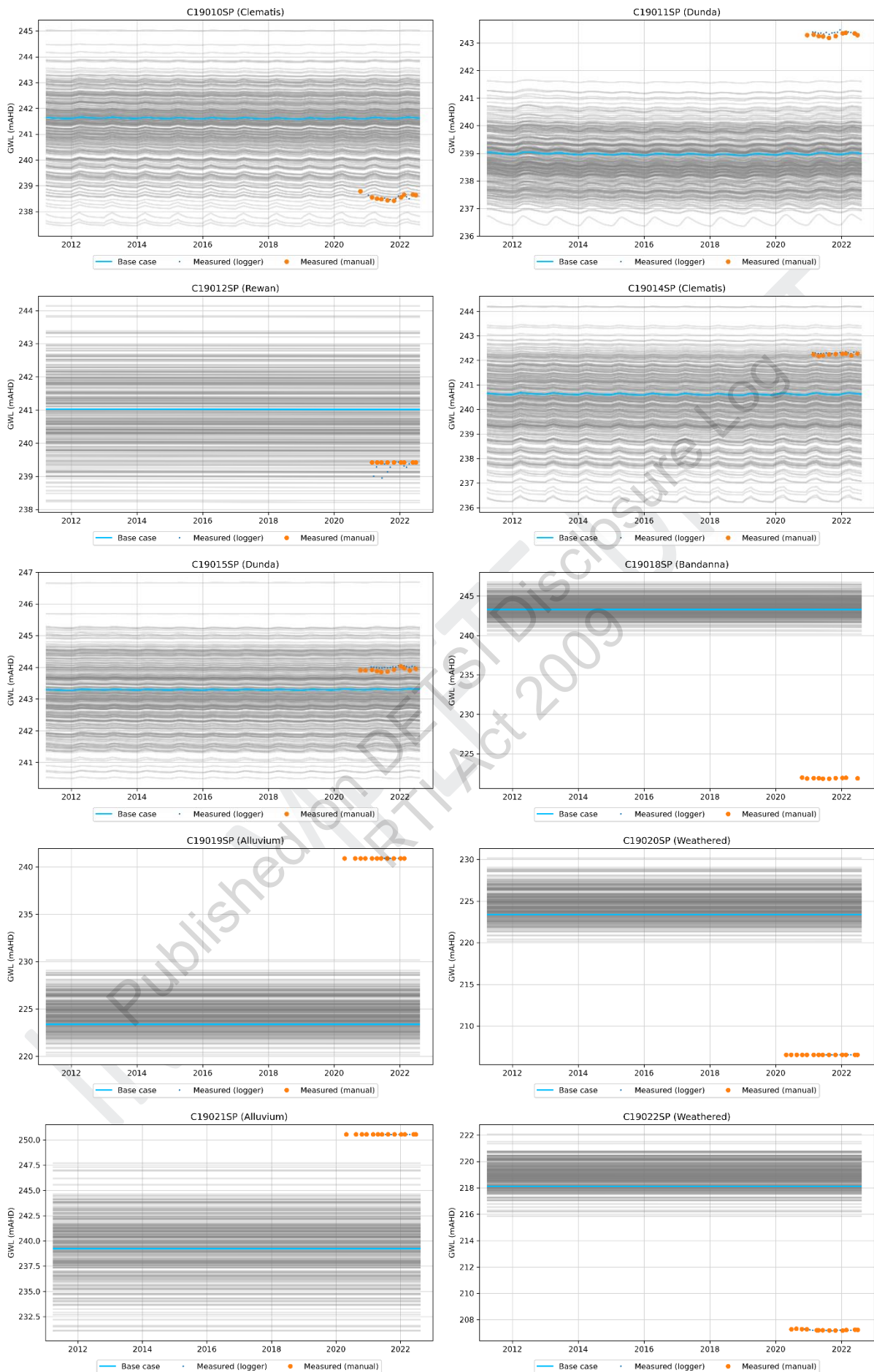


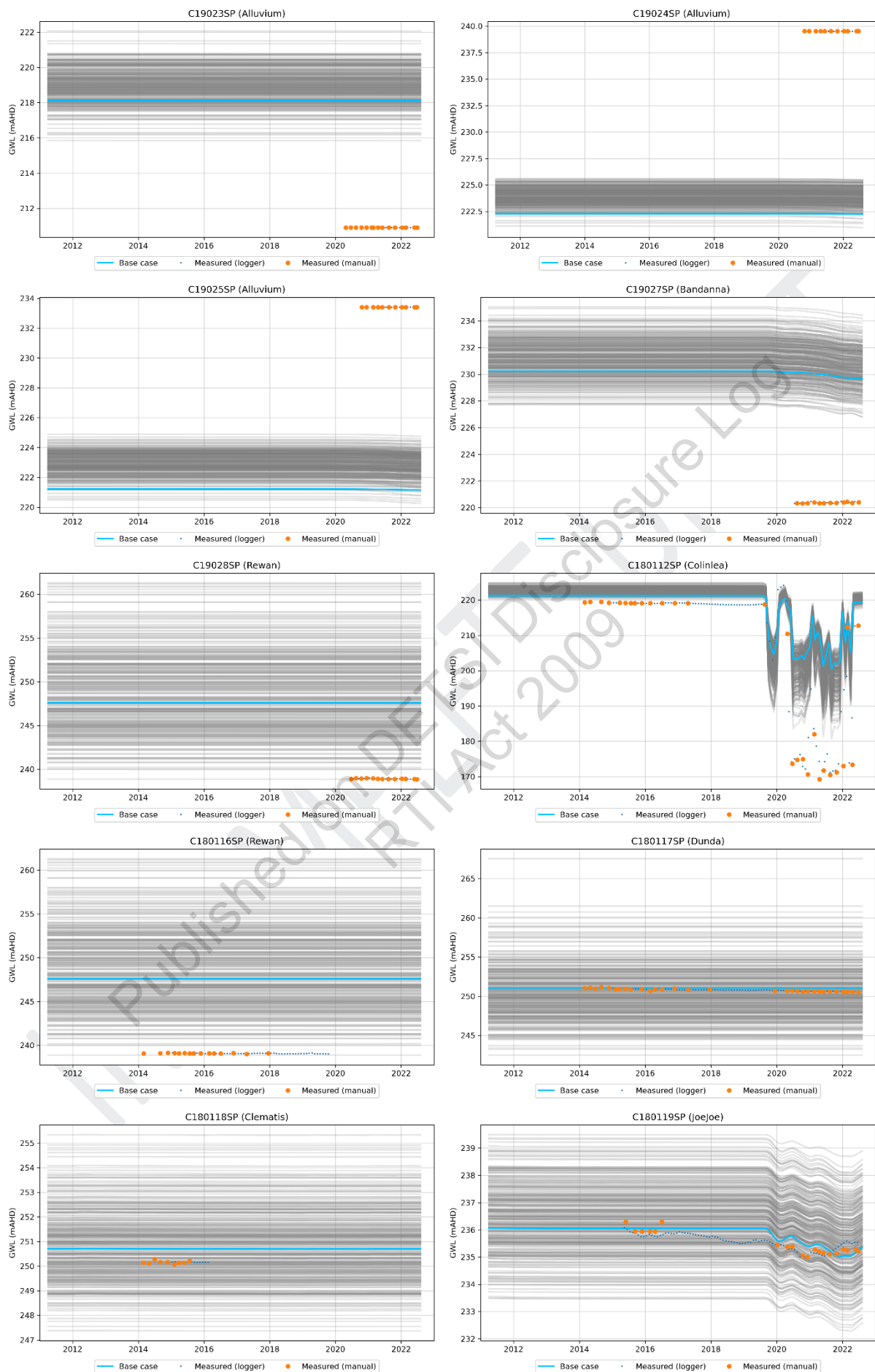


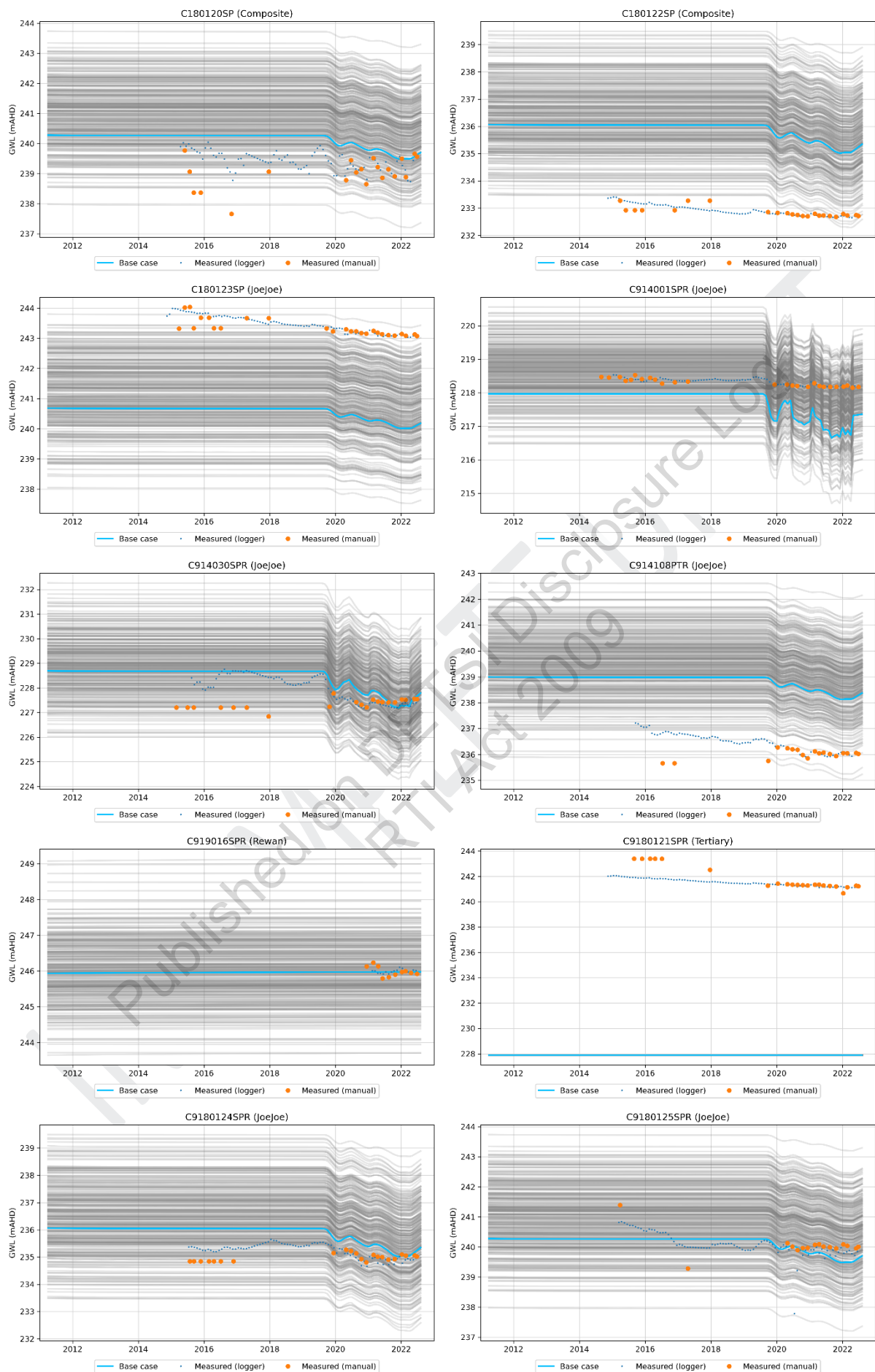


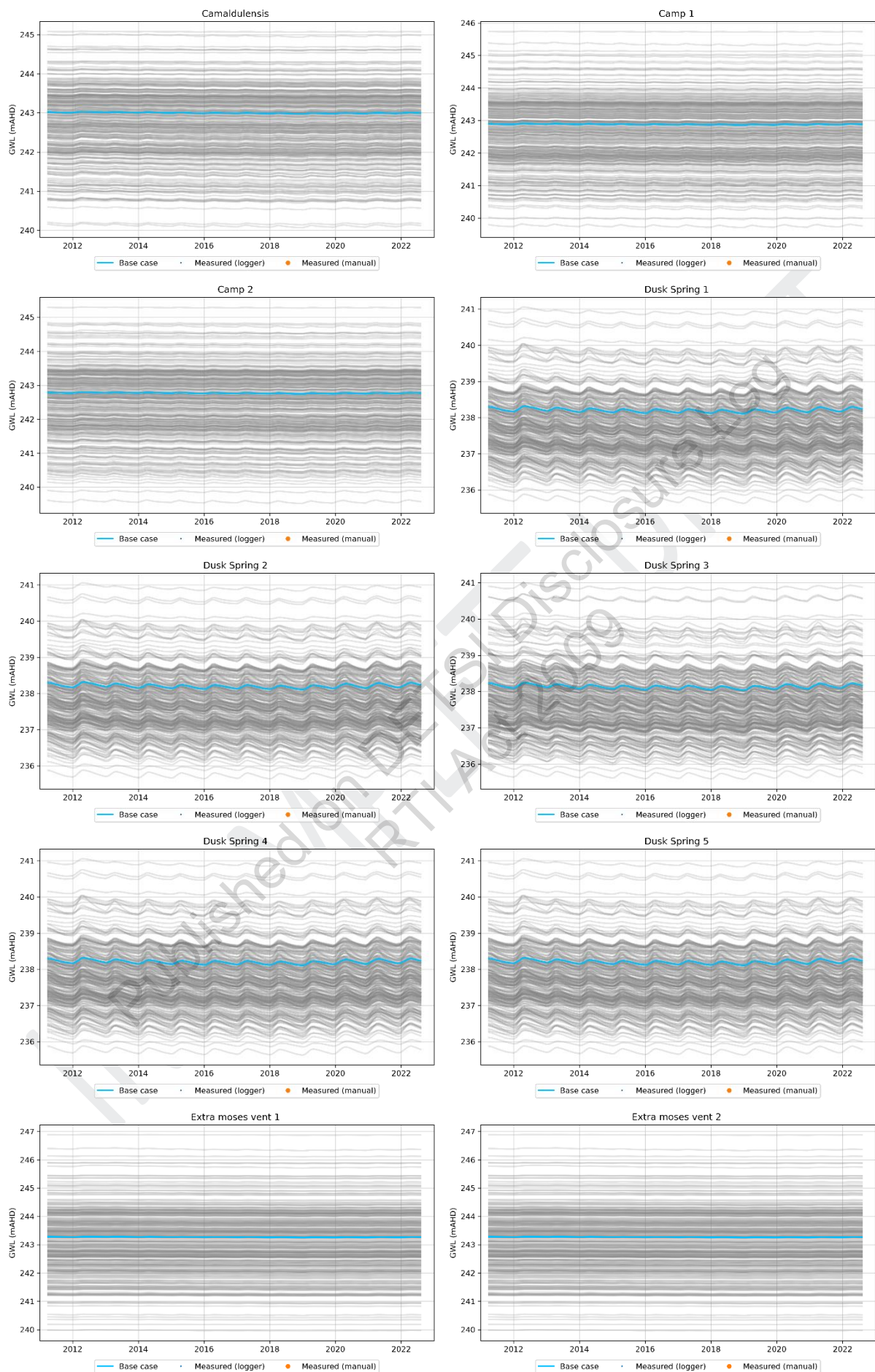


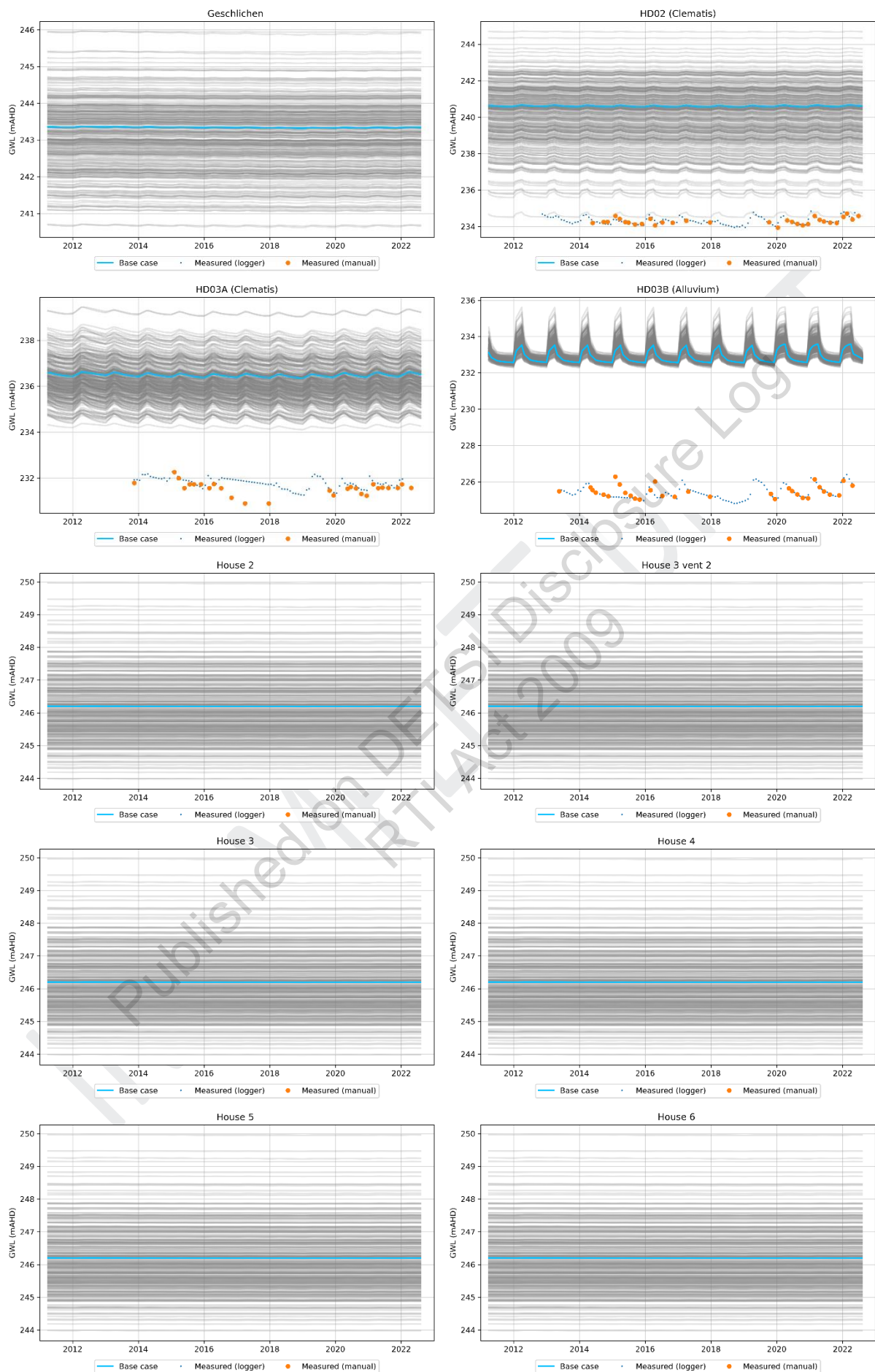


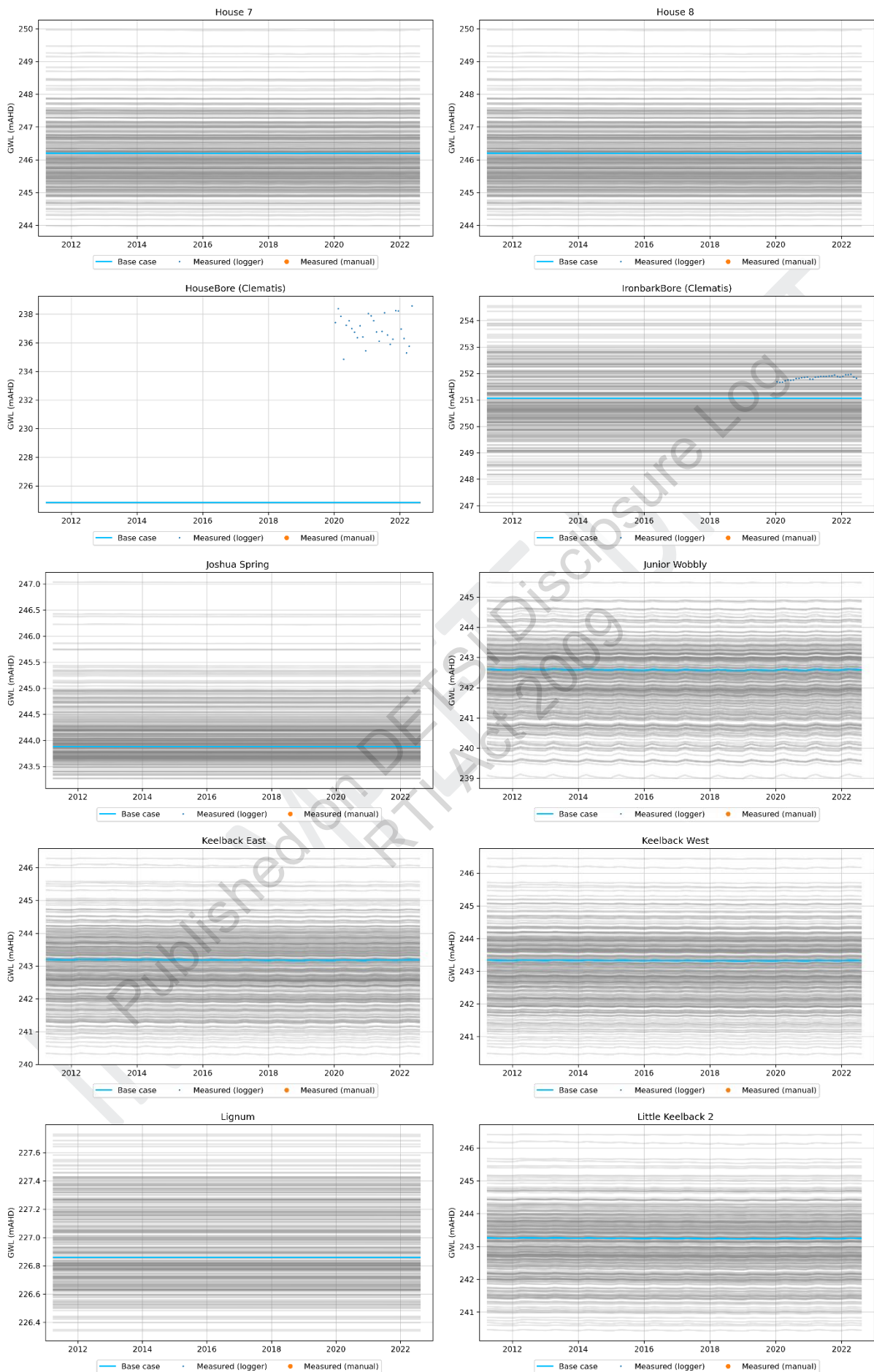


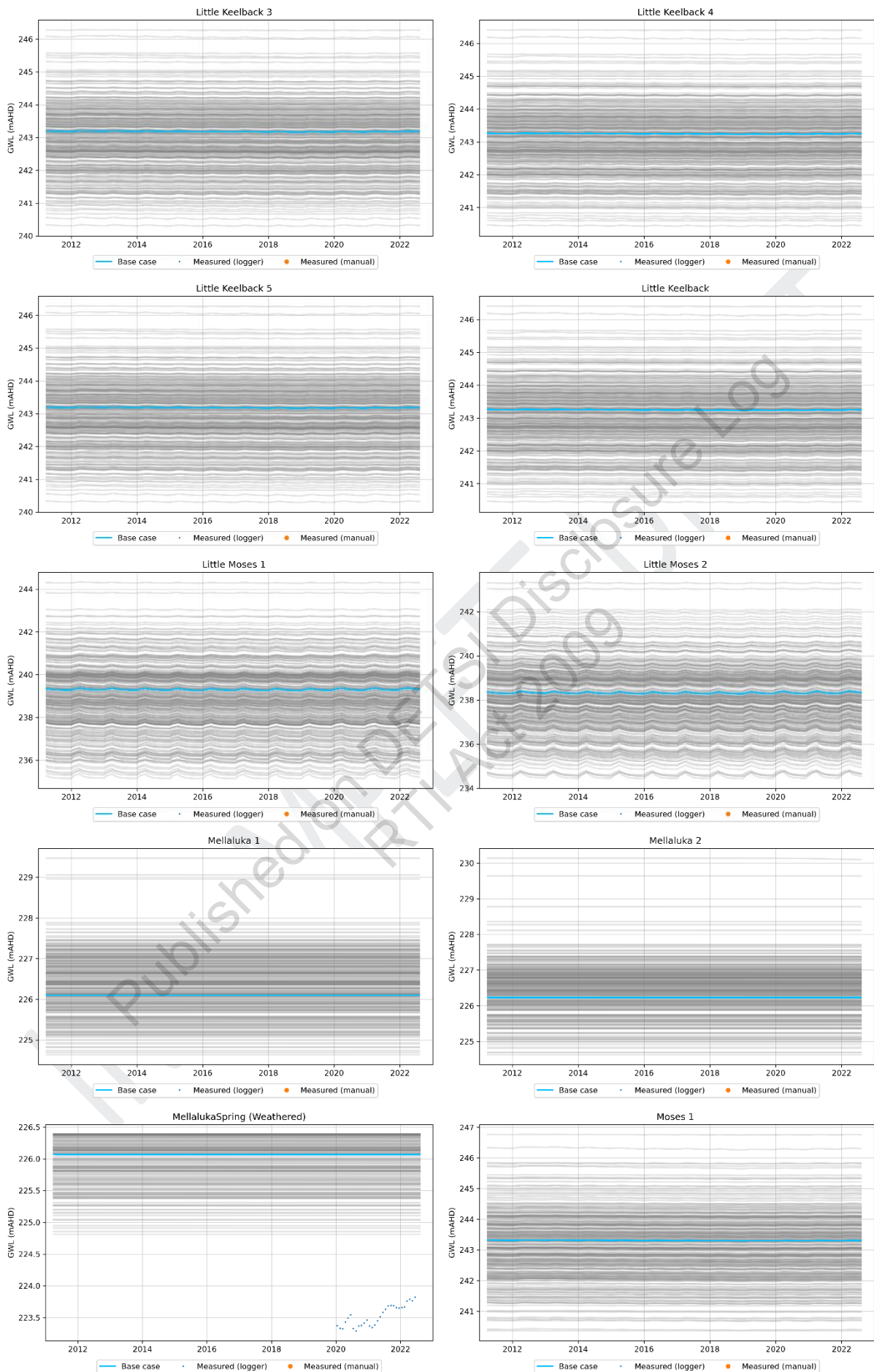


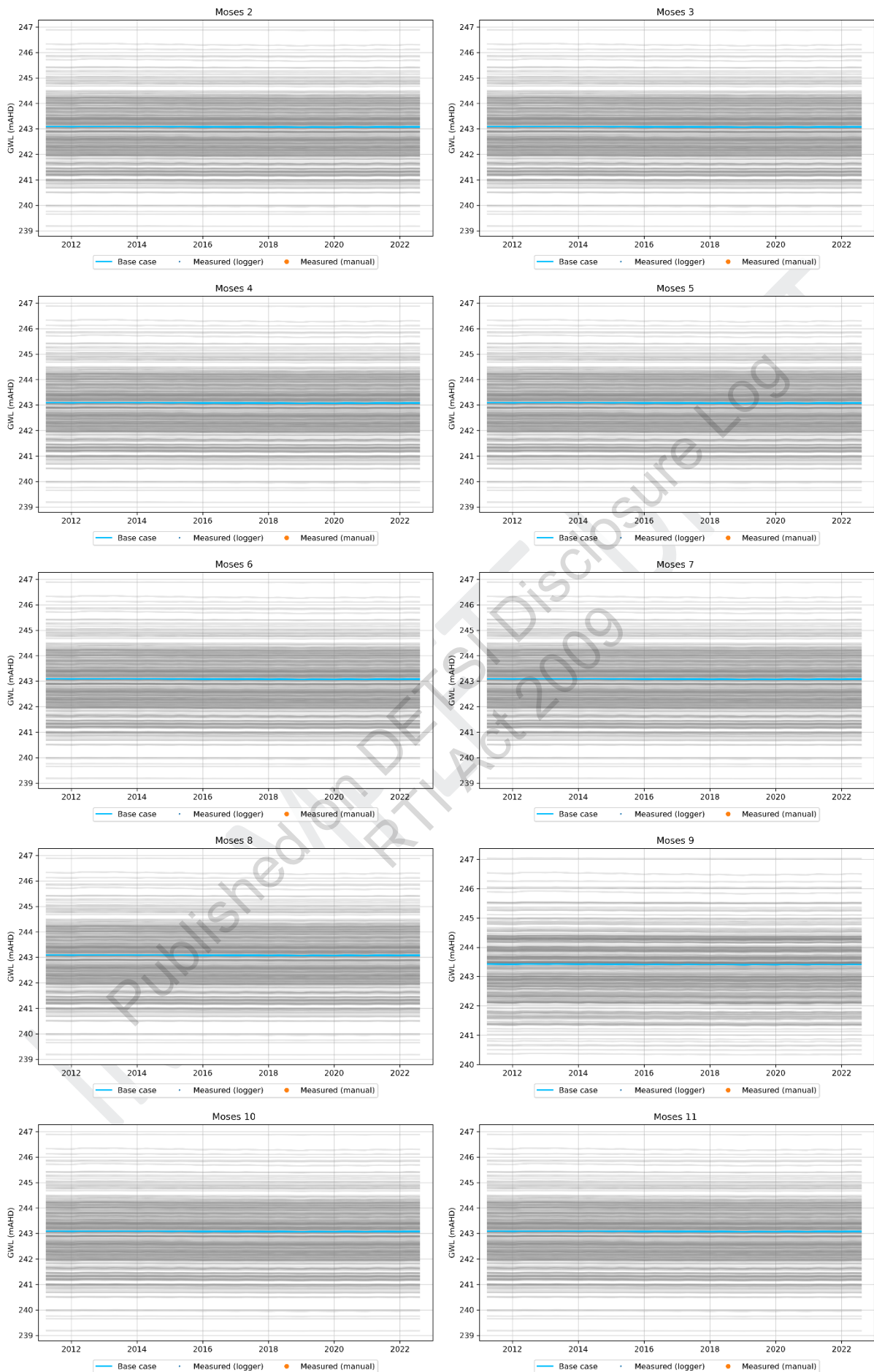


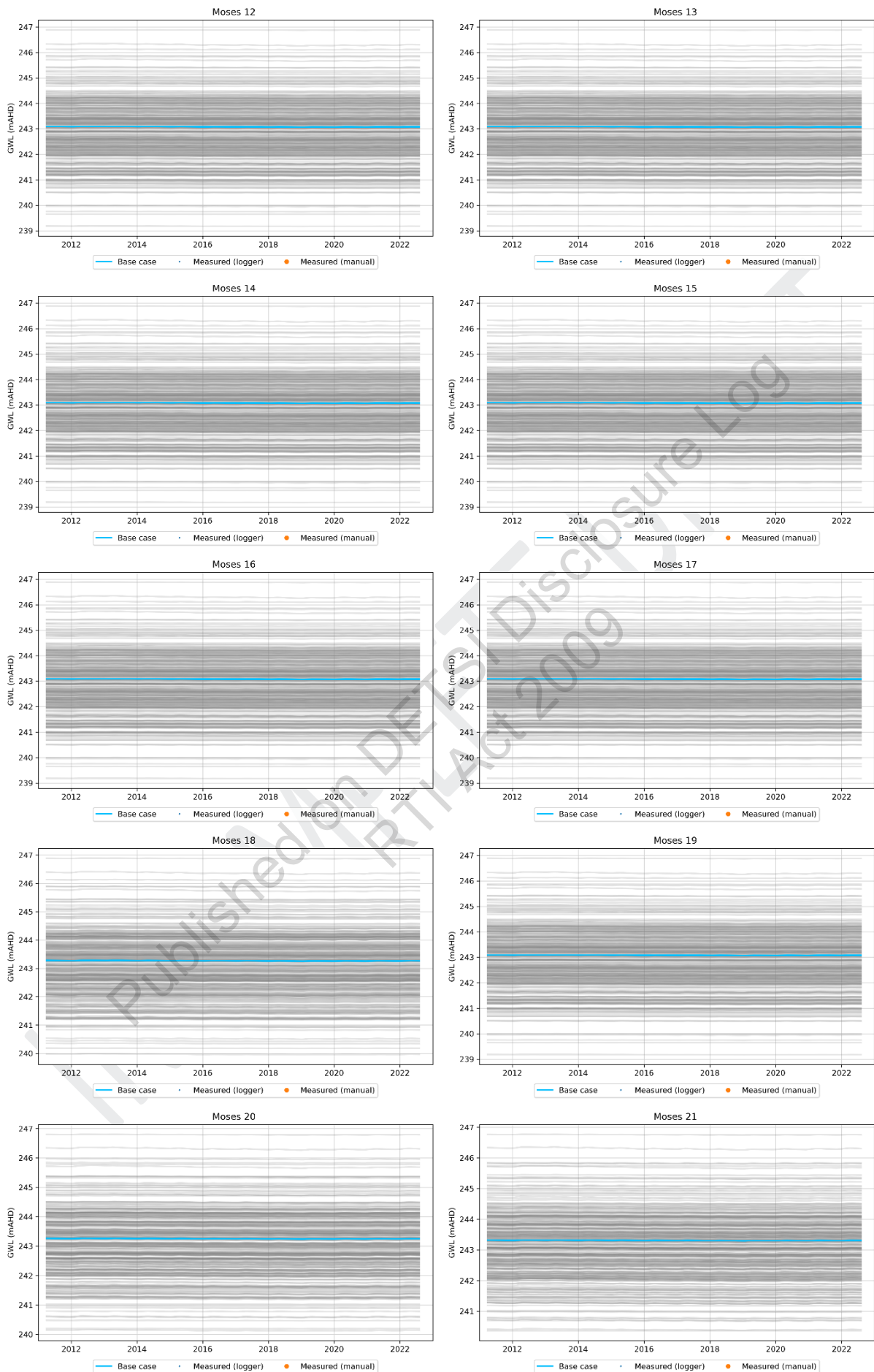


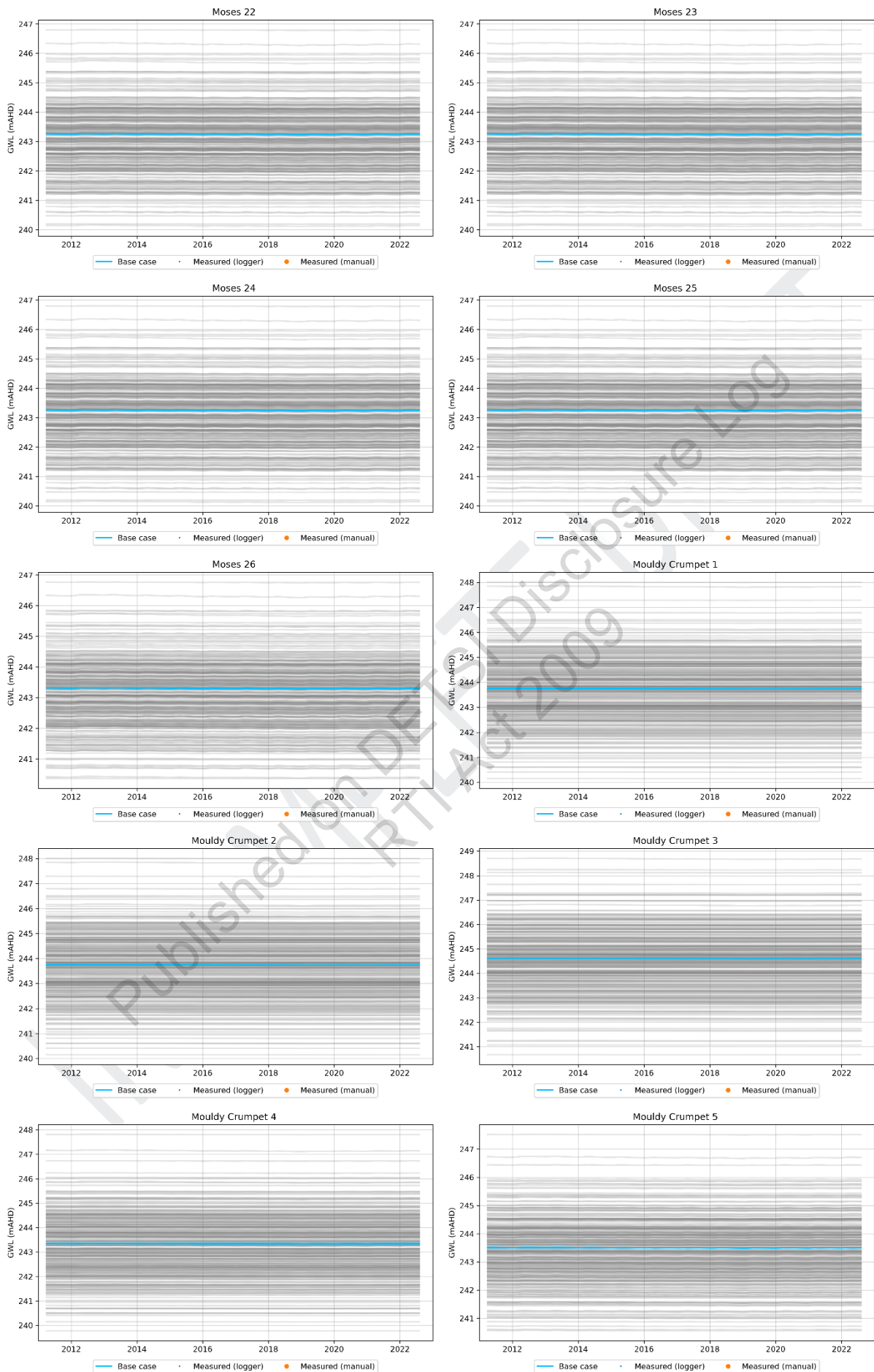


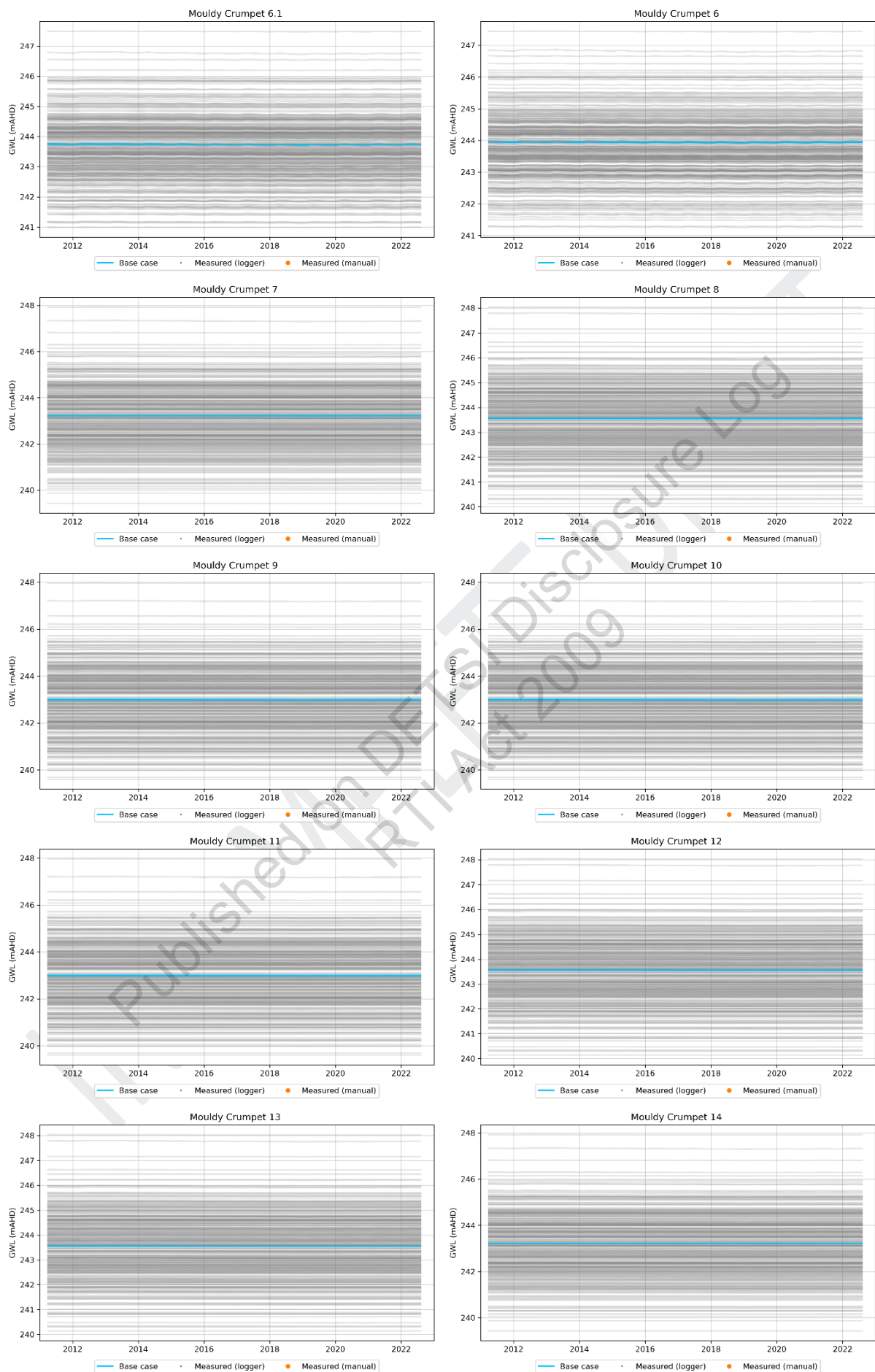


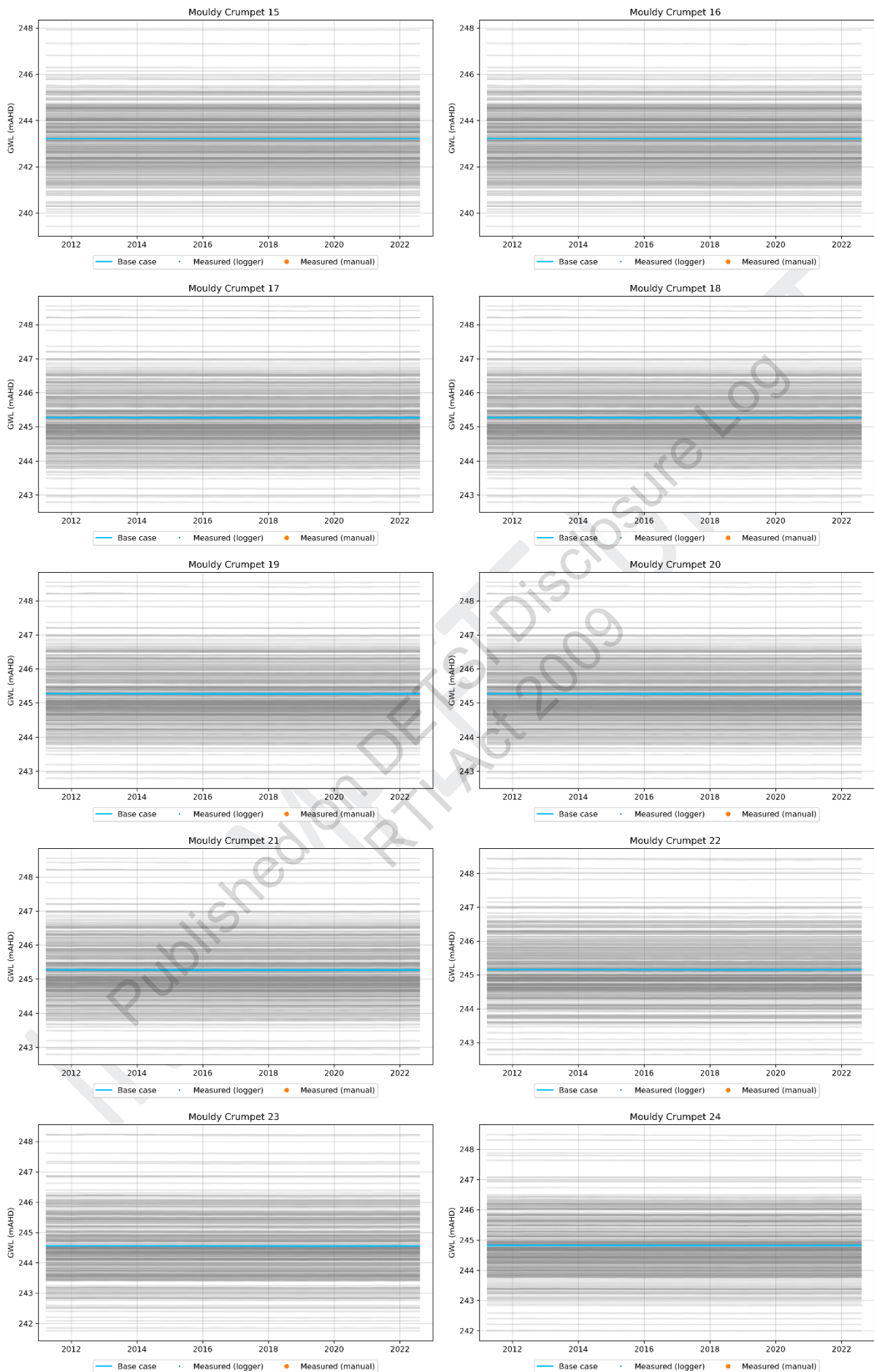


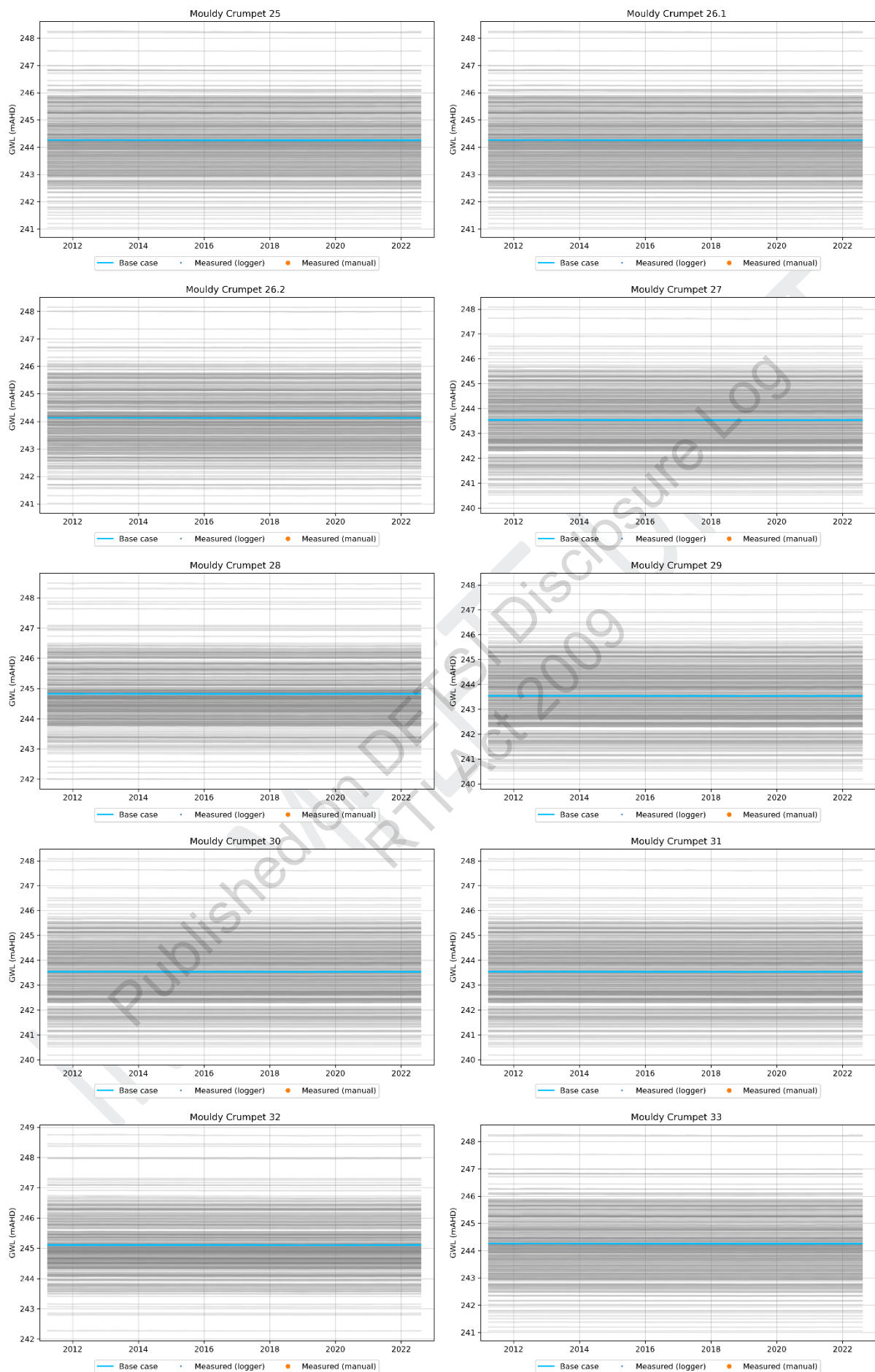


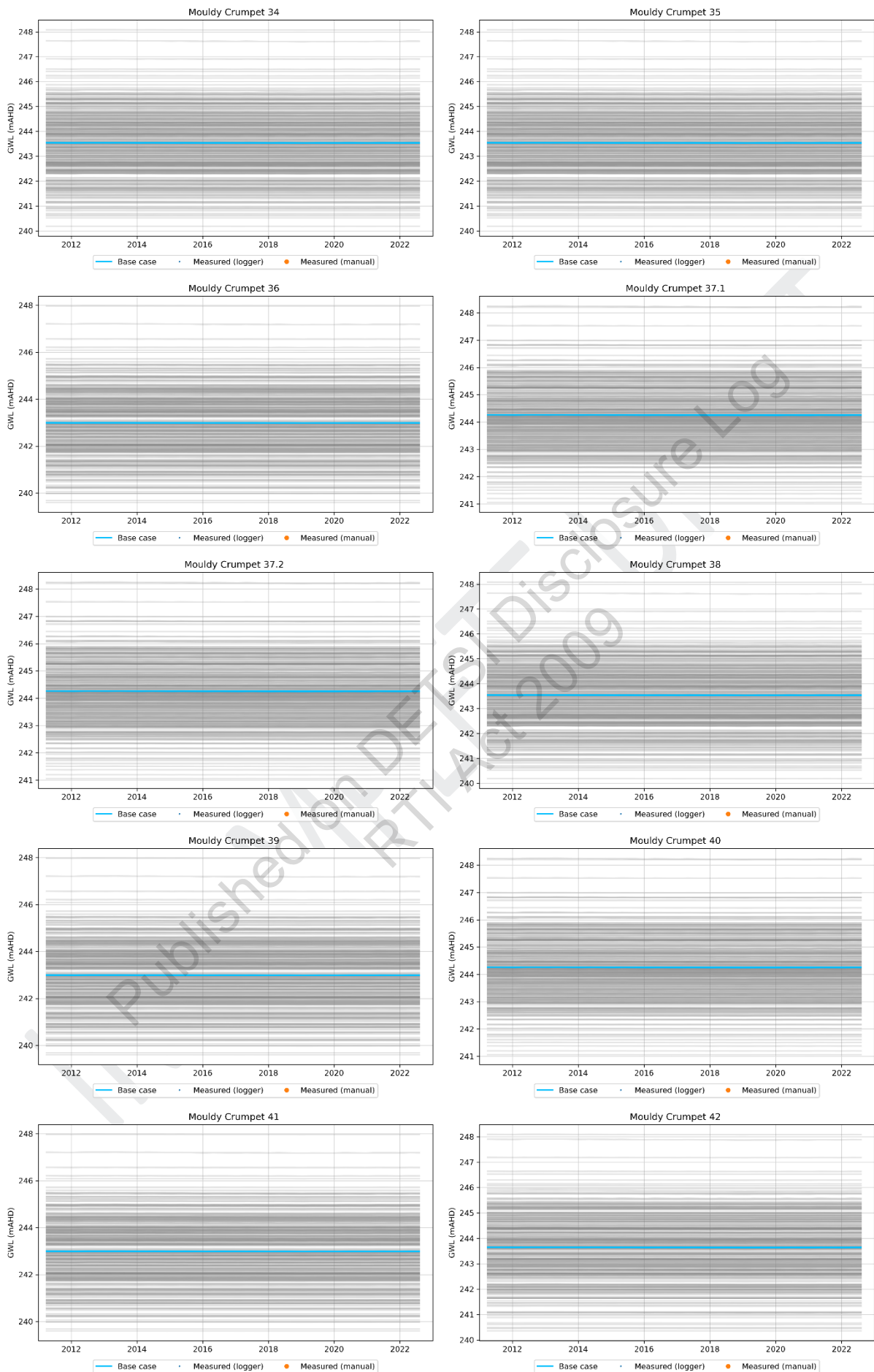


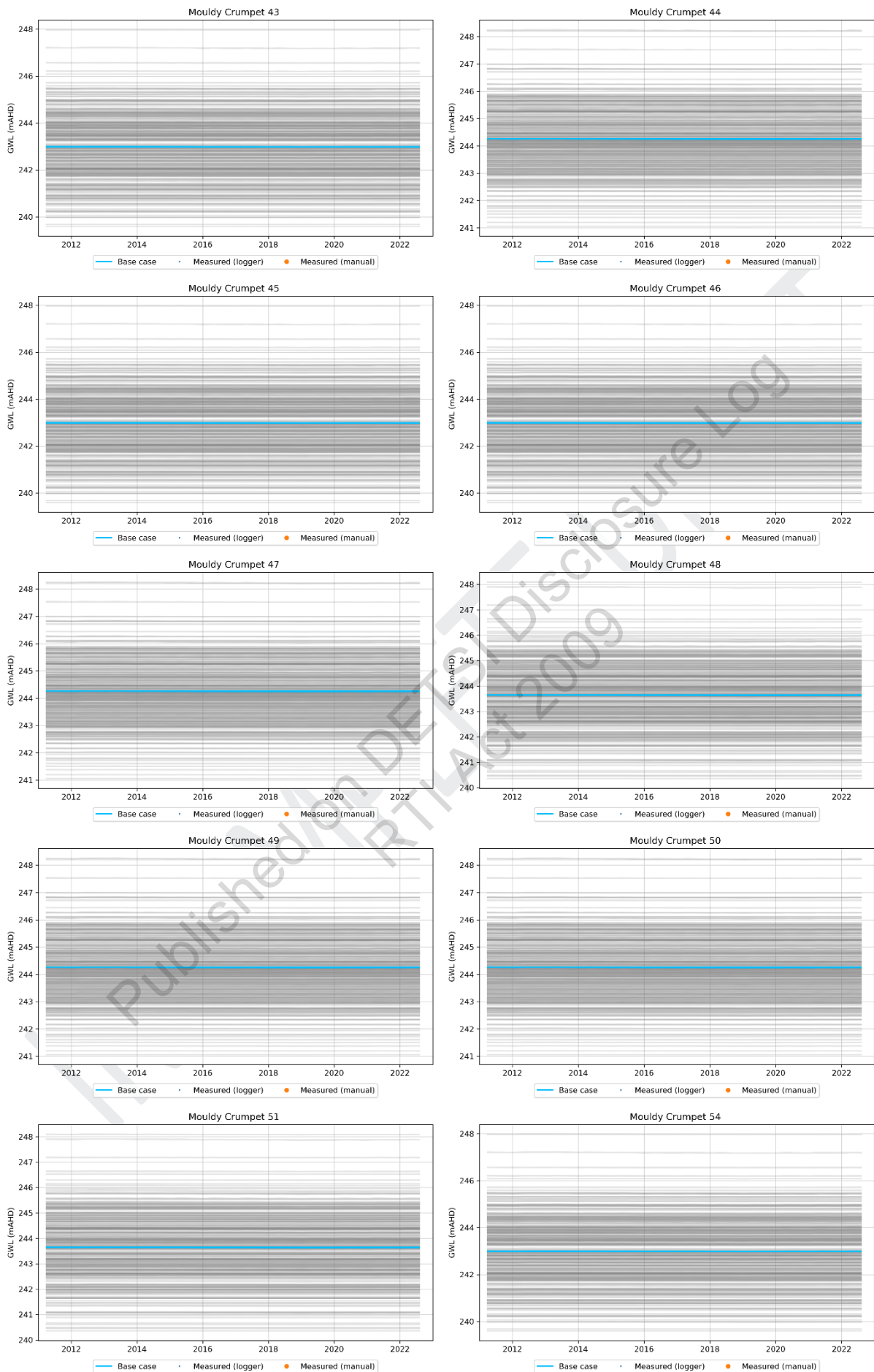


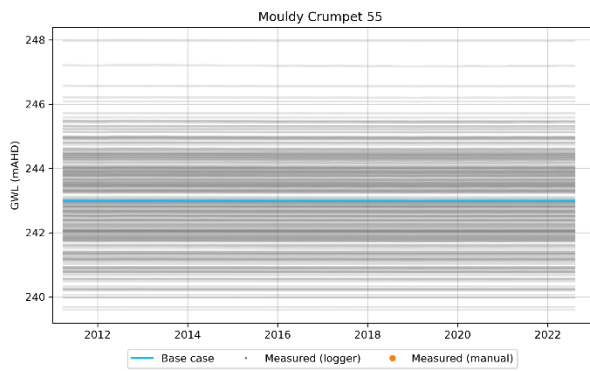
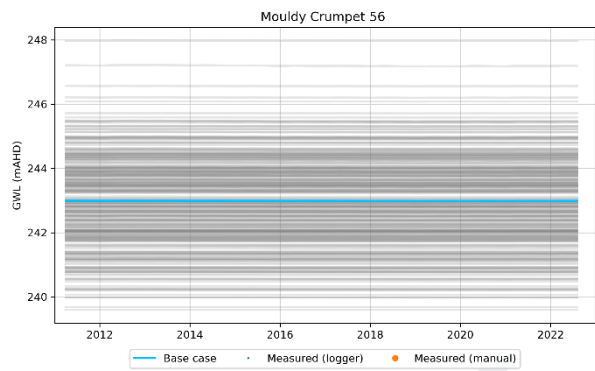
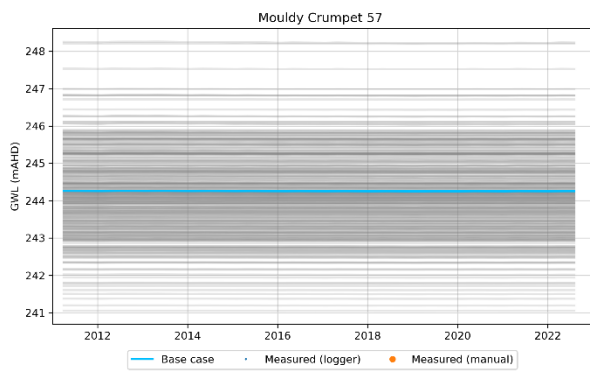
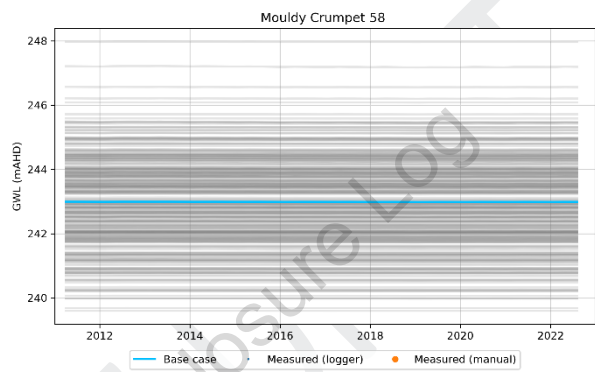
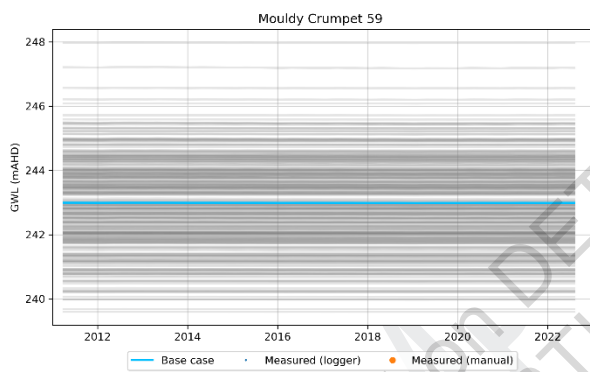
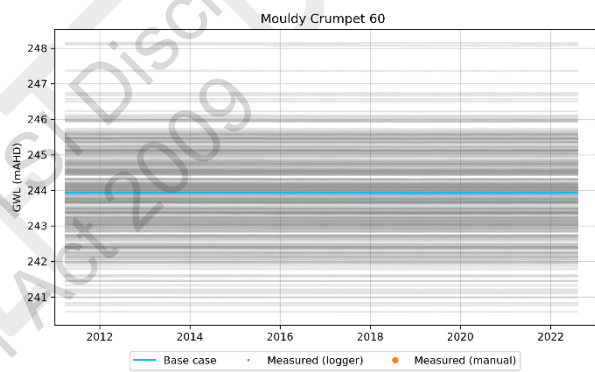
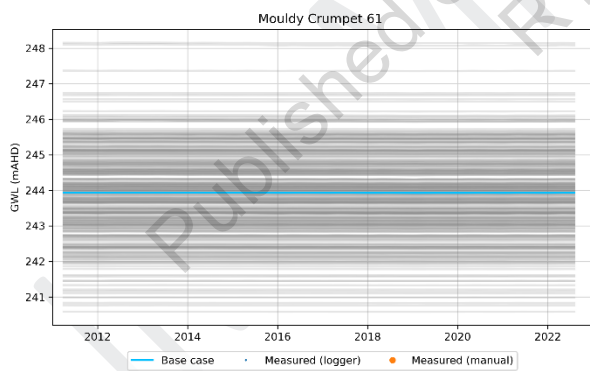
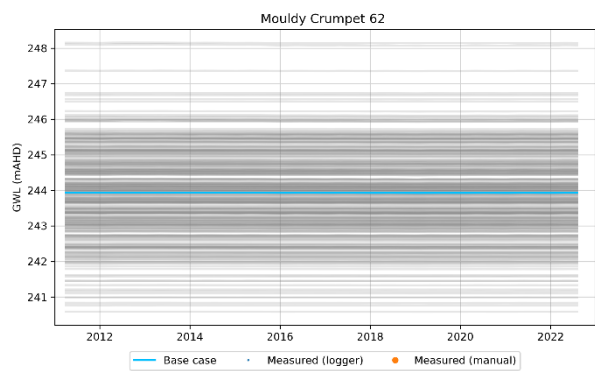
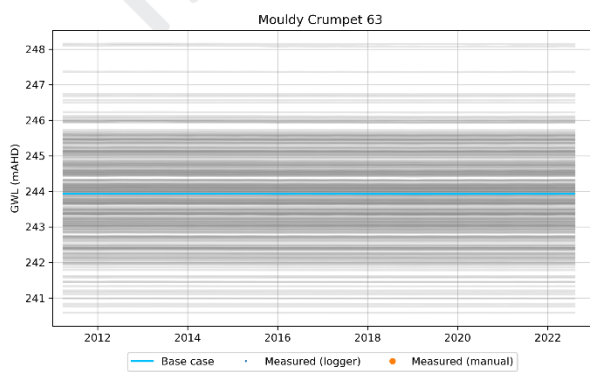
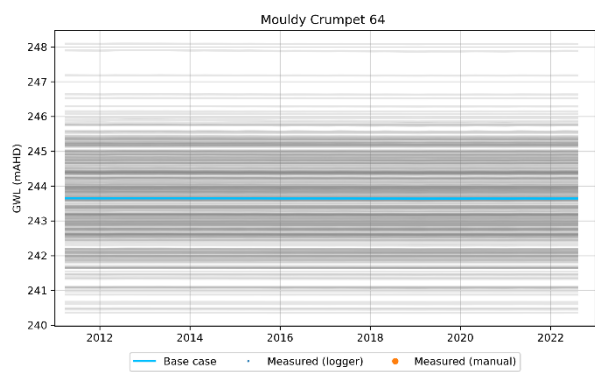


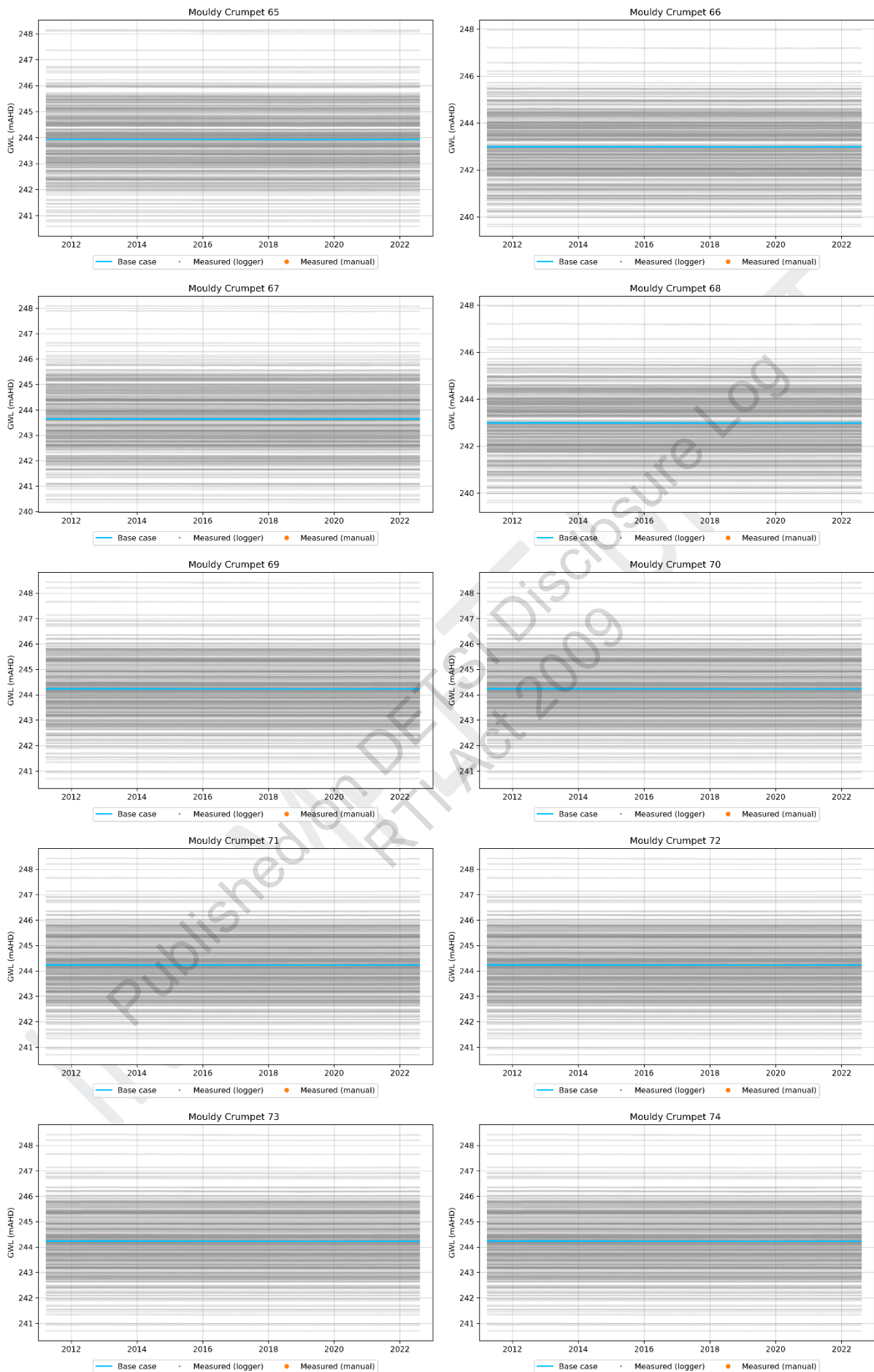


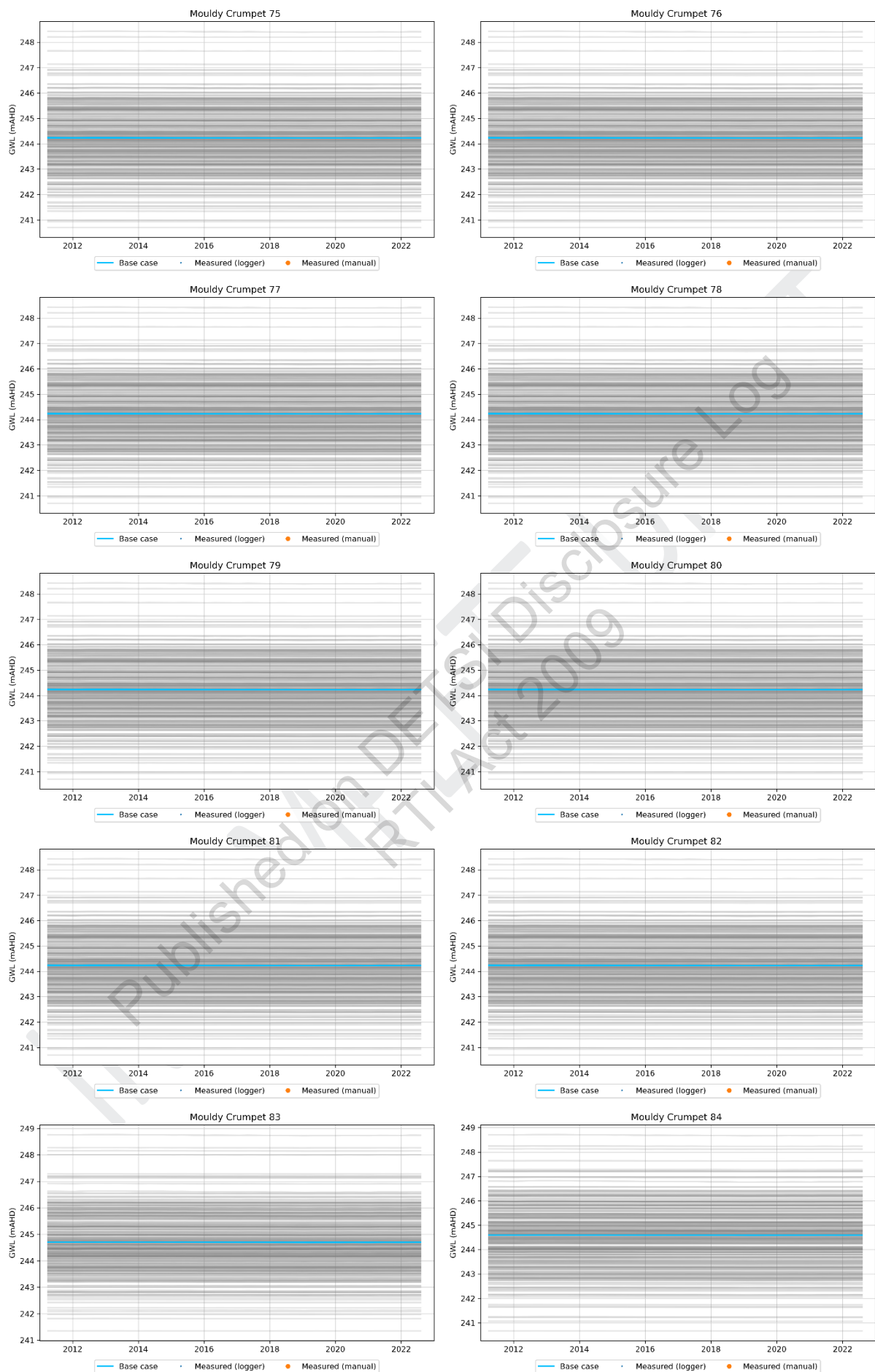


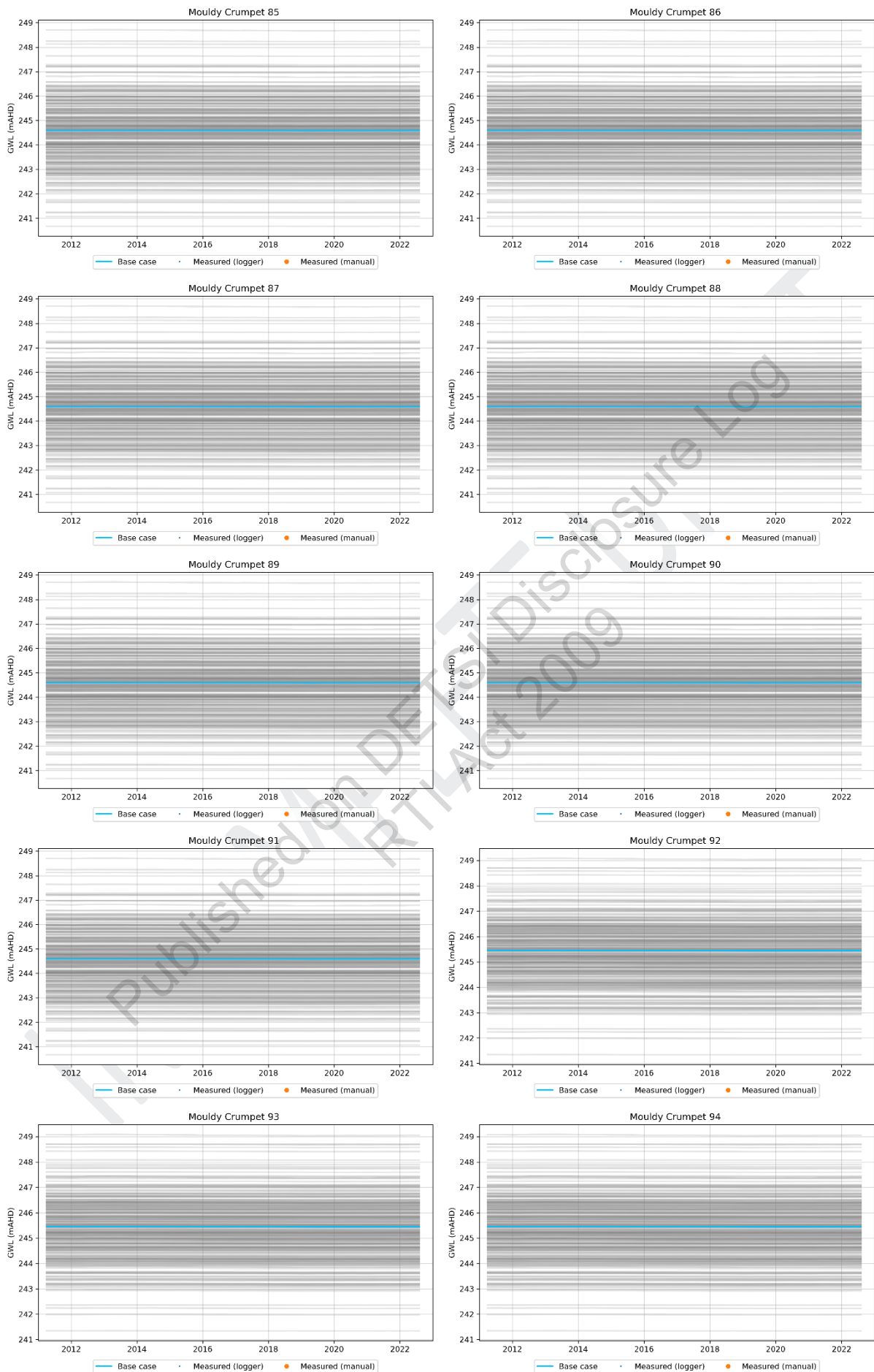


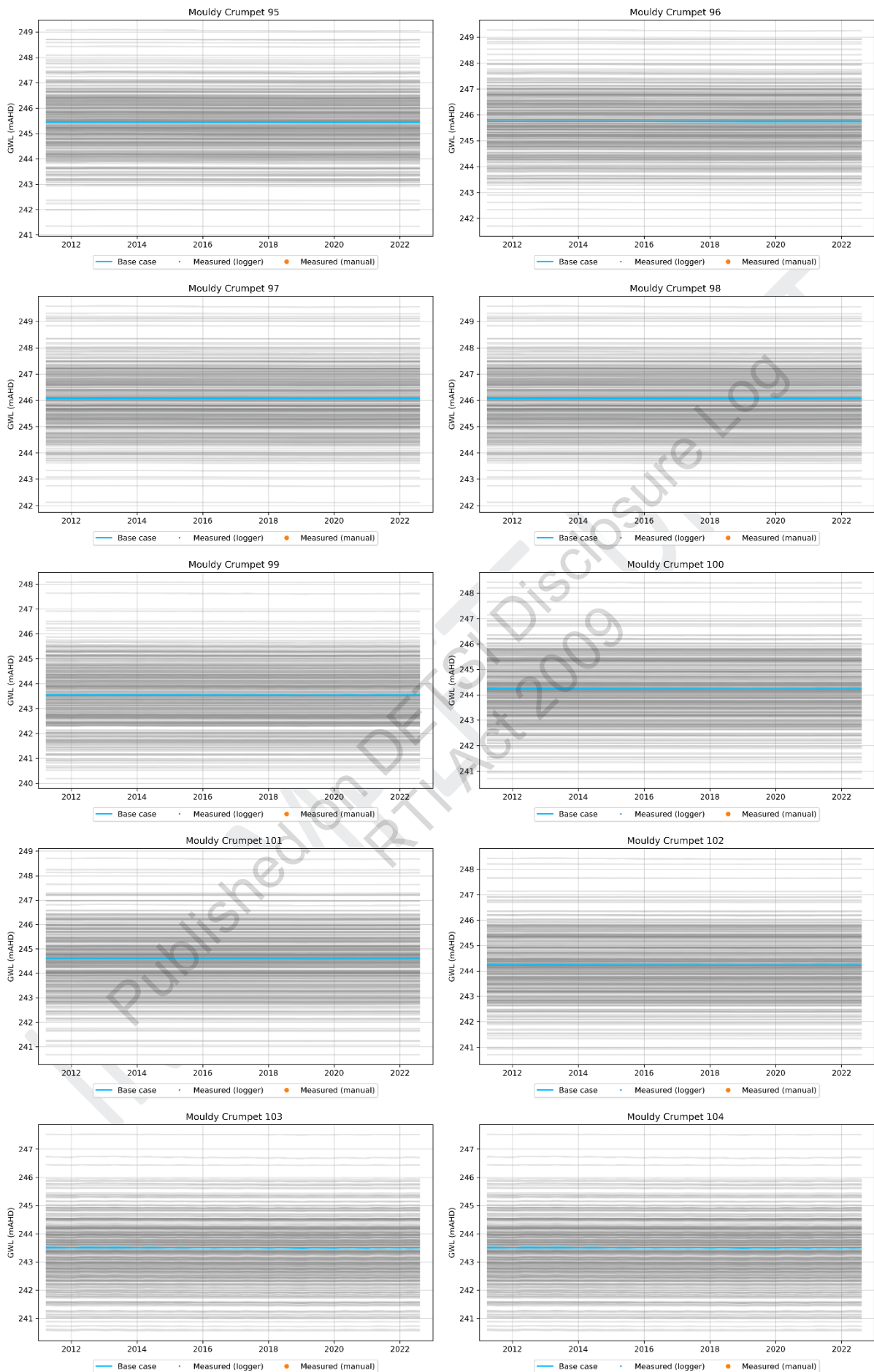


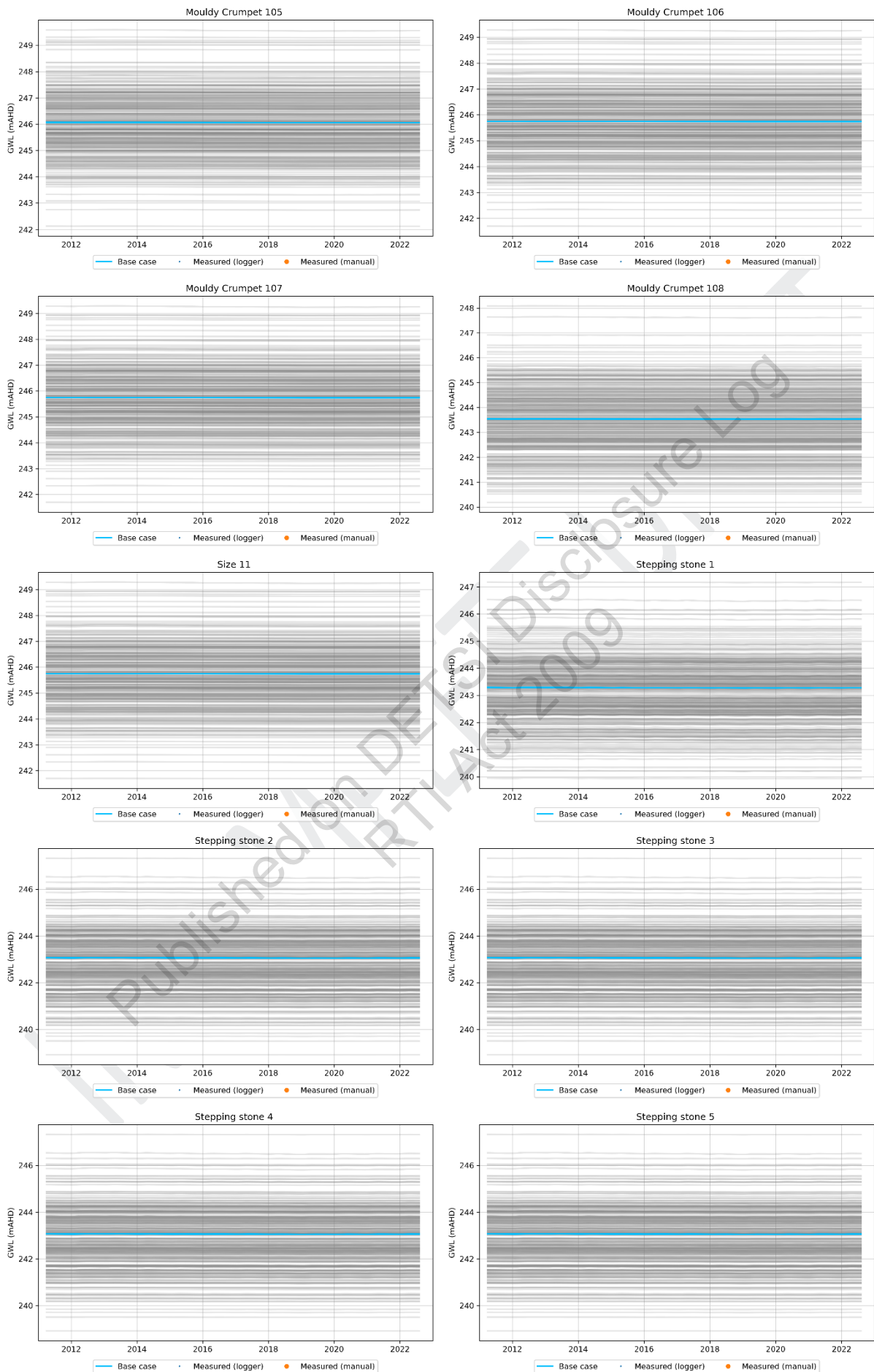


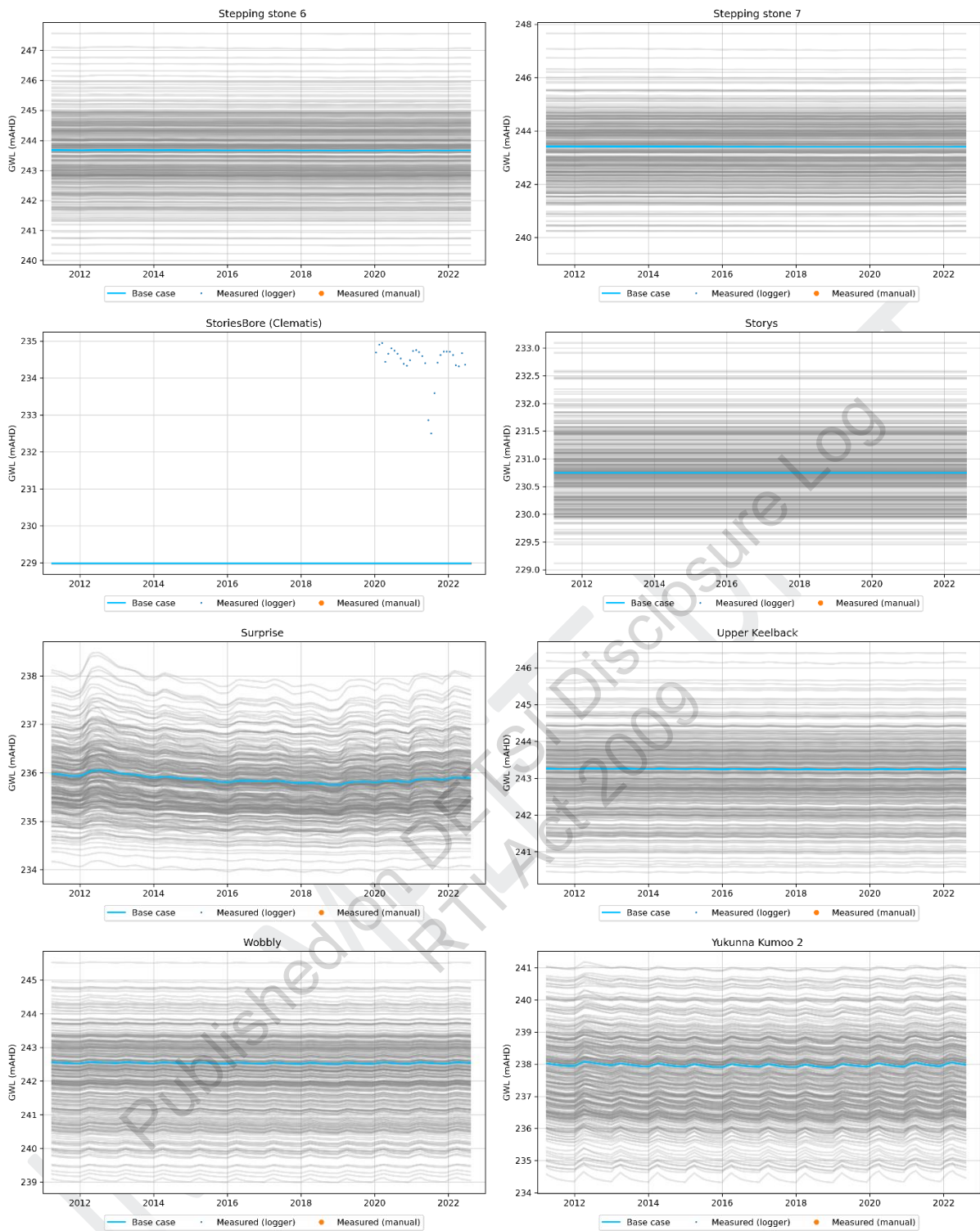


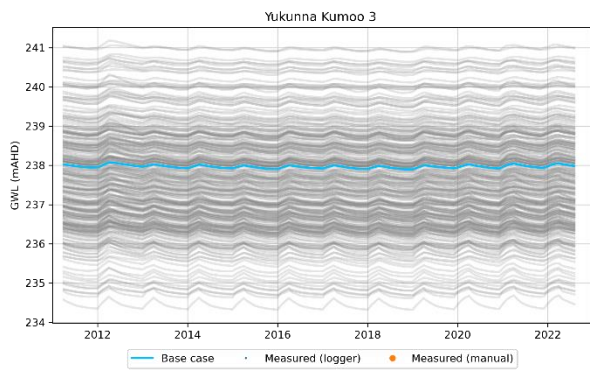
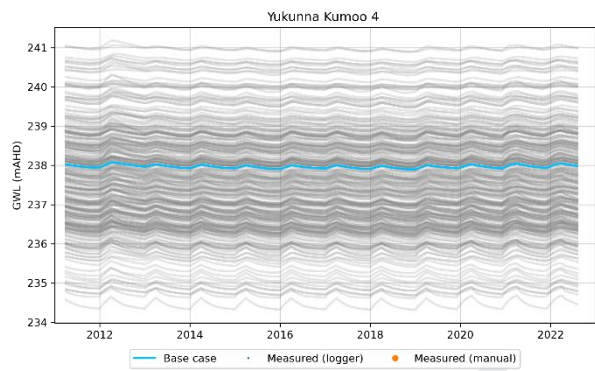
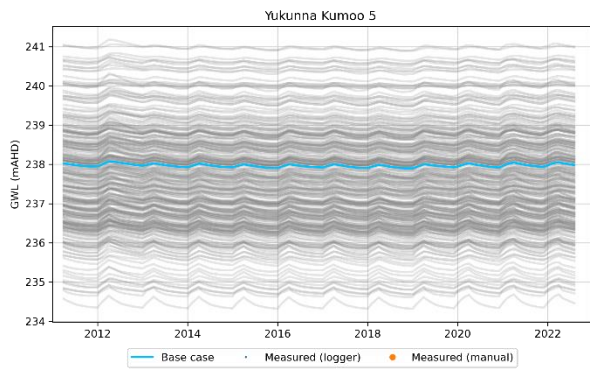
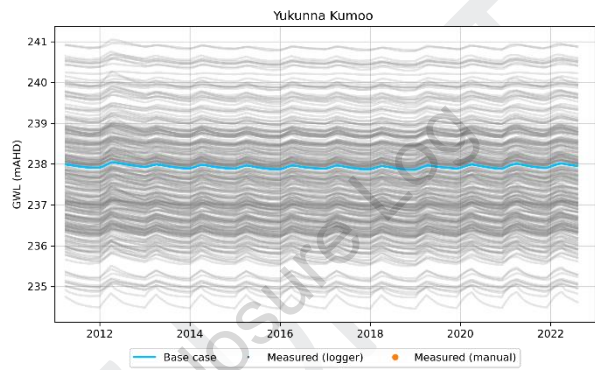












Appendix D

Hydrographs: mining

D.1 Appendix Heading

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Appendix E

Hydrographs: mining and recovery

E.1 Appendix Heading

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Appendix F

Hydrographs: predictive uncertainty drawdown

F.1 Appendix Heading

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MINING & RESOURCES

Carmichael Coal Mine Project

Groundwater Model Review - Progress Meeting - 4

Tuesday 10 January 2023

BRAVUS

MINING & RESOURCES

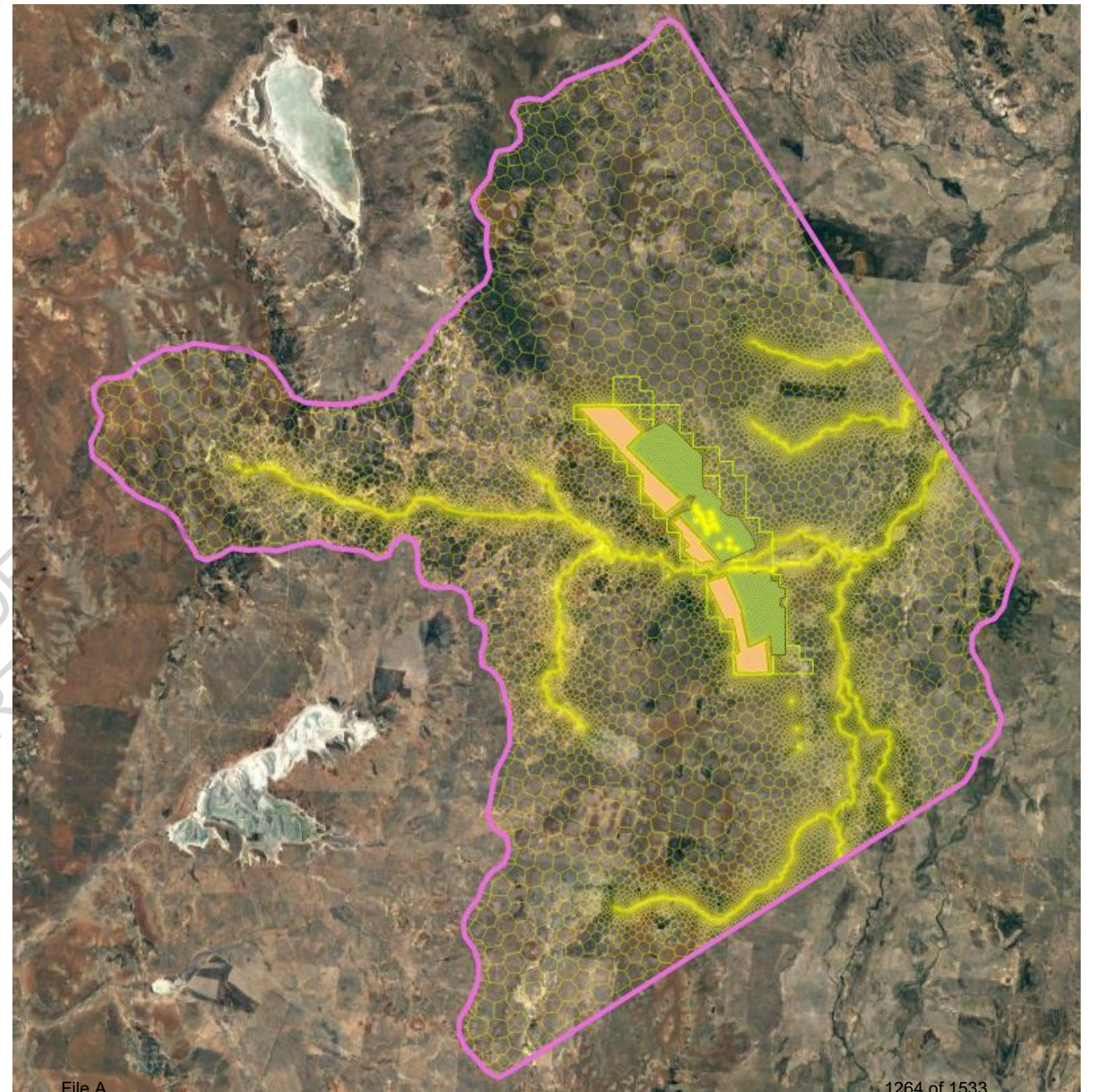
Model design information

Model design overview

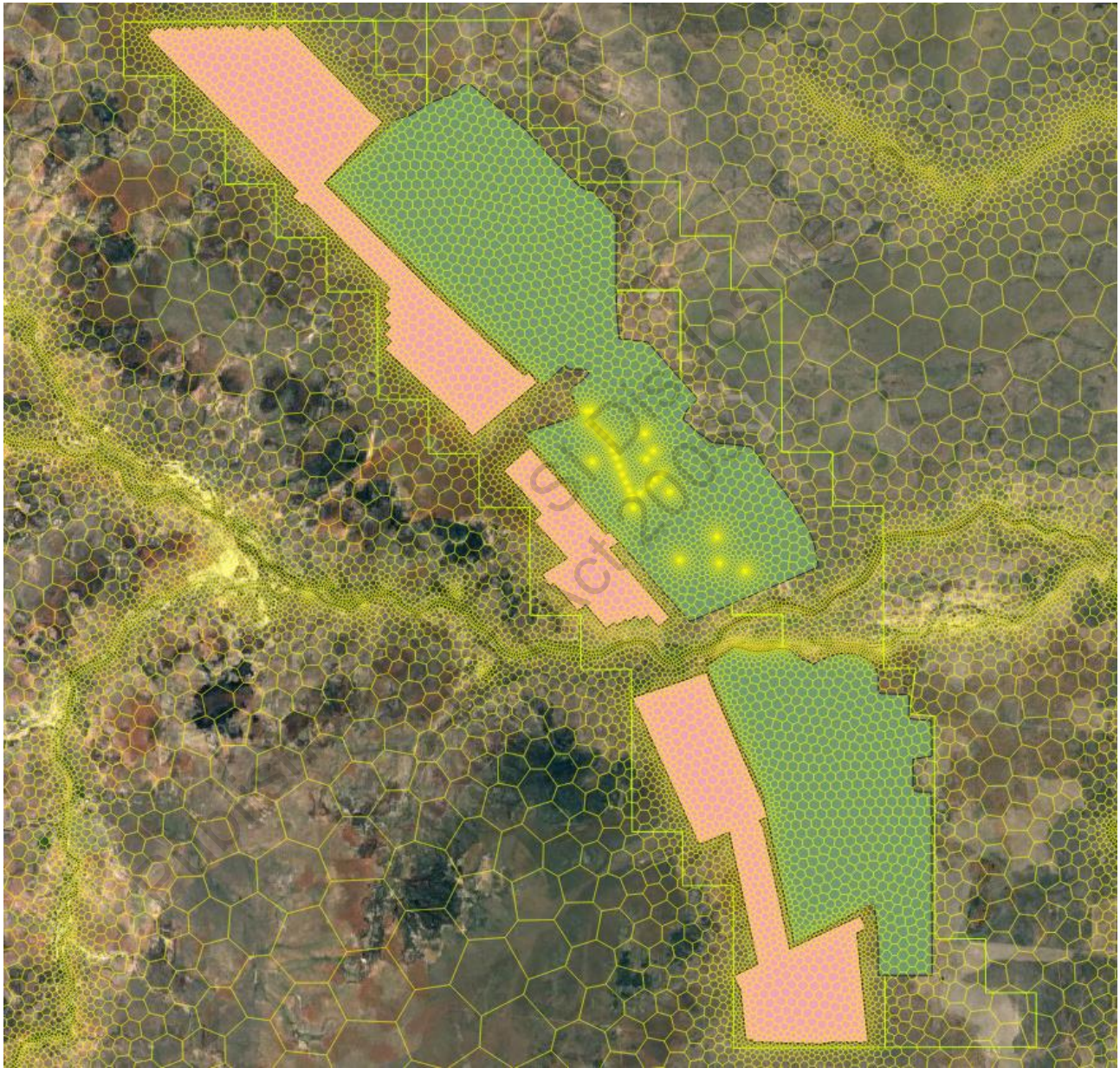
- MODFLOW-USG Transport v1.10
- Maintain domain from SEIS groundwater model
- Unstructured Voronoi polygon mesh; 34,624 nodes per layer
 - Refinement for major creeks, mapped springs, open cut and underground mine area, and dewatering bores
- 14 HSUs, one per model layer, with Rewan Formation split across 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

