5 August 2021

Our Reference: 15630-21-EOLR-1Rev0_210805

Sarah Blake
Manager Environment and Approvals
Roy Hill Iron Ore Pty Ltd
5 Whitham Road
Perth Airport WA 6150

Dear Sarah,

Re: Roy Hill Mine – Surface Water Flows – Memo, August 2021

This letter outlines subject matter expert advice to Roy Hill Iron Ore Pty Ltd (Roy Hill) from Astron Environmental Services (Astron) to assist Roy Hill with responding to comments received from The Western Australian Environmental Protection Authority (EPA) related to a referral under Section 38 (S38) of the *Environmental Protection Act 1986*.

Roy Hill has requested that Astron provide advice on the potential impact of the Roy Hill iron ore mine (the Mine) on surface flow dependent vegetation, taking into account proposed changes to surface water management at the Mine associated with the S38 referral (the Revised Proposal).

Our advice is provided in the form of reviews and assessments of the following components:

- outputs from Astron's surface flow dependent vegetation risk assessment model (Section 2)
- hydraulic structures associated with the Revised Proposal (Section 3)
- assessment of sheet flow areas and sheet flow dependent vegetation (Section 4)
- assessment of change in vegetation cover and health since baseline (Section 5)
- timeline of potential impacts (Section 6).

The advice contained in this letter is based on an assessment of available reports and data. Where information is lacking, opinions are provided based on our knowledge and experience.

1 Background

In 2015, Roy Hill engaged Astron to prepare a Surface Flow Dependent Vegetation (SFDV) Risk Assessment model for the purpose of improving the annual vegetation health monitoring program implemented to comply with Ministerial Statements 979/980 (Astron Environmental Services 2016a). In 2020, Roy Hill engaged Astron to revise the SFDV risk assessment in preparation for the S38 referral and a review of the Vegetation Condition Environmental Management Plan for the mine. This revision incorporated updated information on approved and pending mine disturbance, hydraulic structures and improved vegetation classification procedures for identifying SFDV.

Key background information is contained in the previous SFDV risk assessment reports (Astron Environmental Services 2016a, 2020a). Readers are referred to these documents for detailed descriptions and literature reviews of surface water dependent vegetation, including:

- definition of surface flow dependent vegetation, including riparian and sheet flow dependent vegetation
- plant responses to changes in surface water hydrology
- factors influencing plant dependent on surface water flow, including topography and hydraulic structures
- key vegetation types and species, including mulga vegetation (*Acacia aneura*, and other trees in the mulga species complex).

2 Risk assessment model for surface flow dependent vegetation

The original scope provided to Astron was to conduct a SFDV Risk Assessment for the purpose of improving the vegetation monitoring program for the Roy Hill Mine. Astron developed a risk model based on the framework provided by the Department of Water and Environmental Regulation (then Department of Environmental Regulation (DER)) in 2017 (Guidance Statement: Risk Assessments. Part V, Division 3, Environmental Protection Act 1986) (Department of Environmental Regulation 2017), which sets out how the department determines risk event acceptability (acceptable and tolerable, or unacceptable and not tolerable) and treatment (appropriate treatments and degree of regulatory control).

A key aspect of Astron's SFDV risk model is that it modelled inherent risk, not residual risk. Risk controls and management were not considered in the model. The model was conservative in line with a precautionary approach. Residual risk may be lower than specified by the outputs of the model if such controls were put in place.

Elements of the risk model that were particularly conservative were:

- identification of land areas where sheet-flow is likely to occur (all land area with slope < 2 degrees)
- classification of mulga vegetation (70% probability from classification model)
- identification of sheet flow-dependent vegetation (assumed to be areas of banded mulga vegetation identified by inspection of aerial imagery)
- likelihood ratings (assigned for any type of impact, positive or negative, and applied to the entire length of waterways assuming no diminishing impact with increasing distance from hydraulic structures)
- definition of the disturbance boundary line (entire boundary used to assess shadow effects rather than individual structures)
- total risk assessment area (5 km buffer from the disturbance boundary to account for cumulative effects downstream and closer to the Fortescue marsh; this compares with the 500 m buffer in place inside the western boundary of tenement M46/518).

We do not believe it is appropriate to include tabulated risk areas produced by the inherent risk model in cumulative vegetation impact or clearing budgets. Inclusion of inherent risk areas in impact budgets, especially medium and low areas, does not allow for the possibility that risk can be managed, using regulatory controls if necessary.

Most of the land area considered by the inherent SFDV risk model was identified as being Medium or Low risk, with some selected areas of High risk that have been reviewed based on updated information (see Sections 3 and 4 below). Under the DER framework, High risk "may be acceptable subject to multiple regulatory controls" and high-risk events "may be tolerated". Medium risk is "acceptable" and medium risk events are "tolerable" with the possible need to apply "some regulatory controls" where practical and appropriate. "Low" risk and low risk events are "acceptable". This suggests that the risk to surface water dependent vegetation at Roy Hill is manageable through the implementation of mitigation measures to further reduce risk.

3 Hydraulic structures

The potential impact of surface water hydraulic structures at the Mine on riparian vegetation was assessed following a review of the GHD report titled *Section 38 Referral: Hydraulic Structures* (Rev3, March 2021) (GHD 2021), and an accompanying clarification letter addressed to Wendy Kozak at Roy Hill, dated 18th June 2021 (together referred to as the GHD report). The GHD report presents a plan for future hydraulic structures at the Mine for the Revised Proposal, both during mine operations and mine closure. The letter provides clarification on key changes to hydraulic structures and riparian vegetation impacts between the Revised Proposal and the Original Proposal.

Compared to the Original Proposal, the major changes to hydraulic structures in the Revised Proposal are modifications to new permanent channels and levees designed to re-route water around mine pits in a more strategic manner, avoiding backfilled pits and cascading storage structures, while retaining existing waterway alignments as much as possible. There are no major changes to outflow points, with the whole system designed to return runoff to the same waterways from which the runoff was diverted.

