Cadia Valley Operations

Riparian Release Ecology Assessment

March 2019 to June 2020

August 2020

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1. Introduction

Cadiangullong Dam is a key water supply for mining activities undertaken by Cadia Valley Operations (CVO) and is located upstream of the main mining facilities. The Dam is also a source of water for environmental flows released into Cadiangullong Creek (riparian releases) that maintain connectivity and the ecological health of riparian vegetation, aquatic macroinvertebrates and fish populations. Under normal conditions, CVO release approximately 2.8 ML/day to achieve 0.9 ML/day at Oaky Creek. CVO applied to the NSW Department of Water and Energy (DWE) for a variation to the riparian release conditions and to temporarily cease the riparian releases into Cadiangullong Creek.

To support the DWE application and address specific questions related to ecological risks should the riparian releases cease, GHD prepared a report (GHD, 2019) that recommended a three stage monitoring program. The aims of the program were to determine the current distribution of platypus and Mountain galaxias in Cadiangullong Creek, predicting changes to aquatic values during the cease-to-flow period, and identifying potential management actions to mitigate against potential impacts. The key objectives of the program were to:

Stage 1

- Identify the location of key pools that may provide refuge habitat for platypus and Mountain galaxias during cease-to-flow events based on water quality, habitat conditions and any logistical constraints that may present issues for future monitoring.
- Assess the current spatial distribution of platypus and Mountain galaxias in Cadiangullong Creek prior to ceasing the riparian releases.
- Develop a Stage 2 monitoring program.

Stage 2

- Implement a monitoring program during cease-to-flow events to assess any changes in the spatial distribution of platypus and Mountain galaxias, and any changes in the condition of the key pools and their capacity to act as refuge habitat to maintain ecological values. To enable this program to be cost effective, timely and efficient, eDNA as well as observational data were combined with *in situ* water quality monitoring to compare against a Trigger Action Response Plan (TARP - Appendix A) developed from a combination of historical data and data collected in the initial survey of Cadiangullong Creek (GHD, 2019).

Stage 3

- Mitigate any potential impacts to platypus and Mountain galaxias through adaptive management actions to maintain the quality and quantity of refuge pools and/or ecological values.

1.1 Purpose of this report

This report provides the final outcomes of Stages 1 and 2 of the monitoring program. Adaptive management actions to mitigate any potential impacts to platypus and Mountain galaxias during Stage 3 have also been implemented through the use of a trialled pulse release of water from Cadiangullong Dam. This involved a release of approximately 2 ML/day from 25-29 July 2019 to determine the water required to flush and/or maintain the habitat pools. Consequently, the purpose of this report is to:

- Summarise the monitoring that has occurred in Cadiangullong Creek
- Identify changes in ecological values due to the cessation of the riparian releases

- Attempt to quantify the benefits of the trialled pulse flow release
- Assess potential changes to ecological values if the cessation of the riparian releases was extended
- Assess the potential to refine the TARP Indicators and trigger values

Note that this report consolidates the results of monitoring associated with the riparian releases from Cadiangullong Dam. Further details can be found in reports associated with the previous monitoring. The approach to the monitoring program, undertaken over the three stages, is detailed in GHD (2019).

Stage 1 monitoring occurred during a period of riparian releases from the 13-14 March 2019 and a map of monitoring locations in included in Figure 1. The riparian releases ceased on the 8 April 2019 and Stage 2 monitoring was undertaken following this period on the following dates: 1 May, 23 May, 6 June, 18 June, 2 July, 23 July 2019, 31 July 2019 13 August 2019, 27 August, 9 September, 23 September, 4 November and 17 December 2019, and 15 January, 11 February, 7 April, 19 May and 20 June 2020.

1.2 Scope and limitations

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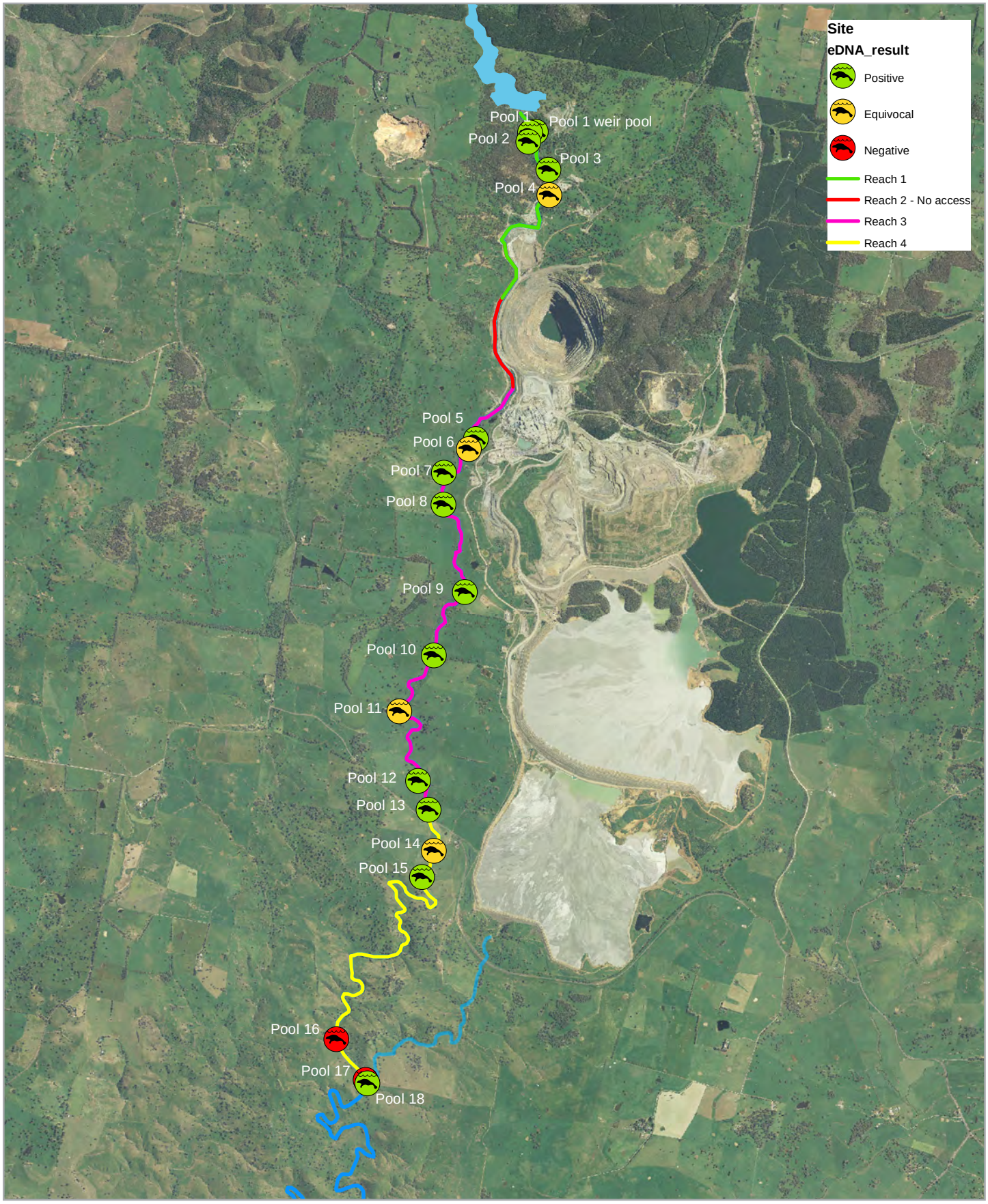

