Corunna Downs Project – Assessment of Groundwater Drawdown Impacts to Vegetation

Prepared for: Atlas Iron Ltd
Job Number: Atlas18-09
Report Number: Atlas18-09-01
Cover Photograph: Part of pool (CO-WS-13) west of the Corunna Downs Project, April 2014.

**DOCUMENT REVISION AND STATUS**

<table>
<thead>
<tr>
<th>Revision</th>
<th>Status</th>
<th>Originator</th>
<th>Internal Reviewer</th>
<th>Internal Review Date</th>
<th>Client Reviewer</th>
<th>Client Review Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Draft Report</td>
<td>DC/CG</td>
<td>GW</td>
<td>25/3/2018</td>
<td>Brendan Bow, Natassja Bell, David Nyquest</td>
<td>4/04/2018</td>
</tr>
<tr>
<td>B</td>
<td>Revised Draft</td>
<td>DC/CG/GW</td>
<td>GW</td>
<td>02/05/2018</td>
<td>Brendan Bow</td>
<td>17/05/2018</td>
</tr>
<tr>
<td>0</td>
<td>Final</td>
<td>DC/CG/GW</td>
<td>GW</td>
<td>18/05/2018</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DISCLAIMER**

This document is prepared in accordance with and subject to an agreement between Woodman Environmental Consulting Pty Ltd (“Woodman Environmental”) and the client for whom it has been prepared (“Atlas Iron Ltd”) and is restricted to those issues that have been raised by the Client in its engagement of Woodman Environmental and prepared using the standard of skill and care ordinarily exercised by Environmental Scientists in the preparation of such Documents.

Any organisation or person that relies on or uses this document for purposes or reasons other than those agreed by Woodman Environmental and the Client without first obtaining the prior written consent of Woodman Environmental, does so entirely at their own risk and Woodman Environmental denies all liability in tort, contract or otherwise for any loss, damage or injury of any kind whatsoever (whether in negligence or otherwise) that may be suffered as a consequence of relying on this document for any purpose other than that agreed with the Client.
# TABLE OF CONTENTS

1 INTRODUCTION ........................................................................................................ 1

2 BACKGROUND ........................................................................................................ 1

   2.1 VEGETATION OF THE PROJECT AND POTENTIAL GROUNDWATER RELATIONSHIPS ........................................................................................................ 1

   2.2 IDENTIFICATION OF PERMANENT AND SEMI-PERMANENT SURFACE WATER FEATURES ........................................................................................................ 7

   2.3 MODELLING OF GROUNDWATER IN THE VICINITY OF THE PROJECT .......... 9

   2.4 PROPOSED GROUNDWATER ABSTRACTION .................................................... 9

3 IDENTIFICATION OF GROUNDWATER DEPENDENT VEGETATION ............. 12

   3.1 GROUNDWATER DEPENDENT VEGETATION TYPES ..................................... 12

   3.2 PERMANENT AND SEMI-PERMANENT SURFACE WATER FEATURES .......... 14

     3.2.1 CO-WS-01 ............................................................................................... 15

     3.2.2 CO-WS-02 ............................................................................................... 17

     3.2.3 CO-WS-03 ............................................................................................... 19

     3.2.4 CO-WS-05 ............................................................................................... 20

     3.2.5 CO-WS-08 ............................................................................................... 21

     3.2.6 CO-WS-09 ............................................................................................... 23

     3.2.7 CO-WS-10 ............................................................................................... 25

     3.2.8 CO-WS-11 ............................................................................................... 26

     3.2.9 CO-WS-12 ............................................................................................... 27

     3.2.10 CO-WS-13 .............................................................................................. 28

     3.2.11 CO-WS-14 .............................................................................................. 29

4 RISK ASSESSMENT – POTENTIAL IMPACTS TO GROUNDWATER DEPENDENT VEGETATION ........................................................................................................ 30

   4.1 GROUNDWATER DEPENDENT VEGETATION .................................................. 30

   4.2 PERMANENT AND SEMI-PERMANENT SURFACE WATER FEATURES .......... 38

5 CONCLUSIONS ........................................................................................................ 40

6 REFERENCES ............................................................................................................ 42
FIGURES

Figure 1: Potential Obligate and Facultative GDVs
Figure 2: Important Surface Water Features
Figure 3: Depth to Groundwater potentially used by GDV
Figure 4: Abstraction Locations and life of mine drawdown contours
Figure 5: Potentially Groundwater Dependent Vegetation
Figure 6.1: Potential GDVs at Low, Moderate and High Risk of Impact (Year 1)
Figure 6.2: Potential GDVs at Low, Moderate and High Risk of Impact (Year 2)
Figure 6.3: Potential GDVs at Low, Moderate and High Risk of Impact (Year 3)
Figure 6.4: Potential GDVs at Low, Moderate and High Risk of Impact (Year 4)
Figure 6.5: Potential GDVs at Low, Moderate and High Risk of Impact (Year 5)
Figure 6.6: Potential GDVs at Low, Moderate and High Risk of Impact (Year 6)
Figure 7: Areas of GDV which require Site Specific Assessment or Monitoring

TABLES

Table 1: Potential Groundwater Dependency of Vegetation Types in the Study Area
Table 2: Surface Water Features of the Study Area and their Relation to Groundwater (Stantec 2018b)
Table 3: Total Areas of Potential Facultative and Obligate Groundwater Dependent Vegetation
Table 4: Summary of Likelihood of Presence of Groundwater Dependent Vegetation at Significant Water Features
Table 5: Rapid risk assessment for drawdown association with groundwater dependent vegetation (located on DTGW < 10m)
Table 6a: Rapid Risk Assessment for each Vegetation Type
Table 6b: Rapid Risk Assessment for Groundwater Dependent Vegetation
Table 7: Risk of Impact to Permanent Pool (Stantec 2018b)

PLATES

Plate 1: CO-WS-01 (Photo: Stantec (September 2016))
Plate 2: CO-WS-02 (Photo: Woodman Environmental (May 2014))
Plate 3: CO-WS-02 (Photo: Woodman Environmental (May 2014))
Plate 4: CO-WS-03 (Photo: Atlas Iron (August 2016))
Plate 5: CO-WS-05 (Photo: Atlas (July 2017))
Plate 6: CO-WS-08 (Photo: Atlas Iron (August 2017))
Plate 7: CO-WS-08 (Photo: Atlas Iron (October 2017))
Plate 8: CO-WS-09 (Photo: Atlas Iron (July 2017))
Plate 9: CO-WS-10 (Photo: Atlas Iron (December 2017))
Plate 10: CO-WS-11 (Photo: Atlas Iron (July 2017))
Plate 11: CO-WS-12 (Photo: Woodman Environmental (May 2014))
Plate 12: CO-WS-13 (Photo: Woodman Environmental (April 2014))
Plate 13: CO-WS-14 (Photo: Stantec (March 2014))
1 INTRODUCTION

Atlas Iron Ltd (Atlas) is proposing to mine iron ore at its Corunna Downs Project (the Project), located approximately 30 km south south-west of Marble Bar. The Project will abstract groundwater from a number of bores in the local area for use in construction, potable water supply and dust suppression. As part of the Environmental Impact Assessment (EIA) process for the Project, consideration of potential impacts of groundwater drawdown to Groundwater Dependent Ecosystems (GDEs), including Groundwater Dependent Vegetation (GDV), is required.

Atlas commissioned Woodman Environmental Consulting Pty Ltd (Woodman Environmental) to assess the likelihood of GDV being present in the vicinity of the Project, the potential for groundwater abstraction to impact such vegetation and assess the risk of any such impacts occurring. This report includes an assessment of the potential groundwater-dependence of vegetation associated with specific surface water features (pools) identified in the vicinity of the Project that may be maintained by groundwater.

