DETERMINATION OF ECOLOGICAL WATER REQUIREMENTS FOR WETLAND AND TERRESTRIAL VEGETATION – SOUTHERN BLACKWOOD AND EASTERN SCOTT COASTAL PLAIN.

A Report to the DoW

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CEM report no. 2005-07
ECU Joondalup

March 2006

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Project context

The Department of Water (DoW) is undertaking groundwater allocation planning work in the South West (Bunbury-Augusta) region. As part of the allocation process, the ecological values of the region must be identified and Ecological Water Requirements (EWRs) and Environmental Water Provisions (EWPs) set for groundwater dependent ecosystems.

A range of wetland and terrestrial vegetation mapping, classification and evaluation projects have been undertaken in the south-west in the past. In an attempt to update some of this information a wetland mapping, classification and evaluation project has been completed. This EWR project will link in with the mapping project, recommending EWRs for identified priority wetlands. The project will also build on recent terrestrial vegetation mapping, selecting possible ‘criteria sites’ and proposing intermediary EWRs.

This EWR study is one of several being undertaken as input into the South-west allocation planning work. It is aimed at determining quantitative criteria that, if adhered to, will enable priority wetland ecosystems and terrestrial vegetation to be maintained at a low level of risk. The criteria will be used by the DoW as inputs into groundwater modelling, which will assist in making an assessment of sustainable yield and aid in the determination of EWPs as part of the formal allocation process.

Preliminary EWRs have been proposed for likely groundwater-dependent ecosystems within the study area as part of a broader regional study undertaken by URS (URS, 2004). However, the EWRs proposed were generic and it was recognised that site-specific work would be required before the proposed criteria could be confidently used in any allocation planning or assessment work. This EWR study will build on the URS study and establish site-specific water regime criteria for selected wetlands and representative phreatophytic vegetation within the eastern Scott and southern Blackwood area.

This EWR study addressed the following;

1. Identification of phreatophytic vegetation criteria sites.
2. Establishment of wetland and terrestrial vegetation transects and baseline monitoring.
3. Proposal of ecological management objectives.
4. Determination of ecological water requirements.
5. Description of possible impacts due to water level decline.
6. Proposal of monitoring regimes.

The results of baseline monitoring and proposed monitoring regimes are presented as a separate report (Froend, Loomes, & Bertuch, 2006).

Task 1: Identification of phreatophytic vegetation criteria sites

Background/ Approach

Groundwater dependency

Groundwater dependent ecosystems (GDEs) can be defined as a complex community of organisms where groundwater is a key element required for consumptive use, biophysical processes or as habitat (Clifton & Evans, 2001). Six types of GDEs have been described, although the focus of this report is on groundwater dependent terrestrial vegetation, or vegetation communities with seasonal or occasional dependence on groundwater (phreatophytic) and wetlands, aquatic communities and fringing vegetation dependent on groundwater fed lakes and wetlands (Clifton & Evans, 2001; Hatton & Evans, 1998).

There are a number of groundwater attributes on which the dependency of GDEs is based: flow or flux; level/depth; pressure (for confined aquifers); and quality. While GDEs will respond to changes in any of these attributes, the degree of change will vary. Some GDEs may show a threshold response, whereby exceeding an attribute value will result in ecosystem collapse, while others may only show a gradual change in structure, composition or health (Clifton & Evans, 2001). Knowing which groundwater attribute at a site is most important to a given GDE can prove useful as a management target (Eamus, Froend, Hose, Murray, & Loomes, in press). Depth to groundwater is generally the most important attribute for ecosystems that rely predominately on groundwater, while depth and frequency of inundation are most important to ecosystems that rely on both surface expressions of groundwater and overland flow of surface water (i.e. floodplains, wetlands and base-flow rivers) (Eamus et al., in press).

GDEs can range from obligate to facultative groundwater users (Hatton & Evans, 1998). At species level, obligate groundwater use is evident if all instances of that species presence is dependent upon continuous, seasonal or episodic access to groundwater (Eamus et al., in press). Even if groundwater is relied upon only very infrequently, or frequently but for short periods of time, groundwater dependency is still classified as obligate (Eamus et al., in press). Examples of vegetative processes that may be dependent on groundwater availability include flowering, seed set and germination, seedling establishment and recruitment to reproductive age (Eamus et al., in press). Dependency is deemed facultative when groundwater is used when available although its absence DoWs not result in any adverse impacts to the vegetation (Eamus et al., in press). Facultative dependency may also include individuals that access groundwater when at shallow depths and individuals that have not accessed groundwater throughout their lives (i.e. at higher positions in the landscape) (Zencich, Froend, Turner, & Gailitis, 2002).

Determining the degree of dependence of an ecosystem on groundwater sources is an important step in describing the potential impacts of altered water regimes on dependent ecosystems. The underlying assumption in this process is that the closer the proximity of a plant's rooting zone to groundwater, the greater the potential dependency (Hatton & Evans, 1998). This step is also recognised as a key requirement for the establishment of policy and management systems for GDEs (Clifton & Evans, 2001). Hatton and Evans

(1998, p.1) considered that the "…degree of dependence was proportional to the fraction of the annual water budget that the ecosystem derived from groundwater". They describe five levels of groundwater dependence in which ecosystems may be categorized as entirely dependent, highly dependent or proportionally dependent on groundwater, may use groundwater opportunistically, or may have no apparent dependency on groundwater (Hatton & Evans, 1998). It follows that the greater the level of dependence on groundwater the greater the potential impacts that may arise from altered water levels or changes in water quality.

Eamus *et al.* (in press) review a number of approaches available to determine the degree of groundwater dependence of an ecosystem. Briefly, the first approach involves quantifying the proportion of annual water use derived from groundwater and the assumption that this represents a measure of dependency. It DoWs not however differentiate between obligate and facultative GDEs and is unlikely to accurately reflect the degree of dependence on occasional or episodic groundwater (Eamus *et al.* in press). The second approach involves quantifying the relationship between patterns of change in groundwater availability (i.e. depth, rate of change, decline in depth, duration of excessive depths etc) and vegetation responses. This approach was used by Scott, Lines and Auble (2000) and Shaforth, Stromberg and Pattern (2000) to quantify the relationship between patterns of change in groundwater availability and vegetation response, and applied by Froend, Rogan, Loomes, Bamford and Storey (2004) to *Banksia* woodlands and wetland vegetation of the Swan Coastal Plain, in order to ascertain phreatophytic vegetation response to separation from a groundwater source. This approach is particularly useful for determining individual species dependency on groundwater (Eamus *et al.*, in press). A third approach examines temporal patterns in soil moisture, rainfall and vegetation attributes known to be influenced by these factors (i.e. leaf area index and vegetation water use), although deductions can only be made about the *likely* temporal dependency, rather than the *degree* of dependency of terrestrial vegetation on groundwater (Eamus *et al.*, in press).

Water sources of terrestrial vegetation

Possible water sources of terrestrial vegetation are comprised only of groundwaters (soil water and groundwater), directly recharged by precipitation. The soil layer between the soil surface and water table is termed the unsaturated zone, as soil pore spaces are not saturated with water. The term 'zone of saturation' is designated to the subsurface water below the water table in which all voids between soil particles are filled with water (Freeze & Cherry, 1979). Immediately overlying the water table is the capillary fringe, also known as the tension-saturated zone (Freeze & Cherry, 1979), as the micro-pores are saturated with water and are held above the water table by capillary forces. Deep-rooted species with a dimorphic root structure have a large root capture zone and are therefore capable of using (if available) unsaturated soil moisture (both shallow and at depth) and groundwater (at depth), either derived from the capillary fringe or directly from the water table. Shallow rooted species unable to reach deeper soil at the extent of their root capture zone benefit from increased water availability via hydraulic lift within the capillary fringe, during periods of water stress (Naumberg, Mata-Gonzalez, Hunter, McLendon, & Martin, 2005).

Basis for phreatophytic vegetation categories

Dependency/ susceptibility categories were developed for previous investigations into the dependence of phreatophytic terrestrial, riparian and fringing tree species on various groundwater regimes (Froend & Loomes, 2004a; Froend, Loomes et al., 2004; Froend, Loomes, & Zencich, 2002; Froend & Zencich, 2001). Comparative data on mortality, species composition, groundwater depths before and after drawdown events as well as data from 'control' sites where groundwater drawdown had not occurred were utilised in this process. Figure 1 illustrates three of the four vegetation categories that have demonstrated phreatophytic behaviour to date:

- 0-3 m
- 3-6 m
- 6-10 m
- >10 m (not pictured).

The greater the depth to groundwater, the lower the requirement for groundwater and the more tolerant vegetation is to water table decline due to the corresponding increase in alternative water sources (Froend & Zencich, 2001). The primary alternative source is the larger volume of unsaturated zone (with increasing depth) exploitable by the plant's root system. Quantitative information suggests reduced importance of groundwater to terrestrial vegetation existing at depths to groundwater of >10 m (Eamus et al., in press). It is assumed that at depths of 10-20 m there is a probability of vegetation groundwater use, although it is thought to be negligible in terms of total plant water use, and that at depths of 20+ m this probability is substantially lower (Froend & Zencich, 2001).

