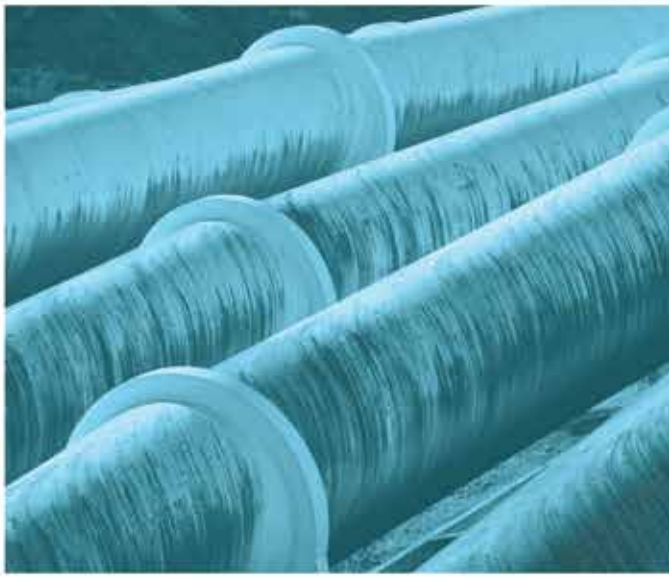



Wongawilli Colliery Modification Report

PA 09_0161 MOD 2 - North West Mains Development
Volume 9 - Appendix I (Part 4) and Appendix J

Prepared for Wollongong Coal Limited
December 2020

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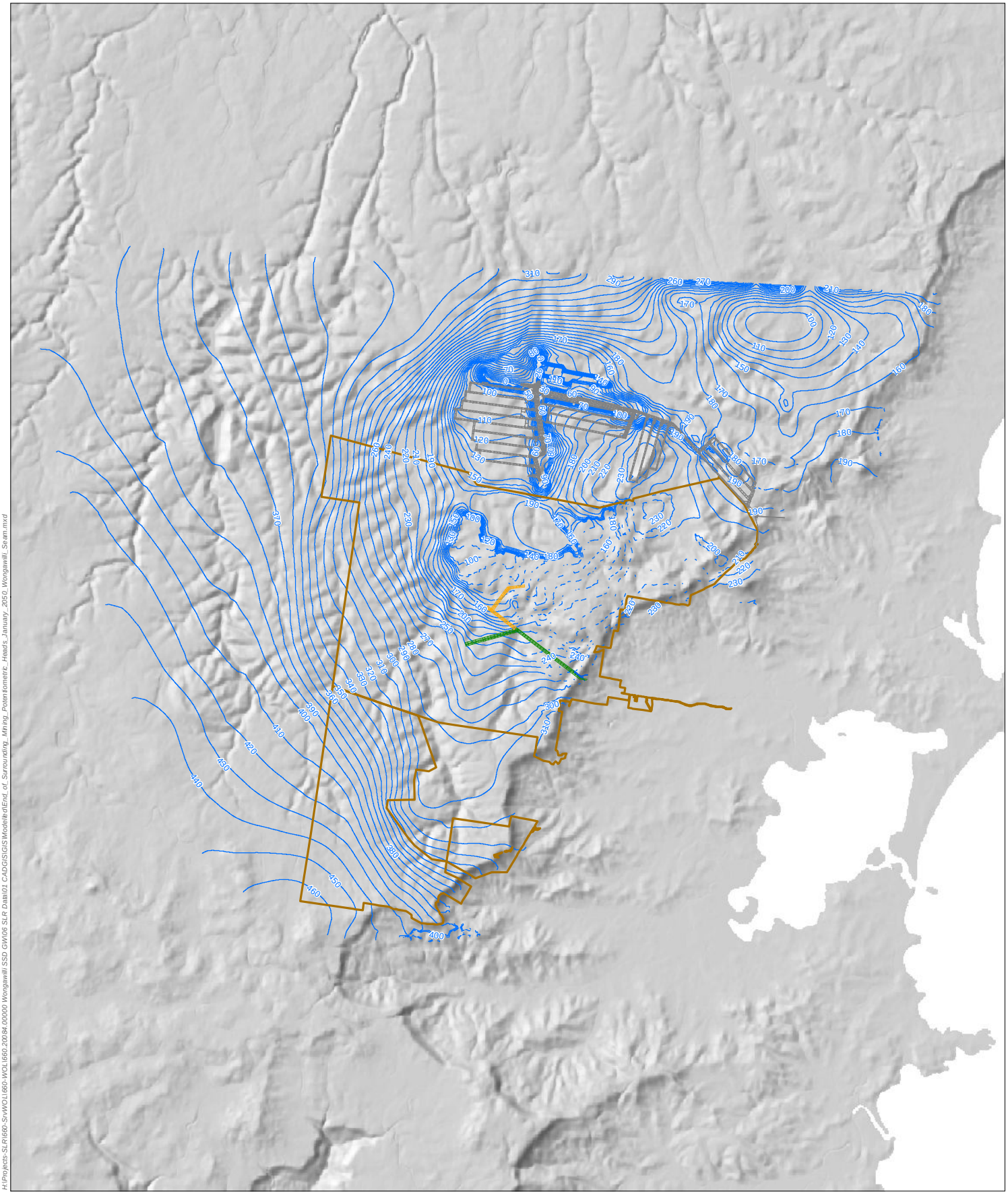
Appendix I - Part 4

Groundwater impact assessment



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Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

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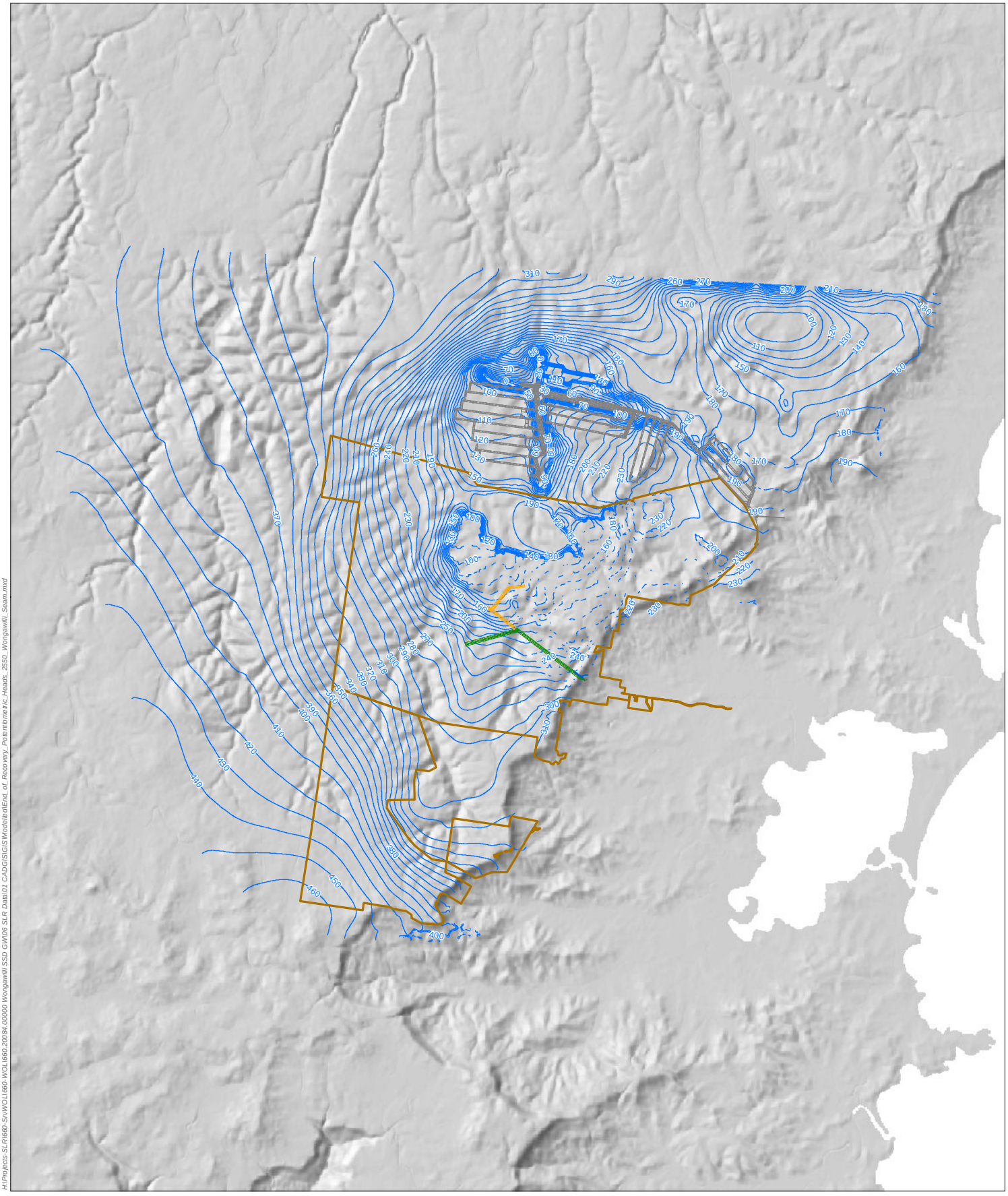
GROUNDWATER IMPACT ASSESSMENT

End of Surrounding Mining - Potentiometric Heads - January 2050 - Wongawilli Seam

C - 31

Legend

- Potentiometric Surface (mAHD)
- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease



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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease
- Potentiometric Surface (mAHD)

GROUNDWATER IMPACT ASSESSMENT

End of Recovery - Potentiometric Heads - 2550 - Wongawilli Seam

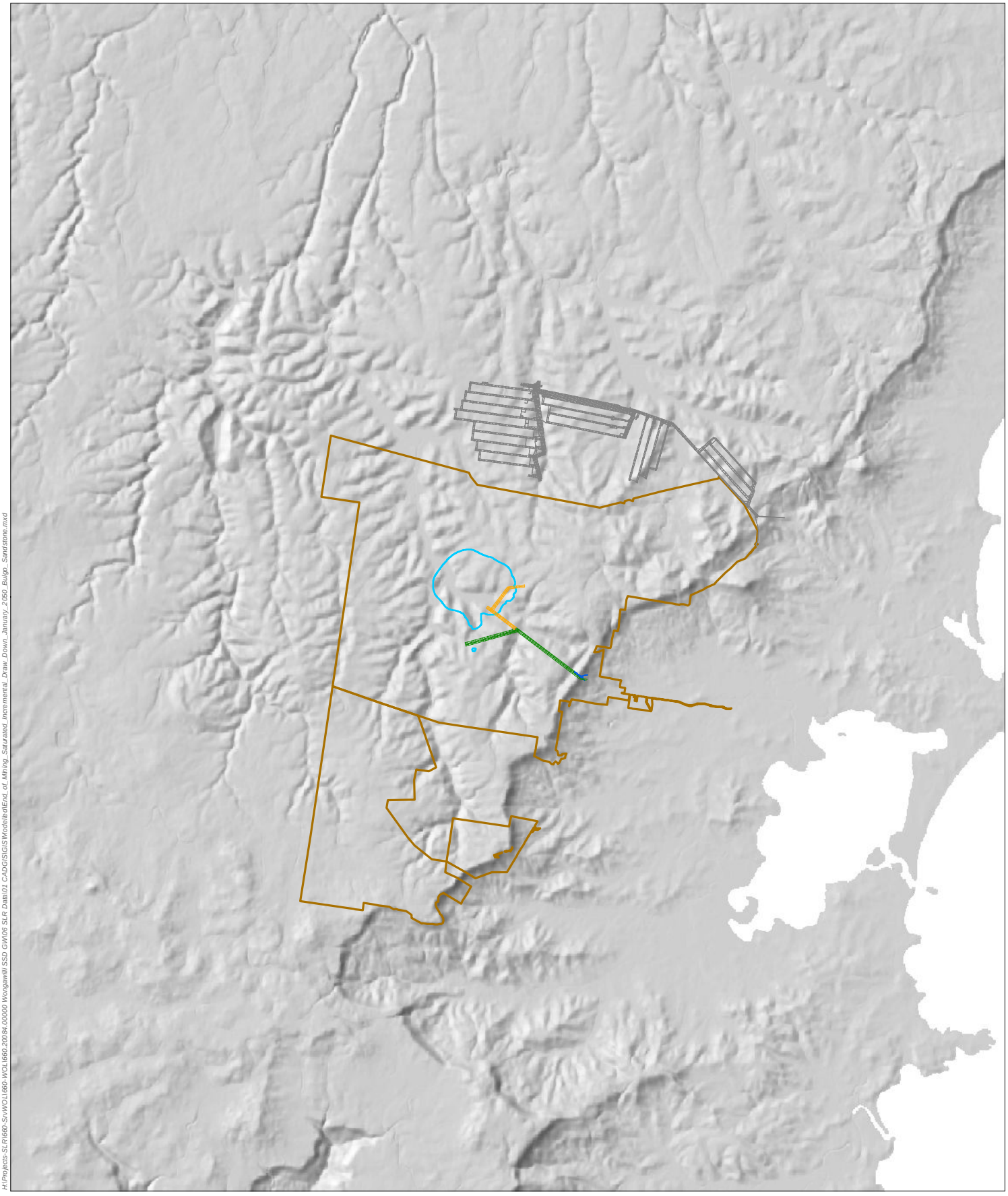
C - 32

APPENDIX D

Predicted Incremental Groundwater Drawdown Plots

Predicted Groundwater Drawdown Plots

D1 Incremental Drawdown -January 2050 – Bulgo Sandstone
D2 Incremental Drawdown -January 2550 (End of Recovery) – Bulgo Sandstone
D3 Incremental Drawdown -July 2022 (End of Year 1 Mining) – Bulli Seam
D4 Incremental Drawdown -July 2023 (End of Year 2 Mining) – Bulli Seam
D5 Incremental Drawdown -July 2024 (End of Year 3 Mining) – Bulli Seam
D6 Incremental Drawdown -January 2025 (End of Mining) – Bulli Seam
D7 Incremental Drawdown -January 2050 (End of Surrounding Mining) – Bulli Seam
D8 Incremental Drawdown -January 2550 (End of Recovery) – Bulli Seam
D9 Incremental Drawdown -July 2023 (End of Year 2 Mining) – Wongawilli Seam
D10 Incremental Drawdown -July 2024 (End of Year 3 Mining) – Wongawilli Seam
D11 Incremental Drawdown -January 2025 (End of Mining) – Wongawilli Seam
D12 Incremental Drawdown -January 2050 (End of Surrounding Mining) – Wongawilli Seam
D13 Incremental Drawdown -January 2550 (End of Recovery) – Wongawilli Seam



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GROUNDWATER IMPACT ASSESSMENT

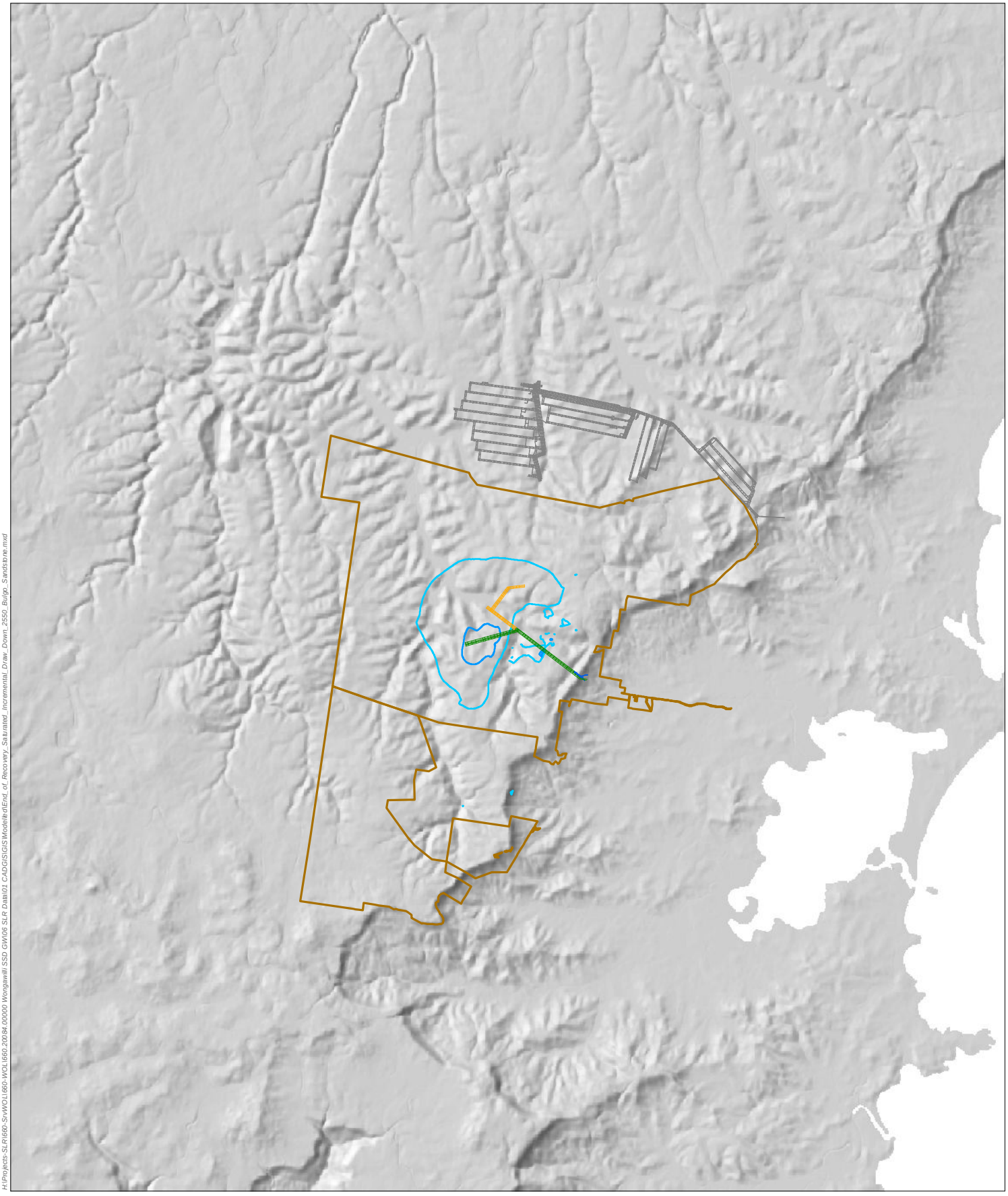
End of Surrounding Mining - Saturated Incremental Draw Down - January 2050 - Bulgo Sandstone

D - 1

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m) 1



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Legend

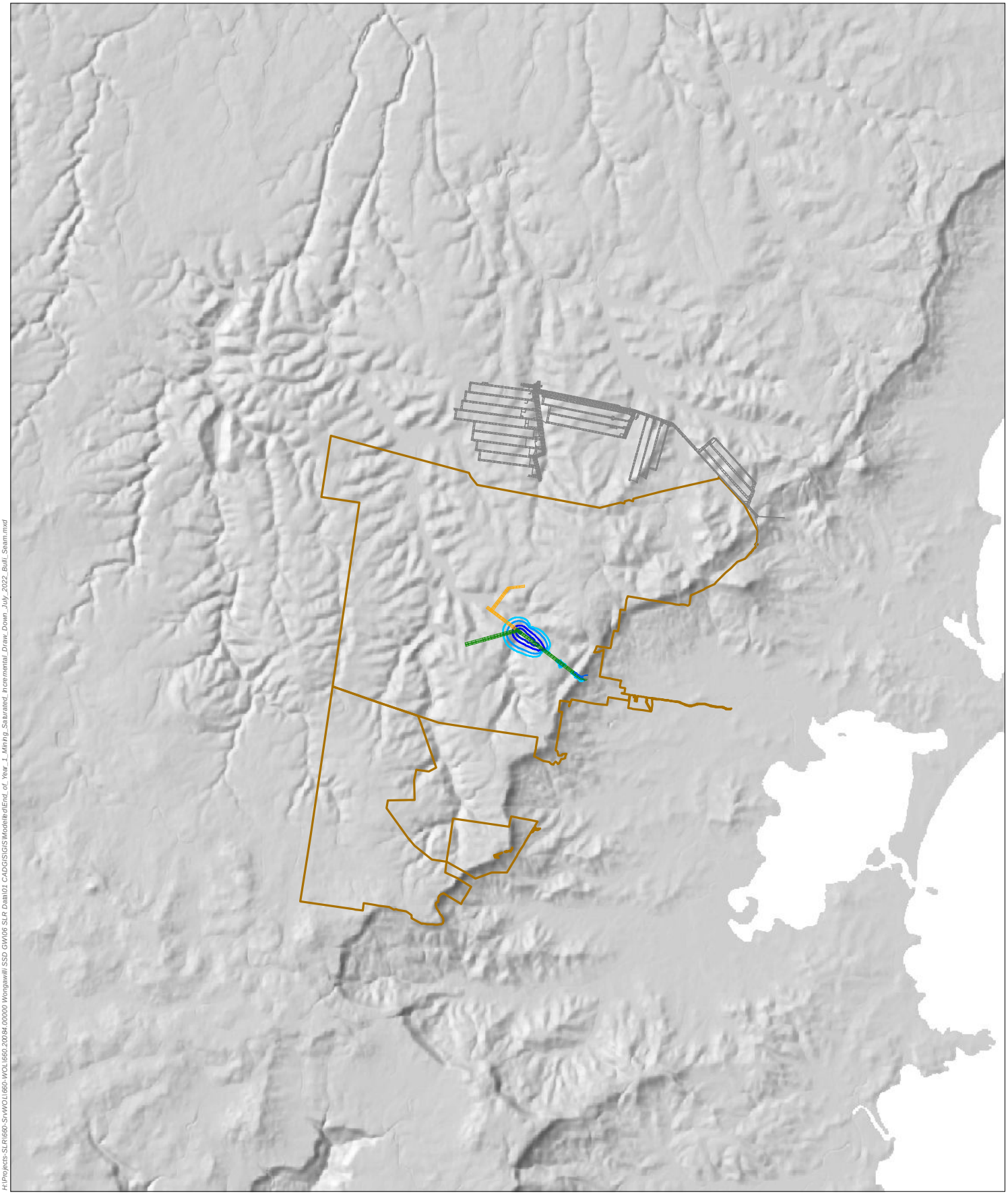
- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)
- 2
- 1

GROUNDWATER IMPACT ASSESSMENT

End of Recovery - Saturated Incremental Draw Down - 2550 - Bulgo Sandstone

D - 2



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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

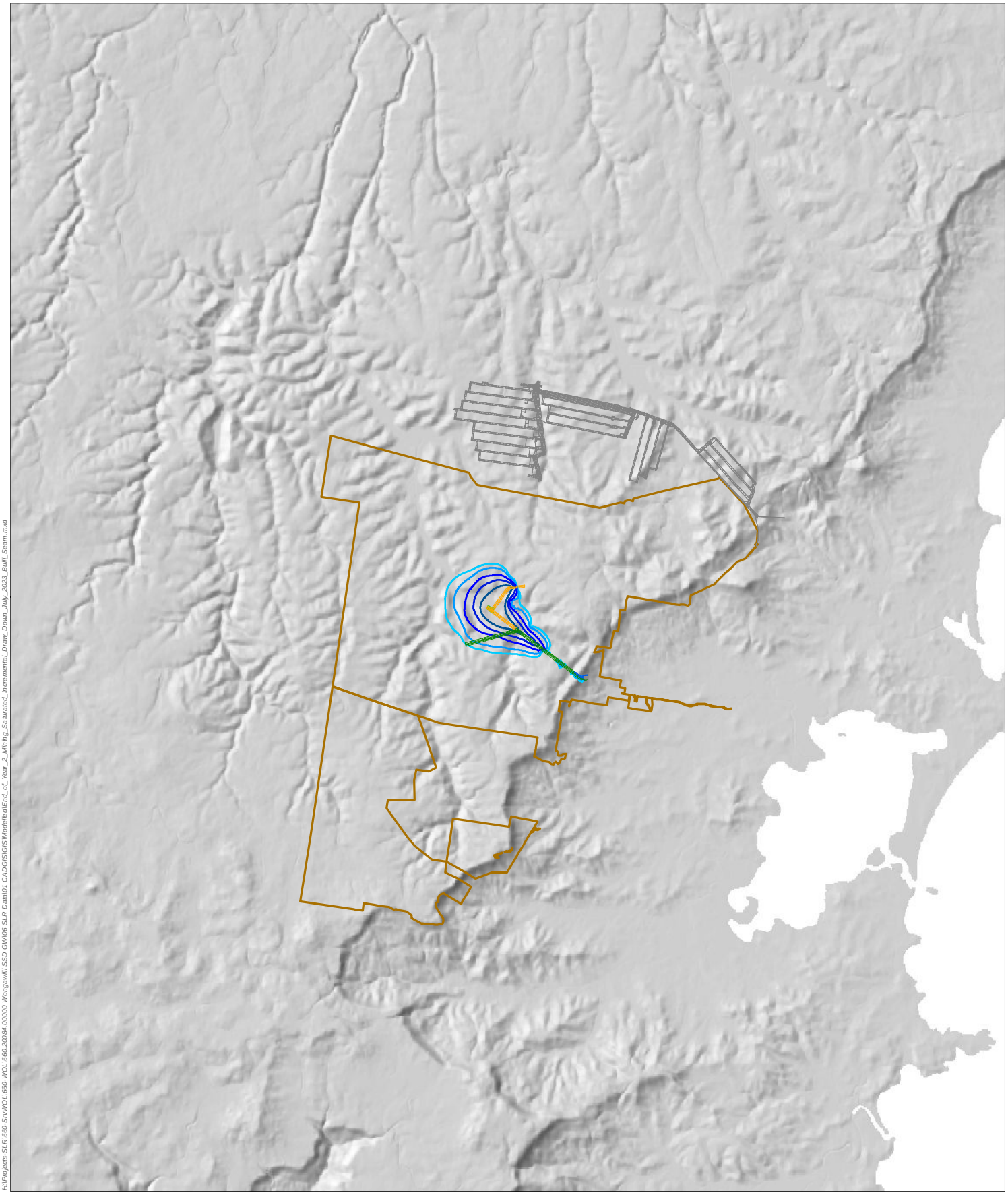
Drawdown (m)