2 BACKGROUND

2.1 Vegetation of the Project and Potential Groundwater Relationships

Woodman Environmental conducted a detailed flora and vegetation survey of the Project Survey Area (Study Area) (Woodman Environmental 2016). This survey defined and mapped 15 vegetation types (VTs) in the Study Area. A preliminary assessment of the potential of these VTs, or parts of these VTs to be GDV identified that five VTs were at least occasionally characterised by taxa that are either known or presumed obligate or facultative phreatophytes, and therefore could represent GDV. These VTs and associated phreatophytic taxa known to occur in these VTs are described in Table 1 with the distribution of these VTs (as a whole) presented on Figure 1. In addition, several of these VTs contain emergent macrophyte taxa that were recorded in areas where surface water was present (Table 1); such taxa are generally ephemeral in nature, usually associated with permanent or semi-permanent pools that may be supported by shallow groundwater (Department of Water 2010). Table 1 presents an assessment of the GDV type (obligate or facultative) of each of these five VTs in relation to the known occurrence of such taxa.
Table 1: Potential Groundwater Dependency of Vegetation Types in the Study Area

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Description (includes characteristic taxa)</th>
<th>Phreatophyte Taxa Present</th>
<th>Emergent Macrophytes</th>
<th>GDV Type (Figure 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Low open woodland of mixed species dominated by species including <em>Corymbia ferritica</em>, <em>Ficus brachypoda</em>, <em>Terminalia canescens</em> over tall sparse shrubland usually dominated by <em>Acacia pruinocarpa</em> and <em>Acacia tumida</em> var. <em>piilabrensis</em> over low open mixed grassland dominated by <em>Triodia epactia, Cymbopogon ambiguus</em> and <em>Eriachne mucronata</em>, on red to brown sand to clay loam on ironstone or metamorphosed granite outcropping, in steep gorges, often with semi-permanent water</td>
<td><em>Melaleuca argentea</em> – obligate (known); <em>Eucalyptus camaldulensis</em> subsp. <em>refulgens</em> – obligate or facultative (known); <em>Atalaya hemiglaucia</em> – facultative (presumed); <em>Melaleuca glomerata</em> – facultative (presumed).</td>
<td><em>Schoenoplectus subulatus</em>; <em>Typha domingensis</em>.</td>
<td>Obligate</td>
</tr>
<tr>
<td>4</td>
<td>Low open woodland usually dominated by <em>Corymbia hamersleyana</em> over tall sparse shrubland dominated by mixed Acacia species including <em>A. trachycarpa</em> and <em>A. ancistrocarpa</em> with <em>Dichrostachys spicata</em> over low hummock grassland dominated by species including <em>Triodia wiseana</em> and <em>T. epactia</em> with <em>Eragrostis eriopoda</em> on brown sandy loams on plains and drainage lines</td>
<td><em>Atalaya hemiglaucia</em> – facultative (presumed); <em>Corymbia flavescens</em> – facultative (presumed); <em>Eucalyptus victrix</em> – facultative (presumed).</td>
<td></td>
<td>Facultative</td>
</tr>
<tr>
<td>8</td>
<td>Low isolated shrubs dominated by <em>Melaleuca glomerata</em> over mid hummock grassland dominated by <em>Triodia longiceps</em> over low mixed sedgeland, grassland and forbland of mixed species including <em>Schoenus falcatus</em>, <em>Trianthema cusackianum</em> and <em>Stemodia grossa</em> on white to brown clay to clayey sand with occasional calcrete and dolerite stones, at the head of drainage lines</td>
<td><em>Acacia ampliceps</em> – facultative (presumed); <em>Eucalyptus victrix</em> – facultative (presumed); <em>Melaleuca glomerata</em> – facultative (presumed).</td>
<td></td>
<td>Facultative</td>
</tr>
<tr>
<td>Vegetation Type</td>
<td>Description (includes characteristic taxa)</td>
<td>Phreatophyte Taxa Present</td>
<td>Emergent Macrophytes</td>
<td>GDV Type (Figure 1)</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>14</td>
<td>Mid open woodland of mixed species including <em>Eucalyptus victrix</em> and <em>Corymbia hamersleyana</em> over tall open to sparse shrubland of mixed species including <em>Acacia coriacea</em> subsp. <em>pendens</em>, <em>Acacia trachycarpa</em>, <em>Acacia pyriformia</em> var. <em>pyriformia</em>, <em>Acacia tumida</em> var. <em>pilbarenis</em> and <em>Melaleuca glomerata</em> over low sparse shrubland of mixed species including <em>Pluchea ferdinandi-muelleri</em>, <em>Cajanus pubescens</em> and <em>Stemodia grossa</em> over mid open grassland and sedgeland of mixed species dominated by <em>Cenchrus ciliaris</em>, <em>Triodia longiceps</em>, <em>Triodia epactia</em>, <em>Chrysopogon fallax</em> and <em>Cyperus vaginatus</em> on red to brown sand to sandy loam with riverstones in minor to medium drainage lines</td>
<td><em>Eucalyptus camaldulensis</em> subsp. <em>refulgens</em> – obligate or facultative (known); <em>Acacia ampliceps</em> – facultative (presumed); <em>Atalaya hemiglauca</em> – facultative (presumed); <em>Eucalyptus victrix</em> – facultative (presumed); <em>Melaleuca glomerata</em> – facultative (presumed); <em>Melaleuca linophylla</em> – facultative (presumed).</td>
<td><em>Schoenoplectus subulatus</em>; <em>Typha domingensis</em>.</td>
<td>Facultative</td>
</tr>
<tr>
<td>15</td>
<td>Mid open forest to woodland dominated by <em>Eucalyptus camaldulensis</em> subsp. <em>refulgens</em> and occasionally <em>Eucalyptus victrix</em> over tall open shrubland dominated by species including <em>Acacia ampliceps</em>, <em>Melaleuca glomerata</em> and <em>Acacia pyriformia</em> var. <em>pyriformia</em> over mid open grassland and sedgeland dominated by <em>Cenchrus ciliaris</em>, <em>Cyperus vaginatus</em> and <em>Triodia longiceps</em> on red to brown sandy to clay loam with riverstone in major drainage lines</td>
<td><em>Melaleuca argentea</em> – obligate (known); <em>Eucalyptus camaldulensis</em> subsp. <em>refulgens</em> – obligate or facultative (known); <em>Sesbania formosa</em> – obligate (presumed); <em>Acacia ampliceps</em> – facultative (presumed); <em>Atalaya hemiglauca</em> – facultative (presumed); <em>Eucalyptus victrix</em> – facultative (presumed); <em>Melaleuca glomerata</em> – facultative (presumed); <em>Melaleuca linophylla</em> – facultative (presumed).</td>
<td><em>Potamogeton tricarinatus</em>; <em>Schoenoplectus subulatus</em>; <em>Typha domingensis</em>.</td>
<td>Obligate</td>
</tr>
</tbody>
</table>
Distribution of Potential Groundwater Dependent Vegetation Types

Legend
- Study Area (WEC 2016)
- Project Indicative Mine Disturbance Footprint
- Development Envelope

Groundwater Dependent Vegetation
- Facultative Phreatophytic
- Obligate Phreatophytic

Projection: GDA 1994 MGA Zone 50
Revision: 0 - 18 May 2018
Scale: 1:75,000 (A3)
Filename: Atlas18-09-01-f01

This map should only be used in conjunction with WEC report Atlas18-09-01.

Figure 1

Author: Cathy Godden
WEC Ref: Atlas18-09-01
Filename: Atlas18-09-01-f01
The phreatophytes recorded in the Study Area are predominantly facultative (either known based on the literature or presumed based on gross morphology and habitat preference). However, *Melaleuca argentea* is known to be an obligate phreatophyte (Graham 2001; cited in Department of Water 2010), and *Eucalyptus camaldulensis* can be obligate or facultative depending on the specific hydrological characteristics of a site (Department of Water 2010). *Sesbania formosa* is also considered likely to be an obligate phreatophyte, as it is restricted to alluvial soils in rivers or major creeks, potentially indicating high groundwater use (Department of Water 2010). *Melaleuca glomerata*, *Atalaya hemiglauca*, *Acacia ampliceps*, *Sesbania formosa* and *Melaleuca linophylla* appear to generally be considered at least partially facultatively phreatophytic, primarily based on their presence in major river channels where groundwater is known to be close to the surface (Loomes 2010a, 2010b; Loomes and Braimbridge 2010). However, this appears to not have been substantiated by any specific investigation; only Loomes (2010a) has investigated depth to water ranges for some of these species, however this investigation considered a limited number of sample sites, all of which were in significant drainage channels.

*Eucalyptus victrix* is another species that has been suggested to be a facultative phreatophyte in some situations (AQ2, 2015; Eastham, 2015; Loomes and Braimbridge 2010; Loomes 2010a), however it is generally considered to be a vadophyte (AQ2, 2015). This is supported by Woodman Environmental’s multi-year monitoring of vegetation considered at risk of impact from dewatering at Atlas’s Pardoo minesite, east of Port Hedland. In an area east of the Bobby deposit, where the pre-dewatering depth to water was known to be between 5 and 10 m (Woodman Environmental, 2012), and large stands of *E. victrix* are present on an alluvial floodplain, drawdown of nearly 10 m from pre-dewatering levels was observed at a bore adjacent to a monitoring site in a *E. victrix* stand over a 3-year period (Woodman Environmental, 2013). No impacts to the health of *E. victrix* that could be related to drawdown were observed over this drawdown period (Woodman Environmental, 2011, 2012b, 2012c, 2013, 2014). Decline in health of a number of *E. victrix* trees was observed, however it occurred at both control and impact sites, and was determined to likely be a fungal pathogen based on collected material (Woodman Environmental 2014), and was unlikely to be related to drawdown.