Within the categories of 0-3 m, 3-6 m and 6-10 m (Figure 1), tree species are assumed to be phreatophytic and to derive some water from groundwater throughout the year. Between these categories the degree to which groundwater is utilised is dependent on the proximity to groundwater, availability of moisture in shallower horizons in the soil profile, root system distribution, maximum root depth and groundwater quality. The highest proportion of groundwater (>50% of daily summer water use) is used by the 0-3 m and 3-6 m depth to groundwater vegetation category. Given the apparent high dependency of trees in these shallow areas on summer access to groundwater, it is suggested that they are particularly susceptible to groundwater drawdown. Wetland plant associations, by definition, are within areas of very shallow depth to groundwater and therefore their response to drawdown is equivalent to that of the 0-3m phreatophyte category vegetation. Vegetation in the 6-10 m category also uses groundwater however, it uses proportionally more water from the upper layers of the soil profile as it has a larger subsurface soil moisture store beyond the influence of direct evaporation (Zencich et al., 2002).

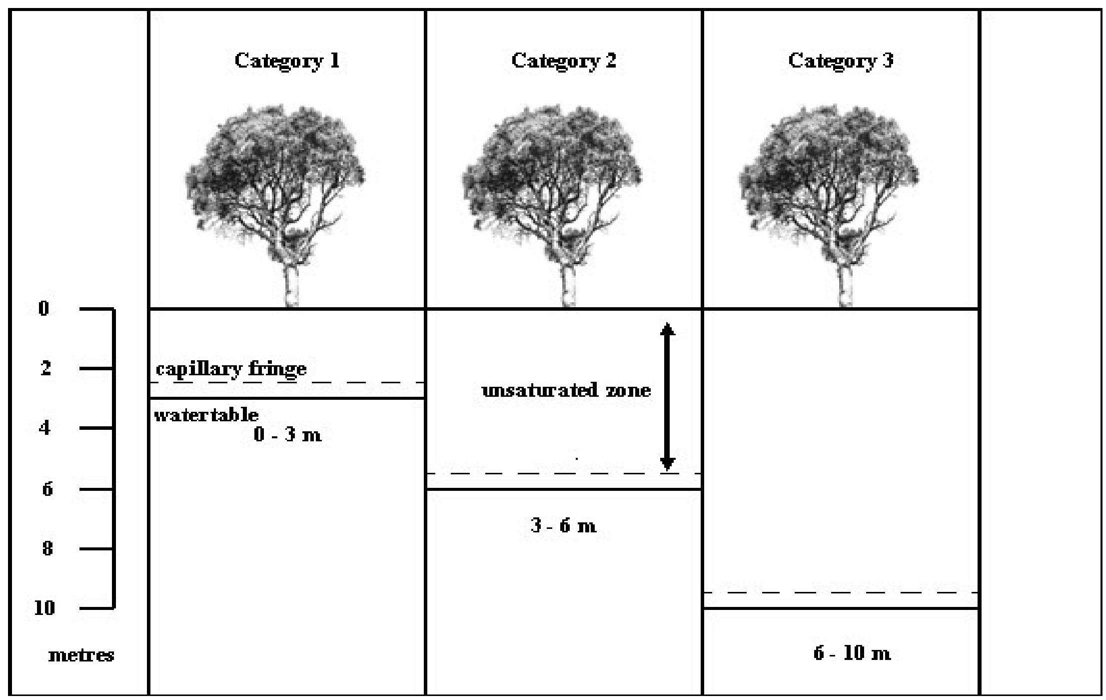


Figure 1: Categories of maximum depth to groundwater that have demonstrated phreatophytic behavior in sandy soils. Clay soils may have more extensive capillary zone of up to 2 or 3 m.

The depth to groundwater categories have been developed based on a gradient of vegetation types on the Swan Coastal Plain, ranging from fringing wetland species to dryland vegetation on upper slopes and dune crests. As a desk-based approach to initially characterise vegetation communities at risk of impact from altered groundwater regimes, this method can be applied to other regions with different soil types and vegetation types, providing these differences are taken into consideration.

Study approach

Existing vegetation mapping/values information, GDE mapping and depth to groundwater contours were complied and a desk-based assessment undertaken to identify sites supporting high value phreatophytic vegetation representative of various vegetation complexes across the study area. Due to project time constraints, five sites supporting appropriate areas of vegetation were identified (Table 1) in close proximity to existing monitoring bores. During field verification of sites in June/July 2005, a further 5 terrestrial sites were identified in close proximity to wetland sites proposed in the concurrent wetland mapping and valuation project. The terrestrial sites have been selected from intact vegetation in areas of high conservation value (eg. National Park, Nature Reserve) where depth to groundwater during April 2004 (autumn minimum) was no more than 10 m from the ground surface (as shown in modelling by DoW).

A search of CALM database during the URS (2004) study indicated that there were no TECs in study area. However, a number of Declared Rare Flora (DRF) species were identified near the Blackwood River, Lake Jasper and Blackpoint, Pneumonia, Stewart, South Coast and Darrdaup Rds. Although known DRF locations were not specifically targeted, these areas are well represented by the criteria sites and habitats supporting DRF should be protected.

Results

Tables 1 and 2 present summaries of wetland and terrestrial vegetation site details including GPS co-ordinates, site name, modelled water depth categories (April 2004), actual depth to groundwater (July 2005), conservation values/ land tenure, vegetation complex and a list of key vegetation species. The location of all sites is presented in Figure 2. Wetland criteria sites were identified and described further in the concurrent wetland project. Photographs of all sites are presented in Appendix 1.

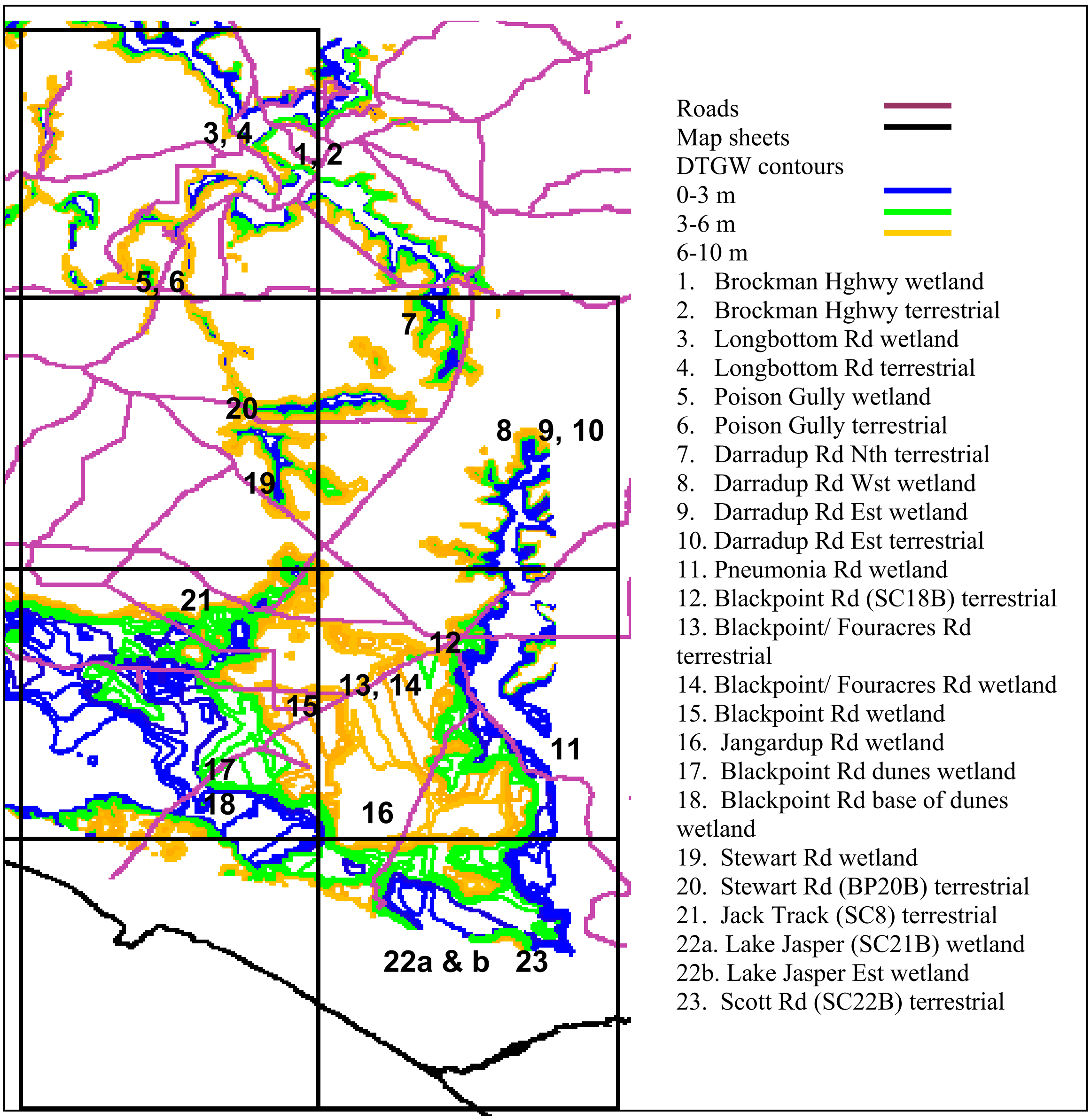


Figure 2: Location of criteria sites

Five of the ten terrestrial criteria sites were located in close proximity to existing monitoring bores; Stewart Rd (BP20B), Darradup Rd North (BP42B), Jack Track (SC8), Scott Rd (SC22B) and Blackpoint Rd (SC18B). The five remaining sites; Blackpoint/ Fouracre Rd., Darradup Rd East, Blackwood River Crossing, Brockman Highway and Poison Gully, were located adjacent to wetland sites identified in the wetland project. Available hydrological data and groundwater levels determined at the time of transect establishment indicates that these sites represent the three currently recognised depths to groundwater categories.