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Map Projection: Mercator Auxiliary Sphere
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GHD

Cadia Valley Operations
Riparian Release
Ecology Assessment

Platypus Survey Sites

Project No. 2316627
Revision No. -
Date 03/04/2019

FIGURE 1

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2. Results

2.1 Hydrology

In recent times, changes in flow of Cadiangullong Creek have been due to the onset of severe drought conditions beginning in early 2017. This led to the application and subsequent approval to cease the release of water (riparian releases) from the Cadiangullong Dam on 8 April 2019. A trial pulse release followed from 25 to 29 July 2019 and regular releases returned on the 27 September 2019. Flow in Cadiangullong Creek is measured in real-time at four gauging stations:

- Upstream of Cadiangullong Dam – Site 412168
- Downstream dam - Site 412144 approximately 0.5 km downstream from Cadiangullong Dam (Pool 1)
- Southern Lease Boundary - Site 412161 approximately 10 km downstream from Cadiangullong Dam (Pool 11)
- Oaky Creek - Site 412702 approximately 16 km downstream from Cadiangullong Dam (Pool 17/18)

A hydrograph illustrating changes in flow between January 2019 and June 2020 is included in Figure 2. The hydrograph indicates that there was an obvious decrease in flow in Cadiangullong Creek from April to late July 2019 following the cessation of the riparian releases. During the trial pulse release, approximately 2 ML/day was released from Cadiangullong Dam (target of 10 ML in total) that resulted in an increase in flow throughout the Creek. Once the releases returned there was an obvious increase in flow at all sites until December 2019 – when flows ceased upstream from the dam (gauge 412168). Flows downstream of the dam (indicated by gauges 412144, 412161 and 412702) naturally ceased from late February until late March 2020. Flows resumed from early April to June 2020 at all sites, with a number of high-flow (i.e. >10 ML/day) downstream from the Cadiangullong Dam.

