Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

Nomination *(to be completed by nominator)*

Current conservation status	
Name of ecological community:	Assemblages of the organic mound springs of the Three Springs area
Other names:	
Description:	The community occurs in the Three Springs area. The mound spring habitat is characterised by continuous discharge of groundwater in raised areas of peat. The peat and surrounds provide a stable, permanently moist series of micro-habitats. There is a high level of heterogeneity of invertebrate fauna assemblages between occurrences, and all are associated with a rich and healthy fauna. The distinctive assemblages are composed of invertebrate groups that commonly include beetles, oligochaetes, non-biting midges and bugs. The vegetation component of the community contains many moisture loving species including an overstorey of *Melaleuca preissiana* (moonah) trees. *Eucalyptus camaldulensis* (river gum) and *Eucalyptus rudis* (flooded gum) are also found in a number of the mound springs. The shrub layer often includes *Hypocalymma angustifolium* and *Acacia saligna* over *Baumea vaginalis* and other sedges. The herbaceous *Patersonia occidentalis* (swamp variant) has been recorded at several occurrences.
Nomination for:	Listing ☐ Change of status ☒ Delisting ☐

1. Is the ecological community currently on any conservation list, either in a State or Territory, Australia or Internationally? *2. Is it present in an Australian jurisdiction, but not listed?*	*Provide details of the occurrence and listing status for each jurisdiction in the following table*

Jurisdiction	**List or Act name**	**Date listed or assessed (or N/A)**	**Listing category eg. critically endangered (or none)**	**Listing criteria eg. B1ab(iii)+2ab(iii) (or none)**
National	EPBC Act			
Western Australia	Current ranking under WA Minister ESA list in policy	21/09/2001	Endangered	B i), B ii)
	Priority list		1 ☐ 2 ☐	3 ☐ 4 ☐
Other State/Territory				

Nominated conservation status: category and criteria (include recommended status for deleted ecological communities)

<table>
<tr><td colspan="3">Critically endangered (CR) ☒ Endangered (EN) ☐ Vulnerable (VU) ☐ Collapsed (CO) ☐</td></tr>
<tr><td colspan="3">Priority 1 ☐ Priority 2 ☐ Priority 3 ☐ Priority 4 ☐ None ☐</td></tr>
<tr><td colspan="2">What criteria support the conservation status category for listing as a threatened ecological community or collapsed ecological community?
Refer to Section 32 of the Biodiversity Act 2016 for definition of ‘Collapsed’, and Appendix 5 table ‘IUCN Red List Criteria for ecosystems version 2.2’.</td><td>CR B1a(ii),b.</td></tr>
<tr><td colspan="3">Eligibility against the criteria</td></tr>
<tr><td colspan="3">Provide justification for the nominated conservation status; is the ecological community eligible or ineligible for listing against the five criteria. For <u>delisting</u>, provide details for why the ecological community no longer meets the requirements of the current conservation status.</td></tr>
<tr><td>A.</td><td>Reduction in geographic distribution
(evidence of decline)</td><td>☐ A1
☐ A2a
☐ A2b
☐ A3</td></tr>
<tr><td></td><td>Justification of assessment under Criterion A.</td><td>For criteria A and B, the ecosystem was assumed to collapse when the mapped distribution declines to zero.
• A: A reduction in geographic distribution has occurred in the past 50 years (A1, A2) with some springs completely destroyed, however the level of loss does not meet the minimum 30% reduction in geographic distribution required over any 50-year period, or meet the required 50% reduction since 1750 (ie. the minimum requirements to meet the category VU under criterion A).
• Does not meet criterion A</td></tr>
<tr><td>B.</td><td>Restricted geographic distribution
(EOO and AOO, number of locations and evidence of decline)</td><td>☒ B1 (specify at least one of the following): CR
☐ a)(i) ☒a)(ii) ☐a)(iii) ☒b) ☐c);
☐ B2 (specify at least one of the following):
☐ a)(i) ☐a)(ii) ☐a)(iii) ☐b) ☐c);
☐ B3 (only for Vulnerable Listing)</td></tr>
<tr><td></td><td>Justification of assessment under Criterion B.</td><td>• B1: EOO is 133km^2 (≤2,000km^2 which is the threshold for CR).
• B2: AOO is four 10x10 km grid cells (threshold for EN is 20, and for CR is two grid cells).
• aii): Modelling data are available to infer continued decline in a measure of disruption to environmental quality to support ranking under B1aii and B2aii. Groundwater model indicates groundwater extraction from the Yandanooka borefield will result in substantial drawdown at a number of springs (see Appendix 1).
• b): Continuing decline has been observed from grazing by stock, weed invasion and too frequent fire; and future decline is inferred in the next 20 years as a consequence of declining groundwater levels that are likely to cause declines</td></tr>
</table>

		in environmental quality or biotic interactions (see Appendix 1 for further information on threats). • c) Ecosystem exists at two threat-defined locations based on the inferred impacts from groundwater abstraction to five northern occurrences, and the southern occurrences that are further from the borefield and not as likely to be as significantly impacted by groundwater extraction (threshold for CR is one and for EN is 5 threat-defined locations). • B3: Known from two threat-defined locations and prone to impacts of groundwater decline, altered fire regimes, reduced rainfall, and impacts of feral animals. Level of threat is considered non-trivial and community is considered prone to effects of human activities or stochastic events within a very short time period in an uncertain future and thus capable of collapse or becoming CR within a very short time period (meets VU as <5 threat defied locations). • **Meets criteria for critically endangered B1a(ii),b. Meets endangered B2a,b,c. Meets Vulnerable B3.**
C.	Environmental degradation of abiotic variable *(Evidence of decline over 50-year period)*	☐ **C1** ☐ **C2** ☐ **C3**
	Justification of assessment under Criterion C.	• For criterion C, the assessment of decline in abiotic processes focussed on hydrological change using data on the depth of the watertables. It is assumed very conservatively that the community would collapse if the watertable depth fell to about 10.5 m below ground surface based on the maximum water depth accessed by deep rooted phreatophytic taxa in nearby areas (Froend and Loomes 2006), and observations that the vigour of canopies declined in groundwater dependent trees in association with declining watertable levels (Froend *et al*. 2004). The severity of impacts of groundwater decline are difficult to predict, as the groundwater flows to mound springs are related to complex geologies. Simple determinations of decline in groundwater levels as measured at nearby bores are therefore difficult to reliably extrapolate to predict impacts on flows at the springs, and subsequent impacts to spring vegetation and fauna (see Appendix 1). • Many occurrences of the community have not been recently surveyed as they are located on private property, and their current condition is not known. • C1, C2: Hydrological changes are likely to be the greatest threat to the community. However, there is inadequate evidence to indicate the community meets the thresholds for minimum proportion of the extent (≥30%) or proportional severity of degradation (≥30%) over any 50-year period to meet VU under these criteria. Future decline in particular is difficult to predict as the relationship between groundwater levels and springs flows is based on complex geologies. • C3: Does not meet the minimum proportion of the extent (≥50%) or proportional severity of disruption of abiotic

