DEPARTMENT OF EARTH AND ENVIRONMENTAL SCIENCES
Faculty of Science and Engineering

MACQUARIE University

Report on the geomorphic condition, and protection and rehabilitation priorities for Mulwaree chain-of-ponds

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As part of an Australian River Restoration Centre (ARRC) project.

All photos in this report taken by K. Fryirs.

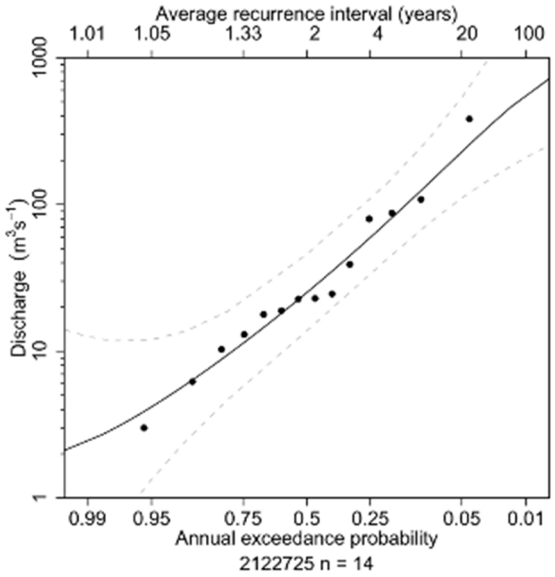
Methods

- Hec-Ras was run on the 5m Digital Elevation Model (DEM) for the full length of Mulwaree from near Lake Bathurst to Goulburn.
- Six discharges were modelled. Only the 1:20 yr AI is provided as it gives the best analysis for identification of erosion hotspots (see Appendix A and B).

Discharges for Komungla Bridge at Tirrannaville

Discharge (m3s-1)	~AEP %	ARI
5	90	1.11
10	75	1.33
20	50	2
40	20	5
100	10	10
200	5	20

Discharge at Mulwaree at The Towers.
From: Rustomji P, Pietsch TJ, Wilkinson S. 2006. Pre and post-European settlement patterns of floodplain deposition in the Lake Burragorang catchment. CSIRO Land and Water Science Report 38/06: Canberra 85, https://doi.org/10.4225/08/585ac5b5b8c99.



- Two days of fieldwork were untaken to walk the focus reaches on the properties of Kelburn and Tirranaville. The river walk was used to undertake reach identification, geomorphic condition analysis and to identify headcuts.
- When combined with the Hec-Ras modelling, field analyses were used to make recommendations on the protection and rehabilitation priorities on the two properties.
- A photo mosaic of reaches showing their condition and the location of headcuts was compiled.

Hec-Ras unit stream power modelling: What does it mean?

This section is accompanied by Appendix A on top of the elevation model. The exact same output is represented in Appendix B on a greyscale (hillshade) version for completeness.

What is unit stream power? – Unit stream power is a measure of energy expenditure per unit width of channel (or flow). It is a measure used to determine erosion potential and the amount of potential geomorphic work that can be undertaken by any particular discharge. Indicative thresholds of erosion and sediment reworking have been defined in relation to critical values of unit stream power. For example, the movement of pebbles and cobbles is indicatively around 1.5 Wm^2 and 16 Wm^2 respectively. The threshold level of channel instability (bed and bank erosion) is around 35 Wm^2.

What do the colours mean? – In Appendix A anything that is yellow, orange or red is considered an erosion hotspot (>30 Wm^2).

What is the interpretation of this modelling? – The erosion hotspots along Mulwaree are mostly occurring at the exit of ponds where flow is being forced into an adjoining connecting (incised) channel downstream. This process is occurring most actively at 'bankfull' stage when pond level rises above its 'exit lip' and flow is filing the connecting channels. You will see that the areas downstream of ponds that are blue or purple are low energy zones. These are areas where preferential flow paths remain intact and flow is dissipated over swampy ground and adjacent floodplains when it exits a pond. The aim of rehabilitation (or conservation) is to retain the blue and treat the orange and red areas to recover them towards blue. Erosion processes start to occur during the 1:10 yr flood (100 m^3s^{-1}) and most actively during the 1:20 yr flood (200 m^3s^{-1}) (Appendix A output). Some minor erosion hotspots occur during the 1:5 yr flood (40 m^3s^{-1}).

How have we used this modelling? – We have used this modelling to identify erosion hotspots and situate them within the prioritisation recommendations.

Geomorphic condition indicators for a chain-of-ponds

Geomorphic characteristic	Good (expected) and poor (unexpected) observations and interpretations
Valley floor (swamp) surface moisture	• **Good** - Water in ponds and in swampy preferential flow paths between ponds, or ground is saturated (boggy) between ponds. • **Poor** - Water in ponds but swampy preferential flow paths between ponds are dry or dessicated.
Preferential flow paths and connecting channels	• **Good** - single or multiple surficial drainage lines on the swamp surface between ponds. • **Poor** - there should be no connecting channels (with bed and banks) between ponds.
Pond morphology	• **Good** - elliptical shaped ponds with reasonable coverage of aquatic bank-side vegetation. • **Poor** - elliptical shaped ponds with no coverage of aquatic bank-side vegetation.
Connecting channel stability	• **Good** – n/a (there should be no connecting channels between ponds) • **Poor** – connecting channels with vertical banks, bank erosion (undercutting and slumping) that represent channel incision and expansion.
Headcuts	• **Good** – n/a (there should be no headcuts in preferential flow paths or at the heads of ponds) • **Poor** – presence of headcuts, either vertical or gradual in morphology.
Sediment regime	• **Good** - preferential flow paths, ponds and any connecting channels should contain peaty/organic materials and fine-grained sediments. • **Poor** – presence or active movement of sands and gravels in connecting channels.

Reach condition along the Kelburn and Tirranaville chain-of-ponds

This table is accompanied by Appendix C.

Reach/Condition	Kelburn Reach 1	Kelburn Reach 2	Tirranaville Reach 1	Tirranaville Reach 2	Tirranaville Reach 3	Tirranaville Reach 4
Description	poor condition chain of ponds with incised channels (contains headcuts as threats)	intact chain of ponds with preferential flow paths (contains headcuts as threats)	incised channel with no ponds remaining	poor condition chain of ponds with incised channel that is now recovering	intact chain of ponds with preferential flow paths (contains headcuts as threats) – already an identified RoC potential site/reach	elongate ponds with rehabilitation
Condition (green = Good, red = Poor)						

Matrix of priorities against river reaches

This table is accompanied by Appendix C.

Priority/Reach	Kelburn Reach 1	Kelburn Reach 2	Tirranaville Reach 1	Tirranaville Reach 2	Tirranaville Reach 3	Tirranaville Reach 4
Priority 1						**already rehabilitated**
Priority 2						
Priority 3						
Priority 4						

River management recommendations and priorities

The overall primary aim is to get the roughness back into the system (via aquatic vegetation (re)establishment) and varied methods of stock management. We recommend no stock access to reaches threatened by headcuts or where intact preferential flow paths occur. Manage stock access into ponds and where connecting channels already occur.

Priority 1 – off-river stock water points and stock management. We recommend this particularly at Kelburn. Stock are an ongoing threat to the integrity of the ponds and are causing further erosion of connecting channels. Exclusion is recommended at headcuts and along 'intact' reaches (see Priority 2 & 3).

Priority 2 - Look after the identified 'intact' reaches at Tirranaville (Reach 3) and Kelburn (Reach 2). The Tirranaville reach has already been identified by RoC as a possible site for work. Extend fencing from existing downstream sites, upstream into this reach. Allow aquatic vegetation to re-establish. Added benefit of working in this reach is that it extends upstream from existing works and previous projects at Tirranaville. At Kelburn there is existing fencing on the west-bank but not on the east bank. Connecting part of the unfenced chain-of-ponds corridor is recommended. Limit or exclude stock access to these reaches.

Priority 3 – Monitor and manage identified headcuts. We identified five headcuts in the system (2 at Tirrannavlle and 3 at Kelbun) in Priority 2 and 4 reaches. Although they have not moved for some time, and all are relatively gradual headcuts, all are exposed to disturbance and could pose a threat to the integrity of ponds in the reaches in which they occur. This is particularly the case in Priority 2 reaches, which we recommend be considered first in parallel with the Priority 2 strategy. We recommend that the headcuts be monitored over time, the reaches fenced off, stock excluded and aquatic revegetation (natural or direct) be undertaken particularly around the headcuts to ensure sufficient roughness to withstand flood flows. At this stage we do not recommend any direct works or heavy interventions at these headcuts that would exacerbate them and make them unstable.

Priority 4 – Kelburn connecting channels. There are several connecting channels between ponds at Kelburn in Reach 1 that are severely eroded. Existing fencing is in place along most of these reaches. Some reed beds are re-establishing at the erosion hotspots at the exit zones to some ponds. The reed beds should be enhanced and extended downstream, particularly at the headcuts in Kelburn Reach 1. Getting aquatic roughness back into the connecting channels at these hotspots and in the reaches immediately downstream will likely prevent further incision and channel erosion in the pond exit zones. More appropriate stock management is required for all these reaches to allow reinforcing grasses and aquatic vegetation to come back naturally or directly along the incised channels.

Appendix A Hec-Ras unit stream power modelling for the 1:20 yr flood (200 m^3s^{-1}) on the elevation layer.

741600 741800 742000 742200 742400 742600

6121000 6120800 6120600 6120400 6120200 6120000 6119800 6119600 6119400 6119200

Note: This is the most upstream map.
Kelburn starts on Map 11 and
Tirranaville of Map 12.

Map 1

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

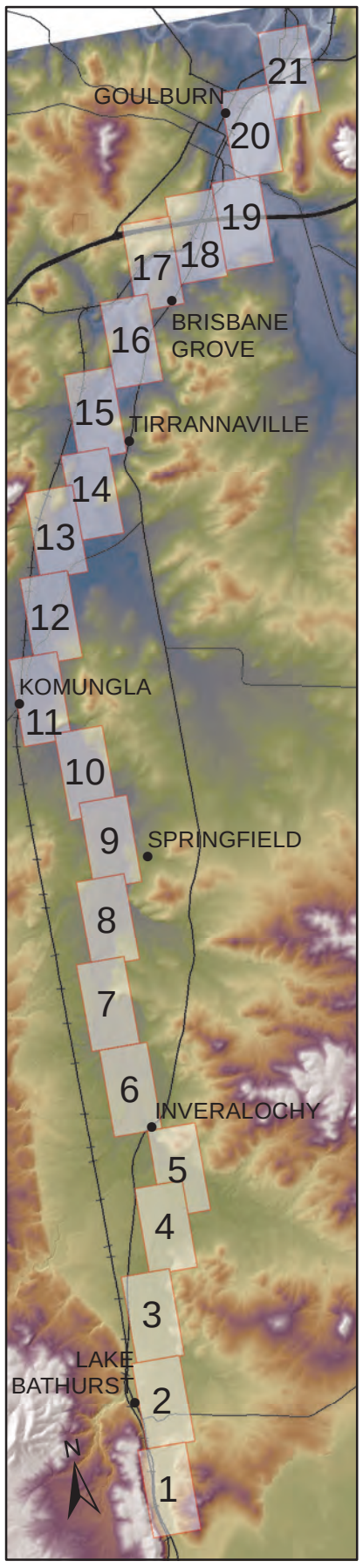
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 2

741800 742000 742200 742400 742600 742800

6123000 6122800 6122600 6122400 6122200 6122000 6121800 6121600 6121400 6121200

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

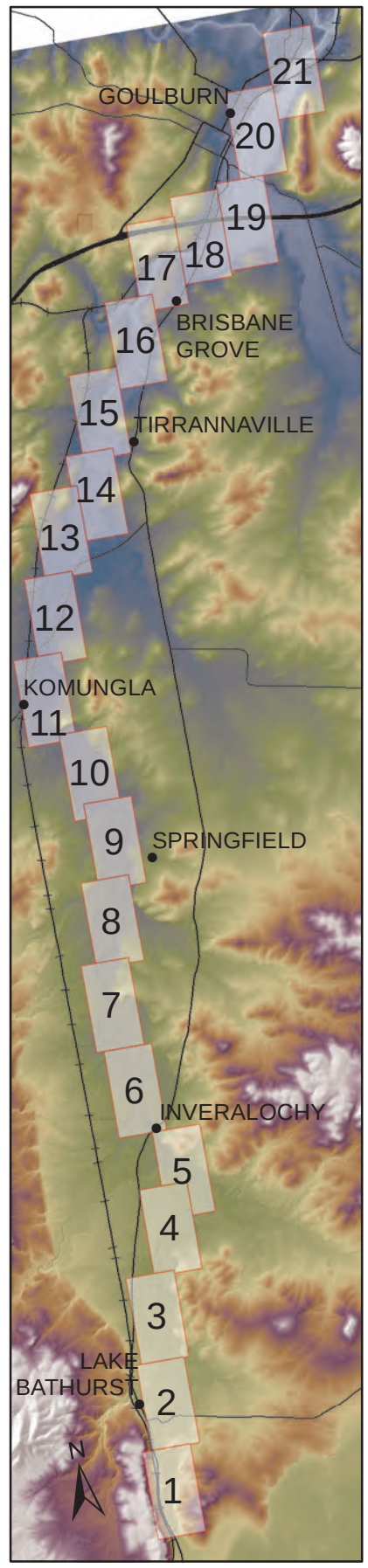
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 3

742000 742200 742400 742600 742800

6125000 6124800 6124600 6124400 6124200 6124000 6123800 6123600 6123400 6123200

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150

Mulwaree River

Ponds

Elevation above channel

10

0 m

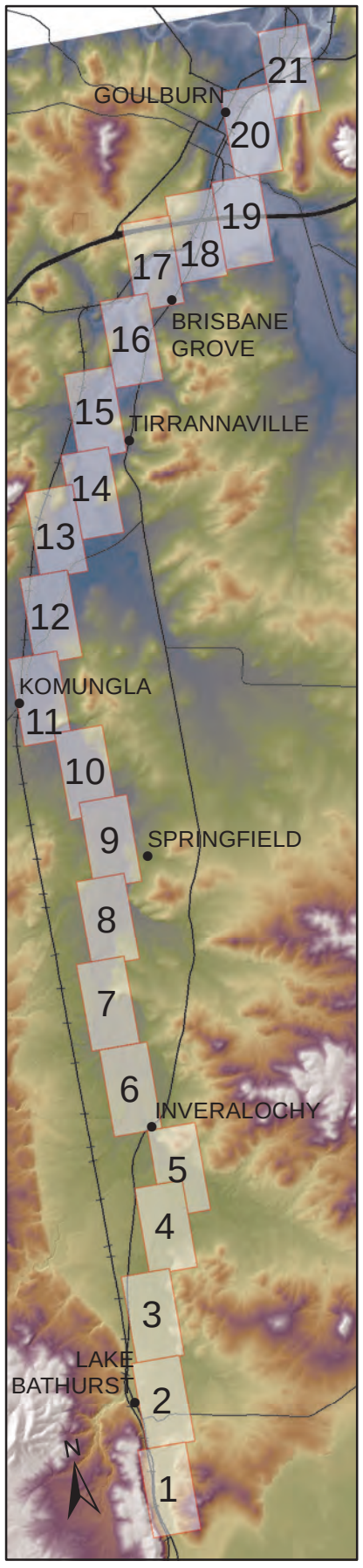
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 4

