WAMBO COAL PTY LIMITED

SOUTH BATES UNDERGROUND MINE

EXTRACTION PLAN
LONGWALLS 11 TO 16

REPORT 3
SURFACE WATER ASSESSMENT REVIEW

Peabody ENERGY

REPORT:

Surface Water Technical Report for South Bates Underground Mine (Longwalls 11- 16)

Wambo Coal Mine

December 2016

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Checked	Rohan Lucas
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1 Introduction

Wambo Coal Mine (Wambo) is an open cut and underground mining operation in the Hunter Valley mining region of New South Wales operated by Wambo Coal Pty Limited (WCPL). WCPL has approval to expand its underground mining operations with the South Bates underground mine which will utilise longwall mining to extract the Whybrow Seam (Longwalls 11 to 13) and Wambo Seam (Longwalls 14 to 16). WCPL has previously developed an Extraction Plan covering Longwalls 11 to 13 which was approved in February 2015. Prior to commencing Longwalls 14 to 16, a consolidated Extraction Plan for Longwalls 11 to 16 is required. This report documents the surface water technical assessment for Longwalls 11 to 16 that informs the development of the Extraction Plan.

One of the effects of underground longwall mining is that after coal is mined, the roof strata falls into the void (goaf) causing the natural ground surface to subside. The environments of the North Wambo Creek Diversion (NWCD), its adjacent floodplains and hill slopes that exist over the area of the South Bates underground mine plan that will be subject to subsidence are the subject of this surface water technical report.

This technical report outlines the pre and post subsidence environment for the mine plan area (as shown in Figure 1-1 and Figure 1-2), addresses potential impacts on surface water caused by subsidence, and proposes mitigation, monitoring and reporting.

To effectively manage the impacts of subsidence this technical report consists of the following aspects:

- Measurement of pre-subsidence baseline data
- Predictive subsidence modelling and impact assessment
- Ongoing subsidence monitoring
- Pre-subsidence and post subsidence mitigation, reporting and maintenance

1.1 Scope

This technical report covers all surface water which has an interface with the South Bates underground mine plan. This includes surface water of the NWCD, its tributaries and surrounding landscape.

The impact assessment of subsidence upon waterways and surface water generally is undertaken in the structure developed during the Isaac River Cumulative Impact Assessment of Mine Developments (Alluvium, 2008), a project jointly funded by Anglo American BHP Billiton. Although not directly applicable to NSW regulation, the findings assisted the development of the Watercourse Subsidence – Central Queensland Mining Industry guideline (DERM, 2011). The framework for assessing impacts on watercourses by subsidence was developed into the following hierarchy, which has been adopted for this study:

- 1st order – direct physical effects of subsidence
- 2nd order – geomorphic response to subsidence
- 3rd order – changes to water quantity and quality
- 4th order – biological response

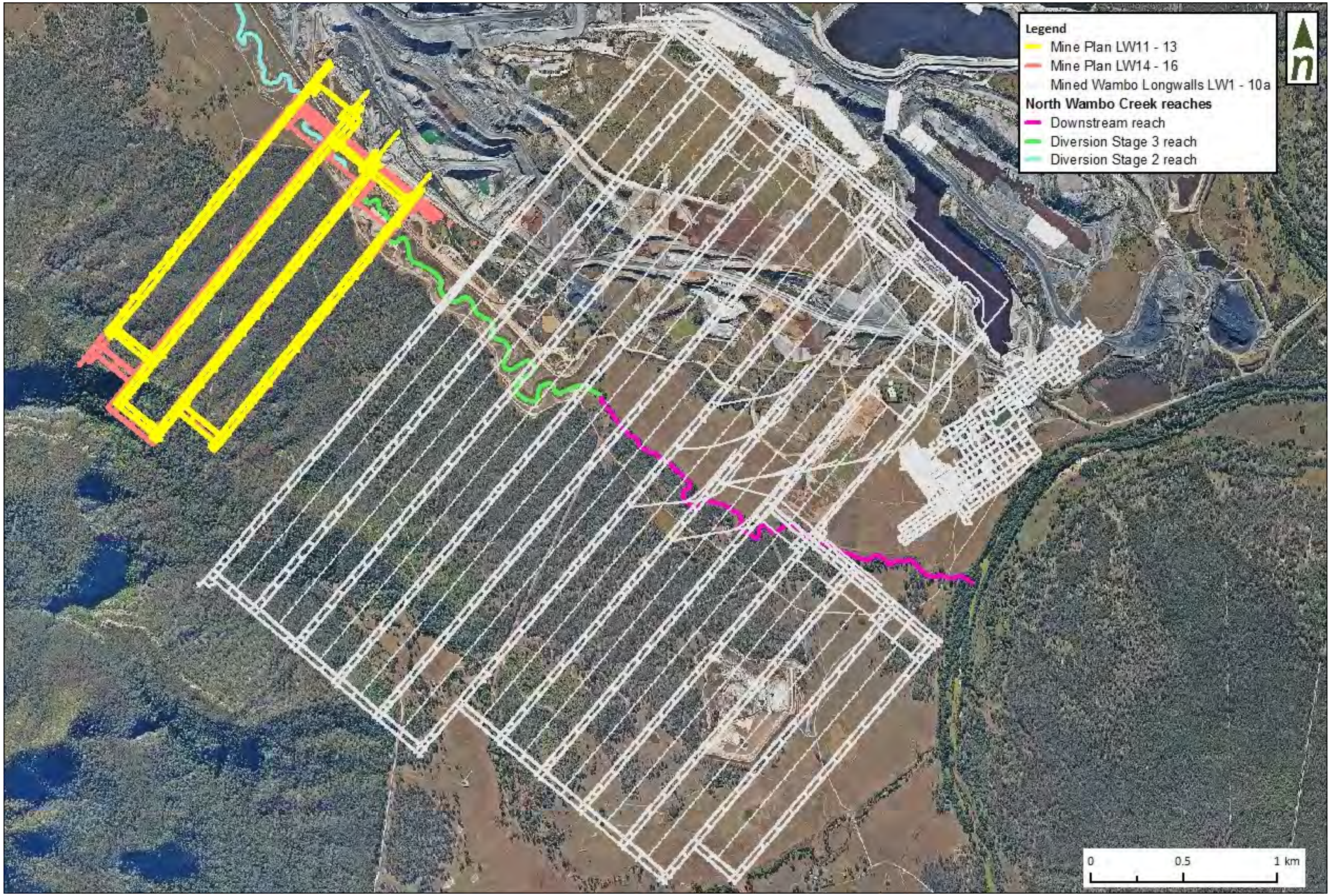


Figure 1-1. Overview of underground mining at Wambo Coal Mine

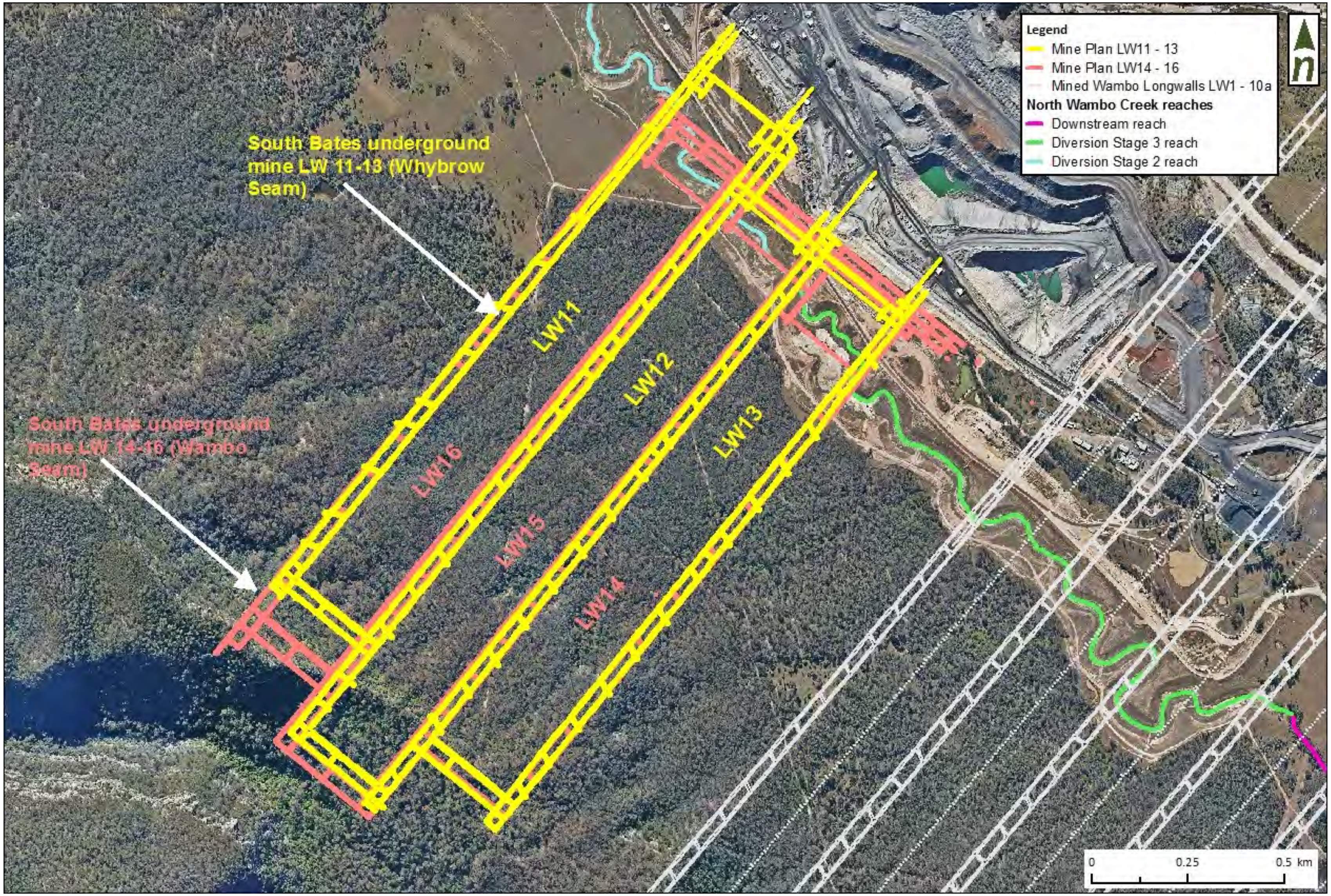


Figure 1-2. Overview of South Bates underground mine plan at Wambo Coal Mine

2 Baseline condition assessment

A snapshot of the condition of the landscape and surface water environments interacting with the South Bates underground mine plan is provided to inform the impact assessment and any mitigation strategies that may be required.

LW11-LW13 directly subsides the NWCD and associated levee that protects the open cut void. LW14-16 provides a much lesser increment of subsidence as the longwalls finish under the southwestern bank of the NWCD as shown on Figure 1-2. The panels intersect both Stages 2 and 3 of the NWCD, which are considerably different in character and condition, which is explained further below.

The downstream extent of NWCD was subsided prior to construction. Downstream of NWCD, North Wambo Creek has been subsided in recent years.

The performance of NWCD was recently subject to review (Alluvium, 2015). That review provides input to this baseline condition assessment in addition to inspection in November 2016. LW11 had been fully mined at the time of inspection, including subsiding NWCD and LW12 was substantially progressed but had not yet reached NWCD.

2.1 Character, behaviour and condition of waterways

Upstream reach
North Wambo Creek debouches from a confined section in the deeply incised range to the west of the site into a broad valley where the channel is largely unconfined by valley margins. The reach immediately upstream of NWCD appears to have undergone phases of incision and partial refilling over the last several decades. Presently the channel in this local reach is relatively inactive with a heavily grassed bed and limited bedload transport occurring. Review of aerial imagery further upstream indicates that mobile bedload is largely deposited where the valley width first expands at the foot of the range.

It is possible prior to a phase of incision that this reach of North Wambo Creek was actually a floodout, where the continuous channel in the confined valley setting, lost the capacity to maintain a channel due to valley width and gradient and the watercourse was the whole valley floor/floodplain. This would have likely provided for swampy conditions with no continuous channel.

It is likely in this setting that much of the flow generated in the range to the west in lower intensity and magnitude rainfall events was as base flow in the alluvial sediments (likely sand dominated). The current open cut operation adjacent to the offtake of NWCD influences the flow regime locally, in NWCD and downstream.

Riparian vegetation in the reach immediately upstream of NWCD is largely limited to ground cover, which has been dense at the time of inspection in both 2015 and 2016. The reasons for limited regeneration of woody species in this reach are not known. The reach is no longer subject to cattle grazing however kangaroo numbers in the area are significant. Changes in the saturation of alluvials due to a steeper hydraulic gradient to the open cut may also be a factor.

Figure 2-1. Upstream view in upstream reach

NWCD Stage 2
The upstream half (approx.) of the diversion is known as Stage 2. This was constructed prior to Stage 3 which replaces the mined out Stage 1. Stage 2 of the diversion is constructed initially in the floodplain of North Wambo Creek then gradually into foot slopes of the range to the west. A low capacity low flow channel, typically 2-3m deep and up to 10m top width has been cut into a constructed floodplain that decreases from around 80m wide to 30m wide moving downstream as depth of cut increases (to about 8m below natural ground surface at the interface with Stage 3).

At the upstream end of Stage 2, overland flow entry has been managed adequately and with a lower gradient and broader cross section the diversion is in similar condition to the upstream reach. Hydraulic energy conditions increase with the depth of cut and the narrower floodplain. This has resulted in deepening and widening of the low flow channel that is likely to continue in the alluvial/colluvial sediments present. This process is occurring in the zone over LW11 and LW12 and immediately upstream.

Overland flow entry to the diversion from the west has not been managed in the vicinity of LW11. This already requires management response to limit further gully erosion. LW11 subsidence has altered the location. Management of the overland flow should be undertaken to suit the post subsidence conditions.

Stage 2 of the diversion is known to have had substantial rehabilitation effort in the form of revegetation largely with a pasture seed mix and some tube stock patches and other remedial works in 2011. It is understood that further revegetation works have been scheduled by WCPL for 2017.

Figure 2-2. Upstream extents of Stage 2 NWCD

Figure 2-3. Mid stage 2 NWCD

Figure 2-4. Downstream extents of Stage 2 NWCD in proximity of LW11-16, already undergoing erosional adjustment

Figure 2-5. Cracking in bank of NWCD over LW11 at a location where new overland flow entry from west will occur

NWCD Stage 3

Stage 3 is largely constructed in foot slopes with much of the channel boundaries being sandstone bedrock. Where not bedrock, the weathered sediments are generally highly dispersive and prone to erosion on the surface and sub-surface.

This section of the diversion presently has very limited vegetation establishment and overland flow entry management issues that require attention. The sandstone boundaries of the channel remain relatively sound in the majority, with only a few instances of bedrock weathering to the extent of it breaking down to constituent sediments.

Elevated energy conditions in Stage 3 combined with the limited finer sediment supplied to the reach under current sediment supply conditions means there is little prospect of deposition and that any fine sediment topsoil in the channel is likely to be stripped in larger flow events. Both of these combine to constrain longer term vegetation establishment potential from regeneration/self-seeding processes. With the shallow bedrock in the reach, vegetation is at further risk of removal due to potential barriers to root penetration where sandstone is massive.

The downstream extents of Stage 3 were constructed over terrain that was already subsided by earlier longwall mining.

Figure 2-6. Downstream view from Stage 2 to Stage 3 over LW12-L13 extents along NWCD

Figure 2-7. Headcut in weak sandstone that will be on LW12-13 pillar and subject to increased erosion. Diversion plug (fill embankment) in background will be subject to cracking adjacent a pit wall

Figure 2-8. Downstream view in upstream extents of Stage 3 NWCD of cut into weak sandstone

Figure 2-9. Typical conditions in mid Stage 3 of NWCD

Figure 2-10. Tunnel erosion associated with overland flow management in Stage 3 NWCD is the subject of a management program by Wambo Coal

Figure 2-11. Tunnel erosion (continued)

Downstream reach
Downstream of NWCD through to the confluence with Wollombi Brook, the remaining alignment of North Wambo Creek has been subsided by five longwalls over the last decade. This reach of North Wambo Creek is relatively low sinuosity and is increasingly incised as it cuts down to the level of Wollombi Brook. Channel migration is limited by consolidated Wollombi Brook terrace sediments. Bedrock controls are occasionally present in the channel bed.

Riparian vegetation remains minimally cleared for much of the reach, however clearing has occurred to top of bank along the north eastern side for much of the reach.

Subsidence pools are present in the reach, providing pool habitat that is otherwise not presently common in North Wambo Creek. There has been limited erosion response in the reach, such as incision through pillars, to date.

A notable threat to the condition of the downstream reach exists in the form of a significant drop through culverts of a track crossing shortly upstream of the Wollombi Brook confluence. Sediment has accumulated upstream of the culverts and has been colonised by vegetation. Should the culverts fail through undermining or outflanking it is likely a considerable amount of deepening would occur through the accumulated sediments.

Figure 2-12. Subsidence pool

Figure 2-13. Subsidence pool where channel abuts a terrace scarp

Figure 2-14. Terrestrial vegetation colonisation of the channel bed downstream of subsidence

Figure 2-15. Subsidence crack in downstream reach from most recent panel mined under North Wambo Creek

Figure 2-16. A significant step in bed profile through culverts near downstream extent of North Wambo Creek

Western tributaries
Several tributaries flow from the sandstone escarpment of the range to the west into NWCD. These tributaries transition from steep deeply incised bedrock controlled gullies to broad flood-outs with no defined channel progressing downstream before entry to the diversion (as illustrated in following photos). These systems are all presently in dynamic equilibrium with relative stability. Riparian vegetation is near intact throughout except at the entry to NWCD where clearing has occurred.

Some of these tributaries have been subject to subsidence by LW11 (complete) and LW12 (partially mined) in 2016. To date no changes are notable in the more defined flow paths. Cracking is readily observable along tracks in the areas mined to date. Those where water has ponded have enlarged due to the dispersive nature of the surficial sediments.

Figure 2-17. Crack above LW11 that has enlarged due to ponding

Figure 2-18. Recent tension crack above LW12

Figure 2-19. Floodout section of tributary with no defined channel providing conditions suitable for ti tree

Figure 2-20. Deeply incised confined gully in the transition from bedrock to flood-out above LW12

Figure 2-21. Flood-out at downstream boundary of LW13

Figure 2-22. Partly confined channel with floodplain pockets in the transition from steep to floodout above LW13

3 Impact assessment

3.1 1st order – direct effects of subsidence

Subsidence modelling
Mine Subsidence Engineering Consultants (MSEC) have provided subsidence predictions for the extraction of the South Bates Whybrow Seam (LW12-13) and Wambo Seam (LW14-16) at Wambo. Subsidence from LW11 was not considered as it has already been subsided. A brief summary of the modelling results is presented below, however, for detailed information regarding the methodology please refer to the reports prepared by MSEC, titled *South Bates Underground Mine Subsidence Assessment* (MSEC855). The subsidence predictions for LW12-16 are as follows:

- The maximum subsidence expressed at the surface for mining of the Whybrow seam is 1.9m.
- The maximum subsidence expressed at the surface for the combined mining of the Whybrow and Wambo seam is 4.0m.
- The chain pillar subsidence ranges from 0.2m to 0.3m for the mining of the Whybrow seam.
- The chain pillar subsidence ranges from 1.5 m to 2.0 m for the combined mining of the Whybrow and Wambo seam.

A plan view of the subsidence contours output from the modelling for LW12-13 is shown in Figure 3-1, while a plan view of the combined subsidence of LW12-16 is shown in Figure 3-2. A representation of the post subsidence digital terrain is presented in Figure 3-3. Shown is the 1m and 5m terrain contours derived from the LiDAR captured in July 2016 (which included the LW11 subsidence) modified to include the predicted subsidence modelled by MSEC.

Surface tensile cracking and compressional buckling
Cracking has been observed above LW11 and LW12 at the surface. Where these cracks occur in colluvial and alluvial sediments surficial and sub surface erosion response can be expected. The sediments across this terrain can be dispersive, which makes them prone to changes in rates of erosion with changes in landscape dynamics.

The areas of greatest risk will be where cracks open in erodible sediments with an orientation down slope. These may be prone to enlargement should the volume of the crack be sufficient that local inputs of sediment don't infill it nor do the clays swell sufficiently to seal it. In these instances some rill/gully erosion may develop. This has not been observed to date in LW11 as insufficient rainfall has occurred since mining.

Where local ponding occurs in the same location as cracking, dispersive sediments are likely to flow down cracks with water, enlarging the crack at surface, which may develop into considerable tunnel erosion. An example of the early stages of enlargement of the crack is provided in the photos for the western tributaries above.

Subsurface cracking of overburden strata
An increase in hydraulic connectivity between the surface and the workings, particularly under waterways, is a considerable third order impact risk. Observations in the downstream extents of North Wambo Creek (downstream of where the panels LW1-10 intercept the creek) indicate that flows reaching this part of the waterway are limited to high intensity rainfall events. Baseflow conditions are likely to have altered due to the effects of underground mining, alluvial drawdown associated with open cut extraction and the removal of alluvium upstream for the construction of the NWCD. Observations of vegetation indicate that baseflow conditions have been altered, including death of aquatic plants and increasing colonisation by terrestrial vegetation. In the fully subsided sections of these longwalls subsidence pools have developed over several panels. This may indicate that loss of baseflow is most likely through tensile cracking along the boundaries of the pillars.

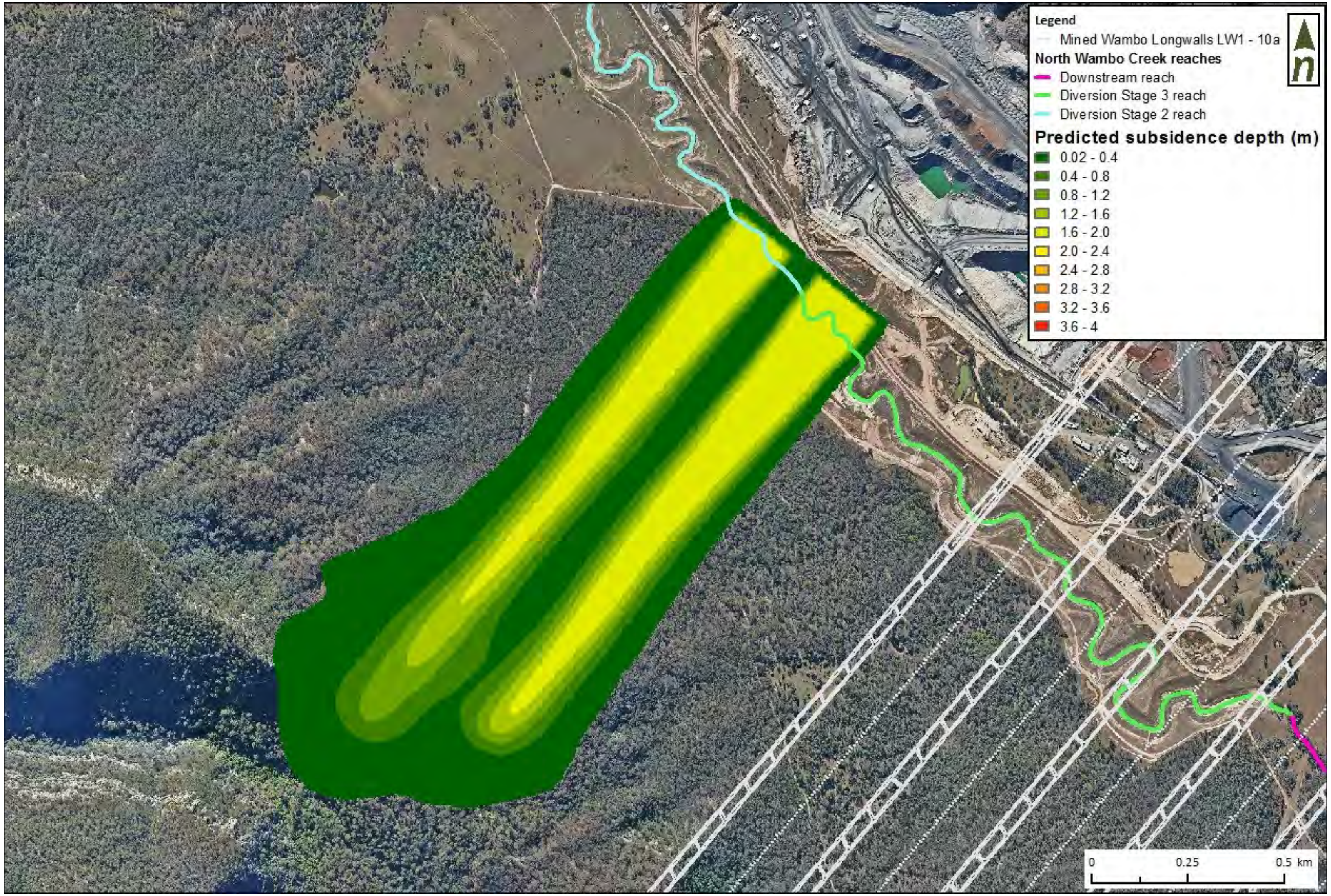


Figure 3-1. Predicted subsidence depths for South Bates underground mine LW12-13 (LW11 previously subsided and not shown as predicted subsidence)

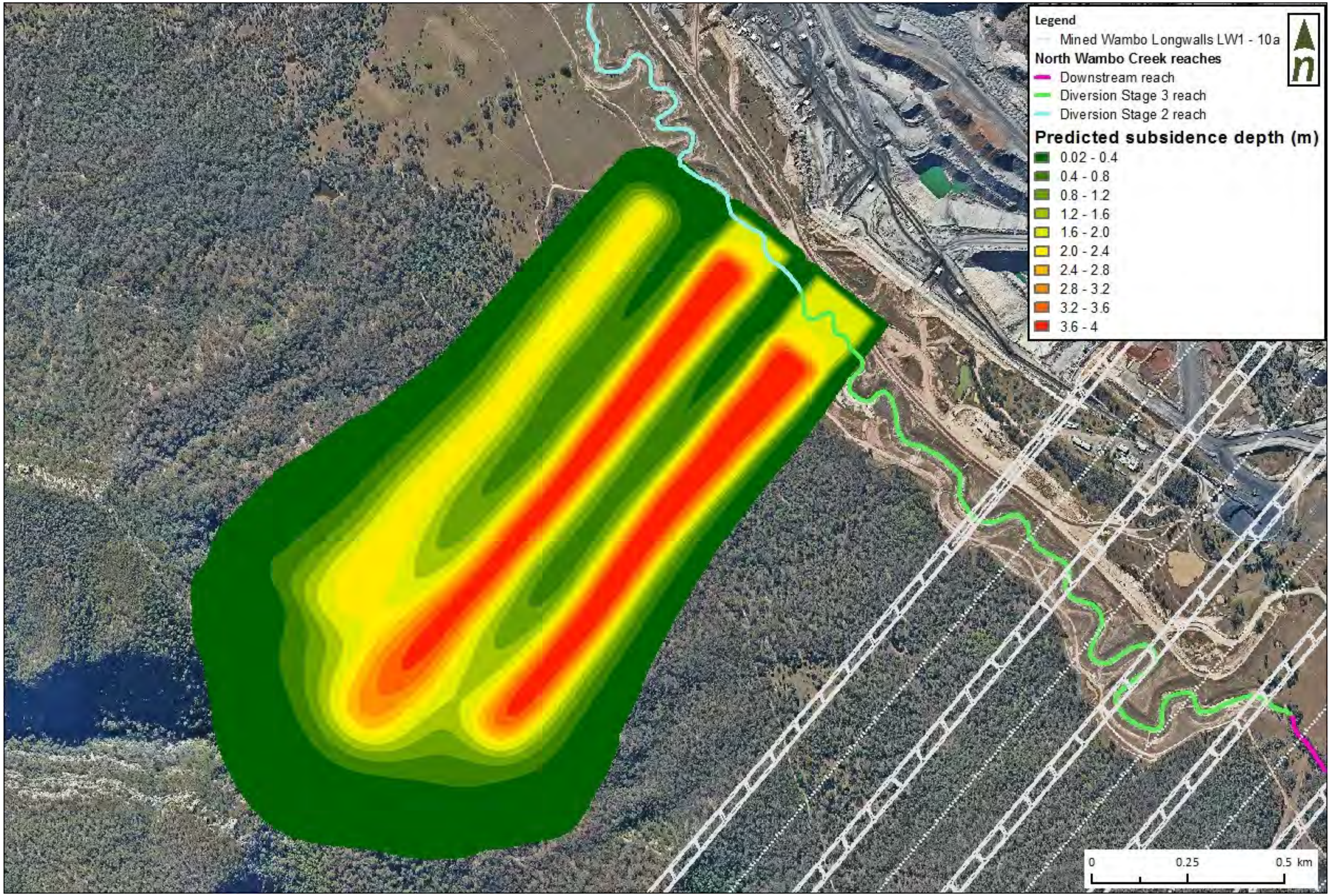


Figure 3-2. Predicted subsidence depths for South Bates underground mine LW12-16

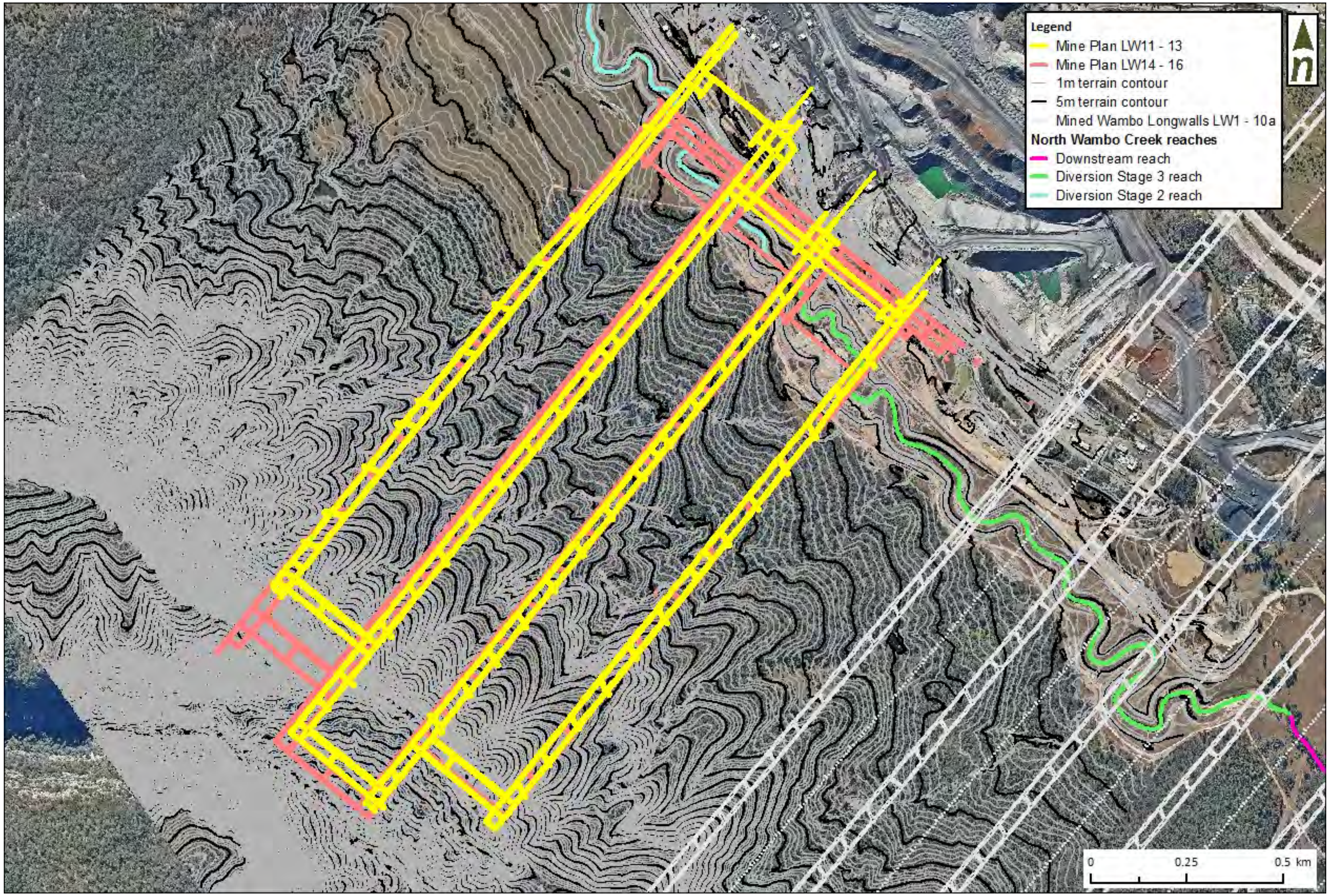


Figure 3-3. Post subsidence digital terrain contours at 1m intervals LW11-16

Predicted subsidence of panel catchments and waterways

Details of the predicted maximum subsidence within NWCD are shown in Table 3-1 below. LW11 has already been subsided and as such, predictions for LW16 do not include the subsidence of LW11 as it has already occurred. The values presented for LW14 and LW15 are the combined subsidence of the Whybrow and Wambo seams. A visual representation of the maximum subsidence depth for each longwall panel are shown in Figure 3-4.

Table 3-1. Maximum predicted subsidence depth by longwall panel

Longwall Panel	Panel Length (km)	Maximum Depth of Subsidence (m)	
		Longwall Panel	**North Wambo Creek diversion**
11	1.7	Already subsided	
12	1.8	1.9	1.9
13	1.7	1.9	1.9
14	1.5	4.0	2.1
15	1.8	4.0	2.1
16	1.6	2.2	0.1

The predicted subsidence void (or pool) volume estimates within the NWCD channel are summarised in Table 3-2. These assume static channel boundaries (no erosion), which in reality will not be the case when flows occur that are capable of eroding the channel boundaries (2nd order response). Such response will change the pool volumes over time. Volumes are calculated from toe of bank to toe of bank of the macro channel, which includes the inset floodplain/bench and the low flow channel. It is notable that LW14-16 add very little to the subsidence volume in the diversion.

Table 3-2. Subsidence void volumes

Longwall Panel	Subsidence Void Volume (m^3)
	North Wambo Creek diversion
11	20,750
12	15,240
13	26,100
14	630
15	1,220
16	285
TOTAL	**64,225**

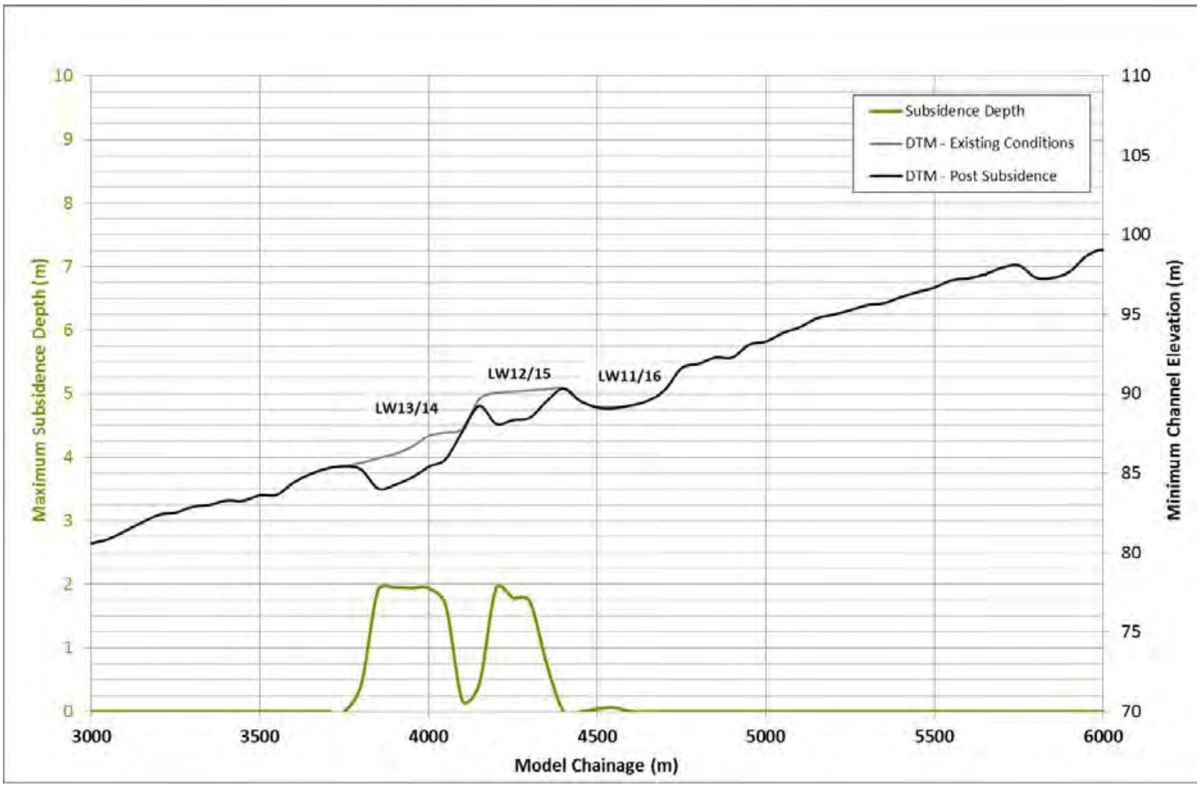


Figure 3-4. NWCD existing and post subsidence (without 2nd order response) longitudinal section (total subsidence after LW16)

3.2 2nd order – predicted geomorphic response of surface water systems to 1st order impacts

NWCD

The LW11-16 panels are oriented roughly perpendicular to the macro channel of NWCD. This means that the subsided cross section geometry of the panel is imposed directly on the longitudinal profile of the channel. LW11 is already subsided in the longitudinal profile shown in Figure 3-4, the differences predicted for the combined LW12/14, LW13/15 and LW16 are shown. LW14-16 impose minimal additional subsidence as the panels finish at approximately the top of western bank of the diversion.

Upstream of LW11/16 is likely to experience erosion in response to the steepening of the channel longitudinal profile. This section of the diversion has been undergoing deepening and widening since construction, the response to subsidence is likely to accelerate this process and increase rates of bed and bank erosion over current. In-channel one dimensional hydraulic assessment (graphs in Attachment A) indicate that stream power, shear stress and velocity are in the range where instability for alluvial channel boundaries is expected and therefore requires management (Section 4).

The LW11/12 pillar is in an erodible section of NWCD channel bed. Initially this raised section of channel bed will create a pool over LW11, however erosion of this elevated section of bed is likely over a series of flow events.

The LW12/15 pillar coincides with a step in the existing channel bed profile at the interface of Stage 2 and 3 of the diversion (as shown on photo below). This has been cut into sandstone, however the erosion head appears likely to migrate upstream slowly. While the sandstone surfaces at this location are likely to remain relatively stable over the short to medium term, increased hydraulic energy conditions associated with the subsidence will increase potential for stripping of any topsoil/alluvium that provides growth media.

The three panels are likely to capture any bedload sediment transported to this point in NWCD, which is presently negligible. This means that flows downstream of the panels are effectively clear and will look to mobilise material from the channel bed. In a section of diversion where potential for deposition is already limited due to diversion configuration, surfaces are likely to remain as bare bedrock, limiting potential for vegetation establishment on lower channel boundaries.

Figure 3-5. Step in channel bed coinciding with LW12-13 pillar

Figure 3-6. Immediately downstream of the LW13/14 pillar

Western tributaries
The flow paths from the range to the west into NWCD are likely to undergo substantially more change than NWCD. This is due to the geometry of these flow paths relative to the subsidence, which includes LW14-16 producing up to 4m of subsidence.

The predicted changes in flow paths are presented in Figure 3-7. The predicted flow path changes are completely reliant on the accuracy of the DTM.

The stream lines shown are those predicted by the software CatchmentSIM using the predicted subsidence digital terrain model (DTM). Flow depths are shown for the 50 year ARI event . The red stream lines are current, the blue stream lines represent the scenario after all panels are mined. The predicted post mining stream lines sit on top of the current stream lines, hence where a red stream line is shown on the map for current conditions, not covered by blue, that section of stream is abandoned post subsidence. The flow depths indicate that some existing flows will split between the existing and post mining.

The tributary inflow for LW11/16 only shows a slight shift from the current situation, which was apparent during inspection in November 2016. There are substantial flows over the diversion batter that will now be more concentrated. Provision for this flow into the diversion via a correctly designed and constructed batter chute is required.

LW12/15 intercepts two easterly flowing tributaries that presently flow into NWCD via a batter chute shortly downstream of where LW13/14 will be situated. Post subsidence these flows are predicted to have a new entry to NWCD approximately in the centre of LW12. This will require provision of a new batter chute and potentially minor earthworks to direct any disbursed flow to it.

LW13/14 captures remaining flows in the tributary that gets diverted by LW12/15 and diverts flows from another tributary from further south on the range. The outcome appears to be split flows with some reporting the existing batter chute and some to a new inflow location. Management of the post subsidence flows in this system will require on ground verification. Ideally flows could be managed to the existing batter chute. The changes in LW13/14 may make an existing batter chute in a straight section approximately 230m downstream redundant.

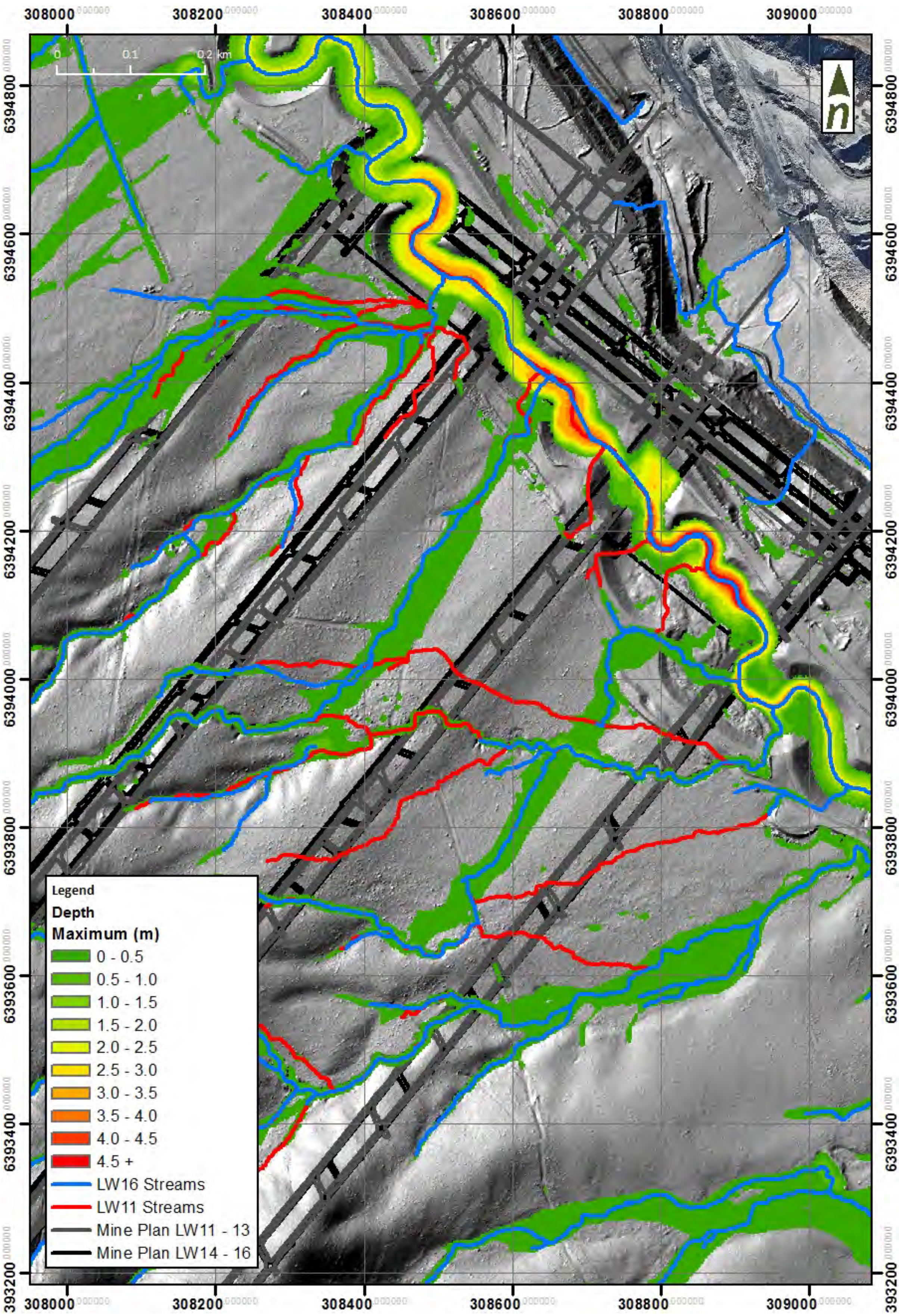


Figure 3-7. Flow path changes for western tributaries (50yr ARI flow depths)

3.3 3rd order – predicted impacts to water quantity and quality

Changes to water quantity

The impact of subsidence on flow and storage in the channel was undertaken using 2D modelling. Using the existing and post subsided landforms, the 2D model was used to determine how the subsidence from LW11-16 would impact on the flow passing through the site. The models were run longer than the duration of the storm events to determine the volume of water remaining ponded in the channel.

Subsidence of Longwalls 12 and 13 will double in-channel storage when compared to existing subsidence resulting from Longwall 11 (Table 3-3). The additional subsidence from Longwalls 14 to 16 will increase in-channel storage by a further by an additional 260m^3 (Table 3-4), however this impact is an order of magnitude smaller than that caused by the subsidence of Longwalls 11-13.

Table 3-3. Residual ponding estimates in NWCD after 2D model runs

ARI	Existing (m^3)	Subsided (m^3) after LW13	Difference (m^3)
50 year	3270	6610	3340

Table 3-4. Residual ponding estimates in NWCD after 2D model runs

ARI	Existing (m^3)	Subsided (m^3) after LW16	Difference (m^3)
50 year	3270	6870	3600

The in-channel storage volumes following the subsidence of each consecutive panel are depicted in greater detail in the following figures:

- Figure 3-8 – ponding after subsidence of Longwall 11 (existing scenario)
- Figure 3-9 – ponding after subsidence of Longwalls 11 and 12
- Figure 3-10 – ponding after subsidence of Longwall 11, 12 and 13
- Figure 3-11 – ponding after subsidence of Longwalls 11 to 14
- Figure 3-12 – ponding after subsidence of Longwalls 11 to 15
- Figure 3-13 – ponding after subsidence of Longwalls 11 to 16

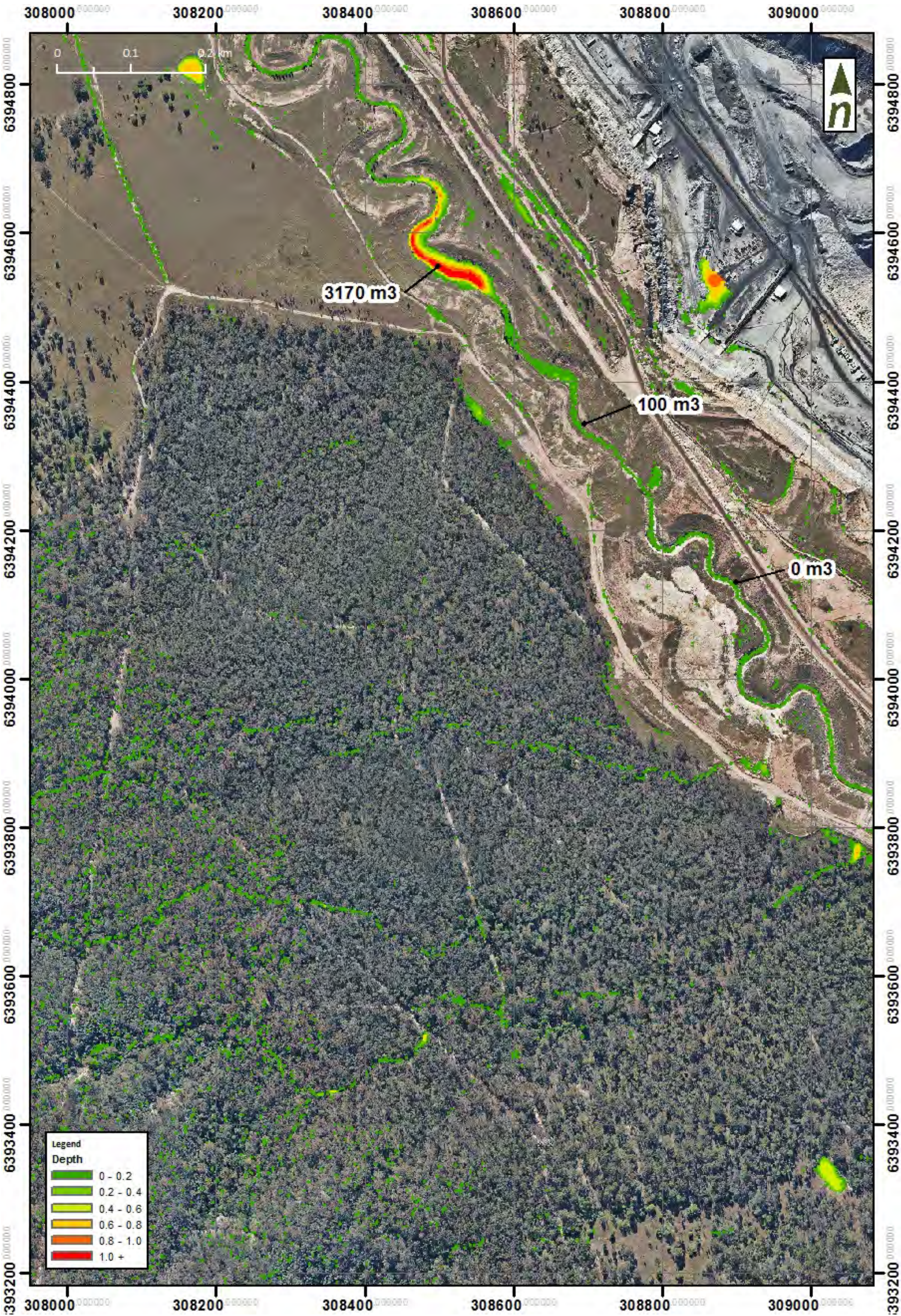


Figure 3-8. Estimates of ponding post subsidence following 50 year ARI event (existing conditions)

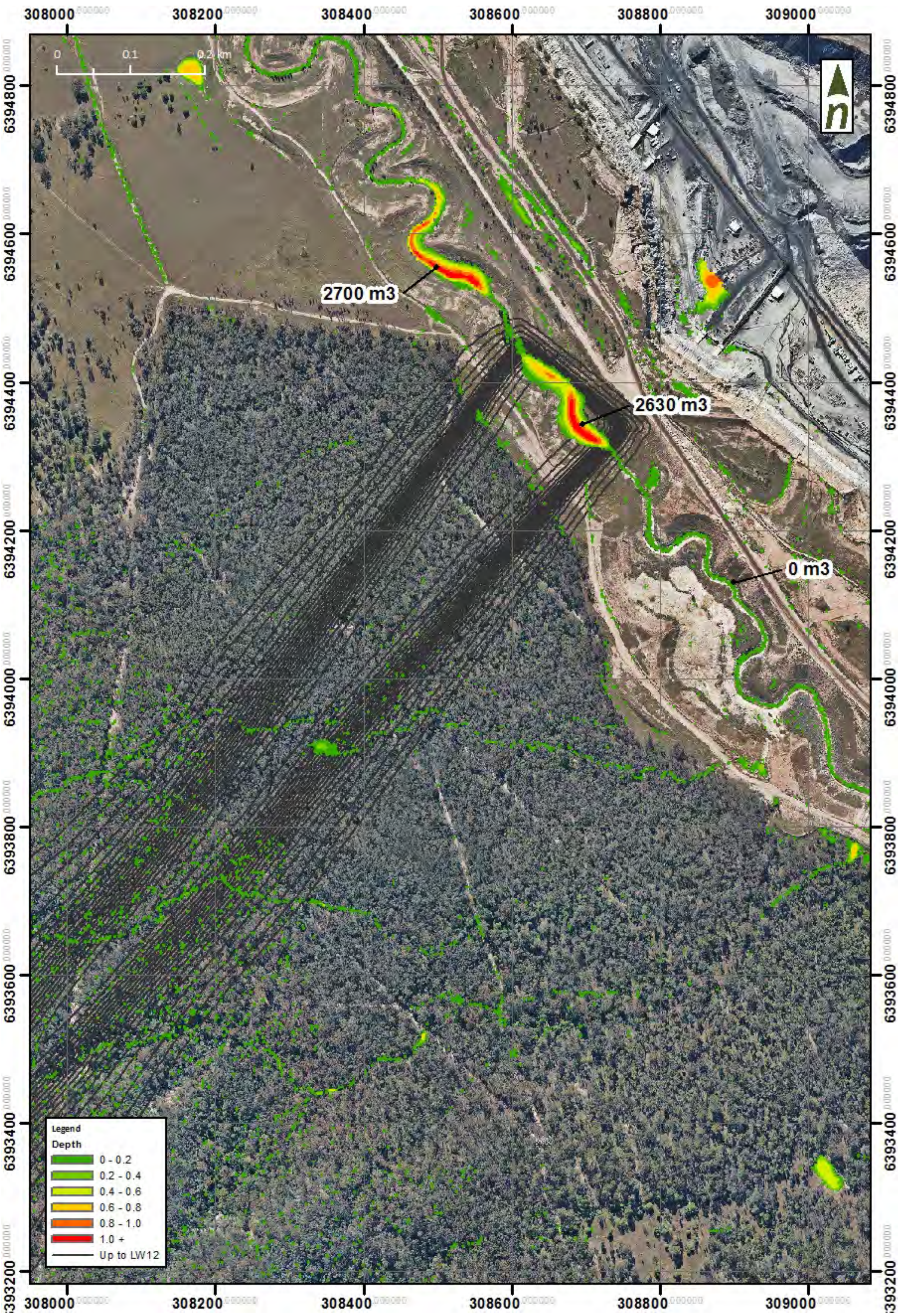


Figure 3-9. Estimates of ponding post subsidence following 50 year ARI event (post LW 12)

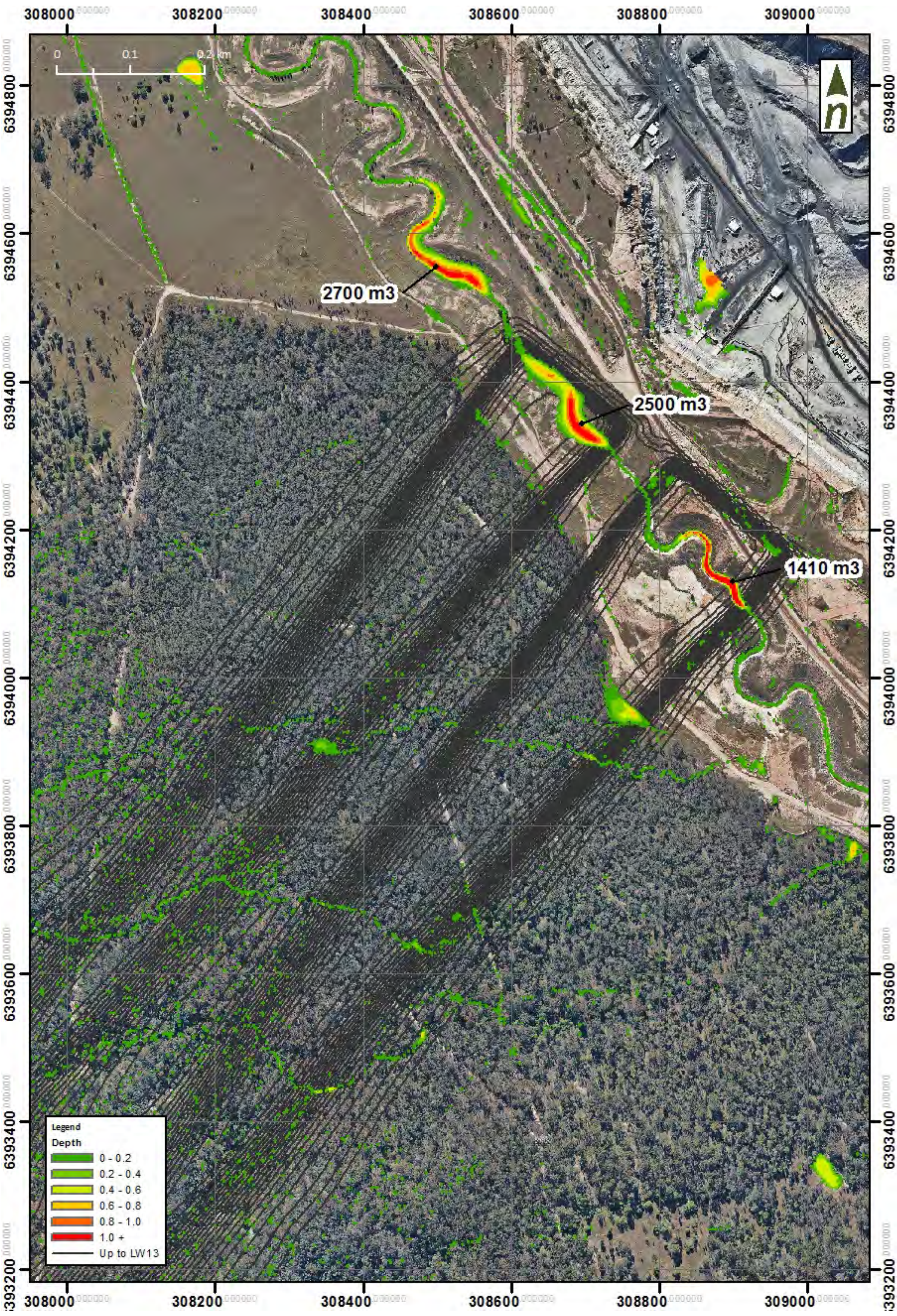


Figure 3-10. Estimates of ponding post subsidence following 50 year ARI event (post LW 13)

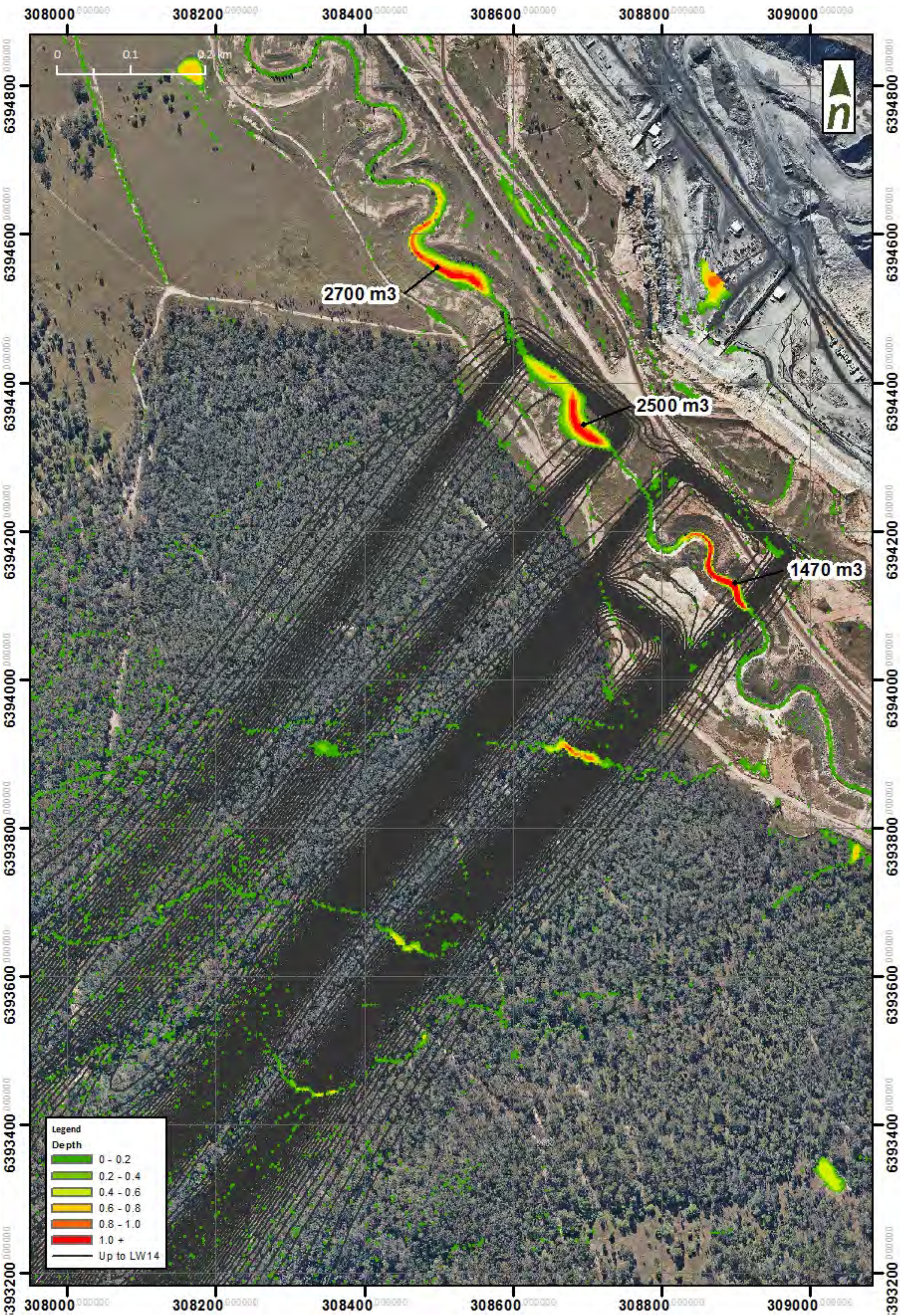


Figure 3-11. Estimates of ponding post subsidence following 50 year ARI event (post LW 14)

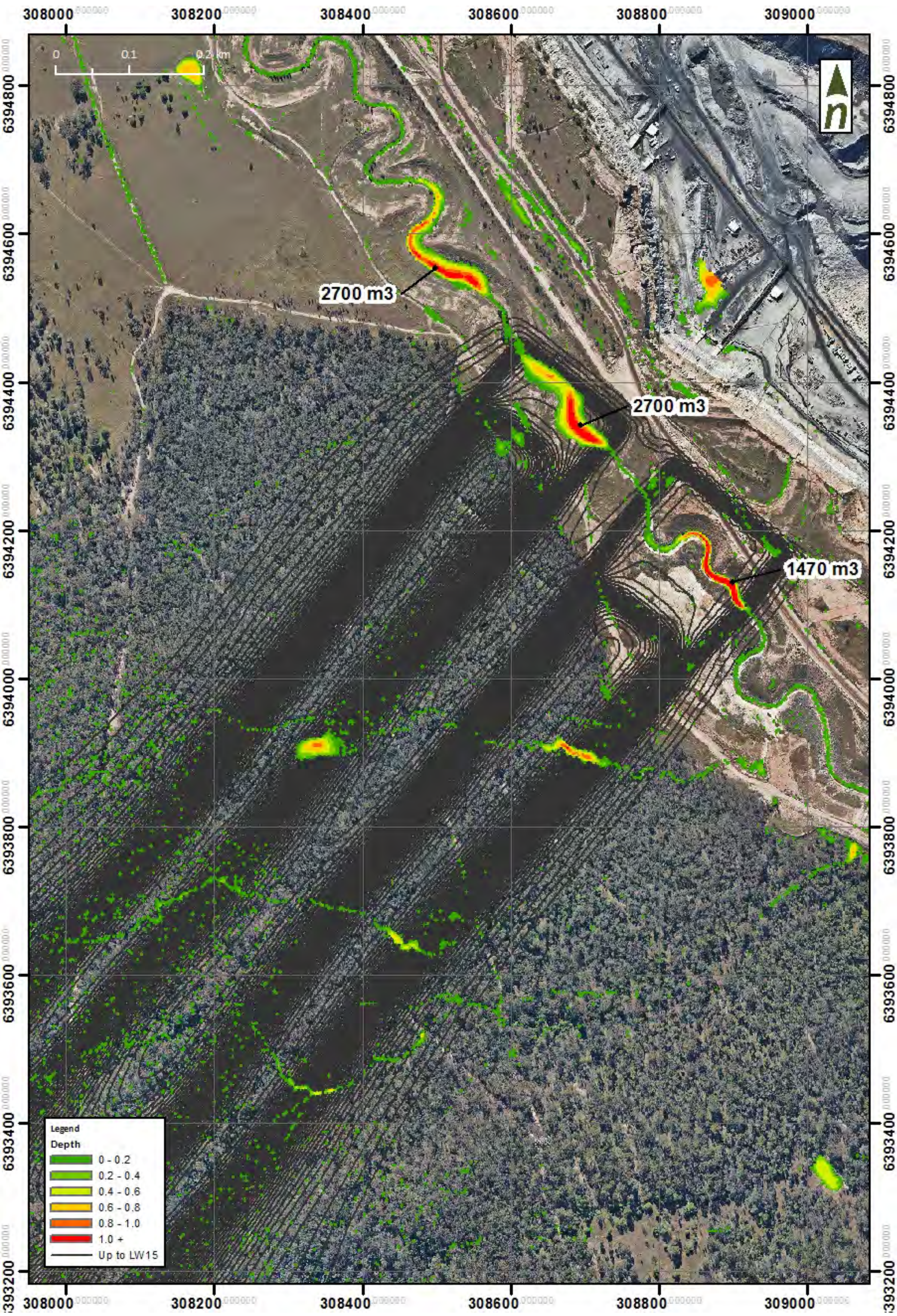


Figure 3-12. Estimates of ponding post subsidence following 50 year ARI event (post LW 15)

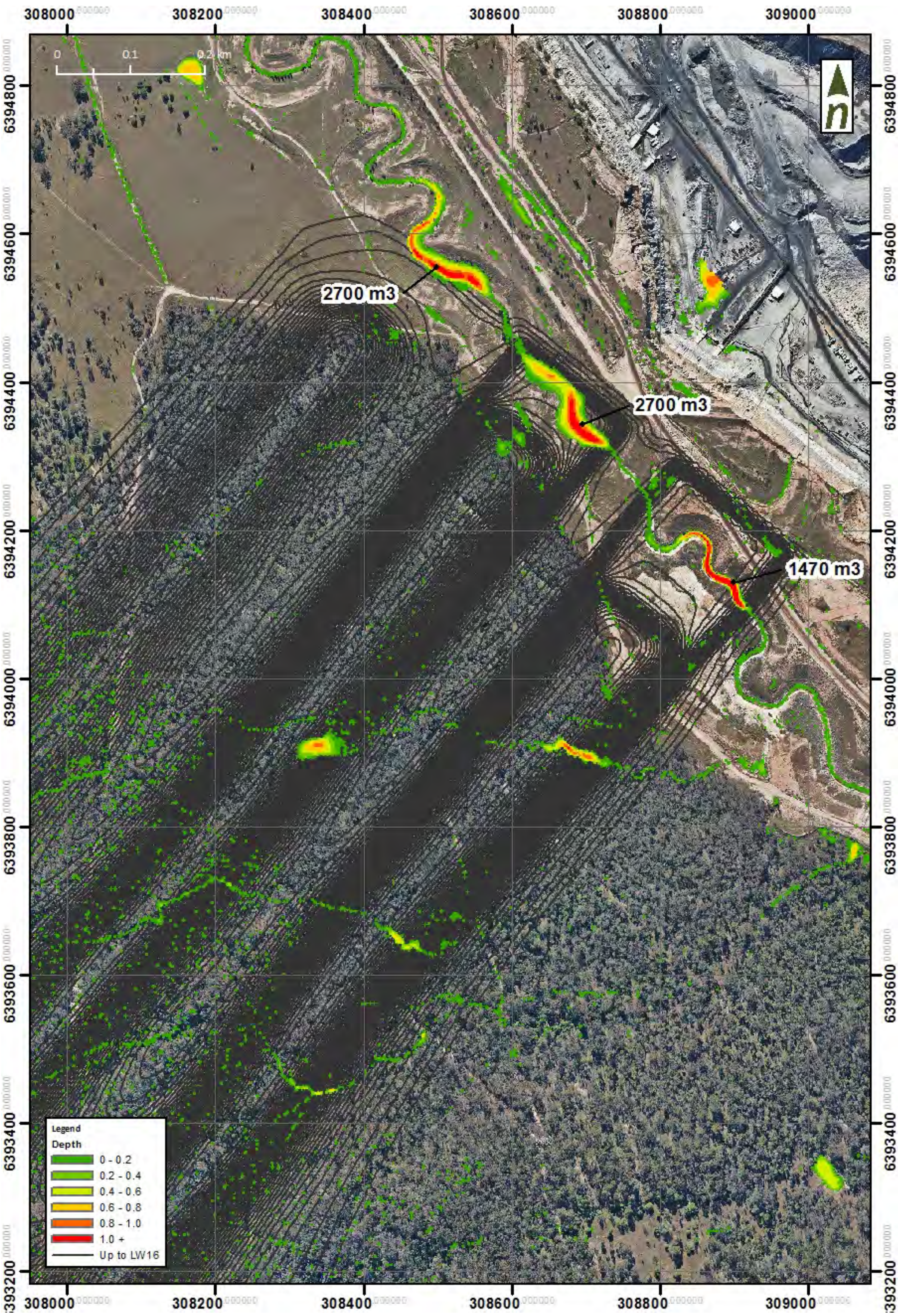


Figure 3-13. Estimates of ponding post subsidence following 50 year ARI event (post LW 16)

The impact of subsidence of Longwalls 11 to 16 on flow in North Wambo Creek is minimal. As demonstrated in Table 3-5 and Table 3-6, the greatest impact occurs following Longwalls 11 to 13, with the greatest change being a reduction in flow volume of 0.44%. The impact on volume decreases as the magnitude of the design flood event increases (as the subsidence driven storage volume does not increase).