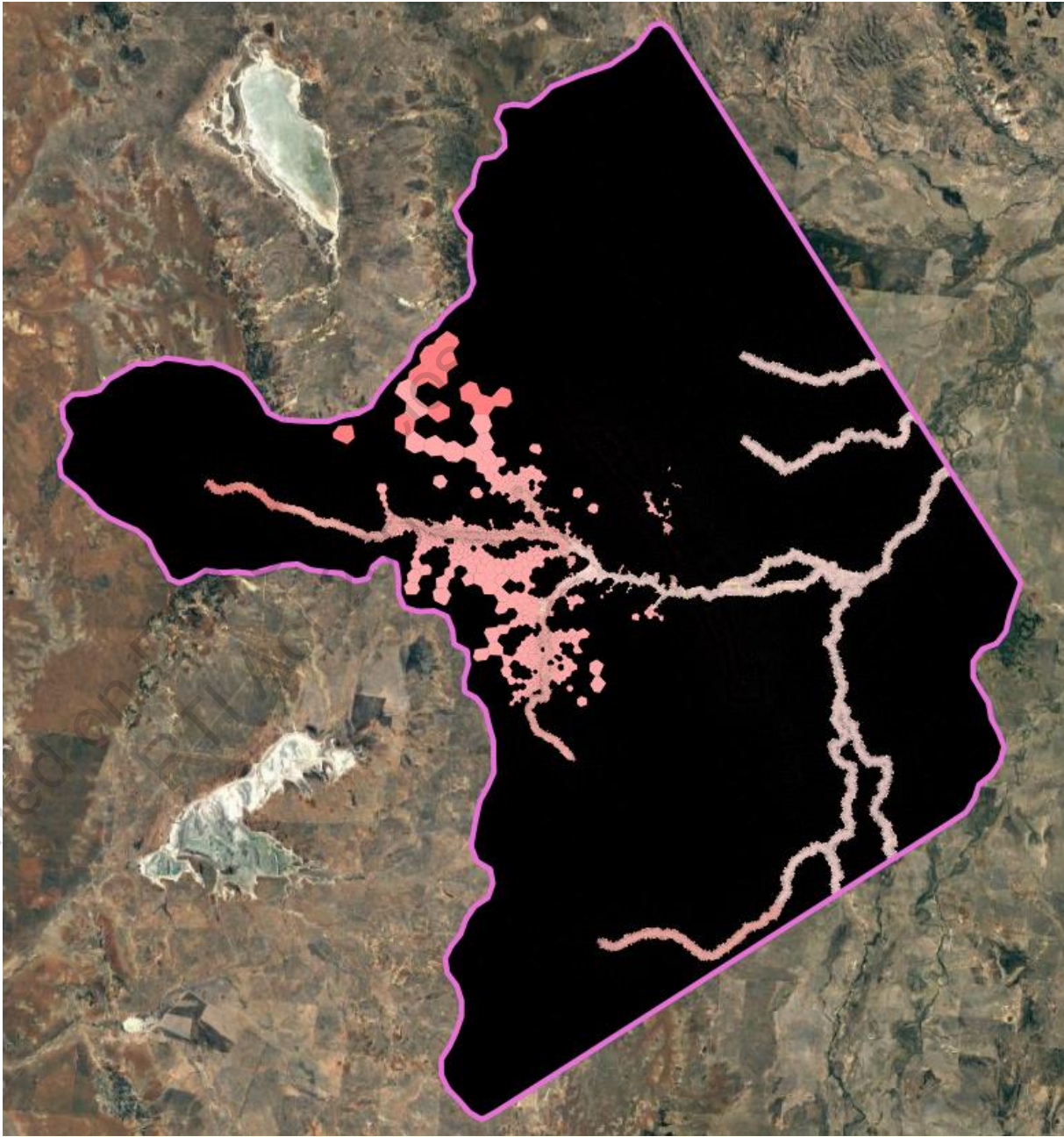
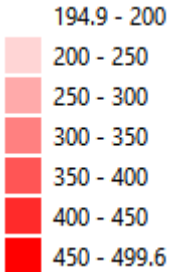
Model layer	HSU
1	Quaternary alluvium
2	Weathering zone
3	Tertiary and non-alluvial Quaternary deposits
4	Moolayember Formation
5	Clematis Sandstone / Warang Sandstone
6	Dunda Beds
7	Rewan Formation (upper)
8	Rewan Formation (lower)
9	Bandanna Formation
10	Bandanna Formation (AB Seam coal)
11	Bandanna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

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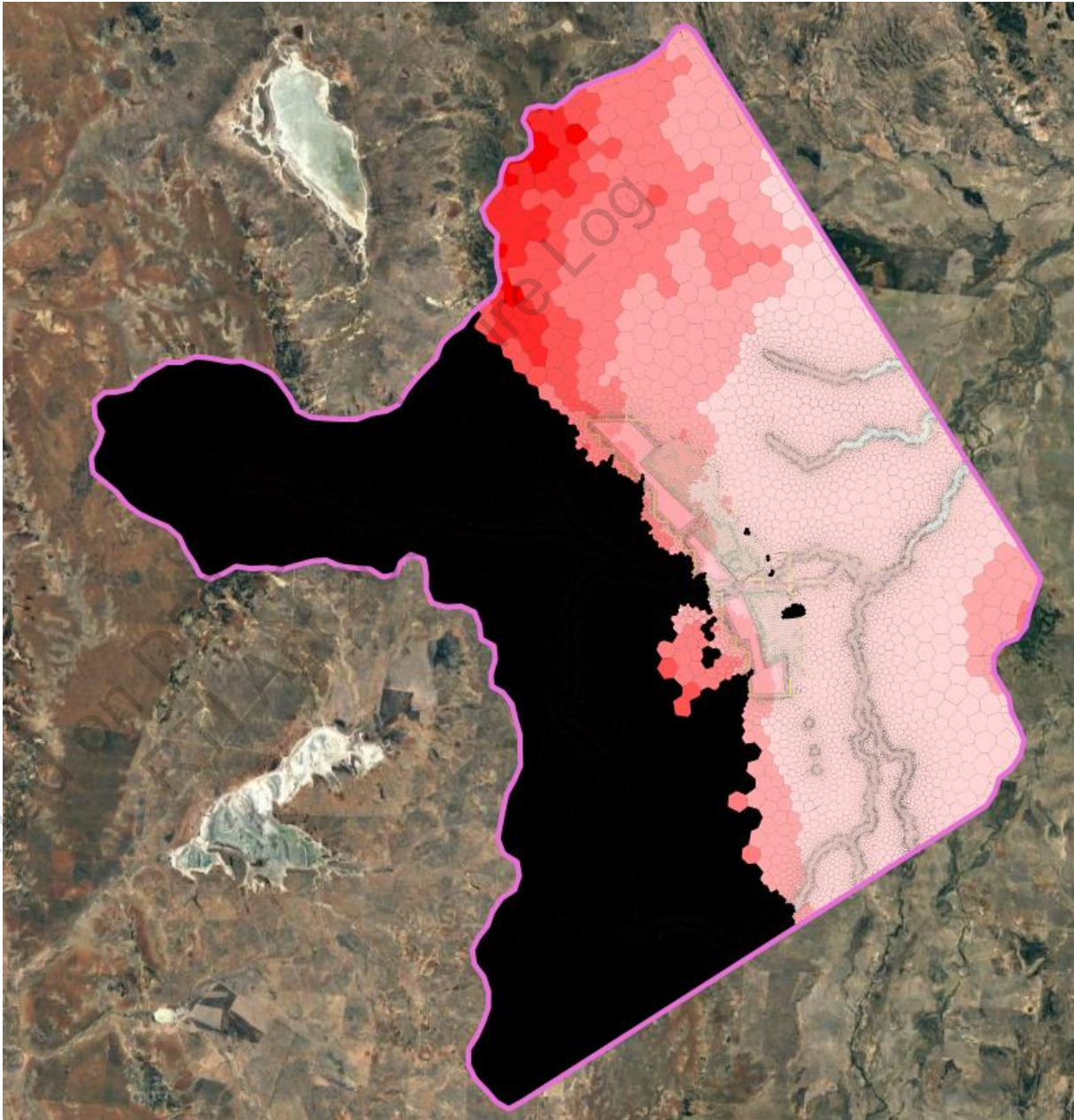
File A

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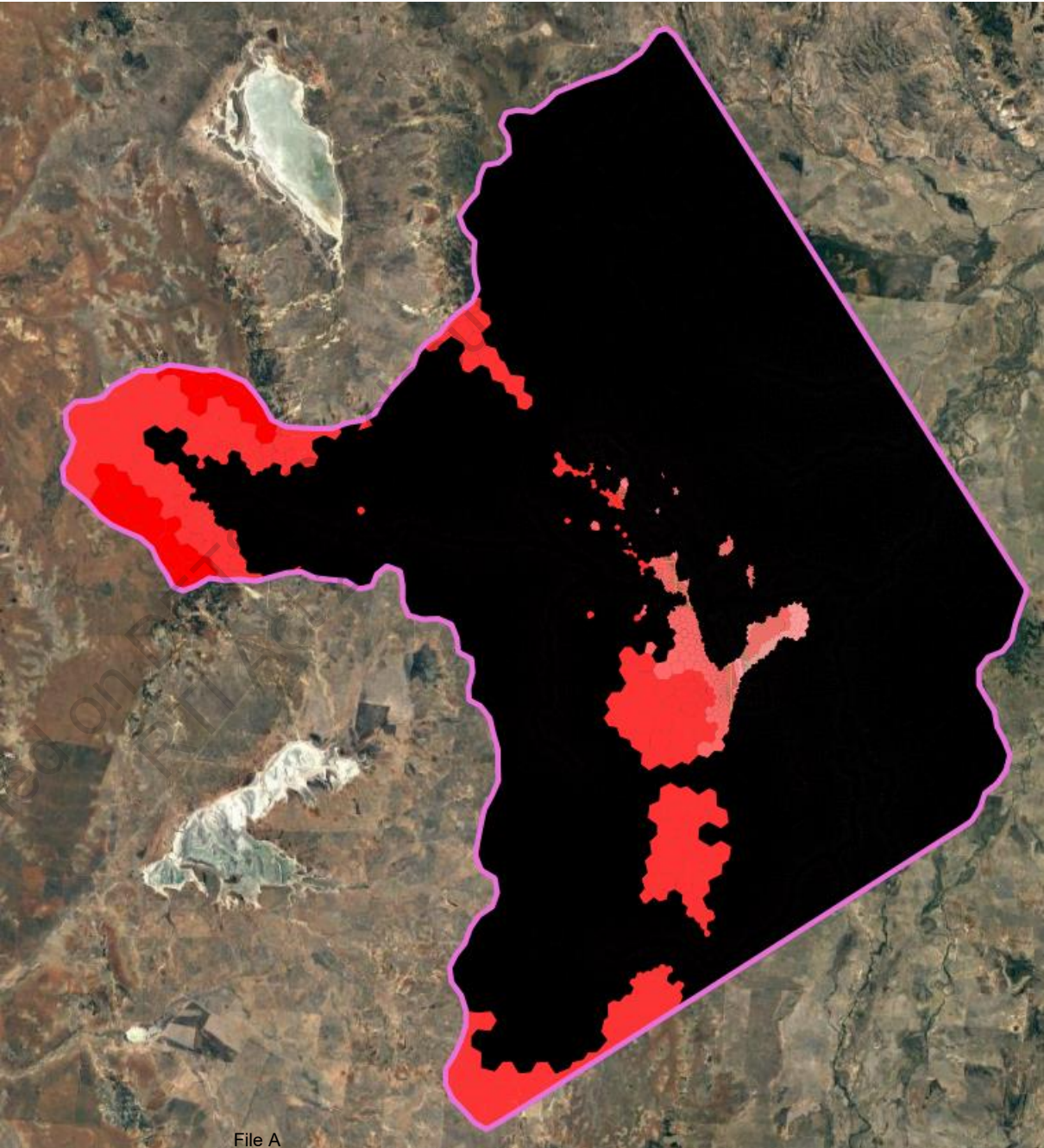
Alluvium top (mAHD)



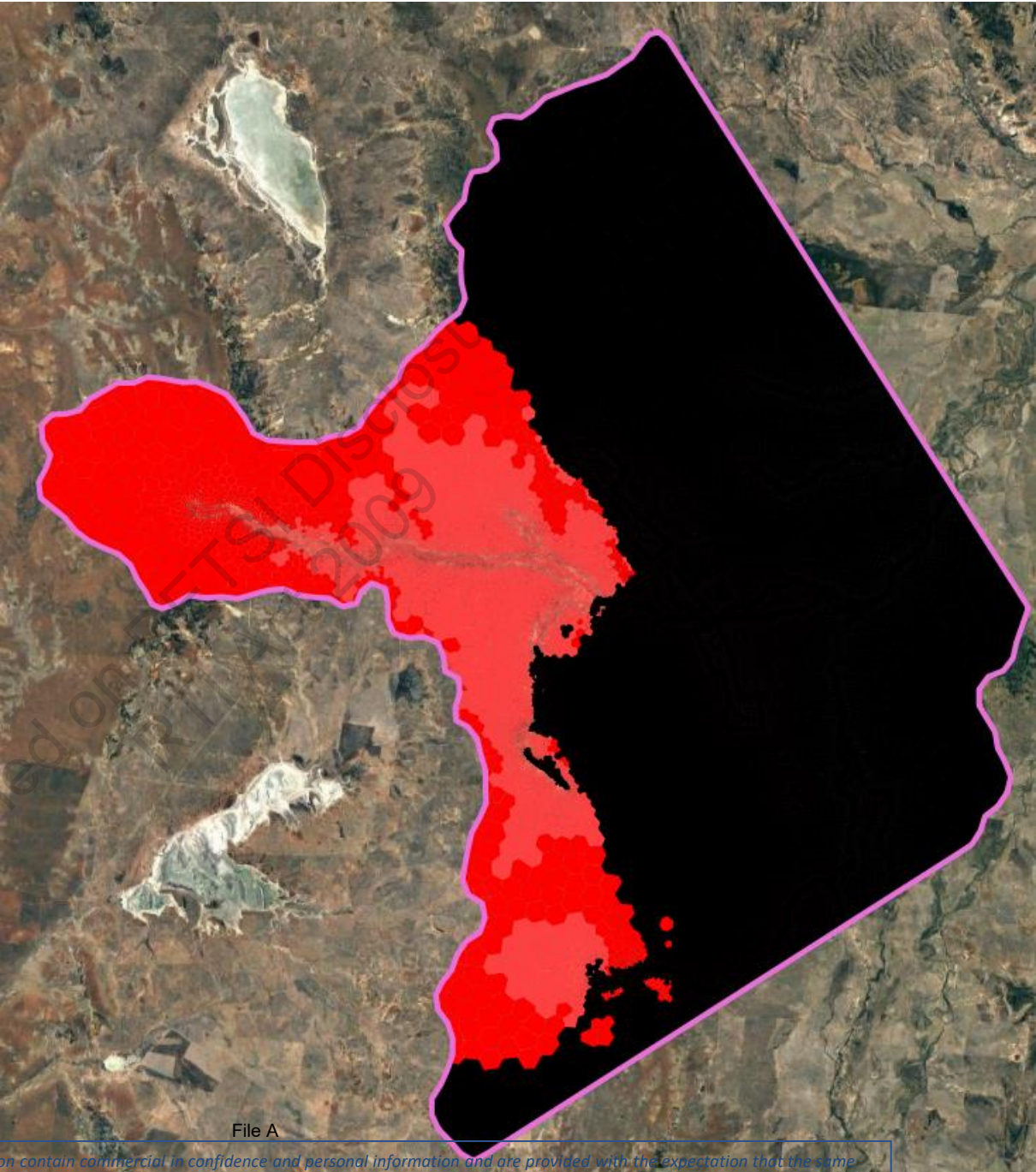
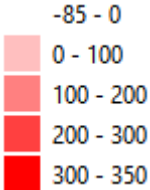
Weathering zone top (mAHD)



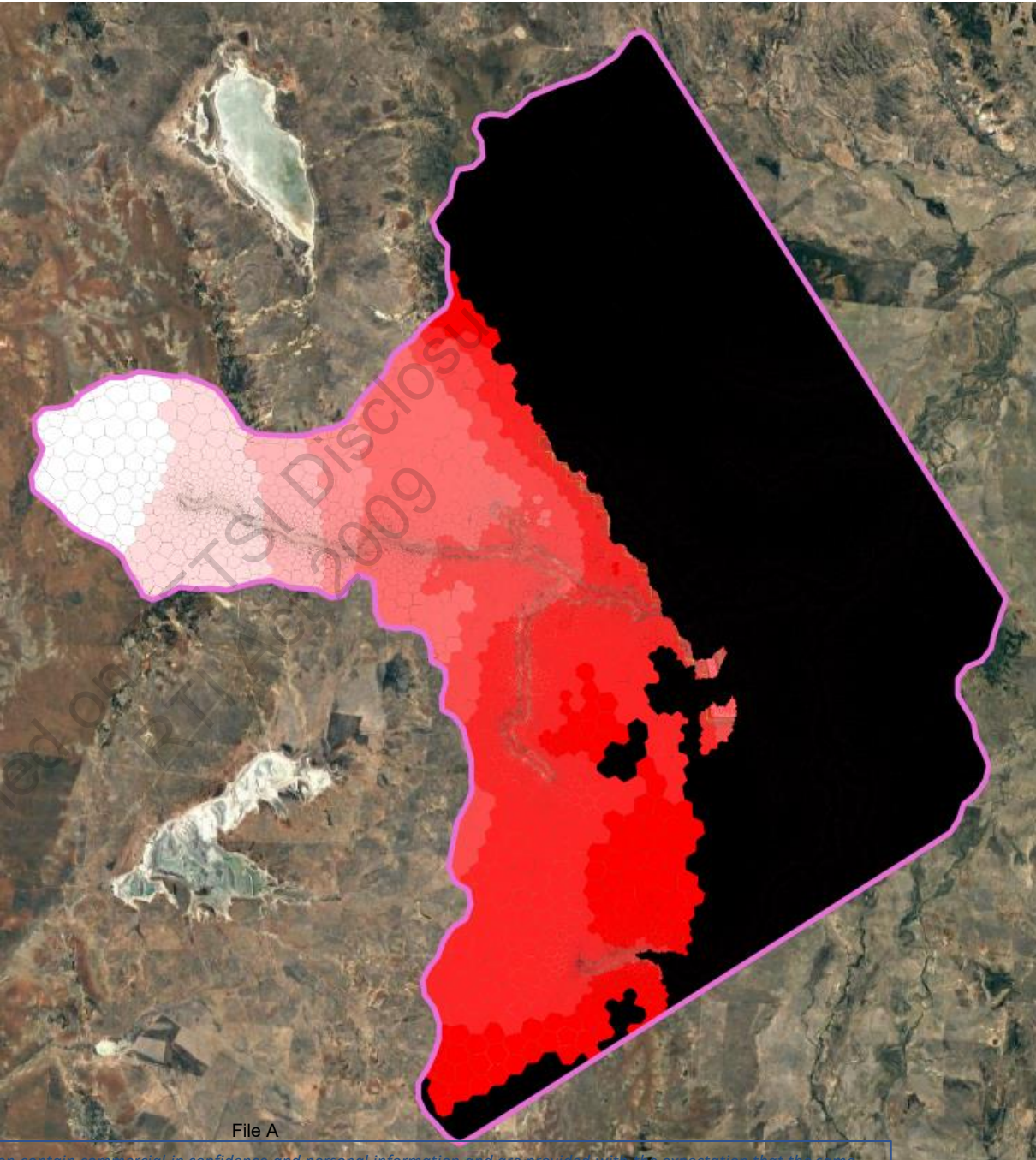
Tertiary top (mAHD)



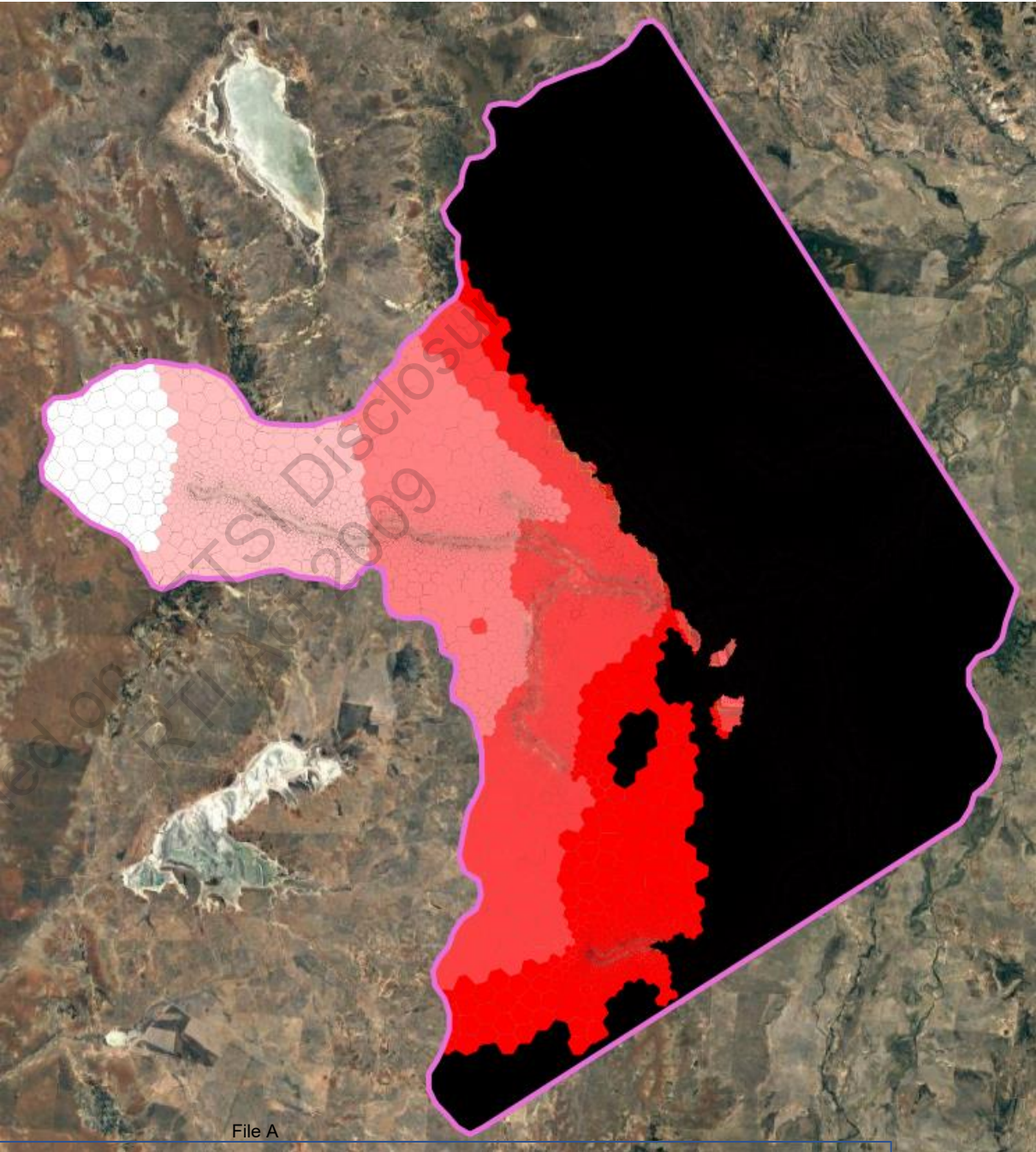
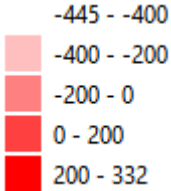
Moolayember top (mAHD)



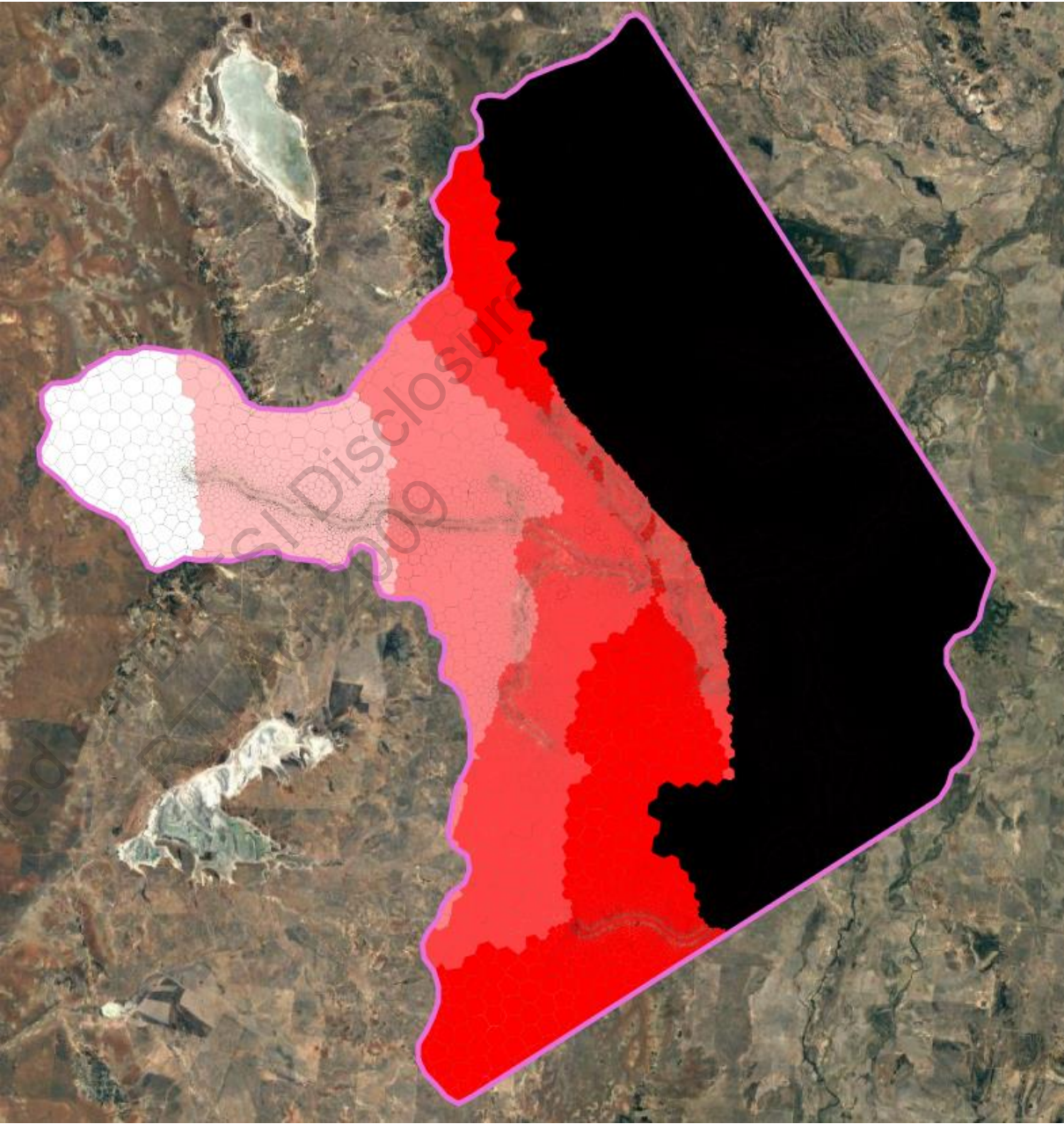
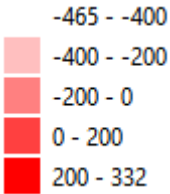
Clematis top (mAHD)



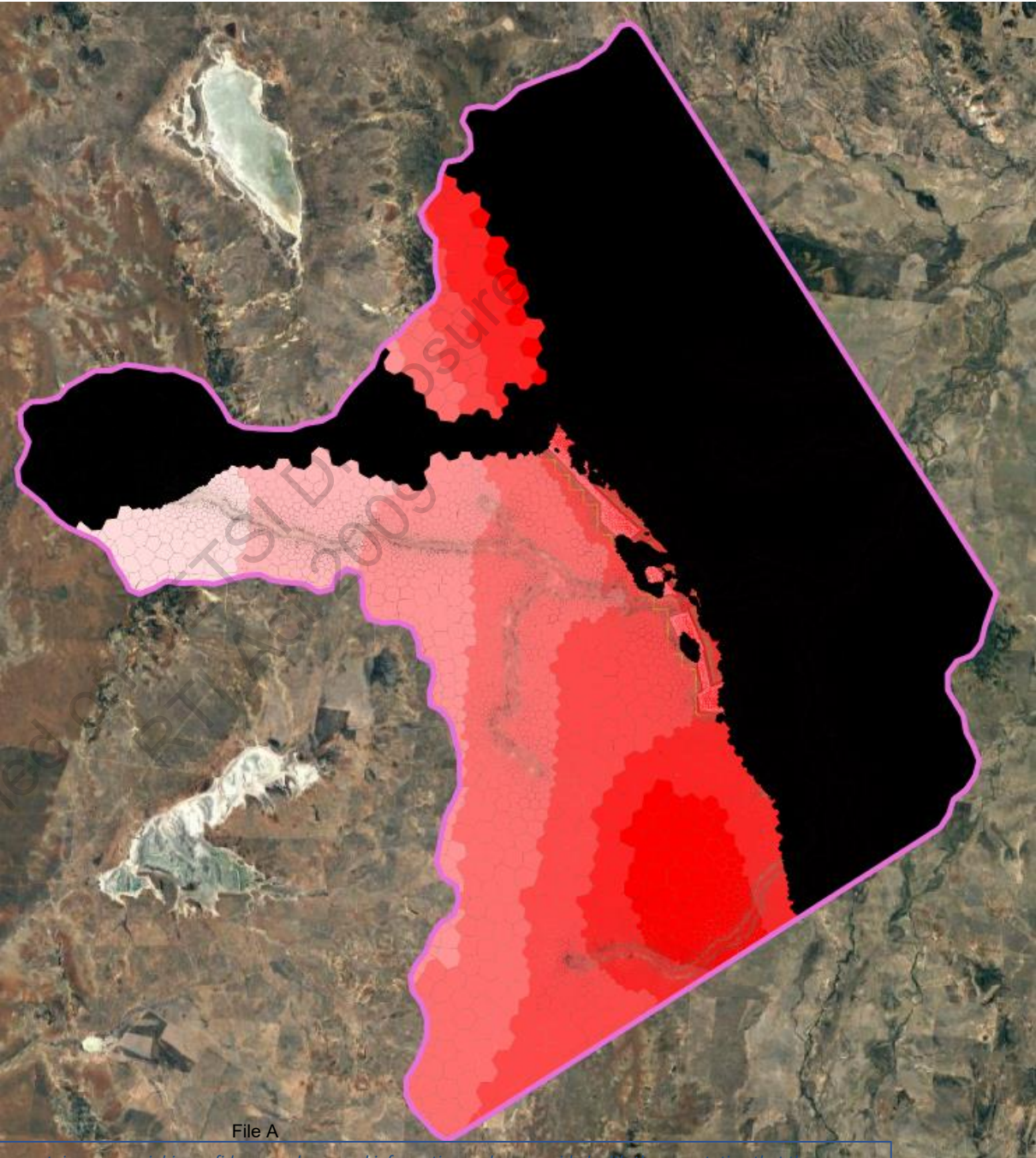
Dunda top (mAHD)



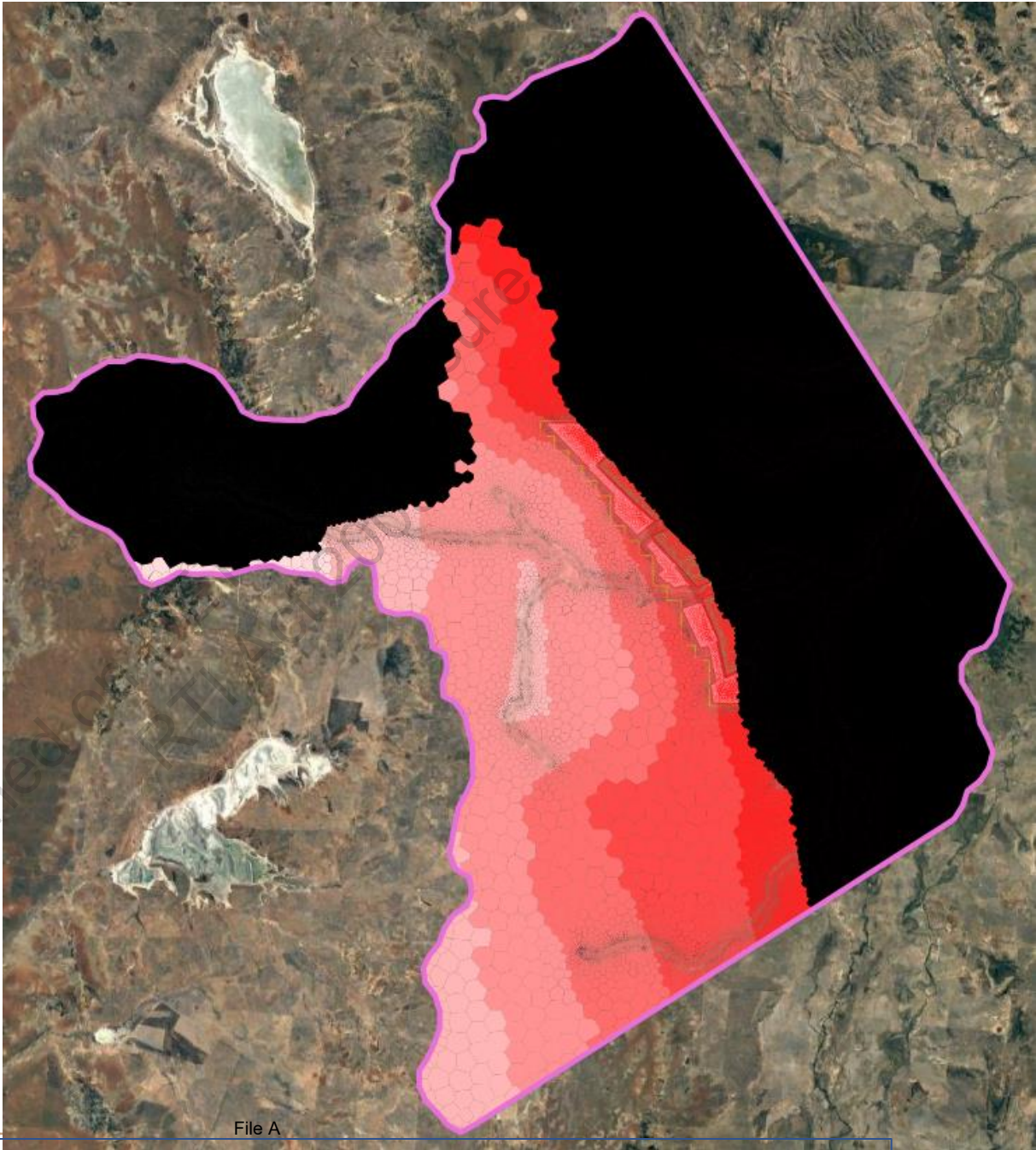
Rewan top (mAHD)



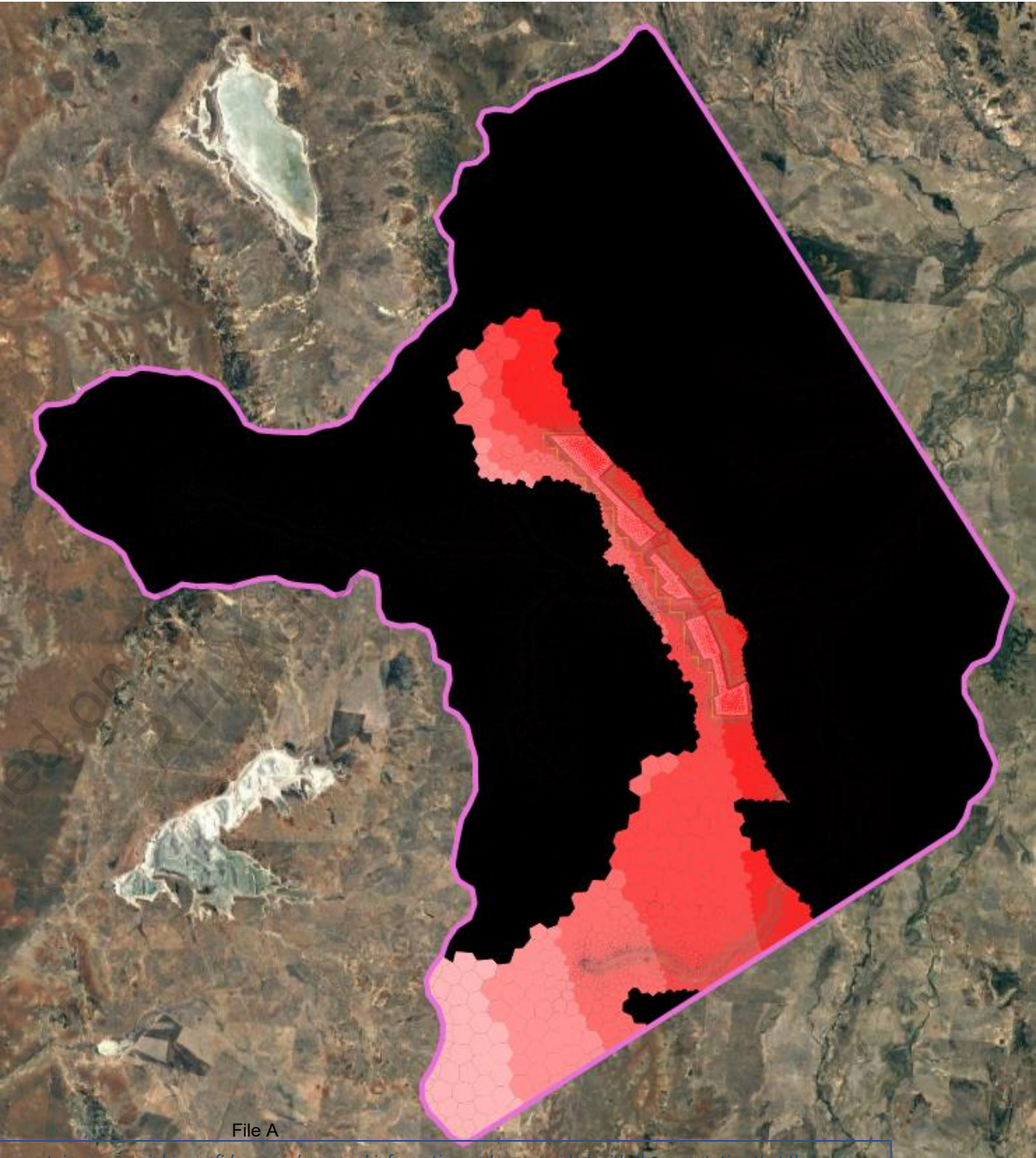
Bandanna top (mAHD)



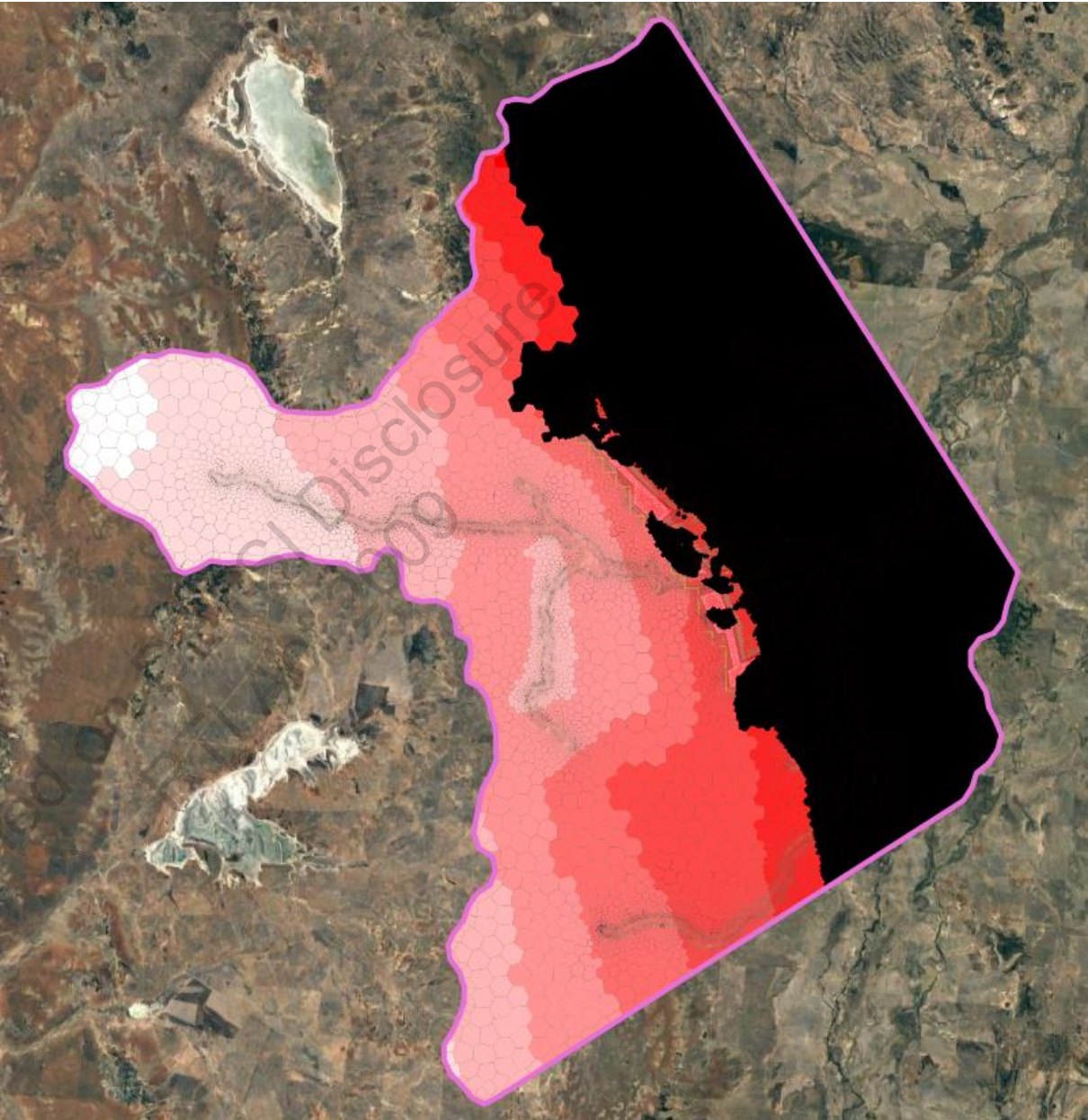
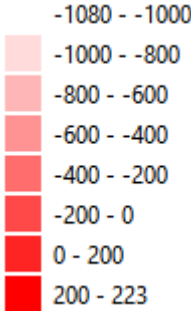
AB Coal top (mAHD)



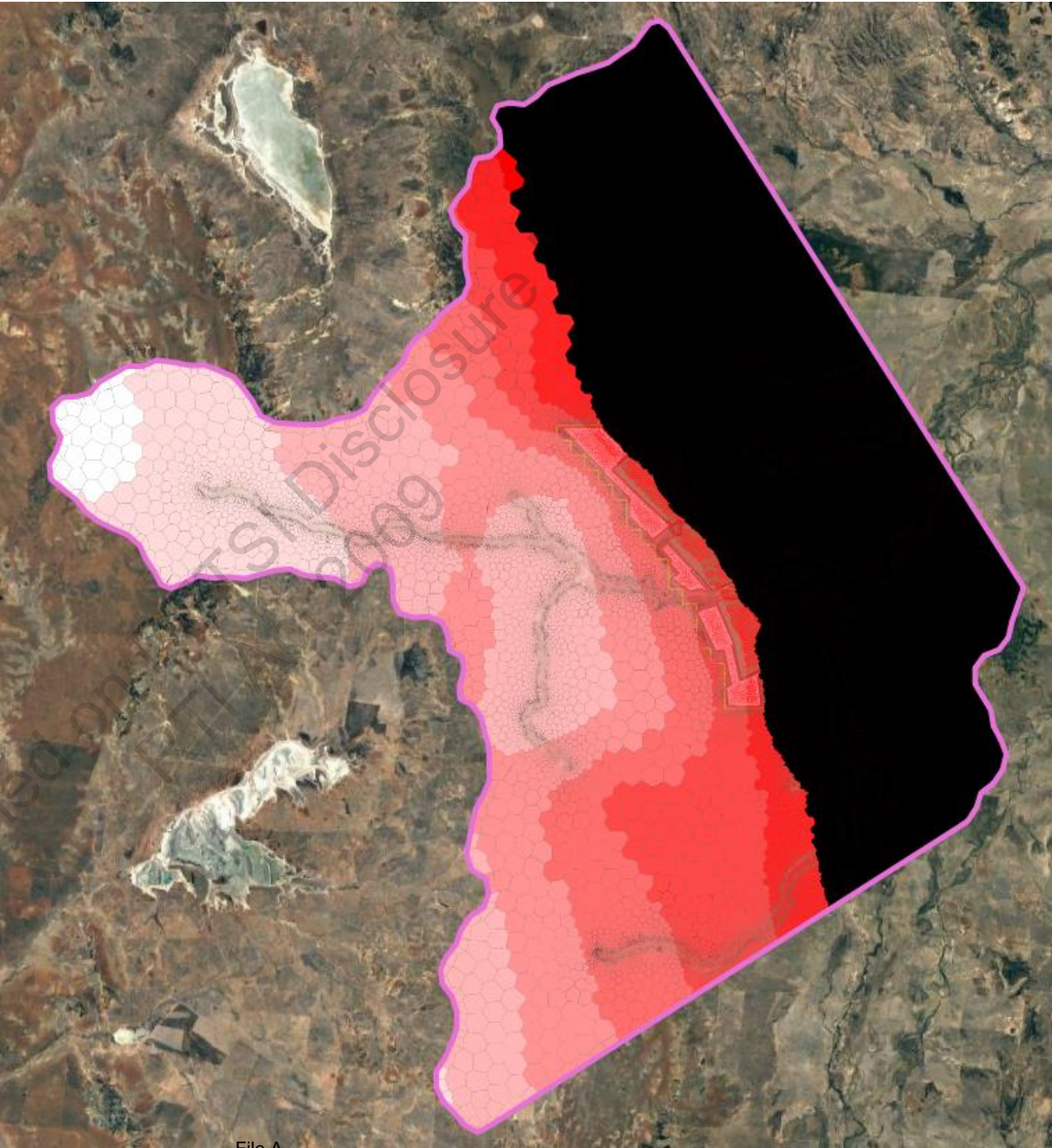
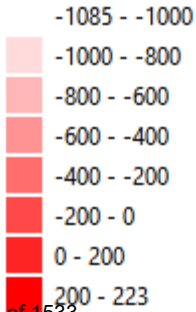
Bandanna (interburden) top (mAHD)



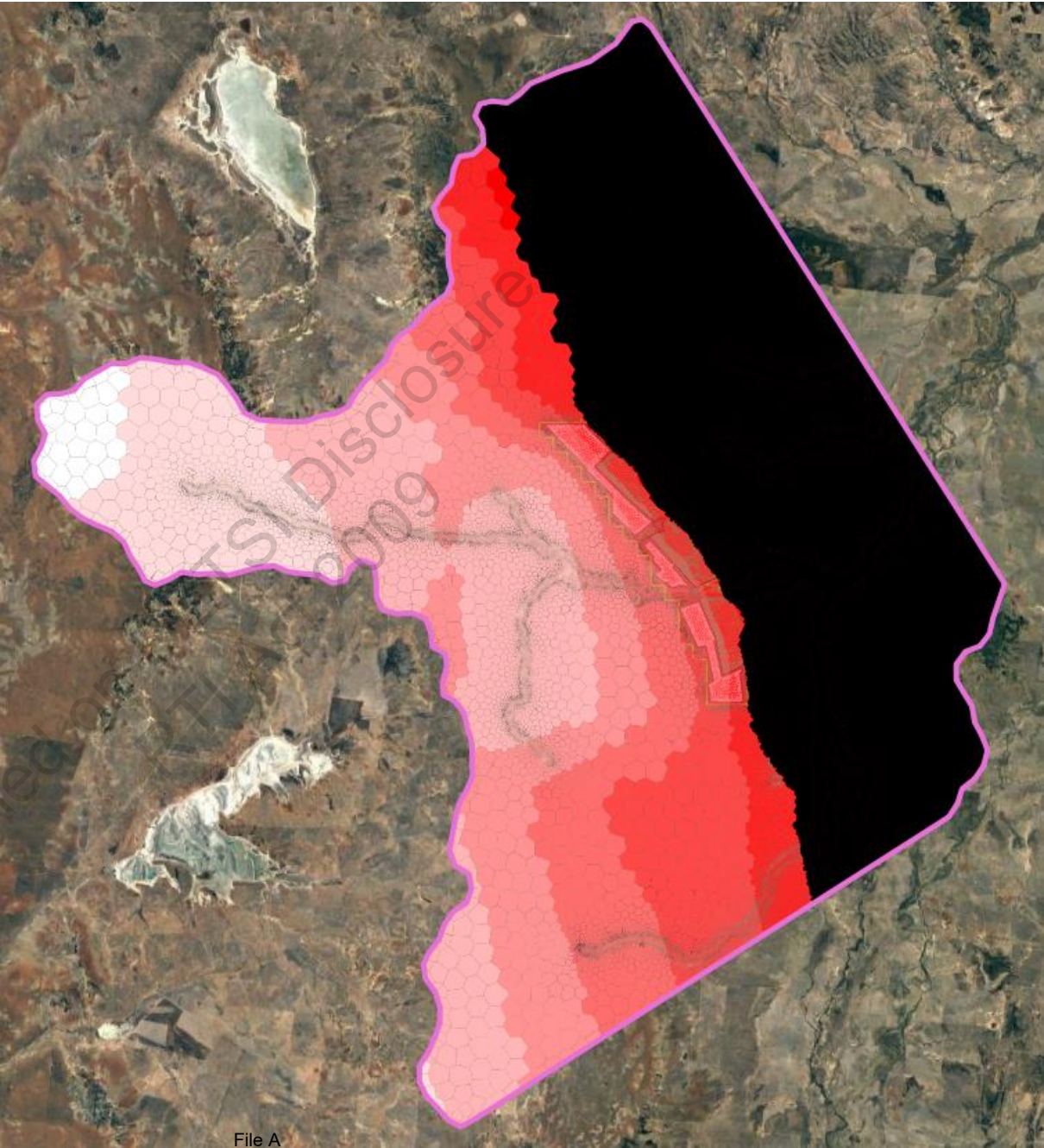
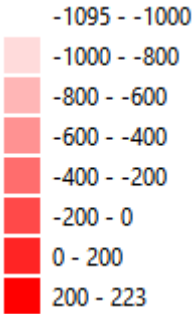
Colinlea top (mAHD)



D Coal top (mAHD)

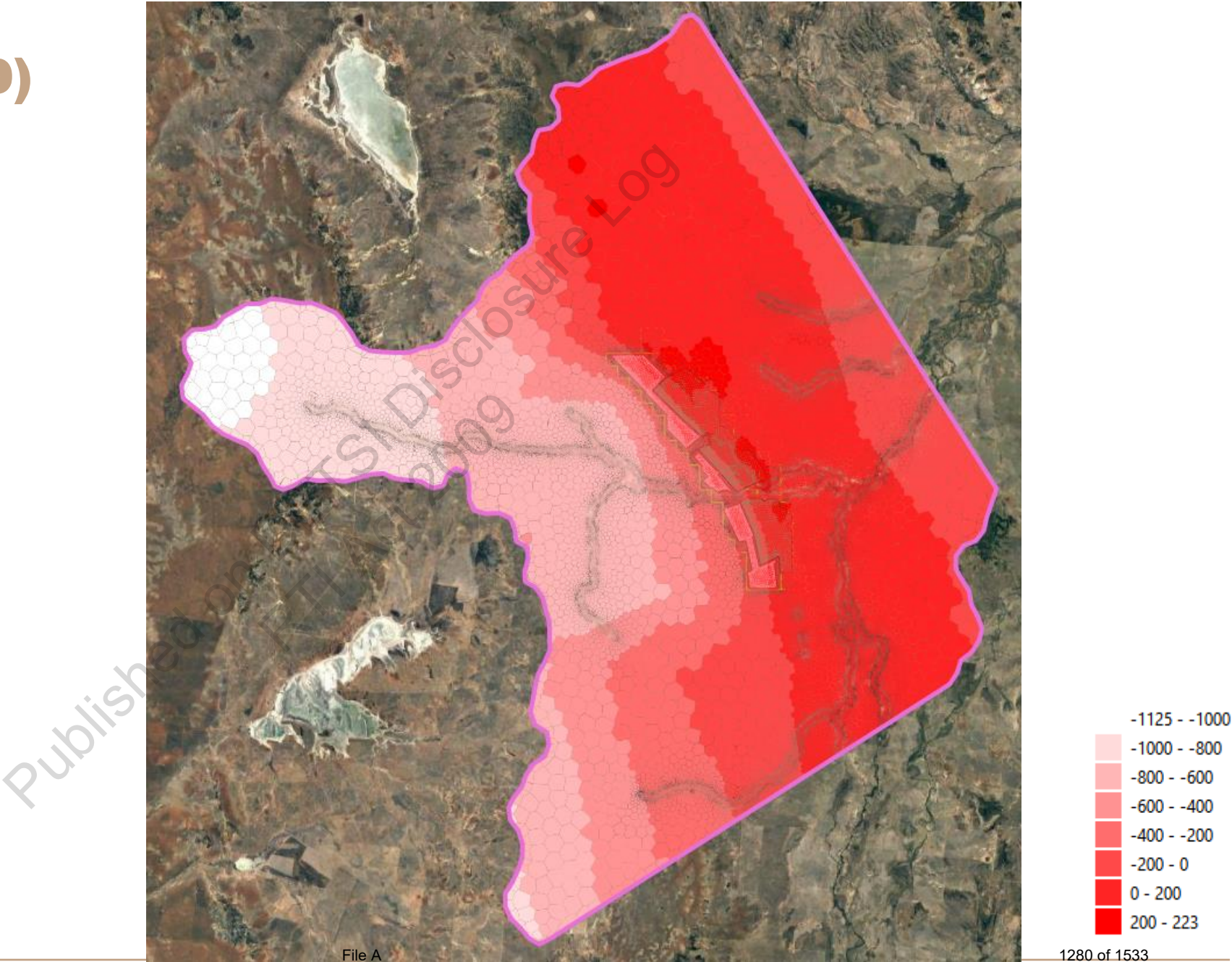


Colinlea (underburden) top (mAHD)

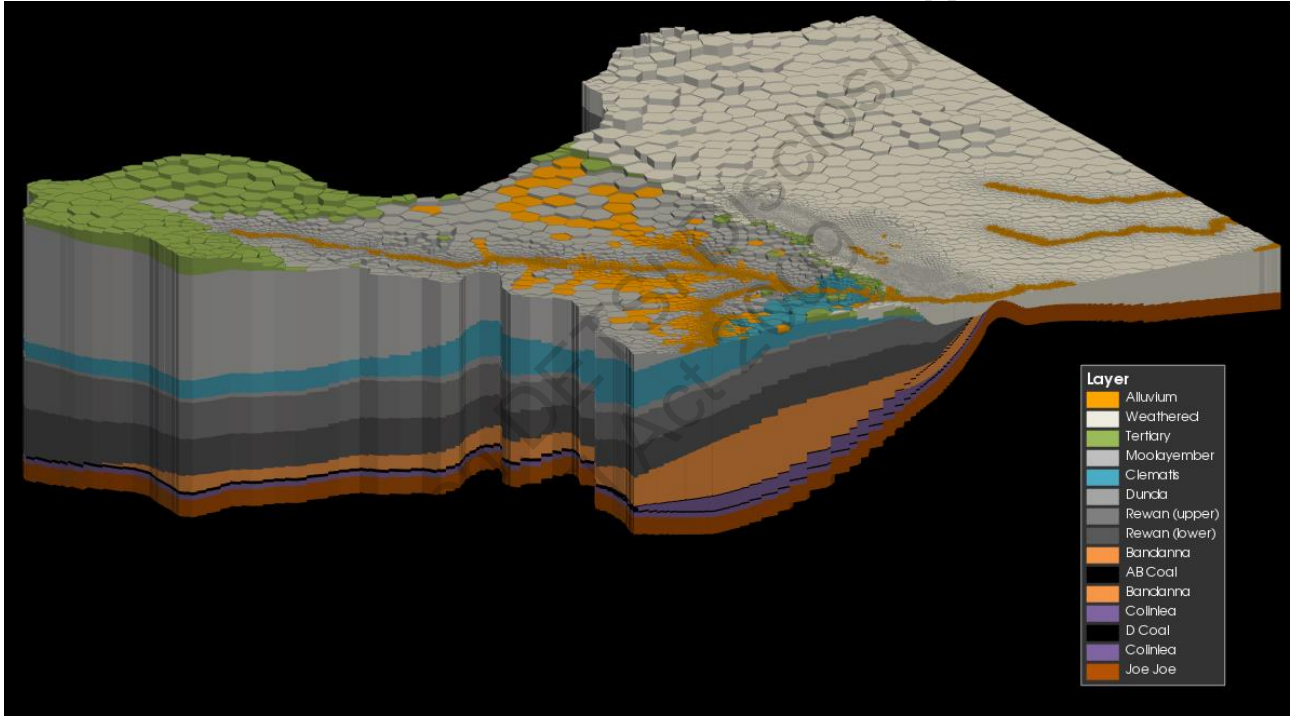


-1095 - -1000
-1000 - -800
-800 - -600
-600 - -400
-400 - -200
-200 - 0
0 - 200
200 - 223

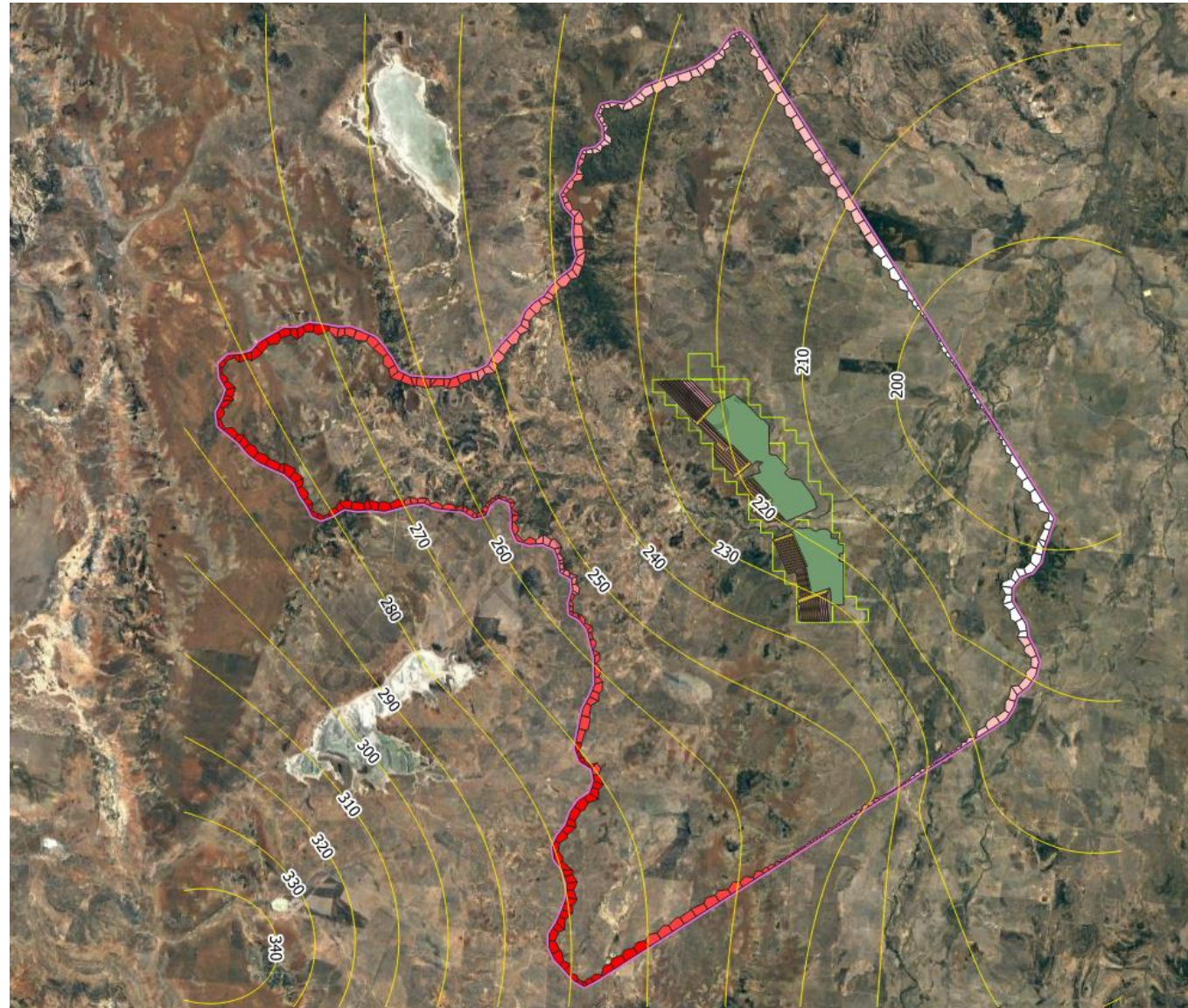
Joe Joe top (mAHD)



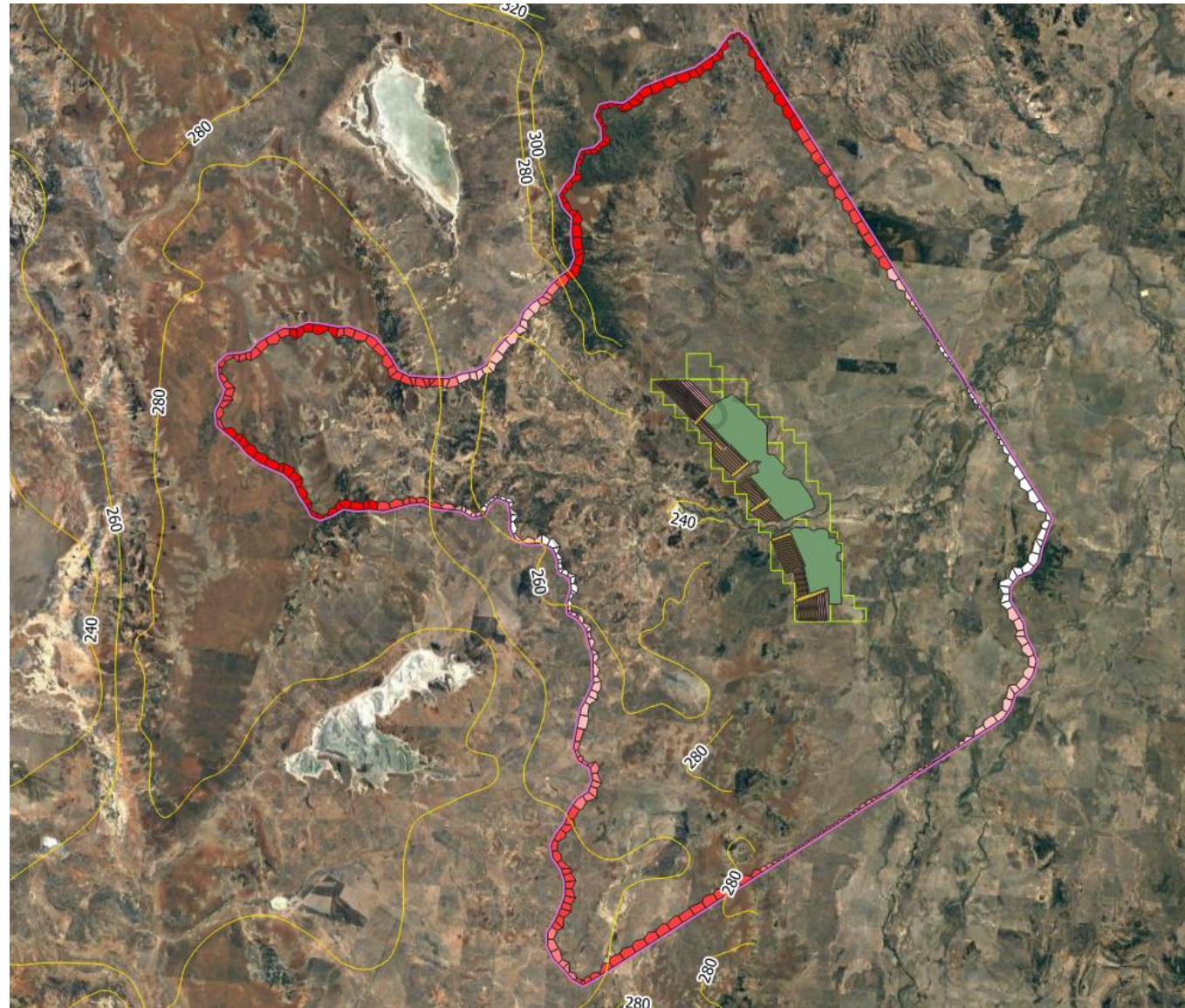
Cross section (west-east)



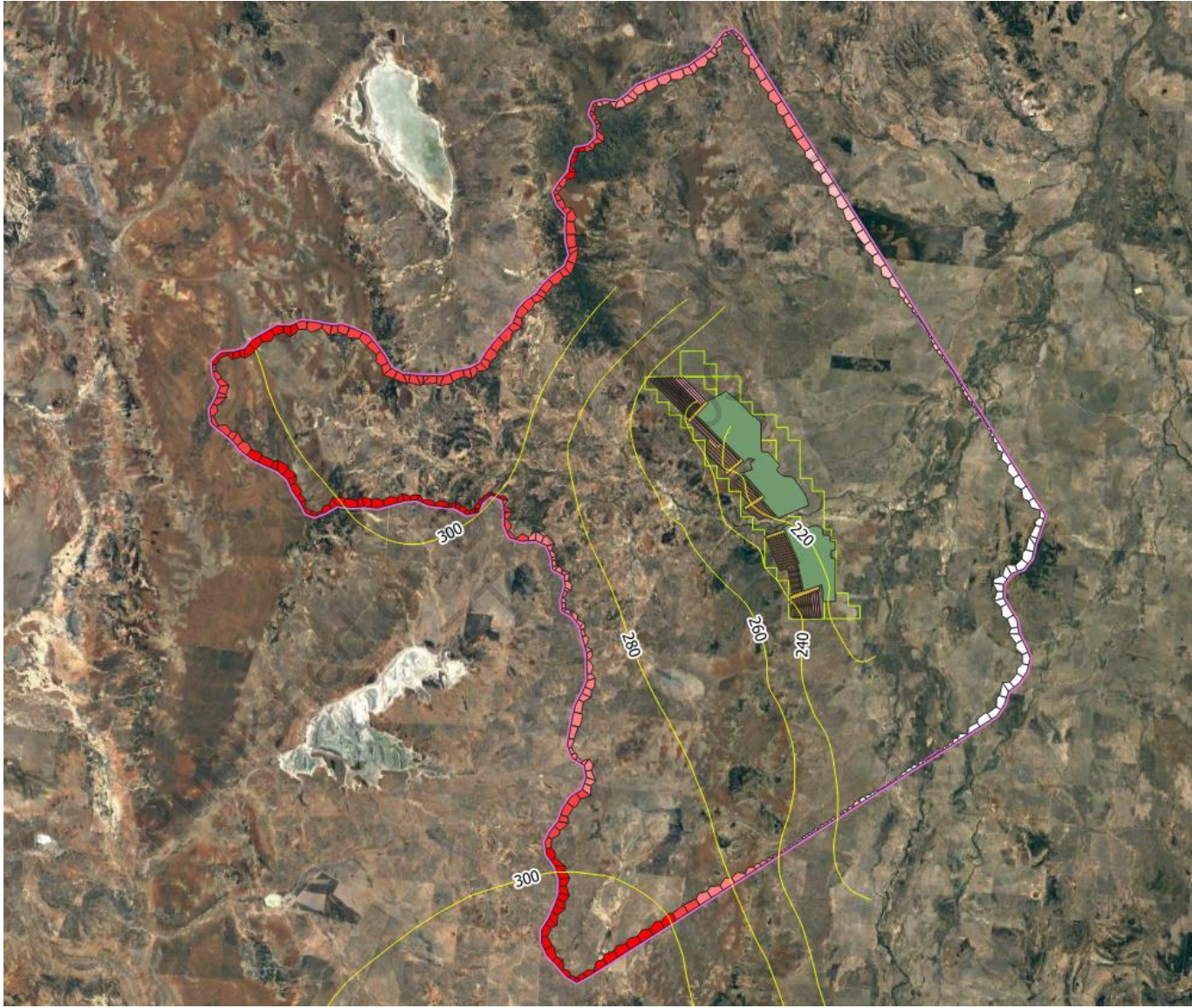
Surficial regional boundaries



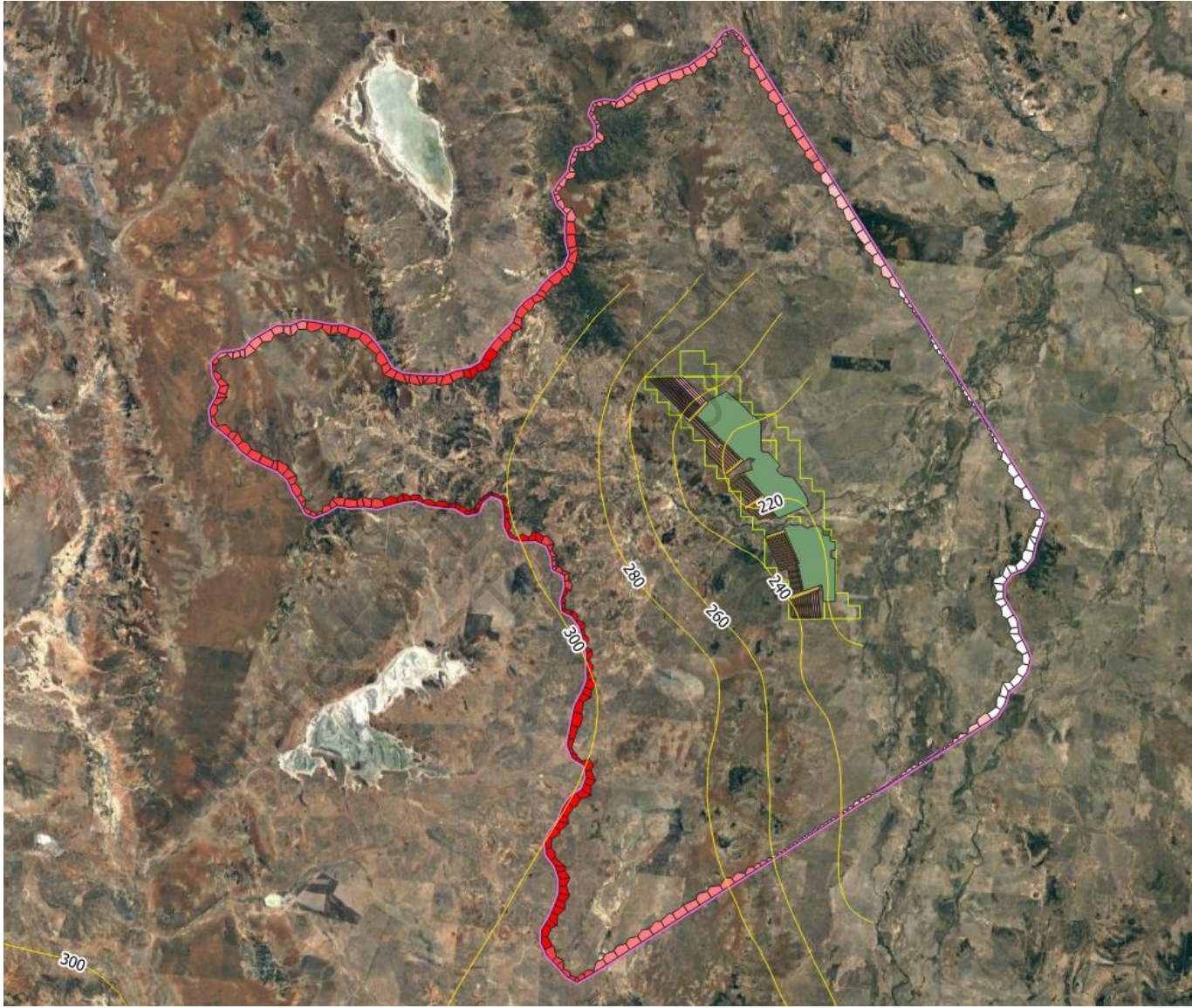
Clematis regional boundaries



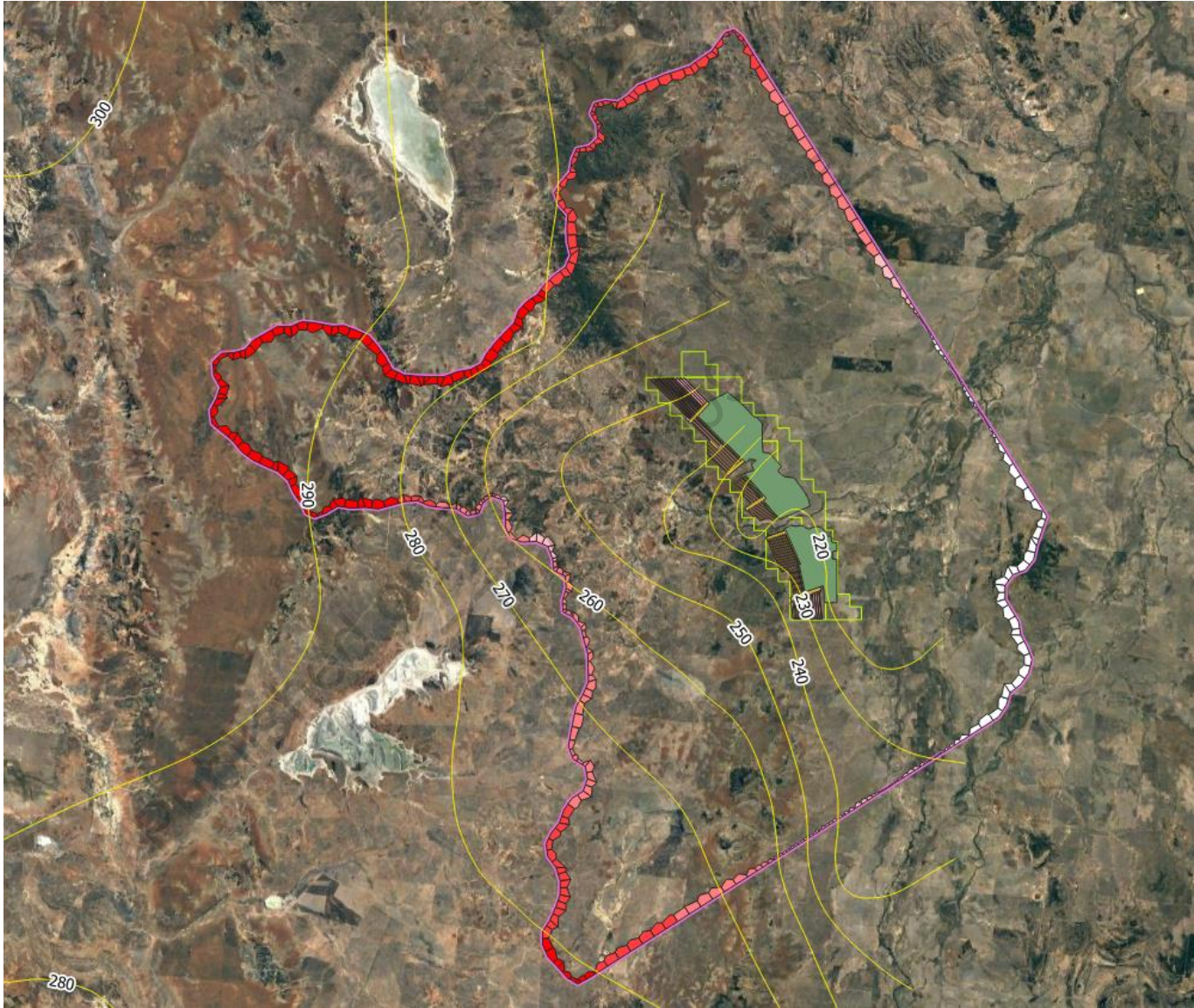
Bandanna regional boundaries



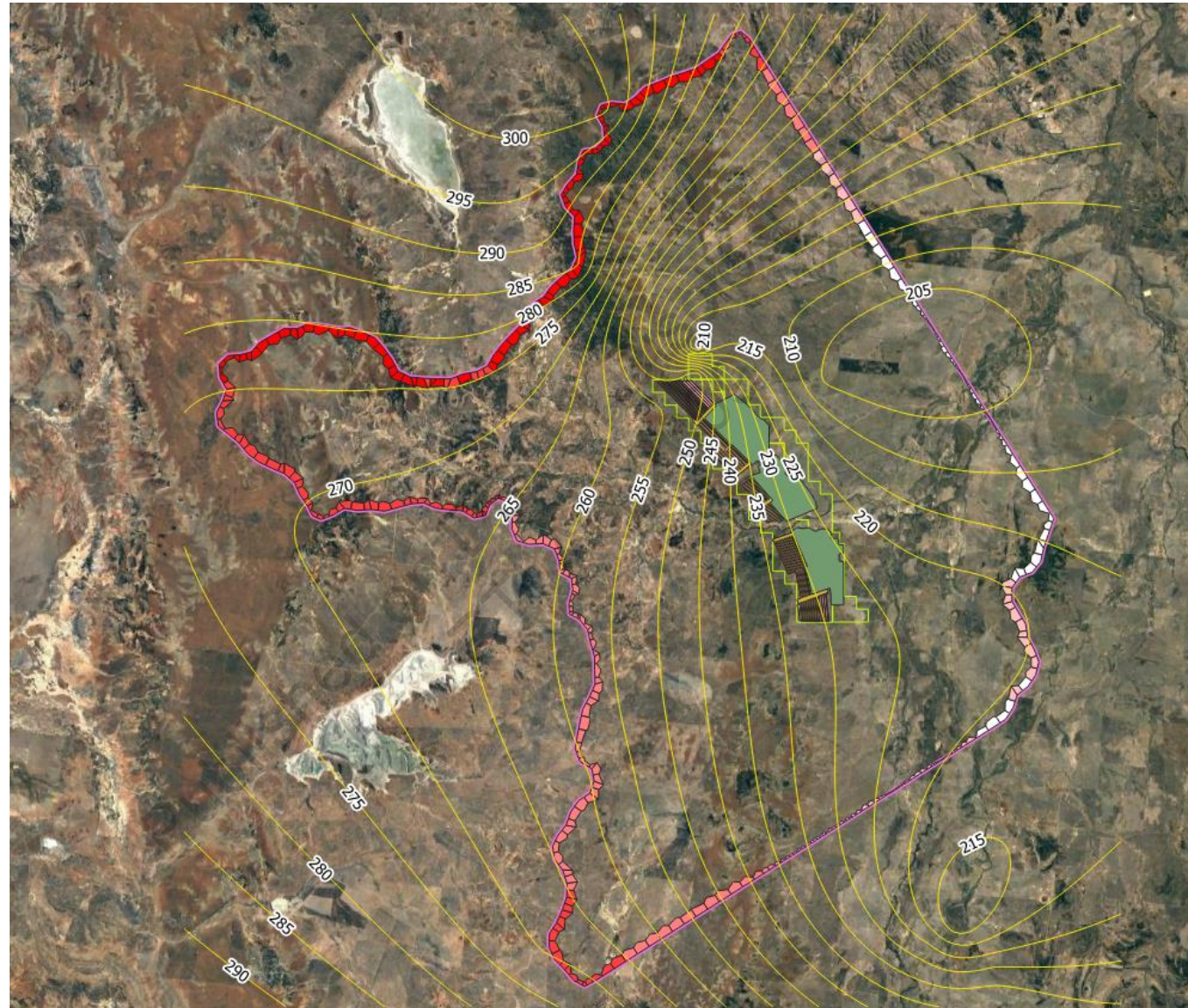
Coal seam regional boundaries



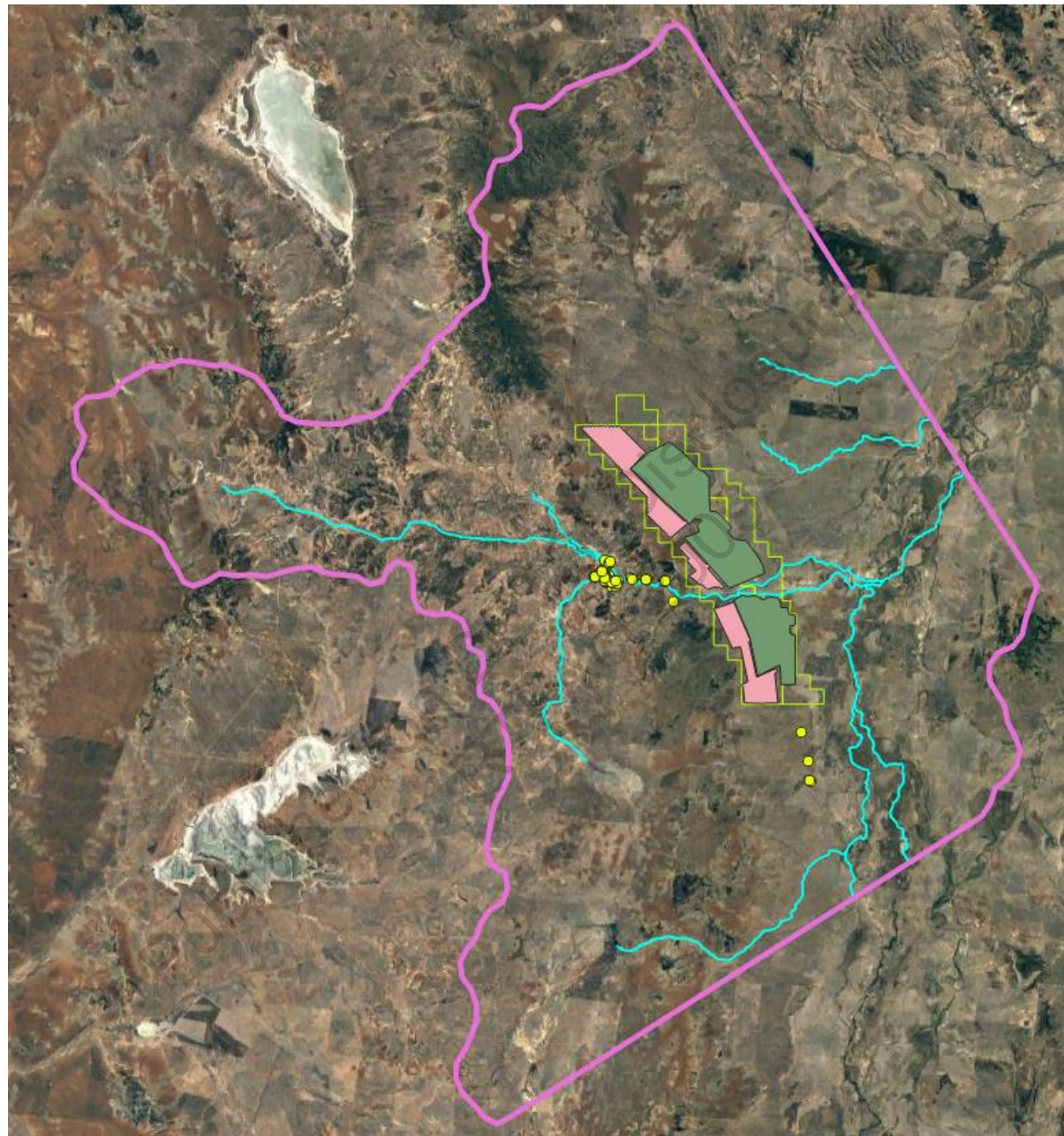
Colinlea regional boundaries



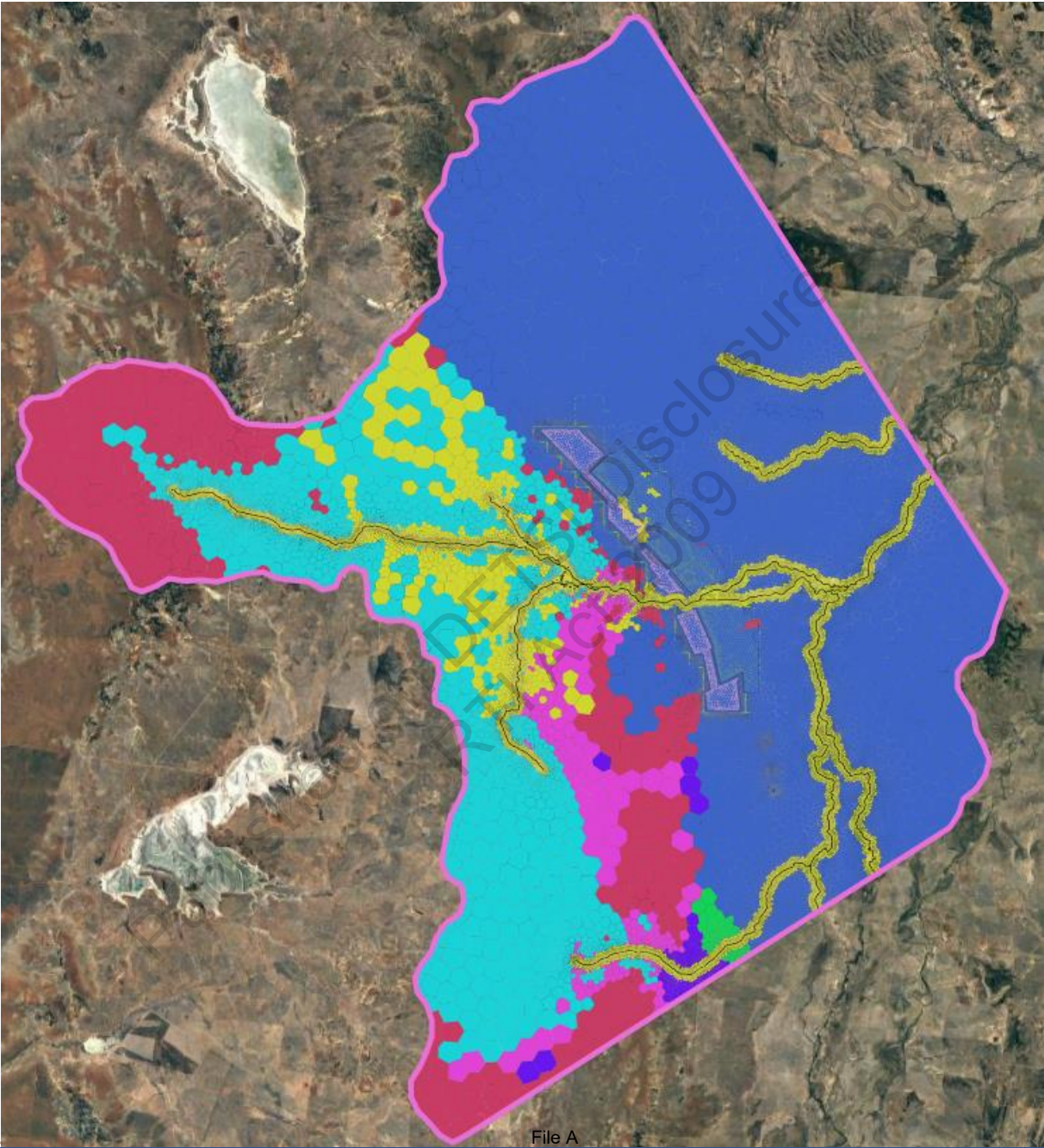
Joe Joe regional boundaries



Surface water



Recharge



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

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MINING & RESOURCES

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

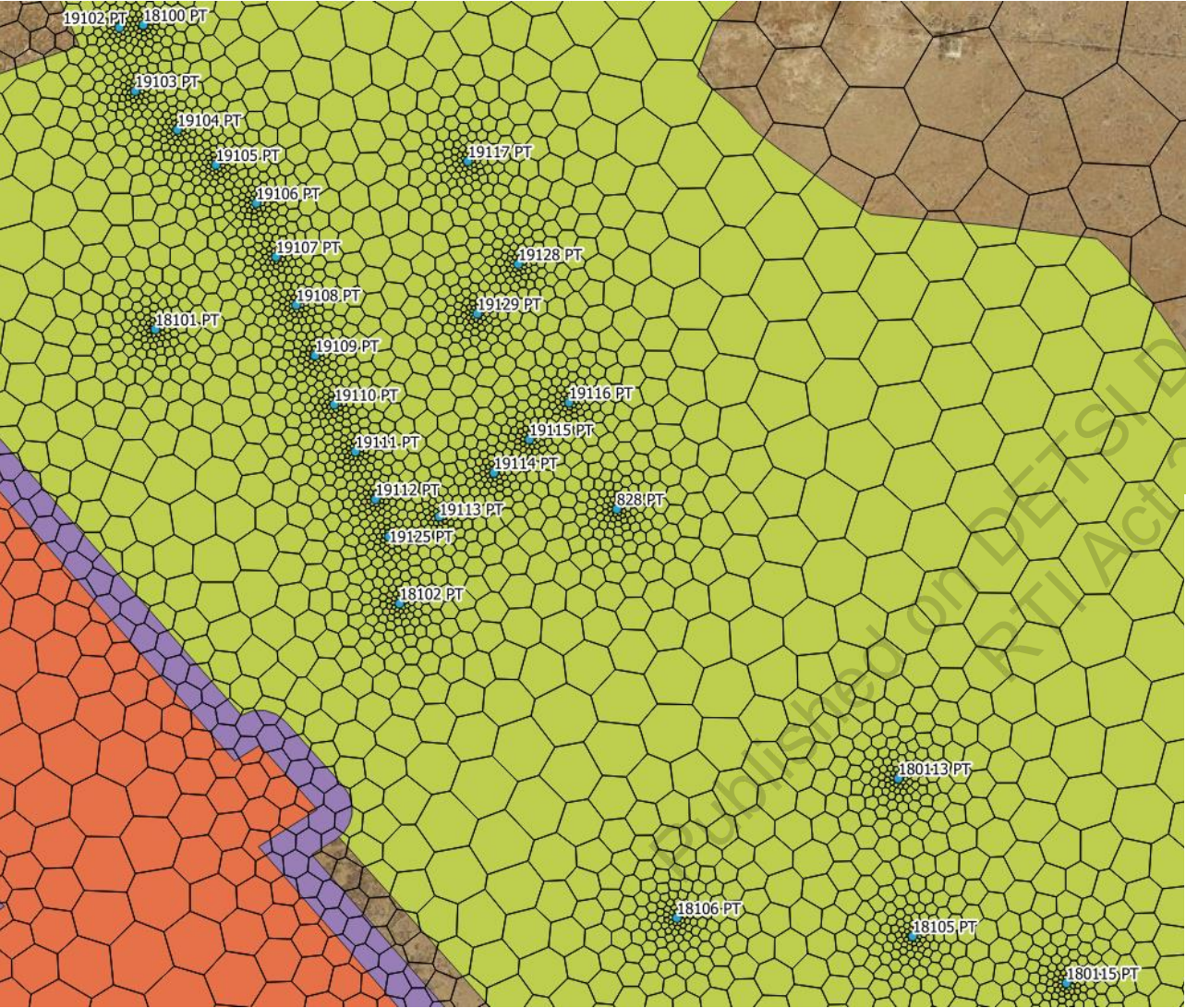
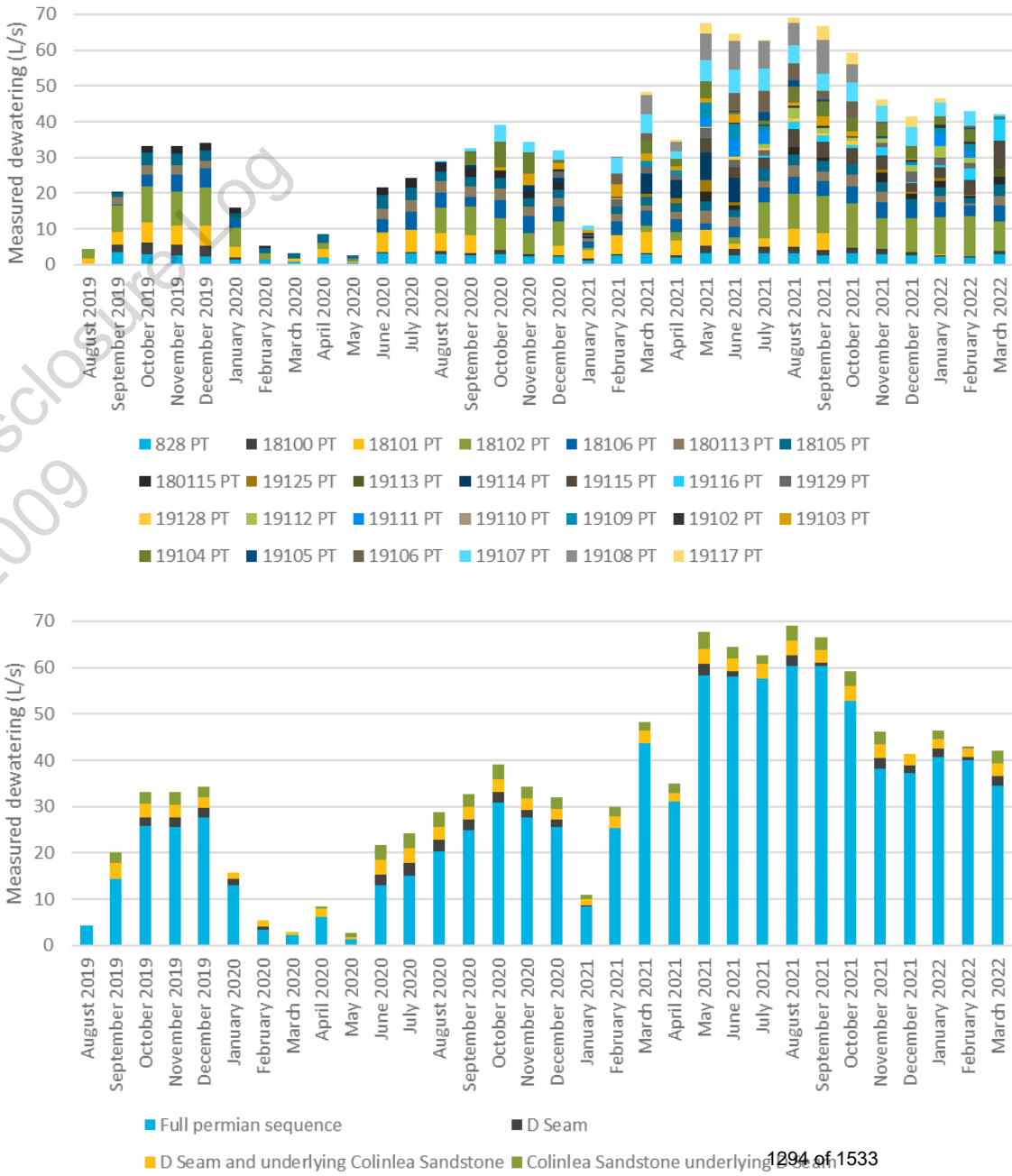
Modelled watercourses