		processes (≥50%) since ~1750 to meet VU under this criterion. • **Inadequate evidence to indicate community meets criterion C**
D.	Disruption of biotic processes or interactions *(Evidence of decline over 50-year period)*	☐ **D1** ☐ **D2** ☐ **D3**
	Justification of assessment under Criterion D.	• D1, D2: Grazing by introduced herbivores is a threat to this community. Vegetation condition is considered to reflect a combination of species richness, species composition and dominance, abundance of key species, and other biotic interactions. Grazing and the associated trampling by introduced herbivores are assumed to be the main current impacts on vegetation condition in this community. In this context vegetation collapse is assumed conservatively to occur when vegetation condition of the mound springs reaches beyond recovery (IUCN condition scales). • Vegetation condition data currently indicate approximately 4% of the community is 'beyond recovery'. The actual proportion current and historical proportion of the extent of the mound springs impacted by grazing is not known as many locations have not been visited recently, or at all. There is inadequate systematic monitoring of vegetation condition as it relates to grazing impacts to indicate the community meets the thresholds for minimum proportion of the extent (≥30%) or proportional severity of disruption of biotic processes (≥30%) over any 50-year period to meet VU under this criterion. • D3: Inadequate evidence to indicate the community meets the minimum proportion of the extent (≥50%) or proportional severity of disruption of biotic processes (≥50%) since ~1750 to meet VU under this criterion. • **Inadequate evidence to indicate community meets criterion D**
E.	Quantitative analysis *(statistical probability of ecosystem collapse)*	• No quantitative estimates of the risk of ecosystem collapse. • **Not assessed**

Reasons for change of status
Genuine change ☐ New knowledge ☐ Previous mistake ☐ Review/Other ☒
Provide details: The community was initially ranked as Vulnerable using ranking criteria developed in WA that differ to those in the IUCN Red List Criteria for Ecosystems (version 2.2).

Summary of assessment information *(provide detailed information in the relevant sections of the nomination form)*			
EOO	133km^2	AOO	Four 10x10 km grid cells

No. occurrences	36	Severely fragmented	Yes ☒ No ☐ Unknown ☐
Justification	The community is naturally fragmented as the isolated springs only occur along a small section of the Dandaragan Scarp, where continuous water discharges or seeps. In addition, clearing has occurred between many of the springs, has further increased their isolation.		
Current known area			58 ha
Pre-industrialisation extent or its former known extent (if known)			Not known as historical locations of springs are not mapped. Based on current knowledge the springs have declined noticeably in extent.
Estimated percentage decline			Not known

Summary assessment against IUCN RLE Criteria

Criterion	Rank indicated	Overall conclusion
A1	-	• Available data do not indicate community meets criterion
A2a	-	• Available data do not indicate community meets criterion
A2b	-	• Available data do not indicate community meets criterion
A3	-	• Available data do not indicate community meets criterion
B1a	CR	• EOO is ≤2,000km^2 • Groundwater model indicates likely decline in environmental quality due to groundwater decline in the next 20 years. • Meets CR
B1b	CR	• EOO is ≤2,000km^2 • Observed and inferred continuing decline from grazing, weed invasion, too frequent or severe fire, and inferred future decline in environmental quality or biotic interactions from groundwater decline • Meets criterion for CR
B1c	EN	• EOO is ≤2,000km^2 • Ecosystem exists at 2 threat defined locations • Meets criterion for EN
B2a	EN	• AOO is four grid cells • Groundwater model indicates likely decline in environmental quality due to groundwater decline in the next 20 years. • Meets EN
B2b	EN	• AOO is four grid cells • Observed continuing decline from grazing, weeds and fire; inferred changes to hydrological regime • Meets criterion for EN
B2c	EN	• AOO is four grid cells • Ecosystem exists at 2 threat defined locations • Meets criterion for EN
B3	VU	• Known from two threat-defined locations • Prone to the effects of grazing, weed invasion, too frequent or severe fire; and inferred future decline in groundwater levels • Meets criterion for VU
C1	-	• Inadequate evidence to indicate the community meets the minimum thresholds for proportion of the extent (≥30%) or proportional severity of degradation (≥30%) over the past 50 years to meet VU.
C2	-	• Although groundwater model indicates substantial groundwater decline in a number of occurrences, actual impacts to springs in the next 50 years cannot be reliably predicted. Inadequate evidence to indicate the community meets the minimum thresholds for

		proportion of the extent (≥30%) or proportional severity of degradation (≥30%) over any 50-year period to meet VU.
C3	-	• Inadequate evidence to indicate the community meets the minimum thresholds for proportion of the extent (≥50%) or proportional severity of disruption of abiotic processes (≥50%) since ~1750 to meet VU.
D1	-	• Inadequate evidence to indicate the community meets the minimum thresholds for proportion of the extent (≥30%) or proportional severity of disruption of biotic processes (≥30%) over the past 50 years to meet VU.
D2	-	• Inadequate evidence to indicate the community meets the minimum thresholds for proportion of the extent (≥30%) or proportional severity of disruption of biotic processes (≥30%) over any 50-year period to meet VU.
D3	-	• Inadequate evidence to indicate the community meets the minimum thresholds for proportion of the extent (≥50%) or proportional severity of disruption of biotic processes (≥50%) since ~1750 to meet VU.
E	NA	• No quantitative estimates of the risk of ecosystem collapse.
		Meets CR under B1a,b. Meets EN B1c, B2a,b,c. Plausible range of ranks: VU to CR. *'The highest risk category obtained by any of the assessed criteria will be the overall risk status of the ecosystem'* (IUCN RLE Guidelines V1.1 page 42). **Meets CR B1a(ii),b.**

Summary of location (occurrence) information *(provide detailed information in the relevant sections of the nomination form)*						
Occurrence	Land tenure	Survey information: date of survey	Condition*	Area of occurrence (ha)	Threats *(note if past, present or future)*	Specific management actions
Flooded sedge Interstitial Hole 1 Interstitial Hole 2 JB09 MSTS01a-c Pool 2	Freehold (DBCA), nature reserve	2001	75% pristine 25% very good	1.38 ha	Clearing, weeds, grazing and trampling, too frequent fire, hydrological change (*past, present, future*)# Drying climate, disease (*future*)# *#Threats apply to all occurrences below*	Install fencing, control weeds, control introduced fauna, secure community through reservation where opportunities arise, establish monitoring to link groundwater and biotic decline, consider community's requirements in regard to groundwater extraction proposals
6 MSTS02 MSTS02JB	Freehold (DBCA)	2001	50% excellent 50% very good	0.22 ha		
JB03 MSTS03	Freehold, nature reserve	2006	Unknown	1.7		
JB04 MSTS04	Freehold, nature reserve	2010	Unknown	2.66		
Dense Sedges JB07a JB07b JB10 MSTS05a MSTS05b	Nature reserve	2010	50% excellent 50% good	3.46	Weeds (*past, present, future*)	
JB06 MSTS06	Freehold (DBCA), nature reserve	2006	Unknown	2.35		
JB32 MSTS07	Freehold	2006	Unknown	0.67		
JB12	Freehold	2006	Unknown	0.91		