Water catchment and stream flow modelling was undertaken by GHD to predict changes in surface water hydrology following implementation of hydraulic structures, with results reported for a series of reporting locations (1 to 11) covering the major waterways that pass through the mining tenement (see Attachment 1, Figure 1). The GHD report presents estimated catchment areas (in hectares) and modelled flow rates for each reporting location, for both pre-mine and mine closure scenarios. The flow rates presented are for the 50% Annual Exceedance Probability (AEP) flood, selected to represent a relatively frequent runoff event occurring every 1 to 2 years on average.

Expected impacts on riparian vegetation downstream of the reporting locations are summarised in Table 1 in Attachment 1. This assessment is based on expected changes to catchment areas and flow rates, and other information presented in the GHD report. Impact was defined as an ecologically significant change in vegetation cover, health, spatial structure, or community composition, in either a positive or negative direction. Impact magnitudes are defined as follows:

- Small impact = composition and species dominance retained but minor change in density.
- Moderate impact = composition retained but change in species dominance and change in density
- Large impact = change in composition and large change in density.

A likelihood rating for residual negative impact over decadal time scales is also provided in Table 1 in Attachment 1, using a standard matrix (Rare, Unlikely, Likely, Possible, Almost Certain). Changes to catchment areas were weighted more heavily than changes to 50% AEP flow rates in the likelihood assessment on the assumption that catchment areas likely provide a better integrated measure of the total runoff volume and long-term water availability to riparian vegetation.

We expect there to be either a positive impact or essentially no impact for 7 of the 11 reporting locations (1, 2, 3, 4, 7, 9 and 11), and only a small negative impact for two other locations (5 and 6). Moderate to large impacts may be expected for reporting locations 8 and 10, however it is noted that the major flow paths of these waterways have already been classified as disturbance (pending clearing area area) under the Revised Proposal for the S38 referral. The timeframes over which impacts (positive or negative) may become evident is estimated to be within 5 years for relatively moderate to large impacts and 5 to 10 years or longer for relatively small impacts (timeframes are further discussed in Section 6). Overall, outside of allocated disturbance areas, the likelihood of there being any negative residual impacts to riparian vegetation systems over decades was considered to be unlikely or rare in most cases.

The waterways most likely to display some form of permanent vegetation change are those associated with reporting locations 5 and 6, but these changes may take years to evolve, and may only lead to a reduction in tree density rather than major changes to vegetation structure or community composition. Reporting location 5 is located along a mulga drainage line without a main channel for water flow, whereas reporting location 6 is located along the major channel of Kulbee Creek. Of note, these areas are covered by active vegetation monitoring sites. For reference, these sites include WLI2 near reporting location 5, sites GDVI3 and GDVI4 near reporting location 6, and site MAR.3 further downstream of Kulbee Creek.

The GHD report states that runoff volumes for the entire catchment are predicted to change by less than 3% of the pre-mine conditions, and that the volume and flow of runoff received by riparian vegetation downstream of affected waterways is maintained close to baseline conditions. Overall, the report concludes that while the Revised Proposal is expected to impact downstream riparian vegetation in a limited number of locations, the impacts are less than those associated with the Original Proposal. We agree with this assessment of potential vegetation impacts.

Based on the updated information, several waterways identified by the SFDV risk model as High risk would be reduced to a lower rating, including the waterways associated with reporting locations 4 (reduced likelihood of negative impact), 9 (positive impact now expected), and 10 (reclassified as disturbance area). However, Low to Moderate risk ratings for riparian areas along waterways associated with reporting locations 5 and 6 would increase by one level. Overall, it is expected these changes are likely to result in a net decrease in the change in area of high risk if included in a re-run of the SFDV risk model.

4 Sheet flow

Although completed for the previous SFDV risk assessment, sheet flow areas and the occurrence of potentially sheet flow dependent vegetation near the Mine were reassessed to gain a better understanding of risk. For this we reviewed:

- land areas downstream of the mine with the potential to support sheet-flow
- vegetation assemblages that are the most dependent on sheet-flow
- the disturbance boundary of the Mine, downstream from which (overland) surface water flows may be blocked and shadow effects may occur.

4.1 Sheet flow areas

Slope class rasters were derived from digital elevation model (DEM) datasets to delineate the area where the slope is less than 2 degrees and where it falls between 0.2 and 2 degrees. Two DEM datasets were used: an open source STRM DEM-H dataset, with coarse (30 m) resolution that pre-dates construction of the mine but covers the entire region, and a 2017 Lidar DEM that was much higher resolution (0.1 m) but restricted to within the mining tenement boundary for the mine and immediate surrounds.

Slope class rasters (not shown) showed that:

- Nearly the whole area downstream of the disturbance boundary from the mine to the Fortescue Marsh has a slope of less than 2 degrees. Areas where the slope is greater than 2 degrees are restricted to major waterways (including the Fortescue River, Kulkinbah Creek, some sections of Kulbee Creek, and some sections of other major drainage lines), and the two isolated hills near to the Roy Hill Station homestead. Minor waterways tended to have a slope of less than 2 degrees.
- Areas where slope falls between 0.2 and 2 degrees are numerous but patchily distributed across the whole area within a mosaic of essentially flat areas where the slope is less than 0.2 degrees. Flat and gently sloped areas occur in this mosaic in roughly equal proportion, with no obvious contiguous large areas where slope is between 0.2 and 2 degrees.

The results above suggest that the whole land area downstream of the mine can potentially support sheet flow under the right conditions. This is supported by flood modelling and mapping presented in the GHD report, which indicates that nearly all land area downstream of the disturbance boundary would become inundated to a shallow depth of at least < 0.2 m during 0.1% and 1% AEP floods (GHD 2021, Appendix B, Figures 1 to 8); this would almost certainly promote sheet-flow across the entire landscape. Existing mine infrastructure (such as the TSF, mine pits and waste dumps) would impede sheet flow during very large but infrequent rainfall events (e.g., 1 in 100 years), however these events would be rare, and in such instances the volume of runoff would almost certainly be large enough to maintain sheet flow to SFDV downslope of infrastructure. Given their rarity and the 20-year life of mine, these types of events are not considered to play a major role in determining SFDV structure or health at Roy Hill.