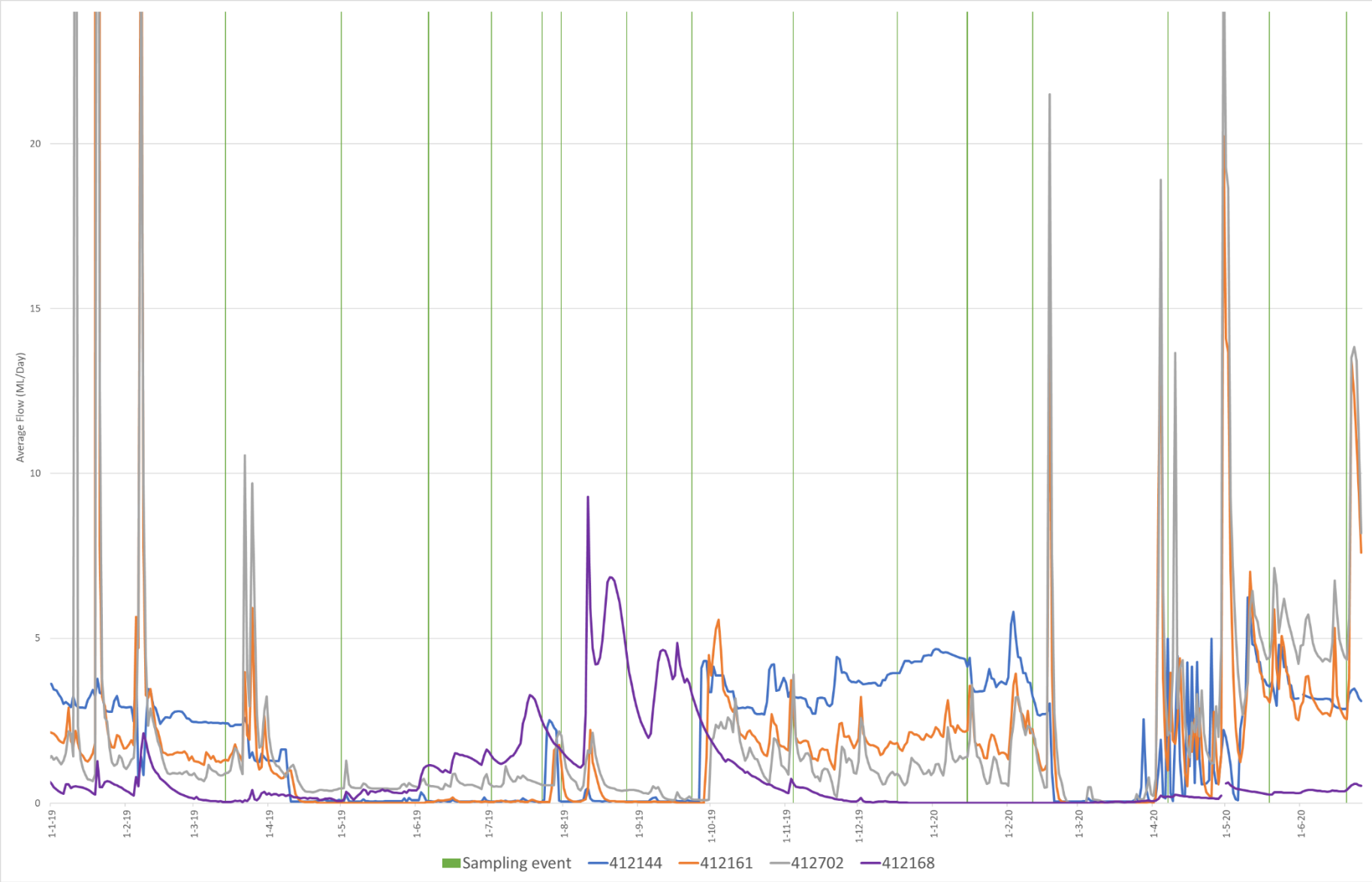

Figure 2 Average daily flow and sampling events (2019-2020) in Cadiangullong Creek

Figure 3 Pool 11 (Gauging Station 412161) during riparian releases in March, while releases were ceased on 23 May, and following the reintroduction of releases in December 2019

The cessation of releases had a noticeable effect on surface water connectivity along Cadiangullong Creek and water levels in the pools (see Figure 3). However, data from gauge 412161 indicate that water levels increased at Pool 11 while no releases were occurring and in the absence of significant rainfall events (Figure 4). Given there are no major tributaries upstream of Pool 11, it is likely that groundwater contributes a greater proportion to baseflow in lower reaches of Cadiangullong Creek during cease-to-flow events (Figure 4). There was an increase in water levels in all pools following the trial pulse release in late July. The cease-to-flow event from December 2019 until March 2020 is evidenced by the drying out of the pool (gauge 412168) upstream from Cadiangullong Dam during this period. Pool depths at locations downstream from the Cadiangullong Dam were maintained during this period.