MSTS08						
JB17 MSTS09	Freehold	2006	Unknown	1.37		
MSTS10	Freehold	2006	Unknown	0.61		
JB19 MSTS11	Freehold	2001	100% completely degraded	1.61		
JB13 MSTS12	Freehold (DBCA)	2011	100% excellent	0.26		
JB01 MSTS13 Plankton Pool	Nature reserve	2011	50% good, 50% excellent	1.12		
MSTS14	Freehold	2011	95% excellent, 5% very good	0.22		
JB29 MSTS15 TSWT	Freehold, freehold (DBCA)	2011	50% medium 50% very good	0.76	Fire (*past*)	
MSTS16	Freehold	2005	95% pristine 5% very good	2.59		
MSTS17	Freehold	2005	100% excellent	0.62		
MSTS18	Freehold		Unknown	0.33		
MSTS19	Freehold		Unknown	1.38		
MSTS20	Freehold	2005	95% excellent 5% very good	18.09		
MSTS21	Freehold	2005	Unknown	1.0		
MSTS22	Freehold	2005	Unknown	0.44		
MSTS23	Freehold	2005	Unknown	0.95		
JB02	Nature reserve	2006	Unknown	0.02		
JB05	Freehold	2006	Unknown	0.96		
MSTS07a	Freehold		Unknown	0.08		
JB37	Freehold	2006	Unknown	1.04		
Yan01	Freehold		Unknown	0.32		
MSTS (Yan02)	Freehold		Unknown	1.47		
Yan03	Freehold		Unknown	0.52		
Yan04	Freehold		Unknown	0.32		
MSTS15a	Nature reserve	2019	100% excellent	3.43		

MSES1	Freehold		Unknown	2.06		
MSES2	Freehold		Unknown	0.05		
ArrowsmithMS1	Freehold	2019	10% very good 90% excellent	2.94		
ArrowsmithMS2	Freehold	2019	100% good	0.04		

*For the purposes of relating condition to IUCN Criteria, condition categories from (Keighery (1994) Vegetation Condition Scale (Government of WA 2000)) are defined below:

Good ('Pristine', 'Excellent', 'Very Good' using Bush Forever (2000) scale): This includes vegetation ranging from 'Pristine' - with no obvious signs of disturbance, to 'Excellent' - Vegetation structure intact, with disturbance only affecting individual species, weeds are non-aggressive species and 'Very Good' - Vegetation structure altered, obvious signs of disturbance eg: from repeated fires, dieback, logging, grazing.

Medium ('Good' using Bush Forever (2000) scale): This includes vegetation categorised as 'Good' - Vegetation structure altered but retains basic vegetation structure or ability to regenerate it, obvious signs of disturbance are present, from activities including partial clearing, dieback and grazing.

Poor ('Degraded' using Bush Forever (2000) scale): Basic vegetation structure severely impacted by disturbance such as partial clearing, dieback, logging and grazing. Scope for regeneration but not to a state approaching good condition without intensive management.

Beyond recovery ('Completely degraded' using Bush Forever (2000) scale): Vegetation structure is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native shrubs and trees.

Table 1. Known vegetation condition of occurrences that have been surveyed (14) of 'Three springs mound springs'

Condition Ranking (Keighery 1994) from Government of Western Australia 2000)	Hectares	IUCN Criteria condition ranking	Hectares
Pristine	**4.2**	**Good**	**32.4**
Excellent	**26**		
Very Good	**2.2**		
Good	**2.3**	**Medium**	**2.3**
Degraded	**0**	**Poor**	
Completely degraded	**1.6**	**Beyond recovery**	**1.6 (~4.4% of total)**
Total	**36.3**	**Total**	**36.3**

APPENDIX 1 THREATS

Hydrological change

The Three Springs Mound Springs was identified by Rutherford *et al*. (2005) as a groundwater dependent ecosystem, relying on fresh groundwater discharging from the semi-confined Parmelia aquifer. Groundwater recharge is mainly through direct infiltration from rainfall and is discharged as spring flow into the Arrowsmith River (DOW 2017). The flora and fauna species that are characteristic of the mound springs community are adapted to permanently moist environments. Increasing water levels may occur in the area of some of the occurrences of the spring community increasing in the short to medium term as a consequence of historic land clearing. Conversely declining water levels will result in the springs 'drying out', with subsequent loss of wetland-adapted flora and fauna, and potential increases in acidity (Australian Government and Department of Environment and Conservation (undated).

Land clearing in the northern Perth Basin catchment in the 1950s and 60s led to a significant rise in rainfall infiltrating the aquifer and hence groundwater levels. Levels continued to rise steadily until 2014/2015 where they started to plateau (see Figure 1). Groundwater levels are now either steady or falling and are expected to fall in the future as a result of natural discharge and groundwater extraction.