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

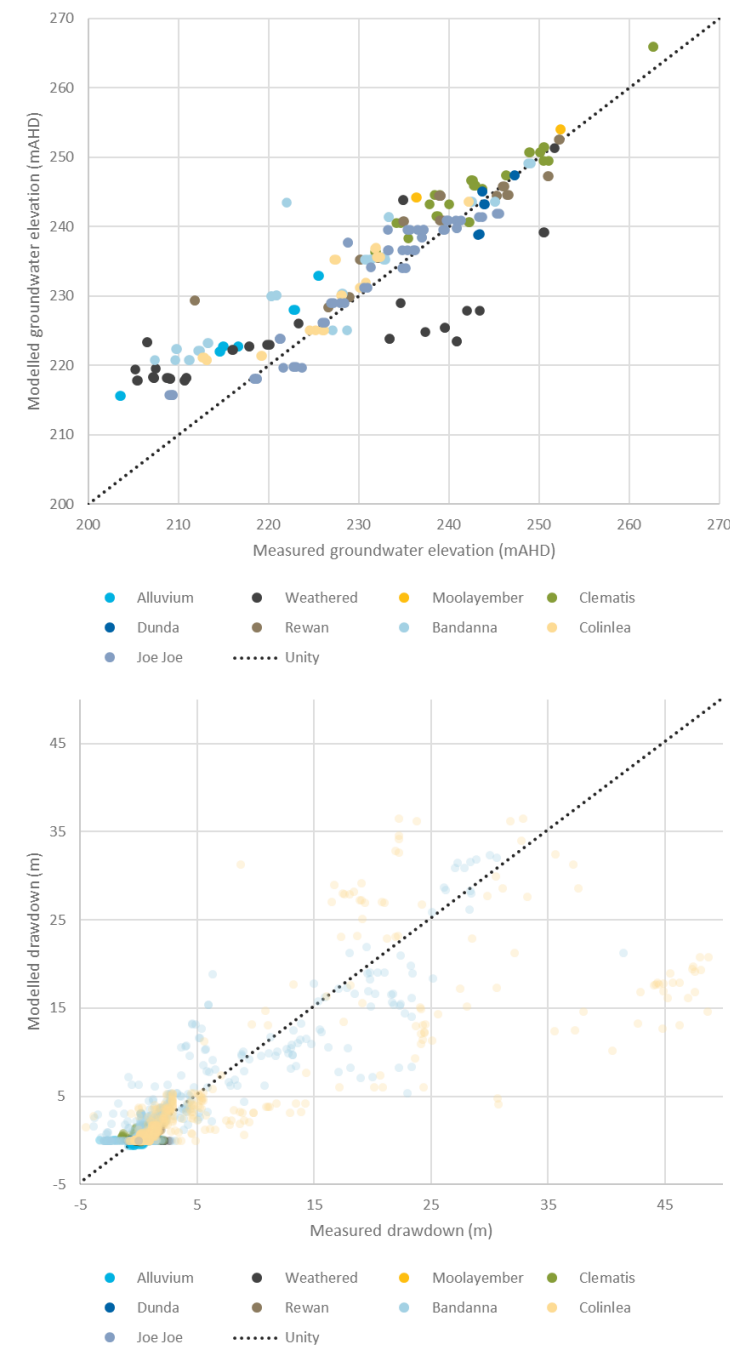
- Set up model with expected hydraulic properties based on hydrogeological conceptual model
- Define measured groundwater level data and estimates of spring flux as targets
 - Group targets by HSU, using first transient measurement as a 'head' target, and the remainder as 'head-change' targets
- Run 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

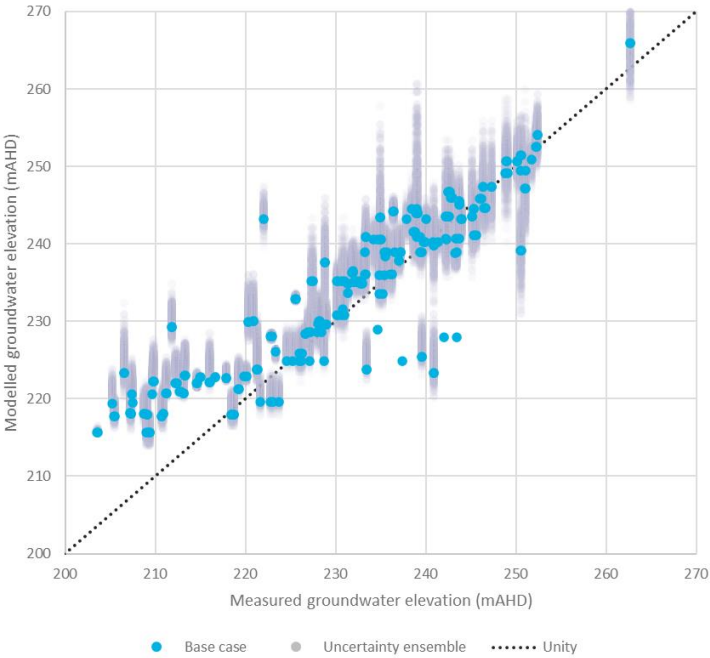
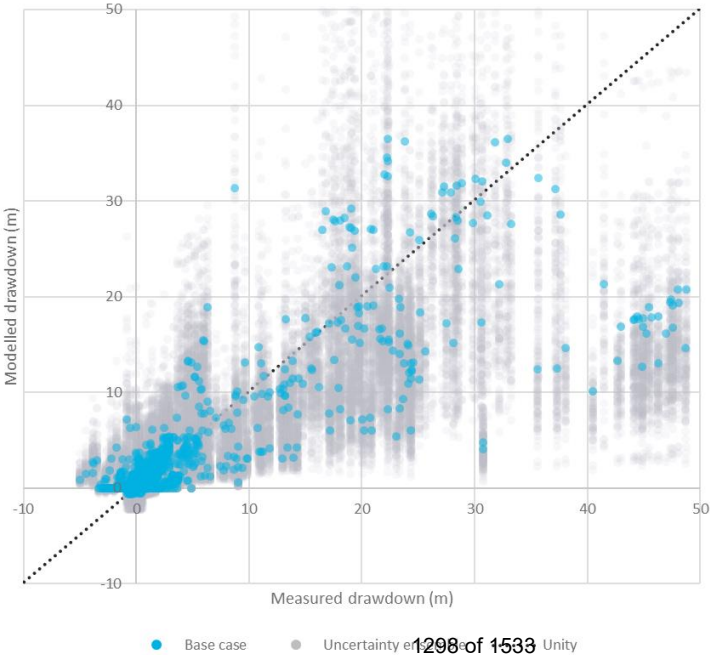
- History-matching undertaken on weighted head and head-change targets
- Performance reported against **unweighted head values**
- **SRMS 6.7%**
- Mean residual -3.6 m
- Mean absolute residual 4.8 m
- Minimum residual -39.4 m
- Maximum residual 17.5 m
- Number of observations 11,441
- Range of observations 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



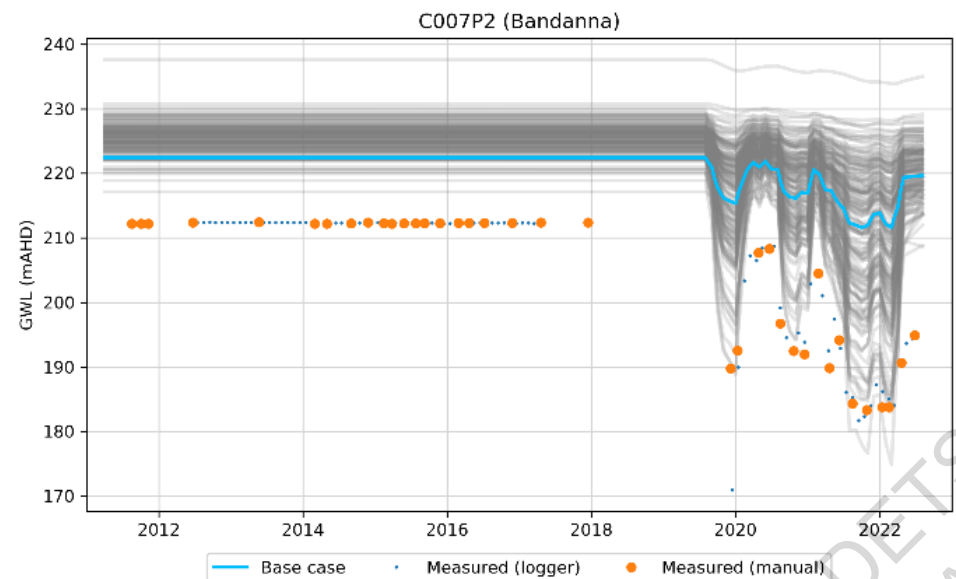
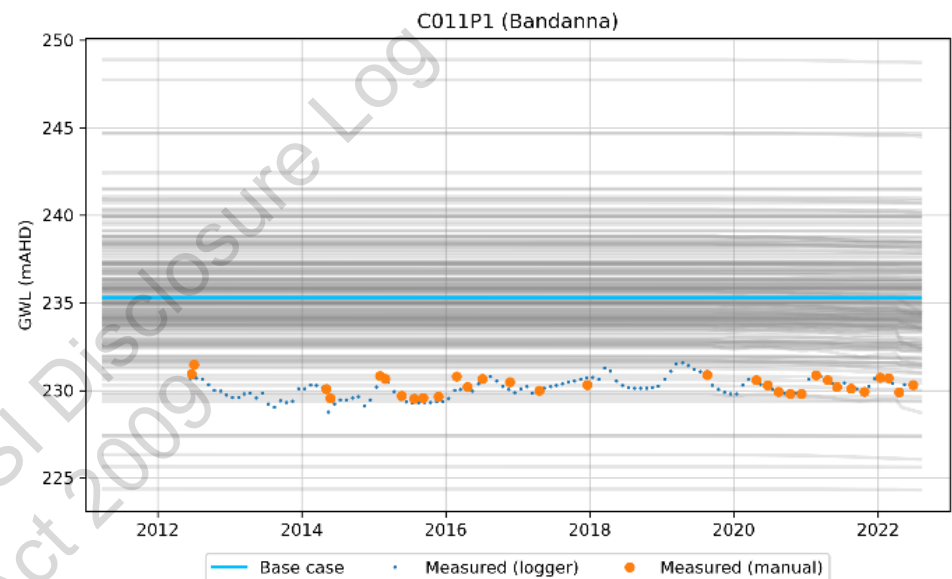
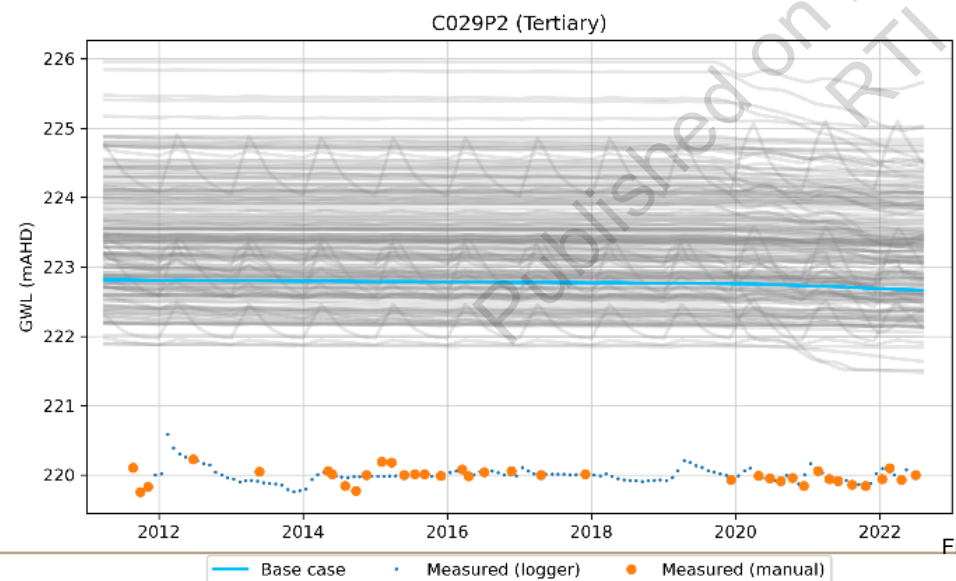
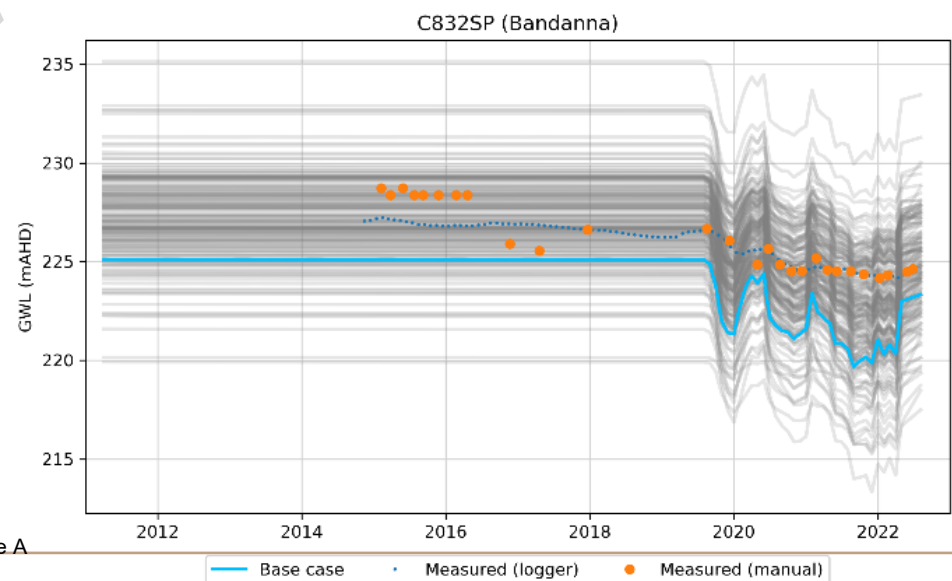
History-matching performance: ensemble

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

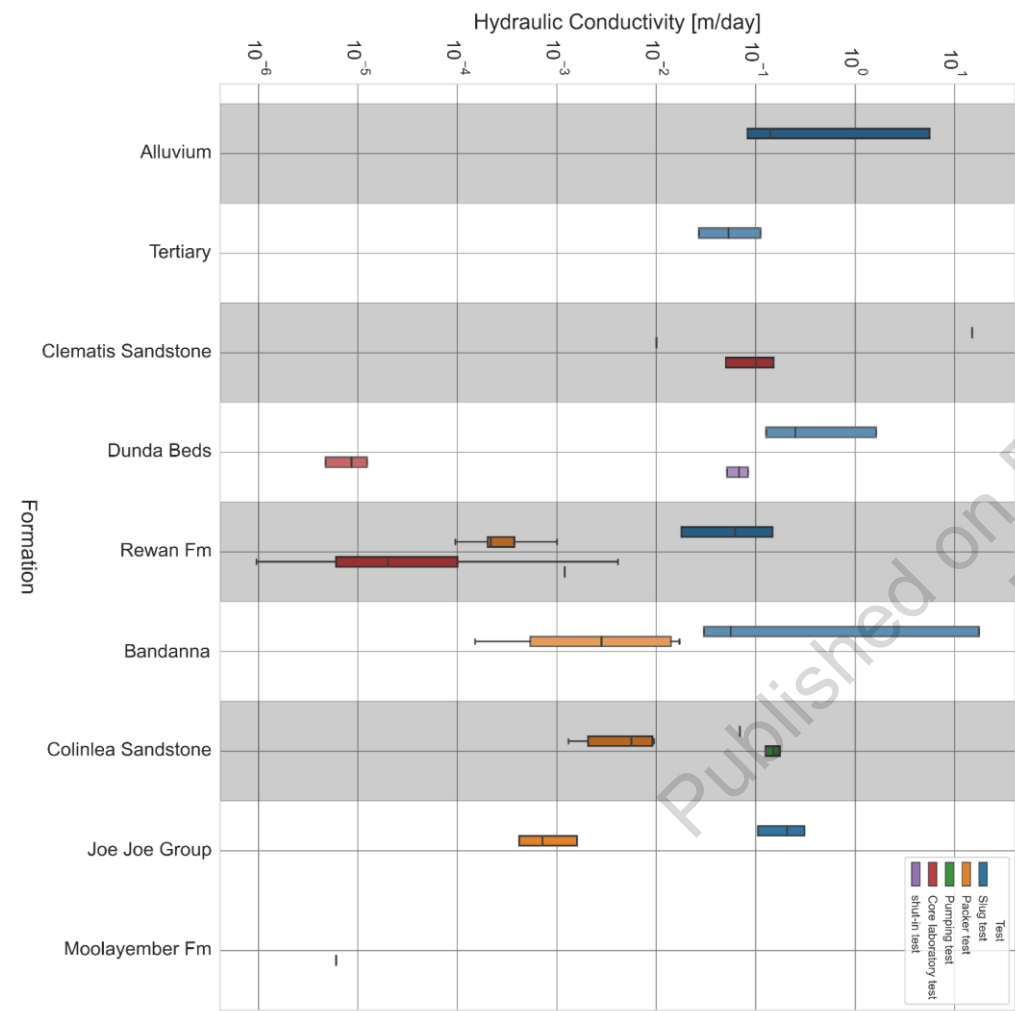


History-matching: example hydrographs

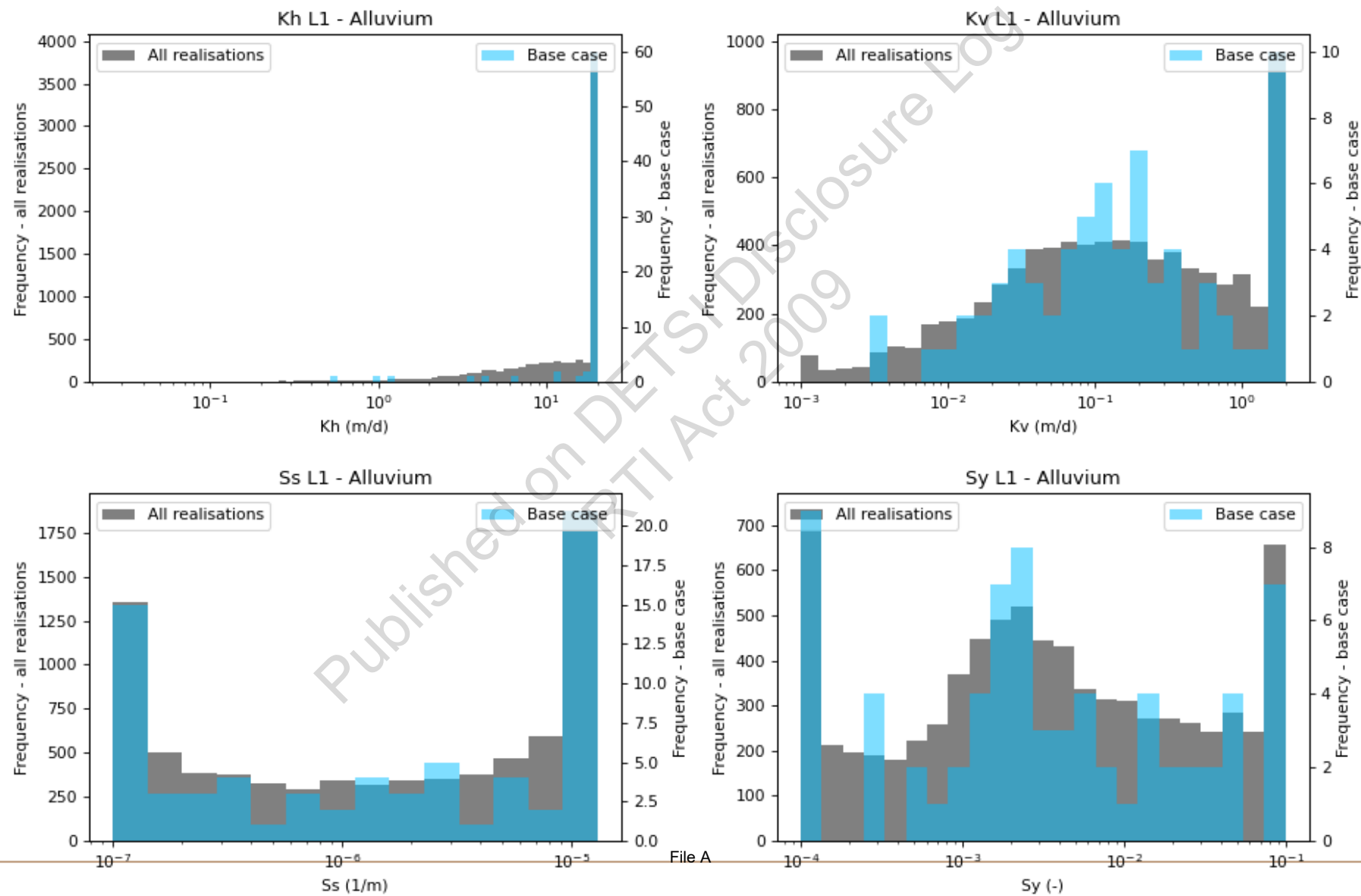


Parameterisation

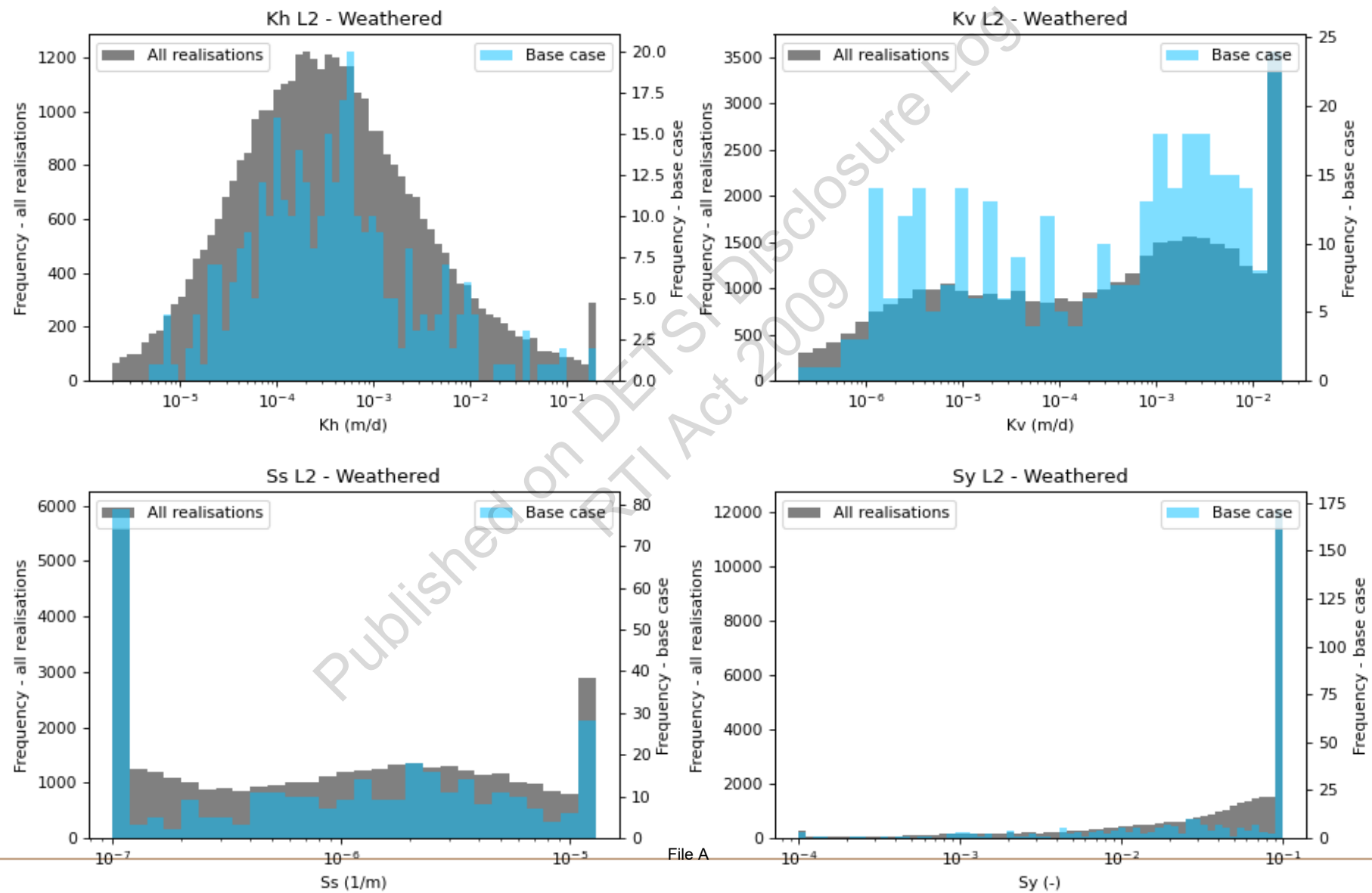
Interpreted hydraulic conductivity



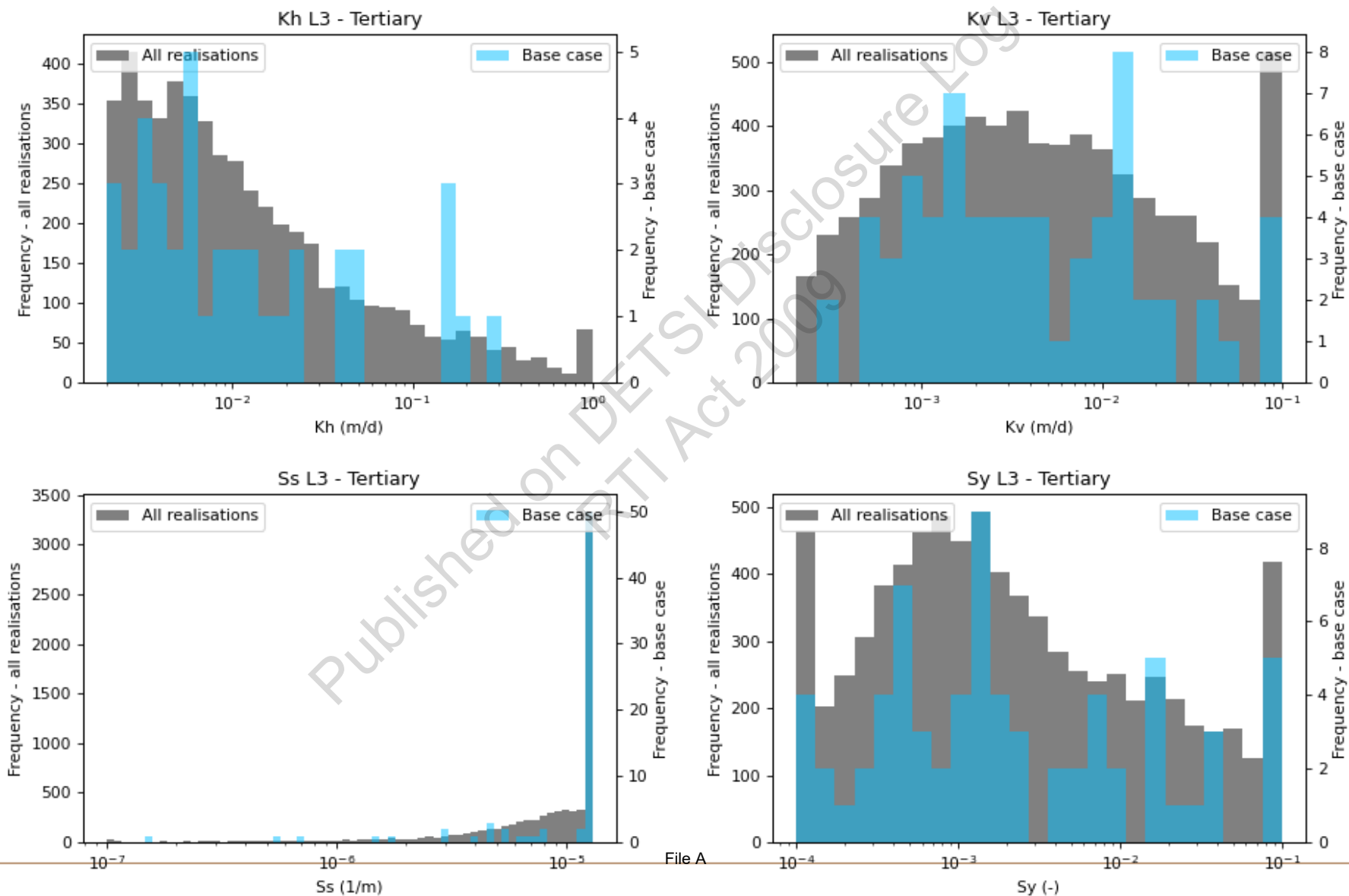
Parameterisation – L1 Alluvium



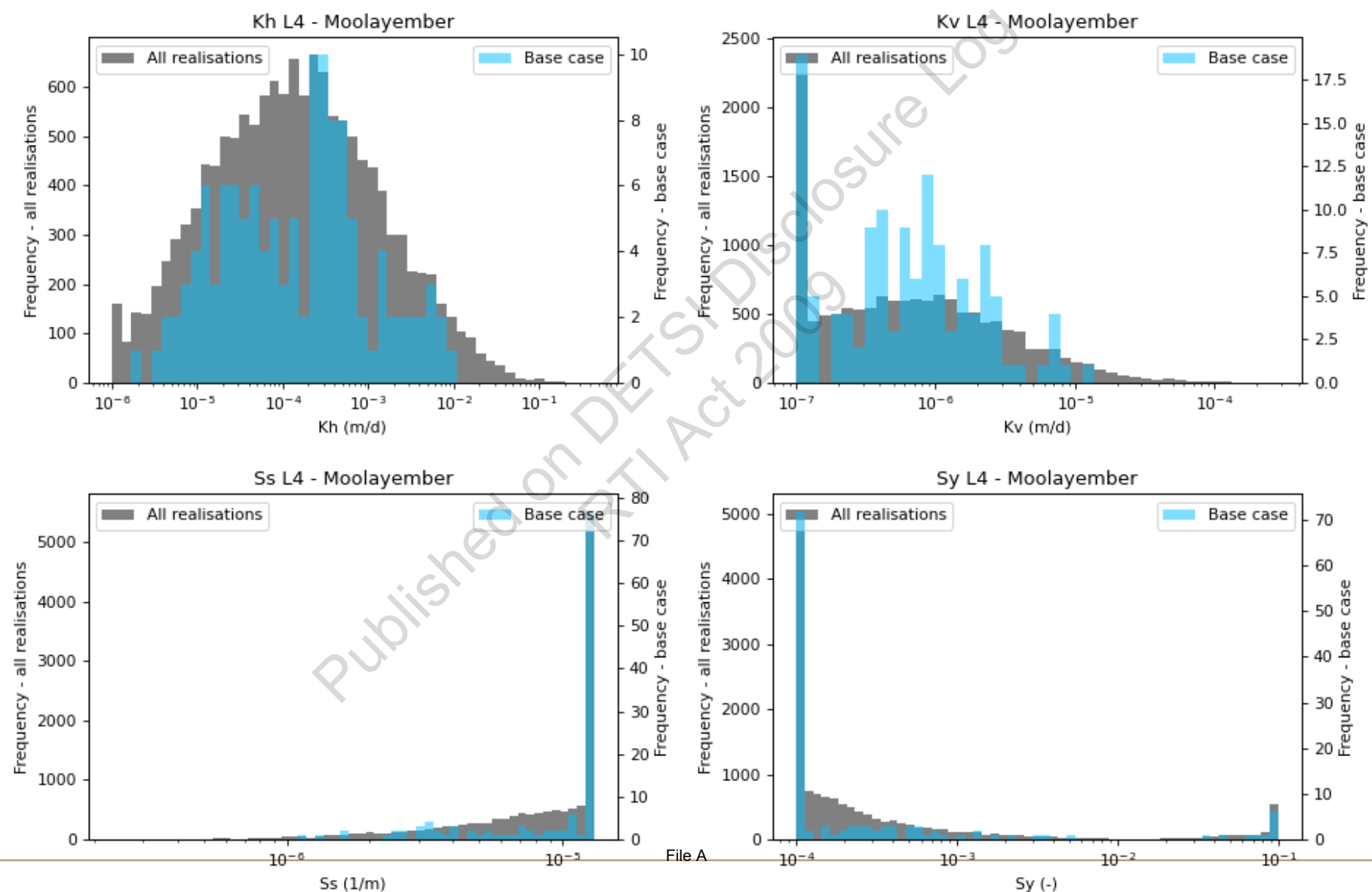
Parameterisation – L2 Weathered



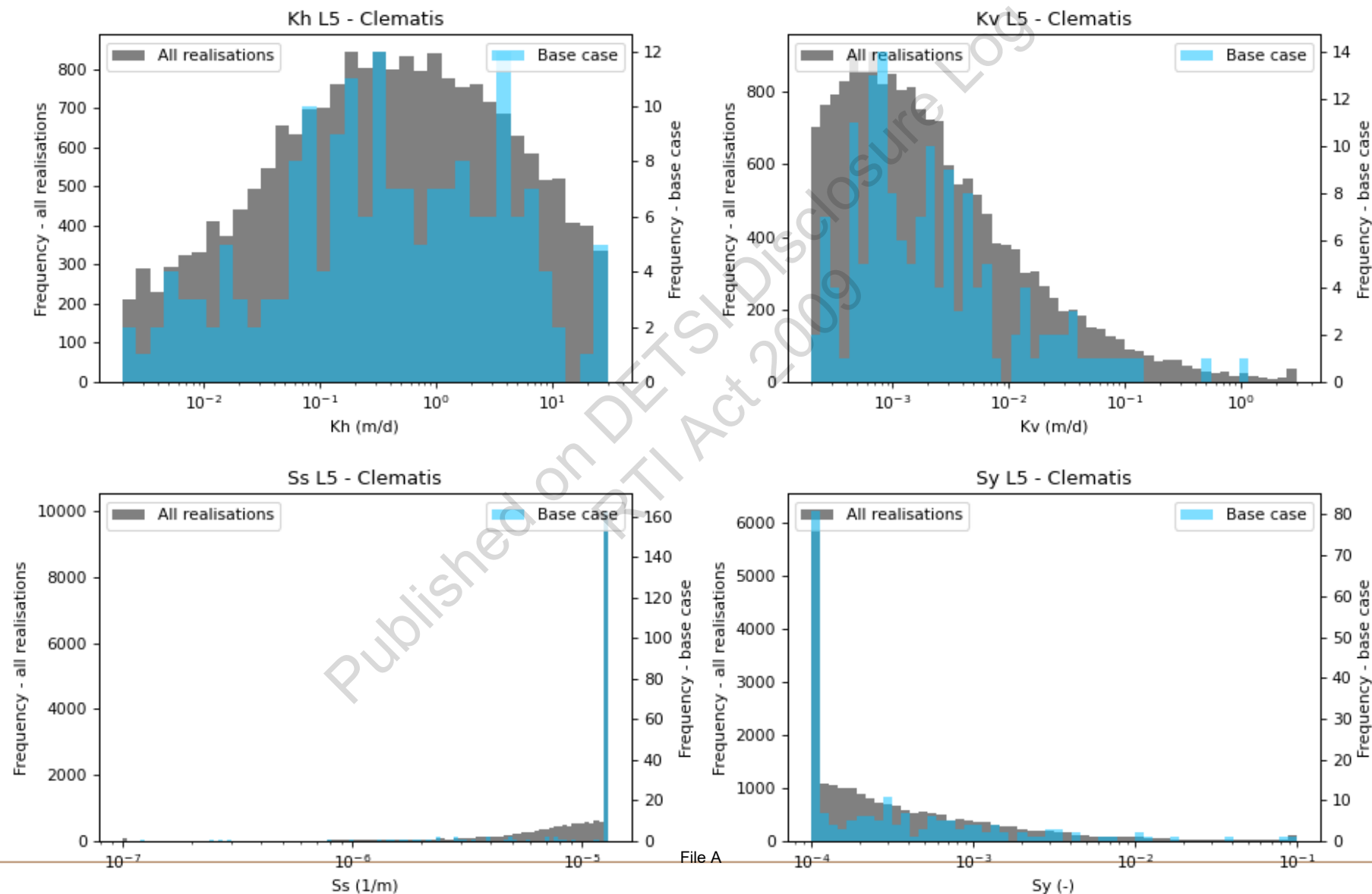
Parameterisation – L3 Tertiary



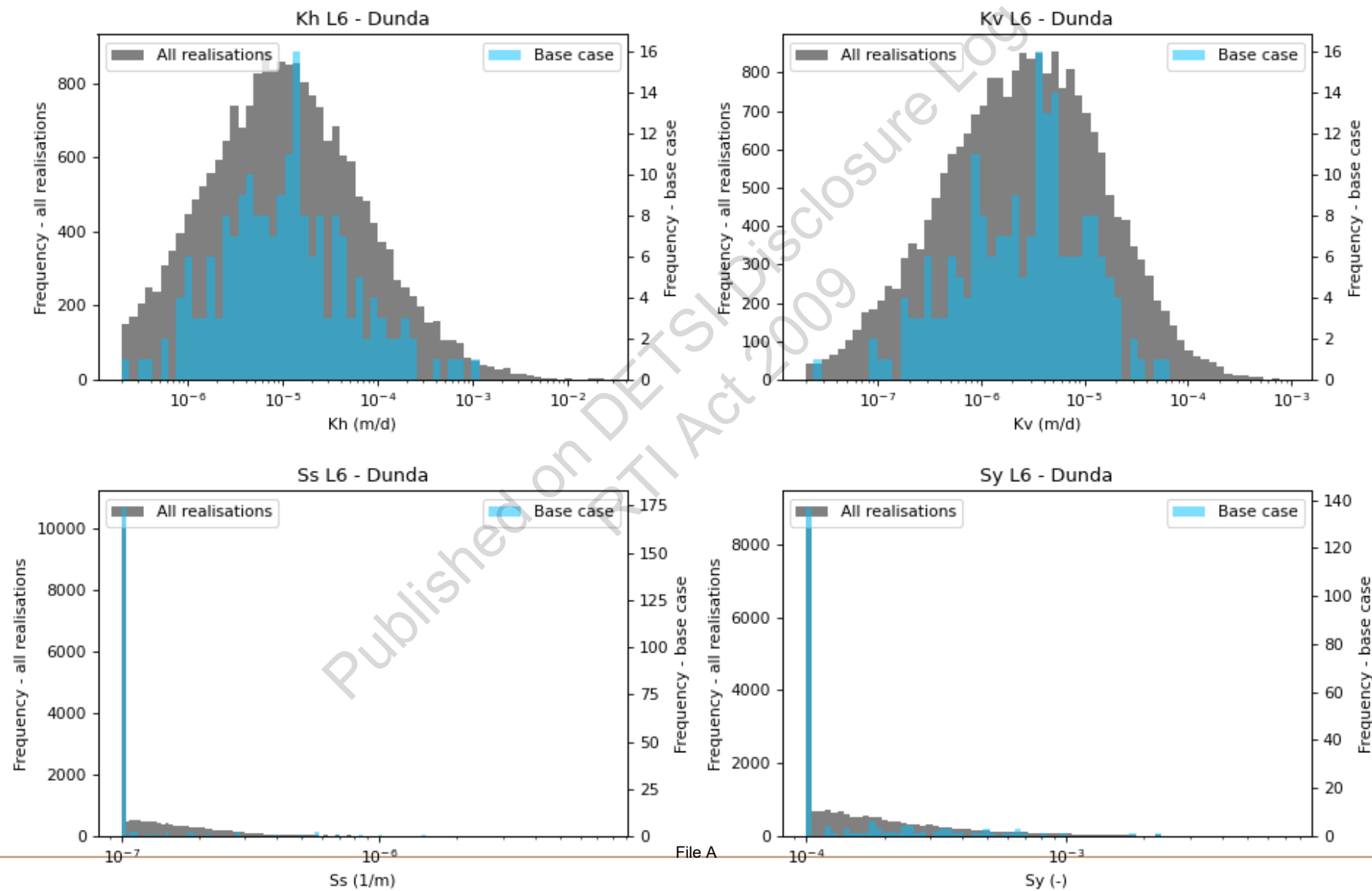
Parameterisation – L4 Moolayember



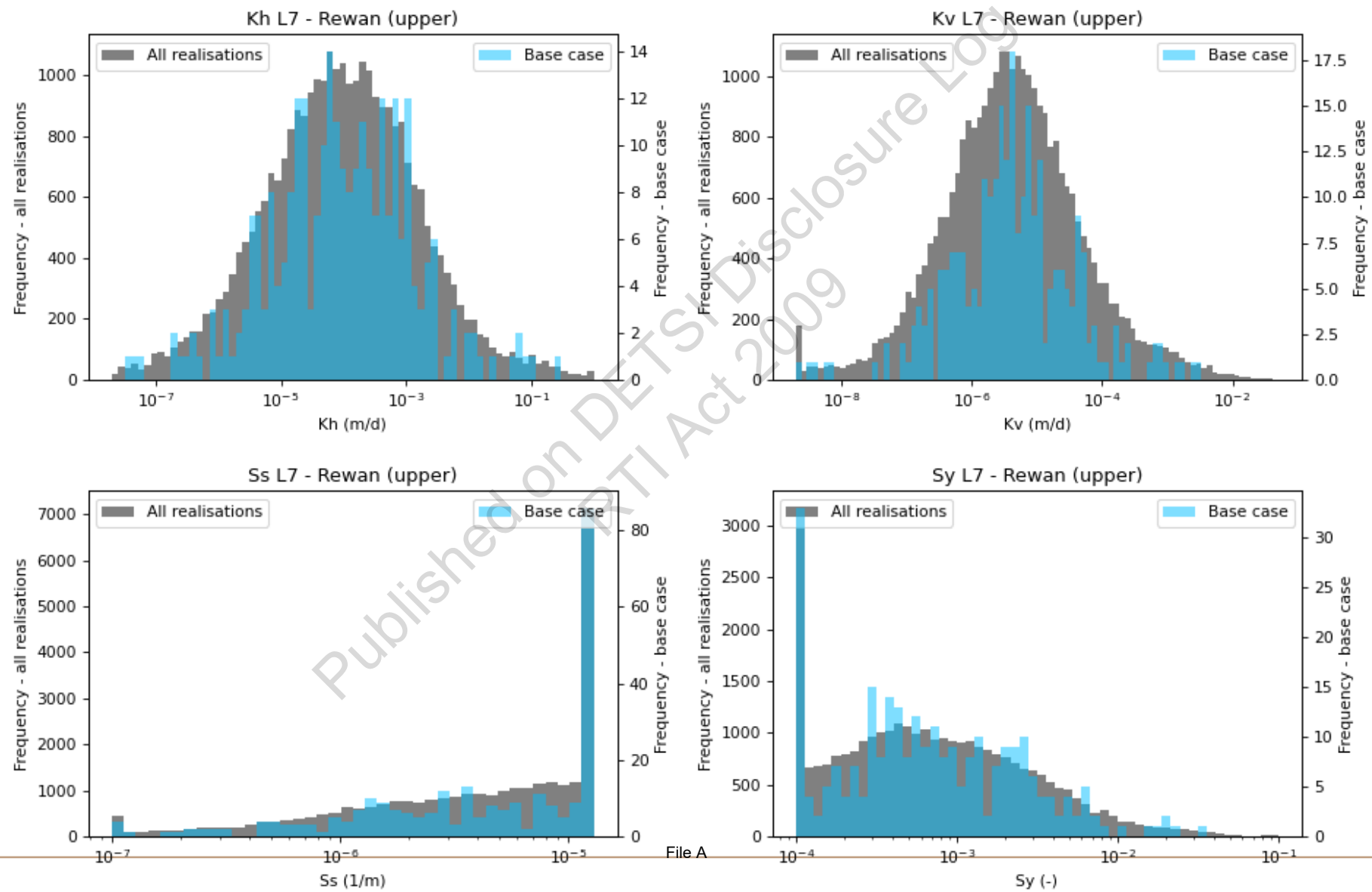
Parameterisation – L5 Clematis



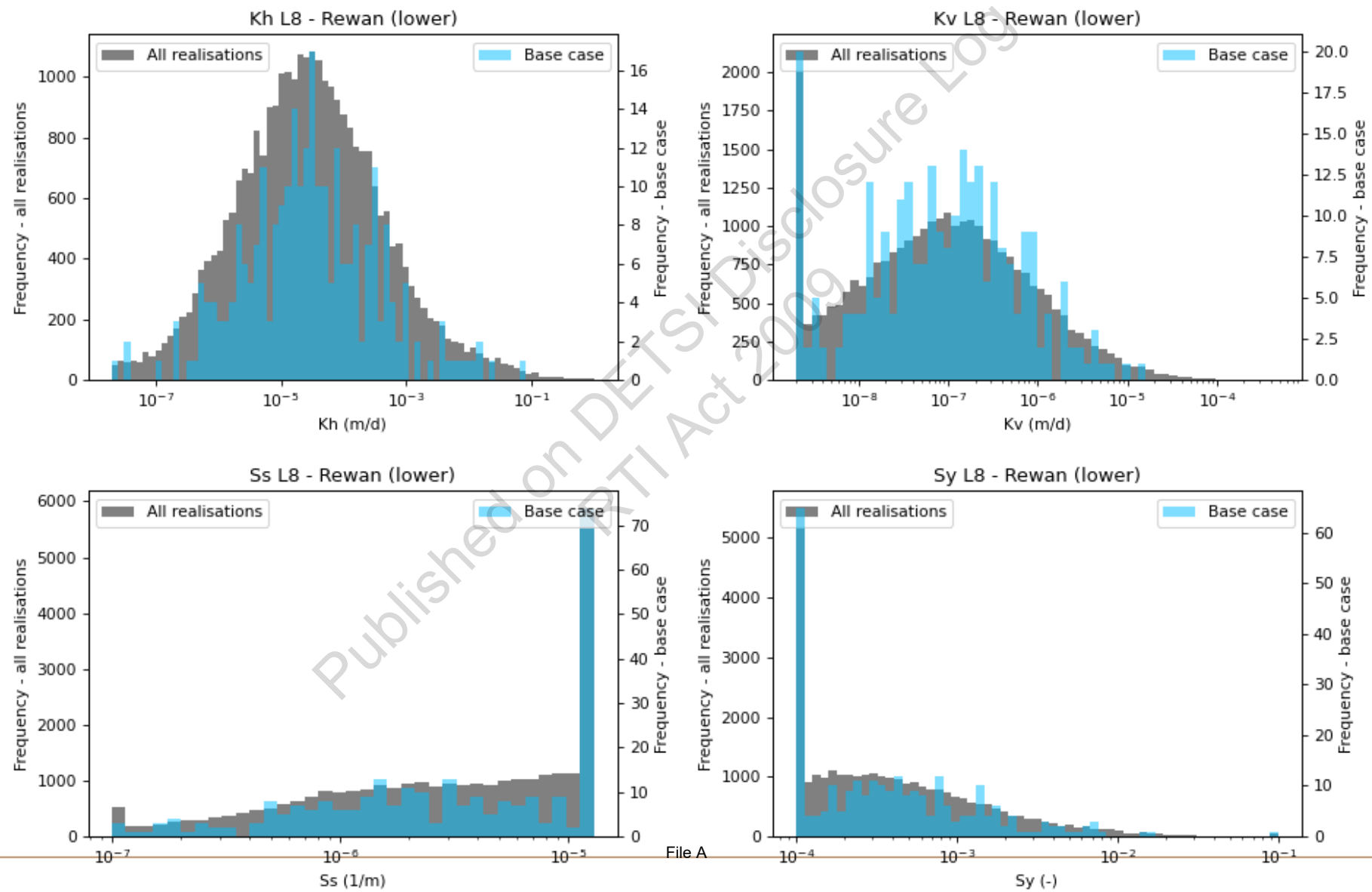
Parameterisation – L6 Dunda



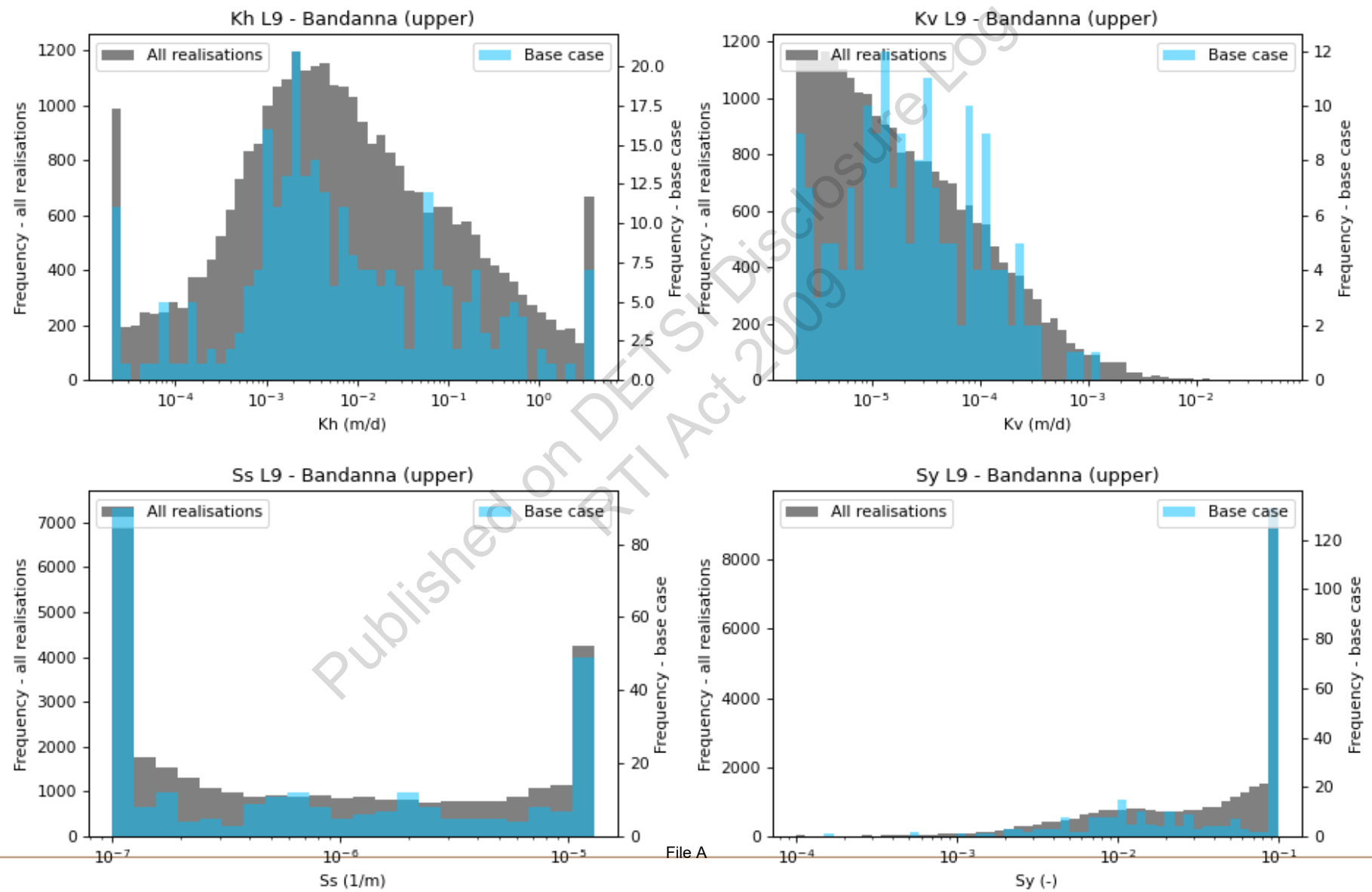
Parameterisation – L7 Rewan (upper)



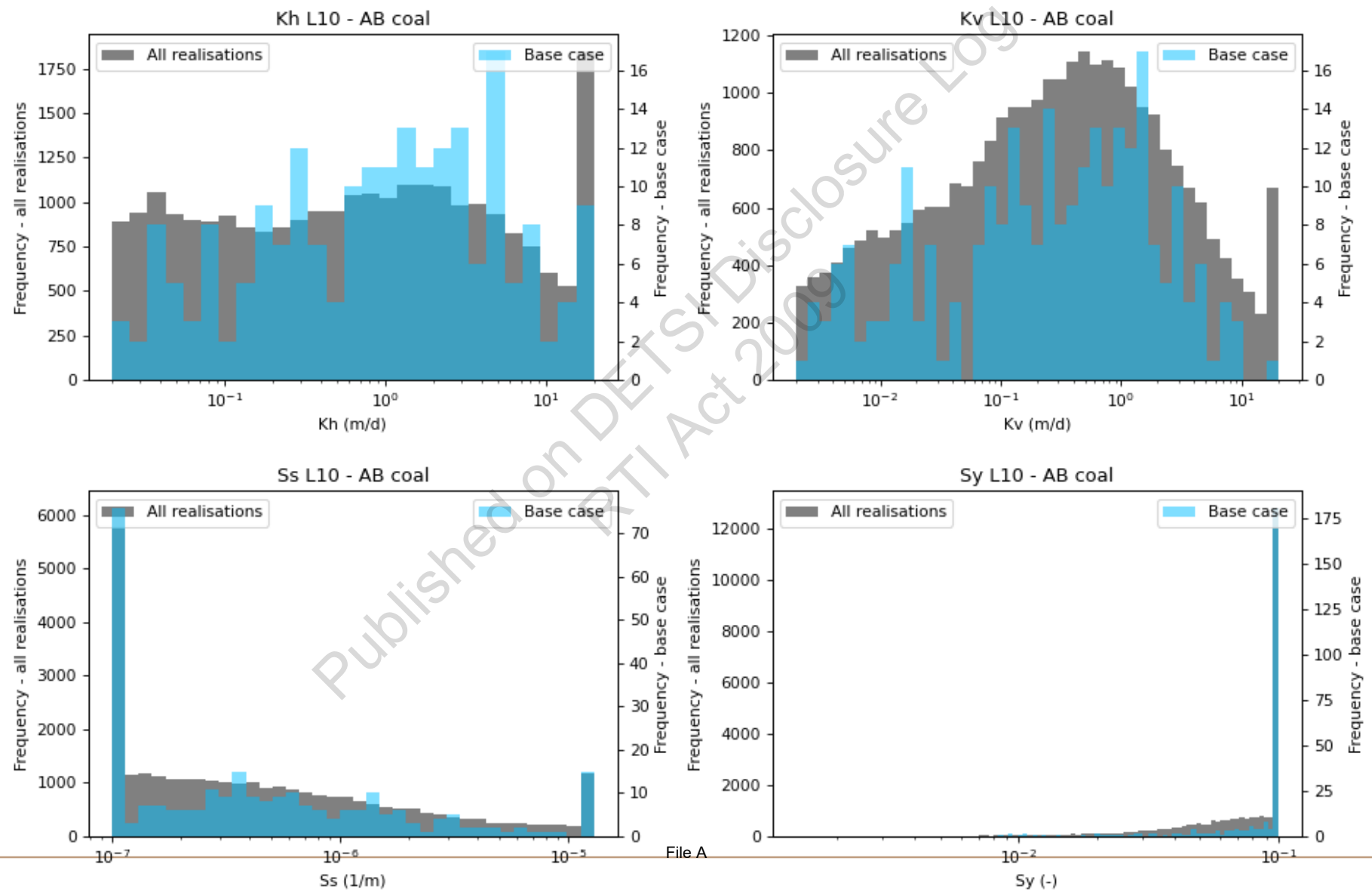
Parameterisation – L8 Rewan (lower)



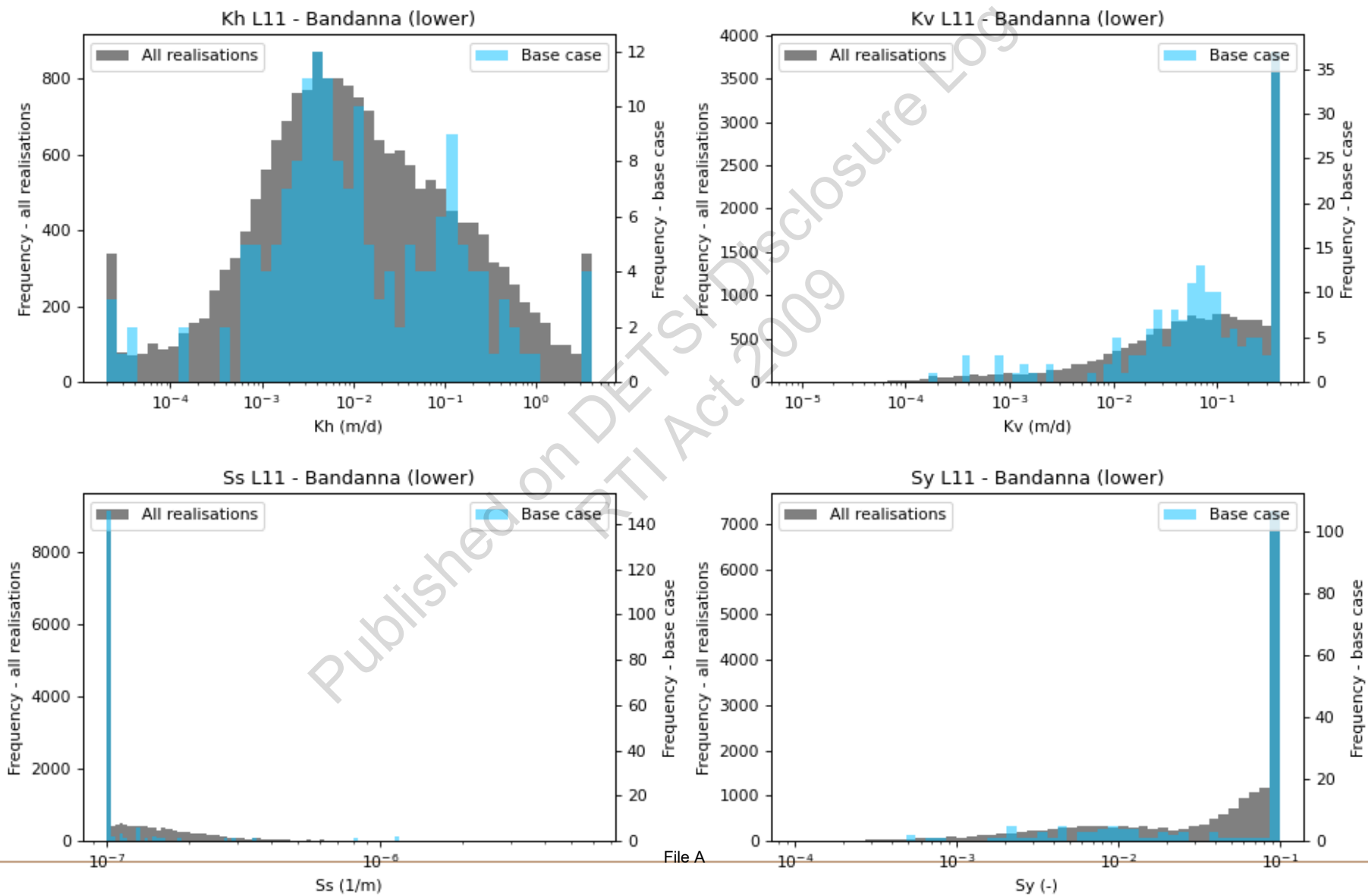
Parameterisation – L9 Bandanna (upper)



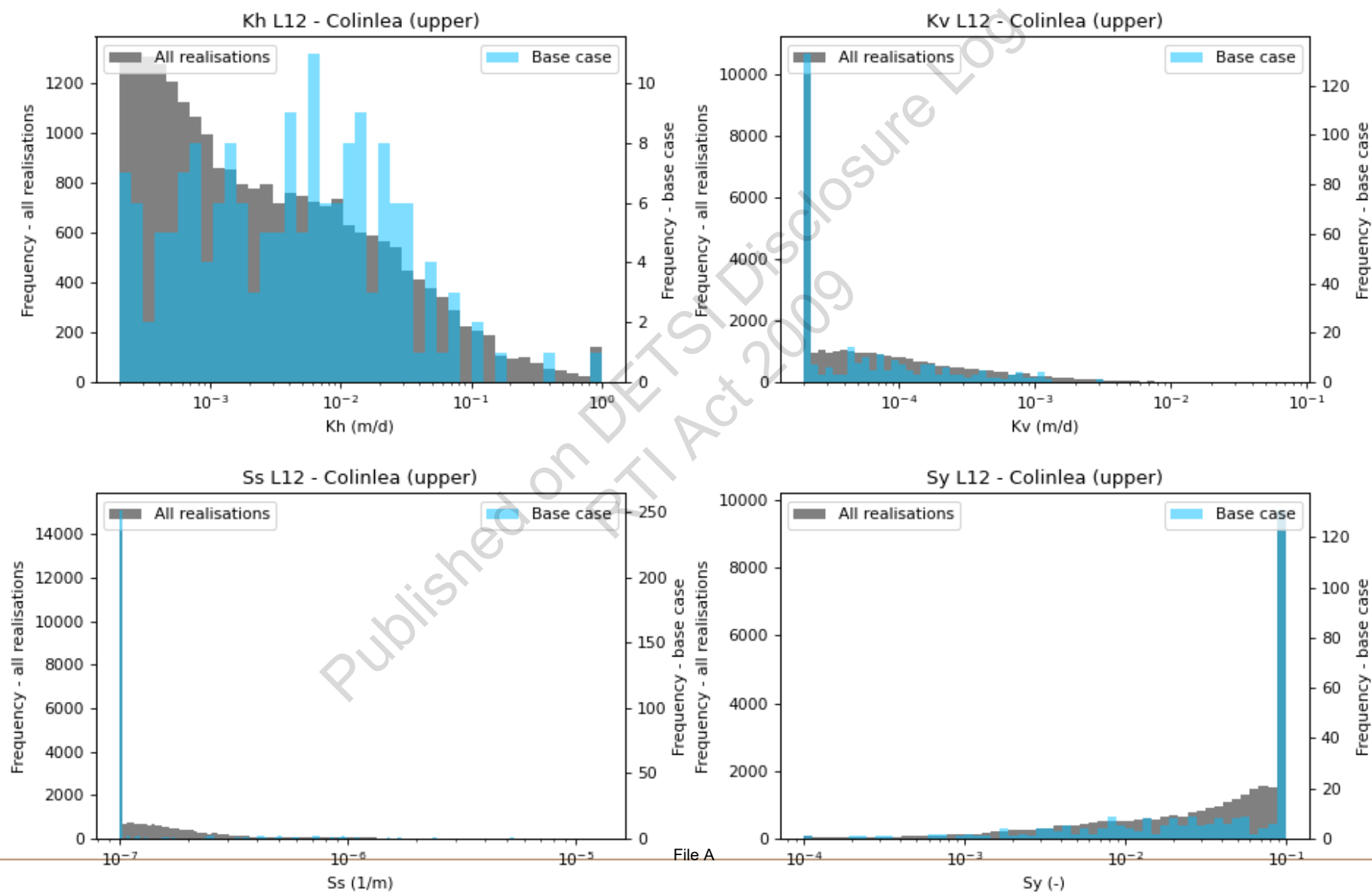
Parameterisation – L10 AB Coal



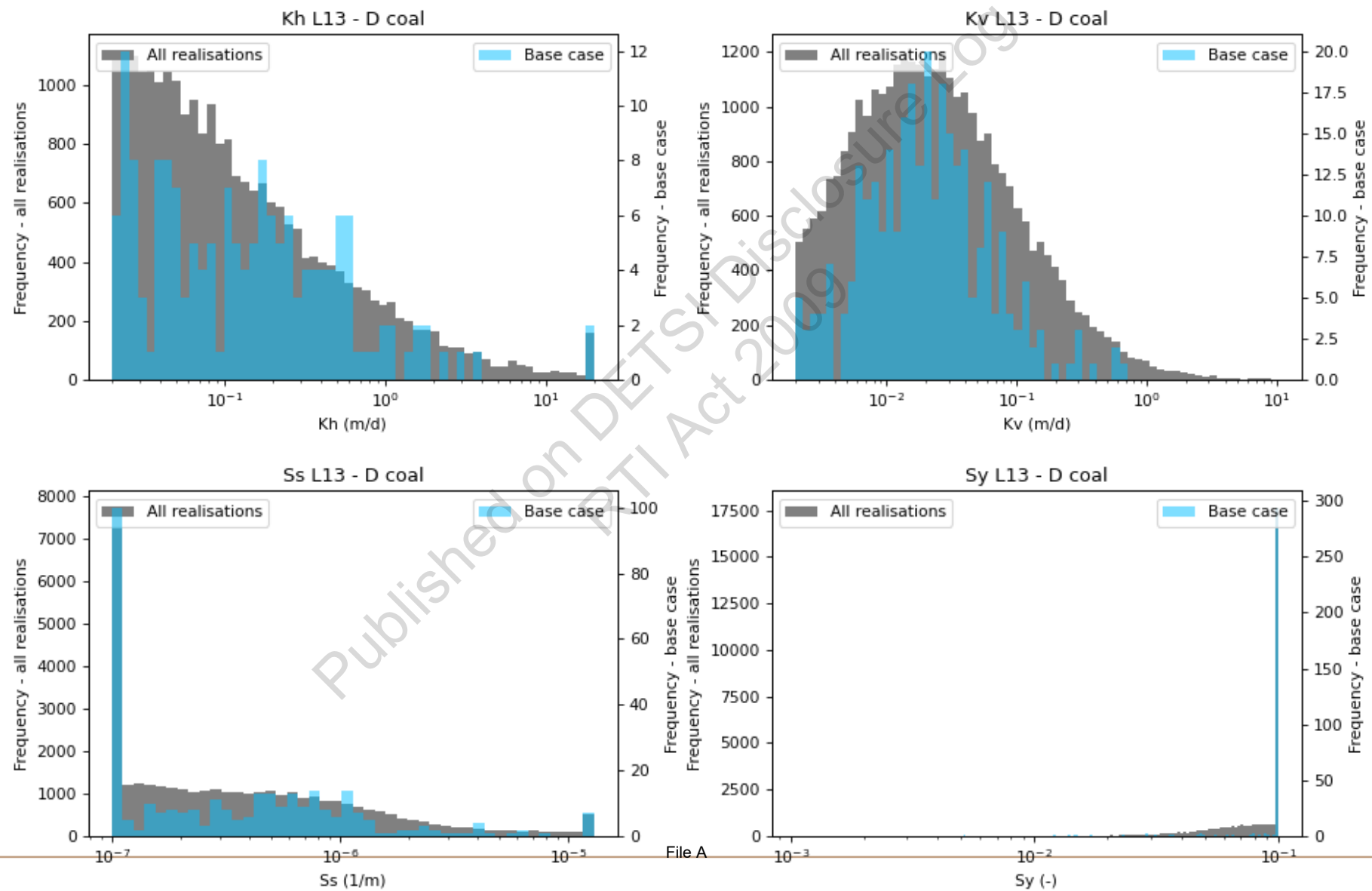
Parameterisation – L11 Bandanna (lower)



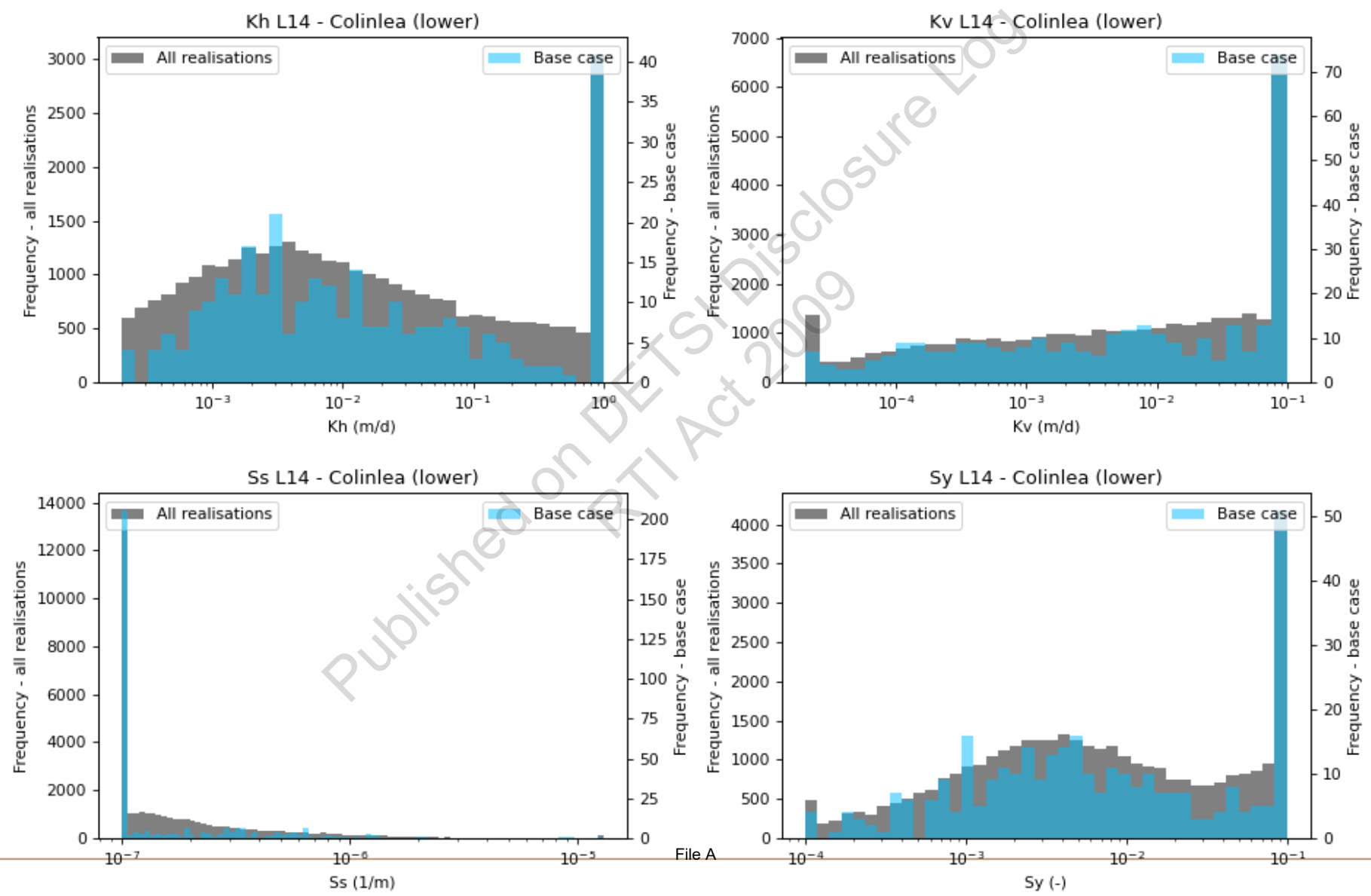
Parameterisation – L12 Colinlea (upper)



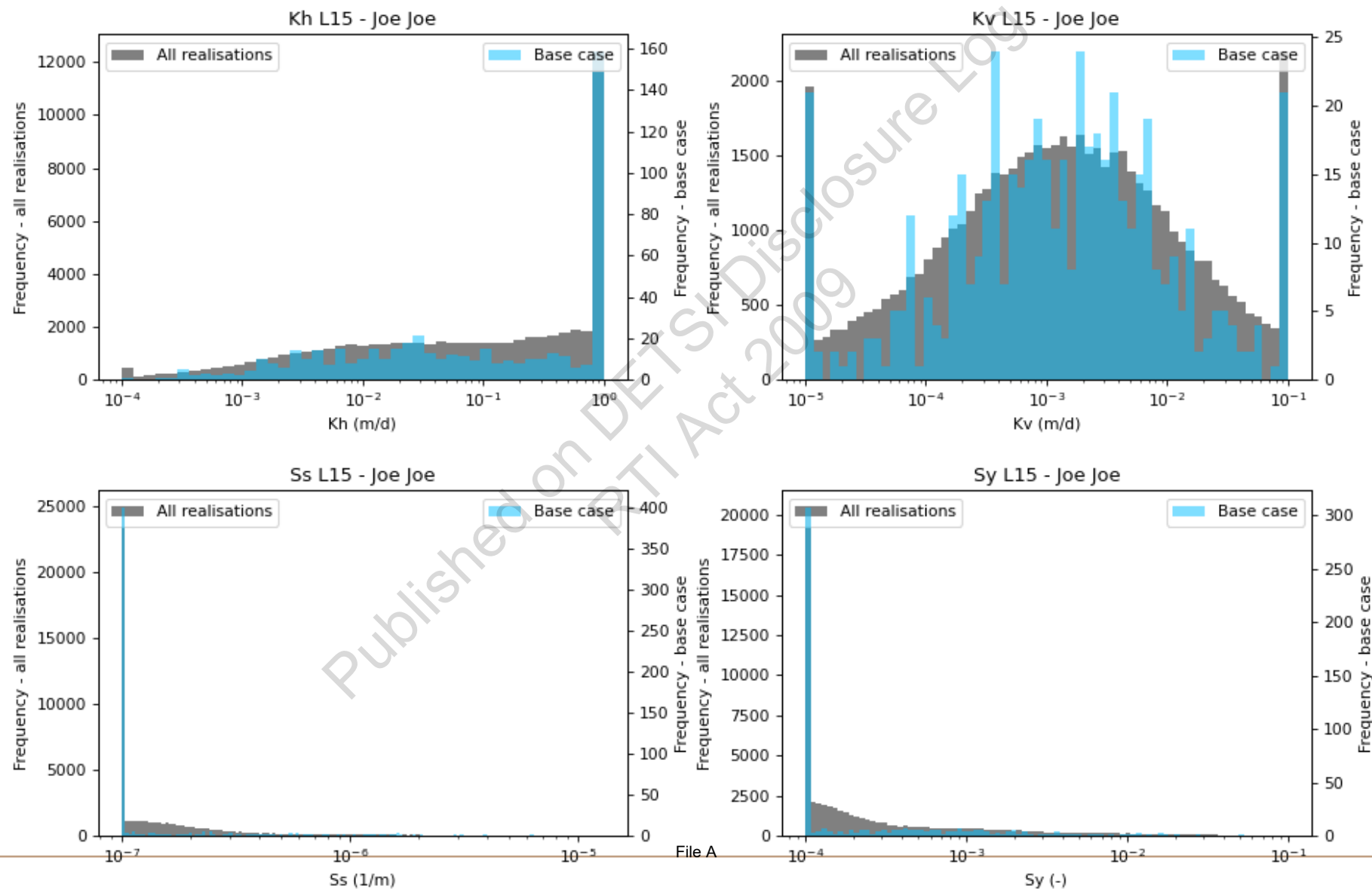
Parameterisation – L13 D Coal



Parameterisation – L14 Colinlea (lower)

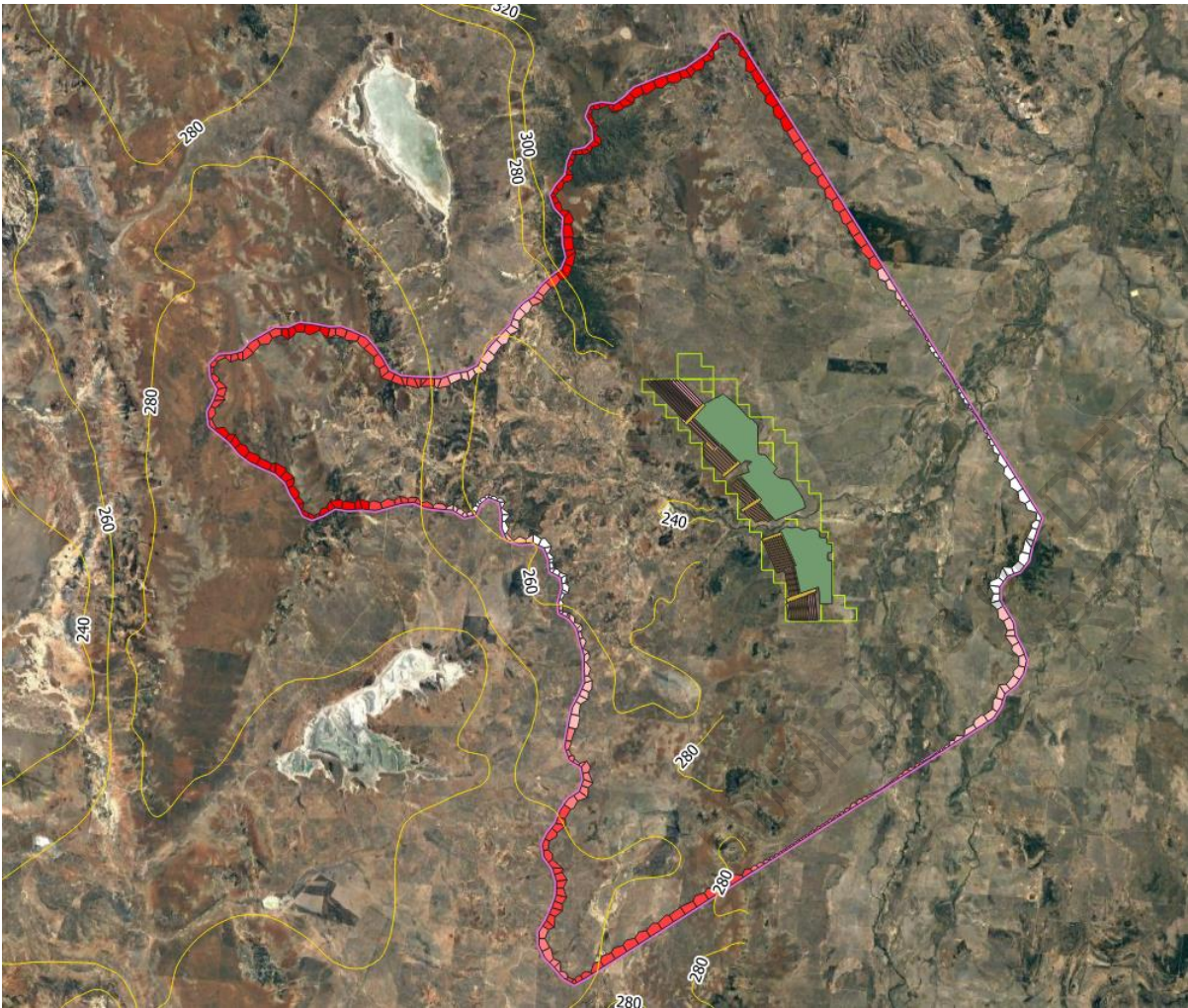


Parameterisation – L15 Joe Joe

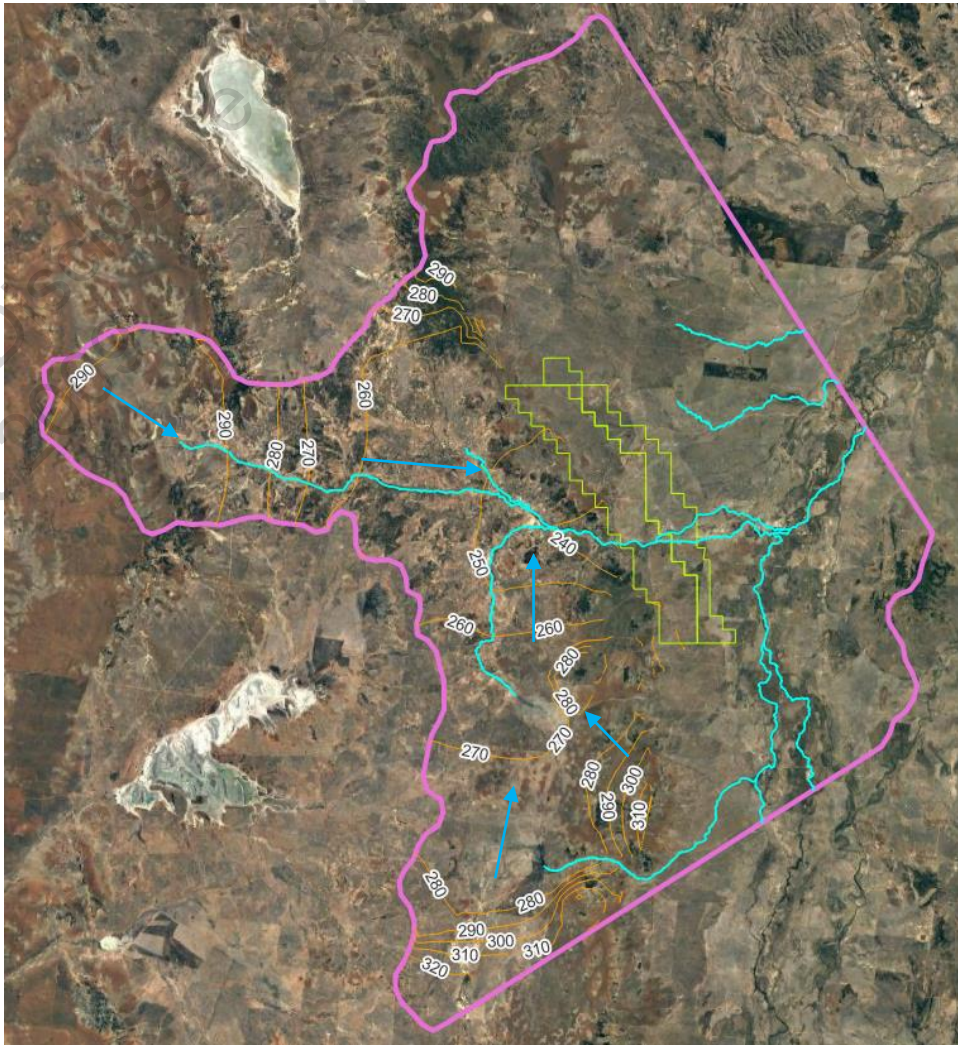


Steady state potentiometric surface – Clematis Sandstone

Interpreted

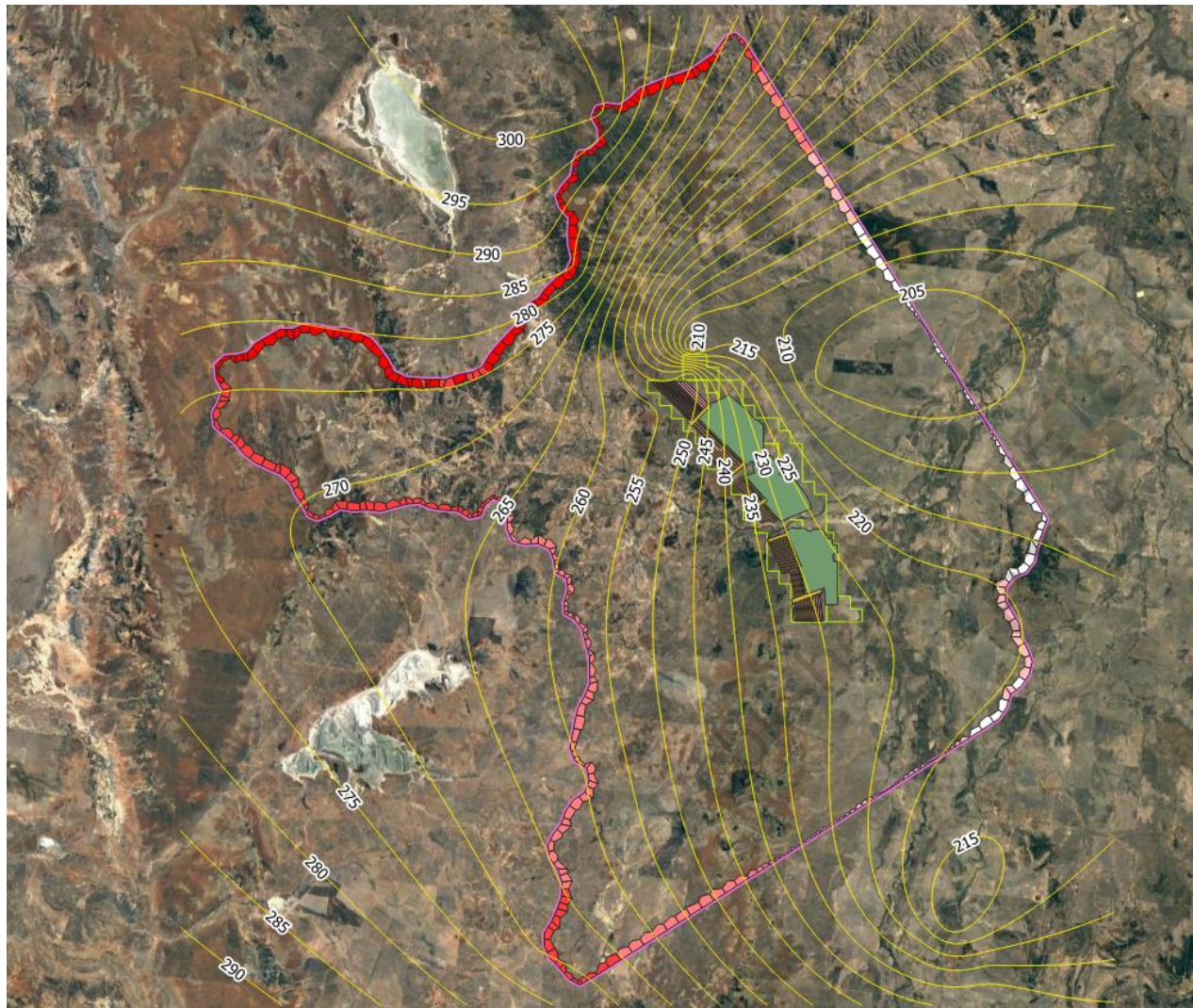


Modelled



Steady state potentiometric surface – Joe Joe Group

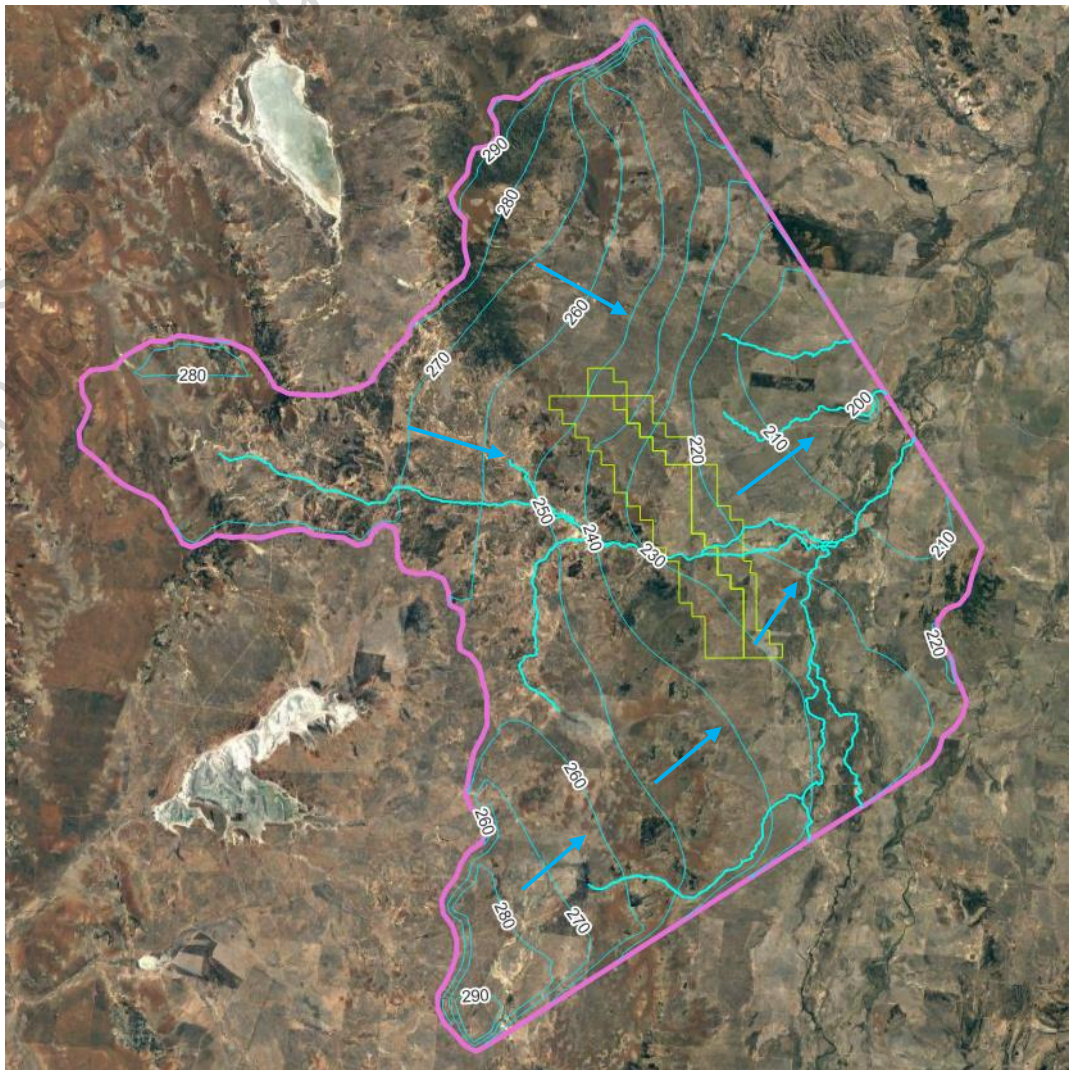
Interpreted



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File A

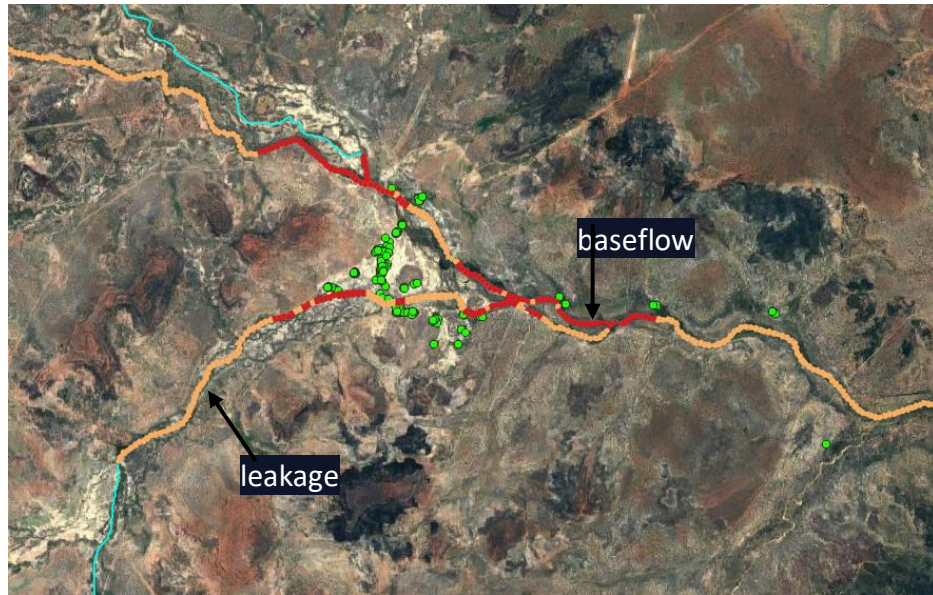
Modelled



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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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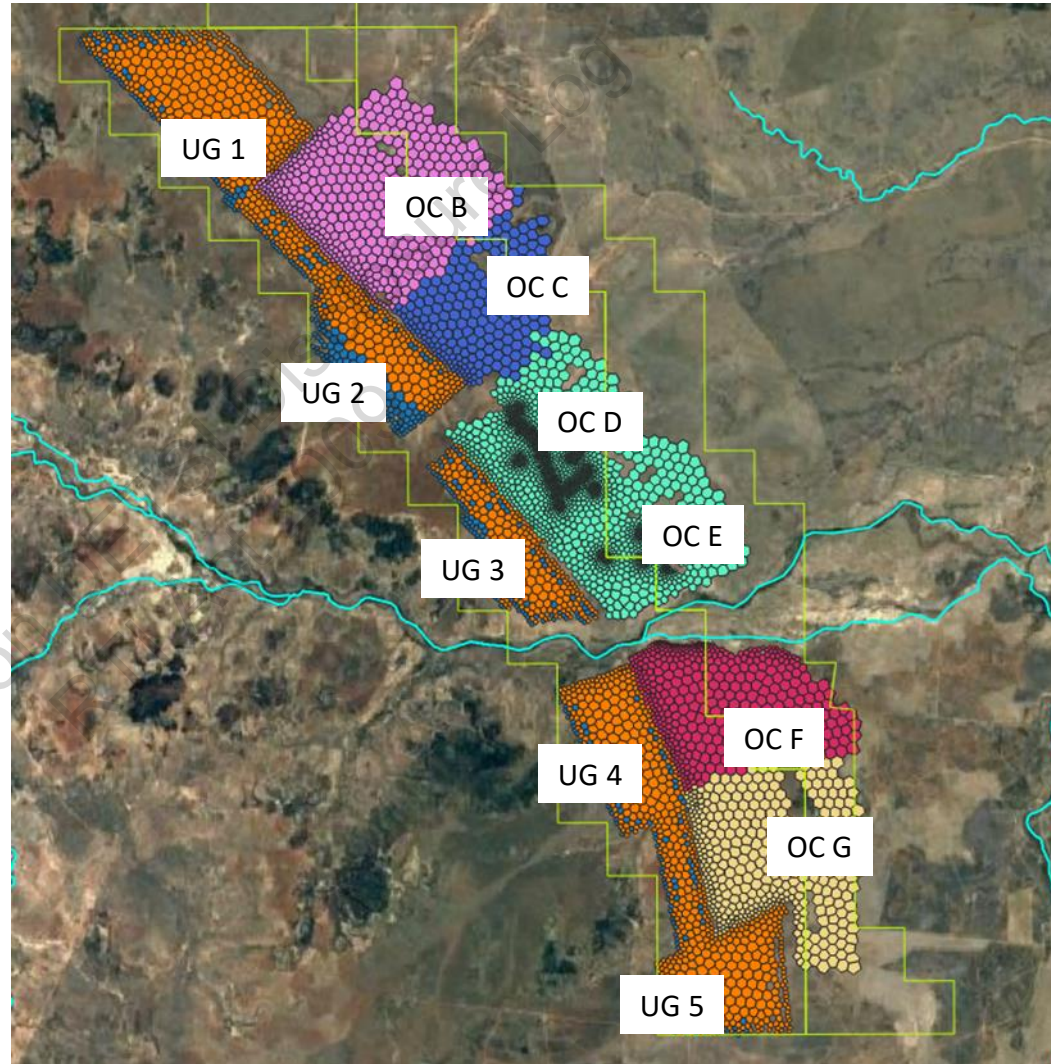
Predictive scenarios