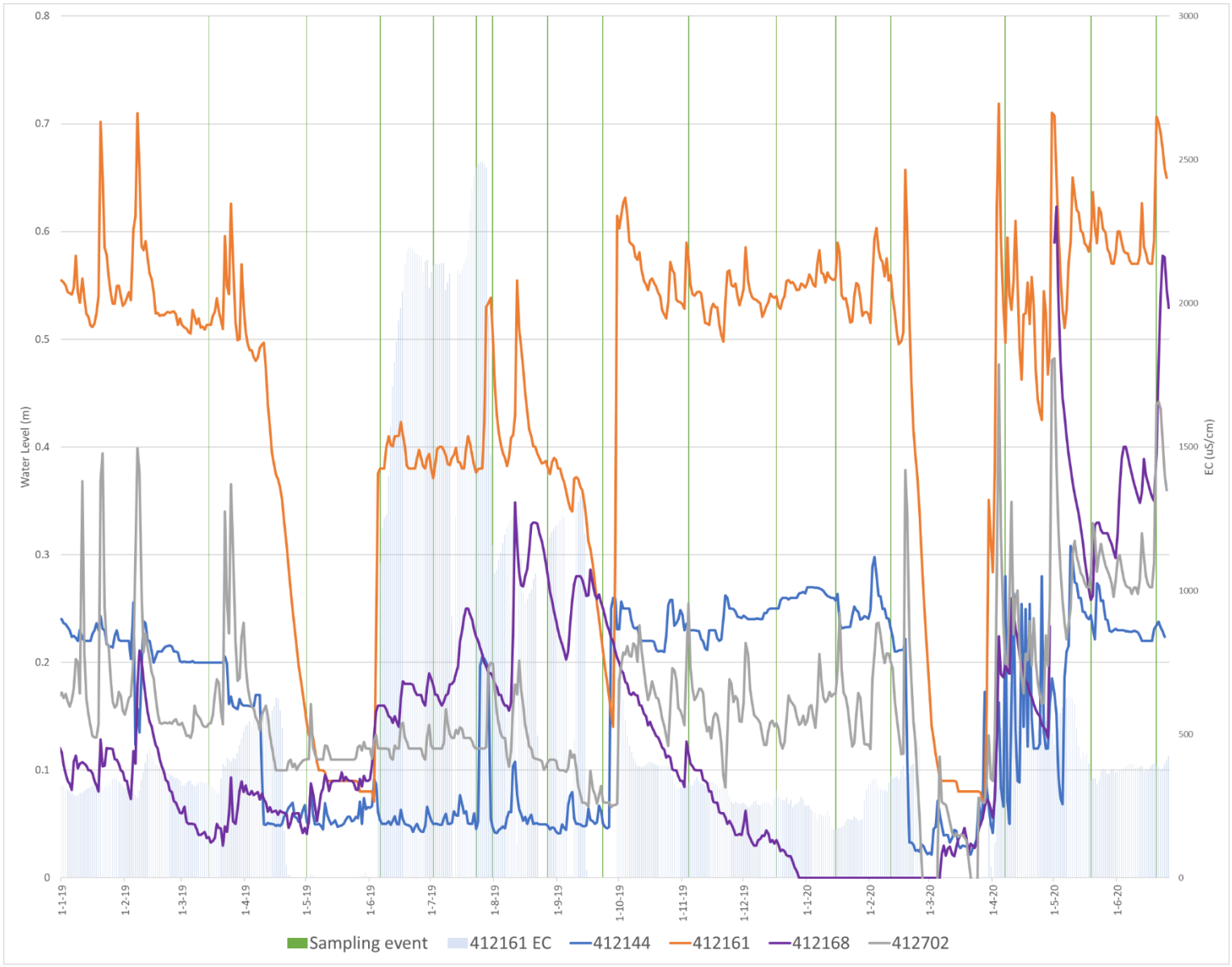

Figure 4 Average daily water level, EC at gauge 412161 and sampling events (2019-2020) in Cadiangullong Creek

2.2 Habitat

Based on the habitat suitability index derived from the initial survey of Cadiangullong Creek during March 2019, the pools considered to have the most diverse and highest quality habitat features were Pools 1, 2, 7, 10, 11, 15 and 18. These had significant logjams, consolidated banks and overhanging vegetation, and were considered likely to persist and provide refuge habitat during periods of low flow for platypus. Example photographs of selected pools are included in Figure 5.

Figure 5 Cadiangullong pools with high habitat value

Based on the findings during the initial survey, five pools were recommended for monitoring as part of Stage 2 (Table 1). These pools were selected based on factors including their habitat conditions and ultimately, the likelihood that platypus and Mountain galaxias would use pools as refuge habitat during a cease-to-flow event. Access was also taken into consideration, which is why pool 15 was removed from the program. Pool 11 dried out in May 2019 and was replaced by Pool 10 (located 100 m upstream from Pool 11). Pool 11 was initially included in the survey because it is the location of the gauging weir at the southern lease boundary.

Data collected during the monitoring program indicates that riffle habitat would have been reduced during the cease-to-flow period, as pools became isolated. The TARP (Appendix A) originally placed 'riffles drying' as a 'critical value'. However, given the maintenance of key indicator species during and after the cease-to-flow event (see Section 2.2) it is recommended that 'riffles drying' should be considered a 'trigger value', not a 'critical value'.

Table 1 Study sites and location

Reach	Location	Latitude	Longitude
1	Upstream weir (Pool 1a) Pool 1	148.993977 148.993211	-33.435316 -33.435430
1	Pool 2	148.992980	-33.436430
3	Pool 7	148.981890	-33.472740
3	Pool 9 Pool 10 Pool 11	148.984680 148.980560 148.976030	-33.485850 -33.492800 -33.498940
4	Pool 17 Pool 18	148.971630 148.971809	-33.539330 -33.539700

2.1 Water quality

In situ water quality results from Stage 2 of ongoing monitoring are included in Figure 6. Changes in temperature reflect season patterns and were generally higher during summer/spring than for winter/autumn. However, during periods of riparian releases, slightly cooler temperatures were recorded at the upstream Pool 1 and Pool 2. While this may have been due to these pools being monitored earlier in the day, it may also represent cool hypolimnetic water (i.e. deep water) being released from Cadiangullong Dam that warms during transport downstream. This was particularly obvious in November 2019, when temperature at downstream pools were 6 to 7°C higher than Pools 1 or 2. Despite the potential influence of the releases on temperature, there was no evidence to suggest potential impacts on waterway health while releases were ceased.

There was no consistent pattern in dissolved oxygen (DO) amongst upstream and downstream pools or between seasons. The variation amongst pools is likely due to algal respiration and photosynthesis that contributed to supersaturated conditions on several occasions. DO was below the TARP Critical Value on one occasion - Pool 18 in April 2020 and below the TARP Trigger Value on two occasions - Pool 11 in May 2019 and Pool 1 in February 2020. However, Mountain galaxias persisted in these pools (see Section 2.2) and DO increased in the following months in each pool so there was no obvious or prolonged impact. Breaching of the critical value at Pool 18 in April 2020 (with a value of 18%) may have been due to instrument error as DO at all other pools ranged from 62-77%. Regardless, even if the value was true, DO returned to within the expected range during subsequent monitoring events.

Note that a TARP Target Value for DO has been developed based on the median value recorded while releases were occurring to represent 'background' levels. There was no evidence to suggest that DO was lower and represented a greater risk to waterway health during the managed cease-to-flow event when compared to monitoring events during normal operation. A review of the TARP indicators and trigger values is provided in Section 3.

There was also no consistent patterns in pH between monitoring event or pools. The lower TARP Target Value of 6.5 was met on all monitoring events. Although the upper target level was exceeded in at least one pool during all monitoring events between May and September 2019, this was irrespective of flow and the riparian releases. All pH values from November 2019 to June 2020 fell within the target range. Increase in pH can occur as algae consume carbon dioxide during photosynthesis with night-time decreases in pH during respiration. Consequently, the variation amongst pools may be related to the time of day recordings were made while the regular high levels may be a reflection of algal photosynthesis.

