GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Nomination *(to be completed by nominator)*

Current conservation status	
Name of ecological community:	Communities of Tumulus Springs (Organic Mound Springs, Swan Coastal Plain)
Other names:	Mound springs Swan Coastal Plain (SCP); SCP mound springs, tumulus springs.
Description:	The community occurs in tumulus springs (organic mound springs) on the Swan Coastal Plain. The habitat of the mound springs is characterised by continuous discharge of groundwater in raised areas of peat. The peat and surrounds provide a stable, permanently moist series of microhabitats, with a high level of heterogeneity of invertebrate fauna assemblages between sites. Groups commonly represented include Ostracoda, Nematoda, Cladocera, Copepoda, Oligochaeta, Tardigrada, Turbellaria and Insecta. Typical and common native vascular plant species associated with the tumulus springs are the trees *Banksia littoralis* (swamp banksia), *Melaleuca preissiana* (moonah) and *Eucalyptus rudis* (flooded gum), and the shrubs *Taxandria linearifolia* (willow myrtle), *Pteridium esculentum* (bracken fern), *Astartea scoparia* (common astartea) and *Cyclosorus interruptus* (swamp shield-fern).
Nomination for:	Listing under BC Act ☒ 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	16/07/2000	Endangered	
Western Australia	WA Minister ESA list in policy	21/11/1995	Critically endangered	A)i,ii; B)i,ii
	Priority list		1 ☐ 2 ☐	3 ☐ 4 ☐
Other State/Territory				

Nominated conservation status: category and criteria (include recommended status for deleted ecological communities)			
Critically endangered (CR) ☒	Endangered (EN) ☐	Vulnerable (VU) ☐	Collapsed (CO) ☐

Priority 1 ☐	Priority 2 ☐	Priority 3 ☐	Priority 4 ☐	None ☐

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 3 table 'IUCN Red List Criteria for ecosystems version 2.2'.*	A3; B1b

Eligibility against the criteria

Provide justification for the nominated conservation status; is the ecological community eligible or ineligible for listing against the five criteria. For ***delisting****, provide details for why the ecological community no longer meets the requirements of the current conservation status.*

A.	Reduction in geographic distribution *(evidence of decline)*	☐ **A1** ☐ **A2a** ☐ **A2b** ☒ **A3**
	Justification of assessment under Criterion A.	• For criteria A and B, the ecosystem is assumed to collapse when the mapped distribution declines to zero. • Keighery and Trudgen (1992) estimated that clearing for agriculture has been extensive on the heavy soils on the eastern side of the Swan Coastal Plain, with some 97% of all vegetation in the area cleared historically (CALM 1990). The level of clearing of this portion of the Swan Coastal Plain is assumed to reflect the clearing of the Communities of Tumulus Springs. Many springs have been cleared, or cleared and packed with limestone (Jasinksa and Knott 1994). The community is currently known from 27ha. As the timing of clearing is not known, it is assumed that the clearing of 97% of the area of the community occurred since ~1750 (≥90% loss is threshold for CR under A3). • **Plausibly meets criterion CR under A3**
B.	Restricted geographic distribution *(EOO and AOO, number of locations and evidence of decline)*	☒ **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)**
	Justification of assessment under Criterion B.	• B1: EOO is 322km^2 (≤2,000km^2). The community's EEO is less than the 2,000km^2 threshold for rank CR. Community meets threshold for rank CR under criterion part B1. • B2: AOO is three 10x10 km grid cells (threshold for EN is 20, and for CR is two grid cells). Community meets threshold for rank EN under criterion part B2. • a): i, ii, iii): Few appropriate data are available to measure decline in environmental quality or disruption to biotic interactions. • b): There is observed or inferred continuing decline from vegetation clearing, too frequent fire, weeds, grazing and inferred future decline in environmental quality from hydrological changes, that are likely to cause continuing decline in the next 20 years (see Appendix 1 for further

		information on threats). **Meets CR under B1b. Meets EN under B2b.** • c): Community is considered to occur at three threat-defined locations, based on the identification of northern, central and southern clusters of occurrences of the community that are likely to be subject to similar threats (including hydrological change associated with particular aquifers that support the community) threshold for CR is one, for EN is five, and for VU is 10 threat-defined locations). **Meets EN under B1c, B2c.** • B3): Known from three threat-defined locations based on the identification of clusters of occurrences of the community that are prone to effects of human activities or stochastic events (for example hydrological change associated with particular aquifers) 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 defined locations). **Meets VU under B3.** • **Meets CR under B1b. Meets EN under B1c, B2b, B2c. Meets VU under 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. Groundwater levels in the Yarragadee and the Perth Superficial Swan aquifers are continuing to decline. A 50-year forecast of groundwater decline in the Yarragadee aquifer at southern occurrences (Wandi, Wellard, Duckpond springs; occurrences 10, 9 and 8 respectively) has indicated the level in this area is predicted to fall by nearly 35m. 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 threats in Appendix 1). • A decline in rainfall resulting from drying climate and higher water temperatures will also likely result in a decline in groundwater recharge. A 16% decline in the rainfall (long-term average) has been recorded for the South West Region

		over a hundred-year period. The likely relative severity of the changes and their impacts on the community is uncertain. • Inadequate evidence to indicate if the community meets the minimum threshold for proportion of the extent (≥30%) or proportional severity of degradation (≥30%) over any 50-year period to meet VU under these criteria. • **Inadequate evidence to indicate if the 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.	• Weed invasion is a significant biotic threat to the community. • The severity of weed invasion associated with collapse is uncertain, but it is assumed conservatively that the community reaches a collapsed state when only 10% (plausible range 0–20%) of its plant species are native. • D1, D2, D3: Historic and current grazing of areas on private property has led to the extensive weed invasion. Weeds have also invaded along tracks, firebreaks and road reserves. • There are no systematically collected data indicative of changes in the level of weed invasion in the community. • Inadequate evidence to indicate if the community meets the minimum threshold for proportion of the extent (30%) or proportional severity of disruption of biotic processes (30%) over any 50-year period, or since 1750 (50% disruption of biotic processes / 50% of the extent) to meet VU under criterion D. • **Insufficient evidence to indicate if the community meets criterion D.**
E.	Quantitative analysis *(statistical probability of ecosystem collapse)*	• No quantitative estimates of the risk of ecosystem collapse. • **Unable to assess**

Reasons for change of status
Genuine change ☐ New knowledge ☐ Previous mistake ☐ Review/Other ☒
Provide details: The community was ranked critically endangered using ranking criteria developed in WA that differ from 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	322km^2	AOO	Three 10x10 km grid cells
No. occurrences	10	Severely fragmented	Yes ☒ No ☐ Unknown ☐
Justification	The tumulus mound springs community is naturally fragmented as springs occur in very specific habitats of continuous groundwater discharge. Extensive clearing has greatly increased fragmentation and isolation.		
Current known area			27ha
Pre-industrialisation extent or its former known extent (if known)			Unknown