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

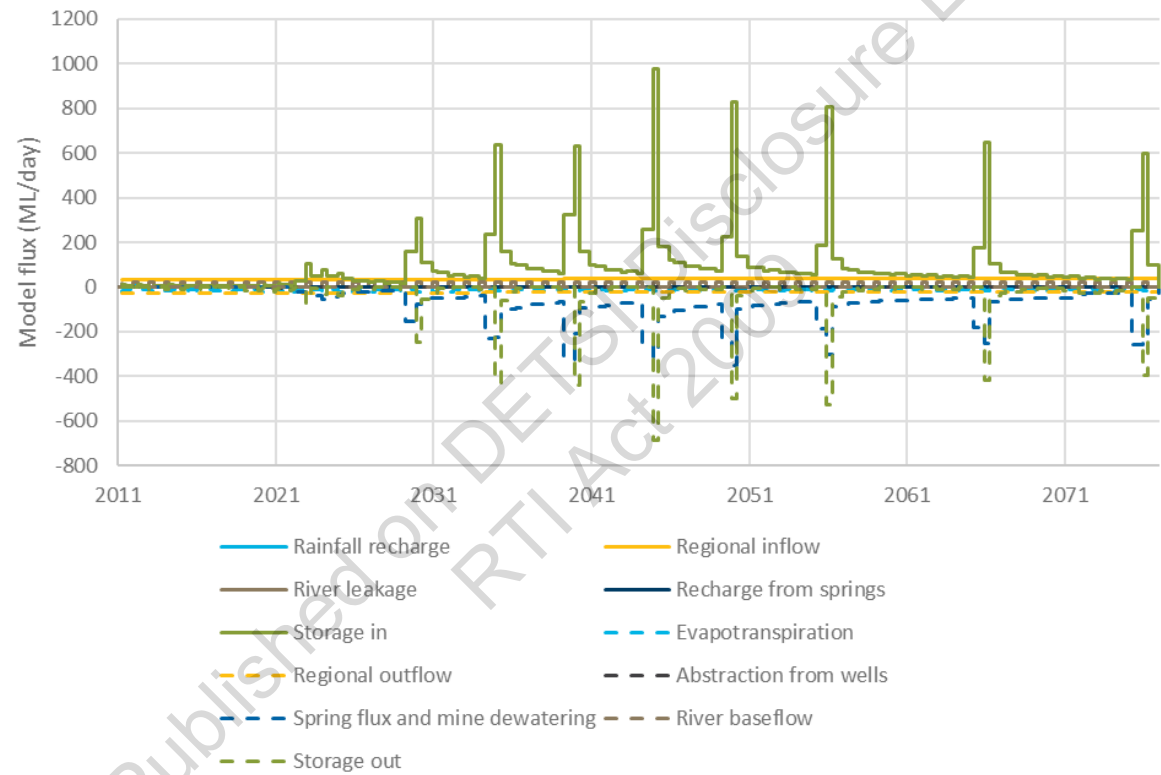
- OC: open cut
- SEIS: open cut and underground



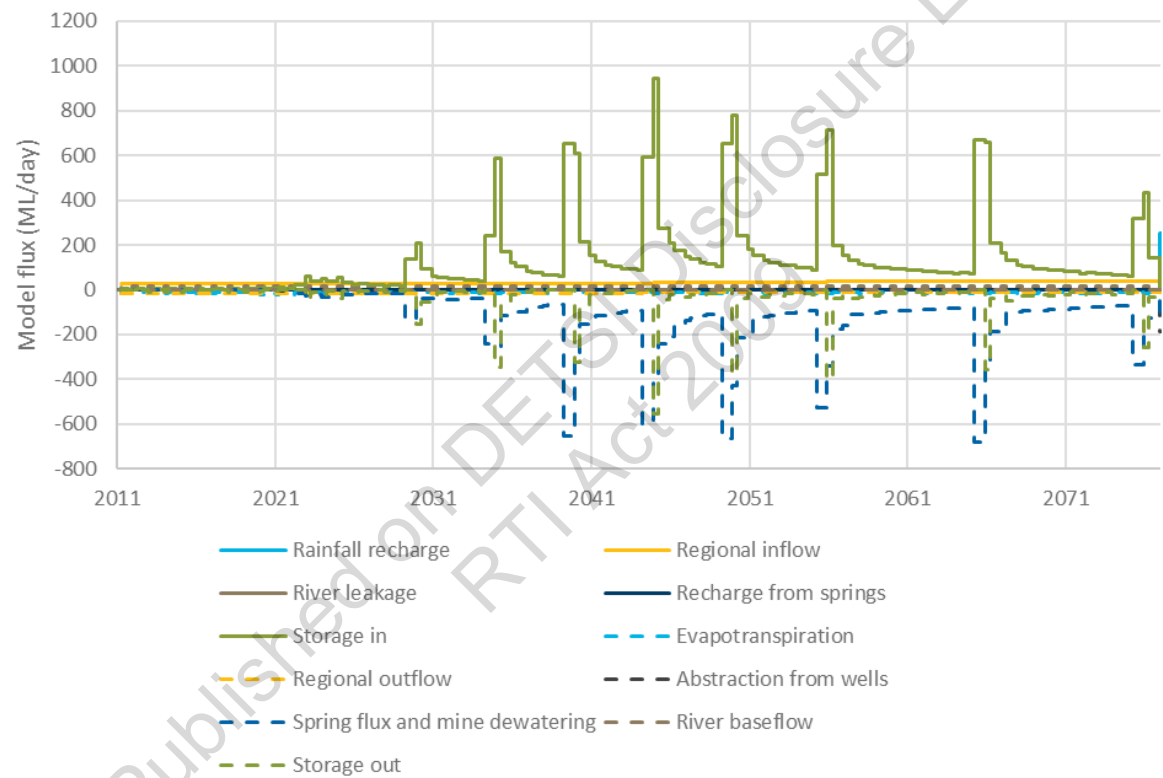
Modelled mine plan (as per SEIS)

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					

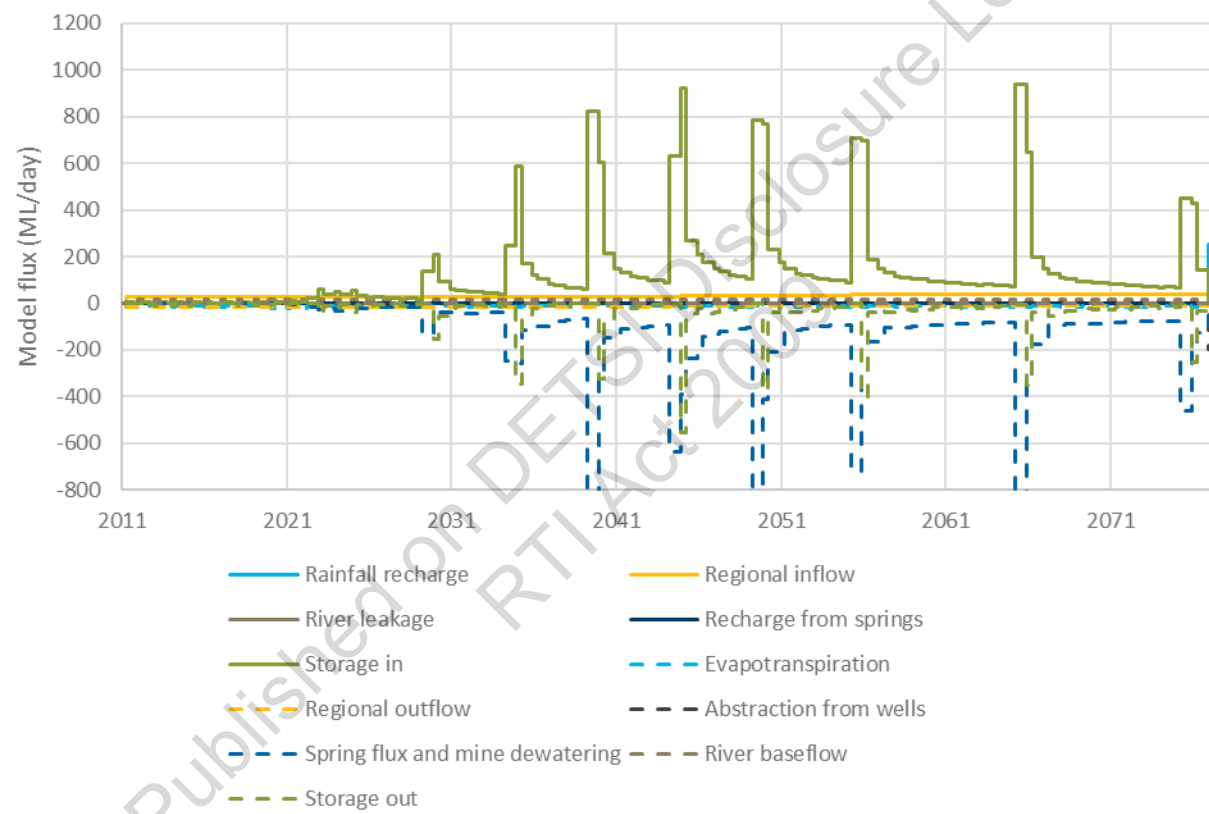
Modelled water balance: OC



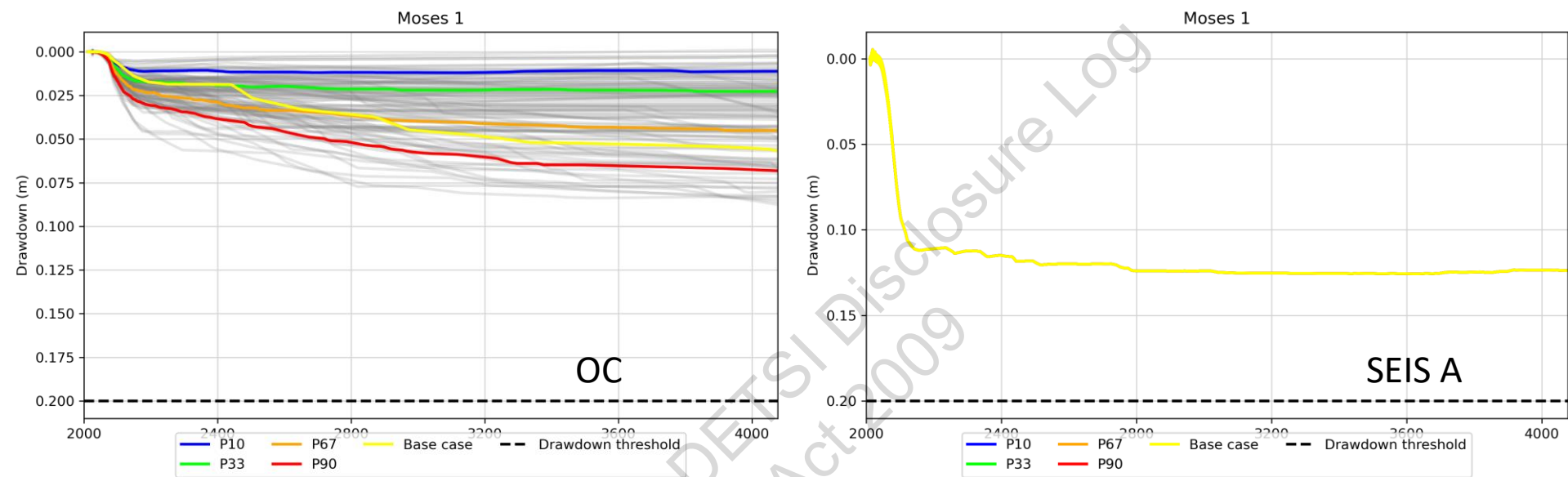
Modelled water balance: SEIS A



Modelled water balance: SEIS B



Modelled hydrographs



Modelled drawdown (m) at springs

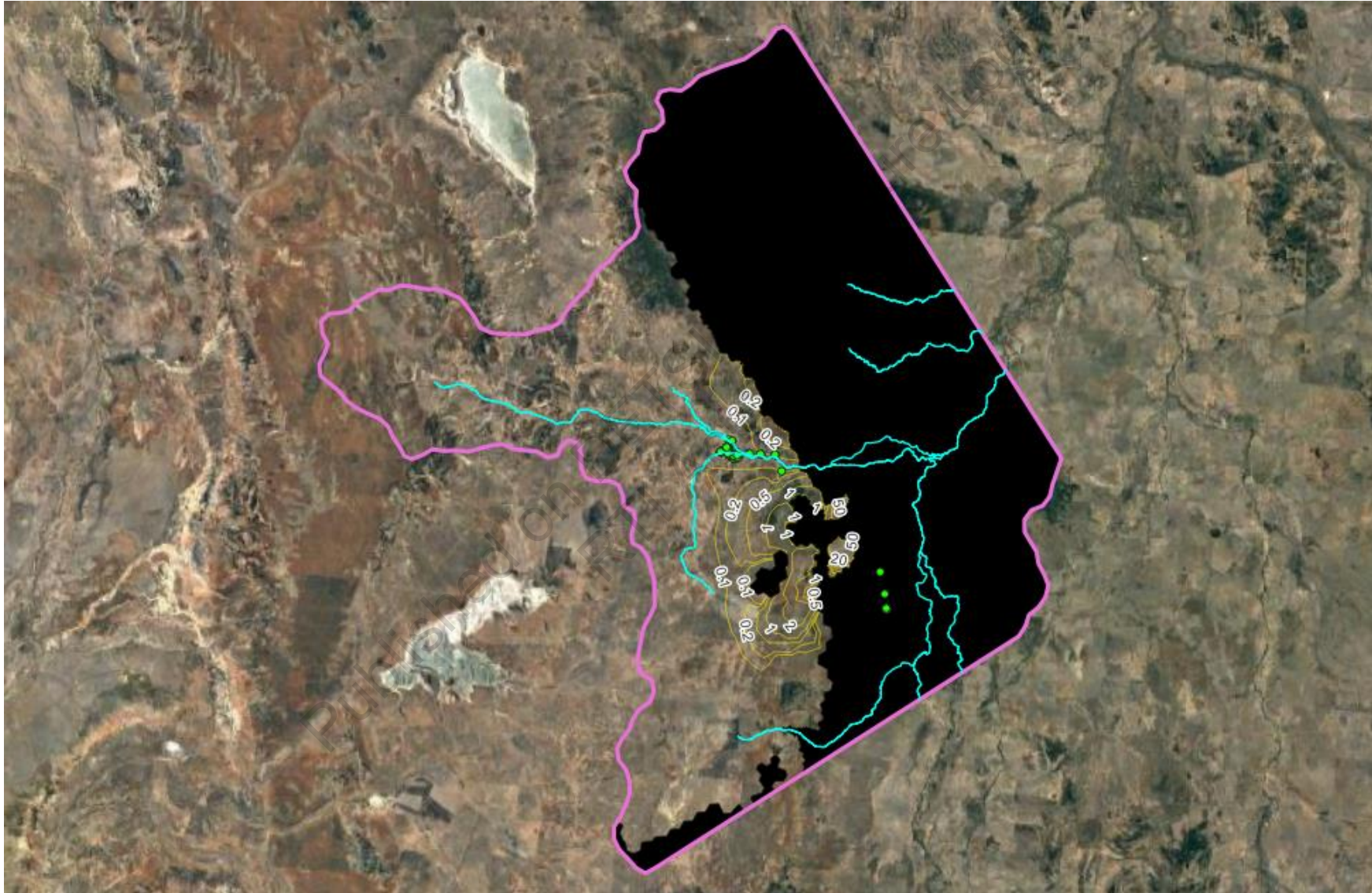
Spring	GHD (2013)	OC	SEIS A	SEIS B
Moses 4	<0.05	0.05	0.12	0.31
Moses 3	<0.05	0.05	0.12	0.31
Moses 2	0.08	0.05	0.12	0.31
Little Moses 1	<0.05	0.05	0.08	0.24
Moses 1	0.06	0.06	0.13	0.32
Moses 7	0.09	0.05	0.12	0.31
Moses 10	0.08	0.05	0.12	0.31
Moses 15	0.07	0.05	0.12	0.31
Moses 20	0.12	0.06	0.12	0.31
Moses 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

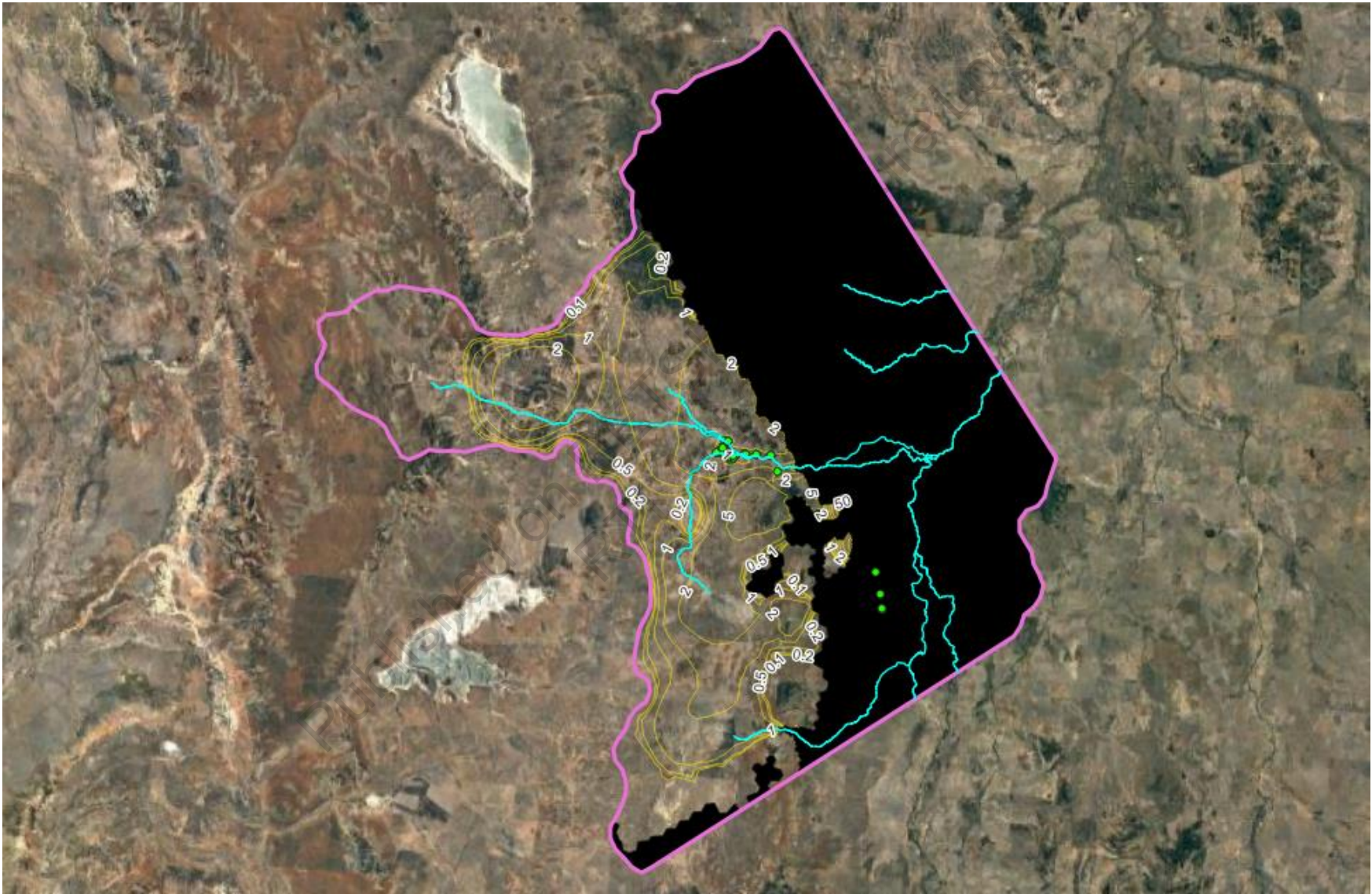
Spring	OC
Moses 4	0%
Moses 3	0%
Moses 2	0%
Little Moses 1	0%
Moses 1	0%
Moses 7	0%
Moses 10	0%
Moses 15	0%
Moses 20	0%
Moses 26	0%
Joshua Spring	0%

Published on DETSI Disclosure Log
RTI Act 2009

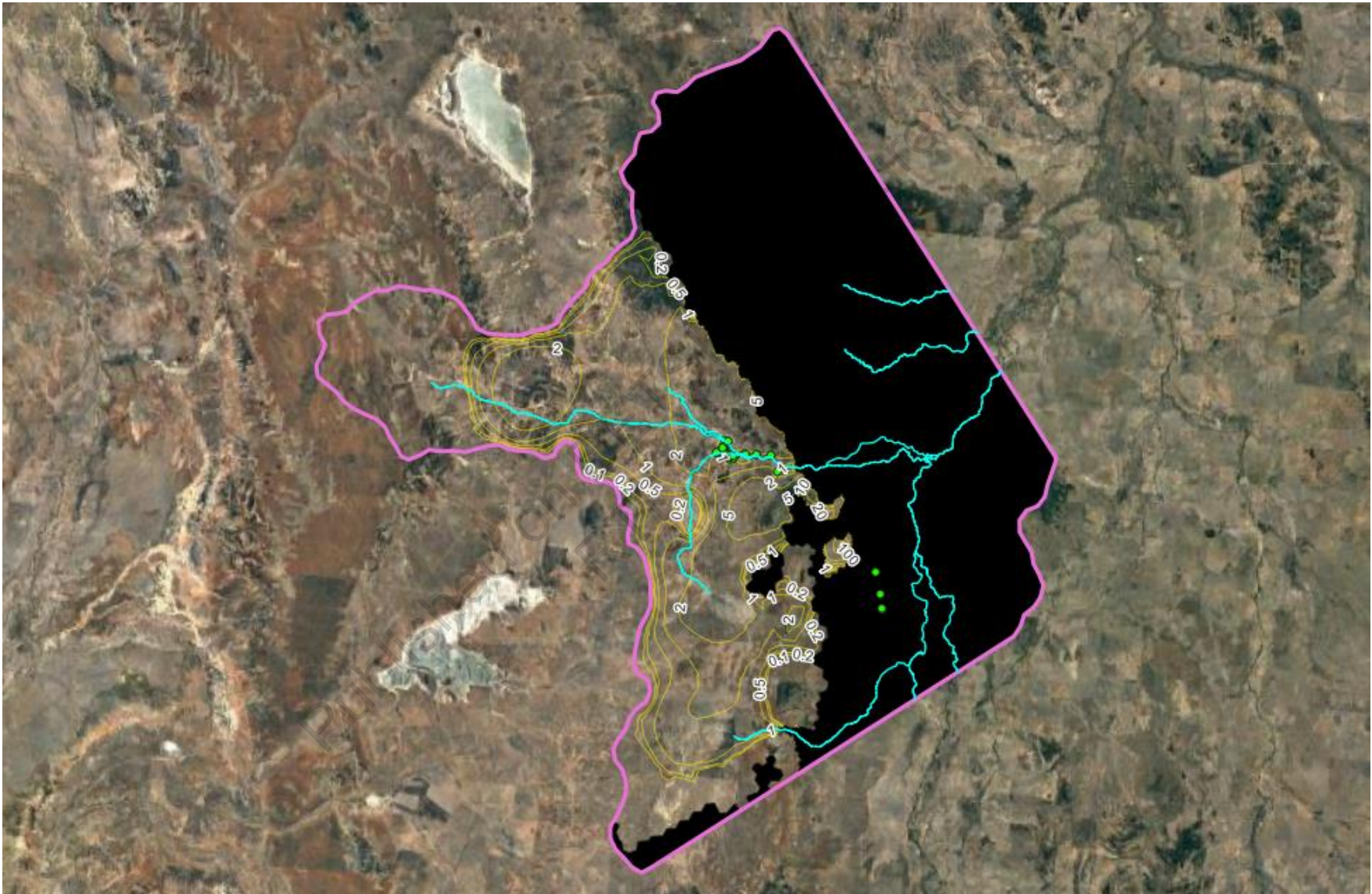
Modelled base case drawdown in Clematis: 0C



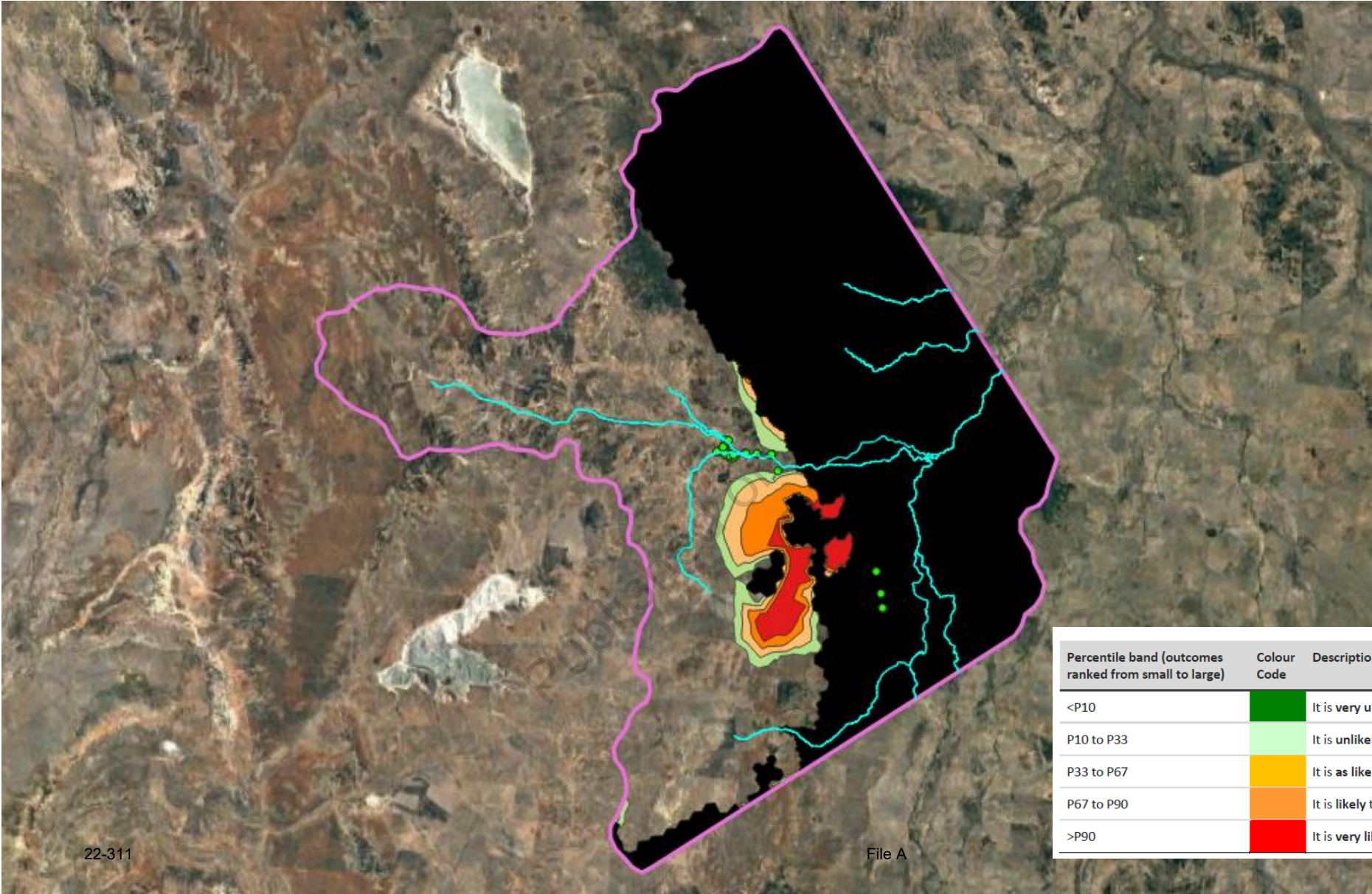
Modelled base case drawdown in Clematis: SEIS A



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



3 Evidentiary basis of review

The reports supplied for review were:

- **Document 1.** EMM (2022), “RP1.6 Hydrogeological conceptualisation review and updated groundwater – Report No. 1 Data review and conceptualisation report”, Prepared for Bravus Resources, June 2022.
- **Document 2.** EMM (2023), “Carmichael Coal Mine Report No. 2: Numerical groundwater flow model report”. Prepared for Bravus Resources, February 2023.

After an initial review of the documents, a series of questions were posed to EMM. Those questions and the corresponding responses provided by EMM are attached (Attachment A) and referred to as:

- **Document 3.** EMM (2023) Carmichael Coal Mine numerical groundwater flow model report – additional information - Memorandum dated 20th February 2023

Other ancillary documents not directly linked to the project that were used during this peer review are:

- **Document 4.** 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, National Water Commission, Canberra (herein referred to as the AGMG).
- **Document 5.** Commonwealth of Australia (CoA), (2018), *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals*, Commonwealth of Australia, May 2018.
- **Document 6.** Middlemis H and 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.

I have not reviewed any other groundwater investigations that have been undertaken since the approval of the CCM, but rather have relied on the information as provided in Document 1.

4 Model Objectives

The model objectives are provided in Section 1.3 of Document 2. In summary, the objectives of the modelling exercise are to provide a revised / updated model that addresses the requirements outlined in the EA Condition E9, and incorporates the updated conceptual model that has been informed by studies and data collection undertaken since the Supplementary EIS (SEIS)¹.

¹ GHD, 2013, *Carmichael Coal Mine and Rail Project SEIS, Appendix K1: Mine Hydrogeology Report*, report prepared for Adani Mining Pty Ltd.

5 Response to Condition E9 of the Environmental Authority.

The following section lists the requirements of condition E9 of the EA, and my comments on how the documents provided have addressed these requirements.

a) *a review of the hydrogeological conceptualisation used in the previous model*

Document 1 provides this review and incorporates the studies undertaken post the SEIS into the current conceptual model. These studies provide more information on the source of water to the nearby springs including the Doogmabulla Springs complex which Bravus has committed to not impacting. The document compares the updated conceptual model with the understanding of the conceptual model at the time the SEIS was prepared. It includes a list of previous criticisms of the SEIS study and how the updated conceptual and numerical modelling addresses these comments (see Table 13.2 of Document 1).

b) *an update of the predicted impacts*

The groundwater model report (Document 2) provides basecase predictions of drawdown in the key hydrostratigraphic units including the Clematis Sandstone and the AB coal seam for three scenarios. The results of the first scenario that simulates only the open cut mining are further explored through uncertainty analysis. The uncertainty analysis explores the influence of different realisations of parameters on model predictions, and concludes that drawdown at the spring locations is less than the threshold of 0.2 m.

c) *a revised water balance model*

Section 10 of the conceptual report (Document 1) describes groundwater and surface water interaction and presents the data that is available and has been collected since the SEIS. There is a water balance provided with a focus on the springs (see Fig 10.34 of Document 1). A water balance is also provided in Section 5.2 of Document 2.

d) *a review of assumptions used in the previous model*

The numerical model assumptions associated with the model build are described in Section 3 of Document 2.

e) *predictions of changes in groundwater levels for a range of scenarios*

The numerical model was used to simulate three scenarios:

1. open cut only;
2. open cut and underground applying the SEIS fracture height; and
3. open cut and underground, with an updated estimate of fracture height applied.

Further to these, the uncertainty analysis explored 105 realisations of parameter distributions creating a range of predicted water levels and allowing for statistical summaries and probability distributions to be created.

f) *any changes made since the previous model review, including data changes*

This is covered in both Document 1, and in Section 3 of Document 2 where the model design is discussed.

g) *a justification for the refined model and the outputs of the refined model*

Changes in the conceptual model and the numerical model are supported by the additional studies and data collected since the SEIS. Document 1 describes the updated understanding of the groundwater regime resulting from the further data collection. Document 2 explains the updates to the conceptual model and associated changes to the model design.

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*

Document 2, Section 4 describes the history matching conducted for the updated model, which is a process intended to improve the accuracy of model predictions. Section 7 of Document 2 provides a series of recommendations for future data collection and updates to the model intended to improve the history matching ability of the model and reduce the range of uncertainty in future predictions. Ultimately the accuracy of predictions can only be assessed in hindsight once further data becomes available.

i) *an independent peer review and certification that the environmental authority holder has undertaken the review in accordance with all commitments in the GMMP*

This document is intended to address this condition.

6 General review comments

6.1 Model design

The following comments are provided on the updated model design:

- The model has been completely rebuilt using new software, and an improved understanding of how the groundwater systems within the main hydrostratigraphic formations may interact, including more information on the source for the Doongmabulla springs from studies undertaken by Bravus per the licence requirements.
- The model extent has been kept consistent with the previous SEIS modelling. This has been driven by the objective to make comparisons to the previous work.
- Conceptually the model domain is a flowthrough system from west, north and south, to the east. This process has been simulated with constant heads in the model. This approach can drive water levels within the model domain and can interrupt the ability to conduct water level history matching. Upon initial inspection the model boundaries appeared to be sufficiently distant to prevent this being a significant issue, however review of the maximum drawdown in the coal seams indicates drawdown does reach the model boundary in the west.
- The springs have been represented by assigning the drain return flow boundary condition to the Clematis Sandstone at the respective spring locations. This boundary condition allows for the distribution of water removed from the Clematis source formation to be returned as recharge to layer 1 in the model, thus replicating the spring flowing to the surface. This approach is considered appropriate.
- Faults have not been specifically modelled as there is little evidence of significant faults occurring in the mining area. This approach is considered acceptable as the model represents some spatial variability / heterogeneity in hydraulic properties that has the potential to capture the influence of any unknown faults if there is a differing water level response on either side.

6.2 Model history matching

The following comments are provided on the history matching process and outcomes:

- It is commendable to see the observation dataset used for history matching includes both absolute water level, as well as relative change / water level behaviour. This is good practice.
- It is not clear if there was an opportunity, and sufficient data, to utilise baseflow recorded at new surface water gauging sites on the local creeks in the history matching process, but this is recommended in further model iterations as the dataset available expands.
- The level of 'fit' achieved during the history matching process is considered acceptable, although there might be some systematic boundary condition influence in the lower discharge areas of the model, as evident in the pre-mining scatter diagram. Here the flattening of scatter and inability of predictions to fall below 215 mAHD indicates a structural influence, likely why the SRMS value for these absolute observations were higher at around 10%. More detail was requested from EMM on this aspect through Question 7 of Document 3 and they confirmed structural controls were likely influencing water level predictions in this area of the model.
- Reviewing the base case parameter distributions in Appendix B of Document 2, it is apparent that a number of the datasets, particularly for specific yield for deeper units have a basecase and the majority of realisations assigned to the upper bounds. In the case of specific yield this has numerous formations with a value of 0.1 (or 10%). This is potentially a higher value than typical and is resulting in predictions of relatively large groundwater inflows to the mining areas.
- The calibrated specific storage value distributions are biased towards low values for the deeper formations, particularly the coal seams, with values reaching their theoretically lowest plausible value, and potentially not representative of the coal seams even at depth. The outcome of this assumption is predicted drawdown within the coal seams will propagate further and at a quicker rate than would occur with less extreme values.
- Through the history matching process there will always be bores that don't match well, or have a poor match in favour of better matches at a numbering of neighbouring bores. Some of the hydrographs presented in Appendix C demonstrate this. However, where there is a mis-match in the starting water level, the model is generally still able to replicate the observed water level trend.

6.3 Model predictions

The following comments are provided on the model predictions:

- Three scenarios were developed which provide insight into the impact of underground mining over just open cut mining, and also the influence of the different fracture height estimates.
- The 'high-K' lake is approach to represent the residual void lake. This approach uses very high values of hydraulic conductivity and storage to represent the open void remaining post mining. The hydraulic conductivity value assigned is nominally high enough to readily connect water between model cells (as would be expected within a lake), and the specific yield value of 100% means that the entire volume of the cell is available to receive water and the unconfined water level changes linearly with added or removed water. Once the water level in the void cell gets high enough, the cell becomes confined (the water level moves above the top of the model cell and starts saturating the cell above). At this point the storage properties of the cell that is confined are described by the specific storage. EMM have assigned a specific storage value of $1.3 \times 10^{-5} \text{ m}^{-1}$ (note there is an error in Document 2 which records the units as m/d, rather than m^{-1}). The adopted value is at the theoretical upper limit of plausible specific storage values in confined media. This means that despite the cell being 'full', the high specific storage means that the cell can continue to receive water. When the cell is full, the value assigned to specific storage should approximate the compressibility of water, with a value of $5.0 \times 10^{-6} \text{ m}^{-1}$. The implications for the model are that the final void water level will fill slower and ultimately be at a lower predicted level for the given inputs. I raised this with EMM and they acknowledged the error (see Question 4 in Document 3). I recognise the equilibrium water level in a void is a balance between the inputs (rainfall recharge and runoff, groundwater inflow) and outputs (evaporation), and in most cases groundwater inflow is significantly smaller than the other components. This means that the influence of this parameter is likely to be small. This issue could be overcome by adding a steady state stress period to the end of the transient post mining recovery to provide the equilibrium levels. Based on the hydrographs in Document 2 Appendix D it is not clear if a pseudo steady state in water levels has been reached at year 4000.
- Document 2 Figure 3.33 indicates the pit void depth which is assumed to be the final landform. I can appreciate that the detailed planning around what the final landform will look like may not be available at this point in time, but I would have expected the backfilling in the pit to bulk up and not be starting at 3 m or more below surface topography for areas along the eastern side of the pits.
- There are no equilibrium / long term drawdowns provided in the report. It would be helpful to visualise where the extent of the pit lake is within the pit extent.
- Water budgets indicate the dominant component is throughflow – water coming in from the west, north and south, and exiting the model domain as either evaporative losses or as throughflow in the east. This representation is supported by the conceptual model, and reflects the concept adopted in the original SEIS model. The assigned constant heads at the western boundary are influencing drawdown extents in the coal seams (and possibly other layers). This can be seen in Document 2 Figures 5.9 to 5.11, with the drawdown becoming zero right around the boundary. Given the dominant volume of throughflow in the model budget I posed Question 13 in Document 3. EMM confirmed that the budget does change in the predictive phase with an increase to the net inflow of 14 ML/day. The drawdown reaching this boundary is a function of the low coal seam specific storage. This will be a feature that needs review in future model updates, particularly as the specific storage values are refined through history matching to water levels influenced by nearby mining.

6.4 Uncertainty analysis

The following comments are provided on the uncertainty analysis:

- The uncertainty analysis has been undertaken on the scenario that simulates the 'open cut only' mining. The report does not treat the uncertainty analysis as a separate exercise, rather it is woven through the various prediction reporting. There is only one drawdown contour plot presented and this is for the Clematis Sandstone. This is an appropriate hydrostratigraphic unit to focus on as evidence to date suggests this is the likely water source for most of the springs in the area.
- The calibration results show not only the basecase model results, but also the results from the other 104 realisations that form the uncertainty analysis. This approach is helpful as it provides insights into the variability of predictions from each history matched model.
- Drawdown hydrographs are provided for observation bores and at spring locations in Document 2 Appendix D (for the open cut only scenario) and show all the realisations as well as the probabilities of the drawdown being less than the indicated hydrograph. These graphs all show the critical spring drawdown, however it is only necessary to show on hydrographs that represent spring predictions.

7 Confidence level classification

The Australian groundwater modelling guidelines provide a method of assessing a model's confidence level and infers typical uses for a model based on specific characteristics. Document 2 did not include a 'self-assessment' according to the modelling guidelines, and as such I have undertaken this as part of the peer review process.

Under the guidelines, this model would be classified as a Confidence Level 2 groundwater model, with the following key indicators (based on Table 2-1 of Barnett et al., 2012):

- rainfall and evaporation data are available for the site (Level 3);
- groundwater head observations and bore logs are available and with a good coverage around the Carmichael site, but without spatial coverage throughout the model domain (Level 2);
- some site and field properties are available, but missing some estimates of storage (Level 2);
- scaled RMS error and other calibration statistics, e.g. mean residual, are acceptable (Level 3); and
- Transient calibration and predictions are conducted (level 2).

The indicated use for the model based on this classification is for the assessments of impacts.

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Table 7.1 Confidence Level Classification (After Table 2-1, Barnett et al, 2012)

Class	Data		Calibration		Prediction		Quantitative Indicators	
1 (Simple) Count=0	×	Not much	×	Not possible	×	Timeframe >> Calibration	×	Timeframe > 10x
	×	Sparse coverage	×	Large error statistic	×	Long stress periods	×	Stresses < 5x
	×	No metered usage	×	Inadequate data spread	×	Poor/no validation	×	Mass balance > 1% (or one-off 5%)
	×	Low resolution	×	Targets incompatible with model purpose.	×	Transient prediction but steady-state calibration	×	Properties < > field values
	×	Poor aquifer geometry					×	No review by Hydro/Modeller
2 (Impact Assessment) Count=12	×	Some	✓	Partial performance	✓	Timeframe > Calibration	×	Time frame = 3-10x
	✓	Ok coverage	✓	Some long term trends wrong.	×	Long stress periods	×	Stresses = 2-5x
	~	Some usage data/ low volumes	✓	Short term record.	×	Ok validation	✓	Mass balance <1%
	×	Baseflow estimates. Some K & S measurements	~	Weak seasonal match.	✓	Transient calibration and prediction	✓	Some properties < > field values. Review by Hydrogeologist
	✓	Some high resolution topographic DEM &/or some aquifer geometry	✓	No use of targets compatible with model purpose (heads & fluxes)	✓	New stresses not in calibration	×	Some coarse discretisation in key areas of grid or at key times
3 (Complex Simulator) Count=9	~	Lots, with good coverage.	✓	Good performance stats	×	Timeframe ~ calibration	×	Timeframe < 3x
	~	Good metered usage info.	×	Most long term trends matched	×	Similar stress periods	×	Stresses < 2x
	✓	Local climate data	~	Most seasonal matches ok.	×	Good validation	✓	Mass balance < 0.5%
	~	Kh, Kv & Sy measurements from range of tests	✓	Present day data targets	×	Calibration & prediction consistent (transient or steady state).	~	Properties ~field measurements
	×	High resolution DEM all areas.	×	Head & Flux targets used to constrain calibration	×	Similar stresses to those in calibration.	✓	No coarse discretisation in key areas (grid or time)
	~	Good aquifer geometry.					✓	Review by experienced Modeller

Notes:
Criteria met = ✓
Criteria partially met = ~
Criteria not met = ×

8 Compliance checklist

The Australian groundwater modelling guidelines provide a generic compliance checklist to assess a model at a high level. Because this assessment has relied on the reporting and not examined model files, nor the background reporting underpinning the conceptual model update, this is the most appropriate level to comment at. The 10 questions that form this checklist cover essential elements of a groundwater model.

The checklist is sourced from Table 9-1 of the Australian groundwater modelling guidelines (Document 4).

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Table 8.1 Compliance Checklist

Question	Yes / No	Comment
1. Are the model objectives and model confidence level classification clearly stated?	Yes	The model objectives are outlined in Section 1.3 of the Document 2. The report does not provide a self assessment of the confidence level classification, but one has been carried out as part of this review.
2. Are the objectives satisfied?	Yes	The updates to the conceptual model presented in Document 1 have been amalgamated into the updated model (see Section 4 of this review).
3. Is the conceptual model consistent with objectives and confidence level classification?	Yes	While there is no self-assessed confidence limit provided in the reporting, one has been undertaken for this review and assessed the model as having a confidence level classification of Level 2. This is supported by the additional data that underpins the conceptual model assumptions and the conceptual model
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	The conceptual model has been presented in Document 1. It was peer reviewed by Dr Noel Merrick who is appropriately qualified to review the document.
5. Does the model design conform to best practice?	Yes	<p>The model uses the most up to date industry standard software (MODFLOW-USG) and applies features (such as adopting Voronoi cells in the mesh) that are best practice.</p> <p>The design has been a little constrained by needing to be comparable to the previous model in some places, such as model extent.</p> <p>The model utilises a transient pre-mining 'warm up' stage to help with solving the steady state model representing pre-mining conditions.</p>
6. Is the model calibration satisfactory?	Yes	<p>The calibration statistics satisfy targets, however the scatter diagram indicates some systematic mis-match – assumed to be due to boundary condition influence, and confirmed by EMM in response to Question 7 in Document 3.</p> <p>The calibration process has been thorough and has utilised emerging techniques with PESTPP-IES and ensemble smoothing to reduce the computational effort.</p> <p>The methodology and approach were sound and following the principles of the GMDSI, whereby after some initial range finding calibration with single values, the model was assigned a significant amount of pilot points totalling 30960 (7,740 per hydraulic parameter) to describe heterogeneity in the system and later explore parameter uncertainty.</p>

Question	Yes / No	Comment
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	<p>Many parameters are matching to the conceptual model and field data that underpins it. However, some resulting hydraulic properties from the calibration, particularly the storage properties have calibrated to the predefined upper and lower bounds. This could be an indication of insensitivity in the parameter and the calibration process searching to make those parameters more sensitive and reaching the bounds. This aspect was explored in Question 9 of Document 3 (attached).</p> <p>It is noted that the calibrated steady state and transient water budgets are dominated by throughflow. This was a feature of the SEIS model and is part of the conceptual model.</p>
8. Do the model predictions conform to best practice?	Yes	<p>The predictive phase and the simulation of the mine dewatering through drains and applying property changes within the fracture zone, are aligned to best practice. The reporting is not clear on the exact details of how the mining progresses, but further information was provided by EMM in response to Question 1 in Document 3. Backfilling of spoil seems to be made at the end of mining.</p> <p>There is a tabulated schedule that indicates that mining remains active in the mining domains once it starts all the way through to the end of mining in 2075. The TVM package is used to make changes to hydraulic properties prior to the post mining phase of the predictions and this can be considered current best practice.</p> <p>Fracture height calculations using best practice have identified a significant change in a previous assumption for this value, thus the formulation of a number of prediction scenarios to explore the difference that this change creates.</p> <p>The presentation of drawdown within the model results comes from the maximum drawdown experienced at that location both during and after mining, which can be considered best practice.</p> <p>There has not been any climate change scenarios run. This included in the next model update.</p>
9. Is the uncertainty associated with the predictions reported?	Yes	<p>Hydrographs at bores and the critical 0.2 m drawdown in the Clematis Sandstone are presented with probabilistic measures. There is no uncertainty analysis provided for the mine inflow predictions, though EMM's response to Question 11 in Document 3 indicates that spot checks were carried out with some of the realisations which suggest variability of $\pm 20\%$ from the basecase prediction.</p>
10. Is the model fit for purpose?	Yes	See Section 9 below.

1.3 Question 3

Q: In regard to the ramp function for fracture zone changes (section 3.5.5 iii), my understanding is that this gets applied to each model cell in the fracture zone (within 230m above the caved zone), where the cell elevation (from centroid?) is applied to the log-linear relationship between to get a new K at that location. Initially, and based on the figure, I thought this could have been relying on whatever host K existed at the 230m above cave zone, and then the interpreted change using that host K for all the layers in that cell column. I think I understand it better now. With that in mind, is this applied to both Kh and Kv, using their respective host K values? As the 230 m was an average from the Merrick 2021 calcs, what was the range? Has Hmax been allowed to vary from location to location (possibly cell by cell)? I am asking because the fracture height calculation uses overburden thickness and I wonder how much this varies across the planned underground footprint.

A: Your understanding of elevation from centroid is correct, as is the modification to the in-situ hydraulic conductivity. This was applied to both Kh and Kv, with the assumption that Kh = Kv in the cave zone. Hmax was held constant for the full mine footprint, acknowledging the variance for the actual mine plan. This is a simplifying assumption that would have an impact on modelled property changes, but it was considered during model design that the uncertainty in estimated fracture height, cave zone properties, and ramp function did not justify the full detail being represented in the groundwater model.

1.4 Question 4

Q: In post mining recovery (Section 3.5.5 iv) the specific storage term for the void is reported to be “ 1.3×10^{-5} m/d”. Looking beyond the incorrect units, this value is very high. The usual approach in a ‘high-k’ lake is to apply a specific storage equivalent to the compressibility of water. Once the water level in a cell representing the void reaches the top of the cell, that cell becomes confined in the model and the water level moves above the top of the model cell and starts saturating the cell above. When this happens, any additional water received by the fully saturated (confined) void cells should be effectively passed to the partially saturated cell above as there should be no additional storage available in the confined cells. Applying a value at the upper bound of specific storage (like that reported) means that this cell will continue to store water that flows into it from surrounding strata, which will ultimately lead to an under prediction of the water level in the void with time, and result in a lower equilibrium water level. It is impossible to say if this will change the conclusion that the final void/s will act as a sink, I suspect not, but I can’t be sure.

A: Acknowledged but given that the post-mining recovery period is run to pseudo steady-state, the values for storage do not influence final modelled groundwater elevations (it more so affects the rate of recovery). The mine is conceptualised to remain a sink because the voids are only backfilled to the coal seam elevations, yet the pre-mining watertable is much higher.

1.5 Question 5

Q: The use of the CLN package in the void is clever, but does it remove the influence of the pit geometry (i.e. lower evaporation due to limited wind, shade, etc), or is that accounted for in other ways?

A: That is accounted for by reducing the maximum ‘evaporation’ rate to 70% of pan evaporation. Again, this is a simplifying assumption but one we typically use to account for geometry impacts for pit void recovery problems. The CLN package was also chosen to promote numerical stability.

1.6 Question 6

Q: There is no presentation of post mining equilibrium groundwater conditions. Is this not required for the project? Water levels at some key bores are shown post mining, but that does not give the overall picture post mining.

A: No request has been made for post-mining groundwater conditions beyond simulated drawdown. However, we agree that a final modelled groundwater contour map would be useful from a readers perspective.

1.7 Question 7

Q: Looking at the scatter diagram (Fig 4.12) for pre-mining conditions, there seems to be a systematic flattening of predicted water levels. Is there something in the model (i.e. boundary condition elevation around 215 mAHD) that might have led to this? I noticed reasonable amount of alluvium and weathered hydrographs were over predicting around that 10 to 20m range. On the other hand, some were well under. Could the over predictions be the influence of stream recharge in the steady state? The hydrographs did seem tight across the range of realisations pointing to a boundary condition influence.

A: There are definite structural controls preventing improved history-matching performance and leading to tighter hydrographs in the uncertainty suite. This was observed through the history-matching process. An improvement we are happy to make is to add a spatial residual map with some supporting commentary. This would clearly show areas where the model over simulates modelled heads and, perhaps, underpredicts discharge processes.

1.8 Question 8

Q: In the hydraulic properties comparison (Table 4.5), does hydraulic conductivity refer to both K_h and K_v ?

A: Yes. Comparisons are slightly 'fuzzy' due to the range of values in the updated model. We can add further clarity in Section 4.4.1 text.

1.9 Question 9

Q: Looking at the basecase parameter distributions in Appendix B, it is apparent that a lot of parameters have clustered around their upper and lower bounds. From memory this was a 'feature' of the ensemble smoothing process. Was there consideration given to that during the history matching phase?

A: Yes, and there was an apparent trade-off between history-matching performance and parameter clustering around the assigned bounds. The reported values were developed to provide as close a match as possible to measurements, acknowledging the influence this would have on clustering. Note that the presented histograms are not for an individual parameter at a single pilot point, but for all pilot point values across an HSU/model layer.

1.10 Question 10

Q: A number of the specific yield values for various deeper units (including the coal seams) have gone to 0.1 (10%), while the corresponding specific storage values are at the theoretical lowest values. Is that result expected and in line with the conceptual model? These values will have an influence on the inflow volume to the mine.

A: The values are highly significant for modelled mine inflows; an increase in S_y compared to previous modelling resulted in a proportional increase in modelled inflow. As discussed in-text, these parameters should be prioritised for future modelling to improve predictive accuracy. In the next 5-year modelling phase, there will be a significant amount of drawdown data to support history-matching within the Permian and thus a tighter range on S_y should be achievable. It is acknowledged that, as it is, the model is likely overpredicting mine inflows. In terms of modelled vs measured aquifer properties, EMM is happy to add box-and-whisker plots within the history-matching chapter to assist with this comparison.

Date : 1/03/2023 4:39:26 PM

From : "Juliana Mccosker"

To : "Holland, Kate (L&W, Waite Campus)" kate.holland@csiro.au, "Hashim Carey" hashim.carey@ga.gov.au, "Peeters, Luk (Environment, Waite Campus)" luk.peeters@csiro.au, "Crosbie, Russell (Environment, Waite Campus)" russell.crosbie@csiro.au

Cc : "Ashley Bleakley" Ashley.Bleakley@des.qld.gov.au

Subject : re. modelling clarification

Attachment : image001.png;image002.png;image003.png;

Hi All,

Please see below responses from Doug . Am organising meeting for Friday.

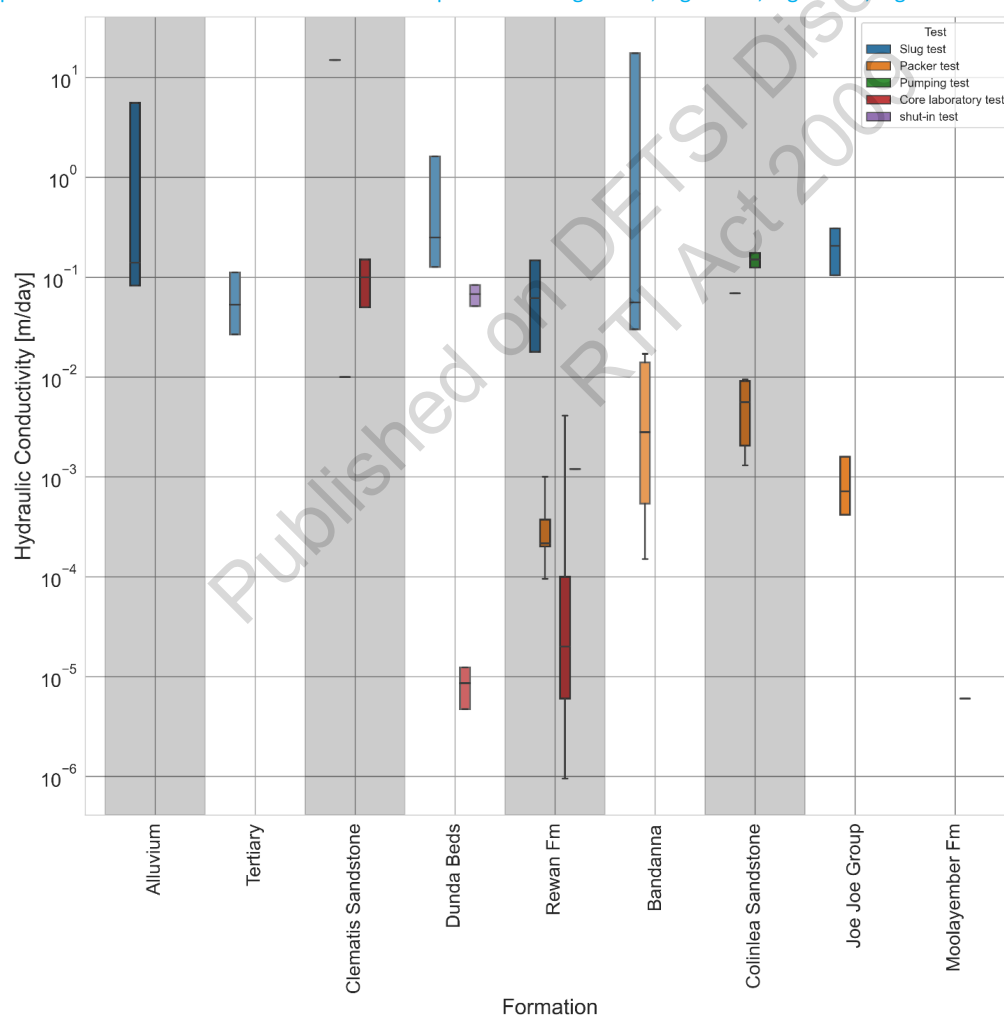
The answers to the questions can largely be found in the draft report. EMM provided locations below to assist CSIRO and GA in locating details.

Q1: How is the uncertainty analysis done? A detailed workflow of the optimisation / history matching and subsequent uncertainty analysis

A: Chapter 4 (p 60–89) provides detail on history-matching (approach, performance and comparison with this SEIS modelling which is the reference point for this update). Appendix B provides 64 histograms documenting the parameter value distributions of a) the base case and b) all realisations. Appendix C provides hydrographs (measured, base case and full suit of 105 realisations) over the history-matching period. Chapter 5 (p 90 to 117) presents predictive uncertainty analysis as an integral part of predictive scenario modelling. It follows on from the stochastic approach implemented in history-matching, using an ensemble of generated realisations (with parameter values as documented in Appendix B). Predicted hydrographs at 162 locations, for the suite of 105 realisations, are presented in Appendix D. In addition to overlaying the full suite of realisations these present series for the base case, P10, P33, P67 and P90.

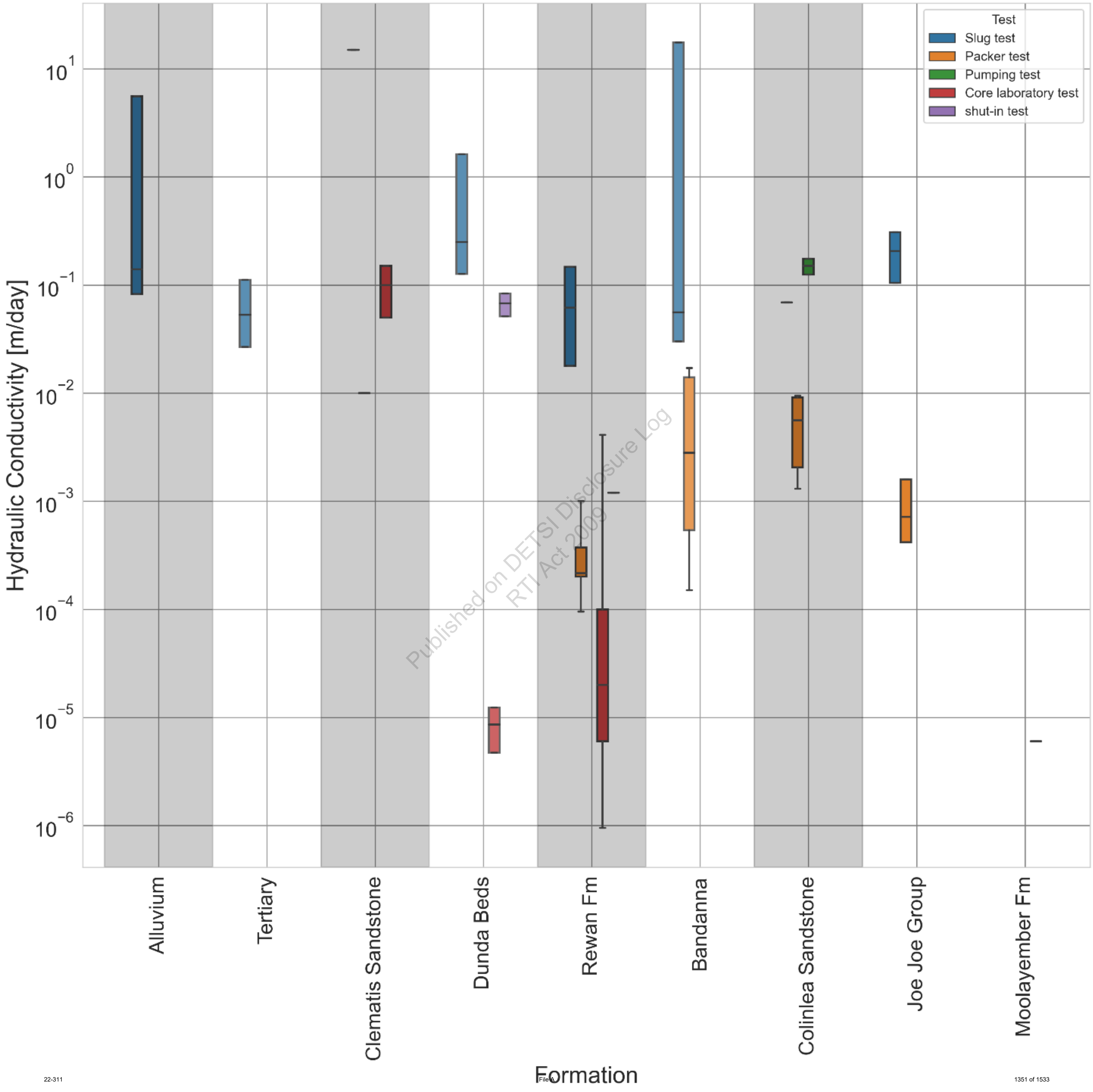
Q2: What are the prior values and ranges used for each of the parameters? How do these relate to values reported in the conceptualisation and other reports? Maps of spatial distribution of parameters (both pilot point and zoned parameters)

A: Whilst presented to DES at previous meetings, the connections between measured ranges (documented in the Data review and conceptualisation report [EMM 2023]) and assigned bounds aren't documented in the draft modelling report (we plan to add this). Below are ranges of measured hydraulic conductivity categorised by HSU and testing method. The attached spreadsheet contains upper and lower bounds (in MODFLOW units) for the parameters allowed to vary in the history-matching process. Spatial distributions of values of selected parameters for the base case realisation are provided in Figure 4.3, Figure 4.6, Figure 4.7, Figure 4.10 and Figure 4.11.



Q3: How are the observation targets derived? Provide detailed information on how the observed groundwater levels are used to derive the objective functions for initial head, transient head and head change.

A: History-matching targets were derived from measured hydraulic head data (see Figure 4.1 for the spatial distribution of targets, categorised by HSU) as well as two spring flux targets: one for Joshua Spring and one for the remainder of the DSC. The spring flux targets were based on modelling of the springs, presented in the Data review and conceptualisation report (EMM 2023). Raw hydraulic head measurements from loggers were resampled to monthly measurements to reduce the volume of target data (where/when they were not contributing additional information on system behaviour). Manual measurements were kept at their measured frequency. At the request of DES all data from WVPs



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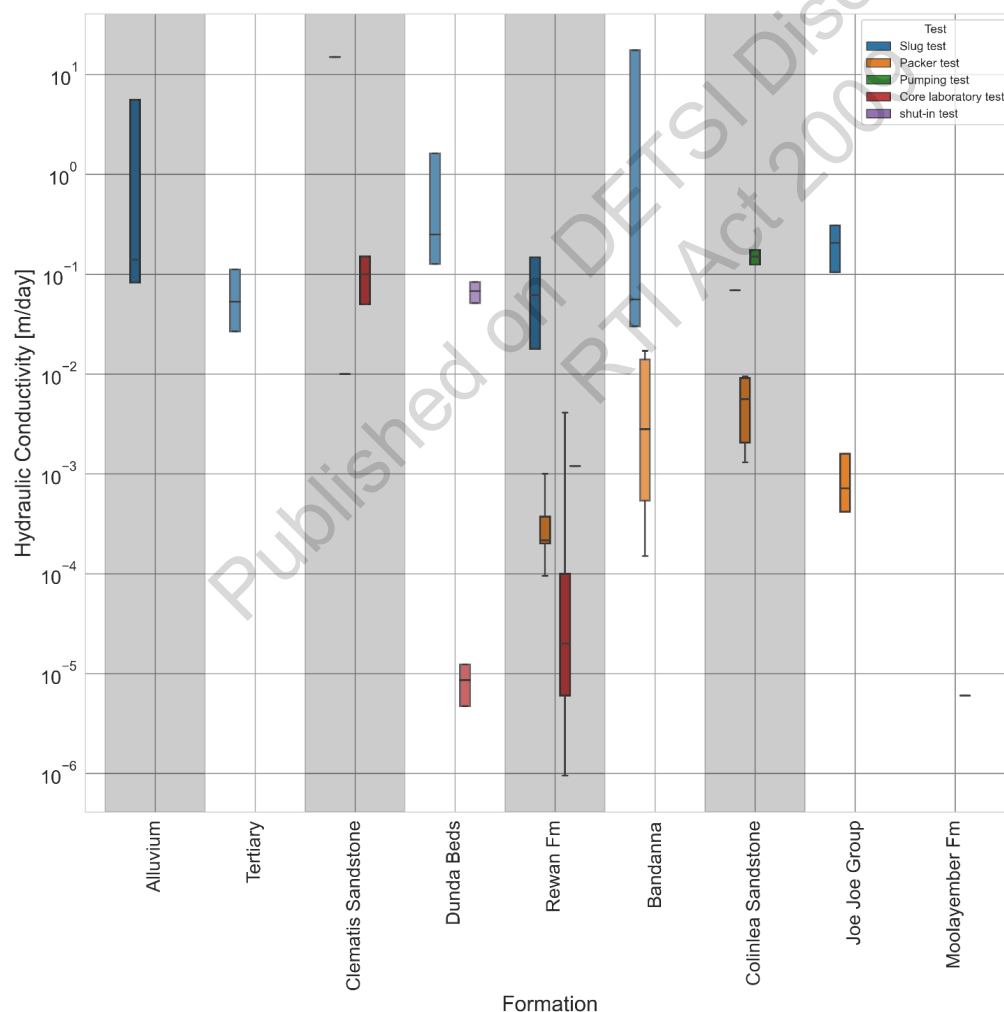
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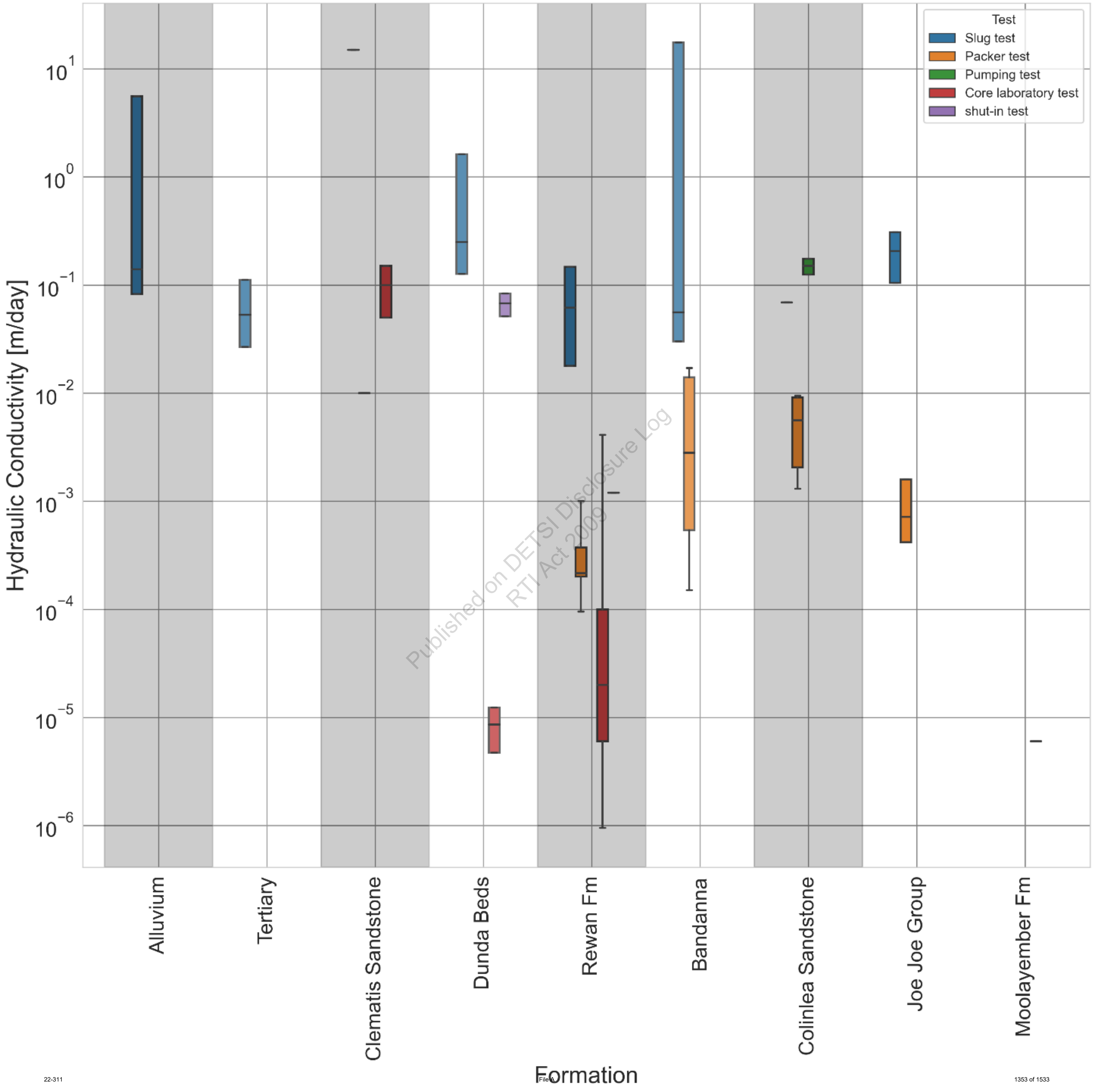
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MINING & RESOURCES

Carmichael Coal Mine Project

Groundwater Model Review - Progress Meeting - 4

Tuesday 10 January 2023

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MINING & RESOURCES

Model design information

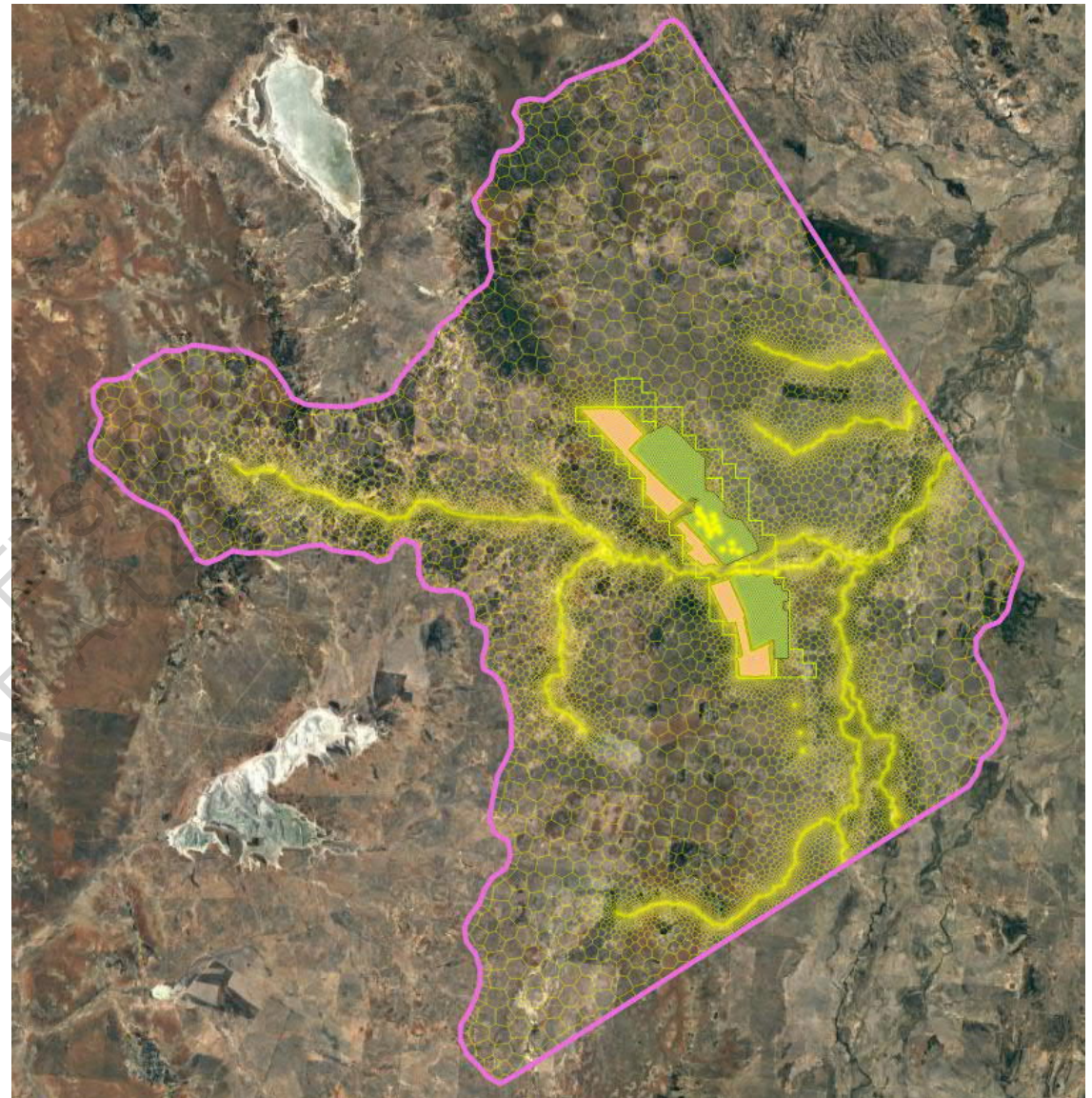
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Model design overview

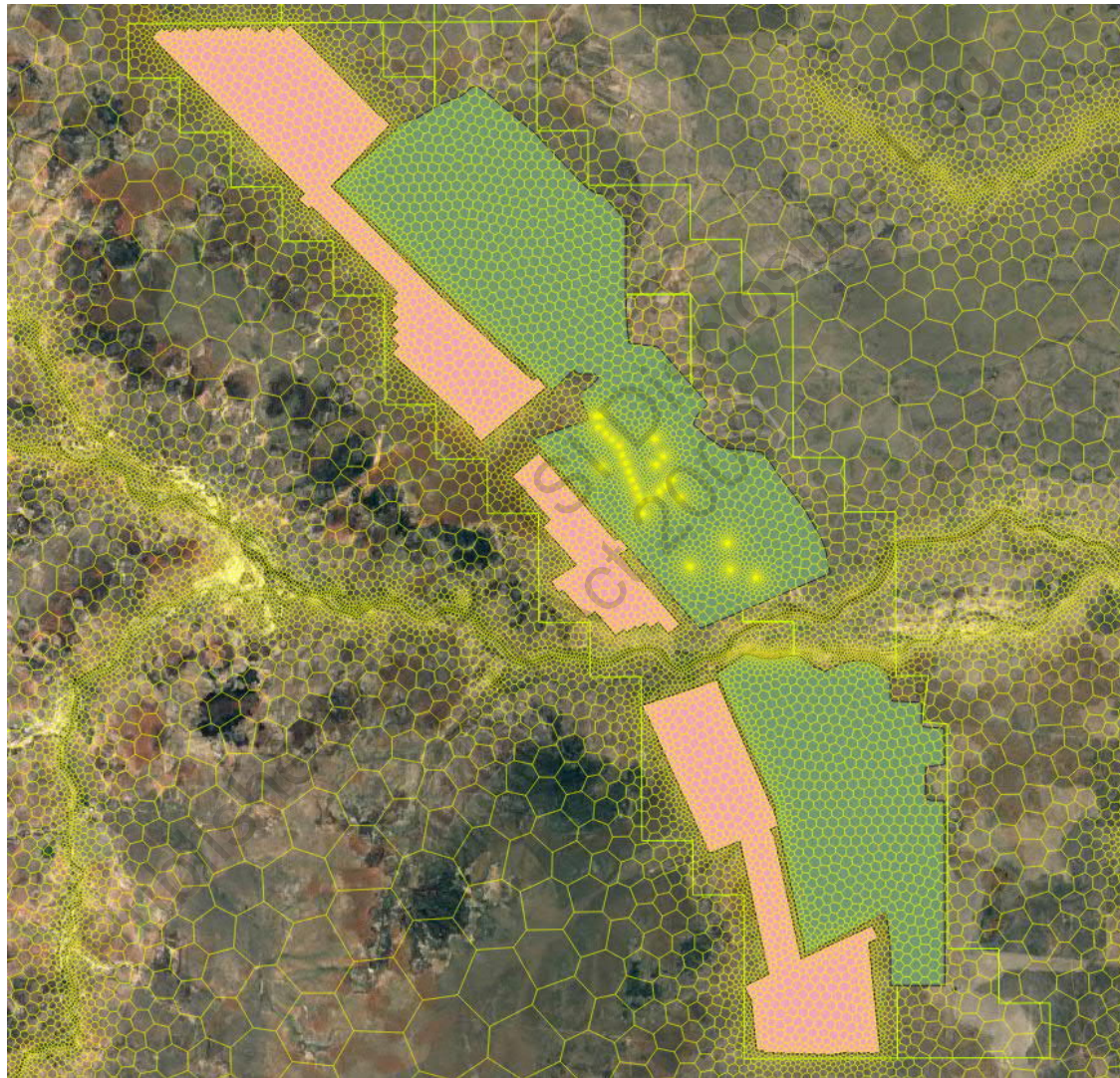
- MODFLOW-USG Transport v1.10
- Maintain domain from SEIS groundwater model
- Unstructured Voronoi polygon mesh; 34,624 nodes per layer
 - Refinement for major creeks, mapped springs, open cut and underground mine area, and dewatering bores
- 14 HSUs, one per model layer, with Rewan Formation split across 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



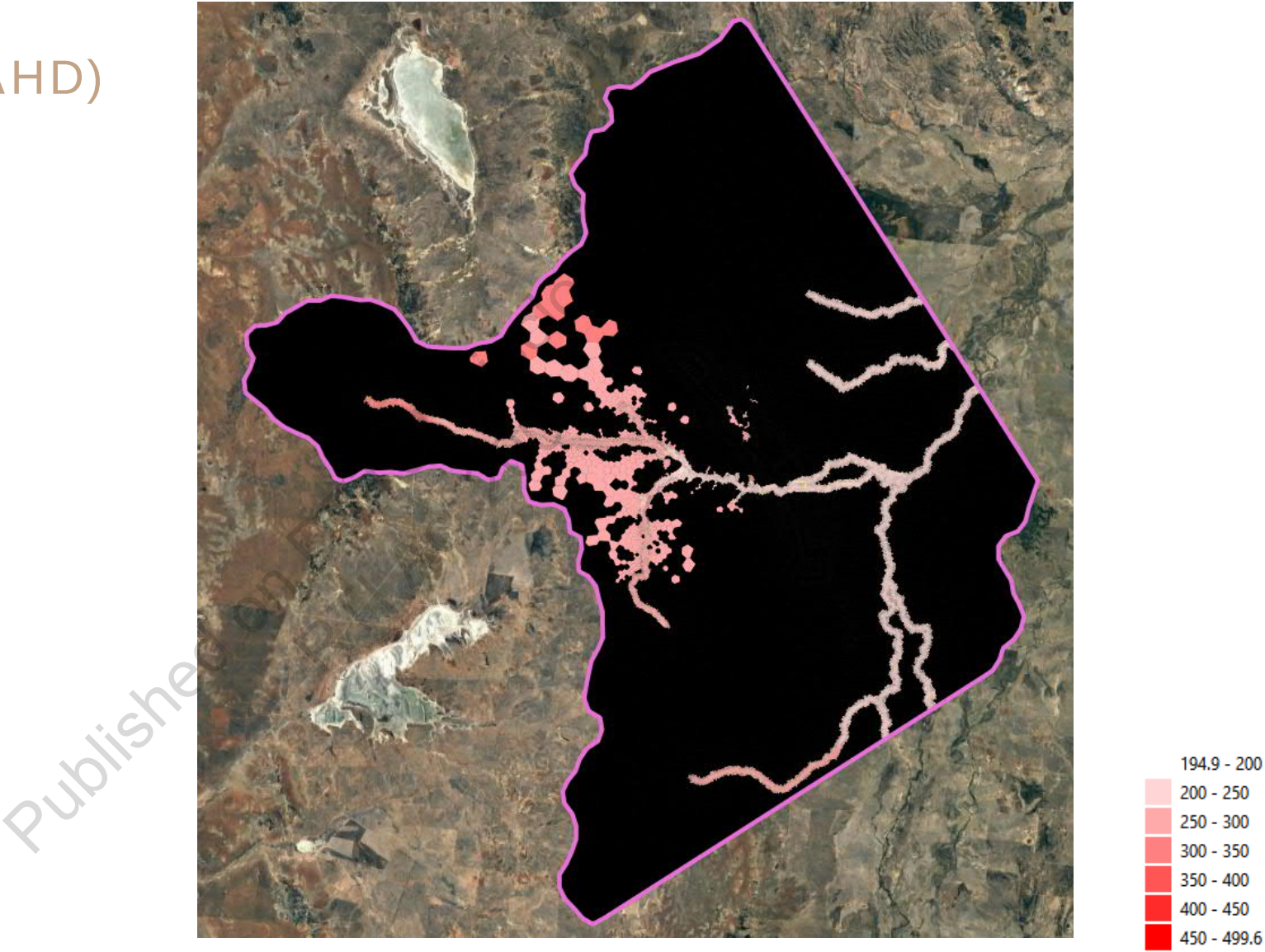
Mesh



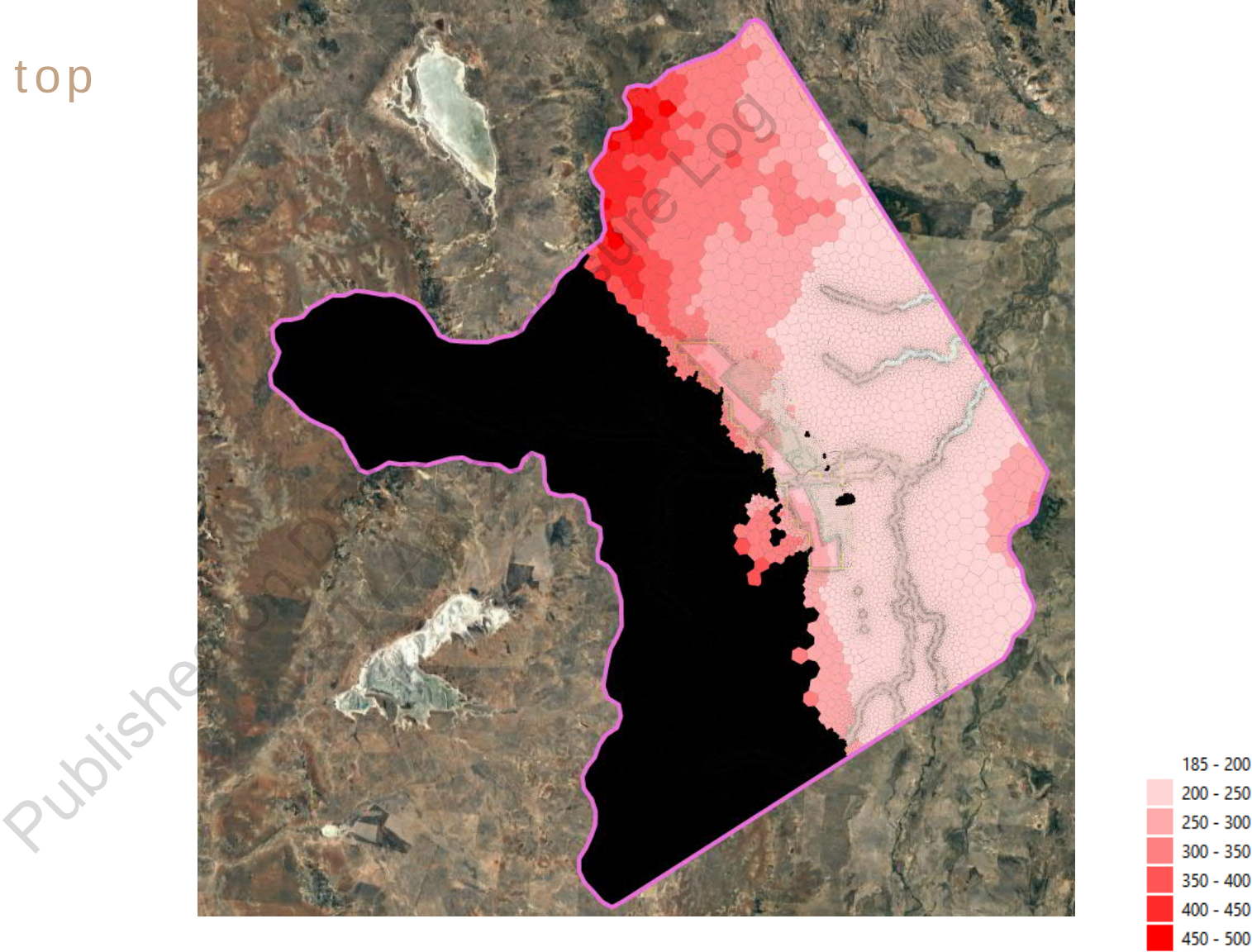
Model layers

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

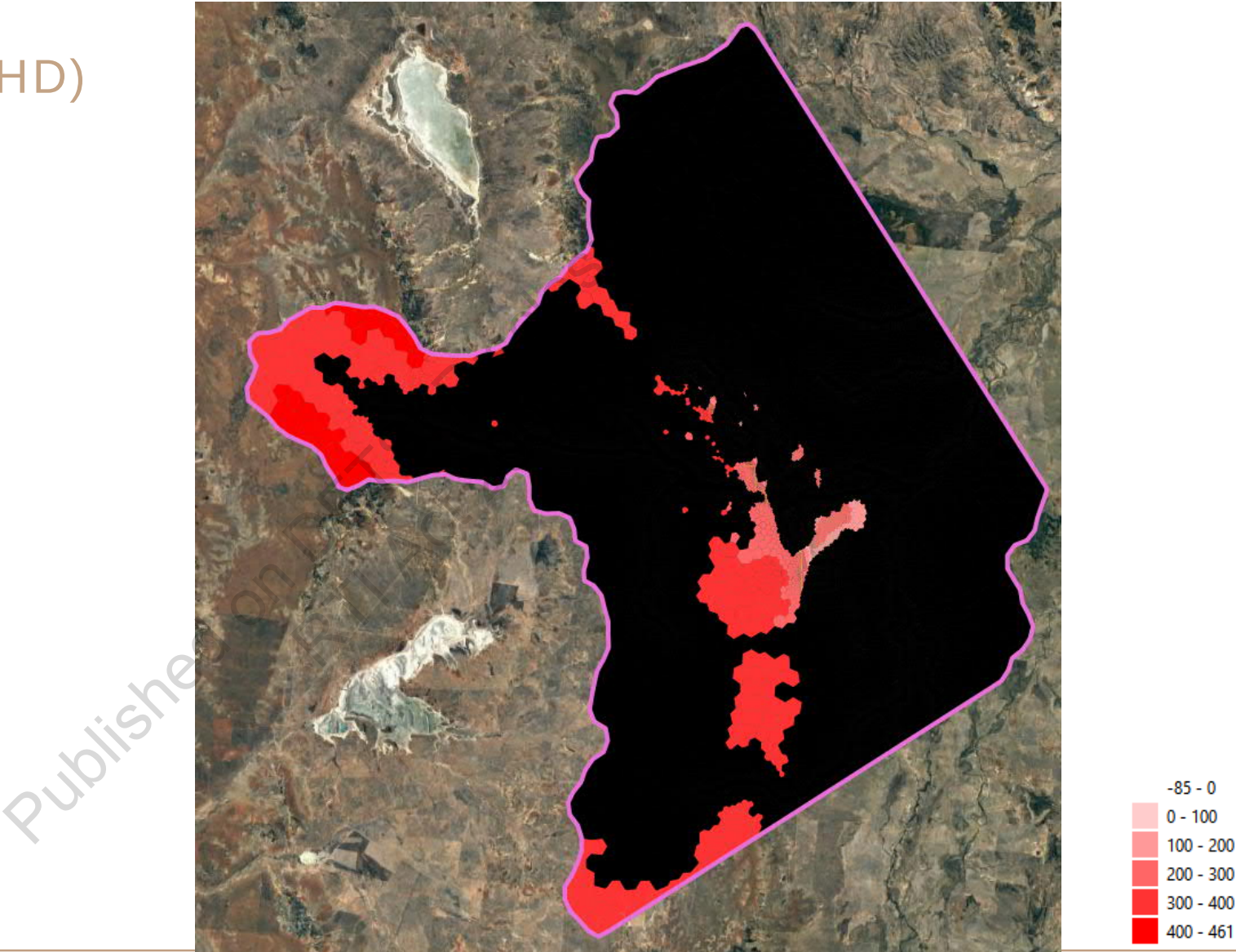
Alluvium top (mAHD)