An electrical conductivity (EC) gradient was present on all monitoring events with levels increasing downstream of Pool 2. This is likely due to an increase in the contribution of groundwater to baseflow. The trial pulse release in late July appears to have reduced EC although the influence of the release did not extend to Pool 18 where levels remained similar to previous monitoring events. Interestingly, the increase in water level at Pool 11 discussed in Section 2.1 was accompanied by an increase in EC that again suggests a greater contribution to baseflow by more saline groundwater (Figure 4). A similar increase in EC was observed at Pool 7, albeit to a lesser magnitude. However, the trial pulse release appears to have mitigated this - with EC in both pools being reduced at this time. EC values rose again in all pools during April and May 2020. As per July 2019, the pool depths were maintained during this period (Figure 4) so it is likely that a groundwater input is assisting in the maintenance of pools. This data indicates the large degree of variation in EC levels in Cadiangullong Creek due to longitudinal variation and groundwater inputs. However, monitoring suggests that the key aquatic fauna monitored as part of this program are able to tolerate this variation.

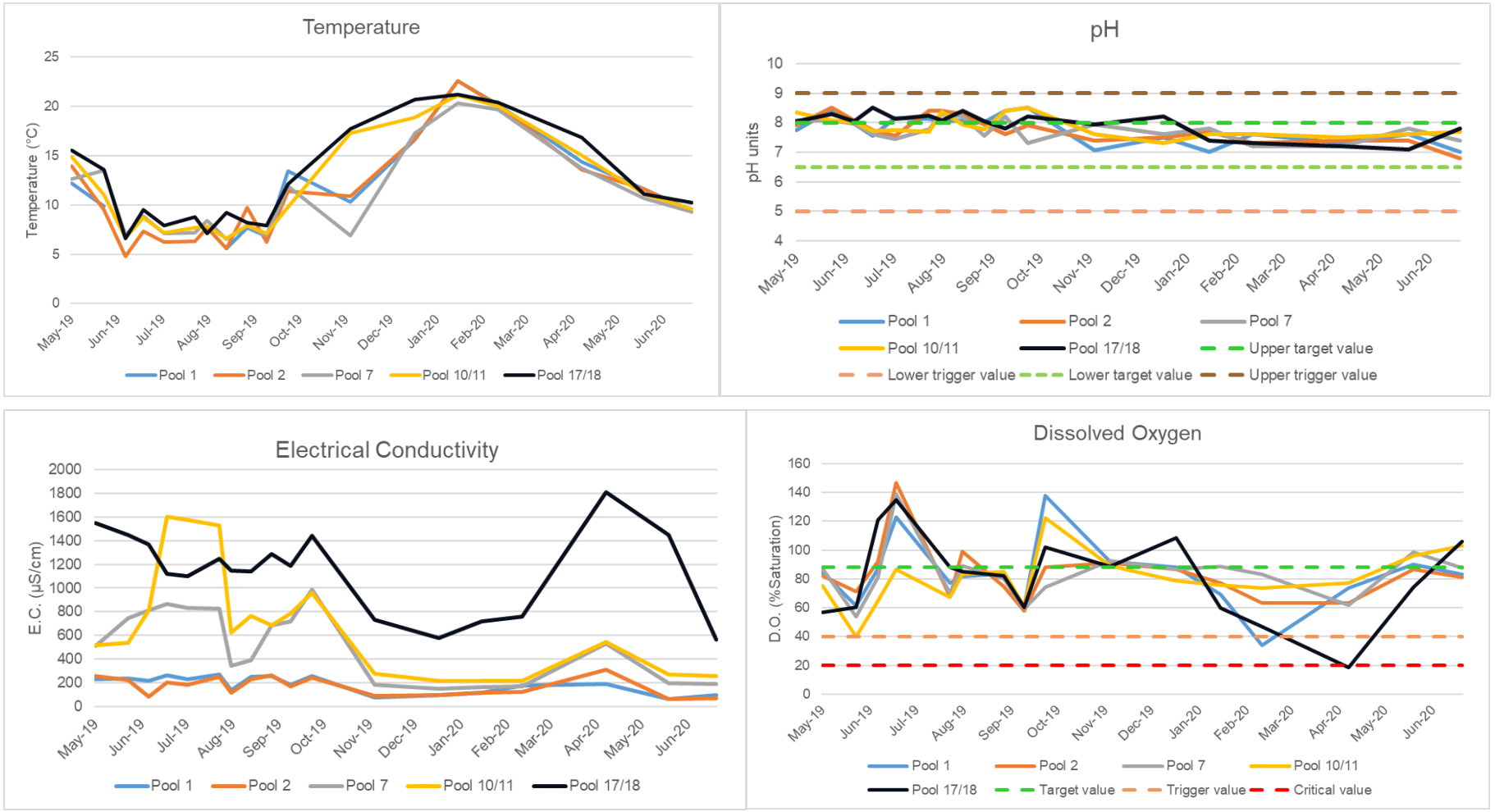

Figure 6 In situ water quality results from Stage 2 of the Riparian Release Monitoring Program. Note the new target value for dissolved oxygen based on the median value recorded during the riparian releases

2.2 Spatial distribution of fish (Mountain galaxias) and Platypus

A summary of Mountain galaxias distribution in Cadiangullong Creek throughout the Stage 2 monitoring are included in Table 2. The results indicate that during the riparian releases in March, and following the cessation of the releases in May, Mountain galaxias were present throughout all pools monitored. However, an increase in turbidity following a May rainfall event and the growth of surface algae limited the ability to observe individuals and negative observations were recorded in a number of pools in June and July. Due to this, monthly eDNA monitoring was incorporated into the Stage 2 monitoring on seven occasions (see Table 2).

Interestingly, the eDNA monitoring detected the presence of Mountain galaxias in all pools when this approach was used. Alternatively, visual observations did not confirm the presence of the species on 13 August and 9 September at any of the pools (noting that eDNA sampling was not scheduled for those monitoring events). While this may have been due to limited water clarity, it does suggest that eDNA monitoring may provide a better approach for determining the presence of Mountain galaxias and should be used when visual observation is not possible or is possible but no fish sighted. Importantly, Mountain galaxias were present throughout all pools monitored prior to the cease of the riparian releases, during the cease-to-flow events, following the introduction of the releases and during the natural cease-to-flow period from late February to late March 2020.