- 1
- 2
- 5
- 10
- 20

GROUNDWATER IMPACT ASSESSMENT

End of Year 1 Mining - Saturated Incremental Draw Down - July 2022 - Bulli Seam

D - 3



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GROUNDWATER IMPACT ASSESSMENT

End of Year 2 Mining - Saturated Incremental Draw Down - July 2023 - Bulli Seam

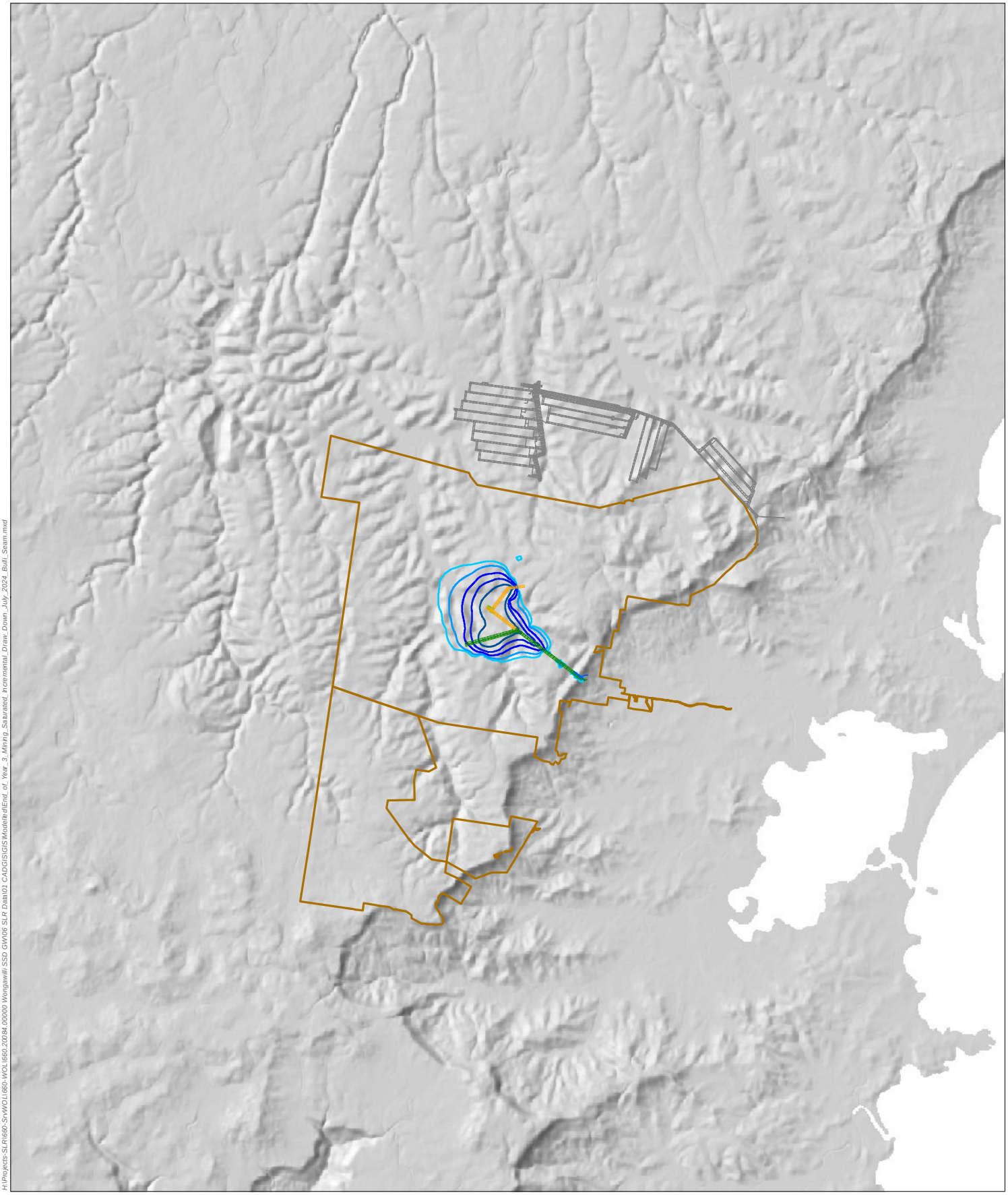
D - 4

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50



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0 2 km

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GROUNDWATER IMPACT ASSESSMENT

End of Year 3 Mining - Saturated Incremental Draw Down - July 2024 - Bulli Seam

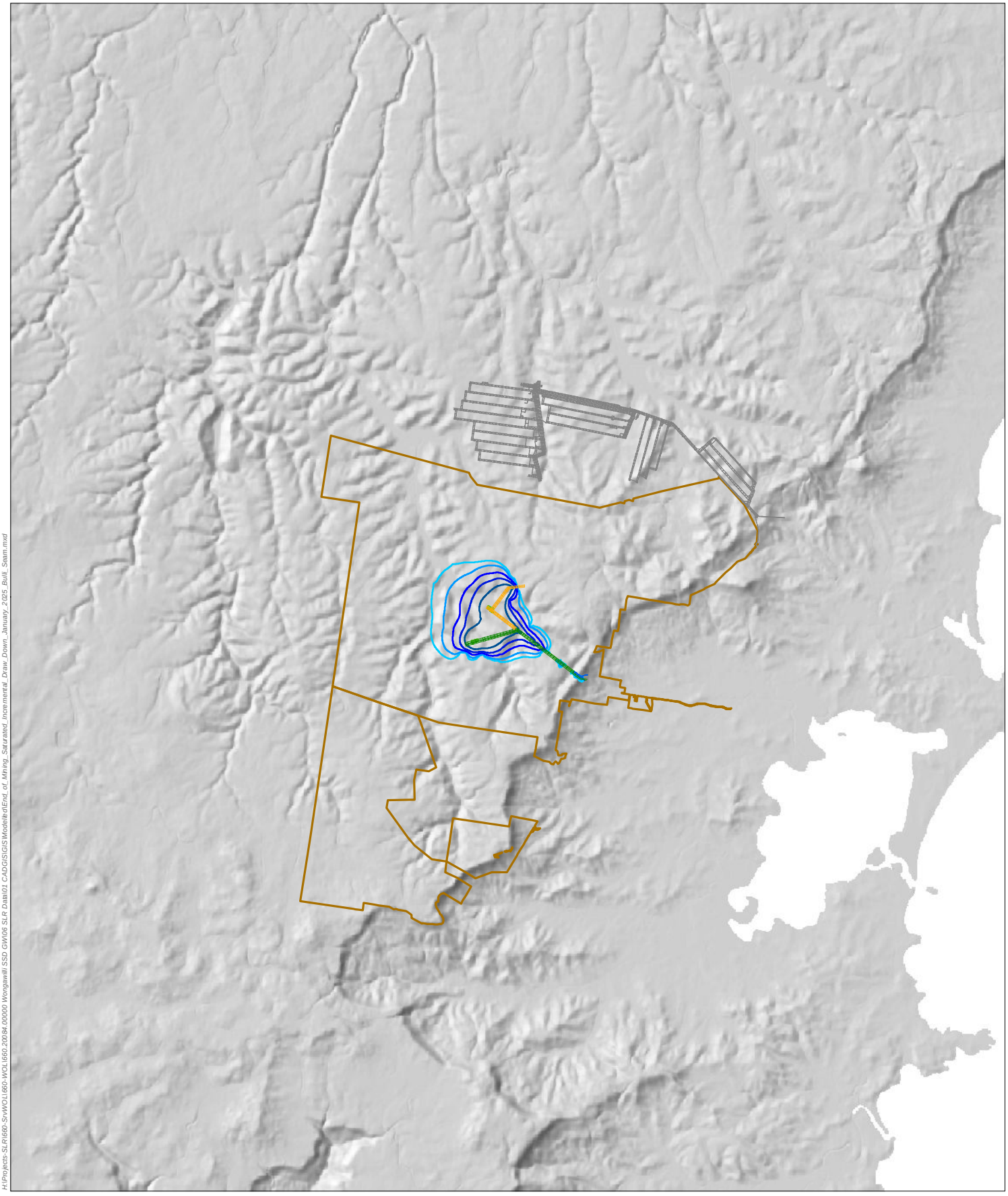
D - 5

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50



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0 2 km

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GROUNDWATER IMPACT ASSESSMENT

End of Mining - Saturated Incremental Draw Down - January 2025 - Bulli Seam

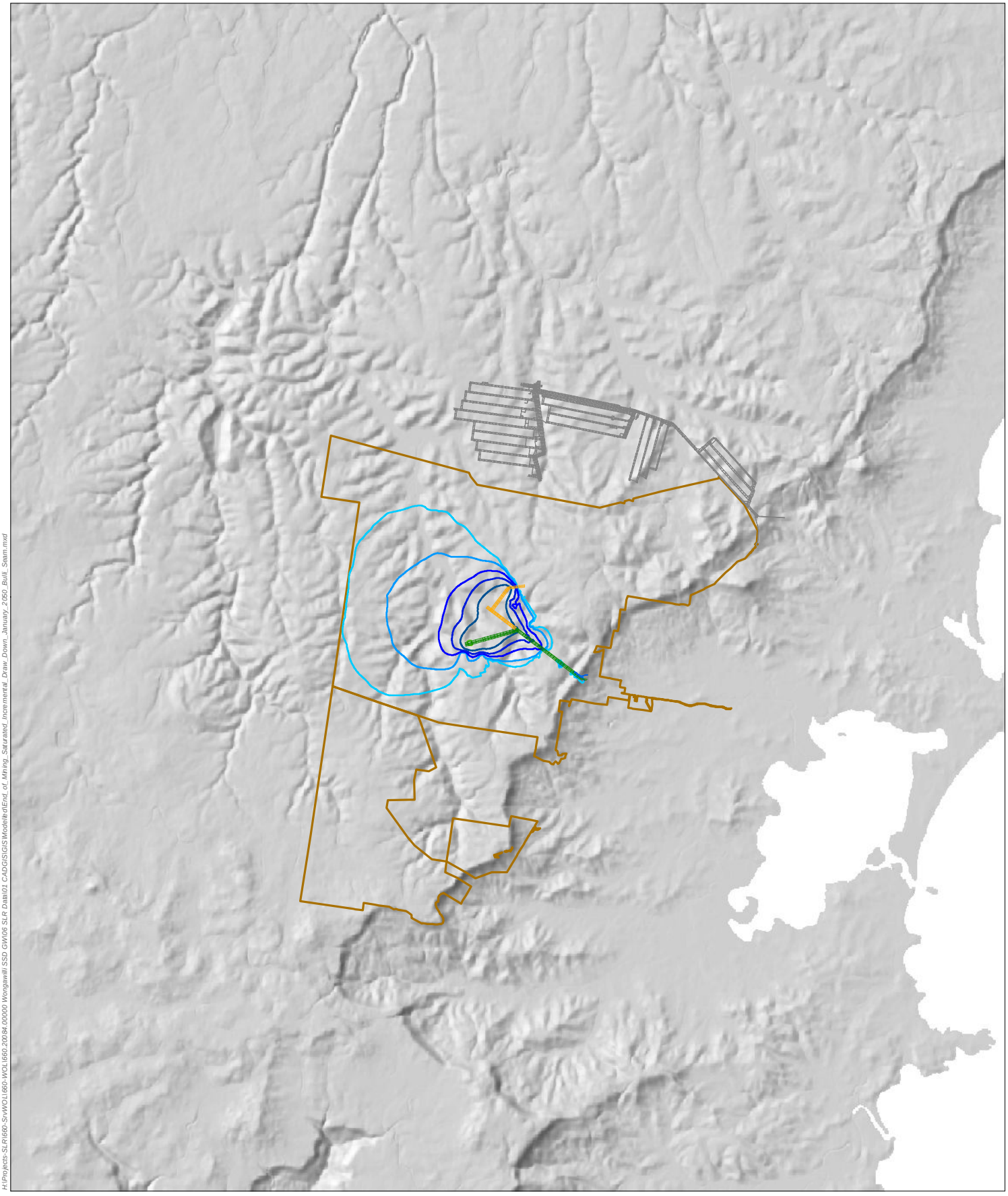
D - 6

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50



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0 2 km

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GROUNDWATER IMPACT ASSESSMENT

End of Surrounding Mining - Saturated Incremental Draw Down - January 2050 - Bulli Seam

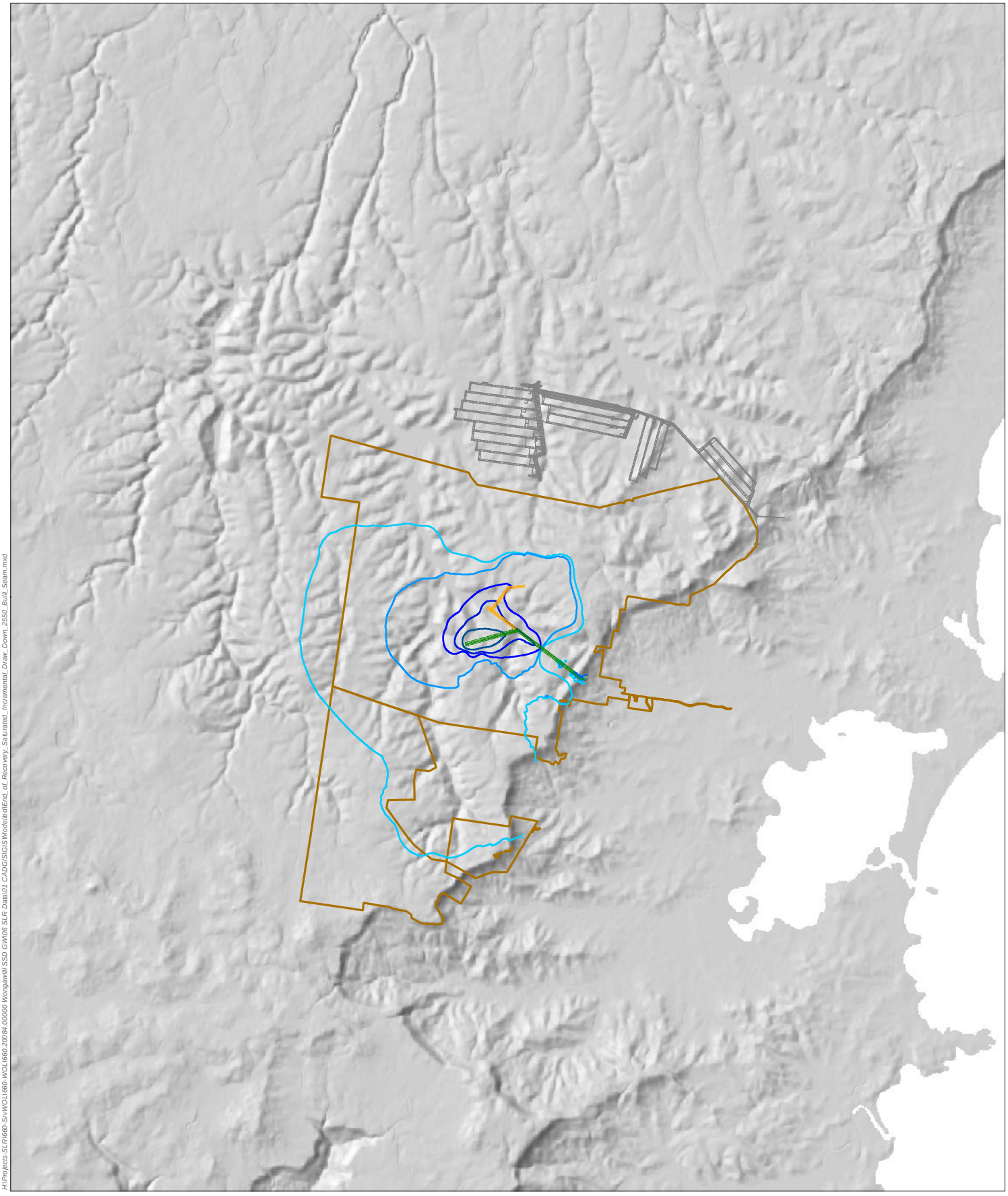
D - 7

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50



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GROUNDWATER IMPACT ASSESSMENT

End of Recovery - Saturated Incremental Draw Down - 2550 - Bulli Seam

D - 8

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20

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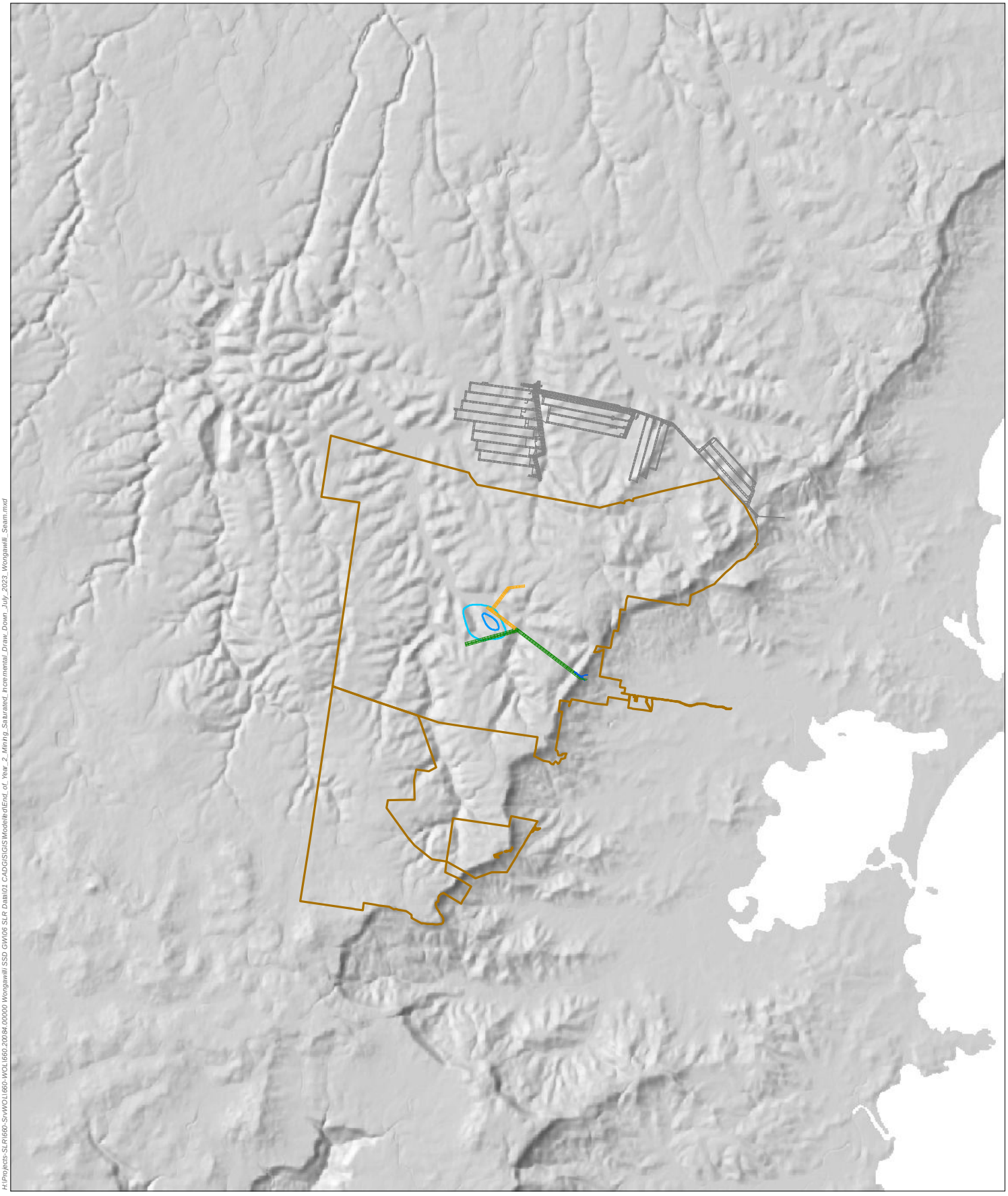

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Projection: GDA 1994 MGA Zone 56
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GROUNDWATER IMPACT ASSESSMENT

End of Year 2 Mining - Saturated Incremental Draw Down - July 2023 - Wongawilli Seam