Both *M. argentea* and *E. camaldulensis* subsp. *refulgens*, which occur in wetter sites relative to *E. victrix* (river beds and major creeks – presumably where the water table is closer to the surface) in the same area at Pardoo described above, appeared to be affected by drawdown of almost identical magnitude to that described above (Woodman Environmental 2013). Numerous individuals either declined observably in health or were killed in this area; such individuals were more numerous for *M. argentea* than for *E. camaldulensis* subsp. *refulgens*. As similar trends were not observed at control sites, it appears likely that drawdown was the causal agent. This reflects the knowledge on the water use strategies of these taxa, and their response to drawdown. Both are known to be obligately phreatophytic; in the case of *M. argentea* this is seemingly true for all situations that it occurs in, however for *E. camaldulensis* subsp. *refulgens*, it appears to be the case only at sites when groundwater is near the surface. Both species are also known to be sensitive to drawdown, particularly if it is of a relatively large magnitude over a short period of time, such as occurred at Pardoo.
It should be noted that *Cyperus vaginatus* has been classed as an emergent macrophyte by other studies (e.g. Loomes 2010a), however is not classed as such by this assessment. Woodman Environmental (2016) recorded this species widely (49 locations) in the Project Study Area and although this species is always restricted to drainage features, in the majority of cases it does not occur in pools but rather in areas that would have surface water only in times of high flow volumes. The presence of this taxon therefore does not indicate groundwater dependence of the vegetation; only that water is present at the surface for some period of the year.

VT 3 contains sites that host the obligate phreatophyte *Melaleuca argentea* and potentially obligate *Eucalyptus camaldulensis*, the presumed facultative phreatophytes *Atalaya hemiglauca* and *Melaleuca glomerata* as well as the emergent macrophytes *Typha domingensis* and *Schoenoplectus subulatus*. However, occurrences of these species are restricted to isolated expressions of surface water within this VT (see Section 2.2), and the characteristic taxa of this VT are not known or presumed phreatophytes. Therefore, the full extent of vegetation in VT 3 may not be GDV, with obligate GDV areas within VT 3 being isolated occurrences depending upon the local hydrology. Similarly, most characteristic taxa in VTs 4 and 8 are not known or presumed phreatophytes, however some occurrences contain presumed facultative phreatophytes and such occurrences may represent facultative GDV.

VT 14 is characterised by a number of presumed facultative phreatophytes, with the potentially obligate/facultative phreatophyte *Eucalyptus camaldulensis* occurring occasionally (6 confirmed locations from 46 sample quadrats in this VT), and therefore it is possible that much of this VT is GDV. It is considered most likely that occurrences of this VT are facultative GDV based on the low frequency of *Eucalyptus camaldulensis*, the only potentially obligate phreatophyte recorded in this VT.

All occurrences of VT 15 (located in the Coongan River channel and other major creek systems) are considered likely to represent GDV. Ruprecht and Ivanescu (2000) noted that ‘along all creeks and rivers in the Pilbara, where riverine vegetation has established (typically Eucalyptus or Melaleuca), it is likely that these are supported by groundwater in the river alluvium’. At least some occurrences of this VT are likely obligate GDV, including those areas where *Melaleuca argentea* (known obligate species) and *Sesbania formosa* (presumed obligate species) are present (for example, those located at five and two occurrences respectively from 16 sample sites of this VT). The remainder of the extent of this VT is potentially obligate GDV, including where the potentially obligate phreatophyte *Eucalyptus camaldulensis* is present.

The vegetation type analysis and mapping (Woodman Environmental 2016) was undertaken using floristic analysis to determine similarities of floral composition between sampling sites; the groundwater dependency of the resulting groupings (VTs) is not consistent throughout any of the particular VTs, except VT 15 as described above. However, as each of the VTs above do contain at least some areas which are potentially obligate or facultative GDV, as a worst-case scenario these have been grouped together as presented on Figure 1.
2.2 Identification of Permanent and Semi-Permanent Surface Water Features

Using the results of baseline flora, vegetation and fauna surveys conducted as part of the EIA process for the Project, Atlas have formally identified 11 permanent and semi-permanent surface water sources (e.g. pools, flowing water or seepage areas) in the vicinity of the Project (Figure 2); such features are considered of high importance in arid ecosystems such as the Pilbara for many organisms (e.g. Burbidge et al. 2010). Such features may be maintained by groundwater if a groundwater aquifer is in close proximity to the surface or pressure forces groundwater to the surface or may be maintained by other means such as surface flows, or seepage or discharge of infiltrating water through hydraulic fractures.

Atlas and its consultant Stantec (2018b) have undertaken a series of investigations to determine the permanency of these features and their groundwater connectivity, as summarised in Table 2.

Two other important hydrological features have been identified in the vicinity by previous surveys:

- A freshwater wetland system was identified by Golder Associates Pty Ltd (2010). This feature corresponds to identified important surface water features CO-WS-05 and CO-WS-13, and is therefore discussed in the context of these individual features; and
- A feature referred to as a “freshwater soak” has been investigated separately in the context of potential impacts of groundwater abstraction (Woodman Environmental 2018), and has been determined to not represent groundwater dependent vegetation. This site is characterized as VT 8 and discussed in later sections.

**Table 2: Surface Water Features of the Study Area and their Relation to Groundwater (Stantec 2018b)**

<table>
<thead>
<tr>
<th>Surface Water Feature</th>
<th>Pool Permanency (Stantec 2018b)</th>
<th>Pool Groundwater Dependence (Stantec 2018b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO-WS-01</td>
<td>Perennial</td>
<td>Likely</td>
</tr>
<tr>
<td>CO-WS-02</td>
<td>Ephemeral</td>
<td>Unlikely</td>
</tr>
<tr>
<td>CO-WS-03</td>
<td>Ephemeral</td>
<td>Unlikely</td>
</tr>
<tr>
<td>CO-WS-05</td>
<td>Perennial</td>
<td>Likely</td>
</tr>
<tr>
<td>CO-WS-08</td>
<td>Ephemeral</td>
<td>Unlikely</td>
</tr>
<tr>
<td>CO-WS-09</td>
<td>Ephemeral</td>
<td>Unlikely</td>
</tr>
<tr>
<td>CO-WS-10</td>
<td>Perennial</td>
<td>Unlikely</td>
</tr>
<tr>
<td>CO-WS-11</td>
<td>Perennial</td>
<td>Unlikely</td>
</tr>
<tr>
<td>CO-WS-12</td>
<td>Perennial</td>
<td>Likely</td>
</tr>
<tr>
<td>CO-WS-13</td>
<td>Ephemeral</td>
<td>Unlikely</td>
</tr>
<tr>
<td>CO-WS-14</td>
<td>Perennial</td>
<td>Likely</td>
</tr>
</tbody>
</table>
2.3 Modelling of Groundwater in the Vicinity of the Project

Modelling of the depth to groundwater in the vicinity of the Project has been conducted (model created by Stantec 2018b) and has been utilised to identify areas where vegetation is potentially using groundwater, and whether groundwater is feeding the important surface water features identified. In the context of GDV, previous studies in Western Australia have indicated that plant roots are unlikely to access moisture beyond a depth of 10 m, or the proportion of water requirements derived from groundwater beyond this depth is relatively low (Department of Water 2009). Additionally, a study by Loomes (2010) on water level ranges of Pilbara riparian species (which assessed the majority of taxa identified as phreatophytic in Table 1 at a limited number of riverine sites in the Pilbara) found that none of the species occurred in areas where the groundwater was at a depth greater than 10 m.

Therefore, for the purposes of this assessment, only areas where the depth to groundwater is 10 m or less are considered relevant. This is also the depth that the Department of Water and Environmental Regulation (DWER) considers relevant in the context of GDV. Depth to groundwater in the vicinity of the Project, in the form of 1 m contour intervals, is presented on Figure 3.

2.4 Proposed Groundwater Abstraction

Atlas is proposing to abstract groundwater from seven locations in the vicinity of the Project. Modelling of drawdown to the groundwater table in the vicinity of the Project has been conducted (Stantec 2018b), with drawdown contours produced at 0.25 m intervals. As the timing and rates of abstraction will vary across the seven locations, drawdown contours have been produced for each year of mining, and cumulatively until end of mining (estimated at six years). The drawdown modelling included a number of key assumptions:

- a pumping rate of approximately 2.6 ML per day;
- the groundwater aquifer is unconfined and of infinite homogenous extent;
- modelled recharge to the aquifer occurs at a constant rate over the life of mine at $9.89 \times 10^{-5}$ m/day within the Cleaverville formation and $4.93 \times 10^{-5}$ m/day over the remainder of the model domain; and
- aquifer thickness varies from 2 to 220 metres.