Table 3-5. Predicted volume changes to North Wambo Creek stream flow post subsidence

ARI	Existing (m^3)	Subsided (m^3) after LW13	Difference (%)
2 year	931,600	927,500	- 0.44
50 year	2,060,700	2,053,600	- 0.34
100 year	2,490,200	2,483,300	- 0.28
1000 year	3,436,200	3,429,800	- 0.19

When comparing Table 3-5 and Table 3-6, the additional reduction in flow quantity down North Wambo Creek from the subsidence of Longwalls 14 to 16 is minimal. The greatest impact is an additional 0.02% decrease in volume.

Table 3-6. Predicted volume changes to North Wambo Creek stream flow post subsidence

ARI	Existing (m^3)	Subsided (m^3) after LW16	Difference (%)
2 year	931,600	927,000	- 0.49
50 year	2,060,700	2,053,700	- 0.34
100 year	2,490,200	2,482,800	- 0.30
1000 year	3,436,200	3,429,100	- 0.21

The changes to the flow hydrograph resulting from subsidence of each consecutive panel are shown in Figure 3-14 (2 year ARI), Figure 3-15 (50 year ARI), Figure 3-16 (100 year ARI), Figure 3-17 (1000 year ARI).

Please note that this assessment has focussed solely on the impact that the topographical changes resulting from subsidence have had on storage and flow in North Wambo Creek. The assessment does not consider the potential for losses to underground due to cracking in the vicinity of the longwall panels.

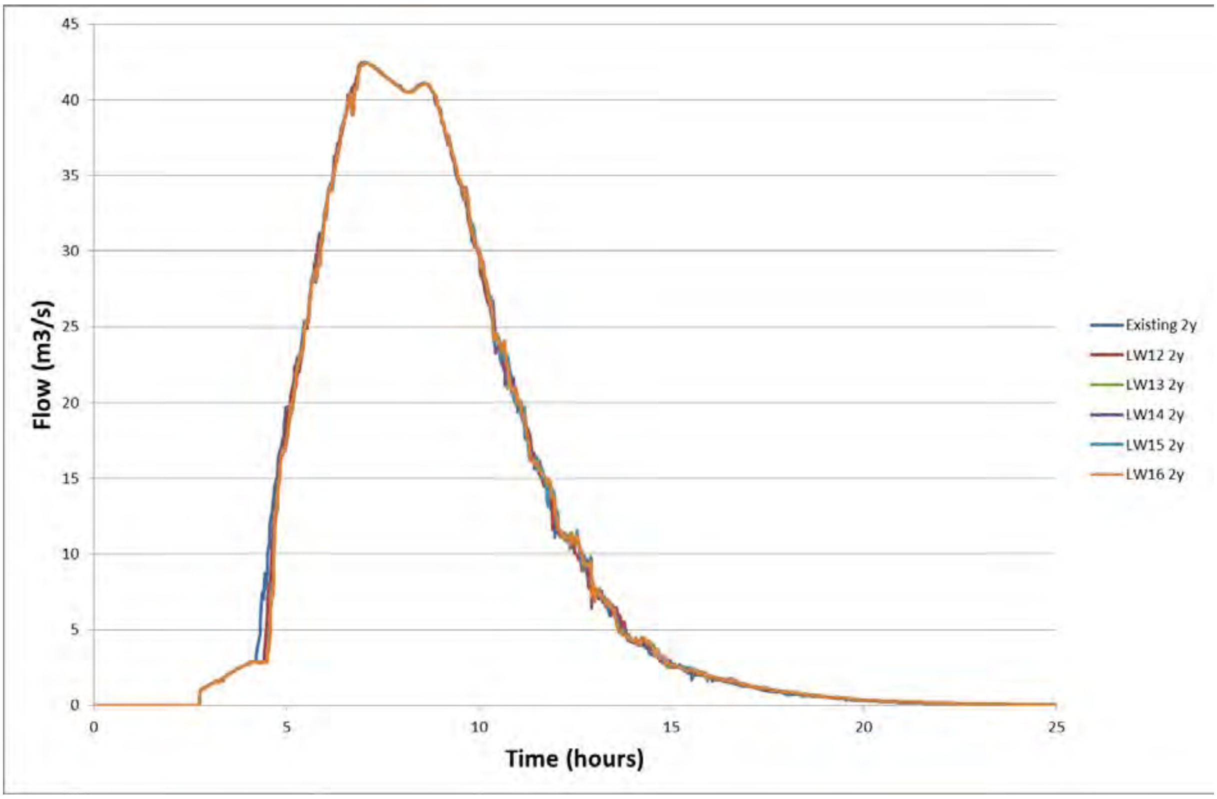


Figure 3-14. Hydrographs for North Wambo Creek for existing conditions and post subsidence conditions (2 year)

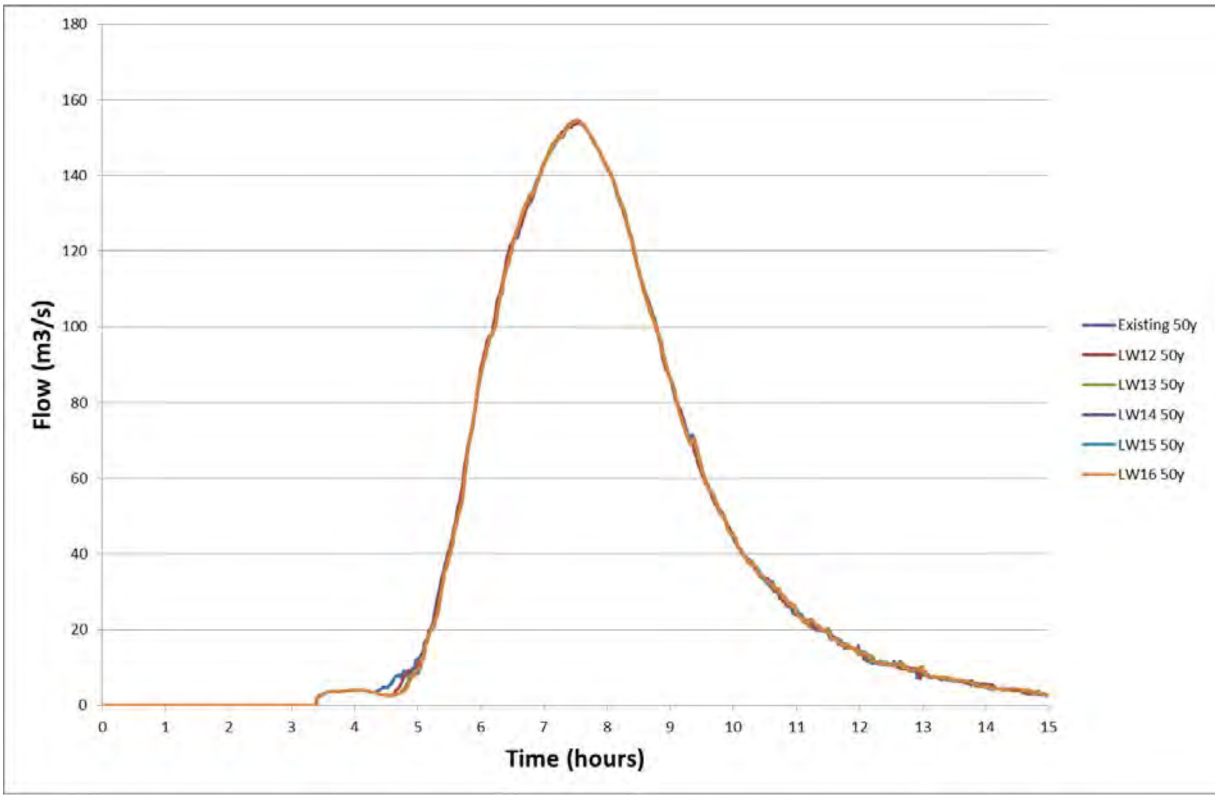


Figure 3-15. Hydrographs for North Wambo Creek for existing conditions and post subsidence conditions (50 year)

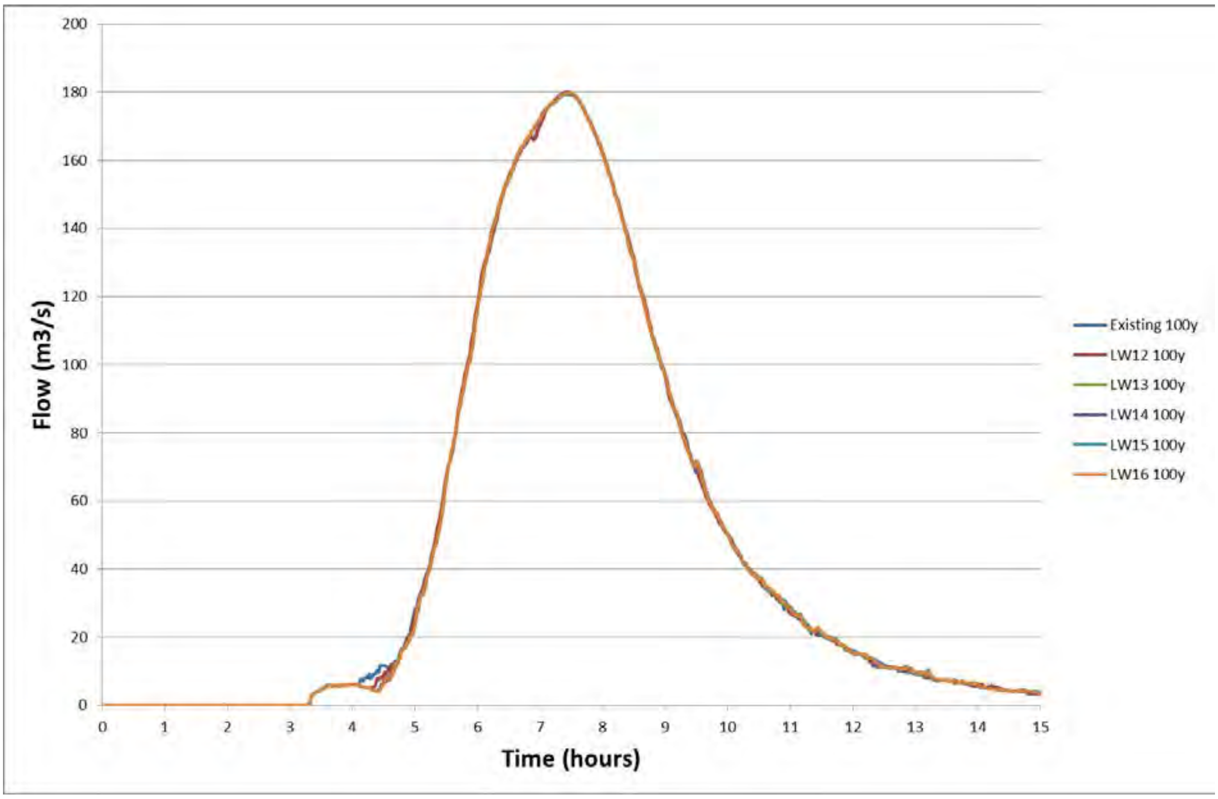


Figure 3-16. Hydrographs for North Wambo Creek for existing conditions and post subsidence conditions (100 year)

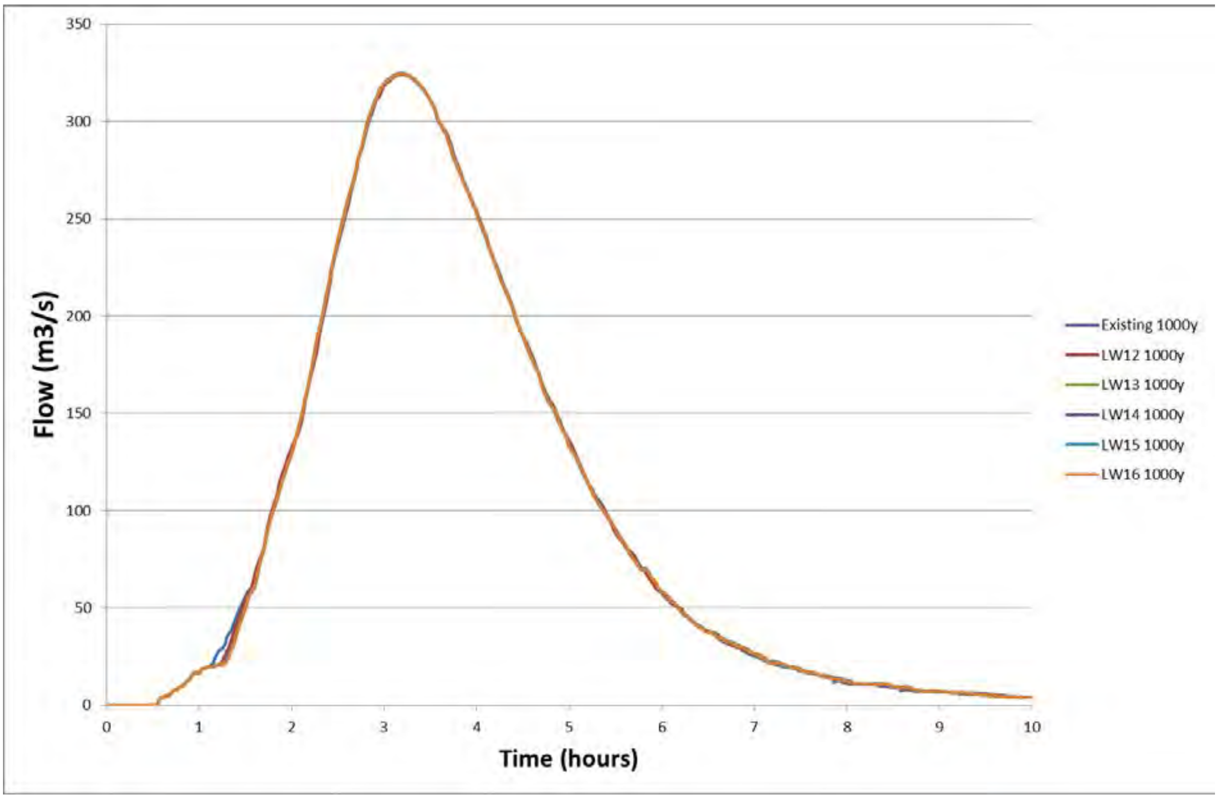


Figure 3-17. Hydrographs for North Wambo Creek for existing conditions and post subsidence conditions (1000 year)

Changes to water quality

An increase in suspended sediments in NWCD is possible from increased erosion upstream of LW11/16 and the pillars and additional erosion from overland flow entry. Management measures can be put in place to reduce that risk to negligible, those same management measures will also serve to reduce current suspended sediment inputs from overland flow entry issues.

3.4 4th order – predicted impacts to flora and fauna

The consequences for ecology associated with impacts described above should be considered by WCPL's ecology specialists. The changes in behaviour of water in the landscape due to subsidence provide potential for both positive and negative impacts, depending on current ecological conditions and the extent of change. The primary changes of note are:

- Creation of subsidence pools in the NWCD provides potential for increased aquatic habitat availability in the waterway.
- Alteration of flow paths in the western tributaries may alter the species composition along the zones that currently receive flows and similarly for those areas that will receive flows post subsidence.

4 Subsidence Management

4.1 Recommendations for Monitoring and Evaluation

Monitoring activities currently undertaken across NWCD, North Wambo Creek and South Bates underground mine subsidence area includes:

- Streamflow monitoring
- Surface water quality monitoring
- Groundwater monitoring
- Riparian monitoring
- Freshwater Macroinvertebrate monitoring
- Bed and bank stability monitoring
- Landscape Function Analysis (LFA)
- Floristic and habitat monitoring sites

While the extent and complexity of the current monitoring satisfies regulatory conditions regarding mining operations, the information is not synthesised to evaluate the impact of subsidence on waterways or the condition of NWCD in relation to reaches of North Wambo Creek, upstream and downstream. It is recommended that existing monitoring is integrated into a diversion and subsidence monitoring program. This could be based upon the "Monitoring and Evaluation Program for Bowen Basin River Diversions" (ID&A, 2001, ACARP project C9068), which was undertaken for the Australian Coal Association Research Program (ACARP). This monitoring program is considered best practice for diversions in the Australian mining industry at present. Despite the methodology being developed for diversions it is readily applicable to monitoring subsidence of a watercourse and it has been successfully implemented at several longwall mines over the past decade (some of which also subside diversions).

Adopting a consistent monitoring methodology for the upstream and downstream reaches of North Wambo Creek, NWCD (Stages 2 and 3) and the subsided reach, means the results are comparable and able to provide an overall perspective on the creek's response to subsidence and overall performance in relation to relinquishment in the longer term.

4.2 Typical monitoring program components

A typical monitoring package from baseline to approvals relinquishment comprises four components as shown in Table 4-1.

Table 4-1. Subsidence and diversion monitoring package components

Monitoring components	Objective
1: Baseline monitoring	To establish a baseline data set that can be used for tracking condition trajectory.
2: Construction / rehabilitation monitoring	Technical overview of construction and documentation of as constructed works including any amendments from design (new or rehabilitation).
3: Operations monitoring	To assess the performance of the diversion and North Wambo Creek following subsidence to maintain or improve channel condition and reduce risk to mining infrastructure and the environment.
4: Relinquishment monitoring	To demonstrate North Wambo Creek through the area of subsidence and the diversion is operating as a waterway in equilibrium with and not adversely impacting on adjoining reaches.

4.3 The monitoring program

The diversion and subsidence monitoring program should form a component of the Surface Water Monitoring Program for Wambo and inform the NWCD Rehabilitation Plan.

The monitoring program should involve quantitative and qualitative components and can be expanded to include or reference monitoring for other risks identified in the extraction plan. This could include the potential erosion issues and response of the various vegetation associations to subsidence outside the river channel, longwall panel catchments, subsidence cracking and loss of surface water. In this instance, there are similarities with some of the current monitoring and ideally most locations on North Wambo Creek and NWCD would be incorporated into a diversion and subsidence monitoring program, particularly where there are established photo-points with historical baseline.

Baseline monitoring

The baseline data provides a reference to measure the condition of all reaches of North Wambo Creek against each other and to themselves over time.

As the NWCD is already constructed, the first round of operations monitoring (described further below) would establish the baseline. This would consider:

- Index of Diversion Condition (IDC) (including establishment of reaches and monitoring points) collected in the first round of operational monitoring
- Expert fluvial geomorphic assessment of potential impacts and risks (the conclusions of this report)
- Aerial photography analysis prior to mining or subsidence
- Vegetation of geomorphic features in the monitoring area (including previous LFA monitoring)
- Analysis of flow event information for frequency and duration
- Analysis of long and cross-section survey for future comparison
- Summary of baseline condition and recommendations for mitigation of risks (the conclusions of this report)

The qualitative component of the monitoring program is the use of expertise in geomorphology, river health and river management to provide bigger picture process and condition interpretation and management recommendations.

Construction/Rehabilitation monitoring

This monitoring component should be undertaken during and immediately after construction of mitigation or rehabilitation works. The purpose of this component is to demonstrate that works have been undertaken to specification and/or meet design intent, like an “As Constructed” report. Construction/Rehabilitation monitoring requirements typically include:

- Execution outputs database to record descriptions of the design activities completed.
- Photographs of the works during construction and immediately after the work is finished. Where possible photographs should be taken from fixed photo points, with details such as date, time and weather conditions noted.
- Aerial photography immediately after works are completed to accurately display the extent of change and provide a baseline reference for changes that may occur in the future.

Operations monitoring

Operations monitoring is usually a continuation of monitoring at sites undertaken at baseline and construction/rehabilitation to provide an assessment of the condition and condition trajectory of North

Wambo Creek through the reaches of Wambo mining influence and adjacent upstream and downstream reaches. As described above, collection of monitoring data at the recommended points would be the first time, hence baseline will be the first operations monitoring. The outcome of this monitoring informs recommendations to manage any identified condition issues to minimise potential threats to infrastructure and negative environmental impacts.

The operations monitoring method consists of:

- Index of Diversion Condition (IDC) (including repeat/new photos at photo points)
- Expert geomorphic and waterway management overview (including interpretation of 2nd order impacts at the reach scale)
- Aerial photography analysis
- An assessment of survival of subsidence management or rehabilitation works and maintenance requirements
- Analysis of flow event information
- Analysis of long and cross-section survey for comparison with previous years and design
- Summary of condition and recommendations for management

The frequency of monitoring is generally higher around the time of impact, such as when longwalls subside the waterway, with intervals increasing over time. Operations monitoring will be undertaken annually initially, likely for the first 3-5 years following subsidence with intervals increased after assessment of geomorphic response to subsidence. Monitoring would also be undertaken following substantial (>10 year ARI) flow events.

Relinquishment monitoring
The objective of this program component is to demonstrate that the diversion is operating as a waterway in equilibrium and not having an adverse impact on adjoining reaches. Relinquishment monitoring can be undertaken prior to mine closure if operations monitoring is showing the diversion to be operating in dynamic equilibrium. However, the diversion should have been operating for a minimum of 10 years and had flow events of sufficient frequency and magnitude to test the performance of the diversion and its response to subsidence.

4.4 Proposed monitoring transects for North Wambo Creek

A series of upstream, diversion and downstream monitoring transects is proposed for NWCD and LW11-16. Where possible these would be co-located with existing riparian monitoring sites for Landscape Function Analysis (as shown on Figure 4-2). Landscape Function Analysis monitoring should be continued in conjunction with the IDC. The monitoring sites for subsidence are proposed on pillar zones for past and proposed longwalls that intercept North Wambo Creek.

Index of Diversion Condition transects
The Index of Diversion Condition (IDC) provides a rapid assessment of the diversion and adjoining reaches of interest along the watercourse(s) and is designed to flag potential management issues rather than provide a detailed scientific assessment of the waterway. It is an integrated suite of indicators that measures the geomorphic and riparian condition of a diversion (Geomorphic Index and Riparian Index, respectively) and its upstream and downstream reaches. Observations are recorded at monitoring points, spaced at regular intervals (preferably no greater than 500 m apart), within each reach to determine an average score for the reach. To provide a consistent approach at each monitoring point, observations are recorded within a limited area known as a transect. Draft monitoring locations are shown on Figure 4-1.

The monitoring reaches for North Wambo Creek are proposed as follows:

- Upstream reach (U1 – U4)
- Diversion Stage 2 reach (Div1 – Div5). Points Div1 to Div4 correspond with 17R, 19 R, 21R and 23R as shown in Figure 4-2.

- Diversion Stage 3 reach (Div 6 – Div11). Points Div8 to Div11 correspond with 28R, 27R, 26R and 25R as shown in Figure 4-2.
- Past underground (WS1 – WS6)
- Downstream reach (D1 – D2)

The reaches are structured around the stages of diversion construction, subsidence and previous monitoring. Monitoring sites should be established at locations to provide reasonable representation of the geomorphic and riparian vegetation characteristics and condition within each of the reaches. Each monitoring point peg is utilised as a photo point for future and ongoing comparison. In general, six photos are taken at each monitoring point, and include views of:

- Upstream, cross-stream, downstream and away from stream – with the monitoring peg in the lower centre of the frame (where possible)
- In-channel bed upstream and downstream – from the centre of the creek bed (or as near as possible)

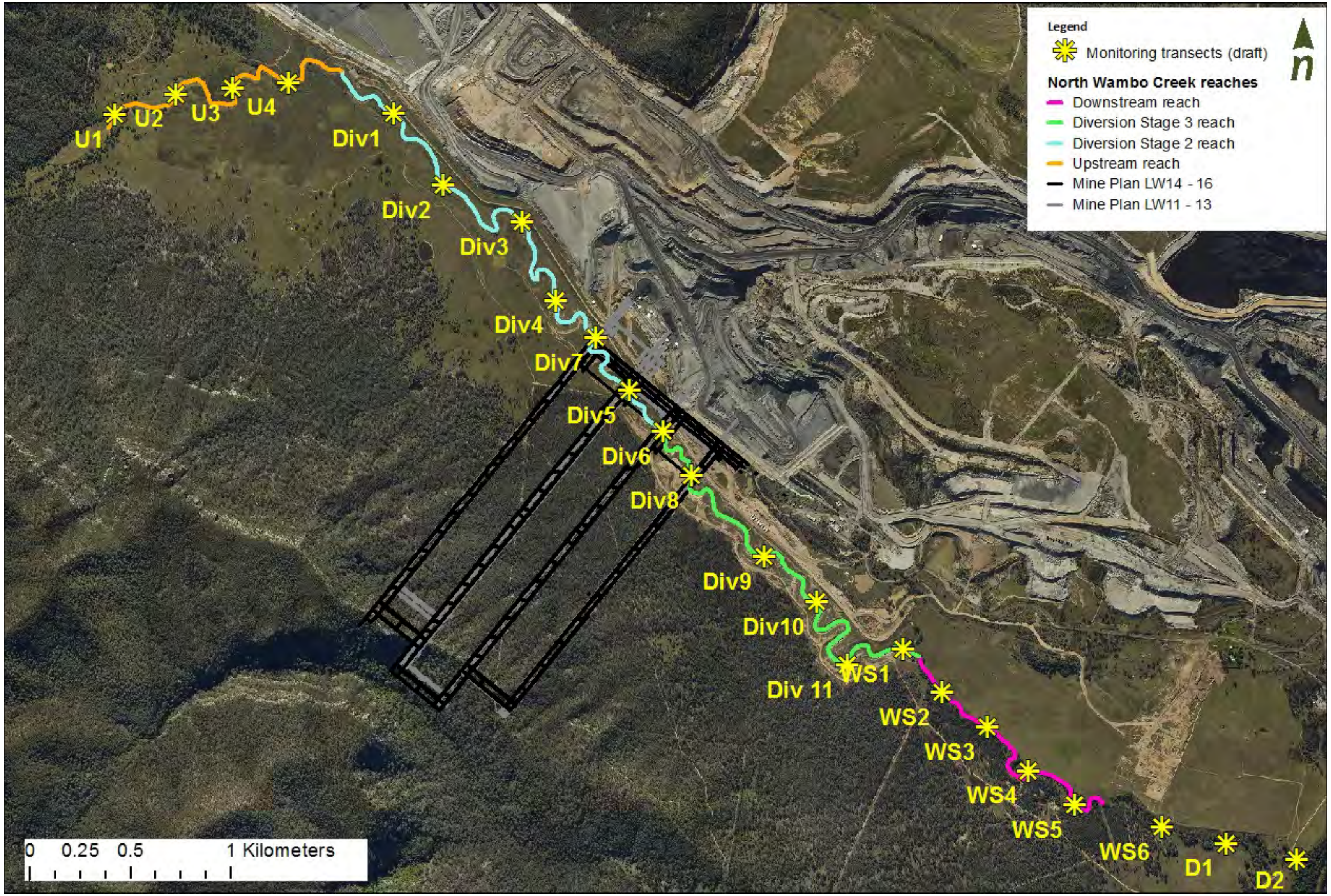


Figure 4-1. Draft monitoring locations for Diversion and Subsidence Monitoring Program

Flow event monitoring
Flow data from the four established gauging stations should be assessed to determine the size and duration of flow events experienced for potential correlation with observed geomorphic processes.

Cross and longitudinal section comparisons
A longitudinal profile and cross sections at each monitoring transect should be extracted from LiDAR or aerial photogrammetry survey data captured annually along the monitoring reaches. Comparison of survey over time provides a quantitative means of assessing changes to channel form.

Riparian vegetation assessment
The IDC includes monitoring basic vegetation structure and extent. A detailed assessment of riparian vegetation at monitoring sites is recommended for baseline and to be undertaken periodically.

Figure 4-2. Landscape function analysis (LFA) sites

Minor tributaries and panel catchments

Post subsidence flow paths should be inspected following runoff events to ascertain whether any channelisation of the unchannelised flow paths is going to occur. The risk of this occurring has been predicted as low, hence no mitigation has been proposed at this time.

Surface water quality

Existing surface water quality monitoring should be continued as part of this monitoring program. An overview of surface water monitoring at Wambo Mine has been reproduced as Figure 4-3.

Monitoring for loss of surface water

Groundwater monitoring and surface water monitoring should be assessed to determine potential for loss to open cut and underground workings and track trajectory of recovery. An overview of groundwater monitoring at Wambo has been reproduced as Figure 4-3.

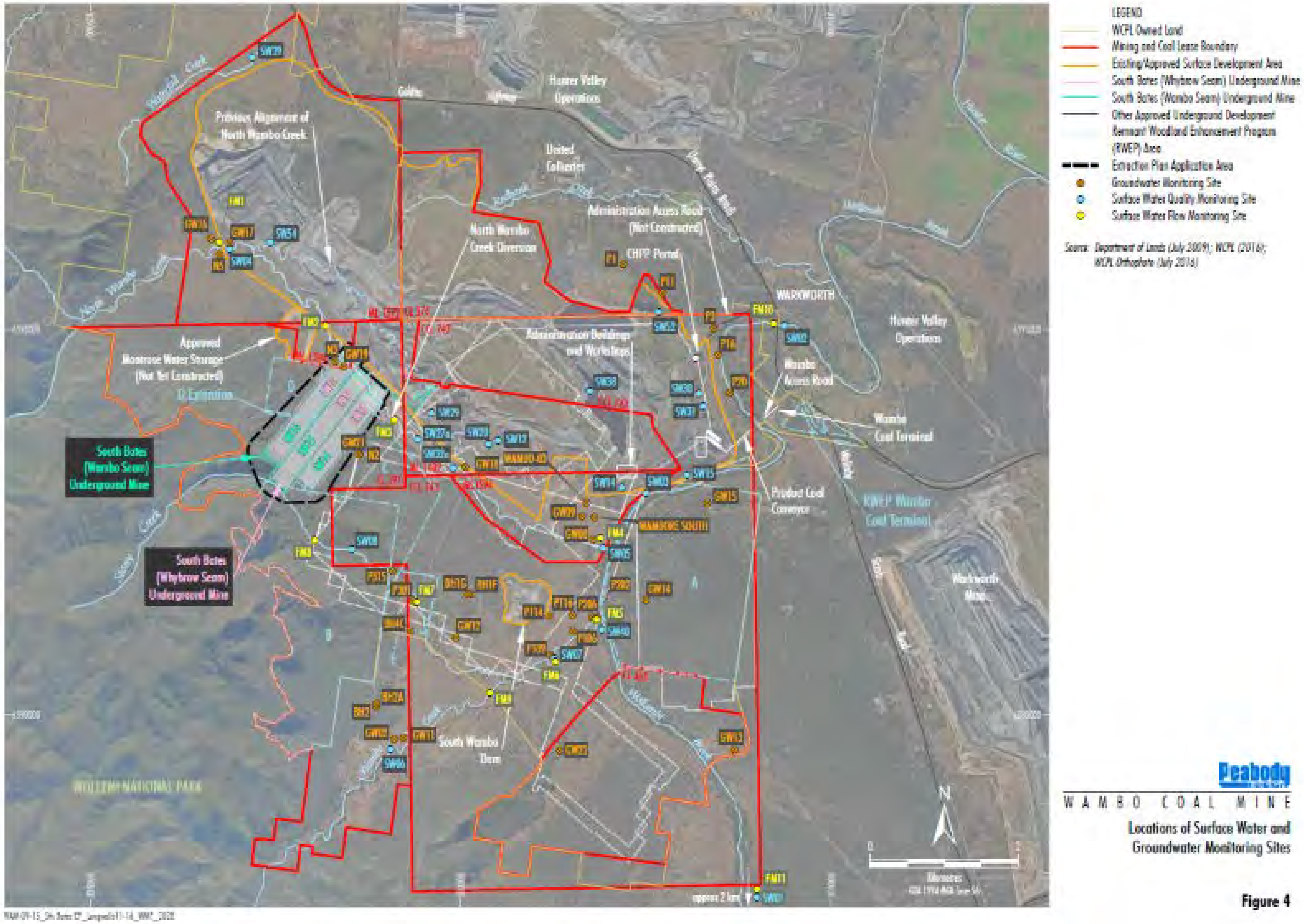


Figure 4-3. An overview of surface water and groundwater monitoring at Wambo Mine

4.5 Impact mitigation

NWCD erosion
Based on comparison of hydraulic modelling outputs to current best practice design criteria for diversions in Australian mining (refer Attachment A) and field observation of NWCD, increased rates of erosion in response to subsidence upstream of LW11/16 and over the LW11-12 pillar is likely.

To achieve a long term stable diversion arrangement in these extents a reduction of hydraulic parameters or a form of channel armouring is required. To create a self-sustaining diversion, the channel geometry (longitudinal profile and cross sectional form) would be altered to reduce hydraulic parameters into the range where stability is expected. To achieve this outcome would likely require increasing channel length by creation of new sections of diversion. However, given the diversion is an approved structure for Wambo and much of the diversion already exceeds hydraulic parameter values that are required to achieve long term stability, an alternate approach may be taken that is consistent with current approvals. This would be in the form of low flow channel armouring and increasing vegetation coverage in the diversion in the areas of concern.

Low flow channel armouring could utilise similar sandstone to that already utilised in Stage 3 of NWCD in the zone upstream of LW11/16 and the LW11-12 pillar. Figure 4-4 identifies zones that are vulnerable to scour or instability. The need for stabilisation measures for the channel bed and low flow channel banks in these zones should be further investigated including armouring of selective locations. Increased woody vegetation coverage on the inset floodplain of the diversion is a complimentary measure that provides for increased potential for stability over the long term.

The mitigation works for upstream of LW11 can be undertaken now while the mitigation works for the LW11-12 pillar should take place after subsidence has occurred.

It is not proposed to regrade pools that may form along the diversion above LW11-16. These pools provide for increased aquatic habitat availability in a system that currently has limited availability.

Overland flow entry
New batter chutes to manage concentrated overland flow entry created by subsidence are required above each of the panels. Minor ancillary earthworks may also be required to ensure these chutes capture and convey all flow from the panels into the diversion without creating further rill/pipe/tunnel/gully erosion on the diversion batters. The batter chutes will have some alterations to those currently in place on NWCD that are subject to poor performance due to specifications and construction. These alterations are important to ensure batter chute function in dispersive soil/sub soil environments. See Figure 4-4.

The batter chute for LW11 can be constructed now however the remaining batter chute should be constructed after subsidence has occurred.

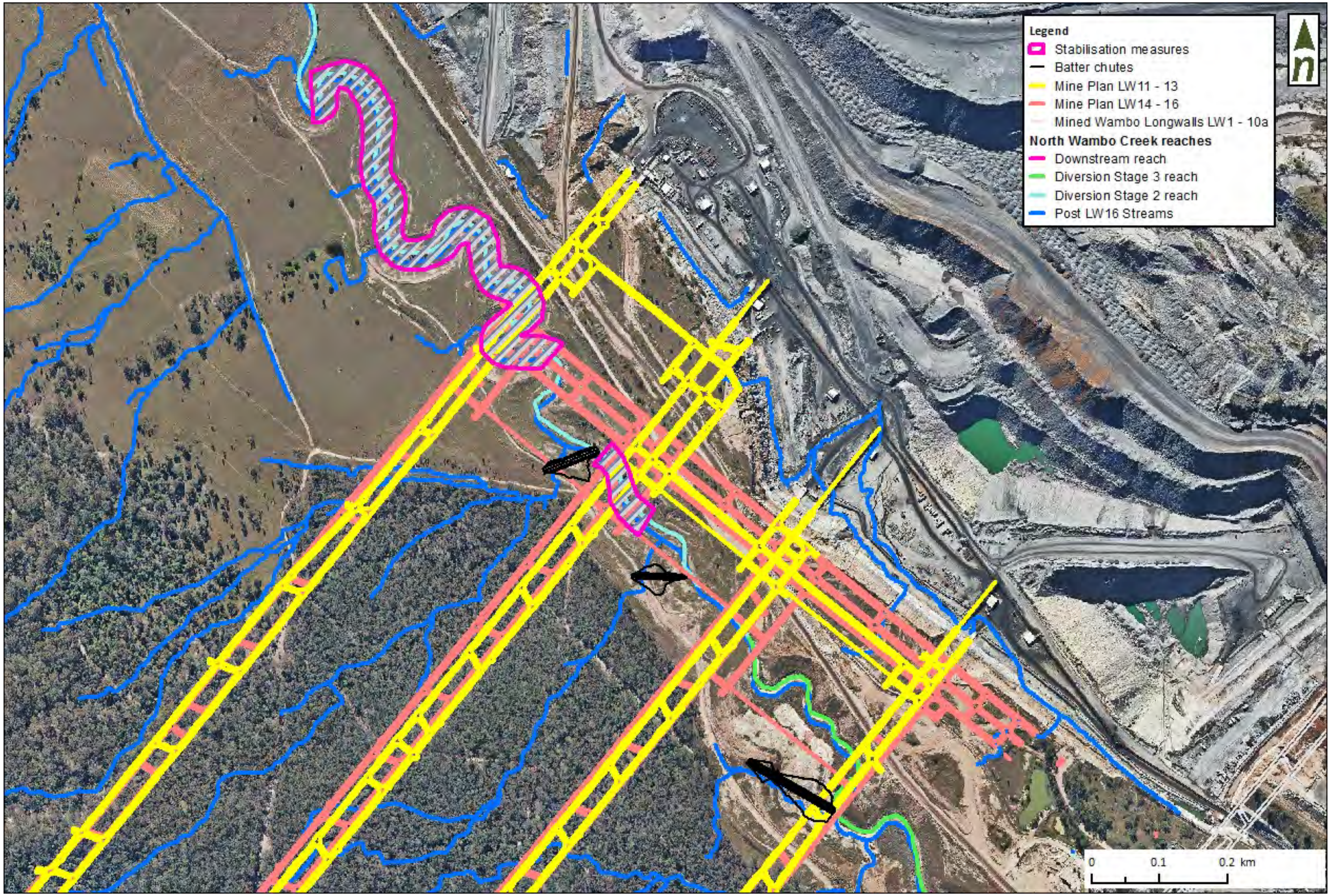


Figure 4-4. Recommended mitigation measures

5 References

Bureau of Meteorology (2003). *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method*. Bureau of Meteorology.

DERM (2011). Draft Central West Water Management and Use Regional Guideline 'Watercourse Subsidence – Central Qld Mining Industry V1'.

ID&A (2001). Monitoring and Evaluation Program for Bowen Basin Diversions, undertaken for the Australian Coal Association Research Program (ACARP), Program No. C9068.

Institute of Engineers, Australia (1987 and newer drafts). *Australian Rainfall and Runoff*. Institute of Engineers, Australia.

Jordan P, Nathan R, Mittiga L, Taylor B. (2005). *Growth curves and temporal patterns of short duration design storms for extreme events*. Sinclair Knight Mertz and Bureau of Meteorology.

Laurenson E.M, Mein R.G. and Nathan R.J. (2007). *RORB Version 6 Runoff Routing Program User Manual*, Monash University Department of Civil Engineering.

Attachment A
1D hydraulic modelling graphs

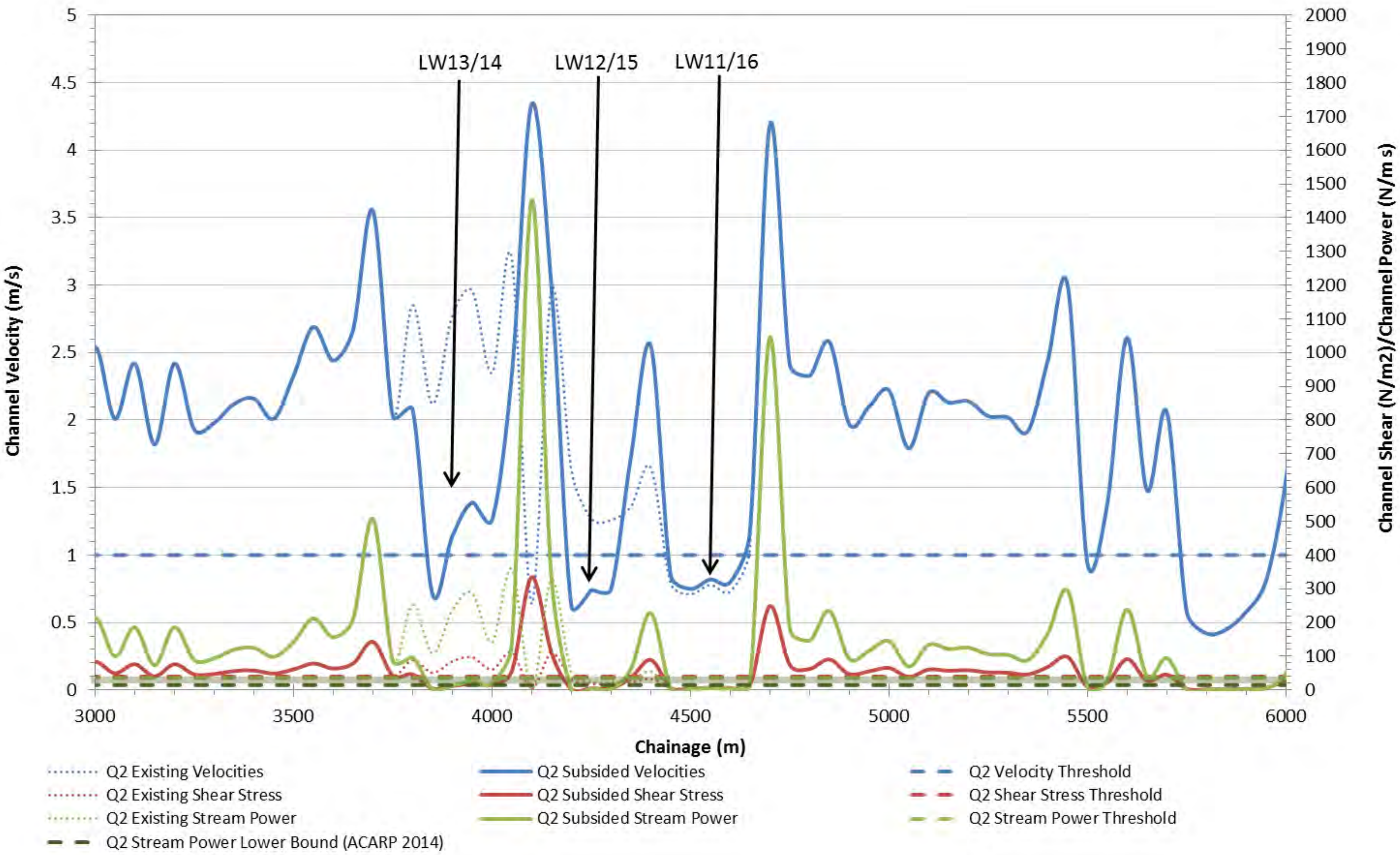


Figure A- 1. Existing and subsided conditions 2 year ARI hydraulic performance

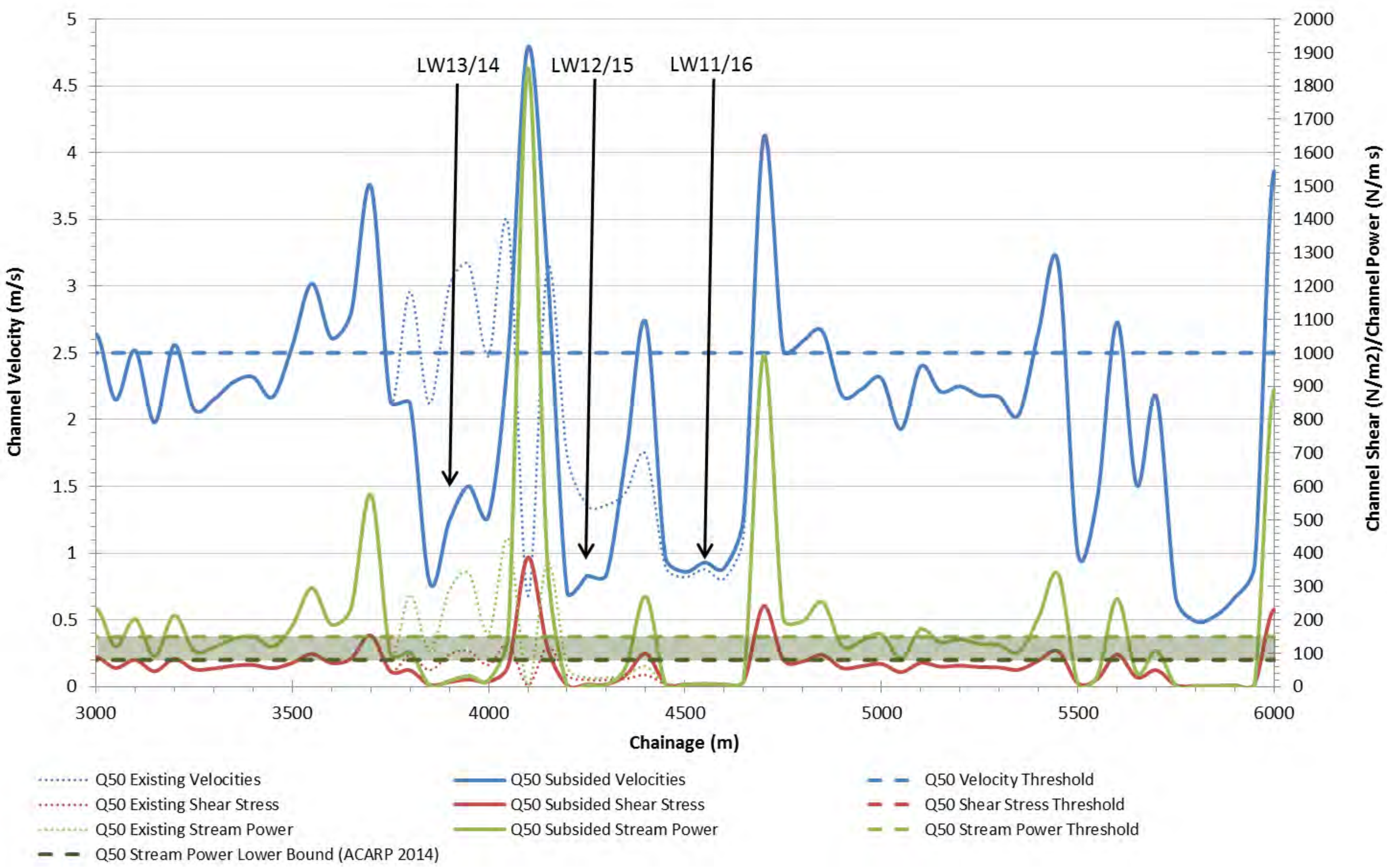


Figure A- 2. Existing and subsided conditions 50 year ARI hydraulic performance

Attachment B
Hydrology

Hydrologic modelling

The North Wambo Creek catchment passes by the Wambo Coal Mine site, initiating in the hills, to the west, and outfalling into Wollombi Brook on the east side of the mine. The catchment, as defined for the study, covers an area of approximately 39.5km^2. See Figure B-1.

A hydrologic model was built for the entire catchment and flows were generated for up to the 1000 year ARI for existing conditions. The hydrologic model has not been directly calibrated as no reliable long-term flow data was available for the catchment. Hydrologic outputs for the catchment have been derived at locations to facilitate flood modelling of existing mining operations.

RORB model description

The hydrologic modelling software used in this study is RORBWin version 6.15, a Windows version of the industry accepted RORB program (Laurenson et al 2007).

A RORB model represents the rainfall runoff process occurring in a catchment by:

- Conceptualising the catchment as a linked series of sub-catchments represented in the model by catchment storages and river reach storages;
- Applying rainfall excess (rainfall minus losses) to each sub-catchment (rainfalls are assumed to enter the sub-catchment at its centroid);
- Calculating the resulting runoff from each sub-catchment storage;
- Routing the runoff through the catchment system, combining flows at channel junctions; and
- Outputting flow hydrographs at points of interest in the catchment.

The model represents only the rapid flow or surface runoff component of stream flow, and the slow response or base flow component has not been included in the model.

Setting up the model comprises:

- Determining the catchment boundary and dividing the catchment into sub-catchments;
- Calculating the area of each sub-catchment;
- Placing model nodes at sub-catchment inflows and junctions;
- Placing reach storages between nodes; and
- Measuring the length of reach between adjacent nodes.

The RORB model requires four parameters to be specified which include k_c, m, initial loss (IL) and continuing loss (CL). The k_c and m parameters are factors in the storage discharge relationship.

The storage discharge relationship for the reach storages in the model has the general form:

$$S = 3600k\,Q^m$$

Where:

S is the volume of water in storage (m^3);
k is related to travel time of a particular reach and the characteristics of the whole catchment;
Q is outflow rate from the reach storage; and
m is a dimensionless exponent representing the non-linearity of catchment response. m varies in the range 0.6 to 1.0 with a value of 1 representing a linear response. Many studies adopt a value of 0.8.

The relationship between k and k_c is given by the equation:

$$k = k_{ri} k_c$$

Where:

k_{ri} is the relative delay time of reach i; and
k_c is an empirical coefficient applicable to the catchment and is a constant for the whole catchment.

The two rainfall loss parameters of initial loss and continuing loss are used in the generation of the rainfall excess hyetograph for the model. Initial loss is the rainfall at the start of a storm event which fills soil and groundwater storage, is intercepted by vegetation, or is lost by another process and does not contribute to runoff. Continuing loss is the ongoing portion of rainfall that falls after the initial loss that does not produce surface runoff. This could be due to deep soil storage, vegetation interception or evaporation. The loss parameters used in the model can be storm and catchment specific.

Catchment delineation

Catchment delineation and subdivision was undertaken using the CatchmentSIM software program which delineates sub-catchments from a Digital Terrain Model (DTM), calculates their properties and creates output files for a range of hydrologic models including RORB.

For this project, the 04/07/2016 LiDAR survey data obtained by WCPLcovered the majority of the catchment. To fill the area beyond the mine, 3 arcsecond NASA SRTM 90m DEM grid data was used. This data was obtained by Alluvium from Geosciences Australia.

The catchment delineation and subdivision took account of all known diversions and watercourses within the project area. Following delineation of the sub-catchments, the CatchmentSIM model was exported as a RORB catchment file using a CatchmentSIM-RORB macro (6.0 v3). This automatically sets up the connections between sub-catchments and reaches and calculates and assigns the sub-catchment areas, reach lengths and slopes in the RORB catchment file. This file was then modified to specify the locations where hydrograph outputs were required.

The existing conditions model for the North Wambo Creek catchment has 35 subcatchments. The resulting layout of subcatchments and reaches is shown in Figure B-1**.**

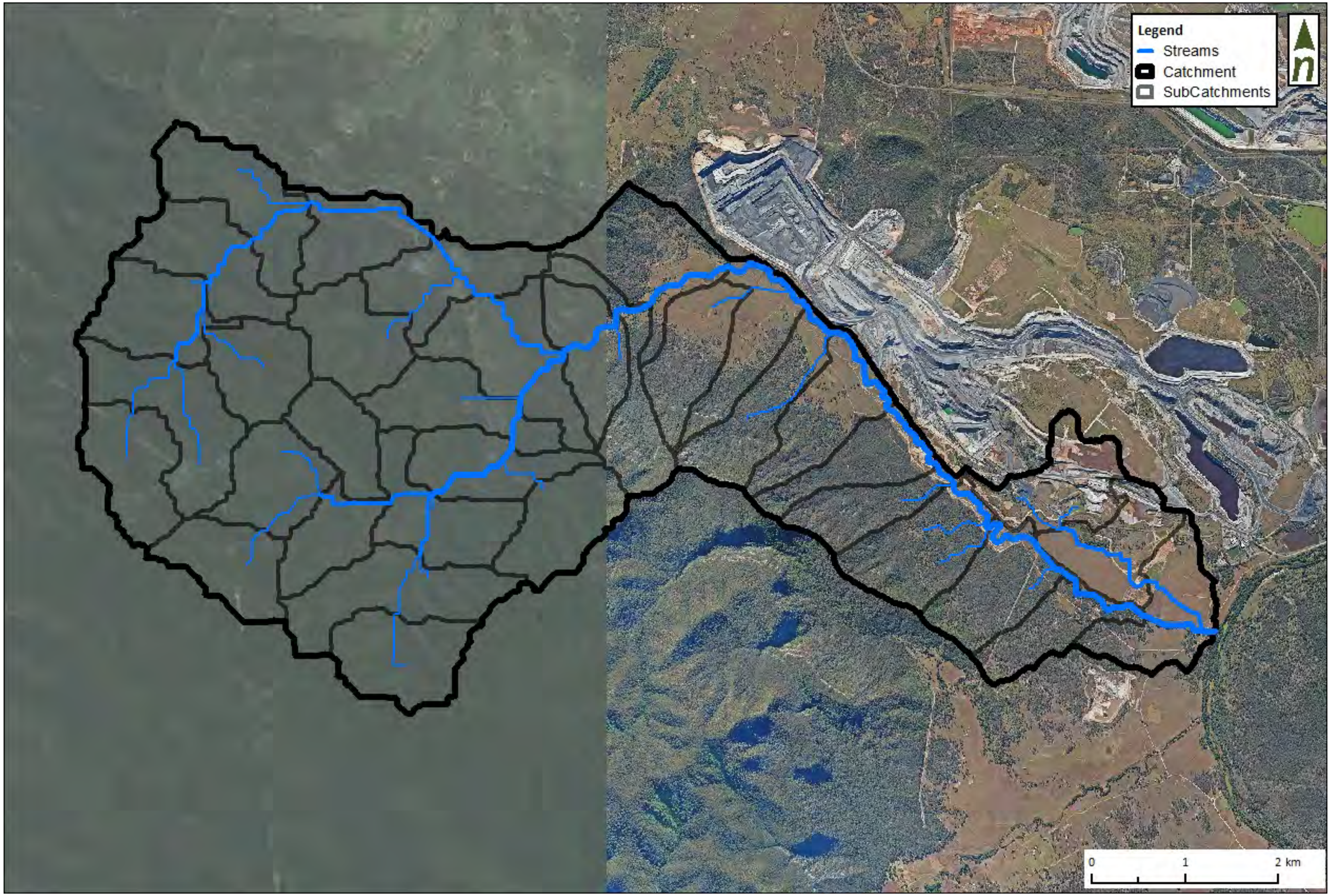


Figure B-1. **Kolar Creek catchment watercourse and features surrounding mine**

Model parameter derivation

Due to the lack of long-term stream flow data for the catchment, it was not possible to directly calibrate the hydrologic model. Therefore, it was necessary to use the Kleemola method.

Weeks regional relationship method

Australian Rainfall and Runoff (ARR) outlines, in section 3.6.2, the regional relationships developed to calculate k_c for ungauged catchments. For eastern New South Wales, the relevant method was derived by Kleemola takes the form:

$$k_c = 1.22 * Area^{0.46}$$

Table B-1, below, lists the Kleemola derived k_c values for existing conditions.

Table B-1. Calculated Kleemola value based on existing conditions scenario

Scenario	Catchment Area (km^2)	Kleemola k_c Value*
Existing Conditions	39.5	6.62

*Note, that the underlying assumption is that m = 0.8.

Other modelling parameters

These losses adopted for this study are presented in Table B-2.

Table B-2. Adopted model parameters for initial loss and continuing loss

Parameter	2yr to 100 year ARI	1000 year
Initial Loss	25mm	0mm
Continuing Loss	2.5mm/hr	1 mm/hr

Design rainfall

Design rainfall depths were generated for events up to the 1000 year ARI for this study. The IFD table for the North Wambo Creek catchment is presented in Table B-3.

The 2 year to 100 year ARI design rainfalls were determined using the ARR method inbuilt in RORB (with site specific parameters determined from ARR (1987) Vol 2). The ARR (1987) Areal Reduction Factors (ARF) were used to convert the point rainfall estimates to areal estimates.

The 1000 year ARI design rainfall was derived by apply the updated Co-operative Research Centre Focussed Rainfall Growth Estimation (CRCFORGE) method detailed in Jordan et al. (2005). CRC Areal Reduction Factors (ARF) were used.

Table B-3. IFD Table for the North Wambo Creek catchment, total rainfall depth in mm (includes ARF)

Event	2yr ARI	50yr ARI	1% AEP	0.1% AEP
15 min	11.8	23.8	26.7	37.1
30 min	16.5	32.3	36.2	51.9
1 hour	23.2	44.0	49.0	69.5
3 hours	35.5	69.8	78.1	110.2
6 hours	45.3	91.1	102.3	146.2
12 hours	57.2	117.9	132.8	194.1
18 hours	67.6	139.3	157.0	230.6
24 hours	75.3	155.3	175.0	(estimated) 260
48 hours	95.7	197.6	222.7	(estimated) 330

Temporal patterns
For events ranging from the 2 to 100 year ARI the ARR zone 1 temporal patterns were used.

A design temporal pattern suitable for the 1000 year ARI was derived from the 10 patterns provided in the Jordan et al. (2005) paper combined with the Bulletin 53 pattern from the Generalised Short Duration Method (GSDM) PMP BOM (2003). The resulting "Rare Design" temporal pattern is depicted in Figure B-2.

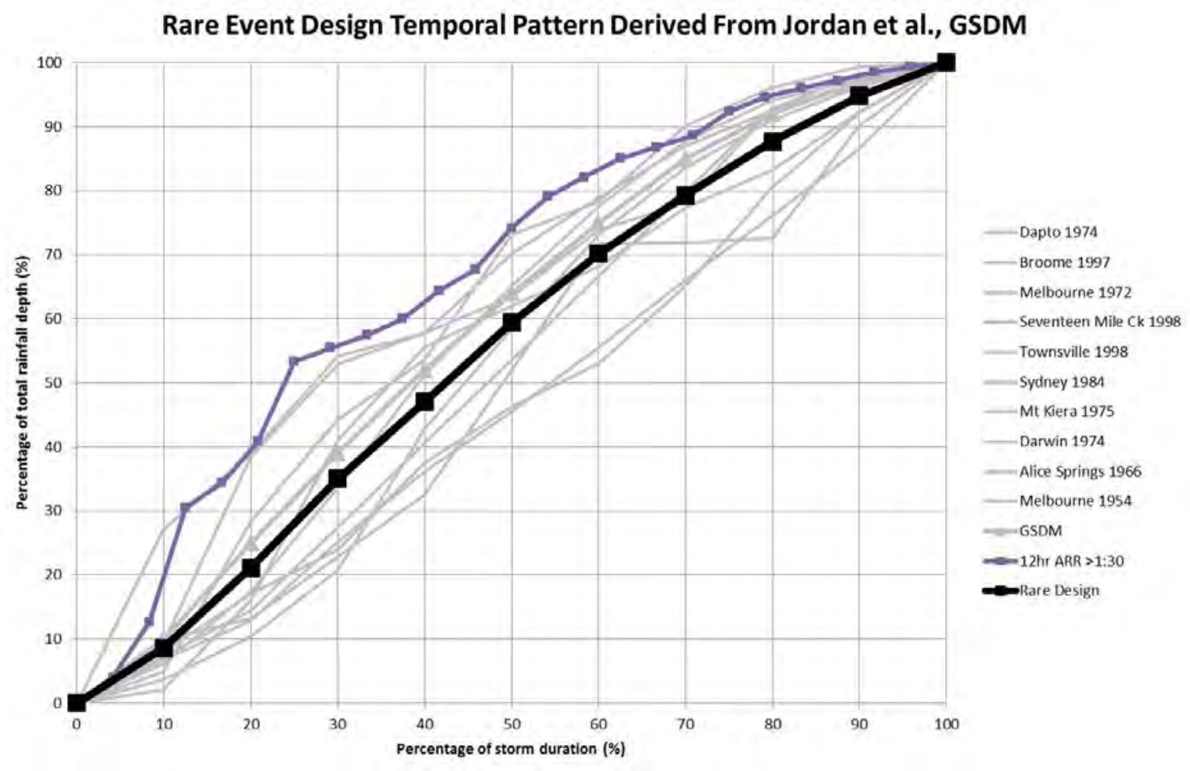


Figure B-2. **Selection of the design temporal pattern for rare events**

RORB model output flow

The RORB model outputs are presented in Table B-4. The output locations are shown in Figure B-1.

Note that the peak flow rates did not all coincide on the same duration storm event – overall the critical duration varied from as long as the 36 hour for the 2 year ARI event to as short as the 3 hour for the 1000 year ARI event, depending on location within the catchment.