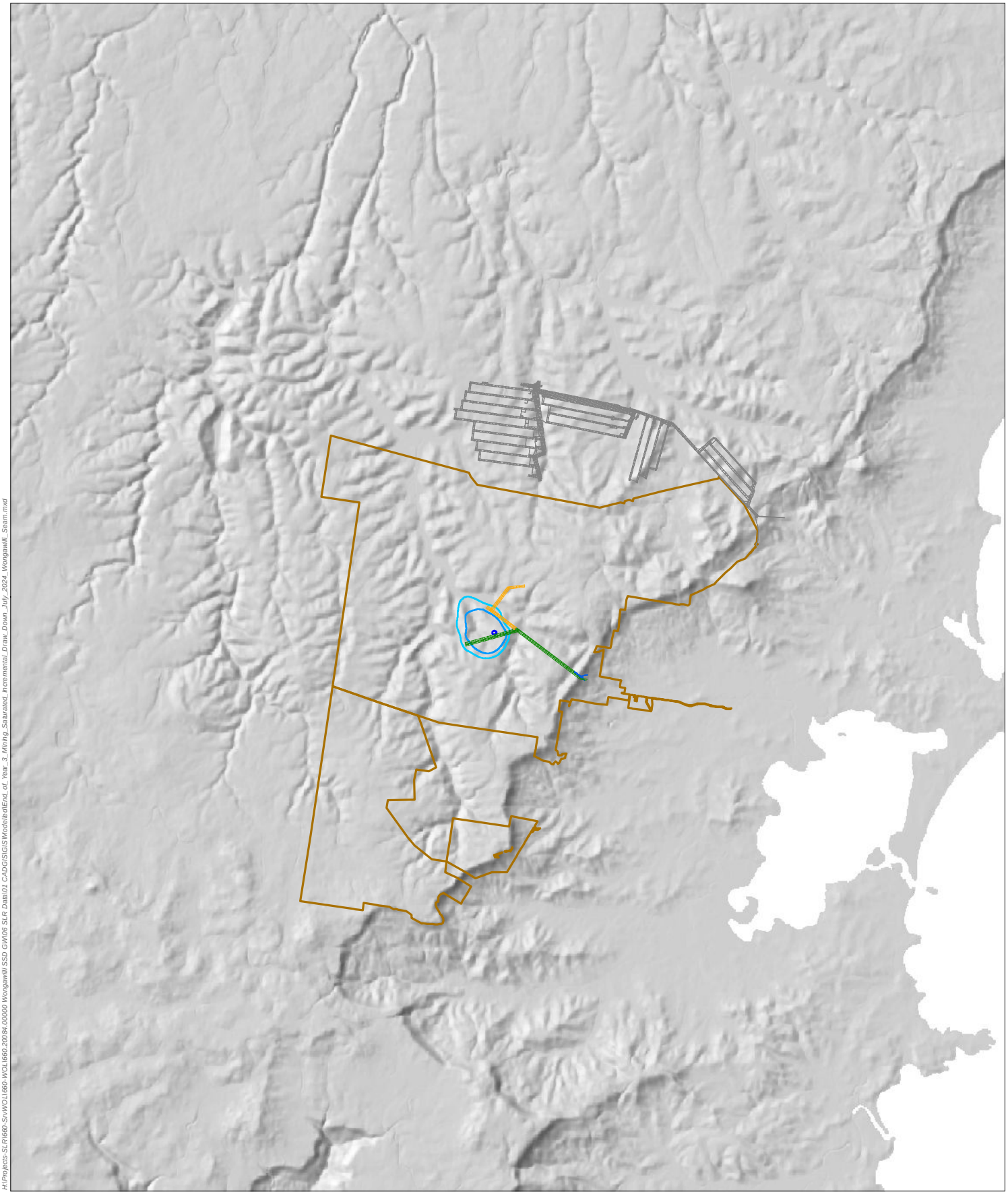
D - 9

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 2
- 1



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Legend

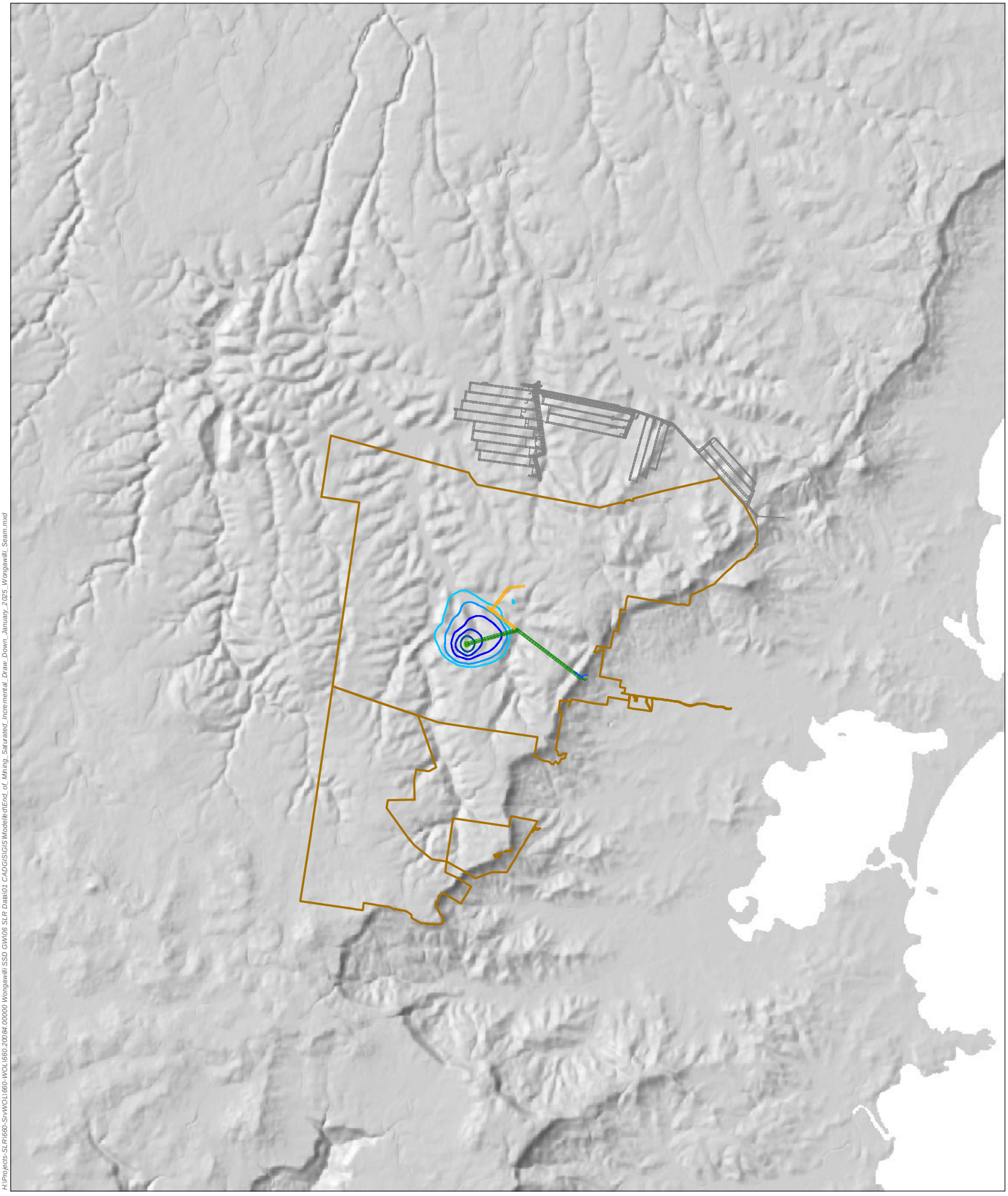
- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)
1
2
5

GROUNDWATER IMPACT ASSESSMENT

End of Year 3 Mining - Saturated Incremental Draw Down - July 2024 - Wongawilli Seam

D - 10



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GROUNDWATER IMPACT ASSESSMENT

End of Mining - Saturated Incremental Draw Down - January 2025 - Wongawilli Seam

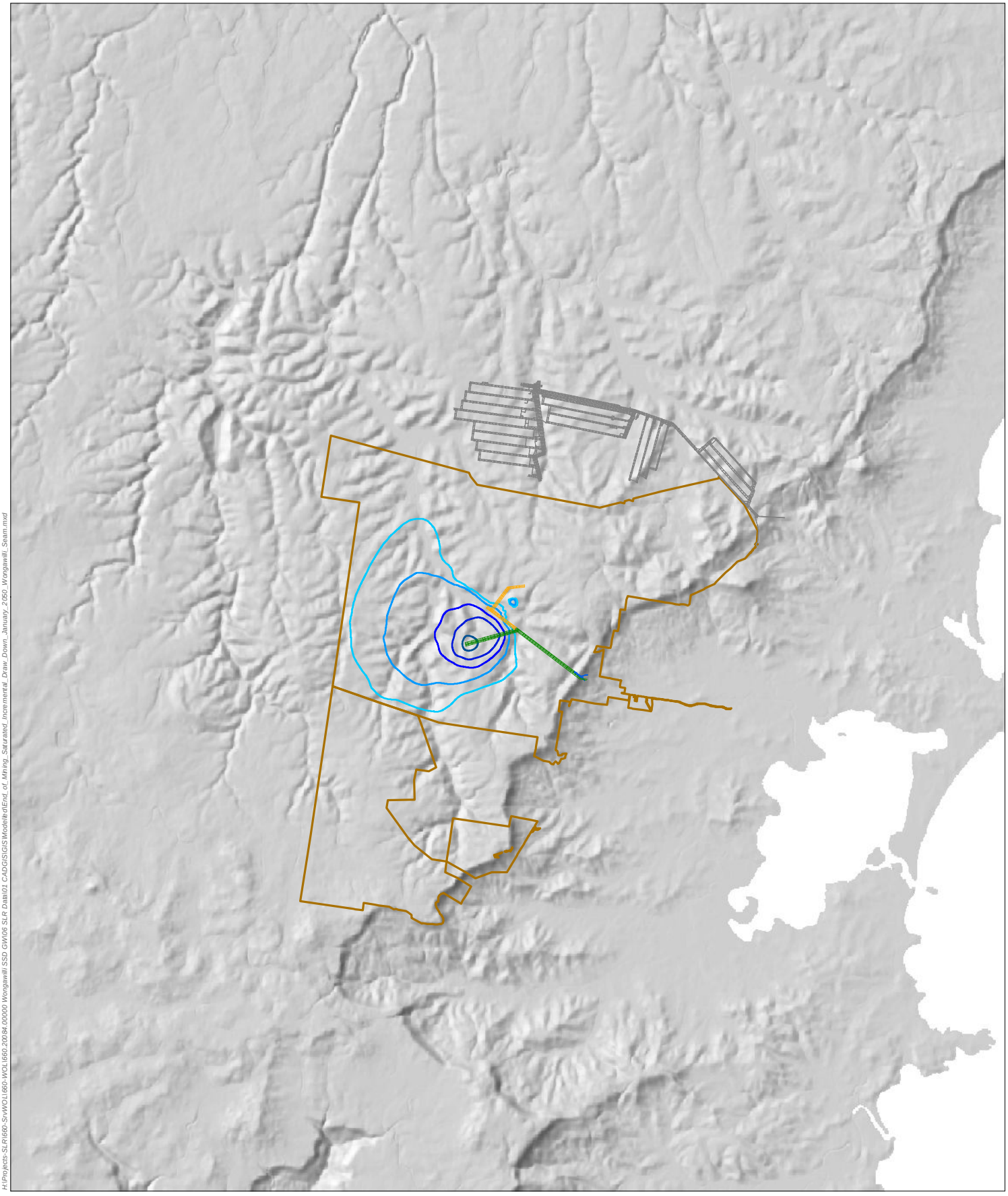
D - 11

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50



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0 2 km

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GROUNDWATER IMPACT ASSESSMENT

End of Surrounding Mining - Saturated Incremental Draw Down - January 2050 - Wongawilli Seam

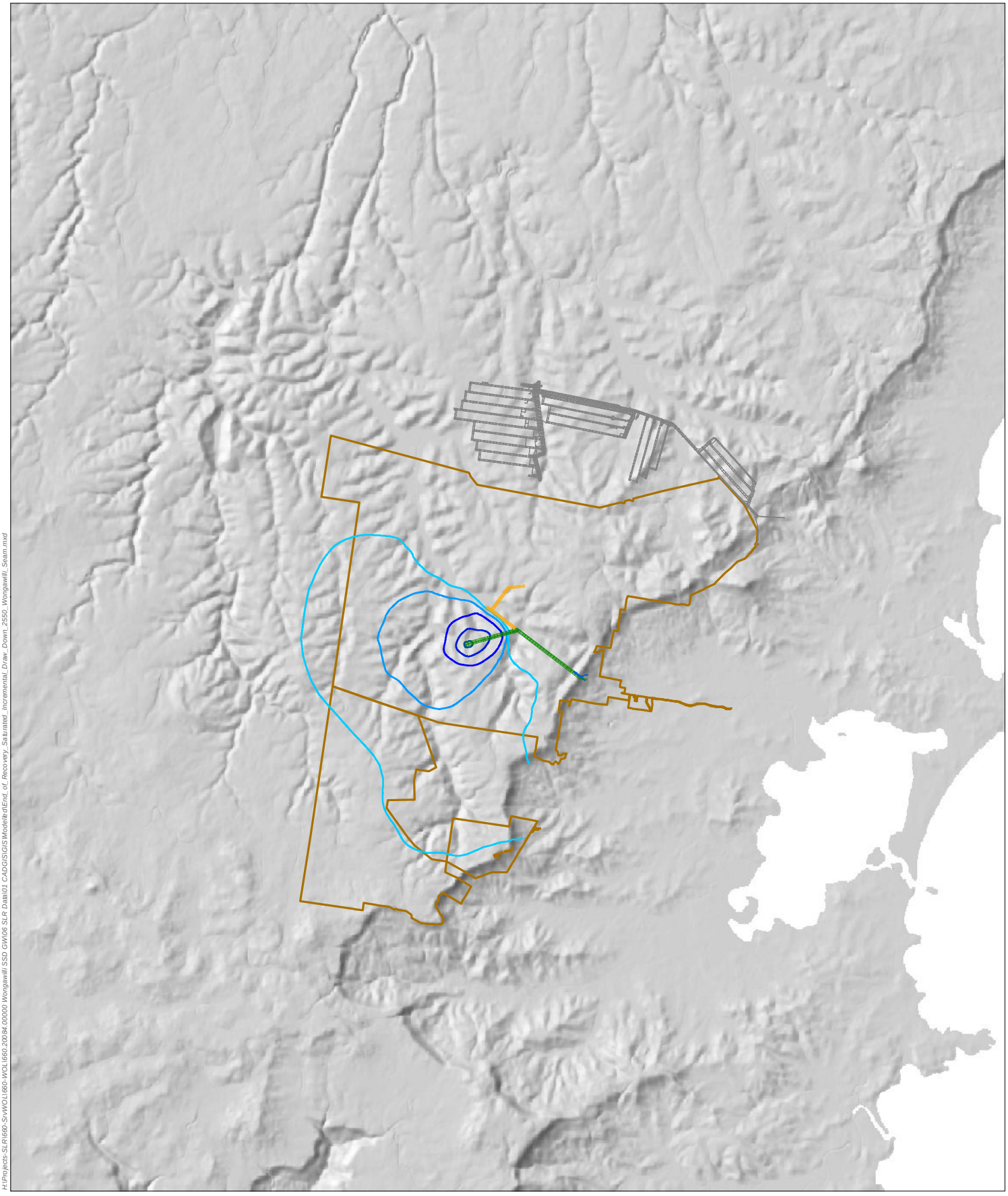
D - 12

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20



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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20

GROUNDWATER IMPACT ASSESSMENT

End of Recovery - Saturated Incremental Draw Down - 2550 - Wongawilli Seam

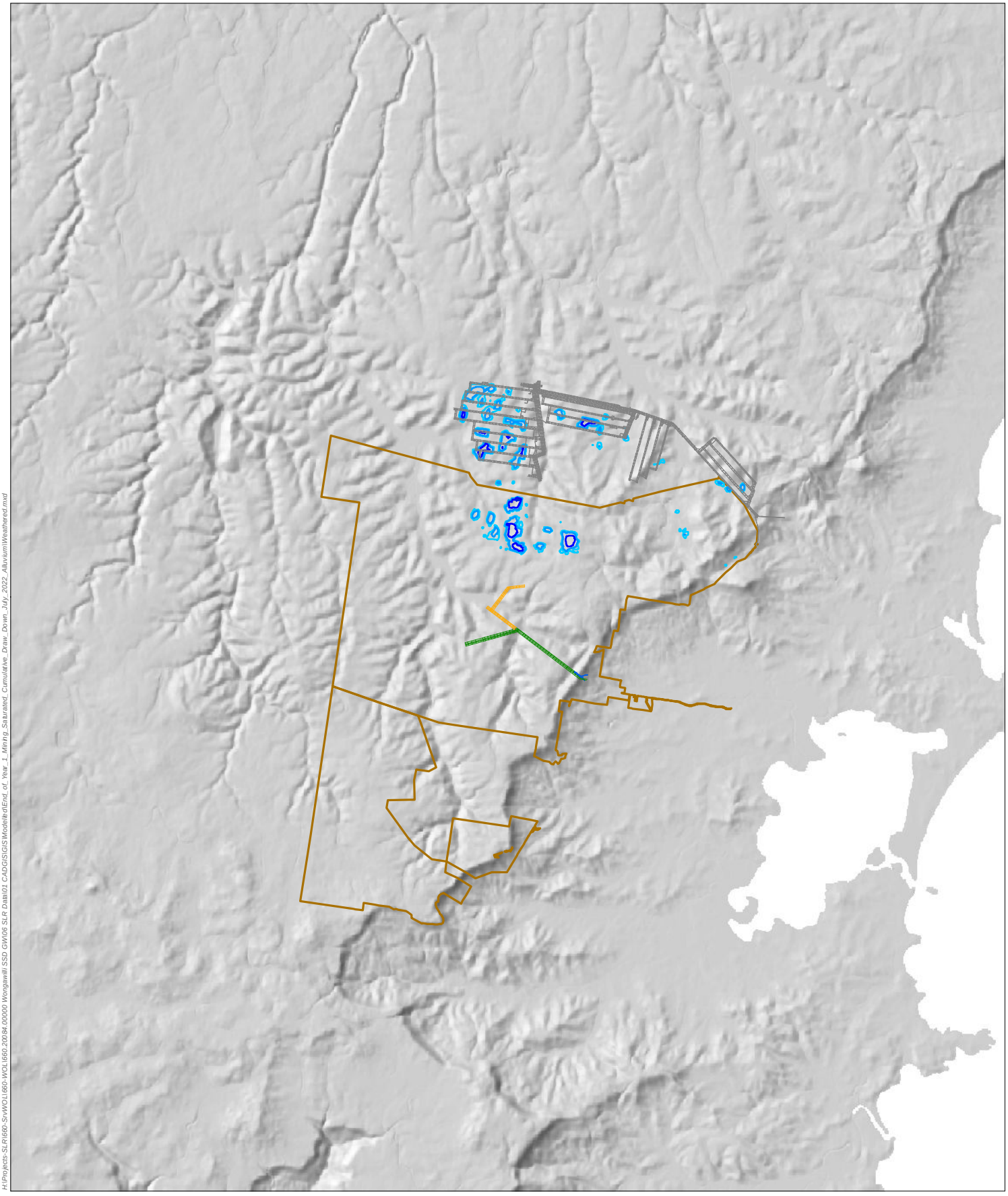
D - 13

APPENDIX E

Predicted Cumulative Groundwater Drawdown Plots

Predicted Groundwater Drawdown Plots

E1 Incremental Drawdown -July 2022 (End of Year 1 Mining) – Alluvium/weathered
E2 Incremental Drawdown -July 2023 (End of Year 2 Mining) – Alluvium/weathered
E3 Incremental Drawdown -July 2024 (End of Year 3 Mining) – Alluvium/weathered
E4 Incremental Drawdown -January 2025 (End of Mining) – Alluvium/weathered
E5 Incremental Drawdown -January 2050 (End of Surrounding Mining) – Alluvium/weathered
E6 Incremental Drawdown -January 2550 (End of Recovery) – Alluvium/weathered
E7 Incremental Drawdown -July 2022 (End of Year 1 Mining) – Bulgo Sandstone
E8 Incremental Drawdown -July 2023 (End of Year 2 Mining) – Bulgo Sandstone
E9 Incremental Drawdown -July 2024 (End of Year 3 Mining) – Bulgo Sandstone
E10 Incremental Drawdown -January 2025 (End of Mining) – Bulgo Sandstone
E11 Incremental Drawdown -January 2050 (End of Surrounding Mining) – Bulgo Sandstone
E12 Incremental Drawdown -January 2550 (End of Recovery) – Bulgo Sandstone
E13 Incremental Drawdown -July 2022 (End of Year 1 Mining) – Bulli Seam
E14 Incremental Drawdown -July 2023 (End of Year 2 Mining) – Bulli Seam
E15 Incremental Drawdown -July 2024 (End of Year 3 Mining) – Bulli Seam
E16 Incremental Drawdown -January 2025 (End of Mining) – Bulli Seam
E17 Incremental Drawdown -January 2050 (End of Surrounding Mining) – Bulli Seam
E18 Incremental Drawdown -January 2550 (End of Recovery) – Bulli Seam
E19 Incremental Drawdown -July 2022 (End of Year 1 Mining) – Wongawilli Seam
E20 Incremental Drawdown -July 2023 (End of Year 2 Mining) – Wongawilli Seam
E21 Incremental Drawdown -July 2024 (End of Year 3 Mining) – Wongawilli Seam
E22 Incremental Drawdown -January 2025 (End of Mining) – Wongawilli Seam
E23 Incremental Drawdown -January 2050 (End of Surrounding Mining) – Wongawilli Seam
E24 Incremental Drawdown -January 2550 (End of Recovery) – Wongawilli Seam



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0 2 km

Projection: GDA 1994 MGA Zone 56
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GROUNDWATER IMPACT ASSESSMENT

End of Year 1 Mining - Saturated Cumulative Draw Down - July 2022 - Alluvium\Weathered

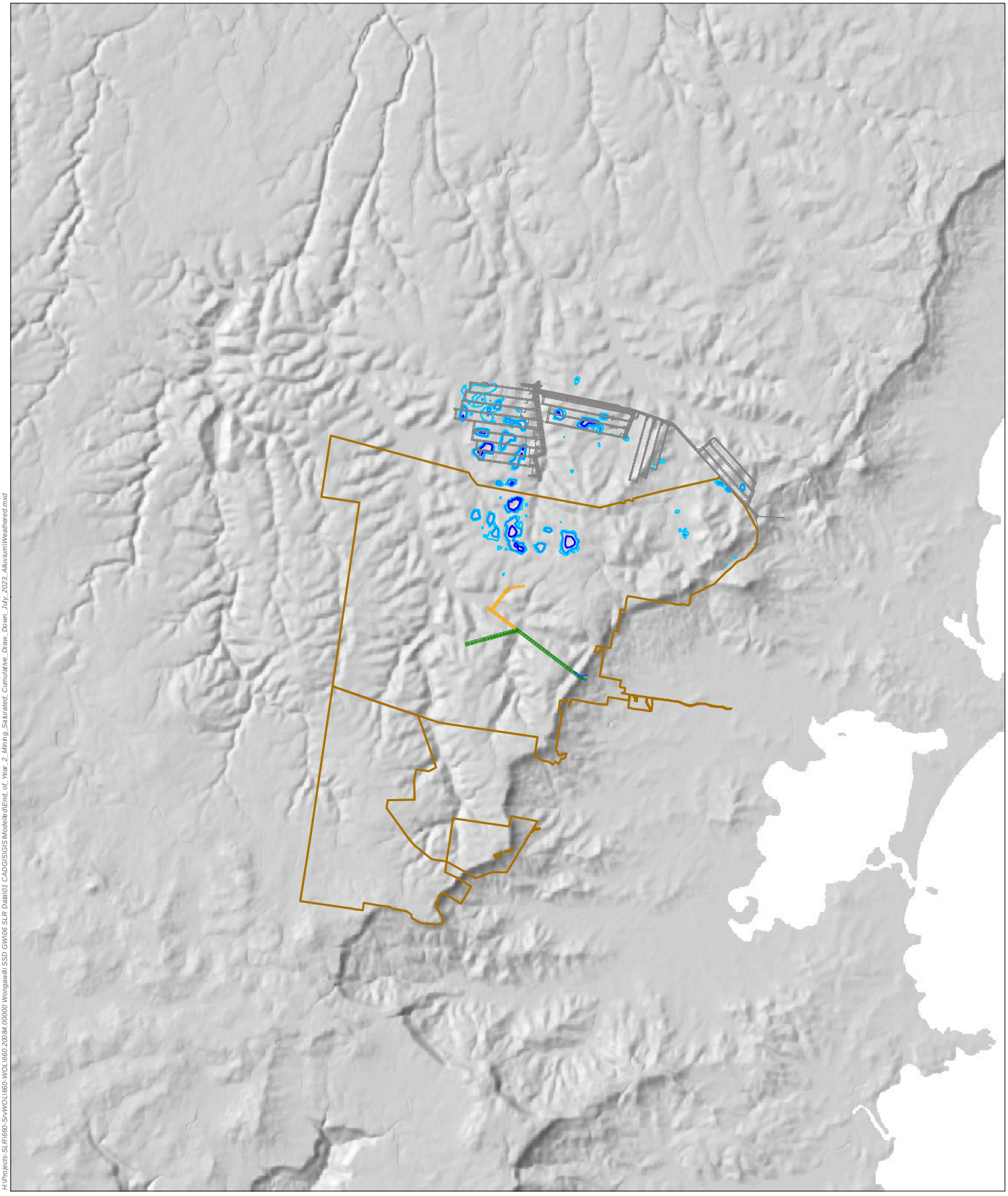
E - 1

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10



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0 2 km

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Sheet Size:	A4

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GROUNDWATER IMPACT ASSESSMENT

End of Year 2 Mining - Saturated Cumulative Draw Down - July 2023 - Alluvium\Weathered