Smaller flood events (2% and 5% AEP floods) would likely promote sheet flow adjacent to flooded waterways and in areas in between waterways where major surface water pooling occurs and conditions are conducive to sheet flow (GHD 2021, Appendix B, Figures 9 to 16). Mine infrastructure may potentially impede runoff following such events, but only in localised areas, and the degree to which SFDV would receive less sheet flow is difficult to predict as it depends on the overall size of the catchment area and other ecohydrological factors at the local scale (particularly slope, flow rate, infiltration rate, topography and existing vegetation). Predicting the exact location and nature of sheet flow for smaller flood events is beyond the scope of Astron's expertise, however it is likely that SFDV sustained by larger catchments would be less affected. In general, it is reasonable to assume that SFDV at Roy Hill is somewhat adapted to sheet flow generated by relatively high but infrequent rainfall events (e.g., 1 in 20 years), more so with respect to structure than health.

Relatively frequent small runoff events (> 5% AEP floods) would most likely promote sheet-flow in localised small areas only, or not at all (GHD 2021, Appendix B, Figures 17 to 28). Sheet flow is mainly generated locally in these instances, and the amount of flow is less dependent on catchment size compared to larger flood events. Therefore, infrastructure is not likely to impede sheet flow if there is a suitable buffer distance between infrastructure and local sheet flow areas. In their report and recommendations for the Roy Hill 1 Iron Ore Mining Project Stage 1, it was the EPA's opinion that with regard to surface water management, implementation of a 500 m buffer zone was sufficient to ensure there would be no shadow effects beyond the boundary of the project (Environmental Protection Authority 2009). In general, it is reasonable to assume that SFDV at Roy Hill is highly adapted to hydrological regimes characterised by frequent small runoff events generated locally (no less frequent than 1 in 5 years), with respect to structure and health.

4.2 Sheet flow dependent vegetation

The specific ecological water requirements and dependencies of vegetation at any given location are difficult to determine without detailed long term studies. Areas of sheet flow dependent vegetation (primarily mulga vegetation) for the Astron SFDV risk model were obtained by inspection of aerial imagery. Imagery was inspected to identify vegetation assemblages that displayed a level of spatial self-organisaton and patterning, such as banding. It is assumed that spatial self-organisaton is indicative of a relatively stronger ecological association with sheet flow, a concept that is well described in the literature, and reviewed in detail in the 2015 version of the SFDV risk assessment (Astron Environmental Services 2016a). The most common form of patterned vegetation in the Roy Hill region is banded mulga.

The approach of identifying banded mulga remains valid for this reassessment. Aerial imagery provided by Roy Hill (annual captures from 2006 to 2020) was inspected to identify additional areas of banded mulga not identified in the original assessment. Banded mulga areas were conservatively delineated from isolated trees or open low-density woodland, with areas included only if banding was obvious.

No new areas of banded mulga were identified. Minor adjustments were made to previous boundaries to define the main banded vegetation 'catchments' rather than individual patches. These adjustments increased the total area delineated as sheet flow dependent by 17% (total area = 2,124 ha), with no increase in the area designated as High risk in the SFDV risk model. Of note, the two most prominent and largest banded mulga 'catchments' identified are covered by active vegetation monitoring sites (sites MAR.13 and MAR.8).

4.3 Disturbance boundary line

The disturbance boundary line was reviewed taking into account updated disturbance layers provided by Roy Hill (S38 granted and pending clearing areas). The updated disturbance layer was almost identical to that used to develop the SFDV risk model and it had no bearing on the definition of the disturbance boundary line, which defines near-contiguous disturbance along the southern boundary of the Mine.

Based on the above reviews (Sections 4.1, 4.2 and 4.3), there is no basis for revising the original SFDV risk model with respect to the land area likely to support sheet flow, or the area and consequence rating of sheet flow dependent vegetation. It remains valid to use the entire boundary in any future revisions of the SFDV risk model if the aim is to assess broad-scale blocking and shadow effects associated with surface water flows. However, it is recognised that localised areas of vegetation downstream from individual structures may be more or less at risk of impact dependent on the nature and size of the structure, for example the tailings storage facility (TSF) and hydraulic structures constructed for creek diversions, however as stated previously, where rainfall is high enough to cause landscape scale sheet flow that would be impeded, such impacts are likely to have minimal impact on vegetation.

5 Assessment of change in vegetation cover and health since baseline

A rapid desktop review was undertaken to assess the extent of change to vegetation health, cover and structure since the mine was constructed. This review had two components: visual assessment of aerial imagery captured annually between 2006 and 2020 (imagery supplied by Roy Hill), and a brief review of annual vegetation health monitoring outcomes since 2014 (post baseline).

5.1 Aerial imagery

All aerial imagery supplied by Roy Hill underwent an initial visual assessment, from which imagery from specific years was selected for more detailed inspection. The years selected represented a timeline from the pre-mine period (baseline) to present, as described in Attachment 1, Table 2. One image was selected to represent the pre-mine baseline period (2006), followed by images from 2012 (first development) and every two years thereafter to present (2020). Overview images of the whole mine area are provided for reference in Attachment 1, Plate 1. Of note, the largest single area of clearing was completed in 2014, for the TSF (Plate 1).

Target areas of interest were extracted from aerial imagery for detailed inspection (rectangular polygons with approximate dimensions of 400 m by 350 m). The target areas covered a range of vegetation types, including minor and major mulga drainage lines, major creeks and banded mulga formations, across a range of locations as near to current disturbance. Target areas were located within or near to the 500 m buffer zone implemented inside the western boundary of the tenement, mostly in the north-western section. Target areas along waterways were aligned with GHD (2021) reporting locations, where possible (Figure 1). Time-series images for target areas are shown in Attachment 1, Plates 2 to 8.

The target areas of vegetation within the 500 m buffer zone were assumed to represent vegetation with highest risk of impact. These areas were located closest to existing disturbance, and subject to the longest history of upstream disturbance. This includes the TSF, the largest infrastructure object with the greatest potential to cause a shadow effect on vegetation, and creek diversions for No Name Creek and Kulbee Creek.

Target areas of interest were assessed for any major (visually obvious) changes to the following: tree deaths, tree density, canopy cover, structural arrangement of vegetation (patterning), community composition (ratio of trees to understorey), and area of bare soil.

