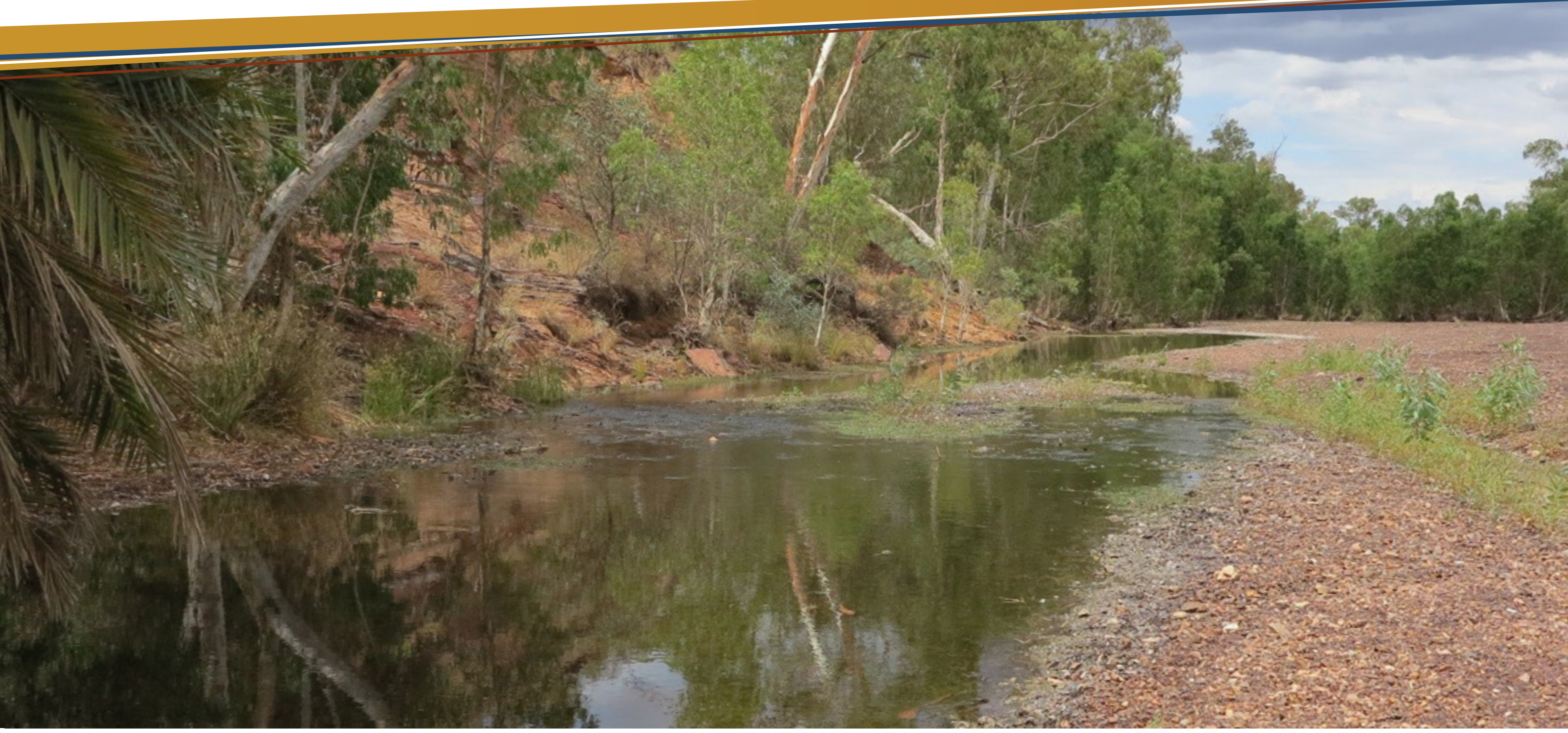
Environmental Protection Authority

GOVERNMENT OF WESTERN AUSTRALIA



Evaluating the environmental condition of Weeli Wolli Creek

Supporting technical report

Evaluation program report series

March 2018

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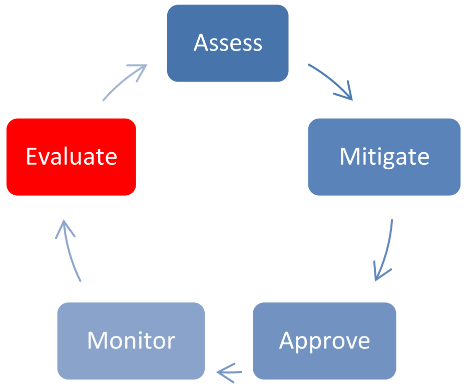
1. Introduction

1.1 Evaluation theme

Environmental Impact Assessment (EIA) processes are used to identify, predict and evaluate potential impacts of proposals, including mines. Once mine sites have been operating for a period of time, it is possible to examine actual impacts and compare them to those predicted in the EIA process. This project focused on the theme area of 'the on-ground environmental outcomes that are achieved after implementation of proposals'.



1.2 Project location

The Weeli Wolli catchment is located within the larger catchment of the Fortescue River and the Fortescue Marsh (figures A1 and A2). The region is rich in ore and there are multiple mine sites in various stages of development.

The Weeli Wolli Creek system is of high ecological and cultural significance. The creek system includes a spring and pools that support a unique community of plants and animals. The creek system is also of considerable spiritual and cultural value to the Traditional Owners. The Weeli Wolli Spring community is listed as a Priority 1 Ecological Community.

The Environmental Protection Authority (EPA) selected the Weeli Wolli Creek system for evaluation due to both its ecological and cultural significance, and the potential cumulative impacts from a number of approved mines in the catchment. As most of the mine sites in the area have been operating for some time a significant volume of monitoring data has now been collected, which provides a basis for the EPA's evaluation.

1.3 Project objectives

This project was undertaken to evaluate the on-ground environmental outcomes in the Evaluation Project Area (project area). The following objectives were addressed as part of that overall theme:

- Whether the environmental values and condition of Weeli Wolli Spring and Creek changed over the period of time during which mines have been operating in the catchment
- To what extent any changes in environmental values and condition are attributable to the impacts of proposals assessed by the EPA
- Whether the changes are consistent with the impacts which were predicted through the EIA.

1.4 Project scope

This project has focussed on a section of the Weeli Wolli Creek up-gradient of the Weeli Wolli Spring to the confluence with Marillana creek. For discussion purposes, and to coincide with how monitoring is reported by mining companies in the area, the creek has been divided into four reaches (Reaches 0 to 3 in **Figure A3**).

The project scope is limited to two of the key environmental factors influencing the values of the spring and creek in the project area; hydrological processes, and flora and vegetation. Other factors relevant to the area, such as subterranean fauna and inland waters environmental quality, have not been considered during this project.

There are five operating mines in the project area; Hope Downs 1 (HD1), Mining Area C (MAC), Yandicoogina, Yandi and Iron Valley (**Figure A3**).

1.5 Methodology

Each mining operation discussed in this report has undergone an EIA and has been issued with one or more Ministerial Statements under Part IV of the *Environmental Protection Act 1986*. Statements for proposals predicted to impact on the Weeli Wolli Spring and/or Creek include requirements to undertake ongoing monitoring and reporting on the condition of the creek. This monitoring is critical to verify the continued effectiveness of mitigation measures and undertake adaptive management, if necessary. As part of this project, the EPA has collated and examined monitoring data which informs the current condition of hydrological processes and vegetation.

In addition, a number of other information sources were used to assess the pre-mining and current conditions of the spring and creek, including, but not limited to:

- groundwater monitoring data, mine water discharge data, vegetation monitoring data and other information provided by mining companies operating in the area for the purpose of this project
- Department of Water and Environment Regulation (DWER) surface water gauging data and borehole logs
- Bureau of Meteorology climate data
- papers and reports, including those prepared by Eastham (2015) and Dogramaci et al. (2012).

2. Pre-mining environmental condition

This section provides an overview of the observed condition of Weeli Wolli Spring and Creek before any mining development in the area.

2.1 Regional hydrology and climate

The Weeli Wolli Creek system forms part of the overall catchment of the Fortescue River basin, which includes the Fortescue Marsh (**Figure A1**).

The Fortescue Marsh is the largest ephemeral wetland in the Pilbara region and is recognised as being nationally important. The Fortescue Marsh extends over approximately 1,048 square kilometres (km^2) and lies within a broader catchment area of the upper Fortescue River (29,791 km^2). It is rich in plant and animal species of high conservation value. The catchment of the Fortescue Marsh is also rich in ore deposits and multiple mining operations operate in the region.

The climate is hot and semi-arid, with annual evaporation typically exceeding annual rainfall. Rainfall occurs as localised, infrequent, high intensity thunderstorms between prolonged periods of drought. The region is warmest and wettest between December and March, with average maximum temperatures often above 40°C. During the winter months, temperatures fall to about 25°C.

The Weeli Wolli Creek catchment itself covers approximately 4,770 km^2 and contributes approximately 5 to 10% of the total catchment area of the Fortescue Marsh. The catchment is underlain by formations of the Hamersley Group, comprising dolomites, shales and ironstone, with minor felsic volcanics and intrusive dolerite dykes and sills. The Brockman, Marra Mamba Iron formations and Channel Iron Deposits (CID) host most of the known major iron ore deposits in the area. The dolomites of the Wittenoom Formation form a regionally important aquifer.

This project focusses on a 35 km stretch of the Weeli Wolli Creek from upstream of the Weeli Wolli Spring to the confluence with Marillana Creek (**Figure A3**). The spring and the flora and vegetation it supports represents an important environmental value in the area.

2.2 Hydrological processes

2.2.1 Groundwater

Under natural conditions, Weeli Wolli Spring is supported by the permeable dolomites of the Wittenoom Formation and overlying Tertiary aged deposits. Before mining, groundwater flowed in the dolomites in a north-easterly direction towards the spring (**Figure A4**). The spring is located where the high permeability dolomite intersects low permeability shale and ironstone. This results in a natural damming effect, forcing groundwater to converge and to discharge to the surface.

Pre-mining, the depth to groundwater was deep (>50m) in the upstream catchment, decreasing with distance towards the spring. Levels came to approximately 9 m depth around BH15, and were typically within at least 5 m of the ground surface closer to the spring.

In the vicinity of the spring and immediately beyond, Weeli Wolli Creek is underlain by a limited thickness of alluvium overlying low permeability shales and ironstone. Before mining commenced in the area, groundwater was shallow, within the root zone of riparian vegetation close to the creek bed.

Approximately 12 km downstream of the spring near the Yandicoogina mine site, the geology changes again to thicker alluvium overlying a transmissive CID aquifer (Dogramaci et al. 2014). There is no known pre-mining groundwater level data for this area, however based on monitoring data collected during mining, groundwater levels generally deepen close to the confluence with Marillana Creek and beyond.

2.2.2 Weeli Wolli Creek flow

Creeks in the Pilbara are typically ephemeral and flashy[1] hydrological systems, with flow only occurring after occasional, localised intense rainfall events. For most its length, Weeli Wolli Creek behaved like other typical Pilbara creeks. It is the ecology of Weeli Wolli Spring that made the creek unique in the region.

Under natural conditions, spring discharge resulted in perennial flow in the creek in the vicinity of, and immediately downstream of the spring (**Figure 1**). Permanent pools were also present in the creek bed in the vicinity of the spring. These pools were not static features, but dynamic features subject to periodic changes in location, depth and dimensions.

Creek flow close to the spring was measurable at the spring gauging station and provides an estimate of spring discharge volumes (refer to **Figure A3** for creek gauging station locations). The average pre-mining spring flow was estimated to be 4,400 kilolitres per day (KL/d) by Hope Downs Management Services (2000).

During storm events, the perennial creek flow component was dwarfed by peak flow events. Large rainfall events (>36 mm/day according to Dogramaci et al. 2014) resulted in creek flow many magnitudes higher than that contributed by spring flow. Peak flows likely resulted in morphological changes to the creek bed and banks, changes to permanent pools and periodic destruction and renewal of vegetation. Therefore, the creek and spring were highly dynamic systems before mining and continue to be so during mining.

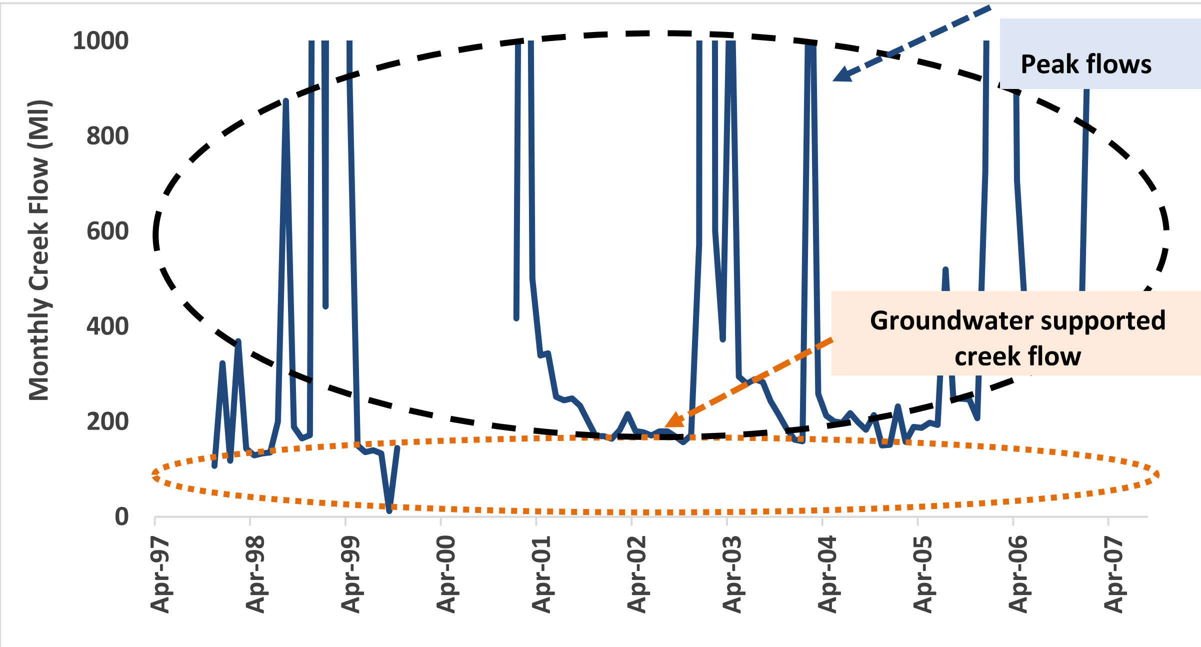


Figure 1: Creek flow at the Spring Gauging Station (2001 – 2007)

[1] A flashy creek has high peak discharges and short lag times between rainfall events and the resulting increase in creek flow.

