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25 February 2016

**BC Iron Limited - Iron Valley Project**
**Cumulative Change Assessment**
**Lower Weeli Wolli Creek Aquatic Ecosystems**

Dear Les,

Current condition of lower Weeli Wolli Creek represents extensive change in surface water regime, surface water quality, and aquatic fauna from baseline condition (pre-mining), which has resulted from various mining developments in the immediate vicinity of the creekline (i.e. operations close enough to cause additive effects on the environment). Following our discussion, please find below a memorandum which outlines, to the best of our knowledge, cumulative change in the aquatic ecosystem along Weeli Wolli Creek downstream of the confluence with Marillana Creek (referred to as lower Weeli Wolli Creek) to date. Additionally, we outline potential changes in surface water regime, water quality and aquatic faunal assemblage structure from preliminary hydrological modelling of dewatering drawdown and surface water disposal of groundwater associated with BC Iron's Iron Valley Project, and Rio Tinto's Pocket and Billiard South Project.

If you have any queries, please don't hesitate to contact me.

Kind Regards,
Adam

AHarman

**Adam Harman | Principal Environmental Consultant**

# CUMULATIVE CHANGE ASSESSMENT
# LOWER WEELI WOLLI CREEK AQUATIC ECOSYSTEMS

## Introduction

'Baseline condition' in ecological monitoring and impact assessment often infers a pristine or minimally-disturbed state for a system prior to development, against which future change may be assessed. Impacts of a mining project are often assessed in isolation through comparison of the post-closure condition to documented pre-development baseline. However, on a system that has been subjected to multiple developments over time, baseline for future developments may no longer be pristine/minimally-disturbed, but will reflect a modified state. This modified state will still be regarded as 'baseline' for a future development, but will reflect the effects of all past/current developments. These combined effects are therefore the cumulative impacts of all development to that point in time. Although the current condition of a system subjected to cumulative impacts is no longer pristine/minimally-disturbed, it is still the baseline against which a future development would assess their impacts. Therefore, the concept of shifting baselines, allows for a significant change in a system from its original 'pristine' state.

In the case of Weeli Wolli Creek (WWC), current (2016) condition represents extensive change in surface water regime, surface water quality, and aquatic fauna values from pristine/minimally-disturbed condition. This is the result of various mining developments along the creekline and upstream of the Project (i.e. operations close enough to cause additive effects on the environment). Established dewatering and/or discharge operations upstream of the Project include Rio Tinto's Hope Downs 1 and BHPBIO Area C mines adjacent WWC and Rio Tinto's Yandicoogina and BHPBIO Yandi operations on Marillana Creek. These operations have resulted in permanent surface flows from Weeli Wolli Springs to the confluence of WWC with Marillana Creek, and semi-permanent / permanent surface water flows extending approximately 6-7km downstream from the confluence of Marillana Creek and Weeli Wolli Creek (i.e. to sampling site WWC3). This represents a considerable change in water regime from seasonal flows under pre-development baseline condition (pre-2007), to perennial flows under current condition (2016).

## Background

BC Iron Limited (BCI) is currently undertaking baseline environmental studies for the proposed below water table (BWT) development of the Iron Valley Project (hereafter referred to as "BCI IV Project") in the East Pilbara region of Western Australia. Preliminary hydrogeological modelling indicates that groundwater dewatering will be required to mine below the water table, which will require surface water discharge of excess water into WWC. Any substantial discharge will add to the cumulative impacts of combined discharge from the numerous operations upstream on WWC. To that end, BCI commissioned Wetland Research and Management (WRM) to undertake a desktop review of the known ecological values of the creeklines involved, evaluate potential impacts to aquatic ecosystem health, and undertake wet season baseline sampling in 2015 (April) to characterise current water quality and aquatic ecosystem values.

Following completion of the first baseline survey for the Iron Valley Project (WRM, 2015a), BC Iron has commissioned WRM to provide a memorandum which assesses cumulative change in aquatic ecosystem values along lower WWC to date, from ‘baseline’ or pre-development condition, as well as outlining potential further changes which may occur should the Iron Valley Project, and Rio Tinto’s proposed Pocket and Billiard South Project commence dewatering and discharge activities.

## Scope of works

The scope of work includes:

(1) Document baseline or pre-development water regime and aquatic ecosystem values of Weeli Wolli Creek,

(2) Document current (2016) water regime, water quality and aquatic ecosystem values of Weeli Wolli Creek, providing an assessment of cumulative changes to date,

(3) Outline potential changes to water regime, water quality and aquatic ecosystem values of Weeli Wolli Creek associated with predicted dewatering drawdown and surface water discharge operations at BC Iron’s Iron Valley Project,

(4) Outline additional potential changes to water regime, water quality and aquatic ecosystem values of Weeli Wolli Creek associated with predicted dewatering drawdown and surface water discharge operations at Rio Tinto’s Pocket and Billiard South Project,

## Study Area

The Project tenement is situated in the East Pilbara region of Western Australia, within Mining Lease M47/1439 and a small area of Exploration Licence E47/1385. The co-ordinates of M47/1439 are as follows:

| | |
|---|---|
| ➢ NW Corner | 22° 42’ 05”S 119° 19’ 02”E |
| ➢ NE Corner | 22° 43’ 02”S 119° 20’ 30”E |
| ➢ SE Corner | 22° 46’ 33”S 119° 17’ 56”E |
| ➢ SW Corner | 22° 45’ 35”S 119° 16’ 28”E |

The Project is located within the Marillana (pastoral) Station, with land-use in the area comprising predominately pastoral activities and more recently, mining. The regional topography of the Eastern Pilbara is dominated by the Chichester Ranges in the north and the Hamersley Plateau to the south, with these features being divided by the Fortescue Valley. The main drainage system in the area is the Fortescue River, which flows north and then northwest into the Fortescue Marsh.

The regionally significant Weeli Wolli Creek (WWC) flows adjacent to, and downstream of the BCI IV Project. The creek is approximately 70 km in total length, with a catchment area of 4100 km$^2$, and the Project location is approx. 60 km from the headwaters and 35 km from where it discharges into Fortescue Marsh. WWC is naturally seasonally flowing, except for a section in its mid-reaches which is fed by Weeli Wolli Spring. The spring, located approximately 20 km upstream (south) of the Project (Figure 1), was historically permanently flowing as a result of groundwater flow being “dammed” by the Brockman Formation, forcing groundwater to the surface. Historically this resulted in perennial surface flows along WWC for approx. 2 km downstream from the spring. However, as a result of the current discharge regime, approximately 25 - 30 km of the creek is now influenced by surface flows (A.W. Storey, WRM, pers. obs.).

Downstream of the Project, WWC flows to the north, and drains into the Fortescue River via the Fortescue Marsh. The two systems are only connected during flooding associated with intense cyclonic events (Kendrick 2001). The Fortescue Marsh, an episodically inundated samphire marsh, approximately 100 km long and 10 km wide (Kendrick 2001, DEC 2009), is located 25 - 30 km downstream, and to the north-east, of the Project. The Marsh is described as an extensive, irregularly inundated inland floodplain system, and is considered to be a highly unique wetland landform in Western Australia (Environment Australia 2001). It is listed on the national Directory of Important Wetlands of Australia (WA066), and is a Priority 1 Priority Ecological Community (PEC) under the DPaW list of Priority Ecological Communities (DPaW 2014). It is also acknowledged that if nominated, the Marsh meets the criteria for listing as a Wetland of International Importance under the Ramsar Convention (Jaensch & Watkins 1999).

## Baseline (pre-development) condition WWC

Prior to Rio Tinto's Hope Downs 1 mine commencing dewatering and discharge operations along WWC in January 2007, the system was naturally seasonally flowing, except for a section in its mid-reaches which is fed by Weeli Wolli Spring. The spring located approximately 20 km upstream (south) of the Project, was historically permanently flowing as a result of groundwater flow being impeded or "dammed" by low permeability basement rock (the Brockman Formation), forcing groundwater to the surface. The source of the spring (point at which the groundwater intersected the surface) is located at 725595 E 7463816 N. The location of the spring head waters likely varied owing to seasonal fluctuations in groundwater levels and the impact of periodic major flooding that erode or deposit alluvial sediment (Wade Dodson, Rio Tinto Hydrogeologist, pers comm.). Historically this resulted in perennial surface flows along WWC for approx. 2 km downstream from the spring, with an average dry season baseflow of approx. 4 ML/day (Aquaterra 2002), beyond which water infiltrated into the subsurface environment. Based on topography, it is likely a series of isolated semi-permanent / permanent pools existed for up to 4 km downstream of the spring source, reflecting where the stream bed intersected sub-surface flows. Downstream of this reach, flows were episodic (highly ephemeral) and the creek rarely contained water. Peak flows occurred within 24 hours of a considerable rainfall event, with flows generally continuing for several days (Hamersley Iron Pty Ltd 1995).