Table 2 Summary of Mountain galaxias results; green blank cells indicate presence based on visual observations; green eDNA cells indicate presence based on eDNA monitoring; red cells indicate absence based on visual observations

	Reach 1		Reach 3		Reach 4
	Pool 1	Pool 2	Pool 7	Pool 9/10/11	Pool 17/18
13/3/19					
1/5/19					
23/5/19					
6/6/19					
18/6/19					
2/7/19					
23/7/19[1]					
31/7/19	eDNA	eDNA	eDNA[2]	eDNA	eDNA
13/8/19[1]					
27/8/19	eDNA	eDNA	eDNA	eDNA	eDNA
9/9/19[1]					
23/9/19	eDNA	eDNA	eDNA	eDNA	eDNA[1]
4/11/19					
17/12/19					
15/01/20					
11/02/20	eDNA	eDNA			eDNA

[1] Non-detection during sampling event due to no visual sighting (no eDNA samples collected).
[2] eDNA result confirmed by visual observation

	Reach 1		Reach 3		Reach 4
	Pool 1	Pool 2	Pool 7	Pool 9/10/11	Pool 17/18
7/04/20	eDNA	eDNA		eDNA	eDNA
19/05/20	eDNA	eDNA	eDNA	eDNA	eDNA
20/06/20	eDNA	eDNA	eDNA	eDNA	eDNA

The eDNA monitoring for Platypus determined that they were regularly present in Pools 1, 2 and 7 throughout the Stage 2 monitoring (Table 3). Although they were detected using eDNA in Pools 9/10/11 and Pool 17/18 in March 2019, they were usually absent during subsequent monitoring events in these downstream pools. Whether Pool 17/18 has ever supported resident Platypus is unknown – they were only recorded using eDNA in March 2019 and as an equivocal result in June 2020. If they were present in Pool 17/18 it is likely they dispersed downstream to the Belubula River following the implementation of the cease-to-flow event. Following the trial pulse release, which concluded on 29 July 2019, Platypus were again detected in Pool 10 but then not recorded again until April 2020. It is likely that the resumption of flows in April 2020 would have allowed Platypus to recolonise these pools from upstream locations. Regardless, Pools 1-7 would have been most likely to be impacted by any changes in habitat availability and the monitoring indicates that Platypus have persisted within these pools.

Table 3 Summary of platypus results; green blank cells indicate presence based on eDNA; green cells with Sighted or Video indicate presence confirmed by chance visual observations or capture on field deployed cameras; orange cells indicate equivocal eDNA results; red cells indicate absence based on eDNA

	Reach 1		Reach 3		Reach 4
	Pool 1	Pool 2	Pool 7	Pool 9/10/11	Pool 17/18
14/03/2019					
1/05/2019					
6/06/2019	Sighted				
2/07/2019					
23/07/2019	Not sampled	Photography	Not sampled	Not sampled	Not sampled
31/07/2019		Sighted		Photography	
27/08/2019	Photography	Photography	Photography		
23/09/2019					
4/11/2019	Photography				
17/12/2019	Not sampled	Photography	Not sampled	Not sampled	Not sampled
15/01/2020					
11/02/2020					
7/04/2020					
19/05/2020					
20/06/2020					

On several occasions, the eDNA results for platypus were confirmed by video footage and/or photographs captured by field cameras deployed in multiple pools of Cadiangullong Creek (Figure 7). Importantly, the results suggest that Platypus remained within the Creek prior to and following the cessation of the riparian releases. Results also indicate that conditions during the natural cease-to-flow event from late February to late March 2020 also provided suitable water quality and habitat conditions without flow inputs – evidenced by their presence during the cease-to-flow event and following resumption of flows.

Figure 7 Photographs of platypus in Pool 2 on 17 July 2019 (left) and Pool 10 on 27 July 2019 (right)

3. TARP Indicator and trigger value review

The Stage 2 monitoring has enabled the collection of data during the cease-to-flow event, and following the reintroduction of the riparian releases. Data collected prior to the cease-to-flow period allowed for a median value for dissolved oxygen to be calculated and included in the TARP as an interim target value (88%). This provided evidence of background conditions known to support platypus and Mountain galaxias based on data available during the monitoring program's development. Target, trigger and critical values for pH were also included, based on recognised default guidelines and a review of literature in relation to impacts of extreme pH levels of aquatic ecosystem. The interim target range for pH was pH 6.5-8.

Completion of the Stage 2 monitoring has allowed for a more comprehensive dataset. In total, 11 monthly data points have been collected during normal operation (i.e. during discharges from Cadiangullong Dam and excluding the managed cease-to-flow period).

The ANZG (2018) guidelines provide methods for the calculation of site-specific trigger values to allow for the protection of aquatic ecosystems. According to the guidelines, site-specific guidelines values should be based on at least two years of monthly monitoring data. For slightly to moderately disturbed ecosystems, test site medians should be compared with the 80th percentile guideline values or 20th percentile for stressors that cause ecosystem health issues at low concentrations, such as dissolved oxygen.

As such, updating of the current target values should still be considered as interim site-specific values but do provide a more robust assessment of background conditions, which can be updated as more water quality data is gathered.

For DO the re-calculated 20th percentile value is 69%. A target maximum value for DO has also been included, as the 2019-2020 data has indicated that super-saturated dissolved oxygen levels occur in Cadiangullong Creek at times. Depending on the duration, super-saturation can lead to 'gas bubble disease' in fish (Boulton *et al.*, 2014). A maximum value of 110% has been selected, based on the ANZG (2018) default guideline value.