Table B-4. Design discharges generated from hydrologic modelling of existing conditions

	Downstream of LW 13/14
Upstream catchment (km^2)	34
ARI/AEP	**Peak Discharge (m^3/s)**
2 year	43
50 year	154
100 year	180
1000 year	324

Attachment C
Hydrodynamic Modelling

Hydrodynamic modelling of South Bates underground mine LW11-16

Hydrodynamic modelling was undertaken to assess the flood behaviour in the area around the planned longwall panels (LW11 to LW16).

2D hydrodynamic model set-up

A 2D hydrodynamic model of the catchment within and adjacent to the project area was built using XPSWMM, a hydrodynamic modelling software package which couples together the SWMM 1D model and the 2D finite difference model TUFLOW.

The hydrodynamic model outfalls on North Wambo Creek, approximately 2km downstream of the diversion. The model is extended up into the catchment to the point where North Wambo Creek approaches the site from the west. See Figure C-1.

The model was configured using a 4m cell size. The extent of the model is shown in Figure C-1.

Manning's n roughness coefficient for the model was set by assessing aerial imagery and site photographs. A single value of 0.04 was considered appropriate following the initial iteration of flood modelling where it was identified that the flow was predominantly in channel for all modelled events.

Design hydrographs were input into the model at the locations shown in Figure C-1 to represent inputs from both the catchments external to the area and runoff generated locally. The hydrodynamic model was tested with a series of storm durations for each event to confirm the critical duration(s) which generated the greatest flood extents.

A second model was developed to assess the impact of subsidence on overland flow. This model was configured the same as the first, with the exception that the hydrology was applied as direct rainfall (ie. rain on grid). The extent of this model is shown in Figure C-2.

It should be noted that the XPSWMM hydrodynamic model does not predict erosion and sediment transport impacts. Dam and other embankment failure scenarios have not been modelled in this assessment and therefore results are based on stable topography over the full length of the modelled events – which is unlikely to occur during a large magnitude event.

Also note that this assessment has focussed solely on the impact that the topographical changes resulting from subsidence have had on storage and flow in North Wambo Creek. The assessment does not consider the potential for losses to underground due to cracking in the vicinity of the longwall panels.

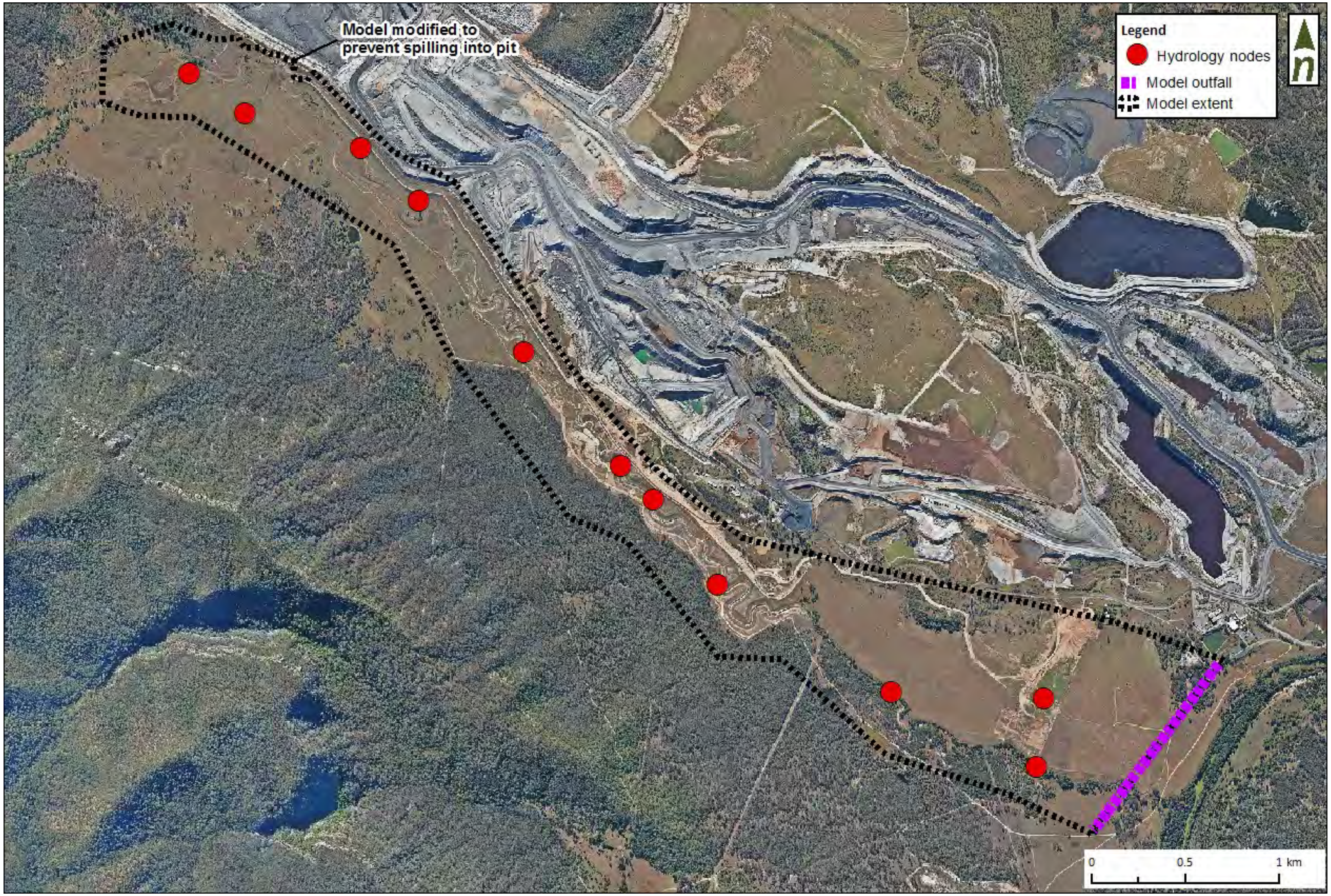


Figure C-1. **2D hydrodynamic 0.1% AEP model set up (existing conditions)**

Figure C-2. **2D hydrodynamic 0.1% AEP model set up (existing conditions)**

2D hydrodynamic modelling results

The figures below are presented in the following order:

- Depth (Figure C-3 to Figure C-26)
- Velocity (Figure C-27 to Figure C-50)
- Shear Stress (Figure C-51 to Figure C-74)
- Stream Power Figure C-75 to Figure C-98)

Within each group, the figures are presented in order of design flood event (i.e. 2 year, 50 year, 100 year then 1000 year ARI), and presented in consecutive order (i.e. LW11, LW12 etc). Note that the 2 year and 50 year ARI events include overland flow whereas the 100 year and 1000 year ARI focus on in-channel flow.

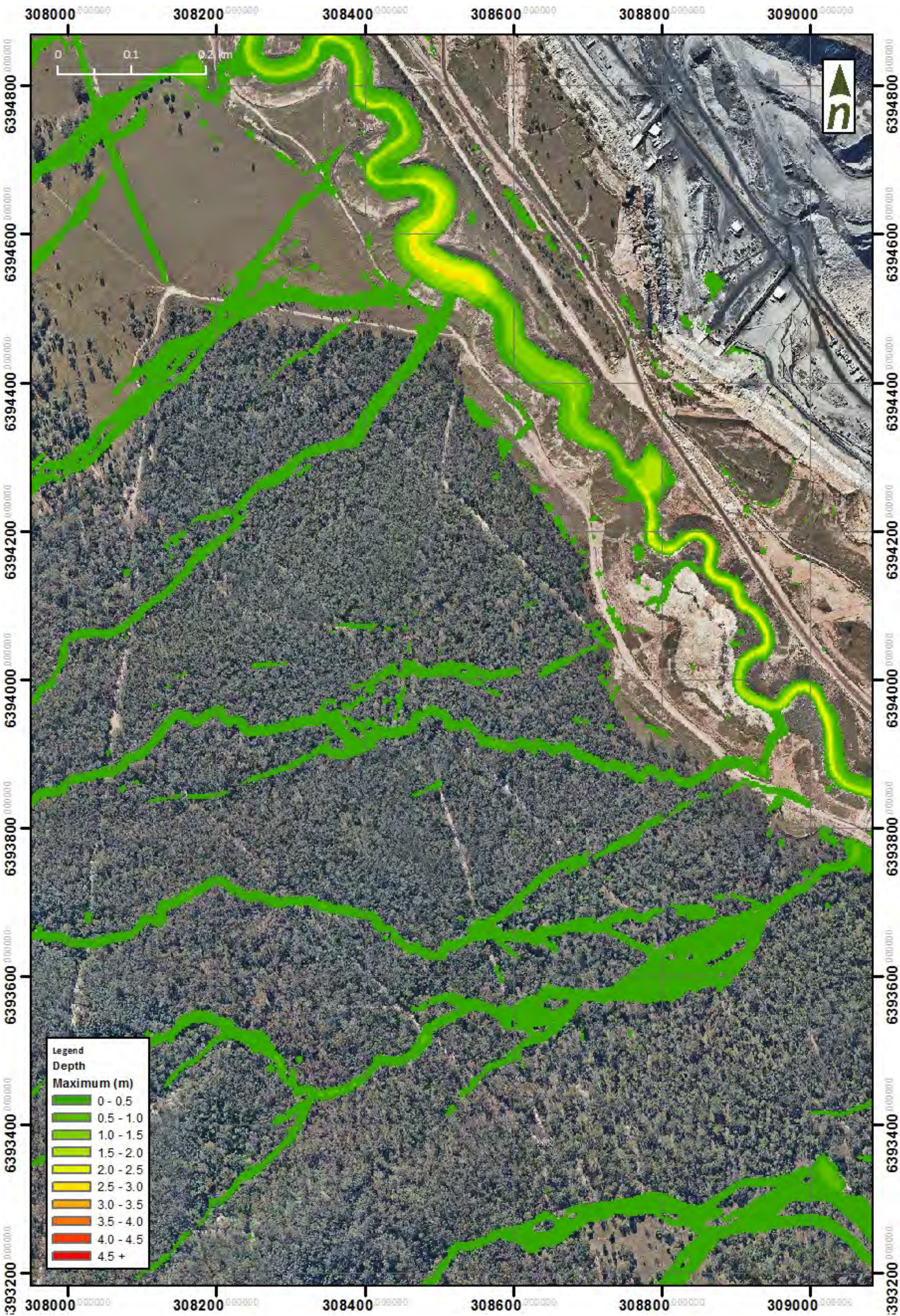


Figure C-3. **2 year ARI flood extents and depth (existing conditions)**

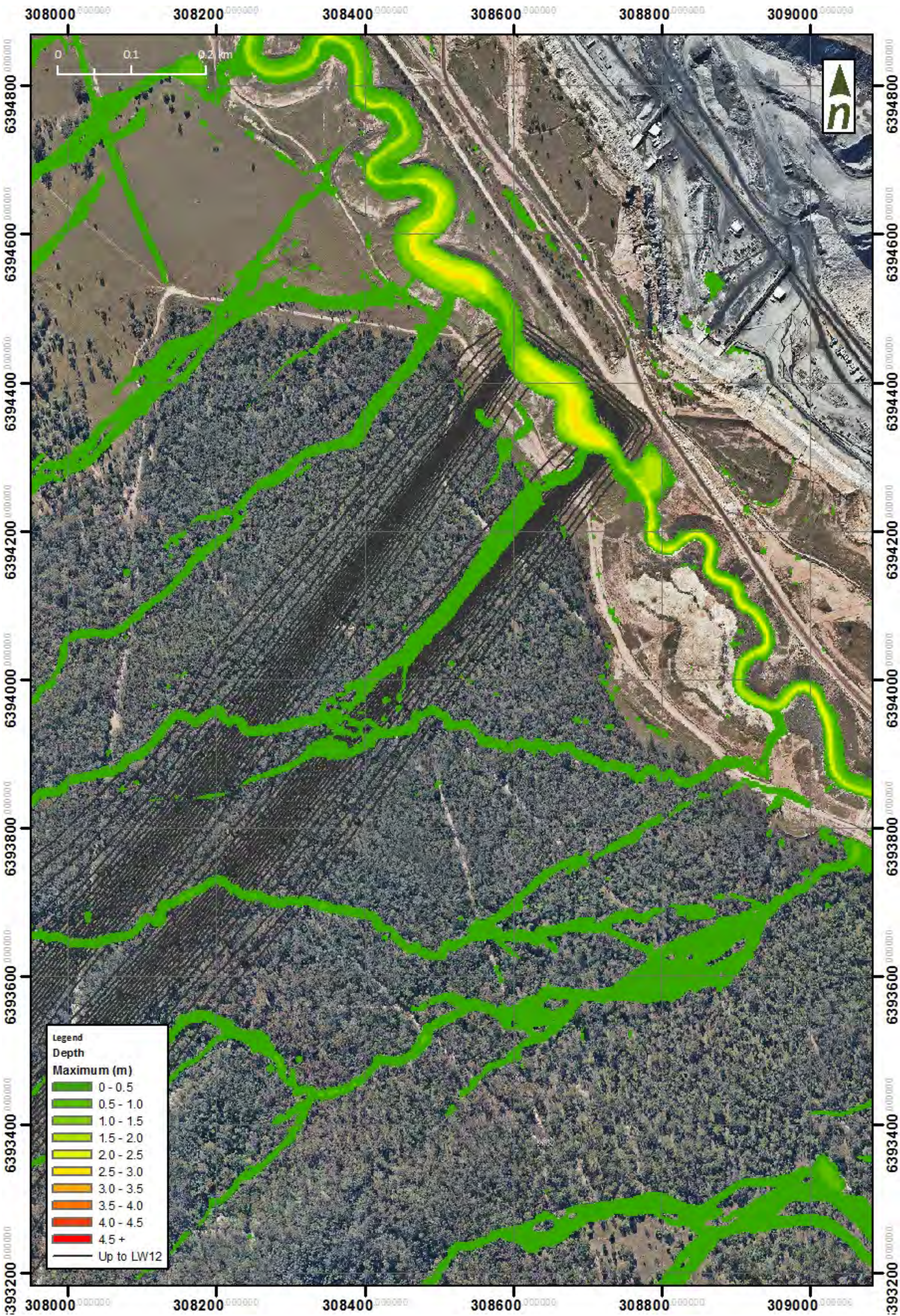


Figure C-4. **2 year ARI flood extents and depth (post LW12)**

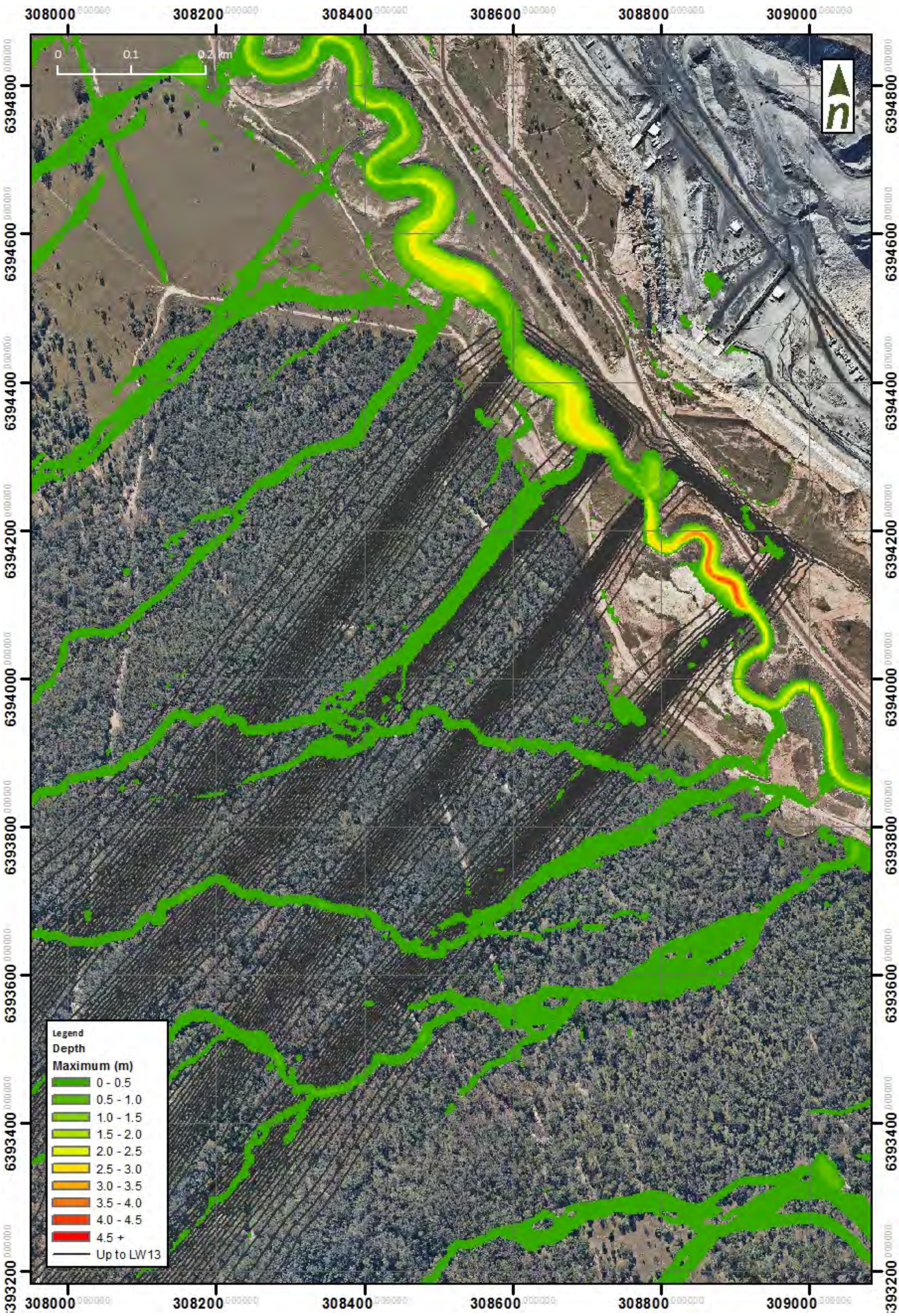


Figure C-5. **2 year ARI flood extents and depth (post LW13)**

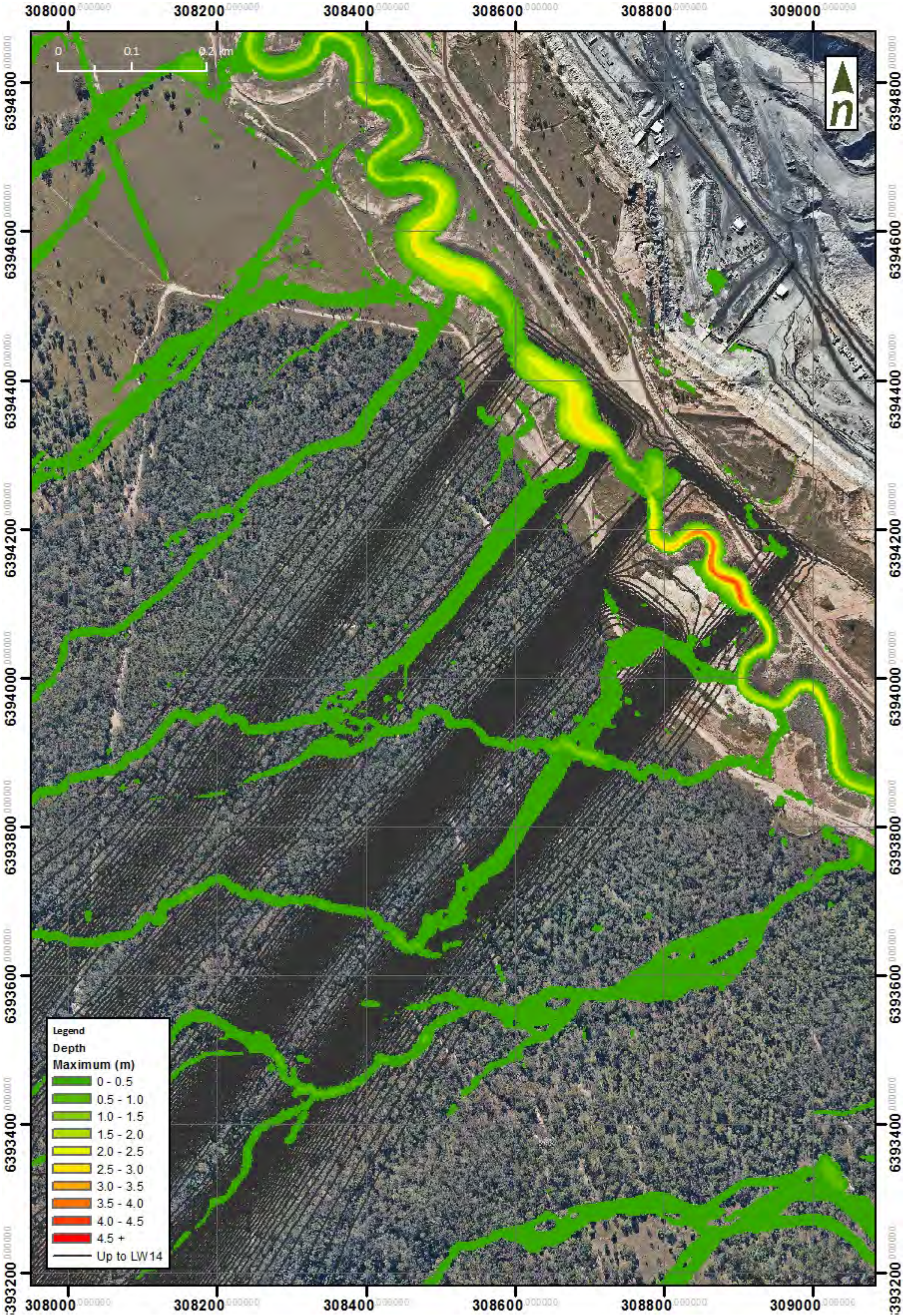


Figure C-6. **2 year ARI flood extents and depth (post LW14)**

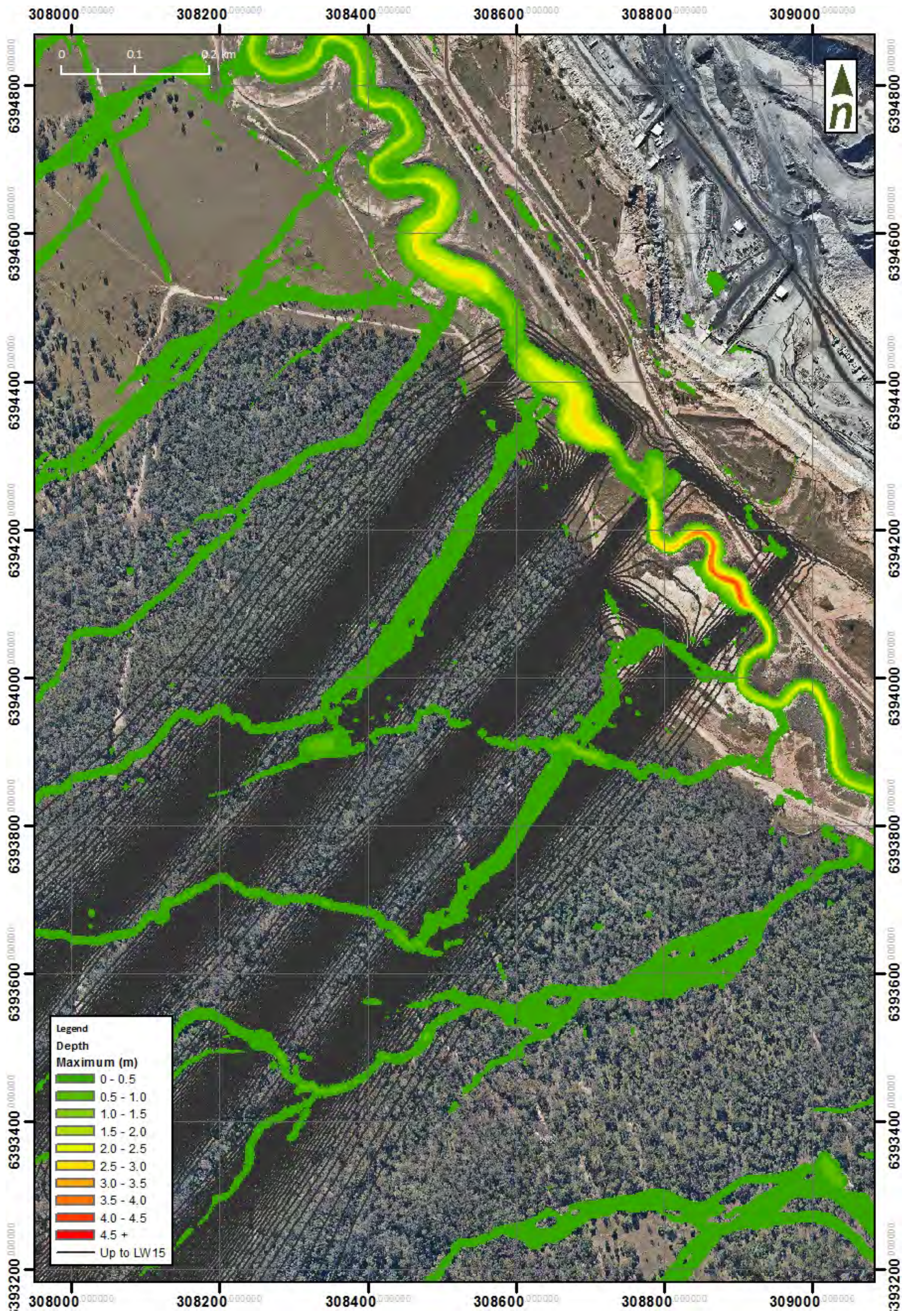


Figure C-7. **2 year ARI flood extents and depth (post LW15)**

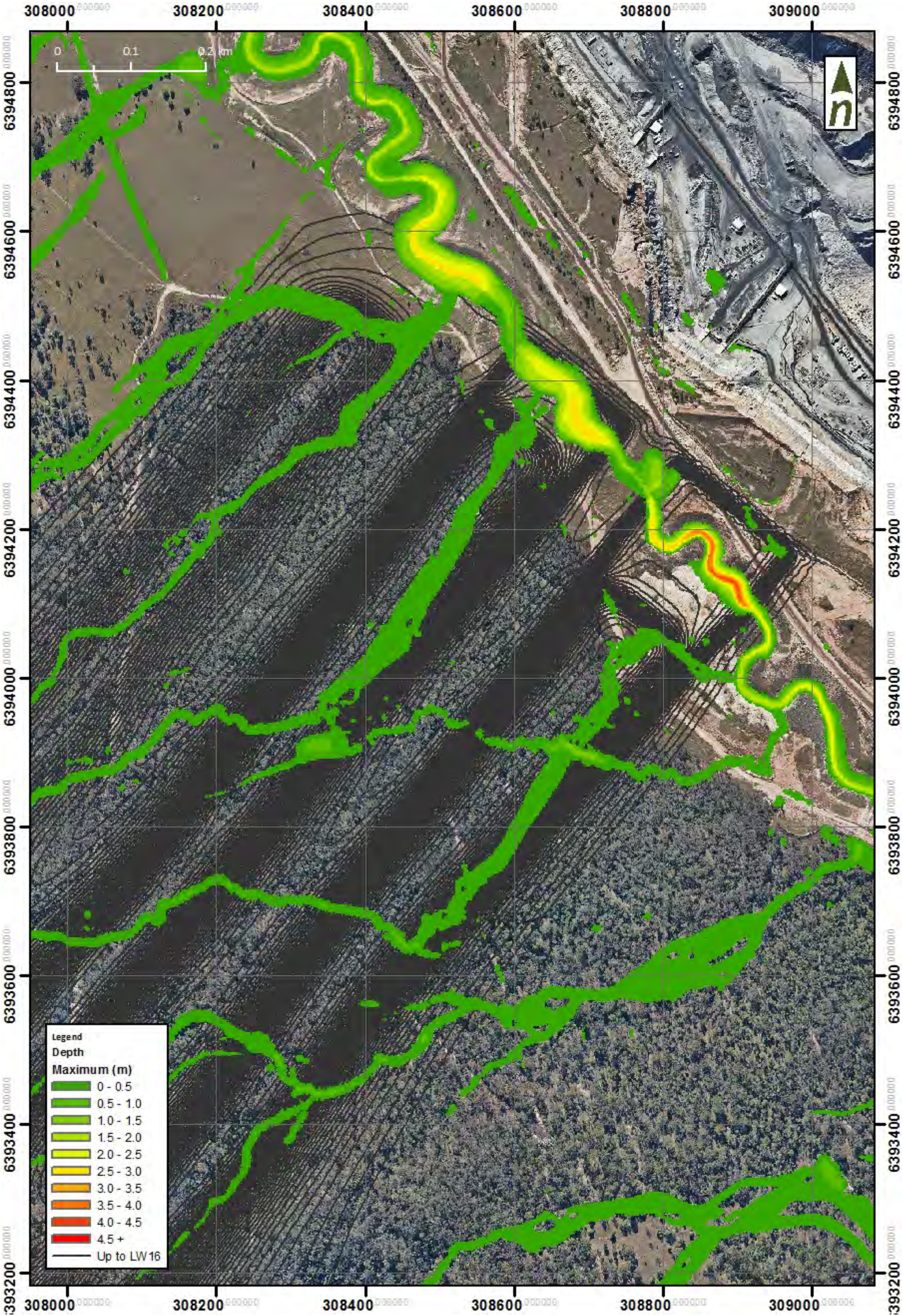


Figure C-8. 2 year ARI flood extents and depth (post LW16)

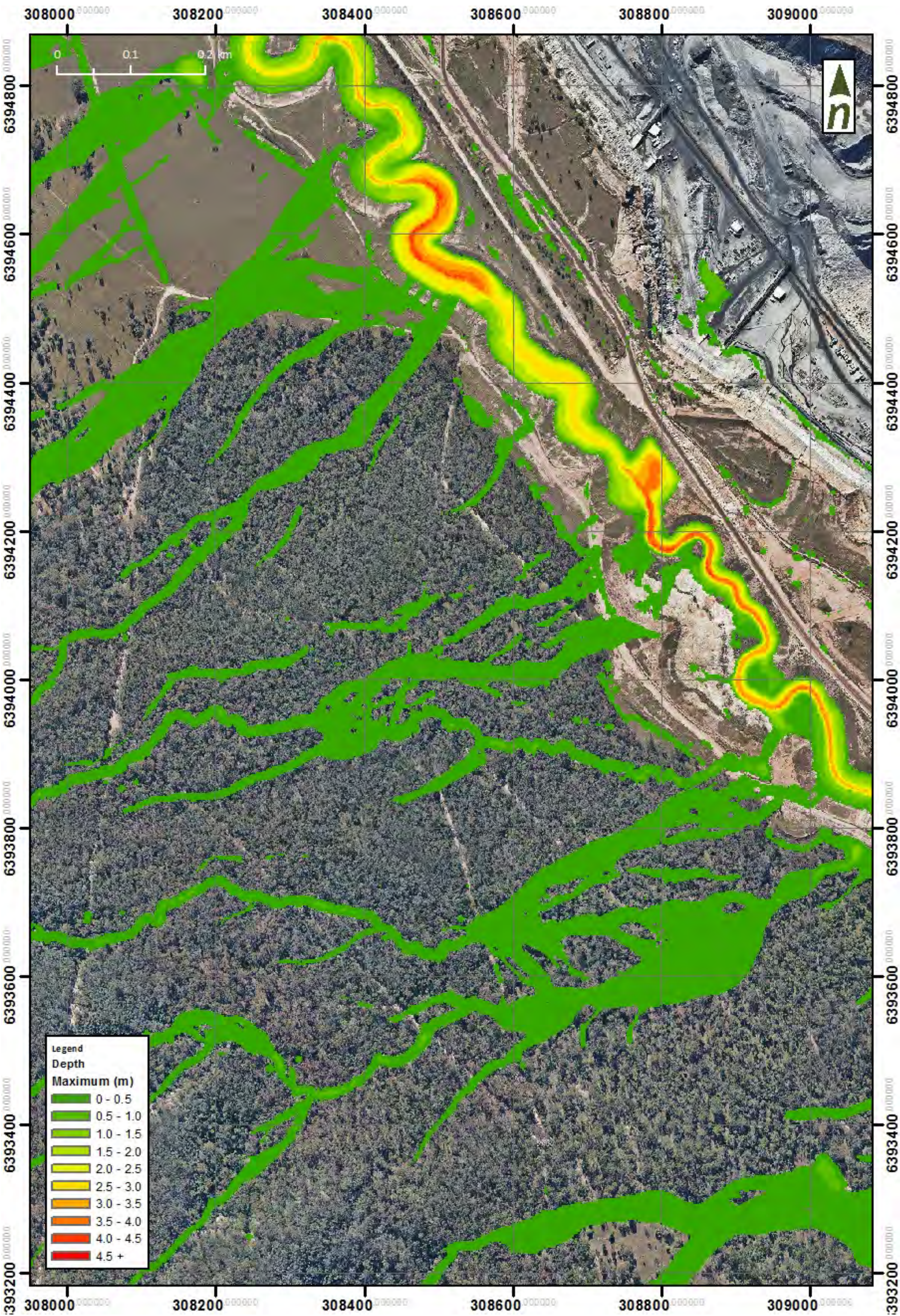


Figure C-9. **50 year ARI flood extents and depth (existing conditions)**

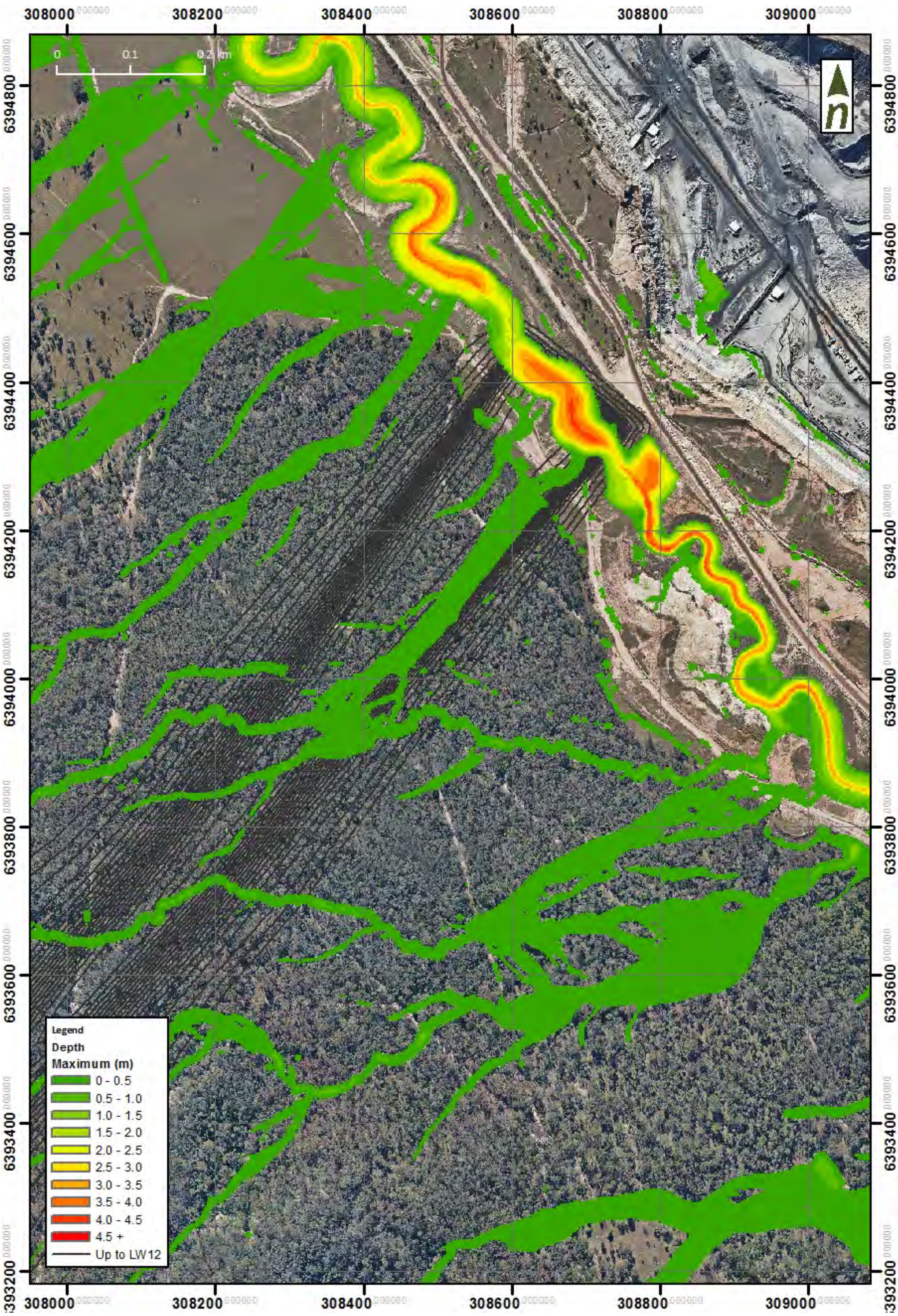


Figure C-10. **50 year ARI flood extents and depth (post LW12)**

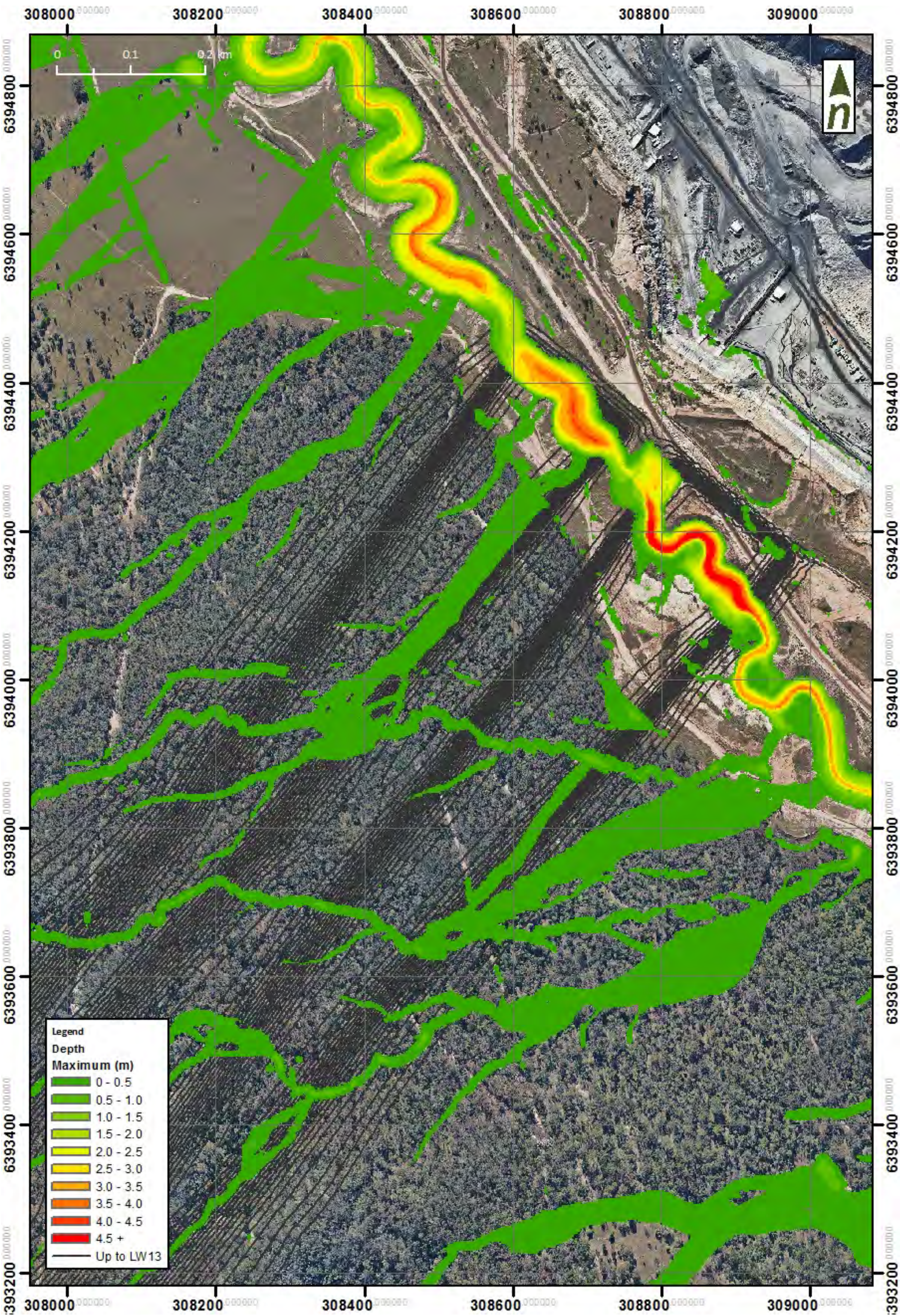


Figure C-11. **50 year ARI flood extents and depth (post LW13)**

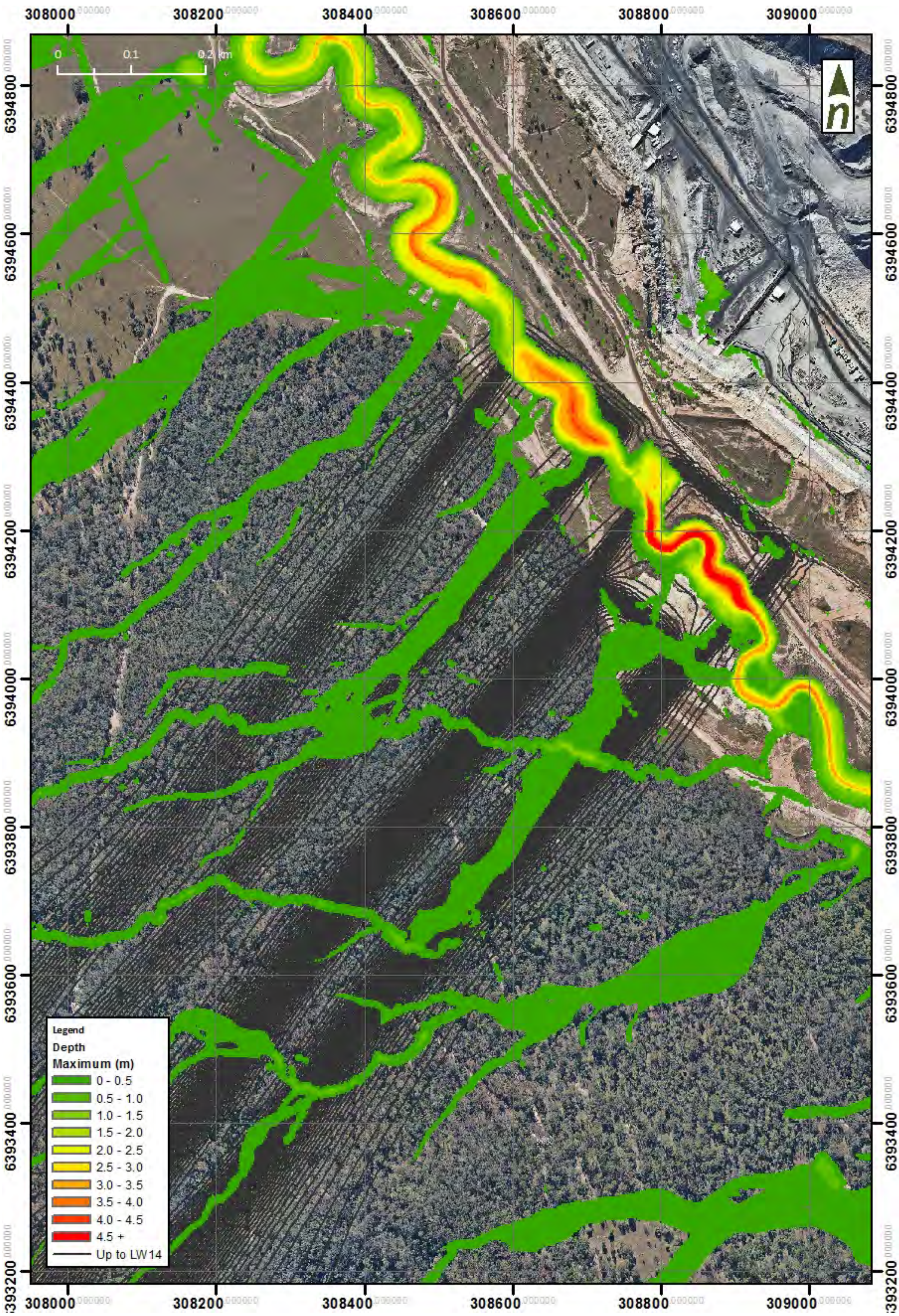


Figure C-12. **50 year ARI flood extents and depth (post LW14)**

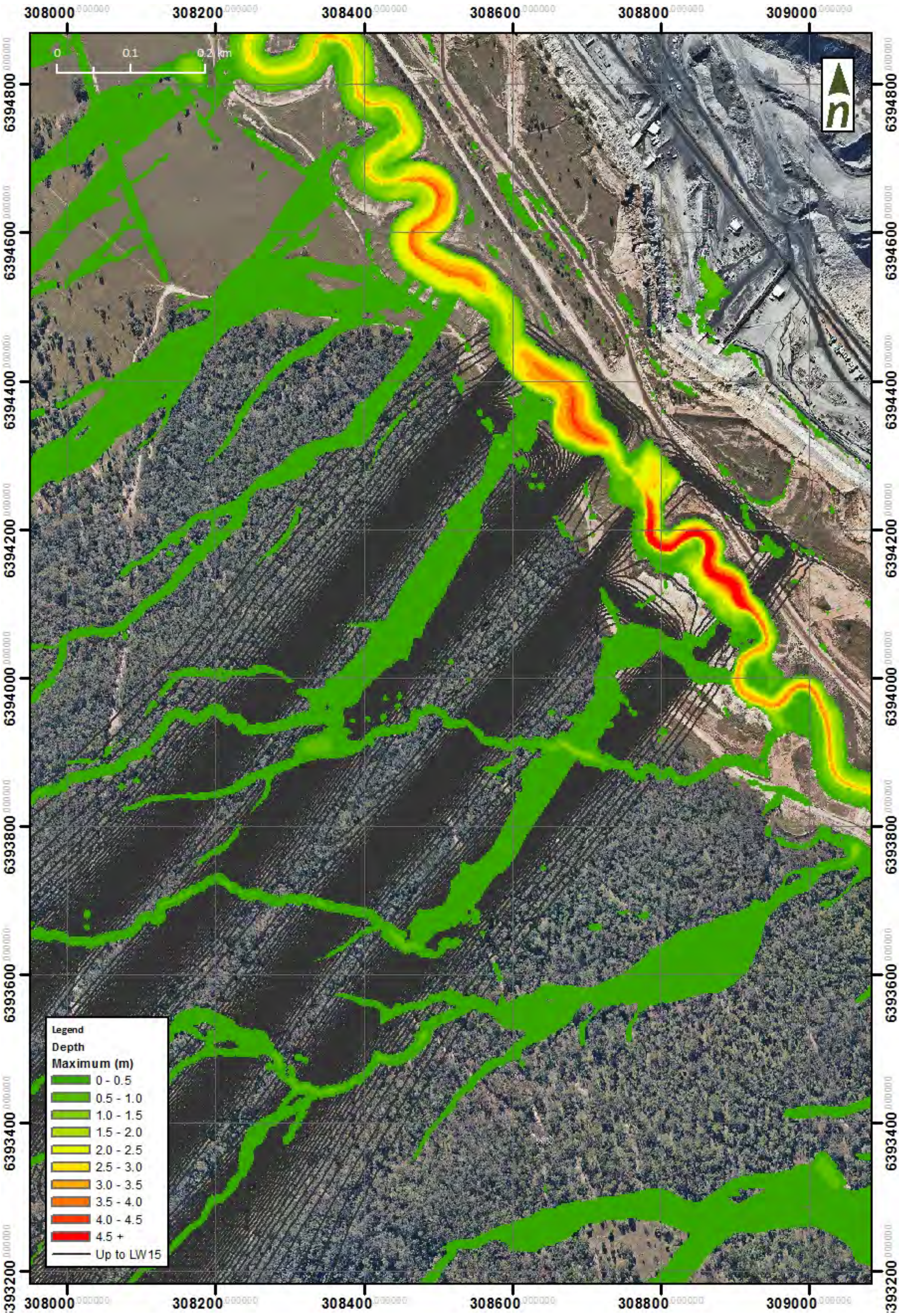


Figure C-13. **50 year ARI flood extents and depth (post LW15)**

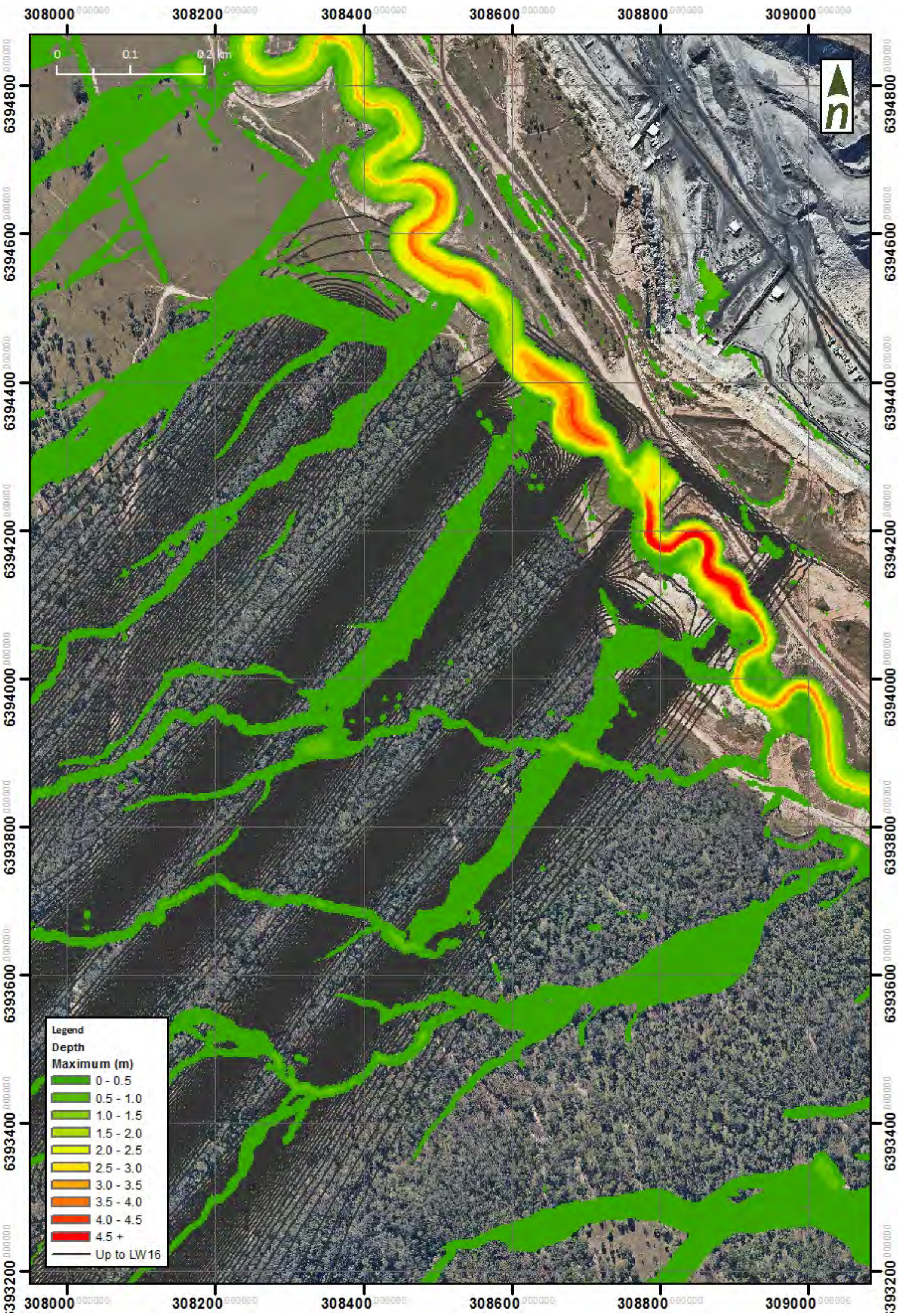


Figure C-14. **50 year ARI flood extents and depth (post LW16)**

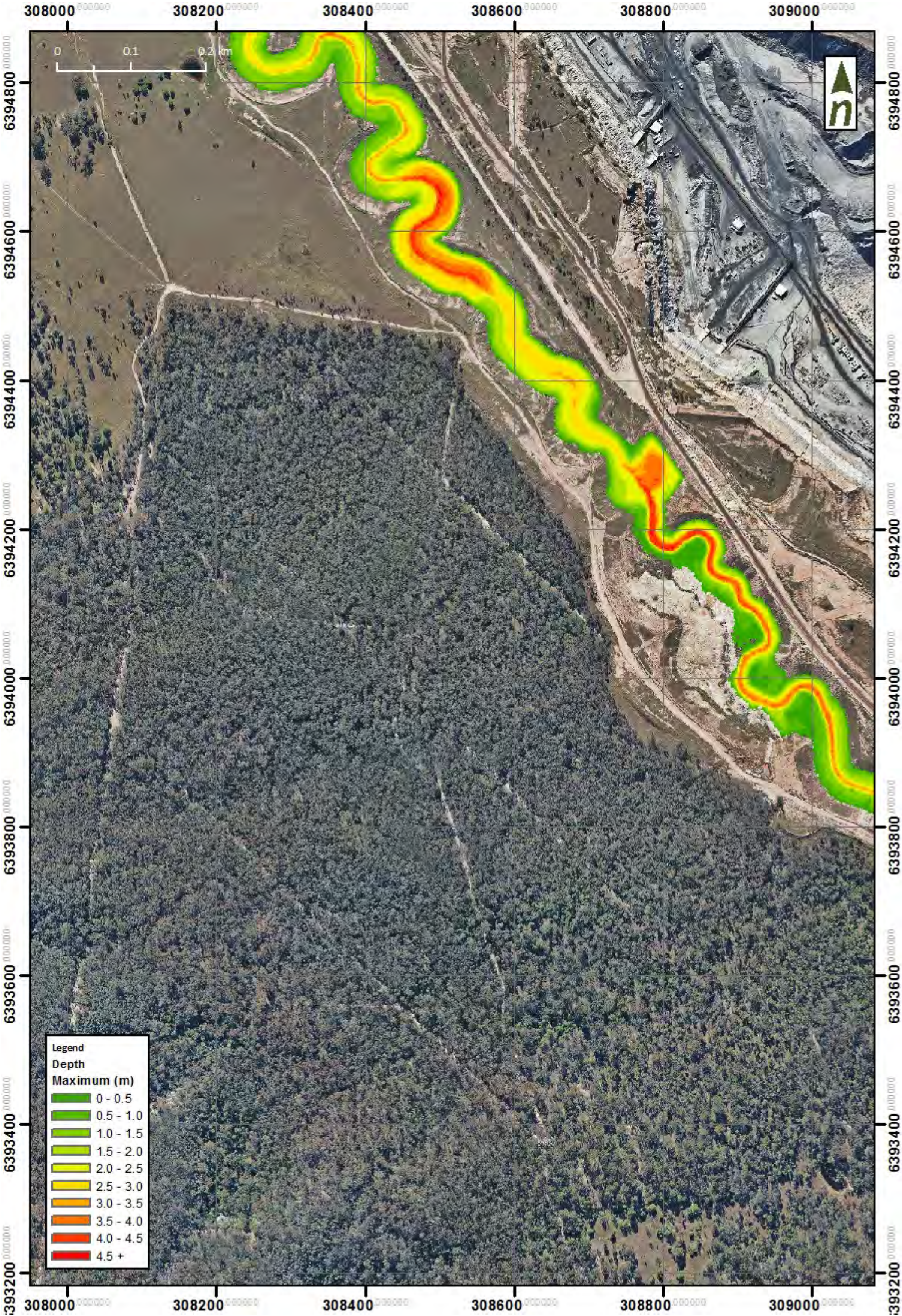


Figure C-15. **100 year ARI flood extents and depth (existing conditions)**

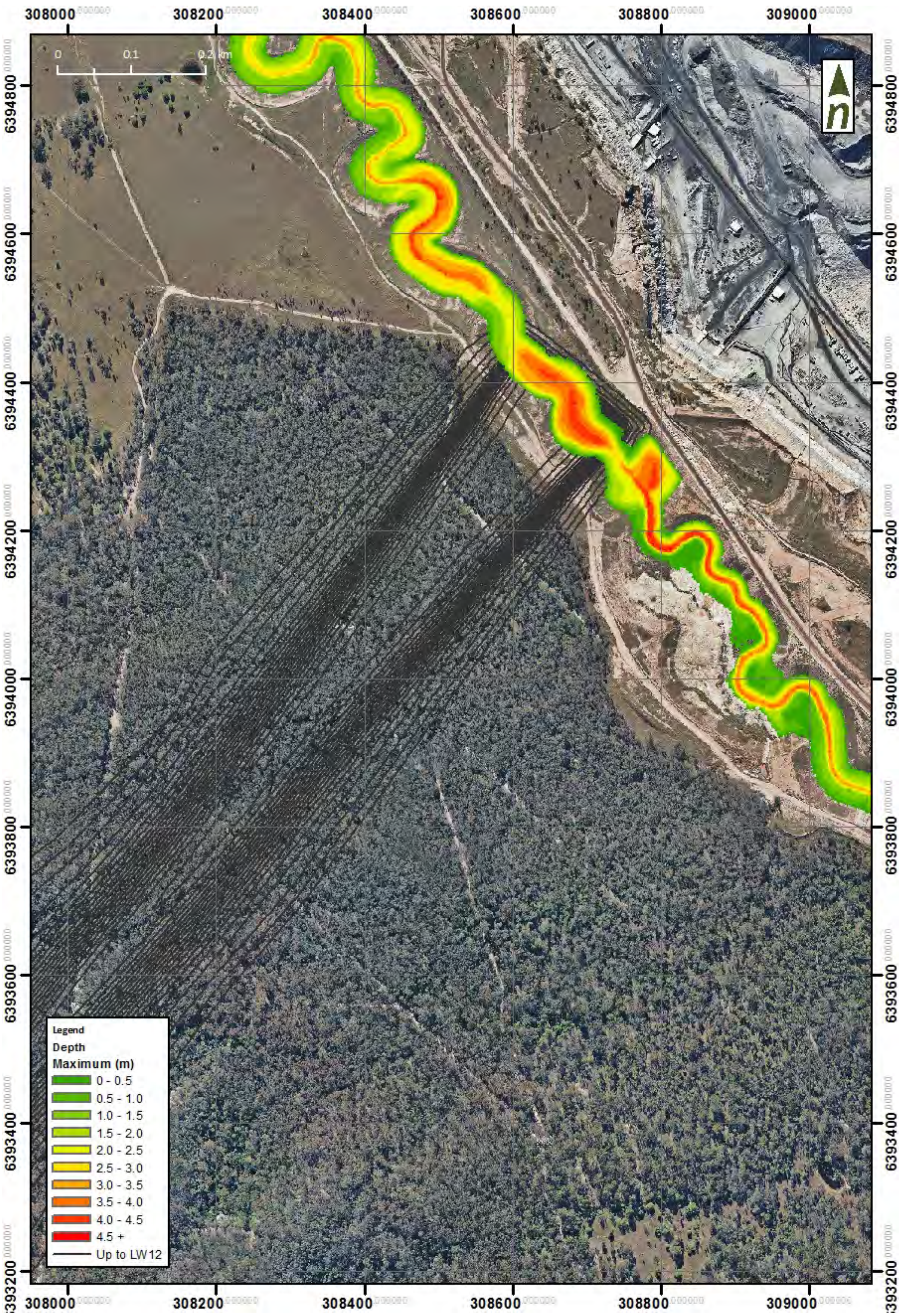


Figure C-16. 100 year ARI flood extents and depth (post LW12)