Prior to any discharge occurring (i.e. pre-development minimally-disturbed baseline condition), it can be assumed Lower WWC (reach downstream of isolated pools) was uniform in hydrological regime, exhibited episodic surface flows following rainfall, had no permanent/semi-permanent pools, and had a relatively homogenous faunal assemblage structure composed of species adapted to intermittent flows (i.e. species with adaptations to survive desiccation). Additionally, the alluvium was likely dry for the majority of the year, therefore, it is reasonable to suggest there was no hyporheic fauna in the near-surface alluvium, with the only subterranean fauna limited to stygofauna in the deeper groundwater.

## <u>Current (2016) condition WWC</u>

*Hydrological regime*

The Rio Tinto mine at Hope Downs 1 (HD1), in the East Pilbara region of Western Australia, is currently de-watering and discharging excess water directly into Weeli Wolli Creek. Discharge from HD1 commenced in January 2007, and is predominantly via a single gabion structure adjacent to the main creek, however a system of spur lines deliver water as seepage flows to maintain phreatophytic trees and pools upstream of the gabion, in the area of the historic springs and permanent pools. The aim of the spurs is to maintain groundwater levels around the historical springs. This has created perennial flow of pools and riffles from Weeli Wolli Spring to just beyond the confluence of Weeli Wolli and Marillana Creeks. In 2014, Hope Downs 1 discharged a combined total (via spurs and gabion) of 38 GL into Weeli Wolli Creek (WRM 2015b). Additionally, since late 2007, excess water from Rio Tinto's Yandicoogina operations has been discharged into WWC (from discharge outlet D06). In April 2013, discharge at Yandi was rationalised and now occurs primarily via a new discharge outlet (D09), located on Marillana Creek approximately 3 km upstream of the Weeli Wolli / Marillana Creek confluence, whilst some discharge still occurs at the existing D06, directly into Weeli Wolli Creek (WRM 2015b). Additional discharge into Marillana Creek occurs upstream of Rio Tinto's Yandicoogina mine, at BHP Billiton Iron Ore's (BHPBIO) Yandi mine. This mine has been in operation since 1994, and also dewaters their developing pit, with excess dewatering water discharged into the upstream section of Marillana Creek.

Including discharge from all outlets into both creeklines, a combined total of approximately 66 GL was discharged to the environment (lower Weeli Wolli Creek) by Rio Tinto operations in 2014. BHPBIO discharge volumes are surplus to this, entering Marillana Creek (MC) upstream of Rio Tinto's Yandi mine, but volumes are not publicly available. For the purpose of this assessment it can be considered discharge volumes entering lower WWC in 2015 were comparable to that documented in 2014. Subsequently, perennial flow of pools and riffles as a result of upstream dewatering discharge operations now extend from the source of Weeli Wolli Spring into the lower WWC approx. 6-7km downstream of the confluence of MC and WWC (i.e. WWC3, Figure 2). Therefore, current (2016) condition represents extensive change in surface water regime, surface water quality, and aquatic fauna values from pristine/minimally-disturbed condition.

Current condition of WWC adjacent the project can be separated into four separate surface water regimes (Figure 2), including:

I. Upper Adjacent Reach of WWC which consists of perennial flow of pools and riffles, extending approximately 6-7km downstream from the confluence of Marillana Creek and Weeli Wolli Creek (i.e. to sampling site WWC3). This reach is characterised by a diverse macroinvertebrate assemblage (lentic and lotic species), rich hyporheic fauna (stygobitic and SRE species), and abundance of fish species;

II. Off-channel Pools, which are most likely perched permanent/semi-permanent pools, and are elevated above, and to the west of the Upper Adjacent Reach of WWC (and therefore not likely to be influenced by cumulative discharge operations upstream). These off-channel pools typically reflect a standing or slow-flowing (lentic condition) hydrological regime, and are characterised by a diverse microinvertebrate (zooplankton) assemblage, but low diversity of macroinvertebrate and fish fauna;

III. Lower Adjacent Reach of WWC which consists of surface expression in the form of isolated permanent and semi-permanent pools upstream and adjacent to the Project that are unconnected by surface flows, except following rainfall events. Pool location shifts depending on the magnitude and duration of rainfall events, and upstream dewatering discharge volumes entering WWC at any point in time. This reach is characterised by little instream habitat, lentic macroinvertebrate assemblage, rich hyporheic fauna (stygobitic and SRE species), and low diversity and abundance of fish species;

IV. Downstream Reach of WWC is the reach downstream of the Project area and exhibits episodic surface flows following rainfall, has no permanent/semi-permanent pools, and has a relatively homogenous faunal assemblage structure composed of species adapted to intermittent flows (i.e. species with adaptations to survive desiccation).

*Water Quality*

Surface water quality is relatively homogenous along the length of lower WWC, both within the Upper Adjacent Reach receiving continuous flow, Lower Adjacent Reach of isolated pools, and further downstream, within the ephemeral, seasonally flowing reach of WWC. Surface waters are generally circum-neutral to slightly alkaline, well buffered, classified as “fresh” (< 1500 µS/cm) as defined by the DoE (2003), with dissolved oxygen concentrations ranging from low to supersaturated (WRM 2015a, WRM 2015b). Nutrient concentrations (nitrogen oxide; $N\_NO_X$, total nitrogen; TN, and total phosphorus; TP) vary between season, however, at times exceed respective ANZECC/ARMCANZ TVs for protection against eutrophication. This reflects a combination of first flush catchment effects (TN and TP), and dewatering discharge activities upstream (i.e. elevated $N\_NO_X$ in groundwaters being dewatered, WRM 2015a, WRM 2015b). Concentrations of dissolved metals are generally low, however, dissolved boron (dB) and dissolved zinc (dZn) at times are elevated above respective 99% ANZECC/ARMCANZ (2000) guidelines. This is of little ecological concern as naturally elevated dB levels are widely recorded from surface waters across the Pilbara, including the Fortescue River, Kalgan Creek, Marillana Creek, Mindy Mindy Creek, Coondiner Creek, Caves Creek and Duck Creek (WRM 2015b), and dZn levels are below hardness-modified trigger values (HMTVs) when water hardness is taken into consideration.

Current condition of the creekline within the Upper Adjacent Reach of WWC (reach of continuous surface flows) suggests no evidence of calcite precipitation or resultant ‘armouring’ of the creek bed, which is occurring further upstream in WWC (downstream of the HD1 discharge outlet). Additionally, there is no evidence to date that discharge has resulted in a significant increase in average water temperature in the downstream receiving environment of Lower WWC (WRM 2015a), although this evident in upper WWC downstream of the HD1 discharge outlet as a result of discharge of groundwater with elevated temperature (WRM, 2015b)

Off-channel permanent/semi-permanent pool water quality differs slightly from the main channel of WWC, with differences related in part to the standing (lentic conditions) nature of isolated off-channel pools, which showed evidence of impacts from unrestricted livestock access. Surface waters show effects of evapo-concentration with spot measurements indicating brackish waters, with associated elevated concentrations of dissolved ions and nutrient enrichment (TN and TP; WRM 2015a).

Currently, there are distinct differences in aquatic fauna assemblages of WWC between the reach of creekline receiving continuous flows, and the reach downstream, which remains ephemeral, holding isolated pools following rainfall.

Microinvertebrates (i.e. zooplankton) are relatively depauperate along the main channel of WWC, particularly within the Upper Adjacent Reach of WWC which receives permanent surface flows from dewatering discharge operations. Conversely, microinvertebrates, in particular periphytic taxa, are abundant in the off-channel permanent/semi-permanent pools (WRM 2015a). This broadly reflects the hydrological preferences of microinvertebrates, which generally favour standing or slow-flowing waters (lentic conditions), with emergence from resting stages dependent on the cues to which they are 'tuned', such as day-length, chemistry, temperature, first flush events, and algal exudates or prey hormones. The majority of microinvertebrate taxa recorded along WWC are common ubiquitous species, with distributions extending throughout Australasia or the world (i.e. cosmopolitan species). Several species of interest have been recorded, and these are either endemic to the Pilbara, Western Australia and/or taxa known to be rare or uncommon throughout their range. Such taxa include the rotifers *Lecane noobijupi, Lindia torulosa* and *Heterolepadella heterostyla,* and the copepods *Australoeucyclops karaytugi* and *Mesocyclops holynskae*, and the cladoceran cf. *Anthalona* sp. (WRM 2015a, WRM 2015b).