742600 742800 743000 743200 743400 743600

6127000 6126800 6126600 6126400 6126200 6126000 6125800 6125600 6125400 6125200

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

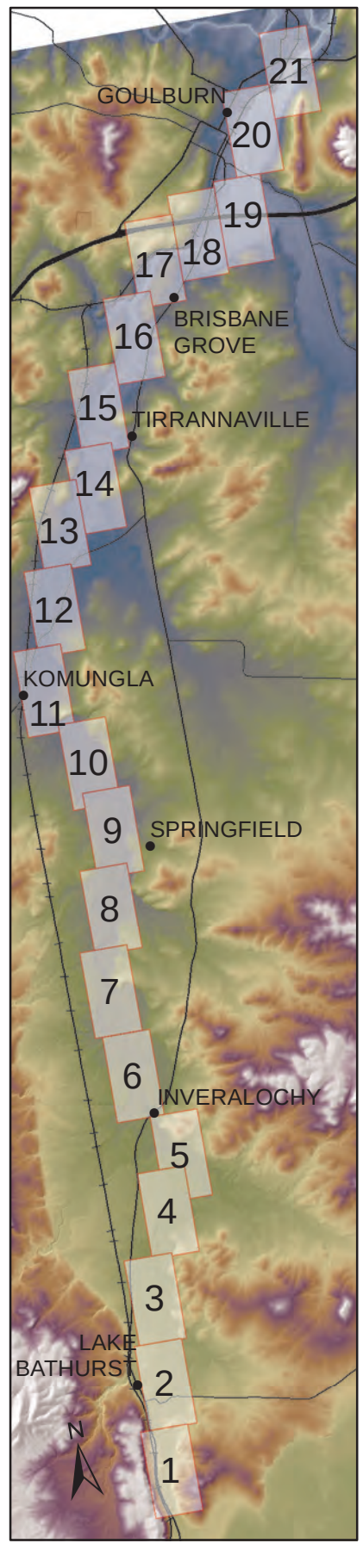
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 5

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

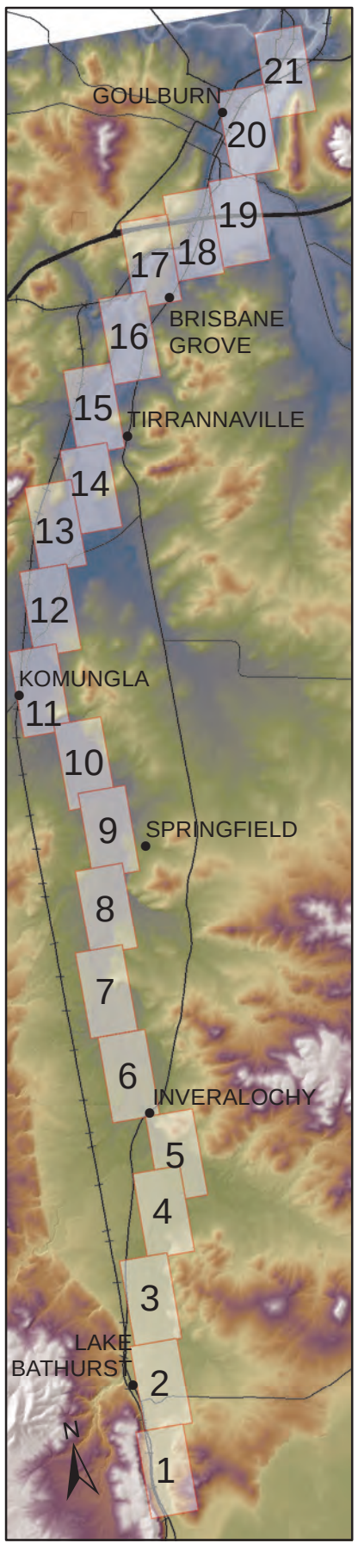
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



743200 743400 743600 743800 744000

6128200 6128000 6127800 6127600 6127400 6127200 6127000 6126800 6126600 6126400

Map 6

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

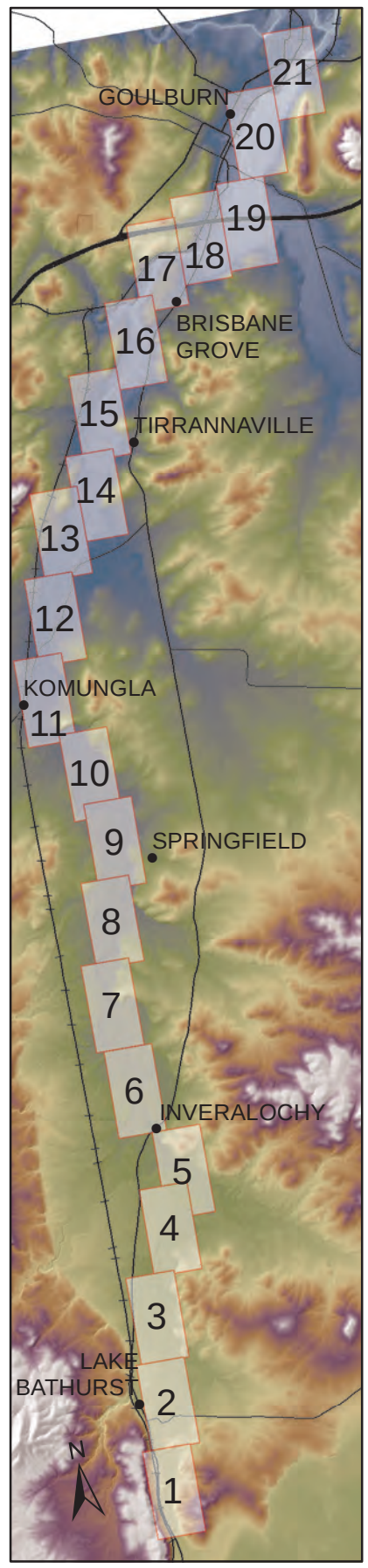
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



742400 742600 742800 743000 743200

6130200 6130000 6129800 6129600 6129400 6129200 6129000 6128800 6128600 6128400

Map 7

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

N

1:5,000

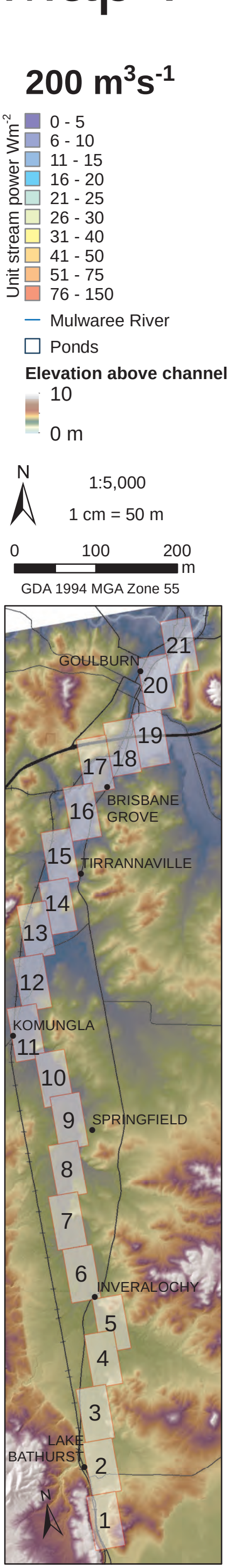
1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55

742200 742400 742600 742800 743000 743200

6132200 6132000 6131800 6131600 6131400 6131200 6131000 6130800 6130600 6130400



Map 8

742600 742800 743000 743200 743400

6134000 6133800 6133600 6133400 6133200 6133000 6132800 6132600 6132400 6132200

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150

Mulwaree River

Ponds

Elevation above channel

10

0 m

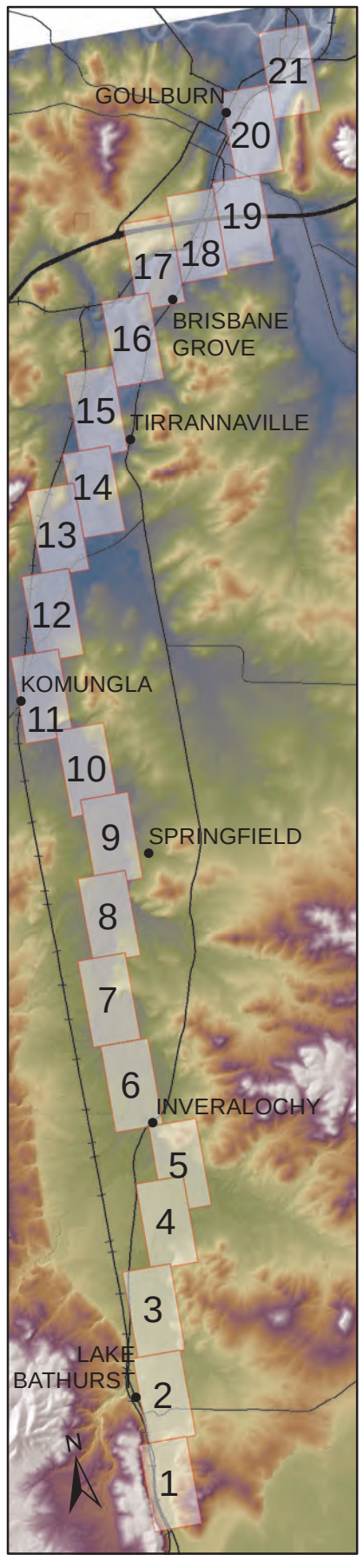
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 9

743000 743200 743400 743600 743800

6135800 6135600 6135400 6135200 6135000 6134800 6134600 6134400 6134200 6134000

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

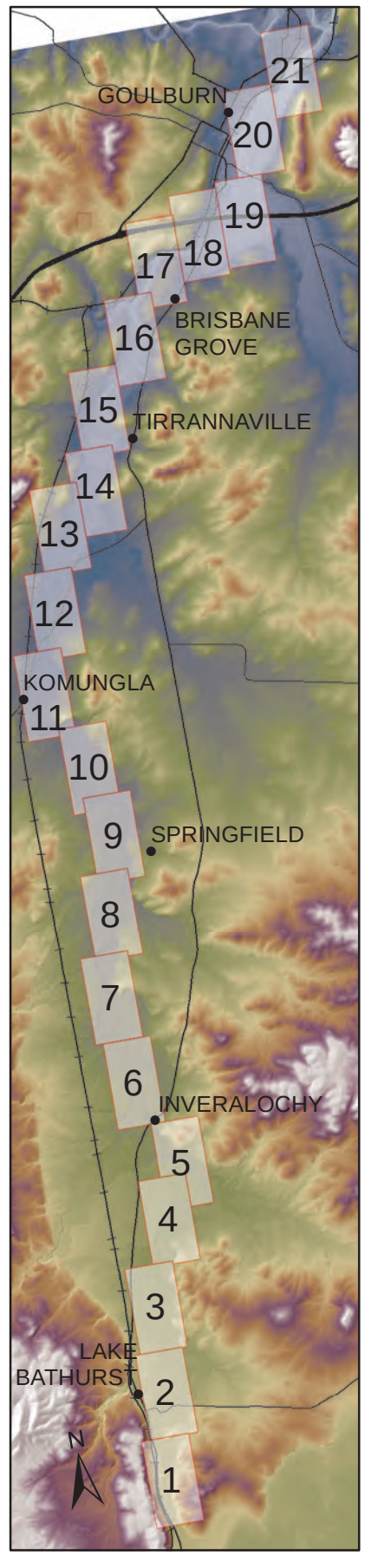
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 10

742600 742800 743000 743200 743400 743600

6137400 6137200 6137000 6136800 6136600 6136400 6136200 6136000 6135800 6135600

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150

Mulwaree River

Ponds

Elevation above channel

10

0 m

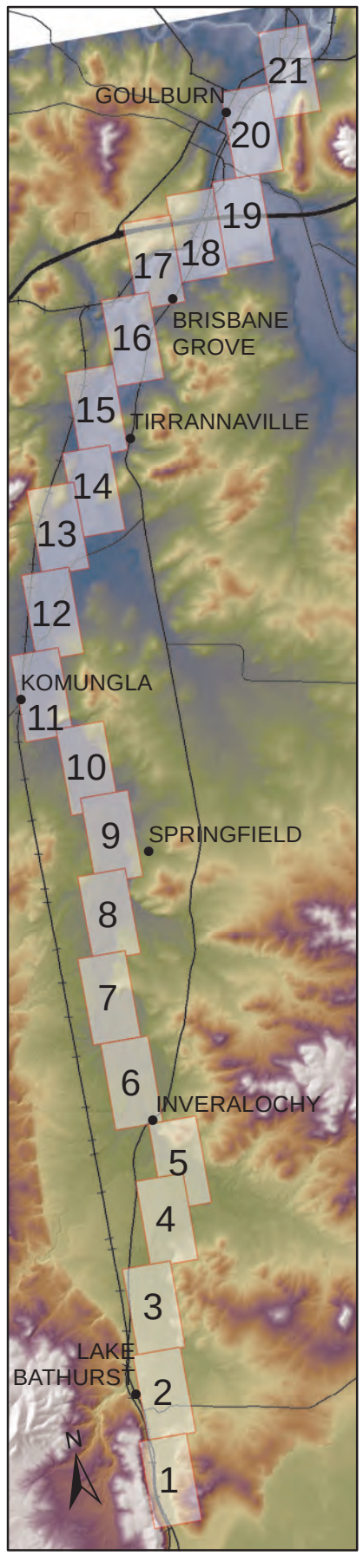
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 11

742000 742200 742400 742600 742800

6139200 6139000 6138800 6138600 6138400 6138200 6138000 6137800 6137600 6137400

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

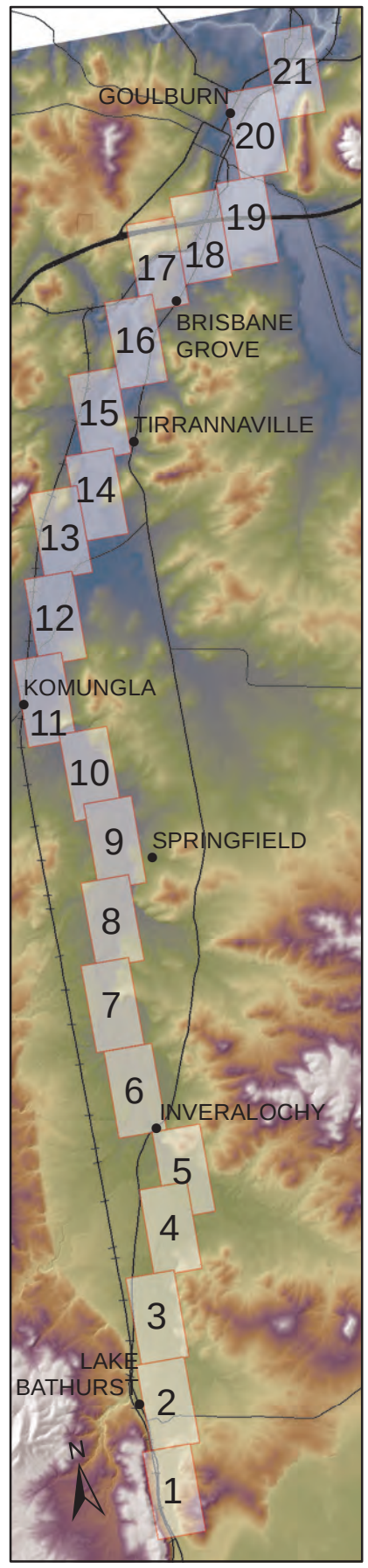
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 12