Perennial creek flow continued downstream of the spring for approximately 2 km, before all water was removed by a combination of evapotranspiration and seepage into the underlying aquifer. It was no longer measurable at the Tarina gauging station, located approximately 4.5 km downstream of the spring gauging station (**Figure 2**).

Outside of the influence of the spring, the creek had an ephemeral flow regime, with flow only occurring after storm events.

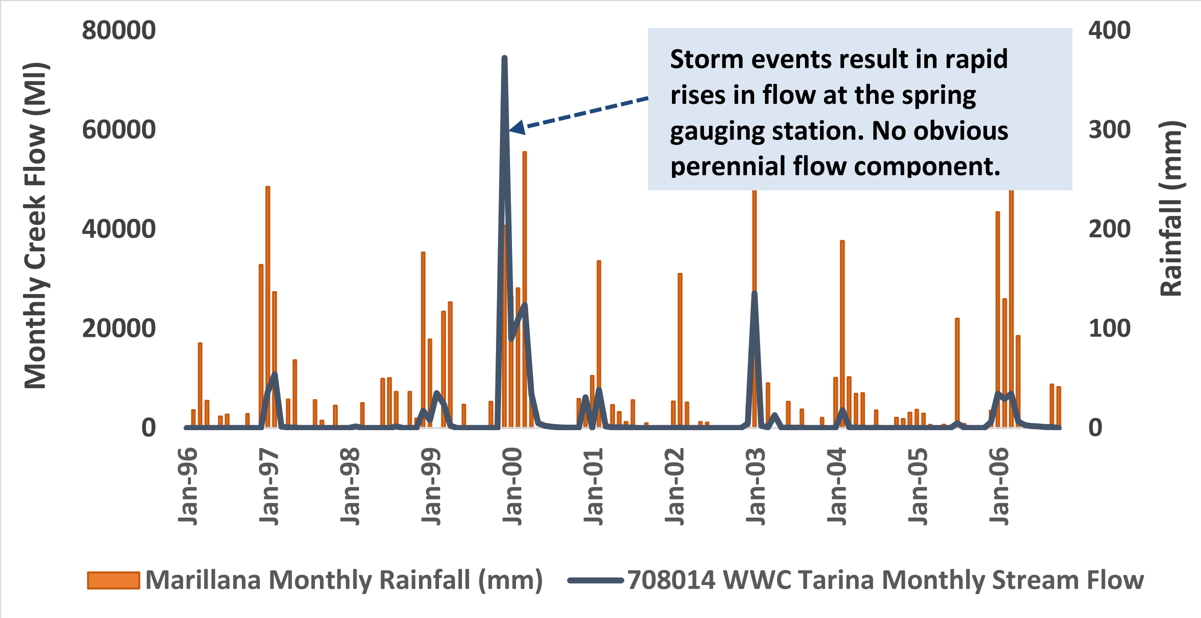


Figure 2: Monthly creek flow at Tarina Gauging Station (1996 – 2006)

2.3 Vegetation

2.3.1 Destruction and renewal processes

Weeli Wolli Creek is a dynamic system, which is subject to periodic disturbances due to large storm events. Like many other creek systems in the Pilbara, storms result in physical alterations in the creek bed and banks due to shifting alluvium. It is a force of both destruction and renewal and the consequences of single storms may last for years or decades. Whilst some trees and other vegetation are destroyed or damaged during storm events, renewal, processes occur, including seed distribution and seedling germination. Although many germinants would die off in the subsequent dry periods, some would survive to eventually become mature plants themselves (with further disturbance events taking place in between, restarting elements of the cycle). It is likely that boundaries of specific vegetation units in the creek would have naturally changed over time due to destructive and renewal processes.

2.3.2 Vegetation types

It is expected that the distribution of the broad types of vegetation present before mining would have been largely dictated by the availability of water sources, including both groundwater and surface water.

The dominant riparian tree species of Weeli Wolli Creek are *Eucalyptus camaldulensis* (River Red Gum) and *Eucalyptus victrix* (Coolibah) and, within the area of the spring,

Melaleuca argentea (Silver Cadjeput). All three species are considered to be phreatophytes, that is, species that utilise groundwater. There are two broad groups of phreatophytes:

- **Obligate phreatophytes** are plants that are completely or highly dependent upon groundwater. This dependence can be continual, seasonal or episodic (Astron 2015). *Melaleuca argentea* is an obligate phreatophyte.
- **Facultative phreatophytes** are plants that can access groundwater but are not totally reliant on groundwater to sustain their water requirement. Rather, they utilise groundwater opportunistically, and can occur in areas where groundwater is inaccessible. Most facultative phreatophytes are large woody trees and shrubs with deep root systems (Astron 2015). *Eucalyptus camaldulensis* and *Eucalyptus victrix* are facultative phreatophytes.

For the purpose of this project, the dominant vegetation types are discussed in relation to the reach in which they occur. **Table 1** provides a summary of the differences in water accessibility to plants per reach, to provide the hydrological context to the discussion on vegetation that follows.

Table 1: Dominant pre-mining hydrological processes

Creek reach[1]	Groundwater level	Creek flow
R0 (10.4 km)	Groundwater was deep in the upper reach (e.g. 29m at BH20) becoming shallower with distance to the spring. Comes within tree root accessibility (~9m bgl) around BH15.	Ephemeral creek flow only after storm events.
R1 (5.2 km)	Groundwater was at or near surface.	The upper part of the reach (upstream of the spring) is ephemeral. The remainder of the reach is characterised by permanent pools then perennial spring flow.
R2 (5.5 km)	Groundwater was close to surface immediately downstream of the spring, potentially deepening somewhat down-gradient.	Perennial flow component in the first 2km of the reach, becoming ephemeral downstream.
R3 (13.5 km)	Groundwater levels pre-mining are uncertain. It is noted that levels measured during mining are between ~5 and 17m bgl close to Marillana Creek but are influenced by mining.	Ephemeral creek flow only after storm events.

Table Notes:

1. *Refer to **figures A3 and A4** for creek reach and monitoring bore locations*
2. *bgl = below ground level*

The pre-mining vegetation of Reach 0 was typical of a Pilbara ephemeral creek. The dominant trees of the riparian vegetation were *Eucalyptus camaldulensis* and *E. victrix*. Deep groundwater in the up-gradient section of the reach (distant from the spring) indicates these trees were not accessing groundwater and would have likely been reliant on rainfall and soil water storage. In the section of the reach closer to the spring, groundwater decreased in depth, coming within the potential range of tree roots by approximately BH15. It is likely that the trees in this part of the reach utilised groundwater opportunistically, especially during drought (facultative phreatophytes). No obligate phreatophytes are known to have occurred in this reach.

The vegetation types present along Reaches 1 and 2 reflected the permanently accessible groundwater and its surface expression. It was dominated by a fringing forest or tall woodland of *Melaleuca argentea* and *Eucalyptus camaldulensis* over trees of *Eucalyptus victrix* and a dense shrub layer dominated by an assortment of wattles, in particular *Acacia*

citrinoviridis (Pilbara Jam). Although the broad vegetation associations present at Weeli Wolli Spring resembled riparian vegetation found throughout the Hamersley Range and inland Pilbara, Weeli Wolli Spring's riparian woodland and forest associations were unusual as a consequence of the composition of the understorey. The sedge and herbfield communities that fringe many of the pools and associated water bodies have not been recorded at any other wetland site in the Pilbara. The occurrence of disjunct outlying populations of tropical plant species provides evidence that the Weeli Wolli Spring and the associated creekline area was refugial habitat (Davis et al. 2013).

The broad distribution patterns of trees, shrubs and herbfields were related to perennial water availability, however the boundaries and extent of these vegetation types would have been regularly altered by disturbance caused by intense rainfall and flooding events.

Specific vegetation mapping and descriptions along Reach 3 for the pre-discharge condition were not readily found for this evaluation project. Pre-mining groundwater levels are also not known with certainty. Levels measured during mining, coupled with the hydrogeology of the area indicate groundwater was potentially accessible to root zones for part of the reach, but levels likely deepened with distance to the confluence with Marillana Creek. Vegetation types were likely similar to those in Reach 0 i.e. facultative phreatophytes and no obligate phreatophytes.

3. Predicted impacts

This report section presents an overview of the predicted impacts to key environmental values, as assessed through the EPA's application of EIA processes.

3.1 Mining operations

Five (5) mine sites were considered as part of this project based on their operations and proximity to the spring and creek in the project area: Hope Downs 1 (HD1), Mining Area C (MAC), Yandicoogina, Yandi and Iron Valley (**Figure A2**).

3.2 Environmental values

The EPA identified the following key environmental values within the area:

- Weeli Wolli Spring was described as an environmental value, with attributes including permanent flow components and vegetation communities (particularly riparian types). The pools were considered to have cultural value, as well as sustaining fauna communities.
- Weeli Wolli Creek was described as an environmental value, with attributes including riparian and groundwater-dependent vegetation, variable flow regimes, shifting creek morphology due to peak rainfall events, connectivity to the Fortescue Marsh, and Aboriginal heritage value.

3.3 Predicted pressures

The EPA predicted that the key pressures with the potential to impact on the environmental values of Weeli Wolli Spring and Creek would be:

- Groundwater dewatering and abstraction for supply purposes
- Discharges.

Where the volume of water removed during dewatering was predicted to exceed operational needs, the surplus water was either planned to be returned to the aquifer (by reinjection) or discharged to Weeli Wolli Creek or its tributaries. The discharge of surplus water was predicted to result in partial passive recharge.

Although creek diversions were also identified as a potential pressure during EIA, the evaluation has focused primarily on dewatering and discharges.

3.3.1 Predicted groundwater dewatering

The vast majority of water abstraction in the area is for mine dewatering purposes, with a relatively minor volume needed for re-use on site for mining operations. Dewatering rates vary across the project area due to variations in ore body depth, heterogeneities in aquifer properties and differences in the extent of hydraulic connectivity between ore bodies and productive aquifers across the area.

The acceptable rate of dewatering was considered as part of the EIA process. This included considering whether the predicted extent of drawdown would impact on the water level and flow of the spring and/or creek. Drawdown predictions were typically undertaken by mine operators using groundwater modelling techniques.

The EPA are mindful that there is a level of uncertainty inherent in any groundwater modelling, with the level of uncertainty typically dependent on how closely the hydrogeological conceptual model (HCM) reflects reality. Generally, HCMs (and

groundwater numerical models) are continually developed and refined by incorporating newly collected monitoring data. This is true for the project area. During the course of mining operations, mine operators reported dewatering requirements higher than predicted for some mine sites, as ore bodies were found to be more hydraulically connected to the regional aquifer than anticipated and/or the capacity of the aquifer to release water from storage was higher than predicted. Dewatering requirements also increased where additional ore bodies (within the overall planned life of mine) were accessed.

Four mining operations have been predicted to result in groundwater drawdown in the vicinity of the spring and/or creek in the project area (MAC, HD1, Yandicoogina and Iron Valley). Of those, dewatering at Iron Valley started in 2016 so limited monitoring data has been collected to date. The dewatering rates approved to date for MAC, HD1 and Yandicoogina are presented in **Figure 3**.

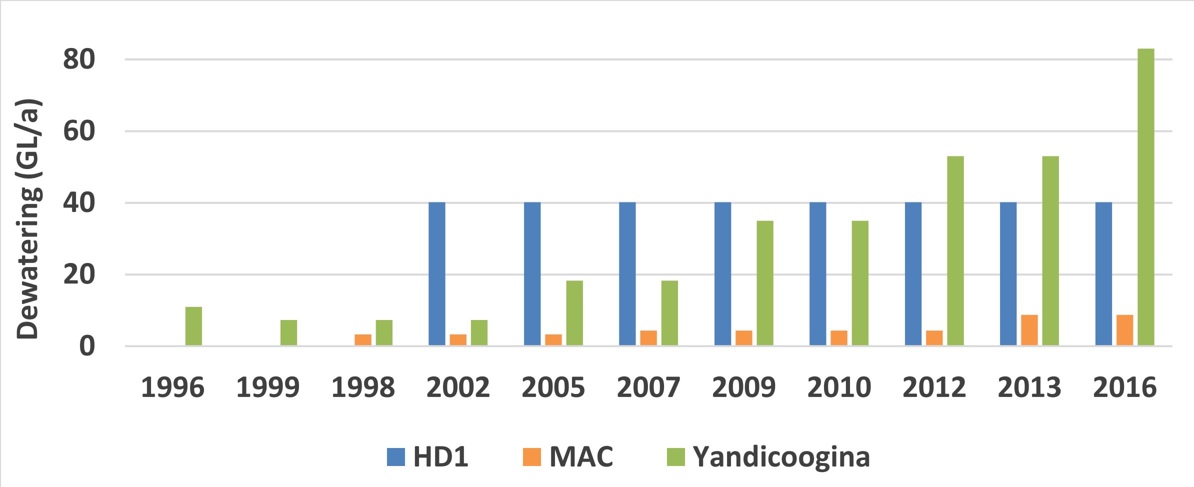


Figure 3: Approved[1] dewatering rates (1996 – 2016).

1. Figures in this graph are representative of the maximum approved dewater rate, and are not representative of an actual rate at which water was extracted over time. Approved rate in Ministerial Statement converted to Ml/d (e.g. from GL/a).

Table 2: Predicted extent of groundwater drawdown

Mine site	Distance & orientation to spring	Dewatering commenced	Predicted groundwater drawdown extent
HD1	3 km SW	2006	Groundwater drawdown was predicted to occur up-gradient and in the vicinity of the spring (Reaches 0 and 1), resulting in cessation of spring flow and associated perennial creek flow and drying of pools.
MAC Northern Flank	23 km W	2010[1]	Negligible impact predicted (≤ 0.1m drawdown in vicinity of the spring)
Yandi	25 km NW	1997	No direct impact predicted for the spring or creek within the project area.
Yandicoogina	16 km NE	1991	Yandicoogina has undergone several expansions since the original proposal. Dewatering was predicted to result in drawdown in the project area within Reach 3. Aquifer reinjection and seepages from water discharges to the creek were predicted to counteract the drawdown to an extent
Iron Valley	22 km NE	2016[2]	The original proposal was revised in 2016 to include mining below the water table, with resulting dewatering requirements. It was predicted that dewatering would lower groundwater levels in parts of Weeli Wolli Creek, including the area close to the confluence of Weeli Wolli and Marillana Creeks.