Blackpoint/ Fouracres Rd

The Blackpoint/ Fouracre Rd site was established approximately 40 m west of wetland site 5A. This site is located in an area modelled as occurring in the 6-10 m depth to groundwater category, within a National Park and in close proximity to vegetation known to support DRF or priority flora (Mattiske, 2004). Vegetation complex mapping indicates the area falls within the Scott (Sd) complex described as 'low open forest and low woodland of *Eucalyptus marginata subsp. marginata* (jarrah), *Corymbia calophylla* (marri) and *Agonis flexuosa* (peppermint) with some *E. patens* and *Banksia* sp.' (Mattiske & Havel, 1998).

The composition of vegetation at the site was assessed and further described in July 2005. The area was logged historically however, *E. marginata* has re-established as the dominant overstorey species, with *B. grandis* prevalent but less dominant, and *Xylomelum occidentale* (woody pear). The dense, species rich understorey supported species common to the region including *Macrozamia riedlei* and *Xanthorrhoea preissii* and shrub species *Taxandria parviceps, Hypocalymma robustum* and *Adenanthos obovatus*. All vegetation appeared in excellent condition with a great number of *B. grandis* seedlings noted.

Darradup Rd east

A terrestrial site was established on Darradup Rd East adjacent to wetland site 13Y. This site is situated within a previously logged area of a National Park modelled as occurring in the 0-3 m depth to groundwater category. The area supports DRF of priority flora (Mattiske, 2004). Mapping suggests the Coate vegetation complex, described as 'low open woodland of *Melaleuca preissiana, Banksia littoralis* and *Banksia ilicifolia* over *Taxandria parvicep*s…' is dominant (Mattiske & Havel, 1998). However, assessment of the site in July 2005 found the vegetation to be low open forest of *E. marginata* and *C. calophylla* with *Allocasuarina fraseriana* and *B. ilicifolia*. The understorey was relatively open and comprised of species including A. *obovatus, A. meisneri, H. robustum* and *Adiatum* sp. All vegetation appeared to be in good condition.

Blackwood River Crossing – Longbottom Rd

The Blackwood River Crossing site is situated within a National Park adjacent to wetland site 21 on Longbottom Rd approximately 20kms south-west of Nannup. Groundwater modelling suggests the site falls in the 0-3 m depth category. Vegetation complex mapping indicates the area falls within the Layman complex described as 'woodland of *E. marginata subsp. marginata* with some *C. calophylla* and *E. patens* over *A. fraseriana, Nutysia floribunda, B. littoralis* and *M. preissiana* with *T. parviceps*…'(Mattiske &

Havel, 1998). During site assessment in July 2005 it was found that the actual community composition closely matched the terrestrial component of the Layman complex, with the wetland elements found within the adjacent wetland site. The site has been logged in the past and although the overstorey has recovered it remains relatively open. All vegetation appeared in good condition.

Brockman Highway

A terrestrial site was established in a State Forest adjacent to wetland site 22 (Milyeanup) on the Brockman Highway approximately 19kms south-west of Nannup. This site is located in an area modelled as occurring in the 0-3 m depth to groundwater category that is known to support DRF or priority flora (Mattiske, 2004). Vegetation complex mapping indicated vegetation of the area represents the Milyeanup complex described as 'Open forest of *E. megacarpa* and *E. patens* over *Callistachys lanceolata*, *Agonis flexuosa*…' with various shrubs (Mattiske & Havel, 1998). However, assessment of the site in July 2005 found the vegetation to be low open woodland of *E. marginata, C. corymbia. littoralis* and *B. grandis*. The understorey was relatively dense comprising species including *T. parviceps*, *M. riedlei, X. preissii* and *Persoonia longifolia*. All vegetation appeared in good condition.

Poison Gully

The Poison Gully site was established in State Forest adjacent to wetland site 31 on Blackwood Rd. west of Brockman Highway within an area modelled as 0-3 m depth to groundwater. The area is known to support DRF or priority flora (Mattiske, 2004). Vegetation complex mapping indicated vegetation of the area represents the Jalbaragup complex described as 'open forest of *E. patens* and *E. rudis* on valley floors over variable soils with *X. occidentale, Hakea lasianthoides, Agonis flexuosa* and *B. seminuda* with *T. parviceps*…'(Mattiske & Havel, 1998). However, assessment of the site in July 2005 found the vegetation to be open woodland of *E. marginata, B. grandis, X. occidentale* and *A. fraseriana* with *B. littoralis* over *T. parviceps*. All vegetation appeared in good condition.

Stewart Rd

The Stewart Rd terrestrial site was established in close proximity to monitoring bore BP20B on Stewart Rd between Blackpoint and Great South Rd. This site occurs within a National Park in an area that supports DRF or priority flora (Mattiske, 2004). Groundwater modelling suggested this site was within the 6-10 m depth category. Vegetation complex mapping indicated vegetation of the area represents the Coate complex (Mattiske & Havel, 1998) as previously described for the Darradup East site. However, assessment of the site in July 2005 found the vegetation to be closed *E. marginata* woodland with *C. calophylla* and *T. parviceps* over a dense, mixed understorey of *X. preissii, Lomandra* sp., *Leucopogon verticillatus, Patersonia occidentalis* and *Adiatum* sp. All vegetation appeared to be in excellent condition.

Darradup Rd North

The Darradup Rd. North terrestrial site was established in close proximity to monitoring bore BP42B in a National Park between Great South Rd. and Brockman Highway. Groundwater modelling suggested this site was within the 6-10 m depth category.

Vegetation complex mapping indicated vegetation of the area also represents the Coate complex (Mattiske & Havel, 1998). However, assessment of the site in July 2005 found the vegetation to be closed *E. marginata* woodland with *C. calophylla*, *A. fraseriana* over a dense understorey of *Astartea juniperiana, A. obovatus, X. preissii, P. occidentalis* and *Adiatum* sp. All vegetation appeared to be in excellent condition.

Jack Track

A terrestrial site was established on Jack Track adjacent to bore SC8 between Jill and Raynor Rds. The Jack Track site occurs within a National Park. Groundwater modelling suggested this site was within the 6-10 m depth category. Vegetation complex mapping indicated vegetation of the area represents the Jangardup complex described as 'low woodland of *M. preissiana* and *B. littoralis* and *T. parviceps, Beaufortia sparsa* and *Evandra aristate* on depressions'(Mattiske & Havel, 1998). Although an assessment of the site in July 2005 found some elements of the vegetation were more representative of a wetland community, the community is best described as open *E. marginata* woodland with *A. fraseriana* and *N. floribunda* over sometimes dense *Pericalymma ellipticum* with *X. preissii, A. obovatus* and *A. meisneri.* The vegetation was generally in very good condition.

Scott Rd

The Scott Rd. site was established in close proximity to bore SC22B south-east of Lake Smith. This site occurs within D'Entrecasteux National Park in an area that supports DRF or priority flora (Mattiske, 2004). Groundwater modelling suggested this site was within the 0-3 m depth category. Vegetation complex mapping indicated vegetation of the area represents the Scott (Swd) complex described as 'varying from low woodland of *E. marginata* and *M. rhaphiophylla* over *T. juniperina* or *M. preissiana* and *B. littoralis* to heaths and sedgelands…'(Mattiske & Havel, 1998). A site assessment in July 2005 found the vegetation to be open *E. marginata* woodland, with *A. flexousa, N. floribunda* and *M. preissiana* over a dense understorey of *Lepidosperma longitudinale, P. ellipticum* and other shrub species. The vegetation was generally in very good condition.

Blackpoint Rd

The final terrestrial site was established in close proximity to bore SC18B on Blackpoint Rd. approximately 2 km south of Stewart Rd. within a National Park. Groundwater modelling suggested this site was within the 3-6 m depth category. Vegetation complex mapping indicated vegetation of the area represents the Bidella complex described as 'varying form open forest of *E. megacarpa* or *E. patens* over *M. preissiana* and *B. seminuda* or *B. littoralis* with *T. parviceps*, A. *meisneri*… to tall shrubland of *T. linearifolia*…'(Mattiske & Havel, 1998). Site assessment in July 2005 found the vegetation to be open *E. marginata*, *C. calophylla* woodland with *B. grandis* and *A. flexuosa* over a dense understorey of *X. preissii, M. reidlei, L. verticillatus, Lepidosperma gladiatum, A. obovatus, P. occidentalis* and *Adiatum* sp. All vegetation appeared to be in excellent condition.

Table 1: Wetland criteria sites showing GPS co-ordinates, depth to groundwater, conservation value/land tenure, vegetation complex and key vegetation species. Positive values represent surface water depths.