Inspection of target areas (Attachment 1, Plates 1 to 8) did not reveal any major change to vegetation since baseline that might be attributed to mining. In general, vegetation communities remained intact, with no obvious areas of tree death and no major change in tree density or spatial arrangement. Overall, there was no evidence of structural change – riparian zones did not expand or contract for minor drainage lines (Plate 2), major drainage lines (Plate 3) or creeks (Plates 4, 5 and 6), and banded mulga formations were unchanged (Plates 7 and 8). Canopy cover (foliage thinning) and understorey cover appeared to vary over time, which can be attributed to rainfall. Imagery from December 2020 showed slightly thinner canopies than imagery from December 2018 and February 2017, however lower rainfall was received leading up to the December 2020 capture date compared to the December 2018 and February 2017 capture dates (Attachment 1, Table 2). Other differences in the images were attributed to unrelated factors including image resolution, sun angle and shading.

The absence of change in the assessed target areas is strong evidence to suggest that the Mine has not had a major impact on vegetation up to December 2020. Based on this assessment, there may be an argument to decrease likelihood ratings for vegetation impact by one level in a re-run of the SFDV risk model, which may lead to a net decrease in the areas of high and medium risk for riparian and sheet flow dependent vegetation.

5.2 Historic on-ground monitoring data

Annual vegetation monitoring reports since 2014 have not provided evidence for any major decline in vegetation health and condition since baseline (Astron Environmental Services 2015, 2016b, 2017, 2018, 2019, 2020b, 2021). This includes sites located closet to disturbance and with the longest history of upstream disturbance, and it includes results from on-ground monitoring and remote sensing analyses. Potential impact sites have behaved similarly to reference sites. Variations in health and condition have been attributed to natural seasonal and inter-annual variations in rainfall. It is noted that vegetation health monitoring programs for the Mine include active monitoring sites for key vegetation types (mulga drainage lines, riparian zones, open plains and banded mulga) spanning a broad spatial area downstream of the disturbance boundary, at various distances from the boundary (Attachment 1, Figure 1). These sites are primarily arranged to monitor for the effects of groundwater change and managed aquifer recharge (MAR) activities; however, we believe they also adequately cover potential changes to surface water flow.

To the best of our knowledge, there has been no major decline in vegetation health at Roy Hill since baseline that is attributable to secondary impacts from mining. The vegetation at Roy Hill is naturally adapted to extreme conditions, and more than a decade of monitoring has demonstrated its resilience in the presence of the Mine, through both relatively wet years and dry years, including extended periods (months to years) of drought.

Although vegetation at Roy Hill does not appear to have been affected by the Mine, it has been impacted by grazing, and this should be considered in any assessment of impact. Severe degradation and erosion of sheet flow areas was observed back in 1996-1999 at the time of the Pilbara Rangeland Survey conducted by the Department of Agriculture, where it was reported that areas in the northern part of the Roy Hill station were in poor to very poor condition (van Vreeswyk et al. 2004). No improvement was observed during a pre-development survey conducted in 2010 by Vital Options Consulting, who concluded that irrespective of any new mining-related activity, ongoing threatening processes and further declines in vegetation can be expected to continue throughout sheet flow and riparian areas until there have been substantial changes to the pastoral land use and management of the area (Vital Options Consulting 2010).

6 Timeline of potential impacts

The response of SFDV to disruption in surface water flow is expected to be incremental, as described in Section 2.2 of the original SFDV risk assessment report (Astron Environmental Services 2016a). A summary and timeline of responses to disruption are provided in Attachment 1, Table 4.

The timing and magnitude of the events described in Attachment 1, Table 4 are highly variable across space and time, and vegetation responses at Roy Hill will depend on the frequency and amount of water that is supplied to the soil by surface water flows. For example, surface water flow disruptions are likely to have a much lesser impact on SFDV adapted to small inputs of water from occasional flows along minor drainage lines or as sheet flow, compared to SFDV adapted to regular large inputs of water from flows along major water courses following major runoff events. It should also be kept in mind that when followed to the end, this sequence of events represents an extreme scenario. Where surface flows are reduced but not stopped, or only disrupted temporarily, effects on vegetation would be less dramatic. For example, a temporary disruption to surface water flows of moderate magnitude may lead to a reduction in leaf area and a small turnover of species, but not an irreversible loss of SFDV and replacement by new species.

Overall, we conservatively estimate that the time it would take for vegetation at Roy Hill to display clear signs of impact following any major disruption to surface water flows would be in the order of 2 to 5 years for tree health decline (decline in foliage density, canopy thinning), 5 to 10 years for major changes in tree density (tree deaths), and > 10 years for major structural change to occur at the community level (loss of species, shift in size and location of riparian zone, loss of spatial organisation of vegetation in sheet flow areas). However, it should also be considered that interannual variation in rainfall in the central Pilbara is considerable, and that furthermore, this variability can drive changes in the structure and composition of vegetation. Fire is another natural agent that can bring about such change. Rainfall and fire regimes may not only affect the timing described above, they also have the potential to bring about changes in vegetation that are of similar or greater significance to those described with respect to changes in surface flow.

Finally, timeframes for potential impacts on vegetation at Roy Hill should be considered in the context of the life of mine, which is in the order of 20 years. We expect that if any decline in SFDV health were to occur, it would be detected by monitoring within 2 to 5 years and managed appropriately to prevent any major loss in density and enable recovery within approximately the same time frame. Structural change to SFDV communities appears less likely to occur given the relatively short life of mine compared to the decadal and longer time scales over which ecohydrological processes operate.

7 Conclusion

In conclusion, based on the available information, there does not appear to be a strong likelihood of impact to vegetation associated with proposed changes to surface water management at the Mine. In particular, the following points are noted:

- There is only a 3% reduction in the catchment area, and surface water flows in riparian zones are maintained close to baseline conditions through the implementation of diversion structures.
- The whole landscape downstream from the Mine can potentially support sheet flow under certain conditions; unpredictable large rainfall events are likely to generate broad scale sheet flow that may be somewhat impeded by mine infrastructure, but SFDV would likely still receive a high volume of sheet flow. SFDV is naturally adapted to smaller rainfall events and sheet flow generated at the local scale, which can be protected via existing buffer zones.
- To date, the Mine has not had a negative impact on SFDV or riparian vegetation. If the Mine was impacting on vegetation, it is likely that this would have become evident in the vegetation monitoring and aerial imagery assessments undertaken to date, given that impacts would likely become apparent within 2 to 5 years.
- If vegetation changes were detected, they would need to be considered in the context of the broader environment, given the variability of rainfall in the Pilbara and the previous history of land management, and also the proposed life of mine, which is relatively short compared to the time scales over which the ecohydrological processes involved operate.