A number of species considered to be restricted to the hyporheos (stygobites), and of conservation significance are currently present along Lower WWC and include:

- The amphipods Paramelitidae sp. D and Paramelitidae sp. B are both currently undescribed species that appear to be restricted to Marillana Creek and Weeli Wolli Creek (Helix 2010a, b, Helix 2011, WRM 2015a, b) and the Coondewanna Flats Catchment (Stuart Halse, Bennelongia, pers comm.). This suggests they are both short range endemics as defined by Harvey (2002), and therefore of high conservation significance. Both species have been recorded in the reaches receiving continuous flows, and ephemeral/seasonal flows, with Paramelitidae sp. B also recorded at off-channel permanent/semi-permanent pools (WRM 2015a),
- The amphipod *Chydaekata* sp. is also an undescribed SRE. It has been recorded from the Lower WWC receiving ephemeral flows and at off-channel permanent/semi-permanent pools, as well as a small number of systems in close proximity; Marillana Creek, Coondiner Creek and Mindy Mindy Creek (Helix 2010a, Helix 2011, WRM 2015a, b),
- The amphipod *Maarrka weeliwolli* is also an SRE and has previously been recorded from multiple bores at Weeli Wolli and Marillana creeks (Finston *et al.* 2011). It appears to be restricted to these two creeklines. *Maarrka weeliwolli* appears to be less commonly recorded than the other three species of stygobitic SRE amphipods. *M. weeliwolli* has been recorded from the hyporheic habitat of Lower WWC receiving ephemeral flows (WRM 2015b),
- The ostracod *Gomphodella* n. sp. (BOS334) is an undescribed species new to science. The species appears similar to described species such as *G. glomerosa* and *G. hirsuta*, but differs in that it has no ventral stria, is dorso-ventrally compressed and has a different shaped hemipenis (Dr Russ Shiel, University of Adelaide, pers. comm.). *Gomphodella* n. sp. (BOS334) has been recorded from the Lower WWC receiving ephemeral flows (WRM 2015b). This is not the first record of the new species. It has previously been recorded from bores in the Yandi area (Dr Stuart Halse, Bennelongia, pers. comm.), as well as from hyporheic zones on Marillana and Weeli Wolli creeks (WRM 2015b). *Gomphodella* n. sp. (BOS334) appears to be a short range endemic restricted to Marillana and Weeli Wolli creeks, and as such is a species of high conservation significance. Several *Gomphodella* species are known only from one locality and are commonly found in springs (Karanovic 2006, Reeves *et al*. 2007).

Studies along upper WWC indicate a loss in seasonality of macroinvertebrate assemblages associated with the continual discharge, reflecting increased abundance of taxa known to prefer faster-flowing habitats (WRM 2015b). Currently it is unknown if increased flow constancy and habitat heterogeneity of the Upper Adjacent Reach of WWC receiving continuous flow shows a similar trend for macroinvertebrate assemblages, as only a single round of wet season sampling has been undertaken for BCI (WRM 2015b). However, it is apparent, in the Lower Adjacent Reach, seasonal hydrological differences still influence the assemblage structure with higher abundances of taxa which prefer slow-flowing waters (and absences of fauna adapted to flows). Additionally, the intermittent nature of episodic flows in the Downstream Reach of WWC, and short residence time of surface waters (either flowing or pools) likely provided insufficient time for a number of aquatic invertebrates to establish populations prior to sampling in 2015. Further, in accordance with other studies, increased habitat complexity and heterogeneity of in-stream habitat within the Upper Adjacent Reach of WWC has led to an increase in species richness (e.g. Erman & Erman 1984, Heino 2000), compared to that documented further downstream (WRM 2015a).

Macroinvertebrate diversity is relatively low at off-channel sites, compared to main channel sites (all reaches). This was somewhat unexpected, given the documented habitat-species richness patterns observed along the main channel, and considering habitat diversity at off-channel sites was more diverse (macrophytes, algae etc) than main channel sites (WRM 2015a). Low diversity may in part reflect hydrology and water quality at off-channel sites (i.e. low dissolved oxygen, lack of surface flows, elevated ions & metals, etc.), with flowing water in the main channel providing additional habitats (e.g. riffle zones) for lotic (flow-adapted) species.

The Pilbara pin damselfly, *Eurysticta coolawanyah*, listed on the IUCN Redlist as **Near Threatened** has been previously recorded from the Lower Adjacent Reach of WWC (WRM 2015b). However, the IUCN listing of the Pilbara Pin is considered to require revision, as it has been recorded from over 40 locations throughout the Pilbara since initial listing (Pinder *et al.* 2010). This increases its distribution above the 500 km$^2$ threshold defined by the IUCN. The absence of *E. coolawanyah* from lower WWC (all reaches) in sampling from 2013-2015 is of interest but not of great concern (WRM 2015a, WRM 2015b). As *E. coolawanyah* is known from areas outside the Weeli Wolli Creek dewatering-discharge impact zones, populations are considered unlikely to be seriously affected at a regional level. The majority of remaining macroinvertebrates encountered are generally common, ubiquitous species, with distributions extending across Northern Australia, Australia or Australasia. However, a number of species endemic to the Pilbara region have been recorded and include:

- Stygobitic amphipod species recorded in the hyporheic zone and also present in surface waters: *Chydaekata* sp., *Maarrka weeliwolli*, Paramelitidae sp. B and Paramelitidae sp. D,
- The Haliplid beetle *Haliplus fortescueensis* is a Pilbara endemic relatively new to science. It was first described from a specimen collected from the Fortescue Marsh during the PBS (Pinder *et al*. 2010, Watts & McRae 2010). It appears to be mainly restricted to the Fortescue River, and most abundant in the Fortescue Marsh (Watts & McRae 2010). However, this species has also been collected once from a claypan near Port Hedland (Watts & McRae 2010), and also from a Claypan on Coondiner Creek (DPaW 2015, WRM unpub. data). *H. fortescueensis* has been recorded within the Downstream Reach of WWC, and appears largely restricted to ephemeral waterbodies (WRM 2015a),
- The diving beetle *Tiporus tambreyi* (Dytiscidae) has been recorded from the Upper Adjacent and Lower Adjacent Reaches of WWC. *T. tambreyi* appears to be common and ubiquitous across the Pilbara region (Pinder *et al*. 2010, DPaW 2015, WRM 2015b).

- The hydrophilid beetle *Laccobius billi* is a Pilbara endemic rarely collected. It was only recorded once during the PBS, from Cangan Pool on the Yule River, approximately 100 km north-west of the Project (Pinder *et al*. 2010). A single specimen has been recorded within the Upper Adjacent Reach of WWC (WRM 2015a). It has also been recorded previously from upper Weeli Wolli Creek, Coondiner Creek and Mindy Mindy Creek (DPaW 2015, WRM 2015b).
- The Pilbara Archtail dragonfly, *Nannophlebia injibandi*, has been recorded from the Lower Adjacent Reach of WWC (WRM 2015b). *N. injibandi* was recorded infrequently during the Pilbara Biological Survey (Pinder *et al*. 2010), however it has been recorded from upper Weeli Wolli Creek, Roy Hill on the Fortescue River, Fortescue Falls in Karijini National Park, and Skull Springs on the DeGrey River (WRM, 2015b). There are also records of *N. injibandi* from Koodaideri Spring (Bennelongia 2011, WRM 2014). As such, this species appears to have a relatively broad, albeit disjunct, distribution throughout the Pilbara, but does not appear to be abundant or commonly recorded.

Three of the twelve freshwater fish species known from the Fortescue River System have been recorded along lower WWC: the spangled perch *Leiopotherapon unicolor*, Pilbara tandan (eel-tailed catfish) *Neosilurus* sp., and the western rainbowfish *Melanotaenia australis*. Low diversity of fish fauna is common in the upper reaches of the Fortescue River and its tributaries (including WWC), in comparison to the lower Fortescue River and other catchments across the Pilbara. Each of these species are common, ubiquitous and widespread across the Pilbara region**.** Within the lower WWC, fish diversity is highest within the Upper Adjacent Reach of continuous surface flows. Fish diversity and abundance is generally lower further downstream, with short residence time of surface water following recent inundation, and consequent lack of in-stream habitat and food source, not allowing for successful fish colonisation. Abundances of all three fish species may well have benefited (at least in the short-term) from higher diversity of in-stream habitat, heterogeneity and security provided by greater permanence of water from dewatering discharge activities. Additionally, low diversity and abundance of fish at off-channel permanent/semi-permanent pools, compared to main channel sites, may in part reflect predation effects by larger spangled perch and/or avian fauna in the confined off-channel sites, and the lack of connectivity to main channel sites preventing recolonisation of these pools.

## Potential change associated with BCI IV Project

### Dewatering drawdown

Drawdown associated with BC Iron's Iron Valley (BCI IV) Project resulting in increased depth to groundwater (Figure 4.38, AQ2 2016) is likely to result in what could be regarded as adverse changes to surface water pools in adjacent reaches of WWC, and their aquatic fauna assemblages. Likely changes to the flow regime include loss of permanent surface flows and pools, loss or reduction in sub-surface (alluvial / hyporheic zone) flows through the alluvium of the main channel of the Upper Adjacent Reach WWC (reach of continuous surface flow), as well as potential loss of permanent/semi-permanent off-channel pools west of the main channel of WWC, adjacent to the Project. The reach will still flow intermittently, following sufficient local rainfall, but pools will quickly drain into the underlying alluvium and dry. Additionally, changes to the water quality of surface water pools, such as increased salinity through evapo-concentration is likely to occur in receding pools. Evapo-concentration of these pools as they dry following rainfall-induced flows may also lead to eutrophication and algal blooms. In the Upper Adjacent Reach, the flow regime will shift from its current state of perennial flow with permanent pools, to an ephemerally flowing regime, with isolated pools present for a short residence time following wet season rainfall events, as is currently present in the lower adjacent reach and in the reach further downstream of the Project (WRM 2015a).