Site/ bore no.	Site name	GPS co-ord of bore/ piezo	Depth to ground water (m)			Cons. value/ tenure	Vegetation complex	Key species
			Modelled (max)	**July 05 (min)**	**April 05 (max)**			
1a	Lake Jasper South (SC21B)	S: 34^{0}25.083' E: 115^{0}39.900'	0-3	1.17	2.37	National Park	Sd - Scott	*Melaleuca preissiana, Banksia littoralis, Agonis flexuosa, Lepidosperma gladiatum*
1b	Lake Jasper East	S: 34^{0}25.224' E: 115^{0}41.493'	0-3	+0.61	0.19	National Park	Sd - Scott	*Melaleuca preissiana, Banksia littoralis, Baumea articulata, Baumea juncea*
2	Jangardup Rd	S: 34^{0}22.490' E: 115^{0}39.600'	6-10	0.06	1.85	Section 62	Sd - Scott	*Pericalymma ellipticum, A. juniperina., Anarthria scabra.*
3	Black Point Rd	S: 34^{0}18.740' E: 115^{0}37.840'	6-10	+0.05	1.74	National Park	Sd - Scott	*M. preissiana, Taxandria parviceps., P. ellipticum*
4a & b	Pneumonia Rd	S: 34^{0}20.745' E: 115^{0}43.365'	0-3	0.08	1.51	Reserve	Sd – Scott	*M. preissiana, P. ellipticum, B. littoralis, E. marginata, Taxandria lineaifolia*
5a & b	Black Point/ Fouracres Rd)	S: 34^{0}18.520' E: 115^{0}38.280'	6-10	1.16	3.11	National Park	Sd - Scott	*M. preissiana, T. parviceps, P. ellipticum, Lepidosperma* sp., *Melaleuca* sp.
6	Black Point Rd – base of dunes	S: 34^{0}21.69' E: 115^{0}33.670'	0-3	0.44	1.34	Section 62	Swd – Scott	*M. rhaphiophylla, A. juniperina., Melaleuca* sp., *B. littoralis*
7	Black Point Rd - dunes	S: 34^{0}22.060' E: 115^{0}33.400'	6-10	0.63	1.53	National Park	Dd – D'Entrecasteaux	*M. preissiana, A. juniperina, Melaleuca* sp.
8y	Darradup Rd east (2 bores)	S: 34^{0}11.610' E: 115^{0}44.504'	0-3	1: 0.05 2: 0.09	1: 1.05 2: 1.05	National Park	CE - Coate	*M. preissiana, Hypocalymma angustifolium, A. juniperina, P. ellipticum, Anarthria scabra*
8x	Darradup Rd west	S: 34^{0}11.75' E: 115^{0}44.10'	0-3	0.07	1.07	National Park	CE - Coate	*M. preissiana, A. juniperina, T. parviceps, Beaufortia sparsa.*
9	Blackwood River Crossing: Longbottom Rd	S: 34^{0}04.016' E: 115^{0}36.500'	0-3	0.44	1.4	National Park	LY - Layman	*M. preissiana, T. parviceps, P. ellipticum, B. littoralis*
10	Brockman Highway	S: 34^{0}04.160' E: 115^{0}36.500'	0-3	0.06	1.02	State Forest	MP - Milyeanup	*A. juniperina, Lepidosperma tetraquetrum, B. littoralis, Eucalyptus rudis*
11a & b	Stewart Rd causeway (2 bores)	S: 34^{0}13.205' E: 115^{0}36.500'	3-6	1: +0.03 2: 0.2	1: 1.97 2: 2.2	National Park	CE - Coate	*M. preissiana, P. ellipticum, B. littoralis*
12	Poison Gully (BP51B and C)	S: 34^{0}07.230' E: 115^{0}33.240'	0-3	0.15	0.45	State Forest	JL - Jalbaragup	*M. preissiana, T. parviceps, P. ellipticum, A. juniperina, Beaufortia* sparsa

Table 2: Terrestrial vegetation criteria sites showing GPS co-ordinates, depth to groundwater, conservation value/land tenure, vegetation complex and key vegetation species.

Site/ bore no.	Site name	GPS co-ord of bore/ piezo	Depth to ground water (m)			Cons. value/ tenure	Vegetation complex	Key species
			Modelled (max)	**July 05 (min)**	**April 05 (max)**			
5a	Black Point/ Fouracres Rd	S: 34^{0}18.488' E: 115^{0}38.271'	6-10	4.85	6.64	National Park	Sd - Scott	*E. marginata, B. grandis, Xylomelum occidentale, X. preissii*
8y	Darradup Rd east	S: 34^{0}11.655' E: 115^{0}44.544'	0-3	0.57	1.57	National Park	CE - Coate	*E. marginata, Allocasuarina fraseriana, A. humilis, C. calophylla, B. ilicifolia*
9	Blackwood River xing: Longbottom Rd	S: 34^{0}04.167' E: 115^{0}36.481'	0-3	1.4	2.36	National Park	LY – Layman	*E. marginata, C. calophylla, B. grandis, Adenanthos obovatus, Eremaea paucifolia*
10	Brockman Highway	S: 34^{0}04.729' E:115^{0}36.988'	0-3	1.1	2.06	State Forest	MP - Milyeanup	*E. marginata, C. calophylla, X. occidentale, B. grandis*
12	Poison Gully	S: 34^{0}07.220' E: 115^{0}33.266'	0-3	1.5	2.41	State Forest	JL - Jalbaragup	*E. marginata, B. grandis, A. fraseriana*
BP20B	Stewart Rd	S: 34^{0}13.065' E: 115^{0}36.226'	6-10	2.37	4.37	National Park	CE - Coate	*E. marginata, C. calophylla, X. preissii, Acacia sp., T. parviceps, Leucopogon verticillatus*
BP42B	Darradup Rd North	S: 34^{0}09.469' E: 115^{0}39.190'	6-10	3.82	6.27	National Park	CE - Coate	*E. marginata, X. preissii, A. fraseriana., Acacia sp., A. juniperina, P. ellipticum*
SC8B	Jack Track	S: 34^{0}16.297' E: 115^{0}33.493'	6-10	3.76	5.36	National Park	JN - Jangardup	*E. marginata, X. preissii, A. fraseriana., Acacia sp., A. juniperina, P. ellipticum*
SC22B	Scott Rd. - near Lake Smith	S: 34^{0}25.874' E: 115^{0}44.026'	0-3	1.21	2.53	National Park	Swd - Scott	*E. marginata, Nutysia floribunda, M. preissiana, A. flexuosa*
SC18B	Blackpoint Rd	S: 34^{0}17.329' E: 115^{0}40.346'	3-6	7.16	8.95	National Park	BD - Bidella	*E. marginata, C. calophylla, T. parviceps, B. grandis, Agonis flexousa, L. verticillatus, Mesomelaena tetragona*

Discussion

The ten terrestrial sites selected as ‘criteria’ sites represent vegetation across the entire study area, incorporating a variety of vegetation complexes and the range of current depth to groundwater categories. All sites however, share similar conservation values as they mostly occur within National Parks or reserves that have been previously logged for timber production.

Although sites are representative of vegetation complexes mapped by Mattiske and Havel (1998), the spatial scale of mapping has been shown to be insufficient to reflect the actual vegetation composition at the scale considered during the current study. Rather than representing the vegetation composition described in the mapping, all sites were found to support *E. marginata* woodland with *C. corymbia* also occurring at most sites. There was however, greater variation in the understorey species composition.

Depth to groundwater modelling provided by the DoW was also produced at a spatial scale insufficient to accurately locate areas within each groundwater category, generally as the mapping had been undertaken using data from a limited number of bores. However, it was of use in narrowing down the area of focus for site location. The selection of five sites within close proximity to existing monitoring bores and the remainder adjacent to pre-selected wetland sites with newly installed piezometers enabled more accurate identification of terrestrial sites at the required depths to groundwater.

The short time frame allocated to the project did not permit the full investigation of all areas of potentially phreatophytic vegetation. A longer time frame dedicated to site selection may have lead to the consideration of sites not adjacent to wetlands. However, this would have been dependent on the installation of piezometers at a greater number of sites to determine groundwater depths.

Although current groundwater depths were established at all sites, there are a number of other factors that should be considered when determining the potential dependence of phreatophytic vegetation. These include the nature of the underlying geology and soils as site stratigraphy will influence water retention. The current condition of vegetation and historic water level changes may also have an impact.

Limitations

Although this phreatophytic vegetation identification process has been applied in various studies the following limitations may reduce the accuracy of the approach;

- Site stratigraphy (may influence water retention).
- Modelled groundwater depths were based on data from a limited number of bores.
- Selection of terrestrial criteria sites could not be based solely on groundwater depth modelling provided by DoW as the mapping scale was too broad to allow accurate location of sites in the appropriate depth to groundwater category.
- Vegetation complex mapping is potentially too broad to reflect actual vegetation composition at each site.
- Depth to groundwater categories are based on *Banskia* woodland of the Perth region.
- Project timeframe did not permit investigation of all areas of potentially phreatophytic vegetation.

Task 2: Establishment of vegetation transects

Approach

A vegetation monitoring transect was established in close proximity to the piezometer (where installed) or existing monitoring bore or staff gauge at each of the selected wetland and terrestrial vegetation criteria sites. GPS readings were recorded at bore and/or beginning point of each transect. Although transects varied in length, the majority were 80 m long, a length adequate to encapsulate areas representative of all potentially groundwater dependent vegetation at the site. Transects comprise a series of contiguous 20 x 20 m quadrats marked with a galvanised steel or jarrah post (Figure 3). The elevational gradient (m) across each transect was determined through the measurement of the elevation at each post using a staff and dumpy. At sites near existing bores or staff gauges, elevations were 'tied into' the bore or gauge and expressed as mAHD. Baseline vegetation monitoring was not undertaken at the time of transect establishment as few species were in flower at that time of year making plant identification problematic. Baseline monitoring was therefore conducted in spring/ summer (November and January) 2005/06. The results of the monitoring are presented as a separate document (Froend et al., 2006).

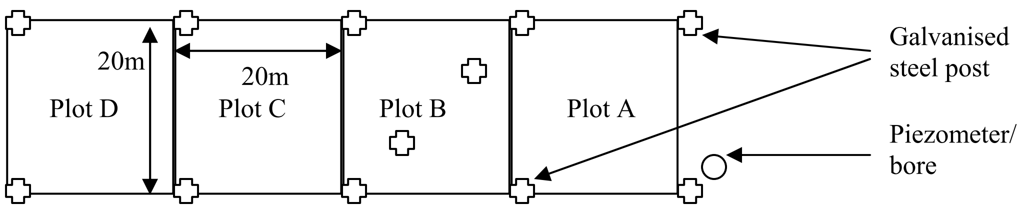


Figure 3: Standard set-up of transects at wetland and terrestrial sites.