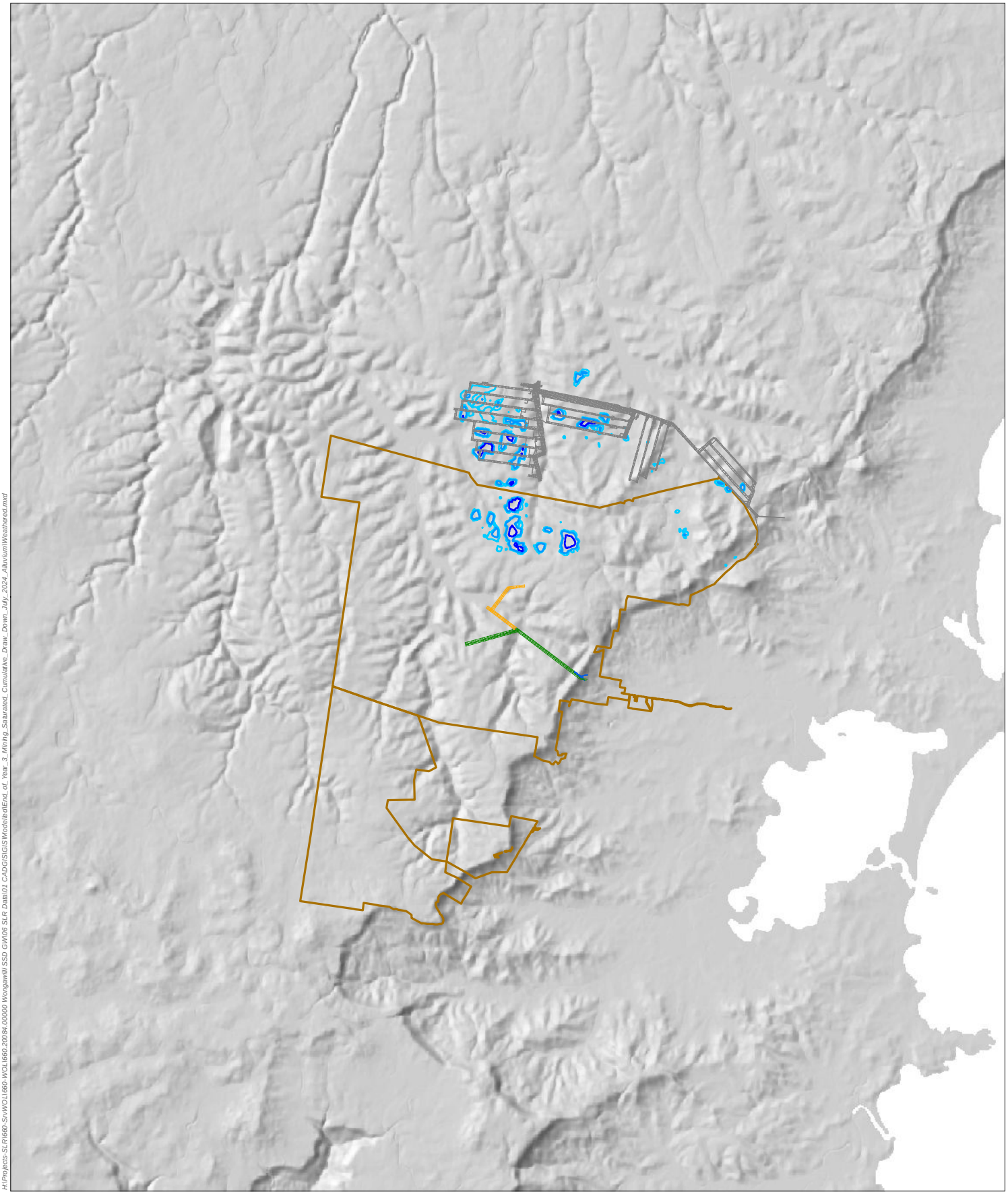
E - 2

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

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GROUNDWATER IMPACT ASSESSMENT

End of Year 3 Mining - Saturated Cumulative Draw Down - July 2024 - Alluvium\Weathered

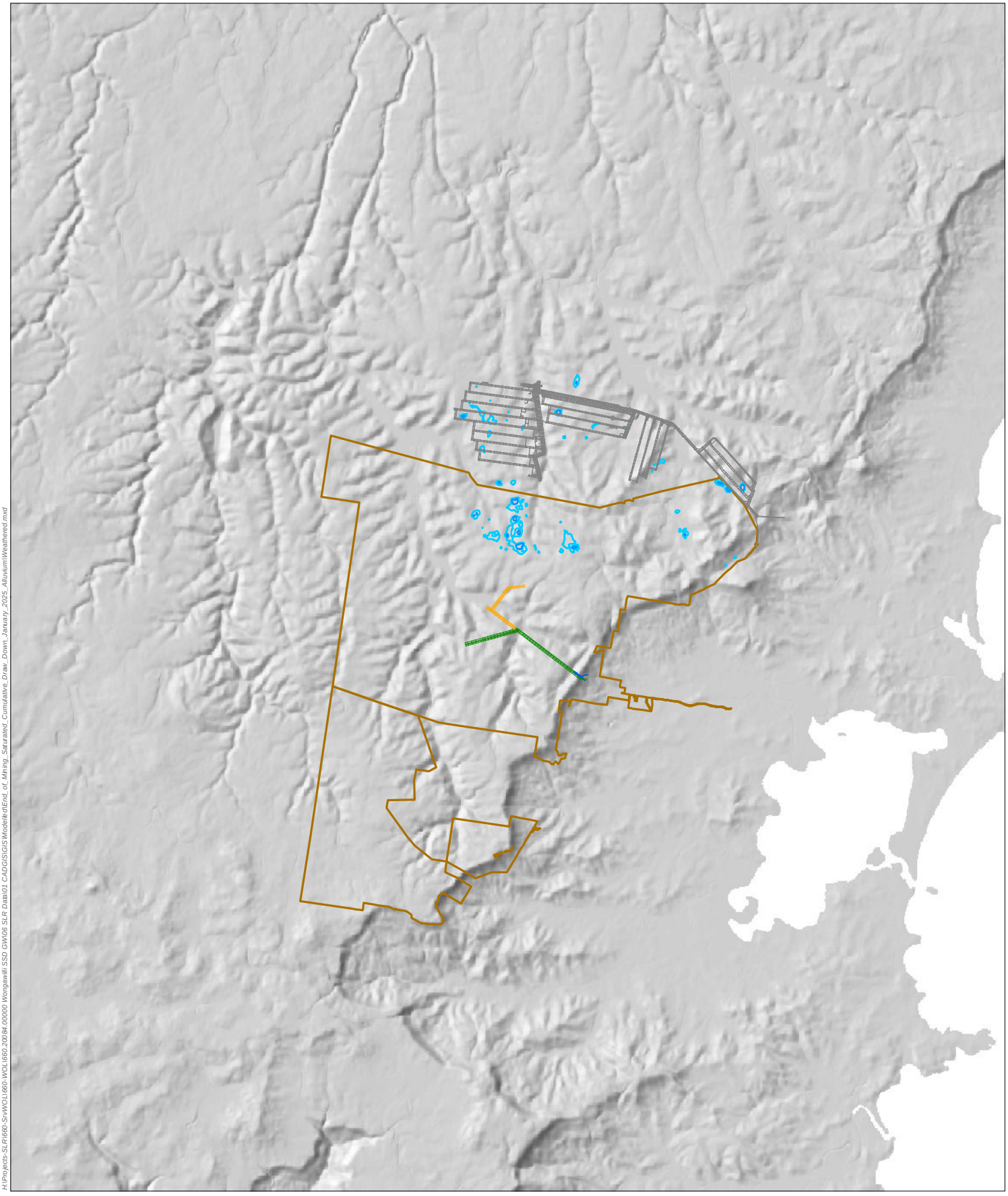
E - 3

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

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GROUNDWATER IMPACT ASSESSMENT

End of Mining - Saturated Cumulative Draw Down - January 2025 - Alluvium\Weathered

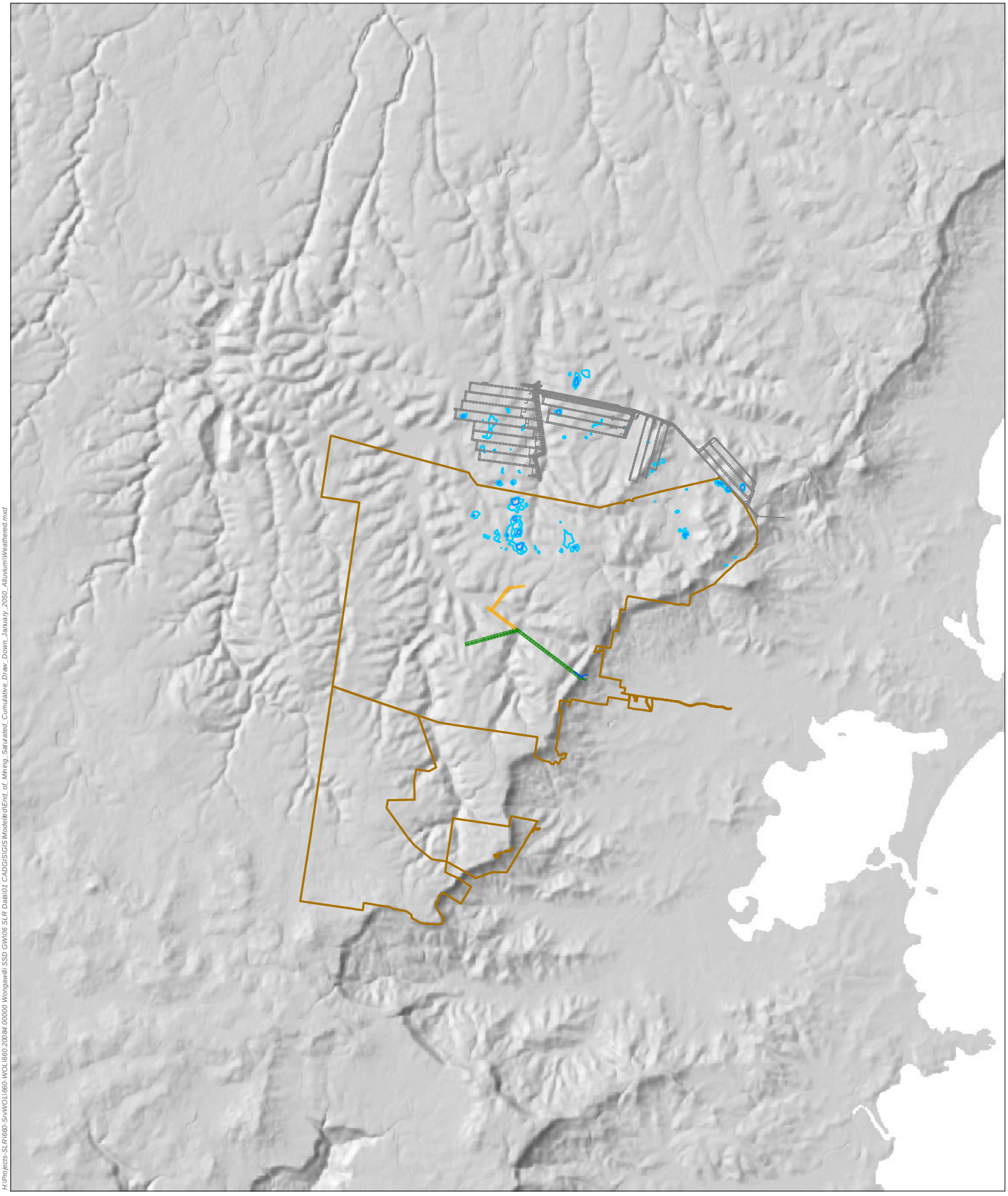
E - 4

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 2
- 1



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

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GROUNDWATER IMPACT ASSESSMENT

End of Surrounding Mining - Saturated Cumulative Draw Down - January 2050 - Alluvium\Weathered

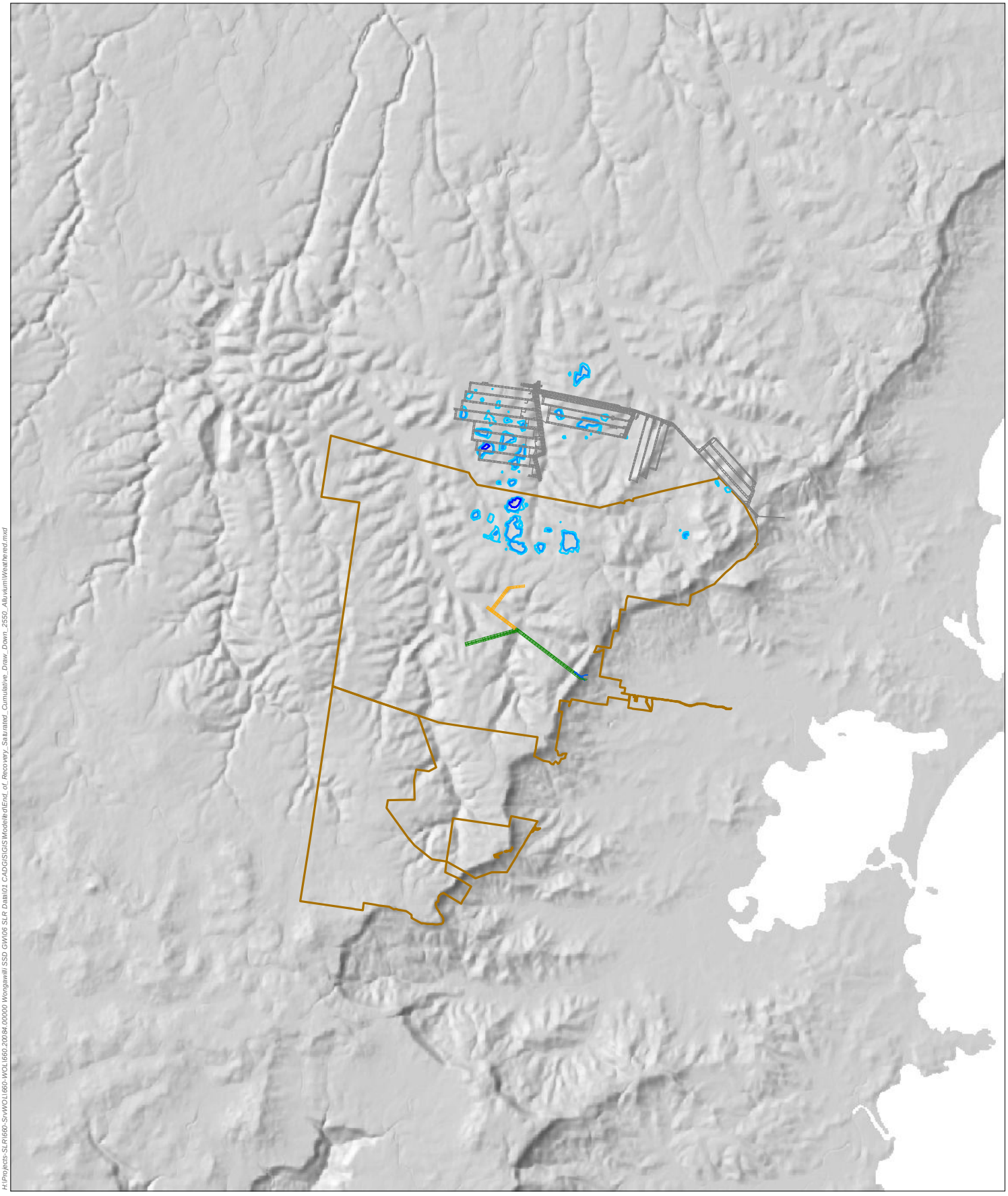
E - 5

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 2
- 1



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

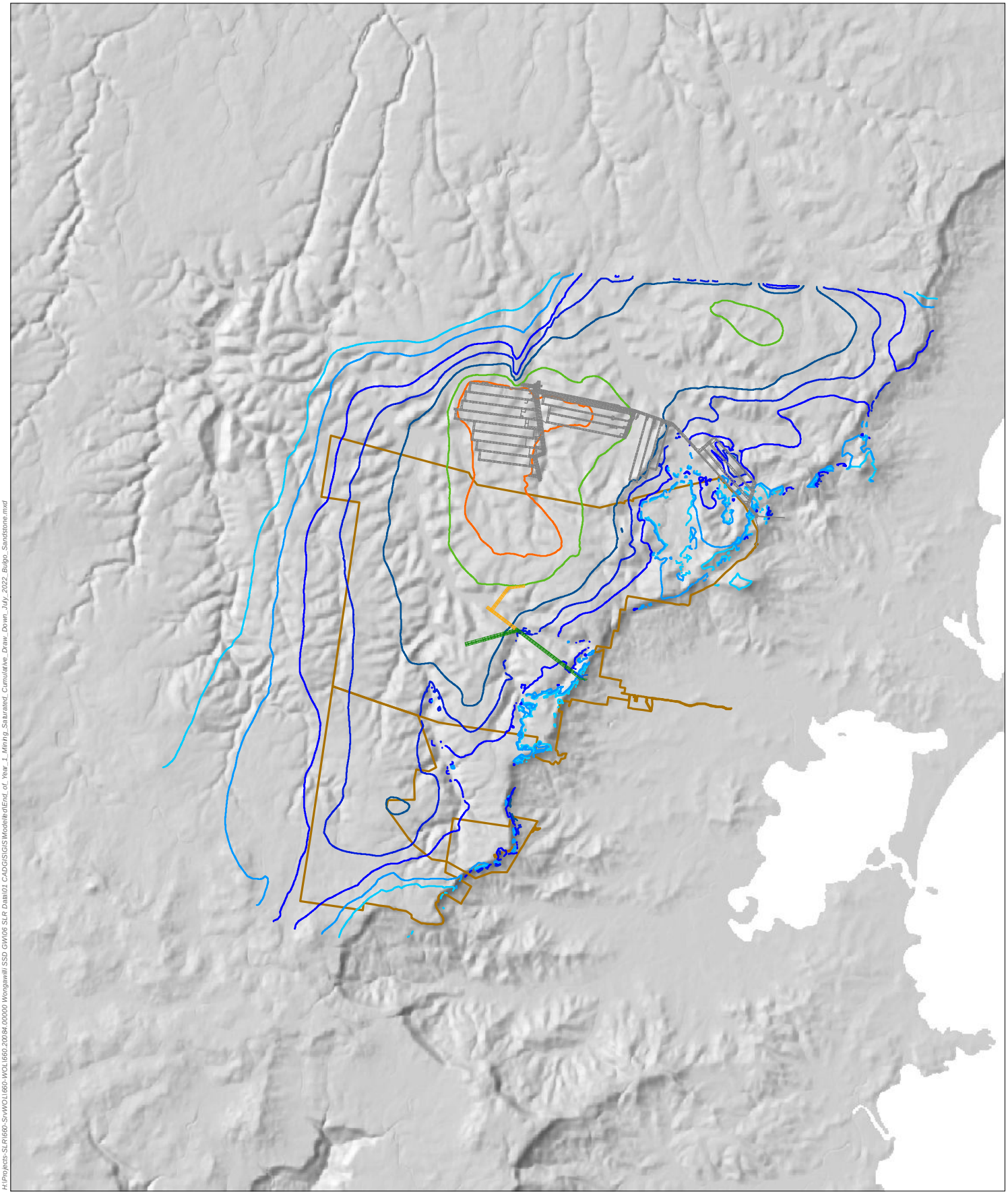
Drawdown (m)

- 1
- 2
- 5

GROUNDWATER IMPACT ASSESSMENT

End of Recovery - Saturated Cumulative Draw Down - 2550 - Alluvium\Weathered

E - 6



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
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GROUNDWATER IMPACT ASSESSMENT

End of Year 1 Mining - Saturated Cumulative Draw Down - July 2022 - Bulgo Sandstone

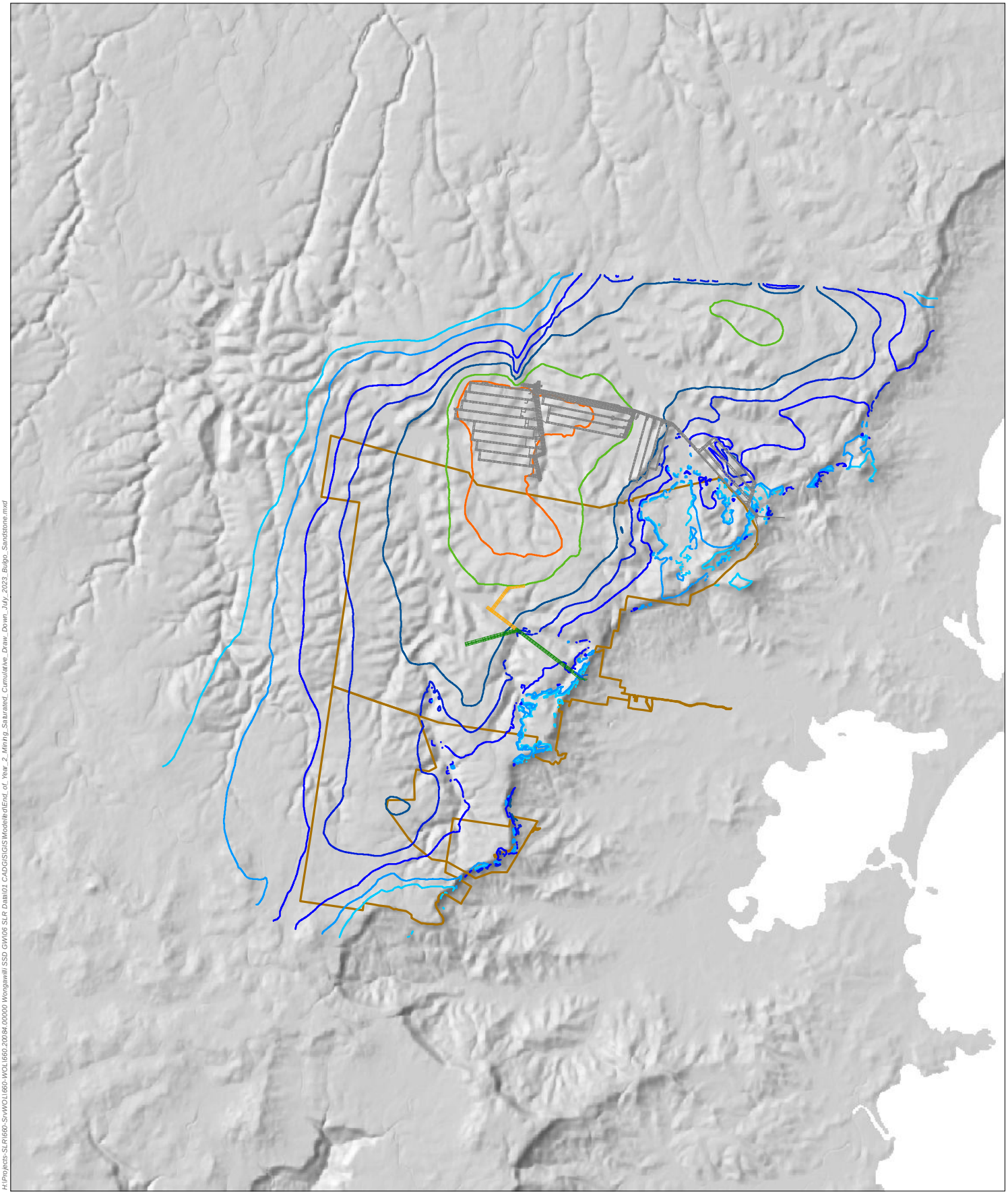
E - 7

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100



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Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
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GROUNDWATER IMPACT ASSESSMENT

End of Year 2 Mining - Saturated Cumulative Draw Down - July 2023 - Bulgo Sandstone