This letter was prepared by Dr Tim Bleby and reviewed by Dr Robert Archibald. Please do not hesitate to contact Robert or Tim should you have any queries.

Yours sincerely
ASTRON ENVIRONMENTAL SERVICES

Jacob Delfos
Manager – Earth Observation

Attachments

Attachment 1: Assessment Results

References

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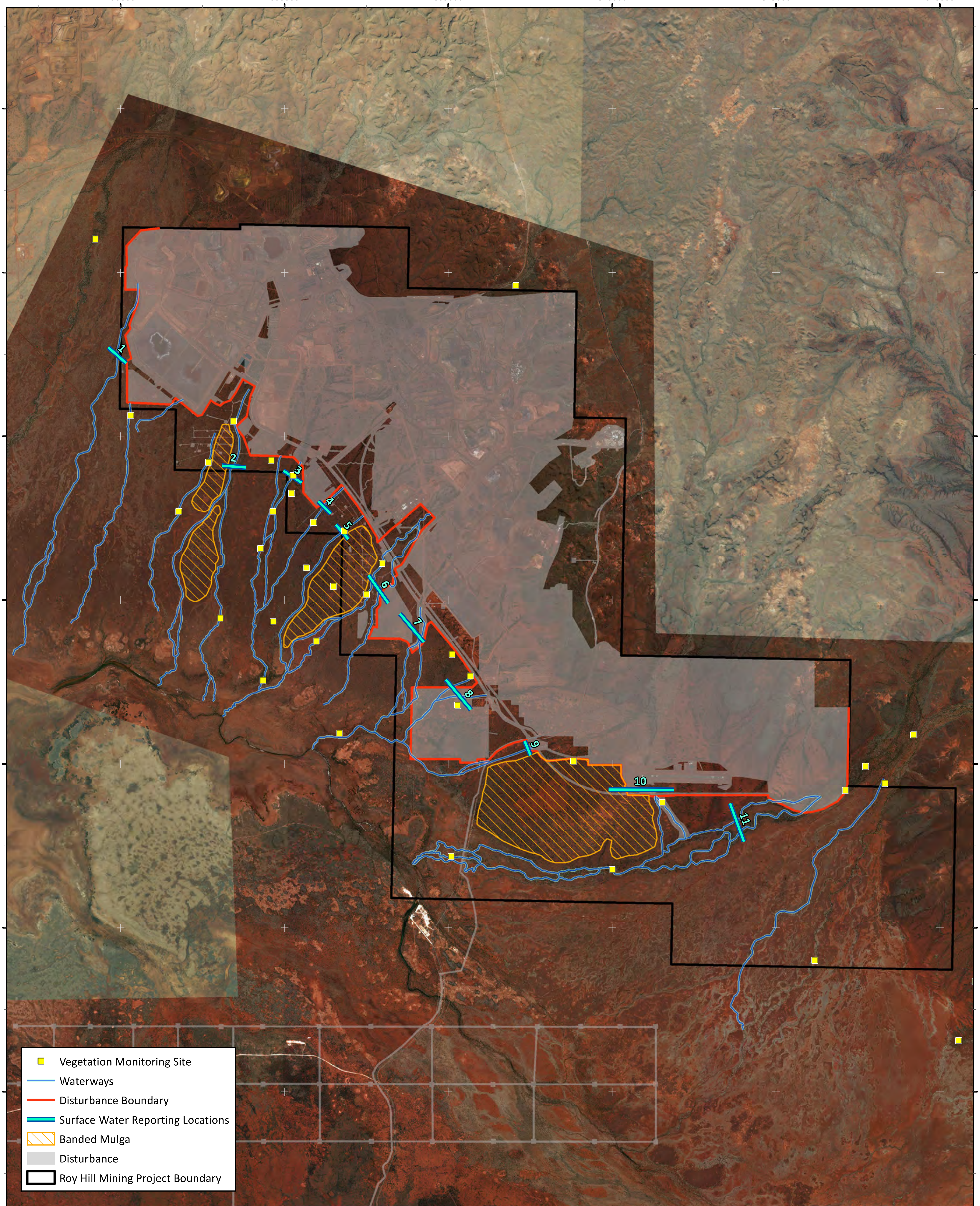
Attachment 1: Assessment Results



Roy Hill
Surface Water Flows Memo
Figure 1: Overview Map

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Author: T. Bleby	Date: 23-07-2021
Drawn: C. Dyde	Figure Ref: RH15630-21-EODR-1RevA_210723_Fig1_Overview

Table 1: Summary of expected vegetation impacts downstream of waterways affected by proposed hydraulic structures implemented to manage surface water at the Roy Hill Mine. Reporting locations are shown in Figure 1.

[1]Reporting location	[1]Pre-mine catchment area (ha)	[1]Revised Proposal catchment area (ha)	Change in catchment area relative to pre-mine (%)	Expected impact[2] on riparian vegetation	Likelihood of residual negative impact[3] on riparian vegetation
1	26,076	26,061	0%	No impact	Rare
2	8,137	8,030	-1%	No impact	Rare
3	3,634	5,977	+64%	Small to moderate positive impact, may become evident within 5-10 years	Rare
4	470	438	-7%	Little negative impact, may include some decline of vegetation in direct flow path given predicted large percentage increase in 50% AEP flow rate	Unlikely
5	662	518	-22%	Small negative impact, may become evident after 10 years	Possible
6	7,472	4,222	-43%	Small negative impact, may become evident within 5-10 years	Likely
7	2,040	1,924	-6%	No impact	Rare
8[4]	2,611	1,062	-59%	Moderate negative impact, may become evident within 5 years	Likely
9	169	4,980	+2,847%	Large positive impact, but may include some decline of vegetation in direct flow path given predicted large percentage increase in 50% AEP flow rate. Low scour risk.	Rare
10[4]	5,458	187	-97%	Large negative impact, may become evident within 5 years	Almost certain
11	74,842	74,559	0%	No impact	Rare
Total	131,571	127,958	-3%	No major impact expected at the regional level	Rare

1. Reporting locations and catchment areas as presented by GHD (2021).
2. Ecologically significant change in vegetation cover, health, spatial structure, or community composition. Takes into account change to catchment areas and other information provided in the GHD (2021) report.
3. Residual long-term impact over decades.
4. Waterways where the major flow path is already classified as disturbance (pending clearing area) under the Revised Proposal for the Section 38 referral.