Results

Transect establishment

Piezometers were installed at five terrestrial sites at the time of transect establishment and soil stratigraphy described at various intervals from the ground surface to the water table (Appendix 2). Piezometers were generally not required at other terrestrial sites as they were in close proximity to existing monitoring bores. However a piezometer was installed at the Stewart Rd site as extrapolation of groundwater levels from bore SC22B suggested surface water occurred at points along the transect, which was in fact dry. A Potential terrestrial site was abandoned when a piezometer failed to reached groundwater at 6.0 m in an area modelled as 3-6 m to groundwater. This supported the decision to establish sites near existing bores. Wetland piezometers were installed under the concurrent wetland project. However a second bore was installed at site 13Y as extrapolation of groundwater levels also suggested transect inundation.

Although hydrological data were available for all existing monitoring bores, readings were generally restricted to spring maximums (September/ October) and autumn minimums (April). Hydrological data for sites not established near existing bores, were restricted to a single reading taken at the time of transect establishment in July 2005. It was pertinent to the EWR process that maximum and minimum groundwater levels are determined for all sites and that they be standardised by year (ie. 2005 min and max). As April 2005 minimums were available for existing bores (SC21B, BP42B, SC8, SC22B, SC18B and BP20B), the mean seasonal range in groundwater levels at each bore over the past five years was added to its April 2005 minimum to establish a 2005 maximum (Table 3). This process was more complicated for sites with no pre-existing bores, especially as a July groundwater level generally DoWs not represent an annual maximum. However, as rainfall in the Pemberton region during autumn/ winter 2005 was much higher than average (supported by anecdotal evidence that water levels were as high in July as at the end of a ‘normal’ winter), the levels measured at piezometers in July could be regarded as average maximums. As there were also no historic water level data from which to establish mean seasonal variations, data from bores nearest the sites were considered and the mean seasonal variation subtracted from the actual July maximum to determine an April minimum (Table 3).

Table 3: Actual and modelled minimum and maximum groundwater levels at bores and piezometers at criteria sites. Positive values indicate surface water depths.

Site	Actual 05 DTGW (min) (July)	Modelled 05 DTGW (min) (Oct)	Nearest bore	mean seasonal GW level variation	Modelled 05 DTGW (max) (Oct)	Actual 05 DTGW (max) (April)
Wetlands						
Poison Gully (BP51C) (site 12)	0.15		BP51C	0.3	0.45	
Stewart Rd (site 11a)	+0.03		BP20B	2	1.97	
Stewart Rd (site 11b)	0.2		BP20B	2	2.2	
Pneumonia Rd (site 4)	0.08		SC20B	1.43	1.51	
Blackpoint/ Fouracres (site 5)	1.16		SC18B	1.79	3.11	
Blackpoint Rd (site 3)	+0.05		SC18B	1.79	1.74	
Blackpoint Rd (site 7)	0.63		SC16B	0.9	1.53	
Blackpoint Rd (site 6)	0.44		SC16B	0.9	1.34	
Brockman Highway – (site 10)	0.06		BP02C	0.96	1.02	
Blackwood Crossing (site 9)	0.44		BP02C	0.96	1.4	
Jangardup Rd (site 2)	0.06		SC18B	1.79	1.85	
Lake Jasper (SC21B)(site 1a)		1.17	SC21B	1.2		2.37
Lake Jasper east (site1b)		+0.61	Staff gauge	0.8	0.19	+0.06
Darradup Rd (site 8y 1)	0.05		KL7B	0.998	1.048	
Darradup Rd (site 8y 2)	0.09		KL7B	0.998	1.052	
Darradup Rd (site 8x)	0.07		KL7B	0.998	1.068	
Terrestrial						
Poison Gully (BP51C)	2.11		BP51C	0.3	2.41	
Blackpoint/ Fouracres	4.85		SC18B	1.79	6.64	
Brockman Highway	1.1		BP02C	0.96	2.06	
Blackwood Crossing	1.4		BP02C	0.96	2.36	
Darradup Rd (east)	0.57		KL7B	0.998	1.57	
Darradup Rd (north) (BP42B)		3.82	BP42B	2.45		6.27
Jack Track (SC8B)		3.76	SC8B	1.6		5.36
Lake Smith (SC22B)		1.21	SC22B	1.32		2.53
Lake Smith (bore 2)	0.34		SC22B	1.32	1.66	
Blackpoint Rd (SC18B)		7.16	SC18B	1.79		8.95
Stewart Rd (BP20B)		2.37	BP20B	2		4.37

Lake Jasper South (wetland 1)

A significant area of bushland in the D'Entrecasteaux National Park, including much of the southern and eastern regions of Lake Jasper, was impacted by bushfires in early 2005. An 80 m transect (Figure 4) running east-west was established approximately 10 m south-west of bores SC21A and B on the south side of Lake Jasper, some 500 m from the lake edge, in an area impacted by the fires. This site was chosen as a replacement for that identified in the concurrent wetland project, as the existing piezometer was destroyed during work on an access track/ fire break.

The transect increased in elevation along its length, with the vegetation changing from relatively dense *Banksia littoralis* and M. *preissiana* to more sparse yet larger *M. preissiana*. Both overstorey and understorey species, including *Taxandria parviceps*, *Astartea juniperiana* and *Lepidospermum gladiatum,* are recovering well from the 2005 fire. The measured depth to groundwater at bore SC21B in autumn 2005 was 2.37 m, the modelled spring depth was 1.17 m.

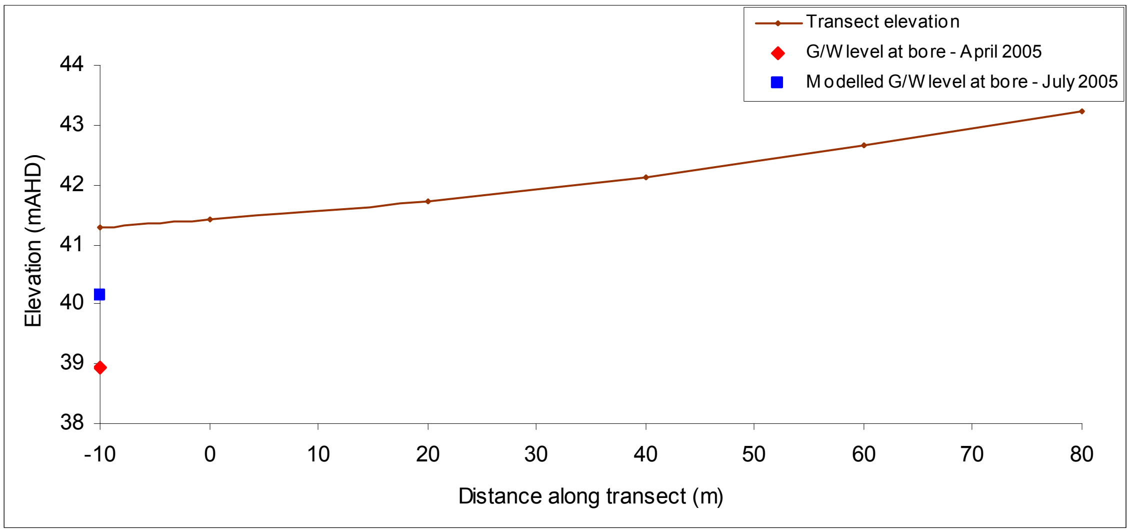


Figure 4: Lake Jasper South wetland transect (site 1) showing transect elevation and minimum and maximum groundwater levels 2005.

Lake Jasper – East

A second site was identified on the eastern side of lake in close proximity to an existing staff gauge within the recreation area. This site had also been burnt during the 2004/05 fires. Plot A of the 80 m transect (Figure 5) was mostly inundated and dominated by the sedges *Baumea articulata* and *B. juncea*. *Melaleuca preissiana* and *B. littoralis* occurred further along the transect with *Eucalyptus megacarpa* and *B. attenuata* becoming dominant in the overstorey with increasing elevation.

The measured surface water depth at the staff gauge in February 2006 was 0.06 m. The modelled spring surface water level (2005) was +0.61 m while the modelled July 2005 depth to groundwater was 0.19 m.

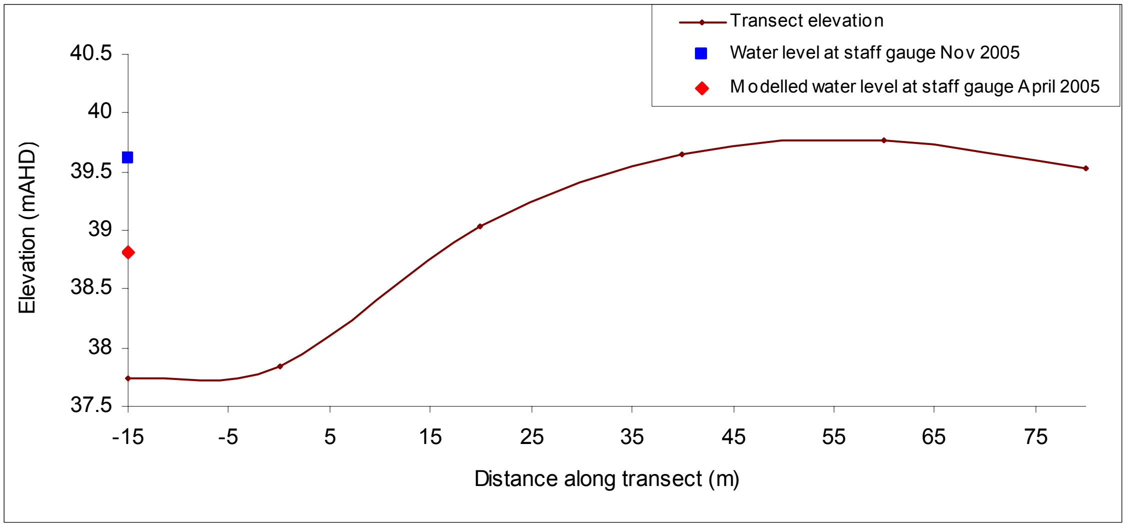


Figure 5: Lake Jasper East wetland transect showing transect elevation and minimum and maximum groundwater levels 2005.