The abstraction locations and life of mine drawdown contours are presented on Figure 4.
Abstraction locations and life of mine drawdown contours

Legend
- Water Abstraction Location
- Study Area (WEC 2016)
- Project Indicative Mine Disturbance Footprint
- Development Envelope
- Less than 0.1m Drawdown

Groundwater level drawdown (m)
- 0.10 - 0.50
- 0.50 - 1.50
- 1.50 - 2.50
- 2.50 - 3.50
- 3.50 - 4.50
- 4.50 - 5.25
- 5.25 - 6.50

Projection: GDA 1994 MGA Zone 50

This map should only be used in conjunction with WEC report Atlas18-09-01.
3 IDENTIFICATION OF GROUNDWATER DEPENDENT VEGETATION

3.1 Groundwater Dependent Vegetation Types

As outlined in Section 2.1, occurrences of five VTs are considered to potentially represent GDV, either wholly or in part. However, it is considered that these occurrences can only be GDV if groundwater is located within 10 m of the ground surface, as per groundwater modelling detailed in Section 2.3. VT mapping polygons were intersected with modelled groundwater depth contours in a GIS environment to identify areas of potential GDV.

Vegetation therefore considered to be potential GDV (combination of appropriate VT and depth to groundwater) is shown on Figure 5. Additionally, VTs are designated as either obligate or facultative GDV on Figure 5 based on species composition as detailed in Section 2.1. This designation is considered conservative due to the uneven distribution of phreatophytic species within each mapped VT as noted in Section 2.1:

- The majority of vegetation mapped as VT 3 is not likely GDV; however, this assessment assumes that all occurrences of this VT are obligate GDV because of the occasional occurrence of obligate phreatophytes in VT 3;
- The majority of occurrences of VT 4 and some occurrences of VT 8 are also not likely GDV, however, all occurrences of these VTs are considered to be facultative GDV because of the occasional occurrence of facultative phreatophytes;
- VT 14 is considered to be facultative GDV; and
- VT 15 is considered to be obligate GDV.

The total area of potential facultative and obligate GDV that occurs in areas where the groundwater has been modelled to be <10m from the surface is presented in Table 3.

Table 3: Total areas of Potential Facultative and Obligate Groundwater Dependent Vegetation

<table>
<thead>
<tr>
<th>GDV Area</th>
<th>Obligate (ha)</th>
<th>Facultative (ha)</th>
<th>Total (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Area of GDV</td>
<td>491.4</td>
<td>1731.2</td>
<td>2222.5</td>
</tr>
<tr>
<td>Area of GDV where groundwater is &lt;10m</td>
<td>473.48</td>
<td>833.42</td>
<td>1306.9</td>
</tr>
</tbody>
</table>

The above assessment is extremely conservative in light of the existing literature regarding the interactions between native plant taxa and changes in groundwater. The evidence presented in Section 2.1, and in particular the documented impacts of severe groundwater drawdown at Atlas’ Pardoo operations clearly indicates that potentially facultative vegetation types in the Pilbara are unlikely to suffer impacts as a result of groundwater drawdown. Impacts of groundwater drawdown observed in obligate phreatophytic vegetation is generally restricted (at least in early years where the period of drawdown is not prolonged) to the sensitive taxa *M. argentea* and *E. camaldulensis* subsp. *refulgens*. As a result this assessment considers only those vegetation types regarded as obligate phreatophytes to be at risk of groundwater drawdown impacts.
Potentially Groundwater Dependent Vegetation

Legend
- Hydrological Feature
- Baseline groundwater level within 10m of ground surface
- Project Indicative Mine Disturbance Footprint
- Development Envelope
- Study Area (WEC 2016)
- Groundwater Dependant Vegetation
  - Facultative Phreatophytic
  - Obligate Phreatophytic

Scale: 1:75,000 (A3)

This map should only be used in conjunction with WEC report Atlas18-09-01.
3.2 Permanent and Semi-Permanent Surface Water Features

All but one of the permanent or semi-permanent surface water features outlined in Section 2.2 fall outside the modelled 10 m groundwater depth contour (Figure 5). Within this model, the permanent surface water feature CO-WS-14 is located between the 9 and 10 m depth contours, however, as discussed further below, given the location of this feature in a rocky gorge, it is not expected that vegetation could access groundwater (the modelled aquifer) at this depth, and the location of this feature within the 10 m groundwater depth contour may be related to the scale at which the contours have been defined within the model. However, there is the possibility that these features may be fed by groundwater, either by perched aquifers not considered in the model, or via localised upwelling of groundwater (Stantec 2018b).

Site specific investigations by Stantec (2018b) have indicated that the groundwater level at several of the pool areas is actually situated within 10m of the surface (see Table 2). Therefore, further assessment below uses the Stantec (2018b) assessment with regards to the pool areas.

An assessment of the likelihood of these features to represent GDV based on specific site vegetation characteristics is provided below and summarised in Table 4.

Table 4: Summary of Likelihood of Presence of Groundwater Dependent Vegetation at Significant Water Features

<table>
<thead>
<tr>
<th>Surface Water Feature</th>
<th>Phreatophyte / species present</th>
<th>Macrophyte</th>
<th>Other Observations</th>
<th>Likelihood of GDV present</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO-WS-01 (perennial and likely GW dependency)</td>
<td>Presumed Facultative Phreatophyte Atalaya hemiglauca</td>
<td>Typha domingensis, Schoenoplectus subulatus</td>
<td>VT 14 Vegetation generally typical of this VT</td>
<td>Unlikely</td>
</tr>
<tr>
<td>CO-WS-02 (ephemeral and unlikely GW dependency)</td>
<td>Presumed Facultative Phreatophyte Atalaya hemiglauca</td>
<td></td>
<td>VT 3 Vegetation typical of this VT</td>
<td>Unlikely</td>
</tr>
<tr>
<td>CO-WS-03 (ephemeral and unlikely GW dependency)</td>
<td>Nil</td>
<td></td>
<td>VT 14 Vegetation typical of this VT</td>
<td>Unlikely</td>
</tr>
<tr>
<td>CO-WS-05 (perennial and likely GW dependency)</td>
<td>Obligate Phreatophyte Eucalyptus camaldulensis subsp. refulgens (potentially ob.) Presumed Facultative Phreatophyte Eucalyptus camaldulensis subsp. refulgens, Eucalyptus victrix, Melaleuca glomerata, Melaleuca linophylla Macrophyte Schoenoplectus subulatus</td>
<td></td>
<td>VT 14 Vegetation not typical of this VT</td>
<td>Potentially GDV</td>
</tr>
<tr>
<td>Surface Water Feature</td>
<td>Phreatophyte / species present</td>
<td>Macrophyte</td>
<td>Other Observations</td>
<td>Likelihood of GDV present</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------------------</td>
<td>------------</td>
<td>-------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>CO-WS-08</td>
<td>Presumed Facultative Phreatophyte Eucalyptus victrix, Melaleuca linophylla</td>
<td>Typha domingensis</td>
<td>VT 3 Vegetation not typical of this VT</td>
<td>Potentially GDV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO-WS-09</td>
<td>Presumed Facultative Phreatophyte Melaleuca glomerata</td>
<td></td>
<td>VT 3 Vegetation typical of this VT</td>
<td>Unlikely (due to site conditions)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO-WS-10</td>
<td>Presumed Facultative Phreatophyte Eucalyptus victrix</td>
<td></td>
<td>VT 14 Vegetation typical of this VT</td>
<td>Unlikely (due to site conditions)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO-WS-11</td>
<td>Nil</td>
<td></td>
<td>VT 3</td>
<td>Unlikely (due to lack of phreatophytic species and site conditions)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO-WS-12</td>
<td>Obligate Phreatophyte Melaleuca argentea, Eucalyptus camaldulensis subsp. refulgens</td>
<td>Schoenoplectus subulatus</td>
<td>VT 3 Vegetation not typical for this VT</td>
<td>GDV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO-WS-13</td>
<td>Obligate Phreatophyte Eucalyptus camaldulensis subsp. refulgens (pot.); Presumed Facultative Phreatophyte Eucalyptus camaldulensis subsp. refulgens; Eucalyptus victrix, Melaleuca glomerata, Melaleuca linophylla, Acacia ampliceps</td>
<td>Schoenoplectus subulatus</td>
<td>VT 14 Vegetation typical for this VT</td>
<td>Potentially GDV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO-WS-14</td>
<td>Obligate Phreatophyte Eucalyptus camaldulensis subsp. refulgens; Melaleuca argentea</td>
<td>Typha domingensis</td>
<td>VT 3 Vegetation not typical for this VT</td>
<td>GDV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.2.1 CO-WS-01

CO-WS-01 was visited by Woodman Environmental in May 2016 as part of baseline flora and vegetation survey for the Project (Woodman Environmental 2016), with observations also made by Atlas and Stantec during visits in September 2016, and August, October and December 2017 and March 2018. CO-WS-01 is located at the base of the large ridge upon which mining is proposed, in a rocky drainage line. Water apparently flows permanently (observed during all visits) from the ground and feeds the rocky pool where the drainage...
line has cut through a large rock ridge. Water continues to flow out of the pool, however becomes shallow and eventually dissipates.