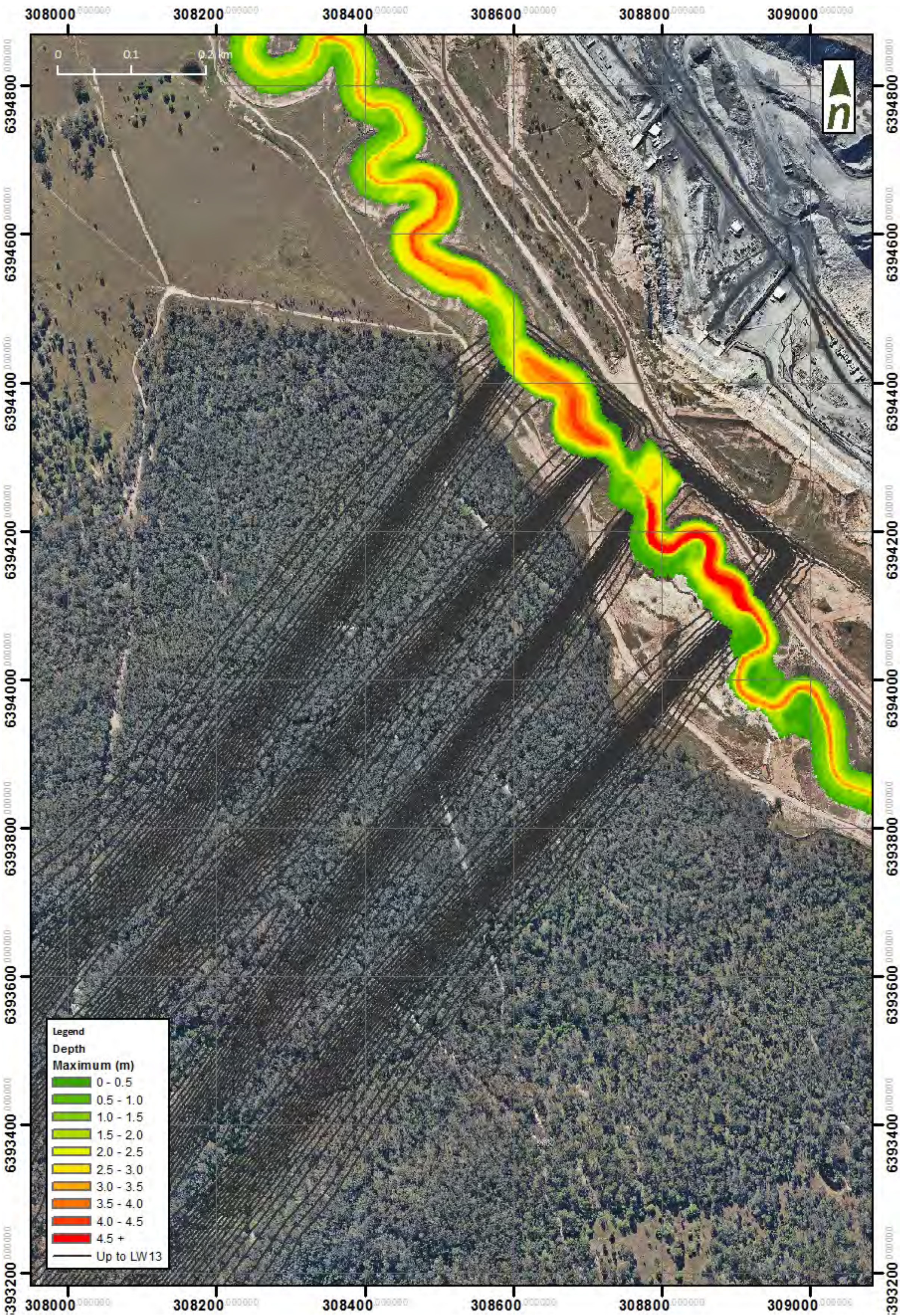


Figure C-17. **100 year ARI flood extents and depth (post LW13)**

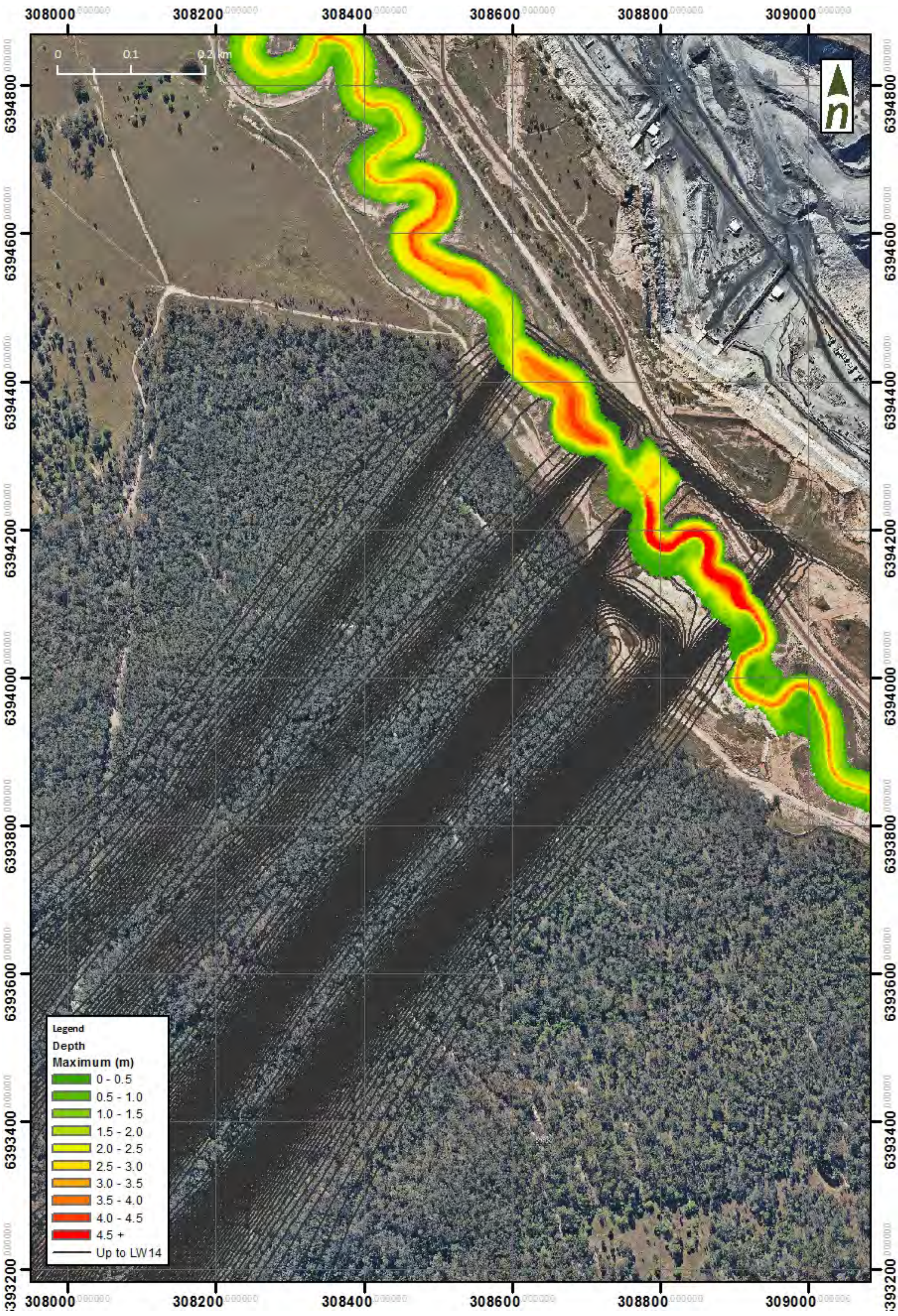


Figure C-18. **100 year ARI flood extents and depth (post LW14)**

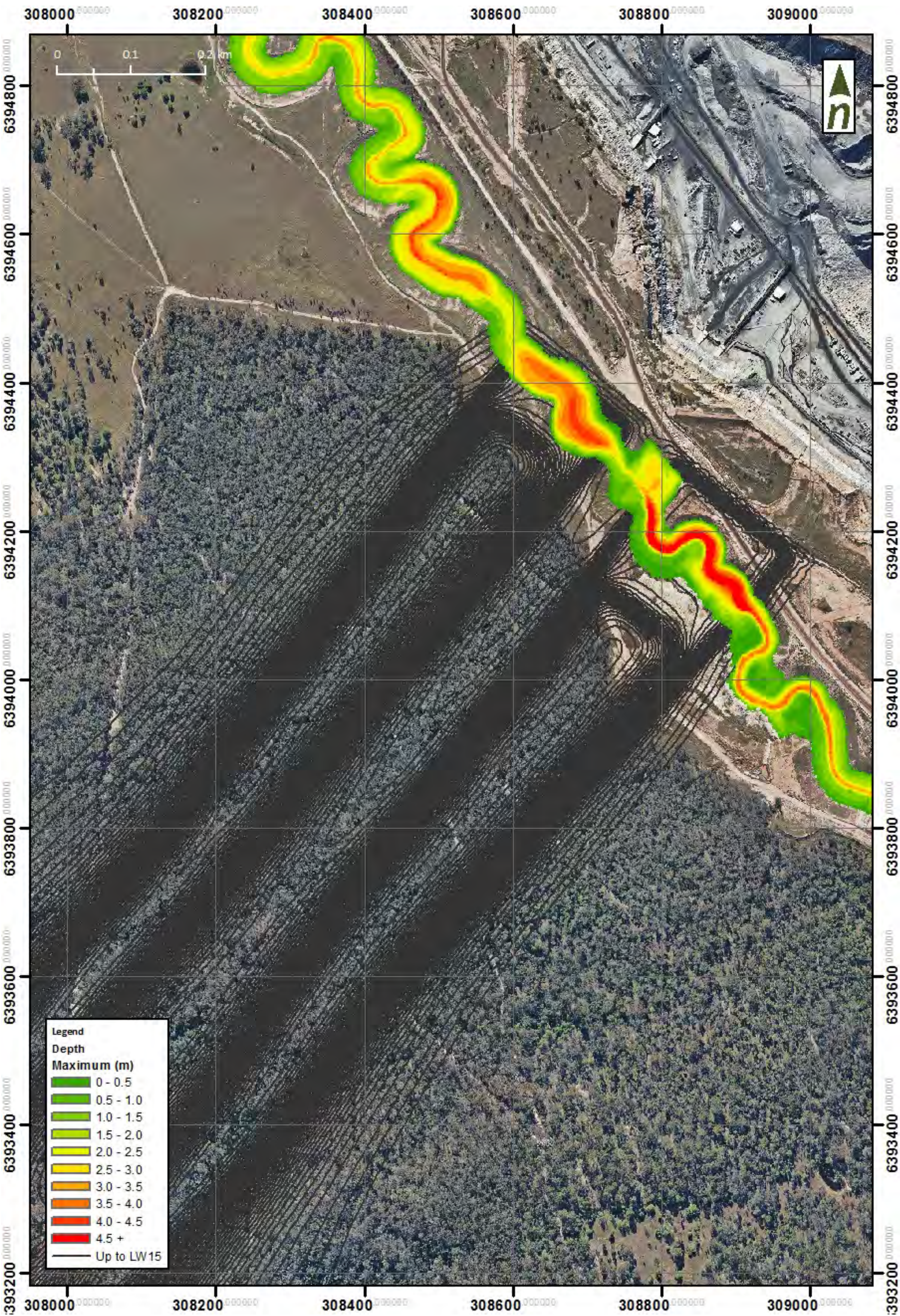


Figure C-19. **100 year ARI flood extents and depth (post LW15)**

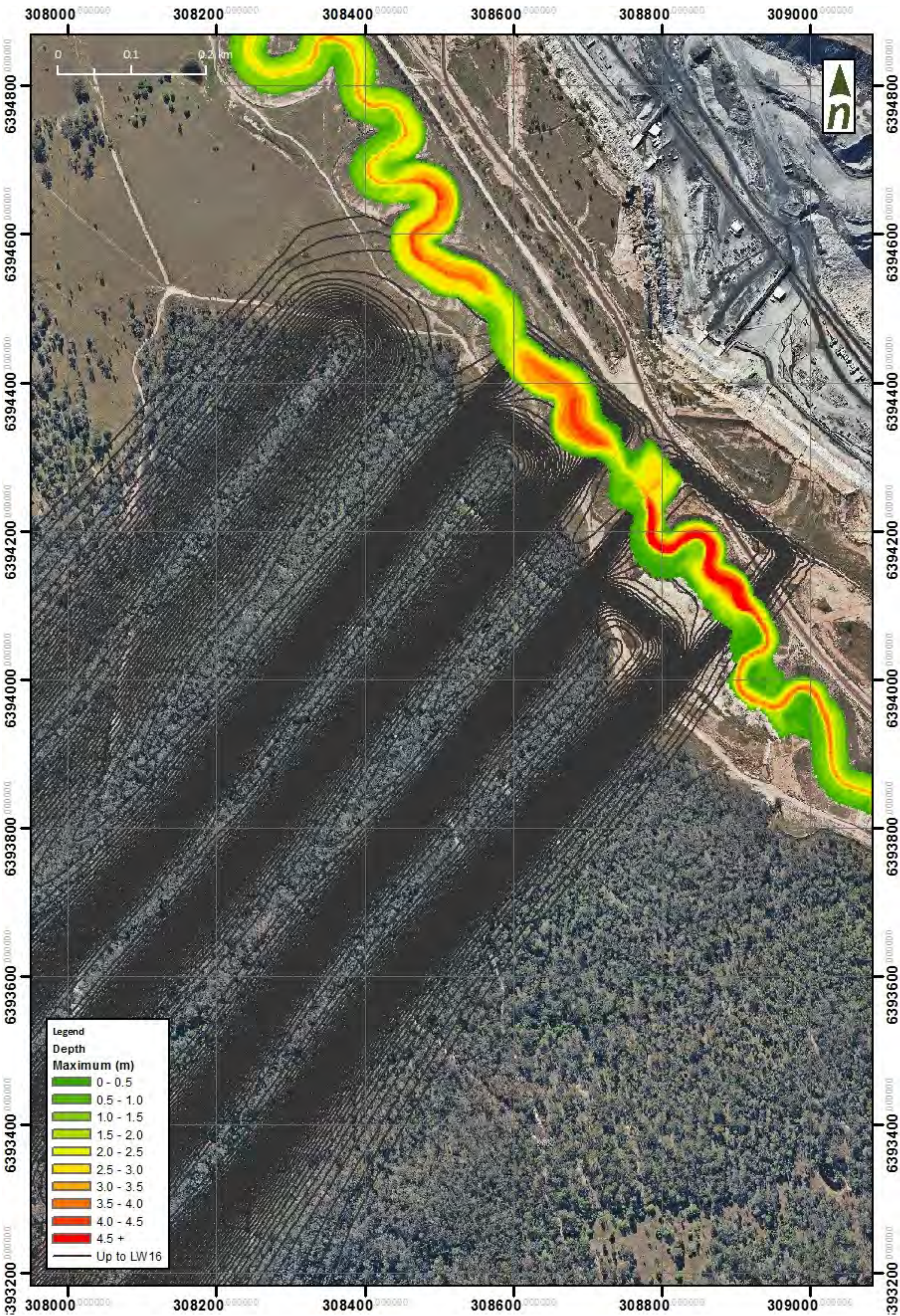


Figure C-20. **100 year ARI flood extents and depth (post LW16)**

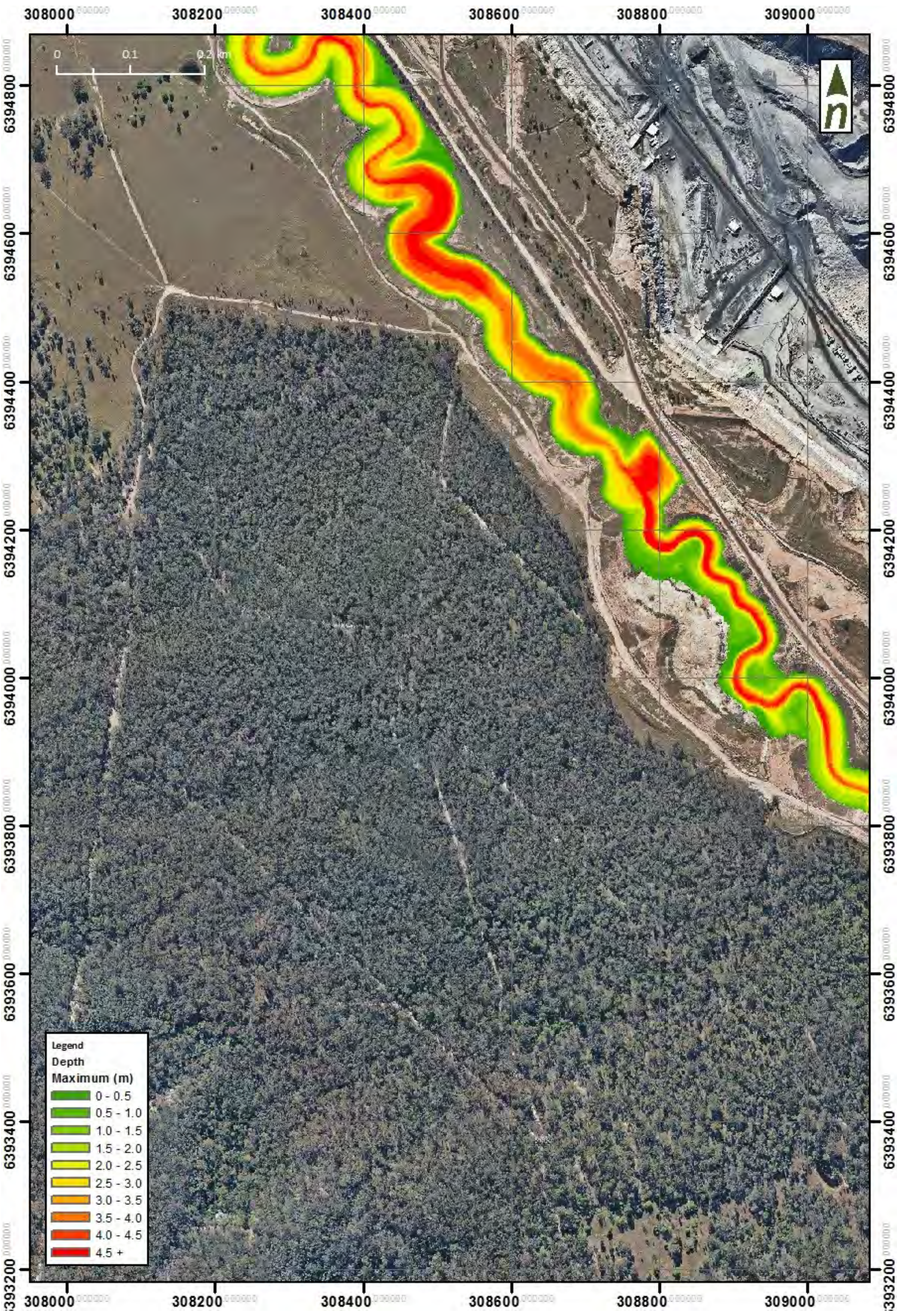


Figure C-21. 1000 year ARI flood extents and depth (existing conditions)

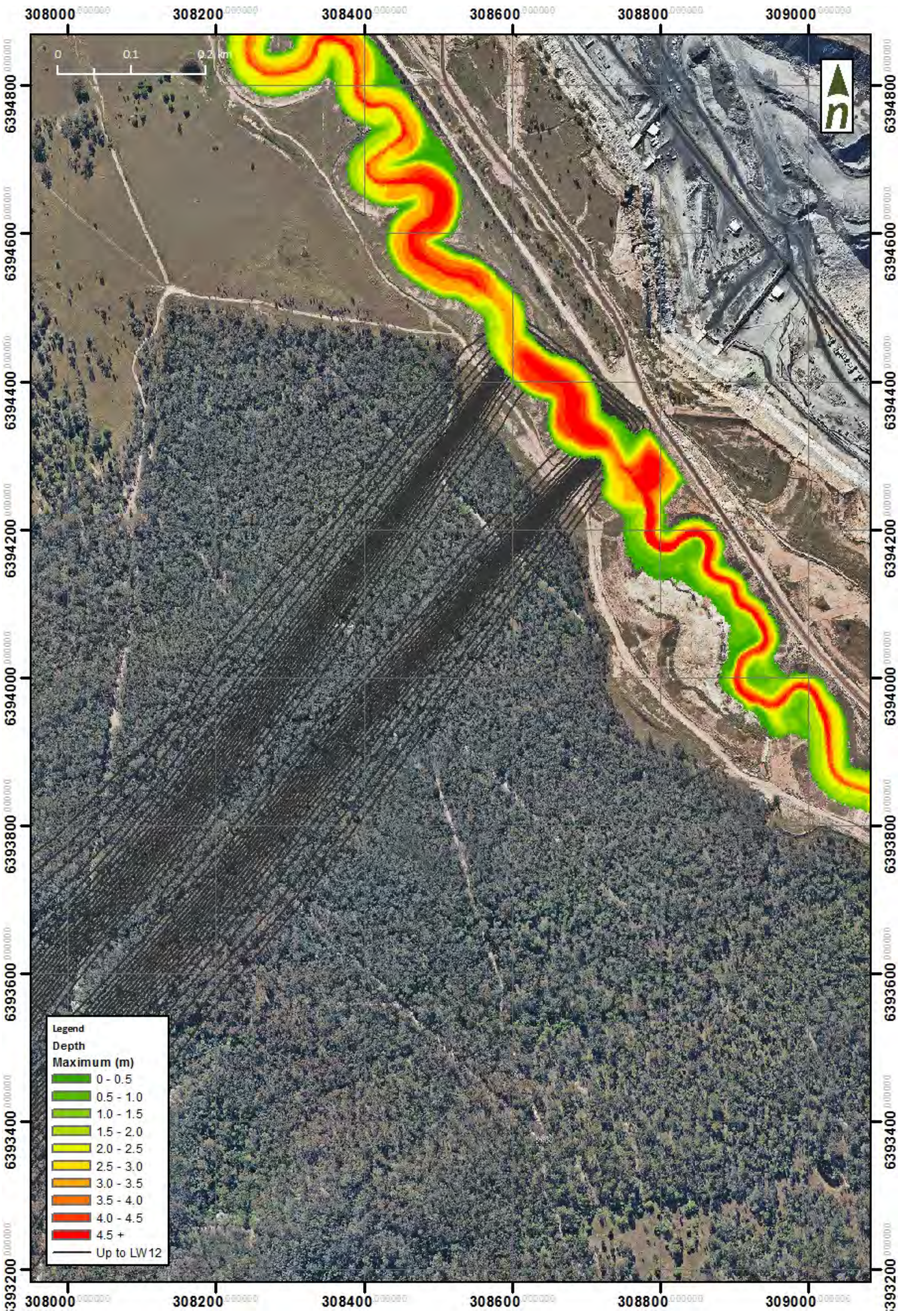


Figure C-22. **1000 year ARI flood extents and depth (post LW12)**

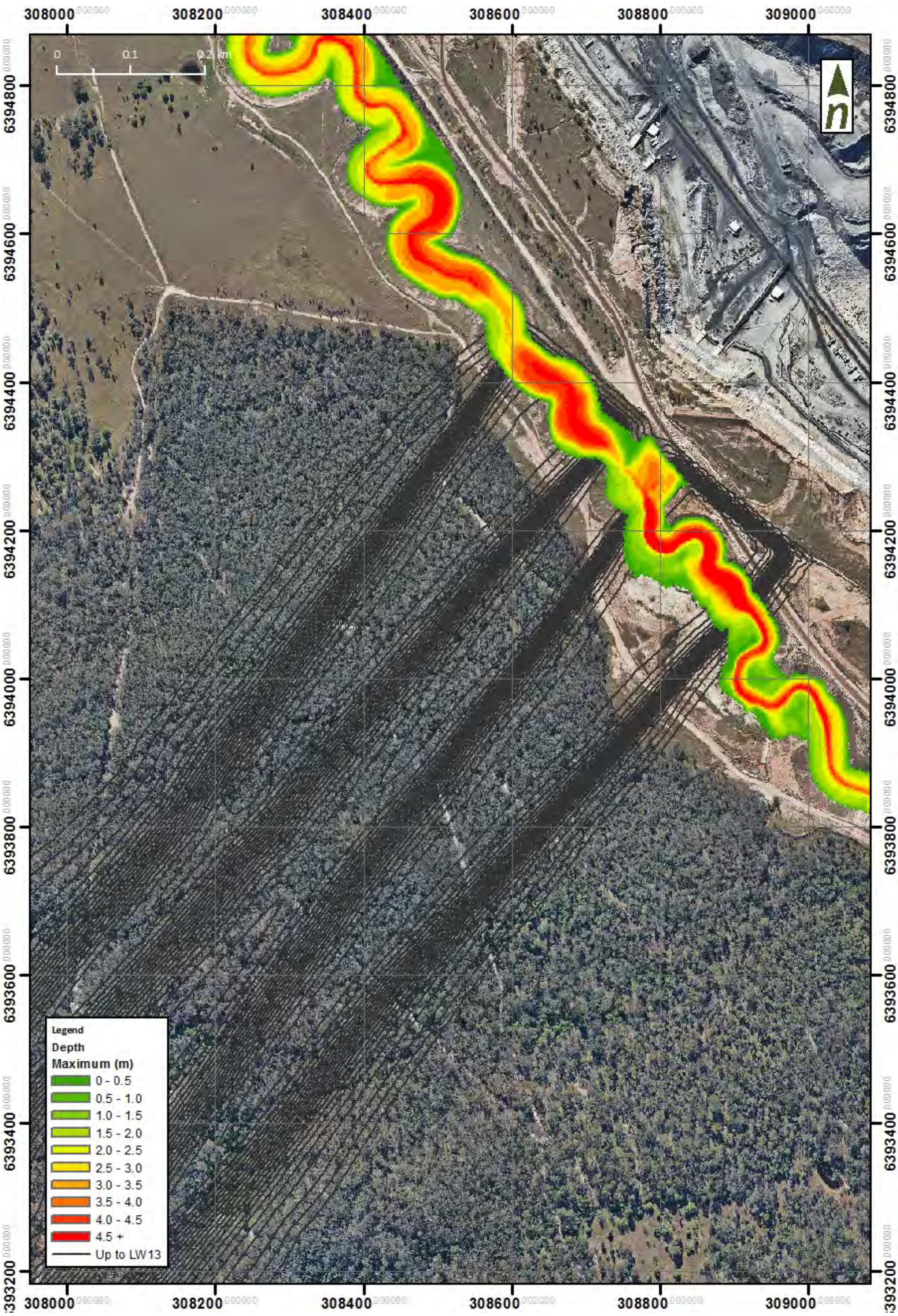


Figure C-23. **1000 year ARI flood extents and depth (post LW13)**

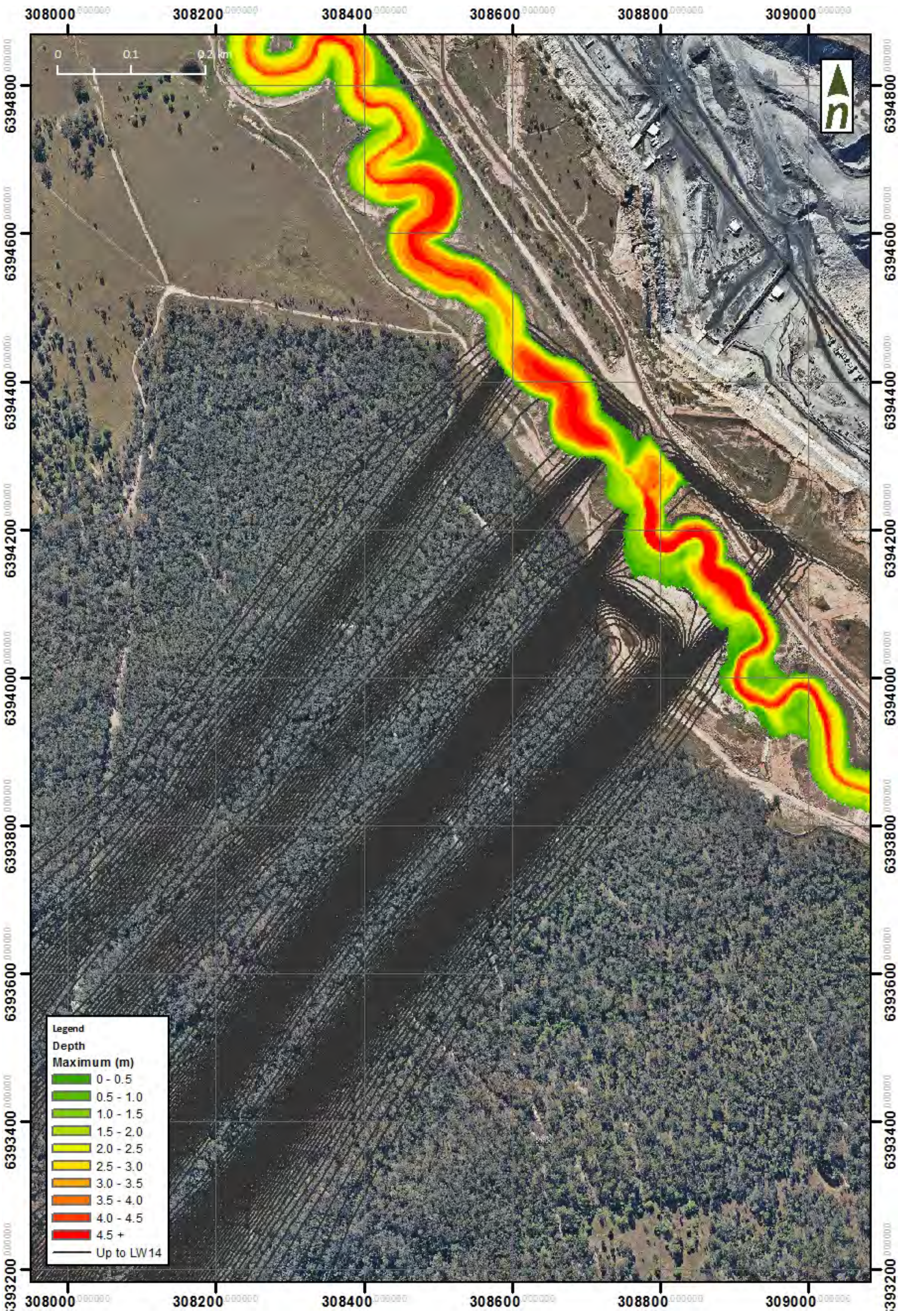


Figure C-24. **1000 year ARI flood extents and depth (post LW14)**

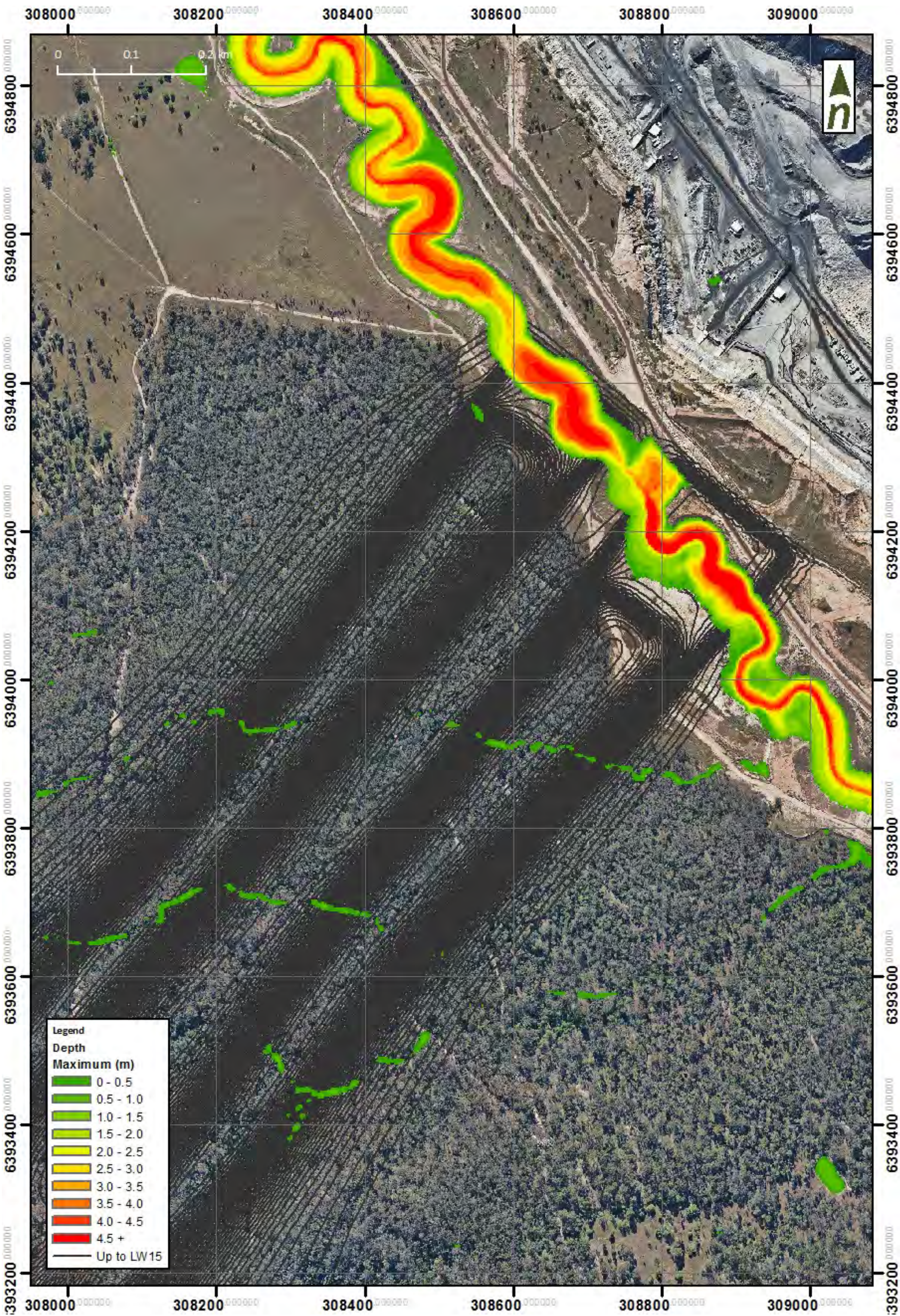


Figure C-25. **1000 year ARI flood extents and depth (post LW15)**

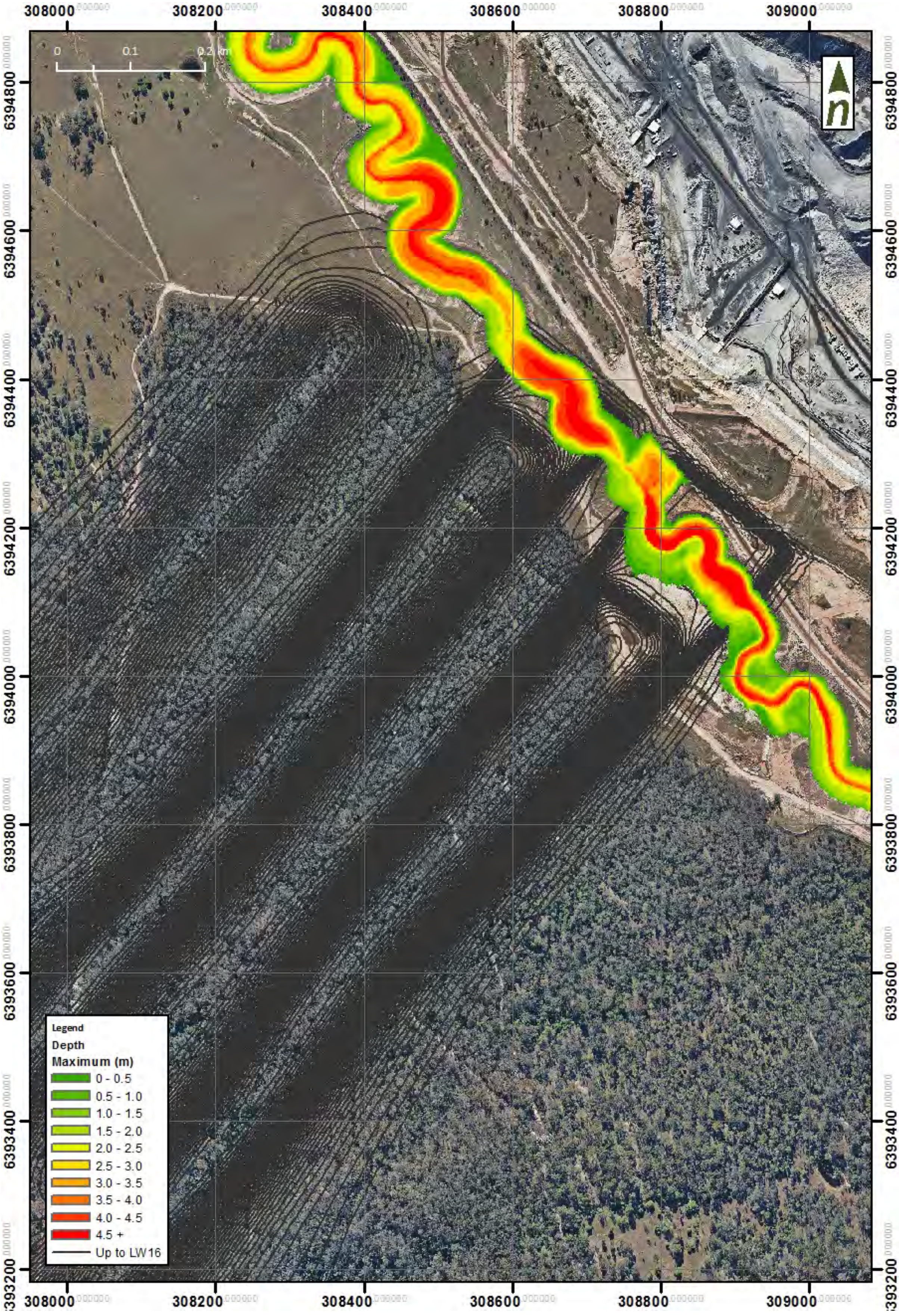


Figure C-26. **1000 year ARI flood extents and depth (post LW16)**

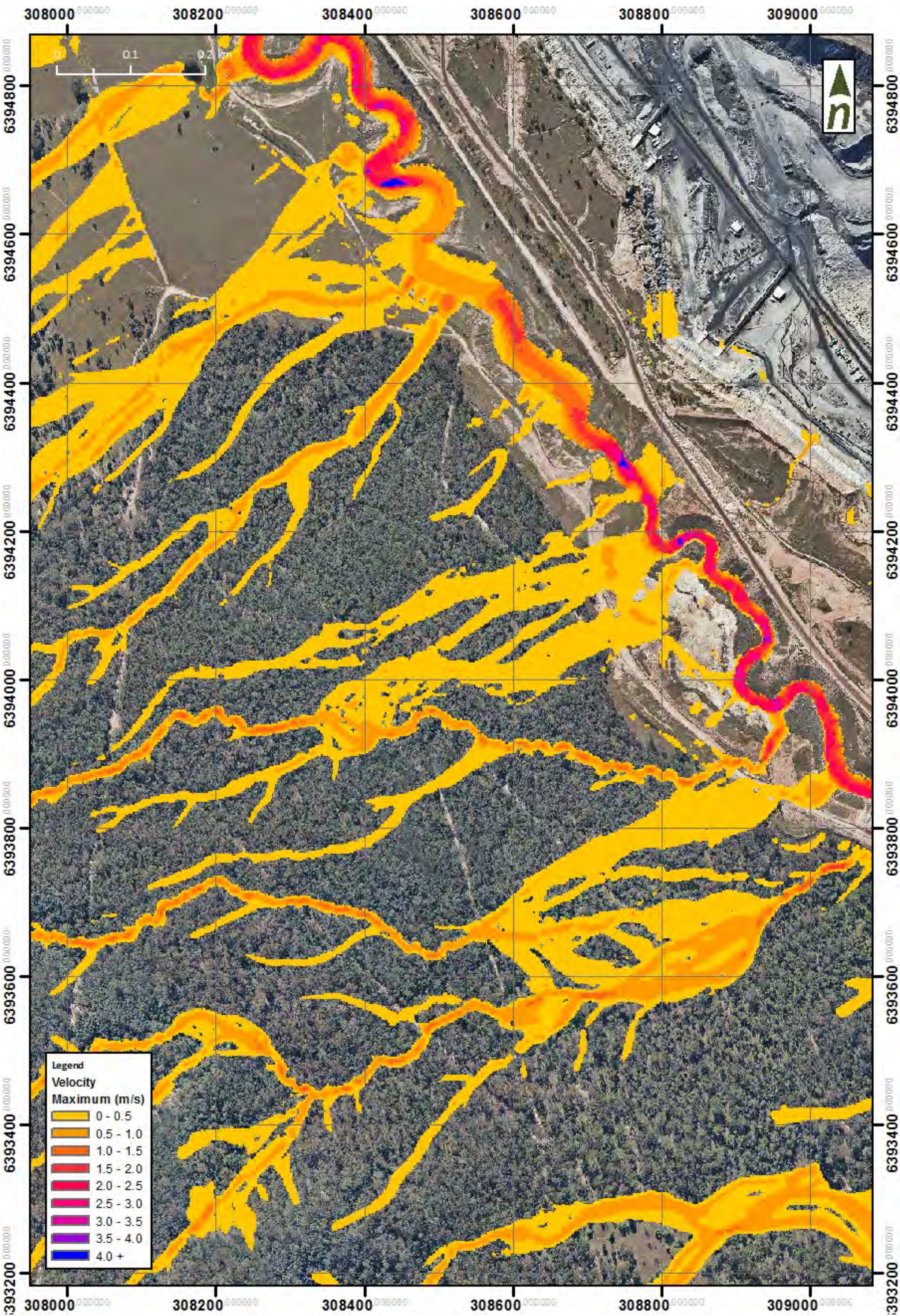


Figure C-27. **2 year ARI flood velocities (existing conditions)**

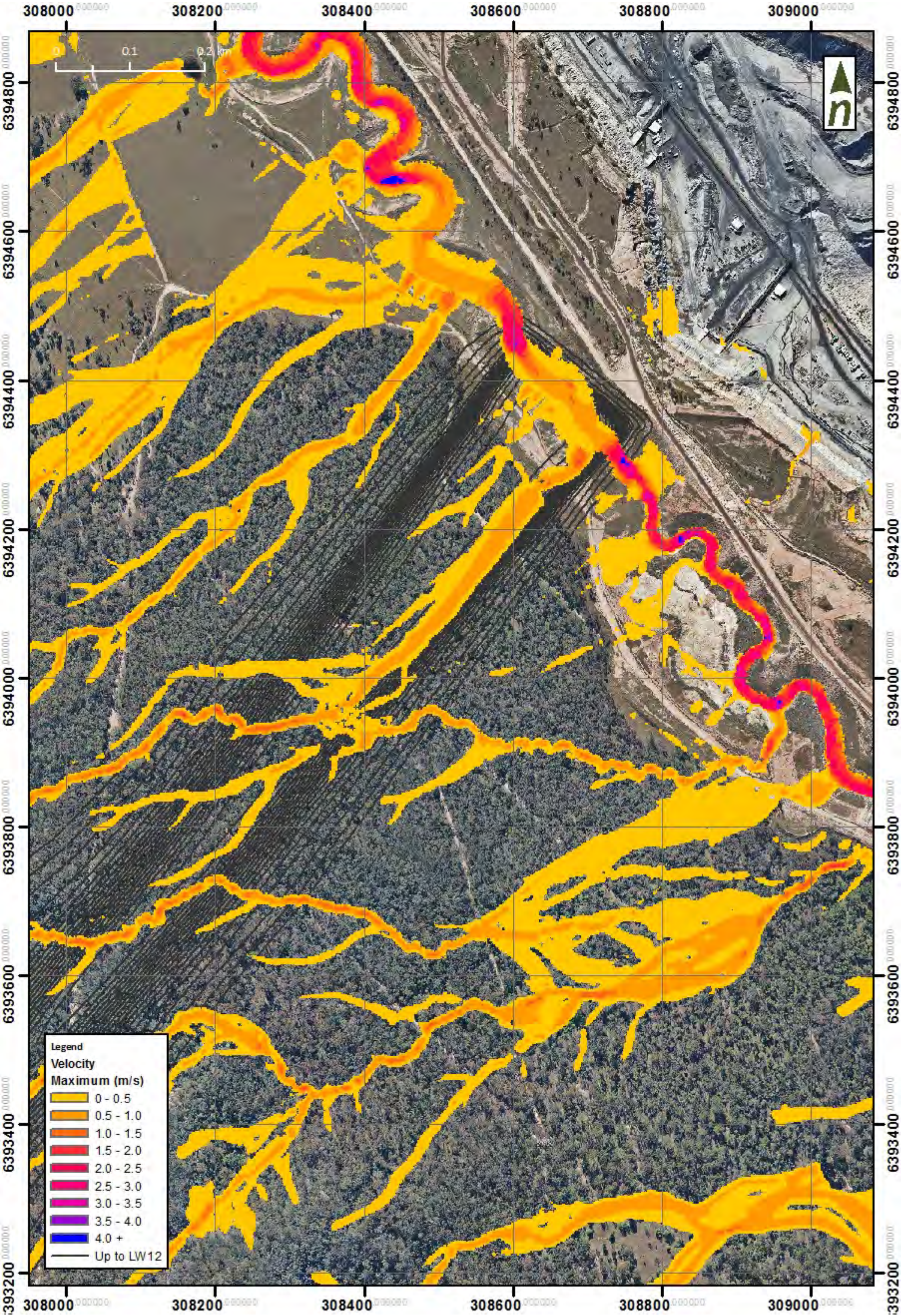


Figure C-28. 2 year ARI flood velocities (post LW12)