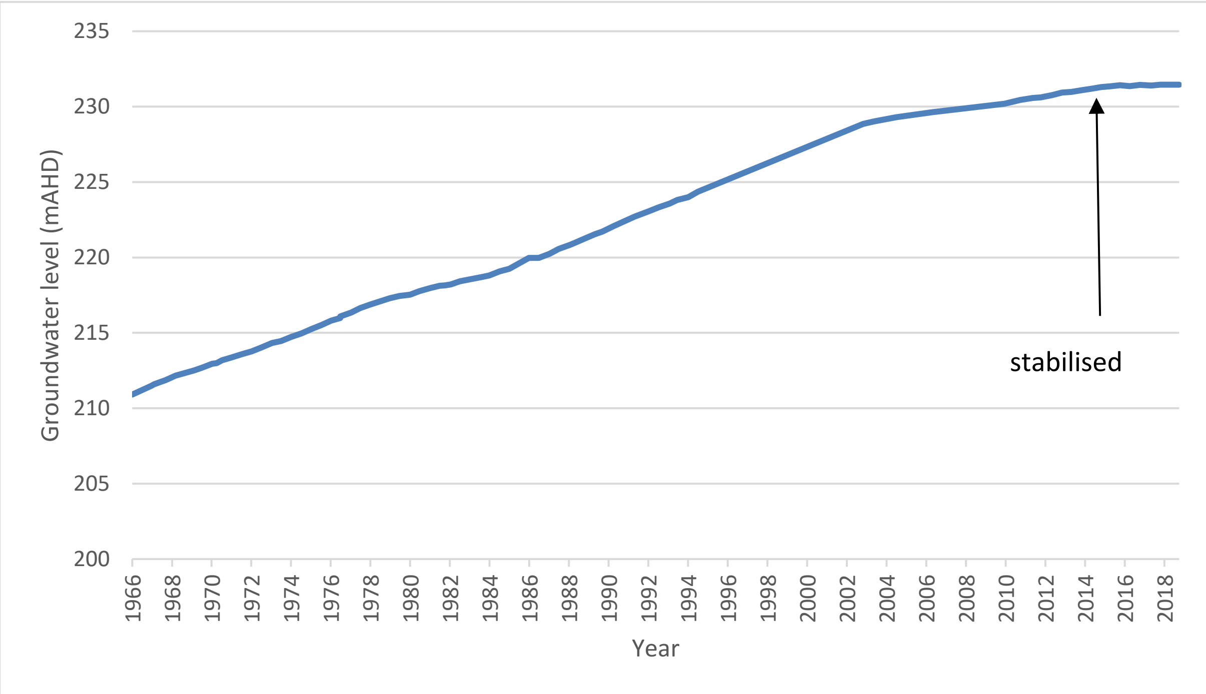


Figure 1. Monitoring bore AR22 (located 6km to the north of occurrence MSTS16) hydrograph (mAHD). Data obtained from Water Information Network website (http://wir.water.wa.gov.au/Pages/Water-Information-Reporting.aspx).

Bekele *et al*. (2003) calculated an average recharge for a cleared area of 33 to 50mm per year for the area, which is equivalent to about 8 to 12.5% of the average annual rainfall. If regional rainfall continues to decline (see figure 2), this may impact on the amount of recharge to the aquifer, eventually resulting in a decline in groundwater levels. Groundwater monitoring by DWER indicates that when yearly average rainfall falls below 300mm, very little to no recharge will occur (DWER 2019).

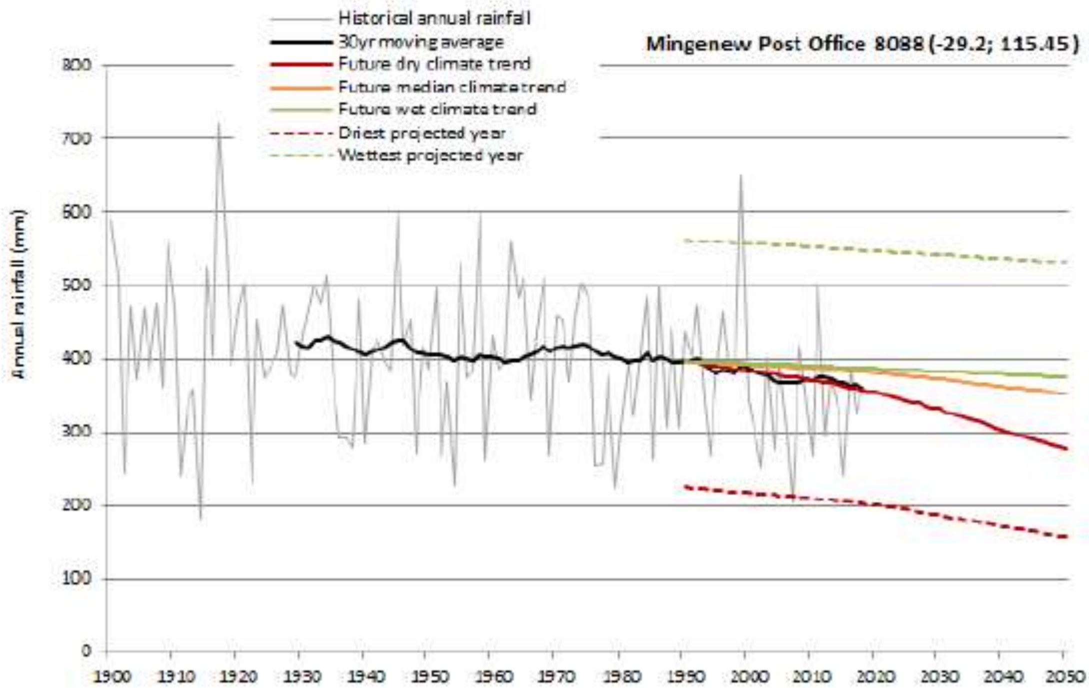


Figure 2. Predicted future trends in annual rainfall at Mingenew Post Office (located approximately 28.6km north of occurrence MSTS19) (from DWER 2019).

Increasing future extraction of groundwater from the superficial Parmelia for domestic and industrial use has the potential to impact the community due to drawdown. The community occurs between two prospective groundwater resource areas/groundwater supply options, Mingenew and Tathra, in the Midlands area. Here groundwater is abstracted for agricultural purposes, including flower farming, olives, and pasture, from the Parmelia aquifer. The community also falls within the Water for Food Midlands project area (Hydroconcept 2018). Eighteen occurrences of the community are partly or completely located in areas classified as “better groundwater resource potential and prospectivity” (Hydroconcept 2018; Groundwater Prospectivity from Water for Food Midlands data from DWER) (see Appendices 3 and 4). The allocation limit for the Parmelia aquifer was set by the DoW as 8.2GL/year in 2010 (DoW 2010) and in 2019 was reduced to 6.2GL/year (DWER 2019). More recently, orange and almond orchards have been established near the southern portion of the community, 14km southwest of occurrences MSES1 and MSES2. A proposed 120GL of groundwater will be abstracted from the Tathra subarea of the Arrowsmith Groundwater area from the Perth-Yarragadee North aquifer for the purpose of these orchards (data from DWER Water Register website). The impacts on the superficial aquifer are not known.

The Yandanooka borefield, located within 9km to the northeast of the northern most occurrence of the mound springs, was constructed in 2010 and supplies water for an iron ore mine. The borefield uses 65% of the available allocation of the Leederville-Parmelia aquifer for the Mingenew subarea (5.3GL of 8.2GL per year) (DOW 2010). The borefield consists of a minimum of three production bores and extracts 5.3GL of groundwater per year from the Parmelia aquifer in the Mingenew groundwater subarea (Rockwater 2010). Modelling using a 25mm per year recharge rate (KML 2011), estimated that after 20 years of abstraction a predicted drawdown of two to three meters will extend to occurrences of the mound springs named MSTS16, MSTS17, MSTS18 and MSTS19, and one to two meters drawdown will reach MSTS20 (see figure 3). More recent groundwater level modelling by Rockwater (2017) conversely found that levels in the area of MSTS19 and MSTS23 are predicted to rise by 3.2m to 3.8m under 6GL abstraction scenario and a rise of 2.5 to 3.6m under a 10GL abstraction scenario. It is not fully understood what impact the changes to the water levels will have on the community and there are no nested bores located between the abstraction bores and the TEC bores to provide more data on groundwater patterns. As a consequence of complex geologies, drawdown can be propagated in unpredictable ways around the springs. Decline in water levels in wetlands can result in loss of wetland-adapted flora and fauna, and potentially can increase acidity (Department of Environment and Conservation undated).