Subsequently, faunal assemblages will likely shift towards those adapted to a seasonal hydrological regime, with an anticipated reduction or complete loss of fauna adapted to flows (i.e. filter feeding macroinvertebrates), replaced by assemblages with adaptations to avoid desiccation and survive in seasonally dry systems. Hyporheic fauna, dependent on saturated alluvium along the creek bed will also be lost as this habitat dries as a result of drawdown. These changes will result in replacement of the fauna with species that adapted to seasonal drying with desiccation-resistant stages (i.e. zooplankton). The extent of any change will depend on the depth of drawdown, and its effect on surface (streams and pools) and subsurface (hyporheic) habitats and associated faunas. Assuming drawdown is sufficient to result in loss of surface flows, loss of permanent pools, and drying of the hyporheic habitat, local populations of a number of stygobitic and SRE hyporheic fauna, microinvertebrate and macroinvertebrate taxa endemic to the Pilbara may be lost from this reach of creekline. However, the majority of these taxa have known regional distributions outside the Project area. Intermittent flows, and short residence time of surface waters (either flowing or pools) will also result in a loss of fish species from this reach of creekline, except where pools remain for a sufficient length of time post-wet season, and wet season flow events provide connectivity of surface waters to either Marillana Creek or upper WWC allowing opportunistic colonisation. Current perennial flows and the saturated alluvium has allowed the establishment of a dense riparian and instream flora, with significant recruitment of eucalypt and melaleuca species along the edge of the active channel.

Although drawdown associated with the BCI IV Project is predicted to have significant effects on current flow regime and current ecological condition of the adjacent reaches, it is important to acknowledge that current condition is an altered baseline which has resulted from various mining activities in the immediate vicinity of the creekline (i.e. operations close enough to cause additive effects on the environment). Although pre-development ecological data for this reach do not exist, WRM have data for comparable seasonally-flowing rivers in the Pilbara, and based on the ecological values of these comparable systems, it can be assumed that pre-development, Lower WWC was uniform in hydrological regime (seasonal flows, ephemeral pools), with a relatively homogenous faunal assemblage structure, with species adapted to intermittent flows, with life history adaptations to avoid desiccation. Additionally, the alluvium was likely dry for the majority of the year, therefore, it is reasonable to suggest groundwater (stygobitic) fauna were absent within the hyporheic zone. Therefore, it can be considered that these predicted change in surface water regime and aquatic fauna assemblages as a result of drawdown associated with the BCI IV Project reflect a shift back towards pre-development 'baseline'.

Groundwater discharge to WWC

*Hydrological regime*

Current modelling indicates that over the life of the Iron Valley mine (2016 – 2025), taking into account mine use and evaporative losses, approximately 90M KL of surplus water will be discharged into WWC adjacent to the Project tenement (ranging between 2000 – 17000 ML/yr) (AQ2 2016). Preliminary hydrological modelling indicates the wetting front from the discharge of this dewatering water will extend approximately 5km-6km downstream of the proposed discharge outlet, beyond which the water will infiltrate into the subsurface environment (AQ2 2016). Currently, there are three proposed discharge outlets, with dewatering from the South deposit proposed to be discharged directly to WWC discharge point DL1 (in the Upper Adjacent Reach WWC), whilst all groundwater dewatering from the Northern, Centre and East deposits will be pumped to a centrally located turkeys nest, where water surplus to site requirements is proposed to be piped to WWC discharge points DL3 and DL5 (Lower Adjacent Reach WWC; Figure 5.1 AQ2 2016, WRM 2015a).

On the assumption dewatering discharge enters within the Lower Adjacent Reach of WWC, this will alter the current surface water flow regime from isolated permanent and semi-permanent pools, and episodic surface flows further downstream, to permanent surface and sub-surface (alluvial / hyporheic zone) flows through the alluvium of WWC. Baseline surveys of the study area (WRM 2015a) indicated microinvertebrate fauna, which generally favour standing or slow-flowing waters (lentic conditions), and are adapted to a narrow range of water quality, were relatively depauperate at sites receiving permanent surface flows from dewatering discharge operations upstream (i.e. WWC1 – WWC3). Therefore, diversity and abundance of microinvertebrate assemblages may be reduced in the section of WWC receiving permanent surface flows as a result of BC Irons IV dewatering discharge, in comparison to ephemeral and off-channel pools.

Provision of continuous surface flows to WWC *via* dewatering discharge will likely lead to the saturation of the coarse alluvium within the 5-6km discharge footprint, and increase the extent of habitat available for hyporheic fauna. This may in turn lead to the increased presence of short range endemic (SRE)[1] species, such as stygal[2] amphipods, isopods and syncarids (crustaceans) of high conservation value in the hyporheic zone downstream of the discharge outlet.

Baseline surveys (WRM 2015a) also showed macroinvertebrate and fish diversity and abundance was greatest within the Upper Adjacent Reach of WWC at sites receiving permanent surface flows from discharge operations upstream (i.e. WWC1 & WWC2), declining with increasing distance downstream and as the system became more ephemeral. It was postulated that this was due to the greater extent of permanent aquatic in-stream habitat at upstream sites, compared to the ephemeral and less-complex habitat of pools further downstream. Therefore, the development of permanent surface flows due to dewatering discharge would likely cause an increase in habitat heterogeneity, and thereby an increase in the diversity of macroinvertebrate and fish fauna along the receiving section of WWC. However, although increased biodiversity through provision of surface water may be regarded as enhancing ecological values along the receiving section of WWC (lower adjacent reach), macroinvertebrate and fish assemblage and community structure will likely shift away from those currently occurring. With a hydrological switch to permanent flows, the

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[1] Short range endemic as defined by Harvey (2002): a species occupying an area of less than 10, 000 km$^2$.

[2] Taxa which are obligate inhabitants of aquatic subterranean environments, such as aquifers or the hyporheic zone. Common morphological adaptations to subterranean environments include loss of eyes and pigmentation, reduction in body size, and the lengthening of appendages (e.g. antennae).

seasonal/ephemeral signature of fauna will likely be lost, as has been the case on upper Weeli Wolli Creek (WRM 2015b). Further, any ecological values enhanced due to the provision of permanent flows and increased habitat heterogeneity will be lost upon cessation of discharge.

*Water quality*

Groundwater data from two BC Iron production bores (PB1 and PB2) in the Iron Valley project area were used to provide an indication of the current quality of groundwater that will be discharged (AQ2 2016). This assumes there is no substantial change in bore water quality when discharged on the surface. The available groundwater data included concentrations for a limited suite of dissolved metals, major ions, alkalinity, electrical conductivity (EC), pH, and total dissolved solids (TDS) from a single sampling event for each bore in May 2015. It is acknowledged these data are one-off spot-measurements, which provide only a snap-shot of groundwater quality, with no data provided on water hardness or any forms of dissolved nutrients (specifically forms of nitrogen; AQ2 2016).

The limited data from the two Iron Valley production bores indicated that pH and EC of groundwater within the Project tenement (likely to be discharged to the surface environment) were in exceedance of ANZECC/ARMCANZ (2000) default guidelines for the protection of 95% of species in slightly-moderately disturbed systems in Tropical Northern Australia (Table 1). The values for pH (8.2, 8.3) were however, only slightly above the upper default guideline (pH 8, Table 1) and within the existing annual range for MC (7.0 - 8.5), though slightly lower than WWC downstream of the MC confluence (6.6 - 8.0) (WRM 2015a, WRM2015b, WRM unpubl. data). The pH in the bores was also well within the annual range commonly recorded in other natural freshwater creeks across the Pilbara (pH 6 - 10) (Pinder *et al.* 2010, WRM unpubl. data).

Although EC in both bores (830 µS/cm, 850µS/cm) exceeded the default guideline (250 µS/cm, Table 1), waters were still considered "fresh" (i.e. < 1500 µS/cm; DoE 2003) and slightly below the existing annual range for MC (900 - 1120 µS/cm) and WWC downstream of the MC confluence (900 - 1,000 µS/cm) (WRM 2015a, WRM2015b, WRM unpubl. data). EC in the bores was also well within the annual range commonly recorded in other natural freshwater creeks across the Pilbara (250 - 2000 µS/cm) (Pinder *et al*. 2010, WRM unpubl. data). An EC of 830 - 850 µS/cm in groundwater is therefore not expected to have an adverse effect on fauna if released into surface waters however, there is little published information on the sensitivity of Pilbara freshwater organisms to increases in EC and few studies on sub-lethal or long-term effects or more sensitive life stages. It is generally believed that biota of freshwater ecosystems will be adversely affected as the salinity increases to ca. 1,500 µS/cm (1,000 mg/L) (Hart 1991). Spot measurements indicate groundwater salinity is below this threshold, and therefore presents a low risk to aquatic fauna.