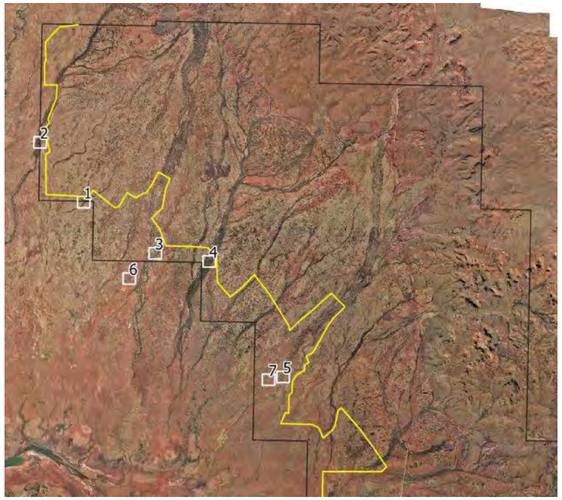
Table 2: Aerial photograph capture dates, mine phase descriptions and rainfall received at the Roy Hill Mine. Data from the Roy Hill meteorological station available since 2014. Long-term average comparisons use the regional long-term average from the Bureau of Meteorology weather station at Newman Aero (Station number 7176). TSF = tailings storage facility.

Aerial photo capture date		Description	12 months prior to capture date		Period since previous capture date	
Year	Month		Rainfall (mm)	Percentage of long-term average	Rainfall (mm)	Percentage of long-term average
2006	July	Pre-mine baseline	NA	NA	NA	NA
2012	September	Construction commenced – accommodation, roads, tracks, drill pads, small service areas	NA	NA	NA	NA
2014	December	Construction on-going – process plant, TSF, service areas, first mine pits, Kulbee Creek diversion structure	416	132%	NA	NA
2017	February	Operational phase – mine pits	373	118%	1,040	148%
2018	December	Operational phase – mine pit expansion	378	120%	594	130%
2020	December	Operational phase – mine pit expansion	395	125%	559	94%

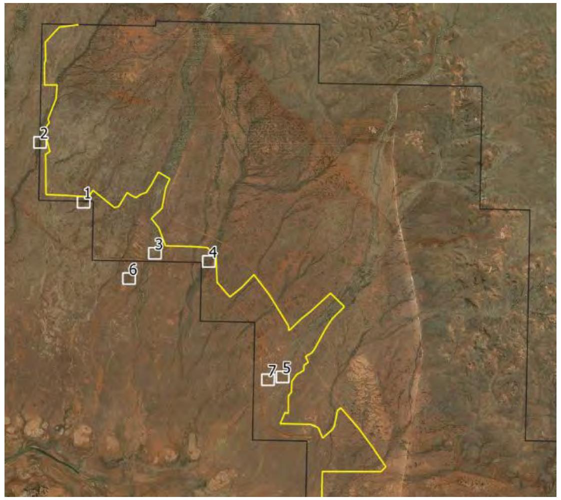
Table 3: Extracts from Aerial images selected for assessment, as shown in Plates 1 to 8. TSF = tailings storage facility.

Aerial photo extract area ID	Description	GHD (2021) Reporting location
Mine	Mine area	NA
1	Minor mulga drainage line directly intersected by TSF	NA
2	Mulga drainage line	1
3	No Name Creek	2
4	West Kulbee Creek	3
5	Kulbee Creek	6
6	Banded mulga formation	2 (adjacent downstream)
7	Banded mulga formation	6 (adjacent)

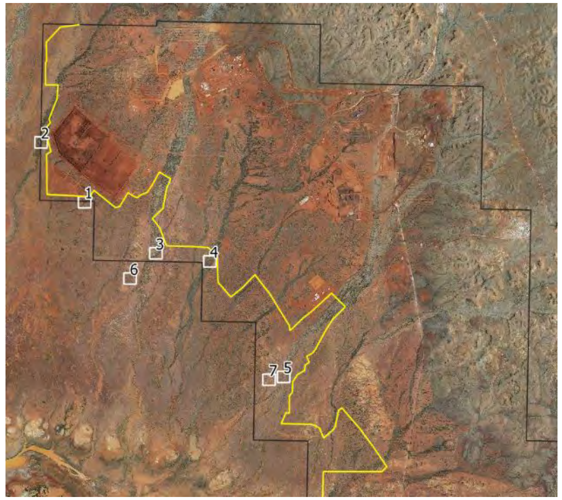
Plate 1: Change in Mine disturbance area between 2006 (baseline) to 2020. Includes disturbance boundary for Revised Proposal (yellow line) and location of vegetation extract areas shown in Plates 2 to 8.