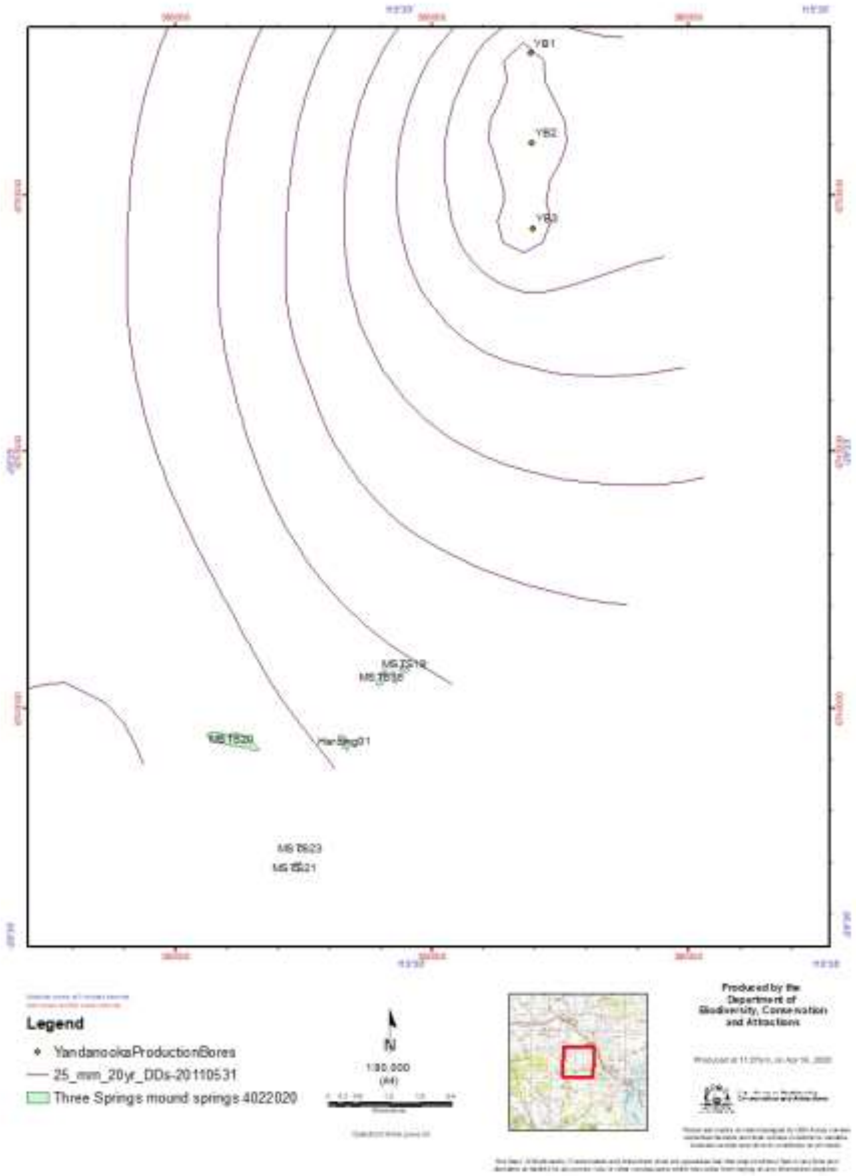


Figure 3. 25mm 20-year drawdown contour modelled from Yandanooka Borefield (using modelled rates from KML 2011). Drawdown is highest near production bores.

A monitoring bore was installed in 2012 700m to the northeast of occurrence MSTS19 to monitor impacts to the community. Bore log information and monitoring data collected since installation shows seasonal variations in water depth and electrical conductivity as expected. As part of the licence conditions, DWER has set a water level of 1.7 metres below the top of casing as a trigger for follow up investigation if the levels are recorded below this. The trigger levels for groundwater decline were met in 2016 and 2018 but was likely a result of measurement error (pers. comm. [redacted], DWER [1]) (Figure 4). It is not possible, however, to reliably extrapolate the impacts of specific levels of decline in groundwater in nearby bores to impacts on the spring flows (see below) and hence to determine the likely impacts on the mound spring assemblages (Rutherford *et al*. 2017).

[1] NRMO, Department of Water and Environmental Regulation, Regional Delivery Directorate Midwest Gascoyne Water Licensing

Figure 4. Water level (blue line) and trigger depth (red line) from Karara monitoring bore (located -29.452309; 115.5069797), from 2012 to 2019.

High nitrogen and phosphorus concentrations were recorded at occurrences MSTS12 and MSTS13 in October 2008 (nitrogen 6300 and 3100 ug/L respectively; phosphorus 170 ug/L and 190 ug/L respectively). It is not clear whether the higher nutrient concentrations are a result of natural processes or anthropogenic enrichment from surrounding agricultural land (Pinder and Leung 2010).

A trigger for electrical conductivity is set at 3,000µS/cm for close monitoring and 4,000µS/cm as a trigger for further investigation (pers. comm. [redacted], DWER).

Clearing

A number of the mound springs in the Three Springs area have in the past been affected by clearing with some being completely cleared and converted to farm dams or partly excavated to provide permanent pools for on-farm water use. Several occurrences have been partially bulldozed and the mound compacted during cropping activities. Construction of boundary access tracks around the reserves and private property that contain occurrences of the community has damaged the vegetation surrounding some mound springs and soil was pushed up into mound spring vegetation near one occurrence. Maintenance of these access tracks causes further damage to the vegetation and has the potential to introduce weeds and disease to these sites (Rees and Broun 2005).

Introduced herbivores

Rabbits occur on all land parcels that contain occurrences of the community and can increase nutrient levels from their droppings and the introduction of weeds as well as the direct impacts of grazing and digging. Many of the occurrences are unfenced and therefore accessed by sheep and cattle. Grazing causes alterations to the species composition by the selective grazing of edible species, the introduction of weeds and nutrients, trampling and general disturbance (Rees and Broun 2005).

Weed invasion

Disturbances such as fires, nutrient enrichment, grazing and plant deaths from disease can predispose areas to weed invasion if weed propagules are present. Weed species have been noted in some areas where some weedy grasses and a species of *Solanum* were found. These species are thought to have been introduced as a result of grazing and trampling when this area was historically used as a stock watering point (Rees and Broun 2005).

Altered fire regimes

Increase in the frequency of fire and severe fires can prevent species from completing growth and reproductive cycles, resulting in altered community structure or local extinction of species. Fire can also influence species composition by increasing the number of weeds. Too-frequent fires are a potential concern for all occurrences. According to the department's ARCGIS fuel age layer, fifteen occurrences (JB01-06, 12, 17, 19, 32, 37, flooded sedge, dense sedge, MSTS07a and MSTS10) were last burnt in 2005; and JB29 was last burnt in 2014. Fires are unlikely to be common in the permanently moist habitat of the mound spring but have the potential to burn out the peat mounds themselves if they occur during especially dry periods. Decreased rainfall with a drying climate is likely to increase aridity and lead to increased risk of fire.