<u>Jangardup Rd (wetland 2)</u>

The transect at this site runs 80 m north-west from the roadside into an area of vegetation also burnt during the 2005 fires. The first 15 m of the transect was inundated to 0.04 m before drying with increased elevation (Figure 6). The dominant vegetation also changed with elevation moving from sedges, including *Anarthria scabra,* and *A. juniperiana* to *Pericalymma ellipticum* and *Acacia sp*. Although the vegetation is recovering from the fire, it remains relatively sparse.

Although the ground surface adjacent to the base of the piezometer was inundated to a depth of 0.04 m at the time of monitoring in July 2005, the measured depth to groundwater in the piezometer was 0.06 m. The modelled autumn depth was 1.85 m.

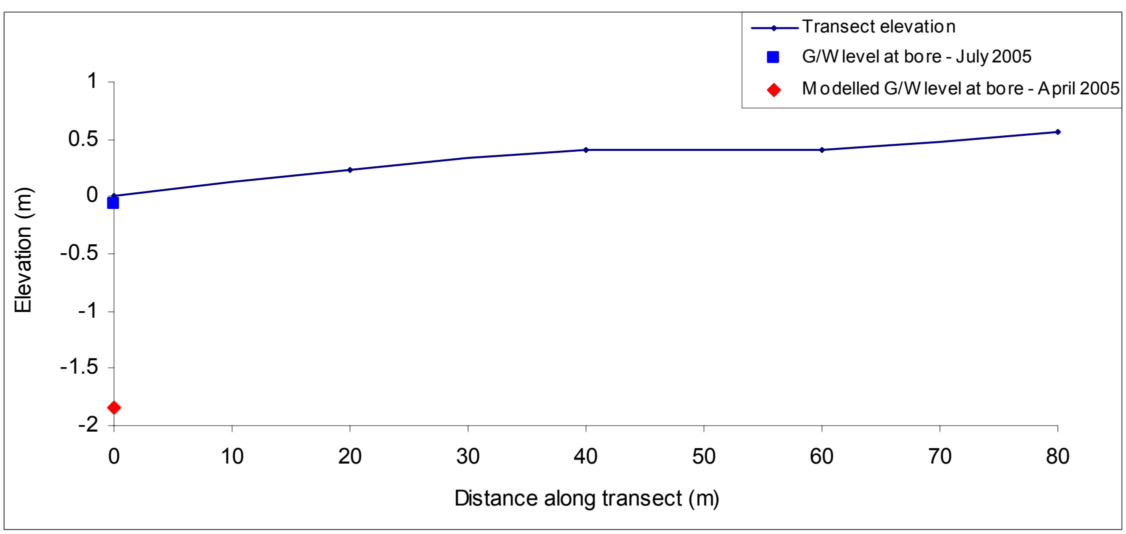


Figure 6: Jangardup Rd wetland transect (site 2) showing transect elevation and minimum and maximum groundwater levels 2005.

Blackpoint Rd (wetland 3)

The transect at this site started at the piezometer approximately 20 m from the roadside running 80 m in a north-westerly direction across the wetland (Figure 7). The first 10 m of the transect was inundated to 0.05 m as was much of the surrounding area. The dominant vegetation changed with increased elevation moving from sedges and sparse *P. ellipticum* and *A. juniperiana* through an area of denser shrubs and into *Meleleuca preissiana* woodland with *Eucalyptus marginata* and a variety of understorey species. The groundwater depth at the piezometer during July 2005 reflected the surface water depth, with a modeled autumn depth of 1.74 m to groundwater.

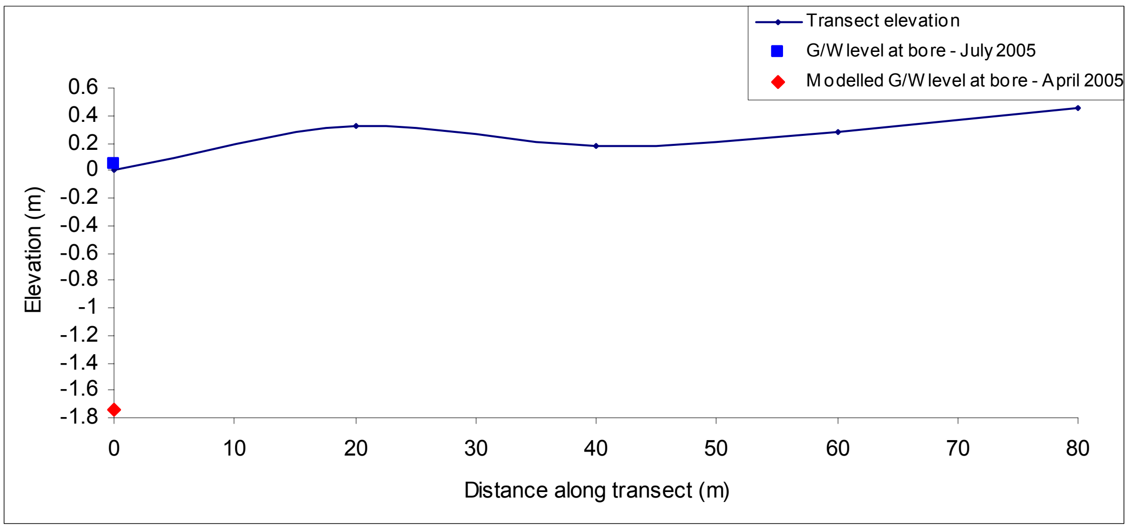


Figure 7: Blackpoint Rd wetland transect (site 3) showing transect elevation and minimum and maximum groundwater levels 2005.

Pneumonia Rd (wetland 4)

The Pneumonia Rd transect was established at the piezometer approximately 200 m north-east of the road near the end of a drainage ditch. The 80 m transect decreased in elevation with distance moving from an area of open *E. marginata* woodland with a terrestrial understorey across the wetland dominated by *P. ellipticum* and sedges with emergent *M. preissiana* and *T. linearifolia*.

Although the transect was inundated to 0.05 m from 8.6 m to 80 m, the depth to groundwater measured at the piezometer in July 2005 was 0.08 m, the modelled 2005 m autumn depth was 1.51 m (Figure 8).

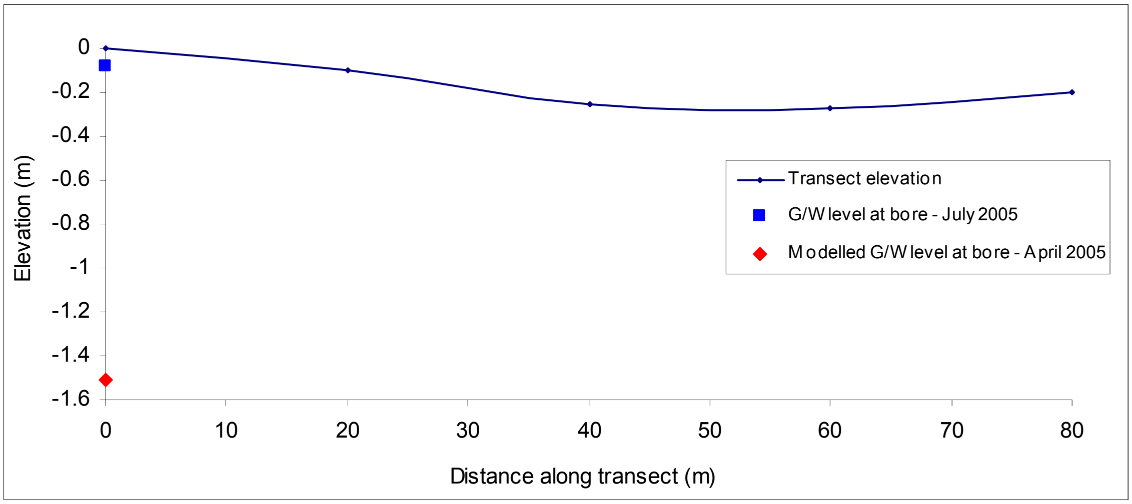


Figure 8: Pneumonia Rd wetland transect (site 4) showing transect elevation and minimum and maximum groundwater levels 2005.

Blackpoint/ Fouracres Rd (wetland 5)

This transect at this site, near the intersection of Blackpoint and Fouracres Rds., was established to run south-east between a piezometer on the roadside and a second piezometer 80 m into the wetland. The transect decreased in elevation with distance with a corresponding change in dominant species. *E. marginata* with a predominately terrestrial understorey occurred over the first 15 m changing to vegetation dominated by *P. ellipticum* and emergent *M. preissiana* with more mesic species in the understorey.

The piezometer closest to the road was dry in July 2005. However the measured depth to groundwater at the second piezometer was 1.16 m with a modelled autumn minimum depth of 3.11 m (Figure 9).