742400 742600 742800 743000 743200 743400

6141000 6140800 6140600 6140400 6140200 6140000 6139800 6139600 6139400 6139200

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150

Mulwaree River

Ponds

Elevation above channel

10

0 m

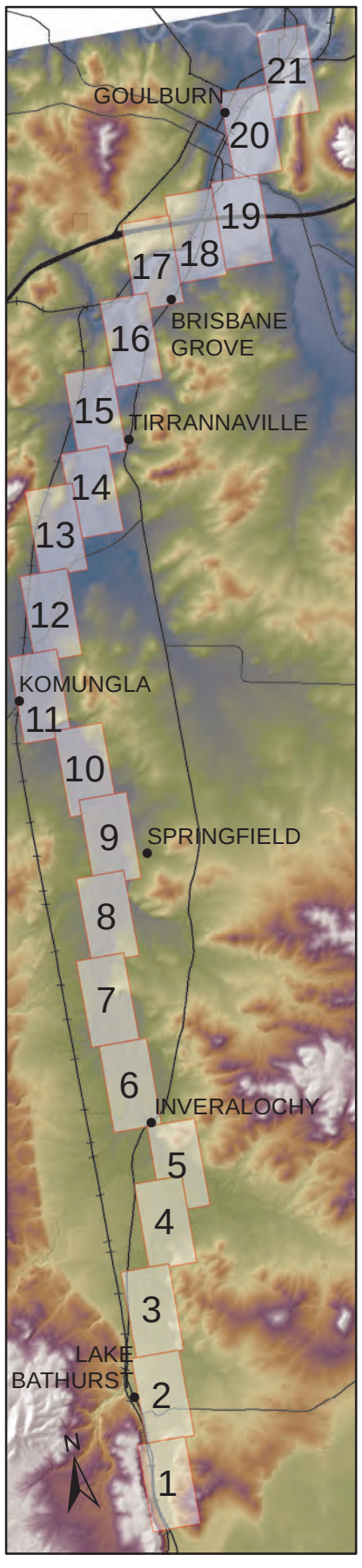
N

1:5,000

1 cm = 50 m

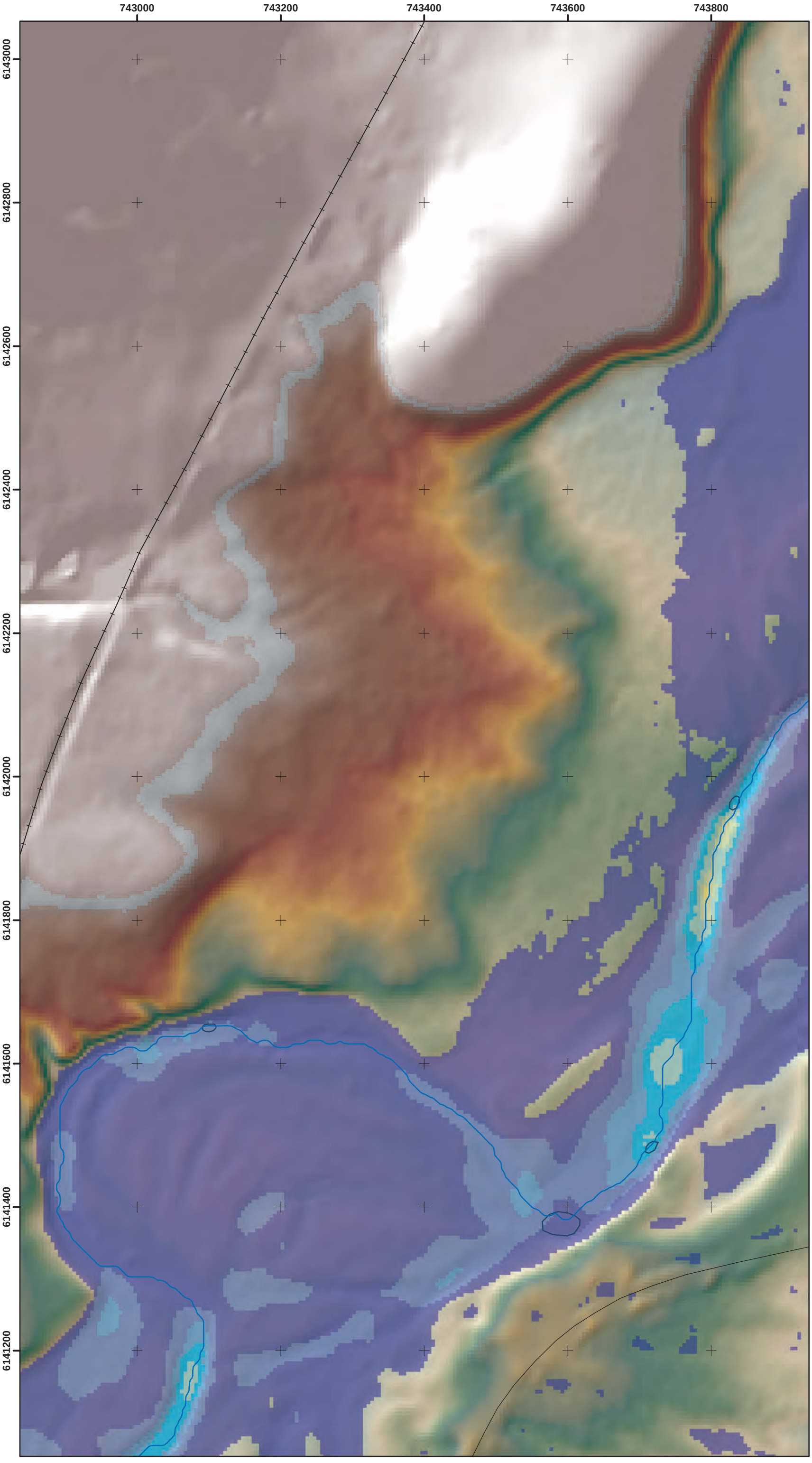
0 100 200 m

GDA 1994 MGA Zone 55



Map 13

200 m^3s^{-1}



Unit stream power Wm^{-2}
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150

Mulwaree River

Ponds

Elevation above channel

10

0 m

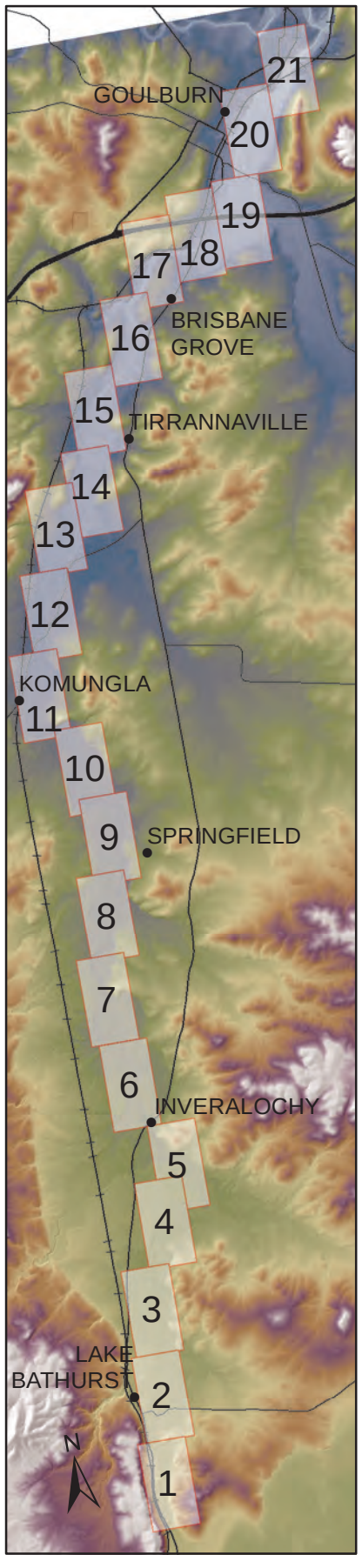
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 14

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

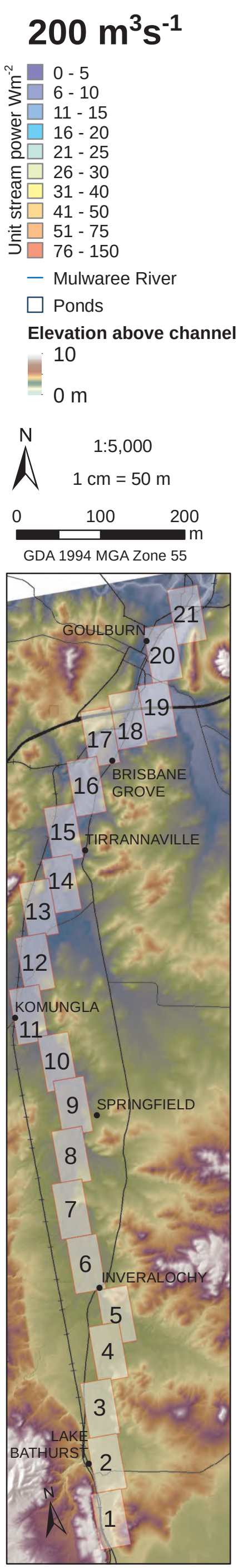
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



743800 744000 744200 744400 744600 744800

6143600 6143400 6143200 6143000 6142800 6142600 6142400 6142200 6142000 6141800

Map 15

744200 744400 744600 744800 745000 745200

6145400 6145200 6145000 6144800 6144600 6144400 6144200 6144000 6143800 6143600

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

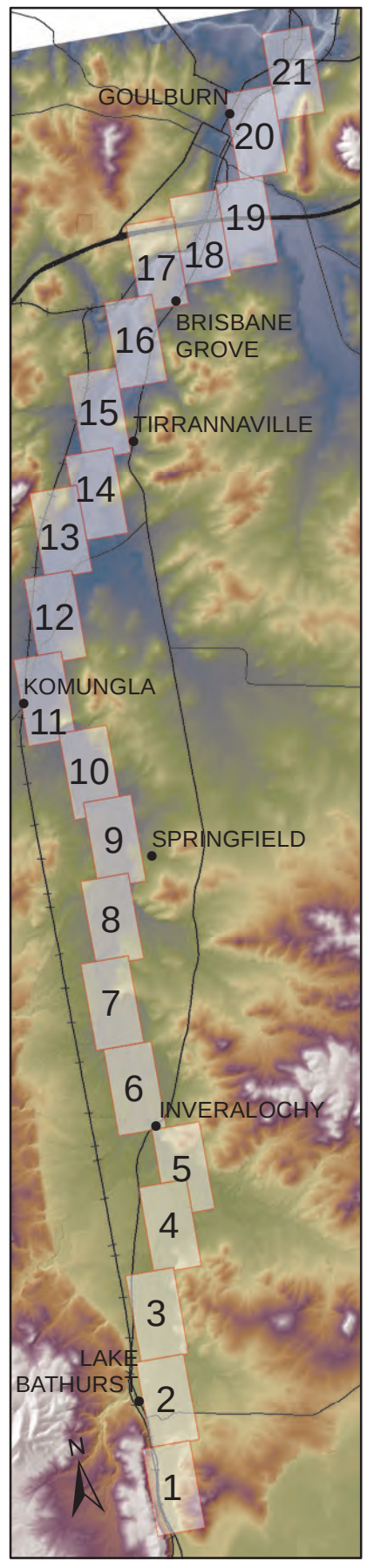
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 16

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

N

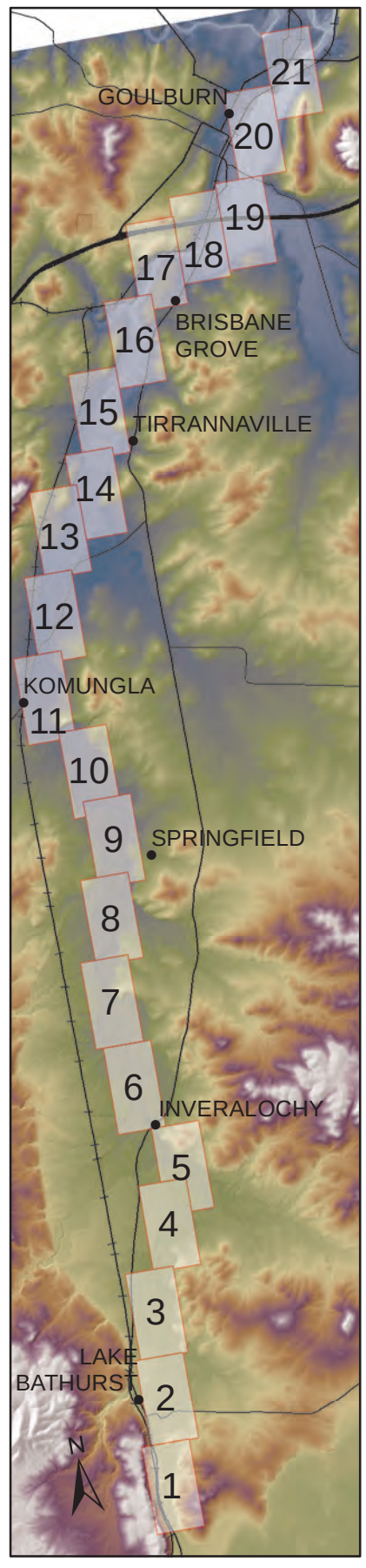
1:5,000

1 cm = 50 m

0 100 200

m

GDA 1994 MGA Zone 55



745400 745600 745800 746000 746200

6147000 6146800 6146600 6146400 6146200 6146000 6145800 6145600 6145400 6145200

Map 17

746200 746400 746600 746800 747000

6148600 6148400 6148200 6148000 6147800 6147600 6147400 6147200 6147000 6146800

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150

Mulwaree River

Ponds

Elevation above channel

10

0 m

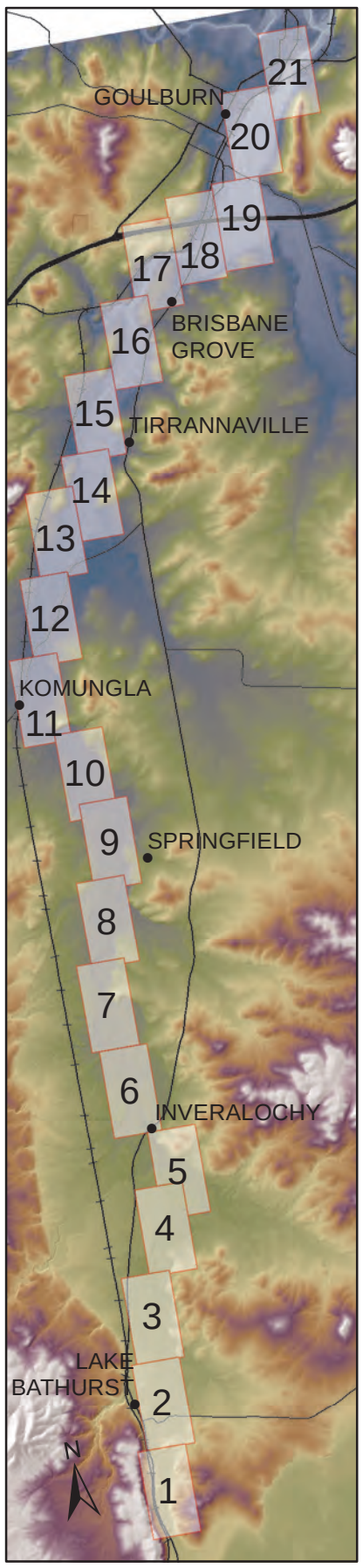
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 18

200 m^3s^{-1}

Unit stream power Wm^{-2}
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150