Ionic composition of waters in both bores was dominated by sodium cations ($Na^{2+}$) and hydrogen carbonate anions ($HCO^{3-}$). ANZECC/ARMCANZ (2000) do not provide guidelines for major ions or TDS.

Dissolved zinc concentrations were well above ANZECC/ARMCANZ (2000) guidelines for both 95% and 99% species protection at bore PB2 (Table 1). However, elevated levels of total dissolved metals such as zinc do not automatically imply that levels are toxic to aquatic biota. The toxicity of dissolved metals is dependent on the form of metal present and the degree to which it is bioavailable (i.e. labile). Many metals readily bind to organic matter and clays and precipitate out of the water column, making them unavailable for direct uptake by plants and fauna and hence of low toxic risk. It is recommended that once discharge to creeklines commences, and if concentrations of dissolved metals remain above TVs, then labile concentrations of those metals that exceed TVs should be determined to assess their potential toxicity.

**Table 1.** Selected physicochemical parameters recorded from two production bores (PB1 & PB2) in the Iron Valley tenement, sampled by AQ2 in May 2015. Corresponding ANZECC/ARMCANZ (2000) trigger values are provided for 99% species protection and 95% species protection for moderately-slightly disturbed systems in Tropical Northern Australia. Note: only parameters with applicable ANZECC/ARMCANZ (2000) guidelines are presented.

| Parameter | PB1 | PB2 | 99% species protection | 95% species protection |
|---|---|---|---|---|
| pH | 8.3 | 8.2 | - | 6 - 8 |
| EC (µS/cm) | 830 | 850 | - | <250 |
| Dissolved cadmium (µg/L) | <0.1* | <0.1* | 0.06 | 0.2 |
| Dissolved copper (µg/L) | <1* | <1* | 1.0 | 1.4 |
| Dissolved manganese (µg/L) | 9 | 26 | 1200 | 1900 |
| Dissolved lead (µg/L) | <1* | <1* | 1.0 | 3.4 |
| Dissolved zinc (µg/L) | <5* | 37 | 2.4 | 8.0 |
| Dissolved mercury (µg/L) | <0.05* | <0.05* | 0.06 | 0.6 |
| Dissolved nickel (µg/L) | <1* | <1* | 8 | 11 |
| Dissolved selenium (µg/L) | <1* | <1* | 5 | 11 |
| Dissolved chromium (µg/L) | <1* | <1* | 0.01 | 1.0 |

* value was below the limit of detection (LOD).

Concentrations of other dissolved metals were below ANZECC/ARMCANZ (2000) guidelines for the protection of 95% of species (Table 1). It must be noted, however, that the majority of dissolved metal levels recorded from PB1 and PB2 were below the limits of detection (LOD) (see above Table 1). It should be noted, LODs for dCd (PB1 and PB2) and dZn (PB1) were not sufficiently low as to compare against corresponding ANZECC/ARMCANZ (2000) guidelines for the protection of 99% species.

It should be also noted that a number of physicochemical parameters, which have the potential to impact the surface water environment if elevated, and are known to be elevated in other Pilbara groundwaters, were not recorded by AQ2 (2015). For example, dissolved nutrients, and in particular nitrates were not recorded. Elevated nitrate has been recorded in groundwater environments throughout the Pilbara (WRM unpub. data), which if discharged into surface waters, may lead to eutrophication and algal growth at lower concentrations, and direct toxicity to fauna at higher concentrations (ANZECC/ARMCANZ 2000). There may be some attenuation of nitrates once discharged to the creeks, i.e. in saturated sediments of the creek beds and banks. However, there has been little research on this in Australia, making it difficult to predict how much nitrate might be removed in this way. Further, baseline surveys in the Project area suggest nitrate levels may be inherently elevated in WWC surface waters, possibly due to unrestricted livestock access from pastoral stations nearby, or from water discharged from mines upstream (WRM 2015a). Therefore, it is recommended that nutrient levels in the groundwater to be discharged from Iron Valley be adequately monitored, in order to document levels and assess potential impacts to the surface water environment.

Although dissolved ion and metal concentrations in the groundwater to be discharged into WWC are generally low, changes to the water chemistry (increases in dissolved ions or metals), and dissolution of calcrete, may still occur in the receiving section of WWC as a result of dewatering discharge. When groundwater with high concentrations of calcium and sulphate mix with stream water already nearly saturated with calcite, degassing of carbon dioxide and the common ion effect quickly causes calcite precipitation. This phenomenon has been observed previously by the authors downstream of other mine dewatering discharge outlets in the Pilbara, resulting in 'armouring' and heavy compaction of the creek bed, and consequent increases in surface flows and reductions in aquatic habitat and aquatic biodiversity.

There is also the potential for changes to surface water temperature (thermal pollution), and associated impacts to the receiving section of WWC, due to the discharge of excess dewatered groundwater of different temperature to surface waters. Surface water temperatures tend to reflect ambient air temperature, but are also influenced by water colour, water depth and degree of riparian shading (ANZECC/ARMCANZ 2000). Groundwater tends to be warmer than ambient surface water, especially as depth of abstraction increases. Discharge of excess dewatering water will likely provide warmer water to the creek in the dry season, when ambient temperatures tend to be lower.

Due to the paucity of groundwater data available from production bores, combined with the absence of data available for any form of dissolved nutrients and a limited suite of dissolved metals, and the unknown quality of groundwater once it is discharged to the surface environment, the implications for aquatic fauna in relation to discharge water quality cannot be accurately quantified at this stage. It is recommended that a greater suite of water quality analytes be monitored in groundwater prior to the commencement of dewatering discharge, including dissolved nutrients, in order to develop a broader understanding of the groundwater quality at Iron Valley to be discharged into WWC. Notwithstanding, the parameters analysed thus far are unlikely to cause ecological stress to the aquatic fauna of WWC, and so, assuming other analytes are similarly at low concentrations relative to default ANZECC/ARMCANZ TVs (or alternatively site-specific trigger values once derived) , changes in water quality, are considered unlikely to have an influence on aquatic fauna assemblages following the commencement of dewatering discharge from Iron Valley.

## <u>Potential change associated with Rio Tinto PBS Project</u>

### <u>Groundwater discharge to WWC</u>

#### *Hydrological regime*

Rio Tinto is currently developing three new deposits at Yandi Junction South West (JSW-A & JSW-C) and Yandi Oxbow (Rio Tinto 2014). Rio Tinto is also proposing to develop the Yandicoogina Pocket and Billiard South deposit (the "PBS" project) (Rio Tinto 2014). Additional dewatering and discharge operations are necessary as part of these developments, as around 95% of the ore occurs below the water table (Rio Tinto 2014). Rio Tinto baseline hydrological modelling indicates that under maximum potential discharge, approximately 37 - 43 GL/annum will be released into the surface water environment over the life of the PBS development (2016 – 2031), taking into account evaporative losses and on-site mine usage (total abstraction will be ~53 GL/annum; Rio Tinto 2014). This equates to around 99 - 115 ML/day, but will ultimately depend on dewatering discharge rates by BHPBIO's Yandi operations located further upstream on Marillana Creek, which may further extend any wetting front.

Currently, dewatering discharge operations upstream (Rio Tinto Yandicoogina, Rio Tinto HD1 & BHBPIO Yandi) provide permanent flows extending 6-9 km downstream of the WWC/Marillana Creek confluence, reaching to the south-eastern border of the Iron Valley tenement (AQ2 2016).

WRM field visits confirmed surface water flows extending 6-7km downstream of the WWC/Marillana Creek confluence in March 2015 (WRM 2015a). Should Rio Tinto proceed with the development of their PBS mine (Rio Tinto 2014), preliminary hydrological modelling suggests their excess water disposal will override the predicted drawdown in the Upper and Lower Adjacent reach of WWC, resulting in a net groundwater level increase, and surface flows that would extend past the BCI IV Project tenement to approximately 23kms downstream from the Weeli Wolli Creek and Marillana Creek confluence for the life of the Iron Valley mine (2016 – 2025, Figure 4.34 AQ2 2016). This wetting front will be reduced to 17 km downstream of the WWC/MC confluence once Iron Valley operations cease in 2025 (AQ2 2016).

It is assumed that BCI dewatering and associated drawdown will commence before PBS comes on-line, and therefore the current perennial flows in the Upper Adjacent Reach will become seasonal and the permanent/semi-permanent pools in the Lower Adjacent Reach will be lost, with associated ecological effects as described above. Once PBS comes on-line, the Upper and Lower Adjacent Reaches will receive significant recharge, with mounding, and perennial surface flows will occur throughout this reach. The change once again from ephemeral conditions to permanent surface flows has numerous implications for aquatic fauna, particularly in the lower adjacent reach and reach downstream of the BCI Iron Valley tenement which currently remains ephemeral (episodic flows). Diversity and abundance of microinvertebrate communities may be reduced in the lower adjacent reach of WWC and further downstream, as these fauna generally favour standing or slow-flowing waters (lentic conditions), and are adapted to a narrow range of water quality. Conversely, the provision of permanent flows will increase the extent of subsurface hyporheic habitat, inducing the movement of stygal amphipods, isopods and syncarids (crustaceans) of high conservation value into the hyporheic zone downstream of the discharge outlet. This may provide an apparent increase in the conservation significance of the fauna recorded, and offset any potential losses of stygobitic fauna within the upper adjacent reach of WWC from drawdown effects.