Estimated percentage decline	Based on Keighery and Trudgen (1992) estimate of 97% clearing of eastern side of the plain, original area ~900ha (ie 3% remaining: 27ha x100/3)

Summary assessment against IUCN RLE Criteria

Criterion	Rank indicated	Overall conclusion
A1	-	• Insufficient evidence to indicate if community meets criterion
A2a	-	• Insufficient evidence to indicate if community meets criterion
A2b	-	• Insufficient evidence to indicate if community meets criterion
A3	CR	• An estimate loss of 97% of all vegetation where community occurs since ~1750. • Plausibly meets criterion for CR
B1a	-	• Few appropriate data are available to measure decline in environmental quality or disruption to biotic interactions. • Does not meet criterion
B1b	CR	• EOO is ≤2,000km^2 • Observed and inferred threats likely to cause continuing decline within the next 20 years • Meets criterion for CR
B1c	EN	• EOO is ≤2,000km^2 • Ecosystem exists at three threat-defined locations • Meets criterion for EN
B2a	-	• Few appropriate data are available to measure decline in environmental quality or disruption to biotic interactions. • Does not meet criterion
B2b	EN	• AOO is three grid cells • Observed and inferred threats are likely to cause continuing decline within the next 20 years • Meets criterion for EN
B2c	EN	• AOO is three grid cells • Ecosystem exists at three threat-defined locations • Meets criterion for EN
B3	VU	• Known from three threat-defined locations • Prone to the effects of human activities or stochastic events within a short time period in an uncertain future • Meets criterion for VU
C1	-	• Inadequate evidence to indicate if 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	-	• Inadequate evidence to indicate if 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 if 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 if the community meets the minimum thresholds for proportion of the extent (≥30%) or proportional severity of degradation (≥30%) over the last 50 years to meet VU.

D2	-	• Inadequate evidence to indicate if 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.
D3	-	• Inadequate evidence to indicate if 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.
		Plausibly meets criteria for critically endangered under A3, B1b. Meets EN under B1c, B2b, B2c. Meets VU under B3. ***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 under A3; B1b**

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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
1. EG01 EgertonSprings01	Freehold (WAPC)	2018	100% excellent	3.6	Hydrological changes, weeds, grazing, too frequent fire (*past*, *present, future*), climate change (*current, future*)	
2. PETERS01	Nature reserve	2018	100% good-degraded (repeat fires have greatly increased drying and weed invasion. No surface water early October 2018 despite preceding very wet winter)	1.2	Hydrological changes, weeds, grazing, too frequent fire, dieback disease (*past*, *present, future*), climate change (*current, future*)	Area containing occurrence secured through purchasing and reservation
3. KINGS01 KINGS02	Freehold (WAPC), nature reserve	2016	80% very good 20% good (weeds, peat drying)	6.0	Grazing and trampling (kangaroos), hydrological changes, weeds, too frequent fire, dieback disease in adjacent vegetation (*past*, *present, future*), climate change (*current, future*)	Area containing occurrence secured through purchasing and reservation; fencing undertaken
4. MEECHIN01	Freehold (WAPC)	2004	100% excellent	1.0	Hydrological changes, weeds, too frequent fire (*past*, *present, future*), climate change (*current, future*)	
5. Alpaca01	Freehold	2017	100% good	0.8	Weeds, hydrological changes, too frequent fire (*past*, *present, future*), climate change (*current, future*)	

[redacted]	Freehold	2017	100% very good to good	7.3	Grazing (feral pigs), weeds, hydrological changes, too frequent fire (*past*, *present, future*), climate change (*future*)	
7. RAAFBomb01	Unallocated Crown land	2008	100% excellent	0.3	Weeds, hydrological changes, horses, too frequent fire (*past*, *present, future*), climate change (*current, future*)	
8. DuckpondSpring01 Love01	Freehold, rail reserve	2012	50% very good 50% excellent	0.7	Weeds, hydrological changes, grazing, too frequent fire (*past*, *present, future*), climate change (*current, future*)	
9. Wellard01	Freehold	2018	80% excellent 20% very good	2.7	Weeds, hydrological changes, too frequent fire (*past*, *present, future*), climate change (*current, future*)	
10. Wandi01	Crown reserve, DPLH	2019	100% very good	2.6	Weeds, hydrological changes, too frequent fire (*past*, *present, future*), climate change (*current, future*)	

*Condition categories from Keighery (1994) Vegetation Condition Scale (in 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 and native plant species diversity fully retained or almost so, zero or almost so weed cover/abundance, to ‘Excellent’ - Vegetation structure intact, with disturbance only affecting individual species, weeds are non-aggressive species, and the area contains high native plant species diversity, with less than 10% weed cover, and ‘Very Good’ - Vegetation structure altered, obvious signs of disturbance eg: from repeated fires, dieback, logging, grazing, aggressive weeds are present, with moderate native plant species diversity, and typical weed cover is less than 20% (5 – 20%).

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, logging, grazing, and very aggressive weeds are present, with low native plant diversity (5 – 50%).

Poor (‘degraded’, ‘completely degraded’ using Bush Forever (2000) scale): This includes vegetation ranging from ‘Degraded’ Basic vegetation structure severely impacted by disturbance, the vegetation requires intensive management, and disturbance such as partial clearing, dieback, logging and grazing are present, very aggressive weeds are present at high density, and very low native plant species diversity is observed (20 – 70%) to ‘Completely Degraded’ where vegetation structure is no longer intact and the area is completely or almost completely without native flora, referred to also as ‘Parkland Cleared’, with very low to no native species diversity (weed species greater than 70%).

APPENDIX 1 THREATS

Land clearing

Clearing for agriculture has been extensive on the heavy soils on the eastern side of the Swan Coastal Plain, with some 97% of all vegetation in the area cleared historically (Keighery and Trudgen 1992; CALM 1990). In particular, the tumulus springs on heavy soils were often perceived as a hindrance to farming practices as they were excessively wet and boggy and many were cleared, levelled, packed with limestone and planted with kikuyu grass, excavated and dammed, or the spring brooks dammed (Ahmat 1993: Jasinksa and Knott 1994). Residential or rural development surrounds the majority of the spring areas, with significant potential to impact on local groundwater flow and quality, in addition to general impacts of rainfall decline and abstraction on the regional flows from Gnangara and Jandakot Mounds that support the spring flow.

Figure 1. Aerial photos showing the growth of urban areas surrounding Egerton springs from 2004 to 2019 (from WRM 2020).