When DO data collected during the April to July 2019 cease-to-flow event is compared to the updated 69 to 110% range it is apparent that 13 of the 31 DO values recorded as being less than the original 88% target value are now within the target range and five values were in excess of 110% so could be considered outside the updated range.

For pH, the range has been re-calculated based on 20th and 80th percentile values. The re-calculated target range is pH 7.4 to 8.2.

When pH data collected during the April to July 2019 cease-to-flow event is compared to the updated pH 7.4 to 8.2 range three (of 25) values fell outside the range as opposed to 14 out of 25 using the original target range.

The TARP initially provided two key water quality variables to assess protection of aquatic ecology values in Cadiangullong Creek. Water quality collected during the monitoring program has indicated that salinity (measured as EC) is a parameter that noticeably varies – both longitudinally (with higher EC in downstream reaches) and due to flow changes (with noticeable increases during low flow periods, likely due to groundwater inputs). As such, a target EC value was calculated based on logger data at gauge 412161, to determine the 80th percentile value during normal operation (i.e. excluding the managed cease-to-flow period). This gauge was selected as this location appears to receive groundwater inputs but still supports both Mountain Galaxias and Platypus. The target value for EC is 465 µS/cm.

When compared to EC values recorded during the cease-to-flow event it is apparent that these values are often exceeded within Cadiangullong Creek, especially in downstream reaches, and was also exceeded during the cease-to-flow event in Pool 11, where the data was derived from. As such, if EC is included in the TARP should be considered as an initial screening tool to assess whether further investigation is required.

Table 4 provides recommended updated interim target values for sites on Cadiangullong Creek.

Table 4 Updated TARP Indicators and target ranges

Indicator	Interim target range	Data points
pH	7.4-8.2	N=66 (11 months, 6 sites)
DO (% saturation)	69%-110%	N=65 (11 months, 6 sites)
EC (µS/cm)	465	N=2712 (2012-2020)

4. Summary

To support the application to NSW Department of Water and Energy (DWE) to cease riparian releases from Cadiangullong Dam and address specific questions related to ecological risks, a three stage monitoring program was implemented aimed at:

- Determining the distribution of Platypus and Mountain galaxias in Cadiangullong Creek
- Assessing changes to aquatic values during the cease-to-flow period
- Identifying potential management actions to mitigate against potential impacts

The first part of this investigation was to review the results from the previous cease-to-flow event that took place in 2007 (ALS, 2007). This review is detailed in GHD (2019) but the key finding was that in the context of the natural cycling of drought and low flows, the Cadiangullong Creek ecosystem should recover within 6-12 months of prolonged cease-to-flow event. The major findings of the current program in relation to key objectives are discussed below.

4.1 Stage 1

AIM: Identify the location of key pools that may provide refuge habitat for platypus and Mountain galaxias during cease-to-flow events based on water quality, habitat conditions and any logistical constraints that may present issues for future monitoring.

- The *in situ* water quality of Cadiangullong Creek indicates the conditions are suitable to support platypus and Mountain galaxias.
- The geomorphology of Cadiangullong Creek consists of a series of deep pools inter-connected by shallow riffles. Although the habitat suitability index (HSI) for platypus was spatially variable along the waterway, there were several pools considered to have the capacity to provide habitat under a range of flow conditions.
- During a period of riparian releases, platypus and Mountain Galaxias were distributed throughout Cadiangullong Creek.
- Current mining activities and water management did not appear to restrict the Creek in providing habitat for platypus and mountain Galaxias.
- A number of pools suitable for future monitoring during Stage 2 were identified based on potential to provide refuge habitat during cease-to-flow events, and logistics associated with monitoring.

4.2 Stage 2

AIM: Implement Stage 2 monitoring program during cease-to-flow events to assess any changes in the spatial distribution of platypus and Mountain galaxias, and any changes in the condition of the key pools and their capacity to act as refuge habitat for ecological values.

- The cessation of the riparian releases resulted in an obvious decrease in flow in Cadiangullong Creek that decreased connectivity for aquatic fauna passage between the pools in the different reaches.
- Refuge pools with suitable habitat remained throughout Cadiangullong Creek.
- Evidence that releases reduced temperature in upper reaches due to the release of colder water.
- Increases in electrical conductivity were evident in downstream reaches, particularly Pool 7 and Pool 10/11, likely due to an increase in the contribution of groundwater to baseflow.

- Algal photosynthesis was the main driver in daily variation in dissolved oxygen and pH. Evidence of super-saturation was observed in September 2019 only.
- Water quality did not reach critical values during the cease-to-flow period and was suitable for platypus and Mountain galaxias.
- eDNA monitoring coupled with visual surveys and photography confirmed the persistence of platypus and Mountain Galaxias in Cadiangullong Creek during the cease-to-flow period.
- Stage 2 monitoring confirmed specialist advice from Josh Griffiths (CESAR) that:
  (1) Short periods of low flows or cease-to-flow events can be tolerated by platypus if refuge areas are available.
  (2) Temporary reduction or cessation of flows (i.e. <12 months) is not expected to permanently impact the resident platypus population.
- For both platypus and Mountain galaxias, eDNA monitoring appears the superior approach for detecting presence in that it reduces the required effort for physical surveys, and alleviates the limitations associated with reduced water clarity and visual observations.
- The current TARP is provided in Appendix A. Updated TARP Indicators and target values have been calculated based on data collected during the monitoring program. The target values for pH and DO should be considered interim values until 24 months of data are collected. A target upper value for EC has been calculated, based on data collected from gauge 412161. The updated TARP values provided in Section 3 should be considered for inclusion in the TARP.