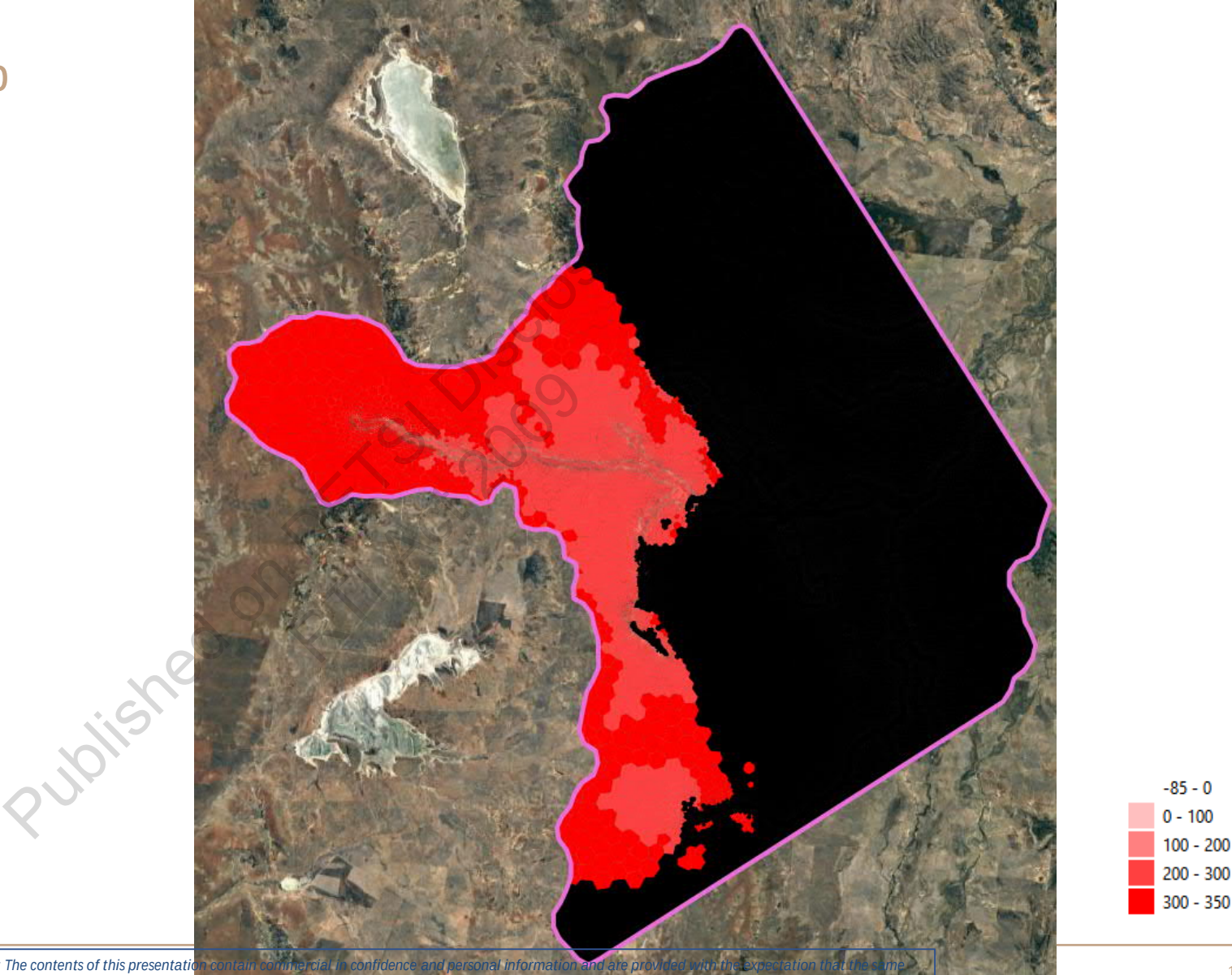
Weathering zone top
(mAHD)



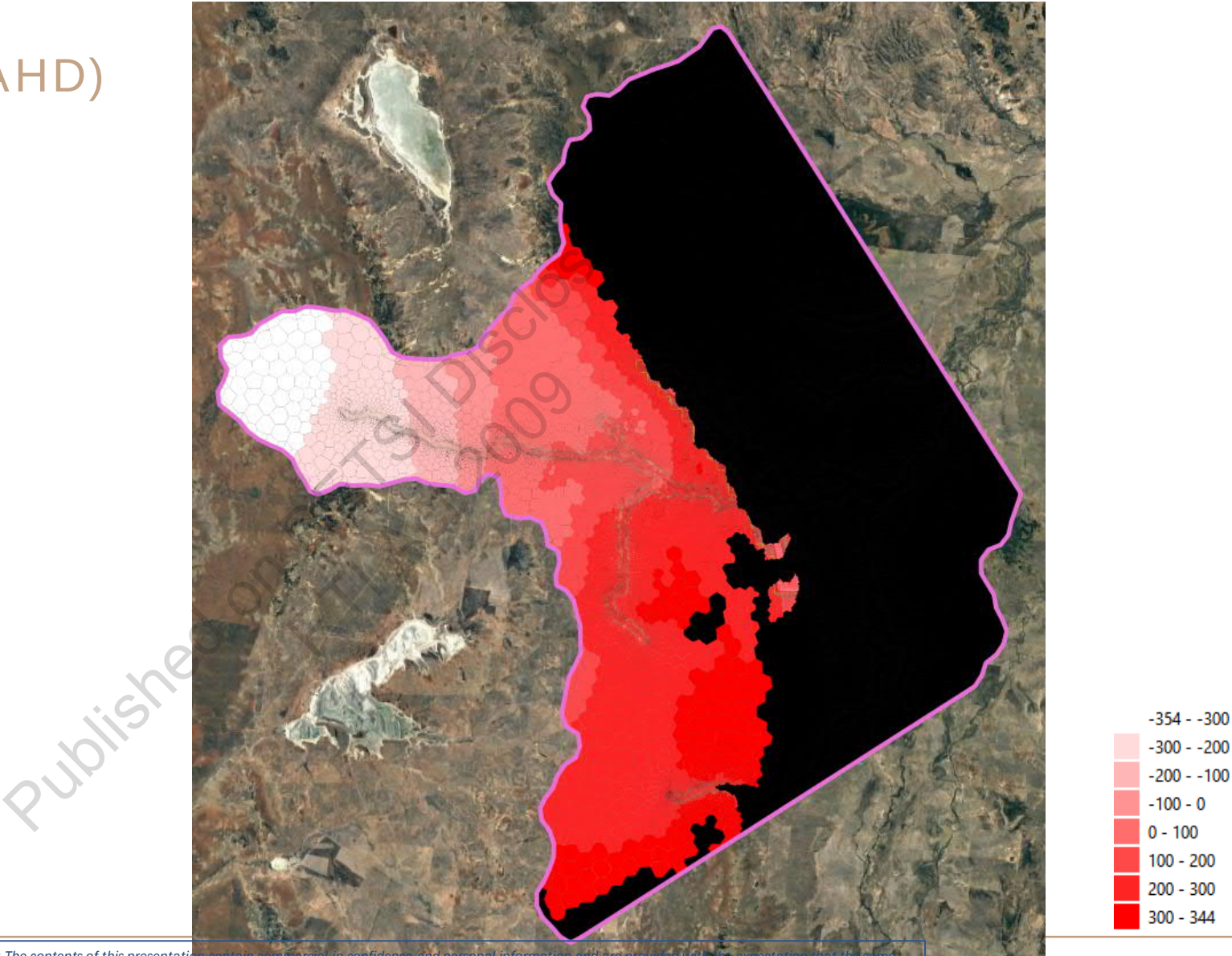
Tertiary top (mAHD)



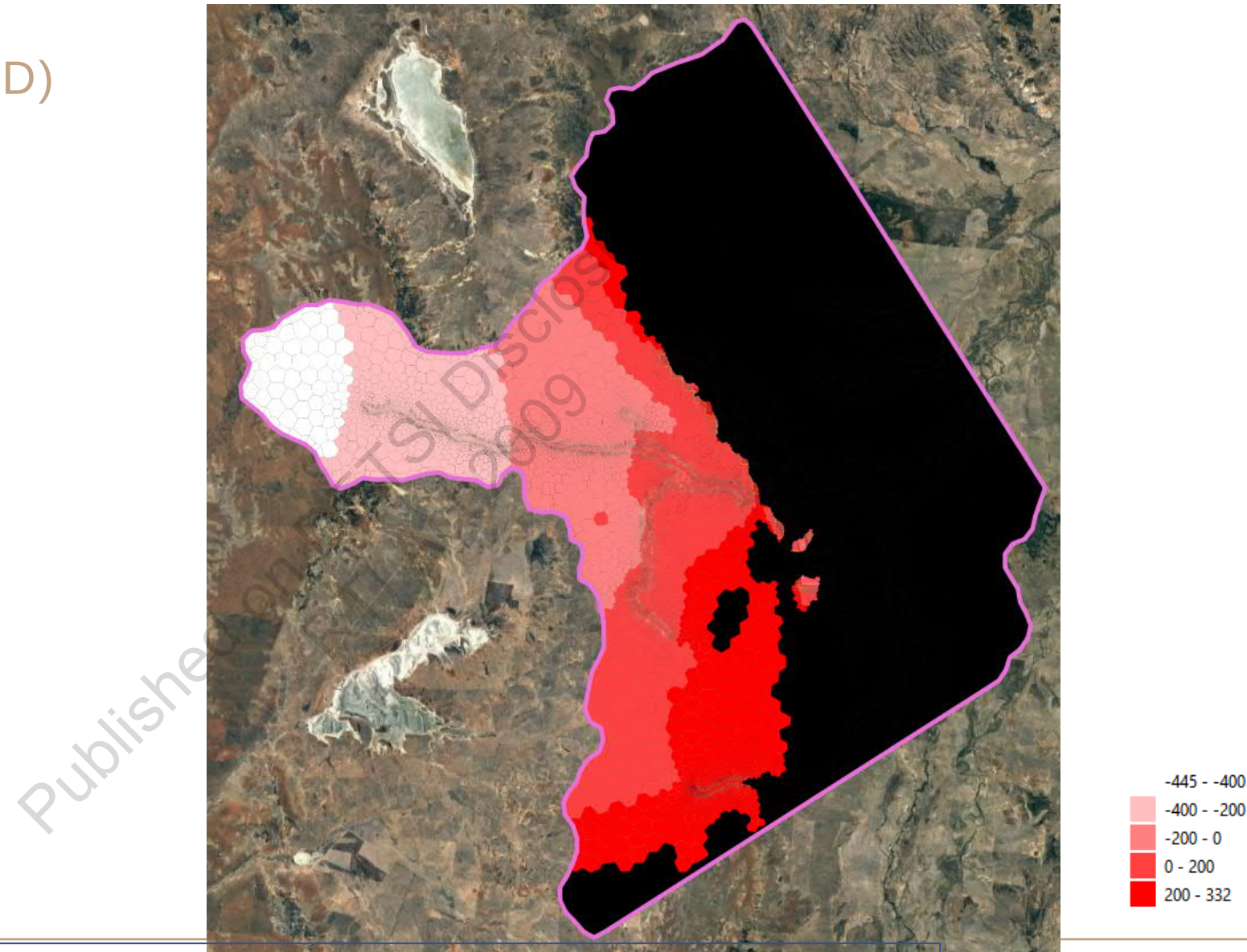
Moolayember top
(mAHD)



Clematis top (mAHD)



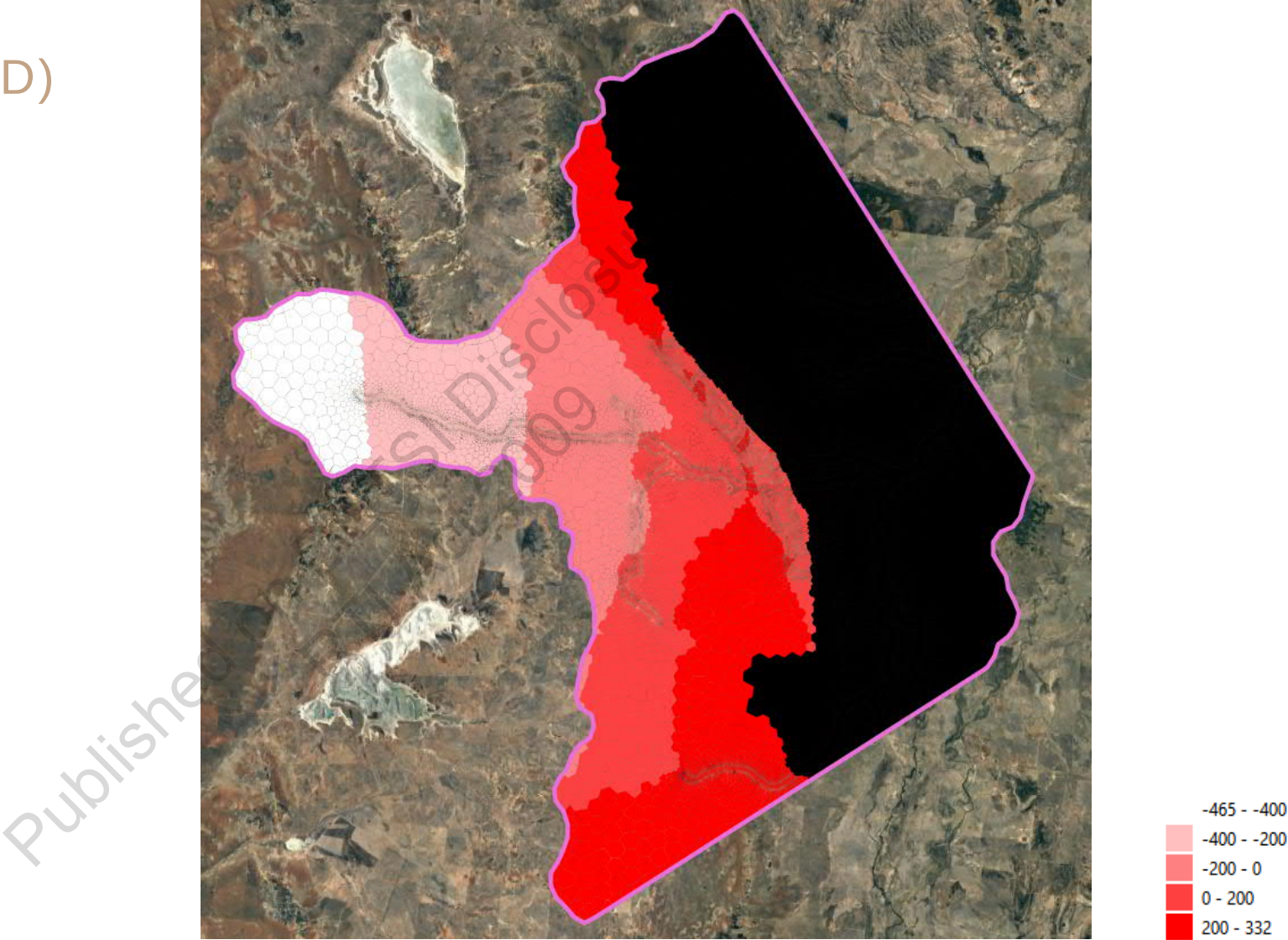
Dunda top (mAHD)



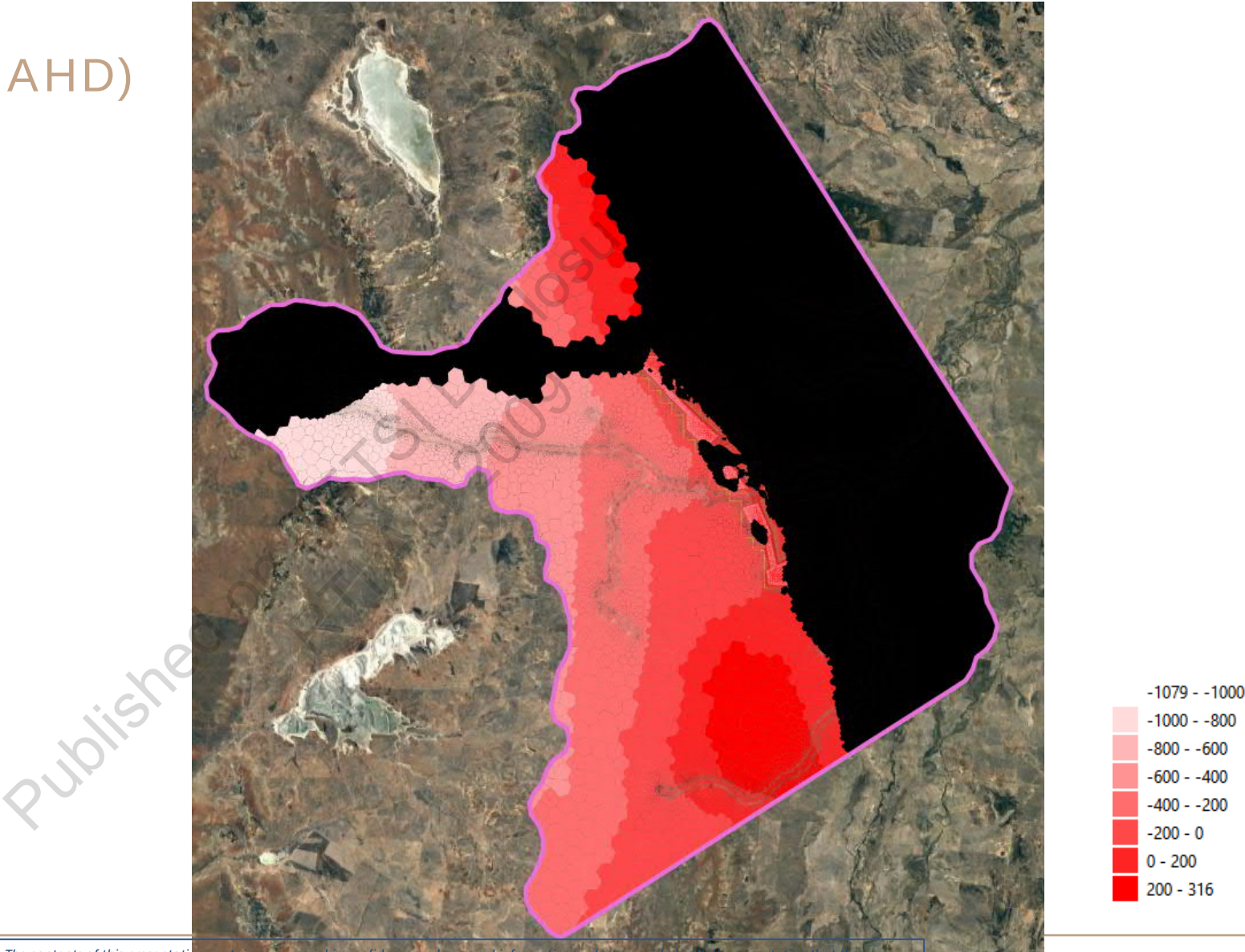
10/01/2023

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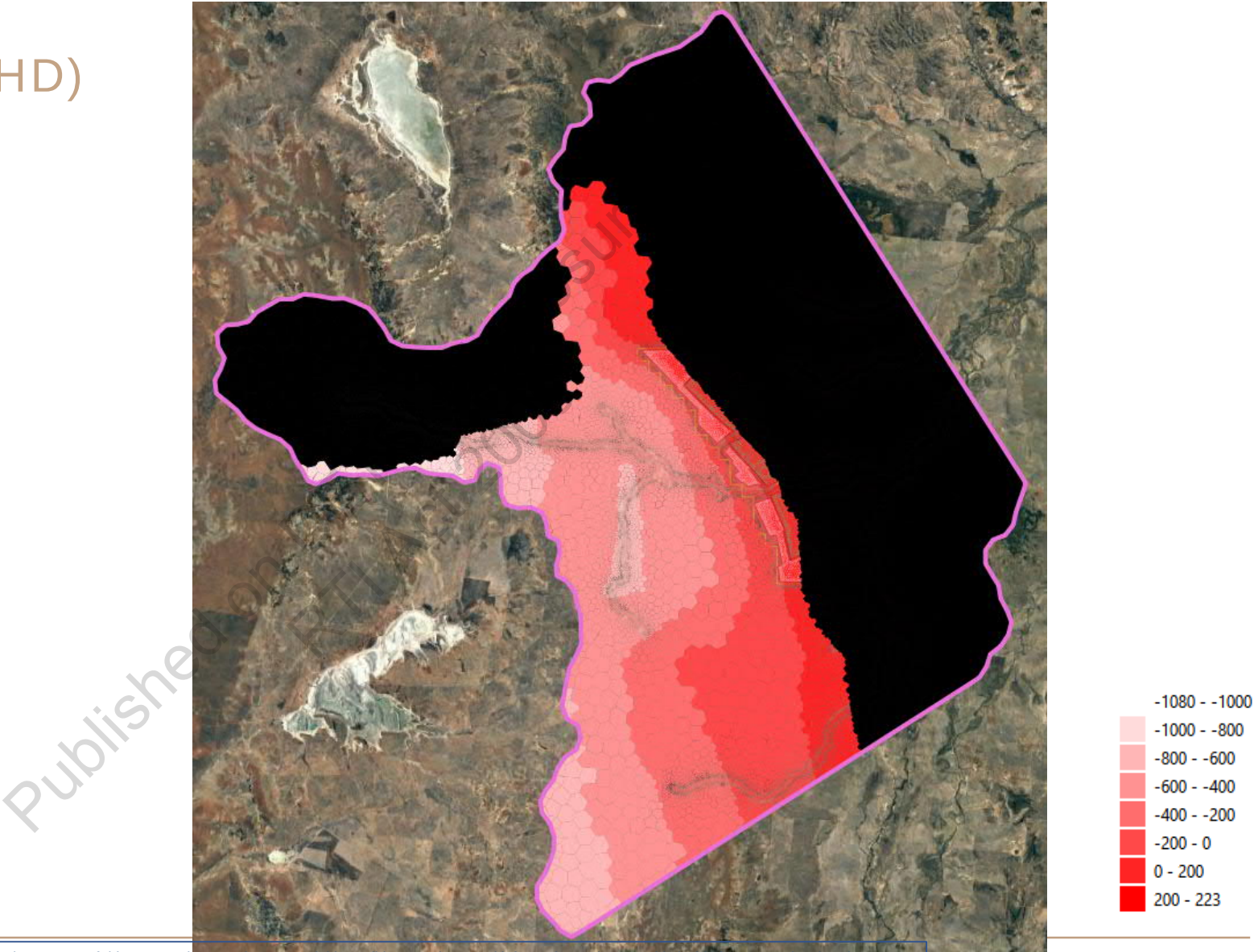
Rewan top (mAHD)



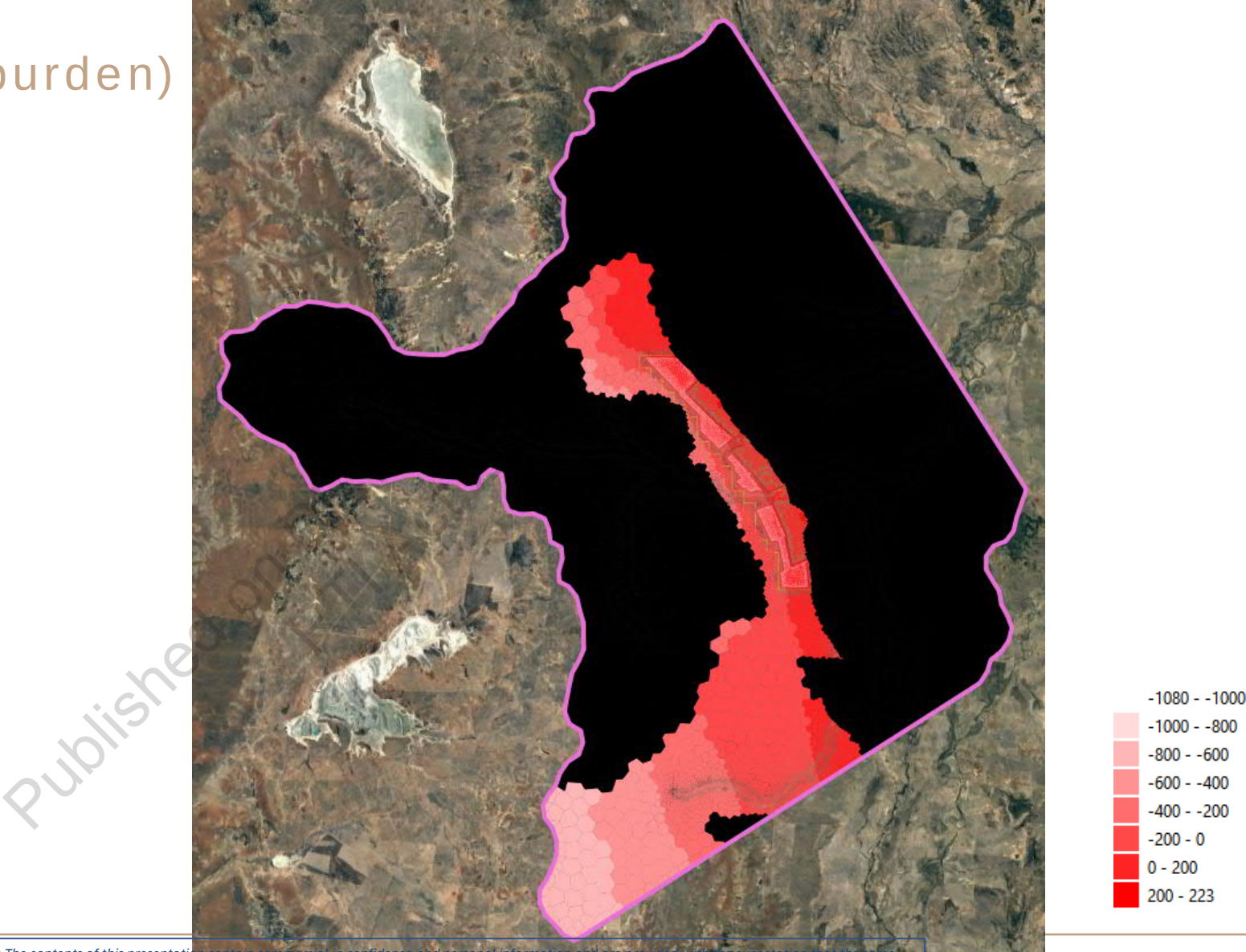
Bandanna top (mAHD)



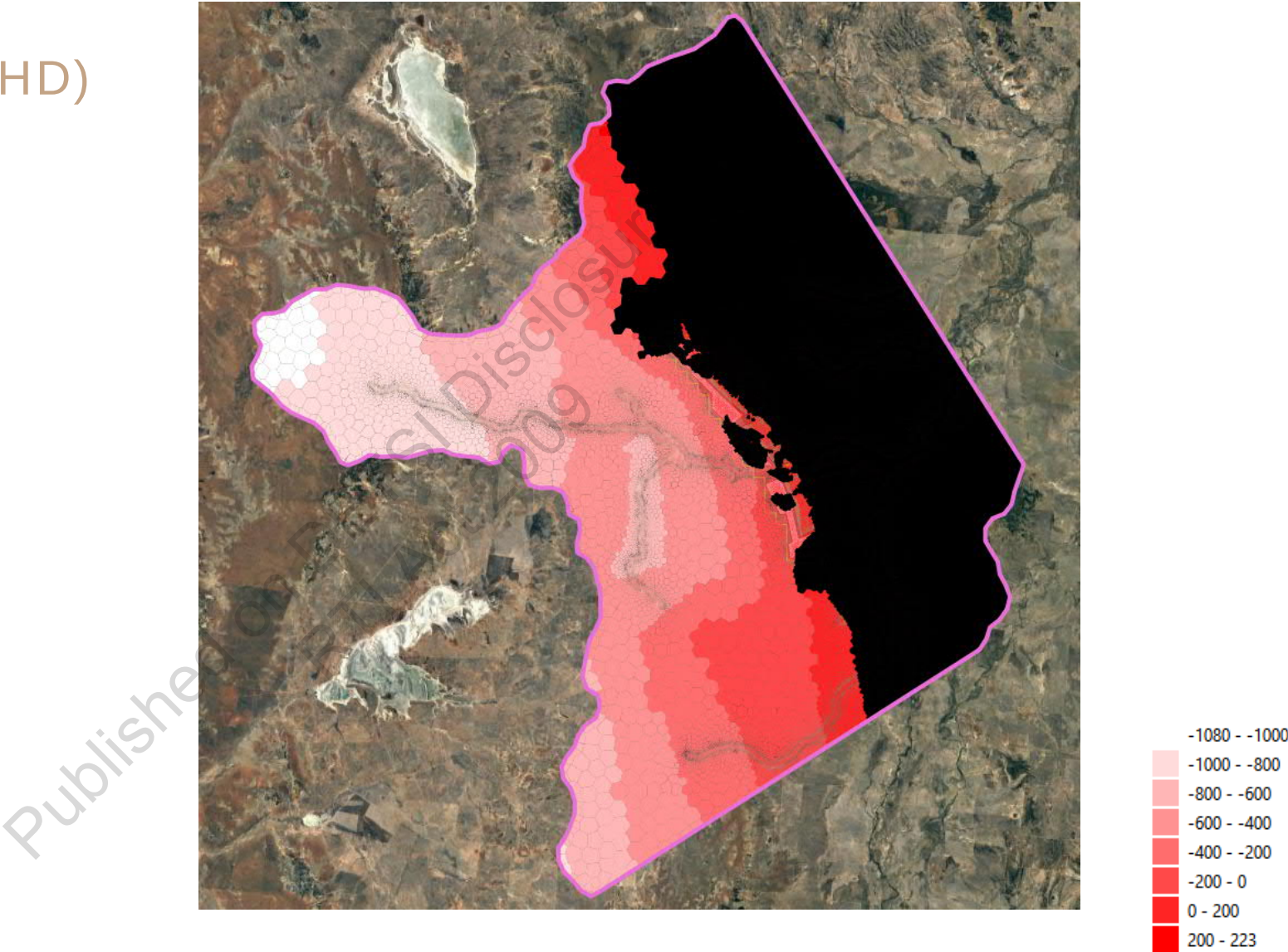
AB Coal top (mAHD)



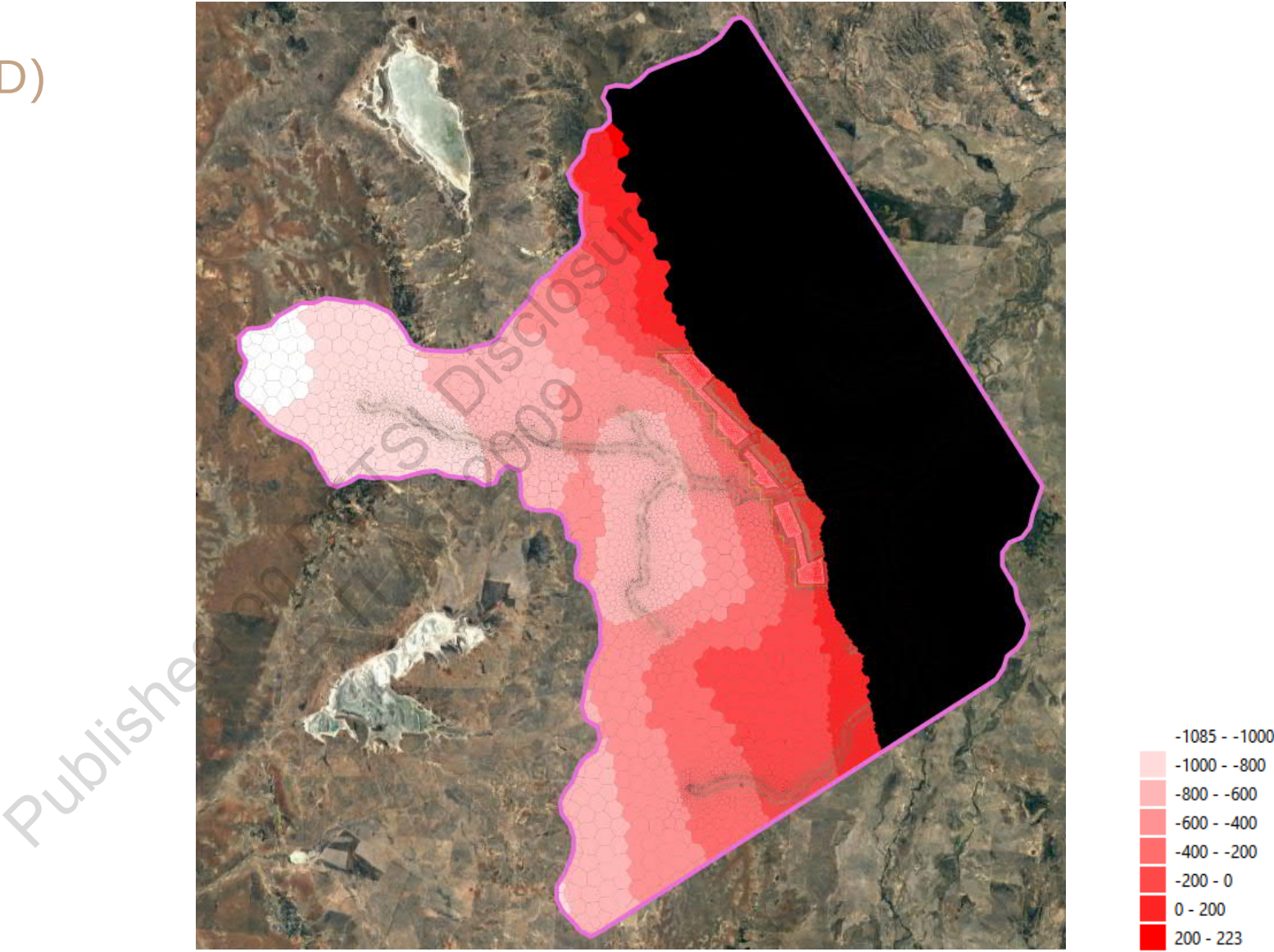
Bandanna (interburden)
top (mAHD)



Colinlea top (mAHD)



D Coal top (mAHD)

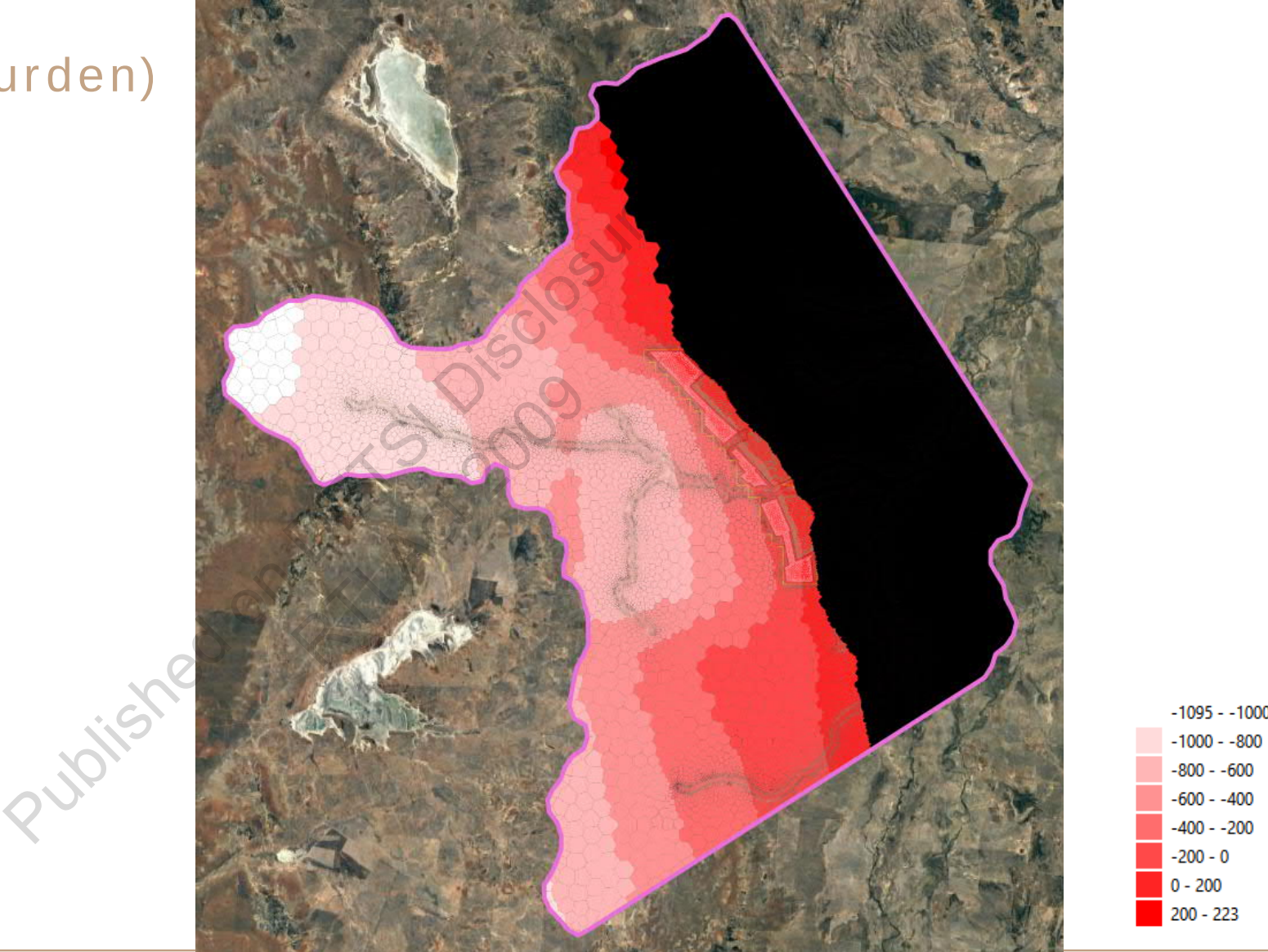


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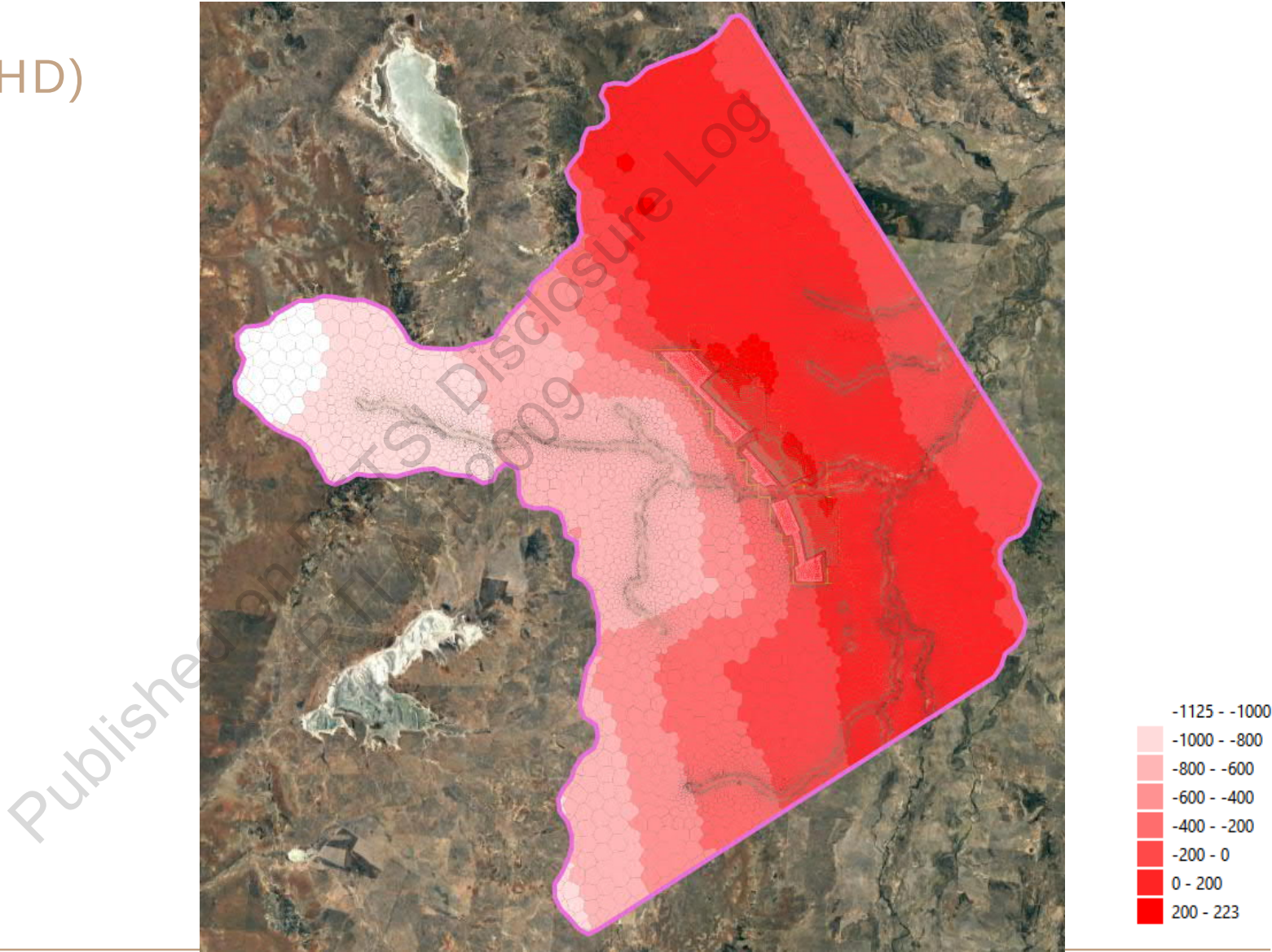
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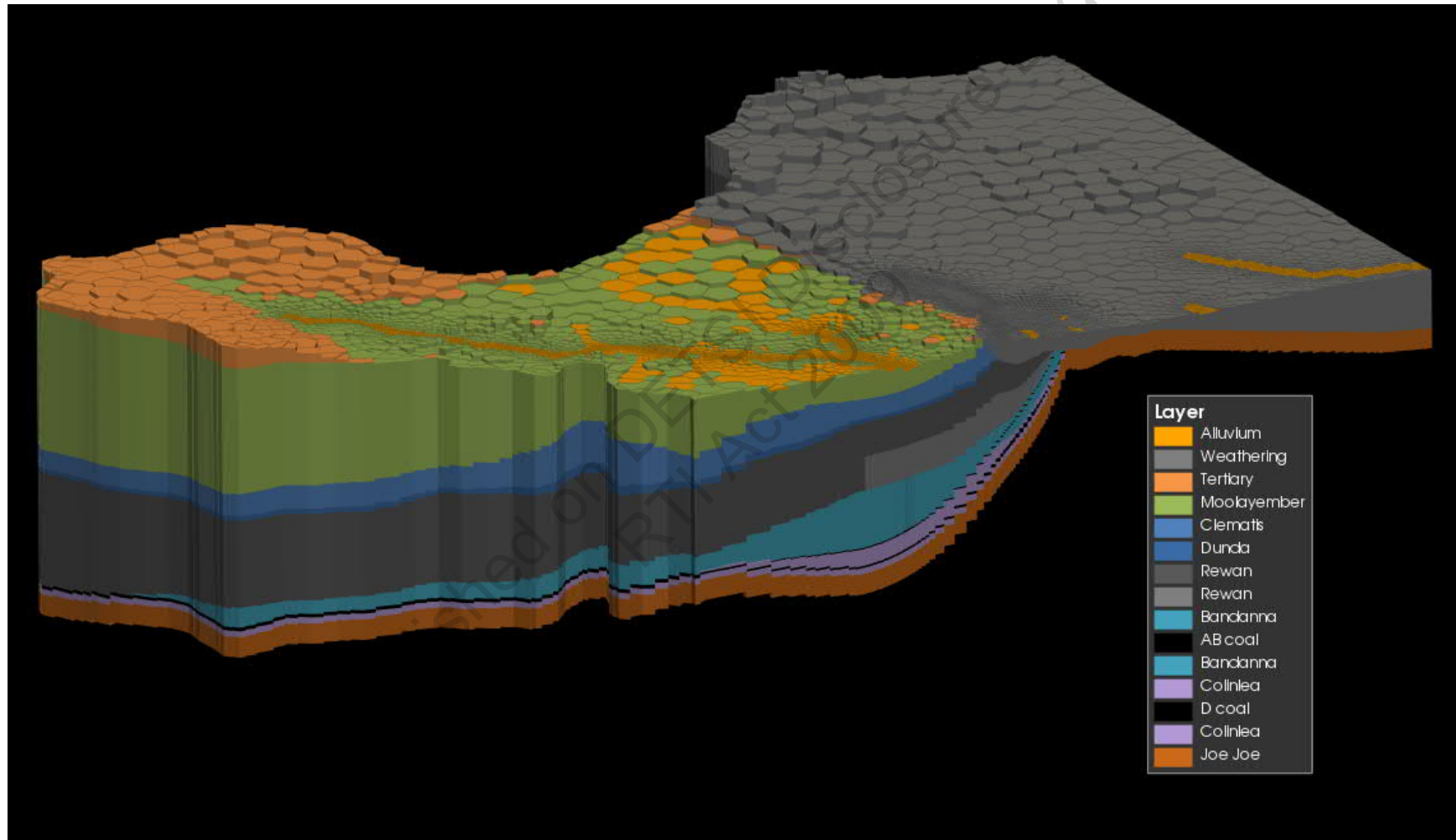
Colinlea (underburden)
top (mAHD)



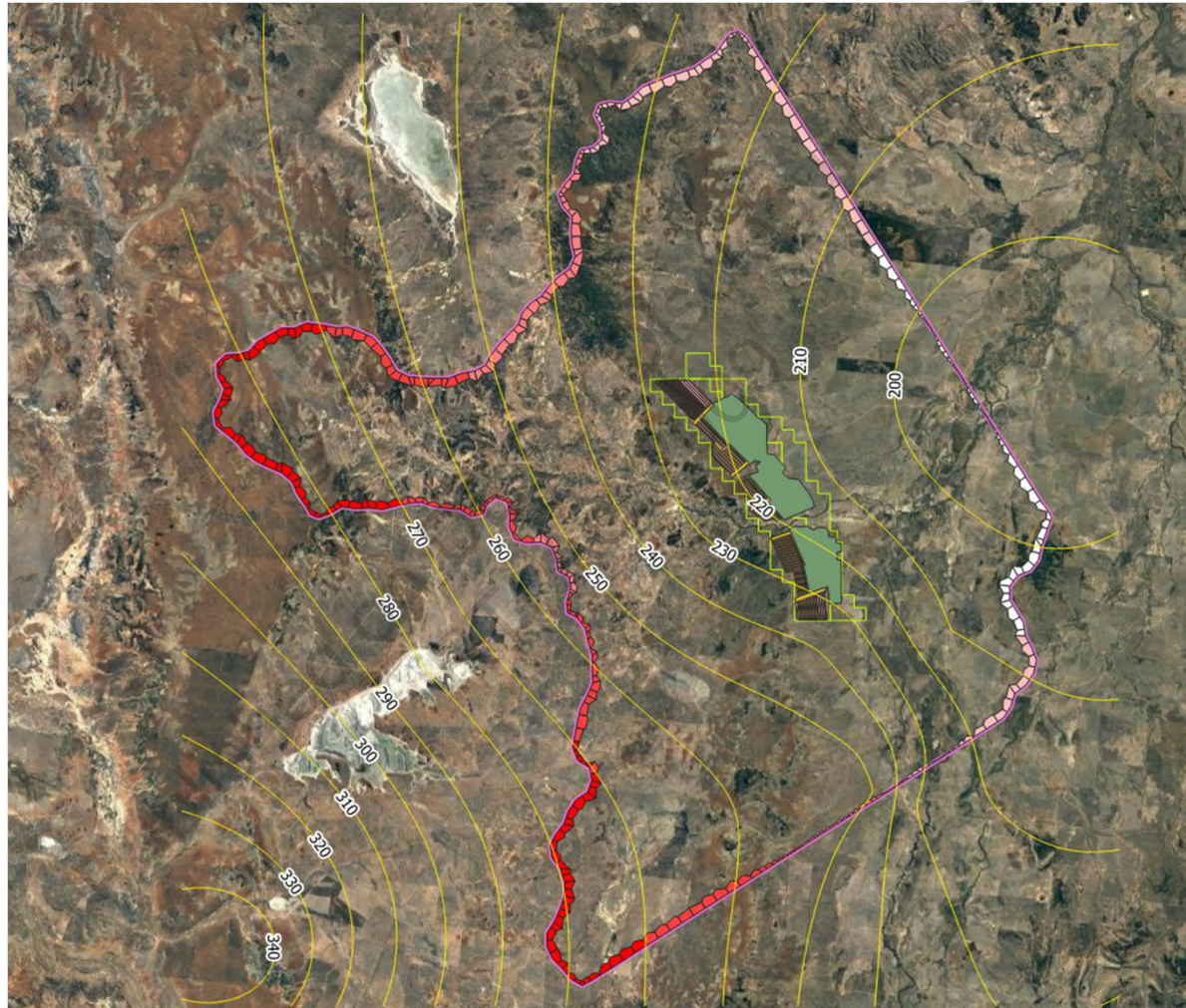
Joe Joe top (mAHD)



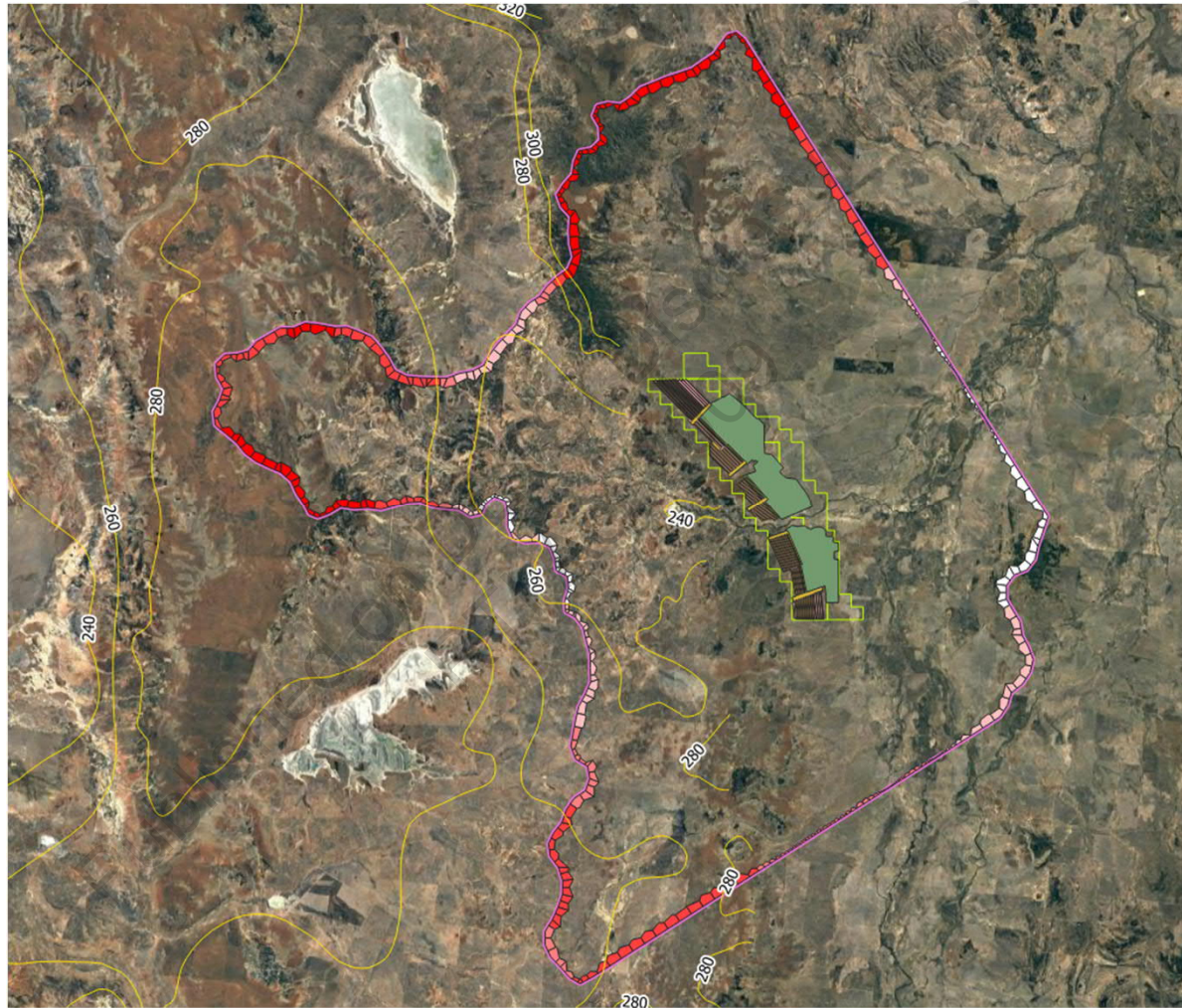
Cross section



Surficial regional boundaries



Clematis regional boundaries

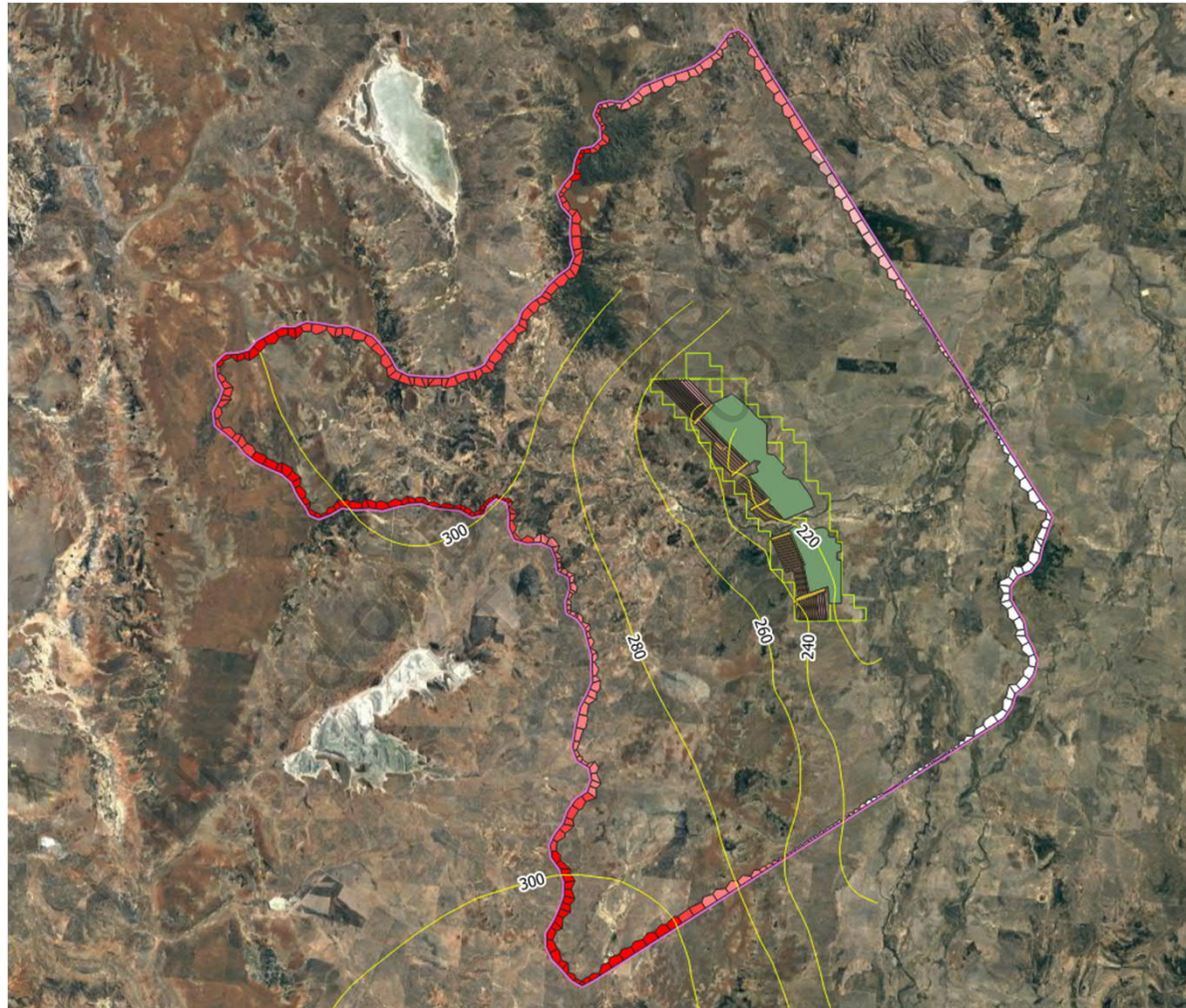


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Bandanna regional boundaries

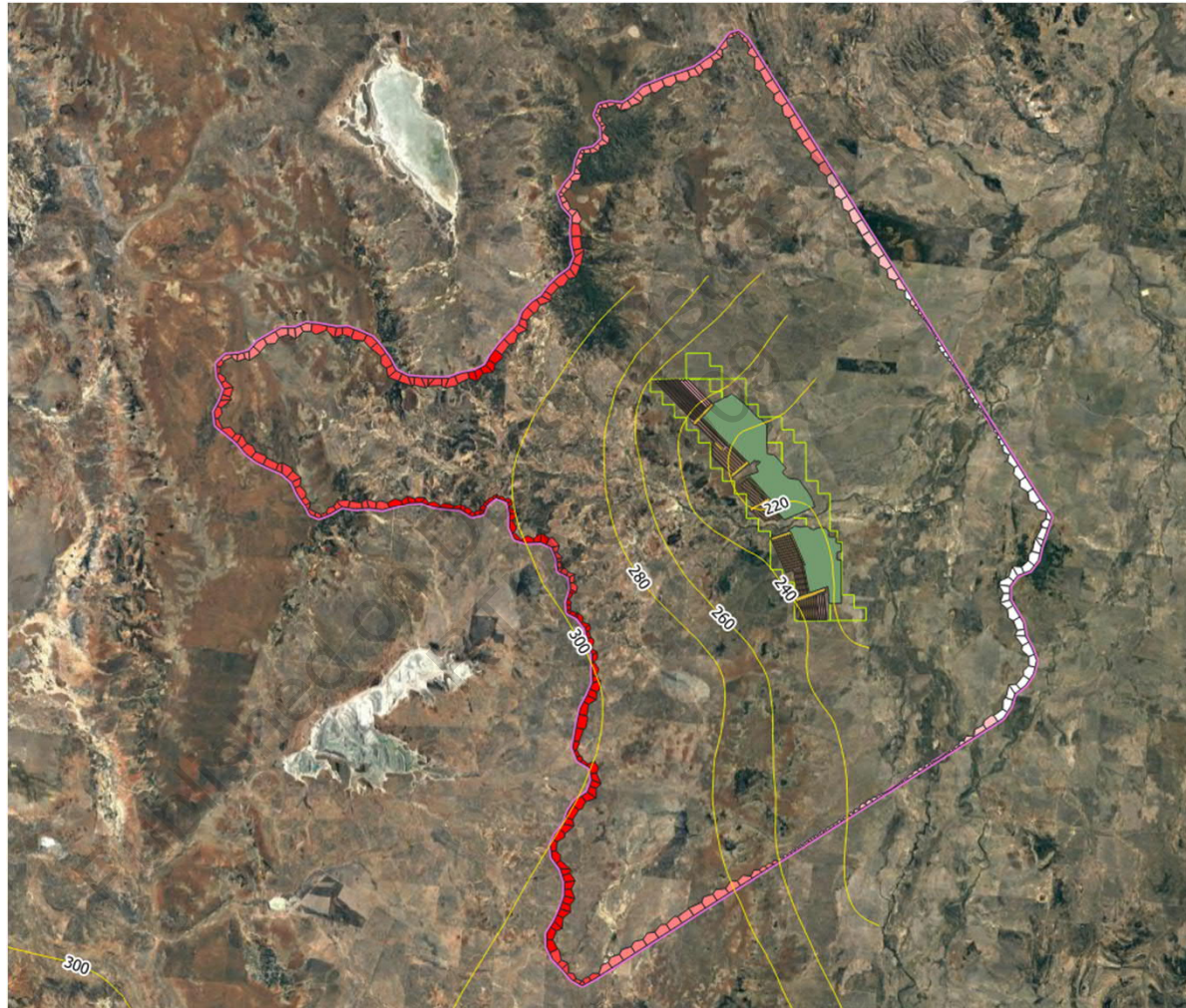


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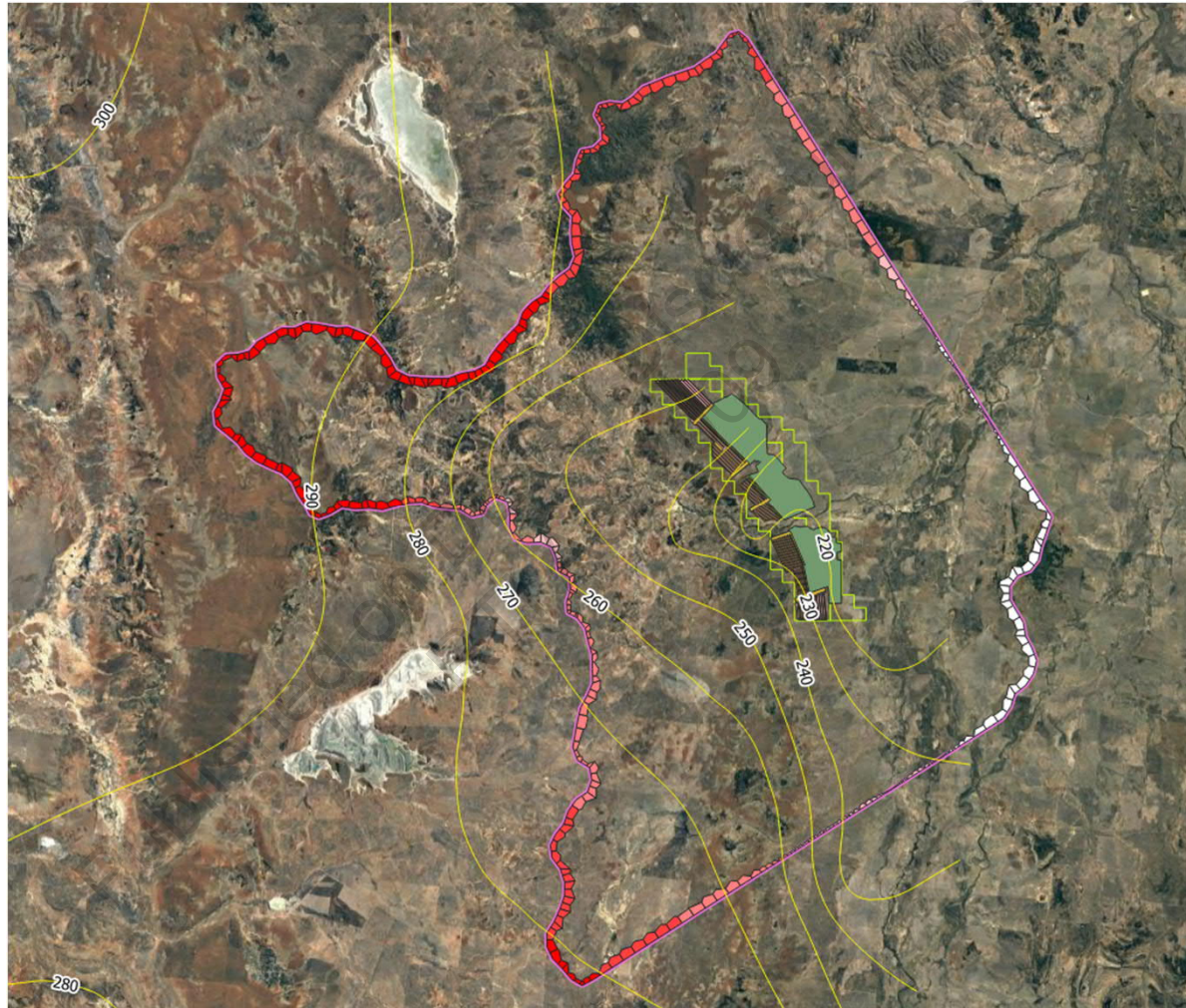
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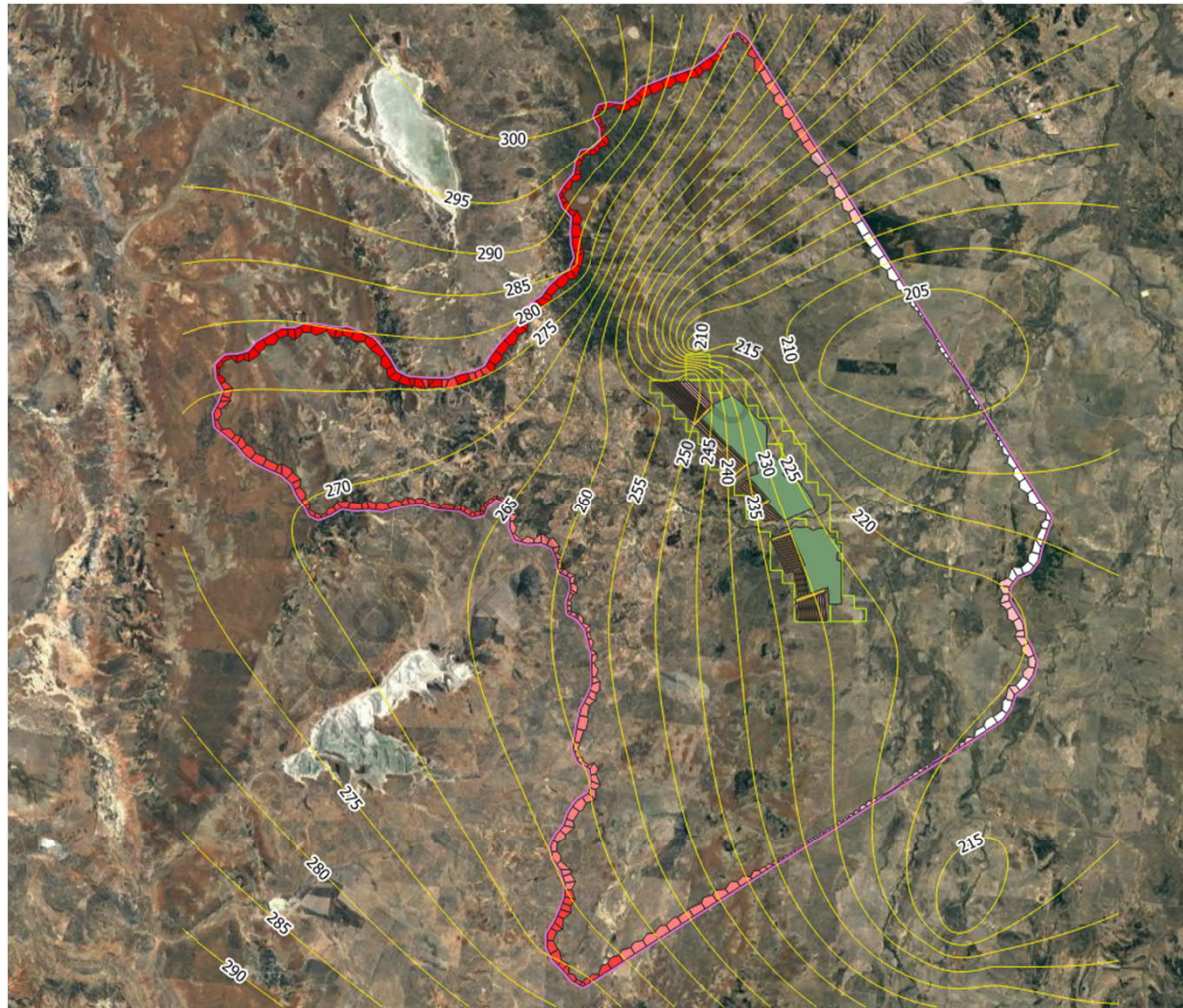
Coal seam regional boundaries



Colinlea regional boundaries



Joe Joe regional boundaries

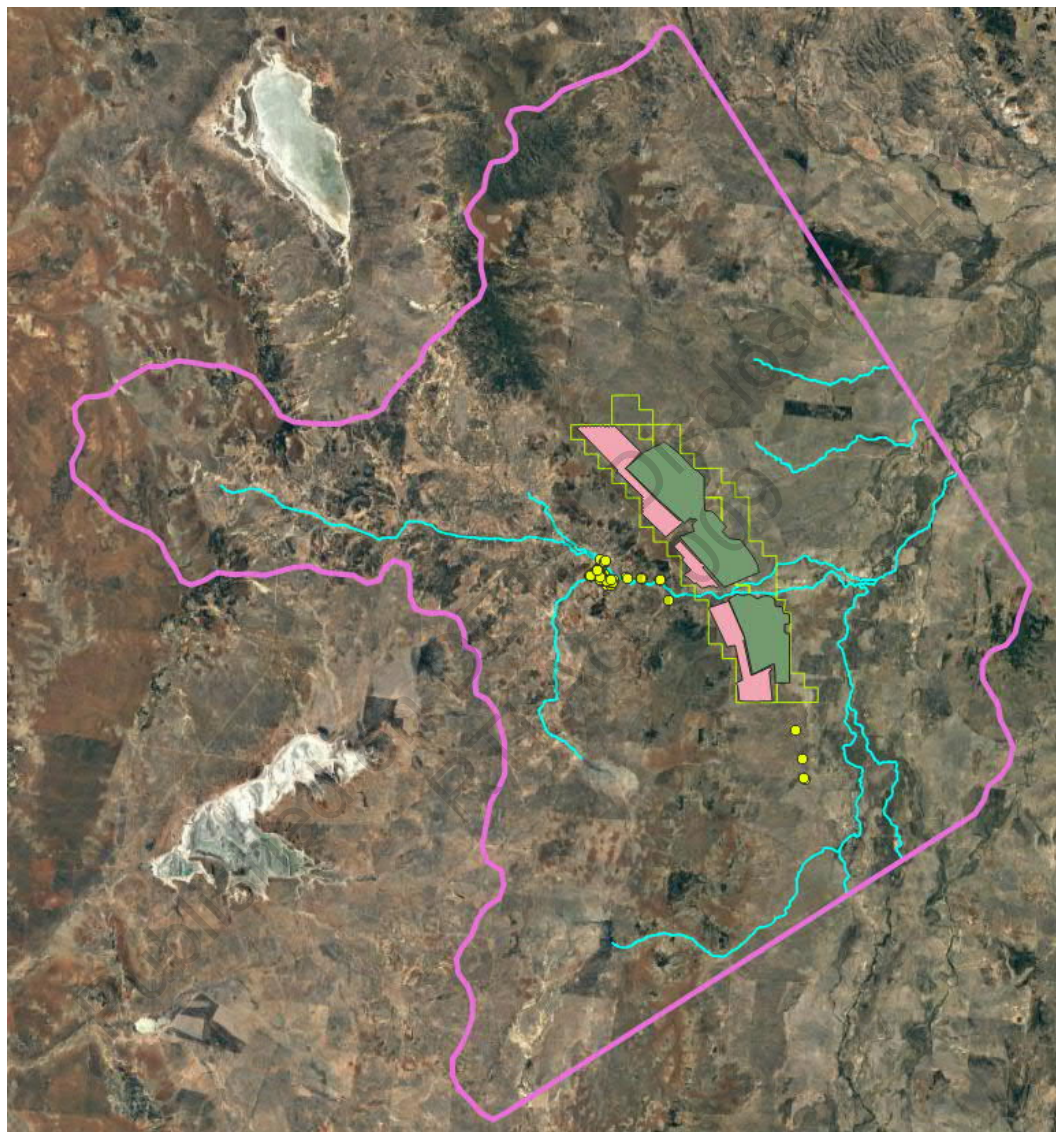


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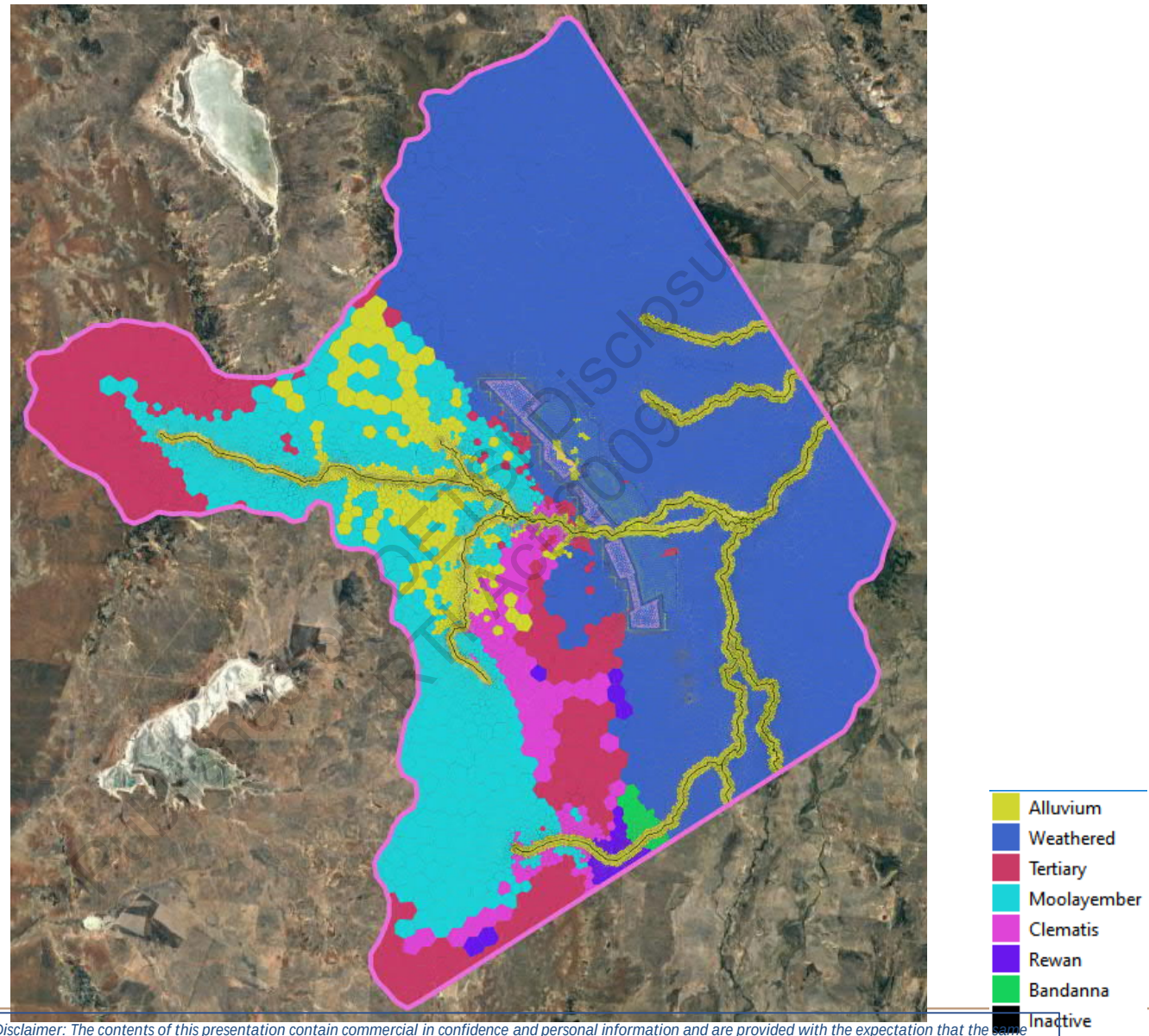
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Surface water



Recharge



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MINING & RESOURCES

History-matching

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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

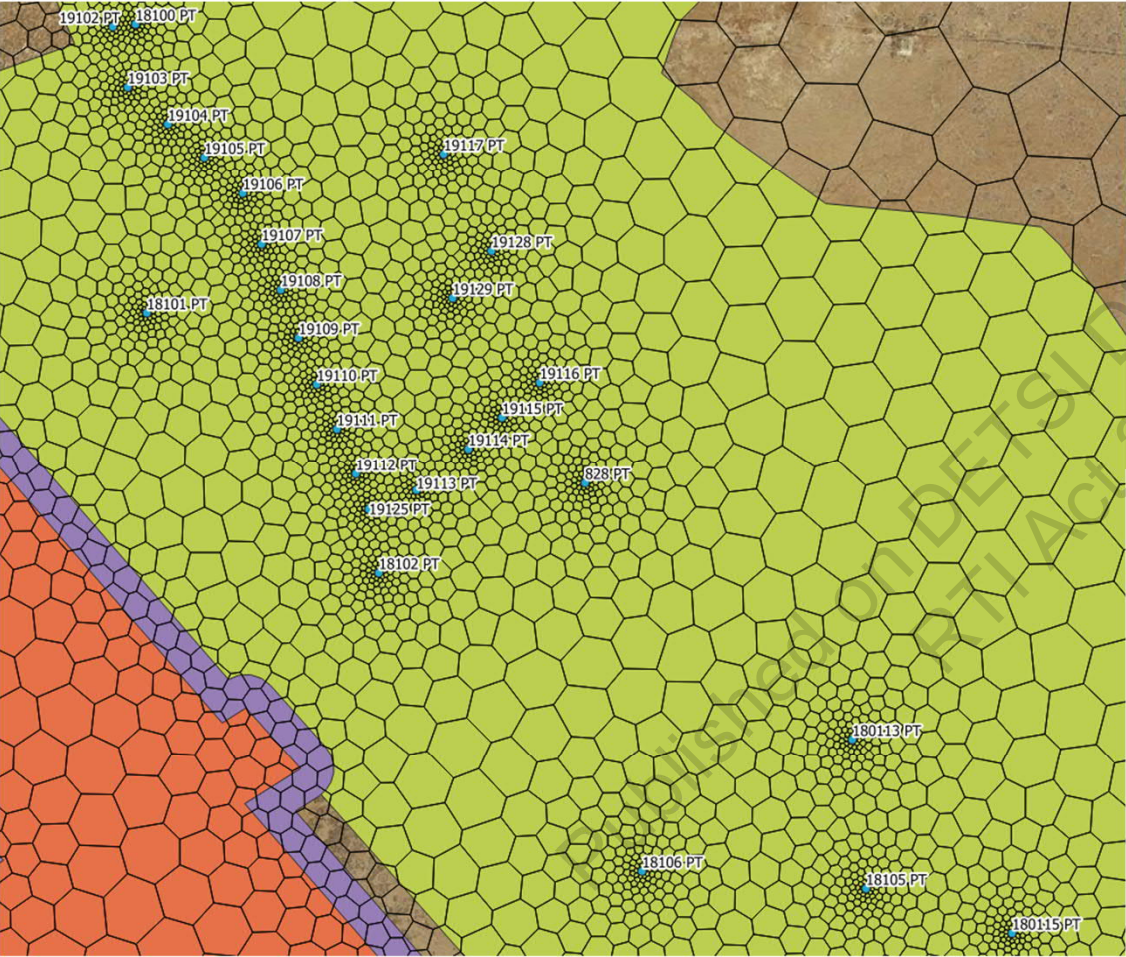
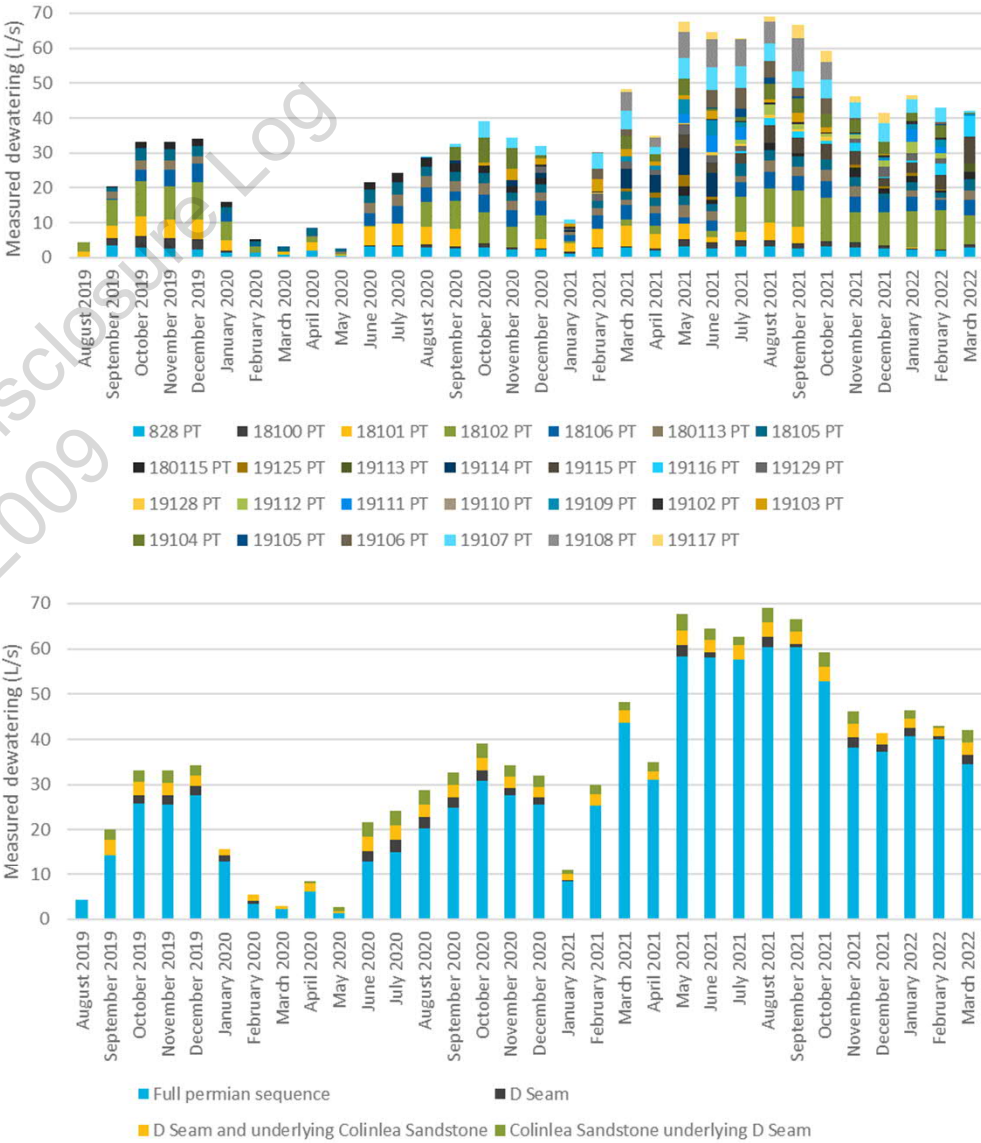
Modelled watercourses

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 Ulcambah 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

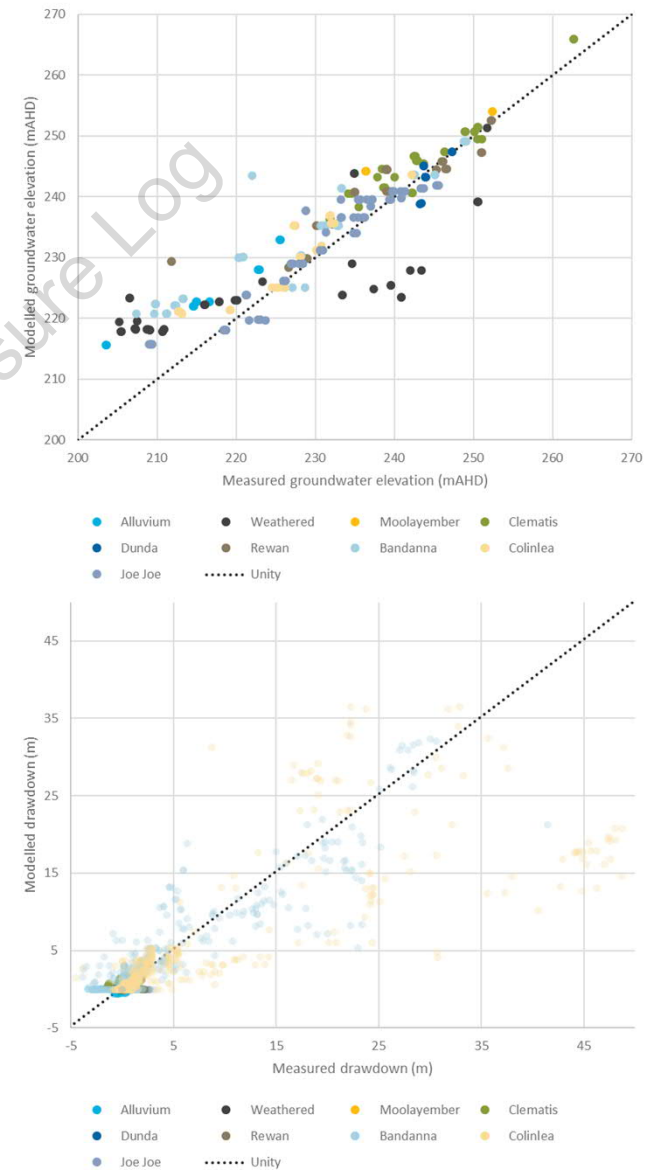
- Set up model with expected hydraulic properties based on hydrogeological conceptual model
- Define measured groundwater level data and estimates of spring flux as targets
 - Group targets by HSU, using first transient measurement as a 'head' target, and the remainder as 'head-change' targets
- Run 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 400 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 $\sqrt{2}$ 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 and uncertainty suite

History-matching performance

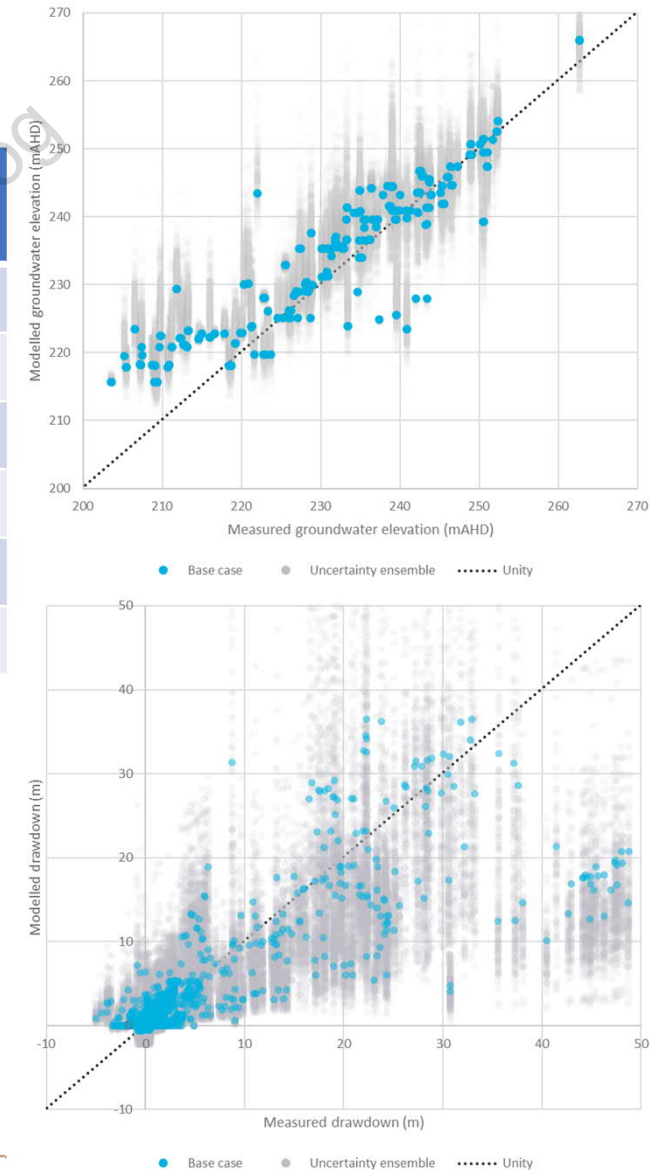
- History-matching undertaken on weighted head and head-change targets
- Performance reported against **unweighted head values**
- **SRMS 6.8%**
- Mean residual -3.6 m
- Mean absolute residual 4.8 m
- Minimum residual -39.4 m
- Maximum residual 17.5 m
- Number of observations 11,441
- Range of observations 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



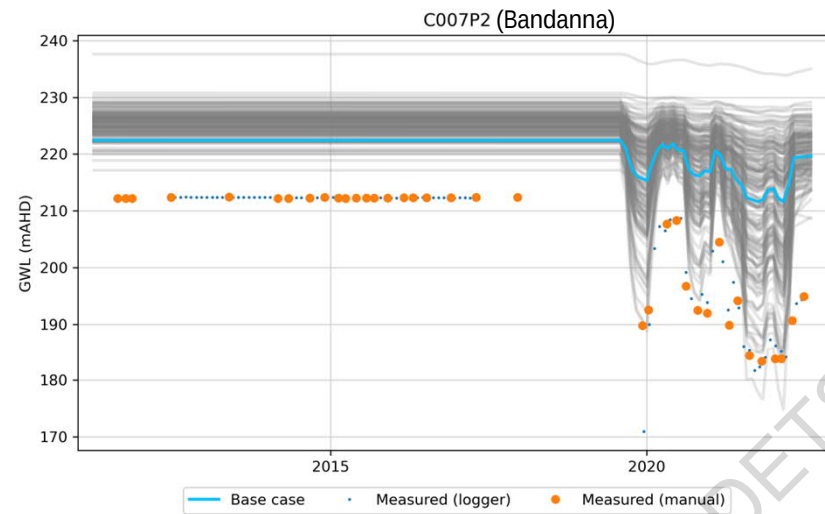
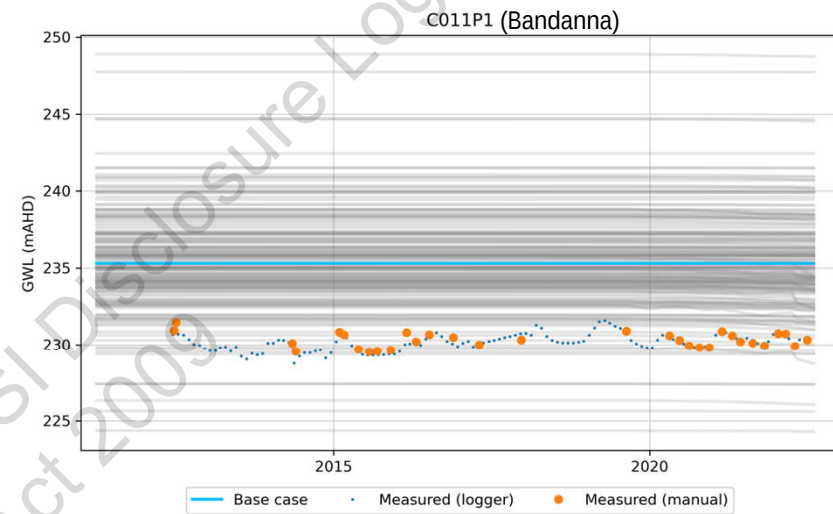
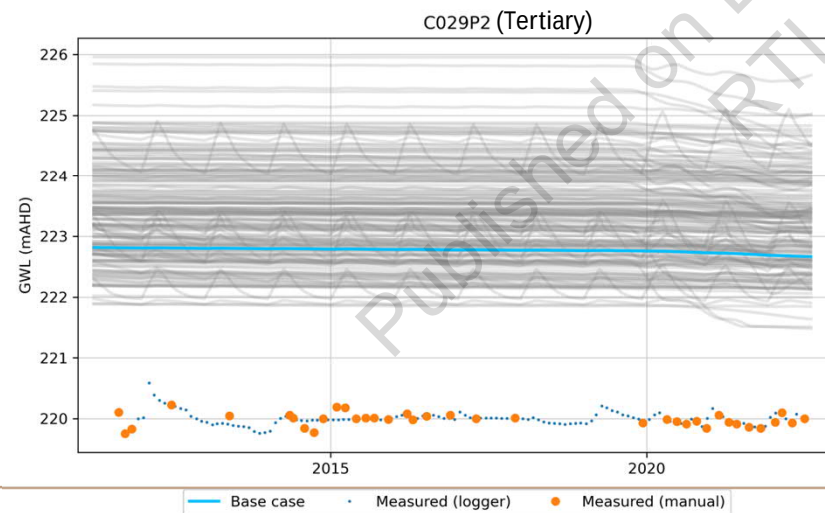
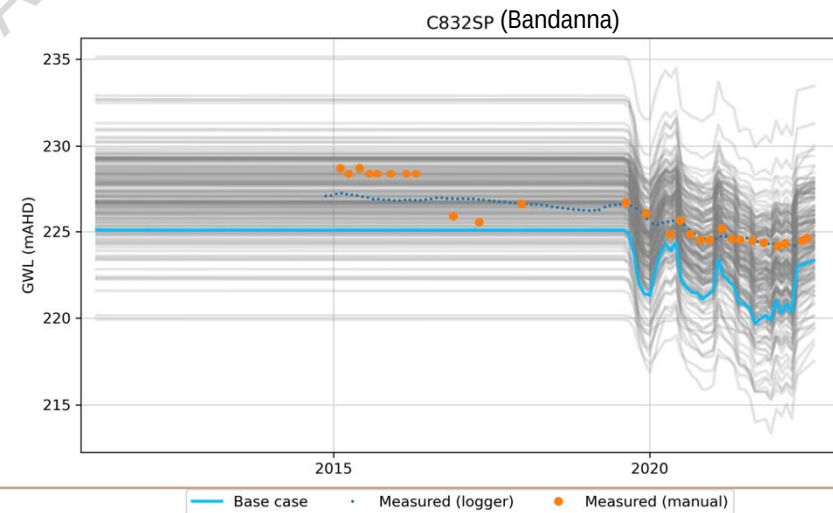
Uncertainty ensemble performance

	Initial hydraulic head	Transient head-change	Transient head
Base realisation	11.7%	3.4%	6.8%
Maximum	22.6%	6.0%	15.5%
90 th percentile	16.3%	4.5%	10.9%
Median	13.5%	3.8%	8.6%
10 th percentile	11.6%	3.3%	7.2%
Minimum	10.5%	2.7%	5.9%

- Performance acceptance criteria adopted for predictive ensemble:
 - Initial hydraulic head SRMS 15%
 - Transient head-change SRMS 5%
 - Transient head SRMS 10%
- 500 parameter realisations
- 67 non-convergences
- 99 rejected on performance
- 334/500 realisations accepted