Dunes of varying sizes occur on the western side of tumulus spring areas and are likely to provide important recharge areas, and to be involved in providing the hydraulic pressure head for the adjacent spring area. A number of occurrences (Wandi, Egerton, and Duckpond springs; occurrences 10, 1 and 8 respectively) are surrounded by developed areas and their recharge dune has been removed or fundamentally altered. These dunes are significant in terms of maintaining spring flow. The Banksia woodland vegetation on the dune to the west of Peters mound spring (occurrence 2) has been largely denuded by a combined process of grazing, dieback deaths and drought. Under normal circumstances, rainfall intersecting the dune surface contributes to recharge of the local groundwater mounds. The sands can become hydrophobic when dry, in the absence of vegetation, or following destruction of vegetation by fire. In this situation, most of the rainfall would drain off and therefore would not contribute to the groundwater recharge (CALM 2006).

Weed invasion

Most occurrences of this community are close to weed sources such as urban and rural areas, and high levels of disturbance have led to significant weed invasion in some cases. Disturbance and increased nutrient levels from historic grazing at Peters spring has led to the introduction of *Isolepis prolifera* (budding club-rush), *Cenchrus clandestinus* (kikuyu) and Perennial veldt grass (*Ehrharta calycina*). Kings spring (occurrence 3) is relatively weed free, but *Rubus ulmifolius* (blackberry) and *Ficus carica* (fig) occur immediately adjacent to the springs and some *Isolepis prolifera* occurs on the mounds themselves. Occurrences subject to frequent fires are more prone to weed invasion. Weeds, including blackberry (*Rubus fruticosus)*, sharp rush (*Juncus acutus*), arum lily (*Zantedeschia aethiopica*), red ink plant (*Phytolacca octandra*), and budding club rush (*Isolepis prolifera*) are invading Alpaca spring (occurrence 5) following a hot fire in 2016. High level weed invasion also occurred at Gaston spring (occurrence 6) following a fire.

Weeds suppress early plant growth by competing for soil moisture, nutrients and light. They also exacerbate grazing pressure and increase the fire hazard due to the easy ignition of high fuel loads, which are produced annually by many weed species. Certain weeds, such as Veldt grass (*Ehrharta calycina*), can also contribute to the hydrophobic nature of soils by causing soils to repel water and should be kept away from the spring areas themselves and the adjacent dunes (CALM 2006). Grazing of areas on private property has led to the extensive introduction of pasture weeds in most private property occurrences.

Grazing and trampling

Peters spring was historically subject to intermittent grazing but was acquired as a nature reserve. Grazing has altered the species composition through the selective removal of edible species, the introduction of weeds as a consequence of disturbance and increased nutrients from animal droppings, contributing to the decline of nonvascular plants that were recorded historically. Kings mound spring is currently subject to grazing and trampling by high numbers of kangaroos. Following the purchase of the land, the spring and vegetated buffer were re-fenced in April 2004 to exclude stock (CALM 2006). Feral pigs were found to be an issue at Gaston spring in 2019, causing destruction of the habitat at the site. Nursery spring was lightly grazed when last surveyed, and Duckpond spring was lightly grazing by cattle. Horse prints were also observed at RAAF spring (occurrence 7).

Altered fire regimes- frequent and intense

Fires are likely to have a significant effect on vegetation composition in Mediterranean ecosystems (Abbott and Burrows 2003). It is also likely that the fire regime around each of the spring areas has been altered since 1750, especially those located in agricultural areas. The wetland vegetation associated with the springs is likely to be less adapted to very hot fires than upland vegetation as the sites are permanently moist and are unlikely to have burnt as readily. In addition, the build-up of peat makes the areas very prone to fires that occur in dry seasons that are capable of destroying the peat mounds themselves. An increase in the frequency of hot fires is likely to pose a significant threat to the wetland-adapted flora and fauna. Recent fires (2016) at Alpaca and Gaston springs resulted in massive weed invasion. Repeat fires at Peters spring have also greatly increased drying and weed invasion. The risk of fire is increased by the presence of grassy weeds in the understorey at Peters spring as they are considerably more flammable than the original native species in the understorey (CALM 2006).

Changes to hydrology

The maintenance of the flora and fauna of the tumulus springs community is dependent on a permanent supply of fresh water and in the local water mounds in dunes adjacent to each of the spring areas. It is likely that the pressure from the superficial aquifer drives the springs. The local hydrologic pressure created in parts of the aquifer within the dunes adjacent to each of the spring areas is also likely to be significant in terms of maintaining the spring flow. Rainfall falling on the dunes adjacent to the springs would be involved in recharge of the groundwater that feeds the springs (CALM 2006).

Two of the occurrences, Peters01 and Kings01, were found to have dry peat when last observed, despite substantial rainfall in the preceding season. This could be due to groundwater drawdown in the local area exacerbated by declining rainfall (CALM 2006). A proposed sand mine to the north of Wellard spring may also result in changes to water level and quality. A proposed high school site adjacent Wandi01 will require significant volumes of water for irrigation. The Alpaca site (Alpaca01) is located adjacent a market garden and water levels are rising and falling rapidly. Gaston spring is also approximately 300m east of where the northern section (Ellenbrook to Muchea) of Northlink WA was constructed and this will likely result in changes to local groundwater levels and watershed hydrology (WRM 2020).

The groundwater feeding the springs consists of three main aquifers – the unconfined Superficial aquifer (in the north commonly known as the Gnangara Mound, in the south – the Jandakot Mound), the deep, partly confined Leederville aquifer and the deep, mostly confined Yarragadee aquifer. The Yarragadee aquifer is recharged directly by rainfall where it outcrops and by downward leakage via the Leederville aquifer and superficial aquifer (Strategen 2006). Therefore decline of the Yarragadee aquifer has potential to impact the superficial aquifer.

Data from bores (from Department of Water and Environmental Regulation's Water Information Network website) that occur adjacent to occurrences provide useful information on the trend of groundwater in the area in both the superficial and deep aquifers. Figures 2a, 4a, 5 and 6 below show declining trends for groundwater of approximately 0.5 to 2m, in the local Perth Superficial Swan aquifer, the aquifer most likely to influence the community. In particular, the 2020 water level recorded near Gaston spring (figure 5) was the lowest ever recorded in the bore (site reference: 61611043). Major construction works associated with development of the northern section of NorthLink WA commenced in November 2017 and localised abstraction of groundwater for dust suppression and to facilitate pavement construction works for the dual carriageway and Neaves Road interchange may account for this notable decline in the water table (WRM 2020). A 50-year forecast of projected groundwater levels for bores 61411044 and 61611021 adjacent to Kings, Peters and RAAF spring occurrences show a potential continuing decline of approximately 2 to 3m (figures 2b and 4b). As the flow of the springs rely on levels in the superficial aquifer, it is not known at what point declines in levels in the aquifer will reach a 'threshold', below which these springs will cease to flow (WRM 2020). The bore at Egerton springs showed a slight increase in groundwater (figure 3). This increase may be associated with a decline in evapotranspiration due to large scale clearing for urban development on adjacent lands, and may be short-lived.