Table Notes:
1. *Groundwater was abstracted at MAC from 2001 but dewatering did not commence until 2010.*
2. *Groundwater was abstracted at Iron Valley from 2013 but dewatering did not commence until 2016.*

In summary, the following creek reaches were predicted to be impacted by groundwater drawdown:

- *R0, R1 and a small portion of R2 closest to the spring:* Dewatering at HD1 was predicted to cause groundwater drawdown, cessation of spring flow (and associated perennial creek flow) and permanent pools; and

- R3: Dewatering at Yandicoogina has been predicted to result in localised groundwater drawdown in the area of R3.

3.4 Water management measures and secondary pressures

Owing to the scale of dewatering required to access ore in the area, a number of mines have surplus water above operational requirements. Of these, two mines (HD1 and Yandicoogina) discharge water to the creek in the project area as follows (refer to **Figure A5** for discharge locations):

- A spur irrigation system of diffuse discharges via 13 off-takes from a main discharge line (HD1); and
- Large point source discharges to the creek at two (2) locations, the gabion (HD1) and DO6 (Yandicoogina).

3.4.1 Mitigation measures: Spur irrigation

It was predicted through EIA that, without mitigation, dewatering would cause Weeli Wolli Spring to dry up and its ecosystem to collapse. The HD1 mine operator designed a spur irrigation system to maintain basal creek flow at the spring, maintain permanent pools and maintain phreatophytic vegetation for the duration of dewatering operations and for as long as it takes for spring flow to return. The return of spring flow was predicted to be achievable within 20 years of cessation of dewatering based on closure plans submitted to the EPA.

As part of the assessment of the initial proposal for HD1, it was predicted that spring augmentation rates of up to 18,000 KL/d would be necessary to maintain the pre-mining spring flow of approximately 4,400 KL/d. It was estimated that 80% of discharged water would infiltrate into the aquifer, resulting in substantial sub-surface flow which would further support the creek flow augmentation process. This was also predicted to result in a saturated soil profile, which would sustain phreatophytic vegetation. It was expected that there would be some flow of discharged water back towards the mine pit due to the hydraulic gradient created by the HD1 dewatering bores.

3.4.2 Secondary pressures: Gabion and DO6 discharges

All surplus water from HD1 not used for irrigation in the vicinity of the spring was expected to be discharged directly to the creek at the gabion discharge location (**Figure A5**). Yandicoogina discharges water to the creek at DO6 located approximately midway between the gabion and the confluence of Weeli Wolli and Marillana Creeks.

Whilst the spur irrigation system was planned as a mitigation measure, discharges at the gabion and DO6 were expected to be a potential pressure through a possible over-supply of water to vegetation. It was predicted through EIA that these discharges would extend the perennial flow extent in the creek for several kilometers downstream of the discharge locations. The EPA Report for HD1 noted that the Water Management Plan would need to address the potential for adverse impacts arising from any long-term increase in average water levels during mining.

Approved discharge volumes for both mine sites have increased over time, reflecting increases in dewatering requirements (**Figure 4**). Yandicoogina has increased the dewatering rate in mine pits surrounding Reach 3 to counteract the increased flow of water into the pits from the Weeli Wolli alluvial aquifer, caused by perennial upstream discharge from the gabion.

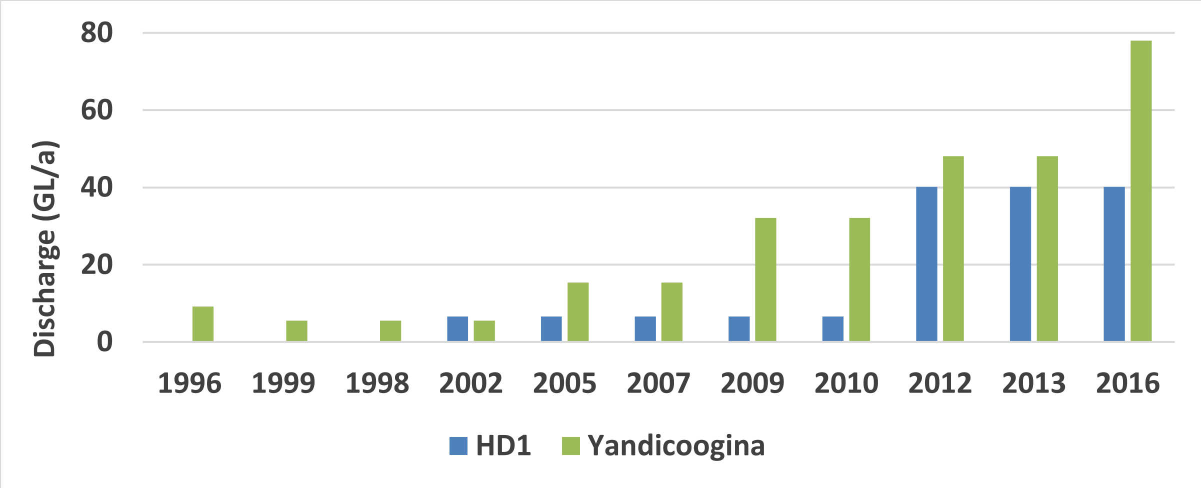


Figure 4: Approved[1] discharge volumes: HD1 and Yandicoogina[2]

1. *Figures in this graph are representative of the maximum approved dewater rate, and are not representative of an actual rate at which water was extracted over time. Approved rate in Ministerial Statement converted to Ml/d (e.g. from GL/a).*
2. *Yandicoogina discharge rate includes water discharge into both Marillana Creek and Weeli Wolli Creek.*

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3.5 Predicted impacts to vegetation

EIA processes focused on designing water management systems which adequately maintain vegetation, given predicted groundwater drawdown and changes to creek flow. Assuming the spur irrigation mitigation measures operated effectively, it was considered that the phreatophytic vegetation of the spring ecosystem would be maintained.

A number of possible adverse impacts to vegetation were considered:

- A potential for 'loss' of irrigated water back towards the HD1 mine pit where spurs were located within the cone of depression[2] of HD1 dewatering bores (predicted to impact Reach 0). A potential decline in phreatophytic tree species was considered, if direct irrigation was not applied; and
- A potential for proliferation of opportunistic species due to an over-supply of water to vegetation downstream of the gabion and DO6 discharges (Reaches 2 and 3).

3.6 Summary of predicted impacts

A summary of predicted changes and impacts to the groundwater, creek flow and vegetation is presented in **Table 3**.

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[2] Cone of depression is a term used to describe the extent of depressed groundwater levels around a pumping well(s).

Table 3: Summary of predicted impacts

Creek reach[1]	Predicted changes		Predicted impacts to vegetation
	Groundwater	Creek flow	
R0 (10.4 km)	Predicted to be within the cone of depression of dewatering bores. Groundwater levels expected to be depressed compared to pre-mining levels.	No significant change to creek flow expected i.e. expected to remain ephemeral, with flow occurring only after storm events.	Some impacts on phreatophytes were expected in groundwater drawdown areas, where groundwater was previously (pre-mining) accessible to tree roots.
R1 (5.2 km)	Groundwater levels expected to be depressed to the extent that natural spring flow ceases. Irrigation was expected to partly infiltrate to the underlying aquifer, thus sustaining near surface groundwater levels.	spring-sourced natural perennial flow expected to cease. Irrigation expected to maintain flow in the creek and maintain water presence in permanent pools.	The planned spur irrigation system was expected to maintain phreatophytic vegetation.
R2 (5.5 km)	Groundwater levels immediately downstream of the spring were expected to behave in a similar way to R1. Groundwater levels further downstream were not discussed in detail, as groundwater level predictions focussed on areas of expected drawdown.	A change in flow regime was predicted, with discharges at the gabion and DO6 resulting in a continuous flow of water in the creek.	Predicted that the discharge would maintain spring flow and thereby maintain groundwater dependent vegetation. The potential for proliferation of opportunistic species was expected.
R3 (13.5 km)	Not known with any certainty. Groundwater levels measured during mining (post-2006) indicate levels approximately ~5 to 17m bgl close to Marillana creek. However the levels were influenced by dewatering, discharges and aquifer reinjection at Yandicoogina.		The potential for proliferation of opportunistic species was expected.

Table Notes:
1. *Refer to* ***figures A3*** *and* ***A4*** *for creek reach and monitoring bore locations*
2. *bgl = below ground level*

3.7 Potential future impacts

The potential for impacts to the spring and creek have the potential to change over time due to factors such as new mines sites, expansions to existing mines and mine closures. Mining at HD1 is planned to cease in 2025 however dewatering will continue for a period of time to facilitate the back filling of mine pits. The mine closure strategy includes returning groundwater levels and gradients to close to pre-mining conditions so that spring flow returns. This is predicted to occur within 20 years of decommissioning.

The EPA is currently assessing proposals for future mining operations in the Weeli Wolli Creek catchment, including an expansion of the MAC operation which would extend the mine life by 27 years. HD1 closure plans, in addition to future expansions and closure have the potential to alter the spring and creek into the future. The potential for cumulative impacts from mine sites and the successful deployment of closure commitments is an important consideration in ensuring the future of Weeli Wolli Spring.

4. Observed changes in environmental condition

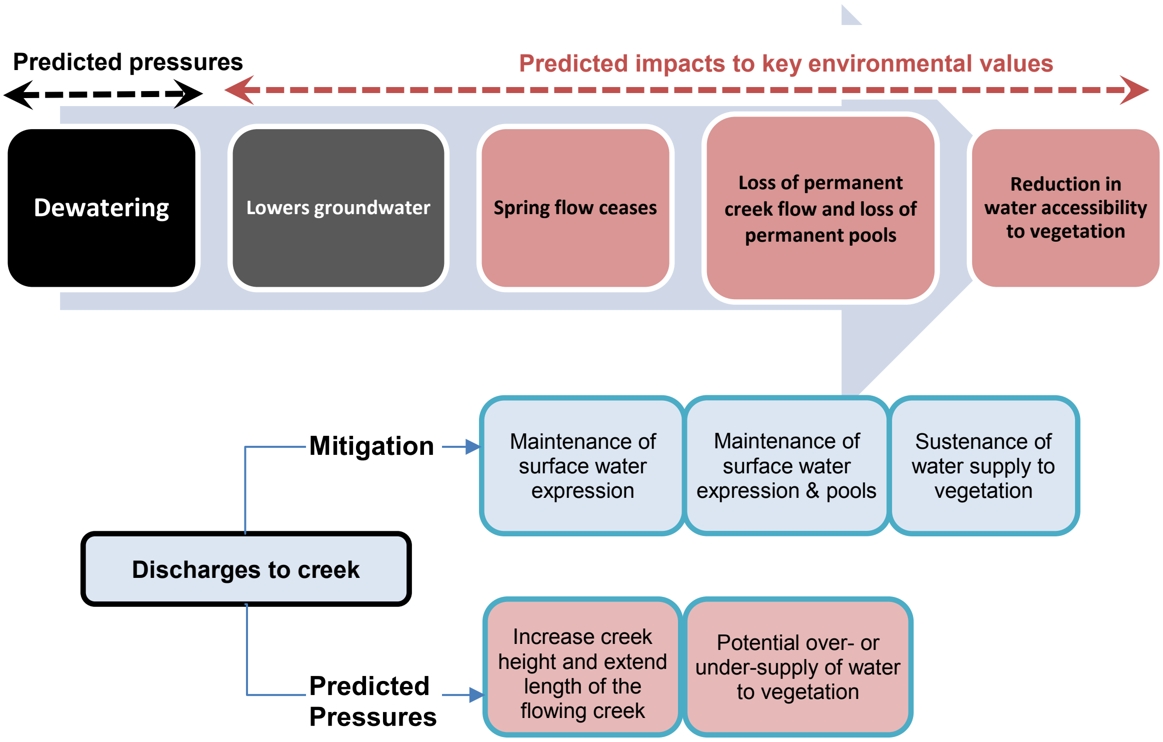
4.1 Evaluation process

Section 2 provided an overview of key environmental values in the project area before mining development was approved in the area. **Section 3** outlined the impacts to those values which were predicted to occur and the mitigation measures planned to counteract those impacts. In this section, the EPA has considered whether changes to the spring and creek have actually occurred as predicted and the effectiveness of EIA processes in predicting impacts and managing risk.

4.2 Dewatering and discharge pressures

4.2.1 Summary of predictions

As outlined in **Section 3**, it was predicted that HD1 dewatering operations would result in the range of impacts depicted in the diagram below, with those impacts largely mitigated by returning a substantial portion of the water removed from aquifers to the spring and creek. The Yandicoogina operations were also predicted to result in groundwater drawdown, but in an area distant from the spring (Reach 3). A potential secondary impact associated with discharges over and above quantities required to sustain the ecosystem was also predicted.



4.2.2 'Actual' dewatering pressures

Based on monitoring data and reports submitted to the EPA, the cones of depressions of HD1 and Yandicoogina dewatering operations intersect the project area, primarily in Reaches 0 and 1 (HD1) and Reach 3 (Yandicoogina). This is consistent with predictions established through EIA.

The approved dewatering rate changed over time for the two mine sites, with increases at Yandicoogina due to mining of additional ore bodies below the water table (also refer to **Figure 3**, **Section 3.3.1**). **Figure 5** indicates that discharge volumes have increased at the

gabion and spurs over time, while discharge at DO6 increased until it was switched off in 2014, however this outlet is once again in use as of 2016.