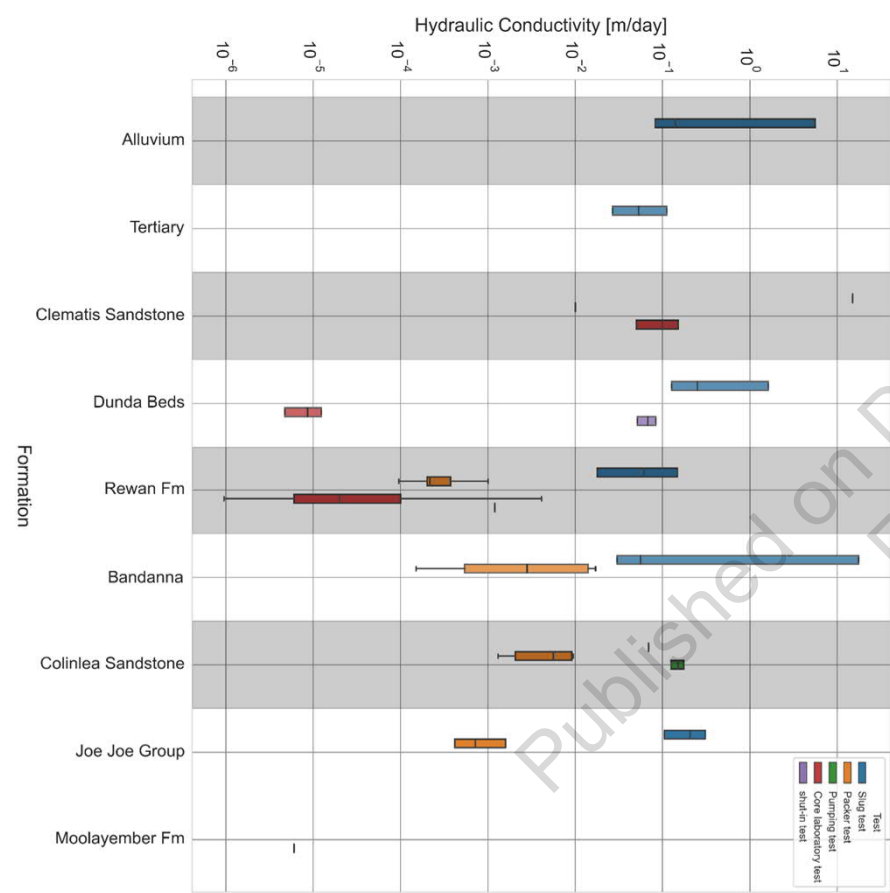


History-matching hydrographs

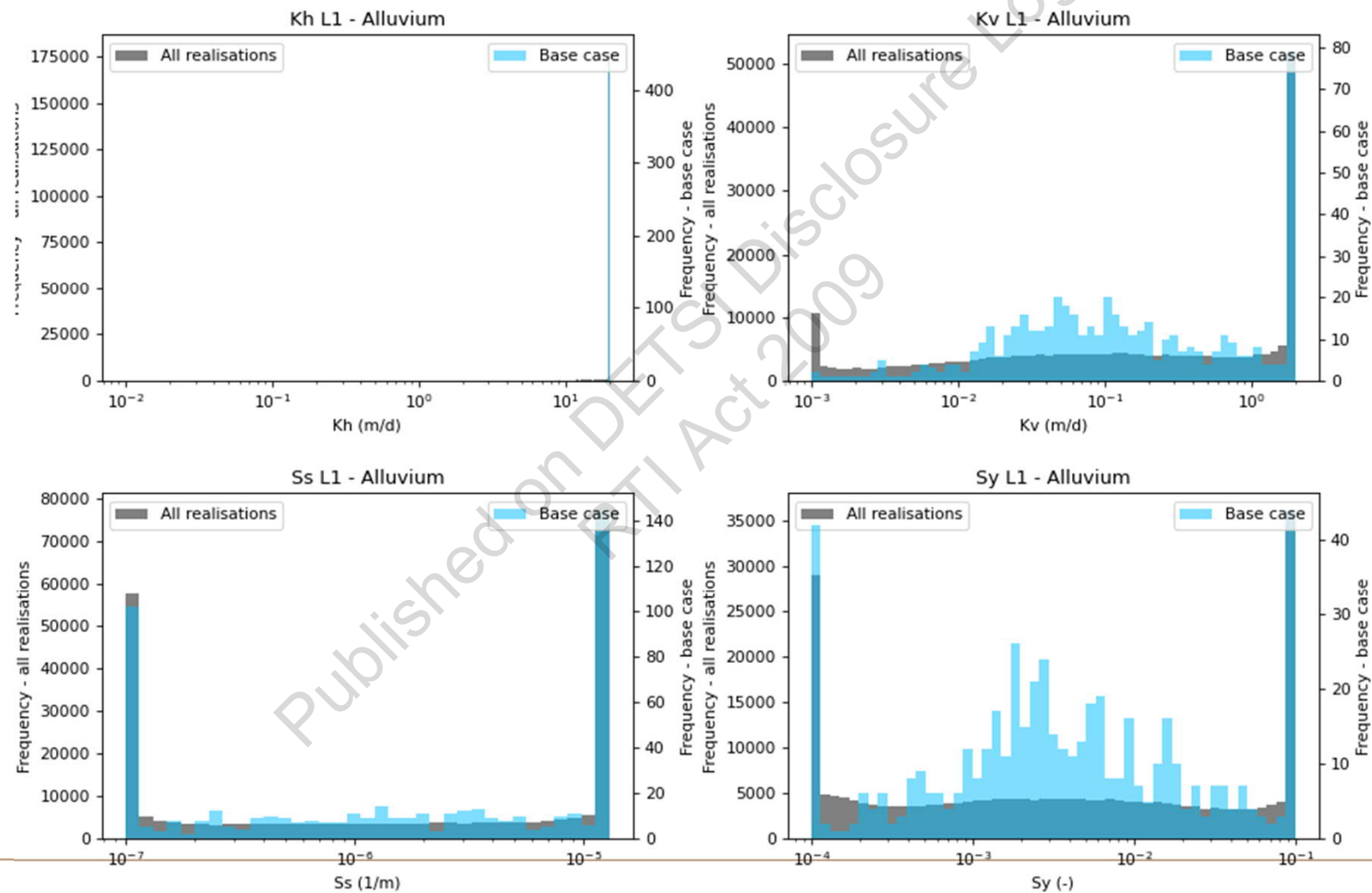


Parameterisation

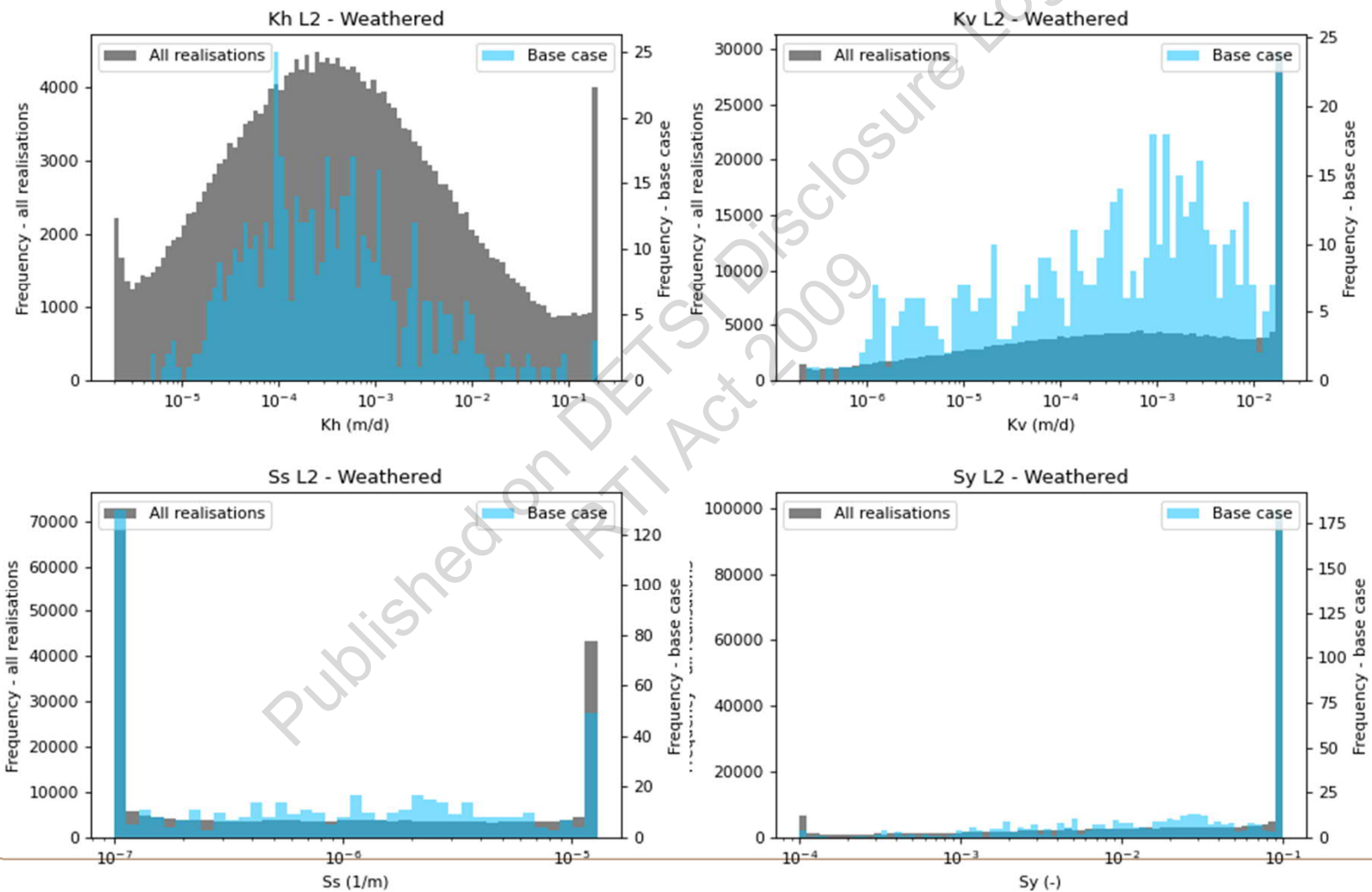
Interpreted hydraulic conductivity



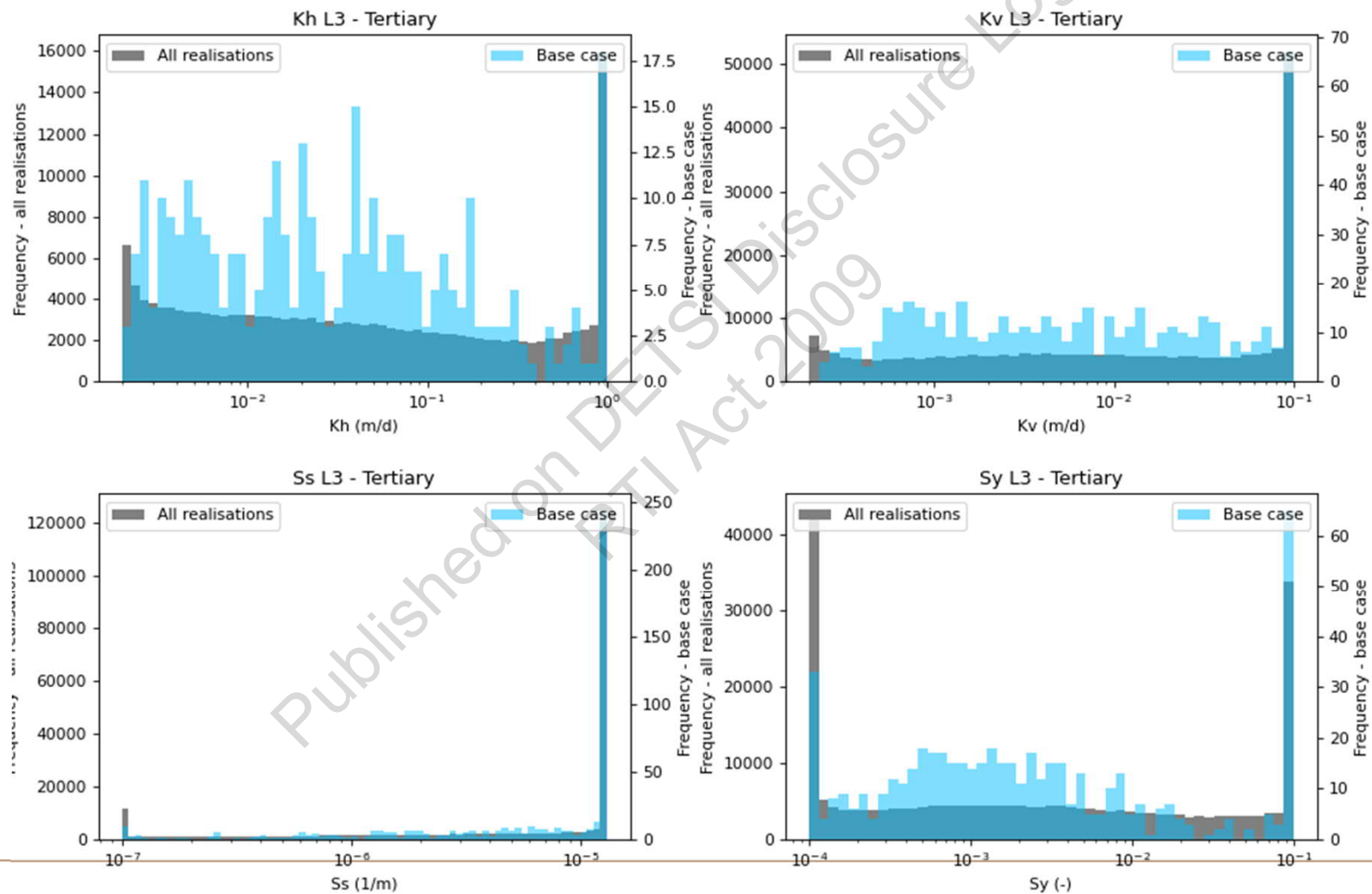
Parameterisation – L1 Alluvium



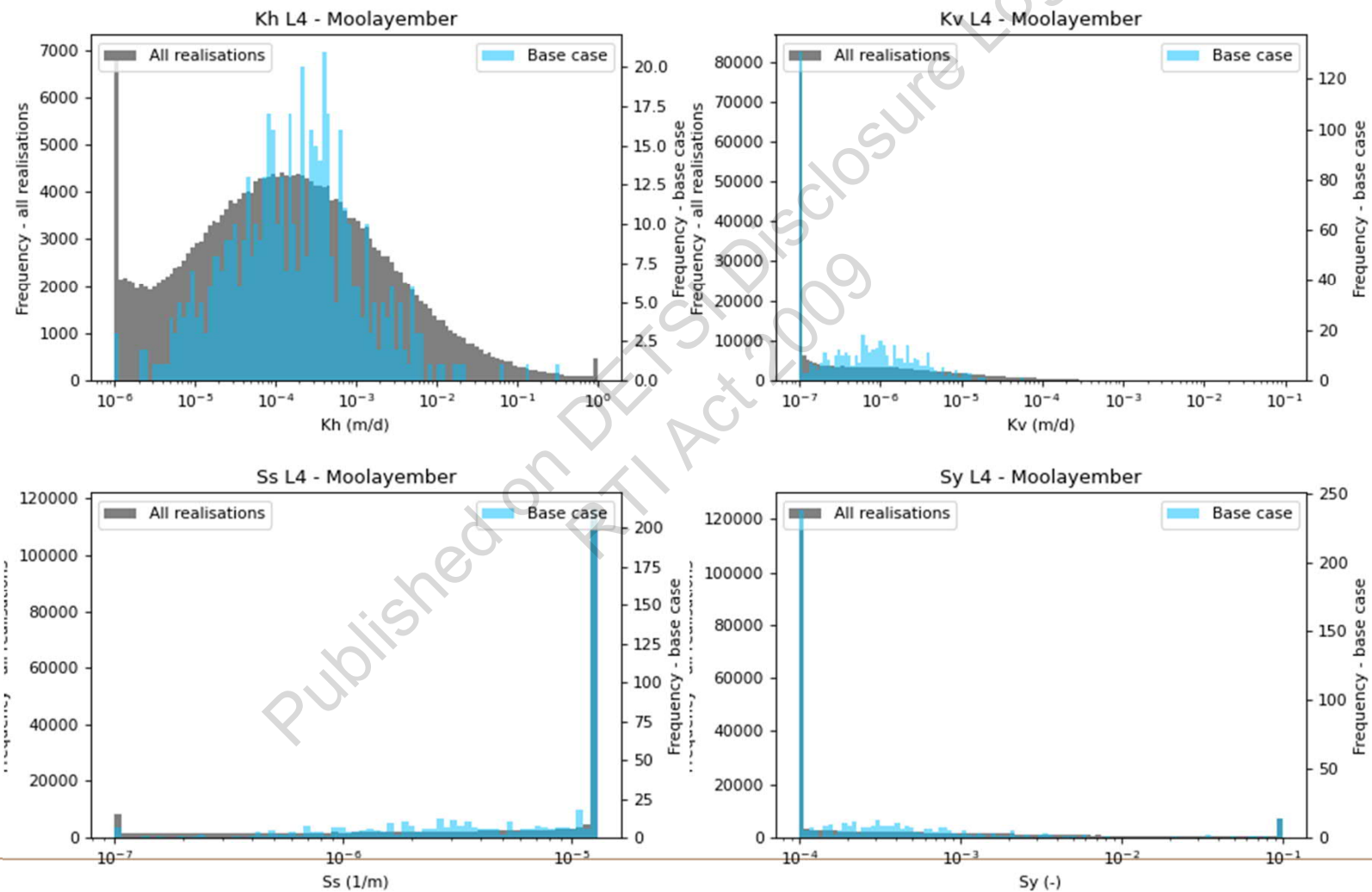
Parameterisation – L2 Weathered



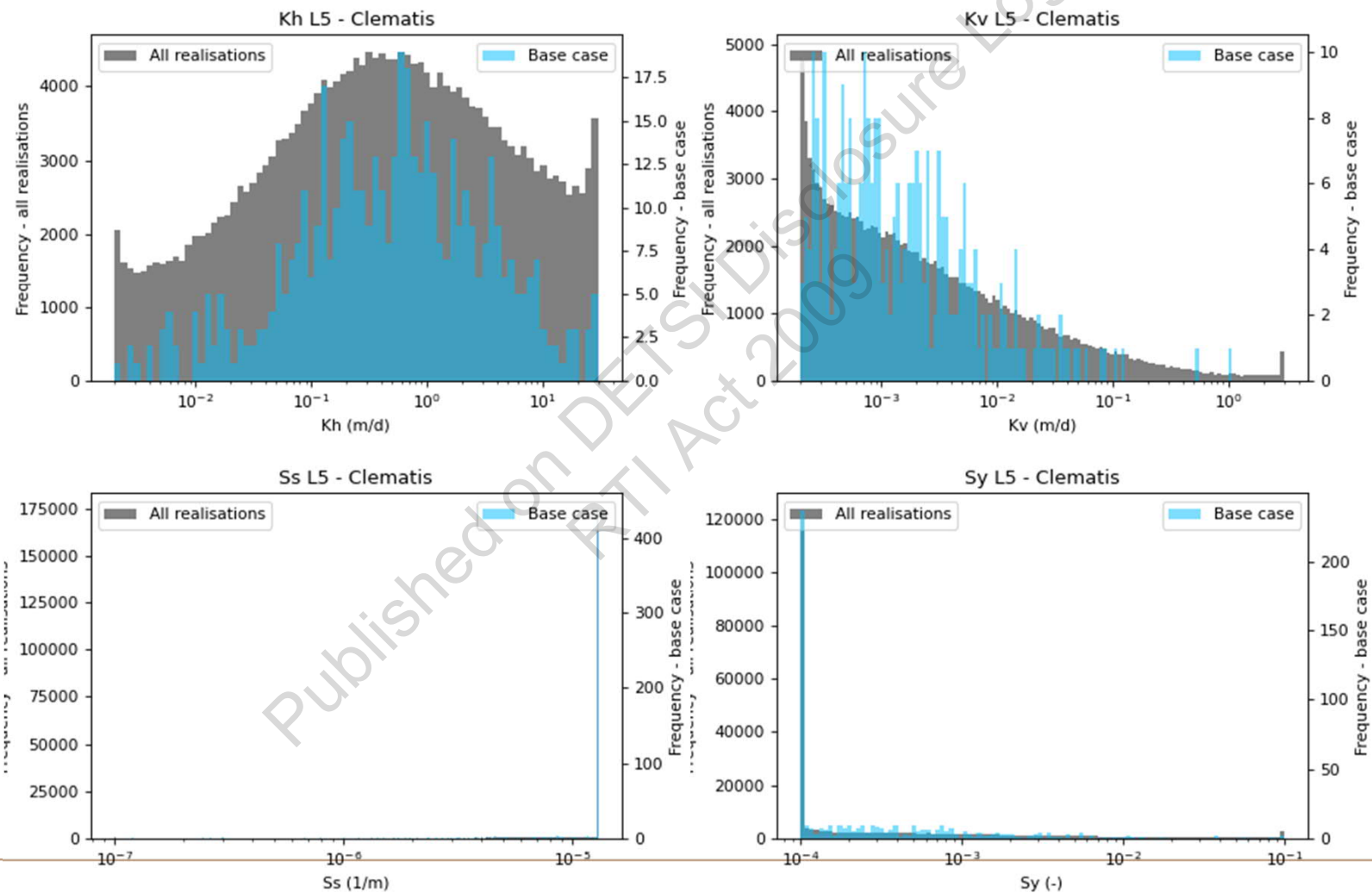
Parameterisation – L3 Tertiary



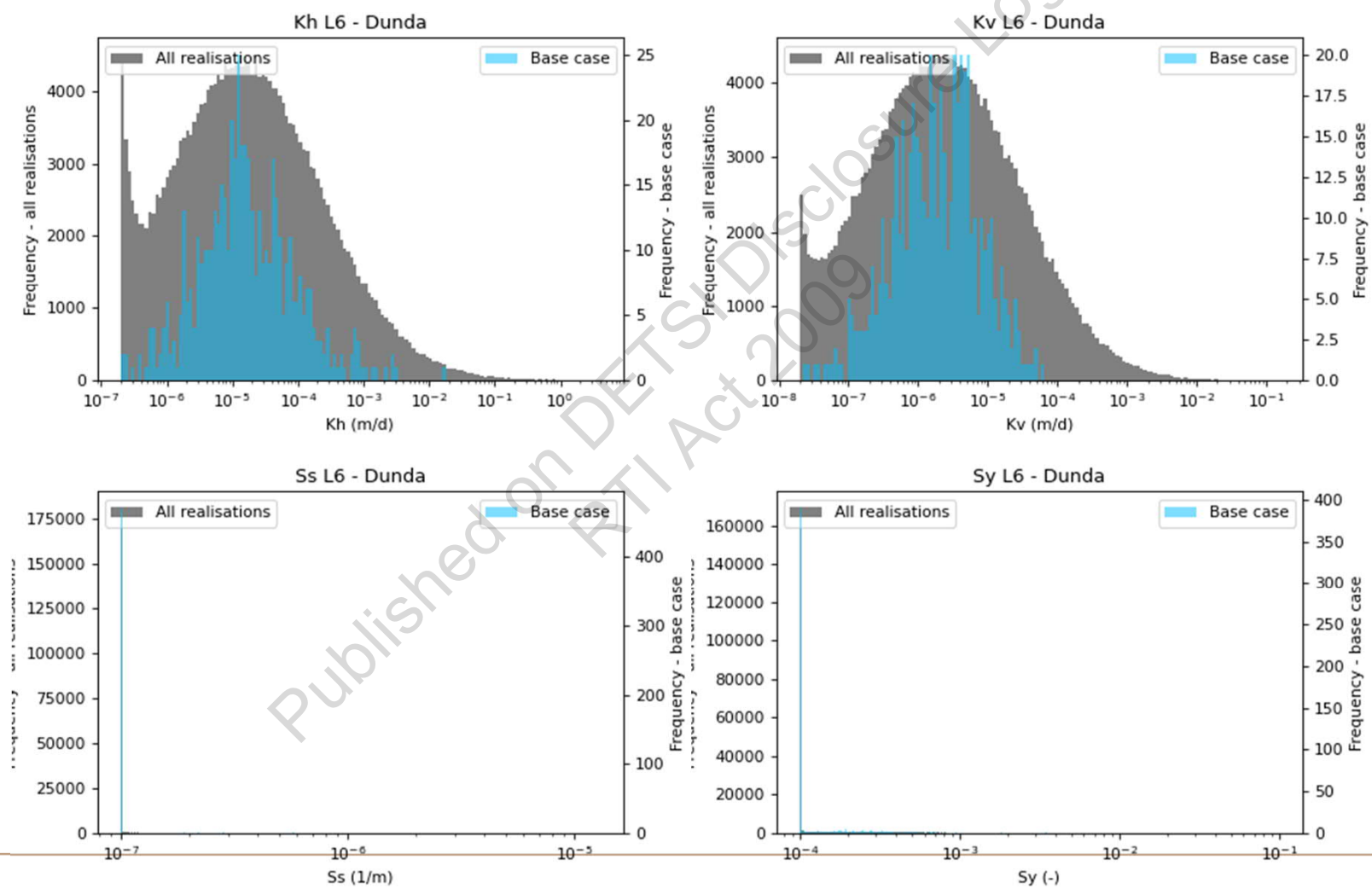
Parameterisation – L4 Moolayember



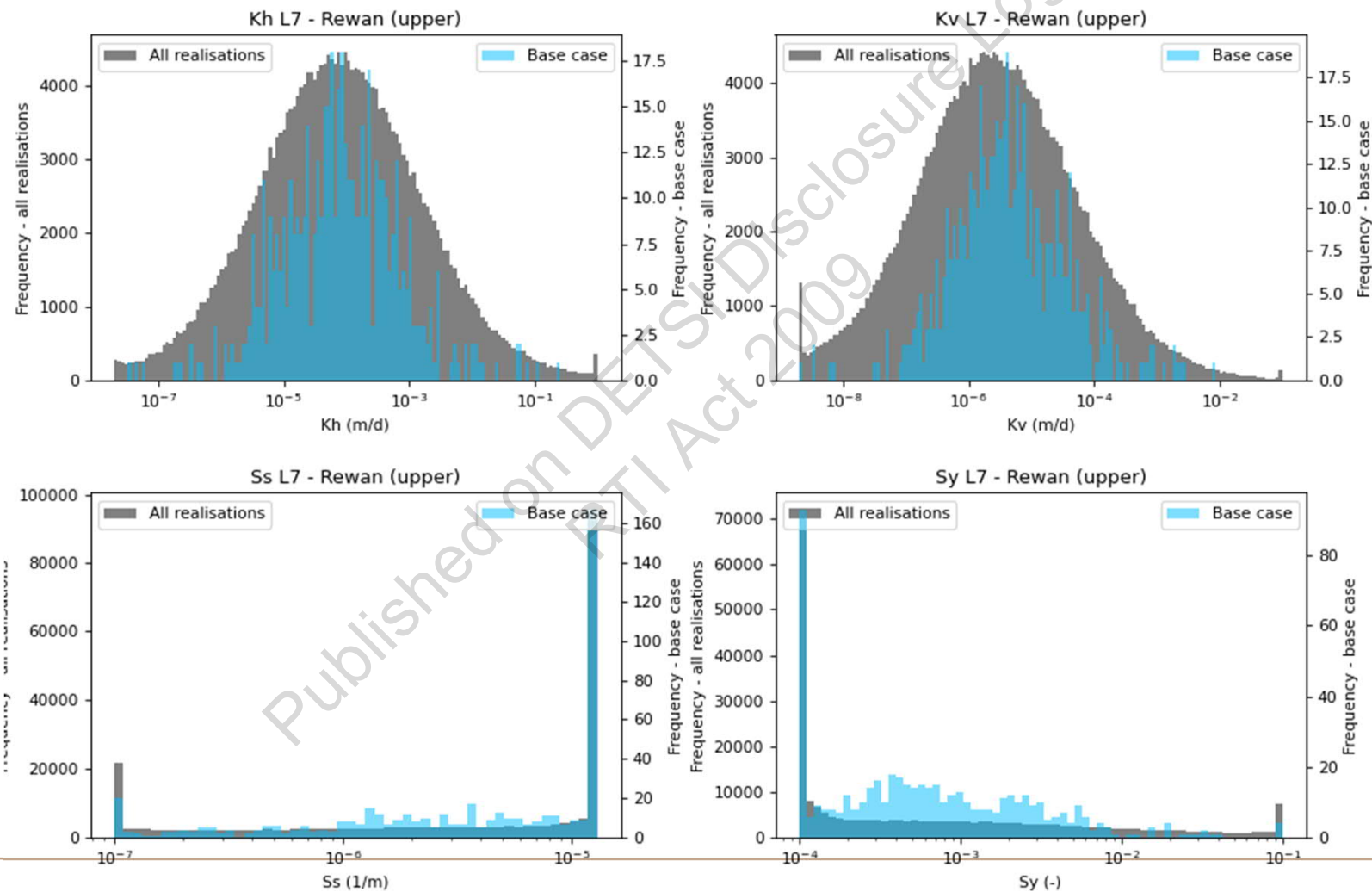
Parameterisation – L5 Clematis



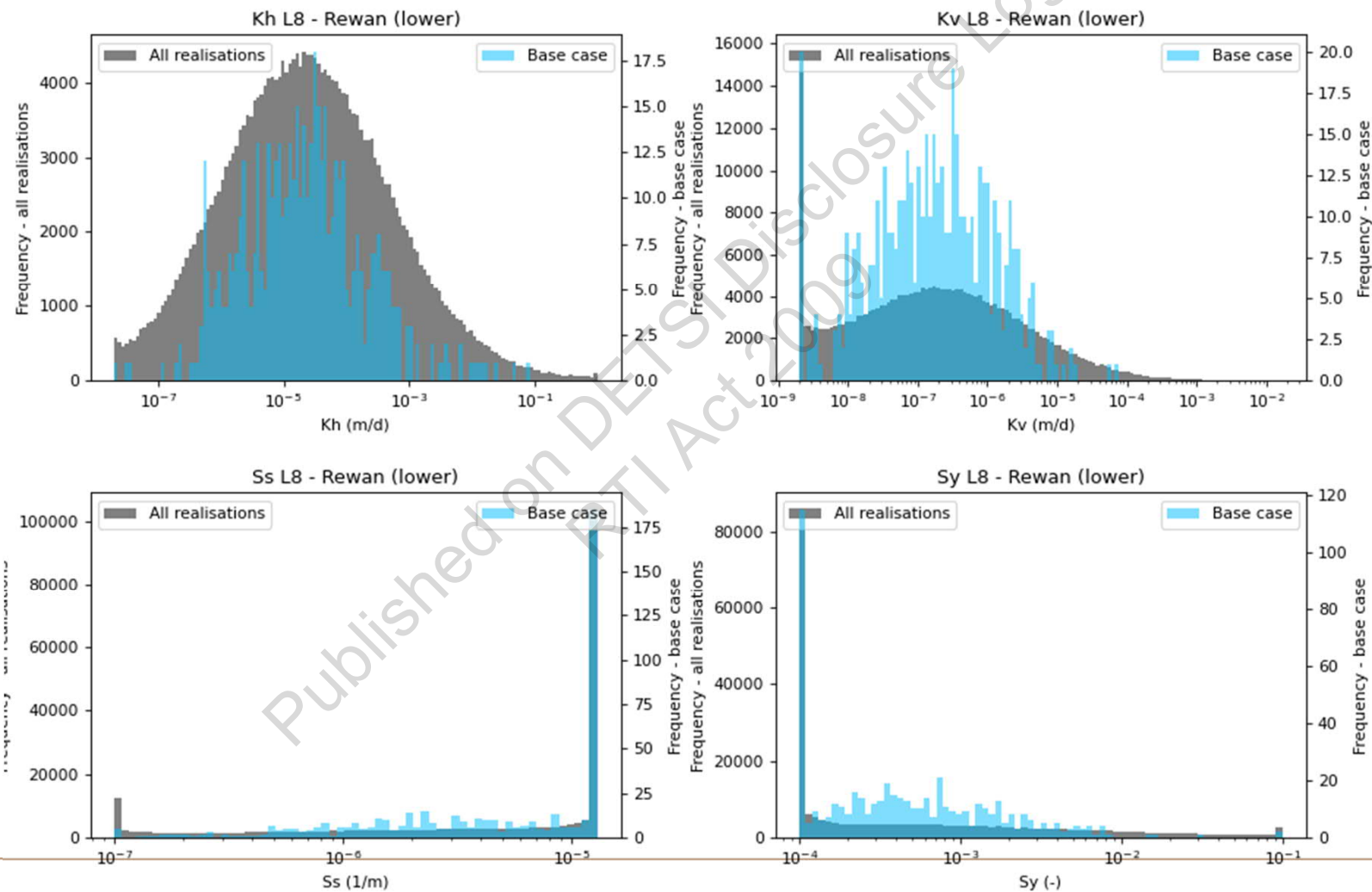
Parameterisation – L6 Dunda



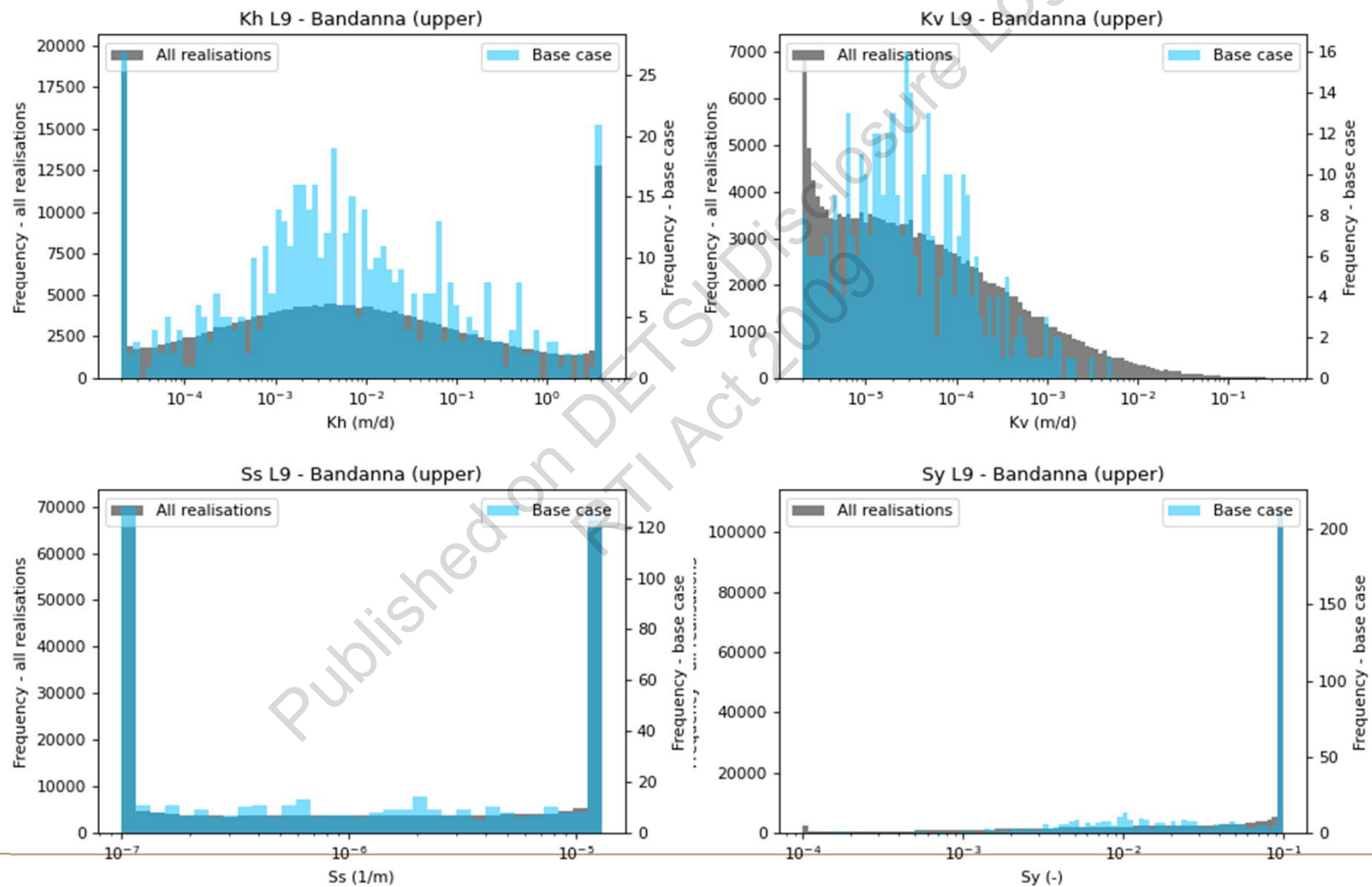
Parameterisation – L7 Rewan (upper)



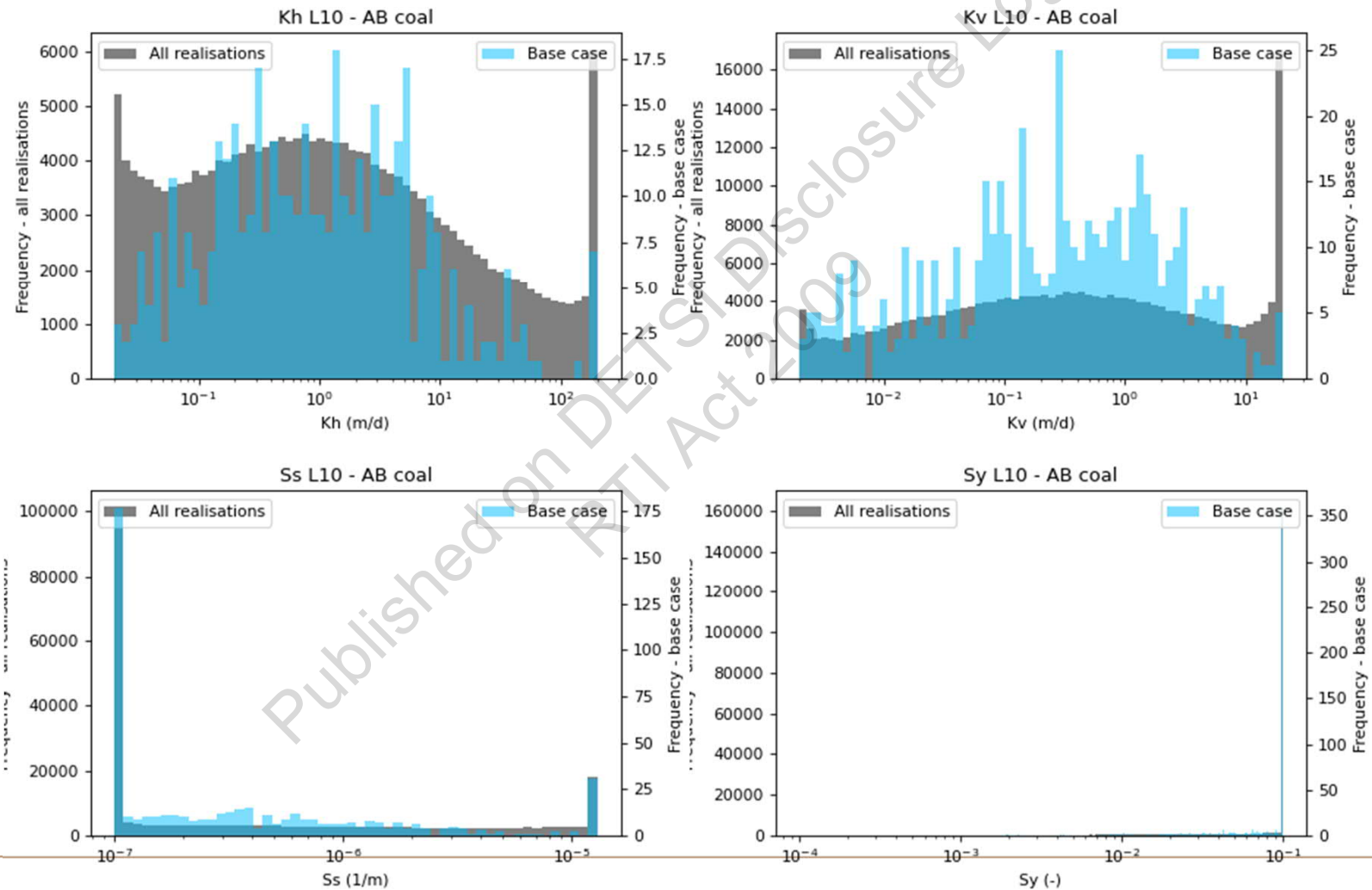
Parameterisation – L8 Rewan (lower)



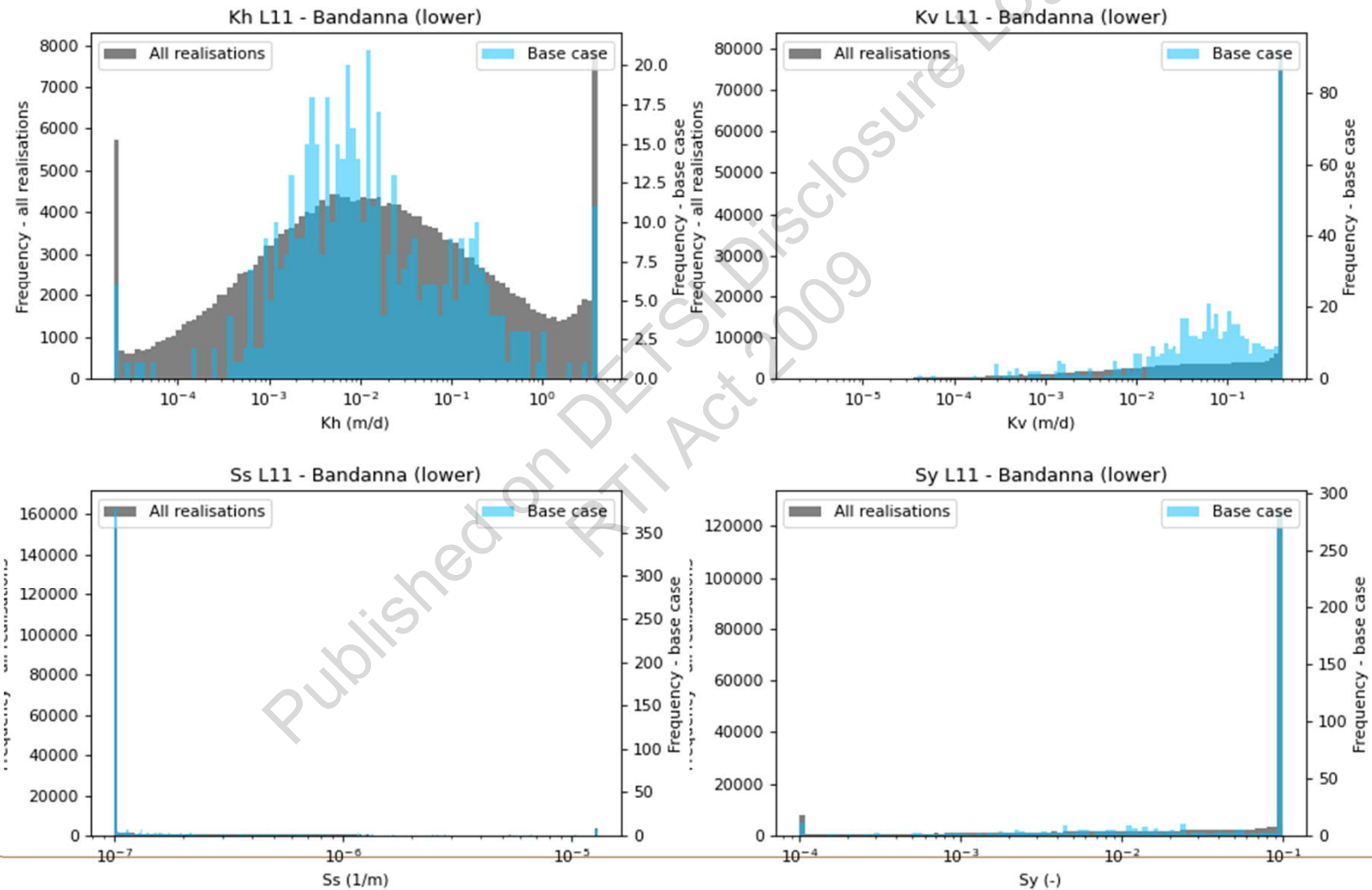
Parameterisation – L9 Bandanna (upper)



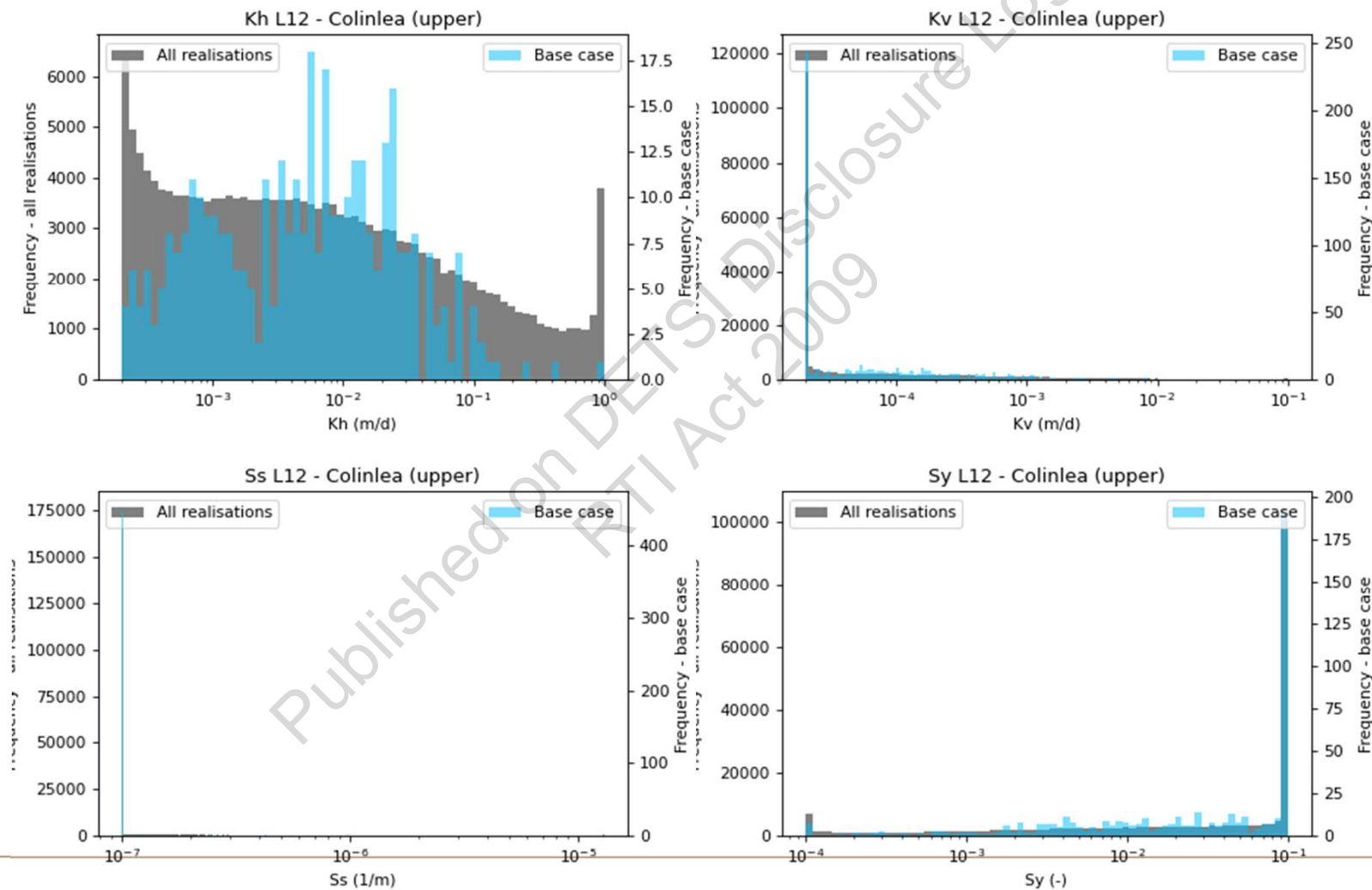
Parameterisation – L10 AB Coal



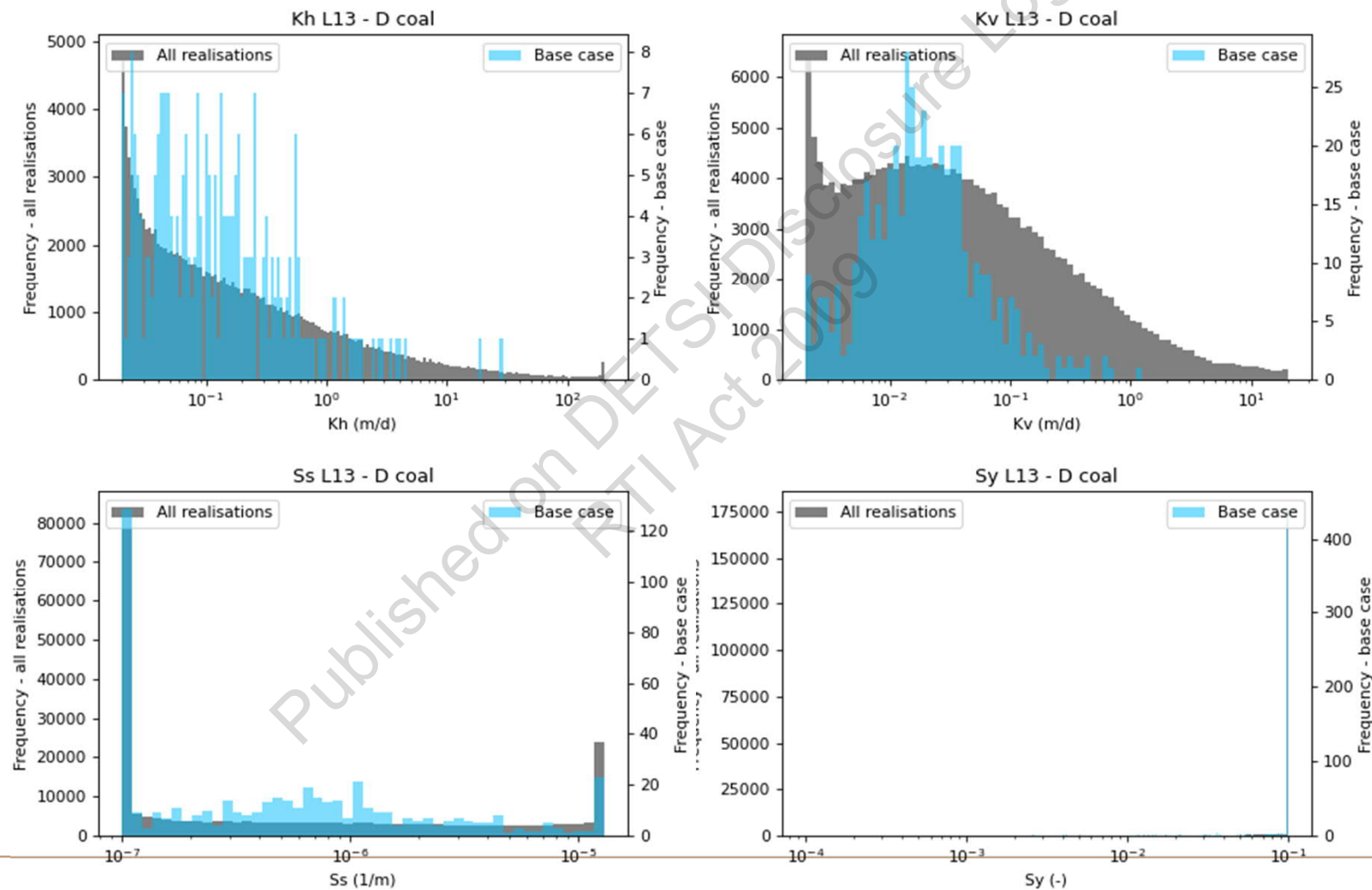
Parameterisation – L11 Bandanna (lower)



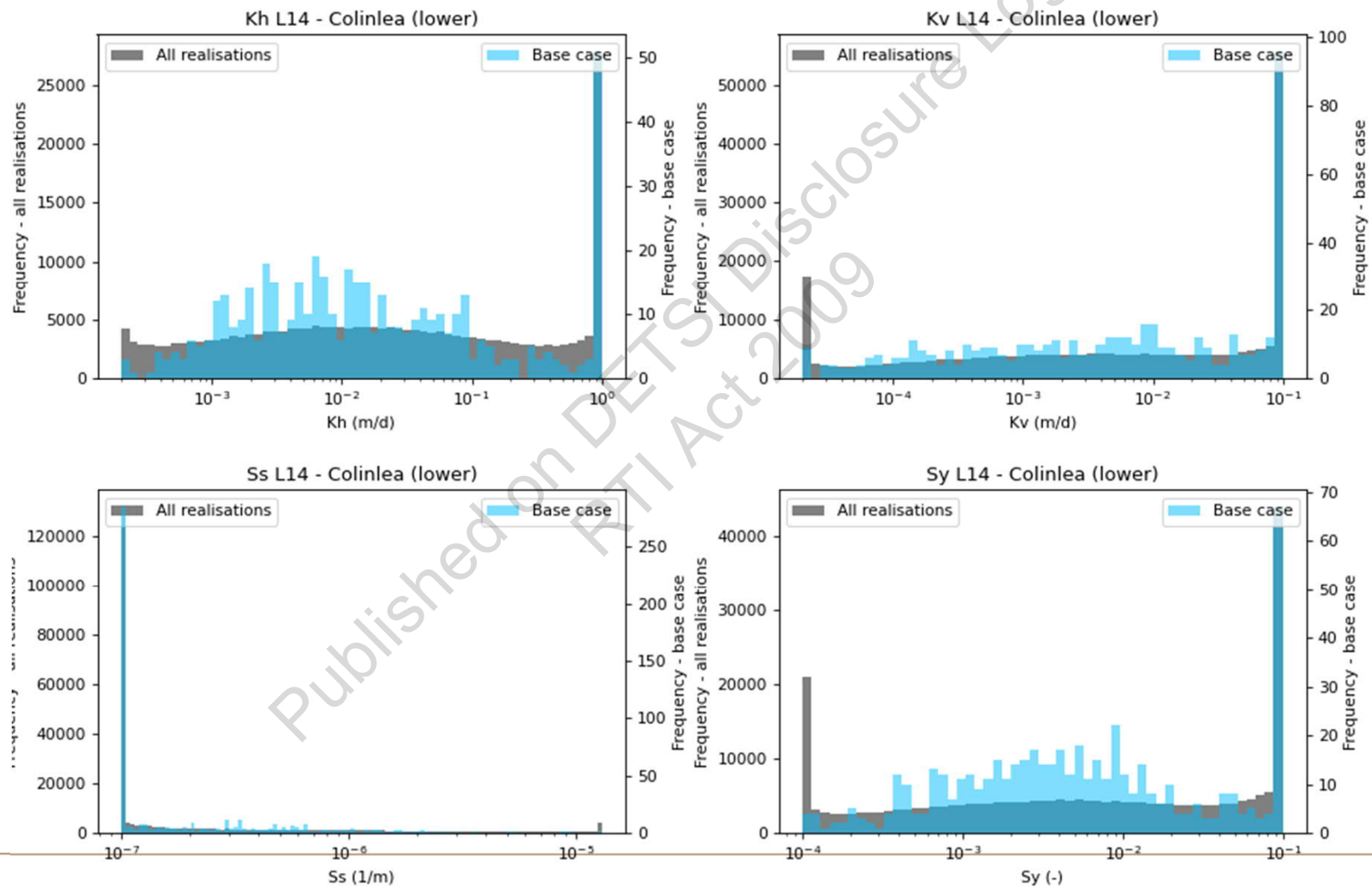
Parameterisation – L12 Colinlea (upper)



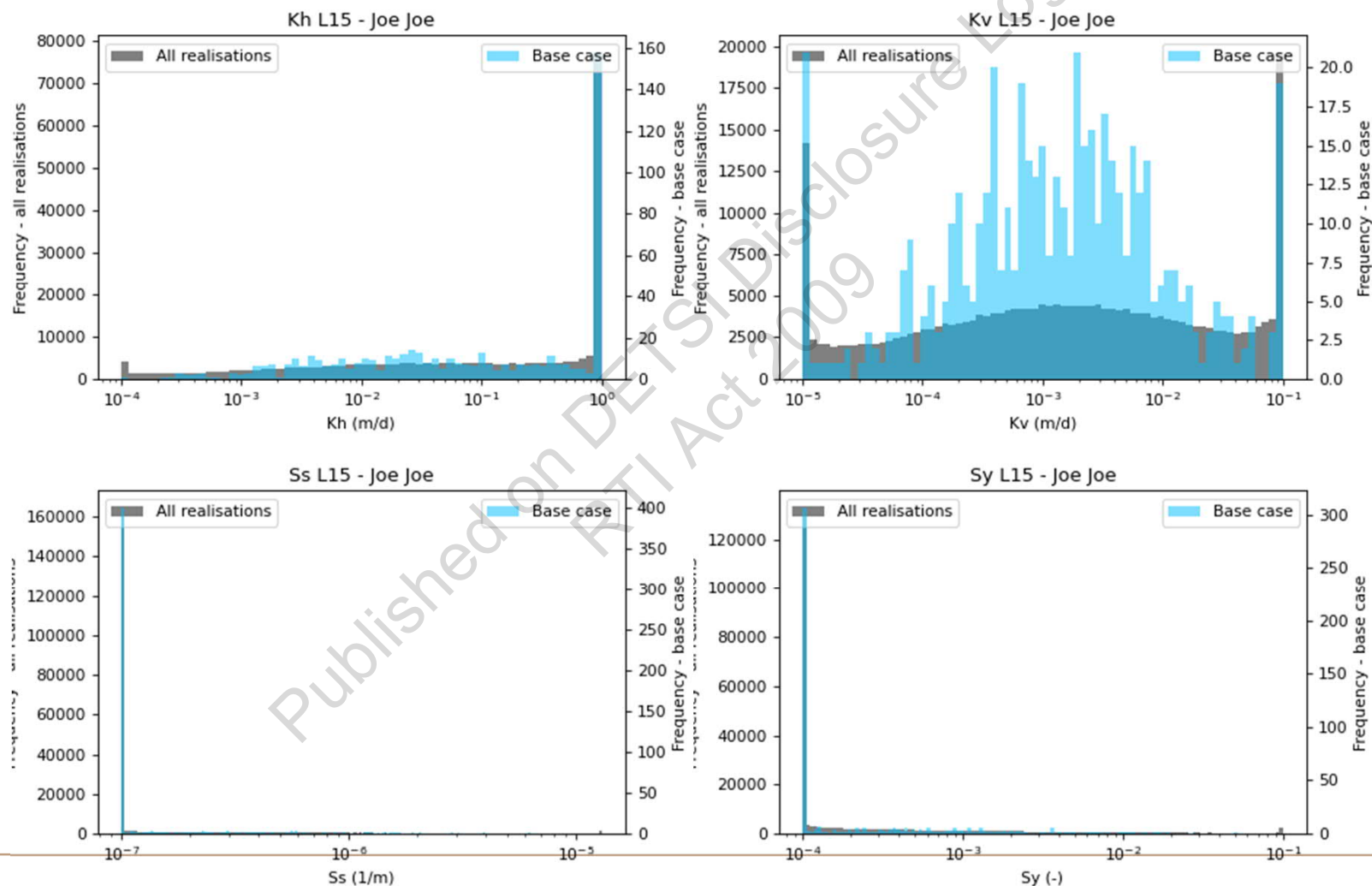
Parameterisation – L13 D Coal



Parameterisation – L14 Colinlea (lower)

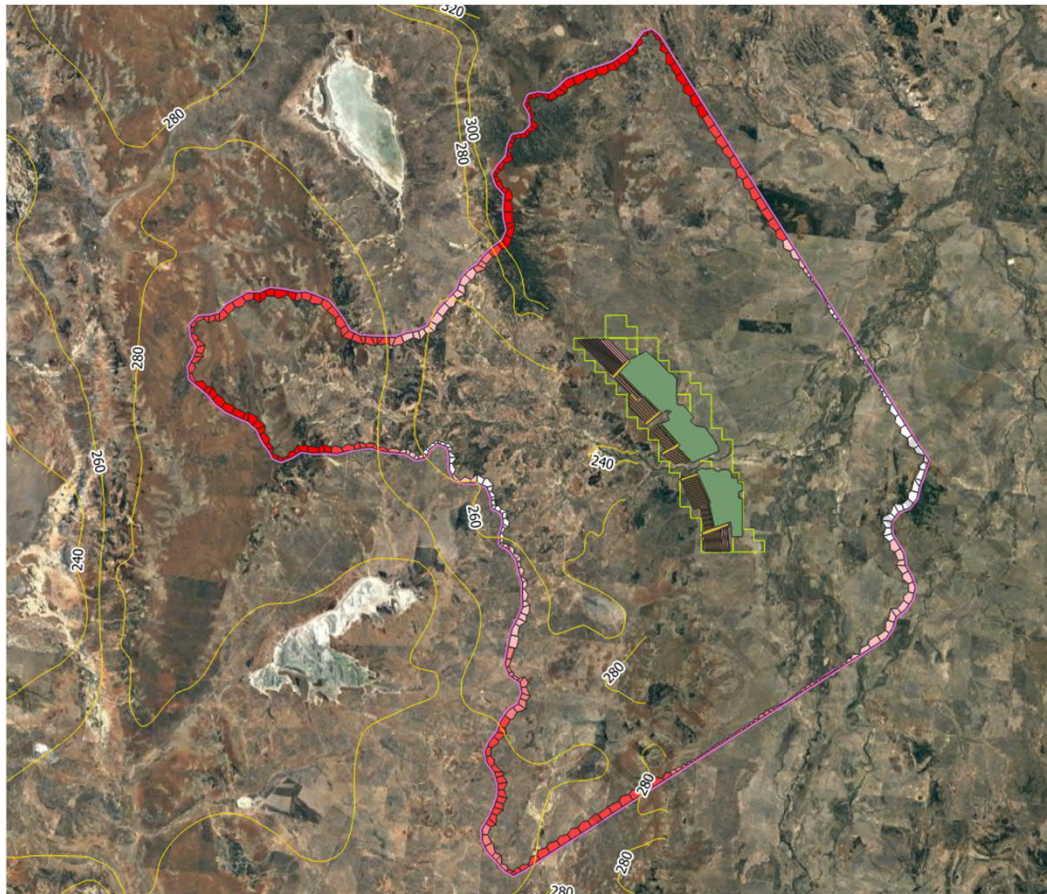


Parameterisation – L15 Joe Joe

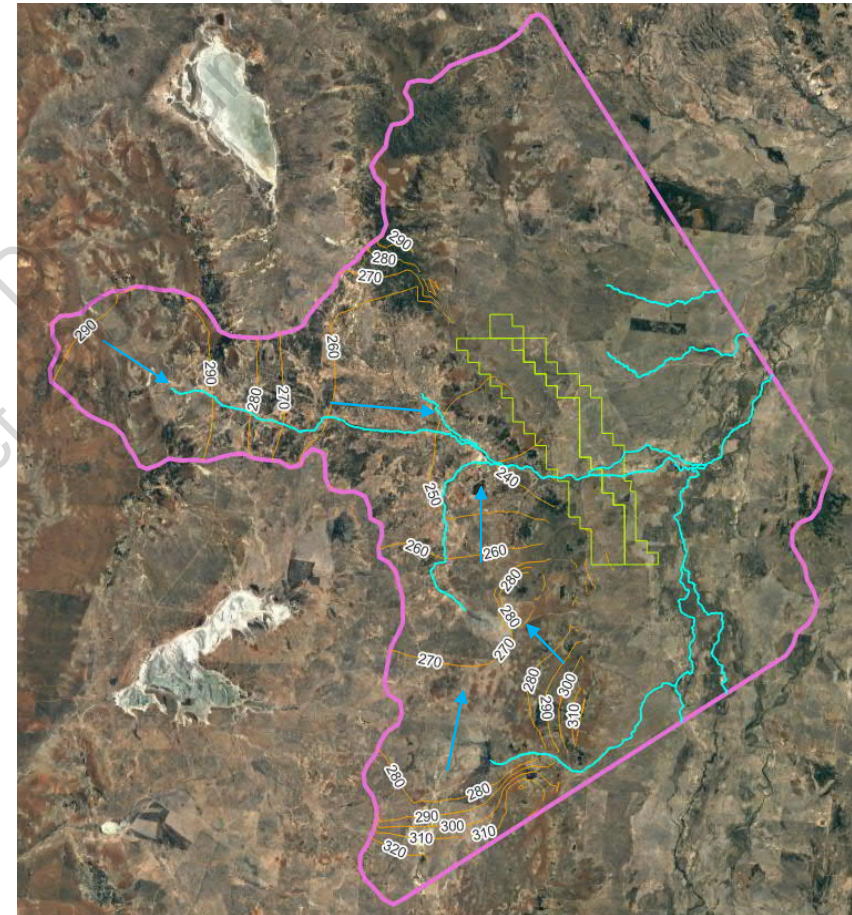


Steady state potentiometric surface – Clematis Sandstone

Interpreted

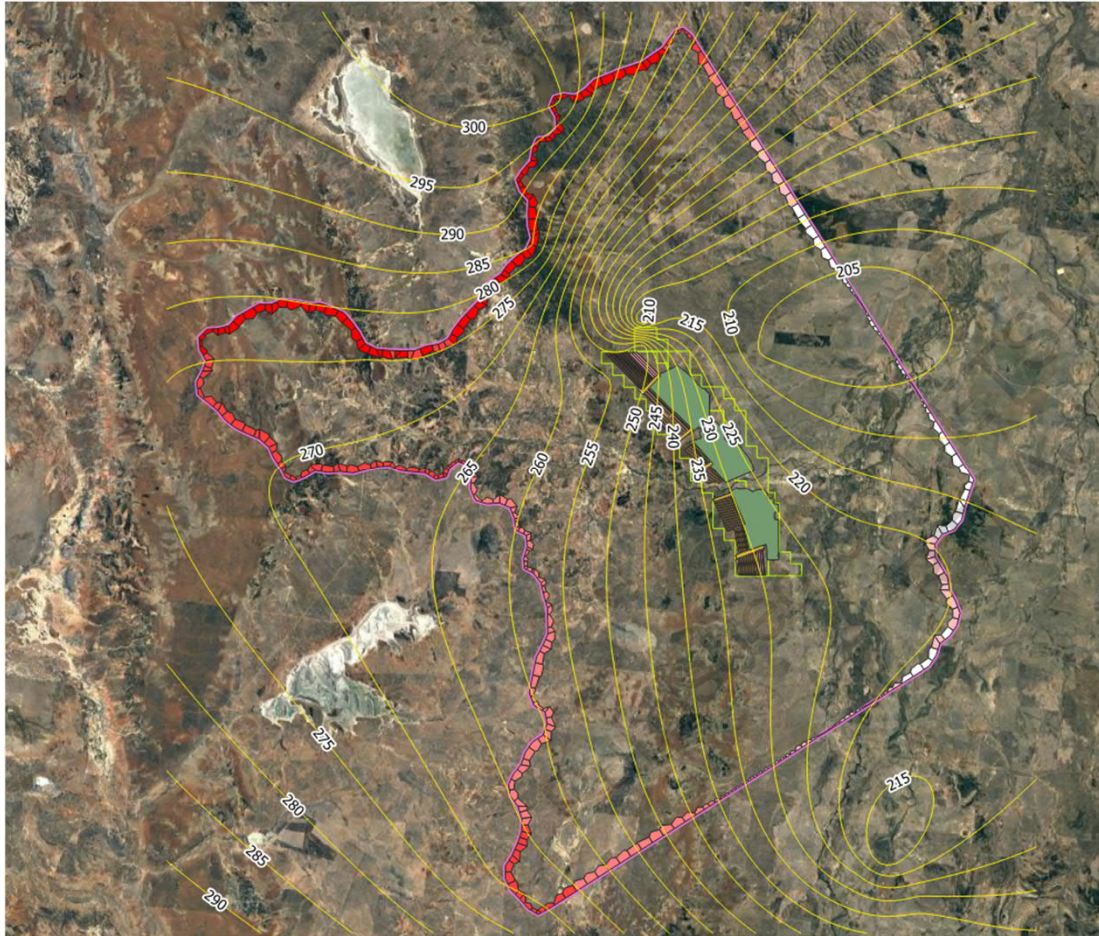


Modelled

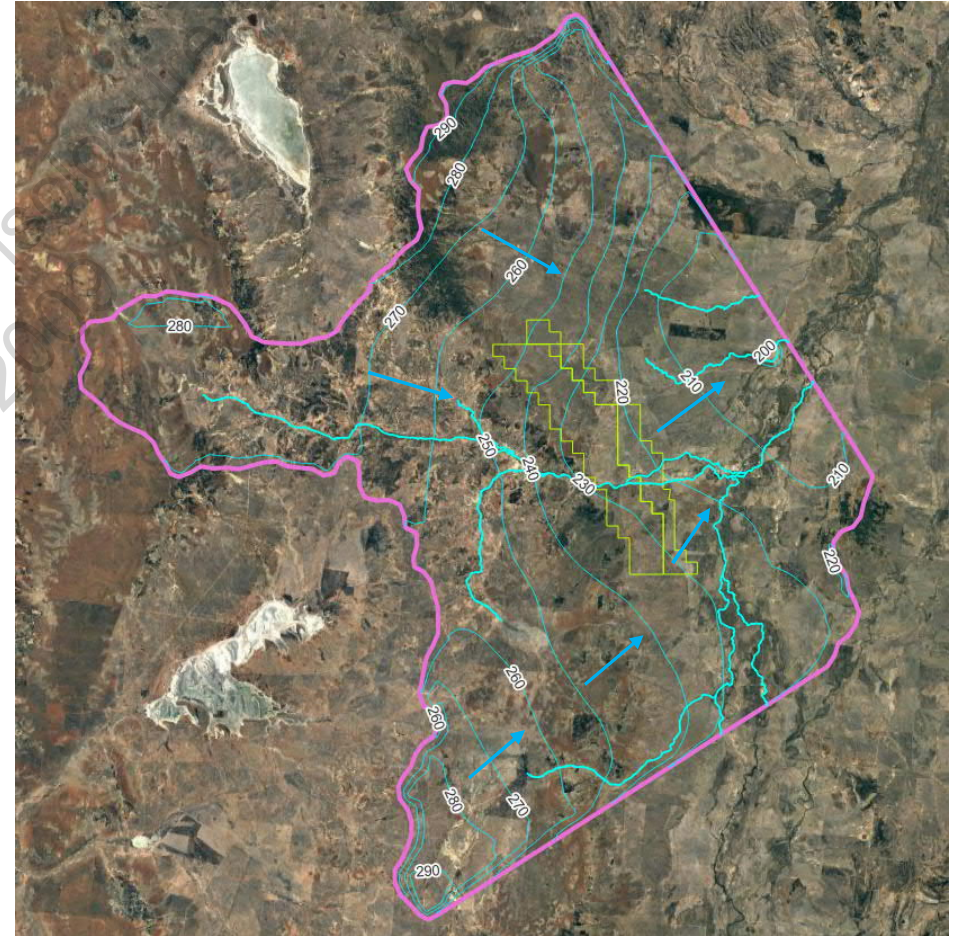


Steady state potentiometric surface – Joe Joe Group

Interpreted



Modelled



Steady state modelled water balance

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%

BRAVUS

MINING & RESOURCES

Predictive scenarios

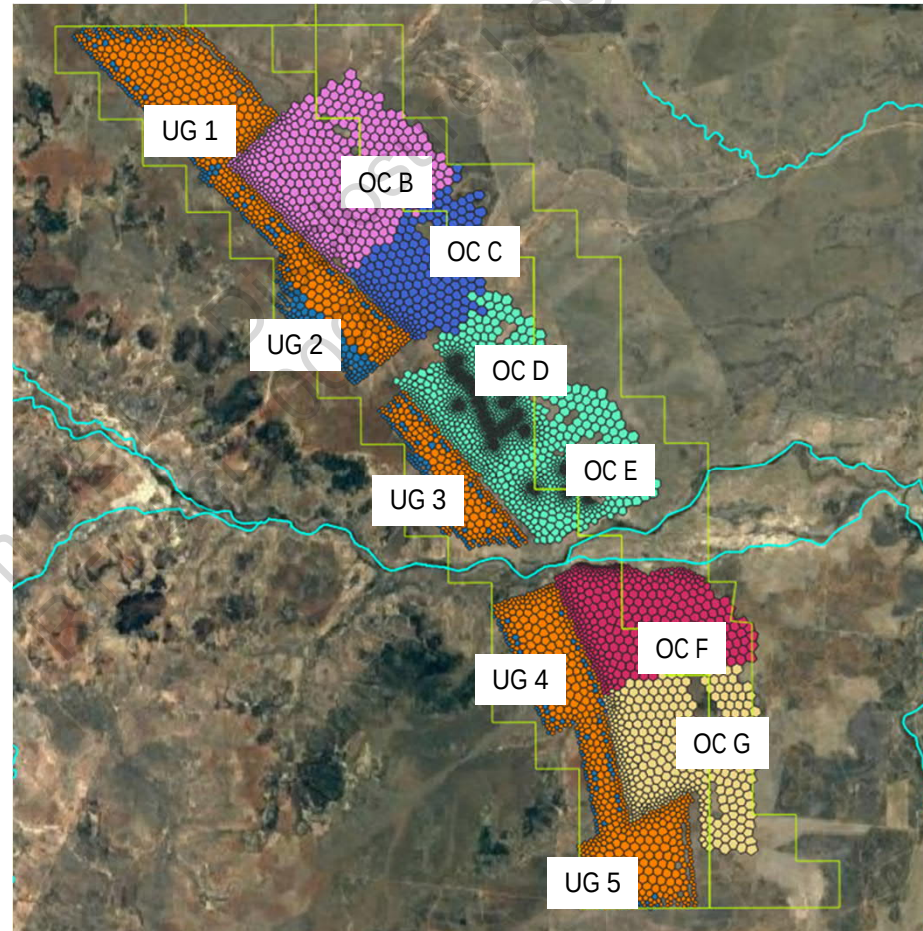
Disclaimer: The contents of this presentation contain commercial in confidence and personal information and are provided with the expectation that the same will remain confidential. They should not be disclosed to or released to any third party including under the Right to Information Act and applicable to all slides

Model predictive scenarios

- OC: open cut mine only; no underground mining
- SEIS: mine plan as per SEIS (2013); full underground mine footprint
- 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 to ground surface above underground mine panels
 - Horizontal and vertical hydraulic conductivity increased by a factor of 100
- Time-varying material properties in open cut mine 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 cells below AB Coal seam (backfilled area)
 - Horizontal and vertical hydraulic conductivity increased to 0.5 m/d
- Post-mining recovery:
 - 2,000-year recovery stress period
 - All mine stresses deactivated, open cut pit, backfill and fracturing properties remain active for duration

Modelled mine plan

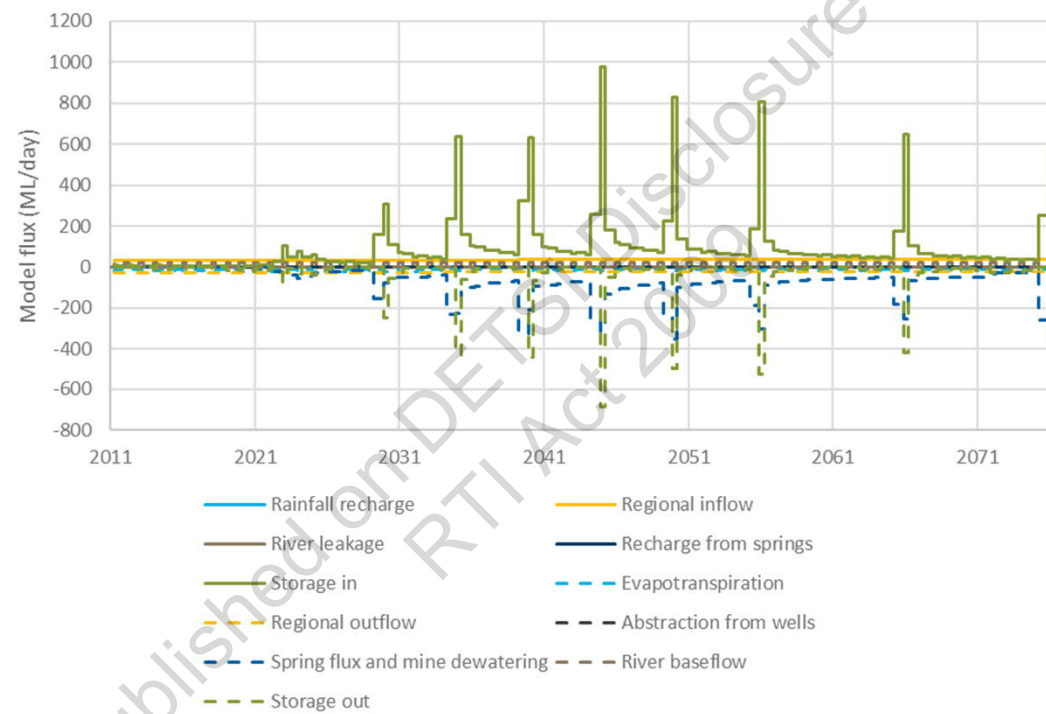
- OC: open cut
- SEIS: open cut and underground



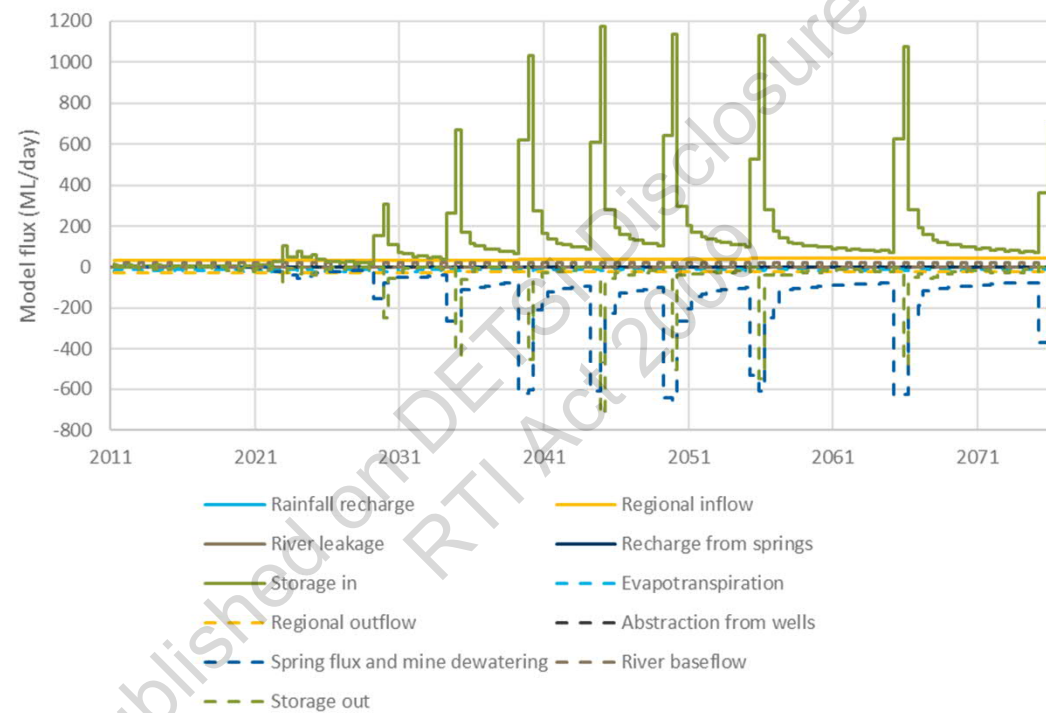
Modelled mine plan (as per SEIS)

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					

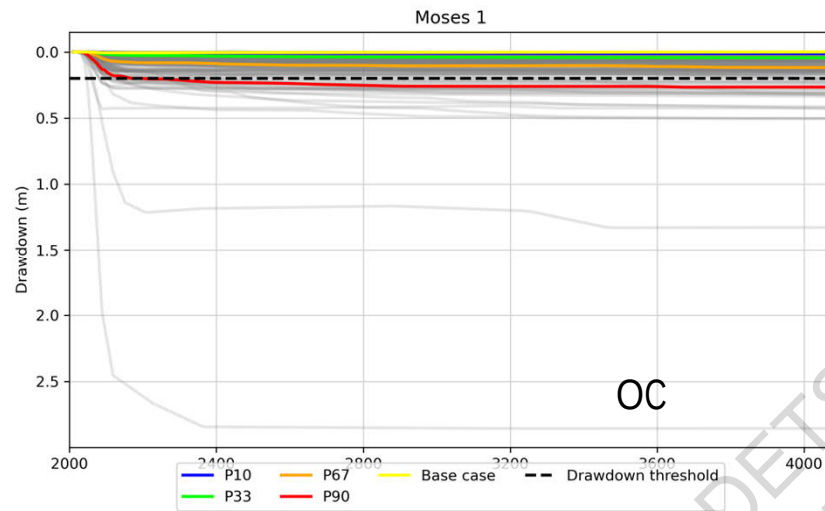
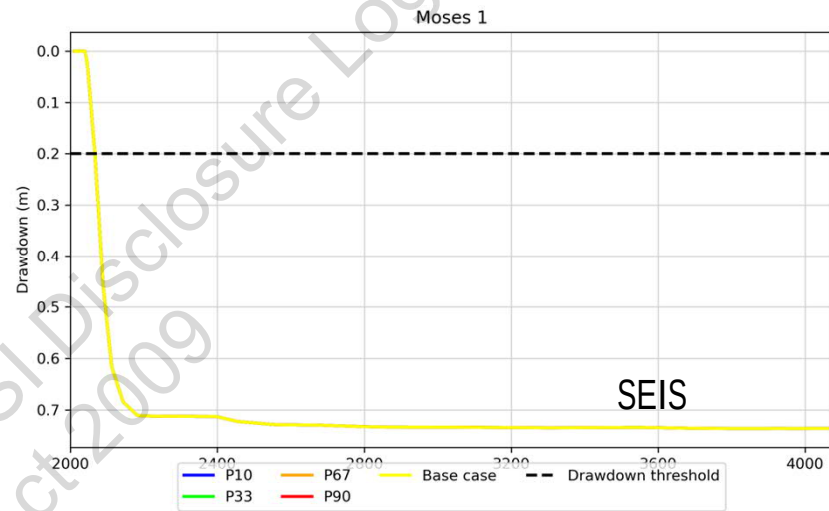
Modelled water balance: OC



Modelled water balance: SEIS



Model hydrographs



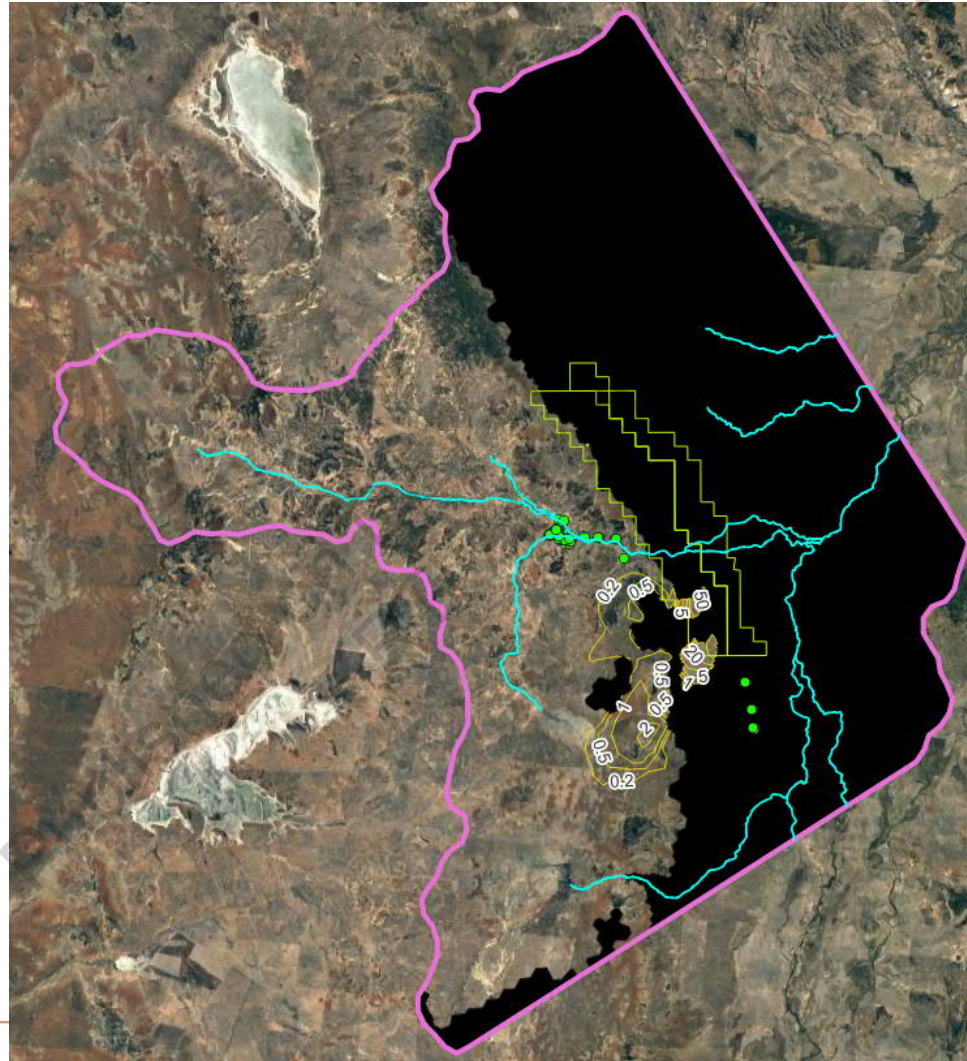
Modelled drawdown (m) at springs

Spring	GHD (2013)	OC	SEIS
Moses 4	<0.05	0.00	0.69
Moses 3	<0.05	0.00	0.69
Moses 2	0.08	0.00	0.69
Little Moses 1	<0.05	0.00	0.78
Moses 1	0.06	0.00	0.74
Moses 7	0.09	0.00	0.69
Moses 10	0.08	0.00	0.69
Moses 15	0.07	0.00	0.69
Moses 20	0.12	0.00	0.72
Moses 26	0.12	0.00	0.74
Joshua Spring	0.19	0.00	0.30
Mellaluka 1	<0.05 – 1.03	>10	>10
Mellaluka 2	<0.05 – 1.14	>10	>10
Storys	<0.05 – 2.34	>10	>10
Lignum	0.06 – 8.22	>10	>10

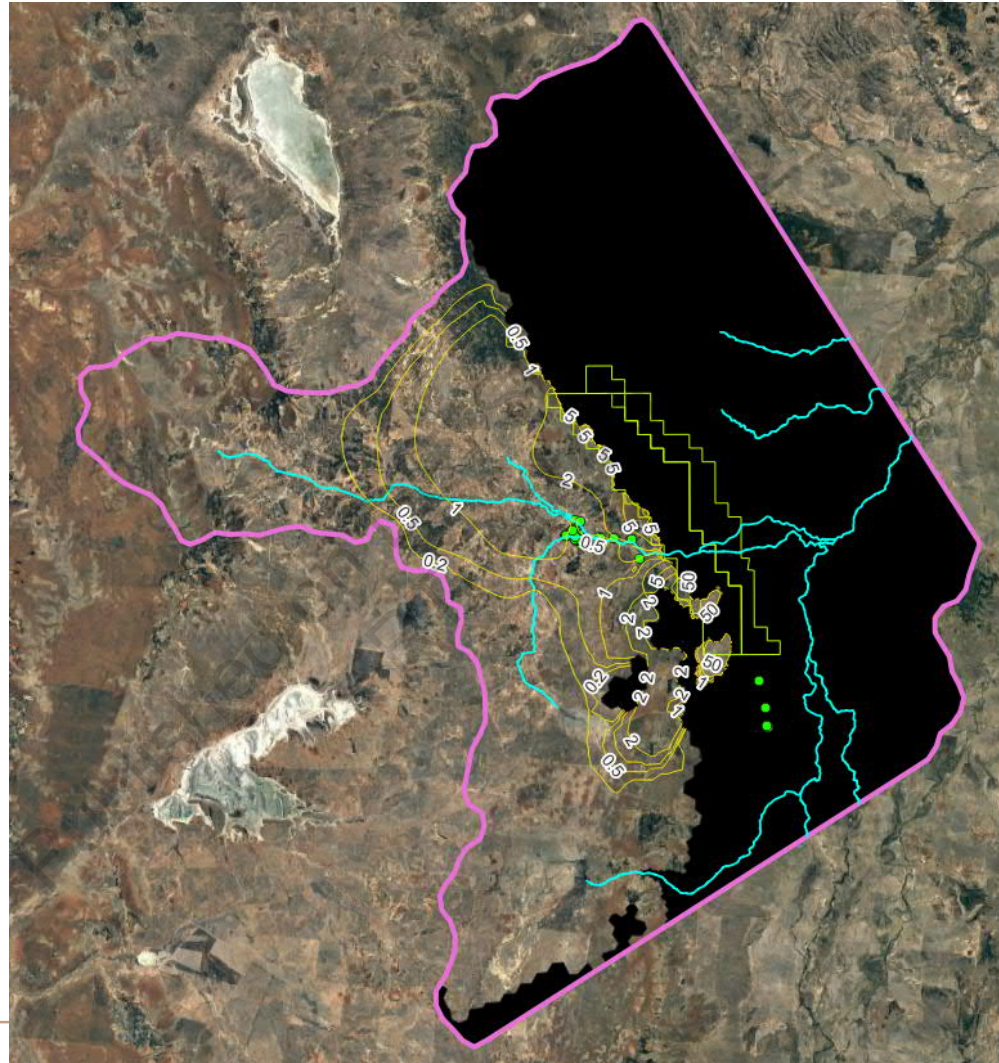
Proportion of runs exceeding
0.2 m drawdown at DSC for open cut
only scenario

Spring	OC
Moses 4	14%
Moses 3	14%
Moses 2	14%
Little Moses 1	16%
Moses 1	16%
Moses 7	14%
Moses 10	14%
Moses 15	14%
Moses 20	15%
Moses 26	16%
Joshua Spring	2%

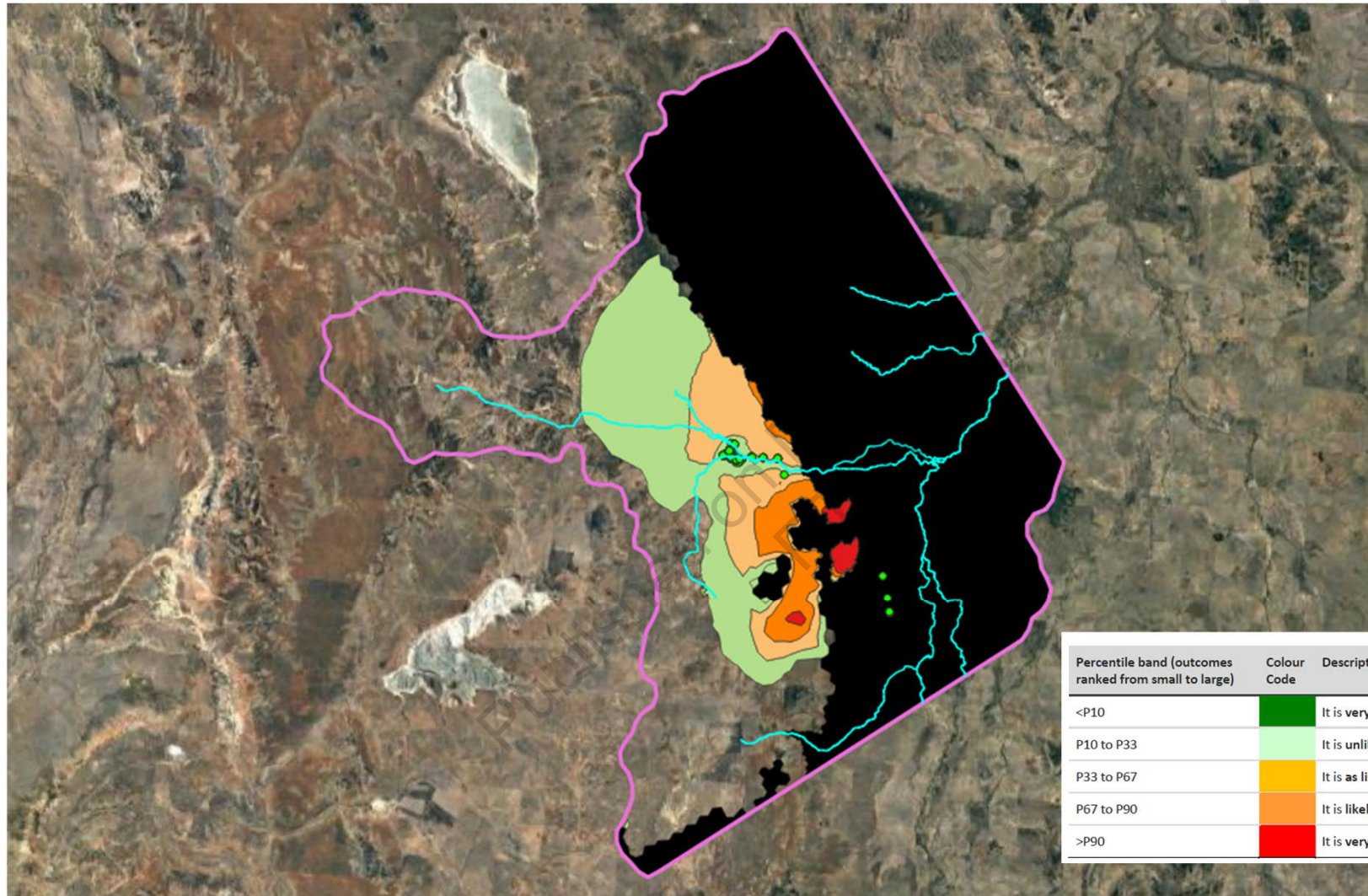
Modelled base case drawdown in Clematis: OC



Modelled base case drawdown in Clematis: SEIS



0.2 m drawdown exceedance in Clematis: OC



- Presented drawdown is maximum regardless of timing

Where to from here?