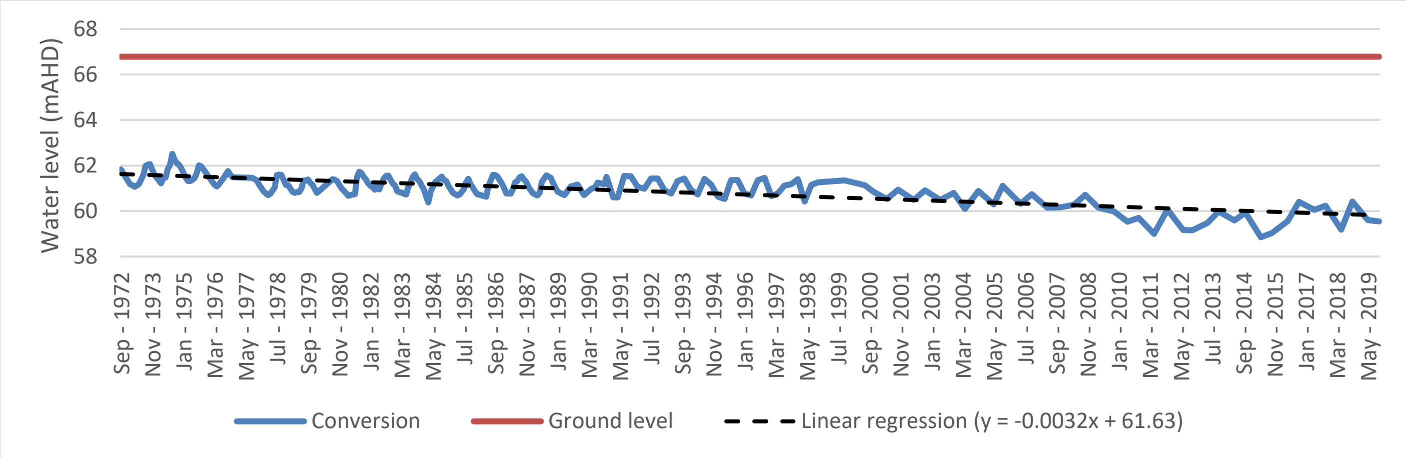

Figure 2a. Hydrograph of bore (site ref: 61611044) located 0.41km northwest of occurrence Peters01 and 1.6km northwest of RAAFBomb01. Bore located on Archibald St, Muchea. Bore data produced by sampling the Perth Superficial Swan aquifer.

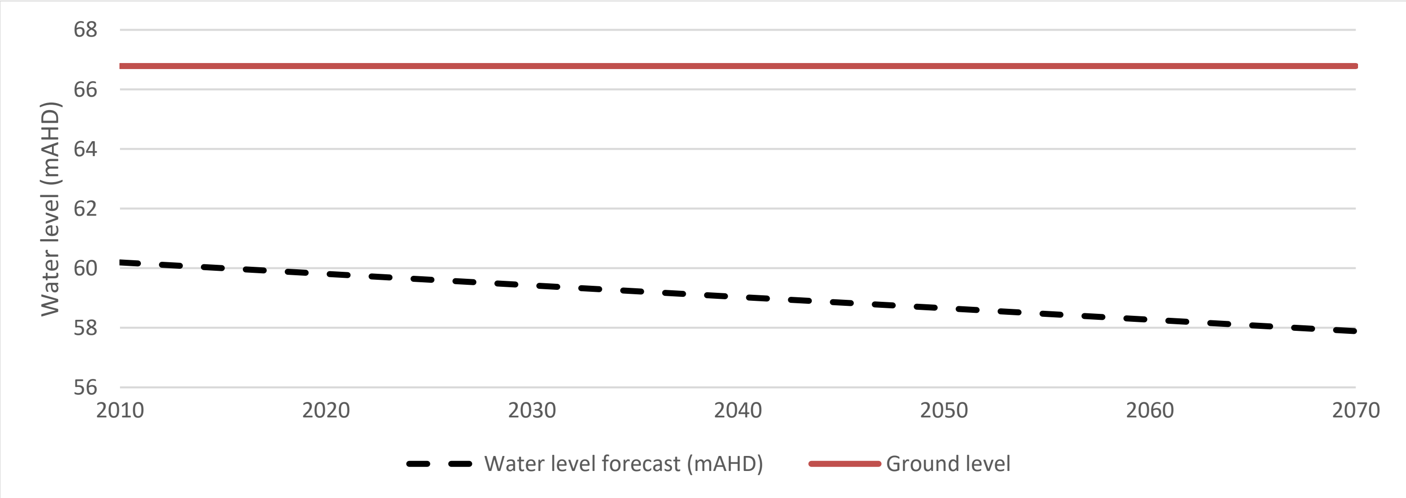

Figure 2b. A 50-year forecast of groundwater level decline at bore 61611044, located 0.41km northwest of occurrence Peters01 and 1.6km northwest of RAAFBomb01, calculated using the trendline (y=-0.0032x + 61.63).