Mulwaree River

Ponds

Elevation above channel

10

0 m

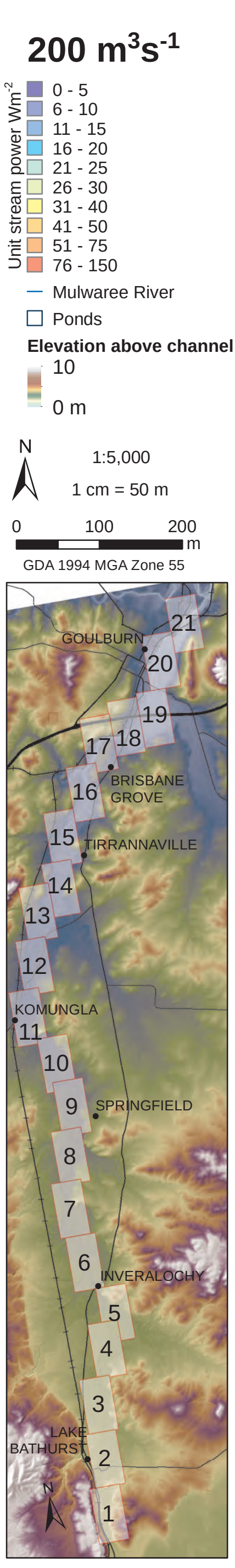
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



747200 747400 747600 747800 748000 748200

6149000 6148800 6148600 6148400 6148200 6148000 6147800 6147600 6147400 6147200

Map 19

748400 748600 748800 749000 749200

6149200 6149000 6148800 6148600 6148400 6148200 6148000 6147800 6147600 6147400

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

Elevation above channel

10

0 m

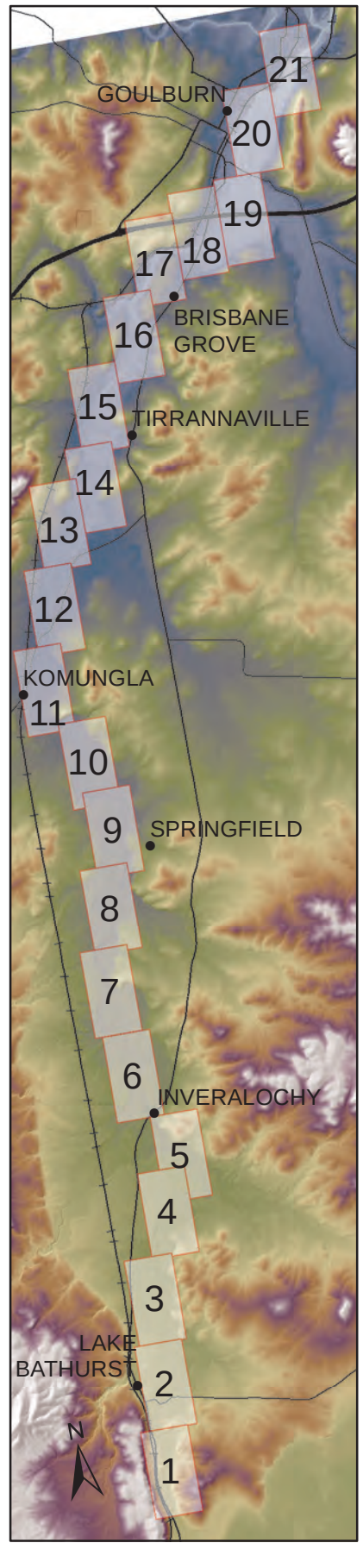
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 20

748800 749000 749200 749400 749600 749800

6151200 6151000 6150800 6150600 6150400 6150200 6150000 6149800 6149600 6149400

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150

Mulwaree River

Ponds

Elevation above channel

10

0 m

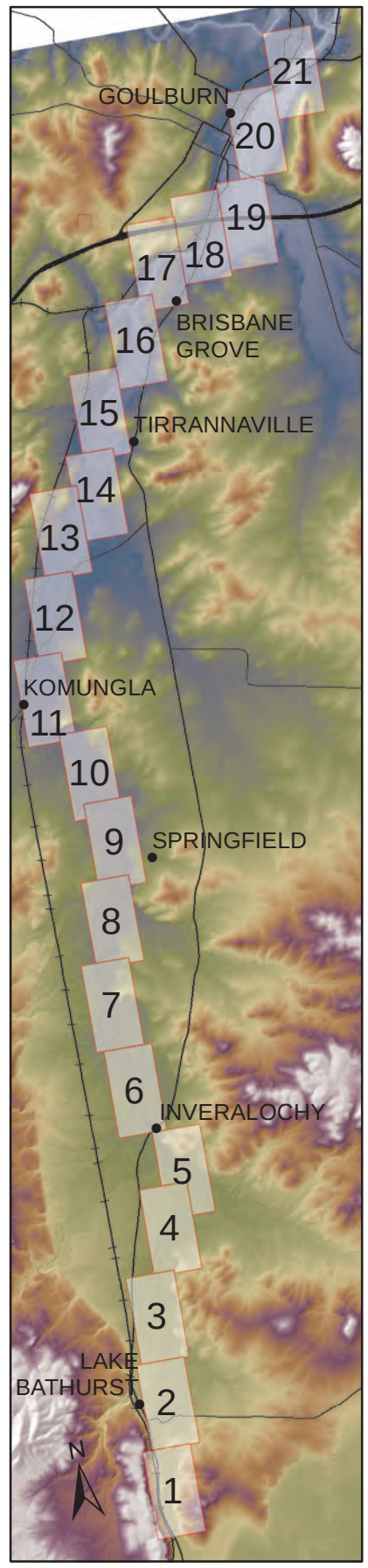
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Map 21

750000 750200 750400 750600 750800

6152400 6152200 6152000 6151800 6151600 6151400 6151200 6151000 6150800 6150600

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150

Mulwaree River

Ponds

Elevation above channel

10

0 m

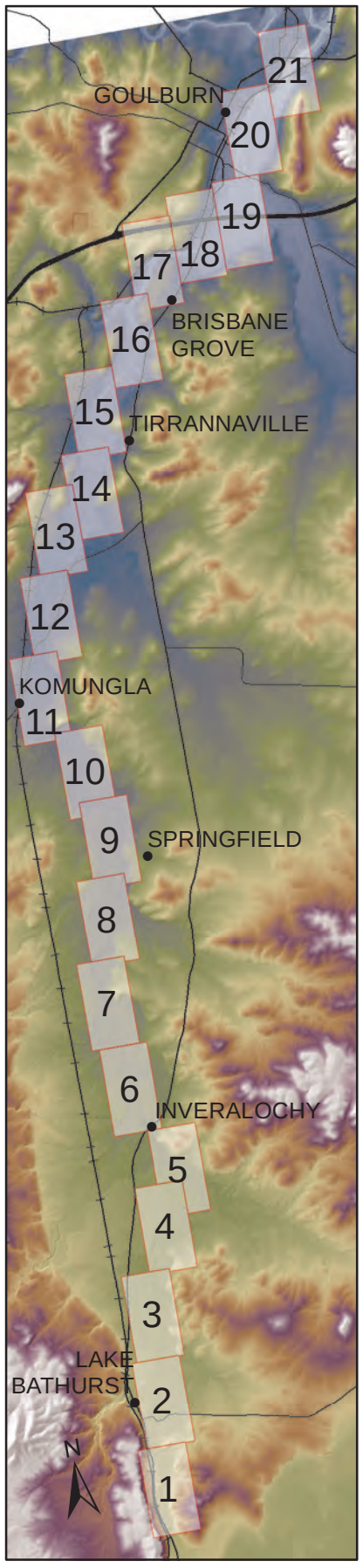
N

1:5,000

1 cm = 50 m

0 100 200 m

GDA 1994 MGA Zone 55



Appendix B Hec-Ras unit stream power modelling for the 1:20 yr flood (200 m^3s^{-1}) on the hillshade layer.

741600 741800 742000 742200 742400 742600

6121000 6120800 6120600 6120400 6120200 6120000 6119800 6119600 6119400 6119200

Note: This is the most upstream map.
Kelburn starts on Map 11 and
Tirranaville on Map 12.

Map 1

200 m^3s^{-1}

Unit stream power Wm^{-2}

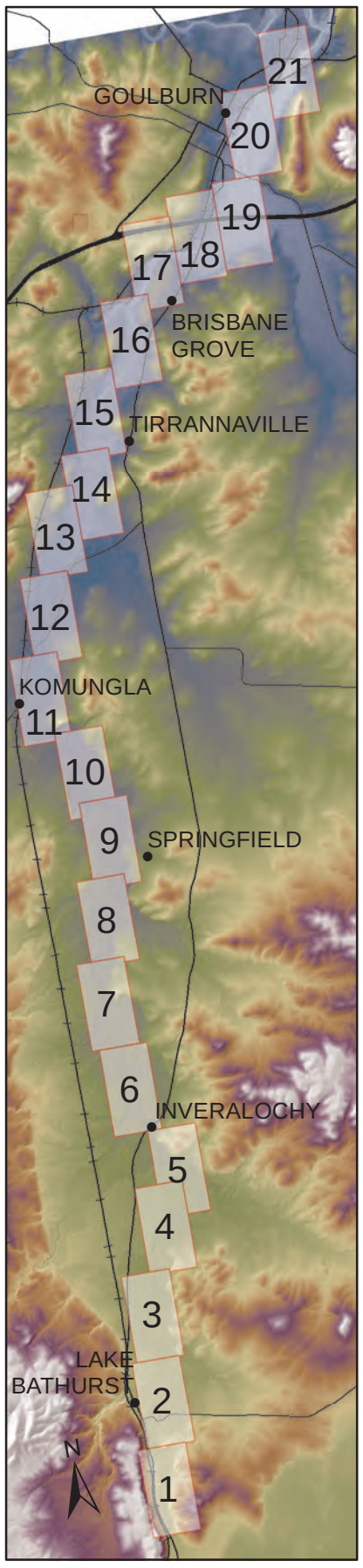
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



Map 2

741800 742000 742200 742400 742600 742800

6123000 6122800 6122600 6122400 6122200 6122000 6121800 6121600 6121400 6121200

200 m^3s^{-1}

Unit stream power Wm^{-2}

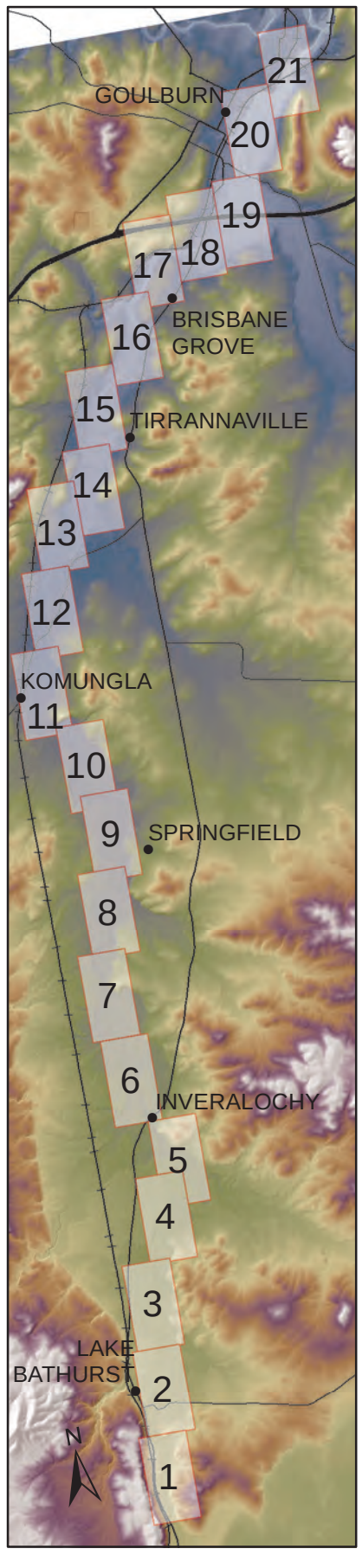
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



Map 3

742000 742200 742400 742600 742800

6125000 6124800 6124600 6124400 6124200 6124000 6123800 6123600 6123400 6123200

200 m^3s^{-1}

Unit stream power Wm^{-2}

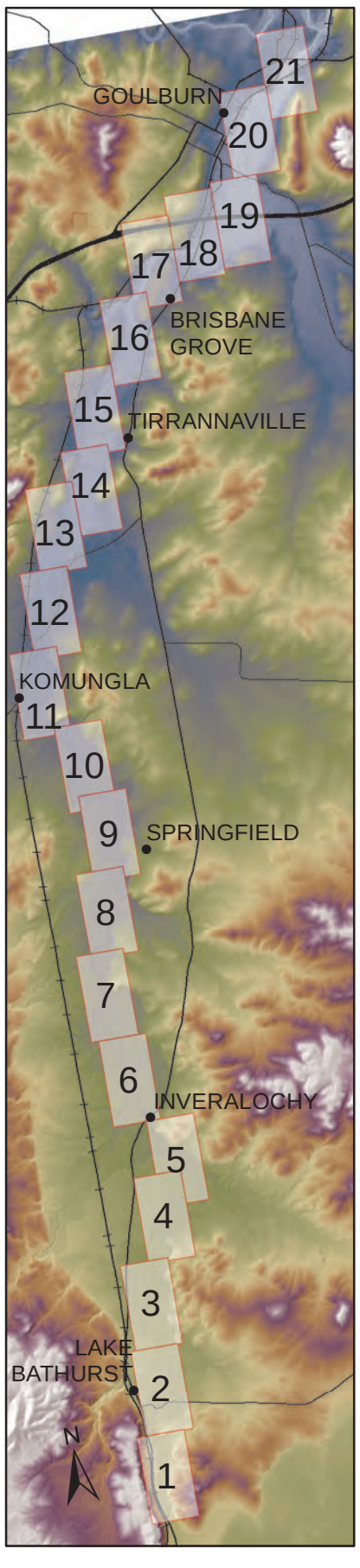
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