The vegetation, which has been mapped as an occurrence of VT 14, is generally typical of other occurrences of this VT located in other rocky drainage lines associated with the aforementioned ridge; the upper strata is a low open woodland of *Terminalia canescens* over a tall shrubland dominated by *Acacia colei var. colei* and *Atalaya hemiglauca*. However, the lower stratum reflects the presence of permanent surface water, with *Cyperus vaginatus* present where the water is of shallow depth, and *Typha domingensis* and *Schoenoplectus subulatus* occurring in deeper water.

The composition of the vegetation at CO-WS-01 indicates that it is likely not GDV. Of the phreatophytic species known to occur in the Study Area, only *Atalaya hemiglauca*, a presumed facultative phreatophyte, occurs at CO-WS-01. However, this taxon was recorded widely in the Study Area, including in habitats where there is no surface water, the site is not water-gaining and groundwater is modelled at more than 10 m below the surface (e.g. cliff tops, stony hill tops); it is considered unlikely to be phreatophytic at CO-WS-01.

The presence of the emergent macrophytes *Typha domingensis* and *Schoenoplectus subulatus* are likely a function of the presence of an impermeable rock base in the drainage line associated with the rock ridge that the drainage line has cut, which has resulted in the retention of the flowing water in the pool. Some of this water may originate from seepage from the surrounding landscape as groundwater (Stantec 2018b) however the substrate is too shallow to support recognised phreatophytic species.

**Plate 1:** CO-WS-01 (Photo: Stantec (September 2016))
3.2.2 CO-WS-02

CO-WS-02 was visited by Woodman Environmental in May 2014, as part of baseline flora, vegetation and fauna surveys for the Project (Woodman Environmental 2016), and by Stantec in October 2016. CO-WS-02 is located in a rocky gorge on the eastern edge of the large ridge upon which mining is proposed. A large, relatively deep, confined plunge pool is present; it was originally classed as semi-permanent, with water observed during all visits; however Stantec (2018b) determined that the pool is unlikely to be groundwater dependent and ephemeral (Stantec 2018b). A small amount of seepage was also observed below the pool along a steep section of the gorge base, however this is considered ephemeral as it was in the process of drying in May 2014 (Woodman Environmental field observations).

The vegetation, which has been mapped as an occurrence of VT 3, is generally typical of other occurrences of this VT located in other gorges along the ridge. The upper strata include a low open woodland of *Corymbia ferricola* and *Ficus brachypoda* over a tall sparse shrubland of *Acacia pruinocarpa* and *Acacia tumida* var. *pilbarensis*. The lower stratum is also typical of other occurrences, comprising a low open mixed grassland dominated by *Triodia epactia*, *Cymbopogon ambiguus* and *Eriachne mucronata*. No emergent macrophytes were noted in the pools or as being associated with the seepage observed, however an aquatic plant, possibly a Charophyte (green algae), was observed under the water surface in the pools (Woodman Environmental field observations).

The composition of the vegetation at CO-WS-02 indicates that it is likely not GDV. Of the phreatophytic species known to occur in the Study Area, only *Atalaya hemiglauca*, a presumed facultative phreatophyte, occurs at CO-WS-02. However, as previously mentioned this taxon was recorded widely in the Study Area in a variety of habitats, some of which are clearly not influenced by groundwater; it is considered unlikely to be phreatophytic at CO-WS-02.
Plate 2: CO-WS-02 (Photo: Woodman Environmental (May 2014))

Plate 3: CO-WS-02 (Photo: Woodman Environmental (May 2014))
3.2.3  CO-WS-03

CO-WS-03 was visited by Woodman Environmental in May 2014 as part of baseline flora and vegetation surveys for the Project (Woodman Environmental 2016), with observations made by Atlas and Stantec, during visits in September 2016, and August and October 2017. A relatively shallow, confined plunge pool has been observed; has been classed as ephemeral (Stantec 2018b), with water not observed during the October 2017 visit.

The vegetation, which was mapped as an occurrence of VT 14, is not typical of other occurrences of this VT as CO-WS-03 occurs where a drainage line has carved through a rocky ridge; the upper stratum is isolated trees of *Terminalia canescens* and *Ficus brachypoda*, with the lower stratum being a low open mixed grassland dominated by *Triodia epactia* and *Eriachne mucronata*. No emergent macrophytes were observed in the pool.

The composition of the vegetation at CO-WS-03 indicates that it is likely not GDV. None of the phreatophytic species known to occur in the Study Area occur in the immediate vicinity of CO-WS-03. The presence of the pool is likely a function of the presence of an impermeable rock base in the drainage line associated with the rock ridge that the drainage line has cut, which has resulted in the retention of run-off.

Plate 4:  CO-WS-03 (Photo: Atlas Iron (August 2016))
3.2.4 CO-WS-05

CO-WS-05 was visited by Golder Associates Pty Ltd (2010) in July/August 2008, and by Woodman Environmental in April 2014 as part of baseline flora and vegetation surveys for the Project (Woodman Environmental 2016); observations have also been made by Atlas and Stantec, during visits in September 2016, and July, October, November and December 2017 and March 2018. CO-WS-05 is located in a rocky drainage line west of the large ridge upon which mining is proposed, with the drainage line commencing on the western edge of the ridge. A large shallow pool has been observed; it was initially classed as semi-permanent (as the pool was almost dry in December 2017 and would likely dry up completely in some years), however it was classed as perennial by Stantec (2018b) as supported by radon and isotope data which suggested possible groundwater signature and the persistence of this pool between October 2018 and March 2018.

The vegetation, which has been mapped as an occurrence of VT 14, is generally typical of other occurrences of this VT located in other drainage lines near the ridge; the upper strata including a low open woodland of *Eucalyptus camaldulensis* and *Eucalyptus victrix* over a tall open shrubland of *Melaleuca glomerata*, *Melaleuca linophylla* and *Acacia coriacea* subsp. *pendens*. The lower stratum is somewhat atypical, being dominated by *Cyperus vaginatus* with *Schoenoplectus subulatus* observed in the pool itself.

The composition of the vegetation at CO-WS-05 indicates that it is potentially GDV. *Eucalyptus camaldulensis* subsp. *refulgens*, *Eucalyptus victrix*, *Melaleuca glomerata* and *Melaleuca linophylla* are all known or presumed facultative phreatophytic species, with *Eucalyptus camaldulensis* subsp. *refulgens* potentially obligate. Additionally, *Schoenoplectus subulatus* is an emergent macrophyte.
3.2.5 CO-WS-08

CO-WS-08 has not been visited by Woodman Environmental; observations have been made by Atlas and Stantec, during visits in March 2014, and July, August, October, November and December 2017 and March 2018. CO-WS-08 is located in a rocky gorge and drainage line west of the large ridge upon which mining is proposed, with the drainage line commencing on the western edge of the ridge. This relatively deep pool has been classified as ephemeral by Stantec (2018b) as it was dry in November and December 2017.

The vegetation has been mapped as an occurrence of VT 3; *Melaleuca linophylla* occurs around the edges of the pool in the base of the gorge as scattered individuals. The lower stratum is dominated by *Cyperus vaginatus*, with *Typha domingensis* prominent in the pool.

Plate 5: CO-WS-05 (Photo: Atlas (July 2017))
The composition of the vegetation at CO-WS-08 indicates that it is potentially GDV. *Melaleuca linophylla* is a presumed facultative phreatophytic species, with *Typha domingensis* being an emergent macrophyte.