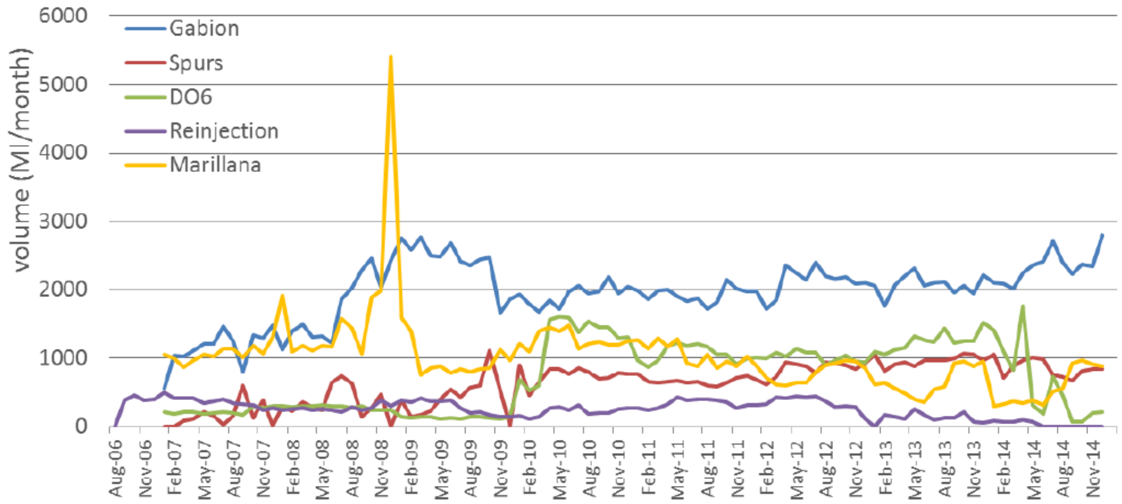


Figure 5: Discharge volumes - Gabion and DO6 (Source: Eastham, 2015)

Note: *Discharges into Marillana Creek are also shown in the graph but are not discussed in this report as they occur outside of the project boundary.*

4.2.3 'Actual' discharge pressures and mitigation measures

Discharge management in the project area has been in operation since early 2007 and is generally operated in accordance with systems designed through EIA, i.e.:

- Spur irrigation has been established in the vicinity of the spring (Reach 1) to counteract groundwater drawdown and associated impacts on spring flows
- Two discharge locations are established downstream of the spring at the gabion (Reach 2) and DO6 (Reach 3).

Discharge locations are shown in **Figure A5** and approximate discharge volumes are presented in **Figure 5**.

The spur irrigation system has been designed to irrigate over a wide area of the creek bed in the general vicinity of the spring. The EPA observe that full and complete replication of natural spring discharges would be difficult to achieve because the creek bed is wide and shallow, and it is likely that natural spring seepages occurred at multiple discrete locations. As predicted, a number of spurs were found to be located within the cone of depression, resulting in discharged water via these spurs being drawn back towards the HD1 mine pit. The majority of spurs are outside of the cone of depression and appear to be successfully augmenting surface water in the creek (see **Section 4.4.1**).

The initial approved discharge rate through the spurs was 18,000 Kl/d. This upper limit was removed in 2012. EPA Report 1424 indicates this was removed due to a drying trend caused by an increase in groundwater drawdown from other mining activities and also due to a drying climate. **Figure 5** indicates that the spur irrigation rate did generally increased between 2010 and 2014 (and possibly beyond). Downstream of the spurs, the remaining surplus water from HD1 operations is discharged at the gabion. The total discharge has generally increased with time, reflecting increasing dewatering rates.

Discharges at DO6 (Reach 3) have also fluctuated over time, with higher rates from 2010, reflecting the increased mining of ore bodies below the water table near Weeli Wolli Creek.

4.2.4 Comparison of predicted and actual pressures

Although dewatering and discharge rates have increased over time, groundwater model predictions and other assessments have been updated to account for these increases. The pressures on the spring and creek are generally close to what was predicted through EIA.

4.3 Observed changes in environmental condition

The flora and vegetation of the spring and creek are closely linked to water accessibility and seasonal availability. Water availability in the area typically varies depending on rainfall patterns, evaporation rates, proximity to groundwater and the presence or absence of surface water.

Due to the semi-arid climate, rainfall availability is sporadic and often occurs as very intense storm events which can cause destruction of vegetation. Before mining, groundwater was close to surface and readily available to vegetation up-gradient of the spring, close to the spring and in part of the creek downstream of the spring. Surface water was also readily available in the vicinity of, and immediately downstream of the spring. This surface water availability was groundwater-dependent (being sourced from the spring).

This section considers how the condition of the spring and creek have changed since the dewatering and discharges described in **Section 4.2** commenced in the area. As changes to creek flow are highly dependent on changes to groundwater (notably spring discharges), groundwater is discussed initially and creek flow is discussed thereafter in the proceeding section.

4.4 Observed changes in groundwater levels and spring flow

4.4.1 Dewatering impacts and mitigation

Groundwater monitoring data indicates that groundwater drawdown has occurred up-gradient of, and close to the spring (Reaches 0 and 1) and downstream, in a localised area of Reach 3 due to dewatering at HD1 and Yandicoogina. Dewatering does not appear to have resulted in drawdown in Reach 2.

4.4.1.1 Drawdown up-gradient and close to the spring (Reaches 0 & 1)

Groundwater levels were collated for monitoring bores located close to the spring area to assess groundwater (and spring) response to pumping at HD1.

Before dewatering commenced in the project area, groundwater flowed in a north-easterly direction in the Wittenoom dolomite aquifer, eventually discharging to surface at the Weeli Wolli Spring, where the dolomite is juxtaposed against much lower permeability shales (also refer to **Section 2.2.1** for an understanding of the geology of the area).

The ore body at HD1 is in hydraulic connection with the dolomite and dewatering has resulted in significant drawdown in the aquifer. Groundwater levels and flow have changed considerably from pre-mining conditions, with groundwater now flowing towards the mine (rather than towards the spring) - **Figure A6**. The groundwater level response in BH15 (**Figure 6**) indicates that the dewatering influence extended rapidly out from the mine site soon after dewatering commenced.

As expected, extensive drawdown occurred up-gradient of the spring (Reach 0). In much of this area, groundwater was deep and below the root zone of vegetation prior to mining development. However, there are areas within the cone of depression where groundwater levels were within the root zone pre-mining but are now too deep for vegetation to access. This general location is shown in **Figure A7**. Adaptive management (through direct irrigation of *Melaleuca argentea* trees) has proven to be important in this area.

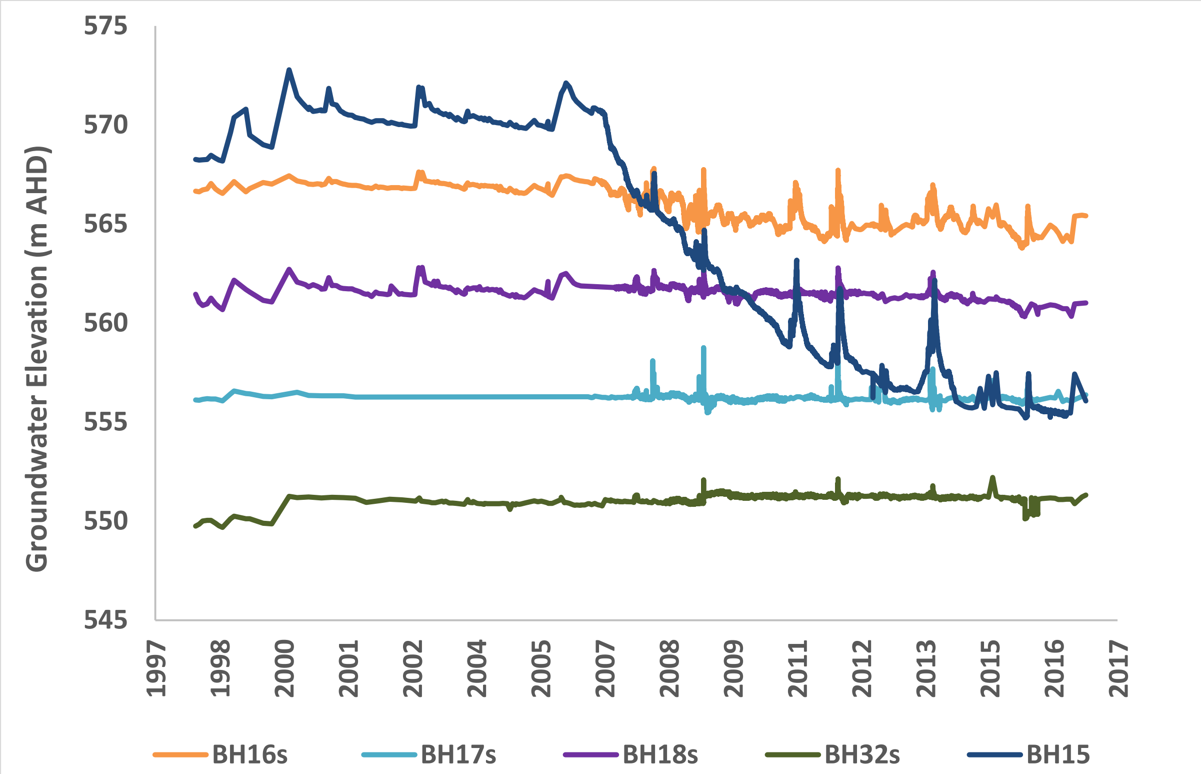


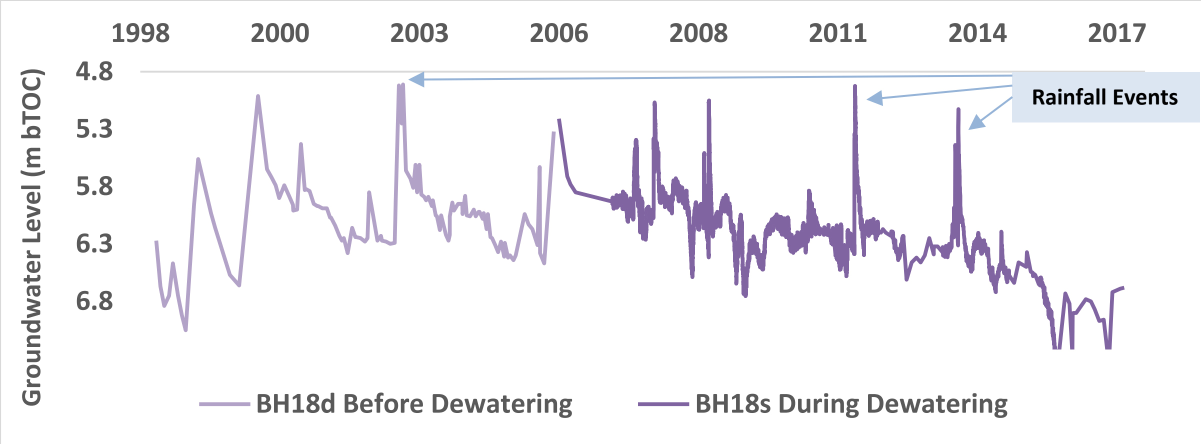
Figure 6: Groundwater levels in Weeli Wolli monitoring bores (1998 to 2017).

Drawdown has reached the Weeli Wolli Spring area, cause spring discharge to cease. This condition was predicted in the initial proposal and subsequent groundwater model updates for HD1.

The greater part of the dewatering influence appears to end close to geological boundary between the dolomite and the shale. A much more muted drawdown response is observed in bores screened in shale (e.g. BH17 and BH18) compared to those in dolomite (BH15, BH16). A groundwater flow divide has been observed close to that location (**Figure A6)**. Groundwater in the dolomite now flows towards the HD1 pit, whereas the flow direction in the shale appears to be relatively unchanged from pre-mining conditions.

The muted response to dewatering in BH17 and BH18 indicates that the groundwater depth to the northeast of the geological boundary (i.e. the location of the spring) has changed relatively little since mining began (refer to **Figure A7**). This indicates the groundwater levels are maintained in the spring area and immediately down-gradient.

In addition to the natural geological setting which supports shallow groundwater levels in the shale, groundwater appears to be further supported by spur irrigation. Groundwater level fluctuations appear to be more frequent and pronounced in BH17 and BH18 following the commencement of spur discharge, this may only reflect the increase frequency of sampling over time. It may also indicate a portion of irrigated water is infiltrating to the groundwater table i.e. spur irrigation appears to be generally functioning as designed (**Figure 7**).



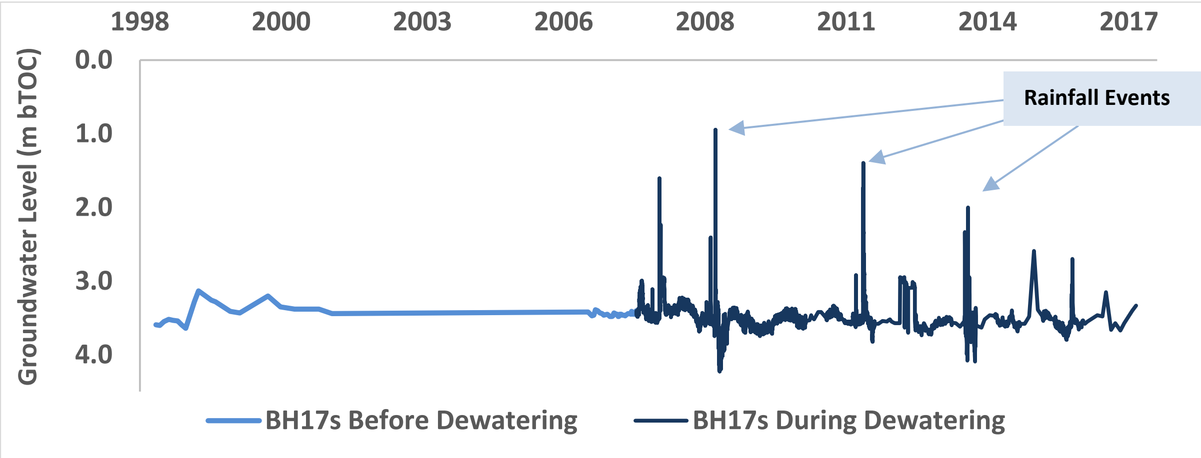


Figure 7: Groundwater levels in Weeli Wolli monitoring bores: 1998 – 2017 (data supplied by RTIO)

Note: *Groundwater levels are shown in metres below top of casing (m bTOC). Ground level was assumed to be approximately 0.6 m below top of casing.*

4.4.1.2 Drawdown in Reach 3

The Yandicoogina dewatering borefield is located close to Reach 3. Dewatering has resulted in localised depressed groundwater levels in the aquifers which underlie this area (Channel Iron Deposit aquifer and overlying alluvium). Drawdown is understood to be counteracted to an extent by aquifer reinjection and infiltration of water discharged to the creek at DO6. The dewatering influence does not appear to extend to the spring and is potentially limited to Reach 3 within the project area.