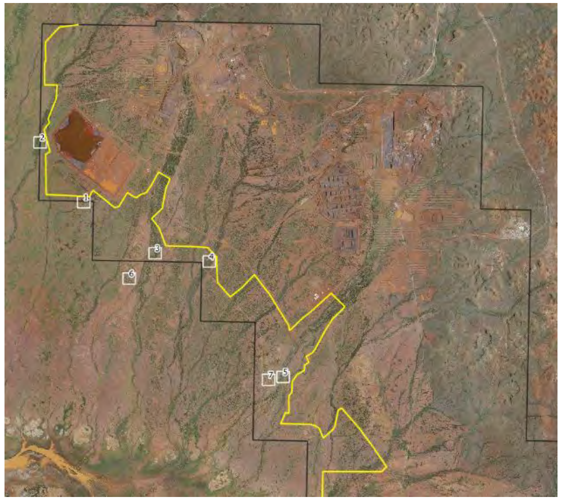
July 2006



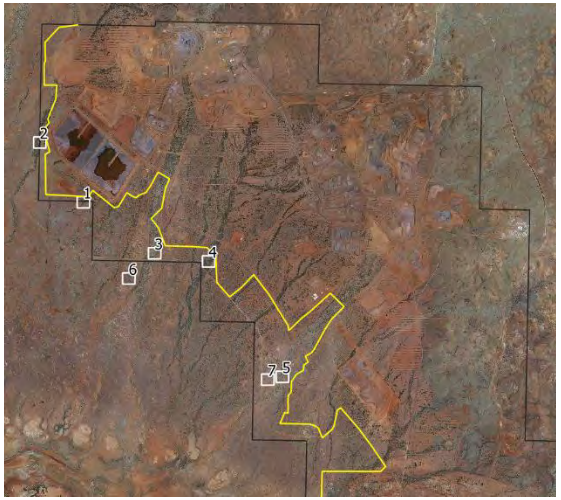
September 2012



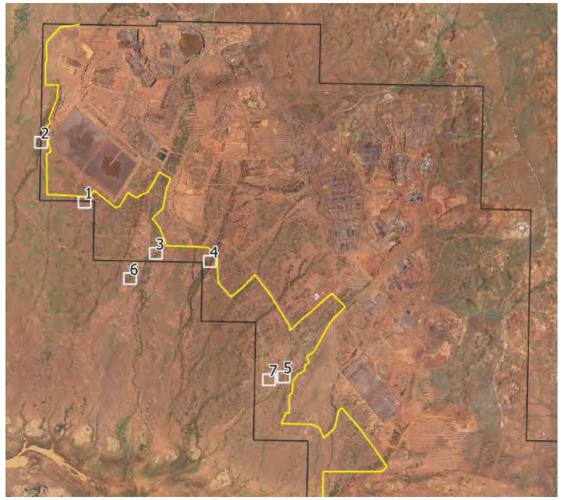
December 2014



February 2017



December 2018



December 2020

Plate 2: Change in vegetation along a minor mulga drainage line intersected by the tailings storage facility between 2006 (baseline) to 2020 (vegetation extract area number 1).

July 2006

September 2012

December 2014

February 2017

December 2018

December 2020

Plate 3: Change in vegetation along a mulga drainage line at GHD reporting location 1 between 2006 (baseline) to 2020 (vegetation extract area number 2).

July 2006

September 2012

December 2014

February 2017

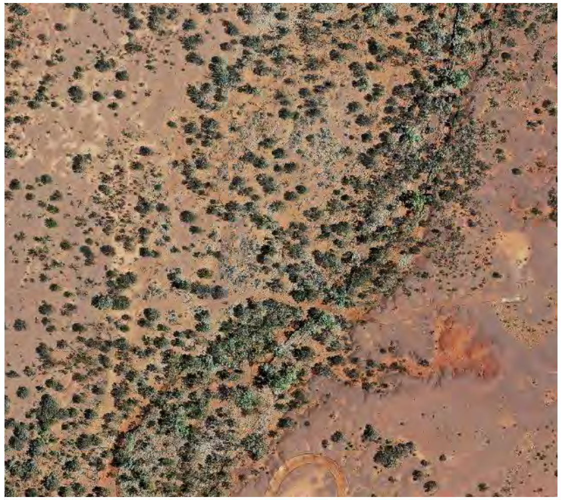
December 2018

December 2020

Plate 4: Change in vegetation along No Name Creek at GHD reporting location 2 between 2006 (baseline) to 2020 (vegetation extract area number 3).

July 2006

September 2012



December 2014

February 2017

December 2018

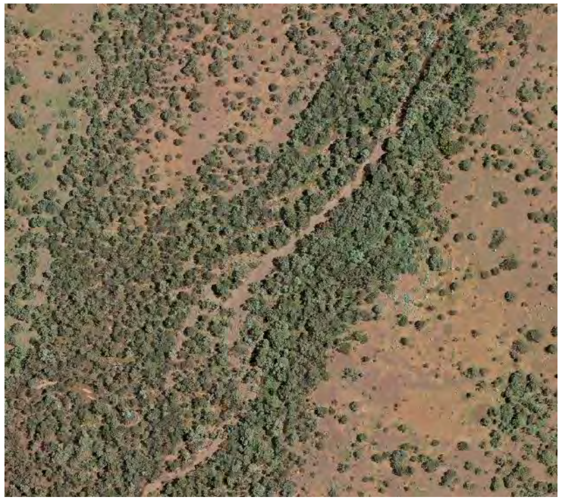
December 2020

Plate 5: Change in vegetation along West Kulbee Creek at GHD reporting location 3 between 2006 (baseline) to 2020 (vegetation extract area number 4).

July 2006

September 2012

December 2014



February 2017

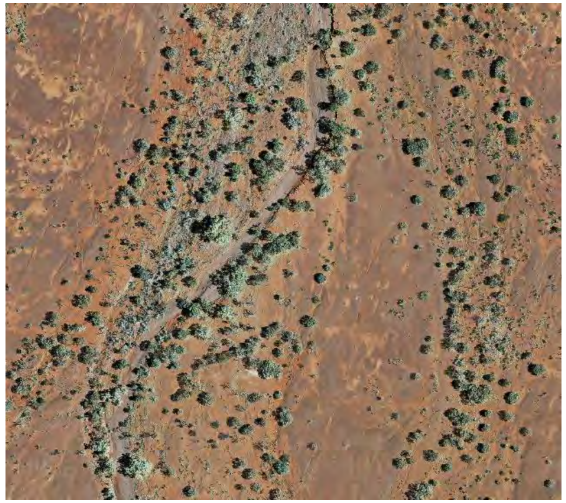
December 2018

December 2020

Plate 6: Change in vegetation along Kulbee Creek at GHD reporting location 6 between 2006 (baseline) to 2020 (vegetation extract area number 5).