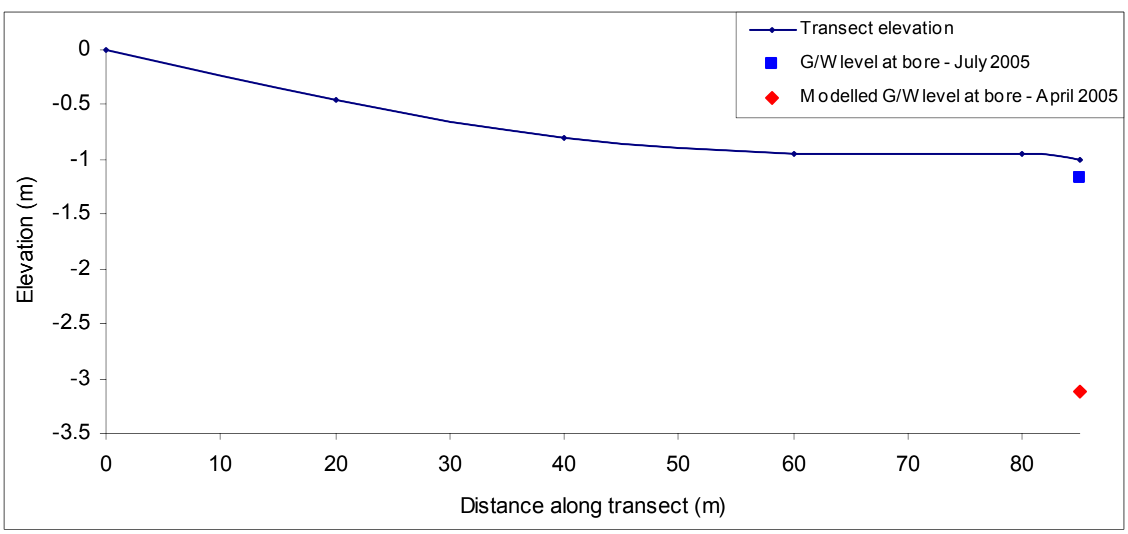


Figure 9: Blackpoint/ Fouracres Rd wetland transect (site 5) showing transect elevation and minimum and maximum groundwater levels 2005.

Blackpoint Rd (wetland 6)

The 80 m transect at this site ran north-west from the piezometer perpendicular to the road. The elevation decreased slightly across the transect with a corresponding change in vegetation composition from shrub/ sedgeland to a *M. rhaphiophylla* woodland with *B. littoralis* over a dense shrub understorey. The dominant shrubs included *A. juniperiana* and *T. parviceps*.

Although there was surface water present across the transect, a groundwater level of 0.44 m was measured at the piezometer during July 2005, the modelled autumn level was 1.34 m (Figure 10).

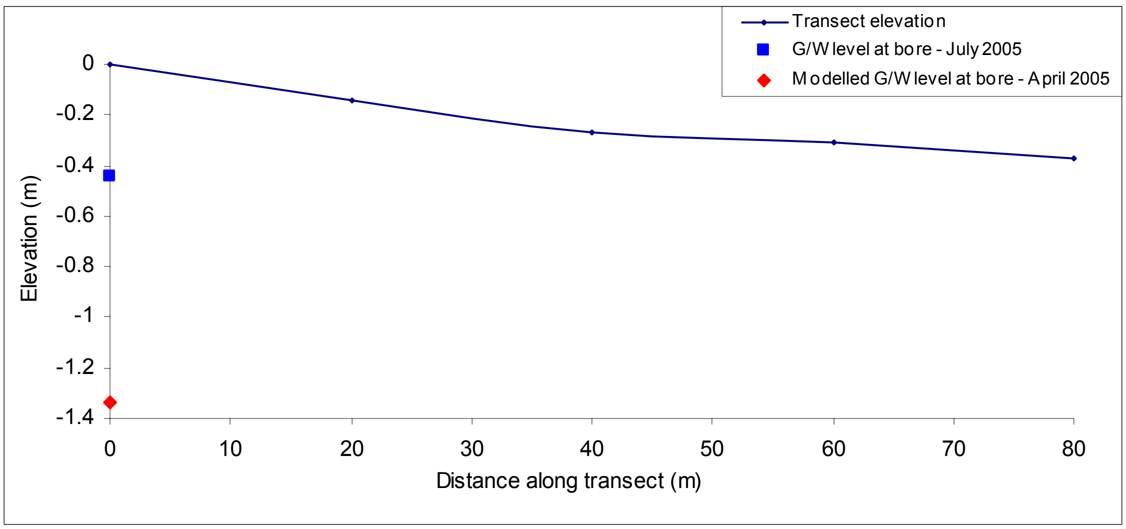


Figure 10: Blackpoint Rd wetland transect (site 6) showing transect elevation and minimum and maximum groundwater levels 2005.

Blackpoint Rd (wetland 7)

The transect established at this site runs 80 m south-east from the piezometer though open *M. preissiana* woodland. This site has been burnt in recent years and the understorey remains relatively sparse. There is little change in elevation and vegetation along the transect other than the introduction of *Banksia littoralis* two thirds of the way along the transect. *Taxandria parviceps, A. juniperiana* and an unidentified *Melaleuca* sp. remained dominant in the understorey over mixed sedges (Figure 11). The depth to groundwater measured at the piezometer in July 2005 was 0.63 m, the modelled autumn depth was 1.53 m.

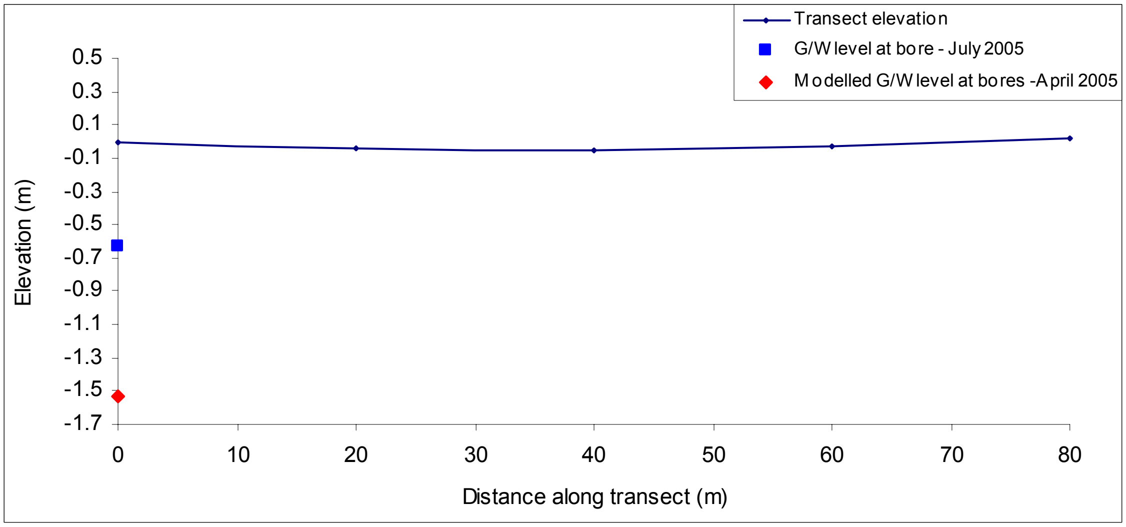


Figure 11: Blackpoint Rd dunes wetland transect (site 7) showing transect elevation and maximum and minimum groundwater levels 2005.

Darradup Rd East (wetland 8Y)

The transect at the Darradup Rd site was established to run north-east between a piezometer on the roadside and a second piezometer installed 80 m into the wetland. This site has also been burnt recently and although the understorey is recovering it remains sparse. There is little change in the elevation across the transect with little change also occurring in vegetation composition. *M. preissiana* is dominant in the open overstorey with some *E. marginata* and *Nutysia floribunda*. The understorey is dominated by resprouting *Hypocalymma angustifolium, P. ellipticum* and *A. juniperiana* over sedges including *Anarthrai scabra*.

Although the transect was inundated to a depth of +0.02 m between 30 and 60 m, depths to groundwater measured at piezometer 1 (on the roadside) and 2 (at the end of the transect) were 0.05 m and 0.09 m respectively. Modelled autumn depths to groundwater were 1.05 m and 1.06m (Figure 12).

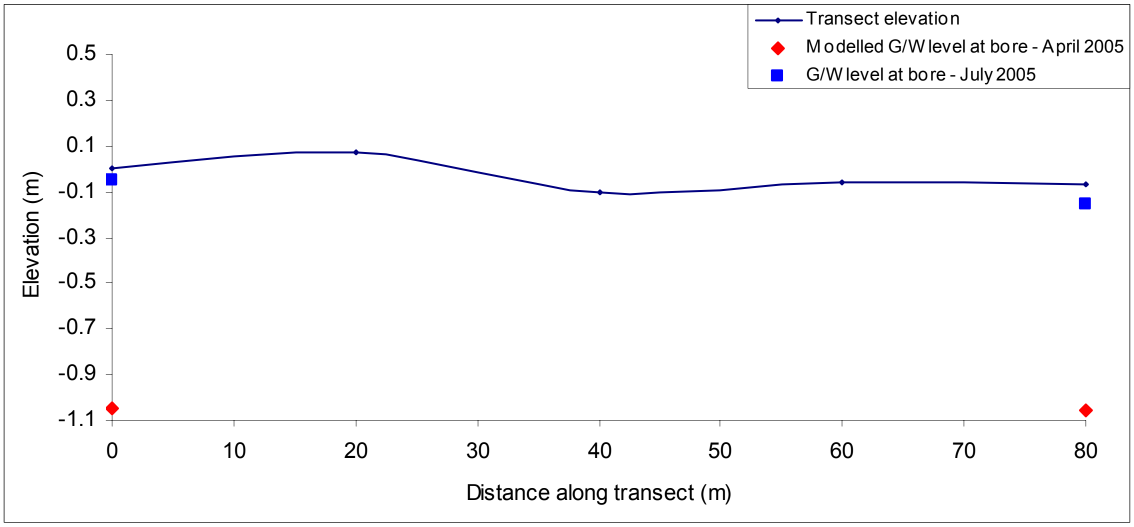


Figure 12: Darradup Rd wetland transect (site 13Y) showing transect elevation and maximum and minimum groundwater levels 2005.