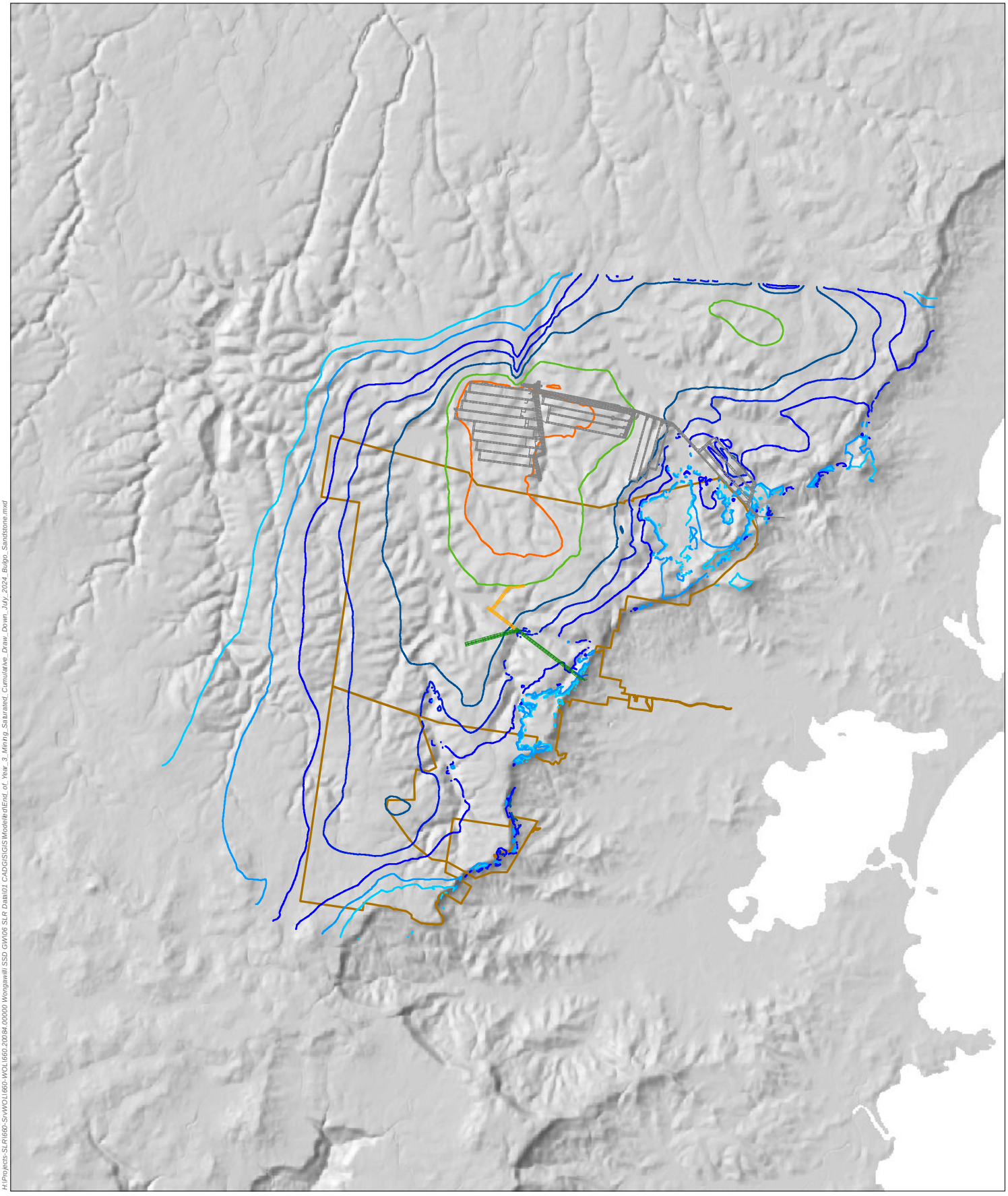
E - 8

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
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GROUNDWATER IMPACT ASSESSMENT

End of Year 3 Mining - Saturated Cumulative Draw Down - July 2024 - Bulgo Sandstone

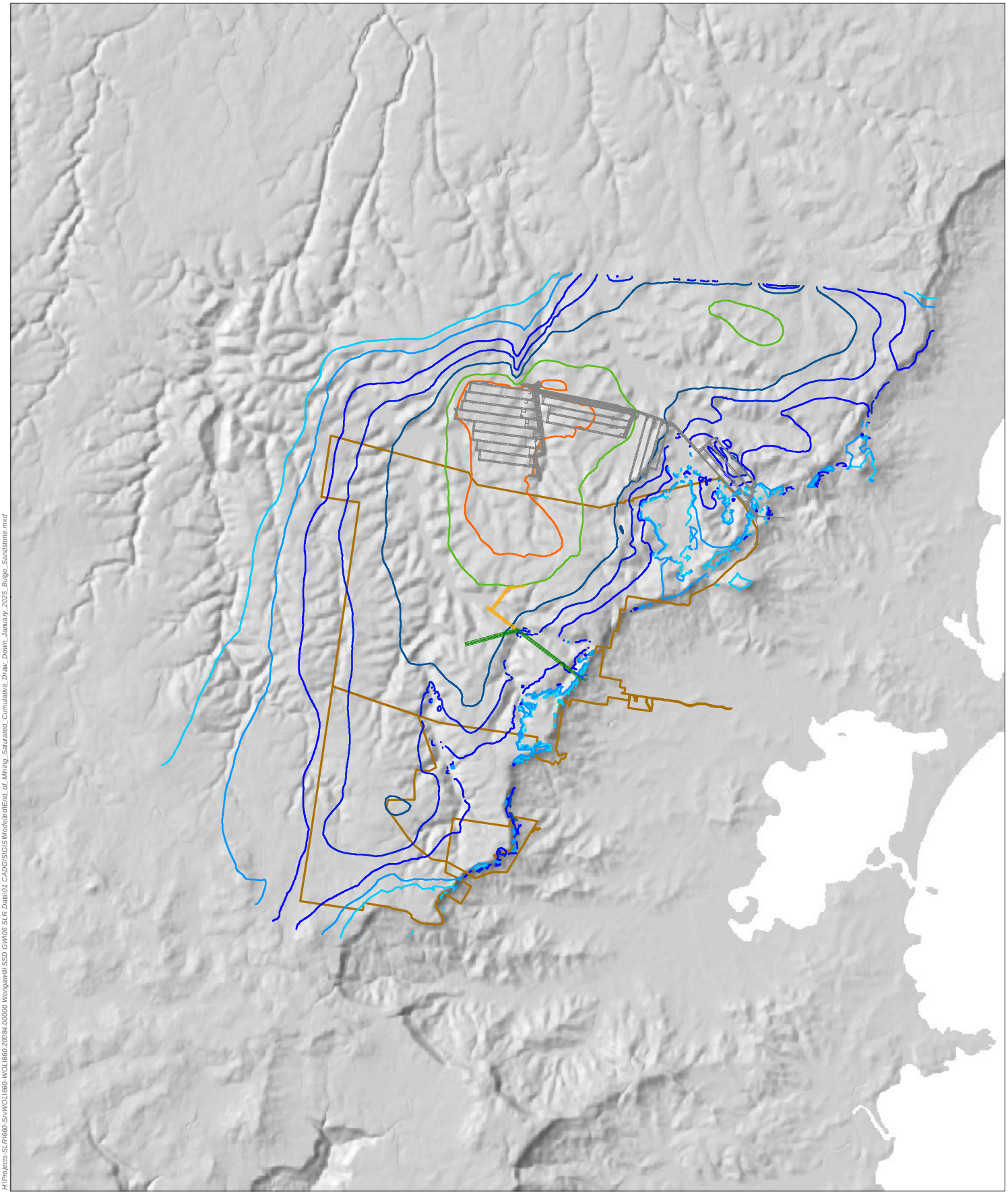
E - 9

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

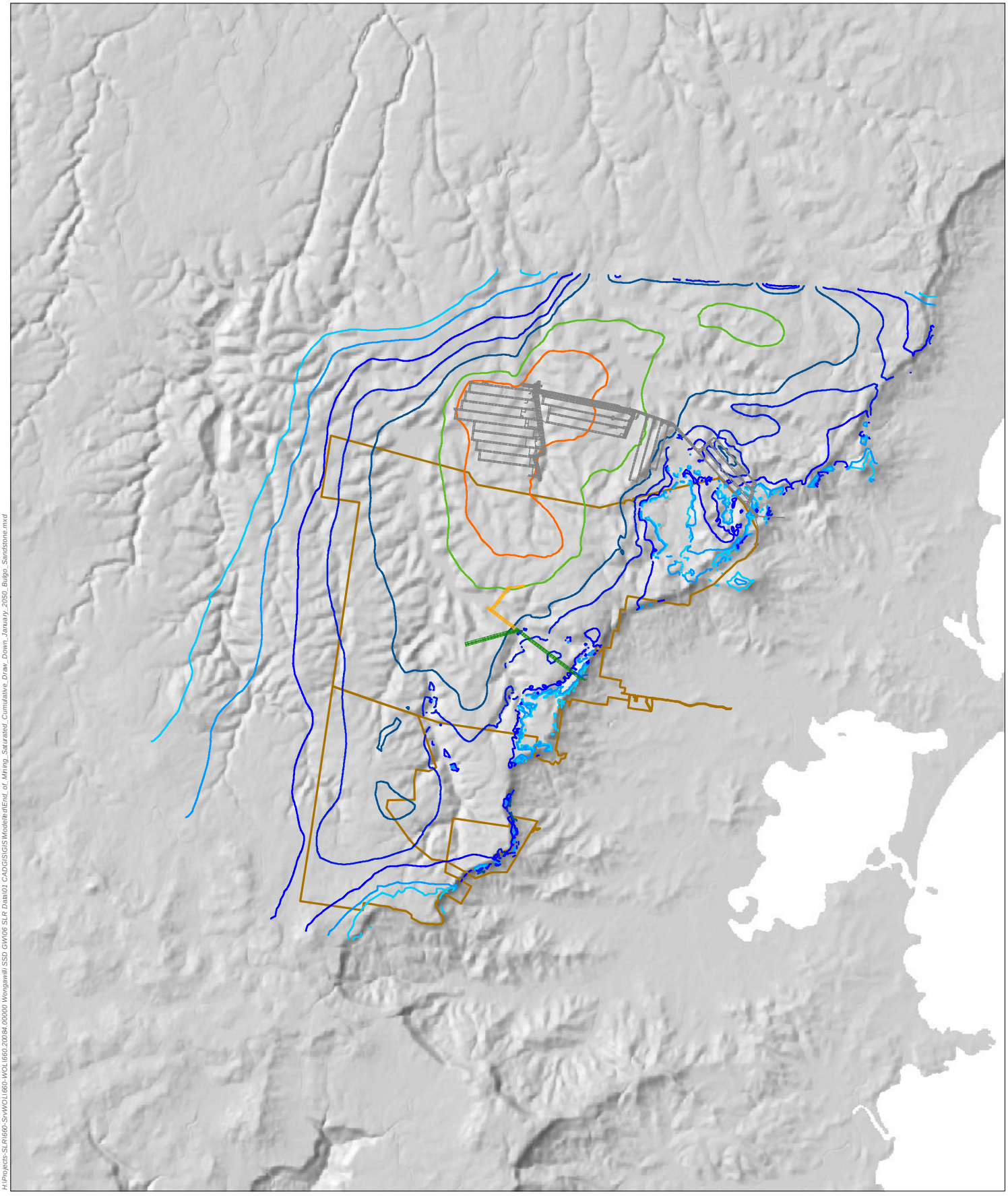
Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100

GROUNDWATER IMPACT ASSESSMENT

End of Mining - Saturated Cumulative Draw Down - January 2025 - Bulgo Sandstone

E - 10



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
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GROUNDWATER IMPACT ASSESSMENT

End of Surrounding Mining - Saturated Cumulative Draw Down - January 2050 - Bulgo Sandstone

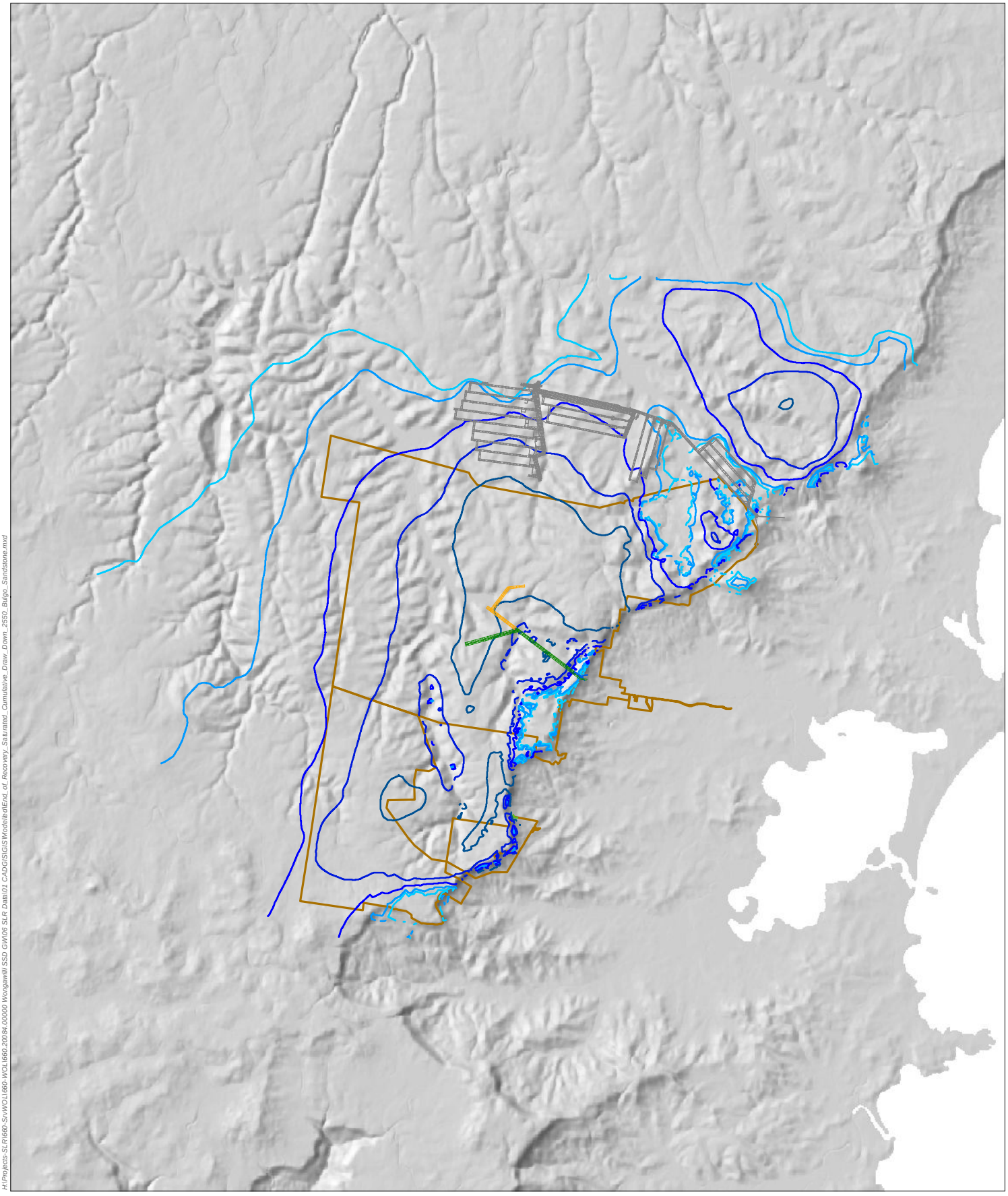
E - 11

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50

GROUNDWATER IMPACT ASSESSMENT

End of Recovery - Saturated Cumulative Draw Down - 2550 - Bulgo Sandstone

E - 12

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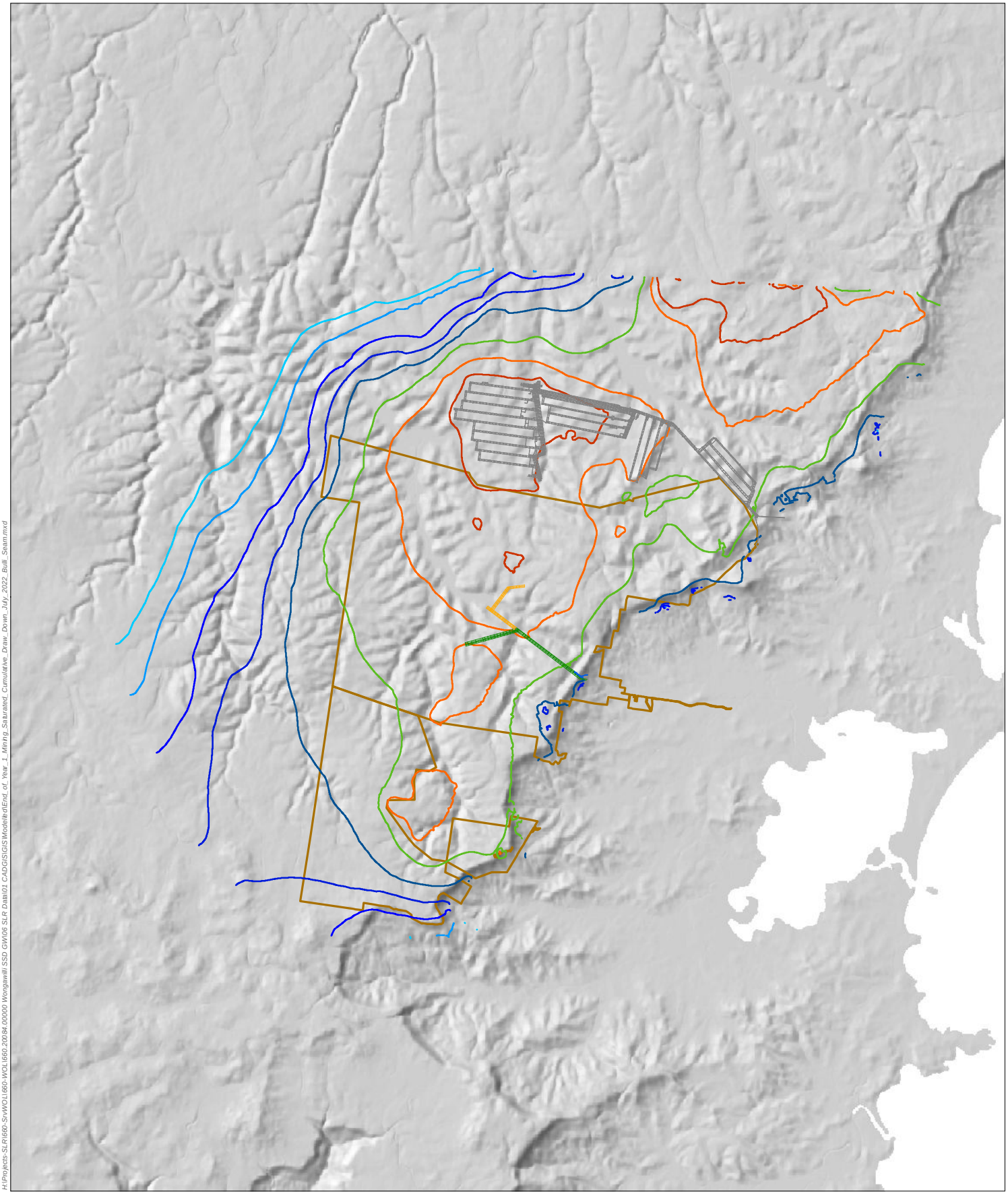

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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
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GROUNDWATER IMPACT ASSESSMENT

End of Year 1 Mining - Saturated Cumulative Draw Down - July 2022 - Bulli Seam

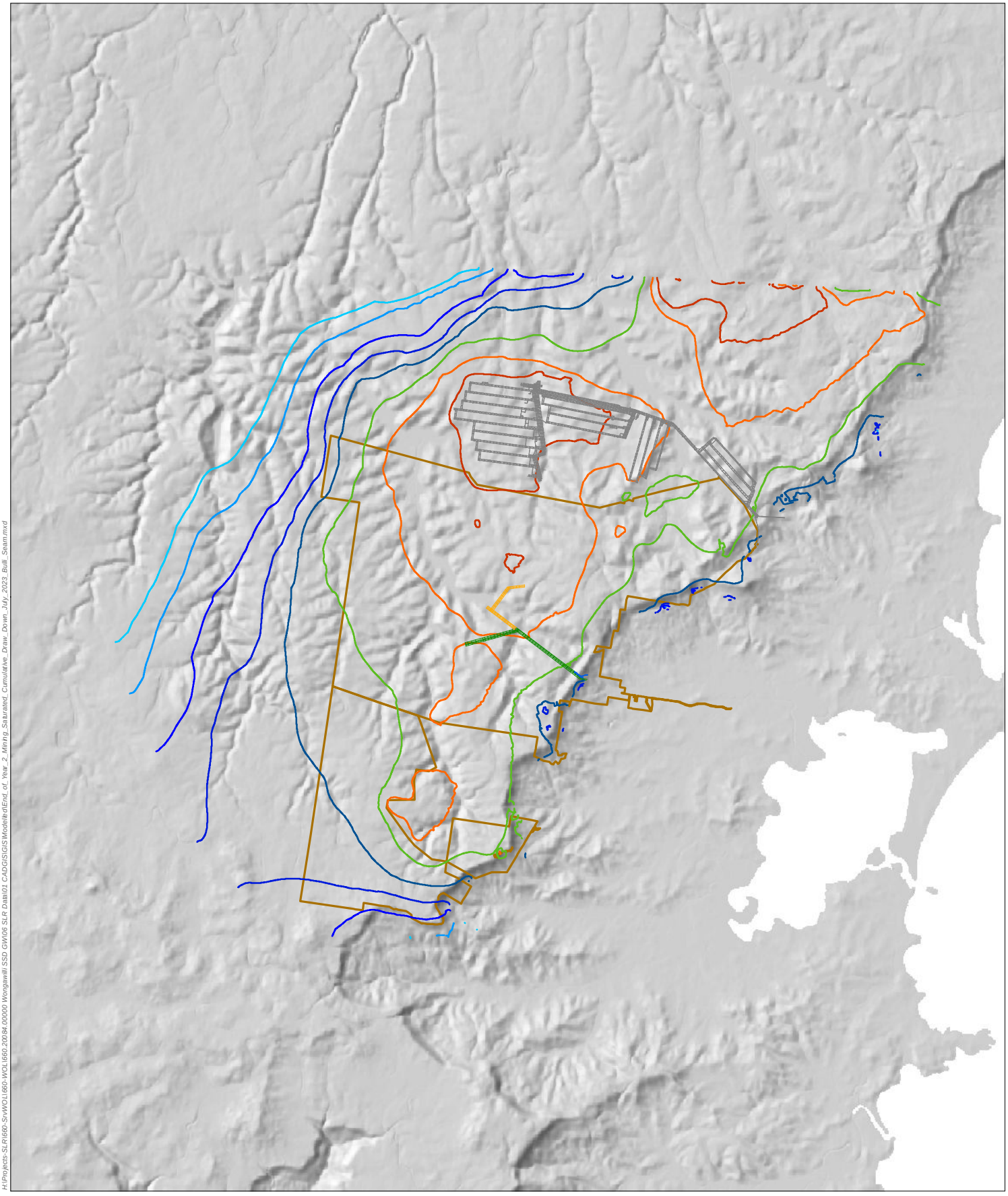
E - 13

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

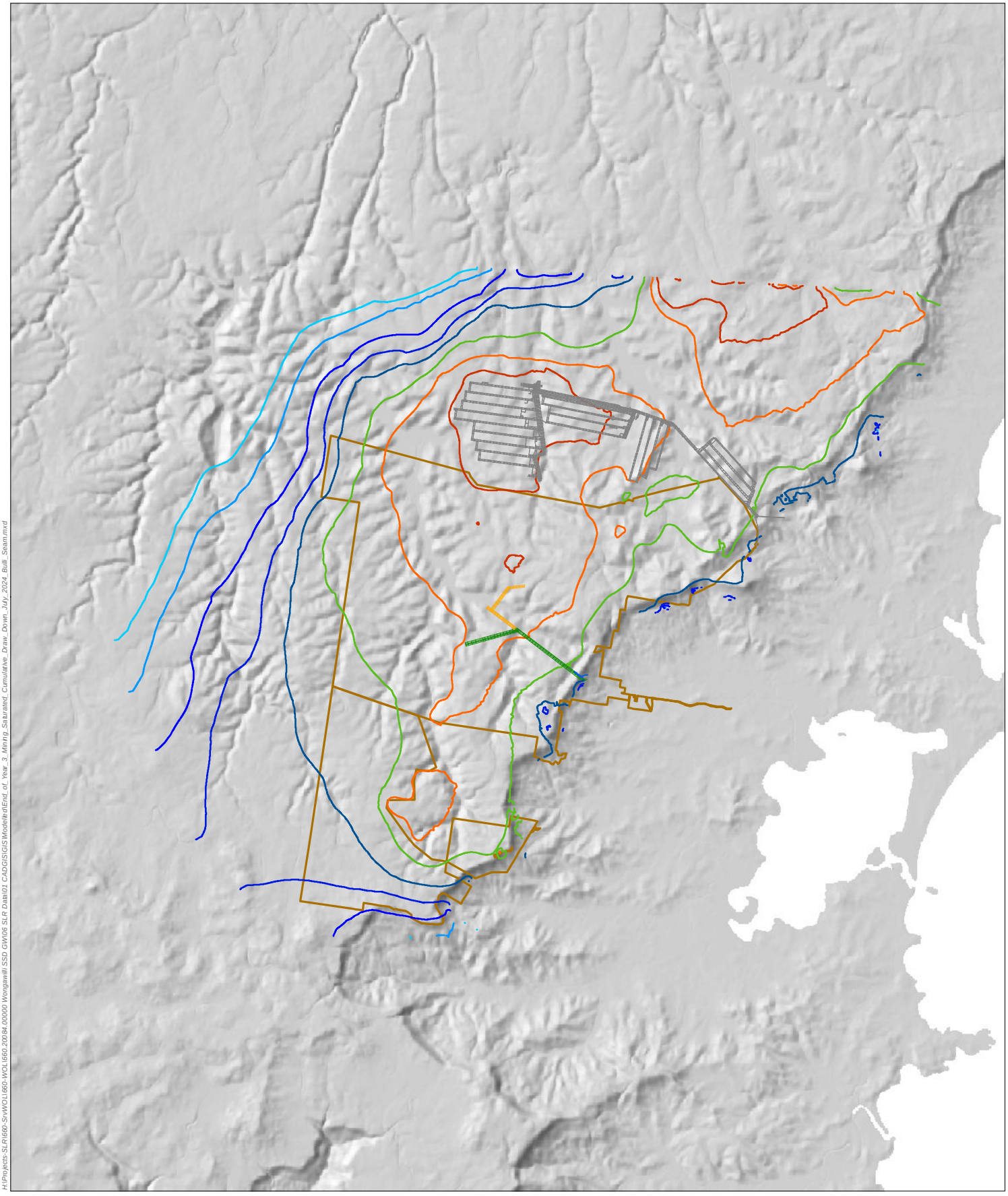
Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200