July 2006

September 2012



December 2014

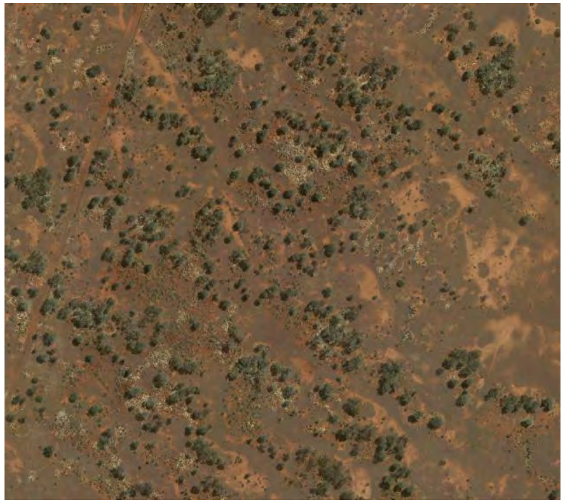
February 2017

December 2018

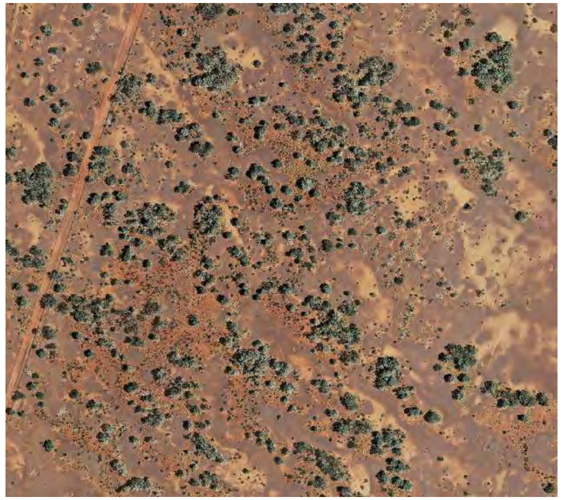
December 2020

Plate 7: Change in vegetation in banded mulga adjacent to No Name Creek and downstream of GHD reporting location 2 between 2006 (baseline) to 2020 (vegetation extract area number 6).

July 2006



September 2012



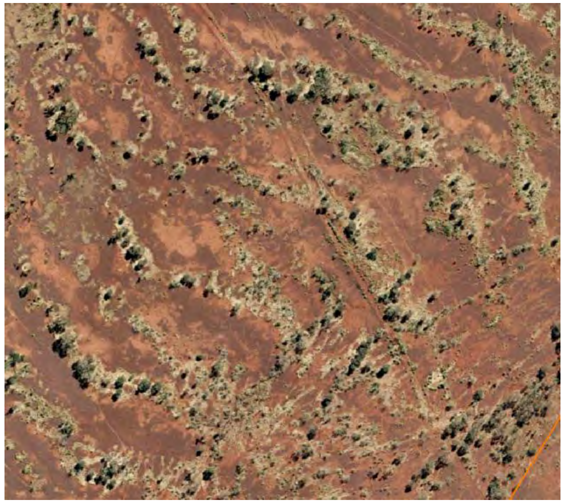
December 2014

February 2017

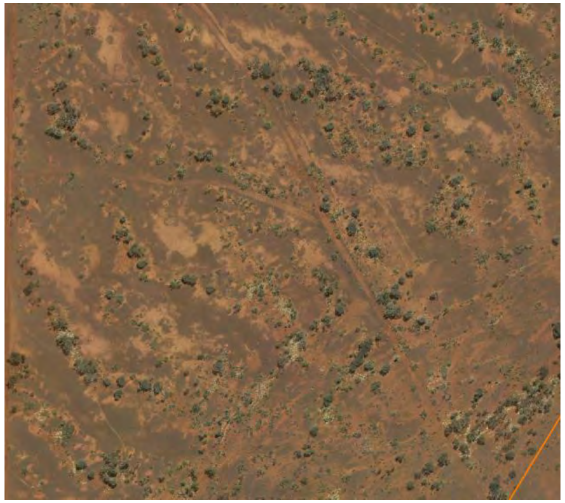
December 2018

December 2020

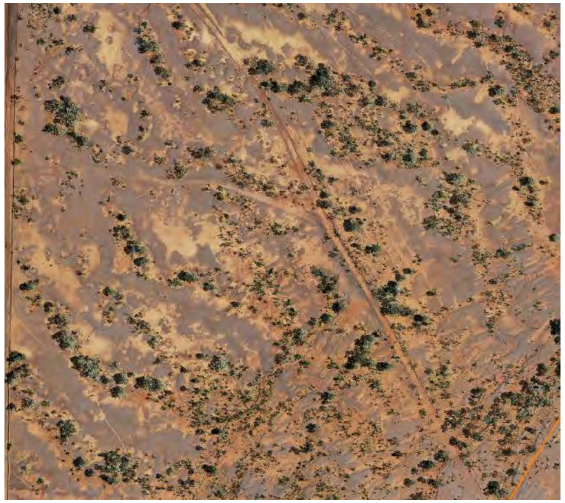
Plate 8: Change in vegetation in banded mulga adjacent to Kulbee Creek and GHD reporting location 6 between 2006 (baseline) to 2020 (vegetation extract area number 7).



July 2006



September 2012



December 2014

February 2017

December 2018

December 2020

Table 4: Summary of incremental response of surface water dependent vegetation (SFDV) to disruption to surface water flows (modified from Astron 2016).

Phase	Change and response	Timing
Surface flow disruption	Switch from recharge of soil water by surface water flow and rainfall to recharge by rainfall only ↓	Diversion structure installed, infrastructure installed that disrupts sheet flow and induces shadow effects
Soil drying	Plant available soil water becomes depleted ↓	Within months to years[1]
	Plant water uptake threshold is exceeded ↓	
Plant response to soil drying	Physiological responses: • Stomatal opening reduced • Transpiration declines • Carbon fixation declines • Leaves wilt ↓	Within weeks
	Structural responses: • Leaf area declines • Branch dieback • Root dieback/new growth ↓	Within months
	Plant growth declines ↓	Within months
	Plant recruitment declines ↓	Within a couple of years
	Plant mortality increases ↓	Within several years
	New species invade ↓	Within a decade
	New community structure and function becomes evident	Within several decades

1. Dependent on depth of unsaturated soil, antecedent soil moisture, timing and volume of rainfall, root system extent, competition for soil moisture, and evaporative demand.