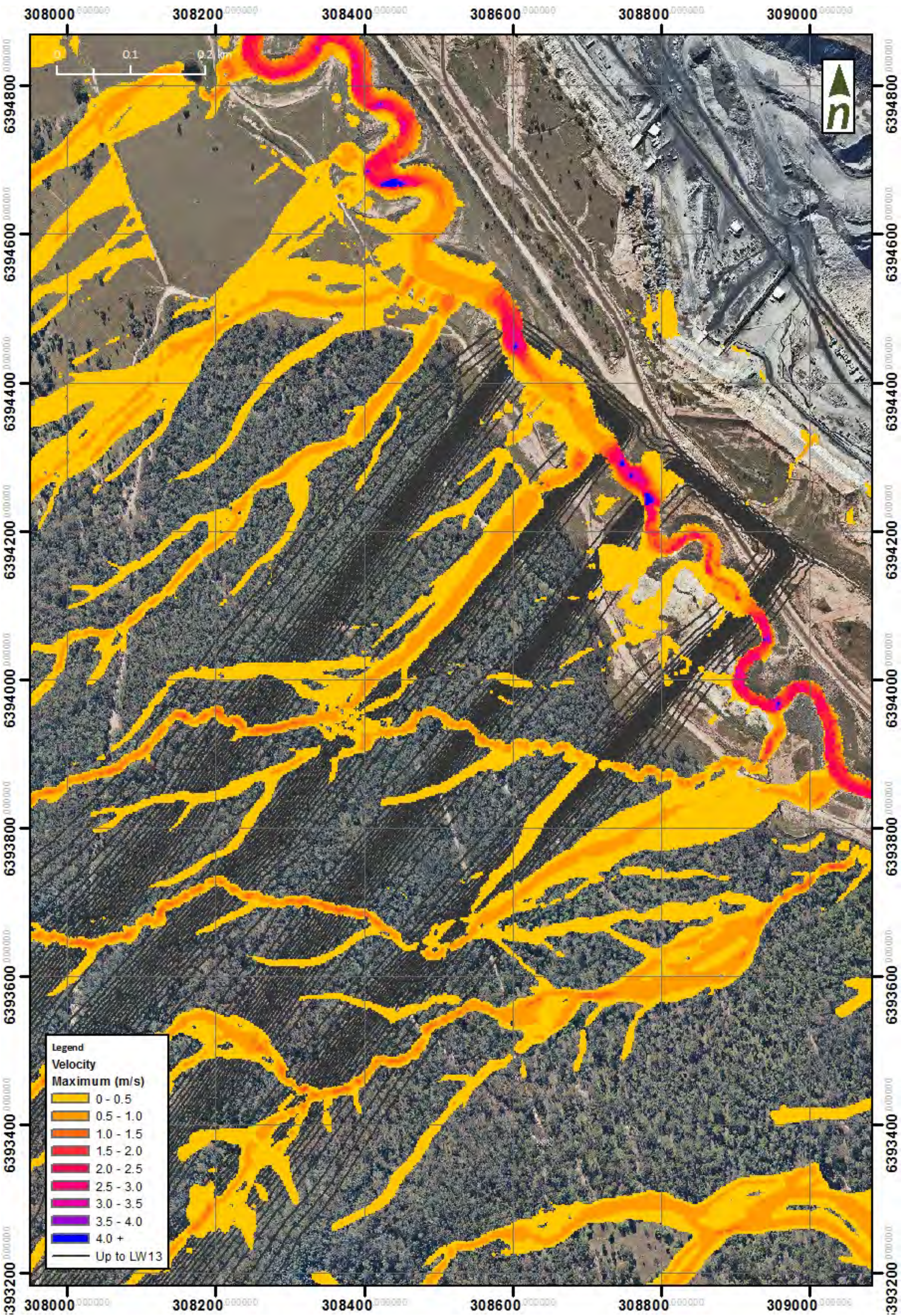


Figure C-29. **2 year ARI flood velocities (post LW13)**

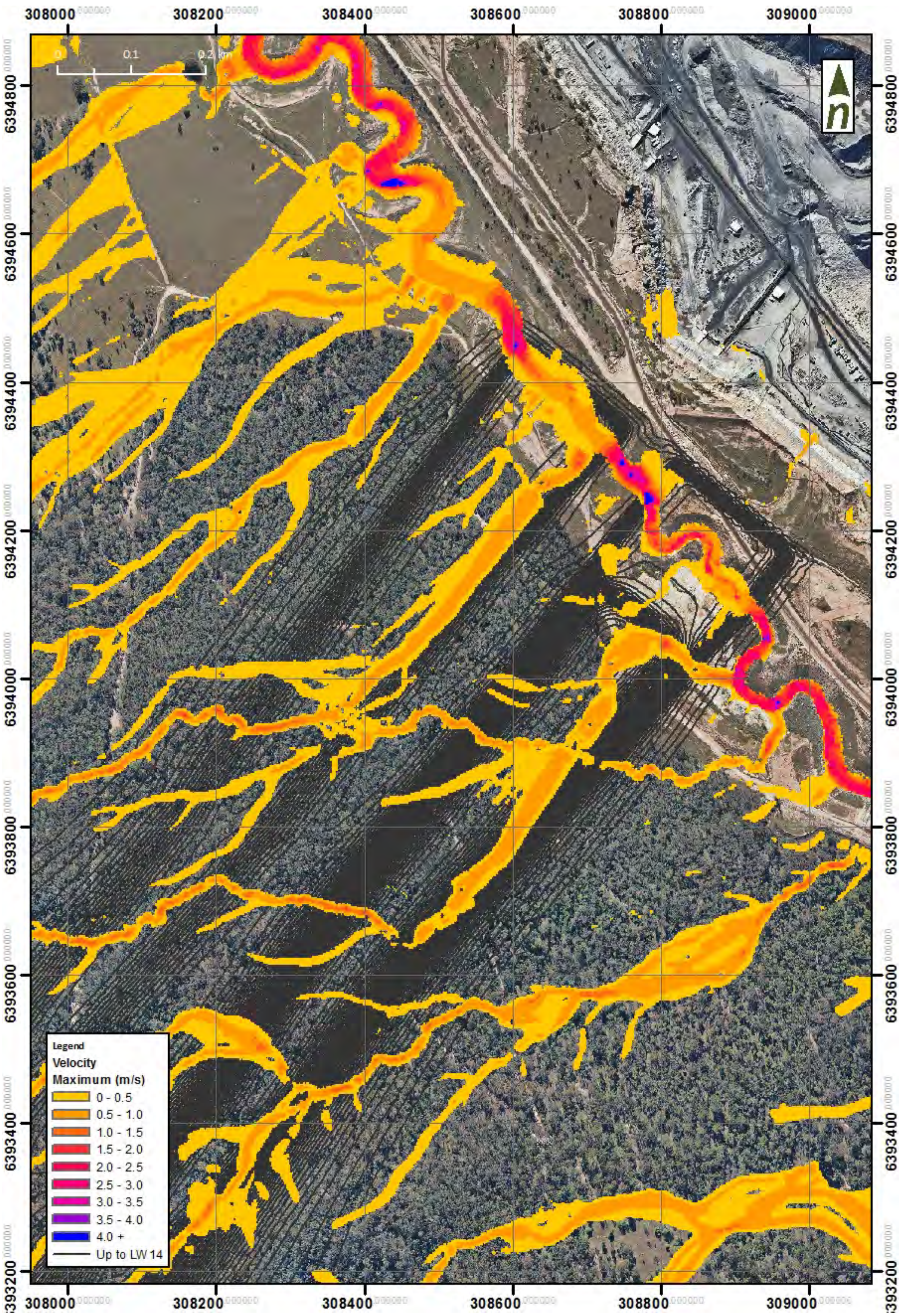


Figure C-30. **2 year ARI flood velocities (post LW14)**

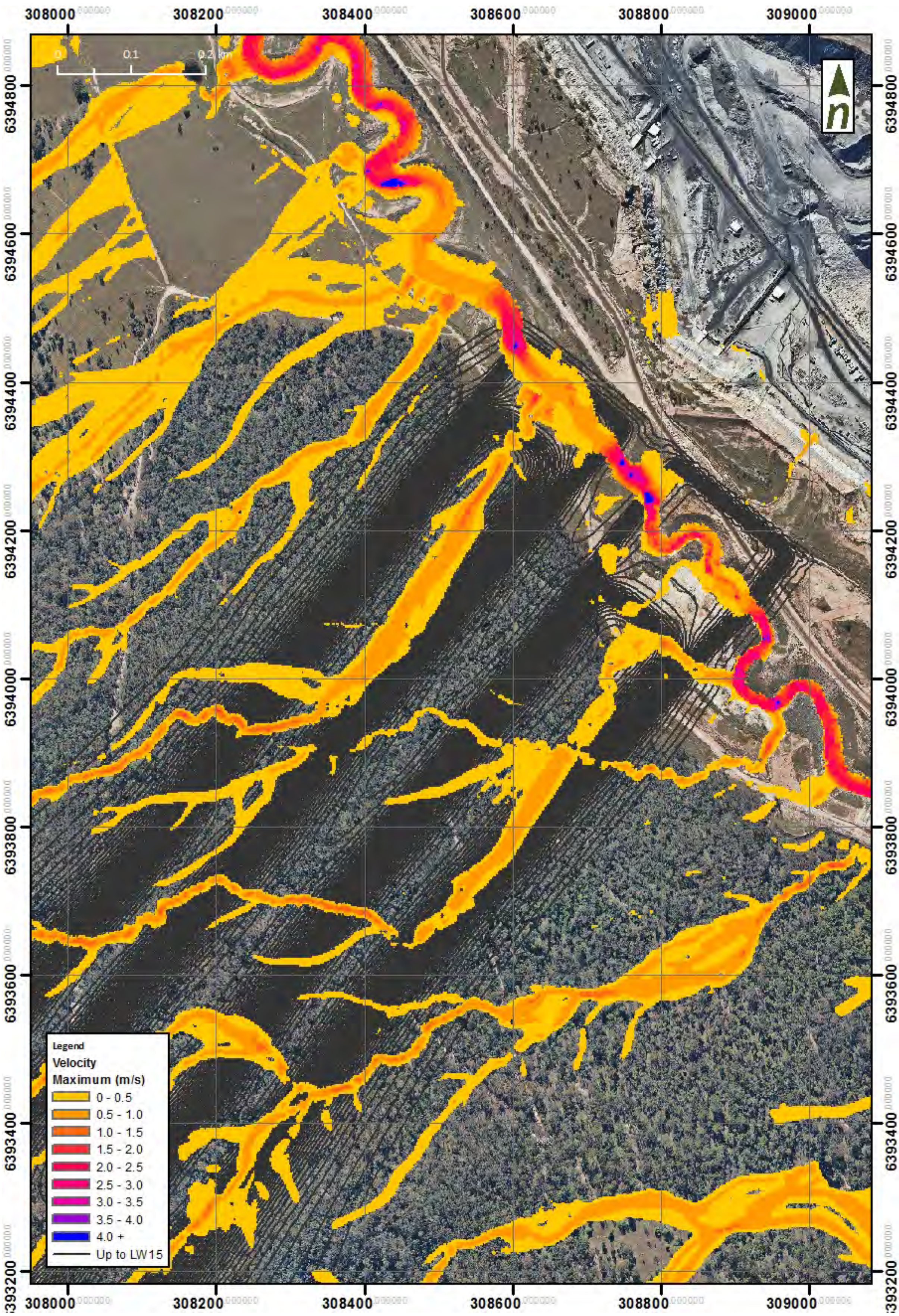


Figure C-31. **2 year ARI flood velocities (post LW15)**

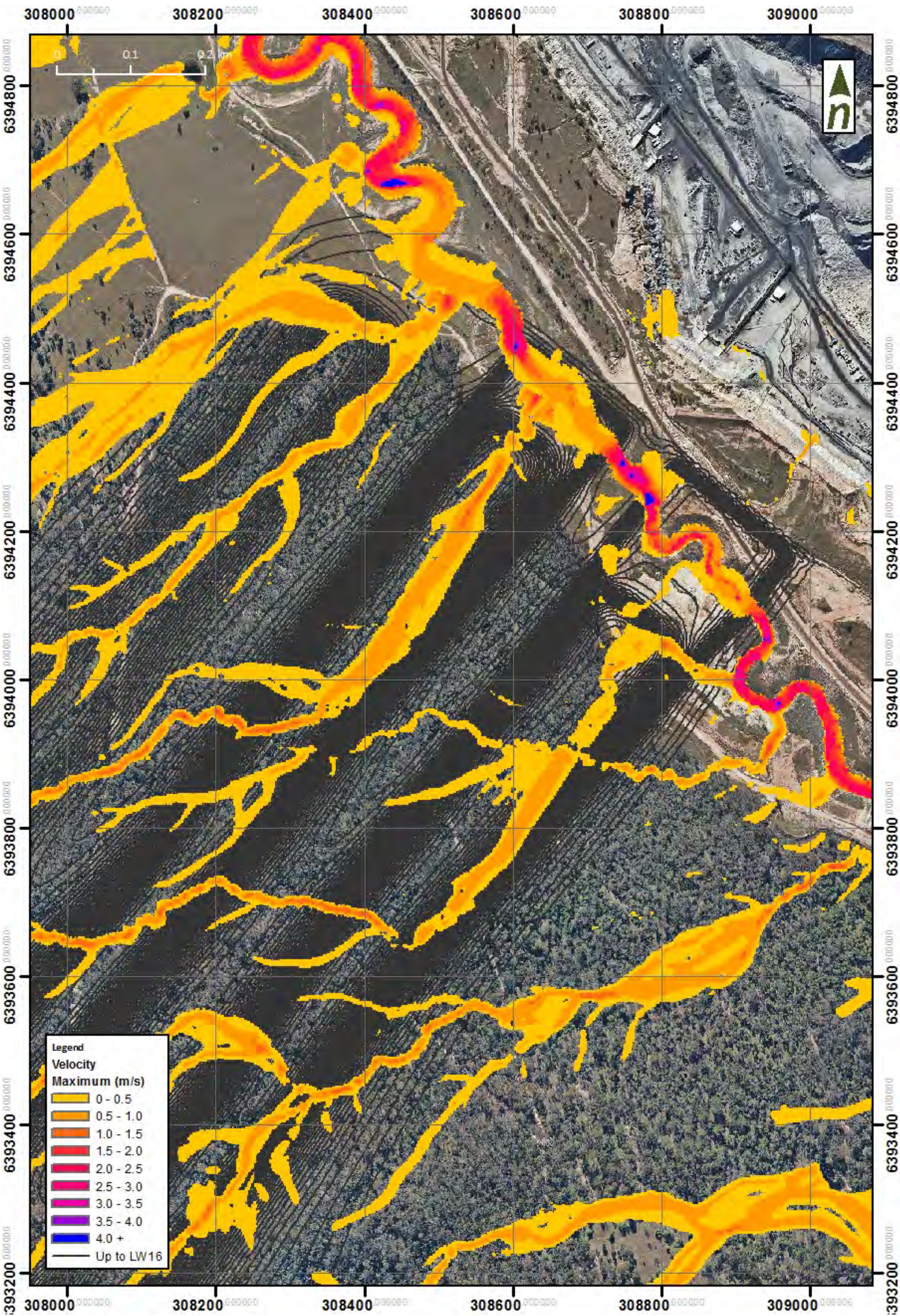


Figure C-32. **2 year ARI flood velocities (post LW16)**

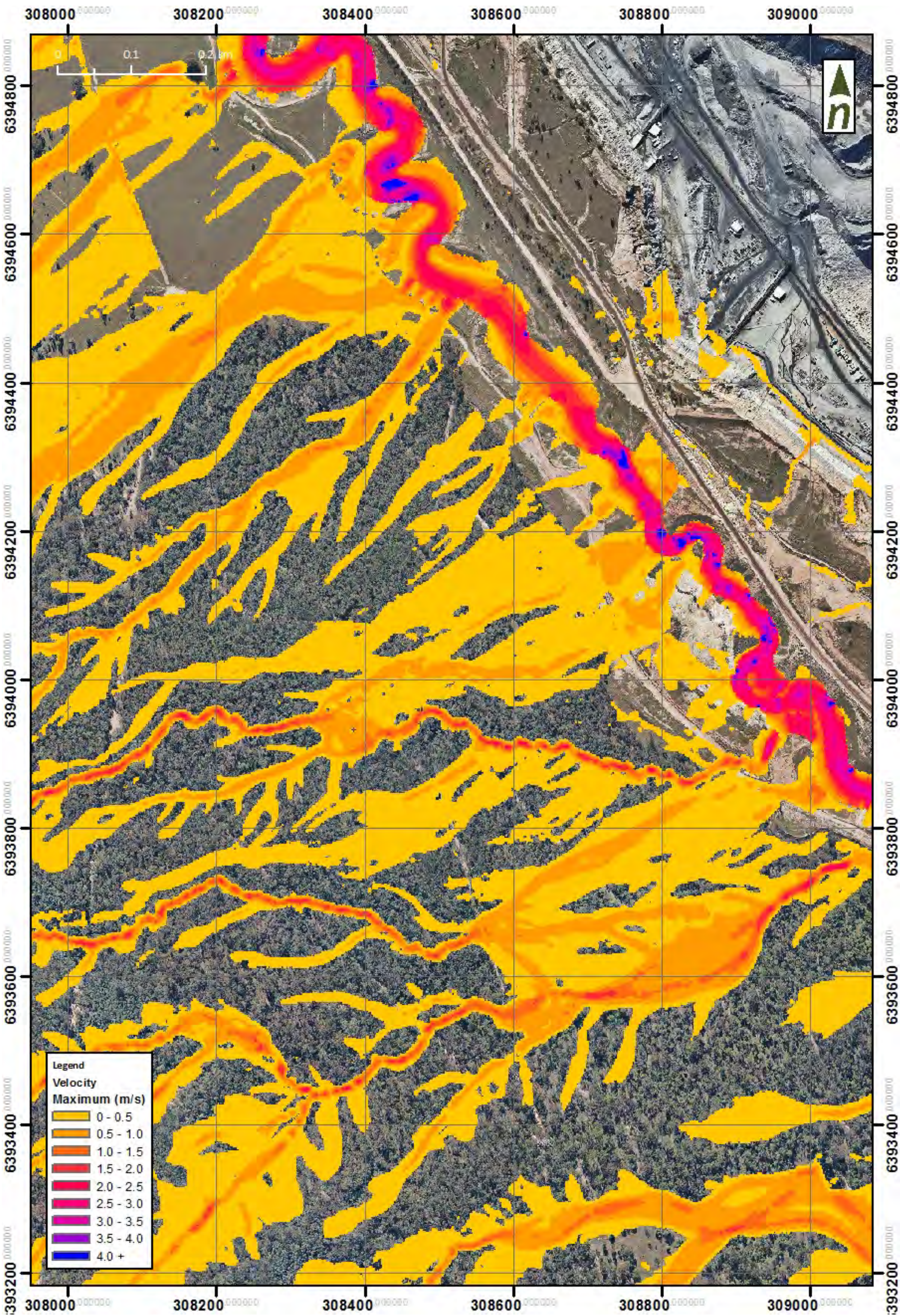


Figure C-33. **50 year ARI flood velocities (existing conditions)**

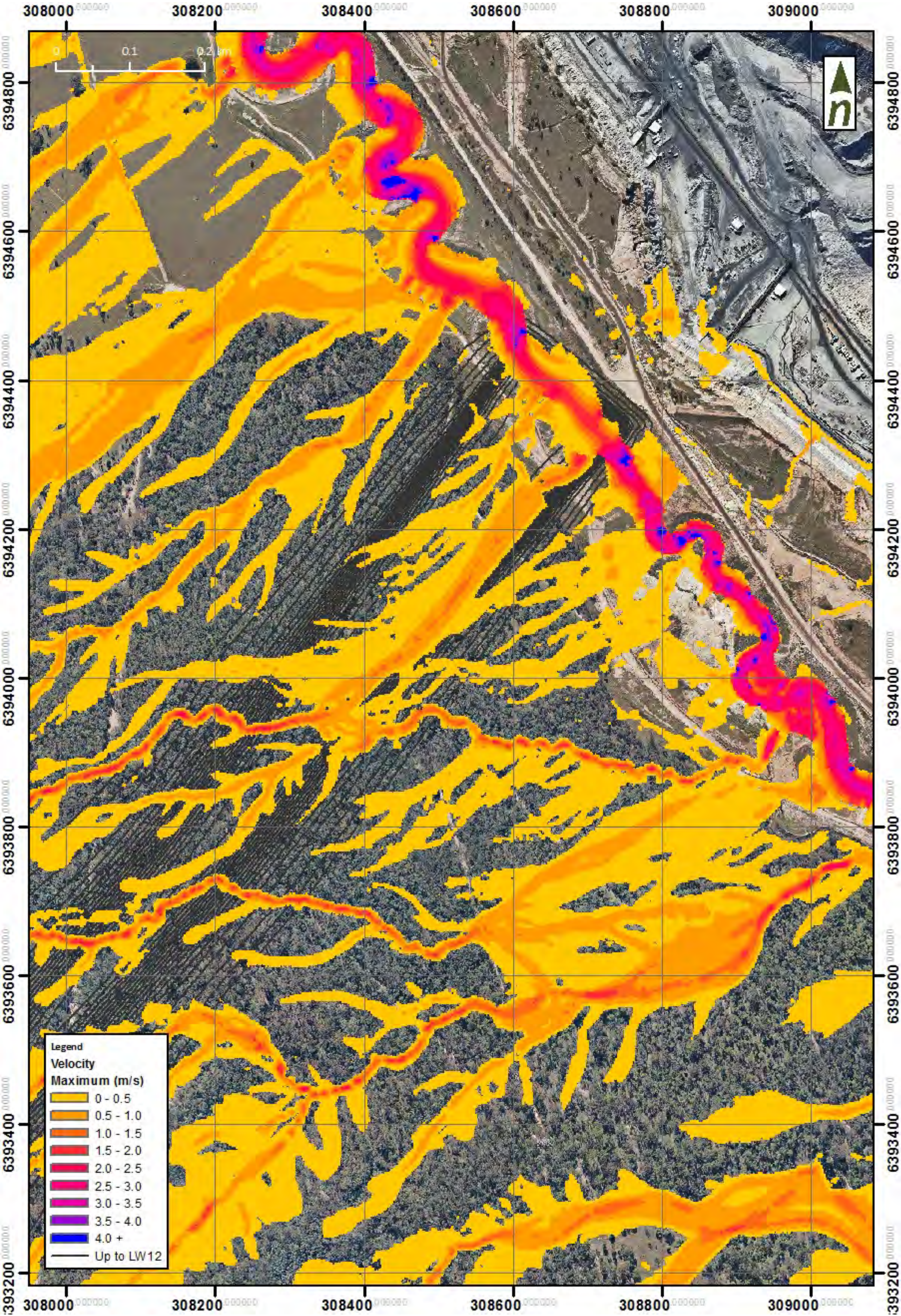


Figure C-34. **50 year ARI flood velocities (post LW12)**

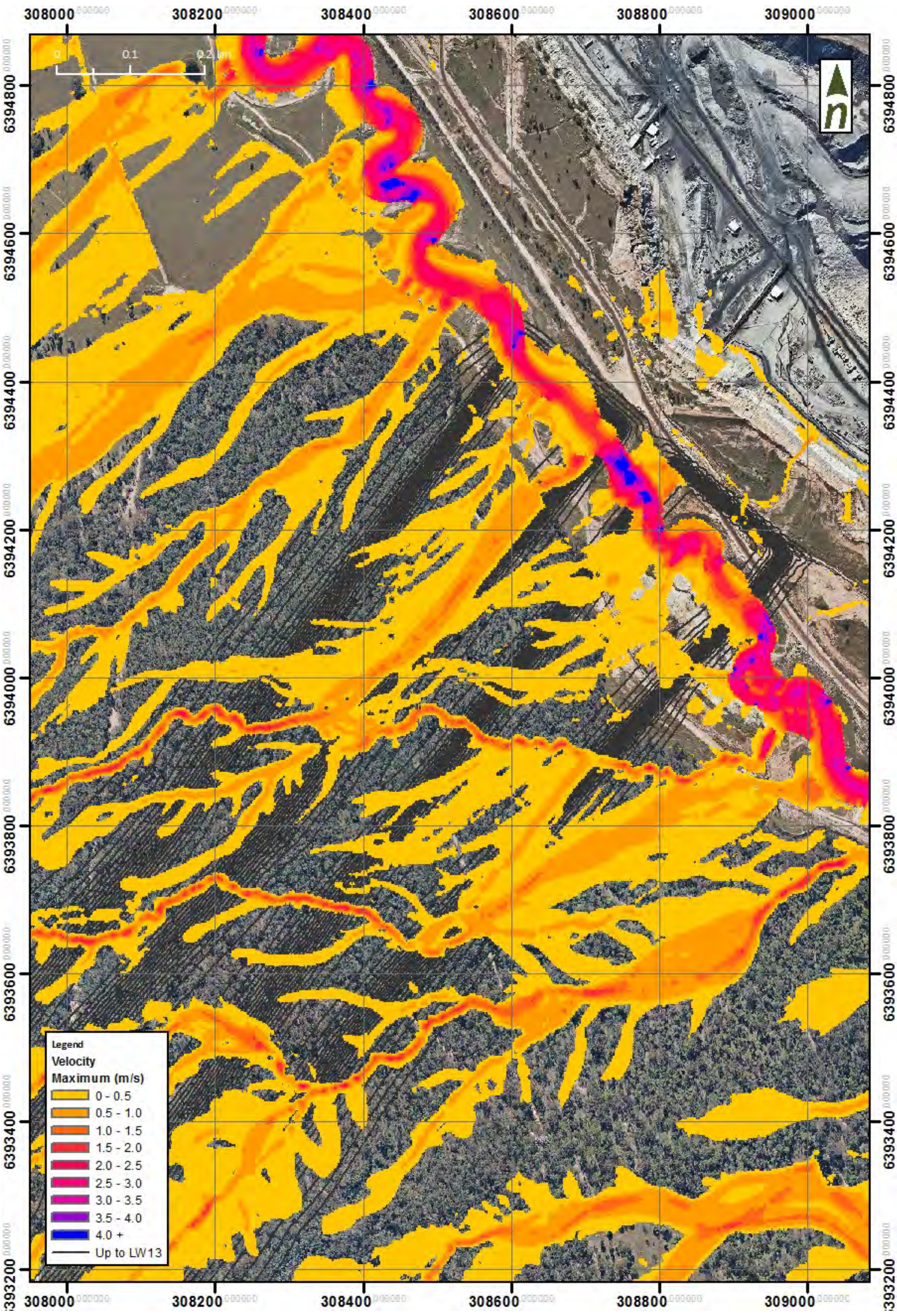


Figure C-35. **50 year ARI flood velocities (post LW13)**

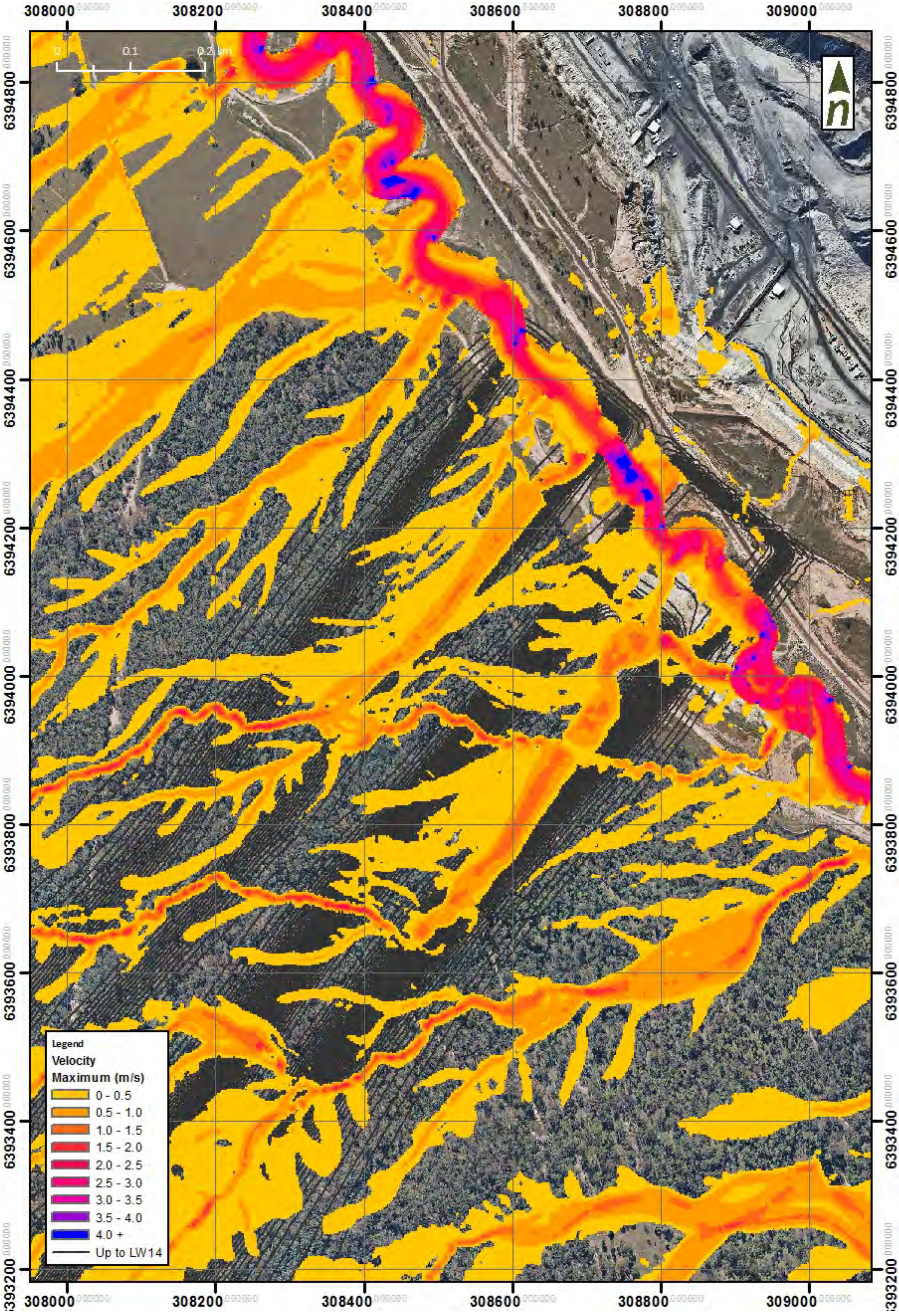


Figure C-36. **50 year ARI flood velocities (post LW14)**

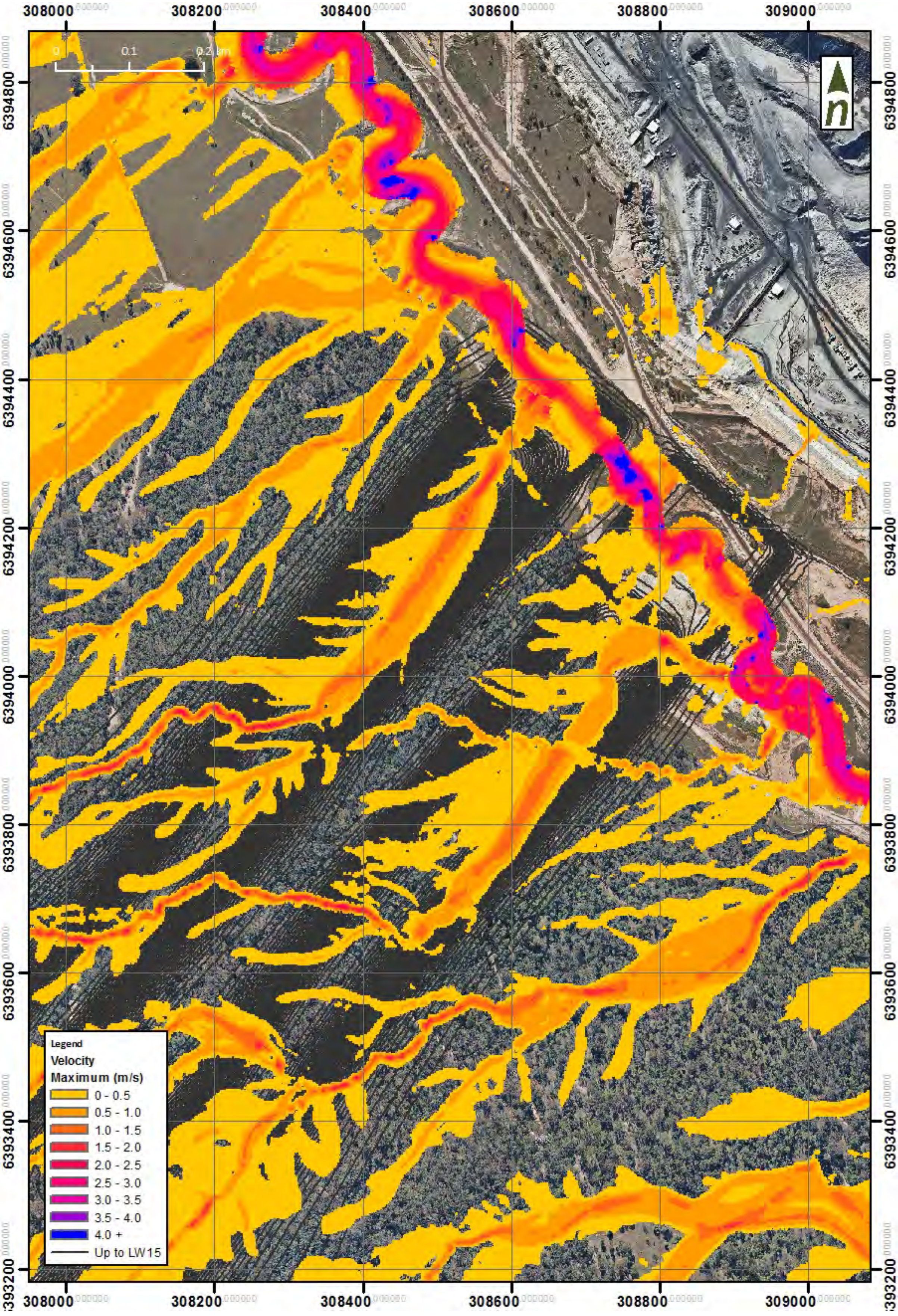


Figure C-37. **50 year ARI flood velocities (post LW15)**

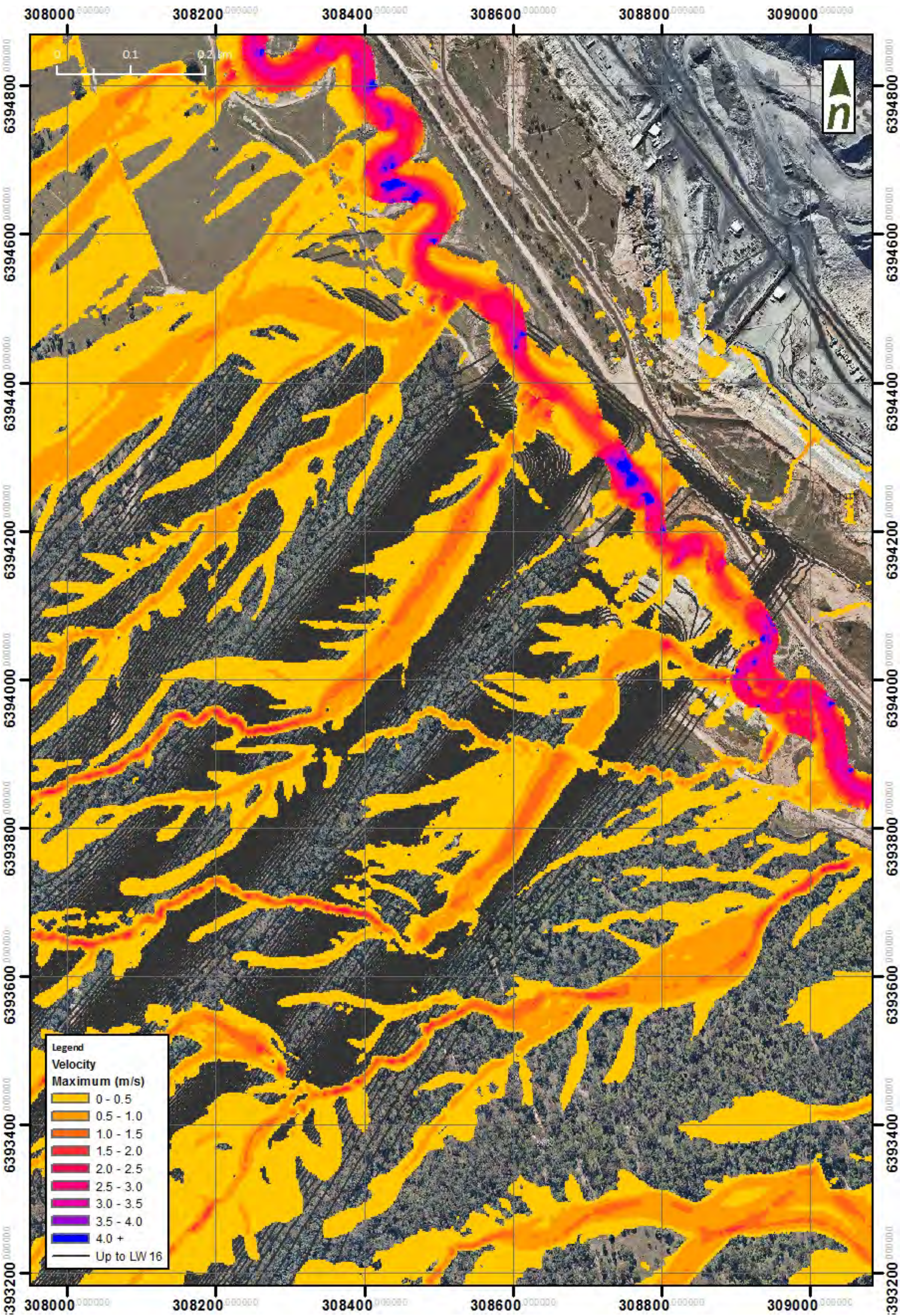


Figure C-38. 50 year ARI flood velocities (post LW16)

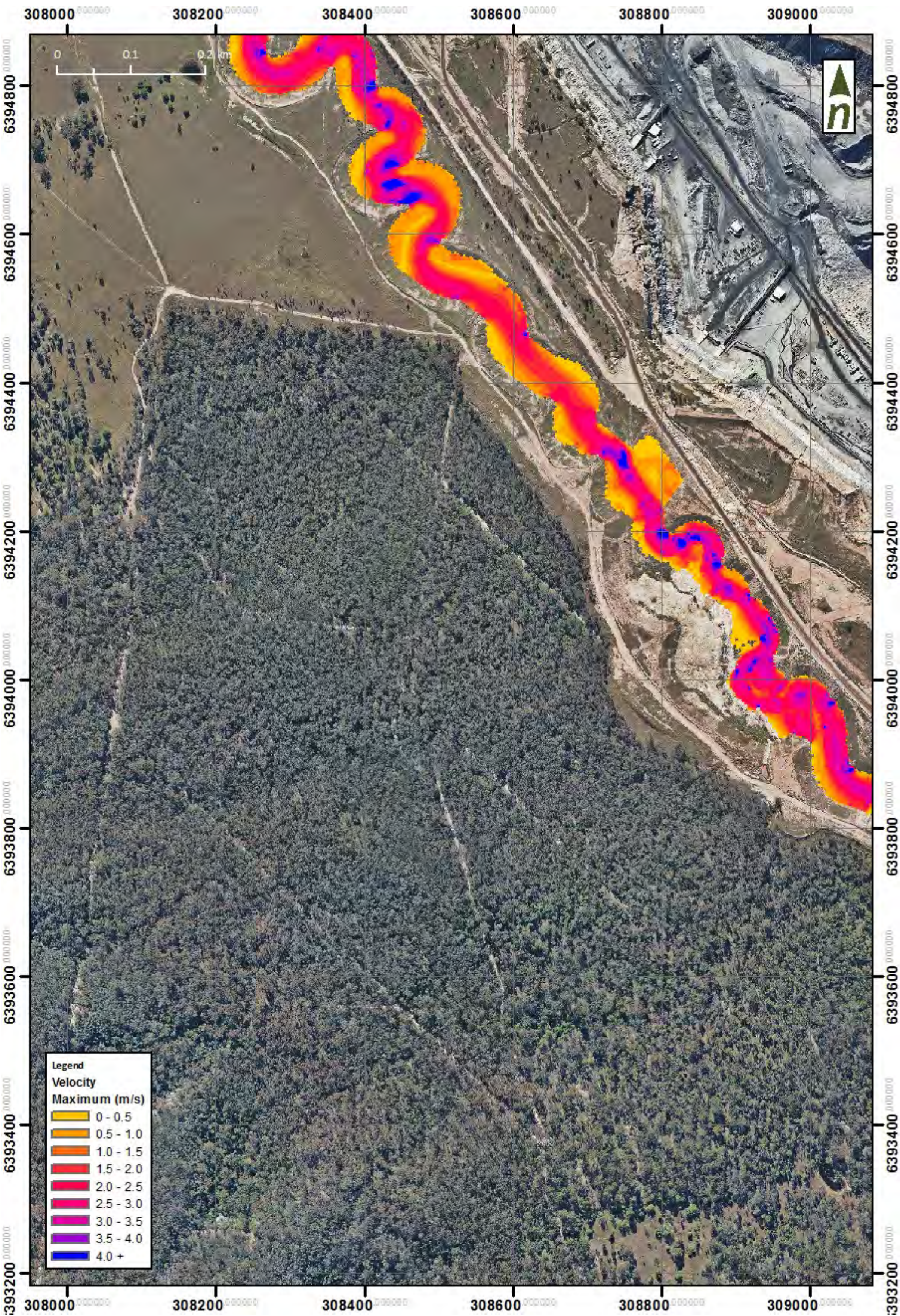


Figure C-39. **100 year ARI flood velocities (existing conditions)**

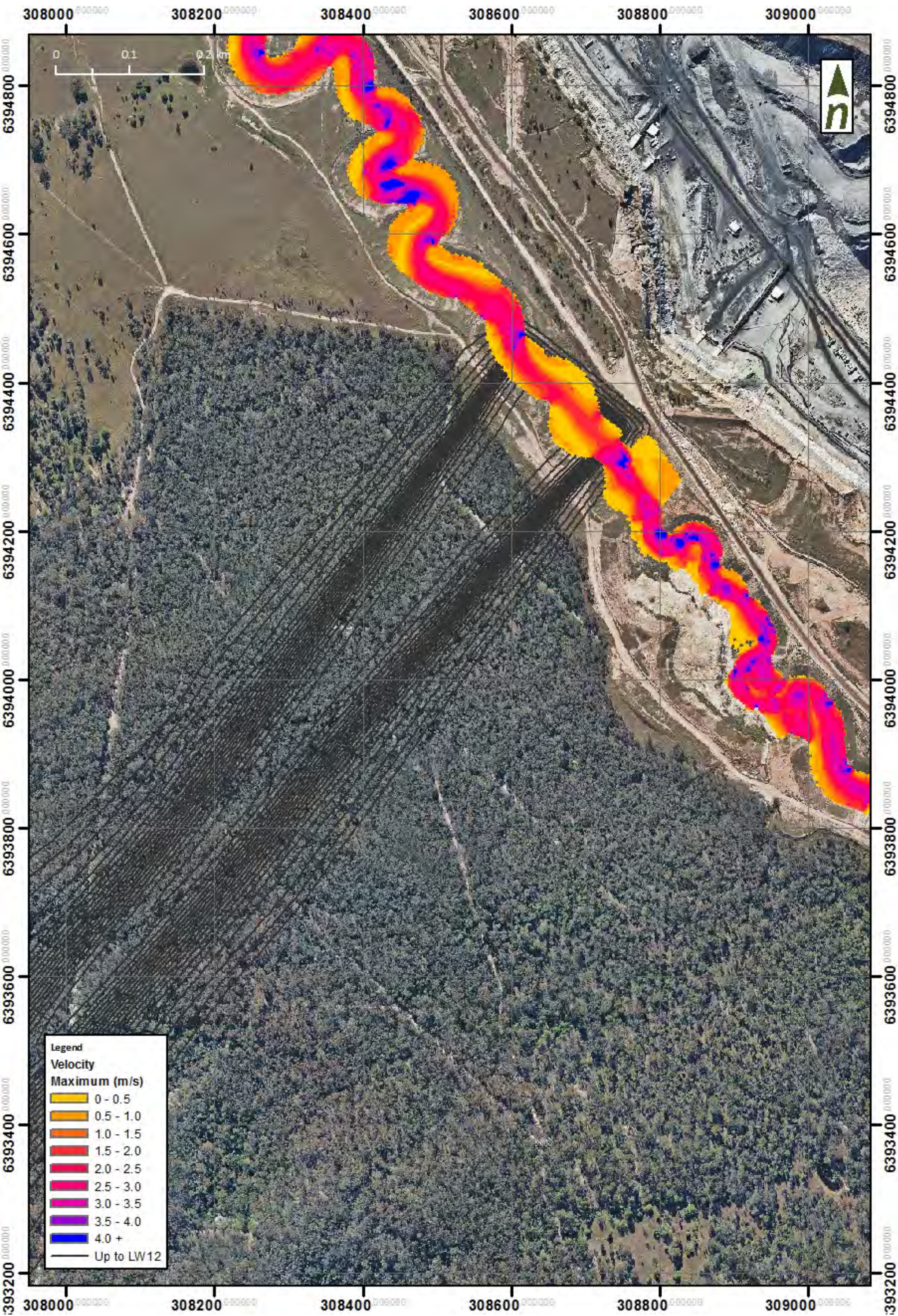


Figure C-40. **100 year ARI flood velocities (post LW12)**

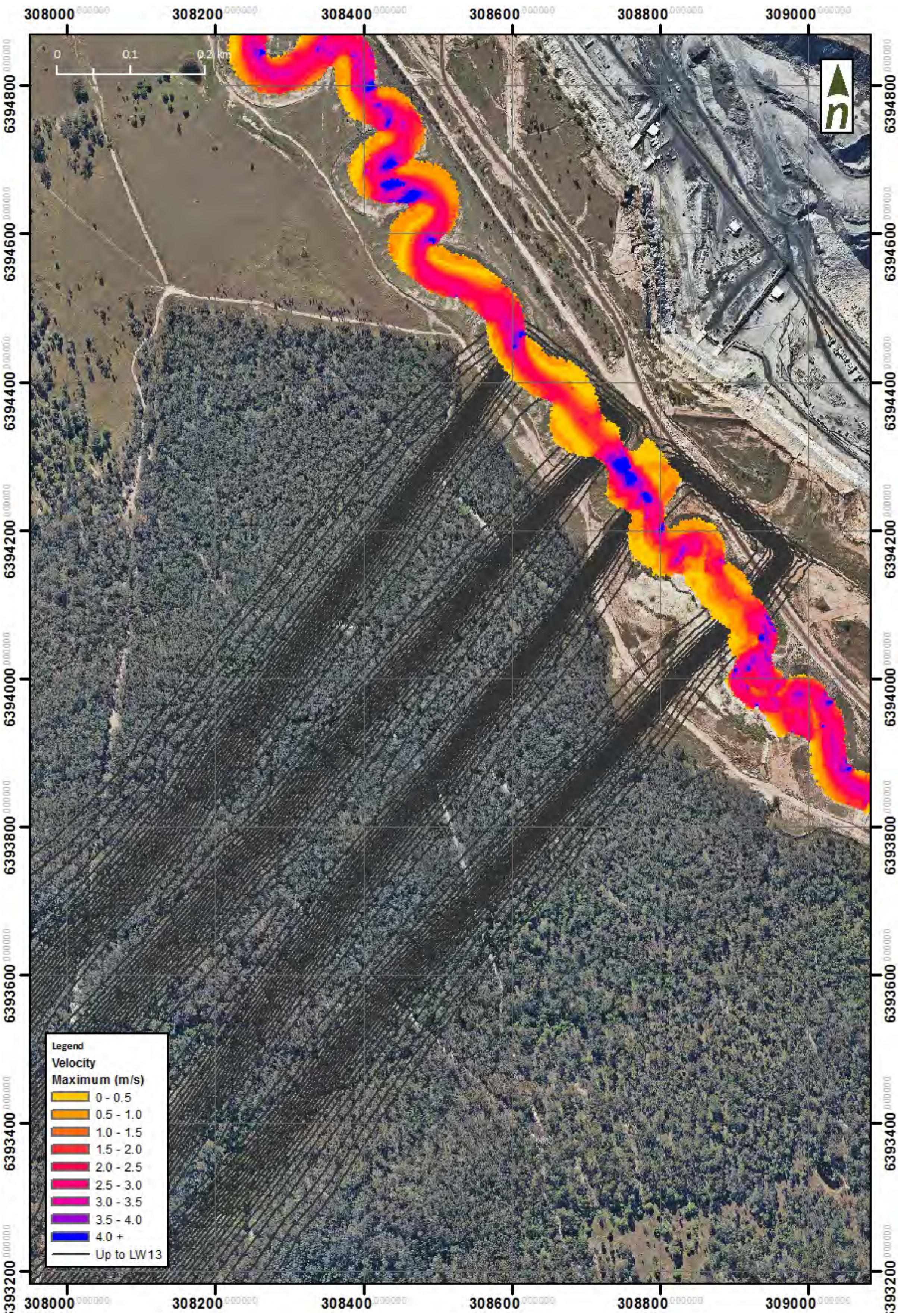


Figure C-41. **100 year ARI flood velocities (post LW13)**

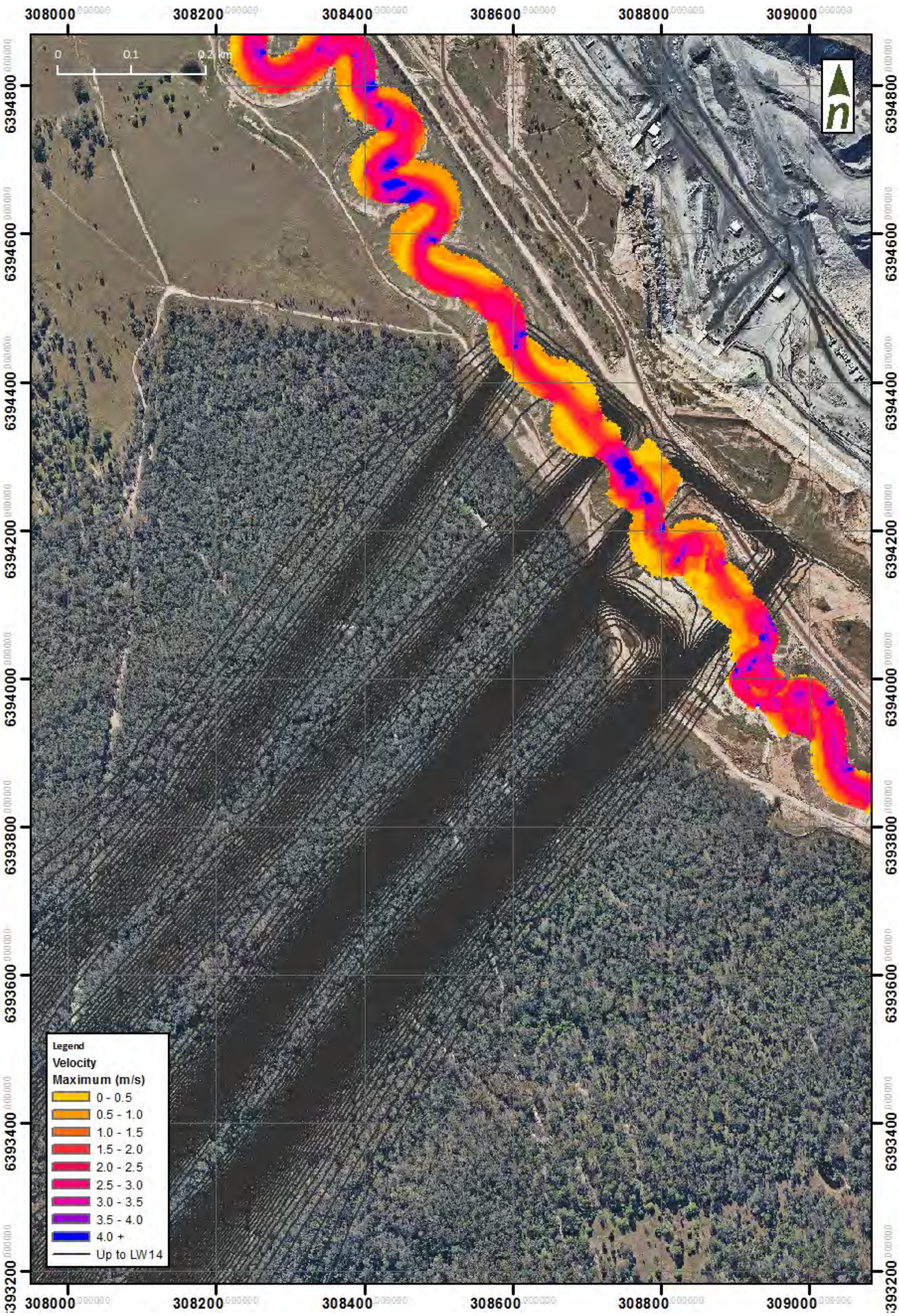


Figure C-42. **100 year ARI flood velocities (post LW14)**

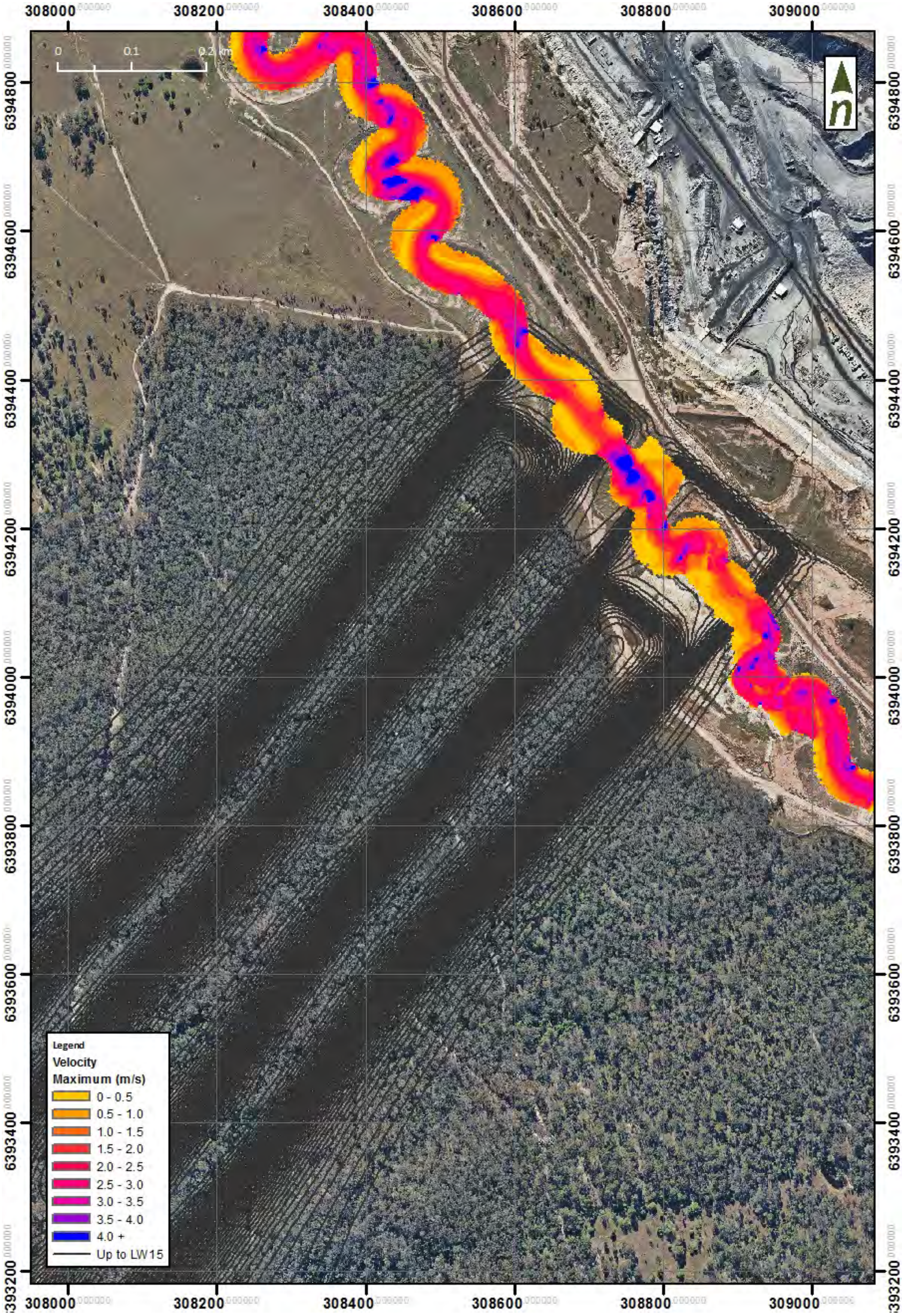


Figure C-43. **100 year ARI flood velocities (post LW15)**

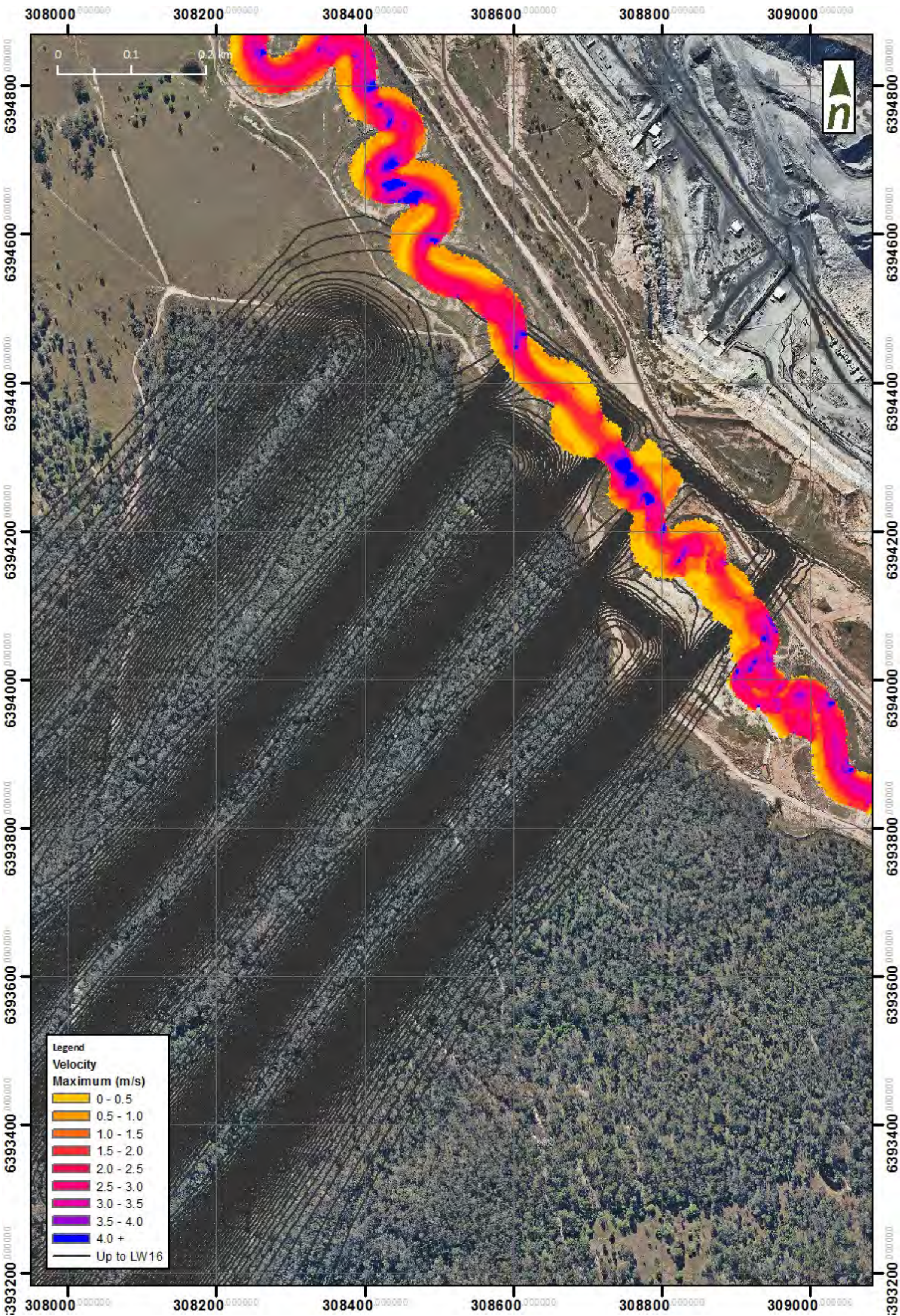


Figure C-44. **100 year ARI flood velocities (post LW16)**

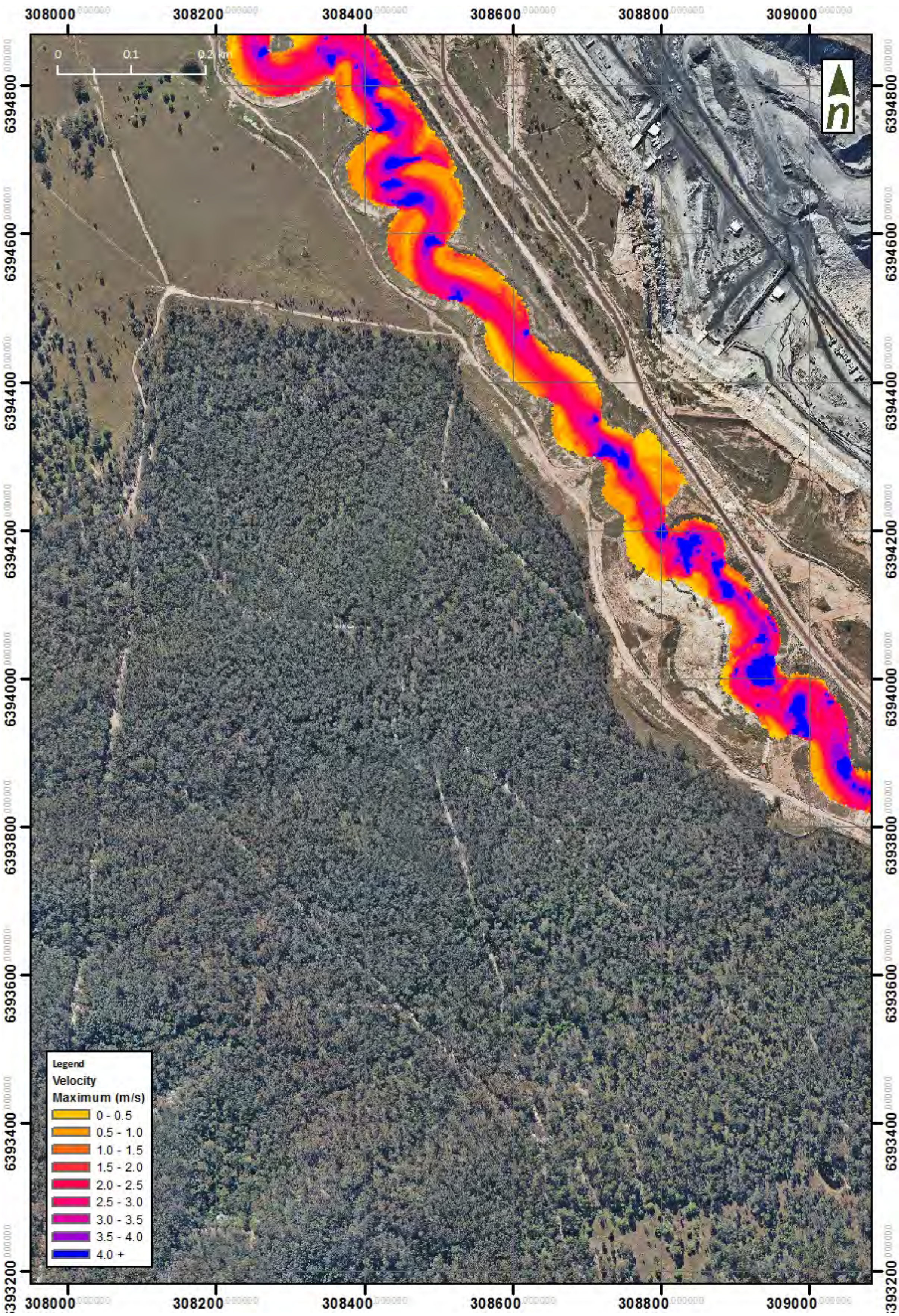


Figure C-45. **1000 year ARI flood velocities (existing conditions)**

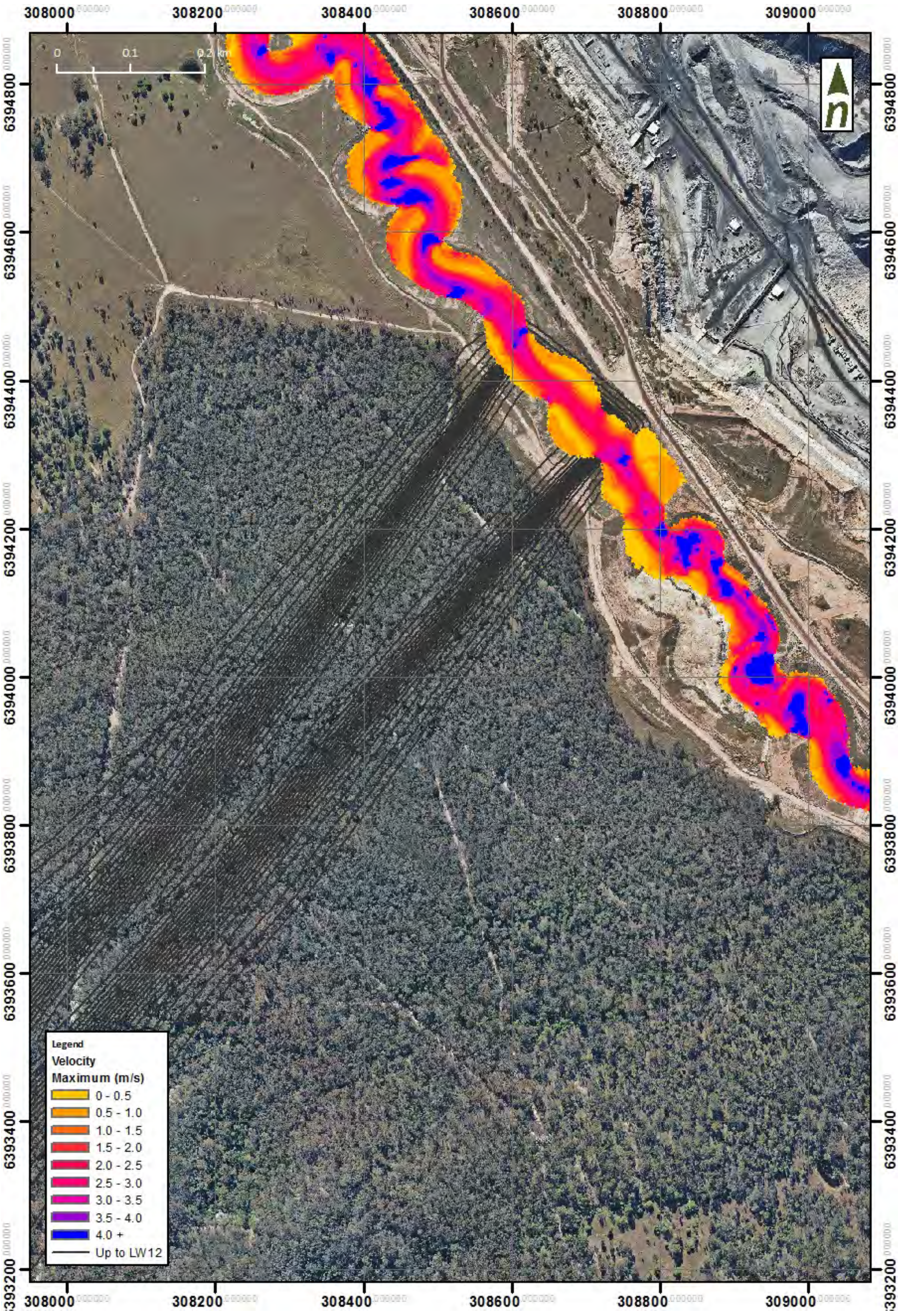


Figure C-46. **1000 year ARI flood velocities (post LW12)**

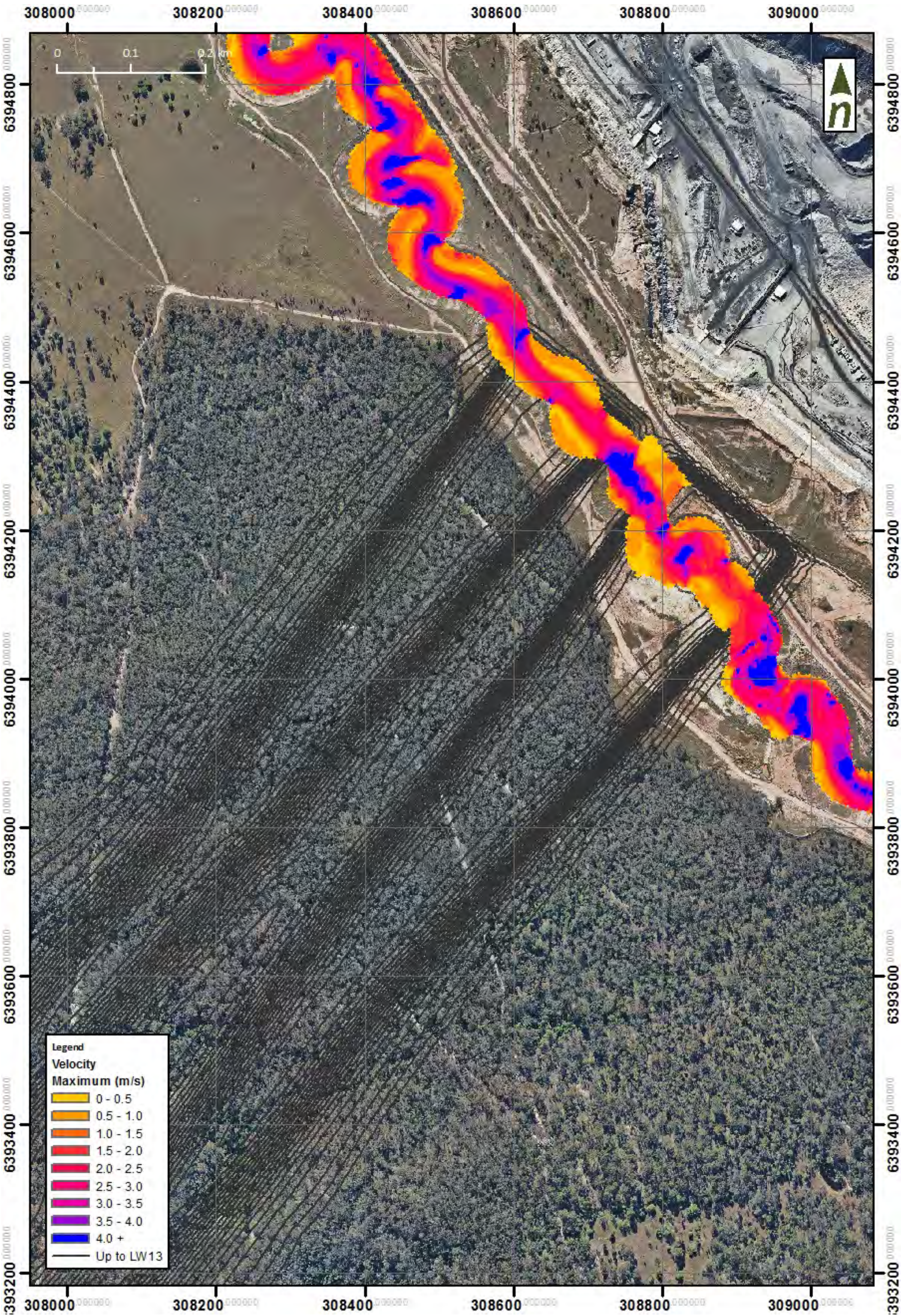


Figure C-47. **1000 year ARI flood velocities (post LW13)**

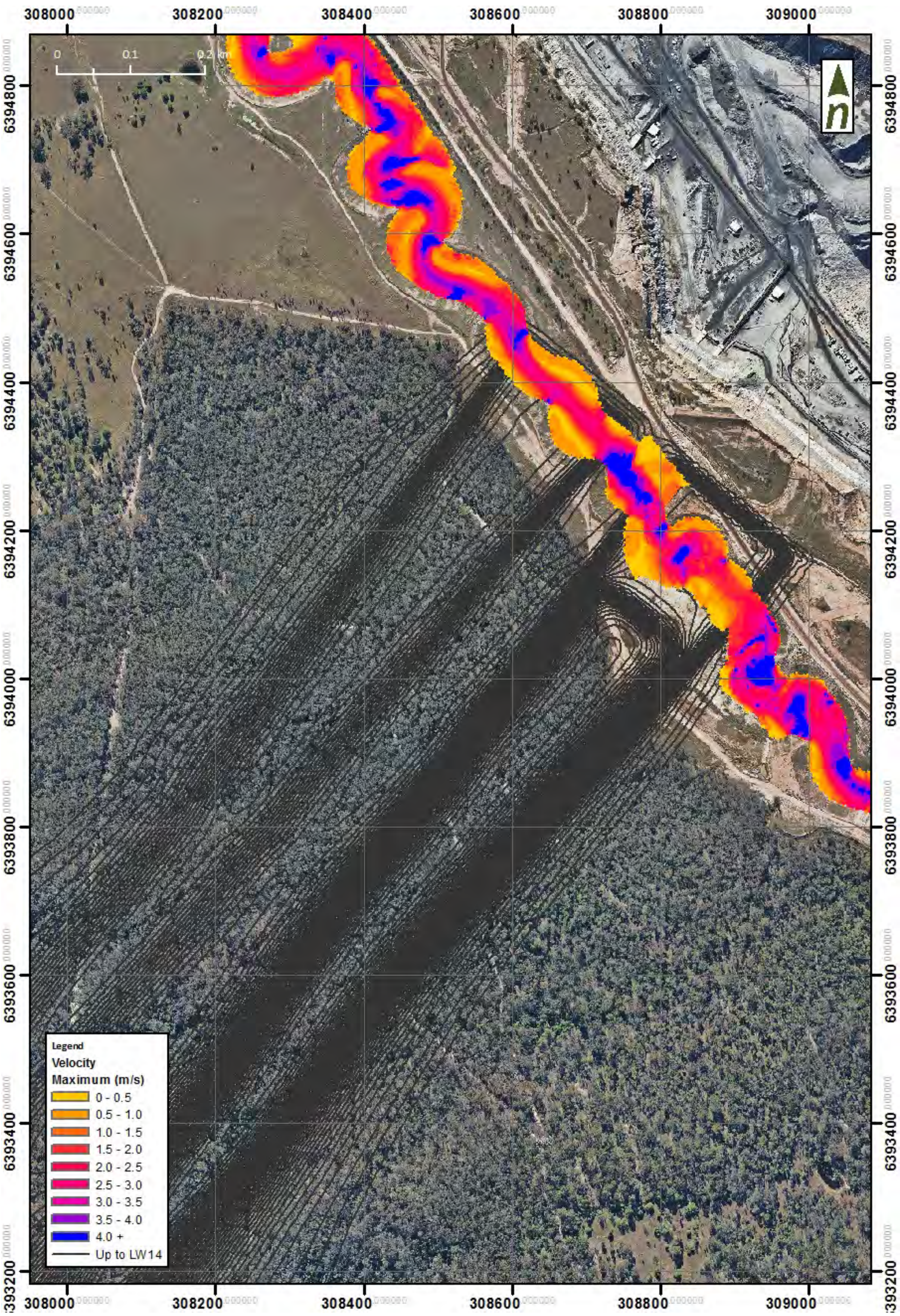


Figure C-48. **1000 year ARI flood velocities (post LW14)**

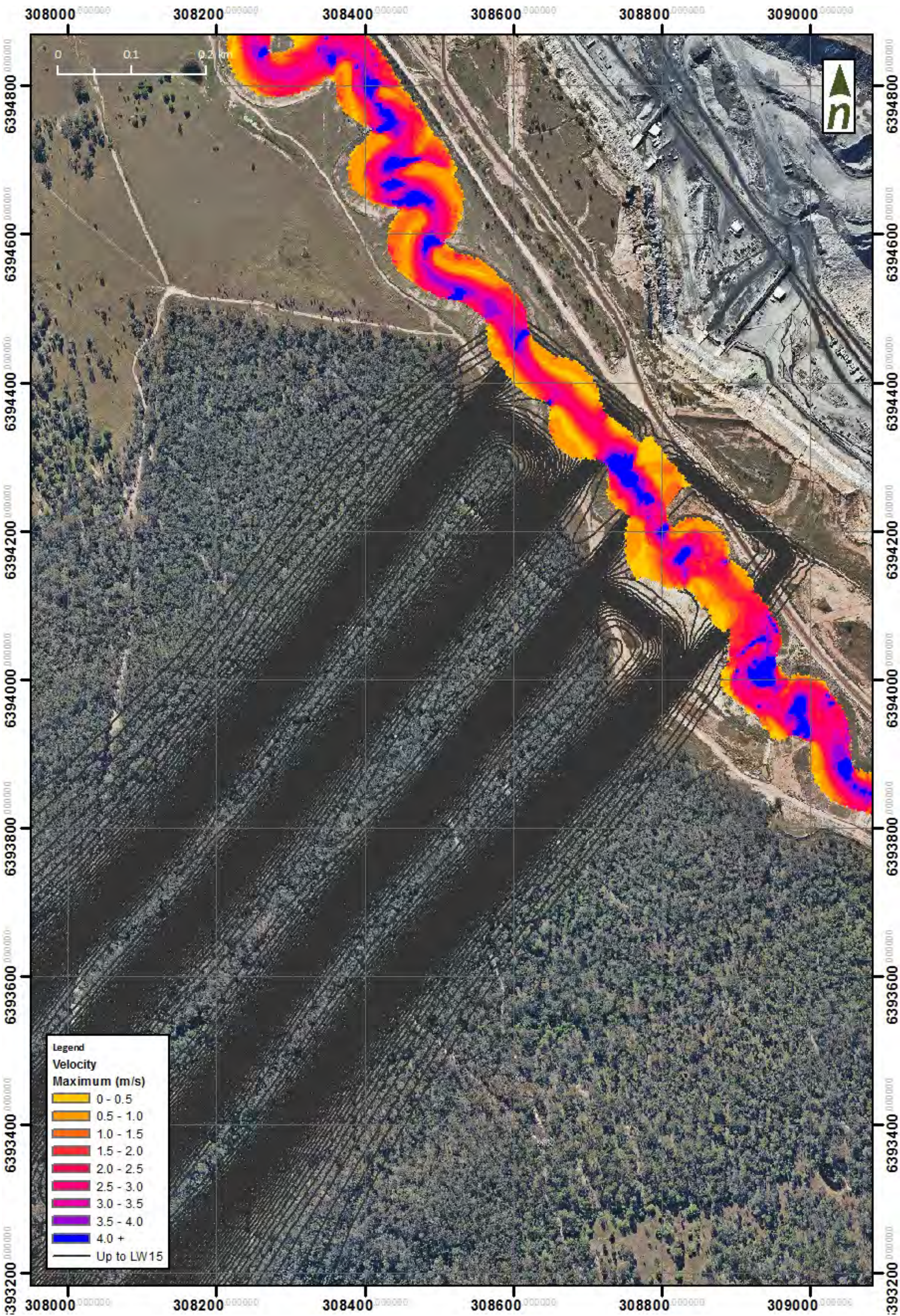


Figure C-49. **1000 year ARI flood velocities (post LW15)**

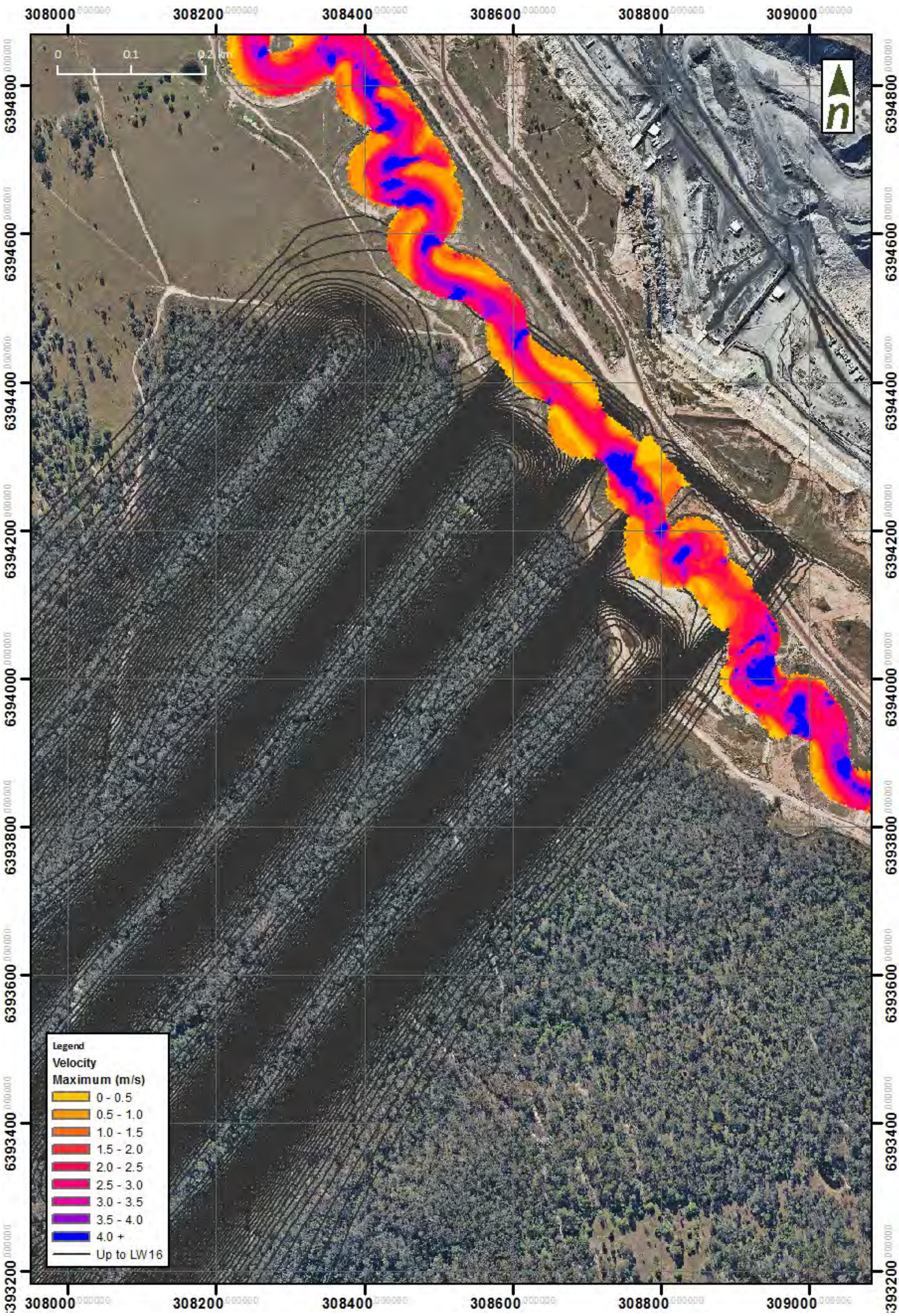


Figure C-50. **1000 year ARI flood velocities (post LW16)**

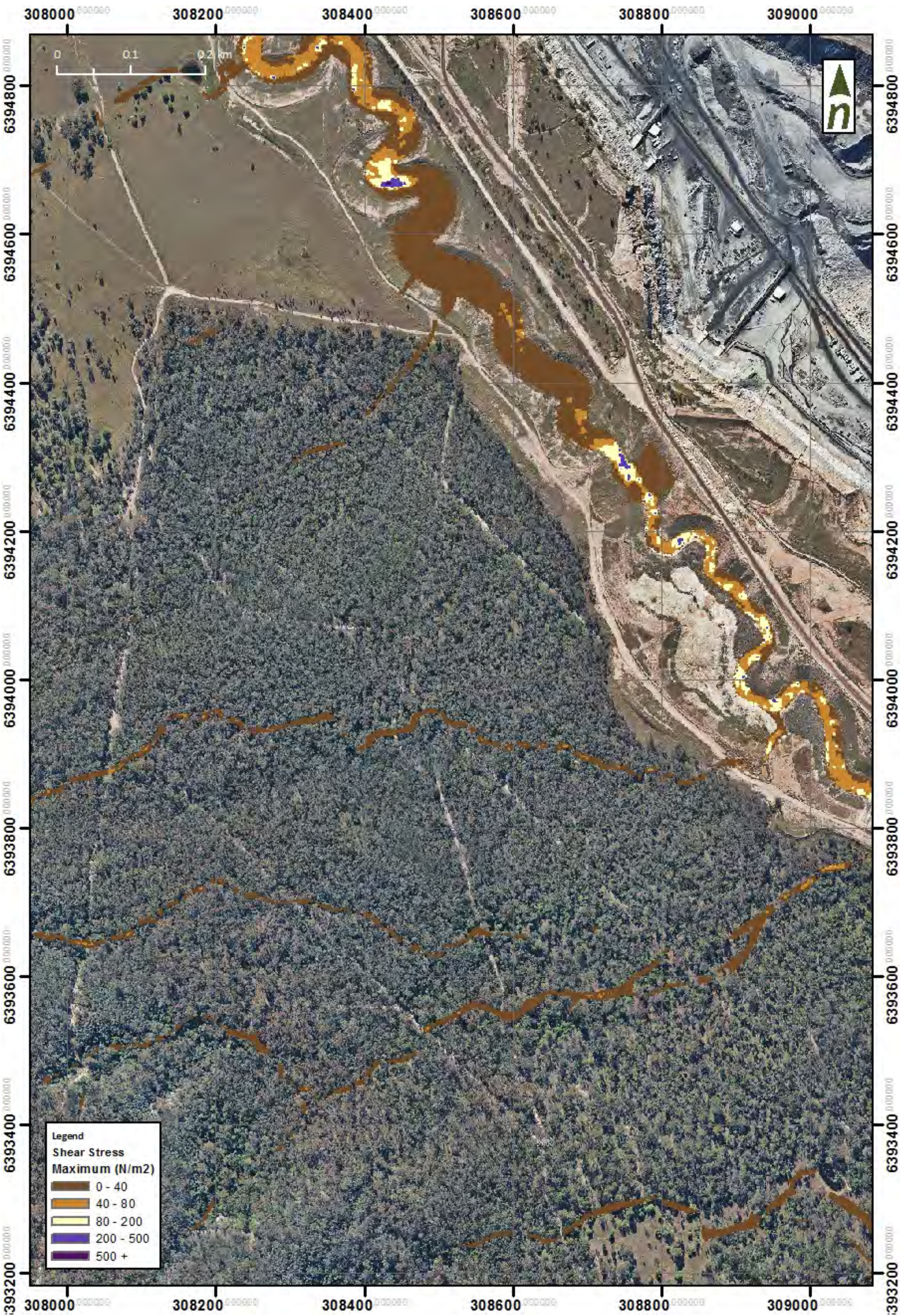


Figure C-51. **2 year ARI flood shear stress (existing conditions)**

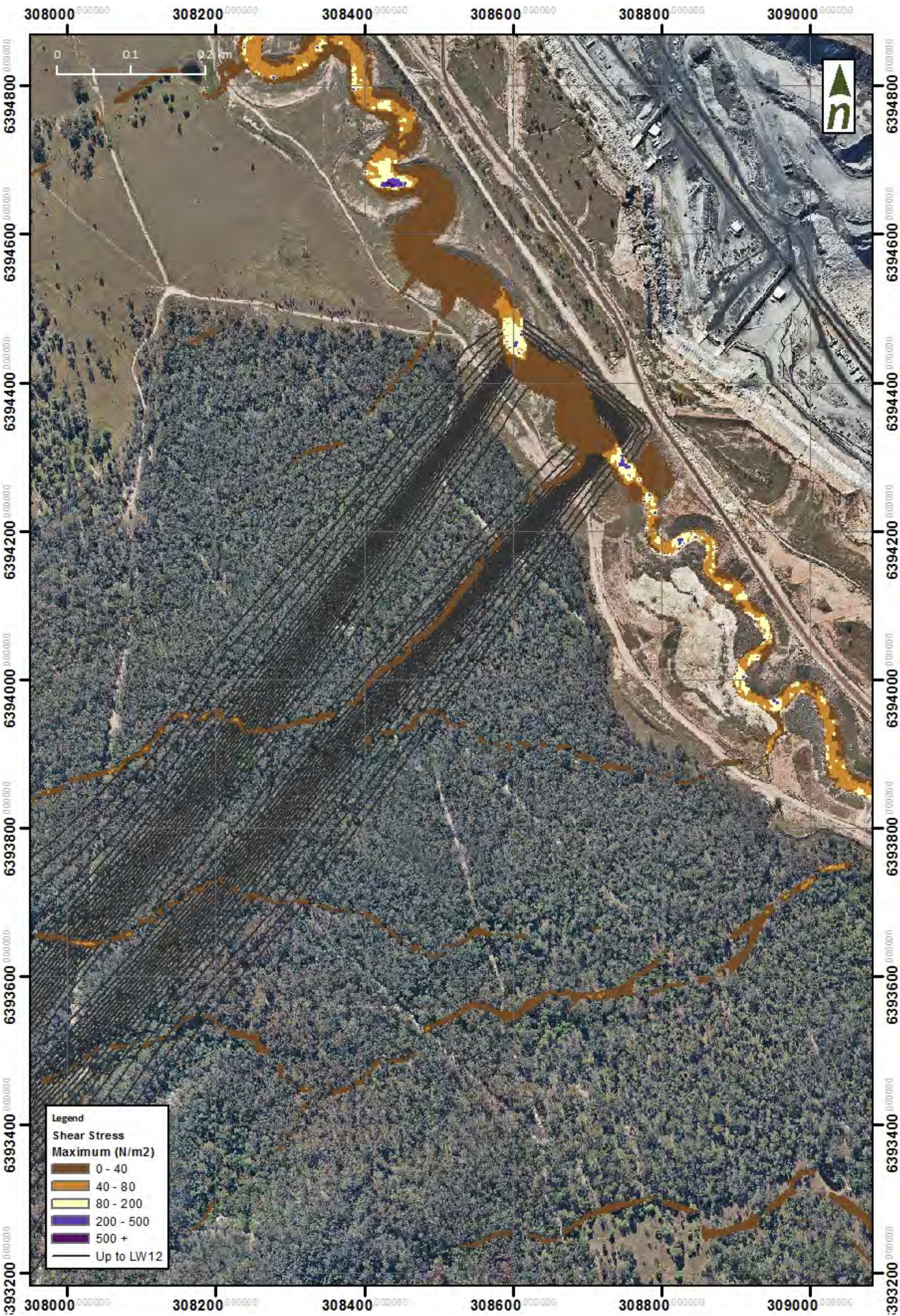


Figure C-52. 2 year ARI flood shear stress (post LW12)