Disease

Dieback disease caused by *Phytophthora* spp. is a threat as there are high numbers of species likely to be susceptible to the disease in and around the community. The *Phytophthora* spp. pathogen, which cause the roots to rot and results in death from drought stress, has not been recorded for any of the occurrences of the community but are commonly introduced and spread in infected soil, mud and gravel and therefore pose a potential threat (Rees and Broun 2005).

Drying climate

The Three Springs mound springs are at risk from a drying climate and decline in rainfall in the south west of the state. The tolerance of particular species to changes that may occur in association with a drying climate is generally unknown. Increased drying would impact on flora and fauna adapted to the currently very wet spring environment. In addition, peat springs are likely to become acidic as they dry, hence becoming less favourable for the current suite of species that inhabit the springs. Dry peat substrate in the community will also be at much greater risk from fires.

Predictions for the south west of WA are as follows (from ***NCCARF*** website: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/PDF%20Report%20Card%20Low%20Res.pdf); accessed 2019):

- Reduction in rainfall by 2030 by 2-14% (median 8%). Southwest to predicted to experience some of the largest reductions in rainfall in all of Australia;
- Reduction in runoff by 10-42% (median 25%) by 2030;
- Decline in groundwater levels by 2030 (extractive yields may decrease by a third to a half in some areas).

References

Australian Government and Department of Environment and Conservation (undated). A guide to managing and restoring wetlands in Western Australia. Wetland Hydrology. Version 1. In Chapter 2: Understanding Wetlands. URL https://www.dpaw.wa.gov.au/images/documents/conservation-management/wetlands/Wetland_management_guide/Wetland_Hydrology.pdf. Accessed 8 November 2019.

Bekele, E.B., Salama, R.B., Commander, D.P., Otto, C.J., Hick, W.P., Watson, G.D., Pollock, D.W. and Lambert, P.A. (2003) Estimation of groundwater recharge to the Parmelia aquifer in the northern Perth Basin 2001–2002, Land and water technical report 10/03, CSIRO.

Department of Water (2010) Arrowsmith Groundwater Allocation Plan. Water Resource Allocation Planning Series Report No 28. Government of Western Australia.

Department of Water and Environmental Regulation (2019) Allocation limit review for the Parmelia aquifer in the Mingenew Subarea. Water Allocation Planning Internal Report Series No 9. Government of Western Australia.

Froend, R. and Loomes, R. (2006) Determination of Ecological Water Requirements for Wetland and Terrestrial Vegetation – Southern Blackwood and Eastern Scott Coastal Plain. Report prepared for the Department of Water by Centre for Ecosystem Management, ECU, Joondalup.

Froend, R., Loomes, R. Horwitz, P., Bertuch, M., Storey, A. and Bamford, M. (2004) Study of Ecological Water Requirements on the Gnangara and Jandakot Mounds under Section 46 of the Environmental Protection Act. Task 2: Determination of Ecological Water Requirements. Report prepared for the Water and Rivers Commission by Centre for Ecosystem Management, ECU, Joondalup.

Government of Western Australia (2000) Bush Forever. Department of Environmental Protection, Perth.

Hydroconcept Pty Ltd (2015) Preliminary Groundwater Assessment of the Midlands Region.

Hydroconcept Pty Ltd (2018) Water for Food. Groundwater prospectivity in the Midlands Project Area.

Karara Mining Limited (2011) Karara Iron Ore Project Yandanooka Borefield. Report on Additional Information Request.

Keighery, B.J. (1994) Bushland Plant Survey. A Guide to Plant Community Survey for the Community. Wildflower Society of Western Australia (Inc.), Nedlands, Western Australia.

Pinder, A. and Leung, A. (2010) Report on the October 2008 sampling of the Aquatic Invertebrate Assemblages of Mound Springs of the Three Springs Area Threatened Ecological Community. Department of Environment and Conservation.

Rees, R. and Broun, G. (2005) Assemblages of Organic Mound Springs of the Three Springs area Interim Recovery Plan #196, 2005-2010. Department of Conservation and Land Management, Western Australia.

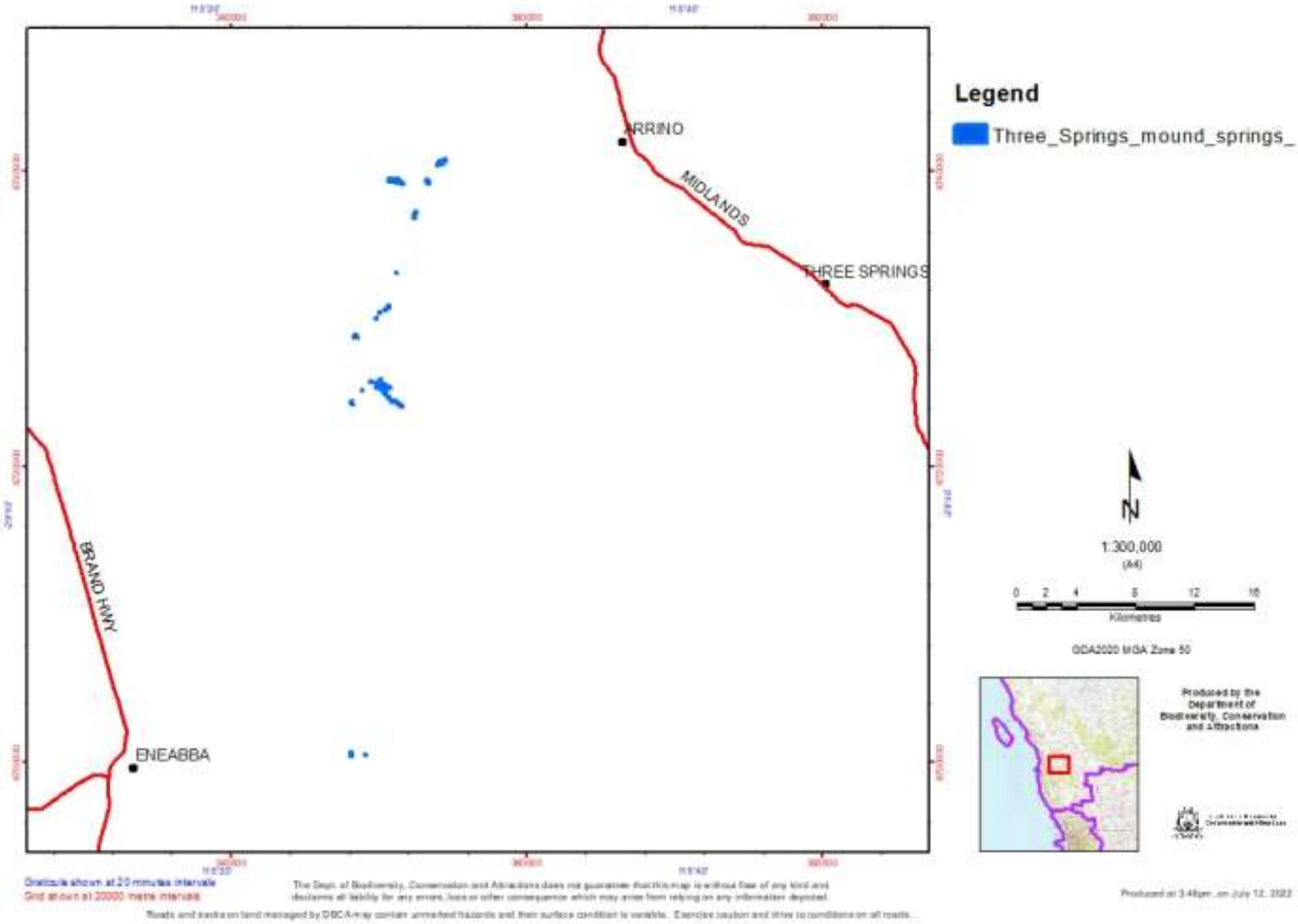
Report Card of Climate Change and Western Australian Aquatic Ecosystems (2011) Eds. K. Kauhanen, J. Chambers and F. D'Souza.