Map 4

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

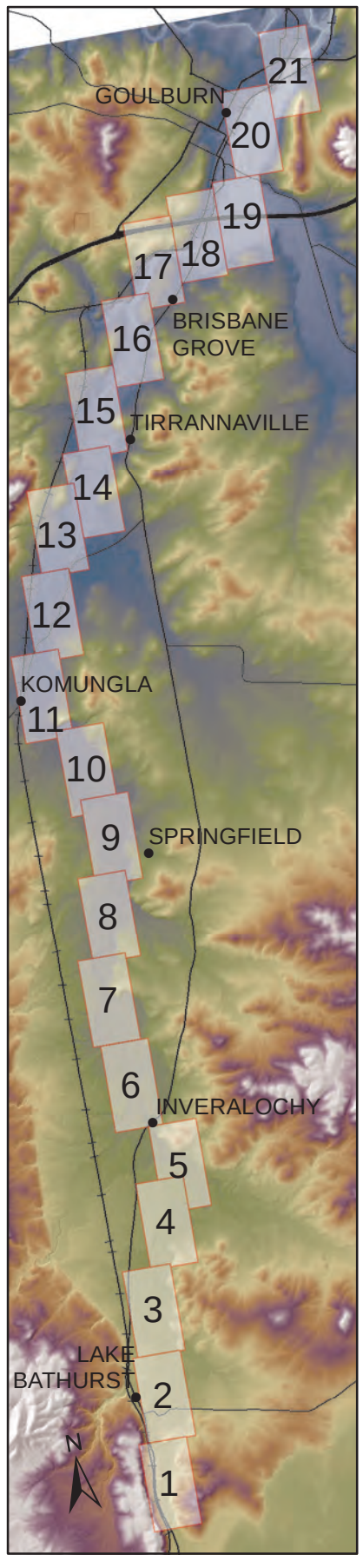
1:5,000

1 cm = 50 m

0 100 200 m

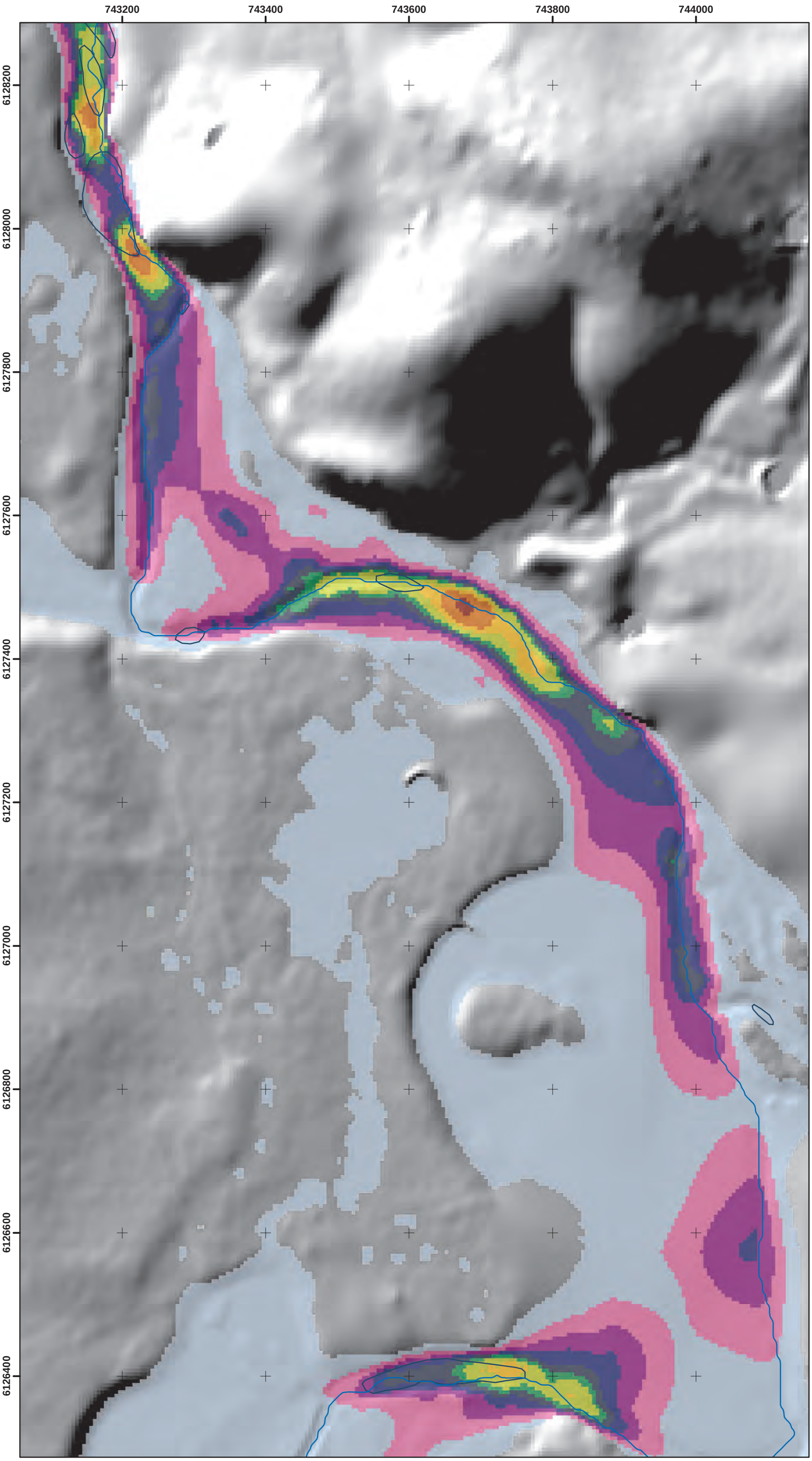
742600 742800 743000 743200 743400 743600

6127000 6126800 6126600 6126400 6126200 6126000 6125800 6125600 6125400 6125200



Map 5

200 m^3s^{-1}



Unit stream power Wm^{-2}

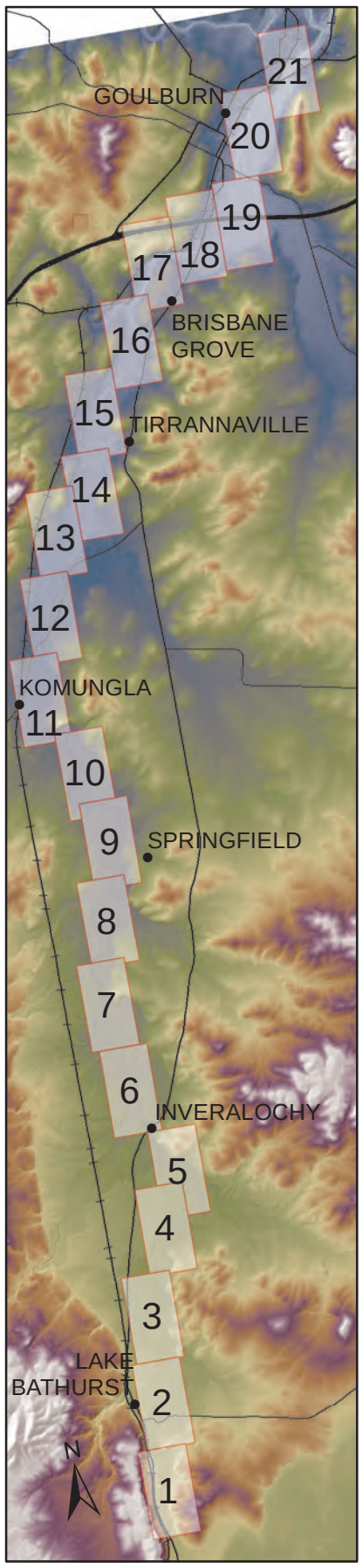
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



Map 6

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

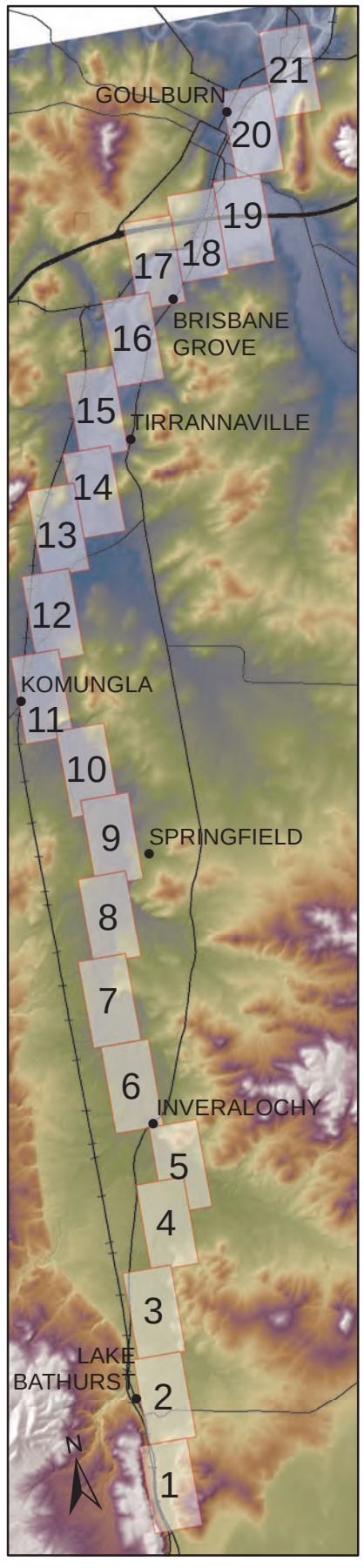
1:5,000

1 cm = 50 m

0 100 200 m

742400 742600 742800 743000 743200

6130200 6130000 6129800 6129600 6129400 6129200 6129000 6128800 6128600 6128400



Map 7

742200 742400 742600 742800 743000 743200

6132200 6132000 6131800 6131600 6131400 6131200 6131000 6130800 6130600 6130400

200 m^3s^{-1}

Unit stream power Wm^{-2}

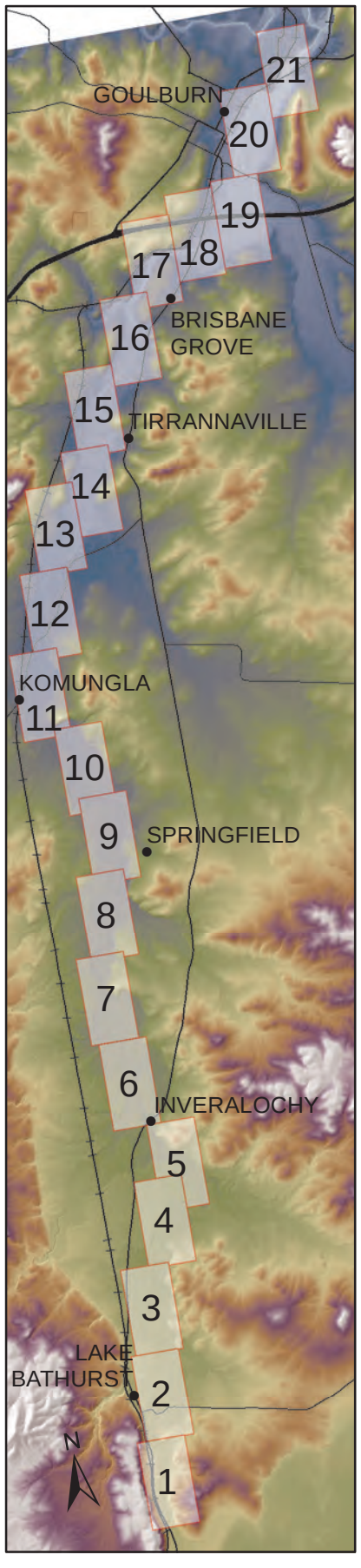
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



Map 8

200 m^3s^{-1}

Unit stream power Wm^{-2}

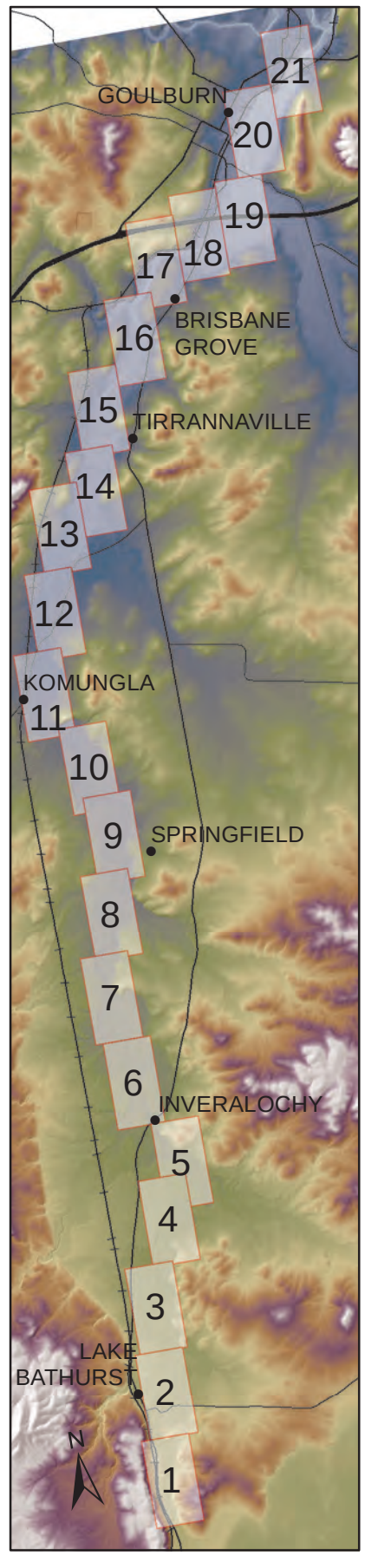
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



742600 742800 743000 743200 743400

6134000 6133800 6133600 6133400 6133200 6133000 6132800 6132600 6132400 6132200

Map 9

200 m^3s^{-1}

Unit stream power Wm^{-2}

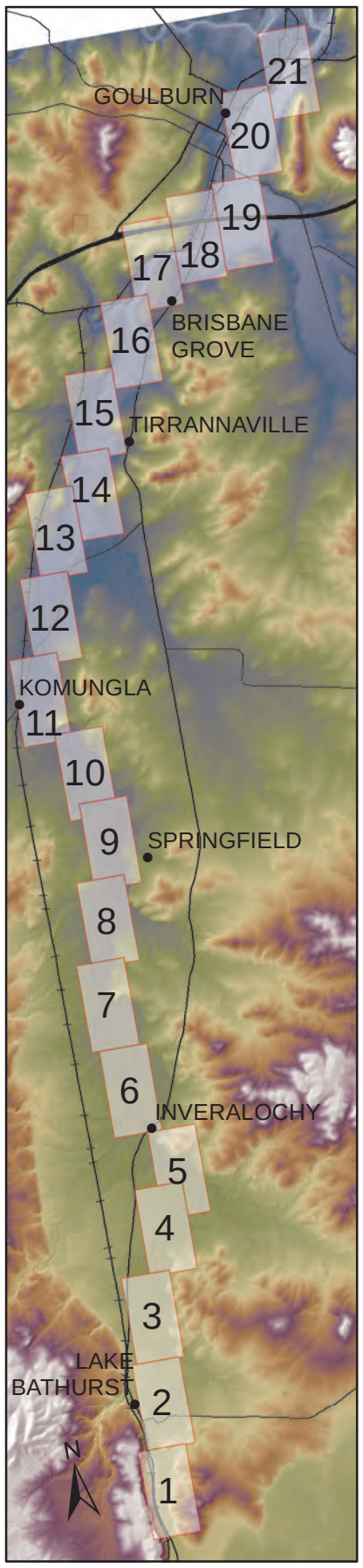
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