GROUNDWATER IMPACT ASSESSMENT

End of Year 2 Mining - Saturated Cumulative Draw Down - July 2023 - Bulli Seam

E - 14



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

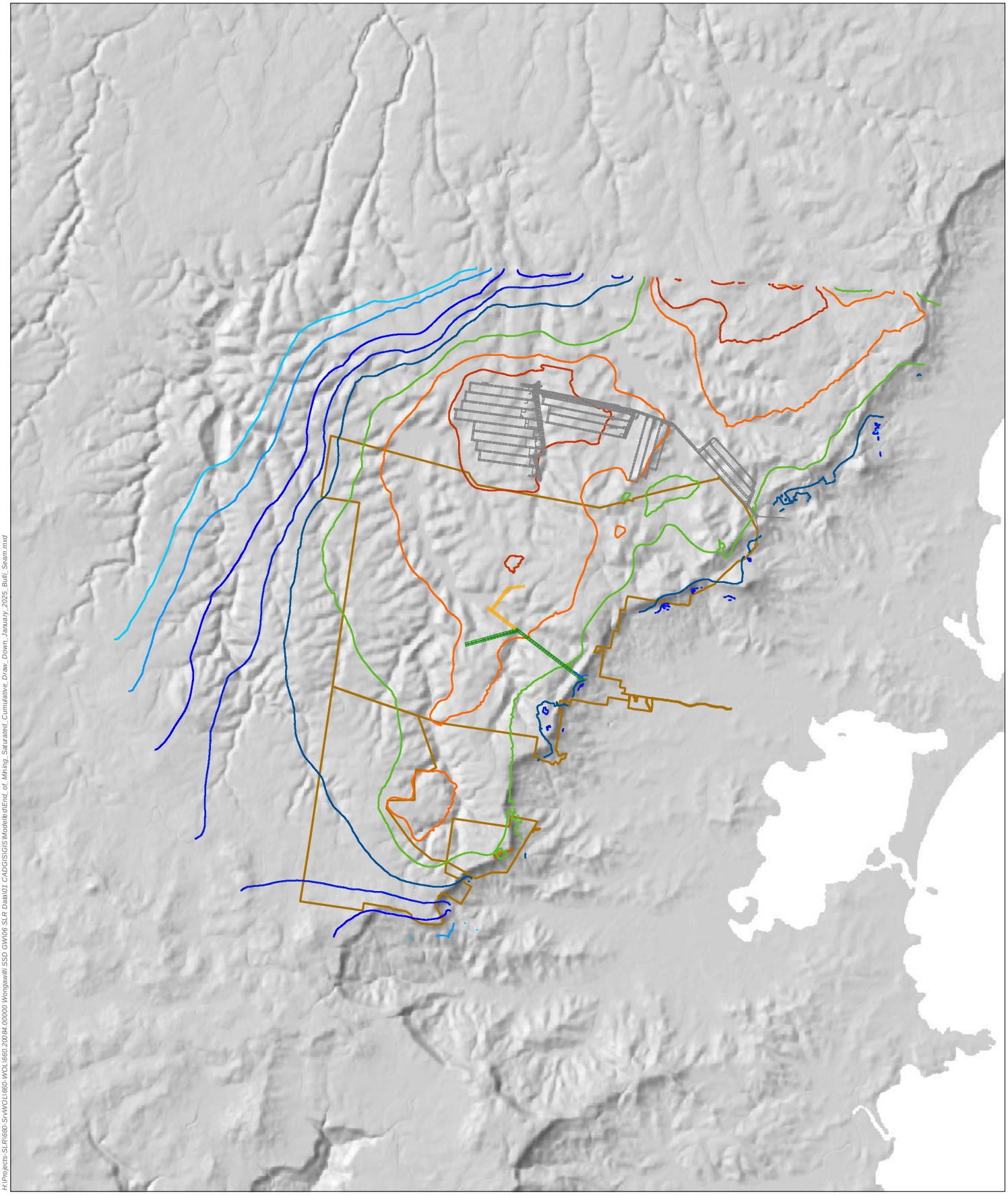
Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200

GROUNDWATER IMPACT ASSESSMENT

End of Year 3 Mining - Saturated Cumulative Draw Down - July 2024 - Bulli Seam

E - 15



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

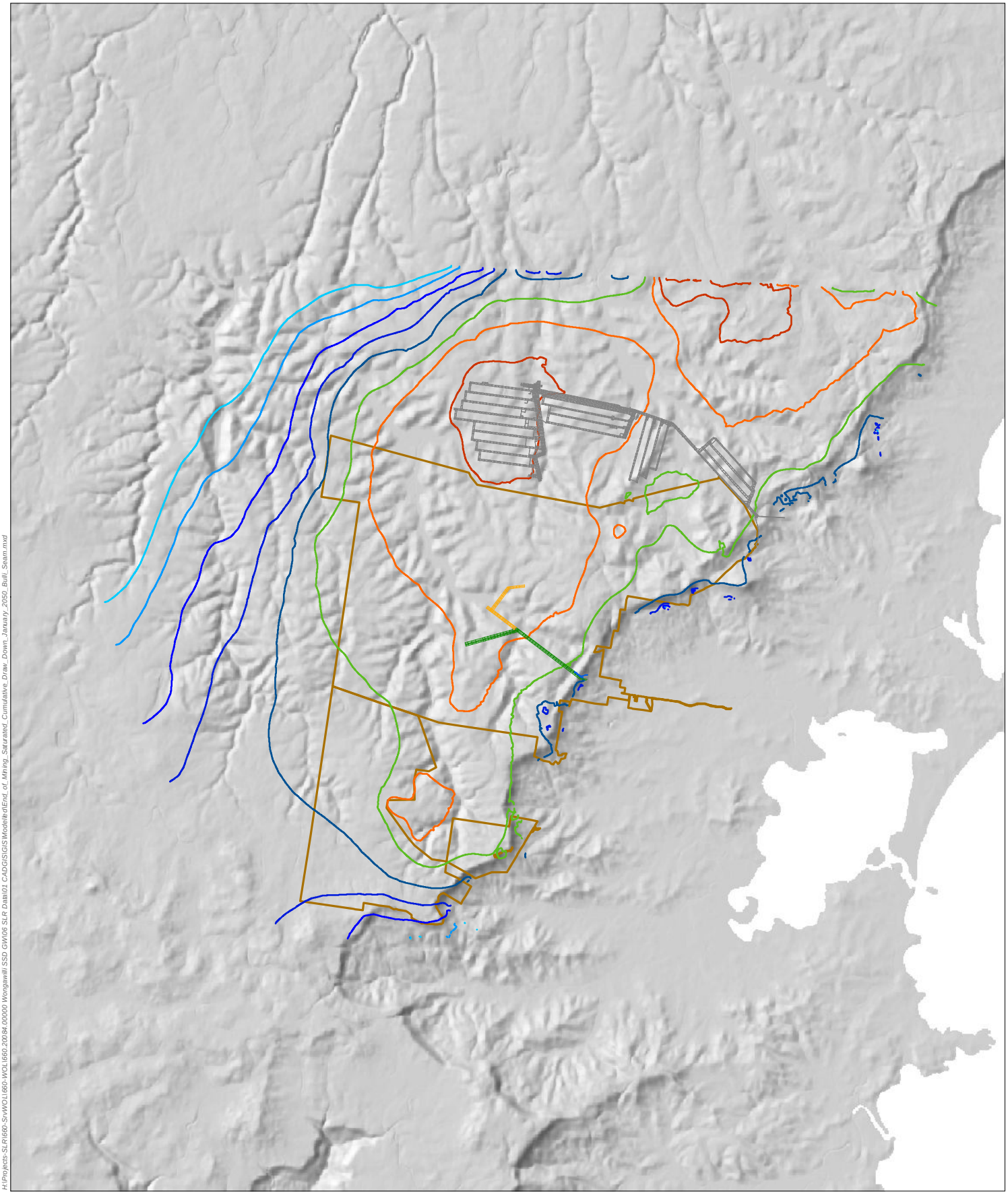
Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200

GROUNDWATER IMPACT ASSESSMENT

End of Mining - Saturated Cumulative Draw Down - January 2025 - Bulli Seam

E - 16



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

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GROUNDWATER IMPACT ASSESSMENT

End of Surrounding Mining - Saturated Cumulative Draw Down - January 2050 - Bulli Seam

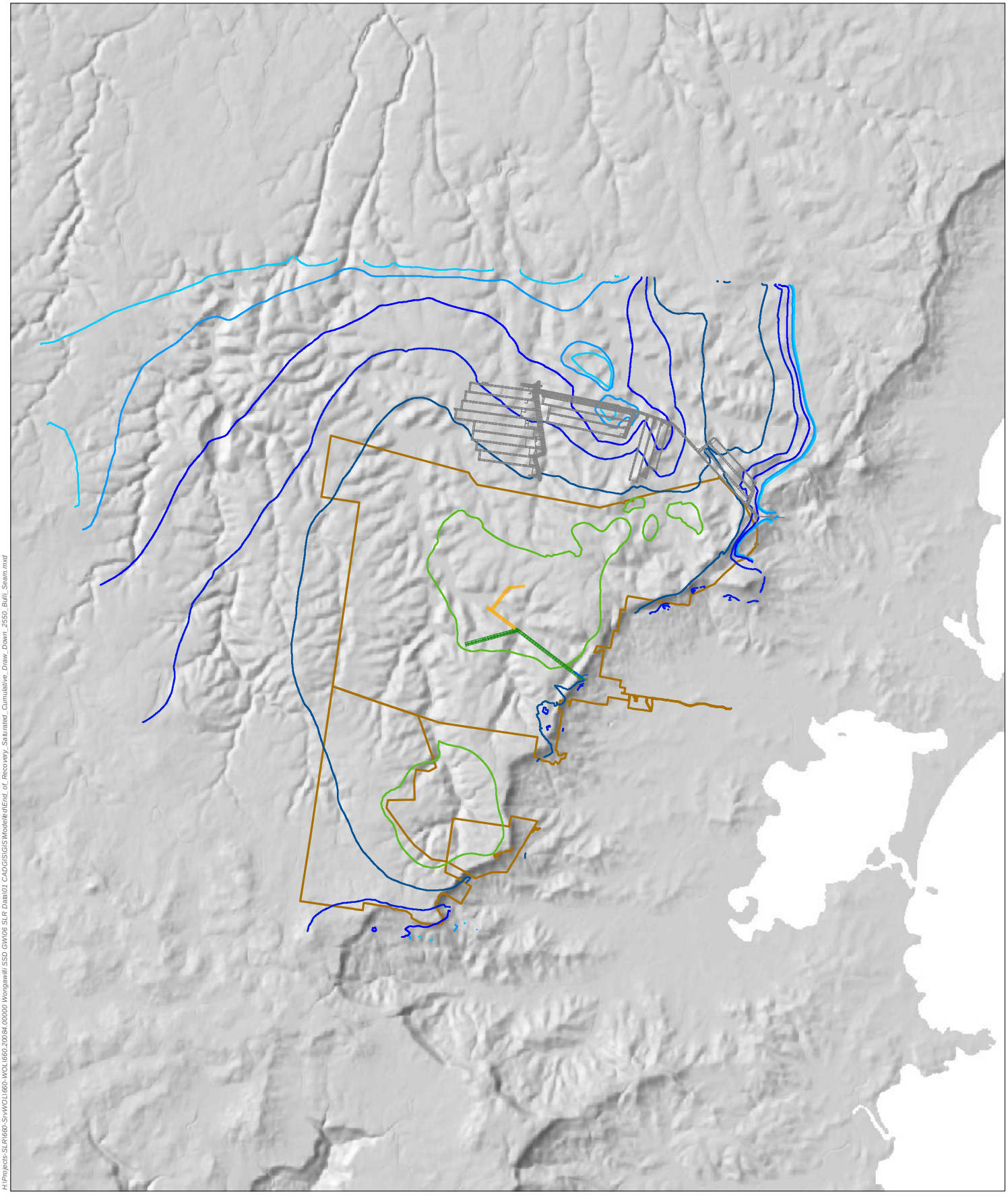
E - 17

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

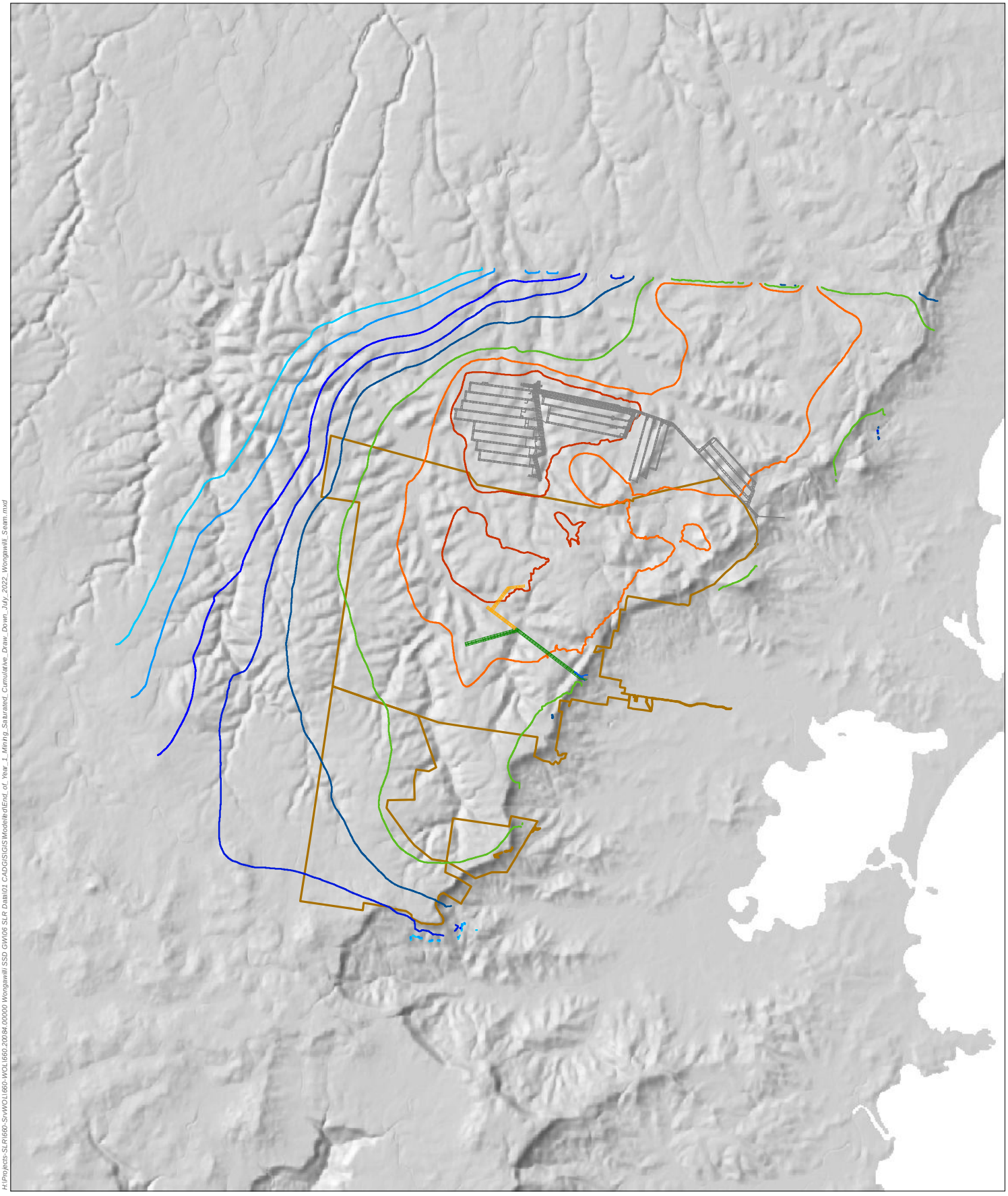
Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50

GROUNDWATER IMPACT ASSESSMENT

End of Recovery - Saturated Cumulative Draw Down - 2550 - Bulli Seam

E - 18



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
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GROUNDWATER IMPACT ASSESSMENT

End of Year 1 Mining - Saturated Cumulative Draw Down - July 2022 - Wongawilli Seam

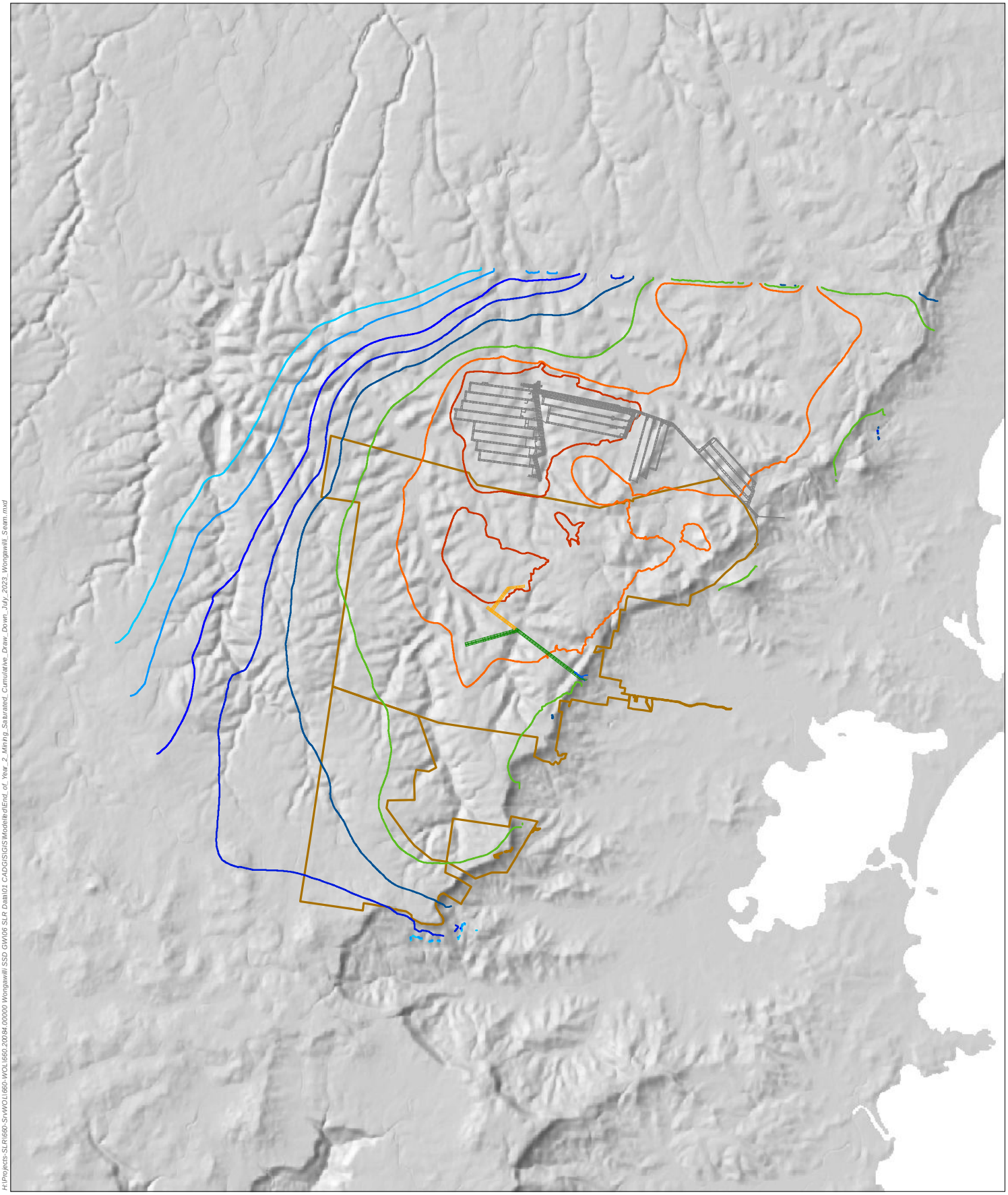
E - 19

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
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GROUNDWATER IMPACT ASSESSMENT

End of Year 2 Mining - Saturated Cumulative Draw Down - July 2023 - Wongawilli Seam

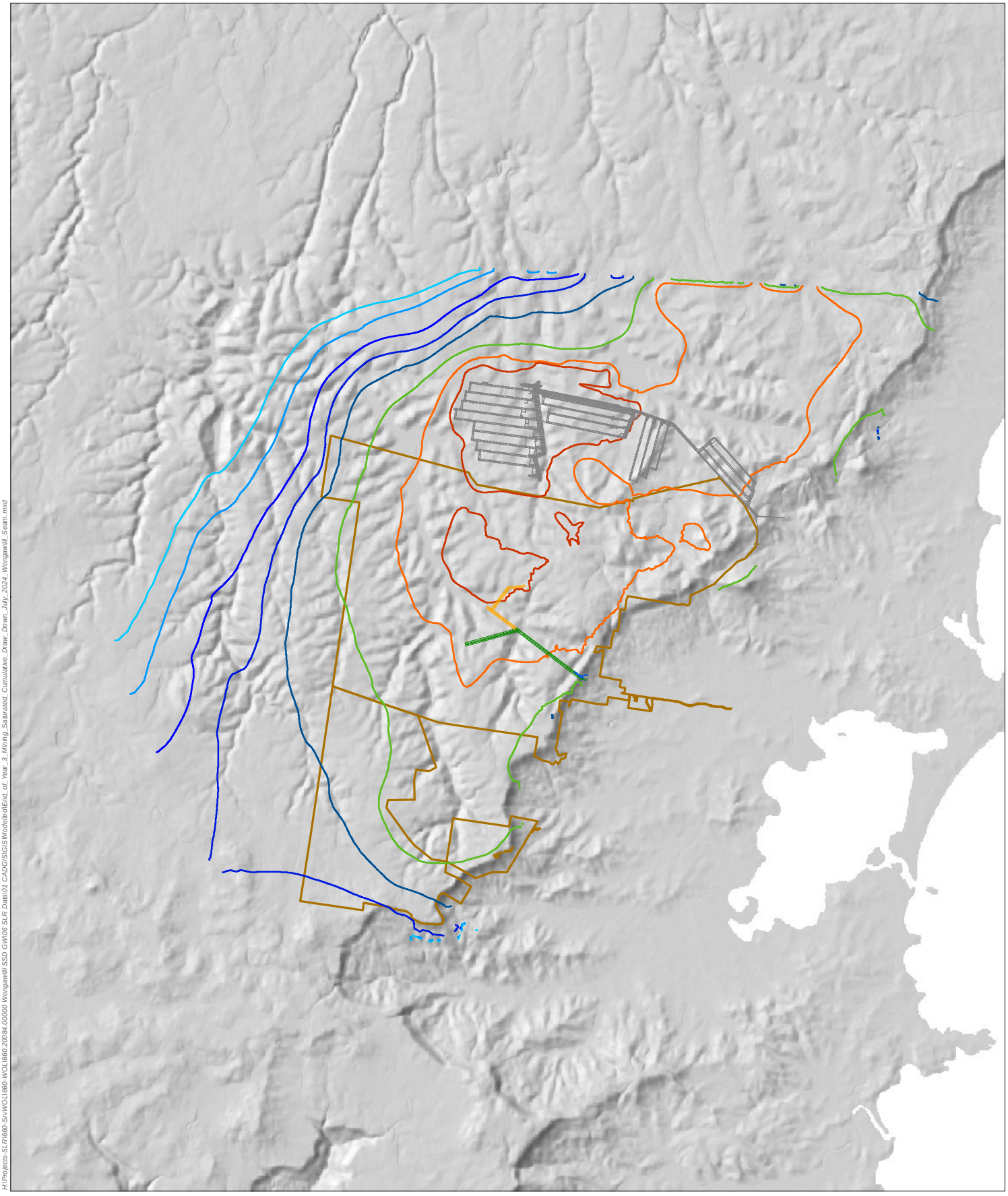
E - 20

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
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GROUNDWATER IMPACT ASSESSMENT