Plate 6: CO-WS-08 (Photo: Atlas Iron (August 2017))

Plate 7: CO-WS-08 (Photo: Atlas Iron (October 2017))
3.2.6 CO-WS-09

CO-WS-09 has been visited by Woodman Environmental in May 2014 as part of baseline flora and vegetation surveys for the Project (Woodman Environmental 2016); observations have also been made by Atlas and Stantec, during visits in July and October 2017. CO-WS-09 is located in a rocky gorge on the eastern edge of the large ridge upon which mining is proposed. This small, shallow pool was classed as semi-permanent, and as ephemeral by Stantec (2018b); no water was observed in October 2017.

The vegetation, which has been mapped as an occurrence of VT 9 immediately adjacent to VT 3, is more typical of VT 3 and typical of other occurrences of this VT located in other gorges along the ridge for all strata, however a number of individuals of *Melaleuca glomerata* have been recorded around the pool.

The overall composition of the vegetation at CO-WS-09 indicates that it is unlikely to be GDV. Although the presumed facultative phreatophyte *Melaleuca glomerata* is present, the fact that the semi-permanent (ephemeral) pools are located in a rocky gorge and are likely a function of the presence of an impermeable rock base in the drainage line which allows temporary retention of run-off (as well as potentially seasonal groundwater), indicates that it is not likely to be phreatophytic at this location.
Plate 8: CO-WS-09 (Photo: Atlas Iron (July 2017))
3.2.7 CO-WS-10

CO-WS-10 has been visited by Woodman Environmental in May 2014 as part of baseline flora and vegetation surveys for the Project (Woodman Environmental 2016); observations have been made by Atlas and Stantec, during visits in September, October, November and December 2017 and March 2018. CO-WS-10 is located in a rocky gorge on the eastern edge of the large ridge upon which mining is proposed. A large, relatively deep, confined plunge pool is present; it has been classed as perennial by Stantec (2018b), with water observed during all visits, however the water level in the pool was very low in December 2017.

The vegetation at this location which has been mapped as an occurrence of VT 14 is more typical of VT 3 located in other gorges along the ridge for all strata, however a single tree of *Eucalyptus victrix* occurs on the edge of the pool which probably led to its classification as VT 14. The overall composition of the vegetation at CO-WS-10 indicates that it is unlikely to be GDV. Although the known facultative phreatophyte *Eucalyptus victrix* is present, the fact that the pool is located in a rocky gorge and is likely a function of the presence of an impermeable rock base in the drainage line which allows retention of run-off, indicates that it is not likely to be phreatophytic at this location.

Plate 9: CO-WS-10 (Photo: Atlas Iron (December 2017))
3.2.8 CO-WS-11

CO-WS-11 has not been visited by Woodman Environmental; observations have been made by Atlas and Stantec, during visits in July, October and December 2017 and March 2018. CO-WS-11 is located in a rocky gorge on the eastern edge of the large ridge upon which mining is proposed. A medium sized, moderately deep, confined plunge pool is present; it has been classed as perennial, with water observed during all visits, however the water level in the pool was very low in December 2017 and unlikely to be groundwater dependent (all hydrochemistry data indicating clear rainwater signature) (Stantec 2018b).

The vegetation, which has been mapped as an occurrence of VT 3, is generally typical of other occurrences of this VT located in other gorges along the ridge for all strata (based on observations from numerous photos taken at the pools).

The composition of the vegetation at CO-WS-11 indicates that it is likely not GDV. Of the phreatophytic species known to occur in the Study Area, none are known to occur in the vicinity of the pool. The presence of the pool is likely a function of the presence of an impermeable rock base in the drainage line associated with the rock ridge that the drainage line has cut, which has resulted in the retention of run-off in the pool.

Plate 10: CO-WS-11 (Photo: Atlas Iron (July 2017))
3.2.9 CO-WS-12

CO-WS-12 was visited by Woodman Environmental in May 2016 as part of baseline flora and vegetation survey for the Project (Woodman Environmental 2016), with observations also made by Atlas and Stantec, during visits in October, November and December 2017 and March 2018. CO-WS-12 is located in a rocky gorge on the eastern edge of the large ridge upon which mining is proposed. Water apparently seeps permanently (water observed during all visits) from a point in the central part of the gorge, extending on the surface for some distance to near the eastern end of the gorge. The seepage forms a small, shallow pool classified by Stantec (2018b) as being likely to be groundwater dependent.

The vegetation, which has been mapped as an occurrence of VT 3, is not typical of other occurrences of this VT located in other gorges along the ridge. The upper strata comprise of a low woodland of *Melaleuca argentea* and *Eucalyptus camaldulensis* subsp. *refulgens* over a tall sparse shrubland of *Acacia tumida* var. *pilbarenensis* and *Acacia colei* var. *colei*. The lower stratum is somewhat typical, being a low open mixed grassland dominated by *Triodia epactia*, *Cymbopogon ambiguus* and *Eriachne mucronata*, however a large number of ephemeral herbs were present, as well as the emergent macrophyte *Schoenoplectus subulatus*.

The composition of the vegetation at CO-WS-12 indicates that it is GDV with groundwater remaining within 2-3 m of the ground surface for most of the year as a perched water table. *Melaleuca argentea* and *Eucalyptus camaldulensis* subsp. *refulgens* are both obligate phreatophytes (although *Eucalyptus camaldulensis* subsp. *refulgens* may be facultative at some sites), with *Schoenoplectus subulatus* being an emergent macrophyte.

**Plate 11: CO-WS-12** (Photo: Woodman Environmental (May 2014))
3.2.10 CO-WS-13

CO-WS-13 was visited by Golder Associates Pty Ltd (2010) in July/August 2008, and by Woodman Environmental in April 2014 as part of baseline flora and vegetation surveys for the Project (Woodman Environmental 2016); observations have also been made by Atlas and Stantec, during visits in July, August, October, November and December 2017 and March 2018. CO-WS-13 is located in a rocky drainage line west of the large ridge upon which mining is proposed, with the drainage line commencing on the western edge of the ridge. This pool was classed as ephemeral by Stantec (2018b) (pools were dry in November and December 2017, and would likely dry up completely in some years).

The vegetation, which has been mapped as an occurrence of VT 14, is generally typical of other occurrences of this VT located in other drainage lines near the ridge; the upper strata are a low open woodland of *Eucalyptus camaldulensis* and *Eucalyptus victrix* over a tall open shrubland of *Melaleuca glomerata*, *Melaleuca linophylla* and *Acacia ampliceps*. The lower stratum is somewhat atypical, being dominated by *Cyperus vaginatus*. *Typha domingensis* and *Schoenoplectus subulatus* were observed in the pool itself.

The composition of the vegetation at CO-WS-13 indicates that it is potentially GDV. *Eucalyptus camaldulensis* subsp. *refulgens*, *Eucalyptus victrix*, *Melaleuca glomerata*, *Melaleuca linophylla* and *Acacia ampliceps* are all known or presumed facultative phreatophytic species, with *Eucalyptus camaldulensis* subsp. *refulgens* potentially obligate. Additionally, *Typha domingensis* and *Schoenoplectus subulatus* are emergent macrophytes. Stantec (2018b) noted that there may be seasonal input of groundwater into this area, and it may occur as a perched system.

Plate 12: CO-WS-13 (Photo: Woodman Environmental (April 2014))
3.2.11 CO-WS-14

CO-WS-14 was visited by Woodman Environmental in May 2014 as part of baseline flora and vegetation surveys for the Project (Woodman Environmental 2016); observations have also been made by Atlas and Stantec, during visits in March 2014, and July, August, October, November and December 2017 and March 2018. CO-WS-14 is located in a rocky gorge on the eastern edge of the large ridge upon which mining is proposed. Water apparently seeps permanently (water observed during all visits) from a point in the eastern part of the gorge, where it flows down a small cliff as a waterfall into a permanent pool (water observed during all visits). The seepage also forms small, shallow pools in some places.

The vegetation, which has been mapped as an occurrence of VT 3, is not typical of other occurrences of this VT located in other gorges along the ridge. The upper strata are a low woodland of *Corymbia ferritlicola*, *Ficus brachypoda*, *Melaleuca argentea* and *Eucalyptus camaldulensis* subsp. *refulgens* over a tall sparse shrubland of *Acacia tumida* var. *pilbarensis*. The lower stratum is somewhat typical, however a large number of ephemeral herbs were present, as well as the emergent macrophyte *Typha domingensis*.

The composition of the vegetation at CO-WS-14 indicates that it is GDV. *Melaleuca argentea* and *Eucalyptus camaldulensis* are both obligate phreatophytes (although *Eucalyptus camaldulensis* may be facultative at some sites), with *Typha domingensis* being an emergent macrophyte.