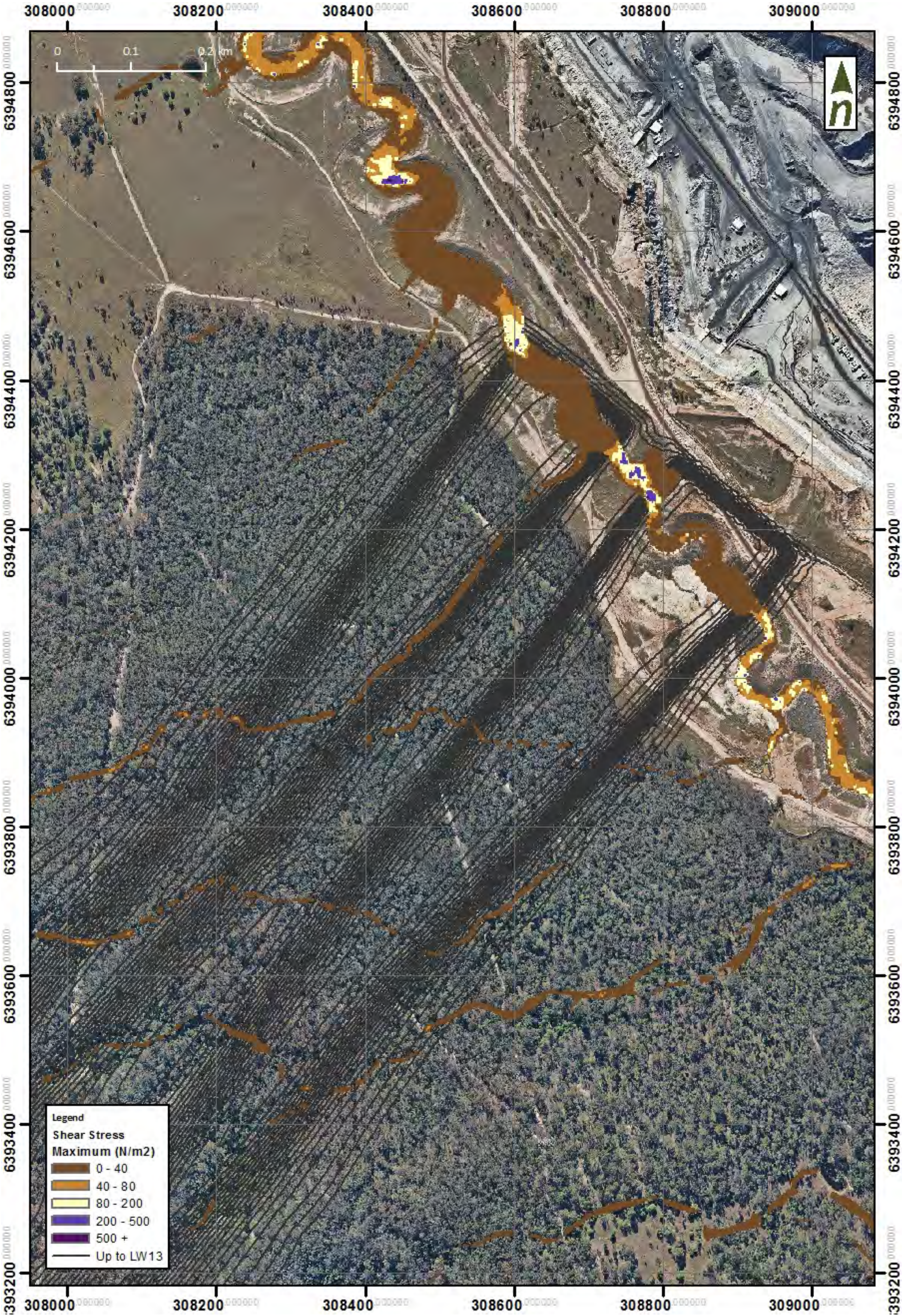


Figure C-53. **2 year ARI flood shear stress (post LW13)**

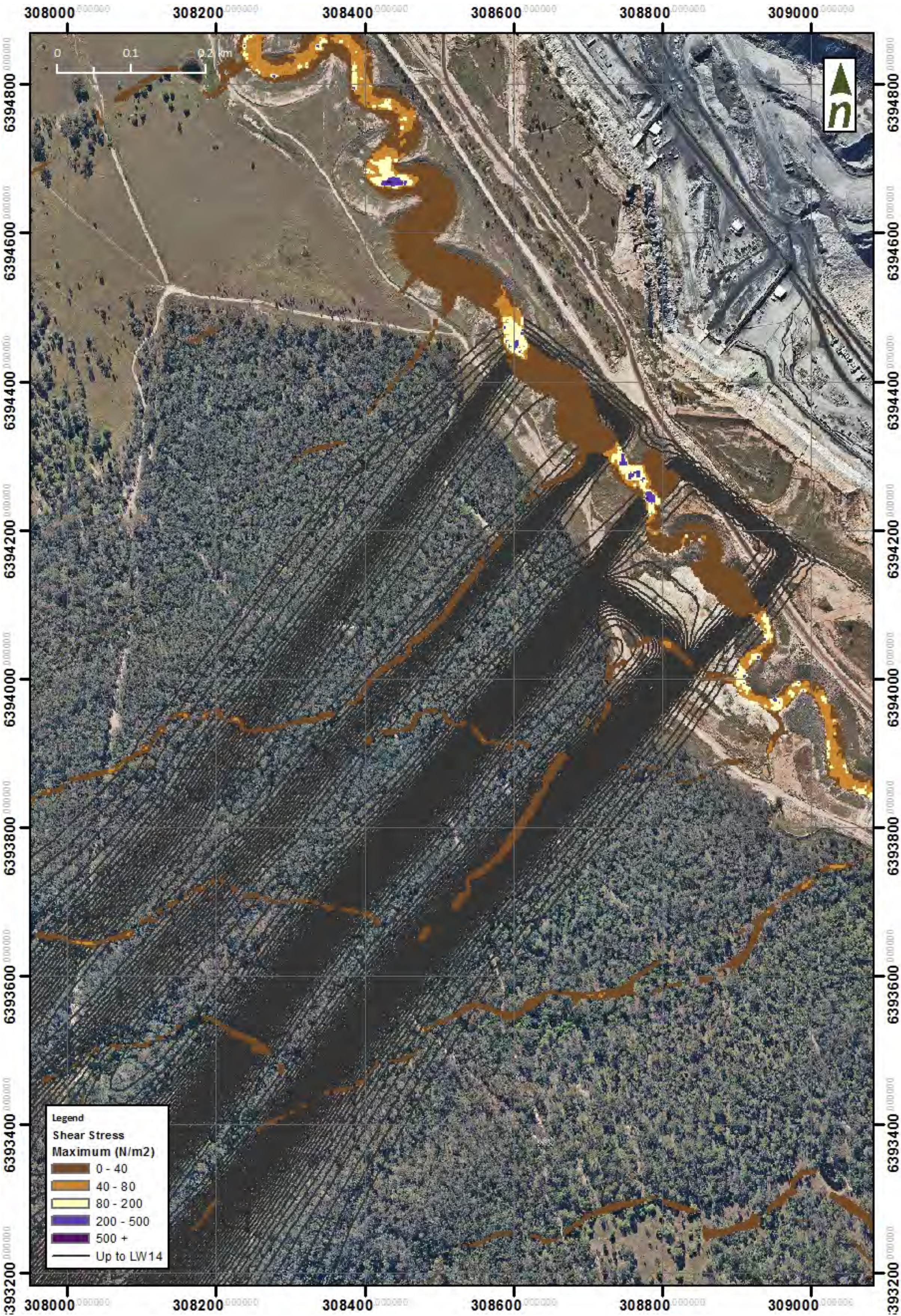


Figure C-54. **2 year ARI flood shear stress (post LW14)**

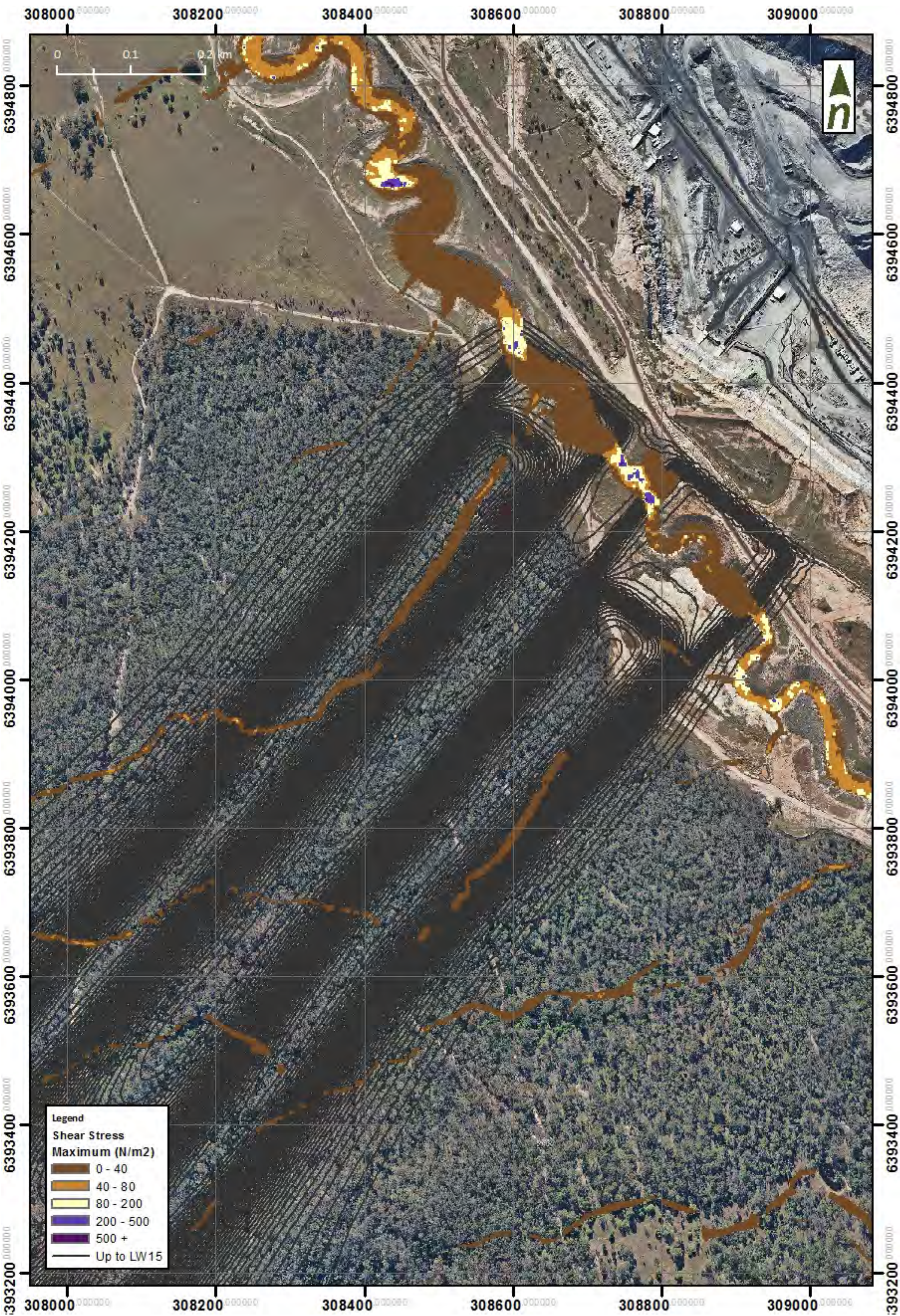


Figure C-55. **2 year ARI flood shear stress (post LW15)**

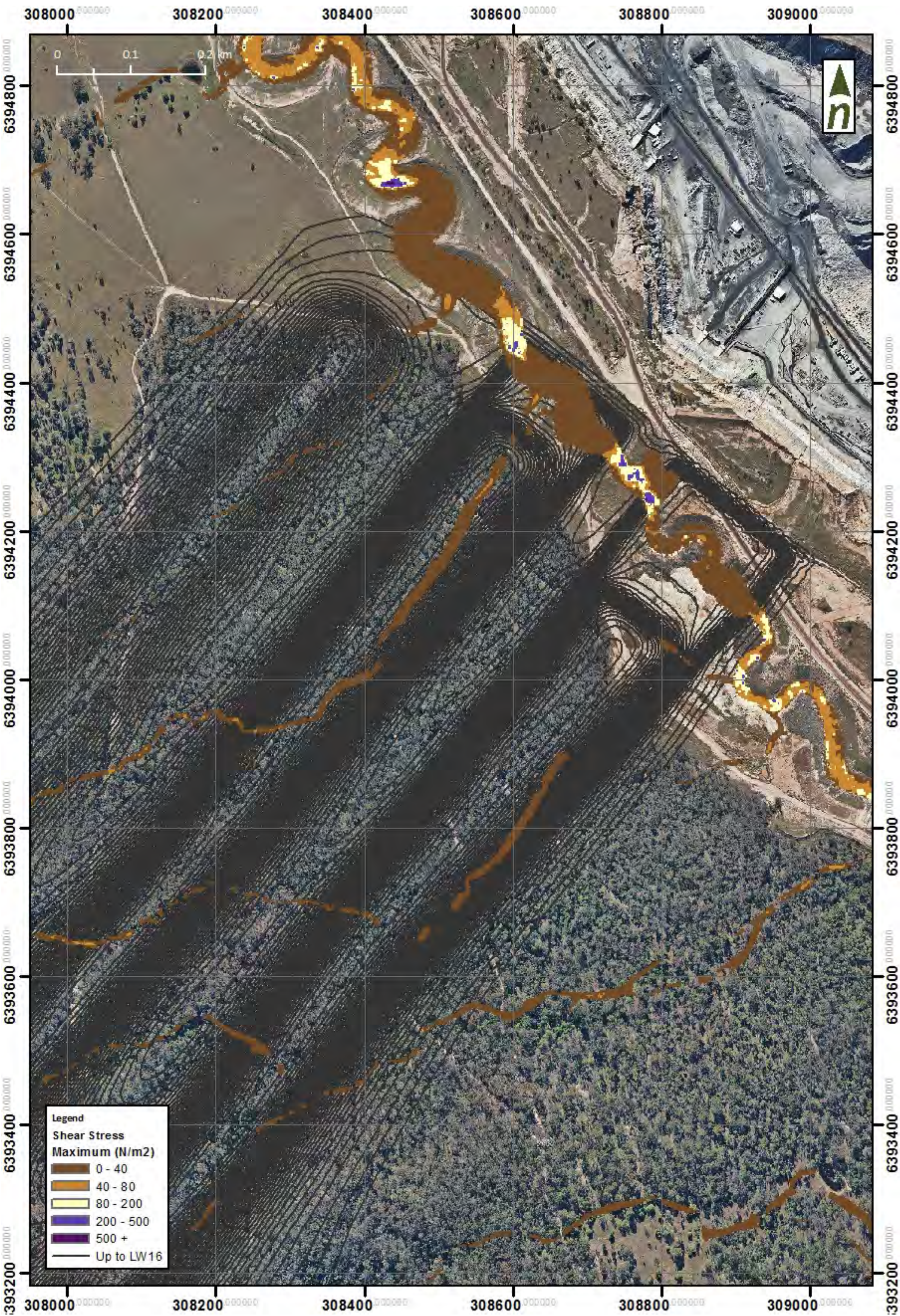


Figure C-56. **2 year ARI flood shear stress (post LW16)**

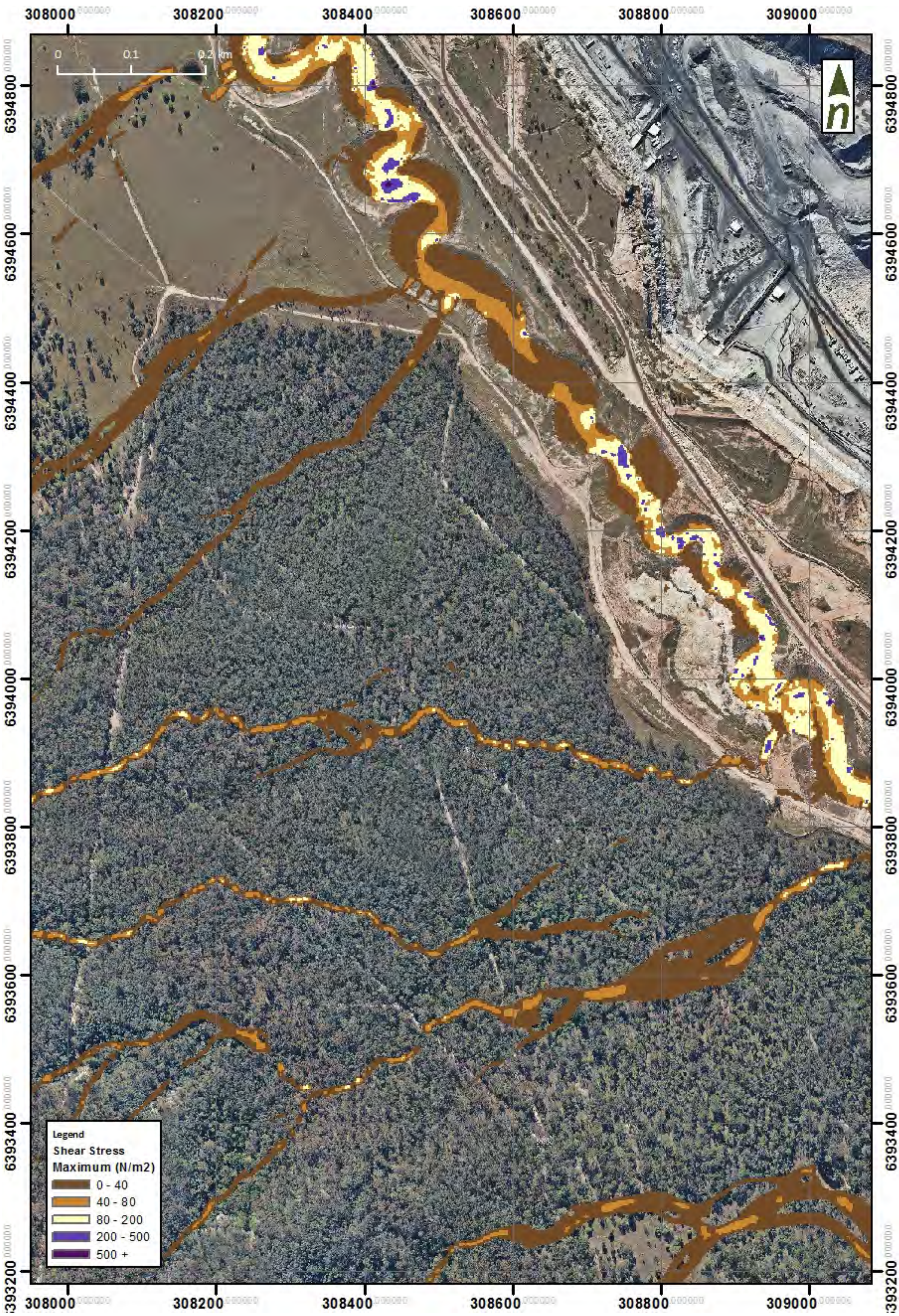


Figure C-57. 50 year ARI flood shear stress (existing conditions)

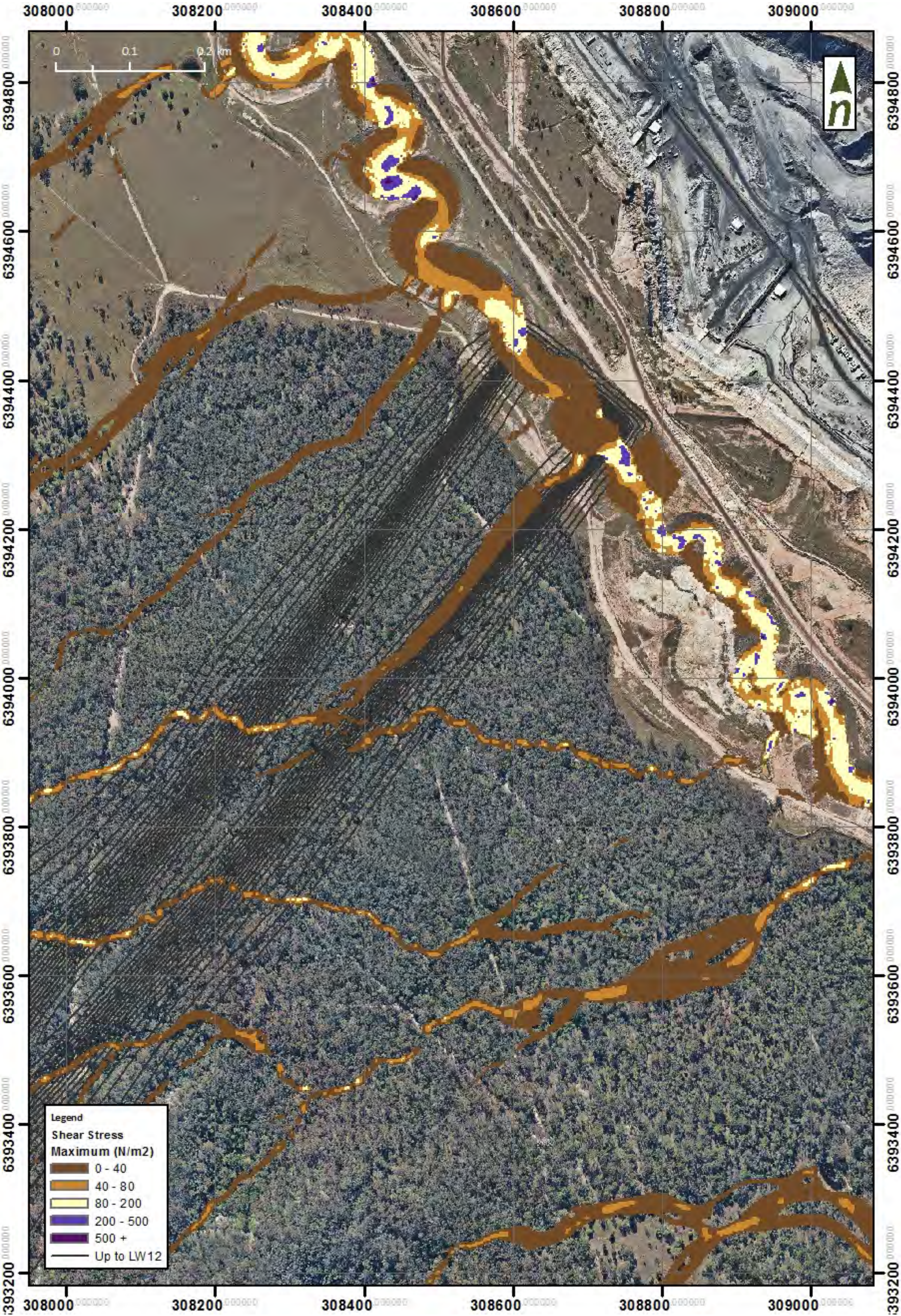


Figure C-58. 50 year ARI flood shear stress (post LW12)

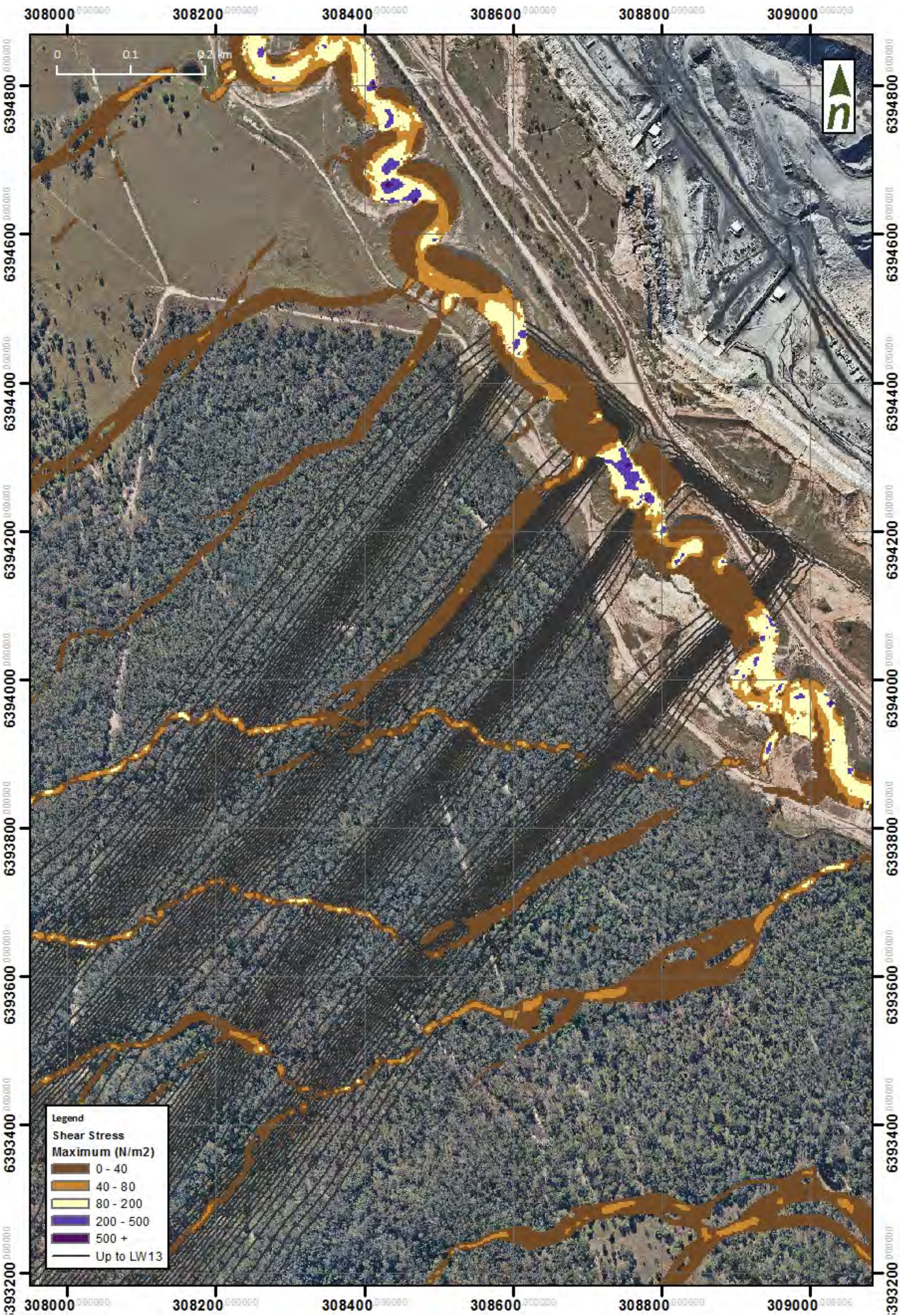


Figure C-59. **50 year ARI flood shear stress (post LW13)**

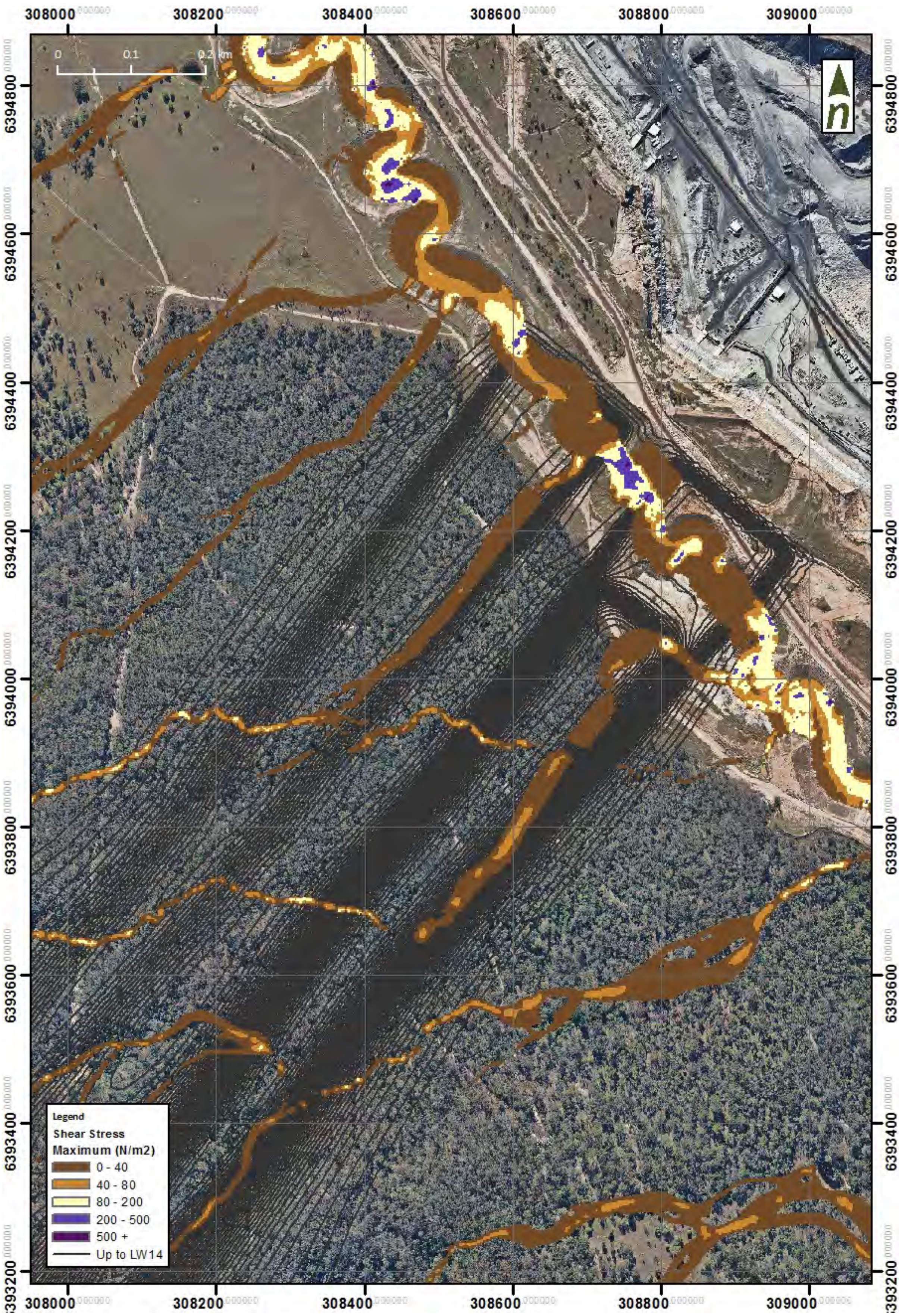


Figure C-60. 50 year ARI flood shear stress (post LW14)

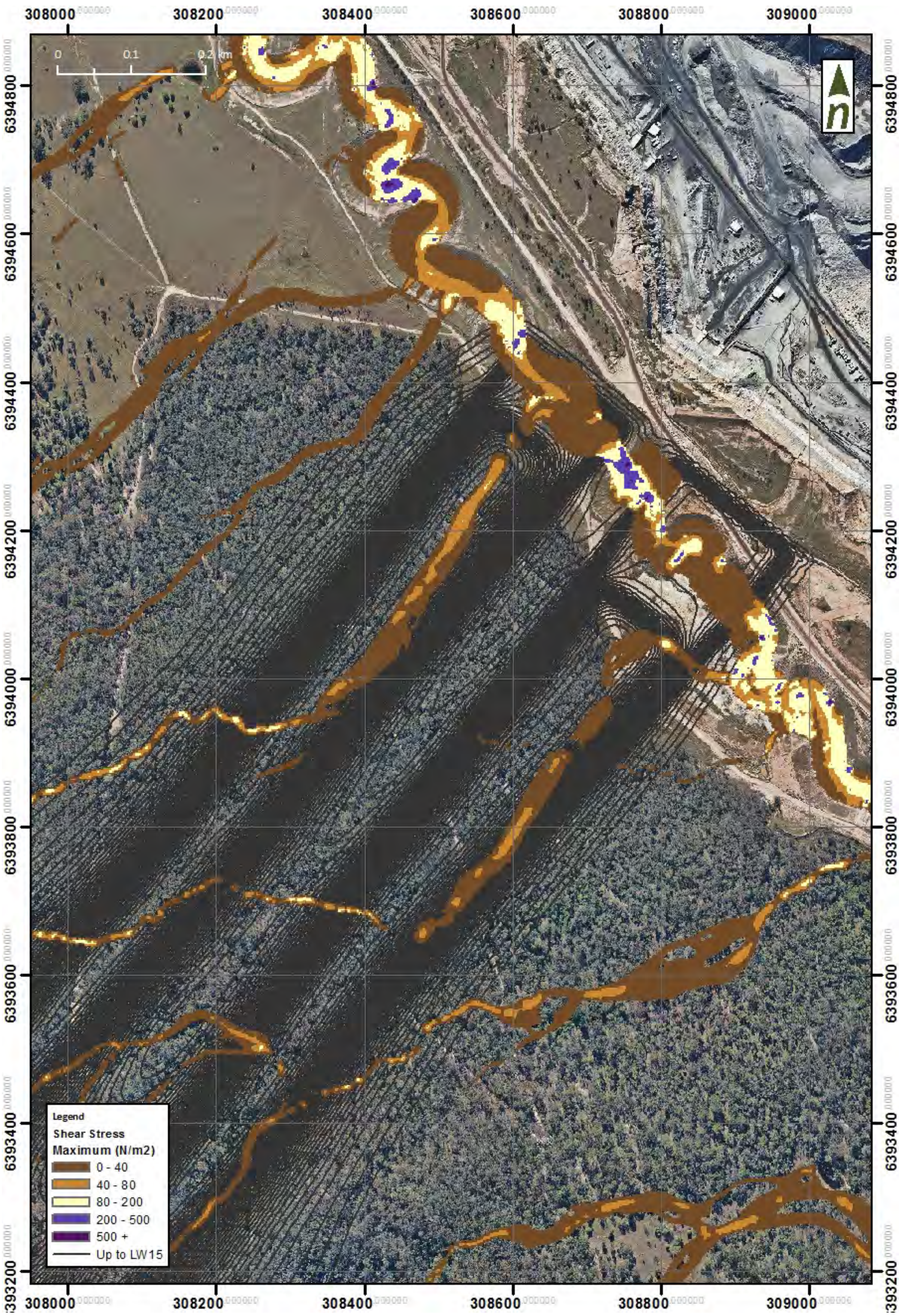


Figure C-61. **50 year ARI flood shear stress (post LW15)**

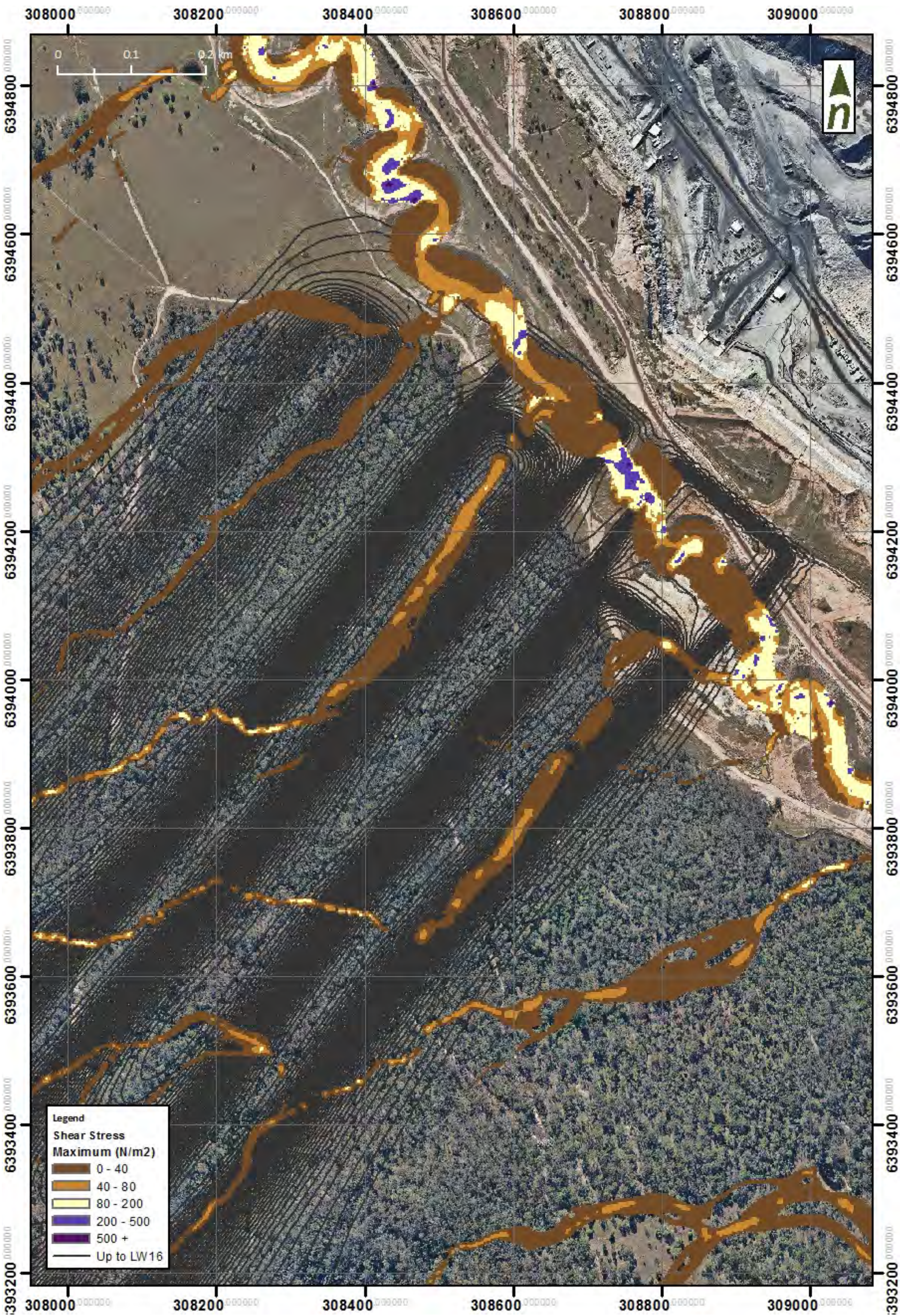


Figure C-62. 50 year ARI flood shear stress (post LW16)

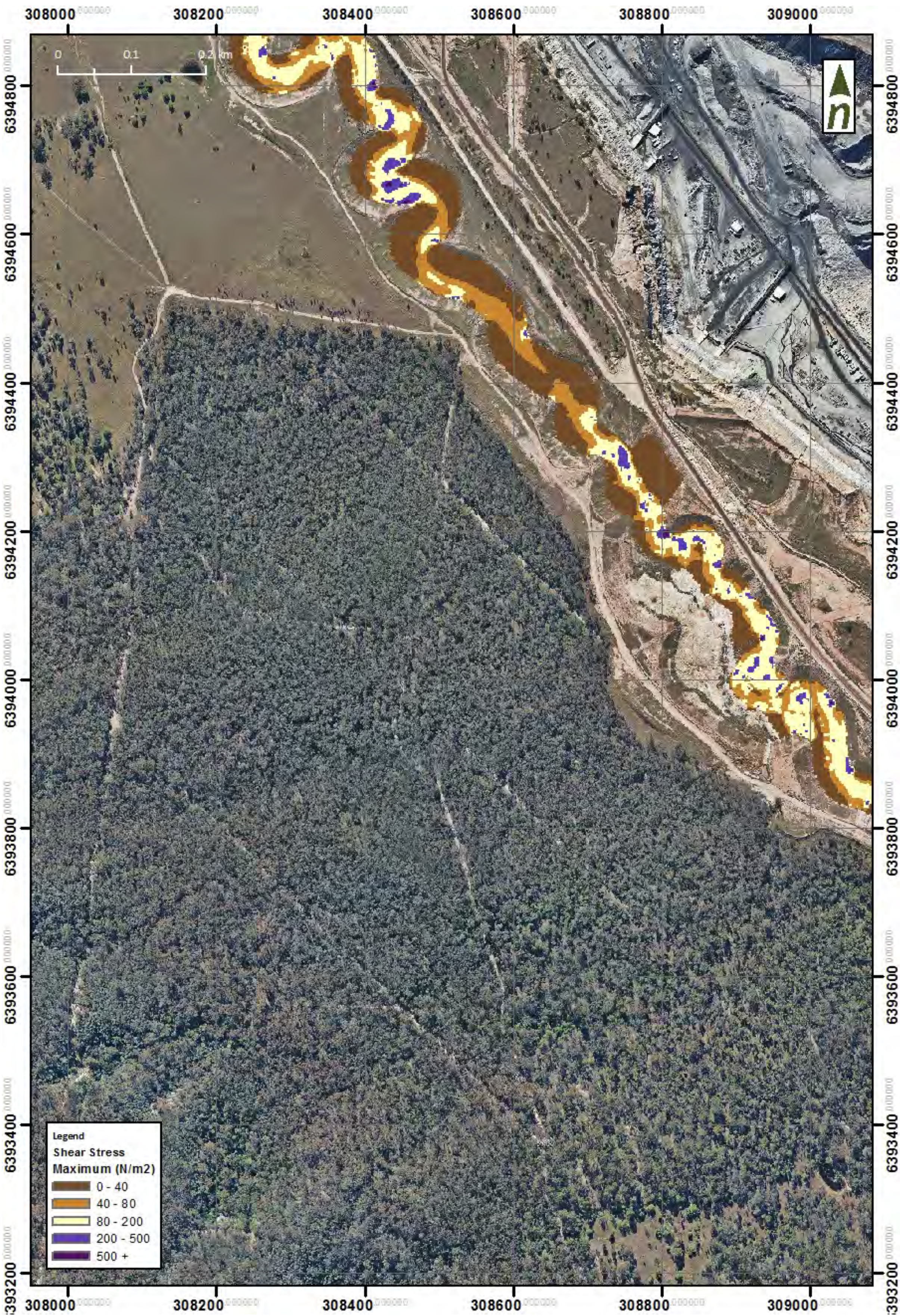


Figure C-63. 100 year ARI flood shear stress (existing conditions)