End of Year 3 Mining - Saturated Cumulative Draw Down - July 2024 - Wongawilli Seam

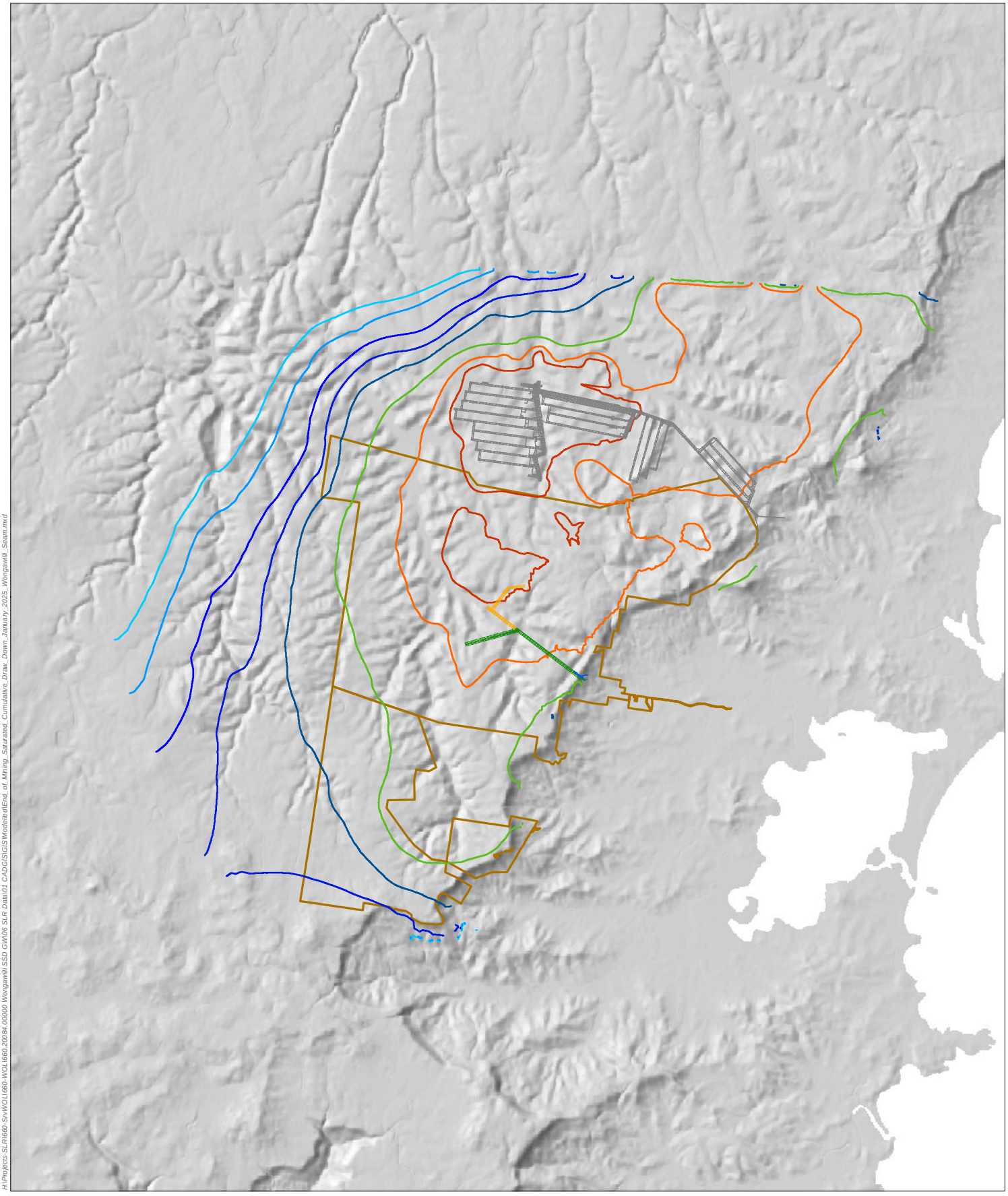
E - 21

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
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GROUNDWATER IMPACT ASSESSMENT

End of Mining - Saturated Cumulative Draw Down - January 2025 - Wongawilli Seam

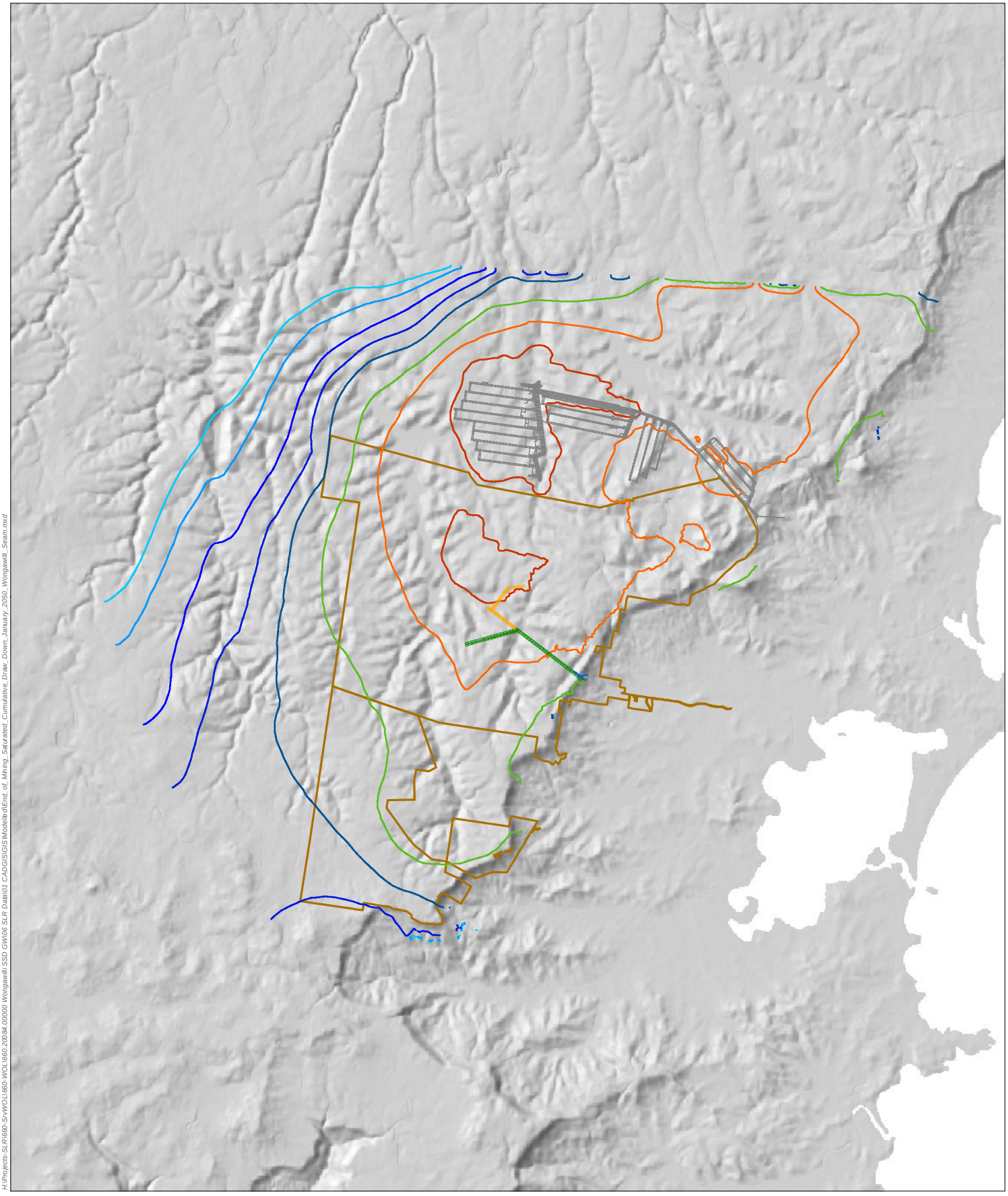
E - 22

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
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GROUNDWATER IMPACT ASSESSMENT

End of Surrounding Mining - Saturated Cumulative Draw Down - January 2050 - Wongawilli Seam

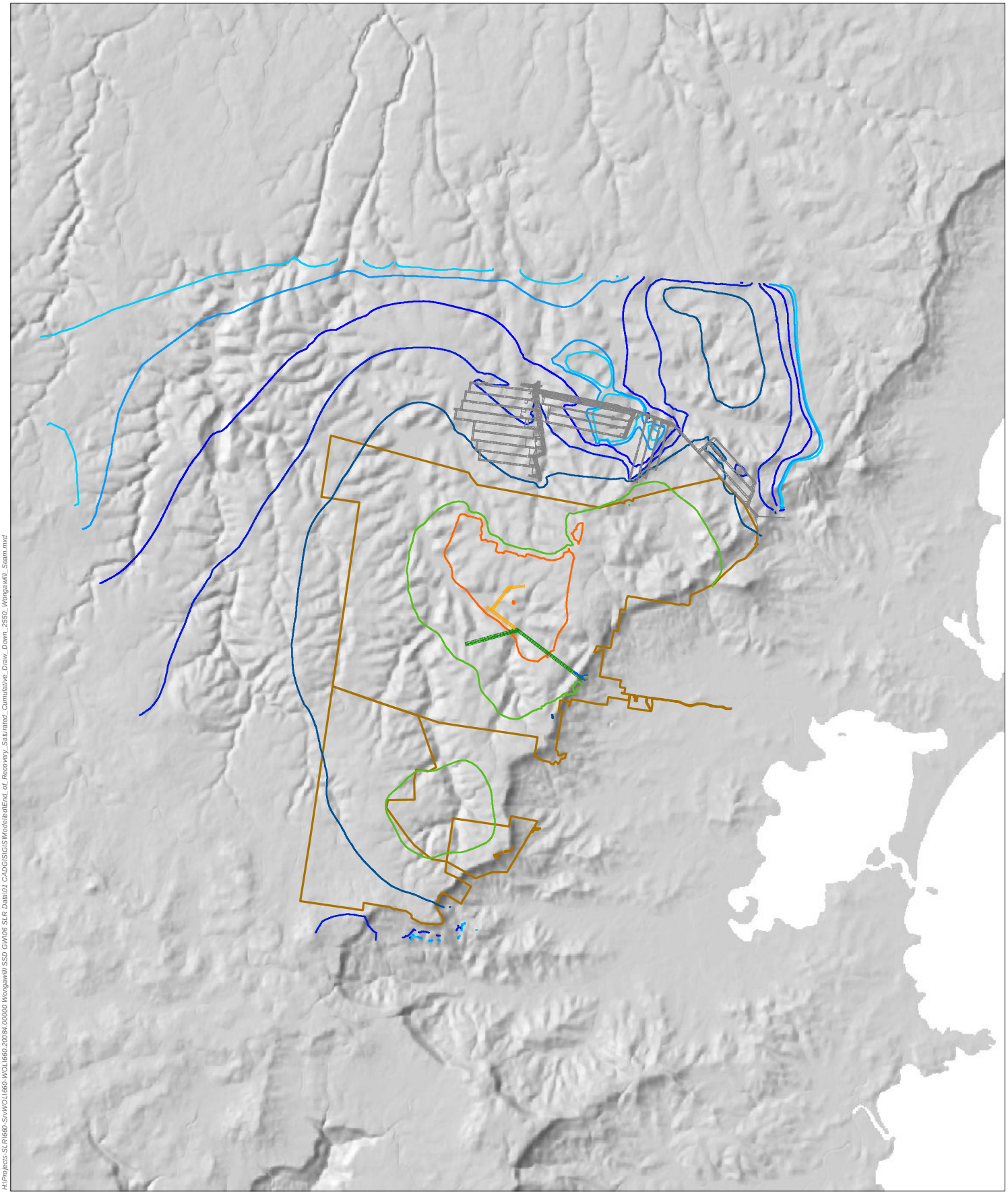
E - 23

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100
- 200



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:190,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

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Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Drawdown (m)

- 1
- 2
- 5
- 10
- 20
- 50
- 100

GROUNDWATER IMPACT ASSESSMENT

End of Recovery - Saturated Cumulative Draw Down - 2550 - Wongawilli Seam

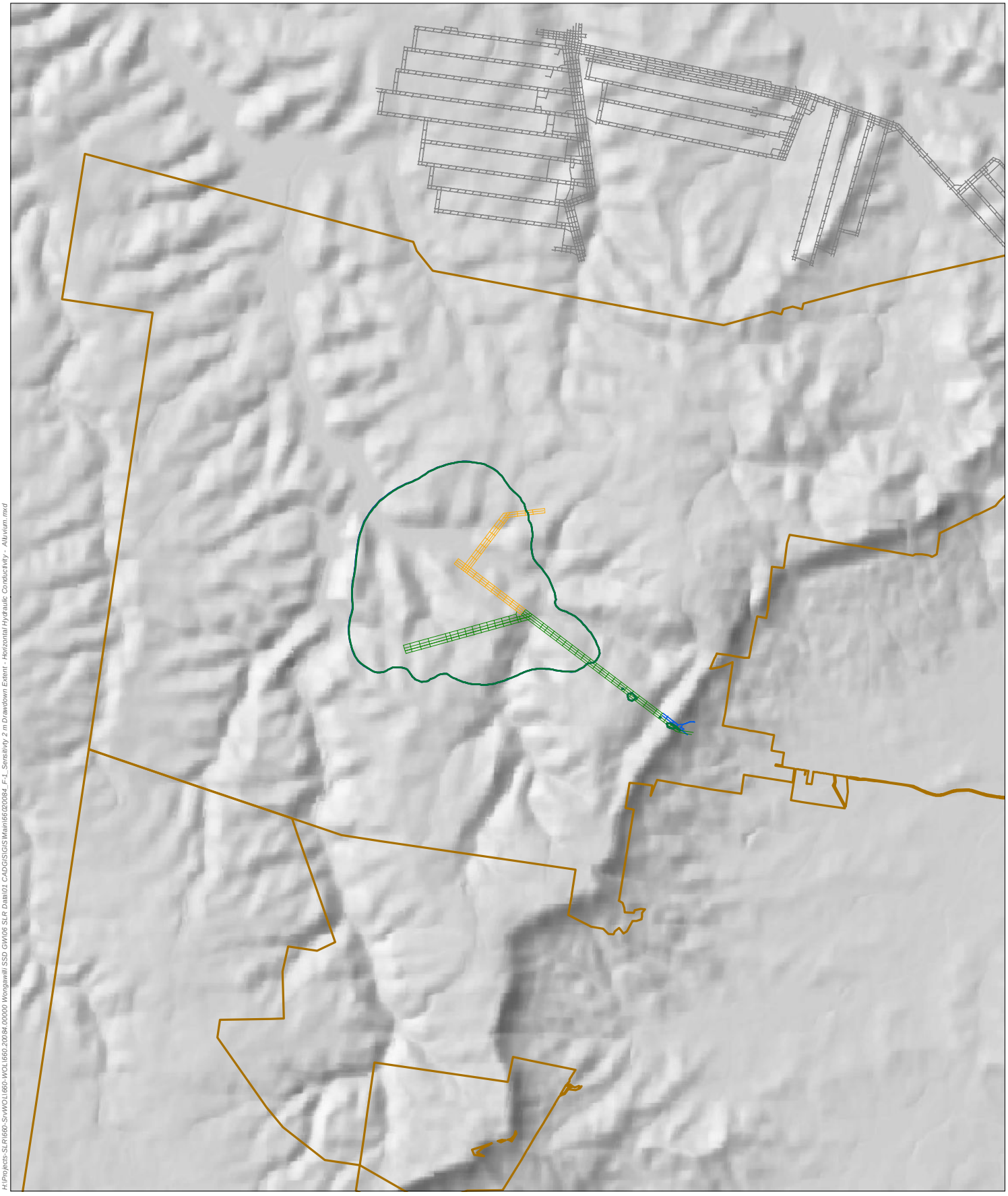
E - 24

APPENDIX F

Sensitivity Drawdown Plots

Sensitivity Drawdown Plots

F-1 Sensitivity 2m drawdown extent (Bulli Seam) – Hydraulic Conductivity (Alluvium)
F-2 Sensitivity 2m drawdown extent (Bulli Seam) – Hydraulic Conductivity (Coal)
F-3 Sensitivity 2m drawdown extent (Bulli Seam) – Hydraulic Conductivity (Bulgo Sandstone)
F-4 Sensitivity 2m drawdown extent (Bulli Seam) – Hydraulic Conductivity (Global Recharge)
F-5 Sensitivity 2m drawdown extent (Bulli Seam) – River Bed Conductance Up



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:80,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
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GROUNDWATER IMPACT ASSESSMENT

Sensitivty 2 m Drawdown Extent (Bulli Seam) - Horizontal Hydraulic Conductivity - Alluvium

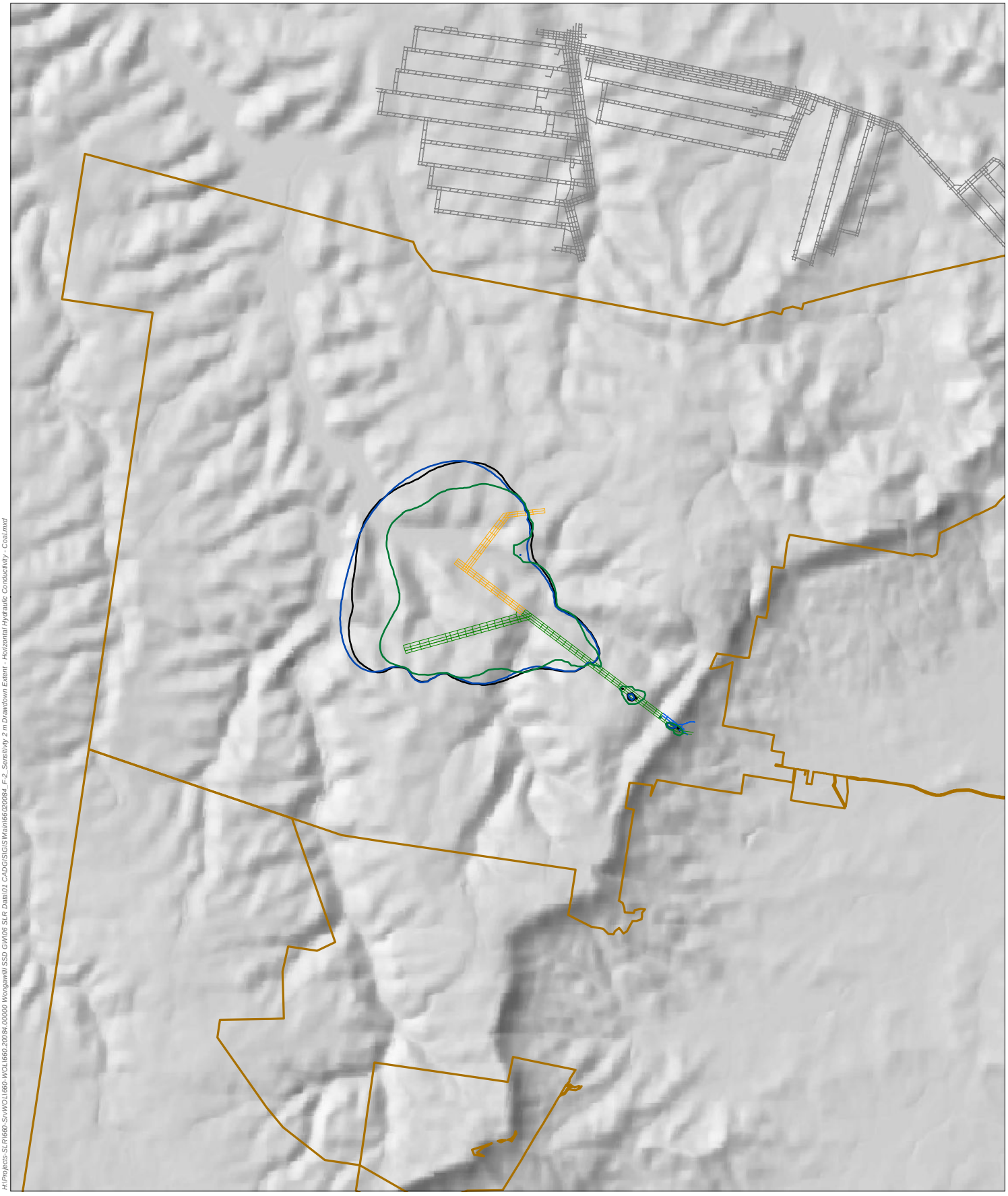
F - 1

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Results Legend

- Alluvium Down 1oM
- Alluvium Up 1oM
- Base



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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:80,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Results Legend

- Base
- Coal Down 1oM
- Coal Up 1oM

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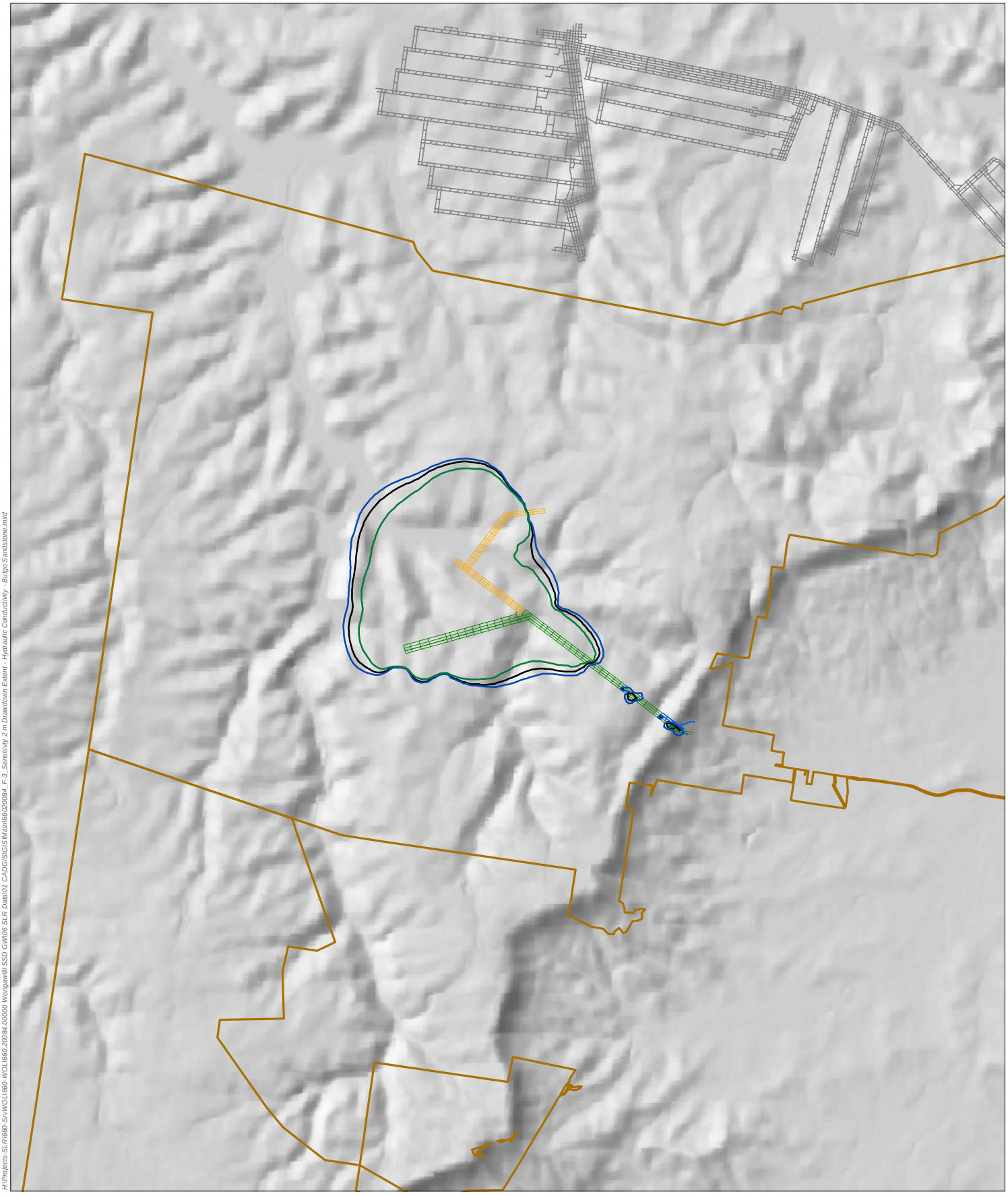
GROUNDWATER IMPACT ASSESSMENT