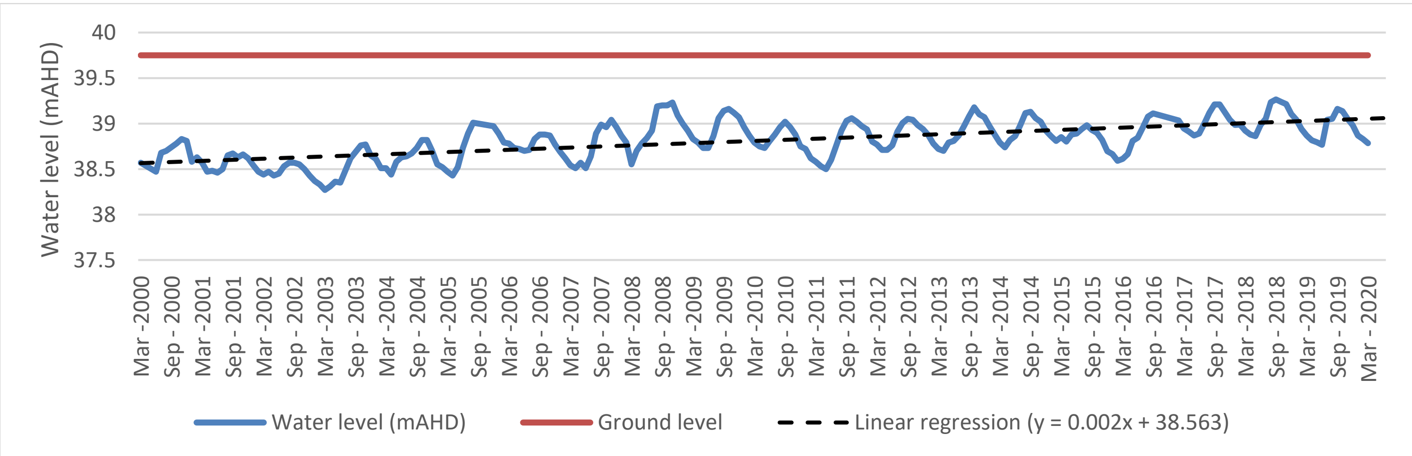

Figure 3. Hydrograph of bore (site ref: 61618607) located within occurrence EG01. Bore located at western side of Egerton Springs, Aveley. Bore data produced by sampling the Perth Superficial Swan aquifer.

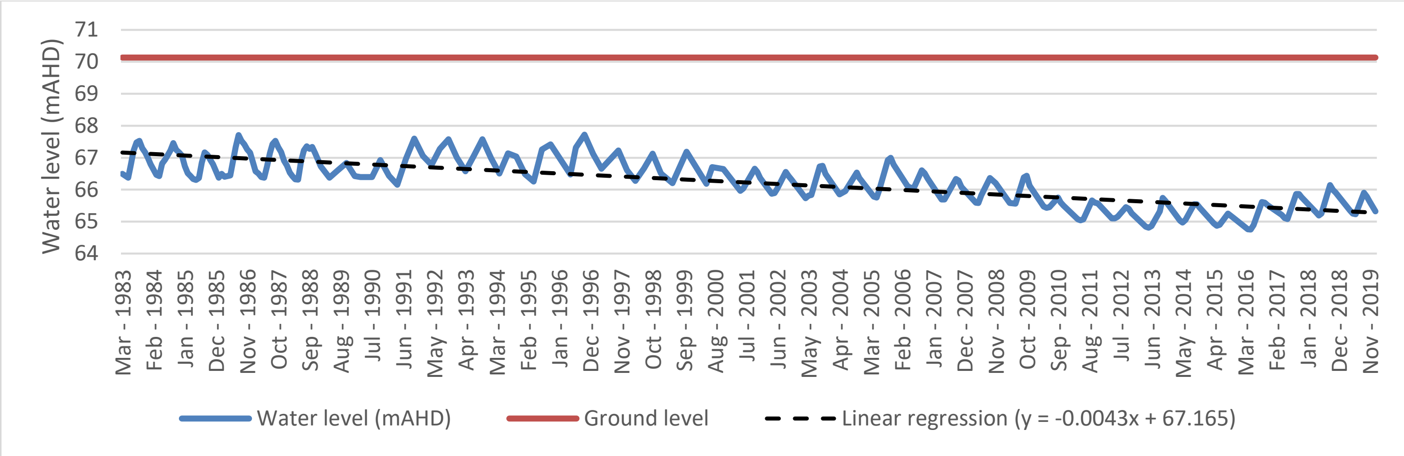

Figure 4a. Hydrograph of bore (site ref: 61611021) located 1.14km northwest of occurrence Kings01/02 and 1.08km west-north-west of occurrence Meechin01 (occurrence 4). Bore located at Kirby Road, Bullsbrook. Bore data produced by sampling the Perth Superficial Swan aquifer.

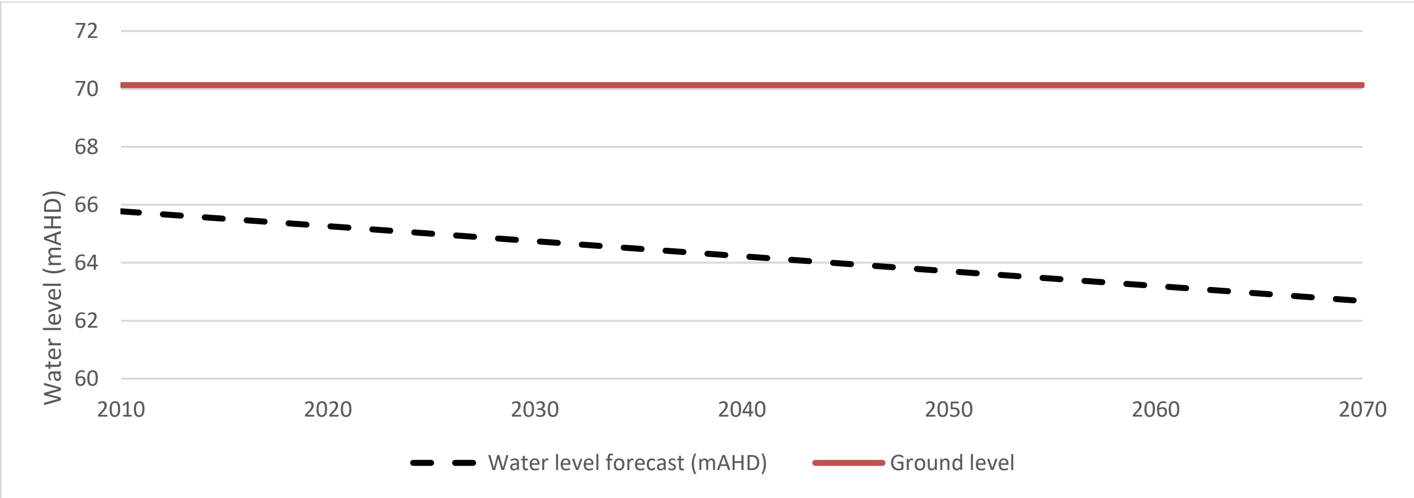

Figure 4b. A 50-year forecast of groundwater level decline at bore 61611021, located 1.14km northwest of occurrence Kings01/02 and 1.08km west-north-west of occurrence Meechin01, calculated using the trendline (y=-0.0043x + 67.165).