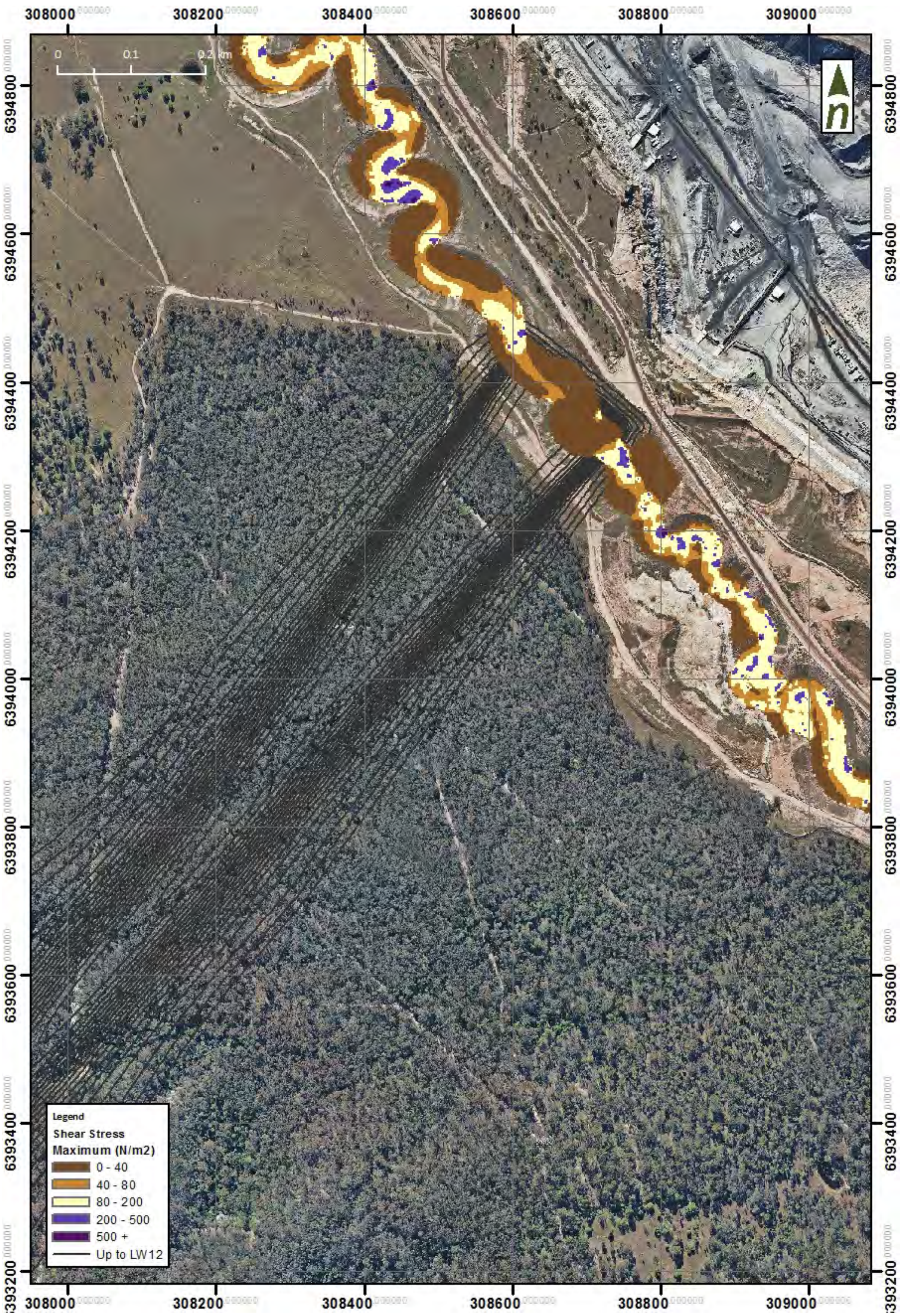


Figure C-64. **100 year ARI flood shear stress (post LW12)**

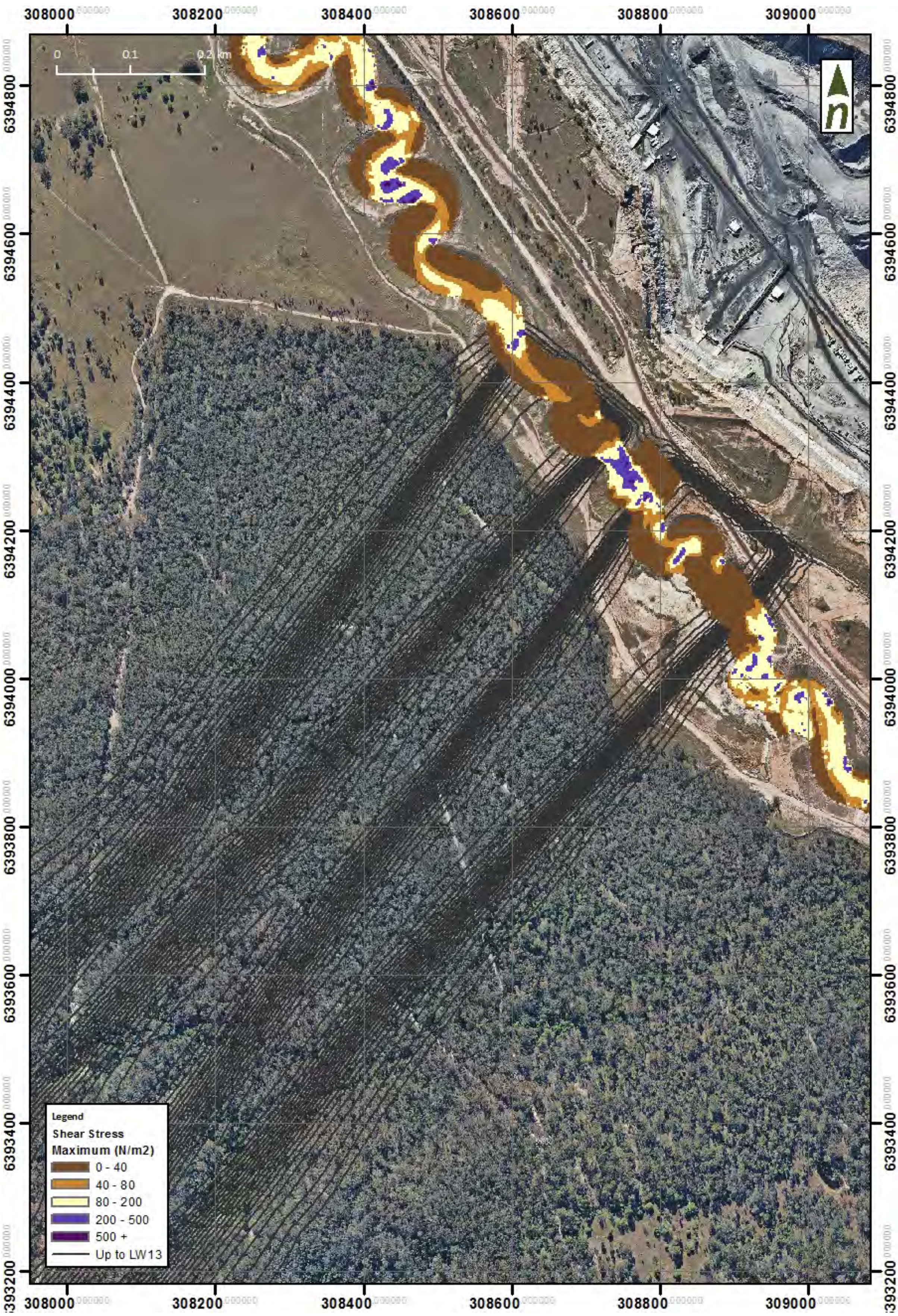


Figure C-65. **100 year ARI flood shear stress (post LW13)**

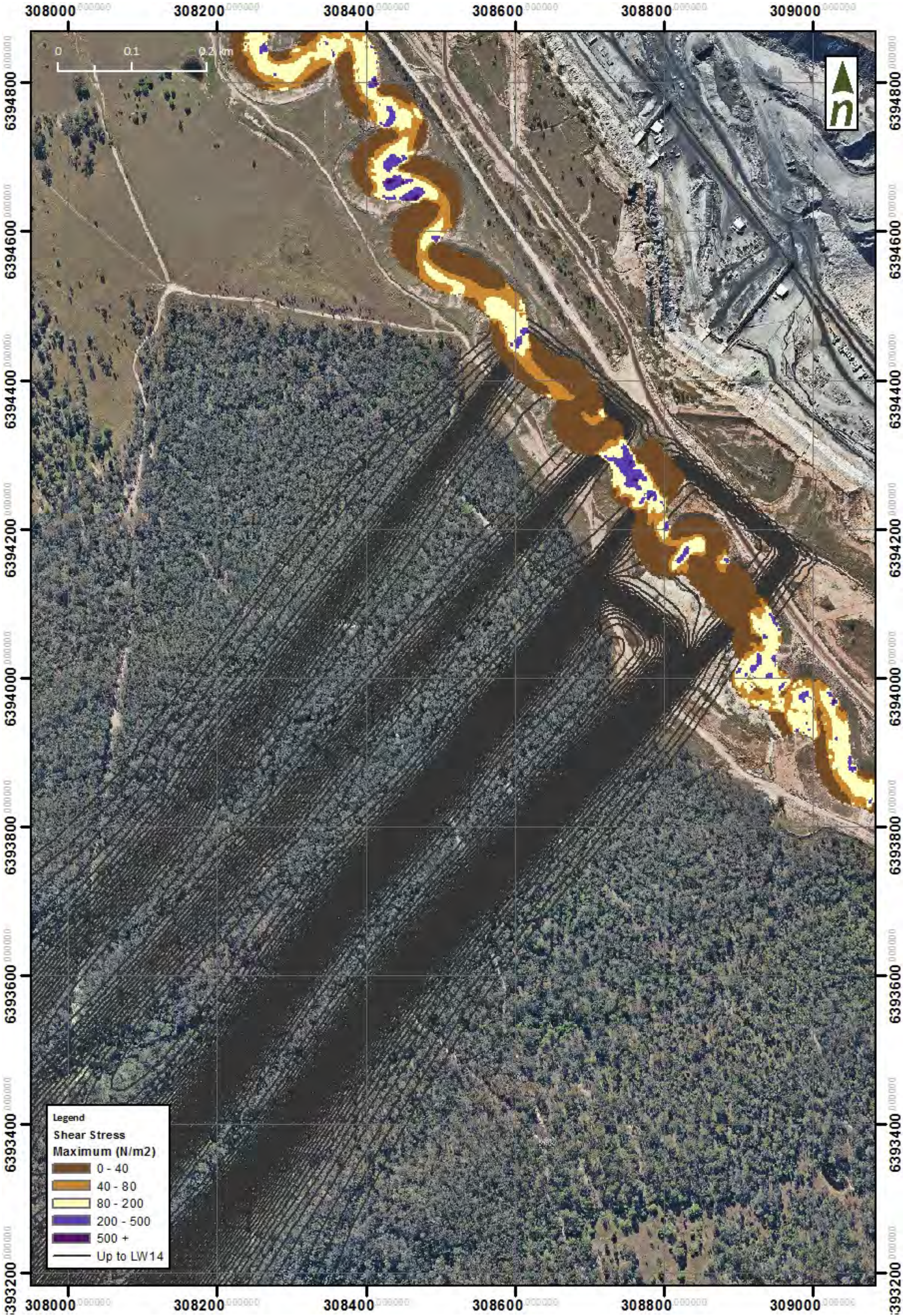


Figure C-66. **100 year ARI flood shear stress (post LW14)**

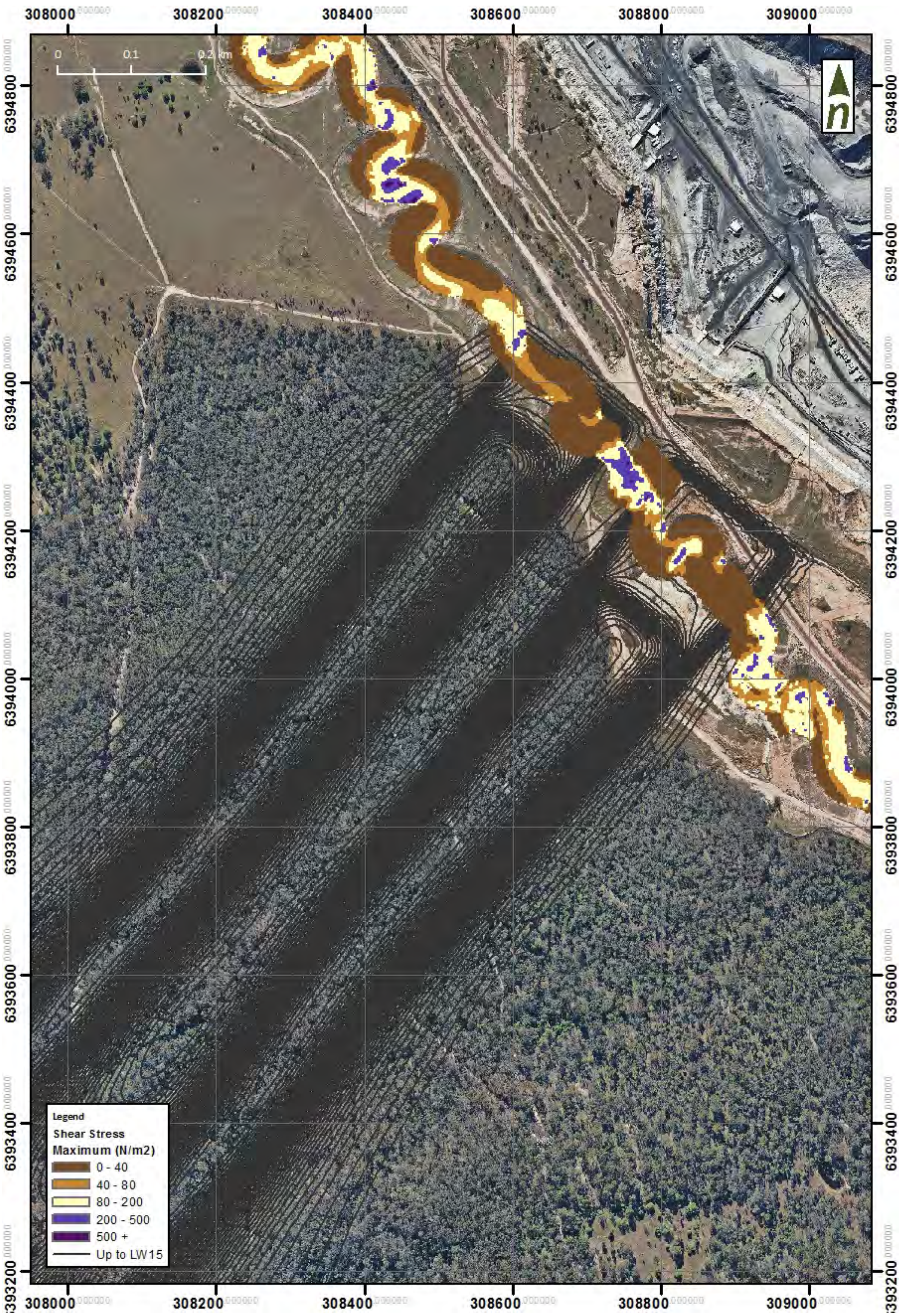


Figure C-67. **100 year ARI flood shear stress (post LW15)**

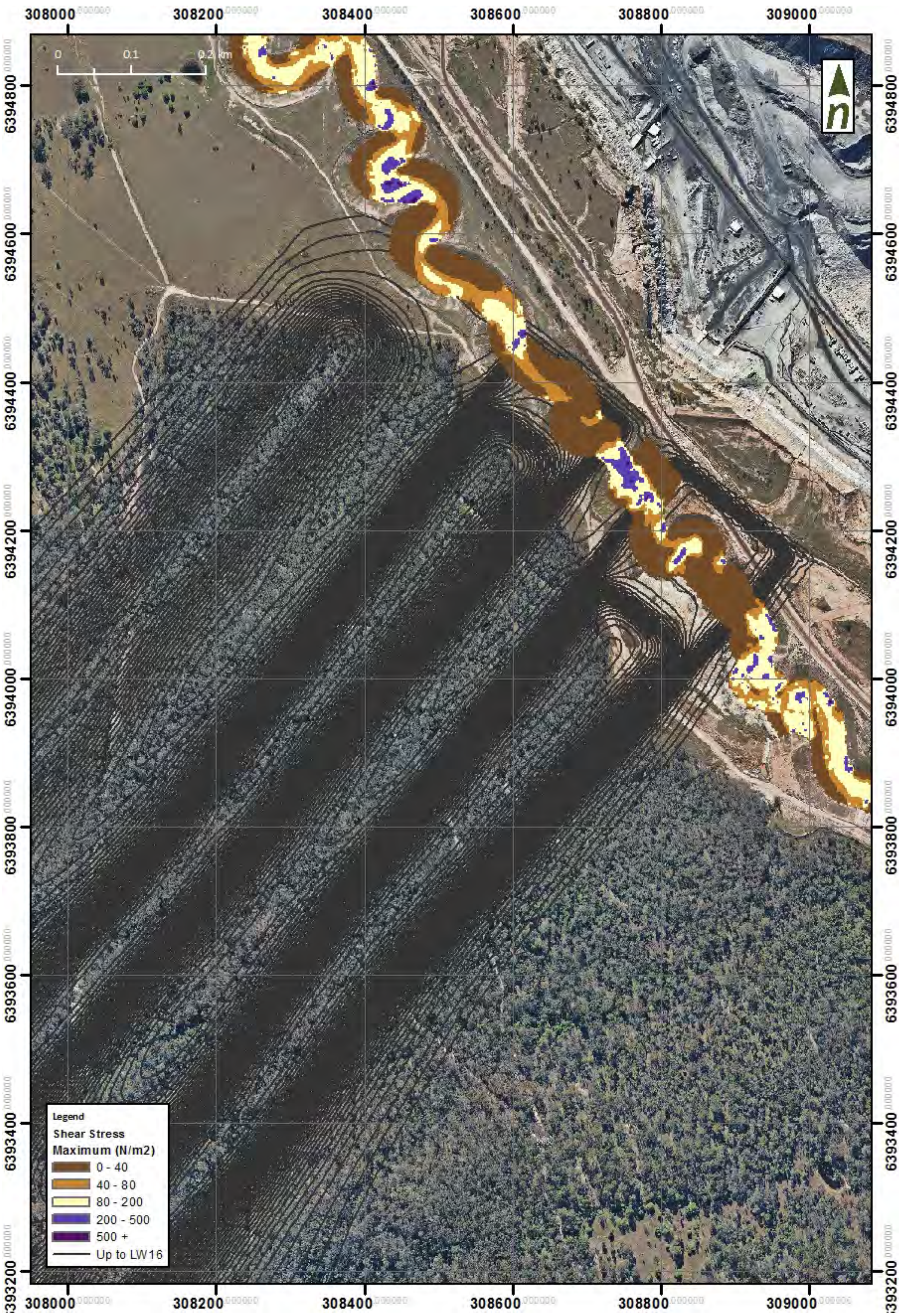


Figure C-68. **100 year ARI flood shear stress (post LW16)**

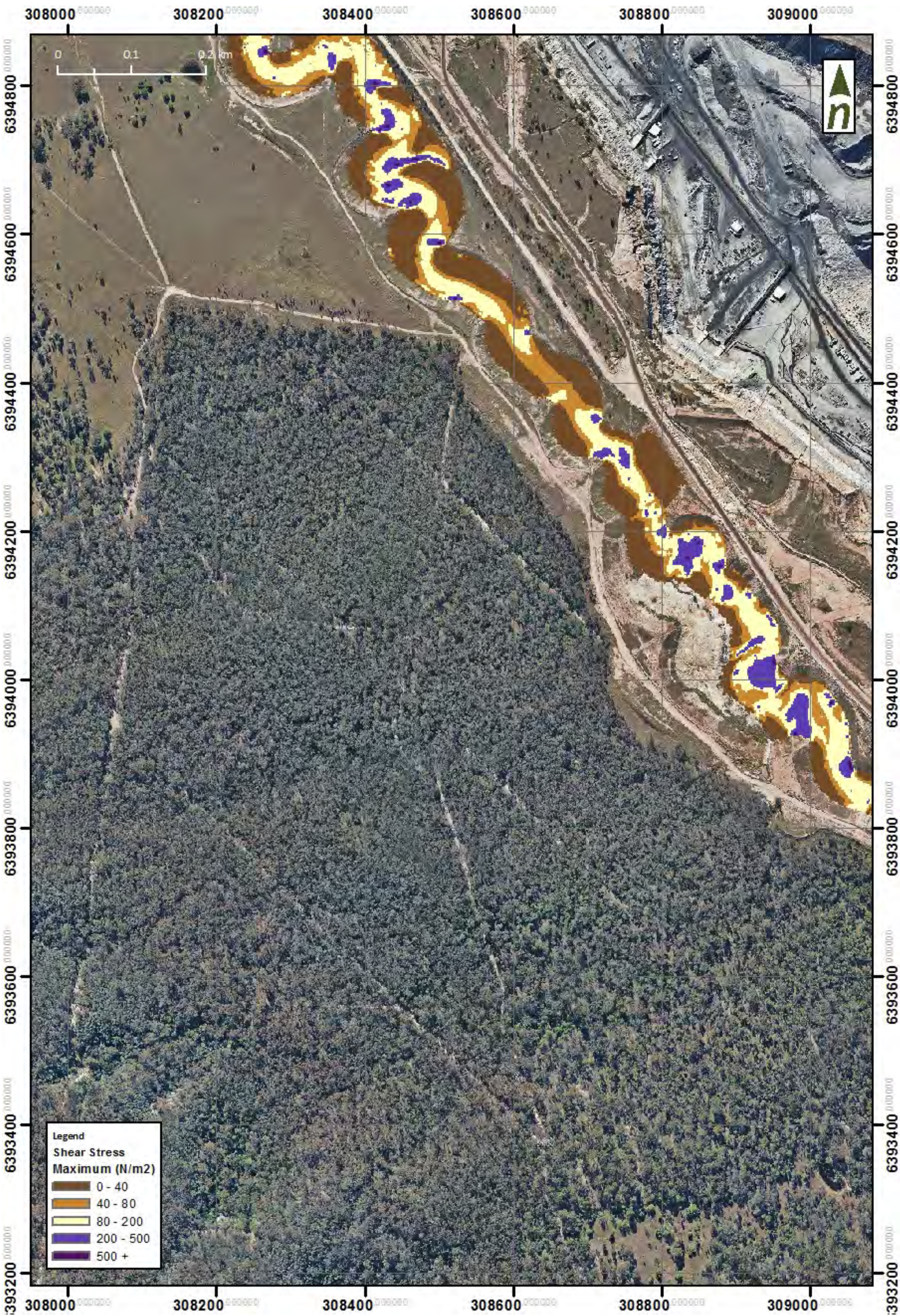


Figure C-69. **1000 year ARI flood shear stress (existing conditions)**

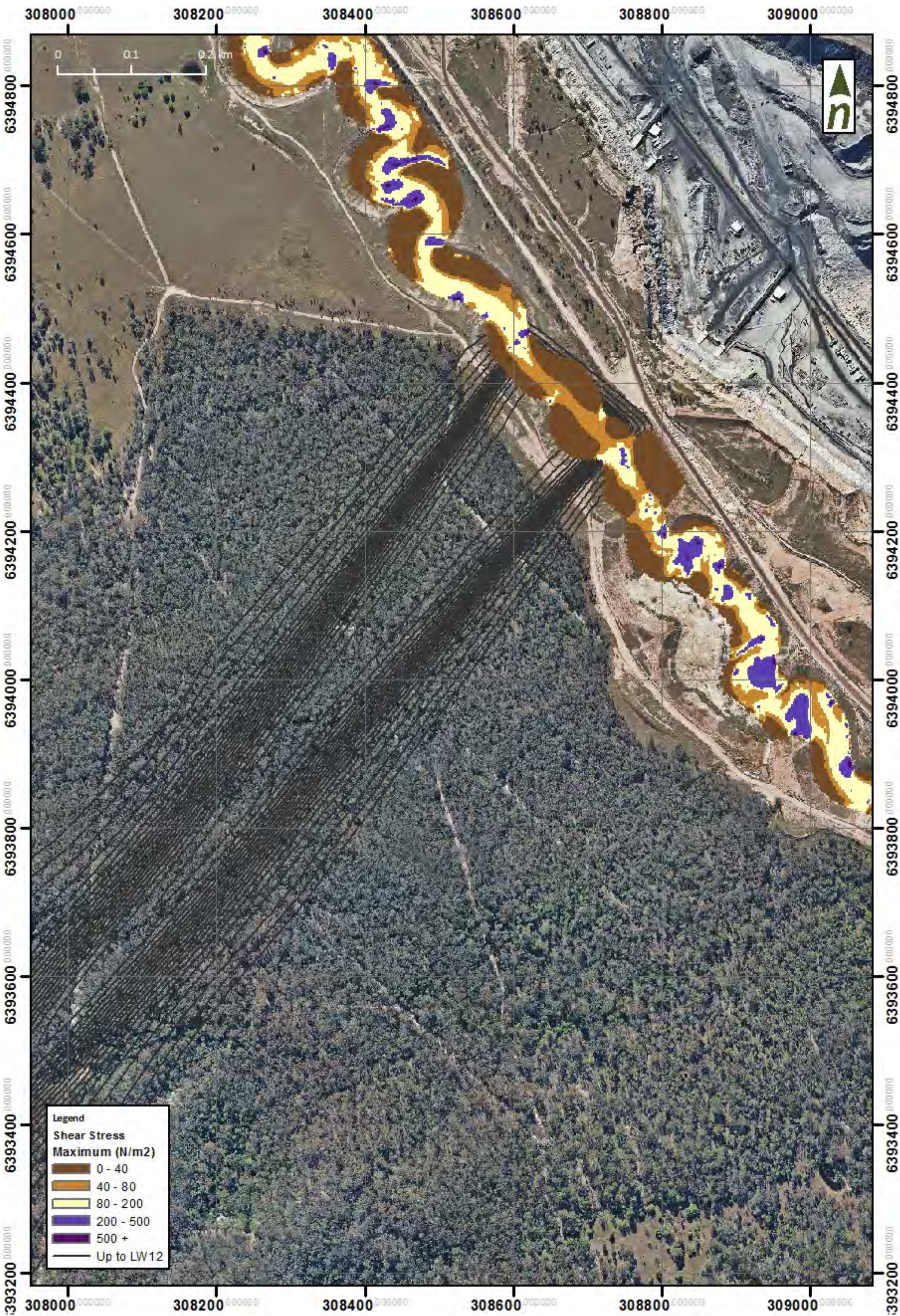


Figure C-70. **1000 year ARI flood shear stress (post LW12)**

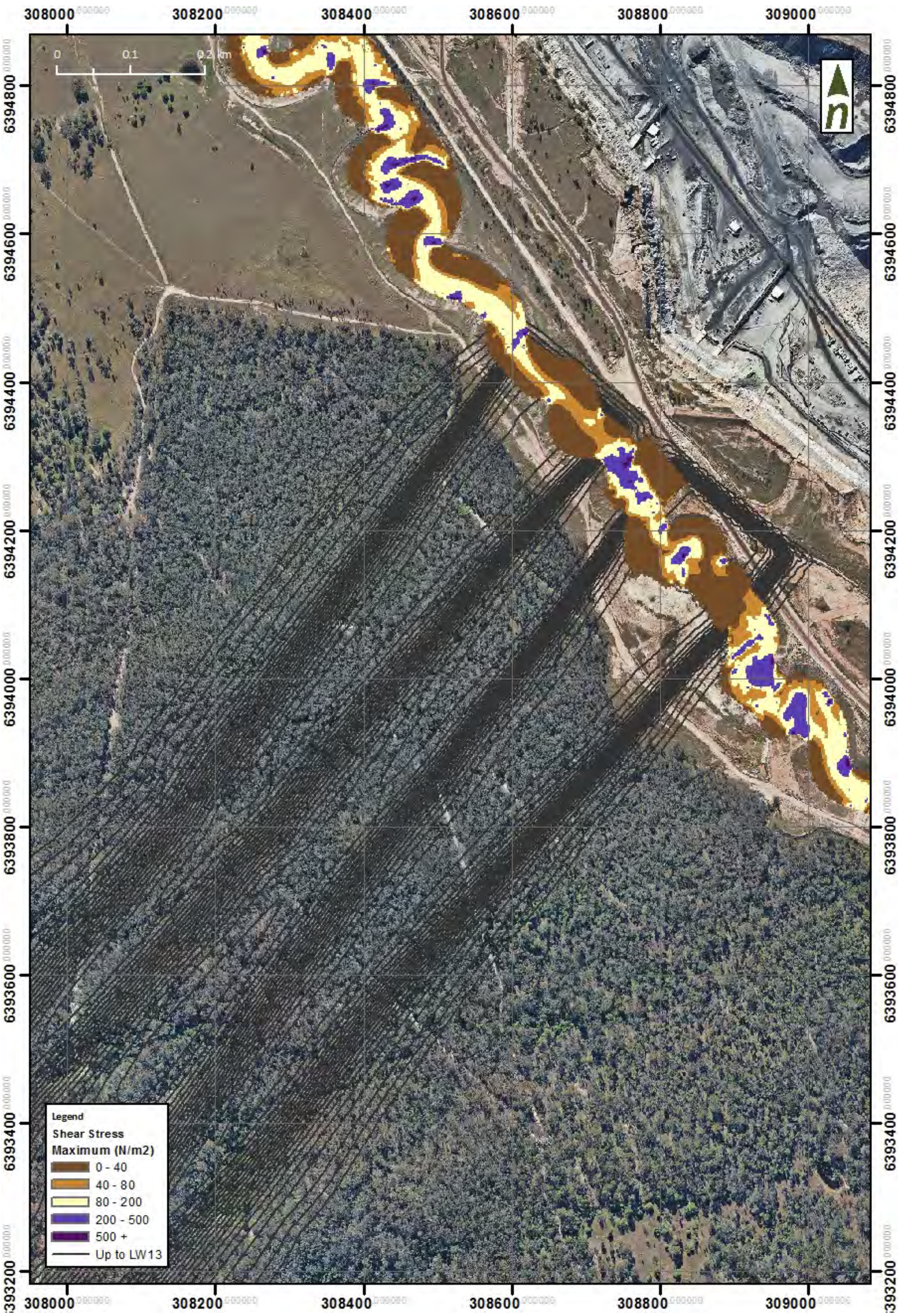


Figure C-71. 1000 year ARI flood shear stress (post LW13)

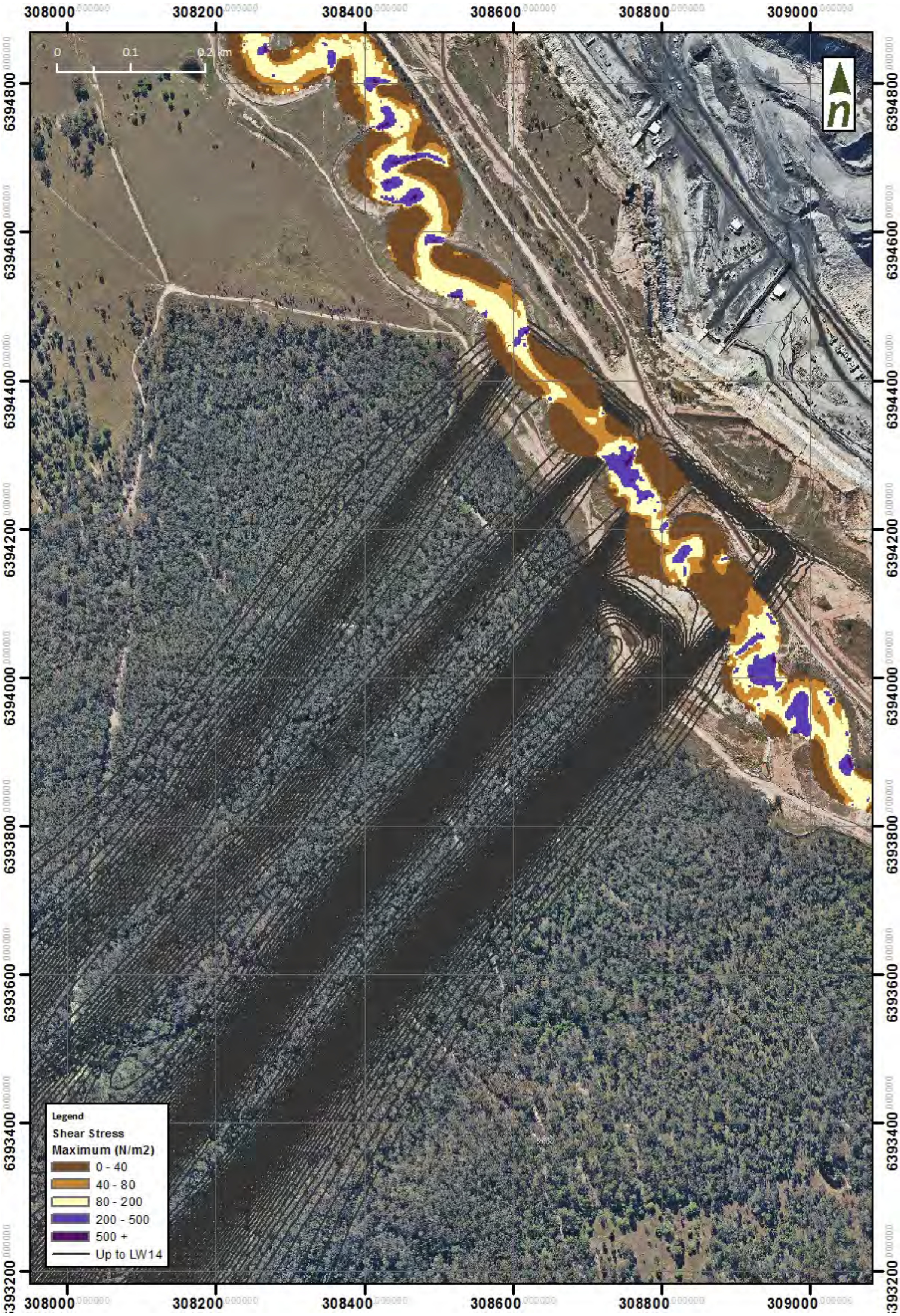


Figure C-72. **1000 year ARI flood shear stress (post LW14)**

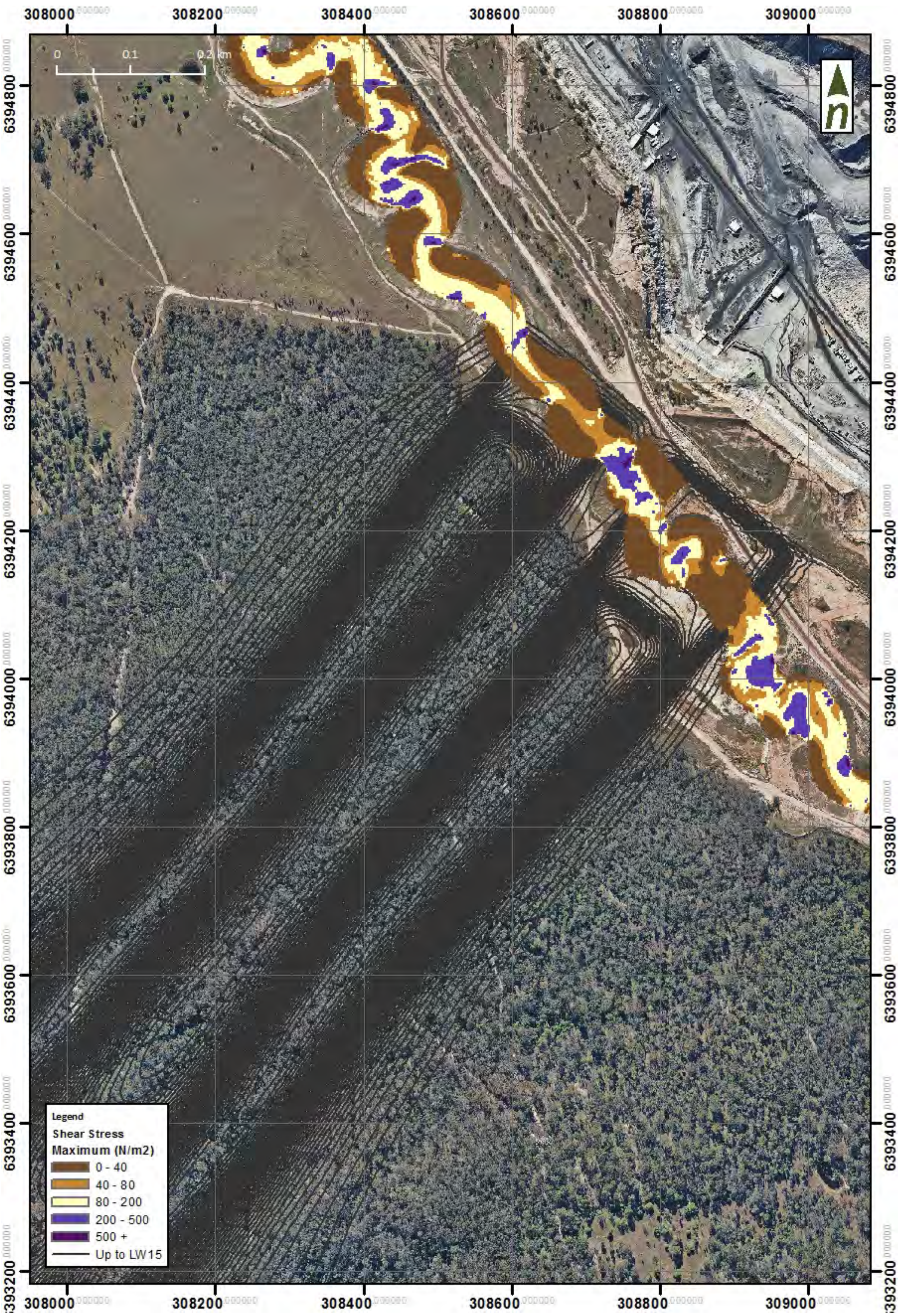


Figure C-73. 1000 year ARI flood shear stress (post LW15)

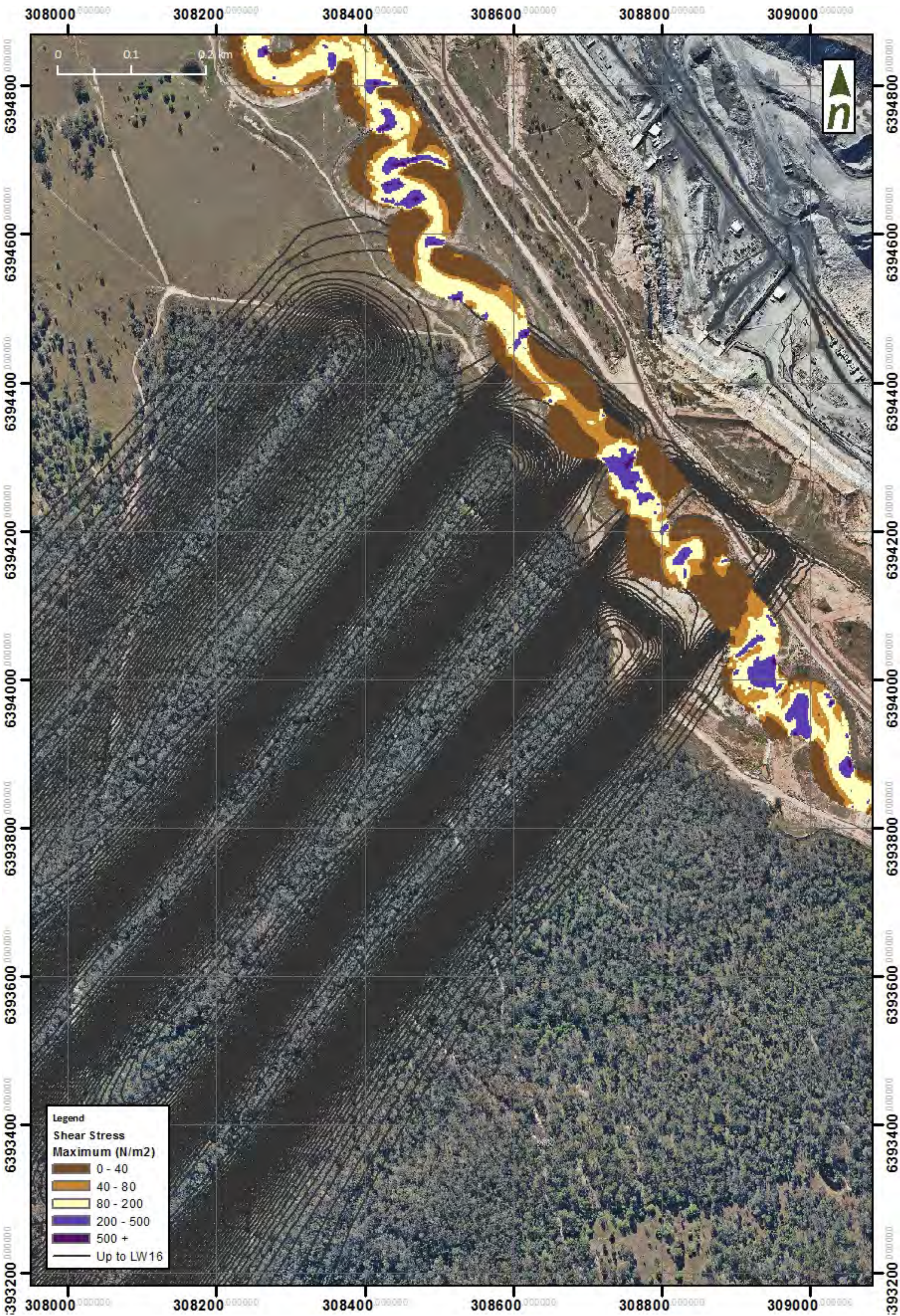


Figure C-74. **1000 year ARI flood shear stress (post LW16)**

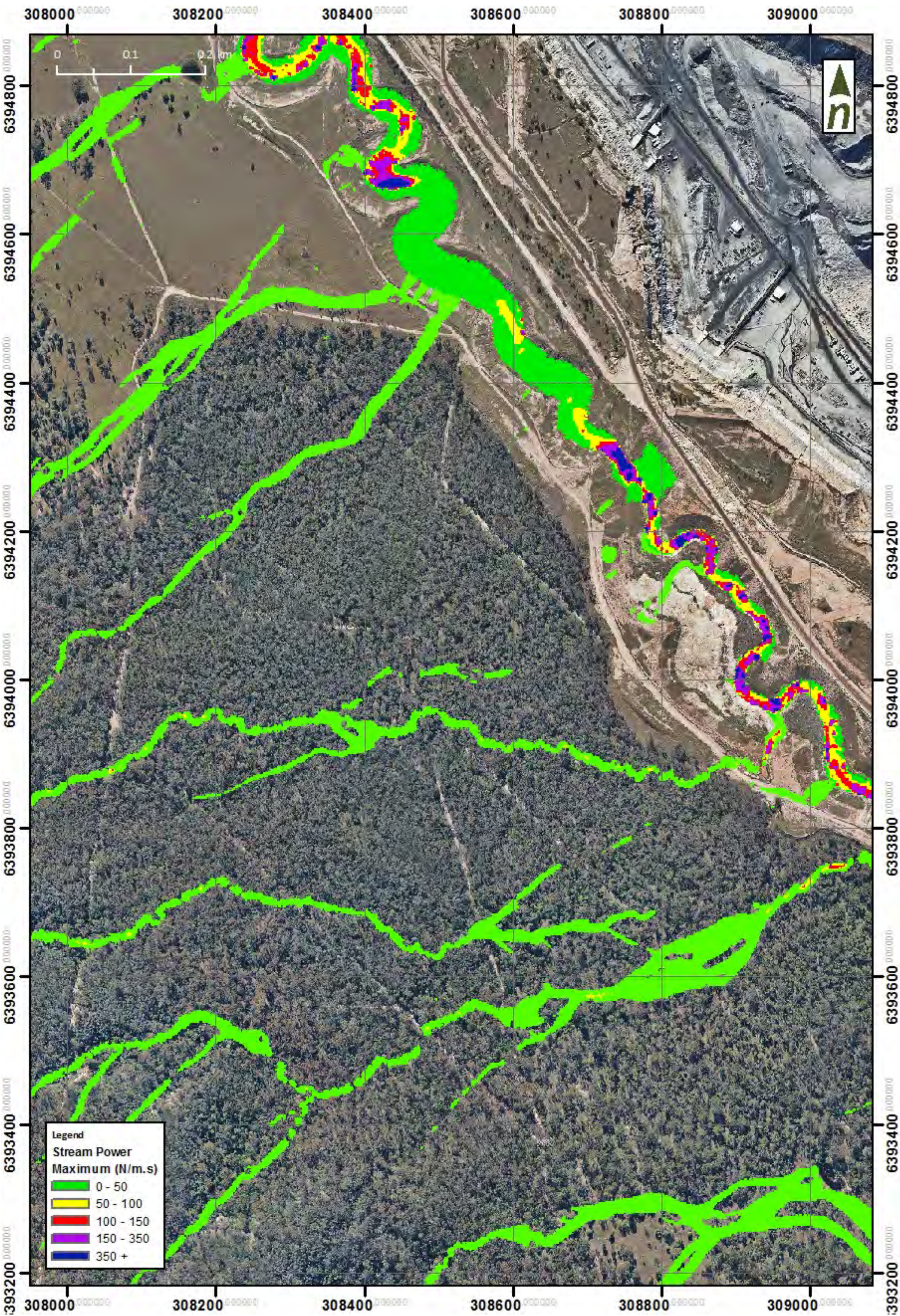


Figure C-75. **2 year ARI flood stream power (existing conditions)**

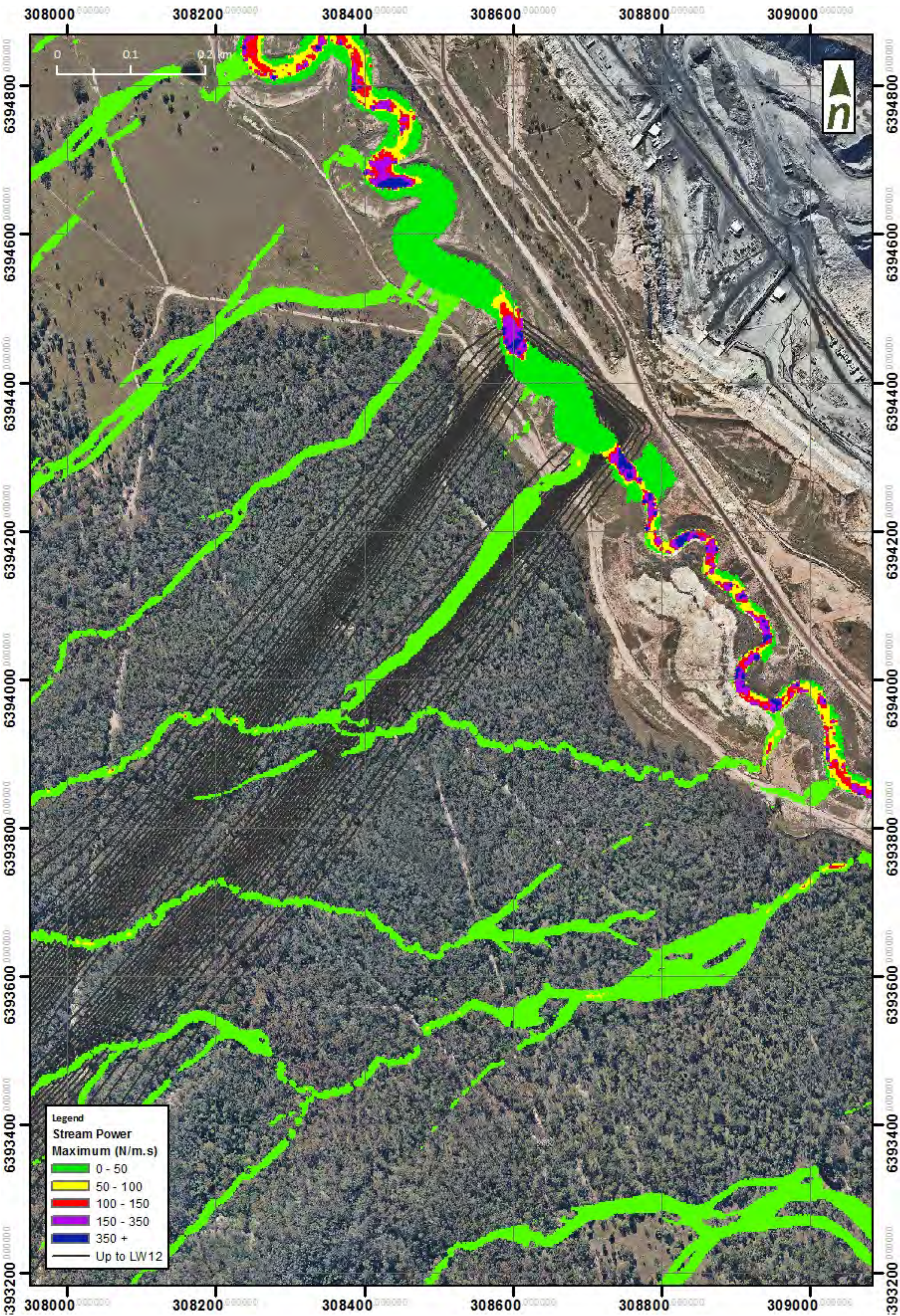


Figure C-76. **2 year ARI flood stream power (post LW12)**

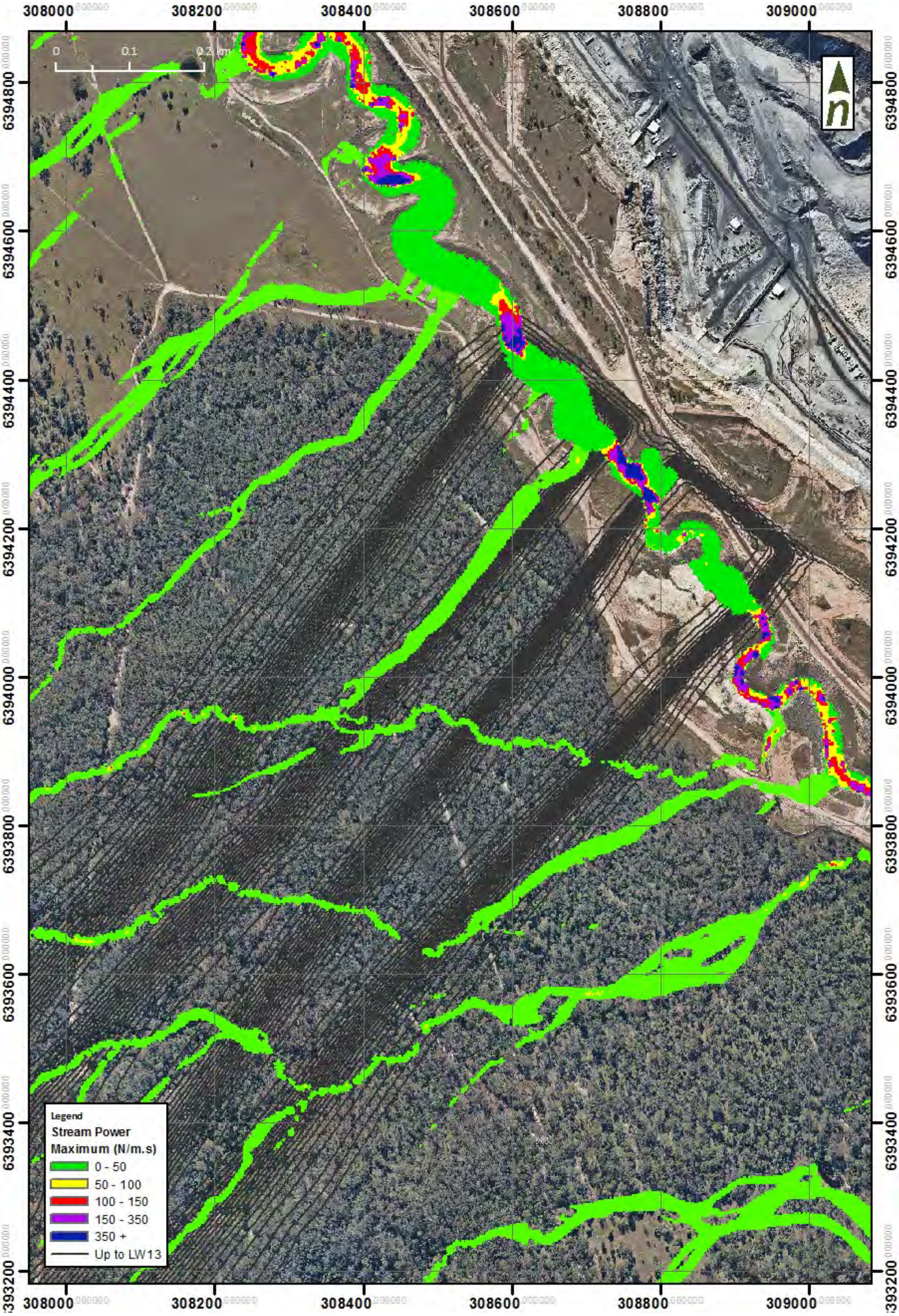


Figure C-77. **2 year ARI flood stream power (post LW13)**

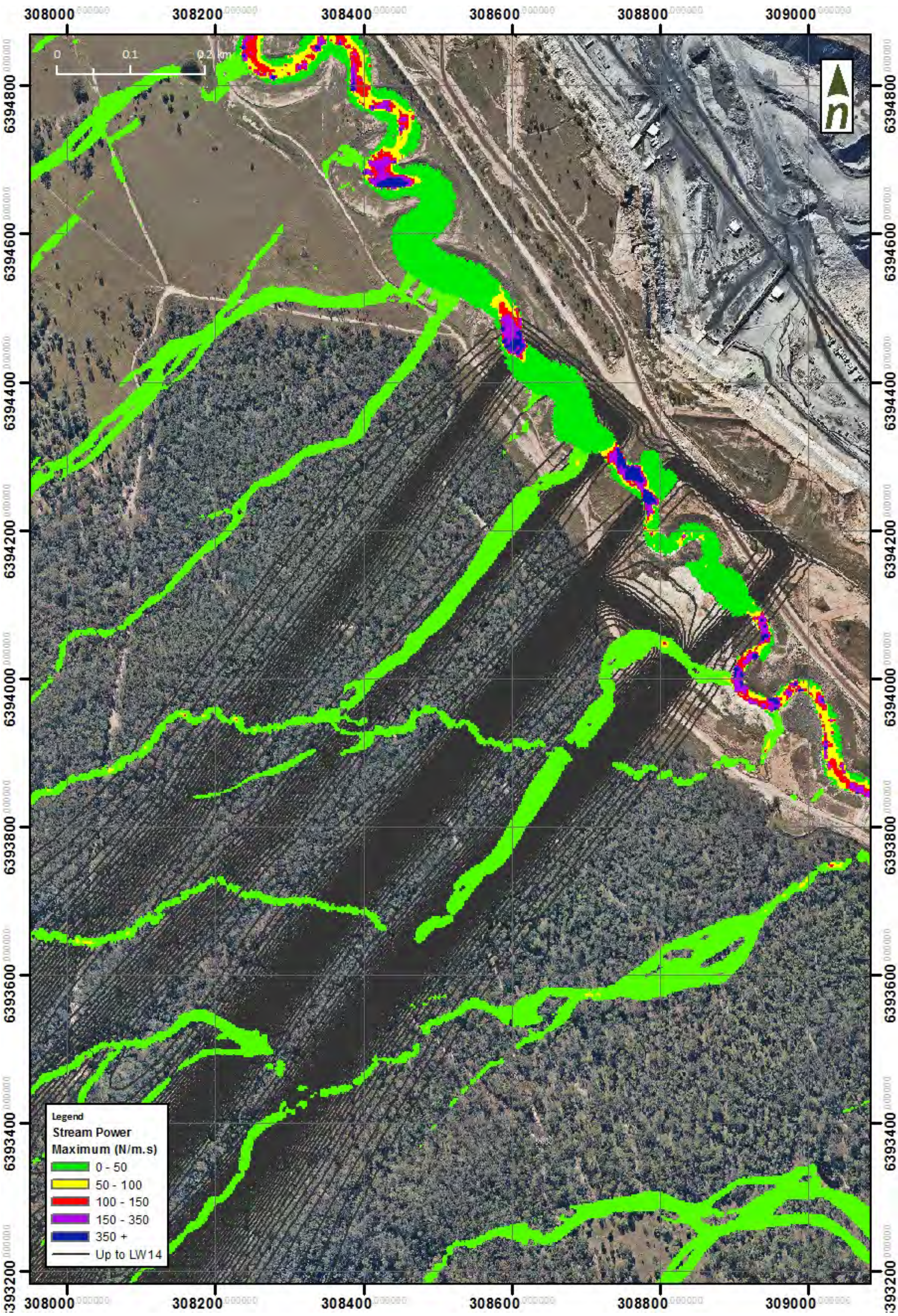


Figure C-78. **2 year ARI flood stream power (post LW14)**

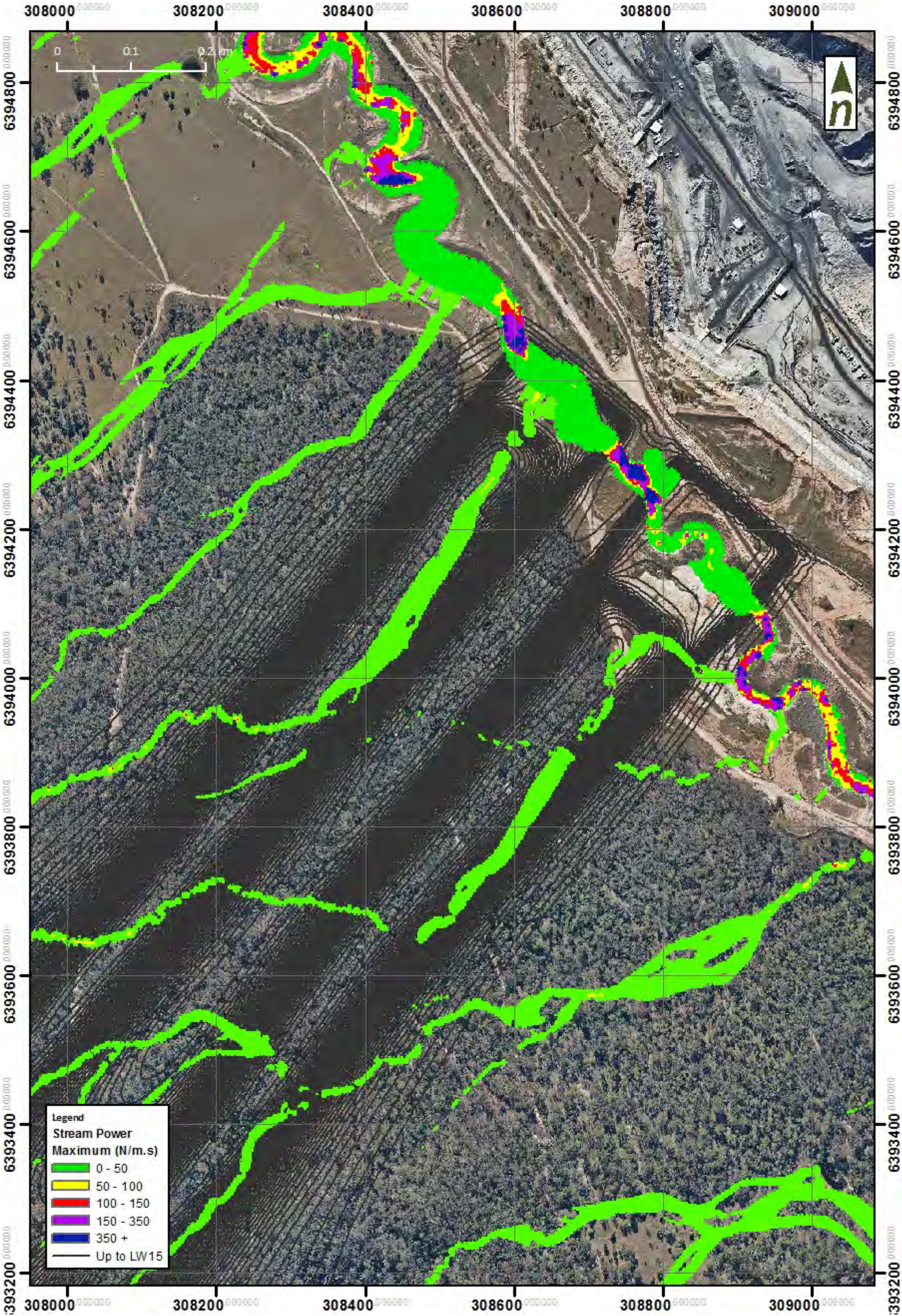


Figure C-79. **2 year ARI flood stream power (post LW15)**

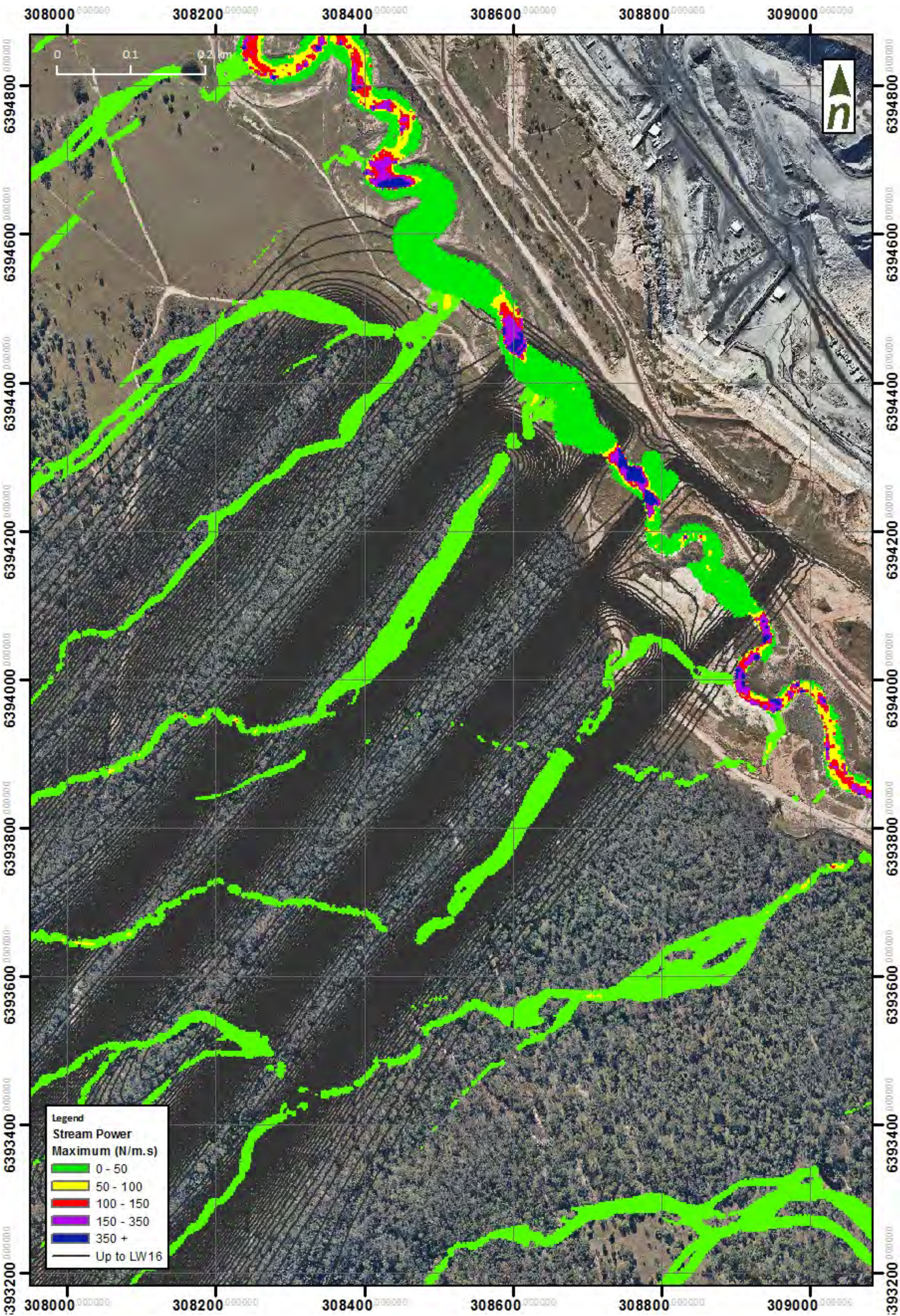


Figure C-80. 2 year ARI flood stream power (post LW16)

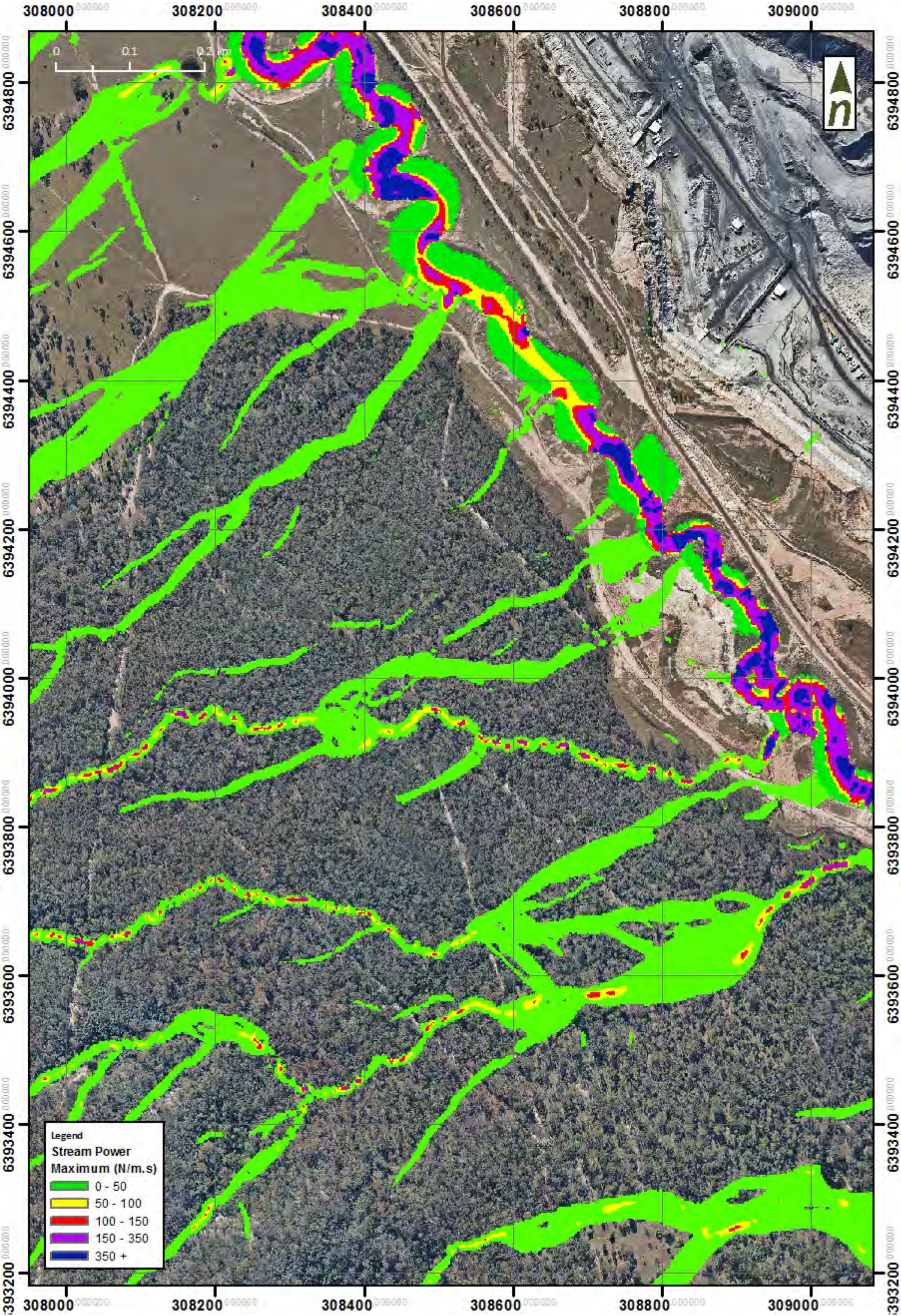


Figure C-81. **50 year ARI flood stream power (existing conditions)**

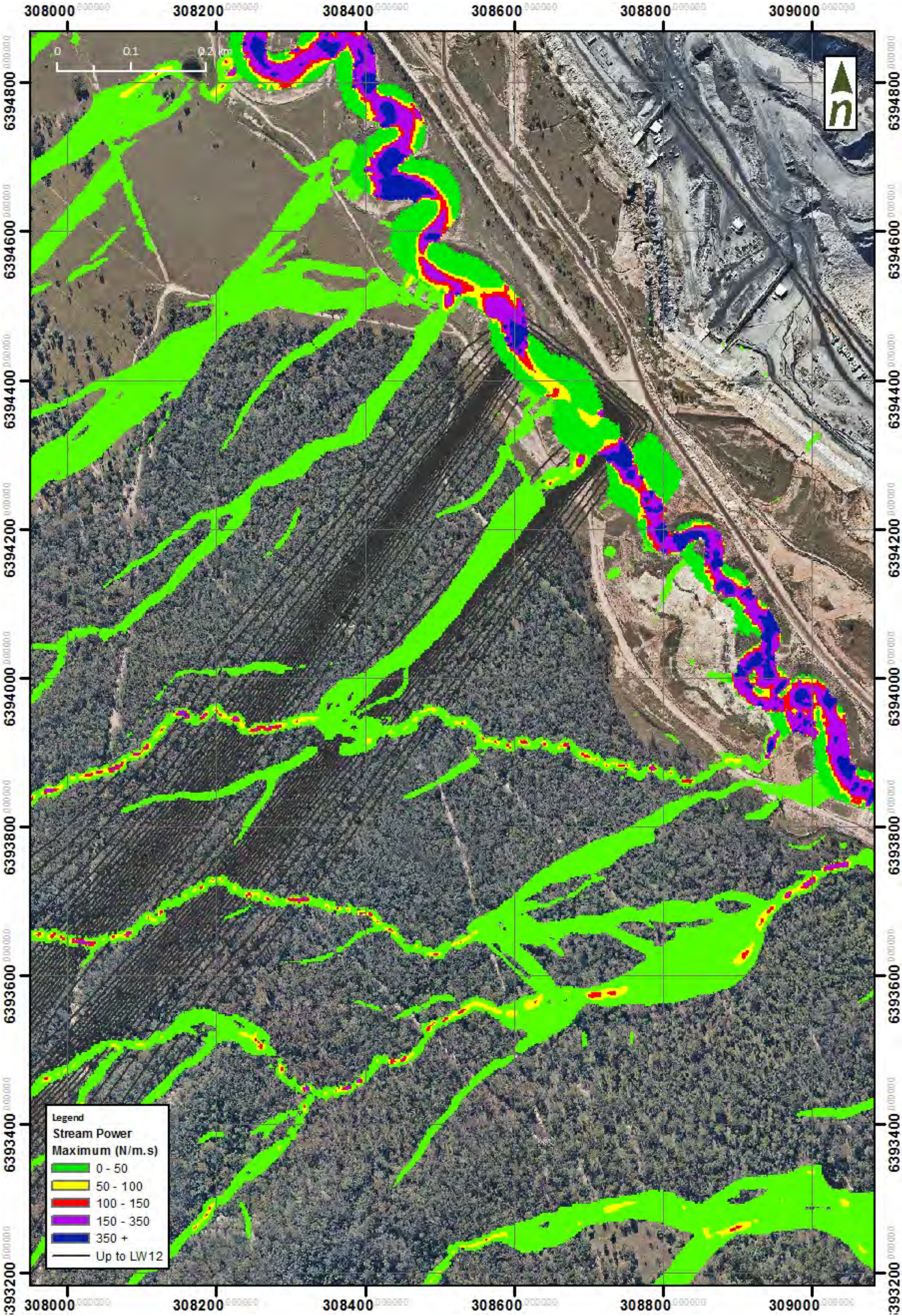


Figure C-82. 50 year ARI flood stream power (post LW12)

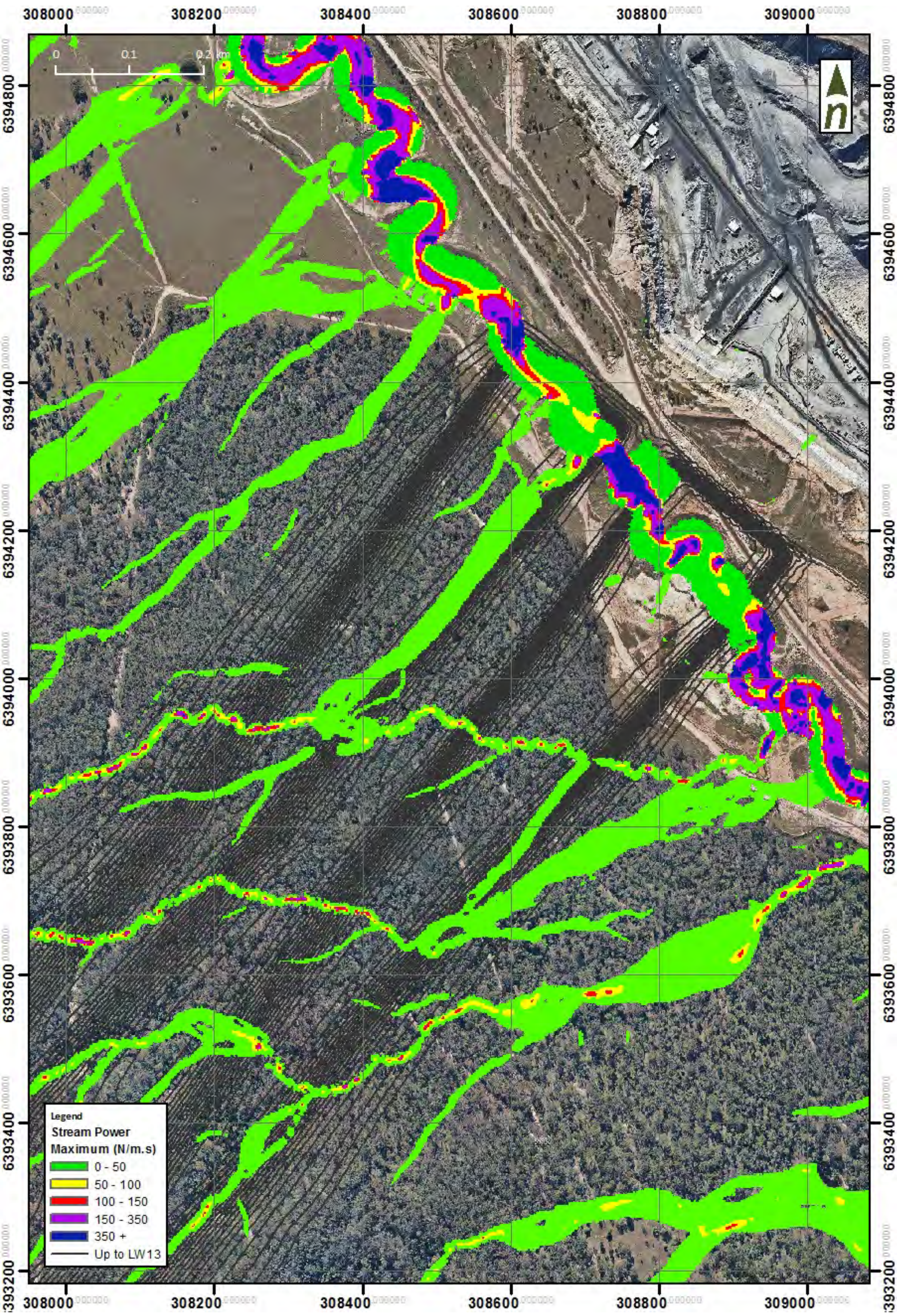


Figure C-83. **50 year ARI flood stream power (post LW13)**

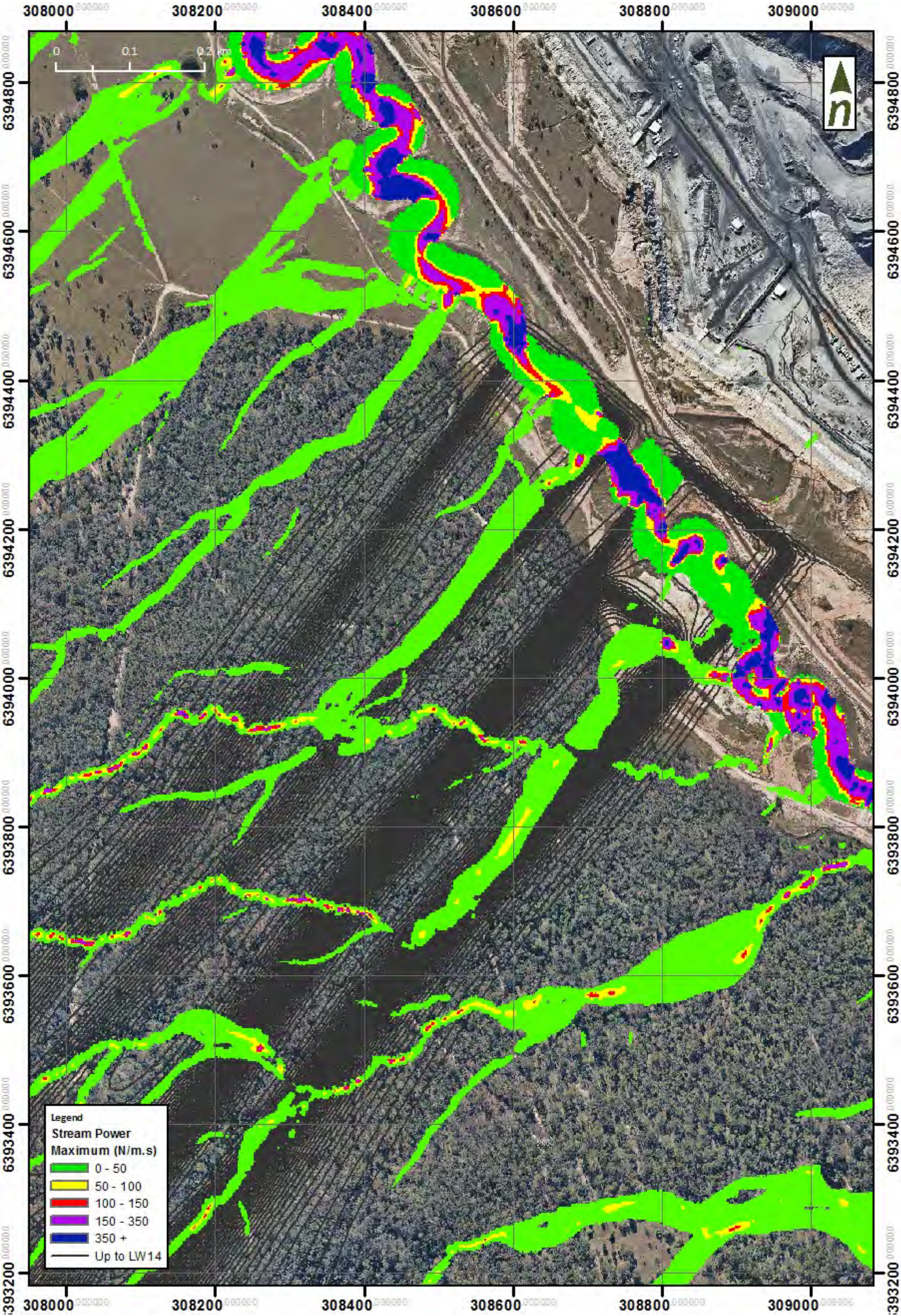


Figure C-84. 50 year ARI flood stream power (post LW14)