4.4.1.3 Cumulative Dewatering Impacts

The dewatering bore networks in the catchment appear to be sufficiently distant from each other such that there are no obvious spatial or temporal cumulative effects.

The majority of groundwater level impacts on Weeli Wolli Spring appear to be due to dewatering at HD1, as was predicted through the EIA process. Dewatering at Yandicoogina has lowered the groundwater table in part of the down-gradient section of the creek (Reach 3) and, whilst there is some uncertainty as to the extent of the influence, it does not appear to have had any impact on the spring.

Predictions indicated that dewatering at MAC undertaken to date would have a negligible impact on the spring. As MAC is located up-hydraulic gradient of HD1 the occurrence of any

synergistic effects are difficult to ascertain, as any fall in groundwater level close to the spring (especially a minor fall) would be masked by the larger impacts due to HD1. Also, the cone of depression has likely reached its maximum extent in the vicinity of the spring due to the presence of a geological boundary (which is also the reason the spring exists).

4.5 Observed changes to creek flow and vegetation

4.5.1 Limitations and uncertainties: vegetation monitoring data

A broad range of vegetation monitoring has been undertaken in the area since 2006/2007 to monitor flora and vegetation. As of early 2017 the following monitoring programs are in place:

- Tree health monitoring (Digital Cover Photography), including *Eucalyptus* and *Melaleuca* trees
- Tree health monitoring (condition scale, transects)
- Vegetation community structure, species diversity and abundance (transects)
- Digital multi-spectral imagery (remote sensing).

Refer to **Figure A8** for tree health monitoring sites and vegetation transect locations.

The EPA encountered a number of challenges in establishing what, if any, changes have taken place in the condition of phreatophytic vegetation and to what degree they can be attributed to the influence of dewatering and mine water discharges. These uncertainties include:

- Vegetation monitoring programs included limited collection of pre-mining baseline data.
- There appears to be a large degree of inherent variability in the condition of riparian vegetation associated with Weeli Wolli Creek, due especially to seasonal influences and the impacts of destructive events, such as floods and fires. The effects of dewatering and discharge may be obscured by these large effects.
- The confounding effects of drawdown, discharge, reinjection and changes in surface water hydrology make it difficult to determine causal influences and the degree to which management is mitigating impact.
- Issues with the establishment and implementation of monitoring programs have resulted in some data being collected with insufficient information, frequency, detail or confidence to adequately interpret species-based responses to change. This results in analyses at best being confined to groups of species, which may obscure differing responses between species.

4.5.2 Broad observations

Before development commenced in the area, Weeli Wolli Creek flow was characterised as a highly dynamic flashy flow system, dominated by peak flows, but with a perennial flow component in the vicinity of a natural spring (refer to **Section 2.2.2**). Since mining commenced, groundwater drawdown and discharges have altered the way in which water enters and moves in the creek bed.

Due to the uncertainties outlined in **Section 4.5.1**, completing a *detailed* analysis of changes in vegetation condition has proven to be difficult. The EPA has been unable to determine with confidence whether and to what extent the unique assemblage of understorey species of Weeli Wolli Spring has changed. Only one monitoring program examines the structure and composition of the vegetation community (as opposed to overstorey tree health). The results of this program are not robust and few of the species that distinguish the priority

ecological community as unique and contribute to its environmental values are captured by the established transects.

Despite the issues in undertaking a *detailed* analysis, the EPA has been able to conclude that, although there have been some changes, the overall ecosystem of the spring and creek appears to be functioning, consistent with the EPA's predictions.

4.5.3 Observations by creek reach

For the purpose of this project, changes to creek flow and vegetation have been discussed by referring to the four creek reaches in the project area (refer to **Figure A3**).

Given the uncertainties preventing a *detailed* evaluation of vegetation condition (particularly understorey species), this discussion has focussed on general observations on phreatophytic tree health, focussing mainly on foliage cover. This discussion is based on monitoring data collected by mine operators and an analysis undertaken by Eastham (2015).

Reach 0:

No significant change to creek flow has been identified for Reach 0, located up-stream of the natural spring. The flow regime remains ephemeral, with flow occurring only after large rainfall events. However, groundwater levels are depressed in this area compared to pre-mining levels.

No obvious adverse tree health effects have been reported in the deepest groundwater areas of Reach 0 i.e. areas where groundwater levels were *not* accessible to tree roots prior to mining and where dewatering has now resulted in even deeper groundwater.

In some areas (close to BH15), groundwater, which was previously accessible to trees has fallen below the root zone of tree species in part of this area (**Figure A7**). In these areas, an initial decline in the foliage cover of facultative phreatophytes was recorded soon after dewatering commenced, however foliage quickly recovered to pre-mining conditions, before stabilising. This is consistent with observations that these species appear to be able to exploit available water sources other than the saturated aquifer. These alternative sources may include greater rainfall capture and higher utilisation of soil moisture and surface water which would be present for short periods after rainfall events.

Reach 1:

Reach 1 includes the (former) spring. Depressed groundwater levels have resulted in the cessation of natural spring flow. As detailed in **Section 4.4.1**, spur irrigation appears to be successfully augmenting shallow groundwater so that water proximity to vegetation is maintained.

Pre-mining spring flow was estimated at 4,400 KL/d (Hope Downs Management Services, 2000). There is no current stream gauge close to the spring, as it was decommissioned in 2007 and therefore it is not possible to determine the current flow. However, surface expression (if not a continuous flow) in the creek appears to be maintained.

Spur irrigation also appears to be sustaining levels in the pools by a process of adaptive management, by continually adjusting irrigated quantities to achieve an optimal water depth and maintain the pool features (**Figure 8**). Adaptive management is essential for both the pools and the spring area due to the dynamic nature of the creek resulting in shifts in the alluvial creek bed and changes to the dimensions and depths of pools.

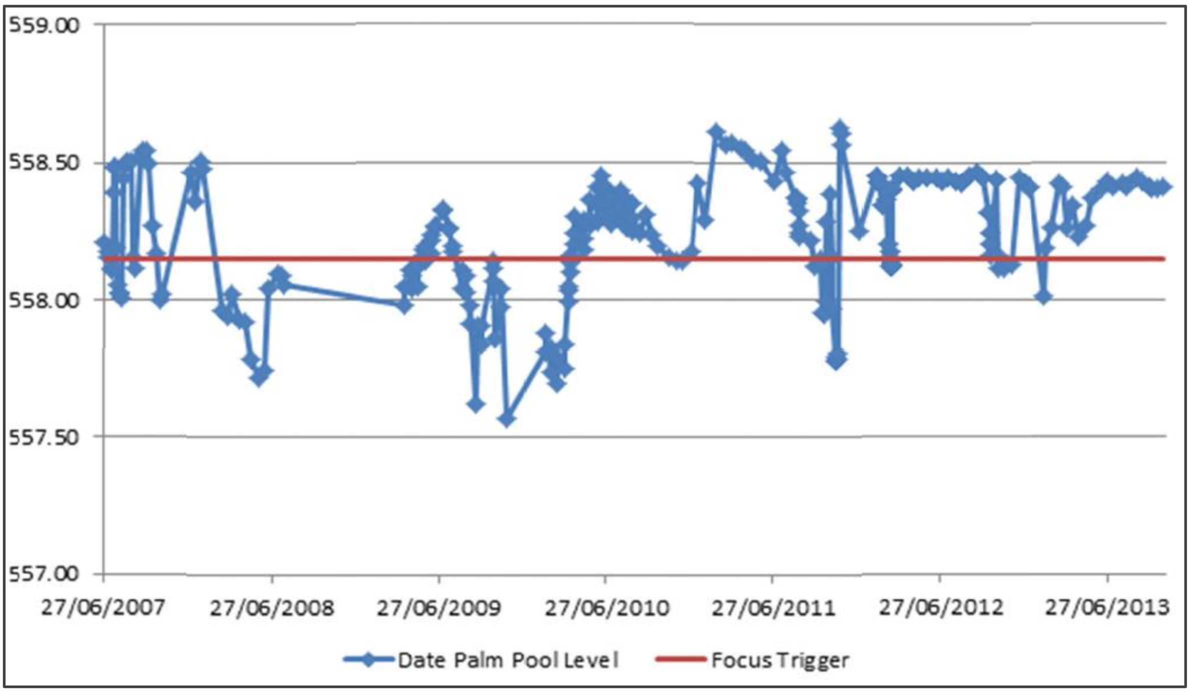


Figure 8: Date Palm Pool water elevation: 2007 – 2013 (*Source: Rio Tinto 2013*)

The following broad observations have been made regarding tree health in Reach 1:

- Eucalyptus species foliage cover generally increased, after an initial slight decline immediately after dewatering commenced, likely due to uptake of the extra water provided by the spur discharges. Eastham (2015) suggests that the increasing trend in foliage cover may potentially indicate that the *Eucalyptus* species have been over-irrigated and the foliage cover is above that expected under undisturbed conditions.
- In contrast, a severe decline in foliage cover and some mortality was observed in *Melaleuca argentea* in 2013 on the western side of the creek (**Figure 9**). This was likely due to water from spur irrigation failing to disperse over the whole creek profile. The issue was managed through the extension of an irrigation spur to the affected side of the creek and there have been some signs of recovery. Based on the response of *Melaleuca argentea* to drawdown in an area where it was not being reached by spur irrigation, the persistence of this obligate phreatophyte within the irrigated area suggests that this species is not resilient to drawdown in this area and spur irrigation is an important ongoing measure.
- Ongoing adaptive management to maintain vegetation accessibility to water has also proven to be essential. This is especially important for root zones which are located at slightly higher elevations in the creek bed and potentially not able to 'tap into' the irrigation water source especially if the creek bed morphology changes during peak flow events.
- An outcome of spur irrigation which does not appear to have been predicted through EIA was the proliferation of *Melaleuca argentea* seedlings around the spur outlets and permanent pools (**Figure 10**). Seedlings in this species establish only with plentiful surface or near-surface water (McLean 2014). The consistent levels of the pools and accessibility of surface water (which would likely have fluctuated seasonally pre-mining) has allowed the seedlings to persist and thrive, potentially to the exclusion of other flora species and changing pool-edge habitats.

Figure 9: Mortality and decline (with some recovery) of *Melaleuca argentea* trees (photo taken November 2015)

Figure 10: Proliferation of *Melaleuca argentea* seedlings around spur outlet

Reaches 2 and 3:

Before mining, Reaches 2 and 3 were ephemeral and only flowed after storm events. This flow regime has changed since discharges at the gabion and D06 commenced. This has resulted in a continuous flow of water in the creek which was not present before mining (**Figure 11**). The 'wetting front' extends downstream from the gabion for the length of Reach 2 and into Reach 3. The 'wetting front' appears to dissipate by the Waterloo gauging

station, 8 km down-gradient of Reach 3 and therefore does not appear to impact on the Fortescue Marsh (**Figure 12**).

Although discharges have changed the flow regime, it is important to note that peak flows have not altered much since before mining commenced. Similar to pre-mining conditions, peak flows generated by large rainfall events result in frequent (natural) changes to the creek system.

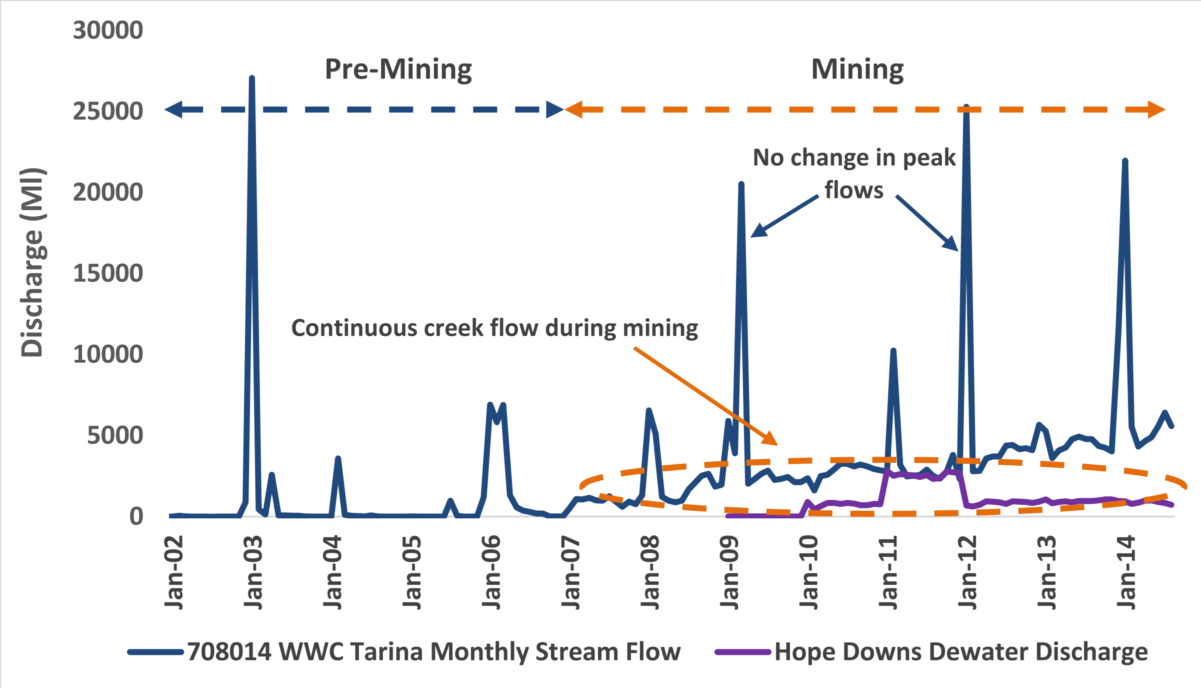


Figure 11: Creek flow at Tarina before and during gabion discharges

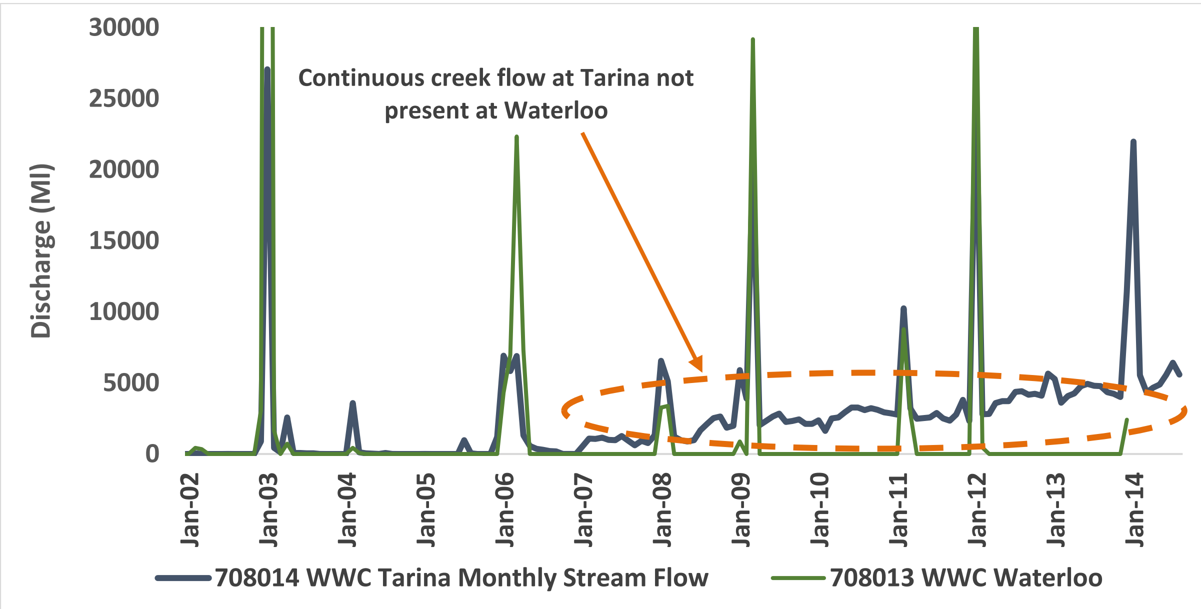


Figure 12: Comparison of flow at Tarina and Waterloo gauging stations

A proliferation of opportunistic species downstream of the discharges was predicted through EIA. This prediction has been borne out as *Melaleuca argentea* seedlings and small trees have proliferated in some areas downstream of the discharge where permanent water is now available. It is not known what effect this may be having on other species in these areas. It is also unknown whether other opportunistic species have responded in a similar way.