743000 743200 743400 743600 743800

6135800 6135600 6135400 6135200 6135000 6134800 6134600 6134400 6134200 6134000

Map 10

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

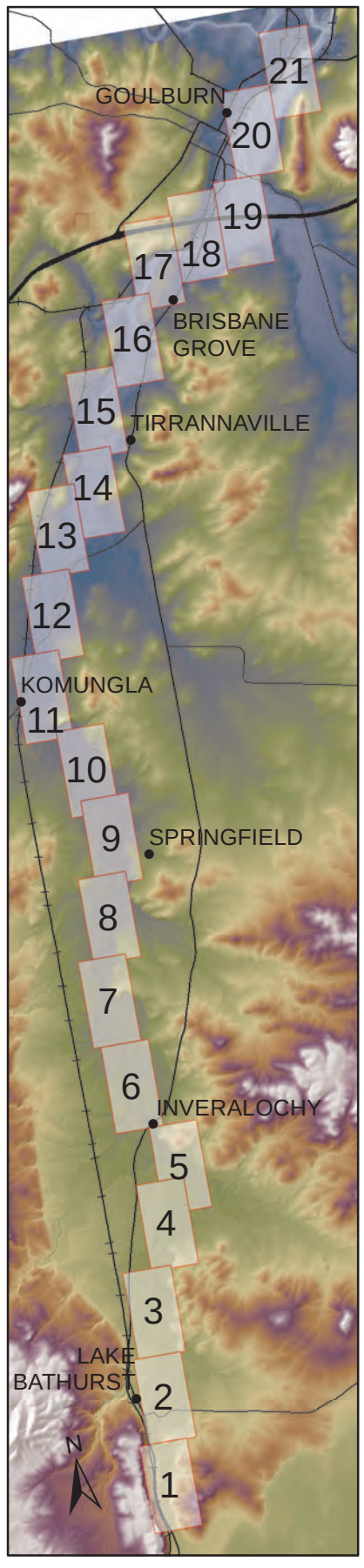
1:5,000

1 cm = 50 m

0 100 200 m

742600 742800 743000 743200 743400 743600

6137400 6137200 6137000 6136800 6136600 6136400 6136200 6136000 6135800 6135600



Map 11

200 m^3s^{-1}

Unit stream power Wm^{-2}

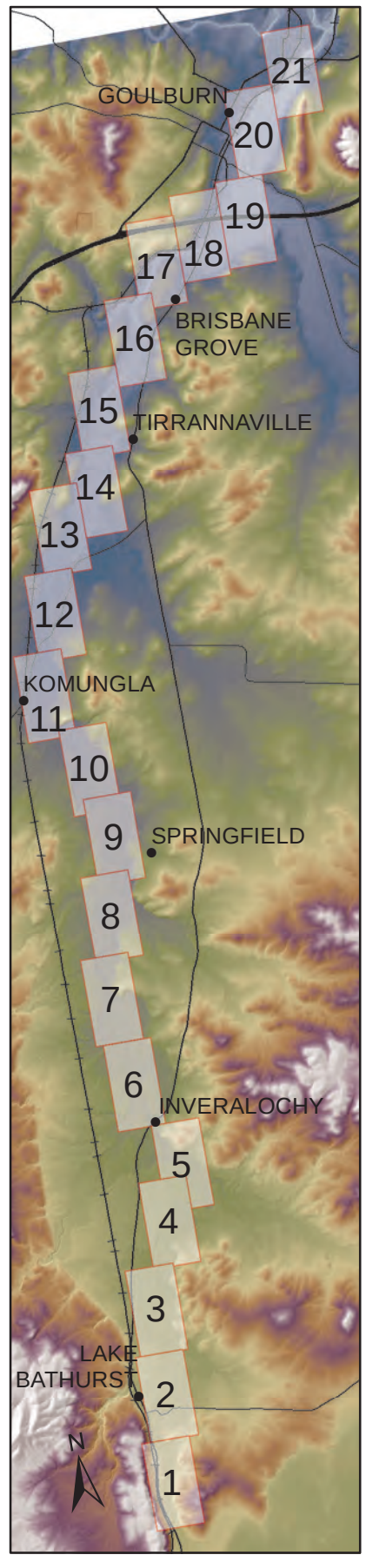
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



Map 12

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

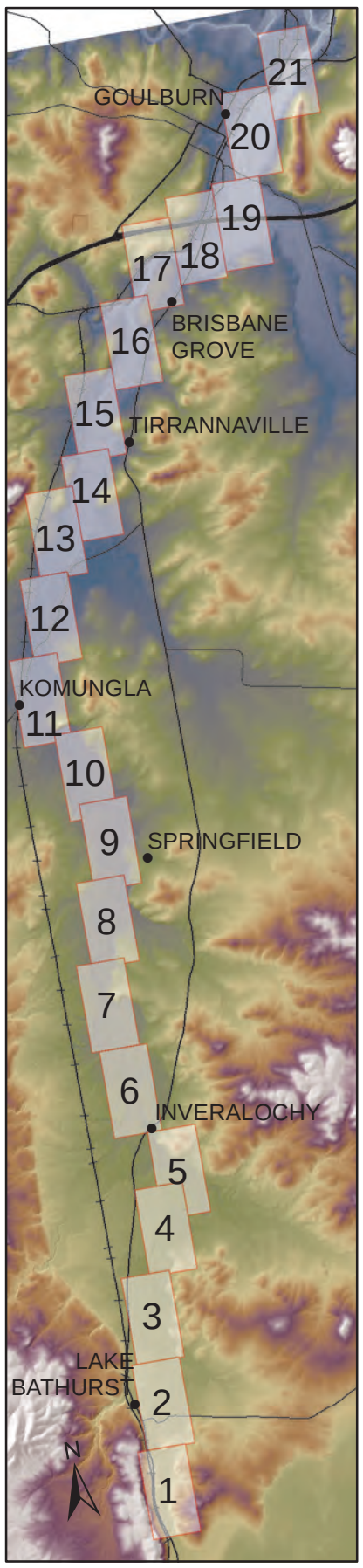
1:5,000

1 cm = 50 m

0 100 200 m

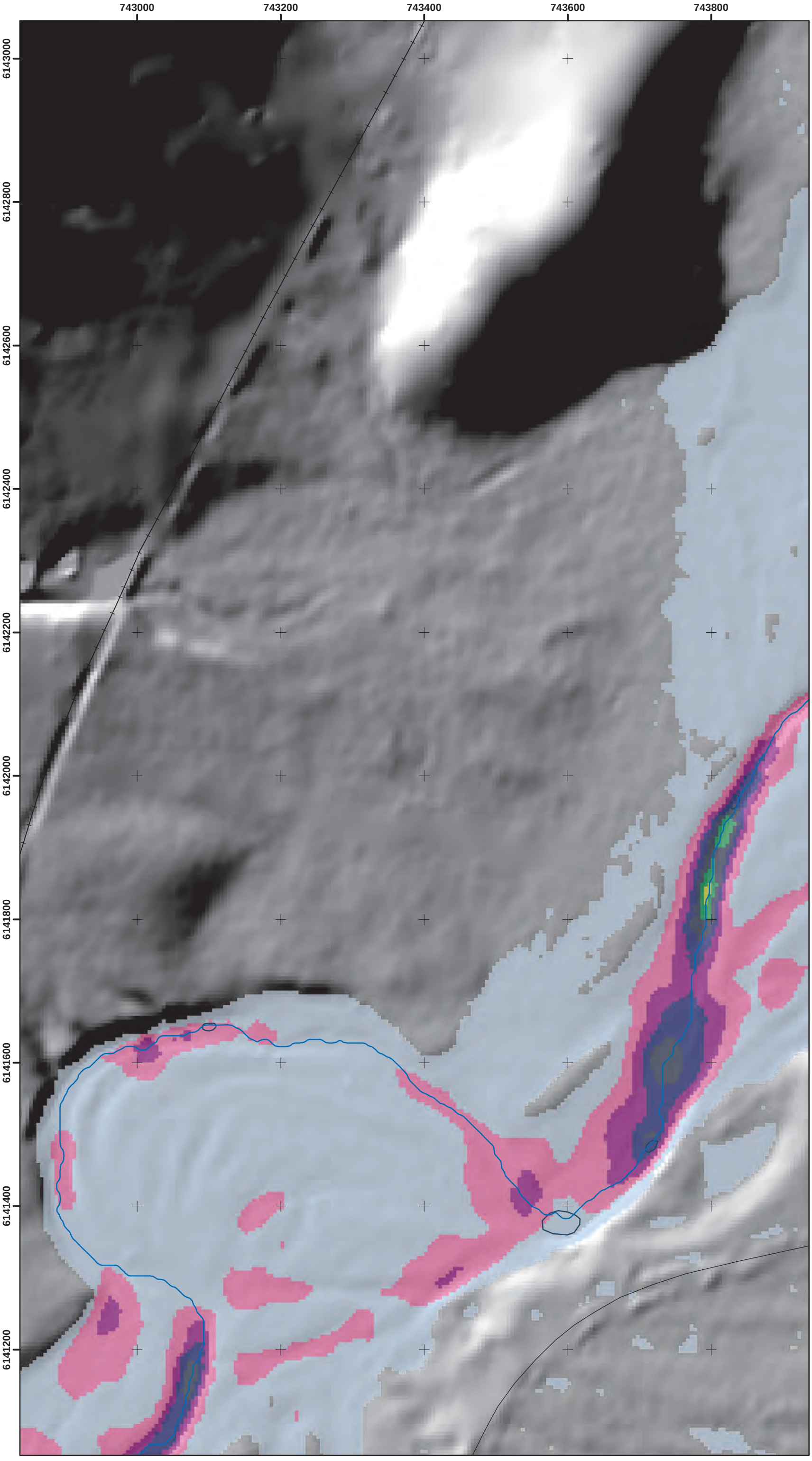
742400 742600 742800 743000 743200 743400

6141000 6140800 6140600 6140400 6140200 6140000 6139800 6139600 6139400 6139200



Map 13

200 m^3s^{-1}



Unit stream power Wm^{-2}

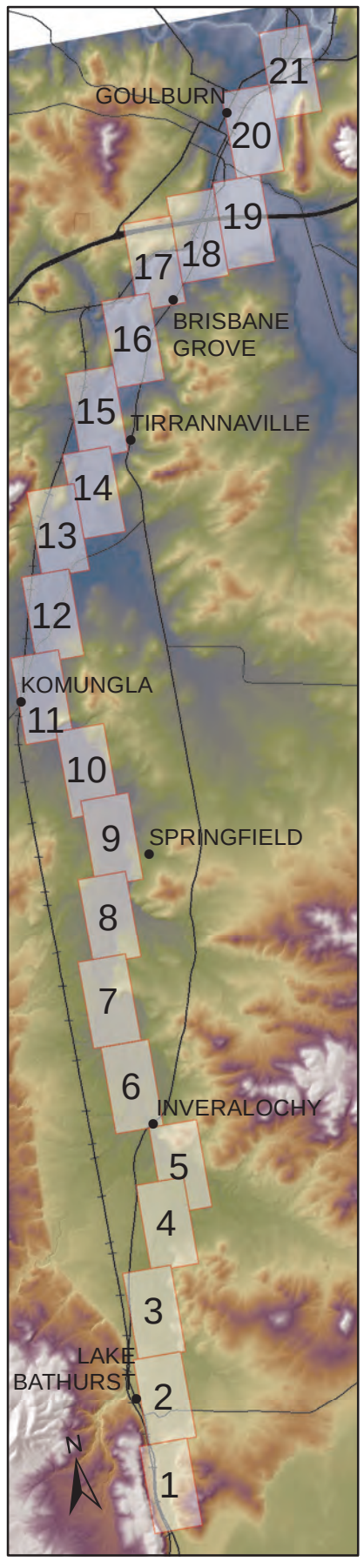
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



Map 14

200 m^3s^{-1}

Unit stream power Wm^{-2}

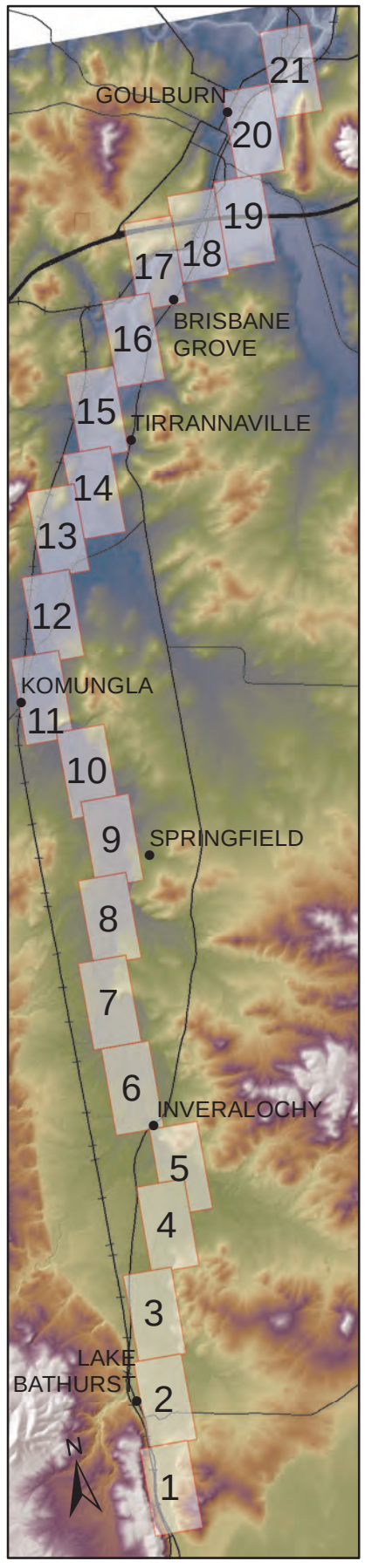
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



743800 744000 744200 744400 744600 744800

6143600 6143400 6143200 6143000 6142800 6142600 6142400 6142200 6142000 6141800

Map 15

744200 744400 744600 744800 745000 745200

6145400 6145200 6145000 6144800 6144600 6144400 6144200 6144000 6143800 6143600

200 m^3s^{-1}

Unit stream power Wm^{-2}

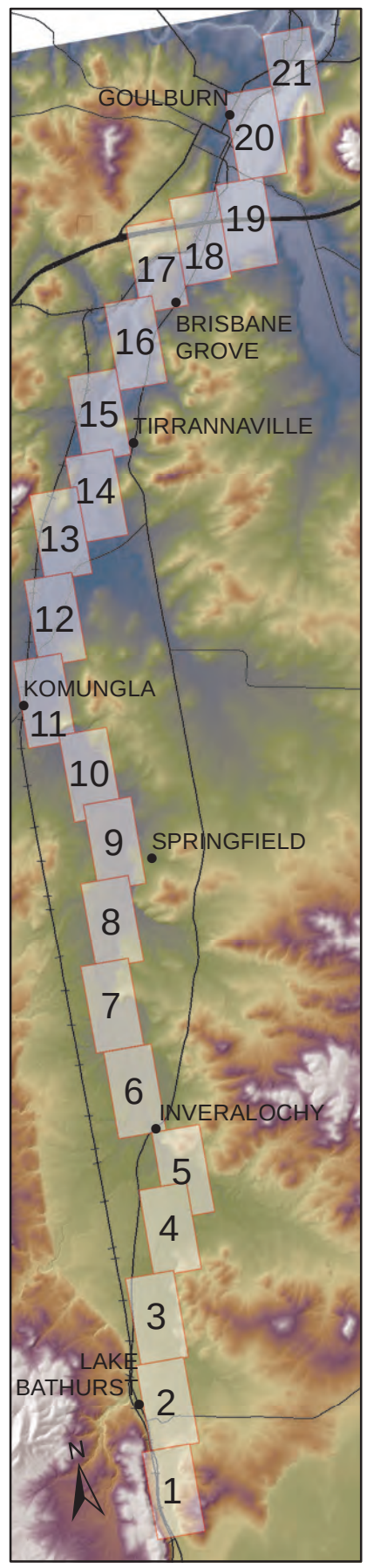
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