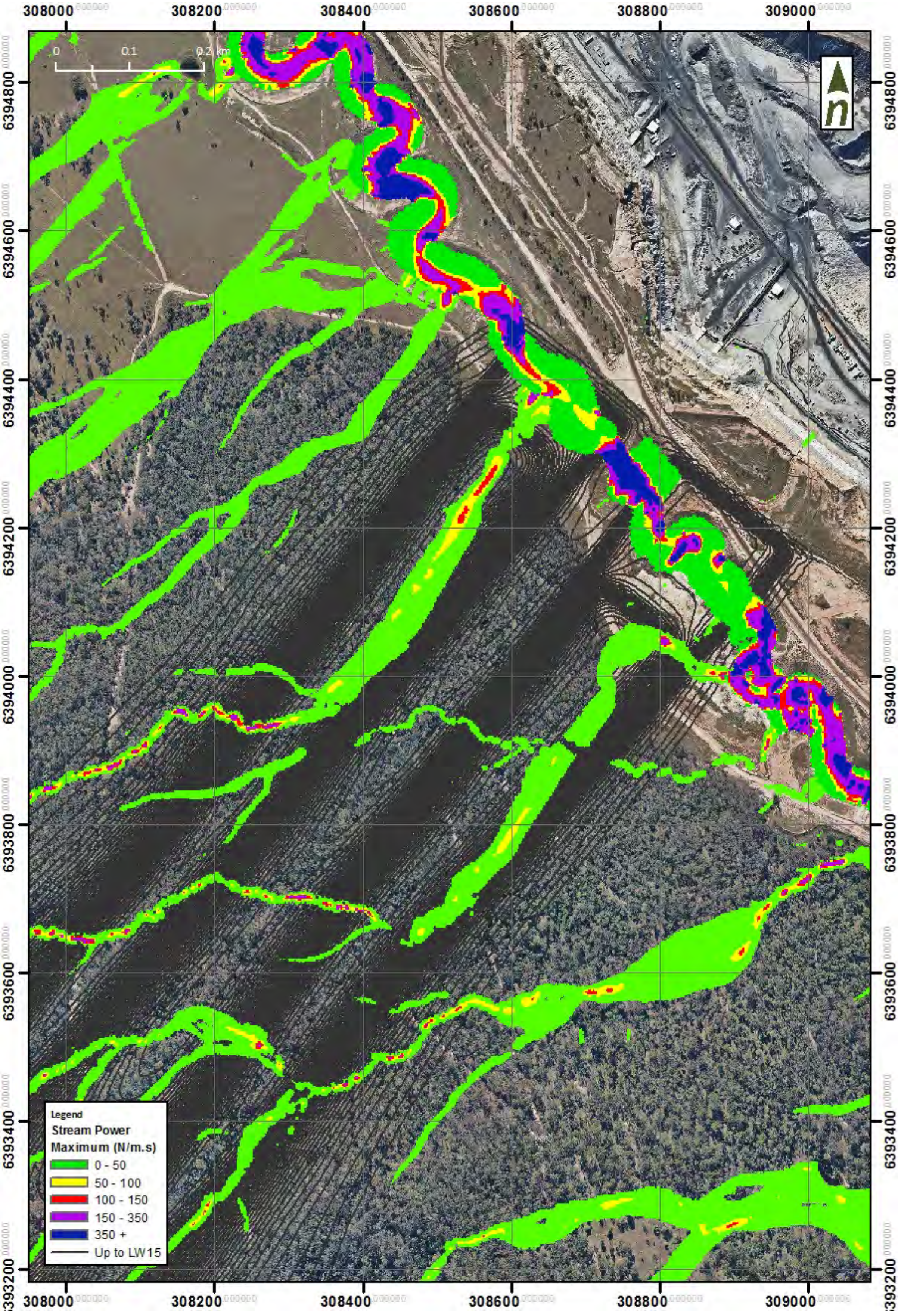


Figure C-85. **50 year ARI flood stream power (post LW15)**

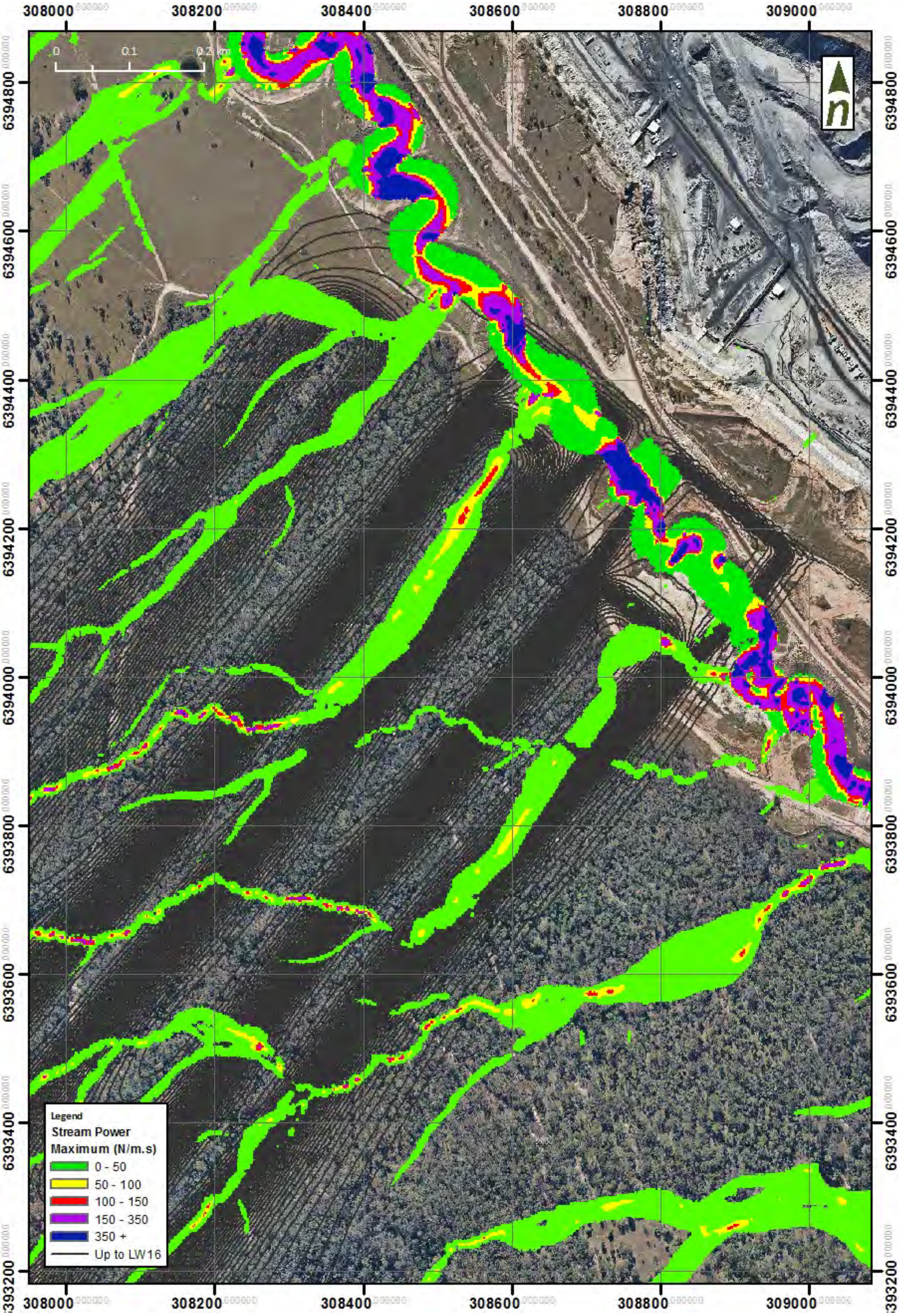


Figure C-86. **50 year ARI flood stream power (post LW16)**

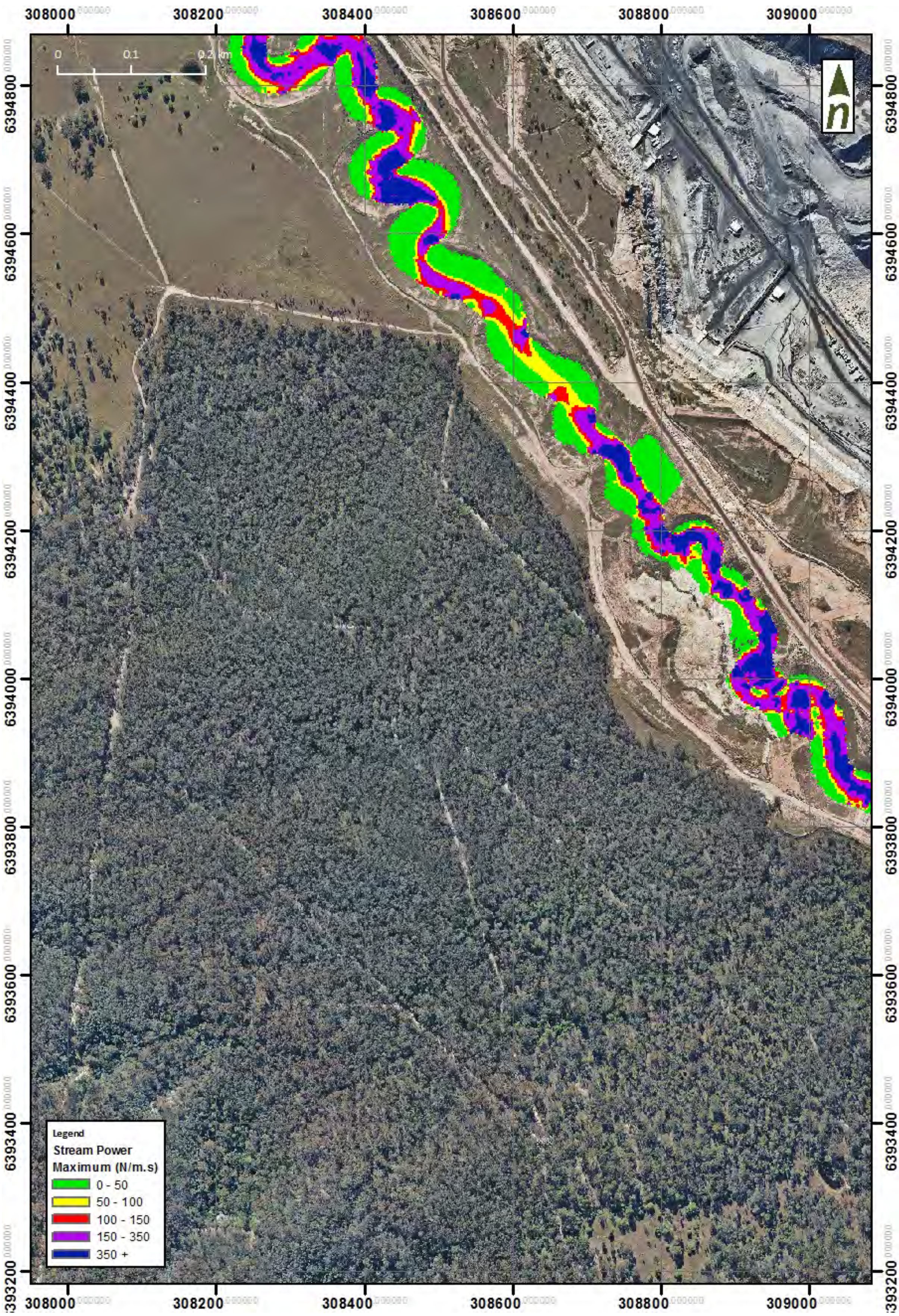


Figure C-87. 100 year ARI flood stream power (existing conditions)

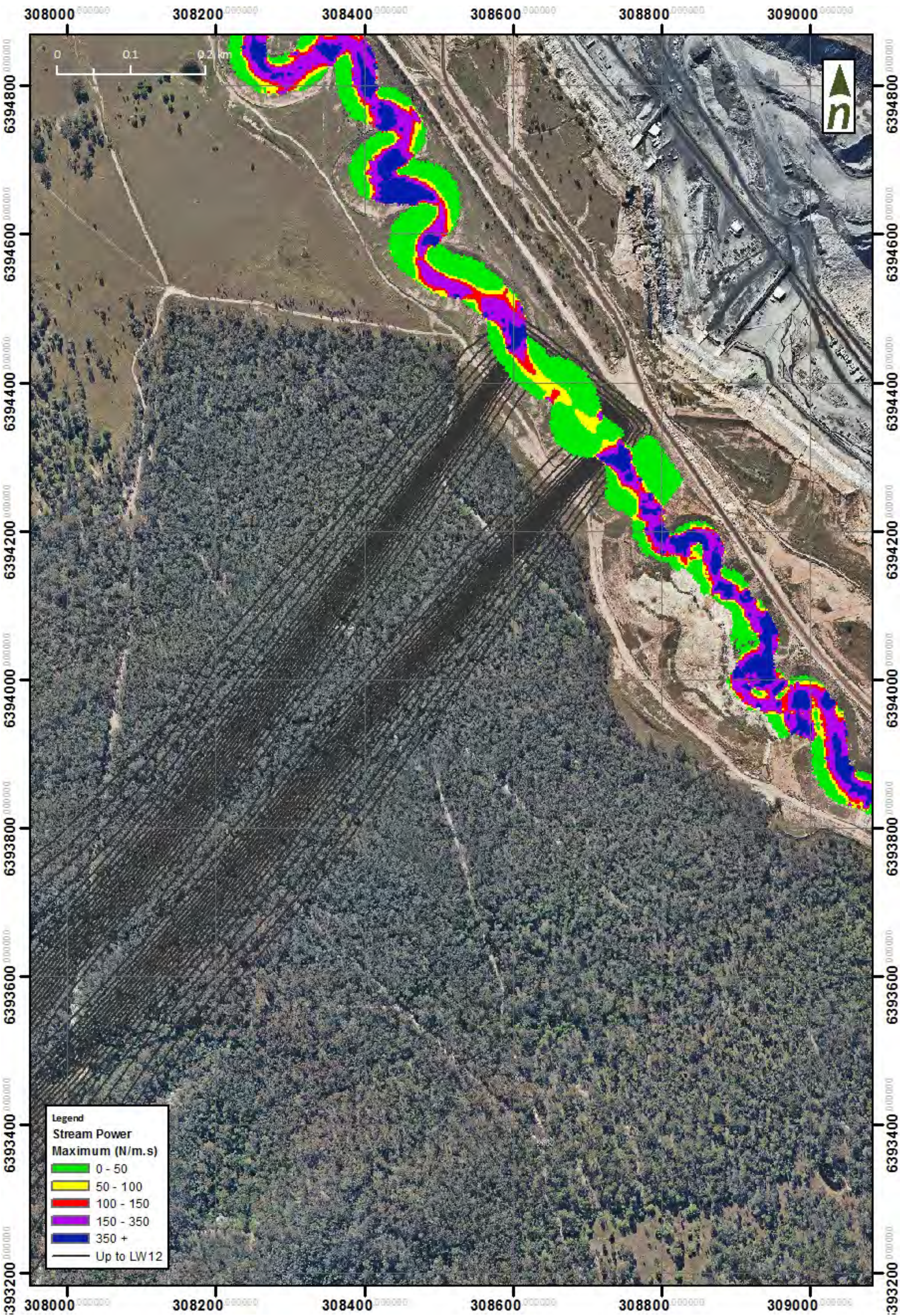


Figure C-88. **100 year ARI flood stream power (post LW12)**

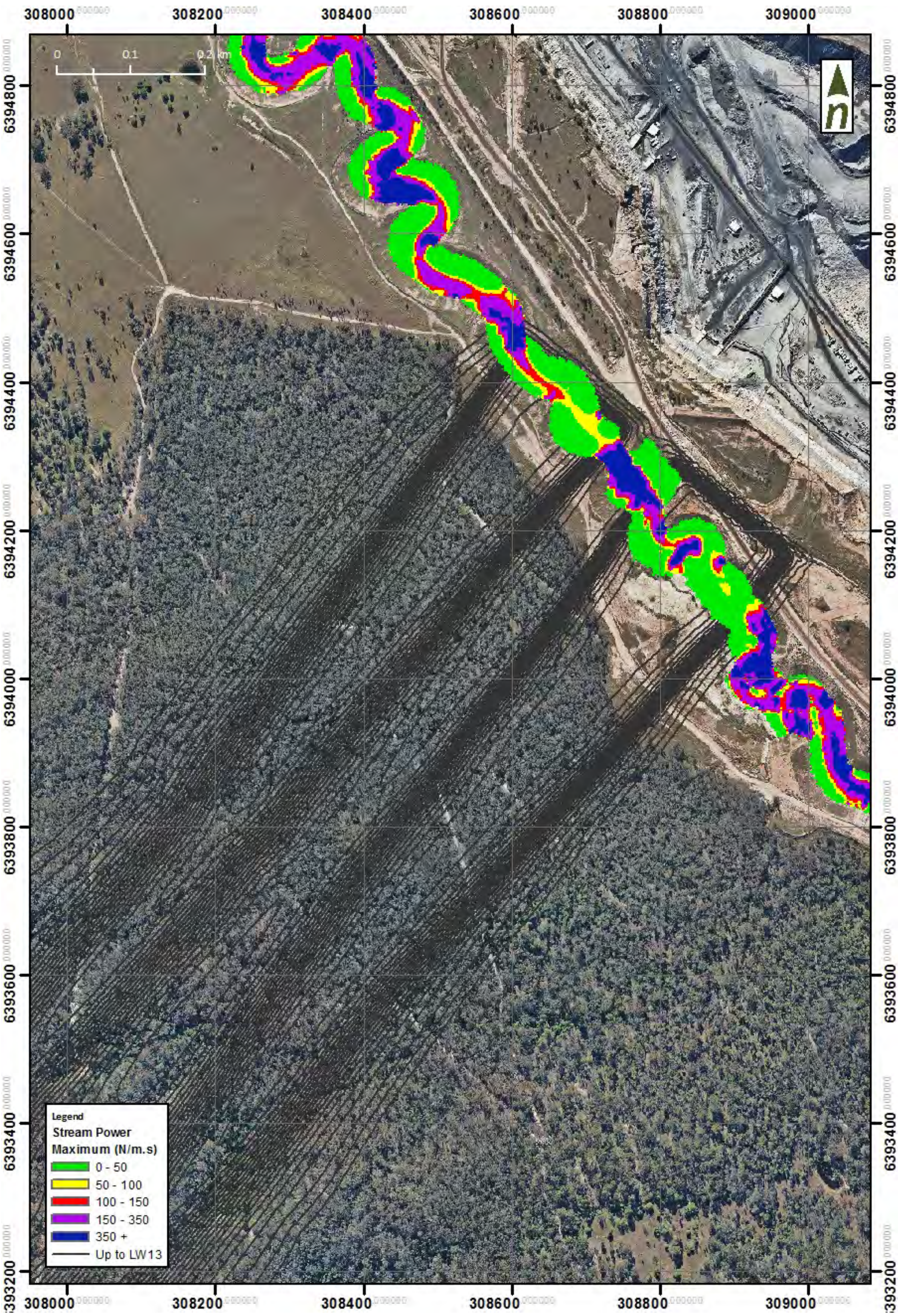


Figure C-89. **100 year ARI flood stream power (post LW13)**

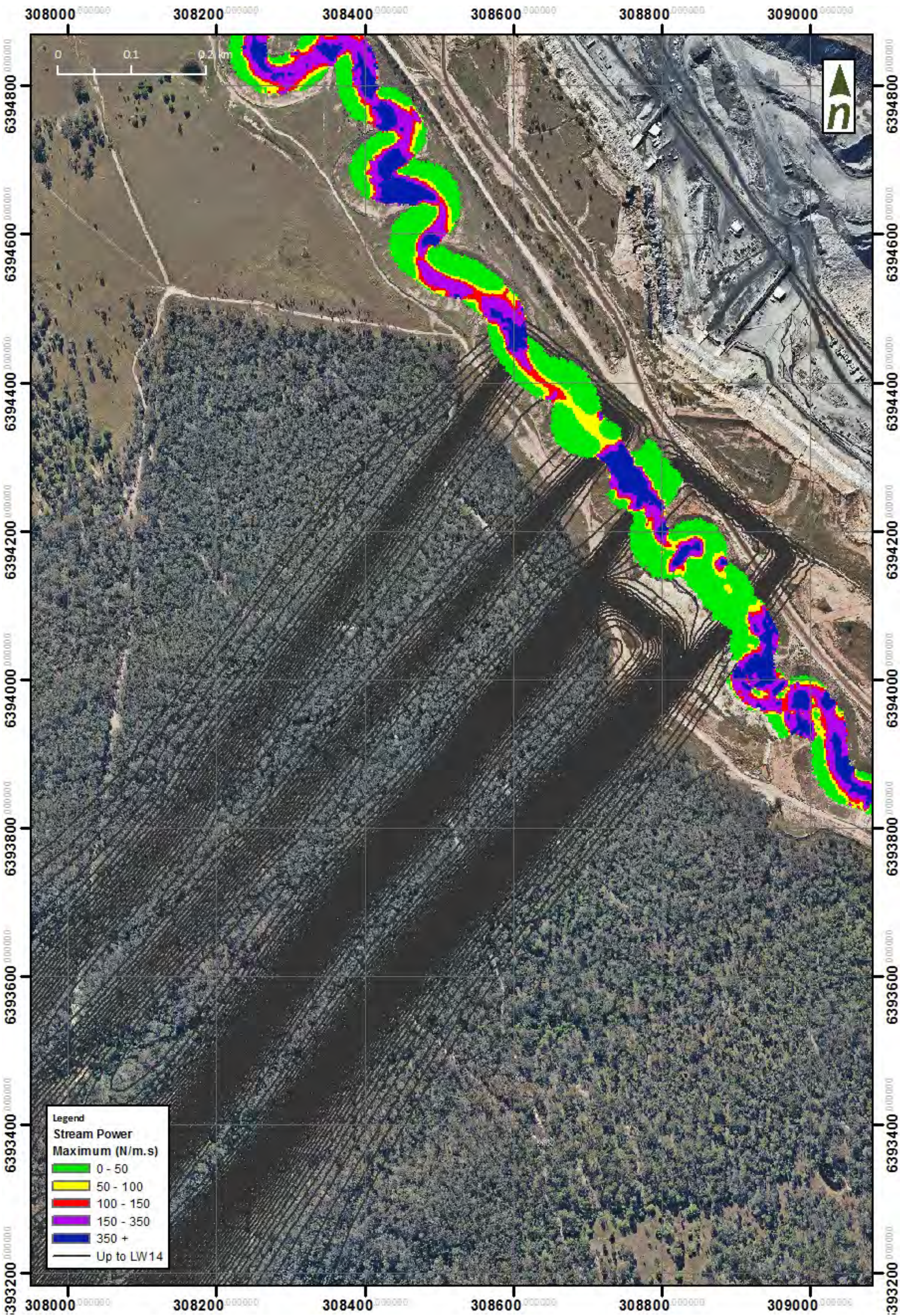


Figure C-90. 100 year ARI flood stream power (post LW14)

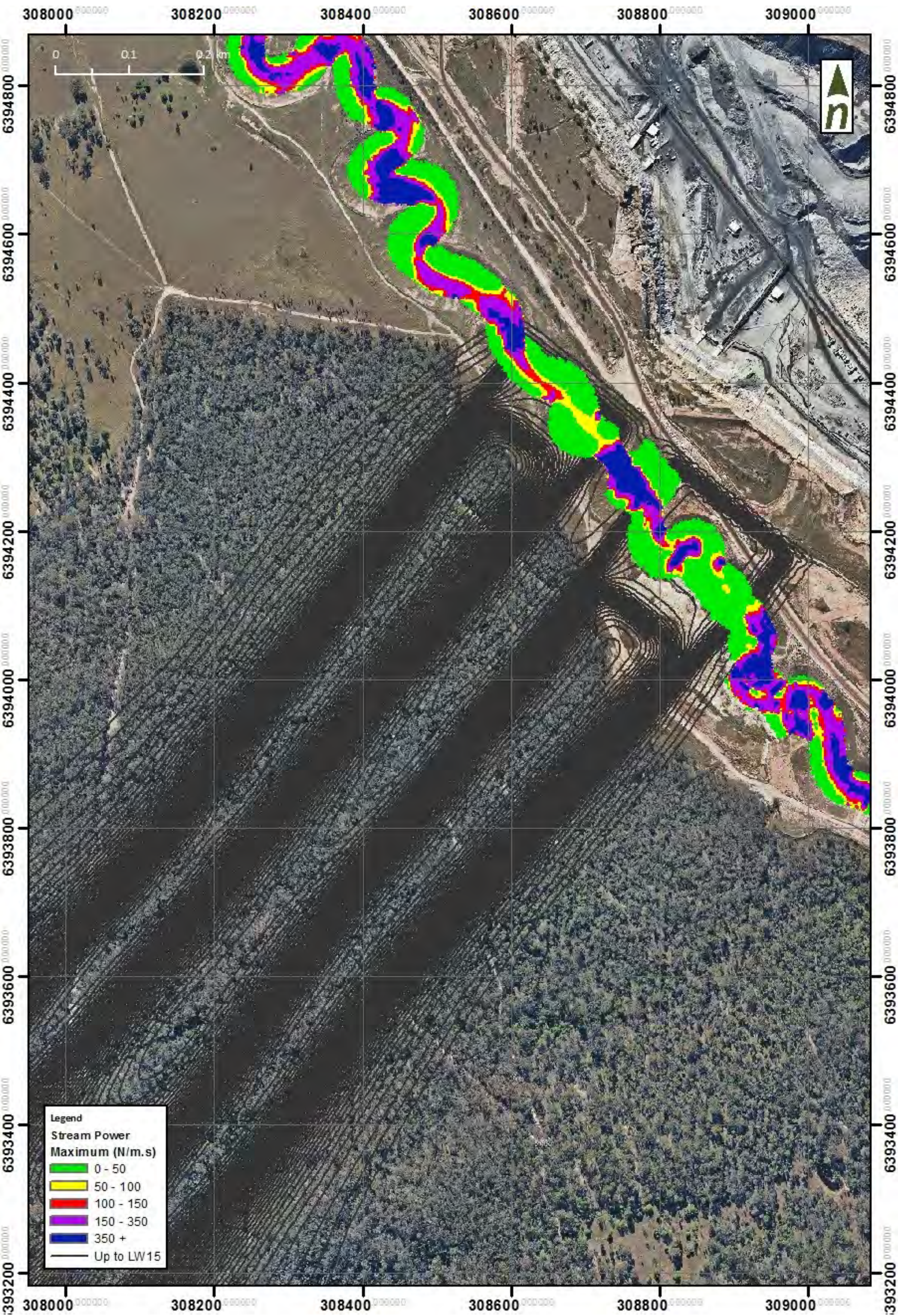


Figure C-91. **100 year ARI flood stream power (post LW15)**

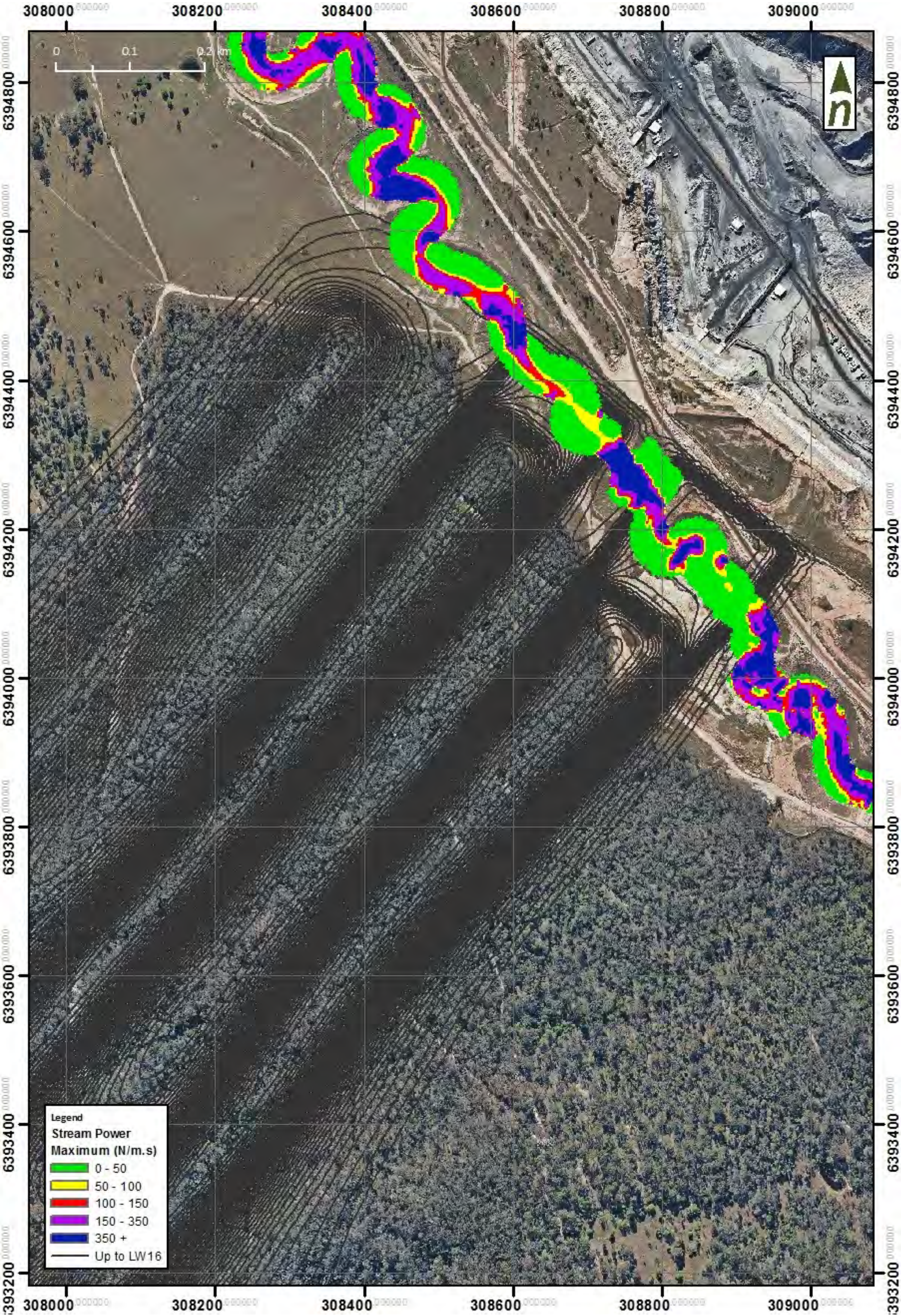


Figure C-92. **100 year ARI flood stream power (post LW16)**

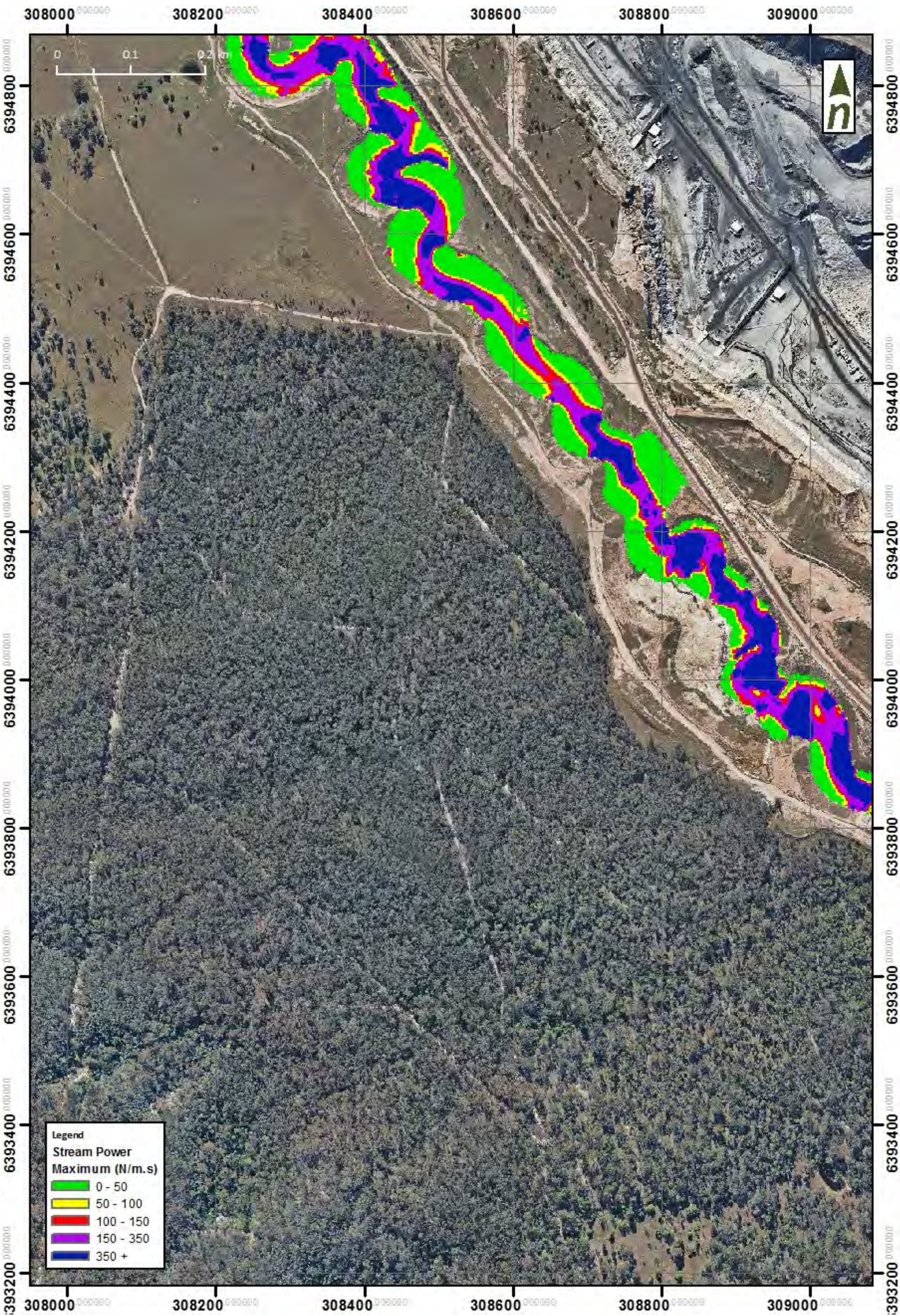


Figure C-93. **1000 year ARI flood stream power (existing conditions)**

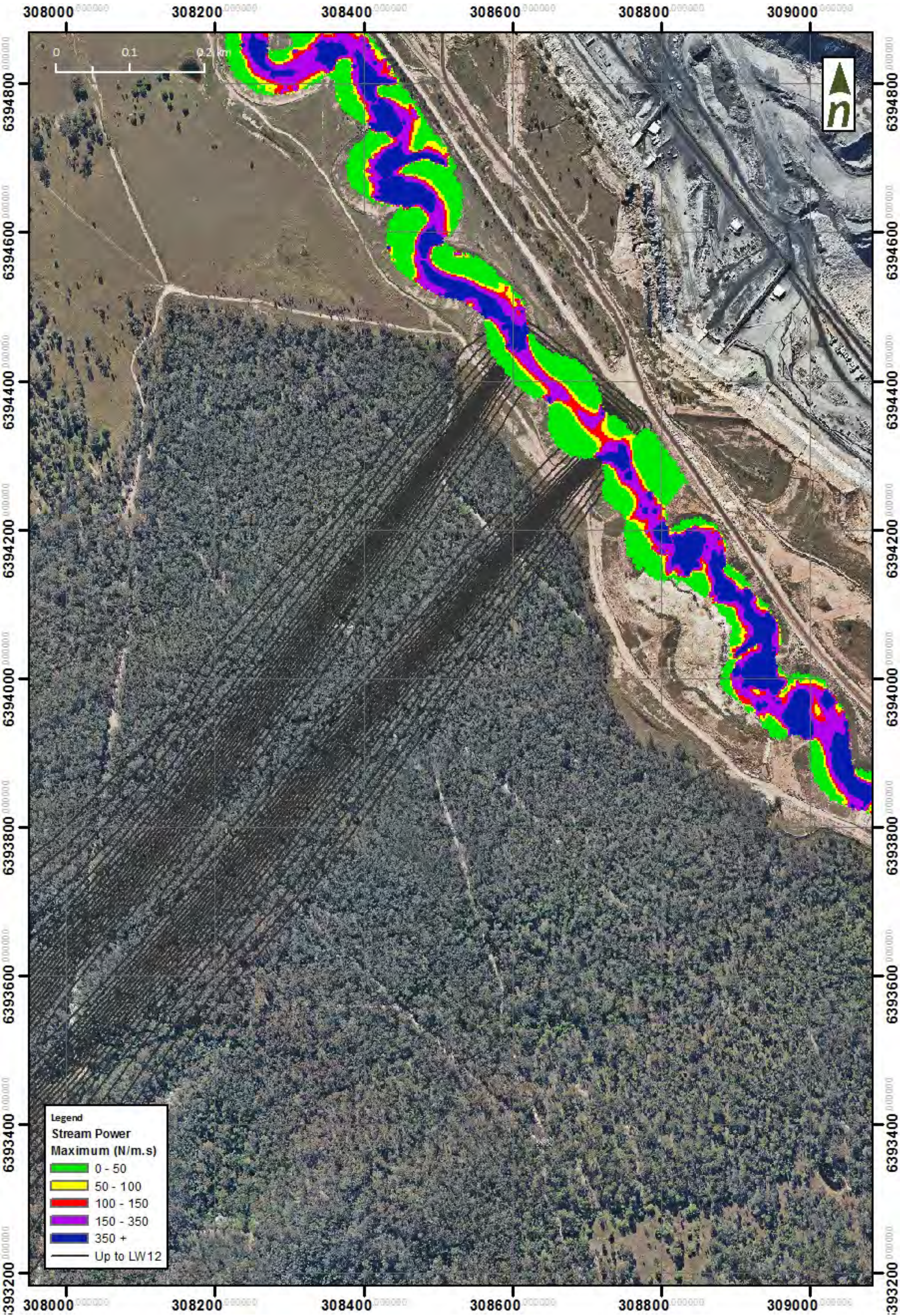


Figure C-94. **1000 year ARI flood stream power (post LW12)**

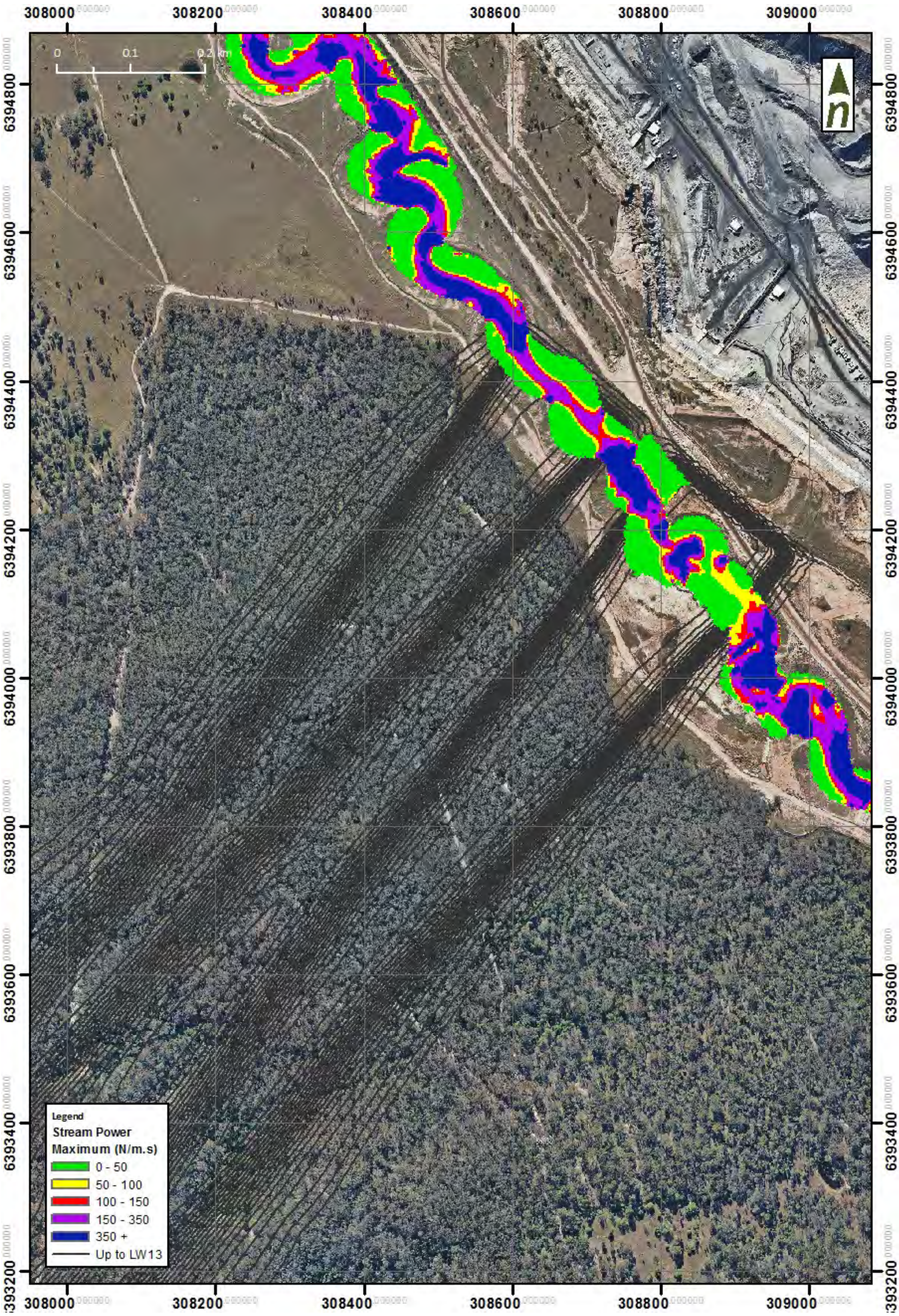


Figure C-95. **1000 year ARI flood stream power (post LW13)**

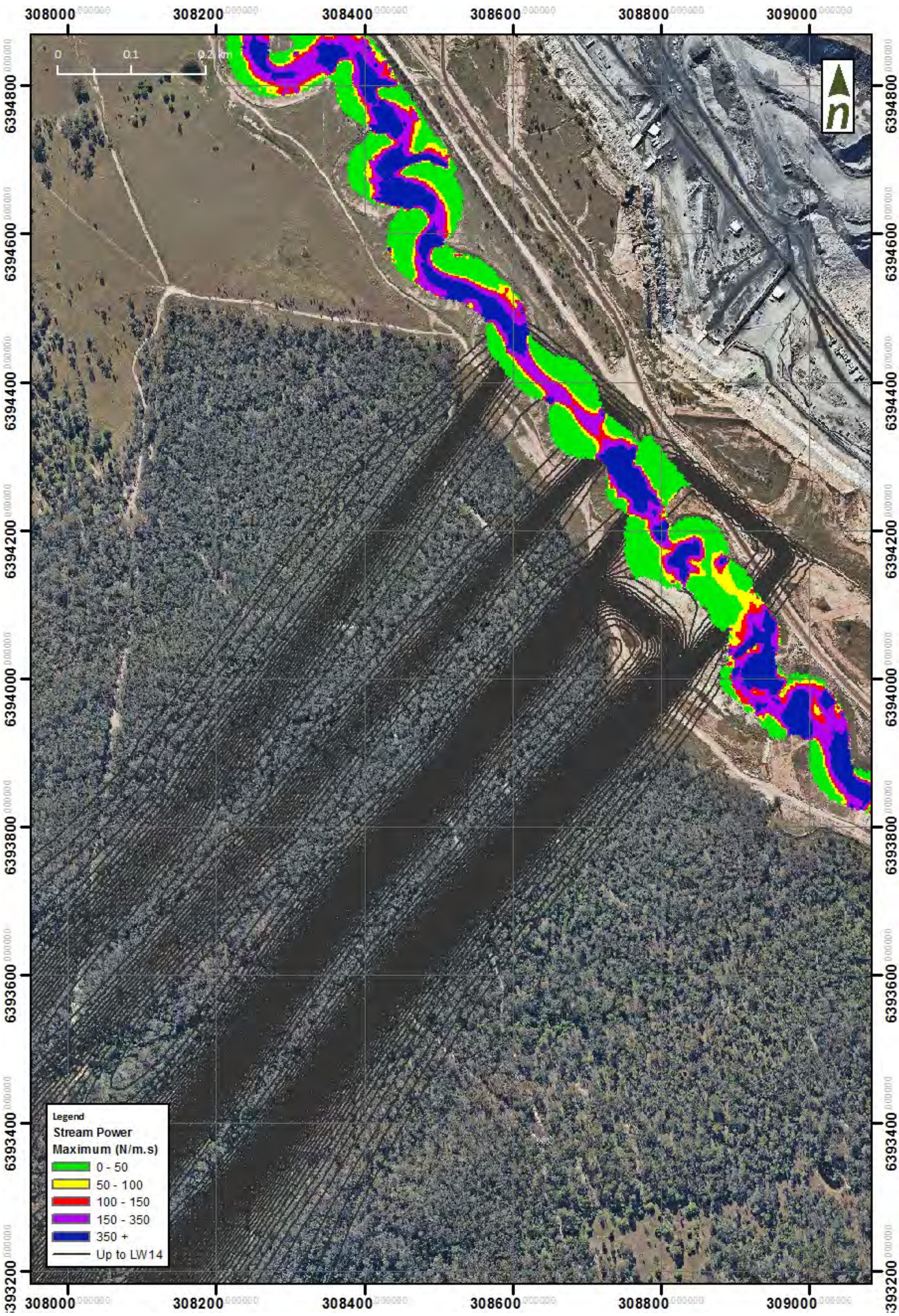


Figure C-96. **1000 year ARI flood stream power (post LW14)**

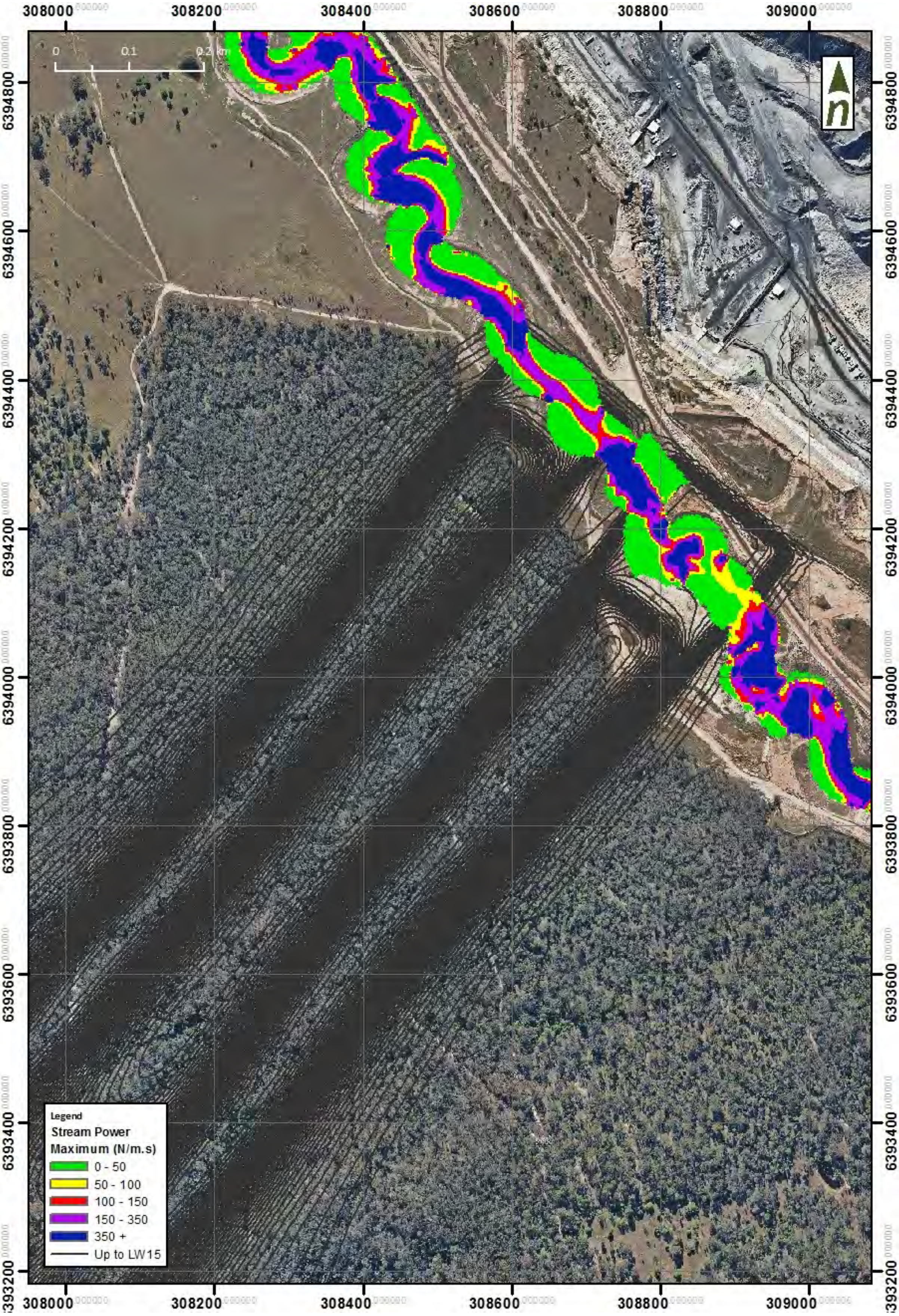


Figure C-97. **1000 year ARI flood stream power (post LW15)**

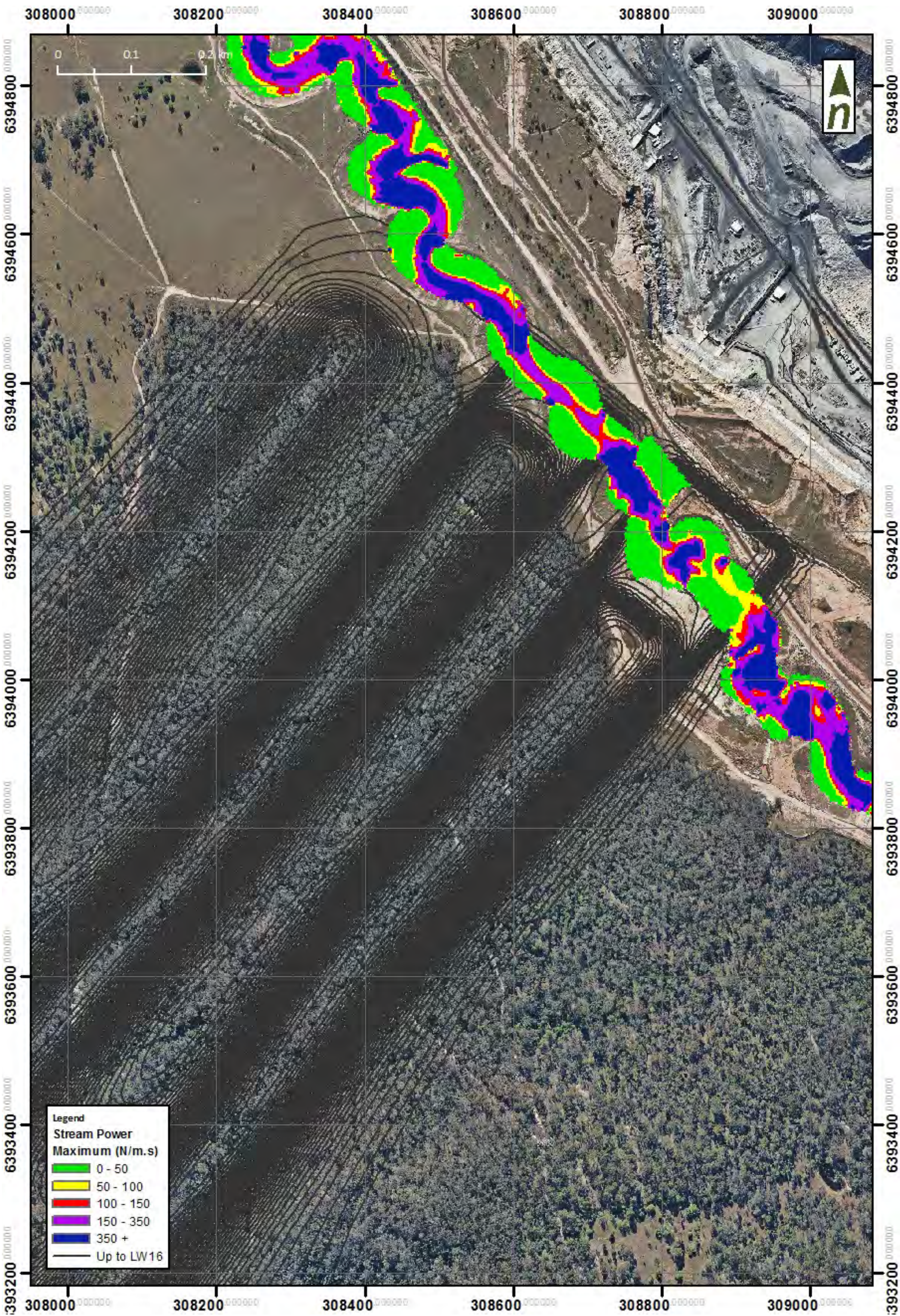
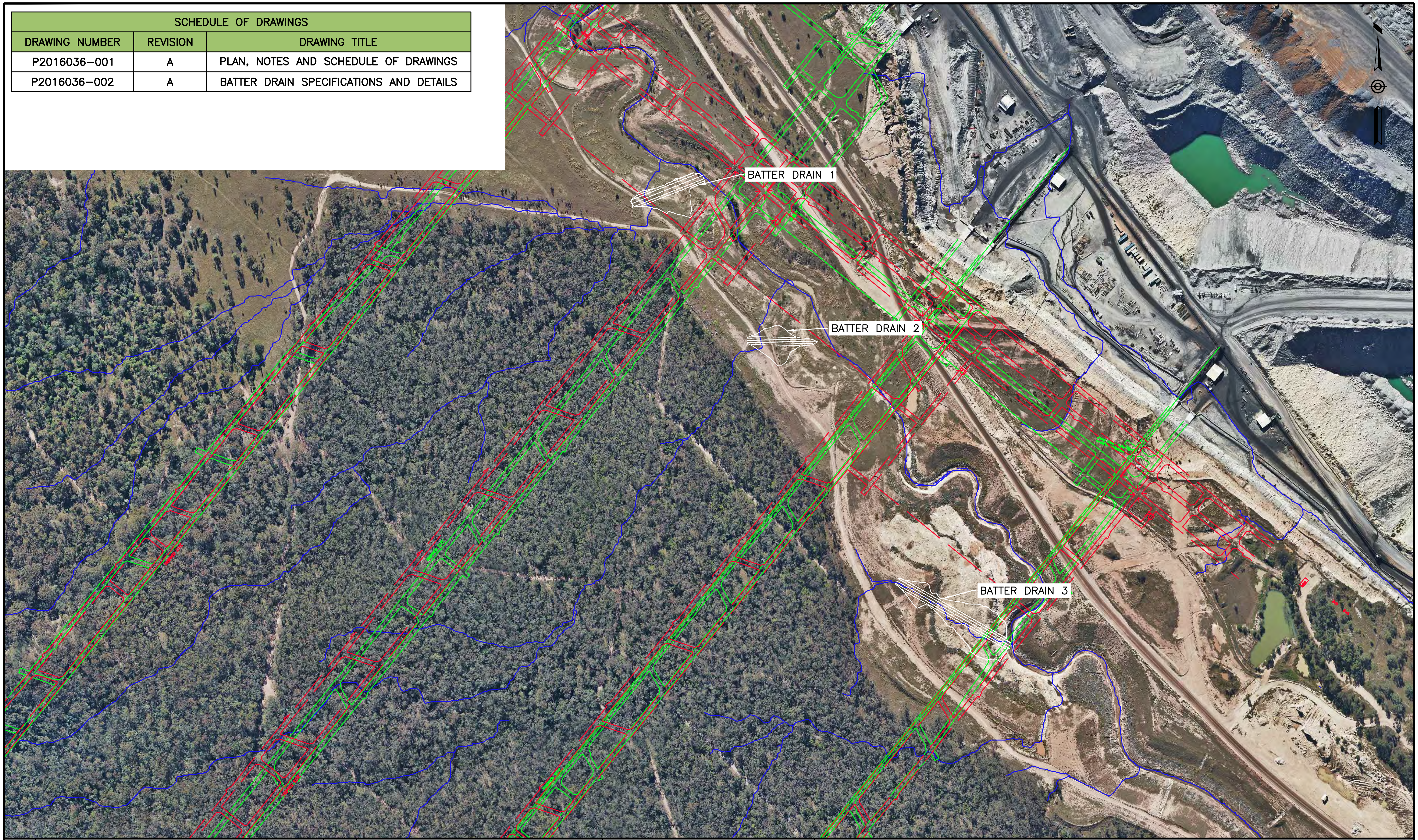


Figure C-98. 1000 year ARI flood stream power (post LW16)

Attachment D
Batter Chutes

SCHEDULE OF DRAWINGS		
DRAWING NUMBER	REVISION	DRAWING TITLE
P2016036–001	A	PLAN, NOTES AND SCHEDULE OF DRAWINGS
P2016036–002	A	BATTER DRAIN SPECIFICATIONS AND DETAILS



REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	08/12/16	TB

REVISIONS

	NAME	DATE
DESIGNED:	A.NEILLY	08/12/2016
DRAWN:	T. BEADLE	08/12/2016
CHECKED:	A.NEILLY	08/12/2016
APPROVED:	R.LUCAS	08/12/2016

SCALE 0 40 80 160 m

A B C

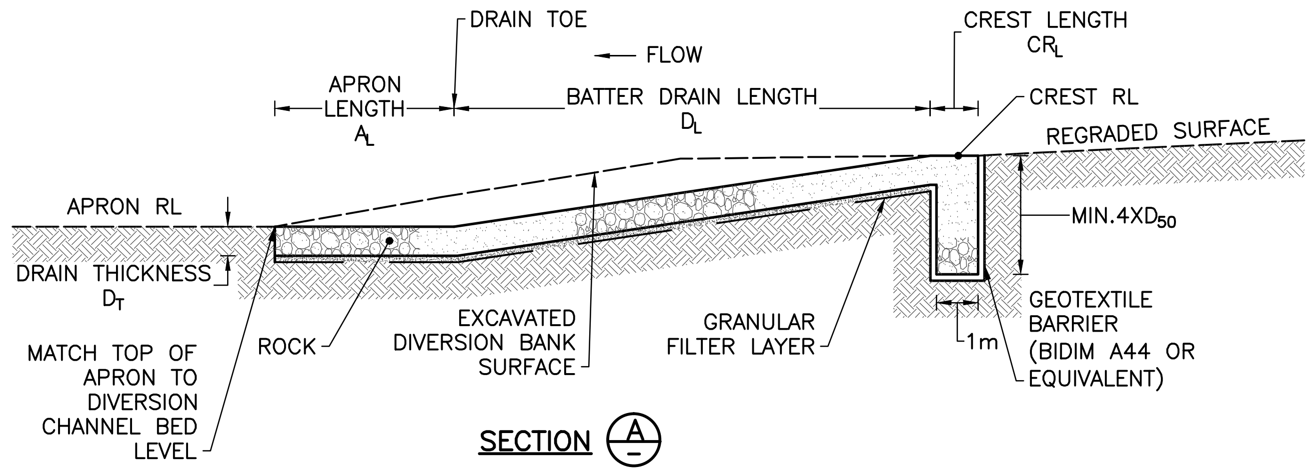
alluvium
www.alluvium.com.au
T +61 7 4724 2170 F +61 7 4724 1639

Client:

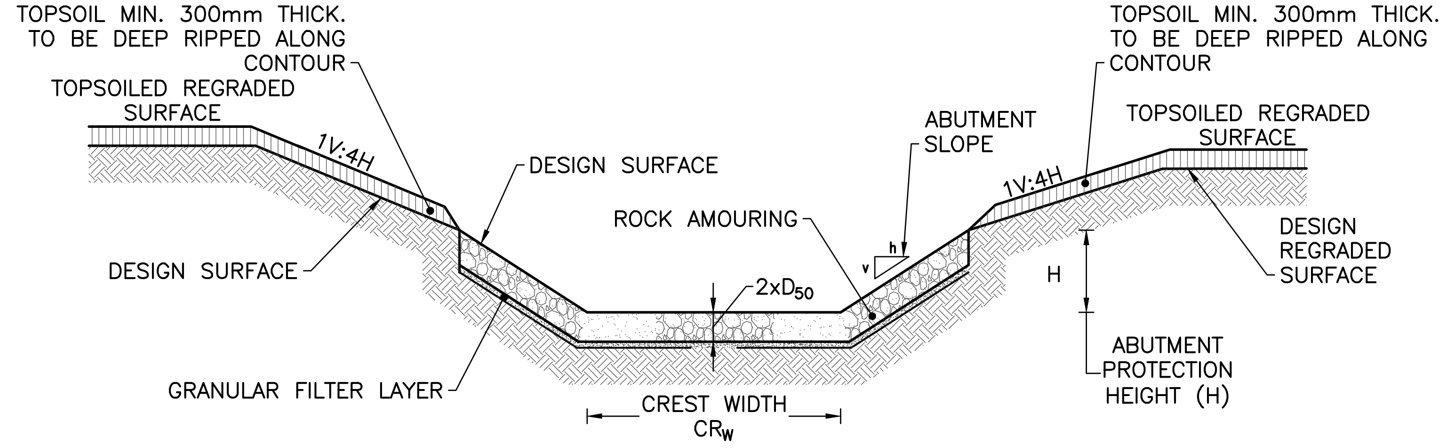
PEABODY
WAMBO MINE
CONCEPT DESIGN
PLAN, NOTES AND SCHEDULE OF DRAWINGS

Drawing No. P2016036-001 Revision No. A
Sheet No. 1 File Name: P216036 001.dwg
©Alluvium Consulting Australia ABN 76 151 119 792 A3

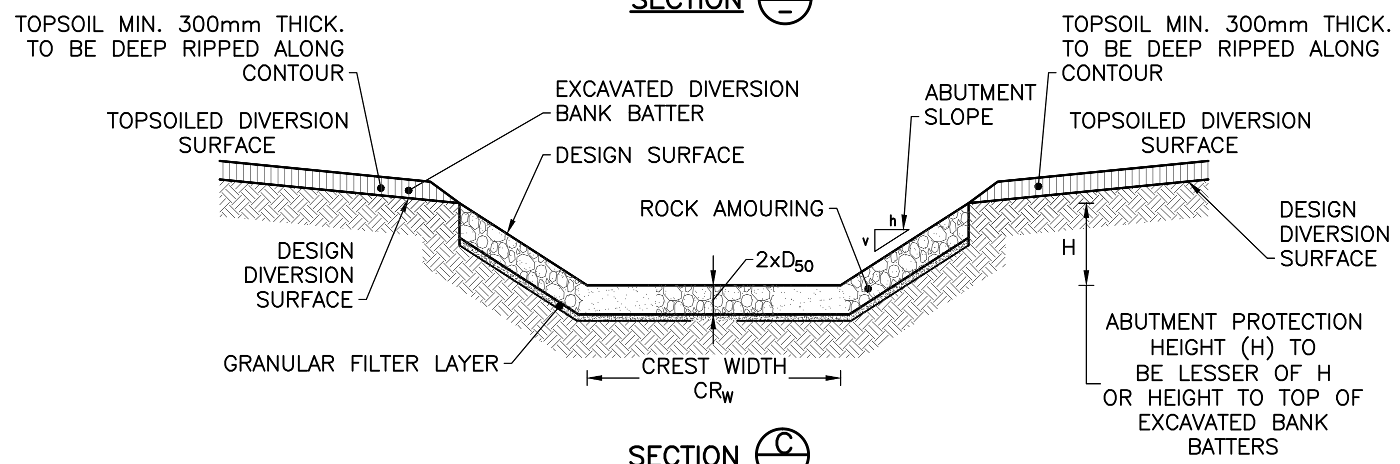
CHUTE ELEMENT	SYMBOL	UNITS	BATTER DRAIN 1	BATTER DRAIN 2	BATTER DRAIN 3
CHUTE LENGTH	CL	m	56	55	116
CHUTE DROP	CD	m	9.00	9.10	11.9
CHUTE WIDTH	CW	m	8.0	4.0	6.0
CREST LENGTH	CRL	m	1	1	1
CREST RL	-	m	94.5	97.2	97.0
APRON LENGTH	AL	m	32	25	33
APRON RL	-	m	89.5	88.1	85.2
CREST SETOUT COORDINATES			E: 308474	E: 308601	E: 308772
			N: 6394495	N: 6394339	N: 6394068
APRON SETOUT COORDINATES			E: 308526	E: 308660	E: 308875
			N: 6394516	N: 6394339	N: 6394009
SIZE OF ROCK	D50	mm	600	400	400
ABUTMENT PROTECTION HEIGHT	-	m	1	1	1
QUANTITY OF ROCK REQUIRED	-	m³	1406	610	1369
	-	tonnes	3881	1686	3778
LENGTH OF GEOFABRIC (4.0 m wide roll)	-	m	18	9	9
GRANULAR FILL	-	m³	110	89	231
EXCAVATION VOLUME		m³	6144	4502	12893
FOUNDATION PREPARATION AREA	-	m2	2204	1789	4614



SECTION A



SECTION B



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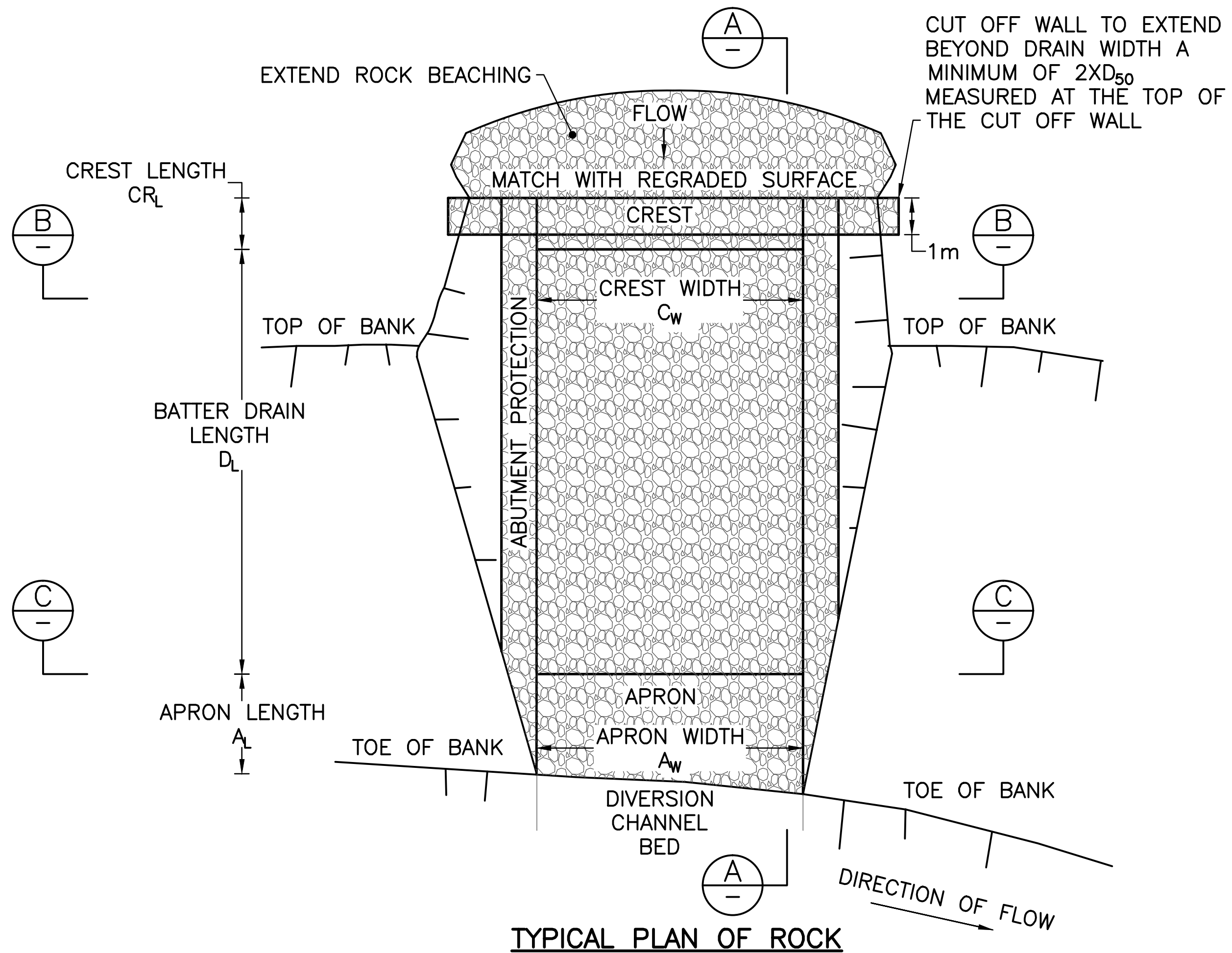

TYPICAL PLAN OF ROCK
BATTER DRAIN

REV	DESCRIPTION	DATE	INTL
A	ORIGINAL ISSUE	08/12/16	TB

REVISIONS

	NAME	DATE
DESIGNED:	A.NEILLY	08/12/2016
DRAWN:	T. BEADLE	08/12/2016
CHECKED:	A.NEILLY	08/12/2016
APPROVED:	R.LUCAS	08/12/2016

SCALE
A
B
C
m
m
m

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T +61 7 4724 2170 F +61 7 4724 1639

Client:

PEABODY
WAMBO MINE
CONCEPT DESIGN
BATTER DRAIN SPECIFICATIONS AND DETAILS

Drawing No. P2016036-002
Revision No. A
Sheet No. 2
File Name: P216036 001.dwg

ABN 76 151 119 792
A3