A potential decline in the foliage cover of facultative phreatophytic species has been recorded Reach 3 (and potentially in Reach 2). The potential for this occurrence does not appear to have been discussed during EIA processes that took place prior to approval of discharge points into Weeli Wolli Creek. Eastham (2015) identified a potential connection between tree health decline and higher groundwater levels and suggested that waterlogging and/or associated impacts may be a possible explanation.

Waterlogging may cause additional vulnerability to flooding in phreatophytic trees as deep tap roots reduce and shallow roots proliferate.

4.6 Summary of changes in hydrological processes and vegetation

Table 4 compares the pre-mining environmental condition against the current observed condition and considers whether the observed changes were predicted through EIA. Groundwater, creek flow and tree foliage cover are considered in this context. The observed changes must be considered in the context of the whole of the creek being a dynamic system, dominated by peak flows.

Table 4: Summary of changes in hydrological processes and vegetation

Creek reach	**Hydrological processes**						**Vegetation (foliage cover)**	
	Depth to groundwater			**Creek flow**				
	Pre-mining	**Current Condition**	**As Predicted through EIA?**	**Pre-mining**	**Current Condition**	**As Predicted through EIA?**	**Pre-mining**	**Current Condition**
0	Deep (29m at BH21, reaching the root zone of trees close to BH15 (~9m bgl)	Levels are depressed (~17m bgl at BH15 in 2014).	Yes	Ephemeral flashy flow system (storm flows only)	No significant change	Not specifically discussed	Facultative phreatophytes dominant by shrubby understorey (typical of an ephemeral Pilbara creek).	Stable trend in foliage cover
1	Surface (spring discharge) & near-surface	Cessation of spring flow. Groundwater depressed up-gradient of spring but remain close to surface beyond the (former) spring discharge area	Yes	Perennial flow and permanent pools.	Pre-mining perennial flow component no longer present. Surface expression in the creek bed and pools being maintained by spur irrigation.	Yes (maintenance of creek flow cannot be confirmed; however surface expression is maintained)	Both obligate and facultative phreatophytes, sedgefields and herbfields. High diversity of flora.	• Possible increasing trend in Eucalypt foliage cover indicating a potential over-supply of water. • A decline and some mortality of *Melaleuca argentea* was observed in the spring area in 2013. This is being managed by spur irrigation extension. • Adaptive management (including direct irrigation) has proven to be important in areas where irrigation is not reaching vegetation roots (e.g. more elevated areas in the creek bed).
2	Near-surface	No significant change	Not specifically discussed	Perennial flow (first 2km) then ephemeral flashy flow system	Pre-mining perennial flow component no longer present. Continuous flow component now present due to discharges.	Yes (potential for increased creek height and extension of the flowing creek noted. Potential impacts of over-supply of water on vegetation noted).	Both obligate and facultative phreatophytes, sedgefields and herbfields. High diversity of flora.	Potential decline in facultative phreatophytes. Signs of proliferation of *Melaleuca argentea.*
3	No known data	~ 5m bgl and potentially shallower in places	Not specifically discussed	Ephemeral flashy flow system (storm flows only)	Continuous flow component now present due to discharges.	Yes (as per Reach 2)	Facultative phreatophytes dominant with shrubby understorey. Typical ephemeral Pilbara creek.	

5. Findings and conclusions

This project has been undertaken to evaluate the on-ground environmental outcomes for Weeli Wolli Spring and Creek within the project area. The scope was limited to the evaluation of the EPA's environmental factors of hydrological processes and flora and vegetation and is not intended as a comprehensive evaluation of the whole of Weeli Wolli Creek or its environment.

5.1 Findings

As outlined at the start of this report, the EPA had three main questions (in the form of project objectives) to address as part of this project. These are addressed below.

Have the environmental values and condition of Weeli Wolli Creek and Spring changed over the period of time during which mines have been operating in the catchment?

Before mining, the creek was characterised by large peak flows occurring after heavy rainfall and also a perennial flow component sourced from groundwater discharging to surface at Weeli Wolli Spring. Weeli Wolli Spring and pools together support a unique community of plants and animals, and are of considerable spiritual and cultural value to the Traditional Owners. The extent to which these values have changed since mines began operating in the area has been a key consideration of this project.

As expected, some hydrological processes have been altered due to dewatering operations and discharges of surplus water to the creek. Despite these changes, the creek remains a predominantly flashy hydrological system, with the vast majority of flow occurring after storm events. Peak flow events result in an ecosystem which continually changes, due to vegetation destruction and renewal processes. These processes are natural occurrences, which were characteristic of the creek system before mining and continue to be so today.

Some important features of the creek have changed, most notably the cessation of Weeli Wolli Spring discharge. Irrigation appears to be successfully maintaining shallow groundwater levels and surface expression in the creek and pools in the absence of natural spring flow, in part due to the favourable hydrogeological setting which supports a shallow groundwater system. As a result, water continues to be accessible to groundwater-dependent and riparian vegetation in the spring area.

The EPA has been able to conclude that, although there have been some changes, the overall ecosystem of the spring and creek appears to be functioning, consistent with the EPA's predictions. Due to uncertainties in vegetation monitoring datasets, a detailed evaluation of vegetation condition changes, particularly for understorey species, has proven to be difficult. The EPA has encountered challenges interpreting vegetation monitoring data due to insufficient information, frequency, detail or confidence to adequately interpret species-based responses to change. The available dataset has facilitated insights on changes to tree health, most notably:

- There are some indications of over-irrigation of some tree species in the spring area (where spur irrigation is augmenting creek flow). Careful management will be required to ensure that tree health is maintained during the transition period following the cessation of dewatering (and associated discharges) and the return to pre-mining spring flow.
- Adaptive management has proven to be important to manage trees affected by groundwater drawdown and which were not receiving adequate irrigation. For example, incidents of declines and mortality of *Melaleuca argentea* in the spring area have been managed by redirecting irrigated water to supply those trees. Adaptive management has

also been important to sustain root zones which are located at slightly higher elevations in the creek bed and potentially not able to 'tap into' the irrigation water source (especially if the creek bed morphology changes during peak flow events).

- There is a potential for cumulative discharges downstream of the spring to result in an over-supply of water to vegetation, particularly where groundwater levels are shallow. A proliferation of *Melaleuca argentea* has been observed in some areas and a possible decline in the foliage cover of facultative phreatophytic species has also been recorded.

Are any changes in environmental values and condition attributable to the impacts of proposals assessed by the EPA?

The changes in hydrological processes appear to be directly attributable to the proposals, specifically dewatering and discharge operations. The EIA process included predictions and plans for changes to groundwater and creek flow. On the whole, irrigation measures have successfully mitigated these changes, however some alterations have been necessary following some observations of vegetation decline. Adaptive management has proven to be essential to the ongoing management of the spring ecosystem.

The EPA consider that the changes to tree health described in relation to the first objective (above) are attributable to dewatering and discharge operations in the area. Any changes in understorey flora and vegetation has proven difficult to evaluate due to issues with the available datasets and large inherent ecosystem variability.

Are changes consistent with the impacts which were predicted through the EIA?

The EPA has recognised for some time that the collection of sufficient baseline data can be problematic. This project has highlighted that this is especially true for highly dynamic ecosystems such as Weeli Wolli Creek, where large natural variations result in complex patterns of vegetation destruction and renewal. This has resulted in difficulties when attempting to quantify the pre-development baseline condition and therefore any changes to that baseline since mining commenced. More targeted flora and vegetation monitoring, which focusses on key environmental values and indicators of ecosystem health may assist in greater ease of interpretation, so that important issues can be readily identified. Monitoring should only be undertaken to address key questions and data should be collated and reported in such a way that contingency actions are triggered at the earliest possible indication of species decline. Consideration should also be given to the feasibility of co-located monitoring locations for environmental values which are inter-related e.g. groundwater-dependent vegetation types and depth to groundwater.

It is important that the EPA's EIA processes effectively capture and acknowledge uncertainty in predictions and/or mitigation measures, so that the suitability of contingencies can be considered at an early stage in the assessment process. The importance of contingency planning is highlighted by the effective use of adaptive management (e.g. modifications to irrigation systems) in maintaining tree health at Weeli Wolli Spring.

This evaluation has also further highlighted the complexity relating to the cumulative impacts from multiple operations. Cumulative impacts may occur where there is insufficient space between impacts from two or more locations e.g. dewatering cones of depression intersect. Although this complexity has not surfaced at Weeli Wolli Spring to date, planned future mine expansions have the potential to result in an accumulation of groundwater drawdown impacts at that location. Cumulative impacts may also occur where there is insufficient time for recovery between impacts, so that effects accumulate. The EPA also recognises the potential for this to occur at Weeli Wolli Spring in the future, most notably at the juncture of the HD1 post-closure stage (when remediation works are due to return groundwater to pre-mining conditions) and potential concurrent development of future proposals.

The potential for cumulative impacts and the successful deployment of closure commitments is an important consideration in ensuring the future of Weeli Wolli Spring. The spring and

creek are tracking well to date, however the effectiveness of the post-closure management phase will be crucial to returning the spring to flow, and maintaining the environmental values of the spring and creek in the interim period.

A gradual phased reduction in water supply may need to be considered to ensure that vegetation has adequate time to re-adapt to pre-mining conditions before irrigation is eventually switched off entirely.

5.2 Conclusions

The EPA has found that its processes have been generally effective in predicting and mitigating impacts and that the Weeli Wolli Creek is generally tracking as predicted.

Given the importance of adaptive management in this area, the EPA recognises that further recognition needs to be given to contingency planning in accounting for and planning for uncertainty. The EPA's preference is to assess Environmental Management Plans during the assessment stage, rather than recommending a condition that requires the Environmental Management Plan to be prepared following Ministerial approval of a project.

As part of this hindsight evaluation, further attention needs to be afforded to incorporating closure scenarios into the assessment process. The likely success of closure in achieving a transition back to the pre-mining environmental condition deserves more attention at an early stage in the assessment.

Finally, this evaluation has identified a need for more targeted monitoring of key environmental values which is focussed on answering key questions in relation to ecosystem health. This monitoring should be sufficient to trigger the initiation of contingency actions at an early stage in the event of species decline.