Map 16

200 m^3s^{-1}

Unit stream power Wm^{-2}

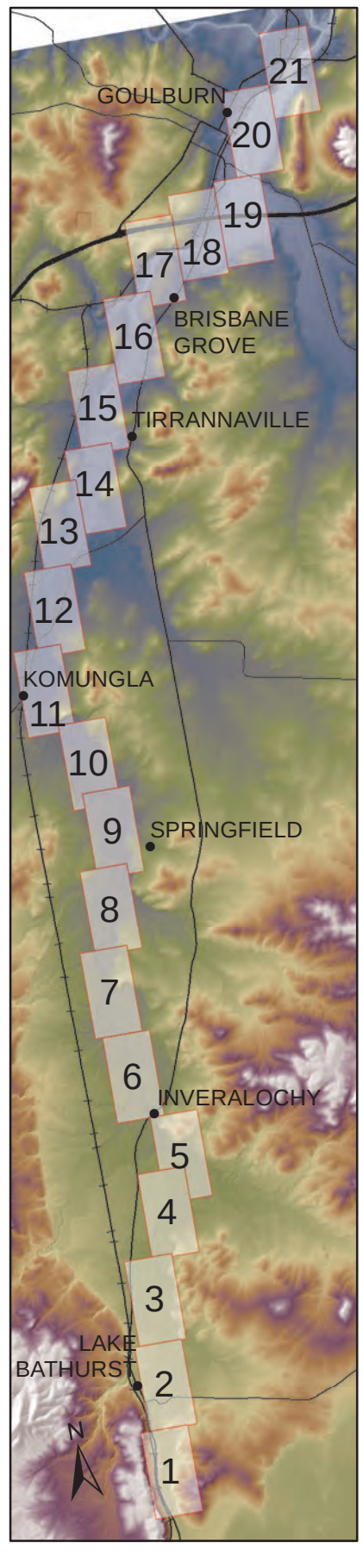
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



745400 745600 745800 746000 746200

6147000 6146800 6146600 6146400 6146200 6146000 6145800 6145600 6145400 6145200

Map 17

746200 746400 746600 746800 747000

6148600 6148400 6148200 6148000 6147800 6147600 6147400 6147200 6147000 6146800

200 m^3s^{-1}

Unit stream power Wm^{-2}

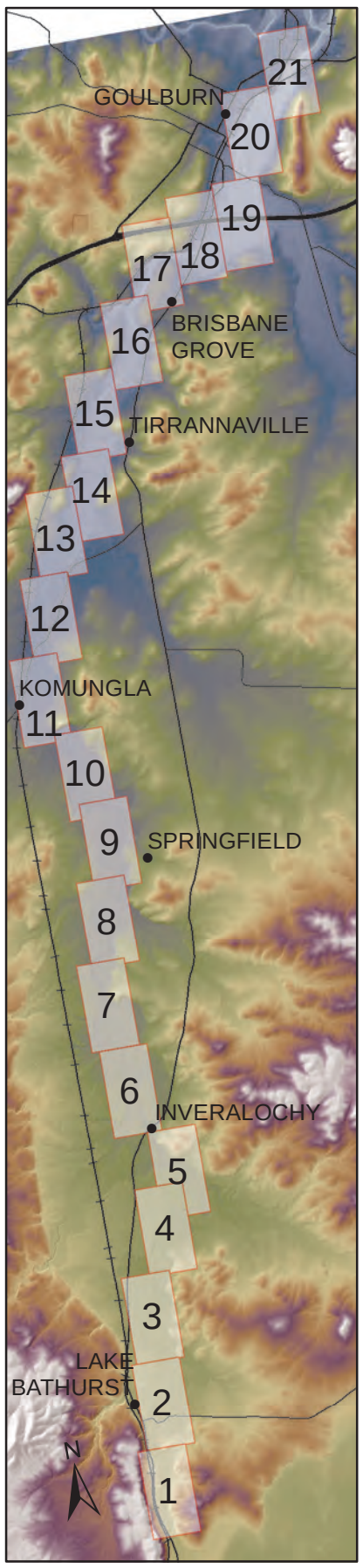
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



Map 18

200 m^3s^{-1}

Unit stream power Wm^{-2}

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

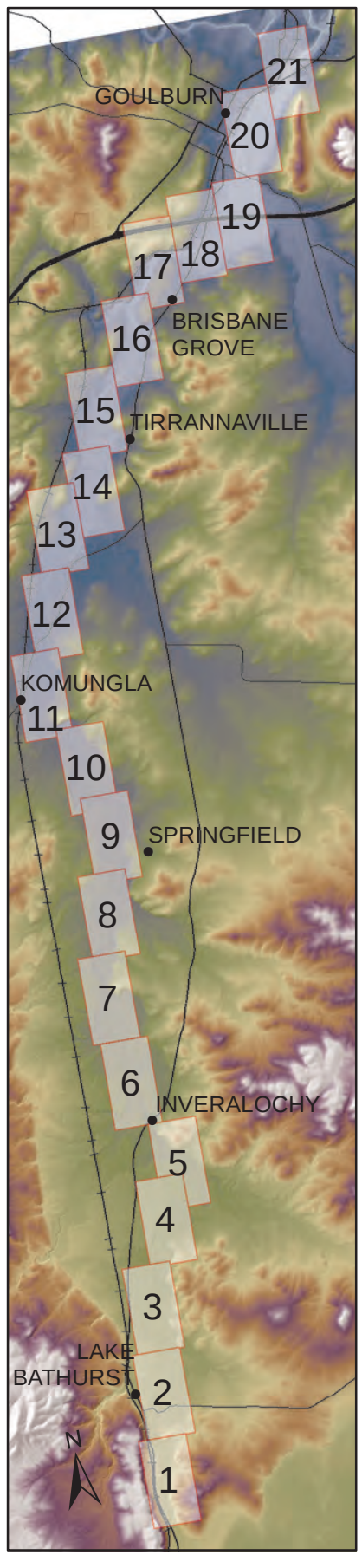
1:5,000

1 cm = 50 m

0 100 200 m

747200 747400 747600 747800 748000 748200

6149000 6148800 6148600 6148400 6148200 6148000 6147800 6147600 6147400 6147200



Map 19

200 m^3s^{-1}

Unit stream power Wm^{-2}

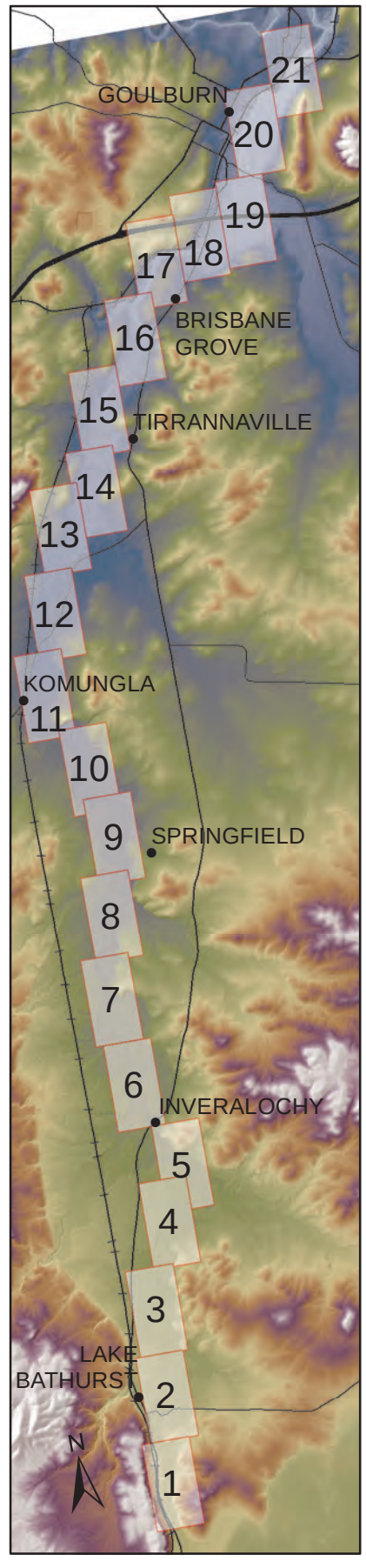
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



748400 748600 748800 749000 749200

6149200 6149000 6148800 6148600 6148400 6148200 6148000 6147800 6147600 6147400

Map 20

748800 749000 749200 749400 749600 749800

6151200 6151000 6150800 6150600 6150400 6150200 6150000 6149800 6149600 6149400

200 m^3s^{-1}

Unit stream power Wm^{-2}

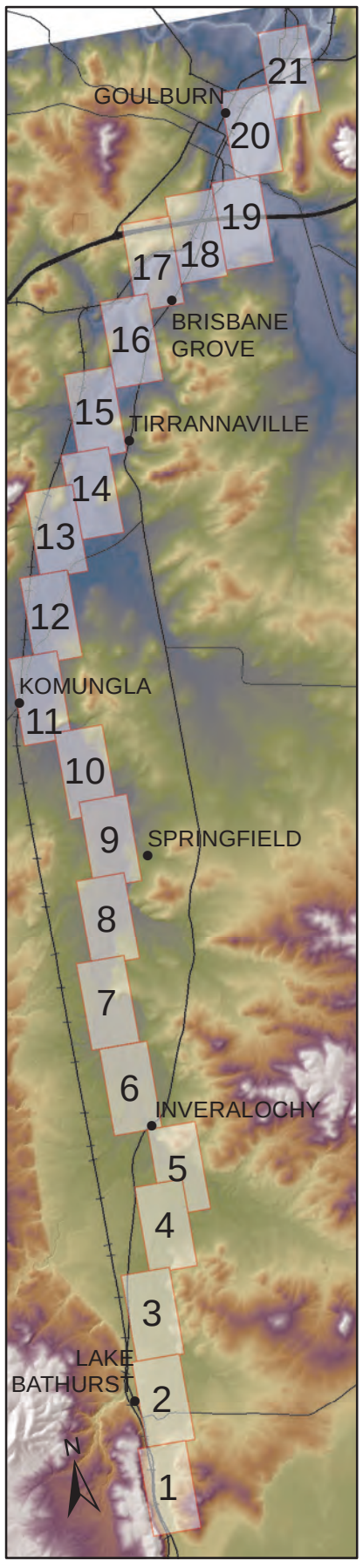
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m



Map 21

200 m^3s^{-1}

Unit stream power Wm^{-2}

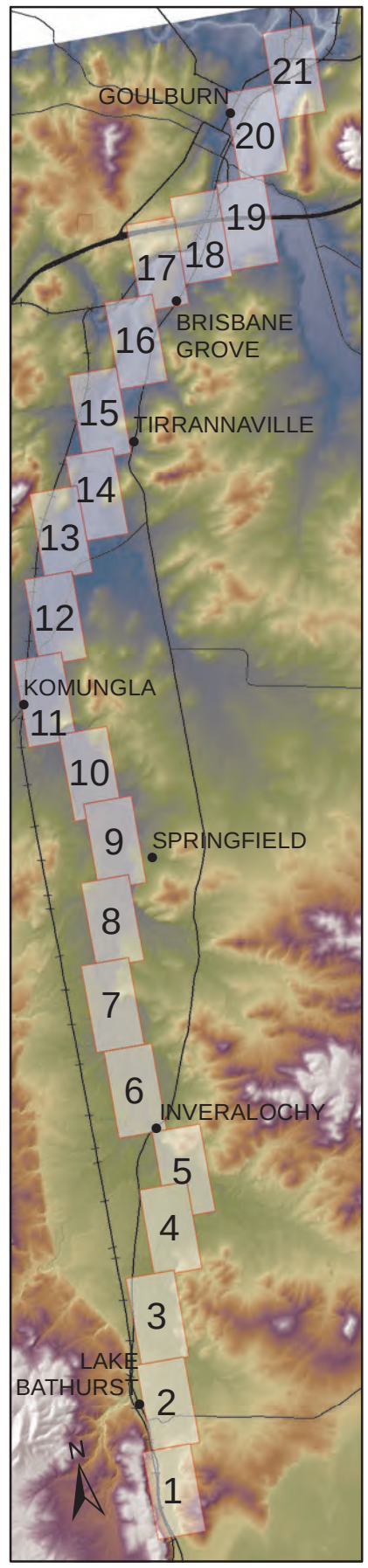
- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 - 25
- 26 - 30
- 31 - 40
- 41 - 50
- 51 - 75
- 76 - 150
- Mulwaree River
- Ponds

N

1:5,000

1 cm = 50 m

0 100 200 m

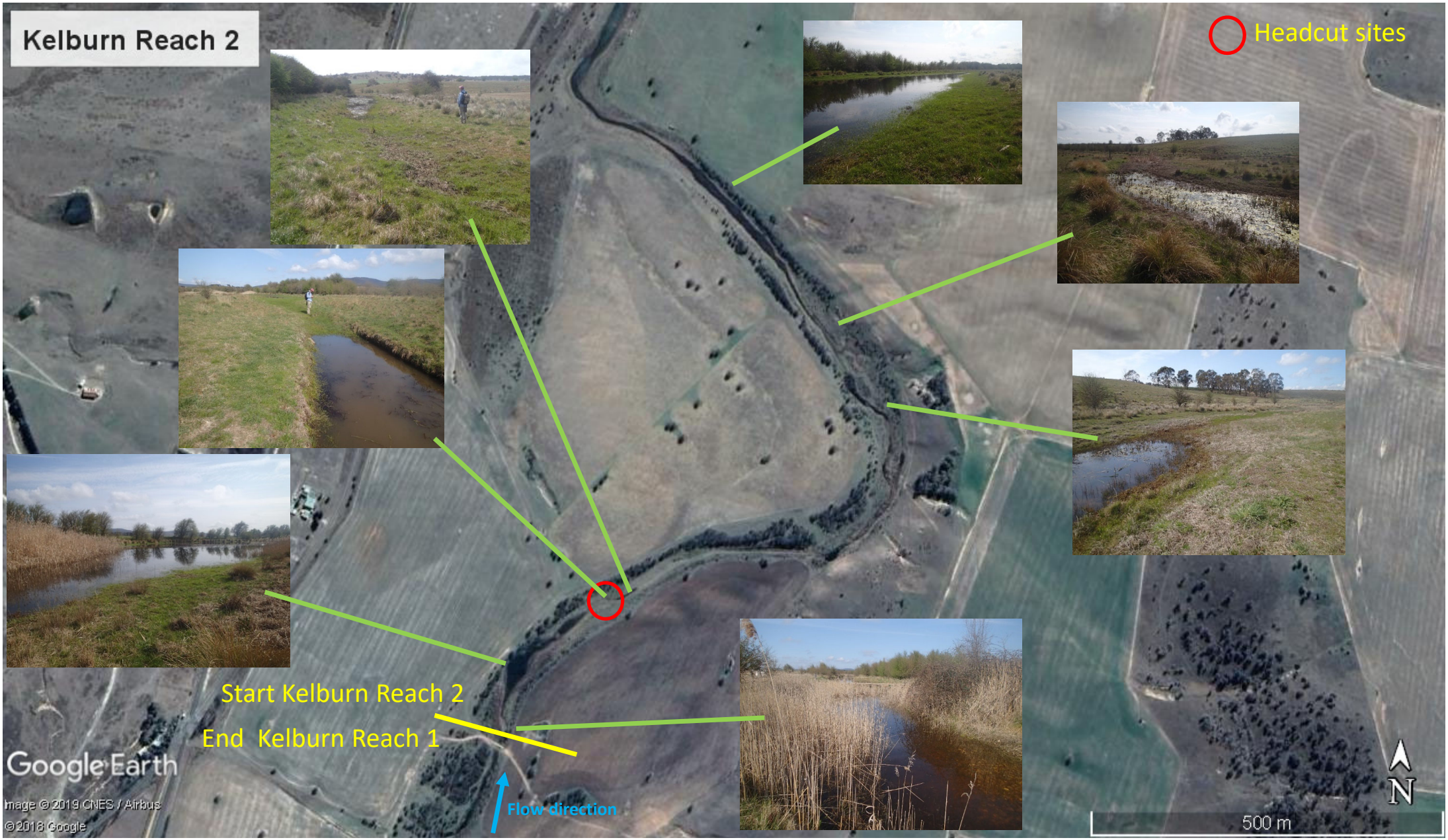


750000 750200 750400 750600 750800

6152400 6152200 6152000 6151800 6151600 6151400 6151200 6151000 6150800 6150600

Appendix C Maps and photo mosaics of reaches and condition along Mulwaree at Kelburn and Tirranaville