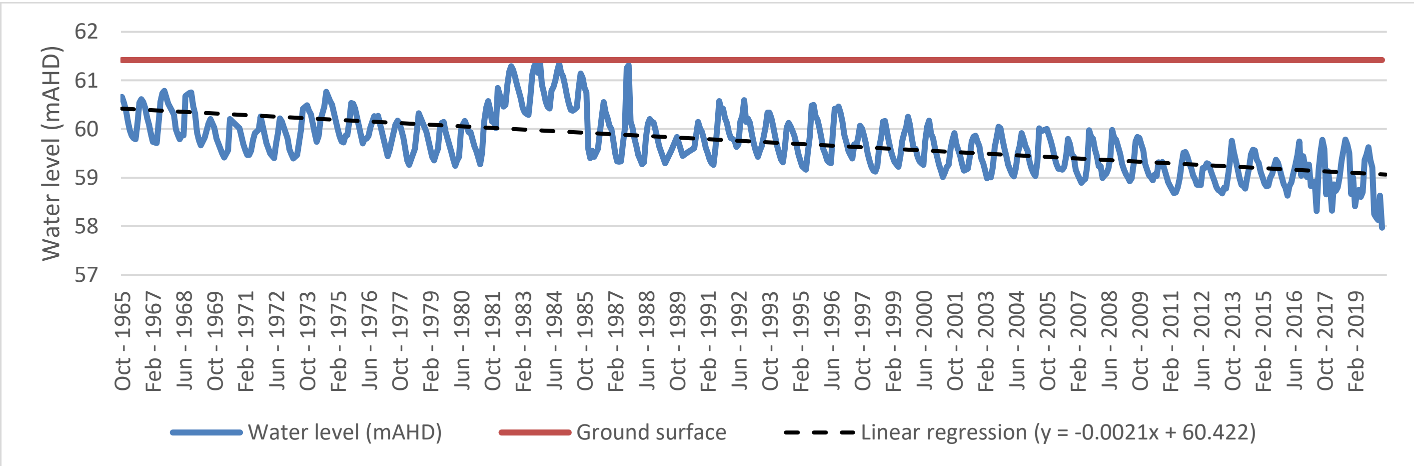

Figure 5. Hydrograph of bore (site ref: 61611043) located 0.42km northwest of occurrence Alpaca01 and 0.55km west of occurrence Gaston01/Nursery01. Bore located on Bingham Road, Bullsbrook. Bore data produced by sampling the Perth Superficial Swan aquifer.

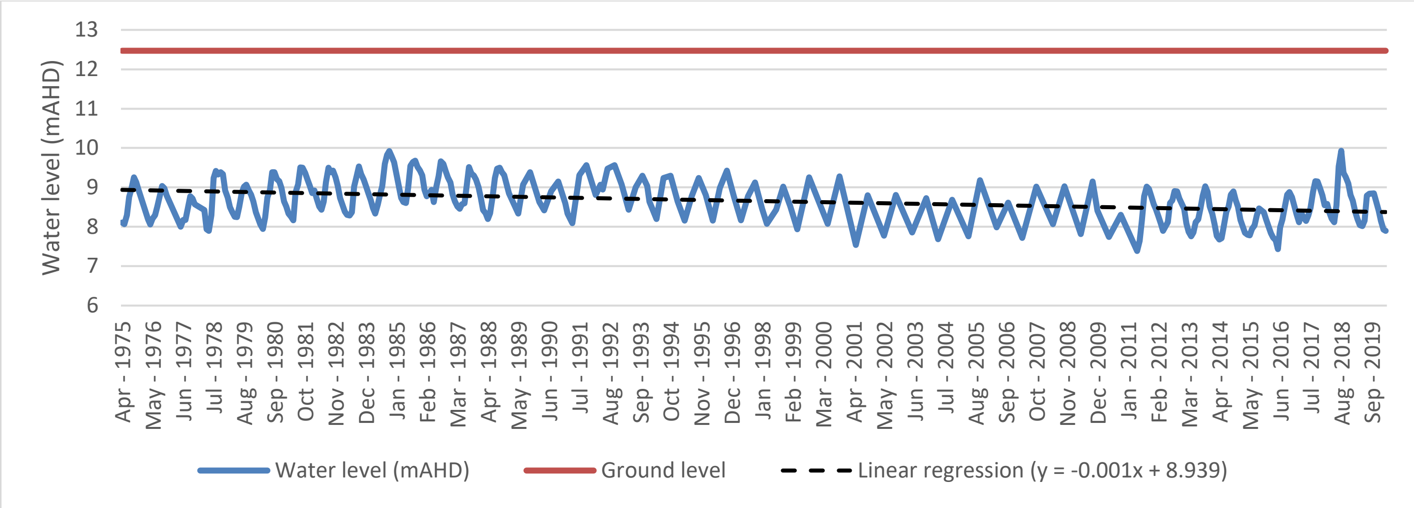

Figure 6. Hydrograph of bore (site ref: 61410095) located 1.44km west of occurrence Wellard01. Bore located on Woolcoot Rd, Wellard. Bore data produced by sampling the Perth Superficial Swan aquifer.

Higher volumes of groundwater are abstracted from the Yarragadee aquifer which has shown a significant decline (figures 8, 9 and 9a). The largest groundwater decline is evident within the southern-most occurrences (Wandi, Wellard, Duckpond), with a decline of nearly 35m occurring over 36 years. A 50-year forecast of the projected groundwater level for bore 61415022 shows a potential continuing decline of up to approximately 50m (figure 9b).

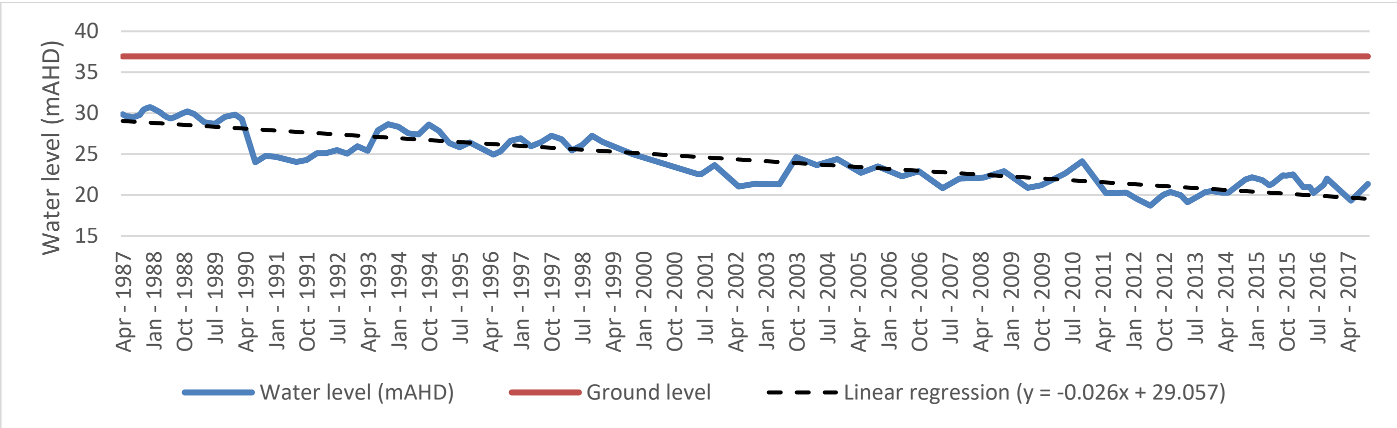

Figure 7. Hydrograph of bore (site ref: 61615107) located <9km from northern most occurrences (Gaston, Nursery, Alpaca, Meechin, Kings, RAAF, Peters). Bore located on Muchea South Rd, Bullsbrook. Bore data produced by sampling the Perth Yarragadee North aquifer.