Plate 13: CO-WS-14 (Photo: Stantec (March 2014))
4 RISK ASSESSMENT – POTENTIAL IMPACTS TO GROUNDWATER DEPENDENT VEGETATION

4.1 Groundwater Dependent Vegetation

A rapid risk assessment of impact to groundwater dependent vegetation has been undertaken using risk assessment parameters provided by DWER. The risk of impact categories have been further defined to identify a lower level at which no risk to vegetation is expected and the assessment did not include all vegetation types considered to be potentially facultative GDV as discussed in Section 3 (as presented in Table 5).

Table 5: Rapid risk assessment for drawdown association with groundwater dependent vegetation (located where DTGW < 10m)

<table>
<thead>
<tr>
<th>Risk of Impact</th>
<th>Drawdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>No risk</td>
<td>No drawdown predicted (&lt;0.1m)</td>
</tr>
<tr>
<td>Low Risk</td>
<td>0.1 to 0.5m, at a rate of &lt;0.25m/year = acceptable risk</td>
</tr>
<tr>
<td>Moderate Risk</td>
<td>0.5 – 1m, at a rate of &lt;0.25m/year and;</td>
</tr>
<tr>
<td></td>
<td>• vegetation does not need to be considered under the EPA factors guidelines = acceptable risk</td>
</tr>
<tr>
<td></td>
<td>• vegetation does need to be considered under the EPA factors guidelines = risk may be acceptable but require adequate monitoring (groundwater and vegetation) or site-specific assessment may be warranted</td>
</tr>
<tr>
<td>High Risk</td>
<td>&gt;1m – site specific assessment may be warranted</td>
</tr>
</tbody>
</table>

As per Table 5, areas of Moderate risk of impact where the vegetation does not need to be considered under the EPA factor guidelines can be considered an acceptable risk. Vegetation that does need to be considered under the EPA factor guidelines is described below (EPA 2016):

- being identified as threatened or priority ecological communities
- restricted distribution
- degree of historical impact from threatening processes
- a role as a refuge
- providing an important function required to maintain ecological integrity of a significant ecosystem.

With regards to the vegetation which would require consideration under the EPA factor guidelines (listed above), VT 3 could be considered to provide a role as a refuge, being mapped on gorge areas with areas of both permanent and semi-permanent surface water. These areas provide comparatively stable environmental conditions, especially with regards to water availability, and therefore would qualify as being refugia (Stantec 2018a).

The rapid risk assessment as per Table 5 has been applied to VTs meeting the requirements of Table 5 (i.e. VTs 3 and 15 located where DTGW < 10m) in a GIS environment. Both the extent and rate of proposed groundwater drawdown for the end of each year of proposed mining operation (Years 1 – 6) was applied, excluding areas proposed to be directly impacted by mining. The total areas (ha) assessed as No, Low, Moderate and High risk of
impact, for the end of each year of mining, is presented in Tables 6a and 6b, and presented in Figures 6.1 – 6.6.

Table 6a: Rapid Risk Assessment for each Vegetation Type

<table>
<thead>
<tr>
<th>VT</th>
<th>Risk Category</th>
<th>Area at Risk of Impact (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>None</td>
<td>0.65 0.53 0.36 0.29 0.25 0.23</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>0.13 0.12 0.29 0.36 0.39 0.36</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>0.29 0.43 0.23 0.15 0.12 0.15</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.00 0.00 0.20 0.28 0.32 0.34</td>
</tr>
<tr>
<td>3</td>
<td>Total (Low - High)</td>
<td>0.42 0.55 0.72 0.79 0.83 0.85</td>
</tr>
<tr>
<td>15</td>
<td>None</td>
<td>376.58 330.88 310.87 294.06 280.54 273.06</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>48.98 94.69 102.05 112.58 123.08 125.78</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>0.00 0.00 12.65 18.92 21.94 25.07</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>46.79 46.79 46.79 46.79 46.79 48.45</td>
</tr>
<tr>
<td>15</td>
<td>Total (Low - High)</td>
<td>95.77 141.48 161.49 178.29 191.81 199.30</td>
</tr>
</tbody>
</table>

Table 6b: Rapid Risk Assessment for Groundwater Dependent Vegetation

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Year 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>377.23</td>
<td>331.41</td>
<td>311.23</td>
<td>294.35</td>
<td>280.79</td>
<td>273.29</td>
</tr>
<tr>
<td>Low</td>
<td>49.11</td>
<td>94.81</td>
<td>102.34</td>
<td>112.94</td>
<td>123.47</td>
<td>126.14</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.29</td>
<td>0.43</td>
<td>12.88</td>
<td>19.07</td>
<td>22.06</td>
<td>25.22</td>
</tr>
<tr>
<td>High</td>
<td>46.79</td>
<td>46.79</td>
<td>46.99</td>
<td>47.07</td>
<td>47.11</td>
<td>48.79</td>
</tr>
<tr>
<td>Total (Low - High)</td>
<td>96.19</td>
<td>142.03</td>
<td>162.21</td>
<td>179.08</td>
<td>192.64</td>
<td>200.15</td>
</tr>
</tbody>
</table>

For each individual GDV VT, the majority of mapped area has been ranked as risk of impact ‘None’ or ‘Low’ (Table 6). These areas are regarded as having an ‘acceptable risk’ of impact as per advice from DWER (Table 5). Areas considered being at ‘Moderate’ or ‘High’ risk of drawdown related impacts as per Table 5, will require site specific assessment, which is further detailed in Section 5 (Conclusions).

Previous experience with groundwater drawdown impacts to vegetation at Pardoo (Woodman Environmental 2013) indicates that impacts are primarily restricted to the larger obligate tree species *M. argentea* and to a lesser extent *E. camaldulensis* subsp. *refulgens*. Potential secondary impacts may result in riverine situations in the event that flow channels or banks become destabilised following loss of these species. However impacts to other associated species has not been recorded to date, and given the restricted period over which drawdown will occur at Corunna, it is likely that any impacts will be restricted to these obligate phreatophytes.
Potential GDVs at Low, Moderate and High risk of Impact Year 1

Legend
- Study Area (WEC 2016)
- Project Indicative Mine Disturbance Footprint
- Development Envelope

Vegetation Risk
- High
- Moderate
- Low
- None

Projection: GDA 1994 MGA Zone 50
Revision: 0 - 18 May 2018
Scale: 1:75,000 (A3)
Fig. 6.2

Potential GDVs at Low, Moderate and High risk of Impact
Year 2

Legend
- Study Area (WEC 2016)
- Project Indicative Mine Disturbance Footprint
- Development Envelope

Vegetation Risk
- High
- Moderate
- Low
- None

Projection: GDA 1994 MGA Zone 50

Revision: 0 - 18 May 2018
Scale: 1:75,000 (A3)
Projection: GDA 1994 MGA Zone 50

Author: Cathy Godden
WEC Ref: Atlas18-09-01
Filename: Atlas18-09-01-f06-2

This map should only be used in conjunction with WEC report Atlas18-09-01.
Legend
- Study Area (WEC 2016)
- Project Indicative Mine Disturbance Footprint
- Development Envelope
- Vegetation Risk
  - High
  - Moderate
  - Low
  - None

Potential GDVs at Low, Moderate and High risk of Impact Year 3

WEC Ref: Atlas18-09-01
Filename: Atlas18-09-01-f06-3
Author: Cathy Godden
Projection: GDA 1994 MGA Zone 50
Revision: 0 - 18 May 2018
Scale: 1:75,000 (A3)
Potential GDVs at Low, Moderate and High risk of Impact
Year 4

Legend
- Study Area (WEC 2016)
- Project Indicative Mine Disturbance Footprint
- Development Envelope

Vegetation Risk
- High
- Moderate
- Low
- None

Projection: GDA 1994 MGA Zone 50
Revision: 0 - 18 May 2018
Scale: 1:75,000 (A3)
Projection: GDA 1994 MGA Zone 50

Author: Cathy Godden
WEC Ref: Atlas18-09-01
Filename: Atlas18-09-01-f06-4

This map should only be used in conjunction with WEC report Atlas18-09-01.
Potential GDVs at Low, Moderate and High risk of Impact

Year 6

Legend
- Study Area (WEC 2016)
- Project Indicative Mine Disturbance Footprint
- Development Envelope

Vegetation Risk
- High
- Moderate
- Low
- None

Projection: GDA 1994 MGA Zone 50

Revision: 0 - 18 May 2018
Scale: 1:75,000 (A3)
Projection: GDA 1994 MGA Zone 50

Author: Cathy Godden
WEC Ref: Atlas18-09-01
Filename: Atlas18-09-01-f06-6

This map should only be used in conjunction with WEC report Atlas18-09-01.
4.2 Permanent and Semi-Permanent Surface Water Features

A rapid risk assessment of the potential impact of the Project groundwater drawdown on the groundwater levels at the significant surface water features (as described in Section 3.2) was undertaken by Stantec (2018b) as presented in Table 7.