The development of permanent surface flows due to dewatering discharge would likely cause an increase in habitat heterogeneity, and consequent increase in diversity of macroinvertebrate and fish fauna along the currently ephemeral reach of WWC. However, although increased biodiversity through provision of surface water may be regarded as enhancing ecological values along the receiving section of WWC, macroinvertebrate and fish assemblage and community structure will likely shift away from those occurring naturally. With a hydrological switch to permanent flows, the seasonal/ephemeral signature of fauna will likely be lost, as has been the case on upper Weeli Wolli Creek (WRM 2015b). This short-term ‘enhancement’ of ecological values (2016 – 2025) will then be lost upon cessation of discharge by BCI and then PBS as the wetting front recedes and the system dries. This will give an apparent loss in biodiversity, and loss of species of conservation significance. In reality, however the system will be returning to its pre-development ‘baseline’ condition, where this reach was dry, had no permanent pools, and flowed episodically following sufficient wet season rainfall, with remanent pools lasting weeks following rainfall.

*Water quality*

There are currently no data publically available relating to the quality of groundwater to be discharged into WWC from the PBS Project. Therefore, comments on the water quality to be discharged into WWC from the PBS project can only be made in general terms. As the PBS project is located downstream of current dewatering discharge from the HD1 mine, it is possible that the groundwater quality in the area is consistent with the quality of water being discharged from HD1 upstream, as this water is likely to infiltrate groundwater in the vicinity of the PBS and be included in any proposed dewatering discharge. Discharge from outlet DO9 will also include dewatering water from Rio Tinto's Yandicoogina mine, which appears to be elevated in some analytes, particularly nutrients, such as nitrogen oxides, total nitrogen and total phosphorous (WRM 2015b).

As previously mentioned, current discharged surface waters reaching the project area are relatively homogenous and characterised by circum-neutral to slightly alkaline pH, well buffered, low salinity, and low to supersaturated dissolved oxygen concentrations. Dissolved metal levels are generally low with elevated dB and dZn which is not un-expected, whilst nutrient concentrations vary, reflecting a combination of first flush catchment effects, and dewatering discharge activities upstream.

Therefore, groundwater discharge downstream of the D09 outlet is likely to cause relatively homogenous water quality along WWC, between the confluence with Marillana Creek and the Iron Valley tenement. It is also worth noting that flows downstream of the Iron Valley discharge outlet will be a combination of PBS water (40 GL/year) from the D09 outlet, and water from Iron Valley (with a peak of 17 GL/year and a minimum 2 GL/year). During the dry season, dewatering water from Iron Valley will contribute a significant portion of the flows, and so the water quality of WWC downstream of the tenement will be influenced by discharge from Iron Valley. Wet season flows will likely constitute a blend of dewatering water from upstream activities (WWC and Marillana Creek) and catchment flows derived from rainfall. Spot measurements indicate the quality of groundwater to be discharged from Iron Valley presents a low risk to aquatic fauna.

Given no groundwater data are publicly available for the PBS Project, combined with the paucity of data available (and lack of nutrient data) for the BCI IV Project, it is not possible to definitively assess potential water quality impacts on the receiving downstream aquatic environment. Provided surface water quality resultant from groundwater discharge is adequate (i.e. below ANZECC/ARMCANZ trigger values for the protection of 99% of freshwater species or SSTVs once derived), it can be considered changes to hydrological regime following the commencement of cumulative dewatering discharge will enhance biodiversity values (hyporheic, macroinvertebrate, and fish) of the lower WWC.

## Conclusion

Cumulative change assessment was undertaken to evaluate potential impacts to the current ecosystem values of aquatic ecosystems in the vicinity of the Project, from proposed BWT mining and dewatering discharge of excess groundwater into WWC. In evaluating potential impacts to aquatic ecosystems, the main issue was considered to be cumulative impacts of combined groundwater dewatering discharge to WWC. The surface water footprint from existing discharge operations upstream of the Project (Rio Tinto HD1 & Yandicoogina, BHPBIO Yandi) currently extends between 6 km and 9 km downstream of the Marillana/WWC confluence. Commencement of discharge in association with Iron Valley and PBS project operations are eventually likely to extend the discharge footprint between 17 - 23 km downstream of the WWC/Marillana Creek confluence over the lives of the mines (2016 – 2025 and 2016 – 2031, respectively).

Prior to the PBS Project coming online, initial drawdown associated with the BCI IV Project will result in increased depth to groundwater within the Upper Adjacent and Lower Adjacent Reach of WWC, and potential loss of permanent surface flows, loss or reduction in sub-surface flows, and loss of permanent/semi-permanent off-channel pools. This will reduce available habitat for a number of conservation significant fauna including the IUCN Redlisted Pilbara pin damselfly, *Eurysticta coolawanyah*, a number of stygobitic and SRE amphipods including Paramelitidae sp. B, Paramelitidae sp. D and *Chydaekata* sp., stygal syncarid species from the families Bathynellidae and Parabathynellidae, which are known to occur in groundwater bores within the tenement and (likely) hyporheic zones of creeks, and the currently undescribed cladoceran (microinvertebrate) cf. *Anthalona* sp. Conversely, reductions in surface water flows may enhance the restricted hydrophilid beetle *Haliplus fortescueensis*, as this species tends to favour ephemeral pools of short residence time. Excluding the cladoceran cf. *Anthalona* sp., populations of all conservation significant taxa have known local and/or regional distributions outside the Project area, therefore distribution and conservation status of these species are unlikely to be impacted by the Project development.

It could be argued surface water discharge of adequate water quality may provide alternative suitable habitat for the above mentioned conservation significant fauna over a distance of approximately 5-6 km downstream of the proposed BCI IV discharge outlet. Continuous surface flows to lower WWC will likely result in an increase in in-stream habitat heterogeneity, and diversity of hyporheic, macroinvertebrate and fish fauna. However, although increased biodiversity through provision of surface water may be regarded as enhancing ecological values along this reach, macroinvertebrate and fish assemblage and community structure will likely shift away from those currently occurring . With a hydrological switch to permanent flows, the seasonal/ephemeral signature of fauna will likely be lost (along with taxa which favour ephemeral conditions such as *Haliplus fortescueensis*). Any short term “enhancement” of ecological values due to the provision of permanent flows and increased habitat heterogeneity will be lost upon cessation of discharge. At this time, it is anticipated aquatic fauna assemblages of lower WWC will shift back towards current altered baseline condition.

There is a risk of creek bed armouring due to carbonate (calcite and dolomite) precipitation from groundwater discharge, as seen in other BWT dewatering projects in the east Pilbara. If calcite precipitation occurs, it is likely to be localised, taking place close to the discharge outlet initially, but with a potential for the longitudinal extent to increase with continuous flow over time. Large magnitude flow events may assist in dislodging or breaking up armoured benthic substrate, however, armouring may re-establish over time. In addition, it is anticipated armouring as a result of dewatering discharge activities from projects upstream of the BCI IV Project will extend into the upper adjacent reach of WWC over time, regardless of the BCI IV Project.

The formation of the calcite precipitate structurally changes the bed of the creek, and likely impacts habitat availability and heterogeneity for macroinvertebrates by infilling interstices and 'cementing' cobbles and pebbles together. Many macroinvertebrate taxa inhabit spaces between and under cobbles, as well as amongst loose surface gravels and pebbles. These habitats are essentially lost when the bed becomes armoured and these substrates are cemented together. Generally, a decrease in habitat diversity leads to a decrease in macroinvertebrate taxa richness.

Given no groundwater data are available for the Rio Tinto PBS Project, combined with the paucity of groundwater data available from BCI IV production bores, absence of dissolved nutrient data, and the unknown quality of groundwater once it is discharged to the surface environment, the implications for aquatic fauna in relation to discharge water quality cannot be accurately quantified at this stage. It is recommended that a greater suite of water quality analytes be monitored in groundwater prior to the commencement of dewatering discharge, including dissolved nutrients and a comprehensive suite of metals, in order to develop a broader understanding of the groundwater quality at Iron Valley to be discharged into WWC. Additionally, efforts should be made to ascertain groundwater quality at PBS to be discharged into WWC, to differentiate potential contaminants between Projects.