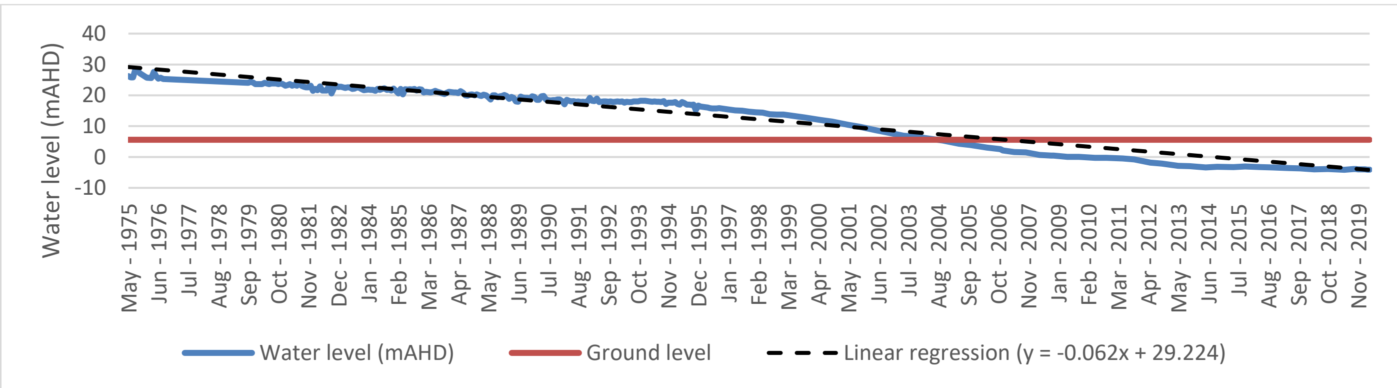

Figure 8. Hydrograph of bore (site ref: 61615104) located 2.5km from Egerton springs (central occurrence). Bore located on Swan St, Henley Brook. Bore data produced by sampling the Perth Yarragadee North aquifer.

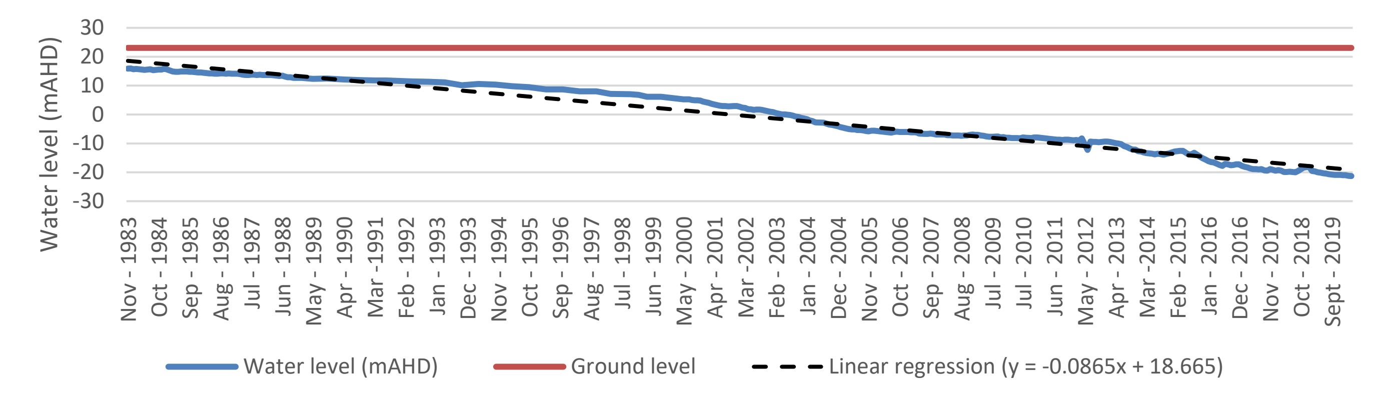

Figure 9a. Hydrograph of bore (site ref: 61415022) located <6km from southern occurrences (Wandi, Wellard, Duckpond). Bore located on Thomas Rd, The Spectacles. Bore data produced by sampling the Perth Yarragadee North aquifer.

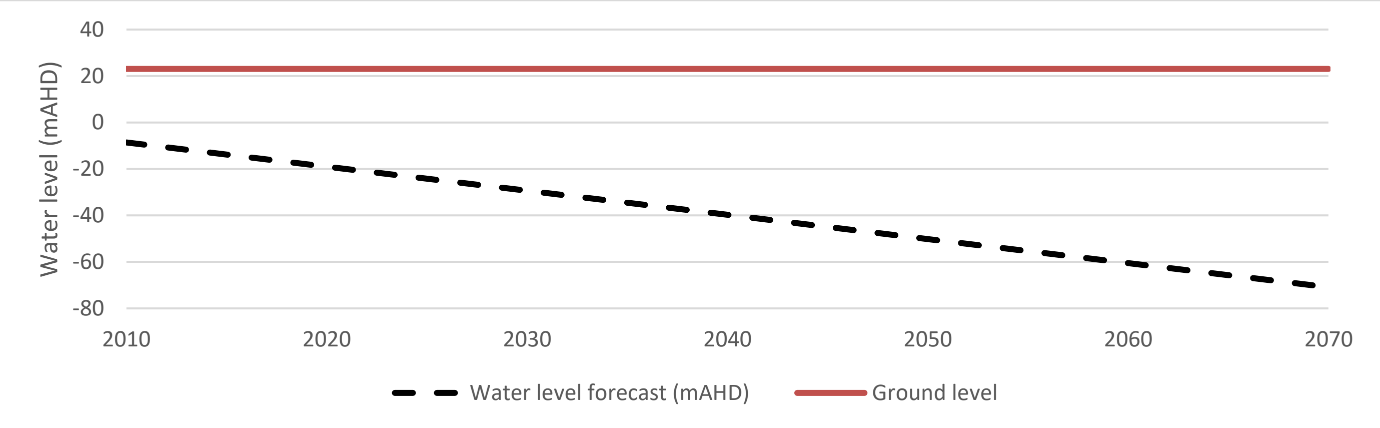

Figure 9b. A 50-year forecast of groundwater level decline at bore 61415022, located <6km from southern occurrences (Wandi, Wellard, Duckpond), calculated using the trendline (y=-0.0865x + 18.665).