  The TARP should be amended with regards to the 'Water Level' Indicator. The '*riffles drying*' descriptor should be considered a 'trigger value', not a 'critical value', based on results of this monitoring program.

4.3 Stage 3

AIM: Based on the findings of Stage 1 and Stage 2, identify potential management actions to mitigate against potential impacts to platypus and Mountain galaxias.

- A potential mitigation technique previously identified in the TARP was a pulse release of water to act as a flushing flow to maintain water quality and habitat. Josh Griffiths (CESAR) also suggested a pulse release would aid in maintaining the ecological vales in Cadiangullong Creek and suggested:
  (1) Initially reducing flows slowly over time (approx. seven days) to allow resident Platypus to disperse into the adjoining Belubula River if desired.
  (2) Continue to release periodic water pulses (e.g. monthly releases over five days) to temporarily achieve aquatic connectivity along the length of the creek to maintain water levels in refuge areas, improve conditions in refuge areas, and provide opportunities for resident individuals to naturally disperse if conditions are unsuitable.
  (3) Implement an ongoing monitoring program and adopt an adaptive management approach to maintain ecological values (e.g. fortnightly releases of two to three days may achieve better water quality outcomes than monthly releases over five days).
- To determine the water required to flush and/or maintain refuge pools a trialled pulse release of approximately 2 ML/day from Cadiangullong Dam occurred during the cease-to-flow event from 25-29 July 2019.

- The trial pulse release resulted in an increase in water level at each of the refuge pools, and a decrease in electrical conductivity. However, the influence of the release on electrical conductivity did not extend to Pool 18 where levels remained similar to previous monitoring events.
- Visual assessments also suggested that surface algae was reduced or flushed through during the trial pulse release.
- The results from the trial pulse release indicated it was a suitable adaptive management action to aid in the protection of ecological values in Cadiangullong Creek.
- In light of the advice from CESAR, the monitoring results to date and a review of pulse flow requirements, an additional requirement of regular pulsed water releases in the absence of natural runoff pulses, has been included in the overall management strategy.

  At the beginning of each month, CVO will review flow data in Cadiangullong Creek and if insufficient rainfall runoff has occurred to provide a water pulse, 8 ML of water, at a rate of 2 ML/day, will be released from Cadiangullong Dam. CVO's management framework remains adaptive and will be updated as additional information becomes available.

5. Conclusion

There is no evidence from either the previous monitoring program (Ecowise, 2007) or the current, more intensive monitoring program, that the cessation of the riparian releases had a lasting detrimental impact upon aquatic ecological values in Cadiangullong Creek.

As expected, flow and water levels were decreased following the cessation of the releases, but Platypus and Mountain galaxias persisted in refuge pools. Although there were some changes to water quality, this was not significant enough to reach critical levels and trigger mitigation actions.

A trial pulse release of 10 ML/d over five days at the end of July 2019 provided some evidence this was a suitable flow regime to restore connectivity between pools and improve water quality. This indicates that should mitigation actions be required, special releases have the ability to improve in-stream conditions. As mentioned above, CVO have updated their management strategy based on the results from the trial release and advice from CESAR.

The findings from this investigation are based on a relatively intensive monitoring program, which will be complemented by other components of CVOs annual monitoring program (e.g. macroinvertebrate communities). The results indicate that conditions during both the managed and natural cease-to-flow events have continued to provide conditions that allow key aquatic ecology values in Cadiangullong Creek to be maintained.

6. References

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Appendices

Appendix A – Trigger Action Response Plan (TARP)

Indicator	Monitoring requirements	Target value Acceptable or 'normal' range based on long-term monitoring data & literature review.	Trigger value Early warning values are tending outside of 'normal' range or becoming a threat to ecological health.	Critical values Unacceptable level of risk to ecological health based on water quality and visual assessments.
Mountain galaxias	Visual observations, eDNA sampling and/or electrofishing surveys.	Present at majority of sites.	NA.	Absent from majority of key refuge pools or evidence of fish kills.
Platypus[3]	eDNA sampling, photographic evidence and/or visual observations.	Present in at least 1 key refuge pool.	Absent from all key refuge pools during 1 monitoring event.	Absent from all key refuge pools during 2 or more monitoring events.
Dissolved oxygen[4]	*In situ* monitoring.	88% saturation[5]	<40% saturation	<20% saturation
pH[6]	*In situ* monitoring.	6.5 – 8.0	5.0 – 6.5 or 8.0 – 9.0	<5 or >9
Water level[7]	Photographic evidence and/or visual observations.	Water level variation within normal & expected range due to climate; connectivity between pools intact.	NA.	Significant (>50%) change to water level; riffles dry; key refuge pools beginning to dry.
Potential mitigation options.		No action required.	Continue monitoring (may include *in situ* and/or grab sampling to validate findings; crosscheck data accuracy; compare against reference sites to identify abnormal catchment-wide activities.	Fish relocation; manual removal of excessive algae; mini aerator units (where possible); special environmental water release (where practical).

[3] Platypus may migrate between pools and provisions should be made for this movement. Negative results at one pool should not necessarily trigger the special environmental water release; but rather assessed in conjunction with the results from all of the monitoring locations. Successful mitigation indicated by positive eDNA result after successive negative results.
[4] Reviewed based on *in situ* data collected during the pool survey.
[5] Target value based on median saturation calculated from monitoring data during riparian releases
[6] Above a pH of 9 certain metals become toxic to aquatic fauna, which may occur if algae proliferates during low flows.
[7] Key refuge pools may be changed or values for indicators altered. For example, if oxygen falls below 20% but platypus and fish remain then critical value for oxygen should be reviewed.

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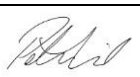
0	S. Harrow	P. Lind		P. Chier		26/08/2020
1	S. Harrow	P. Lind		P. Chier		28/08/2020

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