Rockwater (2010) Karara Iron Ore Project Yandanooka Borefield Completion Report and Hydrogeological Assessment. Report for Karara Mining Ltd.

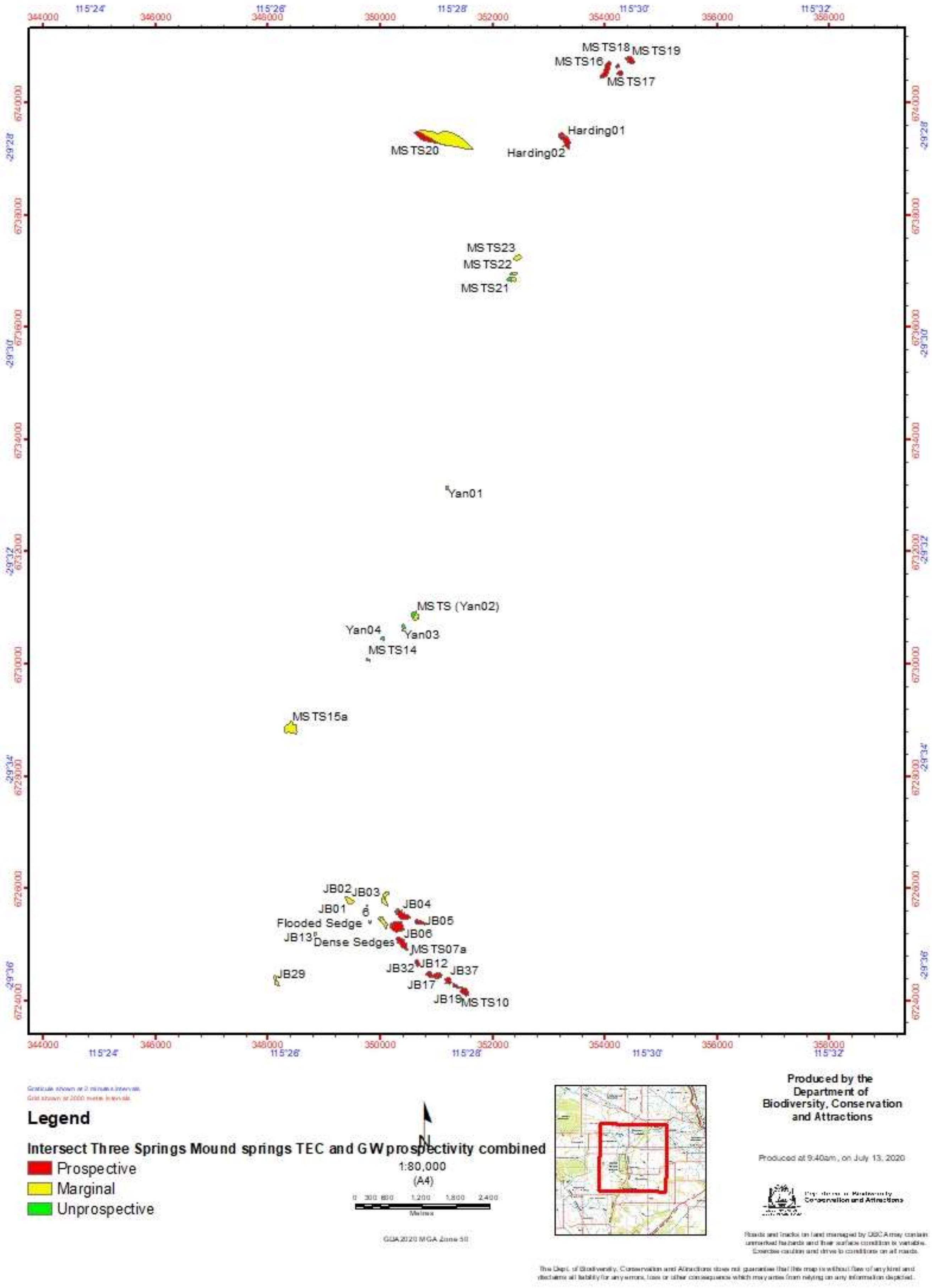
Rockwater (2017) Yandanooka Borefield. Assessment of groundwater availability, Mingenew subarea. Report for Karara Mining Ltd.

Rutherford, J. (2018). Hydrological Conceptualisation of the Walyarta Mound Springs. Department of Biodiversity, Conservation and Attractions Wetlands Conservation Program. July 2018, Perth, Western Australia. URL: https://library.dbca.wa.gov.au/static/FullTextFiles/072271.pdf. Accessed November 2019.