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Appendix A: Figures

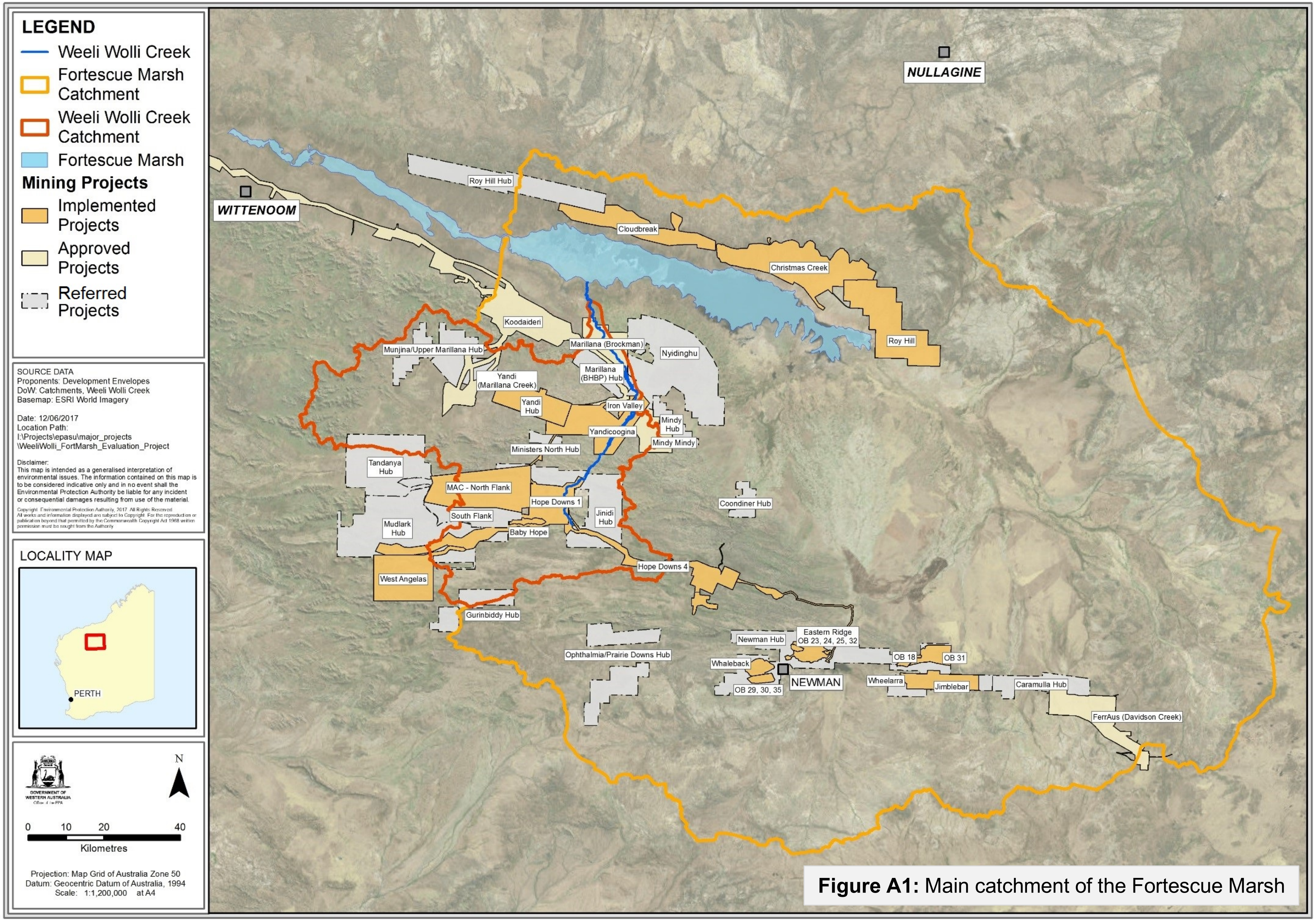

Figure A1: Main catchment of the Fortescue Marsh

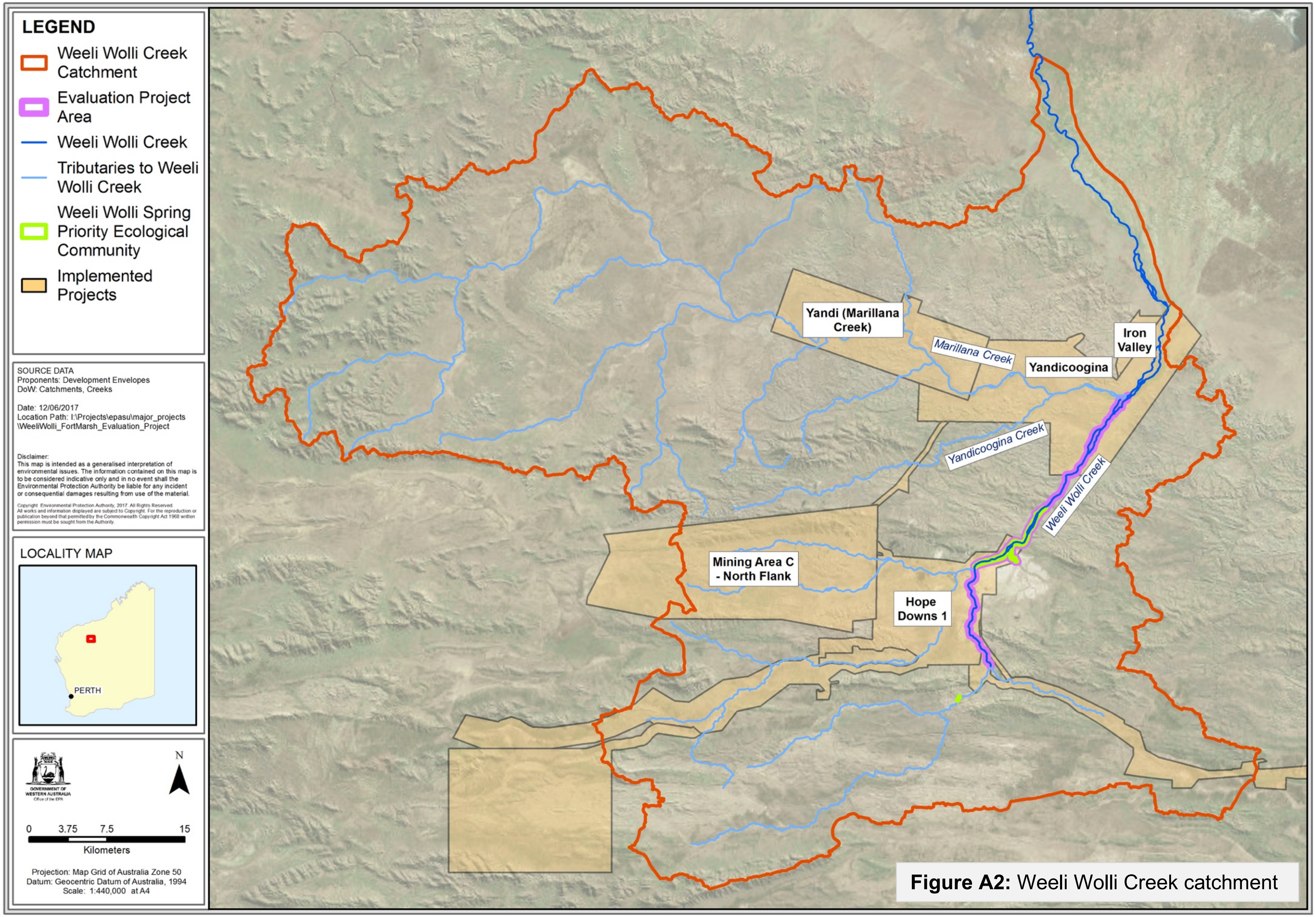

Figure A2: Weeli Wolli Creek catchment

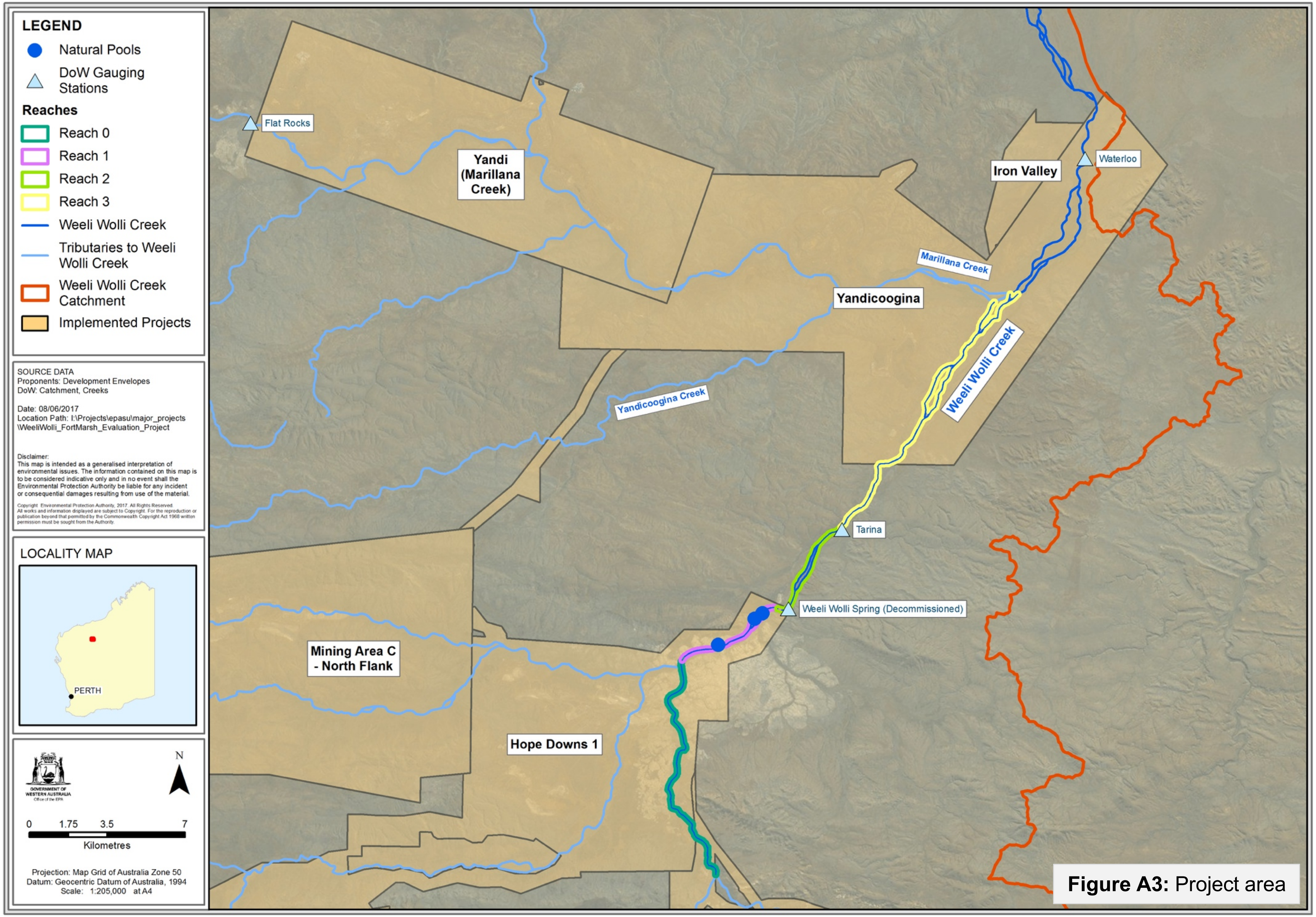

Figure A3: Project area

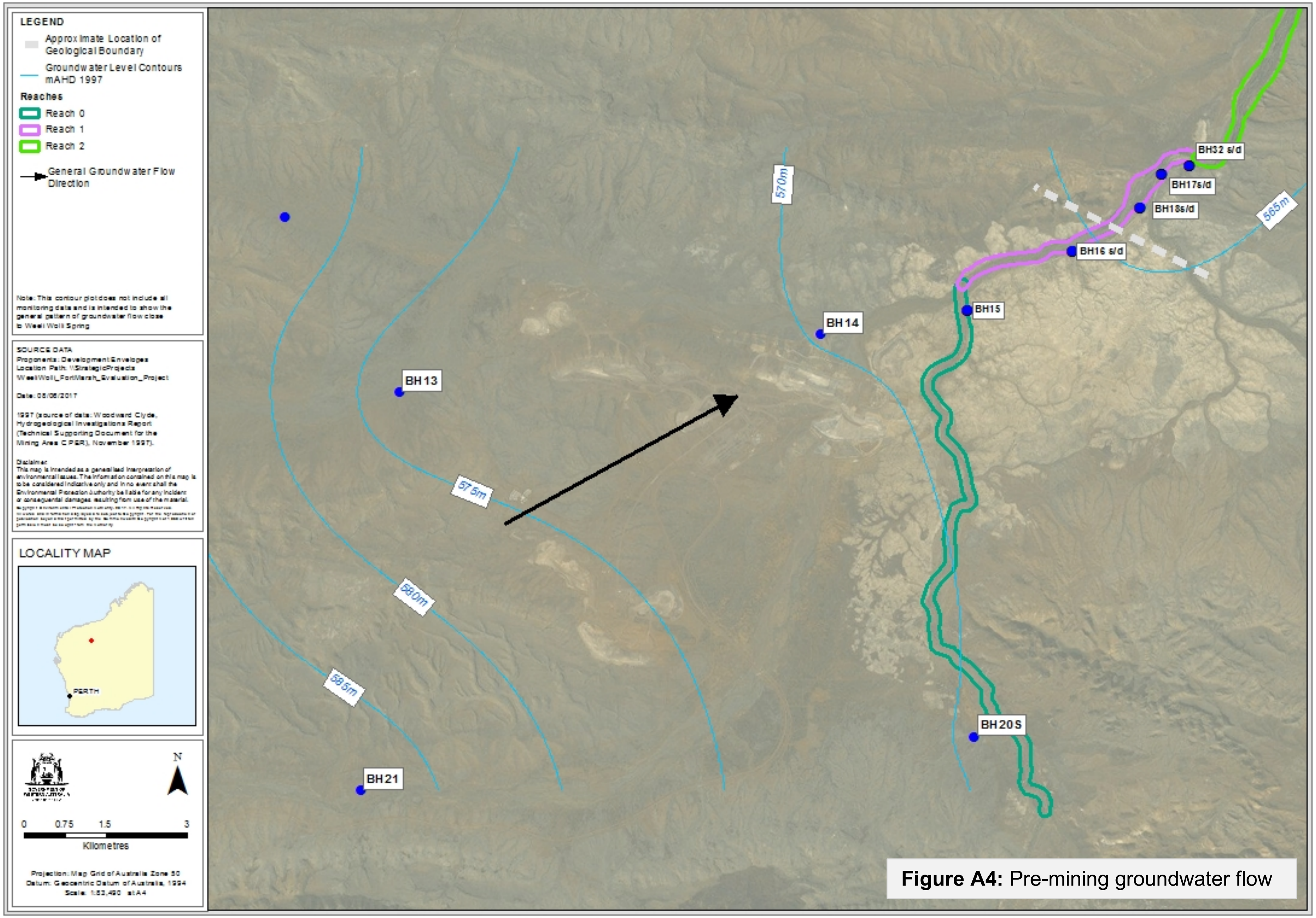

Figure A4: Pre-mining groundwater flow