Notwithstanding, the groundwater parameters analysed thus far are unlikely to cause ecological stress to the aquatic fauna of WWC, and assuming additional analytes similarly show no elevated concentration, changes to hydrological regime, as opposed to changes in water quality, are considered likely to have more of an influence on aquatic fauna assemblages following the commencement of dewatering discharge from Iron Valley. Provided surface water quality resultant from groundwater discharge is adequate (i.e. below ANZECC/ARMCANZ trigger values for the protection of 99% of freshwater species or SSTVs once derived), it can be considered changes to hydrological regime following the commencement of cumulative dewatering discharge will temporarily enhance biodiversity and conservation values (hyporheic, macroinvertebrate, and fish) of the lower WWC relative to pre-development (pre- 2007) baseline for the duration of dewatering discharge.

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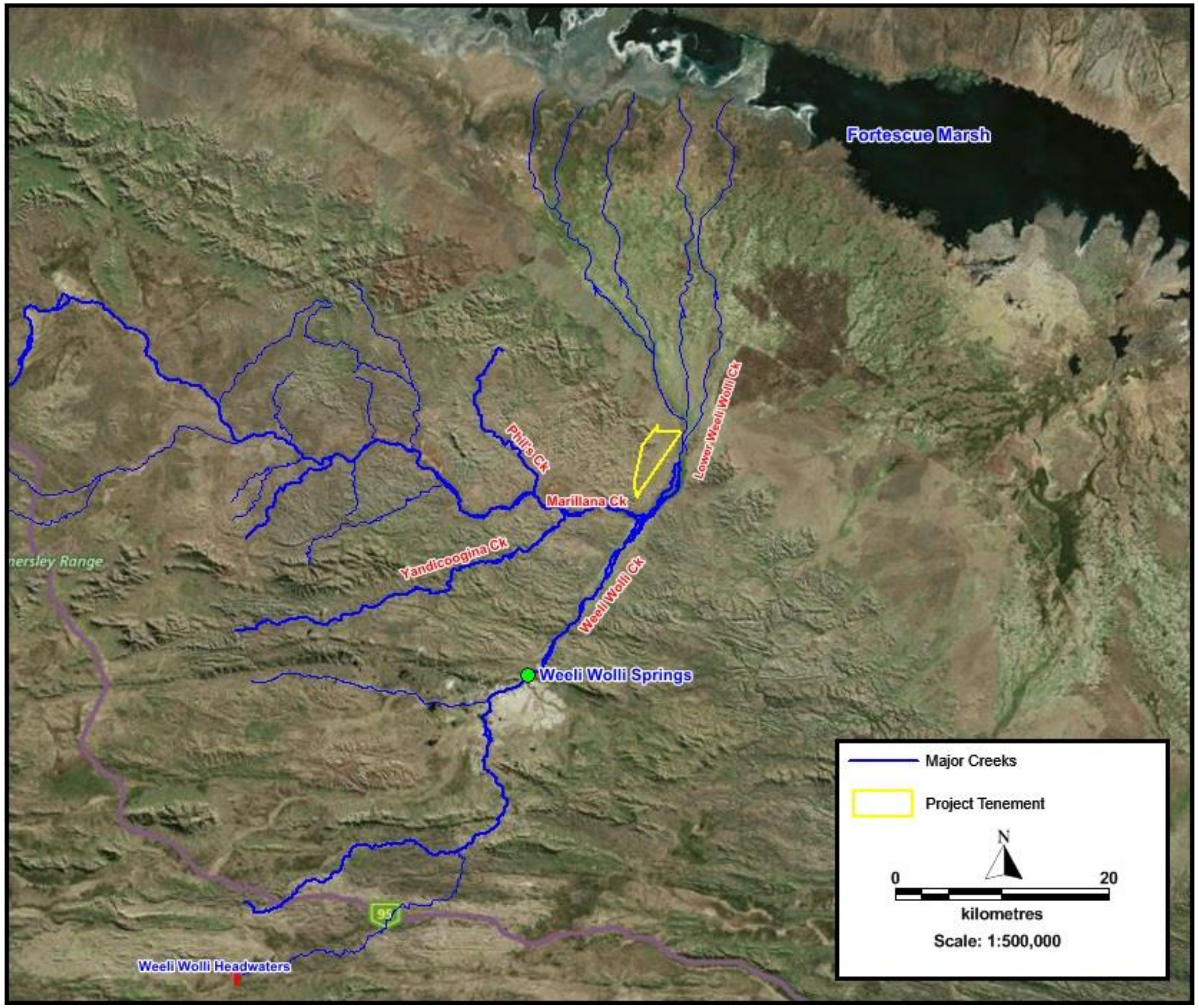


**Figure 1.** Overview of Weeli Wolli Creek, showing location of headwaters, Weeli Wolli springs, convergence with Marillana Creek, BC Iron’s Iron Valley Project Tenement (yellow outline), and the Fortescue Marsh.

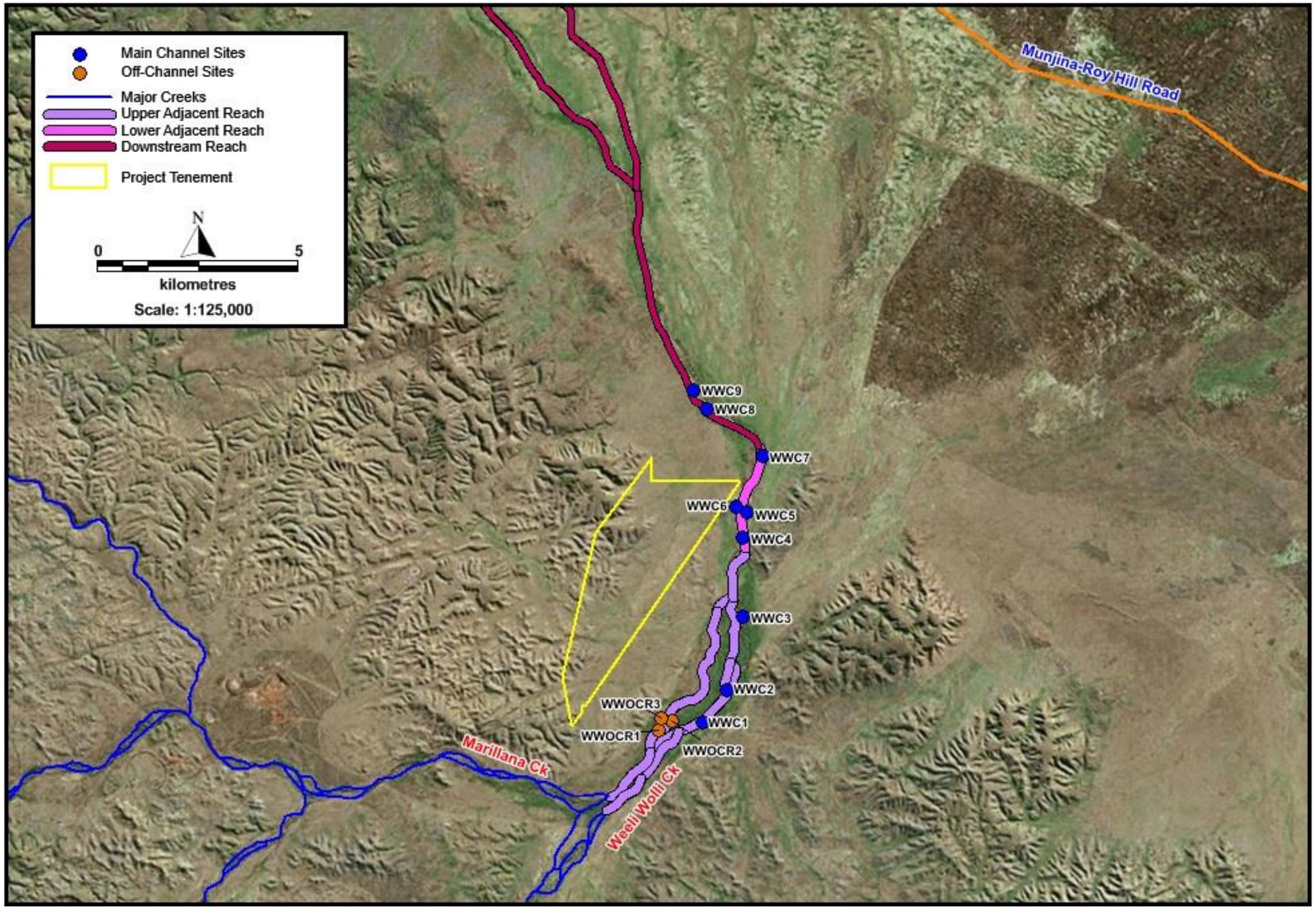
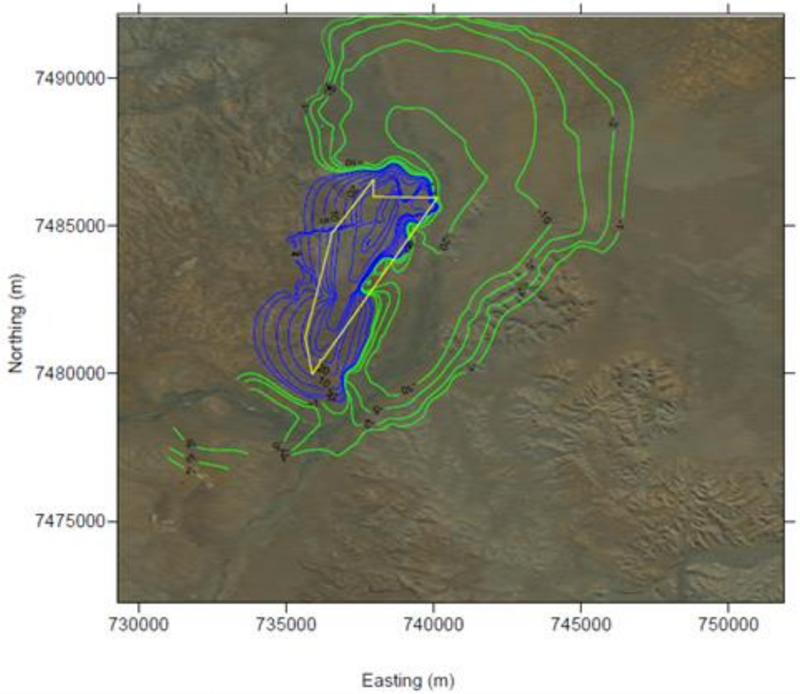