Option 1:

- Revise base case predictions (with inclusion of underground workings) based on review comments, including:
 - Revisit height of fracturing above underground.
 - Modify hydraulic conductivity values of fractured model nodes (differ from current SEIS assumptions).
- Complete PUA for OC and SEIS scenarios with above changes to model design.
- Carry out mine plan optimisation with the following changes:
 - Modification of underground panel widths, if required.
 - Limit modelled drawdown at DSC to less than 0.2 m for a given confidence interval (noting needs to be <P85 based on OC results).
- Additional time required for completion of model and reporting; ~ 2 months from now (early Mar 23).

Where to from here?

Option 2:

- Adopt model results for OC scenario only, with ~P85 drawdown at DSC less than 0.2 m threshold, with the commitment to further optimise mine plan (including UG panels) during next model update.
- Derive groundwater level thresholds for OC mine plan for inclusion in the EA.
- Update the groundwater model at two intervals (2027 and 2032) before commencement of underground mining (estimated start 2035).
- Amend the EA condition for submission of updated groundwater numerical model results with optimized underground and open cut with updated thresholds (OC+UG) one year prior to commencement of underground mining.
- Time required for completion of reporting, late Jan/early Feb23

Discussion



Parameter	Layer/Zone	HSU/location	LowerBound	UpperBound
Kx	1	Alluvium	0.01	10
Kx	2	Weathered	0.000002	0.2
Kx	3	Tertiary	0.002	1
Kx	4	Moolayember	0.000001	1
Kx	5	Clematis	0.002	30
Kx	6	Dunda	0.000001	4
Kx	7	Rewan (upper)	0.00000002	0.1
Kx	8	Rewan (lower)	0.00000002	0.1
Kx	9	Bandanna	0.00002	4
Kx	10	AB Coal	0.02	20
Kx	11	Bandanna	0.00002	4
Kx	12	Colinlea	0.0002	1
Kx	13	D Coal	0.02	20
Kx	14	Colinlea	0.0002	1
Kx	15	Joe Joe	0.0001	1
Kz	1	Alluvium	0.001	2
Kz	2	Weathered	0.0000002	0.02
Kz	3	Tertiary	0.0002	0.1
Kz	4	Moolayember	0.00000002	0.1
Kz	5	Clematis	0.0001	3
Kz	6	Dunda	0.00000001	0.4
Kz	7	Rewan (upper)	0.000000001	0.1
Kz	8	Rewan (lower)	0.000000001	0.1
Kz	9	Bandanna	0.000001	0.4
Kz	10	AB Coal	0.002	2
Kz	11	Bandanna	0.000002	0.4
Kz	12	Colinlea	0.000001	0.1
Kz	13	D Coal	0.002	20
Kz	14	Colinlea	0.000001	0.1
Kz	15	Joe Joe	0.00001	0.1
Ss	1	Alluvium	0.0000001	0.000013
Ss	2	Weathered	0.0000001	0.000013
Ss	3	Tertiary	0.0000001	0.000013
Ss	4	Moolayember	0.0000001	0.000013
Ss	5	Clematis	0.0000001	0.000013
Ss	6	Dunda	0.0000001	0.000013
Ss	7	Rewan (upper)	0.0000001	0.000013
Ss	8	Rewan (lower)	0.0000001	0.000013
Ss	9	Bandanna	0.0000001	0.000013
Ss	10	AB Coal	0.0000001	0.000013
Ss	11	Bandanna	0.0000001	0.000013
Ss	12	Colinlea	0.0000001	0.000013
Ss	13	D Coal	0.0000001	0.000013
Ss	14	Colinlea	0.0000001	0.000013
Ss	15	Joe Joe	0.0000001	0.000013
Sy	1	Alluvium	0.0001	0.1
Sy	2	Weathered	0.0001	0.1
Sy	3	Tertiary	0.0001	0.1

Sy	4 Moolayember	0.0001	0.1
Sy	5 Clematis	0.0001	0.1
Sy	6 Dunda	0.0001	0.1
Sy	7 Rewan (upper)	0.0001	0.1
Sy	8 Rewan (lower)	0.0001	0.1
Sy	9 Bandanna	0.0001	0.1
Sy	10 AB Coal	0.0001	0.1
Sy	11 Bandanna	0.0001	0.1
Sy	12 Colinlea	0.0001	0.1
Sy	13 D Coal	0.0001	0.1
Sy	14 Colinlea	0.0001	0.1
Sy	15 Joe Joe	0.0001	0.1
Recharge	1 Alluvium	0.000000001	0.0002
Recharge	2 Weathered	0.000000001	0.00001
Recharge	3 Tertiary	0.000000001	0.0001
Recharge	4 Moolayember	0.000000001	0.00001
Recharge	5 Clematis	0.000000001	0.0002
Recharge	7 Rewan	0.000000001	0.00001
Recharge	9 Bandanna	0.000000001	0.00001
ET extinction depth	1 Regional	0.5	2
ET extinction depth	2 Riverine	1	6
Drain conductance	999 Joshua	0.0001	1000
Drain conductance	998 Other DSC	0.0001	1000
Drain conductance	997 Eastern DSC	0.0001	1000
Drain conductance	995 Mellaluka	0.0001	1000
Drain conductance	994 Lignum	0.0001	1000
Drain conductance	993 Storys	0.0001	1000
Riverbed conductance	1 Belyando River	0.0001	1000
Riverbed conductance	2 Balyando West Br	0.0001	1000
Riverbed conductance	3 Bimbah Creek	0.0001	1000
Riverbed conductance	4 Carmichael River	0.0001	1000
Riverbed conductance	5 Cattle Creek	0.0001	1000
Riverbed conductance	6 Dunda Creek	0.0001	1000
Riverbed conductance	7 Dyllingo Creek	0.0001	1000
Riverbed conductance	8 North Creek	0.0001	1000
Riverbed conductance	9 Tomahawk Creek	0.0001	1000
Riverbed conductance	10 Dyllingo Breakout	0.0001	1000

Permit

Environmental Protection Act 1994

Environmental authority EPML01470513

This environmental authority is issued by the administering authority under Chapter 5 of the Environmental Protection Act 1994.

Environmental authority number: EPML01470513

Environmental authority takes effect on 19 April 2022

Environmental authority holder(s)

Name(s)	Registered address
ADANI MINING PTY LTD	Level 9 120 Edward St BRISBANE CITY QLD 4000 Australia

Environmentally relevant activity and location details

Environmentally relevant activity/activities	Location(s)*
Schedule 3 Resource Activity - ERA 13 (c): Mining black coal	ML70441, ML70505, ML70506
Ancillary 08 - Chemical Storage 3: Storing more than 500 cubic metres of chemicals of class C1 or C2 combustible liquids under AS 1940 or dangerous goods class 3 under subsection (1)(c)	ML70441, ML70505, ML70506
Ancillary 08 - Chemical Storage 4: storing 200t or more of chemicals that are solids or gases, other than chemicals mentioned in items 1 to 3, under subsection (1)(d)	ML70441, ML70505, ML70506
Ancillary 08 - Chemical Storage 5: storing 200 cubic metres or more of chemicals that are liquids, other than chemicals mentioned in items 1 to 3, under subsection (1)(d)	ML70441, ML70505, ML70506
Ancillary 16 - Extraction and Screening 2: Extracting, other than by dredging, in a year, the following quantity of material (c) more than 1,000,000t	ML70441, ML70505, ML70506

Environmental authority - EPML01470513 – Carmichael Coal Mine

Environmentally relevant activity/activities	Location(s)*
Ancillary 31 - Mineral processing 2: Processing, in a year, the following quantities of mineral products, other than coke (b) more than 100,000t	ML70441, ML70505, ML70506
Ancillary ERA60(1)(a) – Waste Disposal 2: Operating a facility for disposing of, in a year, 2(h) more than 200,000t	ML70441, ML70505, ML70506
Ancillary 63 - Sewage Treatment 1: Operating sewage treatment works, other than no-release works, with a total daily peak design capacity of (d) more than 4000 but not more than 10,000EP	ML70441, ML70505, ML70506
* Note: The ERAs must only be carried out within the authorised footprint approved under this Environmental Authority	

Additional information for applicantsEnvironmentally relevant activities

The description of any environmentally relevant activity (ERA) for which an environmental authority (EA) is issued is a restatement of the ERA as defined by legislation at the time the EA is issued. Where there is any inconsistency between that description of an ERA and the conditions stated by an EA as to the scale, intensity or manner of carrying out an ERA, the conditions prevail to the extent of the inconsistency.

An EA authorises the carrying out of an ERA and does not authorise any environmental harm unless a condition stated by the EA specifically authorises environmental harm.

A person carrying out an ERA must also be a registered suitable operator under the *Environmental Protection Act 1994* (EP Act).

Contaminated land

It is a requirement of the EP Act that an owner or occupier of contaminated land give written notice to the administering authority if they become aware of the following:

- the happening of an event involving a hazardous contaminant on the contaminated land (notice must be given within 24 hours); or
- a change in the condition of the contaminated land (notice must be given within 24 hours); or
- a notifiable activity (as defined in Schedule 3) having been carried out, or is being carried out, on the contaminated land (notice must be given within 20 business days);

that is causing, or is reasonably likely to cause, serious or material environmental harm.

For further information, including the form for giving written notice, refer to the Queensland Government website www.qld.gov.au, using the search term 'duty to notify'.

Environmental authority - EPML01470513 – Carmichael Coal Mine

Take effect

Please note that, in accordance with section 200 of the EP Act, an EA has effect:

- a) if the authority is for a prescribed ERA and it states that it takes effect on the day nominated by the holder of the authority in a written notice given to the administering authority on the nominated day; or
- b) if the authority states a day or an event for it to take effect on the stated day or when the stated event happens; or
- c) otherwise on the day the authority is issued.

However, if the EA is authorising an activity that requires an additional authorisation (a relevant tenure for a resource activity, a development permit under the *Sustainable Planning Act 2009* or an SDA Approval under the *State Development and Public Works Organisation Act 1971*), this EA will not take effect until the additional authorisation has taken effect.

If this EA takes effect when the additional authorisation takes effect, you must provide the administering authority written notice within 5 business days of receiving notification of the related additional authorisation taking effect.

If you have incorrectly claimed that an additional authorisation is not required, carrying out the ERA without the additional authorisation is not legal and could result in your prosecution for providing false or misleading information or operating without a valid environmental authority.

Juliana McCosker
Department of Environment and Science
Delegate of the administering authority
Environmental Protection Act 1994

Date issued: 19 April 2022

Enquiries:
Business Centre (Coal)
Department of Environment and Science
PO Box 3028
EMERALD QLD 4720
Phone: (07) 4987 9320
Email: CRMining@des.qld.gov.au

Obligations under the *Environmental Protection Act 1994*

In addition to the requirements found in the conditions of this environmental authority, the holder must also meet their obligations under the EP Act, and the regulations made under the EP Act (*QLD*). For example, the holder must comply with the following provisions of the Act:

- general environmental duty (section 319)
- duty to notify environmental harm (section 320-320G)
- offence of causing serious or material environmental harm (sections 437-439)
- offence of causing environmental nuisance (section 440)
- offence of depositing prescribed water contaminants in waters and related matters (section 440ZG)
- offence to place contaminant where environmental harm or nuisance may be caused (section 443)

Conditions of environmental authority

The environmentally relevant activity(ies) conducted at the location as described above must be conducted in accordance with the following site-specific conditions of approval.

This environmental authority consists of the following Schedules and Appendices:

Schedule A	General
Schedule B	Air
Schedule C	Waste
Schedule D	Noise
Schedule E	Groundwater
Schedule F	Water
Schedule G	Sewage treatment
Schedule H	Land and rehabilitation
Schedule I	Offsets and biodiversity
Schedule J	Subsidence
Schedule K	Structures
Appendix 1	Definitions
Appendix 2	Rehabilitation requirements
Appendix 3	Subsidence guidance material
Appendix 4	Figures
Appendix 5	Tables

Environmental authority - EPML01470513 – Carmichael Coal Mine

Schedule A: General	
Condition number	Condition
A1	This environmental authority authorises the environmental harm referred to in the conditions. Where there is no condition or this environmental authority is silent on a matter, the lack of a condition or silence does not authorise environmental harm.
Scope of activity	
A2	The environmental authority holder is approved to extract coal at a rate of up to 74.5 million tonnes per year (Mtpa) of run-of-mine (ROM) coal in accordance with this environmental authority.
A3	In carrying out mining activity(ies) authorised by this environmental authority, the environmental authority holder must comply with Table A1 - Mining Domains, and Figures A1 to A2.

Published on DETSI Disclosure Log
RTI Act 2009

Table A1 - Mining domains

Mine Domain	Location	Domain Area (ha)	Maximum Disturbance Areas (ha)			Total Maximum Disturbance Area (ha)
			Year 1–10	Year 11–20	Year 21–60	
Open-cut voids and slopes	Illustrated in Figure A1	8190.95	3599.96	2011.95	2590.04	8190.95
Underground mining and subsidence boundary	Illustrated in Figure A1	7786.78	1931.95	3030.16	2824.67	7786.78
Mine infrastructure	Illustrated in Figure A1	2095.56	1973.92	110.42	11.22	2095.56
Out-of-pit spoil dumps	Illustrated in Figure A1	8185.86	6480.27	1670.8	34.79	8185.86
Water storage areas, including MAW dams, raw water dams	Illustrated in Figure A1	1198.65	919.58	230.69	48.38	1198.65
Stream diversions	Illustrated in Figure A1	460.91	400.57	60.34	0	460.91
Tailings drying cell	Illustrated in Figure A1	47.45	47.45	0	0	47.45
Carmichael River corridor and levees	Illustrated in Figure A1	1799.02	50.78	0	0	50.78
Carmichael River	Illustrated in Figure A1	1748.24	0	0	0	0
Exploration*	Illustrated in Figure A2	NA*	40.51	0	0	40.51
Total						28,057.45

*The exploration domain is outside of domains illustrated in Figure A1.

Environmental authority - EPML01470513 – Carmichael Coal Mine

A4	<p>The environmental authority holder must:</p> <ul style="list-style-type: none"> a) install measures, plant and equipment necessary to ensure compliance with the conditions of this environmental authority; b) maintain such measures, plant and equipment in a proper and efficient condition; c) operate such measures, plant and equipment in a proper manner; and d) ensure all instruments and devices used for measurement or monitoring under any condition of this environmental authority are properly calibrated.
Plans, Programs and Reports	
A5	All plans, programs, and reports required by this environmental authority must be prepared by an appropriately qualified person, including any subsequent review. A copy must be submitted to the administering authority upon request. All plans, programs and reports must be kept until surrender of this environmental authority.
Monitoring, Monitoring Records and Determinations	
A6	All monitoring and determinations required by this environmental authority must be performed by a suitably qualified person and copies of monitoring records must be submitted to the administering authority upon request. Monitoring records must be kept for a period of not less than 5 years.
Risk Management	
A7	The environmental authority holder must develop and implement a risk management system for mining activities which mirrors the content requirement of the Standard for Risk Management (ISO31000:2009), or the latest edition of an Australian standard for risk management, to the extent relevant to environmental management.
Notification of Emergencies, Incidents and Exceptions	
A8	The environmental authority holder must notify the administering authority in writing within 24 hours after becoming aware of any emergency or incident that causes or threatens serious or material environmental harm or the release of contaminants not in accordance, or reasonably expected to be not in accordance with the conditions of this environmental authority.
A9	<p>Within 10 business days following the initial notification of an emergency or incident made under condition A8, or receipt of monitoring results, whichever is the latter, further written advice must be provided to the administering authority, including the following:</p> <ul style="list-style-type: none"> a) results and interpretation of all samples taken and analysed; b) outcomes of actions taken to prevent or minimise unlawful environmental harm; and c) proposed actions to prevent a recurrence of the emergency or incident.

Environmental authority - EPML01470513 – Carmichael Coal Mine

Complaints	
A10	<p>The environmental authority holder must record all environmental complaints received about the mining activities including:</p> <ul style="list-style-type: none"> a) name, address and contact number of the complainant; b) time and date of complaint; c) reasons for the complaint; d) investigations undertaken; e) conclusions formed; f) actions taken to resolve the complaint; g) any abatement measures implemented; and h) person(s) responsible for resolving the complaint.
A11	<p>The environmental authority holder must, when requested by the administering authority, undertake relevant specified monitoring within a reasonable timeframe nominated or agreed to by the administering authority to investigate any complaint of environmental harm.</p> <p>The results of the investigation (including an analysis and interpretation of the monitoring results) and abatement measures, where implemented, must be provided to the administering authority within 10 business days of completion of the investigation, or no later than 10 business days after the end of the timeframe nominated by the administering authority to undertake the investigation.</p>
Third Party Reporting	
A12	<p>The environmental authority holder must:</p> <ul style="list-style-type: none"> a) obtain a report on compliance with the conditions of this environmental authority at intervals not exceeding 3 yearly intervals from 30 October 2018; and b) provide each report to the administering authority within 90 days of its completion.
A13	<p>Where environmental authority conditions require compliance with a document published externally to this environmental authority, and the document is amended or changed subsequent to the issue of this environmental authority, the environmental authority holder must:</p> <ul style="list-style-type: none"> a) comply with the amended or changed standard, policy or guideline within two years of the amendment or change being made, unless a different period is specified in the amended document; and b) until compliance with the amended or changed document is achieved, continue to remain in compliance with the corresponding provision that was current immediately prior to the relevant amendment or change.

Schedule B: Air	
Condition number	Condition
B1	The release of dust, particulate matter, or both, resulting from activities authorised by this environmental authority must not cause an environmental nuisance at any sensitive place or commercial place.
B2	<p>The environmental authority holder must ensure that all reasonable avoidance and mitigation measures are employed so that the dust and particulate matter emissions generated by mining activities do not cause exceedances of the following limits when measured at any sensitive place or commercial place:</p> <ul style="list-style-type: none"> a) dust deposition of 120 milligrams per square metre per day, averaged over 1 month, when monitored in accordance with the most recent version of <i>Australian Standard AS/NZS 3580.10.1 Methods for sampling and analysis of ambient air—Determination of particulate matter—Deposited matter – Gravimetric method</i>. b) a concentration of particulate matter with an aerodynamic diameter of less than 10 micrometres (PM₁₀) suspended in the atmosphere of 50 micrograms per cubic metre over a 24-hour averaging time, when monitored in accordance with the most recent version of either: <ul style="list-style-type: none"> i) <i>AS/NZS 3580.9.6 Methods for sampling and analysis of ambient air—Determination of suspended particulate matter—PM₁₀ high volume sampler with size-selective inlet – Gravimetric method</i>; or ii) <i>AS/NZS 3580.9.9 Methods for sampling and analysis of ambient air—Determination of suspended particulate matter—PM₁₀ low volume sampler—Gravimetric method</i>; or iii) <i>AS/NZS 3580.9.8 Methods for sampling and analysis of ambient air – Determination of suspended particulate matter – PM₁₀ continuous direct mass method using a tapered element oscillating microbalance (TEOM) analyser</i>; or iv) <i>AS/NZS 3580.9.11 Methods for sampling and analysis of ambient air Method 9.11: Determination of suspended particulate matter – PM₁₀ beta attenuation monitors</i>. <p><i>Note: The exceedances of PM₁₀ above 50 micrograms per cubic metre over a 24-hour averaging time as a result of bushfires, dust storms and fuel reduction burning for fire management purposes are not considered a breach of condition B2(b).</i></p>

Schedule C: Waste	
Condition number	Condition
C1	Unless otherwise permitted by this environmental authority or with prior written approval from the administering authority; and in accordance with relevant standard operating procedure(s), waste must not be burnt.
C2	The environmental authority holder may burn vegetation cleared in the course of carrying out extraction activities provided the activity does not cause environmental harm at any sensitive place or commercial place.
Tailings disposal	
C3	<p>A tailings management plan must be prepared prior to the production of tailings.</p> <p>The tailings management plan must include provisions for:</p> <ul style="list-style-type: none"> a) containment of tailings; b) the management of seepage and leachates during operation or independently certified that tailings are safe stable and non-polluting; c) the control of fugitive emissions to air; d) a program of progressive sampling and characterisation to identify acid producing potential and metal concentrations of tailings; e) maintaining records of the relative locations of any other waste stored within the tailings; f) rehabilitation strategy; and g) monitoring of rehabilitation to verify the requirements and methods for decommissioning and final rehabilitation of tailings, including the prevention and management of acid mine drainage, erosion minimisation and establishment of vegetation cover. <p>The tailings management plan must be implemented.</p>
Other Prescribed Waste Stream/s	
C4	Acid sulfate soils must be treated and managed in accordance with the latest edition of the <i>Queensland Acid Sulfate Soil Technical Manual</i> .
C5	Scrap tyres are authorised to be stored awaiting disposal or disposed of on the mining lease in a manner that minimises environmental harm. A survey record must be kept of the number and location (using coordinates) of tyres disposed.

Schedule D: Noise			
Condition number	Condition		
D1	The environmental authority holder must ensure that noise generated by the mining activities approved under this administering authority does not cause the limits in Table D1 - Noise limits to be exceeded at a sensitive place or commercial place.		
Table D1 - Noise limits			
Sensitive place or commercial place			
Noise level dB(A) measured as:	Monday to Sunday		
	7am to 6pm	6pm to 10pm	10pm to 7am
LAeq, adj, 15 mins	41	41	33
LA1, adj, 15 mins	46	46	35
Airblast overpressure nuisance			
D2	The environmental authority holder must ensure that blasting does not cause the limits for peak particle velocity and air blast overpressure in Table D2 - Blasting noise limits to be exceeded at a sensitive place or commercial place.		
Table D2 - Blasting noise limits			
Blasting noise limits	Sensitive place or commercial place blasting noise limits		
	7am to 6pm (daylight hours)		6pm to 7am (non-daylight hours)
Airblast overpressure	115dB (Linear) Peak for 9 out of 10 consecutive blasts initiated; and not greater than 120dB (Linear) Peak for any single blast		No blasting to occur
Ground vibration peak particle velocity	10mm/s for ground vibration of no more than 35Hz; and 25mm/s for ground vibration of more than 35Hz		No blasting to occur

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Monitoring and reporting	
D3	<p>Noise monitoring and recording must include the following descriptor characteristics and matters:</p> <ul style="list-style-type: none"> a) LAN,T (where N equals the statistical levels of 1, 10 and 90 and T = 15 mins); b) background noise LA90; c) the level and frequency of occurrence of impulsive or tonal noise and any adjustment and penalties to statistical levels; d) atmospheric conditions including temperature, relative humidity and wind speed and directions; e) effects due to any extraneous factors such as traffic noise; f) location, date and time of monitoring; and g) If monitoring is conducted because of a complaint as a result of low frequency noise, Max LpLIN,T and one third octave band measurements in dB(LIN) for centre frequencies in the 10–200Hz range.
Schedule E: Groundwater	
Condition number	Condition
E1	The environmental authority holder must not release contaminants to groundwater.
Monitoring and reporting	
E2	All determinations of groundwater quality, groundwater monitoring and biological monitoring must be performed by an appropriately qualified person/s.
Baseline Monitoring Program	

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E3	<p>A baseline groundwater monitoring program must be developed by a suitably qualified person, implemented and be provided to the administering authority. The baseline groundwater monitoring program must result in the environmental authority holder finalising a groundwater dataset that must be provided to the administering authority at least 90 days prior to commencement of box cut excavation.</p> <p>The groundwater dataset must:</p> <ul style="list-style-type: none"> a) contain representative groundwater quality samples from the geological units identified as potentially affected by mining activities including Quaternary alluvium, Tertiary sediments, Bandanna Formation, Colinlea Sandstone, Clematis Sandstone, Rewan Formation, Dunda Beds, and Early Permian sediments; b) include at least 12 sampling events that are no more than 2 months apart over a 2 year period, so as to determine background groundwater quality; c) include background groundwater quality in hydraulically isolated background bore(s); and d) allow for the identification of natural groundwater level trends and groundwater contaminant trigger levels.
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Groundwater Management and Monitoring Program (GMMP)

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E4	<p>The Groundwater Management and Monitoring Program (GMMP) must be developed and implemented and include:</p> <ul style="list-style-type: none"> a) validation of the groundwater numerical model (including review of boundary and recharge conditions) to refine and confirm accuracy of groundwater impacts predicted; b) the groundwater monitoring bore locations and purpose for each bore; 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; d) identification of groundwater drawdown level thresholds for monitoring the impacts to Groundwater Dependant Ecosystems (including spring complexes and Carmichael River alluvium); e) monitoring of aquifers in the area to the south of the mining lease that may affect the Mellaluka springs; f) identifying and refining potential impacts on groundwater levels in the Great Artesian Basin Clematis Sandstone and Dunda Beds geological units; g) estimating groundwater inflow to mine workings and surface water ingress to groundwater from flooding events using the groundwater model; h) monitoring in any identified source aquifers for alternative water supplies, relevant to any approval issued under the Water Act 2000 for the project; i) identify groundwater quality triggers for monitoring potential impacts to groundwater quality from mining activities; 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; k) identifying monitoring bores that will be replaced due to mining activities; and 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).
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Monitoring Program Review	
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.
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.
E7	<p>The draft and final GMMP Review Reports required by Condition E5 and E6, must include:</p> <ul style="list-style-type: none"> a) an assessment of the groundwater management and monitoring program against the objectives in Condition E4; b) an assessment of the GMMP against the commitments in section 7 of the GMMP; c) a review of the adequacy of the monitoring locations, frequencies and groundwater quality triggers specified in Table E1—Groundwater 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. <p><i>Note: Tables E1, E3, and E4 are in Appendix 5 Tables</i></p>
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 3 months from the date the final GMMP Review Report is provided to the Administering Authority under condition E6.

Groundwater Model Review

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E9	<p>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.</p> <p>The review must be completed by 10 October 2022 and at least every 5 years thereafter, or at other intervals specified by the administering authority in writing, if the observed groundwater levels and groundwater flow rates to surface water are not consistent with those predicted by the groundwater model.</p> <p>The 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. The revised model must include:</p> <ul style="list-style-type: none"> a) a review of the hydrogeological conceptualisation used in the previous model; b) an update of the predicted impacts; c) a revised water balance model; d) a review of assumptions used in the previous model; e) predictions of changes in groundwater levels for a range of scenarios; f) any changes made since the previous model review, including data changes; g) a justification for the refined model and the outputs of the refined model; 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; i) an independent peer review and certification that the environmental authority holder has undertaken the review in accordance with all commitments in the GMMP.
E10	<p>A Groundwater Model Review Report outlining the findings and any recommendations from the review required under Condition E9 must be submitted to the administering authority for approval no later than 3 months from the completion of Groundwater model review required under condition E9 and include independent reviews and recommendations as required by condition E9.</p>

Groundwater quality monitoring	
E11	<p>Groundwater quality and levels must be monitored:</p> <ul style="list-style-type: none"> a) at the locations and frequencies defined in Table E1 - Groundwater monitoring locations and frequency, as illustrated in Figure E1 – Groundwater Monitoring Bore Locations, and b) for quality characteristics identified in Table E2 - Groundwater monitoring parameters. Monitoring must commence within 2 months after approval by the administering authority in condition E8.
Trigger level investigation	

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E12	<p>If groundwater quality characteristics from groundwater monitoring bores identified in Table E1 - Groundwater quality monitoring locations and frequency** reach or exceed any of the trigger levels stated in Table E3 - Groundwater quality trigger levels** for two consecutive monitoring events, an investigation must be commenced by the environmental authority holder within 14 days of becoming aware of the exceedance to determine if the exceedance is a result of:</p> <ul style="list-style-type: none"> a) mining activities authorised under this environmental authority; or b) seasonal / natural variation; or c) neighbouring land use, or d) any other potential cause of exceedance. <p>The environmental authority holder must:</p> <ul style="list-style-type: none"> i) notify the administering authority of the analysis results via WaTERS within 10 days of receiving the analysis results; ii) complete an investigation required by this condition within 3 months of the investigation commencing, and iii) provide a report of the investigation to the administering authority via WaTERS within 28 days of completion of the investigation. <p><i>Note*: Where an exceedance of a trigger level has occurred and is being investigated, in accordance with this condition, no further reporting is required for subsequent trigger events for that quality characteristic.</i></p> <p><i>Note** Tables E1 and E2 are in Appendix 5.</i></p>
E13	<p>If the investigation under condition E12 determines that the exceedance was the result of the mining activities, then a further investigation must be undertaken by the environmental authority holder to establish whether environmental harm has occurred or may occur, and the extent thereof.</p>
E14	<p>If the investigation required by condition E13 determines environmental harm has or may occur, the environmental authority holder must:</p> <ul style="list-style-type: none"> a) implement immediate measures to mitigate the potential for environmental harm; and b) develop long-term mitigation measures to address any existing groundwater contamination and prevent recurrence of groundwater contamination, and; c) provide a written report to the administering authority via WaTERS within 28 days after completing the investigation under condition E13.
Groundwater (water levels), monitoring, draw down and investigation	

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E15	<p>In the event that monitored groundwater levels at groundwater monitoring bores identified in Table E1 - Groundwater quality monitoring locations and frequency** exceed the corresponding groundwater level drawdown threshold stated in Table E4 - Groundwater level drawdown thresholds**, the environmental authority holder must:</p> <ul style="list-style-type: none"> a) notify the administering authority of the analysis results via WaTERS within 10 days of receiving the analysis results; and b) commence an investigation within 14 days of becoming aware of the exceedance to determine if the drawdown is the result of; <ul style="list-style-type: none"> i) mining activities authorised under this environmental authority; ii) pumping from licensed bores; iii) seasonal / natural variation; iv) neighbouring land use resulting in groundwater impacts, or v) any other potential cause of exceedance. c) complete an investigation required by this condition within 3 months of the investigation commencing; and d) submit a report of the findings of the investigation to the administering authority via WaTERS within 28 days of completing the investigation. <p>Note** Tables E1 and E4 are in Appendix 5.</p>
E16	<p>If the investigation under condition E15(b) concludes exceedance/s of groundwater level thresholds are result of mining activities, the environmental authority holder must:</p> <ul style="list-style-type: none"> a) determine whether unlawful environmental harm has occurred or likely to occur; b) determine the actions to reduce the potential for unlawful environmental harm; c) undertake an assessment of the associated impact to Matters of State Environmental Significance in accordance with condition I3; d) determine the mitigation measures required to address the affected groundwater resource; and e) prepare a final report of the findings of the investigation which must be submitted to the administering authority via WaTERS within 3 months after submission of the preliminary report in accordance with condition E15(c).
E17	<p>Any and all groundwater monitoring data collected under this schedule must be submitted annually by 1 July to the administering authority via WaTERS.</p>

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E18	<p>An Annual Groundwater Monitoring Report must be submitted by 1 July each year to the administering authority. The Annual Groundwater Monitoring Report must include:</p> <ul style="list-style-type: none"> a) summary of groundwater monitoring activity undertaken during the year; b) 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; c) a summary of investigation of exceedances of groundwater quality triggers and groundwater level thresholds carried out under this schedule; d) month wise dewatering volumes during the year; e) an assessment of any differences between the impacted groundwater level predicted and the actual impacts for the corresponding period; and f) a summary of all recommended changes to the GMMP.
E19	<p>Within 3 months of submitting the Annual Groundwater Monitoring Report required by condition E18, the environmental authority holder must amend the GMMP to include any recommendations, as well as any comments made by the administering authority, and resubmit the GMMP to the administering authority for approval.</p>
Bore construction and maintenance and decommissioning	
E20	<p>The construction, maintenance, and decommissioning of groundwater bores (including groundwater monitoring bores) must be undertaken in a manner that prevents and minimises impacts to the environment and ensures the integrity of the bores to obtain accurate monitoring data.</p>

Schedule F: Water	
Condition number	Condition
Release of contaminants	
F1	<p>Contaminants must not be released to any surface waters except as permitted under the conditions of Schedule F in this environmental authority.</p>
Discharge of Mine Affected Water	
F2	<p>The release of mine affected water to waters must only occur from the release points specified in Table F1 - Mine affected water release points, sources and receiving waters, as depicted in Figure F1: Water release and monitoring locations attached to this environmental authority.</p>

Table F1 - Mine affected water release points, sources and receiving waters

Release Point (RP)	Easting (GDA94—Zone 55K)	Northing (GDA94—Zone 55K)	Contaminant Source and Location	Monitoring Point	Receiving Waters Description
RP1—Central MAW North	443373.41	7558805.00	Mine Affected Water Dam Central - North	Outlet works to Carmichael River	Carmichael River
RP2—Central MAW South	435539.56	7553979.62	Mine Affected Water Dam Central—South	Outlet works to Carmichael River	Carmichael River

F3 The release of mine affected water to internal water management infrastructure installed and operated in accordance with a water management plan that complies with condition F25 is permitted

F4 The release of mine affected water to waters in accordance with condition F2 must not exceed the release limits stated in Table F2 - Mine affected water release limits when measured at the monitoring points specified in Table F1 - Mine affected water release points, sources and receiving waters for each quality characteristic.

Table F2 - Mine affected water release limits

Quality characteristic	Release limits	Monitoring frequency
Electrical conductivity (µS/cm)	Release limits specified in Table F4 for variable flow criteria.	Continuous
pH (pH Unit)	6.5 (minimum) 9.0 (maximum)	Continuous
Turbidity (NTU)	500 ¹	Continuous

¹ Turbidity release limits may be reviewed once sufficient monitoring data is available to adequately characterise the baseline turbidity in the Carmichael River (including consideration of natural spatial and temporal variability).

F5 The release of mine affected water to waters from the release points must be monitored at the locations specified in Table F1 - Mine affected water release points, sources and receiving waters for each quality characteristic and at the frequency specified in Table F2 - Mine affected water release limits and Table F3 - Release trigger levels.

Table F3 - Release trigger levels

Quality Characteristic	Trigger Levels (µg/L)	Monitoring frequency
Aluminium ¹	55	Commencement of release and thereafter weekly during release (first sample to be taken within 2 hours of commencement of release)
Arsenic ¹	13	
Cadmium ¹	0.2	
Chromium ¹	2	
Copper ¹	4	
Iron ¹	300	
Lead ¹	4	
Mercury ¹	0.2	
Nickel ¹	11	
Zinc ¹	30	
Boron ¹	370	
Cobalt ¹	90	
Manganese ¹	1900	
Molybdenum ¹	34	
Selenium ¹	10	
Silver ¹	1	
Uranium ¹	1	
Vanadium ¹	10	
Ammonia as N	900	
Nitrate as NO ₃	1100	
Total Nitrogen	590	
Total Phosphorus	200	
Petroleum hydrocarbons (C6-C9)	20	
Petroleum hydrocarbons (C10-C36)	100	
Fluoride	2000	
Sodium ¹	180,000 (180mg/L)	
Suspended Solids	106	
Sulphate (SO ₄ ²⁻) (mg/L)	1000	

¹ All metals and metalloids must be measured as total (unfiltered) and dissolved (filtered). Trigger levels for metal/ metalloids apply if dissolved results exceed trigger. Measures in mg/L if value is 180 not 180,000.

The quality characteristics required to be monitored as per Table F3 - Release trigger levels can be reviewed with the support of additional baseline monitoring data from the Carmichael River, or if it can be adequately demonstrated that there is negligible environmental risk. It may be determined that a reduced monitoring frequency is appropriate, that a trigger level be increased or reduced or that certain quality characteristics can be removed from Table F3 - Release trigger levels by amendment.

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F6	<p>If quality characteristics of the release exceed any of the trigger levels specified in Table F3 - Release trigger levels, during a release event, the environmental authority holder must compare the downstream results in the receiving waters to the trigger values specified in Table F3 - Release trigger levels and measured at locations specified in Table F6 - Receiving water upstream and downstream monitoring points, and:</p> <ul style="list-style-type: none"> a) where the trigger values are not exceeded then no action is to be taken; or b) where the downstream results exceed the trigger values specified in Table F3 – Release trigger levels for any quality characteristic, compare the results of the downstream site to the data from background monitoring sites and Table F6 - Receiving water upstream and downstream monitoring points and: <ul style="list-style-type: none"> i) if the result is less than the background monitoring site data, then no action is to be taken; or ii) if the result is greater than the background monitoring site data, complete an investigation into the potential for environmental harm and provide a written report to the administering authority via WaTERS within 90 days of receiving the result, outlining <ul style="list-style-type: none"> 1) details of the investigations carried out; and 2) actions taken to prevent environmental harm. <p><i>Note: Where an exceedance of a trigger level has occurred and is being investigated, in accordance with condition F6(b)(ii) of this condition, no further reporting is required for subsequent trigger events for that quality characteristic.</i></p>
F7	<p>If an exceedance in accordance with condition F6(b)(ii) is identified, the environmental authority holder must notify the administering authority via WaTERS within 24 hours of receiving the result.</p>
Mine Affected Water Release Events	
F8	<p>The environmental authority holder must ensure a stream flow gauging station/s is installed, operated, and maintained to determine and record stream flows at the locations and flow recording frequency specified in Table F4 - Mine affected water release during flow events.</p>
F9	<p>The release of mine affected water to waters in accordance with condition F2 must only take place during periods of natural flow in accordance with the receiving water flow criteria for discharge specified in Table F4 - Mine affected water release during flow events for the release point(s) specified in Table F1 - Mine affected water release points, sources and receiving waters.</p>
F10	<p>The release of mine affected water to waters in accordance with condition F2 must not exceed the Maximum Release Rate (for all combined release point flows) for each receiving water flow criterion for discharge specified in Table F4 - Mine affected water release during flow events when measured at the monitoring points specified in Table F1 - Mine affected water release points, sources and receiving waters.</p>

Table F4 - Mine affected water release during flow events

Receiving waters/ stream	Release Point (RP) and Gauging station (GS) Name	GS Easting (GDA94— Zone 55K)	GS Northing (GDA94— Zone 55K)	Receiving Water Flow Recording Frequency	Receiving Water Flow Criteria for discharge (m ³ /s)	Maximum release rate (for all combined RP flows)	Electrical Conductivity Release Limits
Carmichael River	RP1 (Central MAW North) & RP2 Central MAW South (Table F1), to each be monitored via Carmichael River CAR01 downstream gauging station.	443373.41	7558805.00	Continuous (minimum daily)	Low Flow <0.2 m ³ /s for a period of 28 days after natural flow events that exceed 0.2 m ³ /s	0.05 m ³ /s	Electrical conductivity: 168 µS/cm (maximum)
					Medium Flow 1 - 5 m ³ /s	0.25 m ³ /s	Electrical conductivity: 840 µS/cm (maximum)
					Medium Flow 5 - 10 m ³ /s	0.5 m ³ /s	Electrical conductivity: 1850 µS/cm (maximum)
					High Flow > 10 m ³ /s	0.5 m ³ /s	Electrical conductivity: 3,500 µS/cm (maximum)
F11	Releases to waters must be undertaken so as not to cause erosion of the bed and banks of the receiving waters, or cause a material build-up of sediment in the receiving waters.						

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Notification of Release Event	
F12	<p>The environmental authority holder must notify the administering authority via WaTERS as soon as practicable and no later than 24 hours after commencing to release mine affected water to the receiving environment. Notification must include the submission of written advice to the administering authority of the following information:</p> <ul style="list-style-type: none"> a) release commencement date/time; b) details regarding compliance of the release with conditions of Schedule F: Water of this environmental authority (that is, contaminant limits, natural flow, discharge volume); c) release point/s; d) release rate; e) release salinity; and f) receiving water/s including the natural flow rate.
F13	<p>The environmental authority holder must notify the administering authority via WaTERS as soon as practicable within 24 hours after cessation of a release notified under condition F12. The cessation notification must include the following information:</p> <ul style="list-style-type: none"> a) release cessation date and time; b) details regarding the compliance of the release with the conditions of this environmental authority (that is, contaminant limits, natural flow, discharge volume); c) release point/s; d) release rate; e) release salinity; f) receiving water/s including natural flow rate; g) the continuous monitoring data for flow rate, electrical conductivity (EC) and turbidity from downstream monitoring locations; and h) all in situ and any water quality monitoring results (including all laboratory analyses). <p><i>Note: Successive or intermittent releases occurring within 24 hours of the cessation of any individual release can be considered part of a single release event and do not require individual notification for the purpose of compliance with Conditions F12 and F13, provided the relevant details of the release are included within the notification provided in accordance with Conditions F12 and F13.</i></p>

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F14	<p>The environmental authority holder must provide a report to the administering authority via WaTERS within 28 days after cessation of a release event notified under condition F12. The report must include:</p> <ul style="list-style-type: none"> a) release commencement and cessation dates and times; b) natural flow rate in receiving water; c) the total, and daily (24 hour) volumes of water released; d) details regarding the compliance of the release with the conditions of this environmental authority (i.e. contamination limits, natural flow, discharge volume); e) all continuous and in situ water quality monitoring results (including laboratory analyses); and f) any other matters pertinent to the water release event.
Notification of Release Event Exceedance	
F15	<p>If the release limits defined in Table F2 - Mine affected water release limits are exceeded, the environmental authority holder must notify the administering authority via WaTERS within 24 hours of receiving the results.</p>
F16	<p>The environmental authority holder must, within 28 days of a release that is not compliant with the conditions of this environmental authority, provide a report to the administering authority via WaTERS detailing:</p> <ul style="list-style-type: none"> a) the reason for the release; b) the location of the release; c) the total volume of the release and which (if any) part of this volume was non-compliant; d) the total duration of the release and which (if any) part of this period was non-compliant; e) all water quality monitoring results (including all laboratory analyses); f) extent of any environmental harm as a result of the non-compliance; g) all calculations; and h) any other matters pertinent to the water release event.
Receiving Environment Monitoring and Contaminant Trigger Levels	
F17	<p>The quality of the receiving waters must be monitored at the locations specified in Table F6 - Receiving water upstream and downstream monitoring points for each quality characteristic and at the monitoring frequency stated in Table F5 - Receiving waters trigger levels and Table F3 - Release trigger levels.</p>

Table F5—Receiving waters trigger levels

Quality Characteristic	Trigger Level	Monitoring Frequency
Electrical Conductivity ($\mu\text{S}/\text{cm}$)	270	Continuous during release
Turbidity (NTU)	660	
pH	6.5–9.0	Daily during the release
Sulphate (SO_4^{2-}) (mg/L)	250	
Sodium (mg/L)	180	

Table F6 - Receiving water upstream background sites and downstream monitoring points

Monitoring Points	Receiving Waters Location Description	Easting (GDA94—Zone 55K)	Northing (GDA94—Zone 55K)
Upstream Background Monitoring sites			
CAR04	Carmichael River at Upstream Gauging station	433237.06	7554988.83
BEL02	Belyando River at Bygana Waterhole	451391.30	7549162.75
Downstream Monitoring sites			
CAR01	Carmichael River far downstream mining lease	445073.13	7558878.15
BEL01	Belyando River at Carmichael/Moray Rd	464569	7571642

Table F6 - Receiving water upstream background sites and downstream monitoring points notes:

- a) The data from background monitoring points must not be used where they are affected by releases from other mines.

F18

If quality characteristics of the receiving water at the downstream monitoring points exceed any of the trigger levels specified in Table F5 - Receiving waters trigger levels during a release event, the environmental authority holder must compare the downstream results to the upstream results in the receiving waters and:

- a) where the downstream result is the same or a lower value than the upstream value for the quality characteristic, then no action is to be taken; or
- b) where the downstream result exceeds the upstream results, complete an investigation into the potential for environmental harm and provide a written report to the administering authority via WaTERS within 90 days, outlining:
 - i) details of the investigations carried out; and
 - ii) actions taken to prevent environmental harm.

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F19	All continuous environmental monitoring systems required by this environmental authority must have an instrument availability for at least eighty percent (80%) of a calendar year except for the continuous monitoring of release points specified in Table F1 - Mine affected water release points, sources and receiving waters which must have an instrument availability of at least ninety percent (90%) of a calendar year.
Receiving Environment Monitoring Program (REMP)	
F20	<p>The environmental authority holder must develop and implement a Receiving Environment Monitoring Program (REMP) to:</p> <ul style="list-style-type: none"> a) monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. b) this must include monitoring the effects of the mine on the receiving environment periodically (under natural flow conditions) and while mine affected water is being discharged from the site. c) for the purposes of the REMP, the receiving environment is the waters of the Carmichael River and connected or surrounding waterways within 12km downstream of the release (this includes the Belyando River, immediately downstream of the confluence with the Carmichael River and monitoring points Bel 02 and Bel 01 listed in Table F6 - Receiving water upstream and downstream monitoring points). d) the REMP should encompass any sensitive receiving waters or environmental values downstream of the authorised mining activity that will potentially be directly affected by an authorised release of mine affected water.
F21	A REMP Design Document that addresses the requirements of the REMP must be prepared and made available to the administering authority upon request.
F22	A report outlining the findings of the REMP, including all monitoring results and interpretations must be prepared annually and provided to the administering authority by 1 July each year. The annual REMP report must include an assessment of background water quality, the condition of downstream water quality compared against water quality objectives, and the suitability of current discharge limits to protect downstream environmental values.
Water reuse	
F23	Mine affected water may be piped or trucked or transferred by some other means that does not contravene the conditions of this environmental authority and deposited into artificial water storage structures, such as farm dams or tanks, or used directly at properties owned by the environmental authority holder or a third party (with the written consent of the third party).

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Annual Water Monitoring Reporting	
F24	<p>The following information must be recorded in relation to all REMP and water release monitoring required under Schedule F of this environmental authority and submitted to the administering authority via WaTERS by 1 July each year:</p> <ul style="list-style-type: none"> a) the date on which the sample was taken; b) the time at which the sample was taken; c) the location (including coordinates); d) the measured or estimated daily quantity of mine affected water released from all release points; e) the release flow rate at the time of sampling for each release point; f) the results of all monitoring and details of any exceedances of the conditions of this environmental authority; g) and water quality monitoring data.
Water Management Plan	
F25	A Water Management Plan must be developed.
F26	<p>The Water Management Plan required by condition F25 must:</p> <ul style="list-style-type: none"> a) provide for effective management of actual and potential environmental impacts resulting from water management associated with the mining activity and release of Mine Affected Water carried out under this environmental authority; and b) include <ul style="list-style-type: none"> i) a study of the source of contaminants; ii) a water balance model for the site; iii) a water management system for the site; iv) measures to manage and prevent saline drainage; v) measures to manage and prevent acid rock drainage; vi) procedures for release of mine affected water vii) contingency procedures for emergencies; and viii) a program for monitoring and review of the effectiveness of the Water Management Plan.
F27	The Water Management Plan required by condition F25 must be implemented
Stormwater and Water Sediment Controls	
F28	An Erosion and Sediment Control Plan must be developed by an appropriately qualified person and implemented for all stages of the authorised activities on the site to minimise erosion and the release of sediment to receiving waters and contamination of stormwater.

F29	<p>Stormwater, other than mine affected water, is permitted to be released to waters from:</p> <ul style="list-style-type: none"> a) erosion and sediment control structures that are installed and operated in accordance with the Erosion and Sediment Control Plan required by condition F28; and b) water management infrastructure that is installed and operated, in accordance with a Water Management Plan that complies with condition F25, for the purpose of ensuring water does not become mine affected water.
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Schedule G: Sewage Treatment

Condition number	Condition			
G1	Treated sewage effluent is permitted to be released to land or to mine affected water storages in compliance with the release limits stated in Table G1 - Contaminant release limits to land or mine affected water storages.			
Table G1 - Contaminant release limits to land or mine affected water storages				
Contaminant	Unit	Release limit	Limit type	Monitoring Frequency
5-day Biochemical oxygen demand (BOD) ¹	mg/L	20	Maximum	Monthly
Total suspended solids	mg/L	30	Maximum	Monthly
Nitrogen	mg/L	30	Maximum	Monthly
Phosphorus	mg/L	15	Maximum	Monthly
E-coli	Organisms/100ml	10	Maximum	Monthly
G2	All treated sewage effluent released from the treatment plant must be monitored at the frequency and for the parameters specified in Table G1 - Contaminant release limits to land or mine affected water storages.			
G3	The daily volume of treated sewage effluent released to land or mine affected water storages must be measured and records kept of the volumes released.			

Schedule H: Land and Rehabilitation	
Condition number	Condition
Rehabilitation	
H1	Land disturbed by mining activities authorised under this Environmental Authority must be rehabilitated in accordance with Table H1 – Rehabilitation acceptance criteria (in Appendix 2) and Figure H1: Cross Sections of Residual Voids, Figure H2: Final Landform (Northern Section), Figure H3: Final Landform (Central Section) and Figure H4: Final Landform (Southern Section) in Appendix 4.
H2	The rehabilitation completion criteria specified in Table H1 – Rehabilitation Acceptance Criteria (Appendix 2) must be reviewed by an appropriately qualified person by the 2 February 2021 and from then on, every 5 years with any proposed amendments or changes submitted to the administering authority for approval.
Rehabilitation Monitoring Program	
H3	<p>A Rehabilitation Monitoring Program must be developed and certified by an appropriately qualified person and implemented.</p> <p>The Rehabilitation Monitoring Program must contain a schedule for gathering baseline data noting agreed reference sites and conducting rehabilitation trials to support the rehabilitation outcomes detailed in Table H1 – Rehabilitation Acceptance Criteria.</p> <p>Baseline monitoring and rehabilitation trials under this program must be undertaken at a suitable frequency to ensure that the environmental authority holder has a representative dataset to enable:</p> <ul style="list-style-type: none"> a) progressive certification of rehabilitation under Chapter 5A of the <i>Environmental Protection Act 1994</i>. b) surrender of the Environmental Authority under Chapter 5 of the <i>Environmental Protection Act 1994</i>.
H4	Rehabilitation must be undertaken progressively in accordance with the Rehabilitation Management Plan and Progressive Rehabilitation Closure Plan (when approved).
H5	Self-sustaining vegetation and native ecosystem, as per Table H1 – Rehabilitation Acceptance Criteria (Appendix 2), must be consistent with the reference sites identified in Table H2 – Reference Sites and Figure H6: Reference Sites.

Table H2: Reference Sites

Reference Site ID	Final Land Use Objective	Easting (GDA94—Zone 55)	Northing (GDA94—Zone 55)	Regional Ecosystem Reference
1	Pasture	435015.03	7555606.11	Not Applicable
2	Pasture	443025.57	7556465.56	Not Applicable
3	Pasture	440270.90	7555837.51	Not Applicable
4	Woodland and Pasture	444416.00	7554892.00	11.3.7/11.3.10/11.5.3
5	Woodland	420464.05	7462197.97	10.5.5a, 10.5.5a/10.3.6ax1
6	Woodland	426136.73	7577685.88	10.5.5a/10.3.6ax1
7	Woodland	424019.29	7578271.57	10.5.5a/10.3.6ax1
8	Woodland and Pasture	437811.00	7548031.00	10.3.28a/10.3.6a
9	Woodland	444040.04	7541770.08	10.5.5a
10	Pasture	445500.99	7544738.92	Not Applicable
11	Woodland and Pasture	434750.95	7554579.43	10.3.6a

Residual Void Outcome

H6	Residual voids must not cause any serious environmental harm to land, surface waters or any recognised groundwater aquifer, other than the environmental harm constituted by the existence of the residual void itself and subject to condition H7 within this environmental authority.
H7	Residual voids, as detailed and presented in Figure H1: Cross Sections of Residual Voids Open Cut Pits B, C, D, E, F and G are authorised in accordance with Table H3 – Residual Voids.

Table H3 – Residual Voids

Open Cut Pit	Residual Void Treatment
B	Residual void authorised to the depth of the top of the D1 Seam at the highwall face
C	Residual void authorised to the depth of the top of the AB1 Seam at the highwall face
D	Residual void authorised to the depth of the top of the D1 Seam at the highwall face
E	Residual void authorised to the depth of the top of the AB1 Seam at the highwall face
F	Residual void authorised to the depth of the top of the AB1 Seam at the highwall face
G	Residual void authorised to the depth of the top of the D1 Seam at the highwall face

Topsoil Management Plan

H8	A Topsoil Management Plan must be developed and implemented.
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Mining Waste and Rejects Management	
H9	<p>A Mine Waste and Rejects Management Plan must be developed, implemented and include:</p> <ul style="list-style-type: none"> a) characterisation of the waste rock, spoil and rejects to predict the quality of runoff and seepage generated, including salinity, acidity, alkalinity and dissolved metals, metalloids and non-metallic inorganic substances; b) a program of progressive sampling and characterisation to identify dispersive and nondispersive spoil and the salinity, acid and alkali producing potential and metal concentrations of waste rock, spoil and rejects; c) a materials balance d) management of potentially acid forming and acid forming waste rock, spoil and rejects will be selectively placed and/or encapsulated to minimise the potential generation of acid mine drainage; e) a sampling program to verify encapsulation and/or placement of potentially acid-forming and acid-forming waste rock, spoil and rejects; f) a schedule of periodic review of the plan's effectiveness in addressing the requirements of this condition; g) the indicators or other criteria on which the performance of the plan will be assessed; h) a rehabilitation strategy; i) rehabilitation monitoring, and/or trials to verify the requirements and methods for decommissioning and final rehabilitation of the placed materials.
H10	Reject disposal areas must be designed and constructed to ensure that any runoff or seepage from the reject disposal area is contained within the mine water management system.
Contaminated Land	
H11	Before applying for surrender of a mining lease, the environmental authority holder must (if applicable) provide to the administering authority a site investigation report under the EP Act, in relation to any part of the mining lease which has been used for notifiable activities or which the environmental authority holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use.
H12	Before applying for progressive rehabilitation certification for an area, the environmental authority holder must (if applicable) provide to the administering authority a site investigation report under the EP Act, in relation to any part of the area the subject of the application which has been used for notifiable activities or which the environmental authority holder is aware is likely to be contaminated land, and also carry out any further work that is required as a result of that report to ensure that the land is suitable for its final land use under condition H1.

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Chemicals and Flammable and Combustible Liquids	
H13	All flammable and combustible liquids must be contained within an on-site containment system and controlled in a manner that prevents environmental harm and maintained in accordance with AS 1940— <i>Storage and Handling of Flammable and Combustible Liquids</i> .
H14	The storing of chemicals and pollutants on site that have the potential to cause environmental harm must be carried out in an effective containment system, impervious to the materials stored and managed to prevent release of harmful liquids to waters or land.
H15	The environmental authority holder must minimise the potential for contamination of land and waters by diverting stormwater around contaminated areas and facilities used for the storage of chemicals and flammable or combustible liquids.
Schedule I: Offsets and Biodiversity	
Condition number	Condition
I1	<p>The environmental authority holder must provide an offset for impacts on applicable Matters of State Environmental Significance, in accordance with the <i>Carmichael Coal Project Biodiversity Offset Strategy</i>, as approved. The biodiversity offset must be provided:</p> <ul style="list-style-type: none"> a) prior to impacting on Matters of State Environmental Significance; or b) where a land-based offset is to be provided, within 36 months of the later of either of the following: <ul style="list-style-type: none"> i) the date of issue of this environmental authority; or ii) the relevant stage identified in the Biodiversity Offset Strategy; or c) where an offset payment is to be provided, within 4 months of the later of either of the following: <ul style="list-style-type: none"> i) the date of issue of this environmental authority; or ii) the relevant stage identified in the Biodiversity Offset Strategy.
Review of Biodiversity Offset Delivery	
I2	<p>The Biodiversity Offset Strategy must be reviewed by the 2 February 2021, and thereafter every 5 years with a report prepared by an appropriately qualified person. The report must:</p> <ul style="list-style-type: none"> a) assess the area of Matters of State Environmental Significance proposed to be impacted by the mining activities in the Biodiversity Offset Strategy; and b) identify the actual on ground areas of Matters of State Environmental Significance impacted by the mining activities.

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I3	<p>If an investigation conducted under conditions E15 or E16 of this environmental authority indicates that there is a risk of impacting a Matter of State Environmental Significance, or condition J11 is triggered, the Biodiversity Offset Strategy must be reviewed and a report must be prepared within 3 months by an appropriately qualified person. The report must:</p> <ul style="list-style-type: none"> a) assess the area of Matter of State Environmental Significance proposed to be impacted by the mining activities in the Biodiversity Offset Strategy; and b) identify the actual on ground areas of Matter of State Environmental Significance impacted by the mining activities.
I4	<p>If the review under condition I2 or I3 finds that the actual areas of disturbance to Matters of State Environmental Significance are greater than the areas of disturbance as detailed in the Biodiversity Offset Strategy, or that additional Matters of State Environmental Significance will be impacted, the environmental authority holder must amend the Biodiversity Offset Strategy as per condition I5 and deliver the amended offset requirement within 12 months.</p>
I5	<p>In response to condition I4 the environmental authority holder may apply to the administering authority to amend the Biodiversity Offset Strategy within either 30 days, or a lesser period agreed to by the administering authority, prior to impacting on the applicable Matter of State Environmental Significance.</p>

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Black-throated finch (BTF) Management Plan at Carmichael project (BTFMP)	
I6	<p>The environmental authority holder must submit a BTFMP, prepared and certified by a suitably qualified and experienced person to the administering authority for approval prior to commencement of Project Stage 2. The environmental authority holder must publish the BTFMP on its website within 10 business days of receiving the administering authority's approval in writing. The approved BTFMP must be implemented. The holder must align the BTFMP with any Bioregional BTF Management Plan and relevant documentation requirements under the <i>Environmental Protection and Biodiversity Conservation Act 1999</i> including the BTF Recovery Plan, conservation advice and the threat abatement plan.</p> <p>The submitted BTFMP must include:</p> <ul style="list-style-type: none"> a) a baseline research program on the specific nesting and feeding requirements of the species that will be undertaken prior to and during Project Stage 1; b) a baseline research program to establish whether the BTF at the project site are sedentary, locally migratory or regionally migratory; c) a description of how the results of baseline research program are to be used to determine any changes of classification of and/or impact on BTF habitat; d) details of proposed impacts to BTF habitat from each Project Stage including impacts from clearing, subsidence, ecological function changes, hydrological changes and weed and pest infestation changes; e) mitigation measures to be undertaken to avoid, mitigate and manage impact resulting from each stage of the project, including rehabilitation of habitat; f) monitoring of watering points that must be conducted for a minimum 3 hour period commencing from 9am, to accurately capture BTF utilisation of watering points; g) detailed botanical assessment that must occur at all BTF sighting locations in the project area to record habitat values at those locations; h) detailed surveys that must occur across the mining lease area and approved offset areas and must include information on BTF movements. The survey method and effort must be sufficient to accurately describe the BTF home range and detail BTF resource usage patterns between seasons and years (for up to 10 years) and allow robust management actions to be developed for the maintenance of a viable local BTF population; i) survey work that records all birds present when BTF are encountered; j) specific surveys that must be undertaken during the BTF breeding season and include nest location and assessment of the habitat attributes associated with the breeding locations. The survey method and effort must be sufficient to accurately describe the BTF breeding requirements with consideration to spatial and temporal variation of resources of up to 10 years; and k) survey and monitoring that must be undertaken by experienced ecologists.

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I7	<p>The BTFMP required under condition I6 must be reviewed by a suitably qualified and experienced person annually. The review must:</p> <ul style="list-style-type: none"> a) assess the plan against the requirements under condition I6; b) include recommended actions to ensure actual and potential environmental impacts are effectively managed for the coming year; c) identify any amendments made to the BTFMP following the review; d) all revisions of the survey and monitoring program must be carried out in consultation with the BTF recovery team; e) any revisions must be independently peer reviewed, and f) a report of the review that addressed the outcomes of the review must be provided to the administering authority no later than 1 September each year.
I8	<p>The baseline research program must fund a research project to determine the relationship between water sources, woody habitat and the BTF food sources within the mining lease area and approved offset areas to determine the inter-relationships among these factors.</p>
I9	<p>The baseline research program under condition I6 must:</p> <ul style="list-style-type: none"> a) establish whether the Ten Mile Bore and surrounds are high value habitat for the species; and b) establish management actions to maintain the current BTF population of Ten Mile Bore and surrounds.
I10	<p>The environmental authority holder must maintain water troughs for BTF within undisturbed areas and surface areas of underground mining footprint, and where necessary repair troughs, pipes and tanks to a standard that maintains a constant source of water.</p>
Groundwater Dependent Ecosystems Management Plan	
I11	<p>The environmental authority holder must develop and implement a Groundwater Dependent Ecosystems Management Plan (GDEMP) to detail the management of threats to defined environmental values and to report results and corrective actions for each GDE over the full period of mining activities and for a period of five years post mining rehabilitation.</p>
I12	<p>The GDEMP must be approved by the administering authority in writing and the GDEMP published on the environmental authority holder's website before the commencement of Project Stage 2.</p>
I13	<p>For the purposes of conditions I11 and I12, the GDEs include the affected Carmichael River riparian zone (ecosystems associated with the Carmichael River between Doongmabulla Springs and the Belyando River, including populations of Waxy Cabbage Palm), the Lignum, Stories and Mellaluka springs and the Doongmabulla, Spring complex.</p>
I14	<p>A report of the findings of the GDEMP, including all monitoring results and interpretations, must be prepared annually and provided to the administering authority no later than 1 August each year.</p>

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I15	<p>The report submitted under condition I14 must include:</p> <ul style="list-style-type: none"> a) an assessment of groundwater levels against pre-mining groundwater levels, b) a comparison of surface water quality monitoring results to determine any interaction or impact from groundwater on surface water quality results; c) the condition of each GDE compared with previous monitoring results; d) the suitability of current groundwater level thresholds Table E4 - Groundwater level drawdown thresholds in Schedule E; e) detail on the effectiveness of avoidance, mitigation and management actions in curtailing adverse impacts on GDEs; f) a description of any adaptive management initiatives implemented; g) any offsets required for significant residual impacts.
Schedule J: Subsidence	
Condition number	Condition
J1	Subsidence is authorised within the subsidence impact area identified in Figure A1.
J2	A Subsidence Management Plan must be developed and implemented by the environmental authority holder prior to the commencement of activities that result in subsidence.

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<p>J3</p>	<p>The Subsidence Management Plan must:</p> <ul style="list-style-type: none"> a) provide for the proper and effective management of the actual and potential environmental impacts resulting from the mining activity authorised by this environmental authority and to ensure compliance with the conditions of this environmental authority; b) include baseline data; prior to underground mining; c) describe the proposed impacts of subsidence on any land, BTF habitat, watercourse and floodplain including but not limited to: <ul style="list-style-type: none"> i) physical condition of surface drainage: <ul style="list-style-type: none"> 1) erosion; 2) areas susceptible to higher levels of erosion such as watercourse confluences; 3) incision processes; 4) stream widening; 5) tension cracking; 6) lowering of bed and banks; 7) creation of instream waterholes; 8) changes to local drainage patterns; and 9) BTF habitat. ii) overland flow: <ul style="list-style-type: none"> 1) capture of overland flow by subsided long-wall panels; 2) increased overbank flows due to lowering of high bank of watercourses; 3) the portion of local and large-scale catchment likely to be captured by subsided long-wall panels and the associated impacts on downstream users iii) water quality: <ul style="list-style-type: none"> 1) surface water; 2) groundwater. iv) land condition: current land condition to be impacted by subsidence; v) infrastructure: detail of existing infrastructure (pipelines, railway, powerlines and haul roads) should be identified where there is a potential impact from effects of land subsidence; d) propose options for mitigating any impacts associated with subsidence, how these mitigation methods will be implemented, and the extent to which these measures will impact a Matter of State Environmental Significance(s); e) describe cumulative impacts on watercourses, diversions or catchments; f) describe impacts on groundwater; g) quantify the area of on ground impacts to Matters of State Environmental Significance; and h) include a program for monitoring and review of the effectiveness of the Subsidence Management Plan.
<p>Page 23 of 103</p>	<p>Guidance material has been provided in Appendix 3 to assist with the development of the Subsidence Management Plan.</p> <p style="text-align: right;">File A Department of Environment and Science 1466 of 1533</p>

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J4	<p>The Subsidence Management Plan must be reviewed each calendar year and a report prepared on 1 July each year. The report must:</p> <ul style="list-style-type: none"> a) assess the plan against the requirements under condition J3 and the certified reports required under condition J10; b) include recommended actions to ensure actual and potential environmental impacts are effectively managed for the coming year; and c) identify any amendments made to the Subsidence Management Plan following the review.
J5	<p>The environmental authority holder must attach a written response and recommended actions to the review report required by condition J4. The response must detail the actions taken and/or proposed to be taken in order to ensure continuing compliance with this environmental authority.</p>
J6	<p>The review report required by condition J4 and the written response to the review report required by condition J5 must be submitted to the administering authority upon request.</p>
Annual Inspection of Subsidence	
J7	<p>The environmental authority holder must arrange for each subsided longwall panel to be inspected annually by an appropriately qualified person, in accordance with conditions J8 to J10 inclusive.</p> <p>If the appropriately qualified person deems and records under condition J9 that a subsided longwall no longer has an associated environmental risk, the longwall panel does not need to be reinspected in the future annual inspections under conditions J7 to J9 inclusive.</p>
J8	<p>The annual inspection must be conducted between 1 April and 1 November each year.</p>
J9	<p>At each annual inspection, the condition of each subsided longwall panel must be assessed by an appropriately qualified person. The inspection must include assessments of the structural, geotechnical and hydraulic adequacy of the subsided longwall panel and the adequacy of the works with respect to the Subsidence Management Plan.</p>
J10	<p>For each inspection required under condition J9, copies of a report, including any recommendations to ensure the integrity of each subsided longwall panel, must be provided to the administering authority upon request.</p>
J11	<p>If the review under conditions J4 or J7 indicates that the impact to Matters of State Environmental Significance caused by mining activities authorised under this environmental authority differs from the area of disturbance detailed in the Biodiversity Offset Strategy, the environmental authority holder must undertake a review in accordance with conditions I4 and I5.</p>

Schedule K: Structures	
Condition number	Condition
Consequence Category	
K1	The consequence category of any structure must be assessed by a suitably qualified and experienced person in accordance with the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)</i> at the following times: <ul style="list-style-type: none"> a) prior to the design and construction of the structure; or b) prior to any change in its purpose or the nature of its stored contents.
K2	A consequence assessment report and certification must be prepared for each structure assessed and the report may include a consequence assessment for more than one structure.
K3	Certification must be provided by the suitably qualified and experienced person who undertook the assessment, in the form set out in the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)</i> .
Design and Construction of a Regulated Structure	
K4	All regulated structures must be designed by, and constructed under the supervision of, a suitably qualified and experienced person in accordance with the requirements of the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)</i> .
K5	Construction of a regulated structure is prohibited unless: <ul style="list-style-type: none"> a) the environmental authority holder has submitted a consequence category assessment report and certification to the administering authority; and b) certification for the design, design plan and the associated operating procedures has been certified by a suitably qualified and experienced person in compliance with the relevant condition of this authority.
K6	Certification must be provided by the suitably qualified and experienced person who oversees the preparation of the design plan in the form set out in the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)</i> and must be recorded in the Register of Regulated Structures.

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K7	<p>Regulated Structures must:</p> <ul style="list-style-type: none"> a) be designed and constructed in compliance with and conform to the requirements of the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)</i>; b) be designed and constructed with due consideration given to ensuring that the design integrity would not be compromised on account of: <ul style="list-style-type: none"> i) floodwaters from entering a regulated dam from any watercourse or drainage line; and ii) wall failure due to erosion by floodwaters arising from any watercourse or drainage line. c) for regulated dams associated with a failure to contain - seepage; have the floor and sides of the dam designed and constructed to prevent or minimise the passage of the wetting front and any entrained contaminants through either the floor or sides of the dam during the operational life of the dam and for any period of decommissioning and rehabilitation of the dam.
K8	<p>Certification by the suitably qualified and experienced person who supervises the construction must be submitted to the administering authority on the completion of construction of the regulated structure, and state that:</p> <ul style="list-style-type: none"> a) the 'as constructed' drawings and specifications meet the original intent of the design plan for that regulated structure; and b) construction of the regulated structure is in accordance with the design plan.
K9	<p>All affected persons must be provided with a copy of the emergency action plan in place for each regulated structure</p> <ul style="list-style-type: none"> a) for existing structures that are regulated structures, within 10 business days of this condition taking effect; b) prior to the operation of the new regulated structure; and c) if the emergency action plan is amended, within 5 business days of it being amended.

Operation of a regulated structure

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K10	<p>Operation of a regulated structure, except for an existing structure, is prohibited unless the environmental authority holder has submitted to the administering authority in respect of regulated structure, all of the following:</p> <ul style="list-style-type: none"> a) one electronic copy of the design plan and certification of the 'design plan' in accordance with condition K6; b) a set of 'as constructed' drawings and specifications; c) certification of those 'as constructed drawings and specifications' in accordance with condition K8; and d) where the regulated structure is to be managed as part of an integrated containment system for the purpose of sharing the DSA volume across the system, a copy of the certified system design plan; e) the requirements of this environmental authority relating to the construction of the regulated structure have been met; f) the environmental authority holder has entered the details required under this environmental authority into a Register of Regulated Structures; and g) there is a current operational plan for the regulated structure.
K11	Each regulated structure must be maintained and operated, for the duration of its operational life until decommissioned and rehabilitated, in a manner that is consistent with the current operational plan and, if applicable, the current design plan and associated certified 'as constructed' drawings.
Mandatory Reporting Level	
K12	Conditions K12 to K16 inclusive only apply to Regulated Dams which have not been certified as low consequence category for 'failure to contain—overtopping'.
K13	The Mandatory Reporting Level (the MRL) must be marked on a regulated dam in such a way that during routine inspections of that dam, it is clearly observable.
K14	The environmental authority holder must, as soon as practical but within 48 hours of becoming aware, notify the administering authority when the level of the contents of a regulated dam reaches the MRL.
K15	The environmental authority holder must, immediately on becoming aware that the MRL has been reached, act to prevent the occurrence of any unauthorised discharge from the regulated dam.
K16	The environmental authority holder must record any changes to the MRL in the Register of Regulated Structures.
Design Storage Allowance	
K17	The environmental authority holder must assess the performance of each regulated dam or linked containment system over the preceding November to May period based on actual observations of the available storage in each regulated dam or linked containment system taken prior to 1 July of each year.

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K18	By 1 November of each year, storage capacity must be available in each regulated dam (or network of linked containment systems with a shared DSA volume), to meet the Design Storage Allowance (DSA) volume for the dam (or network of linked containment system).
K19	The environmental authority holder must, as soon as possible but within 48 hours of becoming aware that a regulated dam (or network of linked containment system) will not have the available storage to meet the DSA volume on 1 November of any year, notify the administering authority.
K20	The environmental authority holder must, immediately on becoming aware that a regulated dam (or network of linked containment systems) will not have the available storage to meet the DSA volume on 1 November of any year, act to prevent the occurrence of any unauthorised discharge from the regulated dam or linked containment system.

Annual Inspection

K21	Each regulated structure must be inspected each calendar year by a suitably qualified and experienced person.
K22	At each annual inspection, the condition and adequacy of all components of the regulated structure must be assessed and a suitably qualified and experienced person must prepare an annual inspection report containing details of the assessment and include a recommendations section with any recommended actions to ensure the integrity of the regulated structure, or a positive statement that no recommendations are required.
K23	The suitably qualified and experienced person who prepared the annual inspection report must certify the report in accordance with the <i>Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)</i> .
K24	Within 20 business days of receipt of the annual inspection report, the environmental authority holder must provide to the administering authority: <ul style="list-style-type: none"> a) the recommendations section of the annual inspection report; and b) if applicable, any actions being taken in response to those recommendations; and c) if, following receipt of the recommendations and (if applicable) recommended actions, the administering authority requests a full copy of the annual inspection report from the environmental authority holder, provide this to the administering authority within 10 business days of receipt of the request.

Transfer Arrangements

K25	The environmental authority holder must provide a copy of any reports, documentation and certifications prepared under this environmental authority, including but not limited to any Register of Regulated Structures, consequence assessment, design plan and other supporting documentation, to a new environmental authority holder on transfer of this environmental authority.
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Decommissioning and Rehabilitation

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K26	<p>Dams must not be abandoned but must be either:</p> <ul style="list-style-type: none"> a) decommissioned and rehabilitated to achieve compliance with condition K27; or b) be left in situ for a beneficial use(s) provided that: <ul style="list-style-type: none"> i) it no longer contains contaminants that will migrate into the environment; and ii) it contains water of a quality that is demonstrated to be suitable for its intended beneficial use(s); and iii) the administering authority, the environmental authority holder and the landholder agree in writing that the dam will be used by the landholder following the cessation of the environmentally relevant activity(ies).
K27	<p>After decommissioning, all significantly disturbed land caused by the carrying out of the environmentally relevant activity(ies) must be rehabilitated to meet the following final acceptance criteria:</p> <ul style="list-style-type: none"> a) the landform is safe for humans and fauna; b) the landform is stable with no subsidence or erosion gullies for at least 3 years; c) any contaminated land (e.g. contaminated soils) is remediated and rehabilitated; d) not allowing for acid mine drainage; e) there is no ongoing contamination to waters (including groundwater); f) rehabilitation is undertaken in a manner such that any actual or potential acid sulfate soils on the area of significant disturbance are treated to prevent or minimise environmental harm in accordance with the <i>Queensland Acid Sulfate Soil Technical Manual and Soil Management Guideline V 4.0 (2014)</i>; g) all significantly disturbed land is reinstated to the pre-disturbed soil suitability class; h) for land that is not being cultivated by the landholder: <ul style="list-style-type: none"> i) groundcover, that is not a declared pest species is established and self-sustaining ii) vegetation of similar species richness and species diversity to pre-selected analogue sites is established and self-sustaining; and iii) the maintenance requirements for rehabilitated land is no greater than that required for the land prior to its disturbance caused by carrying out the resource activity(ies); and i) for land that is to be cultivated by the landholder, cover crop is revegetated, unless the landholder will be preparing the site for cropping within 3 months of resource activities being completed.
Register of Regulated Structures	
K28	A Register of Regulated Structures must be established and maintained by the environmental authority holder for each regulated structure.
K29	The environmental authority holder must provisionally enter the required information in the Register of Regulated Structures when a design plan for a regulated structure is submitted to the administering authority.

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K30	The environmental authority holder must make a final entry of the required information in the Register of Regulated Structures once compliance with condition K10 has been achieved.
K31	The environmental authority holder must ensure that the information contained in the Register of Regulated Structures is current and complete on any given day.
K32	All entries in the Register of Regulated Structures must be endorsed by the chief executive officer for the environmental authority holder, or their delegate, as being accurate and correct.
K33	The environmental authority holder must, at the same time as providing the annual return, supply to the administering authority a copy of the records contained in the Register of Regulated Structures, in the electronic format required by the administering authority.

END OF CONDITIONS

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APPENDIX 1: DEFINITIONS

Words and phrases used throughout this environmental authority are defined below. Where a definition for a term used in this environmental authority is not provided within this environmental authority and is provided in the EP Act or subordinate legislation, the definition in the EP Act or subordinate legislation must be used.

‘activity(ies)’ means mining activities and / or resource activities as noted within this Appendix.

‘acid rock drainage’ means any contaminated discharge emanating from a mining activity formed through a series of chemical and biological reactions when geological strata are disturbed and exposed to oxygen and moisture.

‘airblast overpressure’ means energy transmitted from the blast site within the atmosphere in the form of pressure waves. The maximum excess pressure in this wave, above ambient pressure is the peak airblast overpressure measured in decibels linear (dBL).

‘annual exceedance probability’ or **‘AEP’** the probability that at least one event in excess of a particular magnitude will occur in any given year.

‘annual inspection report’ means an assessment prepared by a suitably qualified and experienced person containing details of the assessment against the most recent consequence assessment report and design plan (or system design plan):

- a) against recommendations contained in previous annual inspections reports;
- b) against recognised dam safety deficiency indicators;
- c) for changes in circumstances potentially leading to a change in consequence category;
- d) for conformance with the conditions of this authority;
- e) for conformance with the ‘as constructed’ drawings;
- f) for the adequacy of the available storage in each regulated dam, based on an actual observation or observations taken after 31 May each year but prior to 1 November of that year, of accumulated sediment, state of the containment barrier and the level of liquids in the dam (or network of linked containment systems); and
- g) for evidence of conformance with the current operational plan.

‘appropriately qualified person(s)’ means a person or persons who has professional qualifications, training, skills and experience relevant to nominated subject matter and can give authoritative assessment, advice and analysis in relation to the subject matter using the relevant protocols, standards, methods or literature.

‘assessed’ or **‘assessment’** by a ‘suitably qualified and experienced person’ in relation to a consequence assessment of a dam, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit of the assessment:

- a) exactly what has been assessed and the precise nature of that determination;
- b) the relevant legislative, regulatory and technical criteria on which the assessment has been based;
- c) the relevant data and facts on which the assessment has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and

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- d) the reasoning on which the assessment has been based using the relevant data and facts, and the relevant criteria.

‘associated works’ in relation to a dam, means:

- a) operations of any kind and all things constructed, erected or installed for that dam; and
- b) any land used for those operations.

‘authority’ means an environmental authority.

‘background’ with reference to the water schedule means the average of samples taken prior to the commencement of mining from the same waterway that the current sample has been taken.

‘blasting’ means the use of explosive materials to fracture:

- a) rock, coal and other minerals for later recovery; or
- b) structural components or other items to facilitate removal from a site or for reuse.

‘box-cut excavation’ means bulk earthworks excavation required for open cut mining, which for the avoidance of doubt does not include clearing or topsoil stripping.

‘BTF Management Plan’ refers to the Black-throated finch (**BTF**) plan prepared in accordance with the conditions of the environmental authority for the project’s mining activities issued under the *Environmental Protection Act 1994* (Qld)

‘Carmichael Coal Project Biodiversity Offset Strategy’ means the Biodiversity Offset Strategy approved by the Coordinator-General in accordance with the imposed conditions under Section 54B of the *State Development and Public Works Organisation Act 1971* for the Carmichael Coal Mine and Rail project.

‘certifying, certify, certification or certified relating to regulated structures’ means assessment and approval must be undertaken by a suitably qualified and experienced person in relation to any assessment or documentation required by this Manual, including design plans, ‘as constructed’ drawings and specifications, construction, operation or an annual report regarding regulated structures, undertaken in accordance with the Board of Professional Engineers of Queensland Policy Certification by RPEQs (ID: 1.4 (2A)).

In all other cases **‘certifying, certify, certification or certified’** means by an suitably qualified person holding industry certification such as CEnvP or other recognised independent body, who, in relation to any program, plan or report, means that a statutory declaration has been made by that person and, when taken together with any attached or appended documents referenced in that declaration, all of the following aspects are addressed and are sufficient to allow an independent audit at any time:

- a) exactly what is being certified and the precise nature of that certification;
- b) the relevant legislative, regulatory and technical criteria on which the certification has been based;
- c) the relevant data and facts on which the certification has been based, the source of that material, and the efforts made to obtain all relevant data and facts; and
- d) the reasoning on which the certification has been based using the relevant data and facts, and the relevant criteria.

‘chemical’ means:

- a) an agricultural chemical product or veterinary chemical product within the meaning of the *Agricultural and Veterinary Chemicals Code Act 1994* (Commonwealth); or

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- b) a dangerous good under the Australian Code for the Transport of Dangerous Goods by Road and Rail approved by the Australian Transport Council; or
- c) a hazardous substance within the meaning of the Workplace Health and Safety Regulation 2011;
- d) a drug or poison in the Standard for the Uniform Scheduling of Drugs and Poisons prepared by the Australian Health Ministers' Advisory Council and published by the Commonwealth; or
- e) any substance used as, or intended for use as:
 - i) a pesticide, insecticide, fungicide, herbicide, rodenticide, nematocide, miticide, fumigant or related product; or
 - ii) a surface-active agent, including, for example, soap or related detergent; or
 - iii) a paint solvent, pigment, dye, printing ink, industrial polish, adhesive, sealant, food additive, bleach, sanitiser, disinfectant, or biocide; or
 - iv) a fertiliser for agricultural, horticultural or garden use; or
 - v) a substance used for, or intended for use for mineral processing or treatment of metal, pulp and paper, textile, timber, water or wastewater; or
 - vi) manufacture of plastic or synthetic rubber.

'commercial place' means a workplace used as an office or for business or commercial purposes, which is not part of the mining activity and does not include employees' accommodation or public roads. A 'commercial place' is based on Schedule 1 of EPP Noise. That is a commercial place is inside or outside a commercial or retail activity.

'consequence' in relation to a structure as defined, means the potential for environmental harm resulting from the collapse or failure of the structure to perform its primary purpose of containing, diverting or controlling flowable substances.

'consequence category' means a category, either low, significant or high, into which a dam is assessed as a result of the application of tables and other criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.

'construction' or **'constructed'** in relation to a regulated structure includes building a new regulated structure and lifting or otherwise modifying an existing regulated structure, but does not include investigations and testing necessary for the purpose of preparing a design plan.

'dam' means a land-based structure or a void that contains, diverts or controls flowable substances, and includes any substances that are thereby contained, diverted or controlled by that land-based structure or void and **associated works**.

'dam crest volume' means the volume of material (liquids and/or solids) that could be within the walls of a dam at any time when the upper level of that material is at the crest level of that dam. That is, the instantaneous maximum volume within the walls, without regard to flows entering or leaving (for example, via spillway).

'design document' for the purposes of a REMP is a document that demonstrates compliance with condition F24. The document should also address each criterion on what a REMP should be as outlined in the guide.

'design plan' is a document setting out how all identified consequence scenarios are addressed in the planned design and operation of a regulated structure.

‘design storage allowance’ or **‘DSA’** means an available volume, estimated in accordance with the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (ESR/2016/1933) published by the administering authority, must be provided in a dam as at 1 November each year in order to prevent a discharge from that dam to an **annual exceedance probability** (AEP) specified in that Manual.

‘designer’ for the purposes of a regulated dam, means the certifier of the design plan for the regulated dam.

‘disturbance’ of land includes:

- a) compacting, removing, covering, exposing or stockpiling of earth;
- b) removal or destruction of vegetation or topsoil or both to an extent where the land has been made susceptible to erosion;
- c) carrying out mining within a watercourse, waterway, wetland or lake;
- d) the submersion of areas by tailings or hazardous contaminant storage and dam/structure walls;
- e) temporary infrastructure, including any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc.) which is to be removed after the mining activity has ceased; or
- f) releasing of contaminants into the soil or underlying geological strata.

However, the following areas are not included when calculating areas of ‘disturbance’:

- a) areas off lease (e.g. roads or tracks which provide access to the mining lease);
- b) areas previously disturbed which have achieved the rehabilitation outcomes;
- c) by agreement with the administering authority, areas previously disturbed which have not achieved the rehabilitation objective(s) due to circumstances beyond the control of the mine operator (such as climatic conditions);
- d) areas under permanent infrastructure. Permanent infrastructure includes any infrastructure (roads, tracks, bridges, culverts, dam/structures, bores, buildings, fixed machinery, hardstand areas, airstrips, helipads etc.) which is to be left by agreement with the landowner; or
- e) disturbance that pre-existed the grant of the tenure.

‘EC’ means electrical conductivity.

‘effluent’ treated wastewater released from sewage treatment plants.

‘emergency action plan’ means documentation forming part of the operational plan held by the environmental authority holder, that identifies emergency conditions that sets out procedures and actions that will be followed and taken by the owner and operating personnel in the event of an emergency. The actions are to minimise the risk and consequences of failure, and ensure timely warning to downstream communities and the implementation of protection measures. The plan must require dam owners to annually update contact.

‘environmental offset’ has the meaning in Section 7 of the *Environmental Offsets Act 2014*.

‘ERC’ means estimated rehabilitation cost.

‘existing structure’ means a structure that was in existence prior to the adoption of this schedule of conditions under the authority.

‘extreme storm storage’—means a storm storage allowance determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (ESR/2016/1933) published by the administering authority.

‘Financial Provisioning Act’ means the *Mineral and Energy Resources (Financial Provisioning) Act 2018*.

‘**GDE**’ means groundwater dependent ecosystem.

‘**Groundwater Dependent Ecosystem Management Plan (GDEMP)**’ - A GDEMP is a plan developed by a suitably qualified and experienced person that is consistent with any Bioregional Management Plan for the bioregion, the Water Resource (Great Artesian Basin) Plan and relevant threat abatement plans, conservation advice and project species management plans.

‘**groundwater level drawdown threshold**’ means the authorised maximum drawdown of groundwater at the nominated location at any time during the life of mining activities.

‘**GMMP**’ is the most recently approved version of the Groundwater Management and Monitoring Program.

‘**hazard category**’ means a category, either low significant or high, into which a dam is assessed as a result of the application of tables and other criteria in *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.

‘**incident**’ means a set of circumstances arising as a result of activities carried out under an environmental authority which cause or threaten to cause environmental harm.

‘**infrastructure**’ means water storage dams, levees, roads and tracks, buildings and other structures built for the purpose of the mining activity.

‘**LA1,adj,15mins**’ means the A-weighted sound pressure level, adjusted for tonal character or impulsiveness, that is exceeded for 1% of a 15-minute period when measured using a fast standardised response time.

‘**LAeq,adj,15mins**’ means an A-weighted sound pressure level of a continuous steady sound, adjusted for tonal character, that within a 15-minute period has the same mean square sound pressure of a sound that varies with time.

‘**land**’ in the ‘land schedule’ of this EA means land excluding waters and the atmosphere, that is, the term has a different meaning from the term as defined in the *Environmental Protection Act 1994*. For the purposes of the *Acts Interpretation Act 1954*, it is expressly noted that the term ‘land’ in this environmental authority relates to physical land and not to interests in land.

‘**land use**’ –means the selected post mining use of the land, which is planned to occur after the cessation of mining activities.

‘**leachate**’ means a liquid that has passed through or emerged from, or is likely to have passed through or emerged from, a material stored, processed or disposed of at the mining lease or operational land which contains soluble, suspended or miscible contaminants likely to have been derived from the said material.

‘**levee**’ means an embankment that only provides for the containment and diversion of stormwater or flood flows from a contributing catchment, or containment and diversion of flowable materials resulting from releases from other works, during the progress of those stormwater or flood flows or those releases; and does not store any significant volume of **water** or **flowable substances** at any other times.

‘**LOR**’ means limit of reporting.

‘**low consequence dam**’ means any dam that is not a high or significant consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*.

‘**m**’ means metres.

‘mandatory reporting level’ or **‘MRL’** means a warning and reporting level determined in accordance with the criteria in the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* published by the administering authority.

‘manual’ means the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* published by the administering authority.

‘maximum extent of impact’ means the total, cumulative, residual extent and duration of impact to a prescribed environmental matter that will occur over a project’s life after all reasonable avoidance and reasonable on-site mitigation measures have been, or will be, undertaken.

‘measures’ includes any measures or actions to prevent or minimise environmental impacts of the mining activity such as bunds, silt fences, diversion drains, capping, and containment systems.

‘mg/L’ means milligrams per litre.

‘mine affected water’

- a) means the following types of water:
- i) pit water, tailings dam water, processing plant water;
 - ii) water contaminated by a mining activity which would have been an environmentally relevant activity under Schedule 2 of the Environmental Protection Regulation 2008 if it had not formed part of the mining activity;
 - iii) rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage such runoff, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water;
 - iv) groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated;
 - v) groundwater from the mine’s dewatering activities; or
 - vi) a mix of mine affected water (under any of paragraphs i) - v)) and other water.
- b) does not include surface water runoff which, to the extent that it has been in contact with areas disturbed by mining activities that have not yet been completely rehabilitated, has only been in contact with:
- i) land that has been rehabilitated to a stable landform and either capped or revegetated in accordance with the acceptance criteria set out in the environmental authority but only still awaiting maintenance and monitoring of the rehabilitation over a specified period of time to demonstrate rehabilitation success; or
 - ii) land that has partially been rehabilitated and monitoring demonstrates the relevant part of the landform with which the water has been in contact does not cause environmental harm to waters or groundwater, for example:
 - 1) areas that are been capped and have monitoring data demonstrating hazardous material adequately contained with the site; or
 - 2) evidence provided through monitoring that the relevant surface water would have met the water quality parameters for mine affected water release limits in this environmental authority, if those parameters had been applicable to the surface water runoff; or both.

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‘mine site’ means the area of land on which the project is located.

‘mining activities’ means the activities:

- a) authorised as per the definition in section 110 of the *Environmental Protection Act 1994*; and
- b) all environmentally relevant activities authorised under this environmental authority.

‘modification’ or **‘modifying’** (see definition of ‘construction’).

‘natural flow’ means the flow of water through waters caused by nature.

‘non-polluting’ means having no adverse impacts upon the receiving environment.

‘notice of election’ has the meaning in section 18(2) *Environmental Offsets Act 2014*.

‘operational plan’ includes:

- a) normal operating procedures and rules (including clear documentation and definition of process inputs in the DSA allowance); and
- b) contingency and emergency action plans including operating procedures designed to avoid and/or minimise environmental impacts including threats to human life resulting from any overtopping or loss of structural integrity of the regulated structure.

‘peak particle velocity (ppv)’ means a measure of ground vibration magnitude which is the maximum rate of change of ground displacement with time, usually measured in millimetres/second (mm/s).

‘project’ means the Carmichael Coal Mine located within Mining Lease (applications) 70441, 70505 and 70506

‘project stage 1’ means project activities carried out prior to commencement of significant ground disturbance including:

- a) pre-construction surveying and technical assessment including geotechnical, establishment of site security arrangements (including signs, fences, safety barriers, and temporary security personnel facilities) and maintenance of existing roads and tracks;
- b) installation of facilities for the purpose of environmental monitoring compliance; and
- c) other works limited to the existing site facilities and access roads.

‘project stage 2’ means project activities, other than activities carried out under project stage 1, leading to the production of coal including:

- a) removal of existing structures, site clearance;
- b) construction of access roads, potable water treatment and sewage treatment plants, new power plants, mine administrative buildings, water storage infrastructure and hard standing;
- c) removal and stockpiling of overburden and excavation of box cuts for open pit or underground mining; and
- d) commencement of dewatering operations.

‘protected area’ means—a protected area under the *Nature Conservation Act 1992*; or

- a) a marine park under the *Marine Parks Act 1992*; or
- b) a World Heritage Area.

‘receiving environment’ in relation to an activity that causes or may cause environmental harm, means the part of the environment to which the harm is, or may be, caused. The receiving environment includes (but is not limited to):

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- a) a watercourse;
- b) groundwater; and
- c) an area of land that is not specified in a Schedule or Table (Authorised Activities) of this environmental authority.

The term does not include land that is specified in Table A1 of this environmental authority.

‘receiving waters’ means the waters into which this environmental authority authorises releases of mine affected water.

‘Register of Regulated Dams’ includes:

- a) date of entry in the register;
- b) name of the dam, its purpose and intended/actual contents;
- c) the consequence category of the dam as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)*;
- d) dates, names, and reference for the design plan plus dates, names, and reference numbers of all document(s) lodged as part of a design plan for the dam;
- e) name and qualifications of the suitably qualified and experienced person who certified the design plan and 'as constructed' drawings;
- f) for the regulated dam, other than in relation to any levees—
 - i) the dimensions (metres) and surface area (hectares) of the dam measured at the footprint of the dam;
 - ii) coordinates (latitude and longitude in GDA94) within five metres at any point from the outside of the dam including its storage area;
 - iii) dam crest volume (megalitres);
 - iv) spillway crest level (metres AHD);
 - v) maximum operating level (metres AHD);
 - vi) storage rating table of stored volume versus level (metres AHD);
 - vii) design storage allowance (megalitres) and associated level of the dam (metres AHD); and
 - viii) mandatory reporting level (metres AHD);
- g) the design plan title and reference relevant to the dam;
- h) the date construction was certified as compliant with the design plan;
- i) the name and details of the suitably qualified and experienced person who certified that the constructed dam was compliant with the design plan;
- j) details of the composition and construction of any liner;
- k) the system for the detection of any leakage through the floor and sides of the dam;
- l) dates when the regulated dam underwent an annual inspection for structural and operational adequacy, and to ascertain the available storage volume for 1 November of any year;
- m) dates when recommendations and actions arising from the annual inspection were provided to the administering authority; and

- n) dam water quality as obtained from any monitoring required under this authority as at 1 November of each year.

‘regulated dam’ means any dam in the significant or high consequence category as assessed using the *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (ESR/2016/1933)* published by the administering authority.

‘regulated structure’ includes land-based containment structures, levees, bunds and voids, but not a tank or container designed and constructed to an Australian Standard that deals with strength and structural integrity.

‘rehabilitation’ the process of reshaping and revegetating land to restore it to a stable landform that is enduring and unlikely to collapse, erode or subside (*EP Regulations Sch 8 Part 1 (1) Definitions*).

‘rejects’ means all coal waste material generated from the washing of coal at the Coal Preparation Plant.

‘release event’ means a surface water discharge from mine affected water storages or contaminated areas on the mine site.

‘representative’ means a sample set which covers the variance in monitoring or other data either due to natural changes or operational phases of the mining activities.

‘residual void’ means an open pit resulting from the removal of ore and/or waste rock which will remain following the cessation of all mining activities and completion of rehabilitation processes.

‘RL’ means reduced level, relative to mean sea level as distinct from depths to water.

‘saline drainage’ The movement of waters, contaminated with salts, as a result of the mining activity.

‘scheme fund’ means the scheme fund established under the *Mineral and Energy Resources (Financial Provisioning) Act 2018*, section 24.