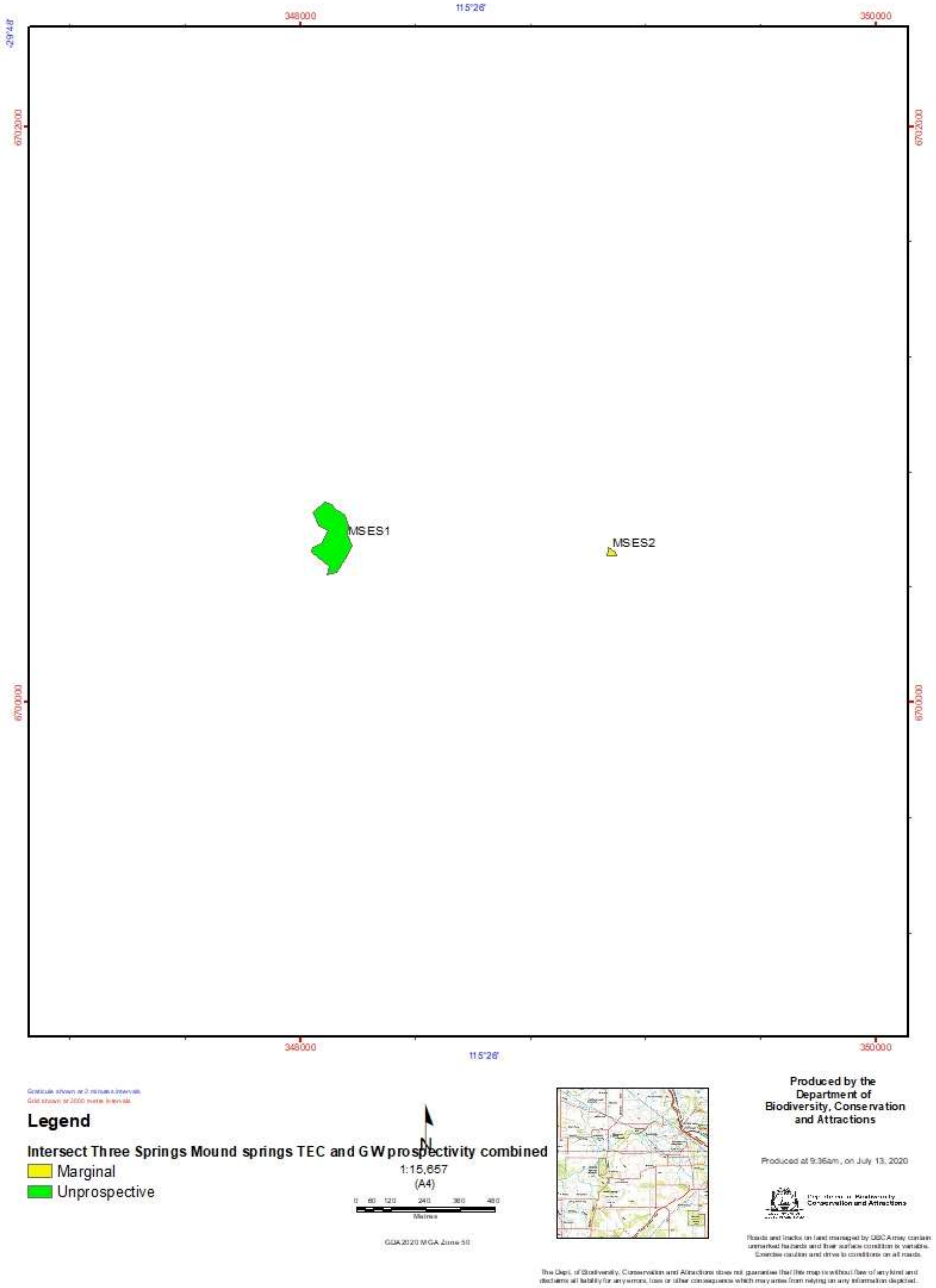
APPENDIX 2 Assemblages of the organic mound springs of the Three Springs area (blue)



APPENDIX 3 Northern occurrences of organic mound springs of the Three Springs area and groundwater prospectivity (Groundwater Prospectivity from Water for food Midlands data supplied by DWER; from Hydroconcept 2018).



APPENDIX 4 Southern occurrences of organic mound springs of the Three Springs area and groundwater prospectivity (Groundwater Prospectivity from Water for food Midlands data supplied by DWER; from Hydroconcept 2018).



APPENDIX 5 IUCN Red List Criteria for ecosystems (version 2.2) (IUCN 2017)

A. Reduction in geographic distribution over ANY of the following time periods:

		CR	EN	VU
A1	Present (over the past 50 years).	≥ 80%	≥ 50%	≥ 30%
A2a	Future (over the next 50 years).	≥ 80%	≥ 50%	≥ 30%
A2b	Future (over any 50 year period including the present and future).	≥ 80%	≥ 50%	≥ 30%
A3	Historic (since 1750).	≥ 90%	≥ 70%	≥ 50%

B. Restricted geographic distribution indicated by EITHER B1, B2 or B3:

		CR	EN	VU
B1	Extent of a minimum convex polygon enclosing all occurrences (Extent of Occurrence)	≤ 2,000 km²	≤ 20,000 km²	≤ 50,000 km²
	AND at least one of the following (a-c):			
	(a) An observed or inferred continuing decline in **EITHER**:			
	i. a measure of spatial extent appropriate to the ecosystem; **OR**			
	ii. a measure of environmental quality appropriate to characteristic biota of the ecosystem; **OR**			
	iii. a measure of disruption to biotic interactions appropriate to the characteristic biota of the ecosystem.			
	(b) Observed or inferred threatening processes that are likely to cause continuing declines in geographic distribution, environmental quality or biotic interactions within the next 20 years.			
	(c) Ecosystem exists at …	1 location	≤ 5 locations	≤ 10 locations
B2	The number of 10 × 10 km grid cells occupied (Area of Occupancy)	≤ 2	≤ 20	≤ 50
	AND at least one of a-c above (same sub-criteria as for B1).			
B3	A very small number of locations (generally fewer than 5) **AND** prone to the effects of human activities or stochastic events within a very short time period in an uncertain future, and thus capable of collapse or becoming Critically Endangered within a very short time period (B3 can only lead to a listing as VU).			VU

C. Environmental degradation over ANY of the following time periods:

			Relative severity (%)		
		Extent (%)	≥ 80	≥ 50	≥ 30
C1	The past 50 years based on change in an <u>abiotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
			≥ 80	≥ 50	≥ 30
C2	The next 50 years, or any 50-year period including the present and future, based on change in an <u>abiotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
			≥ 90	≥ 70	≥ 50
C3	Since 1750 based on change in an <u>abiotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 90	CR	EN	VU
		≥ 70	EN	VU	
		≥ 50	VU		

D. Disruption of biotic processes or interactions over ANY of the following time periods:

			Relative severity (%)		
		Extent (%)	≥ 80	≥ 50	≥ 30
D1	The past 50 years based on change in a <u>biotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 80	CR	EN	VU
		≥ 50	EN	VU	

		≥ 30	VU		
			≥ 80	≥ 50	≥ 30
D2	(D2a) The next 50 years, or (D2b) any 50-year period including the present and future, based on change in a <u>biotic</u> variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table: OR	≥ 80	CR	EN	VU
		≥ 50	EN	VU	
		≥ 30	VU		
			≥ 90	≥ 70	≥ 50
D3	Since 1750, based on a change in a biotic variable affecting a fraction of the extent of the ecosystem and with relative severity, as indicated by the following table:	≥ 90	CR	EN	VU
		≥ 70	EN	VU	
		≥ 50	VU		
E. Quantitative analysis					
			CR	EN	VU
… that estimates the probability of ecosystem collapse to be:			≥ 50% within 50 years	≥ 20% within 50 years	≥ 10% within 100 years