Where animal droppings and other nutrient sources can contaminate surface or groundwater entering the springs, enhanced nutrient levels are likely to favour weed invasion and possibly alter water quality such that some components of the invertebrate fauna cannot survive. Nutrient input is most likely to be from very localised areas in the case of surface flow into the springs, so land use in areas close to the springs may also be very important for conservation of the water quality. It may also be possible for sources of pollution to enter the groundwater and eventually the springs from distant sources. Water quality variables recorded by WRM (2020) from Egerton and Gaston springs in October 2019, were compared to default Australian New Zealand Guidelines for fresh and marine water quality (ANZG 2018) for alternative levels (95%, 90% and 80%) of species protection. Nitrate (NO3-) levels recorded at Egerton Spring (3.37 mg/L) exceeded the 95% level of protection (0.7mg/L). This level represents eutrophication stress to resident fauna and poses increased risk of nitrate toxicity. Water quality data (sulphate concentrations and pH) from Gaston Spring also indicates the spring is susceptible to acidification, most likely associated with sediment dessication (i.e. acid sulphate soils) during periods of low groundwater level (WRM 2020).

Dieback disease

The dune vegetation that occurs to the west of Peters and Kings springs consists of Banksia woodlands that are likely to be important in maintaining the local hydrology of the springs. Banksia communities are highly susceptible to dieback caused by *Phytophthora* species. Loss of Banksia and other dieback susceptible species and replacement with species that use more water, such as taller trees impact the springs through drawdown of the groundwater table. The dune to the west of the Peters spring has been severely degraded, presumably initially through clearing, then from continued loss of juvenile plants through grazing. Dieback has also impacted the Banksia community by killing mature and juvenile individuals of susceptible species (CALM 2006).

Drying climate

The community is at risk from reduced rainfall with effects such as loss of vegetation from reduced groundwater recharge and surface water availability, contributing to the impacts of abstraction on the community. Climate change predictions for the south-western 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 March 2020):

- Rainfall will reduce by 2-14% (median 8%) by 2030, compared to 1975- 2007 baseline. Southwest is predicted to experience some of the largest reductions in rainfall in all of Australia.
- Runoff will reduce by 10-42% (median 25%) by 2030, compared to 1975- 2007 baseline.
- Temperature will increase by 0.5 -2.0ºC by 2030, compared to 1960-1990 baseline.

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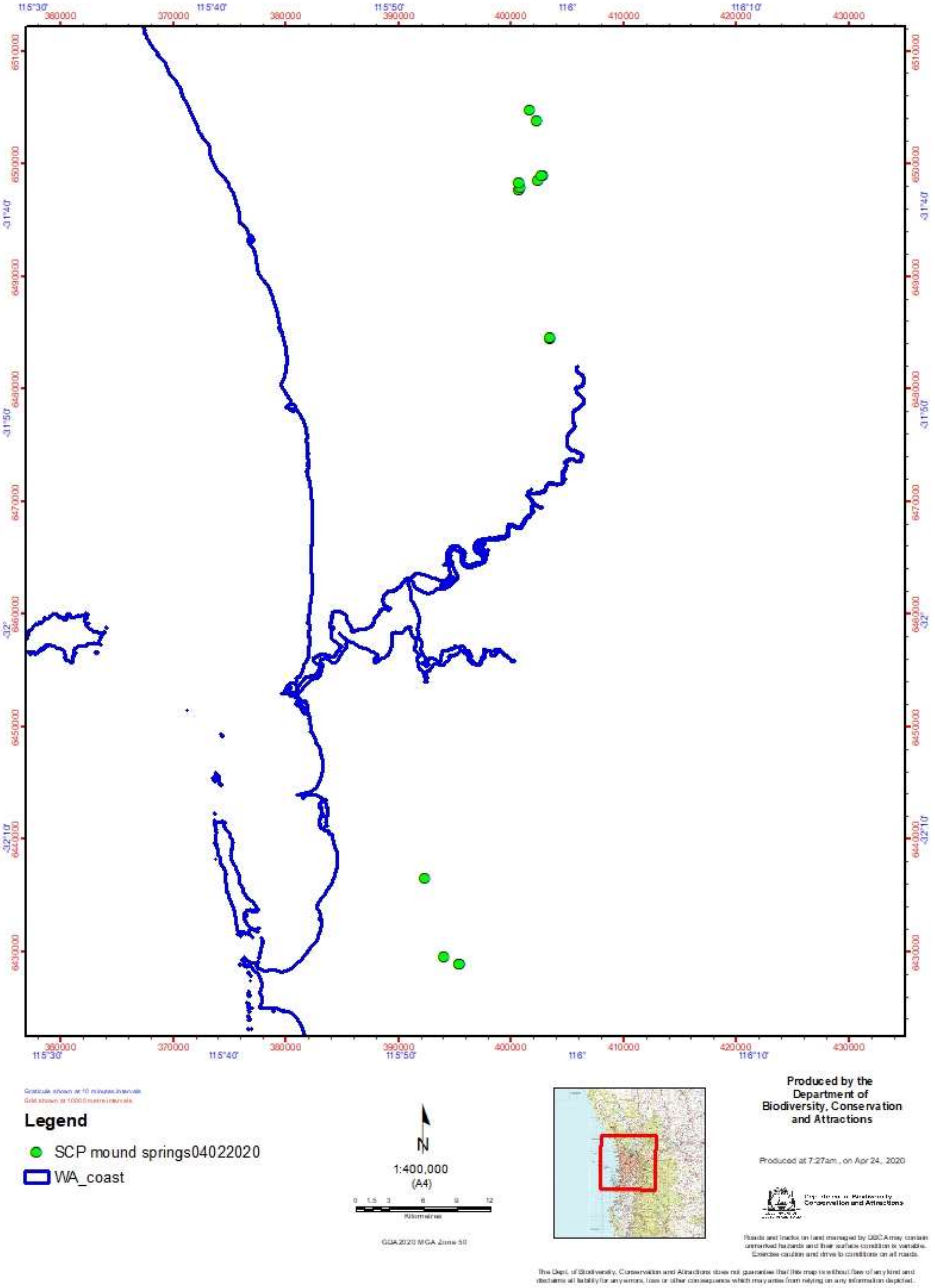
APPENDIX 2: Location of Communities of Tumulus Springs (green dots)



APPENDIX 3 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 abiotic 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 abiotic 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 abiotic 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 biotic 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		
D2			≥ 80	≥ 50	≥ 30

	(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