Kelburn Reach 1
Start Kelburn Reach 2
End Kelburn Reach 1
Headcut sites
Start Kelburn Reach 1
Flow direction
N
500 m
Google Earth
Image © 2019 CNES / Airbus
©2018 Google


Kelburn Reach 2
Headcut sites
Start Kelburn Reach 2
End Kelburn Reach 1
Flow direction
Google Earth
Image © 2019 CNES / Airbus
©2018 Google
N
500 m

Kelburn Reach 2 cont

Komungla

Reach not assessed

End Kelburn Reach 2

Flow direction

N

500 m

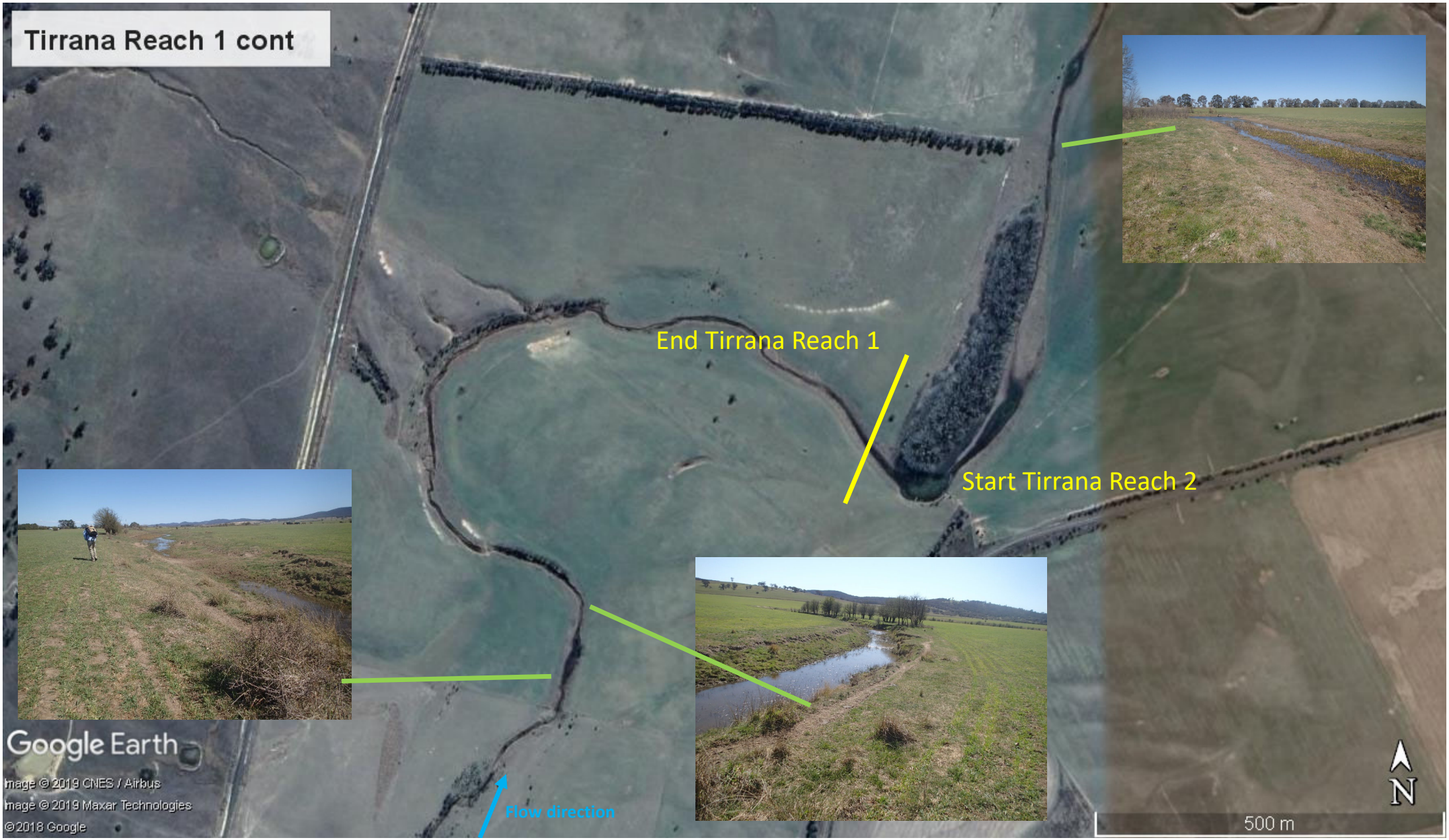
Google Earth

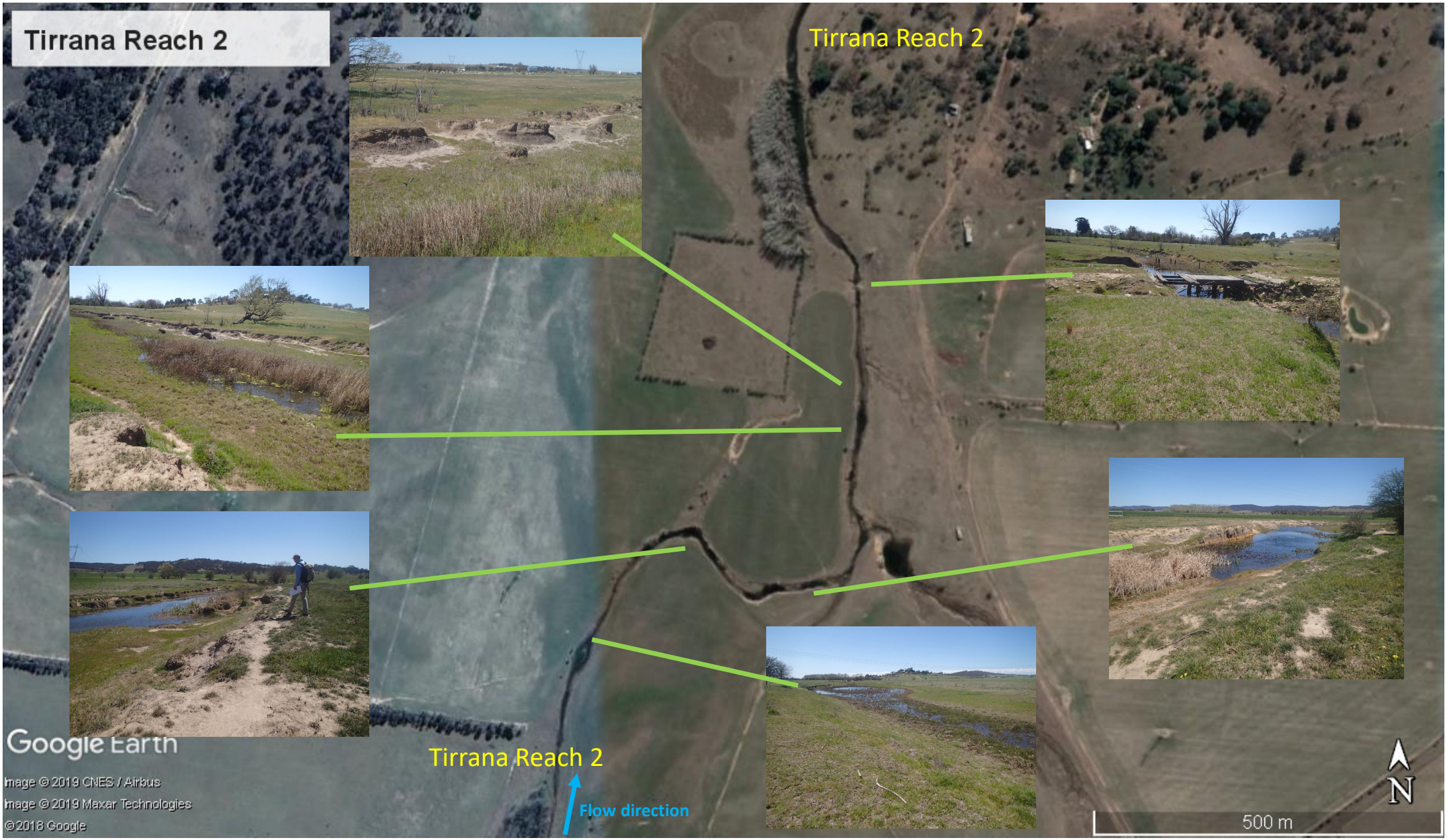
Image © 2019 CNES / Airbus

©2018 Google

Kelburn Reach 2 cont
Reach not assessed
Komungla
Reach not assessed
End Kelburn Reach 2
Flow direction
Google Earth
Image © 2019 CNES / Airbus
Image © 2019 Maxar Technologies
©2018 Google
N
500 m

Tirrana Reach 1
Start Tirrana Reach 1
Reach not assessed
Flow direction
Google Earth
Image © 2019 CNES / Airbus
Image © 2019 Maxar Technologies
©2018 Google
N
500 m


Tirrana Reach 1 cont
End Tirrana Reach 1
Start Tirrana Reach 2
Flow direction
Google Earth
Image © 2019 CNES / Airbus
Image © 2019 Maxar Technologies
©2018 Google
N
500 m


Tirrana Reach 2
Tirrana Reach 2
Tirrana Reach 2
Flow direction
Google Earth
Image © 2019 CNES / Airbus
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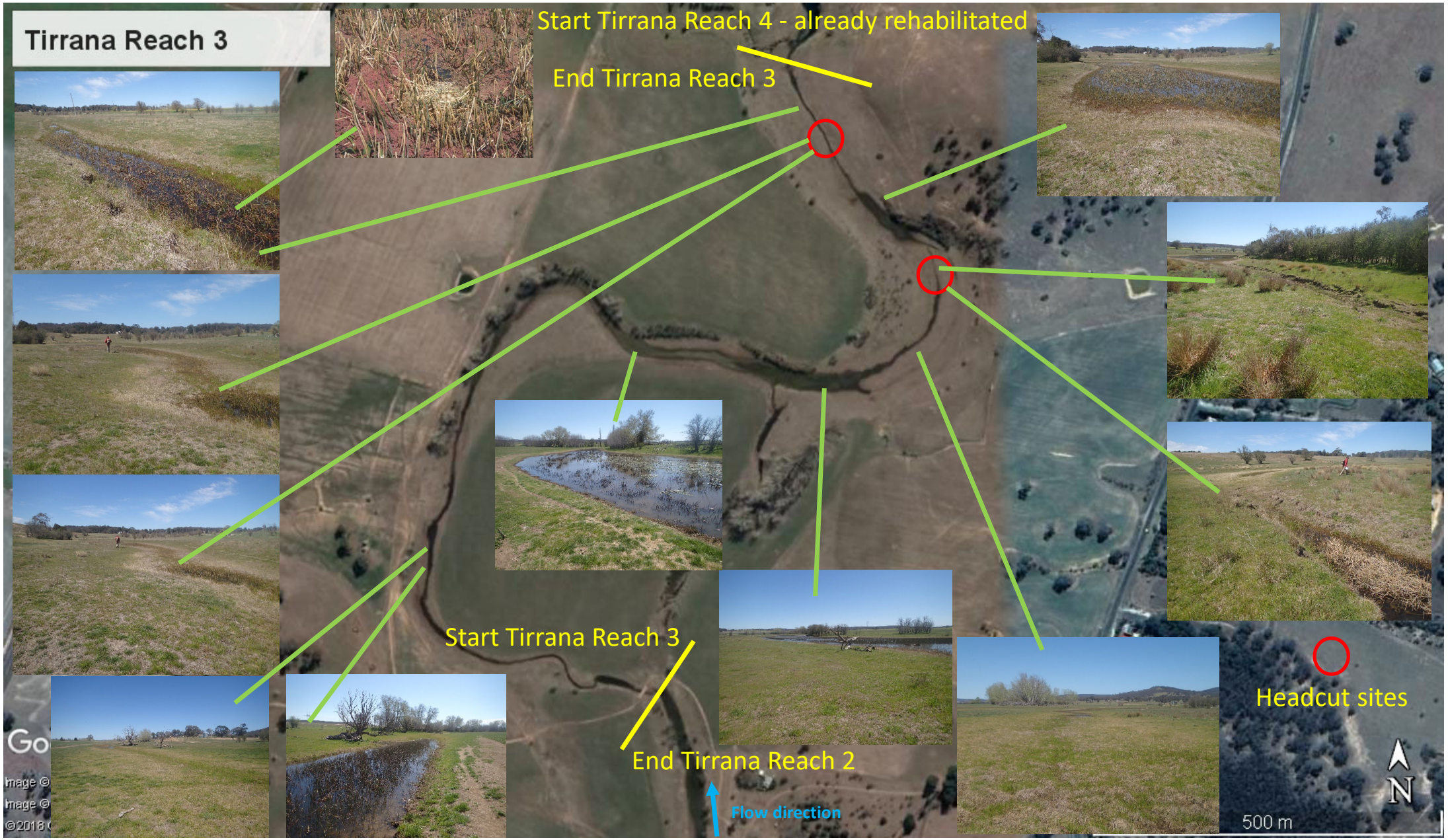
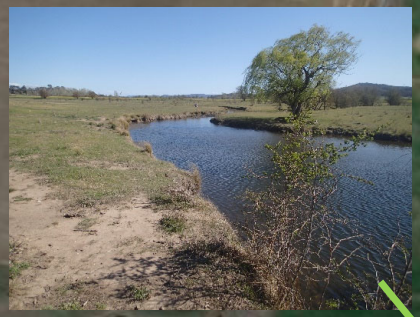
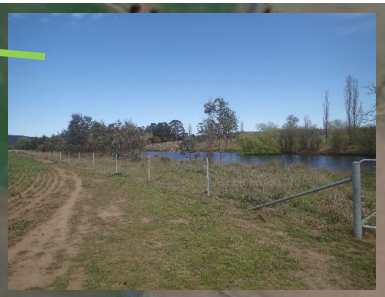
©2018 Google
N
500 m

Tirrana Reach 2 cont
Start Tirrana Reach 2
End Tirrana Reach 2
Flow direction
Google Earth
Image © 2019 CNES / Airbus
Image © 2019 Maxar Technologies
©2018 Google
500 m
N


Tirrana Reach 3
Start Tirrana Reach 4 - already rehabilitated
End Tirrana Reach 3
Start Tirrana Reach 3
End Tirrana Reach 2
Flow direction
Headcut sites
N
500 m

Tirrana Reach 3 cont + rehab'ed





Headcut sites

Start Tirrana Reach 4
already rehabilitated

End Tirrana Reach 3

See previous slide

Flow direction

500 m

Google Earth

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MACQUARIE University

Macquarie University is a vibrant hub of intellectual thinkers, all working towards a brighter future for our communities and our planet.

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Macquarie is uniquely located in the heart of Australia's largest high-tech precinct, a thriving locale which is predicted to double in size in the next 20 years to become the fourth largest CBD in Australia.

Our campus spans 126 hectares, with open green space that gives our community the freedom to think and grow. We are home to fantastic facilities with excellent transport links to the city and suburbs, supported by an on-campus train station.

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We are ranked among the top two per cent of universities in the world, and with a 5-star QS rating, we are renowned for producing graduates that are among the most sought after professionals in the world.

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BUILDING SUCCESSFUL GRADUATES

Our pioneering approach to teaching and learning is built around a connected learning community: our students are considered partners and co-creators in their learning experience.

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