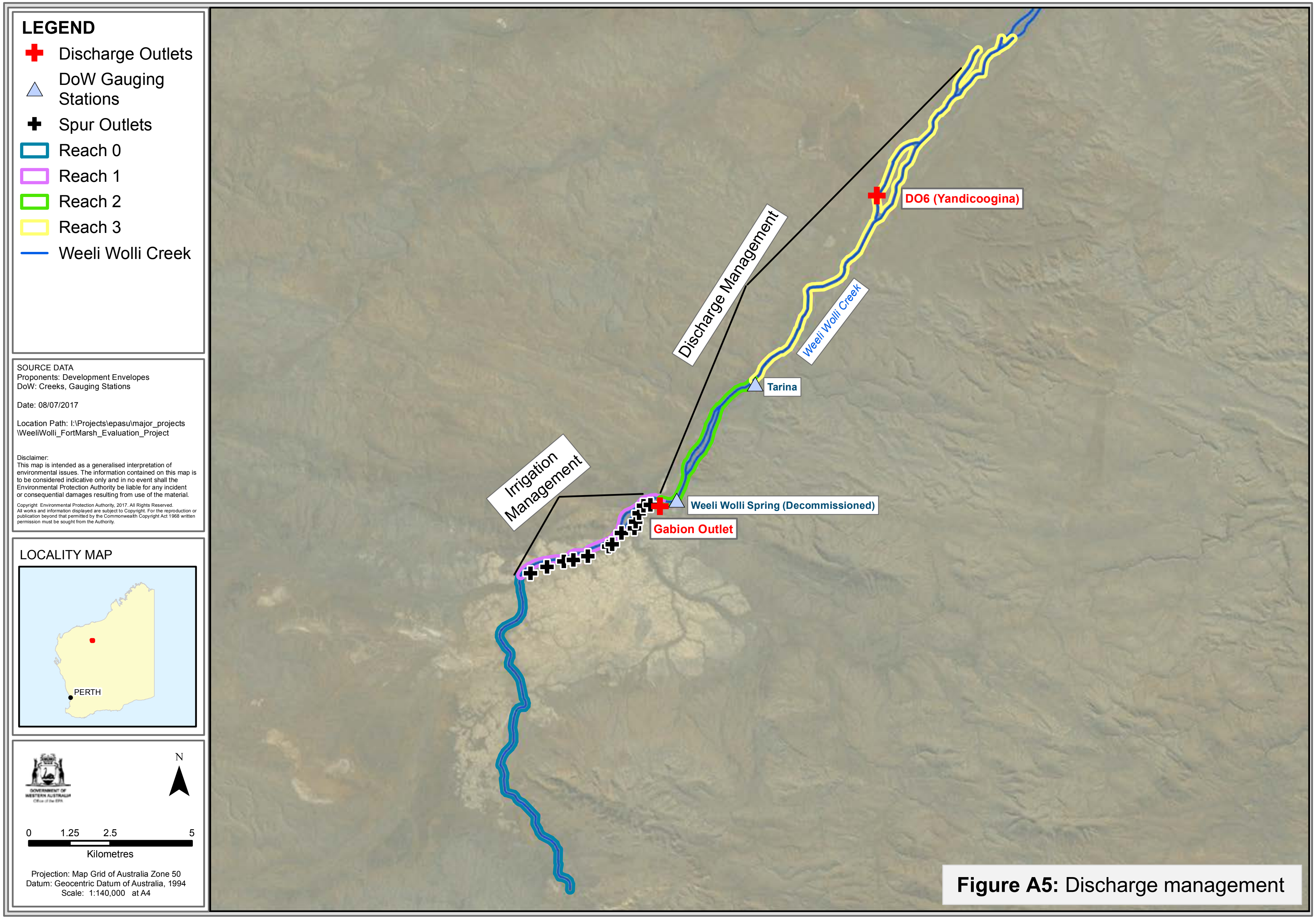

Figure A5: Discharge management

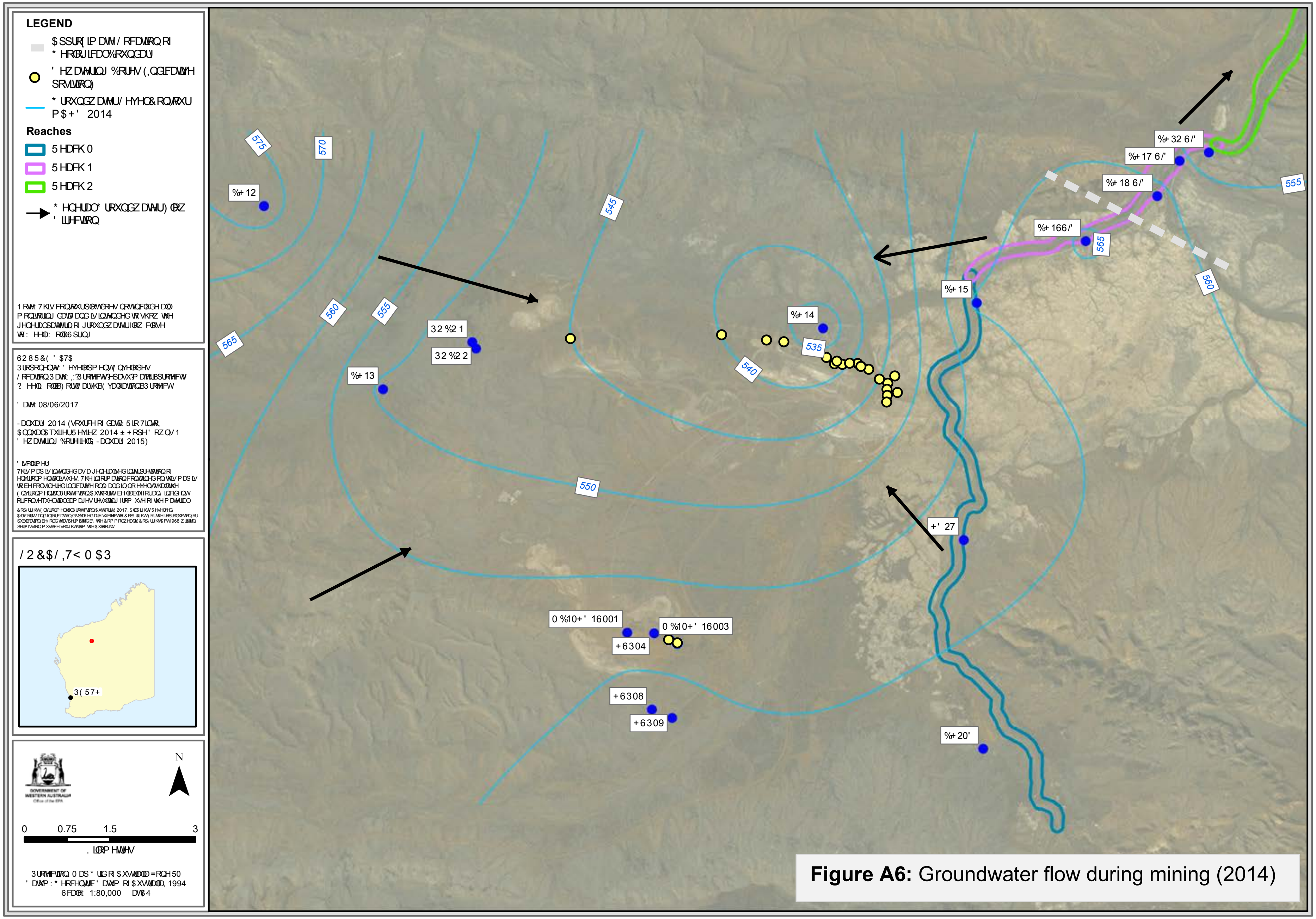

Figure A6: Groundwater flow during mining (2014)

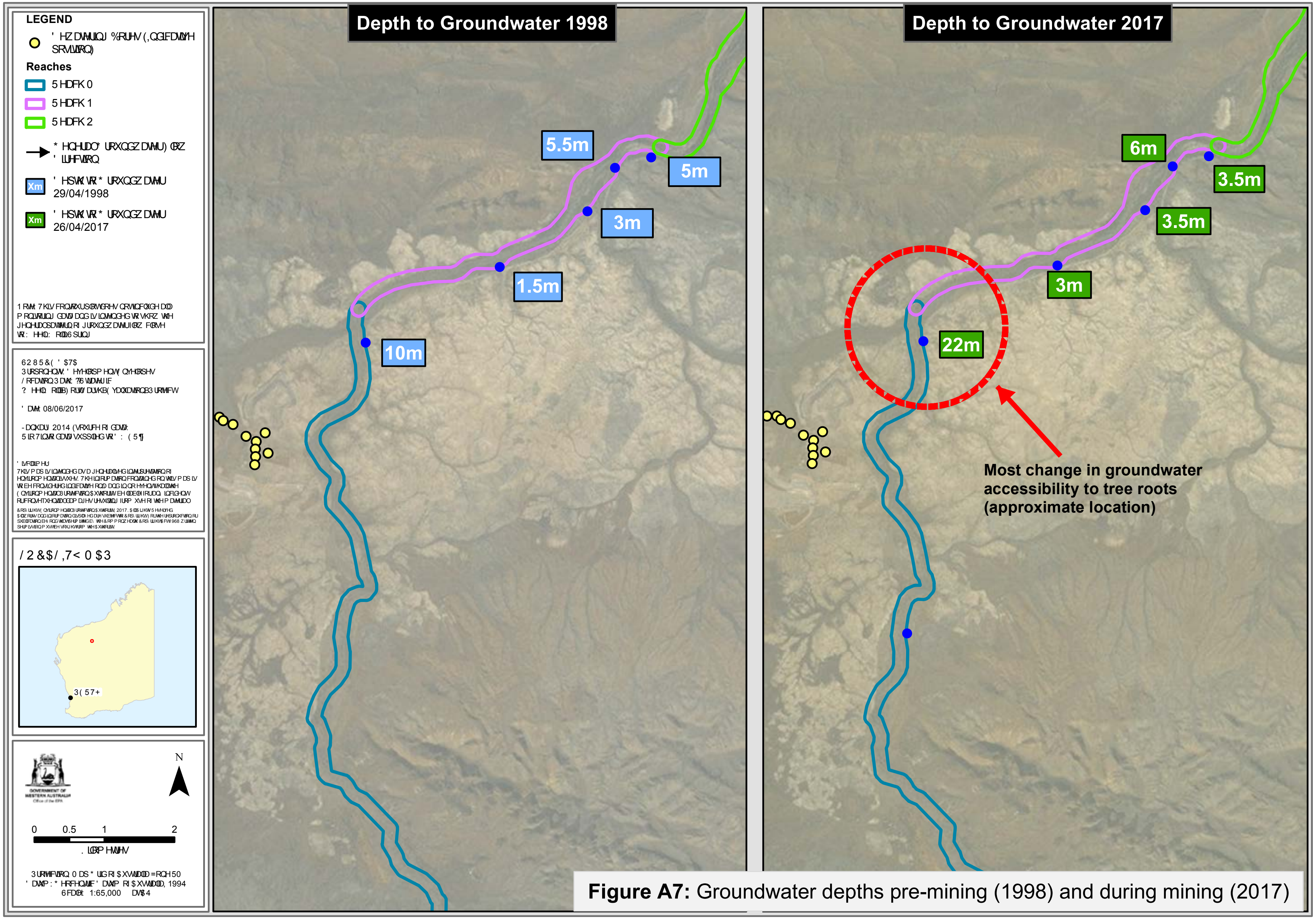

Figure A7: Groundwater depths pre-mining (1998) and during mining (2017)

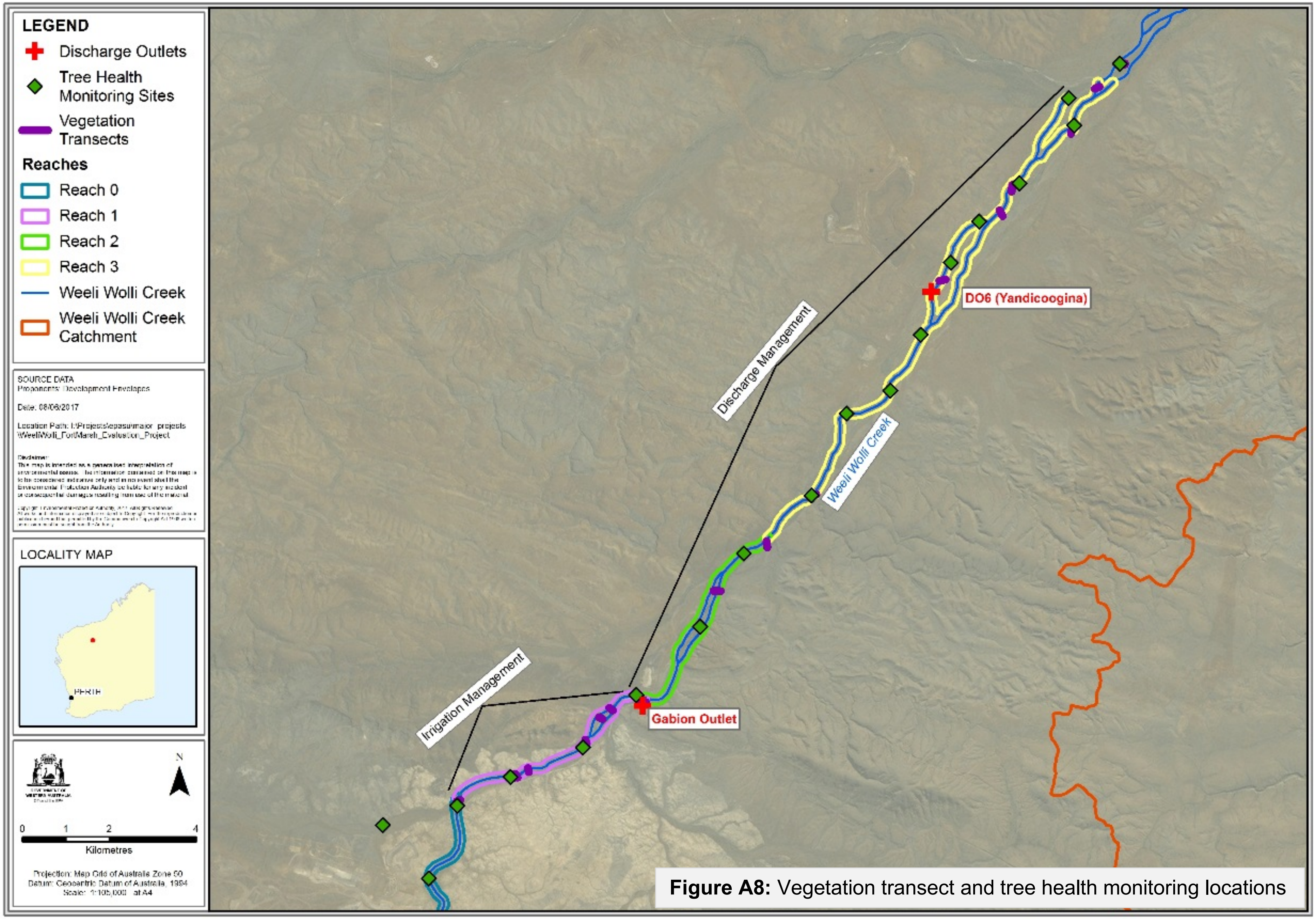

Figure A8: Vegetation transect and tree health monitoring locations