Table 7: Risk of Impact to Permanent Pools (Stantec 2018b)

<table>
<thead>
<tr>
<th>Surface Water Feature</th>
<th>Pool Type</th>
<th>Est. LOM Drawdown (m)</th>
<th>Risk of Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO-WS-01</td>
<td>Perennial</td>
<td>0.02</td>
<td>Low/acceptable risk: Change in pool depth &lt;0.25 m (possibly groundwater fed)</td>
</tr>
<tr>
<td>CO-WS-02</td>
<td>Ephemeral</td>
<td>0.56</td>
<td>Acceptable risk: Non-permanent pool (not groundwater fed)</td>
</tr>
<tr>
<td>CO-WS-03</td>
<td>Ephemeral</td>
<td>2.3</td>
<td>Acceptable risk: Non-permanent pool (not reliant on groundwater)</td>
</tr>
<tr>
<td>CO-WS-05</td>
<td>Perennial</td>
<td>3.52</td>
<td>High risk: Change in pool depth so that it is no longer permanent (pool possibly groundwater fed)</td>
</tr>
<tr>
<td>CO-WS-08</td>
<td>Ephemeral</td>
<td>3.31</td>
<td>Acceptable risk: Non-permanent pool (possible seasonal groundwater contribution to this pool)</td>
</tr>
<tr>
<td>CO-WS-09</td>
<td>Ephemeral</td>
<td>0.11</td>
<td>Acceptable risk: Non-permanent pool (potential seasonal groundwater contribution to this pool)</td>
</tr>
<tr>
<td>CO-WS-10</td>
<td>Perennial</td>
<td>0.02</td>
<td>Acceptable risk: Pool is not groundwater dependent and change in pool depth &lt;0.25 m</td>
</tr>
<tr>
<td>CO-WS-11</td>
<td>Perennial</td>
<td>0.29</td>
<td>Acceptable risk: Pool is not groundwater dependent</td>
</tr>
<tr>
<td>CO-WS-12</td>
<td>Perennial</td>
<td>0.05</td>
<td>Low/acceptable risk: Change in pool depth &lt;0.25 m (potential groundwater contribution)</td>
</tr>
<tr>
<td>CO-WS-13</td>
<td>Ephemeral</td>
<td>0.73</td>
<td>Acceptable risk: Non-permanent pool (potential seasonal groundwater contribution)</td>
</tr>
<tr>
<td>CO-WS-14</td>
<td>Perennial</td>
<td>0.1</td>
<td>Low/acceptable risk: Change in pool depth &lt;0.25 m (groundwater contribution to pool)</td>
</tr>
</tbody>
</table>

Given the parameters in Table 7, surface water features CO-WS-05, CO-WS-08 and CO-WS-13 appear most at risk of groundwater drawdown related impacts as discussed below.

- **CO-WS-05:** This pool is located 10 km west of ROM and Camp pumping bores, and 2.7 and 3.9 km from the ridge line pumping bores. The vegetation of this pool area has the potential to be GDV (i.e. known and presumed facultative species as well as potential obligate species), based on assessment of the species present at the site. In addition, this pool has been classed as permanent, and at risk of losing permanent water due to potential changes in pool depth related to groundwater abstraction (-
3.52m) over the life of the mine. Given the potential drawdown and the presence of GDV at this location the risk of impact to the vegetation according to Table 5 is classed as ‘High’.

- **CO-WS-08:** The vegetation of this pool area has the potential to be GDV, based on assessment of the potentially facultative phreatophytic species present at the site. Although Stantec (2018b) have classified this pool as being non-permanent (dry November to December 2017), there is the potential for seasonal influx of groundwater into the pool area, which may be the source of water which the potentially facultative phreatophytic species utilise. Drawdown by 3.31m may impact on this seasonal influx of groundwater, which has the potential to impact on the vegetation at this pool area. The resulting classification of the risk of impact according to Table 5 is ‘High’.

- **CO-WS-13:** This pool is located 2.1 and 2.3 km west of the ridge line pumping bores and 7 to 8 km from the ROM/camp bores. The vegetation of this pool has the potential to be GDV, based on the species present at the site (i.e. known and presumed facultative species as well as potential obligate species). Although it has been classified as a non-permanent pool, the water levels may be influenced seasonally by groundwater levels. The estimated drawdown at this pool area exceeds 0.5m (Table 5); therefore there is the possibility of impact to vegetation which may be relying on seasonal influx of groundwater. Given the level of potential drawdown at this location the risk of impact to GDV according to Table 5 is ‘Moderate’.
5 CONCLUSIONS

This assessment has evaluated the presence of GDV, both on a landscape scale (VTs) and growing in association with key surface water features, and the projects risk of groundwater drawdown related impact on this vegetation over the life of mine (Table 5). The assessment has identified the following potentially groundwater dependent features that may be at Moderate to High risk of impact and therefore require site specific assessment and potentially monitoring of impacts:

- **Moderate risk of impact:** 0.15 ha of GDV mapped as VT 3 (vegetation may provide a role as a refuge);
- **High risk of impact:** 48.79 ha of GDV (VTs classified as being obligate (VT 15) or facultative and may provide a role as a refuge (VT 3);
- **Surface water features:** CO-WS-05, CO-WS-08 and CO-WS13; due to a combination of GDV presence, groundwater dependence of the pool areas and potential impact on groundwater levels in these areas (as reported by Stantec 2018b).

Figure 7 presents a map of the location of all of these areas described above. Given the short project life, the relatively small areas of the VTs at risk of impact and their broader distributions in the project area, the potential impacts are not considered to be significant in a regional context.

It is recommended that finer detail mapping of the vegetation be undertaken in areas of Moderate and High risk to VT 3, and areas of High risk of impact to VT 15 (points 1 and 2 above), to confirm species presence and refine areas at risk. In particular, the presence or absence of obligate phreatophytic species (for example *Melaleuca argentea*), obligate and/or facultative phreatophytes (for example *Eucalyptus camaldulensis* subsp. *refulgens*), and other facultative phreatophytes will assist in identification of particular areas where the greatest impacts to health of vegetation through groundwater drawdown may be experienced. The collection of multispectral imagery annually could also be used to identify changes in plant cell index (i.e. changes in overall health of vegetation) and map the extent of any decline or death in vegetation that occurs in association with the project.

Negative impacts on the health of vegetation at CO-WS-05, CO-WS-08 and CO-WS-13 may occur due to the reliance, even seasonally, on groundwater by the vegetation in these areas. These pools and associated vegetation should be assessed further to determine the potential extent of GDV and inform ongoing monitoring requirements. It is recommended that impacts to groundwater be monitored between the bores and the pool locations to identify whether groundwater abstraction will affect water levels in these pools. Water levels in the pools and in underlying soil profiles should be monitored in conjunction with vegetation health to provide clear causation should vegetation health decline. Groundwater levels between the bores and pool locations should be monitored on a monthly basis during groundwater abstraction, to determine whether mining is having a measurable impact on levels that would trigger additional monitoring or management actions. In the event that impacts to vegetation are identified then monitoring should extend beyond the LOM to ensure that water levels and vegetation health recovers.
6 REFERENCES

AQ2 Pty Ltd (2015)

Burbidge, A. H., Johnstone, R. E. and Pearson, D. J. (2010)

Department of Water (2009)

Department of Water (2010)

Eastham, J. (2015)
*Understanding Riparian Vegetation Responses to Groundwater Drawdown and Discharge from Below Water Table Mining in the Pilbara.* Unpublished report to Rio Tinto Iron Ore, July 2015

Golder Associates (2010)

Graham, J. (2001)
*The root hydraulic architecture of Melaleuca argentea,* PhD thesis. The University of Western Australia.

Loomes, R (2010a)
*Determining water level ranges of Pilbara riparian species,* Environmental water report series, report no. 17, Department of Water, Perth.

Loomes, R., (2010b)
*Lower Fortescue River - ecological values and issues,* Environmental water report series, Report No. 15 Department of Water, Government of Western Australia, Perth.

Ruprecht, John and Ivanescu, Stella (2000)


Stantec (2018a)

Stantec (2018b)

Woodman Environmental Consulting Pty Ltd (2011)

Woodman Environmental Consulting Pty Ltd (2012)

Woodman Environmental Consulting Pty Ltd (2012b)

Woodman Environmental Consulting Pty Ltd (2012c)

Woodman Environmental Consulting Pty Ltd (2013)

Woodman Environmental Consulting Pty Ltd (2014)

Woodman Environmental Consulting Pty Ltd (2016)  