**Figure 2.** Overview of current nominal reaches of differing hydrological regime along lower Weeli Wolli Creek; Upper Adjacent Reach (purple), Lower Adjacent Reach (pink), and Downstream Reach (red), showing baseline aquatic fauna sites sampled in March 2015. Main channel sites are blue, and off-channel reference sites are orange.  The Project tenement is denoted by yellow outline.



LOCATION MAP

**LEGEND**

- 🟦 Predicted Water Level Decrease (m)
- 🟩 Predicted Water Level Increase (m)
- 🟨 Project Area

Positive drawdown represents a water level decrease while a negative drawdown represents a water level increase.
Contours shown at -20m, -10m, -5m, -2m, -1m, 1m, 2m, 5m, 10m, 20m, 30m, 40m, 50m, 100m, 150m and 200m.

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DATE: 5 Jan 2015

REPORT NO: 062a
REVISION: A
JOB NO: 013B

GDA94 Zone 51
SCALE: 1:175,000 (at A4)

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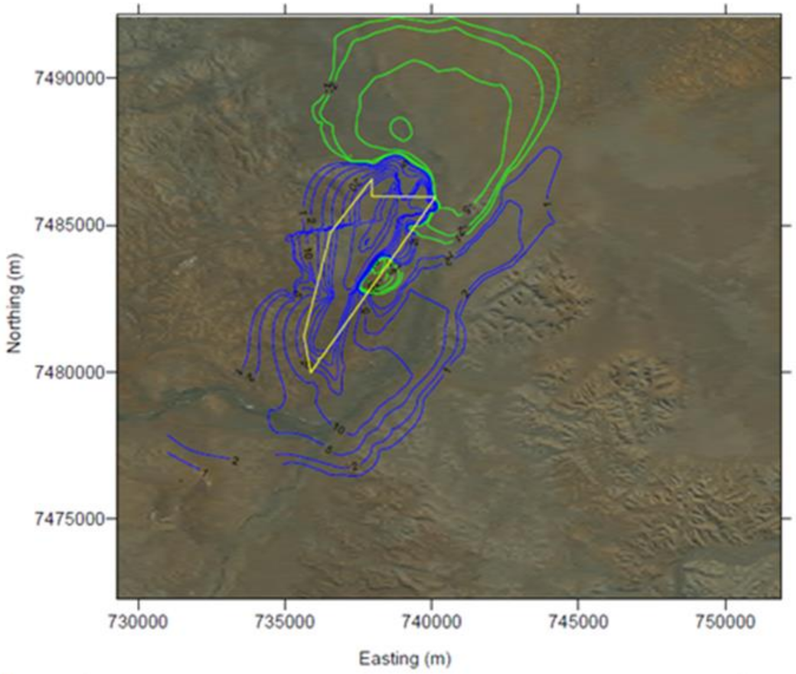
AQ2

FIGURE 4.43
**CONTOURS OF PREDICTED DRAWDOWN END OF 2025 RTIO SURPLUS DISPOSAL CASE**



LOCATION MAP

**LEGEND**

— Predicted Water Level Decrease (m)
— Predicted Water Level Increase (m)
— Project Area
Positive drawdown represents a water level decrease while a negative drawdown represents a water level increase.
Contours shown at -20m, -10m, -5m, -2m, -1m, 1m, 2m, 5m, 10m, 20m, 30m, 40m, 50m, 100m, 150m and 200m.

AQ2

AUTHOR: KR
DRAWN: KR
DATE: 5 Jan 2015

REPORT NO: 062a
REVISION: A
JOB NO: 013B

GDA94 Zone 51
SCALE: 1:175,000 (at A4)

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FIGURE 4.38
**CONTOURS OF PREDICTED DRAWDOWN END OF 2025**

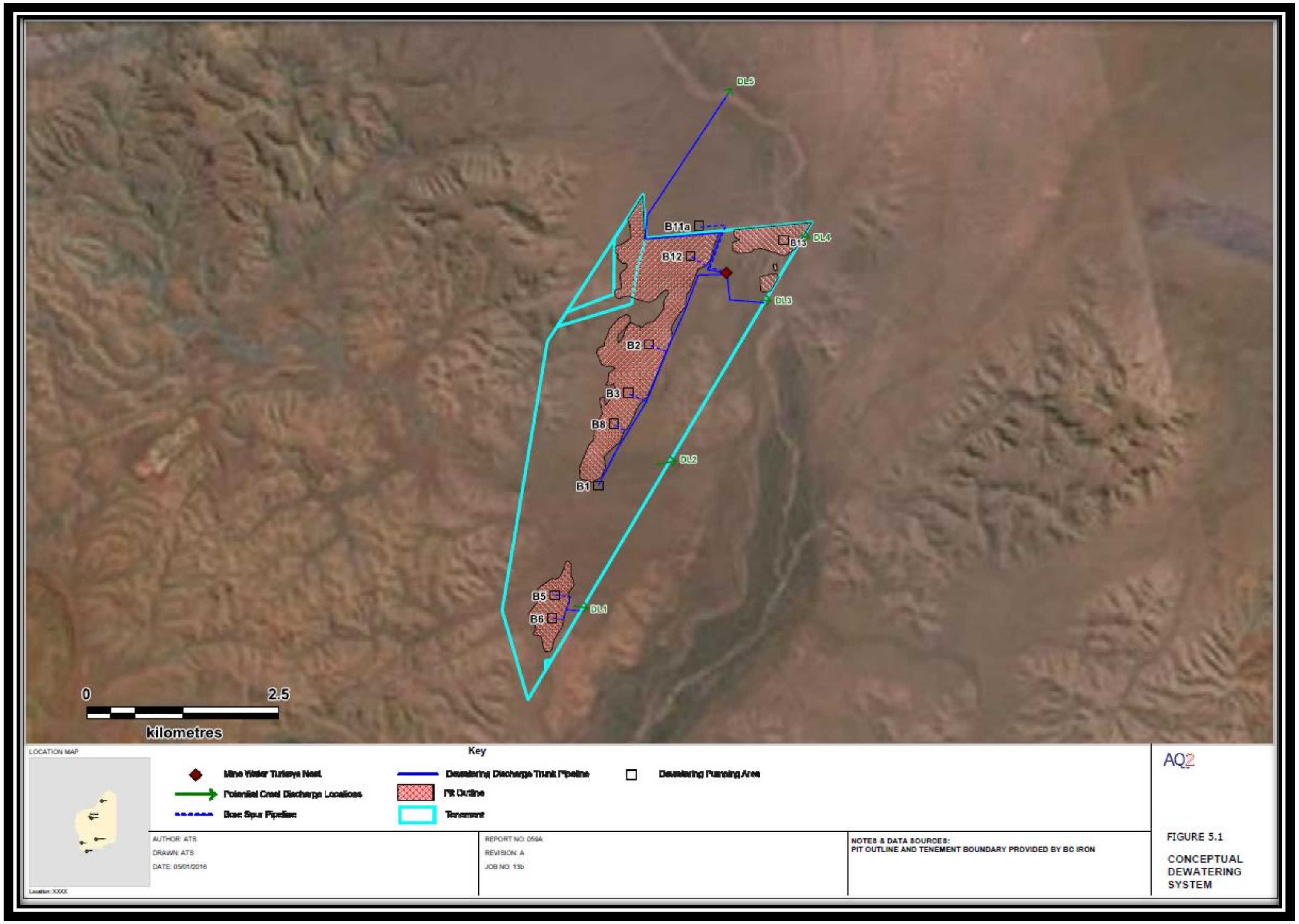

FIGURE 5.1

CONCEPTUAL DEWATERING SYSTEM