‘Scheme Manager’ means the scheme manager (from time to time) under the Financial Provisioning Act and any delegate of that person under the Financial Provisioning Act.

sensitive place’ or ‘sensitive receptor’

- a) a dwelling, residential allotment, mobile home or caravan park, residential marina or other residential premises; or
- b) a motel, hotel or hostel; or
- c) an educational institution; or
- d) a medical centre or hospital; or
- e) Commercial and retail activity (indoors),
- f) a protected area under the Nature Conservation Act 1992, the Marine Parks Act 1992 or a World Heritage Area; or
- g) a public park or gardens,
- h) or other ‘sensitive receptor’, or place based on Schedule 1 of EPP Noise.

‘spillway’ means a weir, channel, conduit, tunnel, gate or other structure designed to permit discharges from the dam, normally under flood conditions or in anticipation of flood conditions.

‘structure’ means dam or levee.

‘suitably qualified person’ means a person who;

- a) is a member of an organisation listed in Schedule 14 of the *EP Regulations 2019*; and

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- b) holds certification as an environmental practitioner (i.e. Certified Environmental Practitioner, (CEnvP) under the CEnvP Scheme) or,
- c) has professional qualifications, training, skills and experience relevant to the nominated subject matter and can give authoritative assessment, advice and analysis on performance relating to the subject matter using the relevant protocols, standards, methods or literature.

‘suitably qualified and experienced person’ in relation to the BTF species management plan means a person who has professional qualifications, certification as an environmental Practitioner (CEnvP), training, or skills, and experience relevant to bird ecology, and can give authoritative assessment, advice and analysis about performance relevant to the subject matters using relevant protocols, standards, methods or literature.

‘suitably qualified and experienced person’ in relation to regulated structures means a person who is a Registered Professional Engineer of Queensland (RPEQ) under the provisions of the *Professional Engineers Act 2002*, and has demonstrated competency and relevant experience:

- for regulated dams, an RPEQ who is a civil engineer with the required qualifications in dam safety and dam design.
- for regulated levees, an RPEQ who is a civil engineer with the required qualifications in the design of flood protection embankments.

‘Surety’ has the same meaning as used in the *Financial Provisioning Act*.

‘system design plan’ means a plan that manages an integrated containment system that shares the required DSA and/or ESS volume across the integrated containment system.

‘the Act’ means the *Environmental Protection Act 1994*.

‘µS/cm’ means micro siemens per centimetre.

‘void’ means any constructed, open excavation in the ground.

‘water quality’ means the chemical, physical and biological condition of water.

‘watercourse’ has the meaning in Schedule 4 of the *Environmental Protection Act 1994* and means a river, creek or stream in which water flows permanently or intermittently—

- a) in a natural channel, whether artificially improved or not; or
- b) in an artificial channel that has changed the course of the watercourse.

Watercourse includes the bed and banks and any other element of a river, creek or stream confining or containing water.

‘waters’ includes all or any part of a river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water in natural or artificial watercourses, bed and banks of a watercourse, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and groundwater.

‘wet season’ means the time of year, covering one or more months, when most of the average annual rainfall in a region occurs. For the purposes of DSA determination this time of year is deemed to extend from 1 November in one year to 31 May in the following year inclusive.

END OF DEFINITIONS

Appendix 2: Rehabilitation requirements

Table H1 – Rehabilitation acceptance criteria

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
Ironbark Woodland	Open pit voids and slopes Out of Pit Spoil dumps	Safe – Safe to humans and stock with safety hazards similar to surrounding unmined landscape	Structurally safe Risk assessment completed with risk mitigation measures implemented.	0 (zero) significant difference to surrounding landscape as defined in AS/NZS ISO 31000:2009. For underground area – no access to underground workings.
		Stable – Landforms are both geotechnically and erosionally stable	Factor of safety Slope gradient Ground cover	Factor of Safety of greater than 1.5 Slope gradient <20% for outer slopes and <40% for inner facing slopes Minimum of 70% native vegetative ground cover. No bare surfaces >20m ² in area or >10m in length down slope. Absence of active gully and rill lines. <u>For Underground mined areas</u> <ul style="list-style-type: none"> Long-term stability of underground mine area achieves 1.5 Factor of Safety All surface cracks remediated No remaining depressions that cause ponding of incident rainfall and water runoff
		Non-polluting – Surface runoff from rehabilitated land is non-polluting to receiving waters	Water Quality Objectives for Carmichael River are met downstream of the mine	pH 6.5 – 8.5 EC <1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L

Environmental authority EPML01470513 – Carmichael Coal Mine

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
				<p>Selenium 10µg/L Sulfate (SO₄²⁺) 129µg/L</p> <p>No PAF or dispersive waste exposed on high wall slopes.</p> <p>Exposed strata do not have elevated concentrations of heavy metals</p> <p>Groundwater quality in all aquifers maintain baseline values</p>
		<p>Sustainable – rehabilitation of Pits B and C residual voids and slopes to attain elements of silver-leaved ironbark woodland (regional ecosystem 10.5.5)</p>	<p>Native species composition and density</p> <p>Weed abundance</p>	<p>Two tree species Three shrub species Five groundcover species</p> <p>At relevant benchmark density as per regional ecosystem biocondition benchmarks for 10.5.5* and 10.3.6</p> <p>4 native perennial pasture species with 80% ground cover</p> <p><5% declared weed cover</p>
Ironbark Woodland and Pasture	Open pit voids and slopes Stream diversions Out of pit spoil dumps	<p>Safe – Safe to humans and stock with safety hazards similar to surrounding unmined landscape</p>	<p>Structurally safe</p> <p>Risk assessment completed with risk mitigation measures implemented.</p>	<p>0 (zero) significant difference to surrounding landscape as defined in AS/NZS ISO 31000:2009</p>
		<p>Stable – Stable Landforms are both geotechnically and erosionally stable</p>	<p>Geotechnical assessment</p> <p>Slope angle and length</p>	<p>Factor of Safety of greater than 1.5</p> <p>Slope <12% and <40% for inner facing slopes</p>

Environmental authority EPML01470513 – Carmichael Coal Mine

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
			Visual assessment of channel morphology, presence/absence of head cuts, presence of deposited sediment and vegetation in channel	<p>Minimum of 80% native perennial vegetative ground cover.</p> <p>No bare surfaces >20m² in area or >10m in length down slope</p> <p>Absence of active gully and rill lines</p> <p>No PAF or dispersive waste exposed on slopes</p> <p>Exposed strata do not have elevated concentrations of heavy metals</p>
		Non-polluting – Surface runoff from rehabilitated land is non-polluting to receiving waters	Water Quality Objectives for Carmichael River are met downstream of the mine	<p>pH 6.5 – 8.5</p> <p>EC <1,000µS/cm</p> <p>TSS <106mg/l</p> <p>Arsenic 13µg/L</p> <p>Molybdenum 34µg/L</p> <p>Selenium 10µg/L</p> <p>Sulfate (SO₄²⁺) 129µg/L</p> <p>Groundwater quality in all aquifers maintain baseline measurements</p>
		Sustainable – Rehabilitation of Pits F and G residual voids and slopes to attain elements of silver-leaved ironbark woodland (regional ecosystem 10.5.5) and pasture	Vegetation assessment	<p>Two tree species</p> <p>Three shrub species</p> <p>Five groundcover species</p> <p>At relevant benchmark density as per regional ecosystem biocondition benchmarks for 10.5.5* and 10.3.6</p> <p>4 native perennial pasture species with 80% ground cover</p>

Permit

Environmental authority EPML01470513 – Carmichael Coal Mine

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
				<p><5% declared weed cover</p> <p>Evidence of baseline fauna species using rehabilitated areas</p>
Pasture	Mining infrastructure areas Out of pit spoil dumps	Safe – Safe to humans and stock with safety hazards similar to surrounding unmined landscape	<p>Structurally safe</p> <p>Risk assessment completed with risk mitigation measures implemented.</p>	0 (zero) significant difference to surrounding landscape as defined in AS/NZS ISO 31000:2009
		Stable – Stable Landforms are both geotechnically and erosionally stable	<p>Geotechnical assessment</p> <p>Slope gradient</p> <p>Ground cover</p>	<p>Factor of Safety of greater than 1.5</p> <p>Slope <12%</p> <p>Minimum of 60% vegetative ground cover.</p> <p>No bare surfaces >20m² in area or >10m in length down slope</p> <p>Absence of active gully and rill lines</p> <p>No PAF or dispersive waste exposed on slopes</p> <p>Exposed strata do not have elevated concentrations of heavy metals</p>
		Non-polluting – Surface runoff from rehabilitated land is non-polluting to receiving waters	Water Quality Objectives for Carmichael River are met downstream of the mine	<p>pH 6.5 – 8.5</p> <p>EC <1,000µS/cm</p> <p>TSS <106mg/l</p> <p>Arsenic 13µg/L</p> <p>Molybdenum 34µg/L</p> <p>Selenium 10µg/L</p> <p>Sulfate (SO₄²⁺) 129µg/L</p>

Environmental authority EPML01470513 – Carmichael Coal Mine

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
				Groundwater quality in all aquifers no different to baseline measurements
		Sustainable – Rehabilitation of Pits F and G spoil dumps to attain pasture	Vegetation assessment Land suitability assessment Evidence that rehabilitated area is able to support a range of fauna species identified in the pre-mining baseline studies. Evidence of habitat elements within rehabilitated area supporting BTF population	4 native perennial pasture species with 70% ground cover Agricultural land class B condition Land Suitability for grazing Class 3 (as per DSITI/DNRM 2015) <5% declared weed cover Evidence of baseline fauna species using rehabilitated areas
Ironbark woodland /pasture	Exploration disturbance as per Figure 2	Safe – Safe to humans and stock with safety hazards similar to surrounding unmined landscape	Bore integrity	Certification by suitably qualified person that all non-artesian exploration drill holes not converted to either a water bore or groundwater monitoring bore have been rehabilitated in accordance with the ' <i>Code of Environmental Compliance for Exploration and Mineral Development projects.</i> '
		Stable – Stable Landforms are both geotechnically and erosionally stable	Vegetation assessment	Minimum of 70% vegetative groundcover is present No bare surfaces >20m ² in area or >10m in length down slope
		Non-polluting – Surface runoff from	Groundwater quality	Groundwater quality in all aquifers no different to baseline measurements

Environmental authority EPML01470513 – Carmichael Coal Mine

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
		rehabilitated land is non-polluting to receiving waters		
		Self-sustaining – Supporting target land use (e.g. pasture and/or Iron bark woodlands).	Achieves a sustainable grazing or woodland outcome Vegetation assessment of plant establishment Land suitability assessment via soil sample	<p>Woodland</p> <ul style="list-style-type: none"> Two tree species >8m tall with canopy cover exceeding 15% Three shrub species Five groundcover species Species at relevant benchmark density as per regional ecosystem biocondition benchmarks for 10.5.5* and/or 10.3.6 4 native endemic perennial pasture species (including <i>Bothriochloa ewartiana</i>, <i>Chrysopogon fallax</i>, <i>Paspalidium sp.</i>, and <i>Panicum sp.</i>) with 60% ground cover <p>Density of dominant species in rehabilitated areas consistent with density of species at reference sites.</p> <p>Pasture</p> <ul style="list-style-type: none"> 4 native palatable perennial pasture species endemic to the local area (including <i>Bothriochloa ewartiana</i>, <i>Chrysopogon fallax</i>, <i>Paspalidium sp.</i>, and <i>Panicum sp.</i>) with 60% ground cover Agricultural land class B condition Land Suitability for grazing Class 3 < than 5% declared weed cover
	Water Storages	Non-polluting – Surface runoff from rehabilitated land is non-polluting to receiving waters	Water quality	<p><u>Absence of contaminants in surface water and runoff does not exceed</u></p> <p>pH 6.5 – 8.5 EC <1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO₄²⁺) 129µg/L</p>

Environmental authority EPML01470513 – Carmichael Coal Mine

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
	Water drainage, diversions and landform levees	Non-polluting – Surface runoff from rehabilitated land is non-polluting to receiving waters	Water quality Geotechnical assessment Erosion assessment	Absence of contaminants in surface water and runoff does not exceed pH 6.5 – 8.5 EC <1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO ₄ ²⁺) 129µg/L All retained water diversion structures are geotechnically and erosionally stable and are assessed as functional.
Pasture	Tailing Drying Cells	Non-polluting – Surface runoff from rehabilitated land is non-polluting to receiving waters	Surface water qualify run off	Absence of contaminants in surface water and runoff does not exceed pH 6.5 – 8.5 EC < 1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO ₄ ²⁺) 129 µg/L
	Contaminated sites	Non-polluting – Surface runoff from rehabilitated land is non-polluting to receiving waters	Surface water qualify run off	Absence of contaminants in surface water and runoff does not exceed pH 6.5 – 8.5 EC <1,000µS/cm TSS <106mg/l Arsenic 13µg/L Molybdenum 34µg/L Selenium 10µg/L Sulfate (SO ₄ ²⁺) 12µg/L

Environmental authority EPML01470513 – Carmichael Coal Mine

Post Mining Land Use	Domain	Rehabilitation Objectives	Indicators	Completion Criteria
				<p>Certification by suitably qualified person that site can be removed from Contaminated Land Register, Environmental Management Register or both.</p> <p>Hydrocarbons and heavy metals met trigger values in Table F3 of EA.</p>
*Silver-leaved ironbark woodland (regional ecosystem - 10.5.5 is the target regional ecosystem)				

END OF APPENDIX 2.

Appendix 3: Subsidence guidance material

When to use

This appendix is to be used by the Environmental Authority (EA) holders in the preparation of a Subsidence Management Plan (SMP) where a watercourse, as defined under the *Water Act 2000*, is to be impacted as a result of underground longwall mining. For a feature to be defined as a watercourse under Chapter 1, Part 2 of the *Water Act 2000*, the feature must possess particular characteristics. Watercourse determinations are regularly undertaken across Central Queensland by authorised departmental officers as it is the determining factor in the requirement for approvals under the *Water Act 2000*.

In addition, this appendix is to be used by the Department when providing advice and assessing Subsidence Management Plans submitted by EA holders or proposed EA holders.

Purpose

The purpose of this appendix is to detail the information to be provided in a SMP and the legislative basis of the requirement for approval. The SMP forms the major reference document regarding subsidence impacts on watercourses as a result of underground longwall mining and is required to accompany proposals for watercourse subsidence.

The objective of the SMP is to ensure that the impacts of subsidence are properly managed. Where surface subsidence intersects a watercourse, it is important for the situation to be managed effectively to ensure no long-term maintenance is required within the watercourse, and to ensure that naturally occurring processes are not impaired.

A SMP should include the following information:

- Location of proposed longwall panels and modelled subsidence effects on the watercourse;
- Pre-subsidence management of watercourses proposed to be subsided;
- Monitoring methods pre and post-subsidence to detect and document any impacts on watercourses;
- Post-subsidence management of impacted watercourses through remediation and rehabilitation;
- Agreed outcome for proposed future landscape between the Department and the EA holder.

Background

Throughout the Bowen Basin, economically viable coal deposits frequently extend beneath watercourses. Consequently, underground mining operations targeting the associated coal seams often also extend beneath watercourses. Underground mining is not a new concept in the extraction of coal throughout the Bowen Basin. This form of mining is preferred when economic constraints reduce the feasibility of mining using open cut methods. Whilst coal deposits located beneath watercourses contribute to total extractable coal, more importantly, extraction of this coal facilitates underground mining activities to continue along a coal seam uninterrupted across both sides of a watercourse. This provides for a more cost effective extraction of coal that might otherwise be uneconomic to mine.

Technological improvements in underground mining methods have provided the ability to extract coal in areas previously inaccessible for mining. Modern day underground coal mining operations commonly utilise longwall mining techniques which allow extraction of more of the coal seam. Longwall mining allows access to the coal seam via a shaft, a decline or a highwall portal and system of underground workings, without the need to remove overburden. This technique is used to extract the coal seam via a series of “panels”, which can be hundreds of metres wide and kilometres in length. As the coal shearer removes the coal in the seam along the length of a panel, the overlying strata is collapsed behind, filling the void (goaf) left by the extracted coal. The collapse and settlement of the overlying strata can extend to the land surface above, resulting in localised lowering of the surface profile, and depressions in the landscape (commonly referred to as subsidence troughs).

Where a watercourse is located above a longwall panel, extraction of the coal seam causes subsidence of the panel can have a number of impacts on the watercourse. Some of these impacts include:

- Lowering of bed and banks

- Creation of in-stream waterholes
- Changes to local drainage patterns
- Incision processes
- Stream widening
- Erosion
- Increased overbank flows due to lowering of the high banks
- Tension cracking through both shallow and deeper underlying strata (including aquifers)
- Root shear and loss of riparian vegetation
- Changes to water quality (surface water and groundwater).

The degree of subsidence is generally a function of thickness of coal extracted, depth of overburden, strata type and panel width. The point of maximum subsidence generally occurs along the centreline of an extracted panel, whilst the pillar zones located between panels remain at natural surface level. Experience gained through widespread adoption of longwall mining processes in the Bowen Basin has seen advancement in the modelling and ability to predict the likely impacts of a subsidence event. This technology has also facilitated improved design and implementation of mitigation measures (engineered structures and associated earthworks) and highlighted potential short and long term maintenance issues which may require specific management intervention.

Subsidence Management Plan

The objective of the SMP is to ensure that the impacts of subsidence are properly managed. Where surface subsidence intersects a watercourse, effective management is required to ensure no long-term maintenance is required within the watercourse, and to ensure that naturally occurring processes are not unduly impaired. Consideration must be given for potential impacts on erosion, groundwater and surface water as a result of a proposed subsidence event.

A Subsidence Management Plan must address the following issues:

- (1) Description of Pre Subsidence Situation & Survey
 - (a) A general description of the area pre subsidence including photographic record should be provided.
 - (b) Survey of cross-section and longitudinal profiles should be undertaken on all watercourses with potential to be impacted through subsidence. Permanent transects should be detailed within the proposed Subsidence Management Plan. Surveys should include the confluence with any other watercourses in the impacted area as well as any infrastructure spanning the watercourse. Surface drainage patterns should be investigated to determine current paths of water movement through the landscape. This path of water movement should be maintained where possible post-subsidence.
- (2) Predicted Subsidence

The degree of anticipated subsidence should be provided, including the length of watercourse to be impacted and the average depth of subsidence across individual panels. The predicted subsidence should be modelled to indicate the change in surface elevations expected. The volumes of water expected to be captured within the bed of the watercourse due to creation of waterholes should be provided. Consequences of any lowering of the high banks of the watercourse should be discussed, including impacts associated with greater floodplain interaction and potential for creation of new channels.
- (3) Infrastructure

Prior to mining, the anticipated impacts from subsidence should be determined on all infrastructure located within or above the watercourse to be subsided along with measures to be implemented to mitigate any impacts. Priority should be given to infrastructure which provides services to external parties (other mines, towns, industry). Measures for dealing with any interruption to such services should be outlined. Relocation of infrastructure may be necessary should the proposed subsidence pose sufficient risk.
- (4) Preventative Works

Where preventative measures are required to ensure the stability of the bed and banks of the watercourse (establishment of pile fields, exclusion of cattle, bentonite treatment) these should be discussed in the Subsidence Management Plan, including supporting evidence outlining the legitimacy of such works. These works may be required where self-repair by natural processes will not provide adequate remediation of impacted areas. Where there is potential for root shear to result in significant loss of riparian vegetation, mitigation measures may be required.

(5) Engineered Structures

Engineered works may be required to maintain the stability and function of a watercourse impacted by subsidence. These works are often constructed prior to subsidence occurring within the watercourse. Such works can include timber pile fields, rock revetment, reshaping of existing stream banks, and river bed treatment to prevent increased ingress of surface water into underground aquifers. Where subsidence mitigation measures require engineered structures be installed, the design, monitoring and maintenance of these structures should be detailed in the Subsidence Management Plan. The plan should detail the purpose of each structure and any consequences should the structure fail to be installed. Appropriate design plans including the location of each structure will be required. As a minimum, fourth and fifth order watercourse will require the installation of engineered structures. Works undertaken within the bed and banks of a watercourse aimed at mitigating or remediating any physical impacts pre or post-subsidence are authorised under the conditions of the Environmental Authority. Where a separate report has been produced for engineered structures, this should be included as an appendix to the Subsidence Management Plan.

(6) Erosion

The Subsidence Management Plan should detail the current watercourse condition to be impacted by subsidence. Identification of erosion zones which are likely to be exacerbated through tension cracking should be stabilised using appropriate methods. Such areas may include reaches with elevated rates of bed and bank erosion, access tracks and areas with poor quality, sparsely populated riparian vegetation. Sufficient riparian vegetation should be established prior to subsidence to assist with initial stabilisation of the bed and banks. Removal of grazing animals to allow establishment or recovery of riparian vegetation may be required for an extended period prior to subsidence.

(7) Groundwater

Where groundwater aquifers exist beneath the mine plan area, investigations should be undertaken regarding the potential for impacts on these aquifers as a result of subsidence. The Subsidence Management Plan should discuss these aquifers, any anticipated impacts on each aquifer and proposed measures for mitigating these impacts. Any anticipated movement of surface water into underlying aquifers should be discussed, as this can result in loss of surface water from the system and impacts on water quality in these aquifers. Geotechnical assessment across the bed and banks of the watercourse should be undertaken to provide an indication of potential permeability issues related to sub-surface cracking and interaction with local groundwater tables. Monitoring bores should be established in each aquifer prior to subsidence and monitored for a period of time sufficient for obtaining background water levels and trends. Monitoring of these bores should continue post-subsidence to aid the detection of impacted aquifers.

(8) Surface Water

(a) Baseline Monitoring

The Subsidence Management Plan should detail baseline condition monitoring of all watercourses likely to be impacted through subsidence. The preferred monitoring assessment technique for stream condition in the Bowen Basin is the Index of Diversion Condition. This methodology was established as a result of the Australian Coal Association Research Program (ACARP) Project C9068. Monitoring of watercourses should extend a minimum of 1km upstream and downstream of the proposed area to be impacted and should include a geomorphic assessment of the entire reach. Where a baseline monitoring assessment has been undertaken as part of an Environmental Impact Statement (EIS) process, this may be considered sufficient provided there has been no subsequent

modification or interference to the watercourse. The condition of riparian vegetation should also be detailed.

(9) Cumulative Impacts on Watercourses

- (a) With an increasing number of mines being established in close proximity to watercourses, an EA holder utilising longwall mining methods may be requested to investigate the cumulative impact of these activities on the watercourse.

Monitoring and Reporting Requirements

The following criteria have been developed to provide detailed direction regarding monitoring and reporting requirements associated with subsidence of watercourses.

These criteria are outlined in a four step approach:

- Monitoring
- Assessment
- Reporting
- Mitigation

Monitoring

- Representative sites need to be identified that allow the impacts of subsidence to be assessed in a particular watercourse with particular attention to the following:
 - Sites must be located at all pillar zones intersecting a watercourse or tributary.
 - Sites must include representative locations at the interface of natural ground level and observed changes in surface elevation from subsidence within a watercourse.
- Control sites beyond proposed mining extents should be established to verify pre-mining conditions. In watercourses, the sites should extend a minimum of 1km both upstream and downstream of the subsidence reach.
- Assessment of watercourse condition: Specific monitoring assessment techniques for watercourse condition should include but not be limited to the Index of Diversion Condition, as outlined in the ACARP Project C9068.
- Vegetation and ecological condition assessments should form part of the baseline dataset.
- Rainfall monitoring should be undertaken within areas proposed to be impacted by subsidence. In addition, flow event monitoring should occur in watercourses proposed to be impacted by subsidence. The type of monitoring devices and locations to be installed should be detailed in the Subsidence Management Plan.
- Where preventative works are undertaken pre-subsidence, subsequent monitoring assessments should include the integrity and effectiveness of these works in reducing the impact of subsidence within the watercourse.
- Surveys must include cross-sectional area and bed slope throughout all monitored reaches of impacted watercourses.
- Annual aerial photography and Digital Terrain Mapping is required to verify predicted subsidence surface profiles, and to identify potential short and long term erosion issues resulting from subsidence of watercourses.
- Surveys pre-subsidence should quantify the following features within watercourses:
 - pool/riffle sequences
 - bed controls
 - entry points of other watercourses and localised tributaries
 - existing bed and bank scour points
 - infrastructure located within the watercourse.
- Surveys post-subsidence should quantify any changes to the pre-mining conditions including:
 - erosion or deposition processes that have occurred as a result of subsidence,
 - migration of head cut erosion within watercourses and tributaries,
 - localised changes to stream bed slope,

- localised widening of channels,
- destabilisation of stream bed and banks including fracturing and incision,
- localised changes to bank heights
- size of subsidence void created within the watercourse.
- The subsidence monitoring program for groundwater must include the following information:
 - Sites must include representative locations at the interface of natural ground surface and observed changes in surface elevation from subsidence.
 - Monitoring bores should be established in each aquifer at each monitoring site.
 - Monitoring must include both water level measurements and water quality sampling in accordance with the following:
 - water level measurement to be taken quarterly
 - water quality field conductivity measurement to be taken 6 monthly
 - full chemical analysis of water samples to be taken annually.

Frequency of Monitoring

A proposed timeframe should be provided by the EA holder in relation to the monitoring outlined in the Subsidence Management Plan. The Department, upon review of the proposed Subsidence Management Plan will determine a suitable monitoring timeframe based on the information provided. Monitoring requirements will depend on a number of factors, including the stream order of the watercourse proposed to be impacted. As a guide:

Stream Order 1, 2 and 3

Monitoring must be undertaken at the following intervals:

- immediately prior to subsidence,
- within two (2) months of the initial subsidence,
- following a rainfall event of **1 in 2-year** ARI for the duration equal to the time of concentration for the catchment at the location of the subsidence.
- following a peak flow event of greater than a **1 in 2 year** ARI and
- annually.

Stream Order 4 and higher

Monitoring (including surveys) must be undertaken at the following intervals:

- immediately prior to subsidence,
- within two (2) months of the initial subsidence,
- following a rainfall event of **1 in 5-year** ARI for the duration equal to the time of concentration for the catchment at the location of the subsidence.
- following a peak flow event of greater than a **1 in 5 year** ARI, and
- annually.

Cumulative Impacts

Where subsidence is proposed in a Subsidence Management Plan, and the watercourse has already been subsided upstream or downstream, the monitoring assessment must determine not only the localised impacts on the watercourse resulting from the proposed subsidence, but also any cumulative impacts on the watercourse as a result of all other subsidence events.

Assessment

The design and assessment of engineered structures should be performed by a Registered Professional Engineer of Queensland (RPEQ). All other assessments should be performed by suitably qualified and experienced persons in the fields that they are assessing.

- The results of all monitoring activities should be reviewed by a suitably qualified person and detailed in the associated monitoring report.
- Recommendations should be made after assessment of the results regarding any specific treatment, remediation works, or engineered structures required post-subsidence to achieve stability in the watercourse.

Reporting

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An annual report will be requested by the administering authority post-subsidence. The report should detail mining activities and all monitoring and rehabilitation activities as outlined within the Subsidence Management Plan. The reporting date will be determined in consultation with the administering authority.

- A monitoring report should contain the results of all monitoring activities, the assessment of these results, and recommendations for any remedial works required. The report should comment on the following:
 - Watercourse condition and geomorphic processes;
 - The condition of vegetation in riparian zones;
 - Examination of pillar zones in watercourses with particular attention to potential for tension cracking;
 - The creation of in-stream waterholes;
 - Any impacts on groundwater.
- Where preventative works were undertaken pre-subsidence, subsequent monitoring assessments should include assessment of the integrity and effectiveness of these works in mitigating the impacts of subsidence.
- An annual report in the form of two (2) hard copies and one electronic copy shall be furnished to the administering authority. The report should in addition to addressing specific monitoring requirements provide comment on:
 - The current state of the groundwater and surface water resources;
 - Any impacts on these features;
 - Any remedial works required to be undertaken including a timetable for implementation.
 - Commitment from the EA holder to addressing the recommendations in the report.

Mitigation

Where recommendations are made regarding specific treatment, remediation works, or engineered structures required post-subsidence to achieve stability in the watercourse, the EA holder must ensure this work is undertaken.

Rehabilitation

The holder of the EA, if directed by the administering authority, will carry out additional remedial works deemed necessary to minimise the impacts of subsidence on the physical integrity of the watercourse.

Relinquishment

Relinquishment of monitoring and rehabilitation responsibilities conditional under an EA holder's EA can only occur after the subsidence and approved mitigation and rehabilitation measures have been subjected to a suitable range of rainfall and flow events, and are deemed by the administering authority to be in a stable and functional condition. Any request for relinquishment will be negotiated with the administering authority and will require a submission containing monitoring data demonstrating stability and functionally in the watercourse over a suitable range of rainfall and flow events.

Acknowledgement

In 2007, BMA and Anglo Coal instigated discussions with the Department into a proposed assessment on the cumulative impacts of longwall mining beneath the Isaac River in Central Queensland. A final report was produced by Alluvium Consulting in July 2009 documenting the outcomes of the study. The Department greatly acknowledges the findings from this report and the assistance provided in the development of this guideline.

R Lucas, J Crerar, R Hardie, J Merritt and B Kirsch, 2009. Isaac River Cumulative Impact Assessment of Mining Developments. Report by Alluvium Consulting. ACARP for Diversion assessment guideline ex C9068.

END OF APPENDIX 3.

Appendix 4: Figures

Figure A1: Overall Site Layout Domain Plan

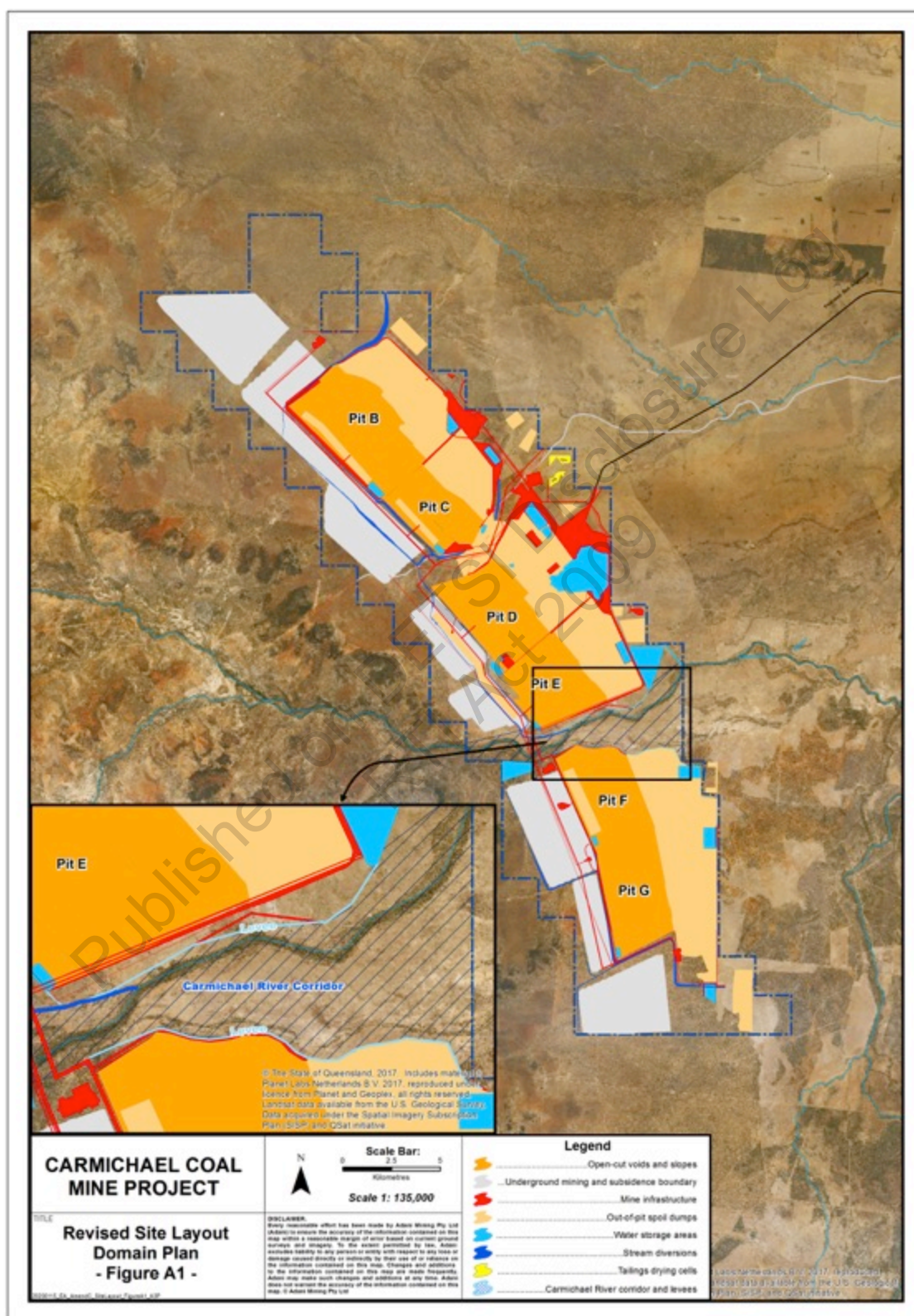


Figure A2: Exploration Disturbance

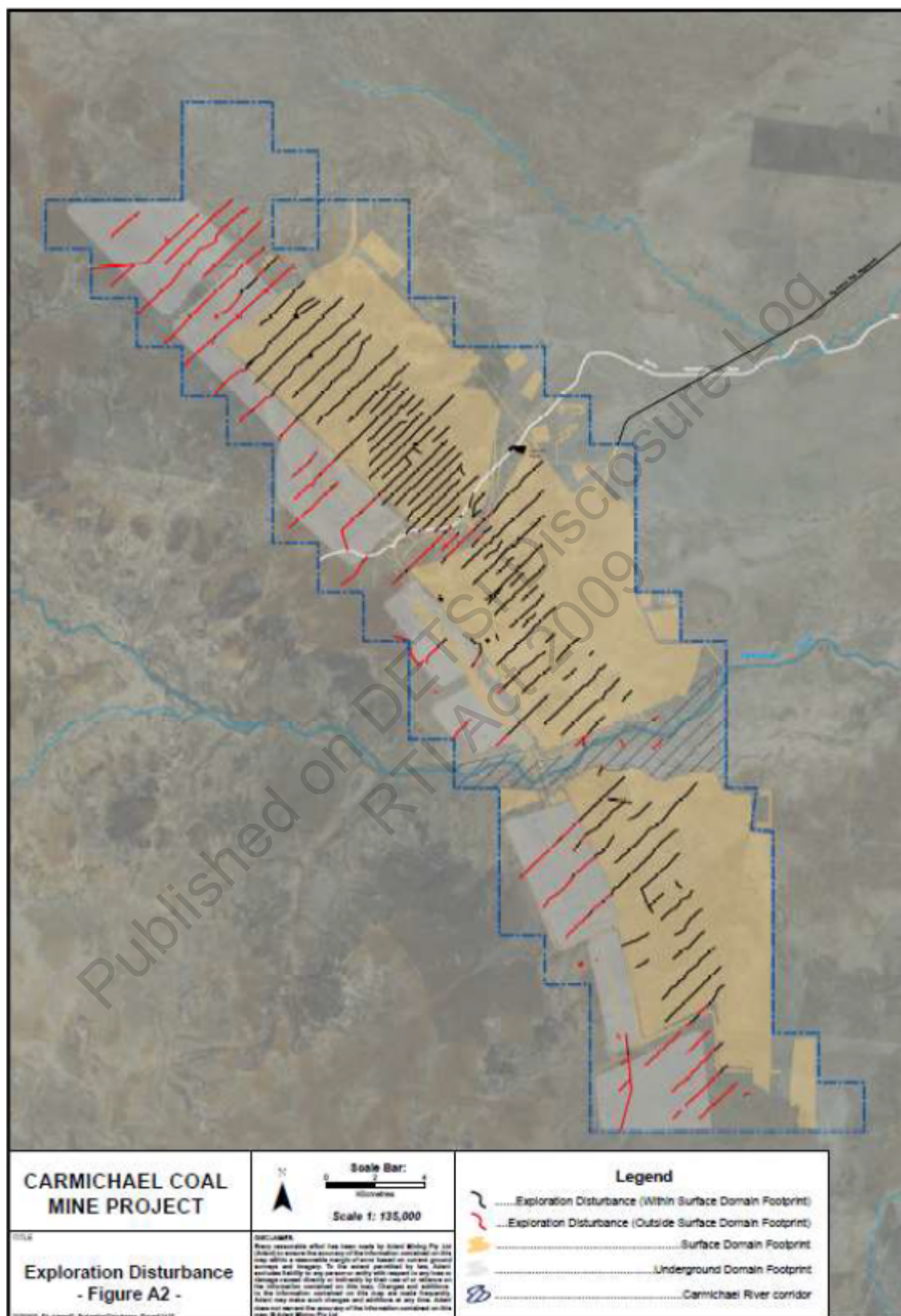


Figure E1: Groundwater Monitoring Locations

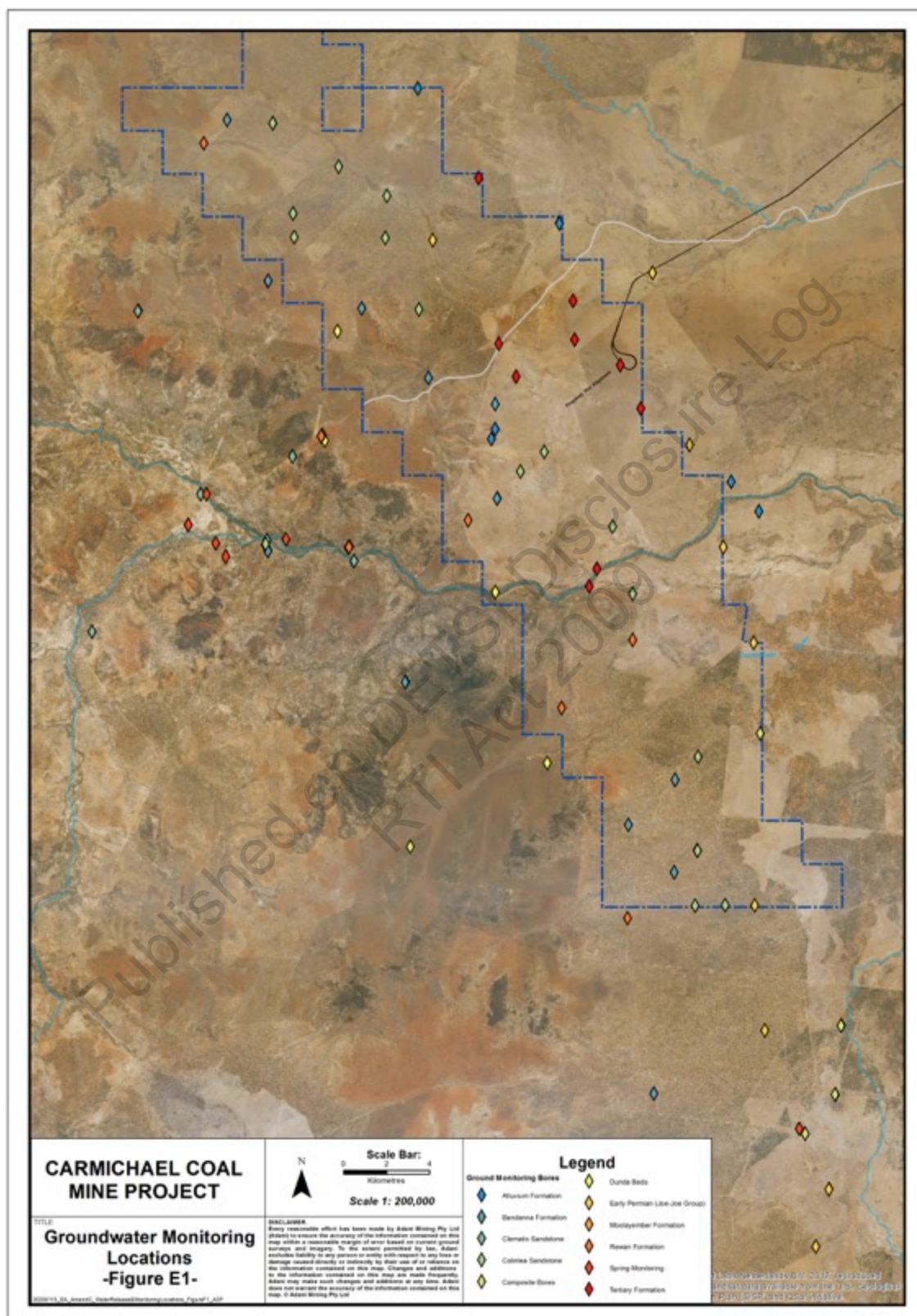
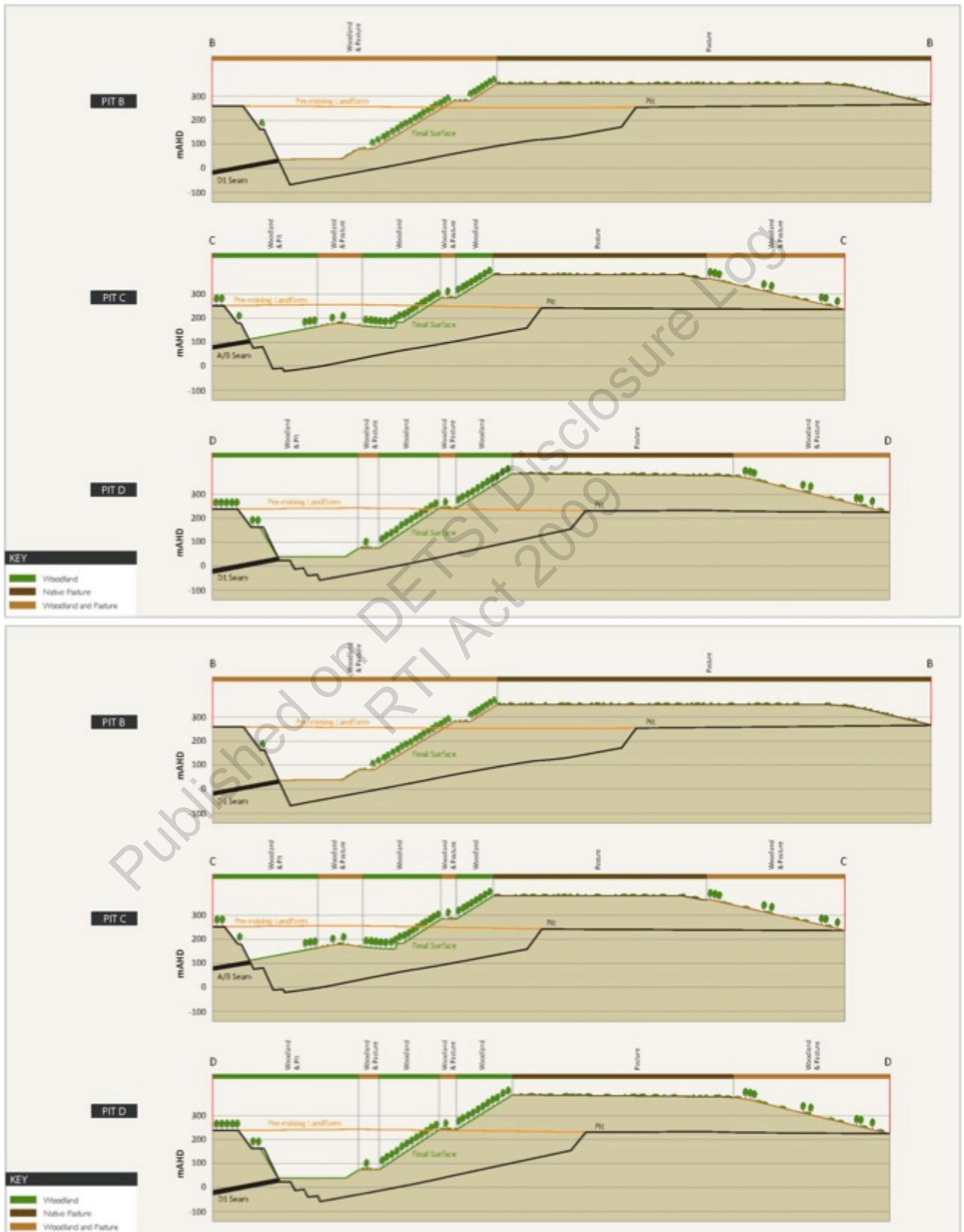


Figure F1: Water Release and Monitoring Locations



Figure H1: Cross Sections of Residual Voids



Note – this figure, as well as figures H3 and H4, are solely to conceptually support the cross-sections illustrated in Figure H1. They are not an authorisation of disturbance, or final land use. That authorisation is contained within other conditions of this environmental authority.



Figure H3: Final Landform (Central Section)

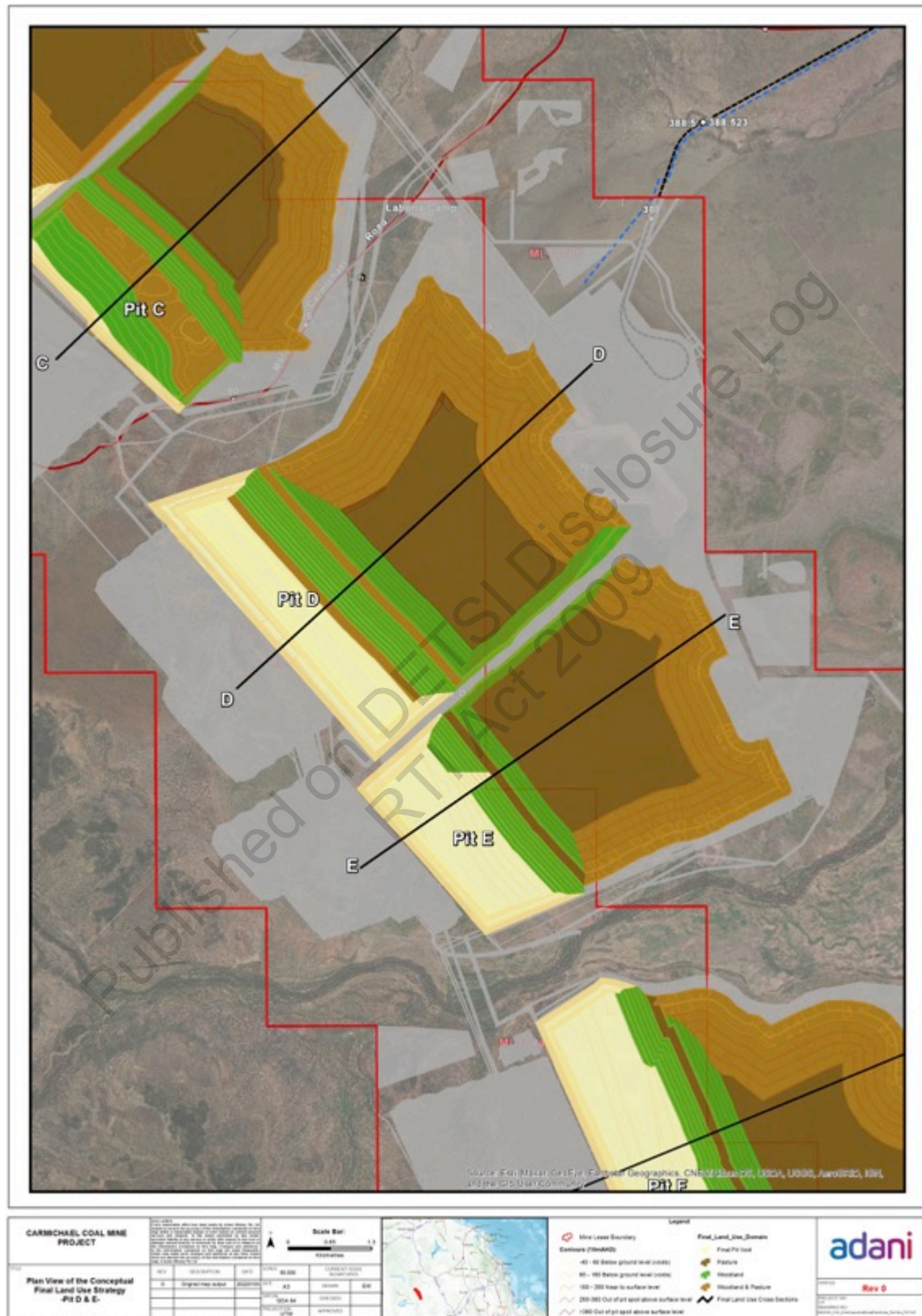


Figure H4: Final Landform (Southern Section)

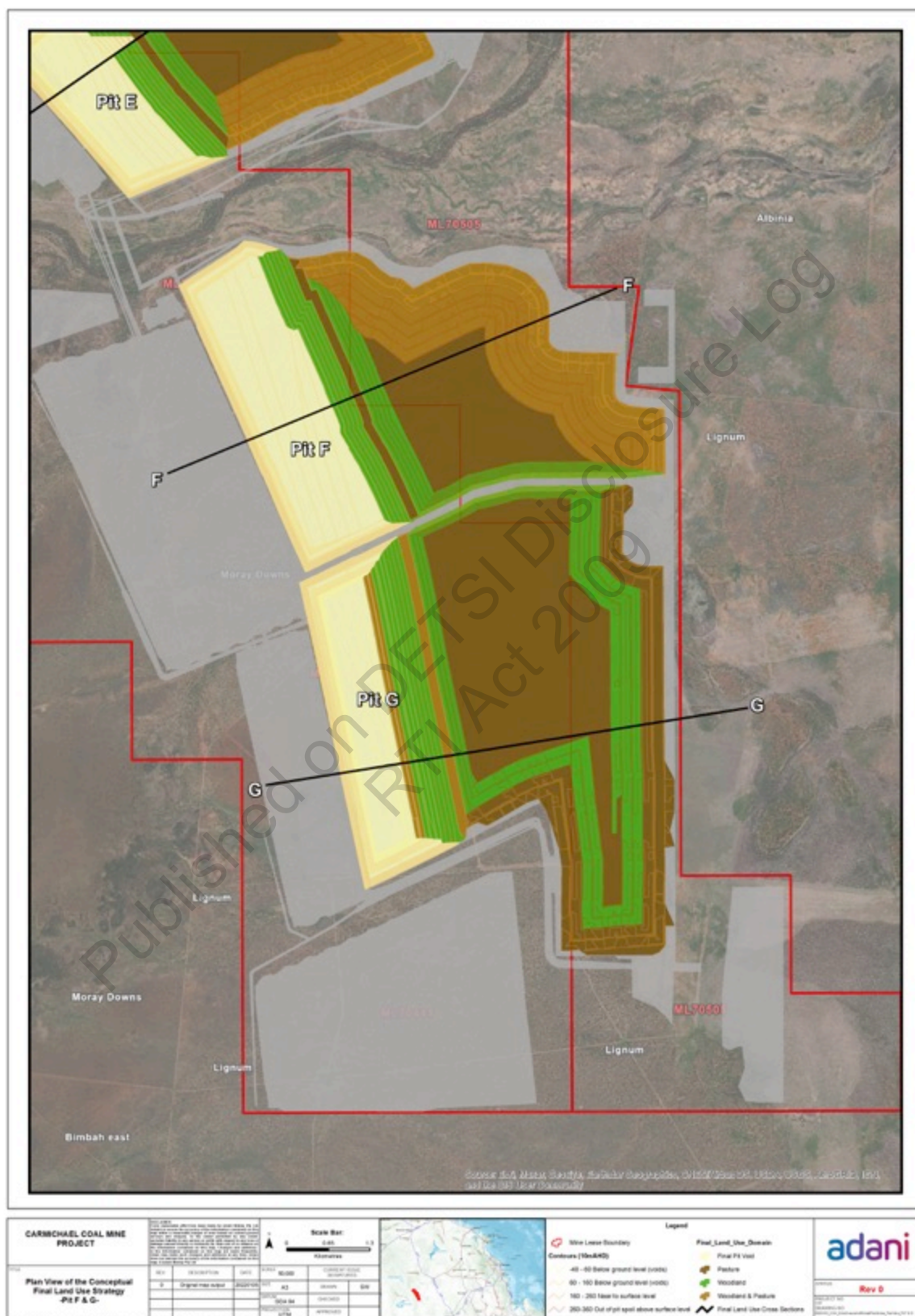


Figure H5: Final Post Mining Land Form

Note – Figure H5 is intended to support the Rehabilitation acceptance criteria detailed in Table H1 within Appendix 2. Where there is an inconsistency between Figure H5, and Table H1, Table H1 prevails.

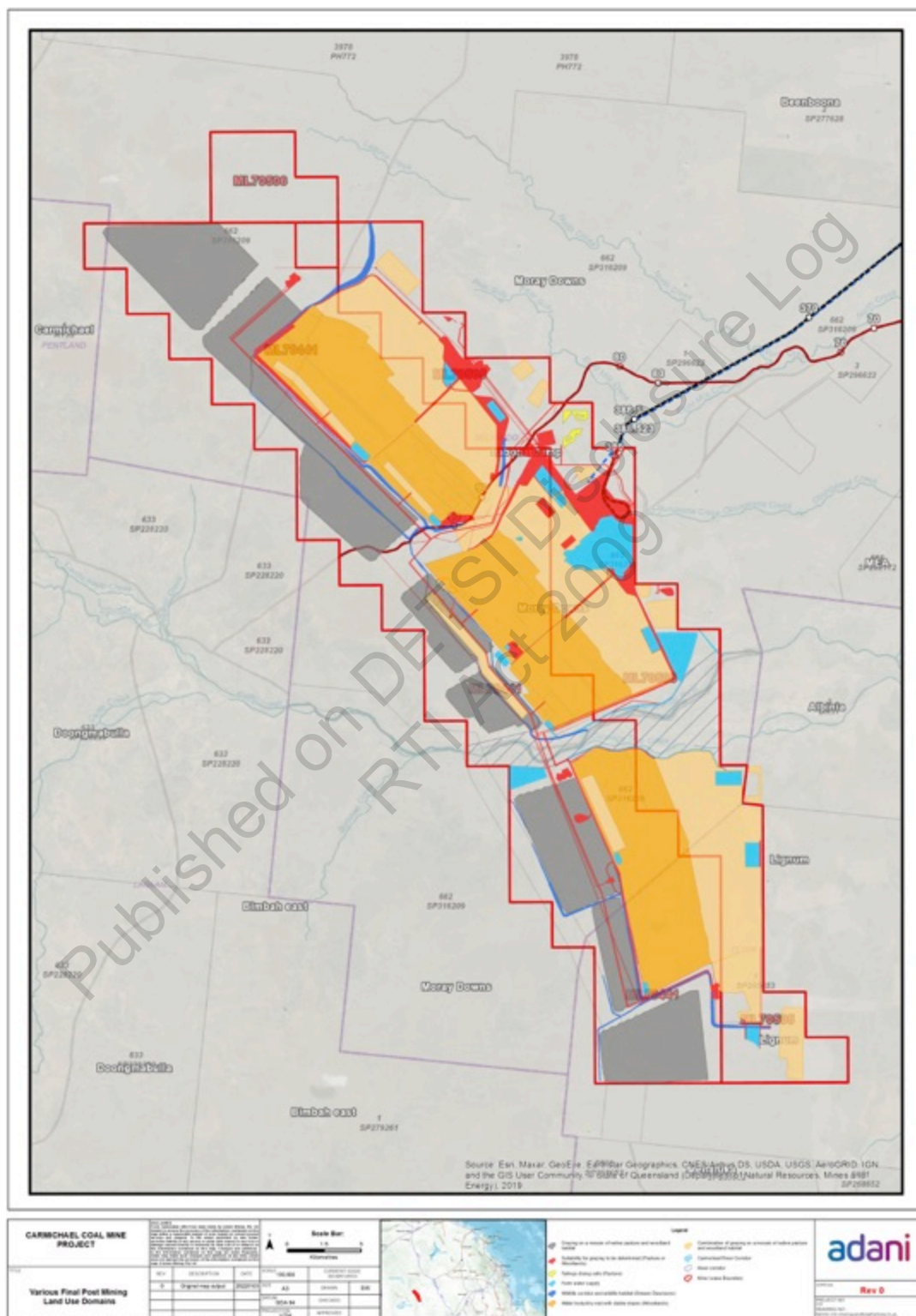
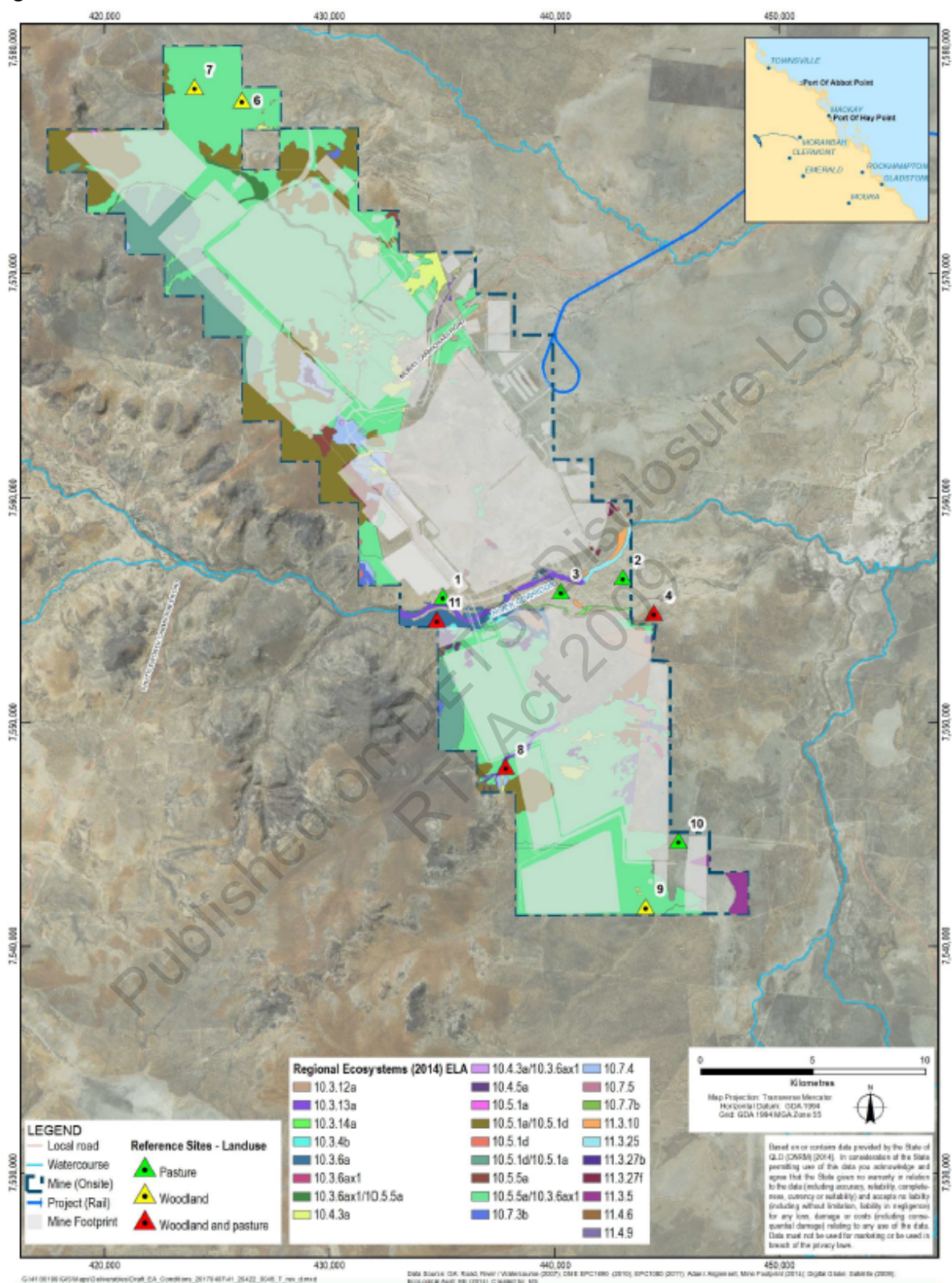


Figure H6: Reference Sites



END OF APPENDIX 4.

Appendix 5: Tables

Table E1 - Groundwater monitoring locations and frequency

Monitoring Point ¹	Monitoring	Location		Surface RL (mAHD)	Reference RL (m AHD)	Monitoring Frequency	Comments Regarding Triggers
		Easting (GDA94 – Zone 55K)	Northing (GDA94 – Zone 55K)				
Alluvium							
C027P1	Water level and quality	433643	7554818	226.95	227.62	At least 2- to 3- monthly	Bore-specific triggers
C029P1	Water level and quality	437691	7555082	225.44	226.05		Bore-specific triggers
C14027SP	Water level and quality	444965	7558330	217.56	218.13		Bore-specific triggers
C14028SP	Water level and quality	443776	7559581	218.86	219.63		Bore-specific triggers
C19001SP	Water level and quality	438025	7555853	227.06	227.95		Bore-specific triggers.
C19019SP	Boundary Bore. Water level and quality	432845	7572555	255.35	255.91		No baseline data, (Dry Bore) triggers to be developed
C19021SP	Boundary Bore. Water level and quality	430226	7576369	264.61	265.55		No baseline data, (Dry Bore) triggers to be developed
C19023SP	Boundary Bore. Water level and quality	436338	7570630	225.15	225.91		No baseline data, (Dry Bore) triggers to be developed
C19024SP	Seepage Bore. Water level and quality	433447	7561376	253.59	254.53		No baseline data, (Dry Bore) triggers to be developed
C19025SP	Seepage Bore. Water level and quality	433612	7561775	247.49	248.41		No baseline data, (Dry Bore) triggers to be developed
HD03B	Water level and quality	427559	7556119	229.41	230.16	Bore-specific triggers	
Tertiary							
C025P2	Water level and quality	438010	7555845	227.48	228.24	At least 2- to 3- monthly	Bore-specific triggers
C029P2	Water level and quality	437688	7555081	225.37	226.00		Bore-specific triggers
C558P1	Water level and quality	430312	7566903	250.07	250.72		Bore-specific triggers
C9845SPR	Water level and quality	439411	7544903	255.41	256.24		Bore-specific triggers

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C9180121SPR	Water level and quality	448085	7529364	226.46	227.75		Bore-specific triggers
C18004SP	Seepage Bore. Water level and quality	437013	7565647	228.79	229.47		Bore-specific triggers
C18005SP	Seepage Bore. Water level and quality	438984	7564556	221.01	221.66		Bore-specific triggers
C18006SP	Seepage Bore. Water level and quality	439880	7562706	221.49	222.27		Bore-specific triggers
C18007SP	Seepage Bore. Water level and quality	434500	7564054	231.53	232.22		No baseline data, (Dry Bore) triggers to be developed
C18008SP	Seepage Bore. Water level and quality	433744	7565456	235.89	236.47		No baseline data, (Dry Bore) triggers to be developed
C18009SP	Seepage Bore. Water level and quality	436936	7567301	226.00	226.75		Bore-specific triggers
C19020SP	Boundary Bore. Water level and quality	432847	7572550	255.86	256.54		No baseline data, (Dry Bore) triggers to be developed
C19022SP	Boundary Bore. Water level and quality	436340	7570625	225.23	225.92		No baseline data, triggers to be developed
Clematis Sandstone							
C14011SP	Water level and quality	426131	7561455	311.67	312.44	At least 2- to 3-monthly	Bore-specific triggers
C14012SP	Water level and quality	424896	7560596	286.37	287.06		Bore-specific triggers
C14013SP	Water level and quality	424895	7560591	286.47	287.26		Bore-specific triggers
C14021SP	Water level and quality	429796	7550966	277.59	278.59		Bore-specific triggers
C14033SP	Water level and quality	418211	7566776	296.47	297.35		Bore-specific triggers
C18001SP	Water level and quality	416312	7553052	246.97	247.35		Bore-specific triggers
C18002SP	Water level and quality	420948	7558952	248.30	249.28		Bore-specific triggers
C19002SP	Water level and quality	423799	7568106	305.33	306.27		Bore-specific triggers)
C19010SP	Nested bore. Water level and quality	427323.404	7556733.58	238.41	239.70		No baseline data. Triggers to be developed

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C19014SP	Nested bore. Water level and quality	423766	7556814	239.27	240.13		No baseline data. Triggers to be developed
HD02	Water level and quality	423822	7557008	236.35	237.42		Bore-specific triggers
HD03A	Water level and quality	427562	7556132	229.41	230.16		Bore-specific triggers
Dunda beds							
C022P1	Water level and quality	426813	7565962	273.76	274.15	At least 2- to 3-monthly	Bore-specific triggers
C027P2	Water level and quality	433648	7554819	227.58	228.38		Bore-specific triggers
C14023SP	Water level and quality	429802	7550969	277.675	278.675		Bore-specific triggers
C180117SP	Water level and quality	435915	7547522	279.59	280.67		Bore-specific triggers
C19007SP	Nested bore. Water level and quality	426268	7561274	310.28	310.94		Bore-specific triggers
C19011SP	Nested bore. Water level and quality	427337	7556725	238.068	238.868		Bore-specific triggers
C19015SP	Nested bore. Water level and quality	423768	7556827	239.385	240.365		Bore-specific triggers
Rewan Formation							
C008P1	Water level and quality	433713	7558834	238.14	238.64	At least 2- to 3-monthly	Bore-specific triggers
C035P1	Water level and quality	441404	7546824	236.31	236.79		Bore-specific triggers
C555P1	Water level and quality	432461	7557893	241.15	241.86		Bore-specific triggers
C556P1	Water level and quality	436524	7549882	260.63	261.42		Bore-specific triggers
C9553P1R	Water level and quality	421010	7573975	294.11	294.63		Bore-specific triggers
C9838SPR	Water level and quality	439558	7552812	228.81	229.6		Bore-specific triggers
C19008SP	Nested bore. Water level and quality	426268	7561277	310.18	311.07		No baseline data; Triggers to be developed
C19009SP	Nested bore. Water level only	426286	7561268	310.15	310.47		No quality triggers assigned
C19012SP	Nested bore. Water level and quality	427331.21	7556730	238.4	239.42		No baseline data; Triggers to be developed
C19017SP	Nested bore. Water level and quality	423736	7556825	239.62	239.935		No baseline data; Triggers to be developed

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C19028SP)	Water level only	439400	7540894	260.68	261.62		No quality triggers assigned
C919013SPR	Nested bore. Water level and quality	427345.98	7556721.4	238.1	238.29		No baseline data; Triggers to be developed
C919016SPR	Nested bore. Water level and quality	423767	7556821	239.4	240.23		Bore-specific triggers
C19842C (VWP)	VWP – assessment of depressurisation trends only	423736	7556821	239.77			No quality triggers assigned
Bandanna Formation ²							
C14200VWP1	VWP – assessment of depressurisation trends only	440547	7533419	247.08		At least 2- to 3-monthly	No quality triggers assigned
C14206VWP_1		429783	7550957	227.15			No quality triggers assigned
C14207VWP1		423807	7568105	305.17			No quality triggers assigned
C851VWP1		441384	7542877	244.67			No quality triggers assigned
C851VWP2		441384	7542877	244.75			No quality triggers assigned
C968VWP_P5		424874	7570989	279.18			No quality triggers assigned
C008P2	Water level and quality	433710	7558830	238.12	238.805		Bore-specific triggers
C014P2	Water level and quality	430731	7563976	256.27	256.9		Bore-specific triggers
C016P2	Water level	422017	7574975	294.45	295.08		No quality triggers assigned
C018P2	Water level and quality	423988	7574849	281.32	282.06		Bore-specific triggers
C032P2	Water level and quality	439404	7544896	256.32	256.92		Bore-specific triggers
C035P2	Water level and quality	441402	7546828	236.24	236.67		Bore-specific triggers
C823SP	Water level	433605	7562864	246.07	247.33		No quality triggers assigned
C847SP	Water level and quality	442385	7543809	237.01	237.92		Bore-specific triggers
C19018SP	Nested bore. Water level and quality	423737	7556834	239.28	239.56		No baseline data; Triggers to be developed
C19027SP	Water level and quality	427832	7566929	262.37	263.34		Bore-specific triggers
Colinlea Sandstone							
C006P3R	Water level and quality	435727	7560835	233.86	234.36	At least 2- to 3-	Bore-specific triggers

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C011P3	Water level and quality	428846	7569955	254.54	255.08	monthly	Bore-specific triggers
C018P3	Water level and quality	423978	7574853	281.36	281.98		Bore-specific triggers
C024P3	Water level and quality	428909	7571761	258.62	259.16		Bore-specific triggers
C034P3	Water level and quality	442389	7547814	227.38	228.26		Bore-specific triggers
C833SP	Water level and quality	439559	7554779	223.3	224.61		Bore-specific triggers
C848SP	Water level and quality	442364	7543815	237.03	237.835		Bore-specific triggers
C975SP	Water level and quality	426824	7573002	266.81	267.81		Bore-specific triggers
C9849SPR	Water level	442384	7543808	236.69	237.69		No quality triggers assigned
C19003SP	Water level	443571	7541484	229.8	231.36		No quality triggers assigned
C19004SP	Water level	442278	7541451	238.43	239.355		No quality triggers assigned
C19026SP	Water level	434698	7559985	238.44	239.28		No quality triggers assigned
C19029SP	Water level and quality	438685	7557647	224.74	225.445		Bore-specific triggers
C056VWP1	VWP – assessment of depressurisation trends only	424924	7569972	283.86			No quality triggers assigned
C558VWP1		430312	7566903	250.05			No quality triggers assigned
C968VWP_P2		424874	7570989	279.18			No quality triggers assigned
C19031SP (VWP)	VWP – assessment of depressurisation trends only	423753	7556845	238.92		No quality triggers assigned	
Joe-Joe Group							
C012P1	Water level and quality	430888	7569874	247.33	247.94	At least 2- to 3-monthly	Bore-specific triggers
C012P2	Water level and quality	430887	7569877	247.25	247.87		Bore-specific triggers
C14002SP	Water level	441978	7561158	226.23	226.925		No quality triggers assigned
C14003SP	Water level and quality	440351	7568519	217.97	218.98		Bore-specific triggers
C14004SP	Water level	440356	7568513	217.97	218.92		No quality triggers assigned
C14006SP	Water level and quality	443447	7556785	218.98	219.68		Bore-specific triggers
C14008SP	Water level and quality	444761	7552698	219.54	220.66		Bore-specific triggers
C14015SP	Water level and quality	445302	7536139	228.22	229.3		Bore-specific triggers

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C14016SP	Water level	444852	7541471	221.75	222.72		No quality triggers assigned
C14017SP	Water level and quality	447525	7526907	229.23	230.43		Bore-specific triggers
C14032SP	Water level and quality	448356	7533401	221.13	222.44		Bore-specific triggers
C180119SP	Water level and quality	448588	7536355	223.13	224.33		Bore-specific triggers
C180123SP	Water level and quality	448079	7529358	226.47	227.85		Bore-specific triggers
C914001SPR	Water level and quality	441973	7561150	226.15	227.25		Bore-specific triggers
C914030SPR	Water level and quality	445072	7548821	216.96	218.06		Bore-specific triggers
C9180124SPR	Water level and quality	448600	7536358	223.19	224.29		Bore-specific triggers
C9180125SPR	Water level and quality	447040	7531739	222.5	223.8		Bore-specific triggers
Additional Monitoring Bores ³							
Moolayember Formation							
C14020SP	Water level and quality	418233	7566780	296.55	297.37	At least 2- to 3-monthly	Triggers not required
C18003SP	Water level and quality	420944	7558964	248.22	249.08		Triggers not required
Composite Bore							
C14024SP (Clematis/Rewan)	Water level	430037	7543917	332.58	333.31	At least 2- to 3-monthly	No quality triggers for composite bores
C14029SP (Tertiary/Joe Joe)	Water level	445059	7548821	216.87	218.17		
C14031SP (Tertiary/Joe Joe)	Water level	448331	7533407	221.06	222.02		
C180120SP (Tertiary/Joe Joe)	Water level	447057	7531730	222.4	223.6		
C180122SP (Tertiary/Joe Joe)	Water level	448580	7536349	222.95	224.14		
Springs							
Joshua Spring	Water level and quality	421202	7559388	241.17 (243.26)*	NA	At least 2- to 3-monthly	Triggers not required
Mellaluka Spring	Water level and quality	446826	7531904.29	224.4	NA		
C18010SP	Water level and quality	421610	7556861	237.84	238.21		

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C18011SP	Water level and quality	422045	7556286	240.11	240.618		
C18012SP	Water level and quality	420424	7557642	239.03	239.541		
C18013SP	Water level and quality	420428	7557637	238.66	239.167		
C18014SP	Water level and quality	424640	7557046	235.48	235.974		

Notes

1. Monitoring is not required where a bore has been removed as a direct result of the mining activity.
2. Bandanna Formation bore C007P2 will be decommissioned within 1-2 years (as at February 2022) and has not been included in Table E1. However, until the bore is decommissioned, water level and water quality monitoring must be undertaken.
3. Although monitoring of composite bores and Moolayember Formation are not required in the EA, these bores will add value to the monitoring network, allowing for additional assessment of potential groundwater impacts.
4. *The two surface RLs for Joshua Spring refer to: the floor of the spring and (top of turkey's nest). Measurements are taken relative to the top of turkey's nest.

- Notes:**
1. Monitoring is not required where a bore has been removed as a direct result of the mining activity.
 2. RL must be measured to the nearest 5cm from the top of the bore casing.
 3. Locations, monitoring frequency and surface RL to be finalised based on information provided to the administering authority under Condition E8 (a). Contaminant trigger levels to be finalised for each aquifer type based on information provided to the administering authority under Condition E8 (a)

Table E2 Groundwater Quality Monitoring Parameters

Parameter Group	Parameter	Units	Trigger Applies
<i>Physiochemical Parameters</i>	Temperature (Field)	°C	No
	Dissolved oxygen (Field)	mg/L	No
	Oxidation Reduction Potential (Field)	mV	No
	pH (Laboratory)	pH Unit	No
	pH (Field)	pH Unit	Yes
	Electrical Conductivity (Laboratory)	µS/cm	No
	Electrical Conductivity (Field)	µS/cm	Yes
	Total Dissolved Solids (Laboratory)	mg/L	No
<i>Alkalinity</i>	Hydroxide Alkalinity as CaCO ₃	mg/L	No
	Carbonate Alkalinity as CaCO ₃	mg/L	No
	Bicarbonate Alkalinity as CaCO ₃	mg/L	No
	Total Alkalinity as CaCO ₃	mg/L	No
	Total Hardness as CaCO ₃	mg/L	No
<i>Major ions</i>	Sulfate as SO ₄	mg/L	Yes
	Chloride	mg/L	No
	Calcium	mg/L	No
	Fluoride	mg/L	No
	Magnesium	mg/L	No
	Sodium	mg/L	No
	Potassium	mg/L	No
	Total Anions	meq/L	No
	Total Cations	meq/L	No
	Ionic Balance	%	No
<i>Total and Dissolved Metals (triggers and limits apply to the dissolved fraction only)</i>	Aluminium	mg/L	Yes
	Arsenic	mg/L	Yes
	Boron	µg/L	Yes
	Cadmium	mg/L	No
	Chromium	mg/L	No
	Cobalt	mg/L	Yes
	Copper	mg/L	Yes
	Iron	mg/L	Yes
	Lead	mg/L	No
	Manganese	mg/L	No
	Mercury	mg/L	Yes
	Molybdenum	mg/L	Yes
	Nickel	mg/L	Yes
	Selenium	mg/L	Yes
	Silver	mg/L	Yes
	Uranium	mg/L	No
	Vanadium	mg/L	No
	Zinc	mg/L	Yes
<i>Flouride</i>	Fluoride	mg/L	No
<i>Nutrients</i>	Ammonia as N	mg/L	No
	Nitrate as N	mg/L	Yes
	Total Nitrogen as N	mg/L	No
	Total Phosphorus as P	mg/L	Yes
<i>Total Recoverable</i>	C6 - C10 Fraction	µg/L	Yes

Parameter Group	Parameter	Units	Trigger Applies
Hydrocarbons	>C10 - C40 Fraction	µg/L	Yes
BTEXN ^a	Benzene	µg/L	No
	Toluene	µg/L	No
	Ethylbenzene	µg/L	No
	Meta- & para-Xylene	µg/L	No
	Ortho-Xylene	µg/L	No
	Total Xylenes	µg/L	No
	Sum of BTEX	µg/L	No
	Naphthalene	µg/L	No

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Table E3 –Groundwater Quality Trigger Levels

Alluvium							
Parameter ^a	Units	HD03B	C027P1	C029P1	C14027SP	C14028SP	C19001SP
pH (field)	N/A	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0
Electrical conductivity	µS/cm	893	7240	33550	50740	45000	24880
Total dissolved solids	mg/L	540	4400	20355	38720	32500	16170
Sulphate	mg/L	13	530	1100	2200	1900	820
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	650	12510	997	4537	1217	60
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 as P	mg/L	0.16	0.1	0.35	0.19	0.1	0.1
Boron	µg/L	180	830	5255	2890	3150	2133
Cobalt	µg/L	1.4	8	12	66	23	1.4
Copper	µg/L	4.5	9	65	180	25	3
Nickel	µg/L	11	22	20	48	11	16
Zinc	µg/L	19.5	50	26	276	72	8

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TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20		
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100		
Tertiary Sediments										
Parameter ^a	Units	C025P2	C029P2	C558P1	C9845SPR	C9180121SPR	C18004SP ^b	C18005SP ^b	C18006SP ^b	C18009SP ^b
pH (field)	N/A	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.8-9.0	5.5 - 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0
Electrical conductivity	µS/cm	14685	12100	9656	2000	3800	40525	53150	61160	25700
Total dissolved solids	mg/L	8698	7485	6232	1200	2300	36400	45880	50510	21560
Sulphate	mg/L	440	310	260	64	98	803	2380	2997	946
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	34
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	7760	1440	410	5	344	120	170	674	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	0.1	0.7	0.7	0.7	0.7	0.7
Total Phosphorus as P	mg/L	0.24	0.1	0.1	0.1	0.1	0.1	0.37	0.1	0.1
Boron	µg/L	1658	1260	840	240	314	1423	5070	5855	1328
Cobalt	µg/L	1.4	1.4	3	1.4	1.4	1.4	17	14	1.4
Copper	µg/L	10	20	122	180	3	1.4	185	1.4	12
Nickel	µg/L	12	11	55	11	11	30	37	23	13

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Zinc	µg/L	22	32	67	41	2160	8	120	8	46	
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20	20	20	
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100	100	100	
Clematis Sandstone											
Parameter ^a	Units	C14011SP	C14012SP	C14013SP	C14021SP	C14033SP	HD02	HD03A	C18001SP	C18002SP	C19002SP ^c
pH (field)	N/A	4.9 - 9.0	6.0 – 9.0	4.9 - 9.0	5.6 - 9.0	5.1- 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.4- 9.0
Electrical conductivity	µS/cm	272	490	410	620	377	633	730	667	380	343
Total dissolved solids	mg/L	173	290	248	369	233	380	430	379	225	202
Sulphate	mg/L	6	6	11	21	4	5	12	9	1	8
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	15	45	13	14	11	1297	640	1648	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	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus as P	mg/L	0.1	0.1	0.1	0.1	0.1	0.19	0.1	0.1	0.18	0.1
Boron	µg/L	110	120	120	130	90	113	140	120	65	110
Cobalt	µg/L	2	1.4	4	1.4	2	2	1.4	1.4	1.4	1.4
Copper	µg/L	13	1.4	16	8	13	1.4	1.4	1.4	1.4	6

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Nickel	µg/L	11	11	11	11	11	11	11	11	11	
Zinc	µg/L	82	22	117	56	60	25	45	96	10	72
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100	100	100	100
Dunda Beds											
Parameter ^a	Units	C022P1	C027P2	C14023SP	C180117SP	C19007SP	C19011SP	C19015SP			
pH (field)	N/A	5.2 - 9.0	5.6 - 9.0	6.0 – 9.0	5.7- 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0		
Electrical conductivity	µS/cm	288	786	748	360	1390	797	712			
Total dissolved solids	mg/L	182	489	432	220	821	468	398			
Sulphate	mg/L	7	21	3	17	27	1	1			
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	44	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	2477	5	1498	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 as P	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1			
Boron	µg/L	130	210	90	76	73	25	100			

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Cobalt	µg/L	51	2	1.4	1.4	1.4	1.4	1.4
Copper	µg/L	68	2	1.4	103	1.4	1.4	1.4
Nickel	µg/L	11	11	11	20	11	11	11
Zinc	µg/L	47	45	8	73	8	8	8
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100
Rewan Formation								
Parameter^a	Units	C008P1	C035P1	C555P1	C556P1	C9553P1R	C9838SPR	C919016SPR
pH (field)	N/A	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.4 - 9.0	5.8 - 9.0	5.2 - 9.0	6.0 – 9.0
Electrical conductivity	µS/cm	22790	4000	830	260	526	414	787
Total dissolved solids	mg/L	15690	2400	490	172	316	252	460
Sulphate	mg/L	244	57	1	11	59	8	20
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	2155	342	1764	65	2700	23	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	0.26	0.1	0.1	0.2	0.3	0.1	0.1

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Boron	µg/L	1580	710	264	110	210	133	60
Cobalt	µg/L	10	1.4	1.4	5	1.4	1.4	1.4
Copper	µg/L	16	1.4	1.4	26	34	10	1.4
Nickel	µg/L	29	11	11	11	11	11	11
Zinc	µg/L	59	50	31	44	40	48	37
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	238	100	100	100	188	100	100
Bandanna Formation								
Parameter^a	Units	C008P2	C014P2	C032P2	C035P2	C19027SP	C018P2	C847SP
pH (field)	N/A	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	5.3 – 9.0
Electrical conductivity	µS/cm	2916	1927	1300	1541	1789	1800	358
Total dissolved solids	mg/L	1800	1077	790	916	1000	1005	257
Sulphate	mg/L	91	40	2	20	27	7	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	58	178	235	444	5	533	22
Mercury	µg/L	0.06	0.06	0.06	0.06	0.06	0.06	0.06

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Nitrate as N	mg/L	0.7	0.7	0.7	0.7	0.7	0.7	0.7		
Total Phosphorus as P	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1		
Boron	µg/L	266	347	370	261	537	570	110		
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	8		
Nickel	µg/L	11	24	11	11	11	11	11		
Zinc	µg/L	24	8	24	24	8	15	54		
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20		
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100		
Colinlea Sandstone (D Seam)										
Parameter ^a	Units	C006P3R	C011P3	C018P3	C024P3	C034P3	C833SP	C848SP	C975SP	C19029SP ^d
pH (field)	N/A	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 11.2	6.0 – 9.0	5.4 – 9.0	6.0 – 9.0
Electrical conductivity	µS/cm	1030	960	1020	1500	2000	1210	3000	608	1127
Total dissolved solids	mg/L	631	574	610	860	1200	800	1800	353	673
Sulphate	mg/L	6	1	15	23	30	8	20	27	1
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	34
Selenium	µg/L	11	11	11	11	11	11	11	11	11

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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	240	474	860	18220	2796	46	1832	91		165	
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 as P	mg/L	0.1	0.1	0.1	0.18	0.1	0.1	0.1	0.1		0.1	
Boron	µg/L	160	450	360	371	250	190	190	190		380	
Cobalt	µg/L	1.4	1.4	1.4	5	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	1.4	15		1.4	
Nickel	µg/L	11	11	11	36	11	11	11	11		11	
Zinc	µg/L	19	15	18	100	307	10	24	153		53	
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20	20		20	
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100	100	100	100	100	100		100	
Joe Joe Group												
Parameter ^a	Units	C012P1	C012P2	C14003SP	C14006SP	C14008SP	C14015SP	C14017SP	C14032SP	C180119SP	C180123SP	C914001SPR
pH (field)	N/A	5.7-9.0	6.0 – 9.0	5.2-9.0	6.0 – 9.0	5.7 - 9.0	6.0 – 9.0	6.0 – 9.0	5.5-9.0	6.0 – 9.0	6.0 – 9.0	5.9-9.0
Electrical conductivity	µS/cm	2067	2600	53230	8600	690	2500	6800	2160	758	840	21300
Total dissolved solids	mg/L	1301	1600	43245	5222	410	1570	4100	1230	441	516	14855
Sulphate	mg/L	56	53	2715	216	14	65	120	33	8	26	1500
Aluminium	µg/L	55	55	55	55	55	55	55	55	55	55	55
Arsenic	µg/L	13	13	13	13	13	13	13	13	13	13	13

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Molybdenum	µg/L	34	34	34	34	34	34	34	34	34	34	34
Selenium	µg/L	11	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	0.05
Iron	µg/L	95	443	17460	7988	2560	580	540	2126	1370	282	9140
Mercury	µg/L	0.06	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	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Total Phosphorus as P	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Boron	µg/L	447	500	3930	502	112	420	766	170	161	356	2000
Cobalt	µg/L	1.4	1.4	36	1.4	10	1.4	3	1.4	1.4	1.4	1.4
Copper	µg/L	1.4	40	660	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Nickel	µg/L	11	11	33	11	11	11	11	11	11	11	11
Zinc	µg/L	79	18	105	195	193	122	80	273	2000	8	170
TRH C6 - C10 Fraction	µg/L	20	20	20	20	20	20	20	20	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	100	289	100	100	100	100	100	100	100	100	100
Joe Joe Group												
Parameter^a	Units	C914030SPR					C9180124SPR			C9180125SPR		
pH (field)	N/A	5.7-9.0					5.5 - 9.0			6.0 – 9.0		
Electrical conductivity	µS/cm	602					473			1000		
Total dissolved solids	mg/L	348					280			607		
Sulphate	mg/L	12					7			18		

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Aluminium	µg/L	55	55	55
Arsenic	µg/L	13	13	13
Molybdenum	µg/L	34	34	34
Selenium	µg/L	11	11	11
Silver	µg/L	0.05	0.05	0.05
Iron	µg/L	749	110	78
Mercury	µg/L	0.06	0.06	0.06
Nitrate as N	mg/L	0.7	0.7	0.7
Total Phosphorus as P	mg/L	0.1	0.1	0.1
Boron	µg/L	119	92	286
Cobalt	µg/L	8	1.4	1.4
Copper	µg/L	1.4	3	3
Nickel	µg/L	11	11	11
Zinc	µg/L	180	656	223
TRH C6 - C10 Fraction	µg/L	20	20	20
TRH >C10 - C40 Fraction (sum)	µg/L	100	100	100

Notes:

^a Trigger values for hydrocarbons are defined at the limit of reporting (LOR) for each parameter, unless sufficient data warranted a bore specific trigger be derived. Since the LOR may vary between analyses due to methods and matrix effects, Table E2 lists triggers for Total Recoverable Hydrocarbon (TRH) fractions C6-C10 and >C10-C40, which have been selected using the lowest historical LOR. The lowest historical LOR thus provides a conservative measure to take into account this potential variation in LORs.

^b Bores with screened intervals in weathered tertiary.

^c C19002SP is a replacement bore for C180118SP. The triggers to be updated after additional data obtained in 2022. Till such time triggers for bore C180118SP will be used.

^d Triggers for C19029SP determined from combined dataset from C19029SP and C180114SP (bore C180114SP was replaced by C19029SP).

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Table E4 –Groundwater level thresholds

Groundwater level drawdown thresholds Monitoring ¹ Location	Unit	Easting (GDA94 – Zone 55)	Northing (GDA94 – Zone 55)	Groundwater Level Drawdown Threshold (m)
Carmichael River Location				
C027P1	Alluvium	433643.08	7554818.39	2.805
HD03B	Alluvium	427559.00	7556120.00	0.63
C027P2	Dunda Beds	433648.21	7554818.54	1.19
C029P1	Alluvium	437691.19	7555082.39	0.67
C029P2	Tertiary sediments	437687.63	7555080.91	0.55
C19001SP	Alluvium	438020.82	7555845.82	1.19
C025P2	Tertiary sediments	438010.34	7555844.69	1.50
C14028SP	Alluvium	443775.64	7559581.18	0.23
C14027SP	Alluvium	444964.65	7558330.02	0.13
C14006SP*	Joe Joe Group	443446.61	7556785.07	0.79
Great Artesian Basin to West of Mine Lease				
C19002SP	Clematis Sandstone	423804.06	7568099.87	2.07
C14033SP	Clematis Sandstone	418210.8	7566775.83	0.32
C14011SP	Clematis Sandstone	426130.96	7561454.81	0.58
C14012SP	Clematis Sandstone	424896.07	7560596.18	0.40
C14013SP	Clematis Sandstone	424895.49	7560591.10	0.43
HD02	Clematis Sandstone	423822.04	7557008.25	0.26

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HD03A	Clematis Sandstone	427562.00	7556132.00	0.69
C14021SP	Clematis Sandstone	429796.25	7550966.33	1.37
C022P1	Dunda Beds	426812.52	7565961.84	3.10
C027P2	Dunda Beds	433648.21	7554818.54	1.19
C14023SP	Dunda Beds	429801.74	7550968.73	0.39
C180117SP	Dunda Beds	435915.16	7547522.16	3.81
C9553P1R	Rewan Formation	421010.11	7573974.87	3.45
C556P1	Rewan Formation	436524.08	7549881.55	76.34
C555P1	Rewan Formation	432461.38	7557892.99	65.88
Doongmabulla to West of Mine Lease				
HD02	Clematis Sandstone	423822.04	7557008.25	0.26
HD03A	Clematis Sandstone	427562.00	7556132.00	0.69
C14013SP	Clematis Sandstone	424895.49	7560591.10	0.43
C022P1	Dunda Beds	426812.52	7565961.84	3.10
C14012SP	Clematis Sandstone / Rewan	424896.07	7560596.18	0.40
C14021SP	Clematis Sandstone	429796.76	7550966.33	1.37
C14206VWP_1 ²	AB Seam	429783.15	7550956.80	<u>32.4</u>
C558VWP1 ²	D seam	430311.51	7566903.01	<u>129</u>
C968VWP_P2 ²	D seam	424873.59	7570989.17	<u>186</u>
C968VWP_P5 ²	AB seam	424873.59	7570989.17	<u>154</u>

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C848SP	D seam	442363.39	7543815.03	115.7
Mellaluka Springs to the southeast of Mine Lease				
C851VWP2 ²	AB Seam	441384.00	7542877.33	122.4
C180120SP	Tertiary sediments/Joe Joe Group	447056.56	7531729.89	1.29
C180122SP	Tertiary sediments / Joe Joe Group	448579.21	7536348.70	0.42
C180119SP*	Joe Joe Group	448587.45	7536355.38	0.29
C180123SP*	Joe Joe Group	448077.54	7529357.50	0.34
C9180124SPR*	Joe Joe Group	448600.00	7536357.00	0.32
C9180125SPR*	Joe Joe Group	447039.74	7531738.83	0.56
Sentinel Bores				
C14016SP*	Joe Joe Group	444852.34	7541471.06	25.57
C9845SPR	Tertiary sediments	439410.87	7544903.28	19.48
C14029SP	Tertiary sediments / Joe Joe Group	445059.11	7548820.62	1.66
C14003SP	Joe Joe Group	440350.8	7568518.85	0.23
C914030SPR	Joe Joe Group	445072.27	7548821	2.07
C14015SP*	Joe Joe Group	445301.98	7536138.69	5.26
C016P2*	AB seam	422017.38	7574974.58	143.77
C14004SP	Joe Joe Group	440355.93	7568513.34	5.52
C14008SP*	Joe Joe Group	444760.74	7552697.83	1.58

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C180116SP	Rewan Formation	439392.91	7540908.81	15.14
C14024SP	Clematis Sandstone / Rewan Group	430036.80	7543917.13	1.92
C14020SP	Moolayember Formation	418230.28	7566782.35	0.27
<p>Note: ¹ The period of measurement for change threshold is the life of the mine.</p> <p>Note: ² VWP triggers for assessing depressurisation impacts from mine dewatering.</p> <p>Note: * The groundwater level threshold drawn for these bores will be updated in 2 years based on a review of groundwater data (logger data validation with future manual readings and datum measurements).</p>				

END OF APPENDIX 5.

END OF ENVIRONMENTAL AUTHORITY.

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MINISTER FOR THE ENVIRONMENT AND THE GREAT BARRIER REEF
MINISTER FOR SCIENCE AND MINISTER FOR MULTICULTURAL AFFAIRS

SUBJECT

- Right To Information (RTI) request for release of information regarding groundwater for the Carmichael Coal Mine.

BACKGROUND

- The environmental authority (EA) for the Carmichael Coal Mine is held by Adani Mining Pty Ltd (trading as Bravus Mining and Resources (Bravus)).

KEY ISSUES

- Rural Services of Coast and Country Incorporated (RSCC) have requested the release of information under the *Right to Information Act 2009* relating to the groundwater conditions of the Carmichael Coal Mine environmental authority (EA), in particular the groundwater model report.
- RSCC has requested all correspondence between DES, CSIRO and Geoscience Australia with respect to the groundwater EA conditions between 1 July 2022 to 2 March 2023.
- As required by a condition of the EA, Bravus submitted a groundwater model report to DES in February 2023. This report is publicly available under the public register provisions.
- DES took swift and strong action in response to the model report, issuing Bravus with an environmental protection order to require a second groundwater model re-run to be completed and a report provided to the department in May 2024.
- The order mandates that Bravus must not commence underground mining until the model report is approved by the department.
- Bravus has now appealed the decision to the court.
- To ensure the department's review of the report was based on the best available science, the department sought independent advice from CSIRO and Geoscience Australia.
- In their advice CSIRO and Geosciences Australia concluded that "the groundwater model is unable to support a robust uncertainty analysis and therefore confidence in the range of predicted impacts is low."
- DES then finalised its review and made the decision to not approve the model report.
- The documents located in the search are email correspondence between officers of a predominately technical in nature and some include attachments which are Bravus documents.

FINANCIAL IMPLICATIONS/GST

- Not applicable.

CONSULTATION

Internal consultation

- Litigation has reviewed the Dot Points for Minister and the Media Holding Statement for this RTI request.

External Consultation

- Not applicable.