Sensitivty 2 m Drawdown Extent (Bulli Seam) - Horizontal Hydraulic Conductivity - Coal

F - 2



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0 2 km

GROUNDWATER IMPACT ASSESSMENT

Sensitivty 2 m Drawdown Extent (Bulli Seam) - Hydraulic Conductivity - Bulgo Sandstone

F - 3

Projection: GDA 1994 MGA Zone 56
Scale: 1:80,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Results Legend

- Bulgo Sandstone Down 1oM
- Bulgo Sandstone Up 1oM
- Base

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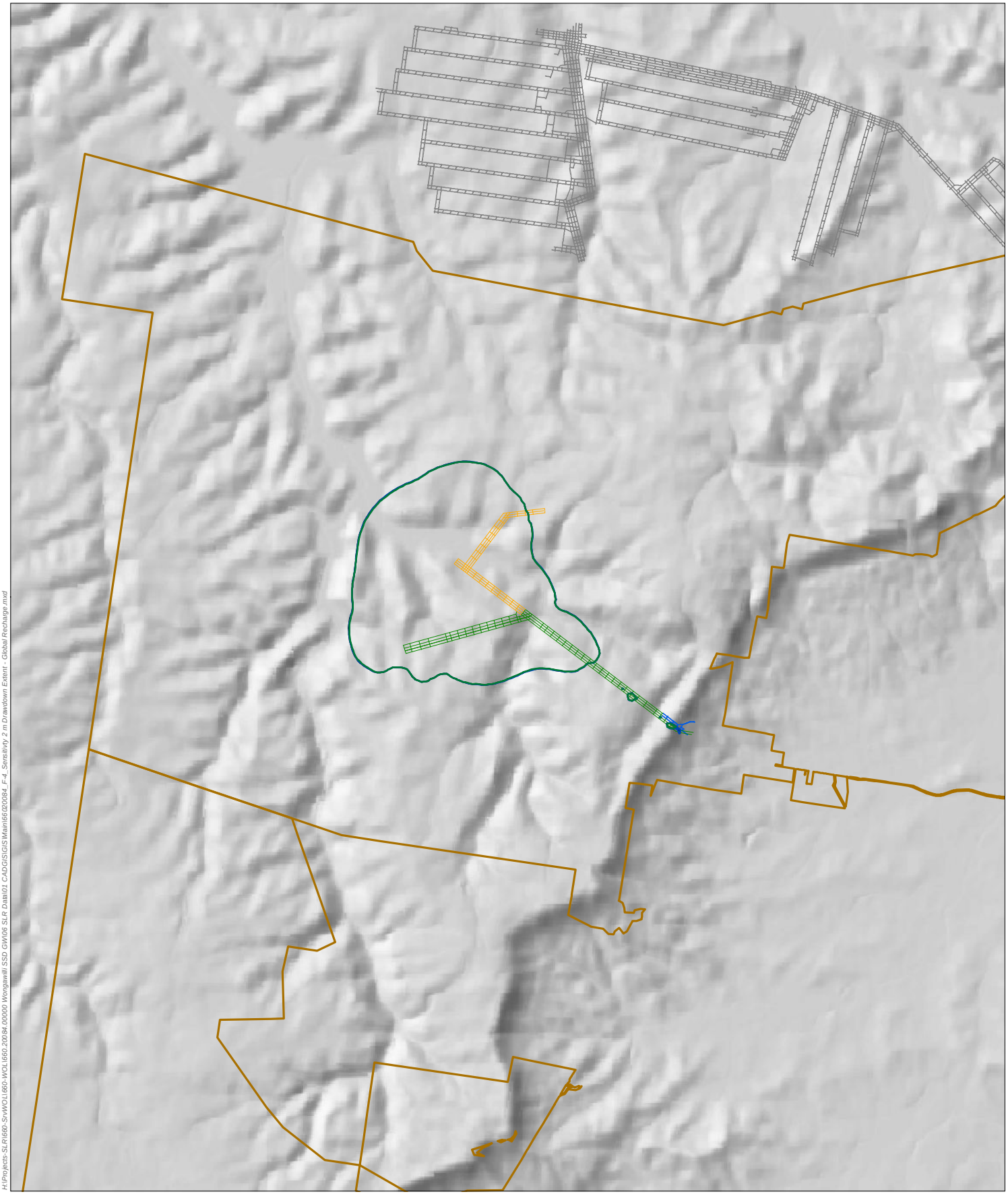

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0 2 km

Projection: GDA 1994 MGA Zone 56
Scale: 1:80,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

Legend
- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Results Legend
- Recharge Down 300%
- Recharge Up 300%
- Base

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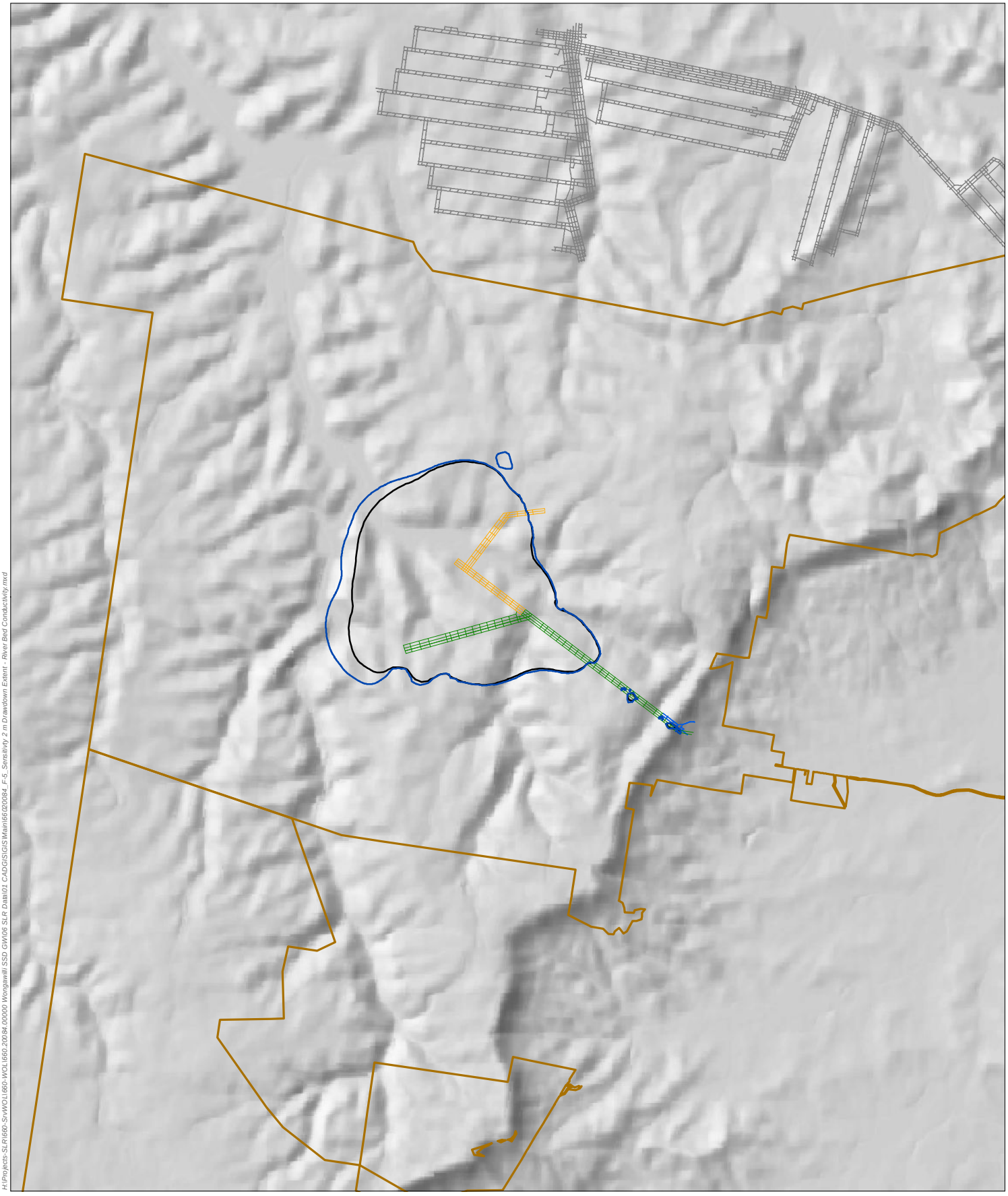
GROUNDWATER IMPACT ASSESSMENT

Sensitivty 2 m Drawdown Extent (Bulli Seam) - Global Recharge

F - 4



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0 2 km

GROUNDWATER IMPACT ASSESSMENT

Sensitivty 2 m Drawdown Extent (Bulli Seam) - River Bed Conductivity Up

F - 5

Projection: GDA 1994 MGA Zone 56
Scale: 1:80,000

Project No.:	660.20084.00000
Date:	10-Nov-2020
Drawn by:	AP
Sheet Size:	A4

Legend

- Proposed workings
- Approved workings
- Dendrobium workings
- Current workings
- Mining Lease

Results Legend

- River Conductance Up 1oM
- Base

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Appendix J

Groundwater peer review report

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13 November 2020

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Re: Wongawilli Colliery North West Mains Modification groundwater modelling independent review

1 Summary

This letter presents the findings of a peer review of numerical groundwater flow modelling of the Wongawilli Colliery North West Mains modification, developed by SLR Consulting Australia Pty Ltd (SLR), for Wollongong Coal Limited (WCL).

This review focusses on the numerical groundwater modelling carried out in support of the groundwater impact assessment. It does not focus on the field testing, data collection and analysis used in support of the groundwater model.

The review was carried out by Dr Doug Weatherill of EMM Consulting Pty Ltd in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012).

An overview of the initial groundwater conceptualisation was presented by SLR on 27 July 2020 and provided in more detail as a draft report on 14 September 2020. A groundwater impact assessment report was provided on 21 October 2020. This was peer reviewed and a revision of the model was recommended. Representation of historical mining, adopted hydraulic properties and recharge were revised as a result of the initial review. A revised groundwater impact assessment was delivered on 10 November 2020 and reporting revisions were recommended. The final groundwater impact assessment (SLR 2020) was delivered on 12 November 2020 and forms the basis for this peer review.

The Australian Groundwater Modelling Guidelines (Barnett et al. 2012) suggests a compliance checklist to summarise key review findings. This is presented in Table 1.1.

It is my view that, despite a number of limitations in the data, model calibration and improvements that could be made to the uncertainty analysis and reporting, the modelling is fit for purpose for scenario modelling to inform groundwater impact assessment and water licensing.

Table 1.1 Groundwater Model Compliance Checklist: 10-point essential summary

Question	Y/N	Comments re Wongawilli groundwater model
1. Are the model objectives and model confidence level classification clearly stated?	Yes	Yes. The report indicates the model is best described by a Class 2 confidence level with a number of attributes of a Class 3 model. The peer reviewer's own assessment is provided in Table 2.1, which suggests the model aligns best with a Class 2 confidence classification.
2. Are the objectives satisfied?	Yes	The groundwater assessment lists a number of tasks. Specific to the numerical modelling they can be summarised as: 1) Construct a model of the Wongawilli mine area that enables use for potential future mine modifications and groundwater impact assessments; 2) Predict drawdown impacts on registered third-party groundwater users and groundwater dependent ecosystems; and 3) Predict inflow to the mine.
3. Is the conceptual model consistent with objectives and confidence level?	Yes	Conceptual model is sound, based on data and local mining experience, modelling objectives and for impact assessment and licensing purposes.
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	The conceptual model refers to groundwater investigations from previous mining and modelling in the area and uses two previous numerical models (GeoTerra 2010 and HydroSimulations 2019) as its basis. The conceptualisation considers ranges of hydraulic property values from field testing as well as previous modelling. Current, during and post-project conceptualisations are presented.
5. Does the model design conform to best practice?	Yes	Industry-leading software (MODFLOW-USG in combination with a flexible Voronoi polygon mesh) is applied. Model domain is sufficiently large to encompass predicted project impacts but does display impacts of other projects at boundaries. Layers, mesh and boundary conditions generally consistent with best practice.
6. Is the model calibration satisfactory?	Yes	Calibration performance is acceptable. SRMS error of 8.44% is okay, but strongly skewed by a 250 m range in hydraulic head across monitoring locations and does not use all available data (Dendrobium data are excluded). Although calibrated in transient mode, the model does not display a good match to seasonality. Only one location, Nebo 1D (Bulli Coal seam) displays a clear response to mining. The model simulates drawdown at this location, but less than measured, and matches the zero impact at the overlying watertable measured at Nebo 1S.
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	Calibrated parameter values are generally consistent with ranges of hydraulic conductivity and effective porosity from testing and previous modelling. Values are presented in tabular format of min, mean and max only, with no illustration of their spatial distributions. Recharge rates, assigned as a percentage of rainfall, are plausible. The high recharge assigned in swamp areas (45% of rainfall) may be reflective of seepage from ponded water rather than episodic rainfall. Modelled historical mine inflows are compared to previously modelled inflows but not against measured inflows.
8. Do the model predictions conform to best practice?	Yes	Mining and post-mining periods are simulated with appropriate boundary conditions to represent mining such that predictions of drawdown impacts and mine inflows can be made.
9. Is the uncertainty associated with the simulations/predictions reported?	Yes	A series of deterministic predictions with selected alternative hydraulic properties was run. Their calibration performance, in terms of SRMS, is reported but it is not used to constrain the alternative predictions. This simple approach can be described as providing predictive sensitivity and aligns best with type 1 uncertainty analysis as outlined in the IESC explanatory note on uncertainty analysis (Middlemis & Peeters 2018).
10. Is the model fit for purpose?	Yes	It is my opinion that the model is fit for the purpose of predicting drawdown impacts and mine inflows for licensing purposes.

2 Model confidence level classification

The Australian Groundwater Modelling Guidelines (Barnett et al. 2012) provides a classification system that takes into account data used to inform the model conceptualisation, model design, calibration and predictive scenarios. Most models will have attributes that align with more than one class and, generally, the overall confidence level class is determined by the clustering of attributes.

The peer reviewer's assessment of the model using a modified version of the classification table is presented in Table 2.1. This assessment indicates that the model best aligns with a Class 2 description, with some attributes of a Class 1 and Class 3 model. This classification indicates that the modelling conducted for Wongawilli Colliery North West Mains Modification is suitable for impact assessment scenario modelling.

Table 2.1 Model Confidence Class characteristics

Class	Data	Calibration	Prediction	Quantitative Indicators
1	Not much / Sparse coverage	Not possible	Timeframe >> Calibration	Predictive Timeframe >10x Calib'n
	No metered usage	Large error statistic	Large stresses/periods	Predictive Stresses >5x Calib'n
	Low resolution topo DEM	Inadequate data spread	Poor/no verification	Mass balance > 1% (or one-off <5%)
	Poor aquifer geometry	Targets incompatible with model purpose	Transient prediction but steady-state calibration	Properties <> field values
	Basic/Initial conceptualisation			Poor performance stats / no review
2	Some data / OK coverage	Weak seasonal match	Predictive Timeframe > Calib'n	Predictive Timeframe = 3-10x Calib'n
	Some usage data	Some long-term trends wrong	Different stresses &/or periods	Predictive Stresses = 2-5x Calib'n
	Some baseflow estimates and some K & S measurements	Partial performance (eg some stats / part record / model-measure offsets)	No verification but key simulations constrained by data	Mass balance < 1% (all periods)
	Some high res. topo DEM and adequate aquifer geometry	Head & Flux targets constrain calibration	Calib. & prediction consistent (transient or steady-state)	Some properties maybe <> field values.
	Sound conceptualisation, reviewed & stress-tested	Non-uniqueness, sensitivity and qualitative uncertainty addressed	Magnitude & type of stresses outside range of calib'n stresses	Some poor performance or coarse discretisation in key areas/times
3	Plenty data, good coverage	Good performance statistics	Timeframe ~ Calibration	Predictive Timeframe <3x Calib'n
	Good metered volumes (all users)	Most long-term trends matched	Similar stresses &/or periods	Predictive Stresses <2x Calib'n
	Local climate data & baseflows	Most seasonal matches OK	Good verification or all simulations constrained by data	Mass balance < 0.5% (all periods)
	Kh, Kv & Sy measurements from range of tests	Calibration to present day head and flux targets	- Steady state prediction only when calibration in steady state	Properties ~ field measurements
	High res. topo DEM all areas & good aquifer geometry	Non-uniqueness minimised &/or parameter identifiability &/or minimum variance or RCS assessed	Suitable computational methods applied & parameters are consistent with conceptualisation	No poor performance or coarse discretisation in key areas (grid/time)
	Mature conceptualisation	Sensitivity &/or Qualitative Uncertainty	Quantitative uncertainty analysis	Review by experienced Hydro/Modeller

(after Table 2-1 of Australian Groundwater Modelling guidelines (Barnett et al. 2012)

Legend

Criterion met at higher Class	Criterion partially met at the relevant Class	Criterion met at the relevant Class	Criterion not met

3 Discussion

The groundwater assessment report (SLR 2020) covers the broad aspects expected in a modelling report, including project background and modelling objectives, conceptualisation, model design, history matching/calibration and associated sensitivity analysis, predictive modelling and uncertainty analysis. However, many of the figures are of low image quality, lack scale or spatial references and/or legends and do not specify what is shown in the figure (eg hydraulic head contours), so the reader requires familiarity with groundwater modelling and/or the project to understand them.

Conceptualisation of the groundwater system covers the geological setting, hydraulic properties of the hydrostratigraphic units, climate, surface water, historical mining activities, measured groundwater responses and aspects of water quality. The modelling then focusses on hydraulics only and water quality is not addressed further.

The model is built using the MODFLOW-USG numerical groundwater modelling code in combination with a flexible Voronoi polygon mesh. The option to pinch out/deactivate model cells where units are absent is employed for more numerically efficient solution than older MODFLOW codes, whilst enabling greater spatial resolution in areas of interest (25 m node spacing at proposed mining areas and 100 m or less at major rivers/creeks, the escarpment and historical mines). The model is discretised vertically into 18 model layers that enable representation of the variability in hydraulic properties, hydraulic head and groundwater flow in the different units. The report does not present the data sources used to define the geometry of the layers but indicates that geological models were used for the coal seams in the project area and the Dendrobium model (HydroSimulations 2019) was used outside of that.

Boundary conditions around the model edge are assigned using the Constant Head (CH) package (ocean and Lake Illawarra), General Head Boundary (GHB) package (inland boundaries) or are no flow boundaries. Whilst the boundary condition types are appropriate, the associated hydraulic head and conductance values are not documented. Surface water features are represented with the River (RIV) package and stage is allowed to vary over time based on gauge data. Conductance is calculated in a meaningful way, using properties of the individual features represented, but the assigned values and their distribution are not presented explicitly in the report. Recharge from rainfall and evapotranspiration are represented using the Recharge (RCH) and Evapotranspiration (EVT) packages and the values adopted are reasonable. Inflow to mine voids is simulated with the Drain (DRN) package. Although not explicitly stated in the report, the reviewer has confirmed with SLR that the boundary conditions do effectively dewater the coal seams during periods of active mining. Hydraulic properties are changed over time to represent mining, goaf and fracture zones using the Time-Variant Materials (TVM) package. Although the method is referenced, the adopted properties are not documented.

Transient hydraulic head monitoring data from five open standpipes and 54 vibrating wire piezometers (VWPs) were used to compile a calibration target dataset. It is not clear why the seven swamp deposit monitoring bores, mentioned in the environmental setting/conceptualisation section of the report, were excluded. The selected monitoring locations are focussed around the project area and do not provide good coverage of the whole model domain. The report indicates that this is due to a lack of groundwater data for other wells in the model domain. An independent check by the reviewer of the available data on the BoM Australian Groundwater Explorer online database (BoM 2020) confirmed that, although there are many bores registered, they do not have recorded hydraulic head data in their records. A data sharing agreement meant that SLR had access to groundwater monitoring data for the Dendrobium mine. The reviewer has confirmed with SLR that these data were not included in the Wongawilli model as it employs a relatively coarse mesh in the Dendrobium area because that is not the focus of the model and, hence, the model is not expected to replicate groundwater responses there.

There appears to be significant “noise” in the measured data for the monitoring sites used as calibration targets. Some of this may be due to VWP stabilisation following installation, recovery from previous mining or underground water storage activity, but this is not explained.

The model was calibrated to transient hydraulic head data using an automated approach. The model generally predicts stable head values at the target sites, not producing a great match to apparent seasonality. However, the model does simulate drawdown at the one monitoring location, Nebo 1D, that does show an apparent measured response to mining. The overlying watertable monitoring site, Nebo 1S, displays no evidence of impact from mining and this is replicated by the model. The key finding is that underground mining has not impacted shallow groundwater monitoring sites and the model is able to simulate this.

There seems to be confusion in the report between steady state and transient calibration results. Table 5-2 indicates an initial steady state stress period is employed pre-1940 to simulate pre-mining conditions. However, Figure 6-4, captioned as "Steady State Calibration (pre-mining) Layer 7 – Bulgo Sandstone", illustrates low hydraulic head in the centre of the model domain that the text explains by "Mining in the Dendrobium underground and Elouera have caused depressurized zones within the centre of the model in the Bulli and Wongawilli coal seams. In addition, the depressurization has extended to the shallower layers (e.g. Bulgo Sandstone) above the longwall panels …". It appears the calibration statistics and figures are likely for transient calibration only, particularly given no hydraulic head data are available for calibration of the time period (pre-1940) represented by the steady state stress period.

The model is also compared to historical modelled mine inflows from two previous modelling reports, but not against measured inflows.

Despite the limitations of the calibration dataset (local sites only, only one site with mining impact and "noise" in measured data), the hydraulic parameters employed in the model were initially based on those from the Dendrobium model (HydroSimulations 2019) which has been calibrated to a more substantial dataset displaying impacts of underground mining. Whilst the parameter values were allowed to vary in the calibration process, they should only have done so to improve the fit to the selected calibration dataset and hydraulic conductivity was not allowed to diverge from the Dendrobium model values more than half an order of magnitude.

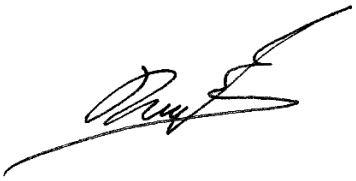
Predictive scenarios are conducted for a null case, approved mining and approved mining plus the project. These scenarios enable identification of groundwater impacts both cumulatively (ie total impact) and incrementally (ie additional impact due to the project). This is consistent with best practice and reduces uncertainty in the results. The report would benefit from presentation of modelled hydrographs at existing monitoring bores and key environmental sites (eg the swamp overlying the project) to document the predicted hydraulic head over time during and post mining. This would enable subsequent validation of predictions.

Uncertainty analysis is conducted in a simple manner, with somewhat arbitrary variations in selected hydraulic properties that are not based on outcomes of the calibration sensitivity analysis. This simple approach best aligns with type 1 uncertainty analysis as outlined in the IESC explanatory note on uncertainty analysis (Middlemis & Peeters 2018). This approach is appropriate in this case given the low risk to third party groundwater users and groundwater dependent ecosystems sensitive to watertable drawdown. This is largely due to the presence of three aquitards overlying the coal seams proposed to be mined. These are the Bald Hill Claystone, Stanwell Park Claystone and Wombarra Claystone. The report does not make this case strongly, nor use it to justify the approach to uncertainty analysis, but it is the reviewer's opinion that the geological setting and risk posed by the project justify a type 1 approach.

4 Conclusion

It is my professional opinion that, despite a number of limitations in the data, model calibration and improvements that could be made to the uncertainty analysis and reporting, the modelling is fit for purpose for scenario modelling to inform groundwater impact assessment and water licensing.

Yours sincerely



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5 References

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