Darradup Rd West (wetland 8X)

This transect at this wetland, also on Darradup Rd, was established to run south from the piezometer to a point 80 m into the wetland. There was a slight decrease in elevation across the transect with some surface water occurring in places. The vegetation however, remained unchanged with emergent *M. preissiana* over a dense understorey of *A. juniperiana, T. parviceps* and *Beaufortia sparsa* and sedges.

Although there was surface water present across the transect, a depth to groundwater of 0.07 m was measured at the piezometer during July 2005, the modelled autumn level was 1.07 m (Figure 13).

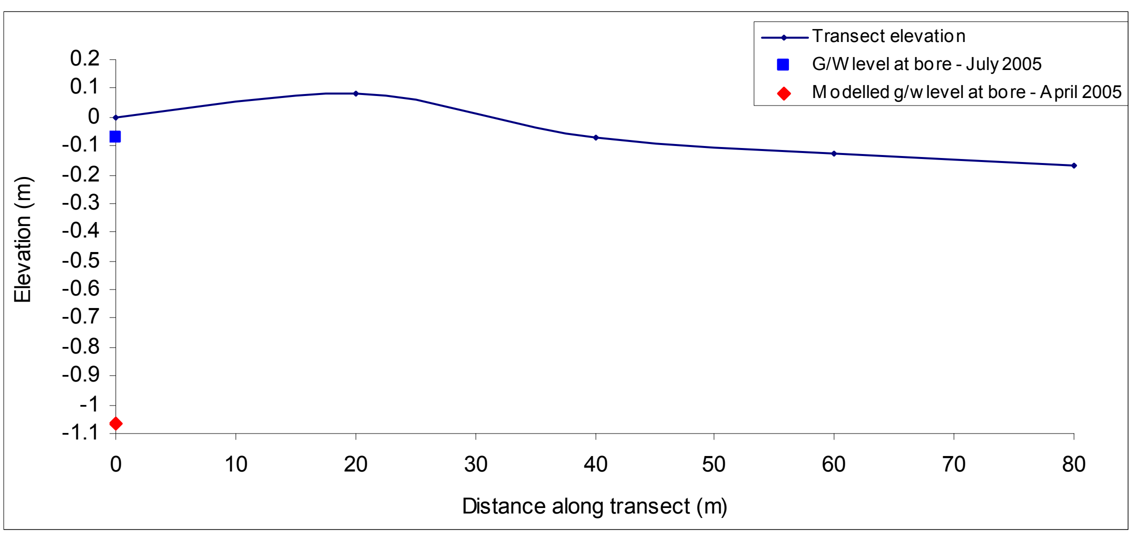


Figure 13: Darradup Rd wetland transect (site 13B) showing transect elevation and maximum and minimum groundwater levels 2005.

Blackwood River Crossing – Longbottom Rd (wetland 9)

The transect established at this site was established to run 120 m north-east from the piezometer to the far-side of the wetland though dense, yet low, *P. ellipticum* shrubland with emergent *M. preissiana* and a single *B. littoralis*. There was an overall decrease in elevation across the transect however, there was no corresponding changes in vegetation composition or structure. A depth to groundwater of 0.44 m was recorded at the bore in July 2005, with a modelled autumn level of 1.4 m (Figure 14).

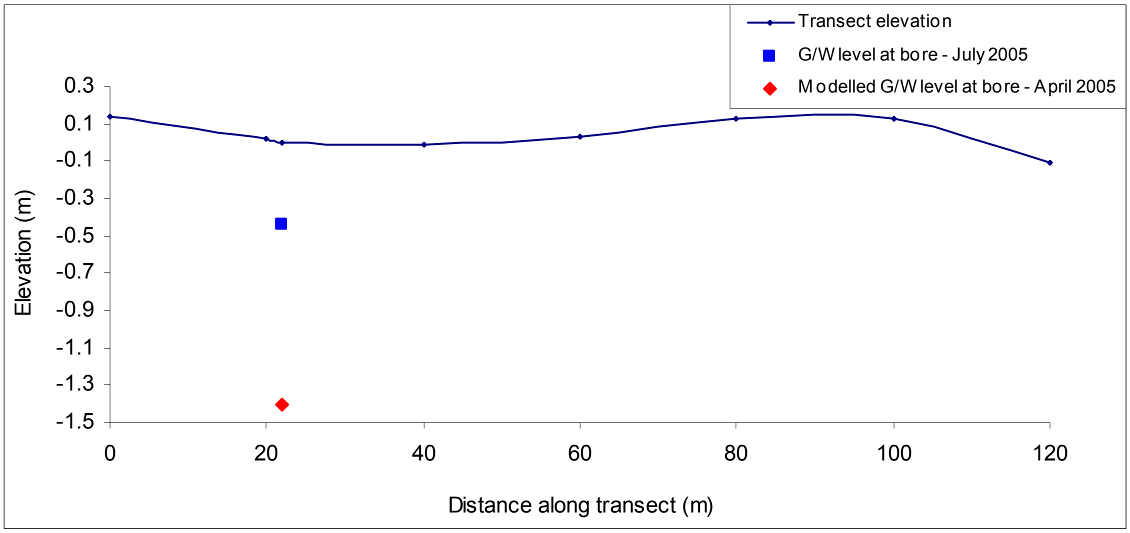


Figure 14: Blackwood River Crossing - Longbottom Rd wetland transect (site 21) showing transect elevation and minimum and maximum groundwater levels 2005.

Brockman Highway (wetland 10)

A 60 m transect was established to traverse the wetland at this site, with the piezometer located near the center of the basin. The elevational gradient of the transect was lowest in the basin, where a number of small creeks were running, increasing towards the wetland fringe. Vegetation composition and structure changed across the wetland in response to changing water levels. The basin was dominated by *A. juniperiana, T. parviceps* and a number of sedge species including *Lepidosperma tetraquetrum*. The wetland fringes comprised fewer sedges, a greater density of shrubs and tree species including *E rudis, B. littoralis, E. marginata* and *C. calophylla*.

Although surface water to approximately +0.5 m deep was present in creek-lines across the wetland basin, a depth to groundwater of 0.06 m was measured at the piezometer during July 2005, the modelled autumn depth was 1.02 m (Figure 15).

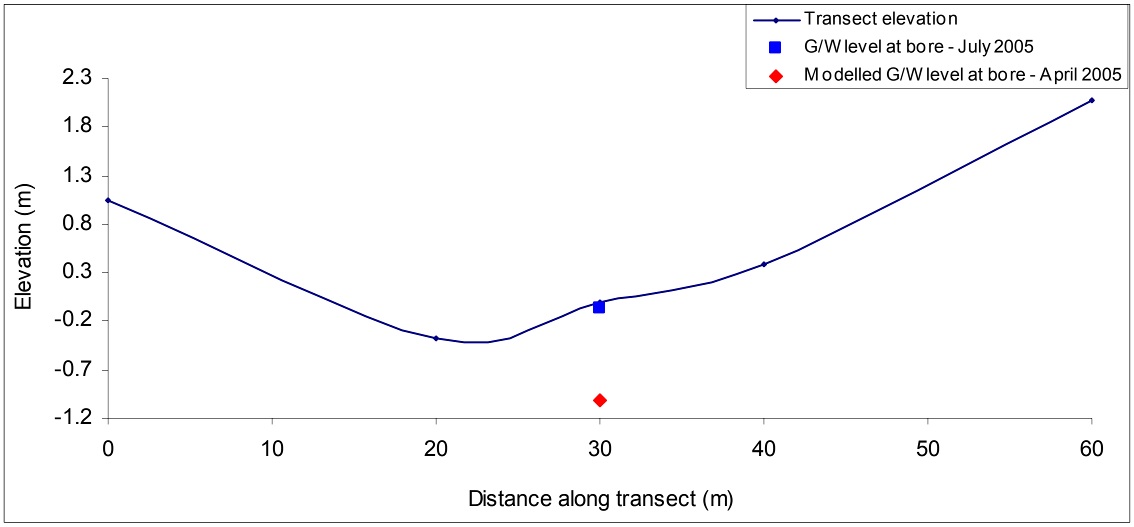


Figure 15: Brockman Highway wetland transect (site 22) showing transect elevation and minimum and maximum groundwater levels 2005.

Stewart Rd (wetland 11a and b)

The transect at this site was established to run south-west from a piezometer on the roadside to a second approximately 30 m into the wetland. This site has been burnt recently and although the understorey is recovering it remains sparse. There was very little change in elevation across the transect reflected in vegetation composition and structure, which remained low, open, shrub/ sedgeland dominated by *P. ellipticum*. A large number of *P. ellipticum* seedlings were also noted in the understorey. Although only one tree, a *B. littoralis* sapling, was located on the actual transect, the elevations of three *M. preissiana* and a second *B. littoralis* north-west of the transect were recorded. These trees will be assessed during future monitoring.

Although the entire transect was inundated to a depth of +0.03 m, only the piezometer closest to the road (piezo. a) recorded surface water of that depth in July 2005. The depth to groundwater measured at the second piezometer was 0.20 m. Modelled autumn groundwater levels were 1.97 m (piezo a) and 2.2 m (piezo. b) (Figure 16).

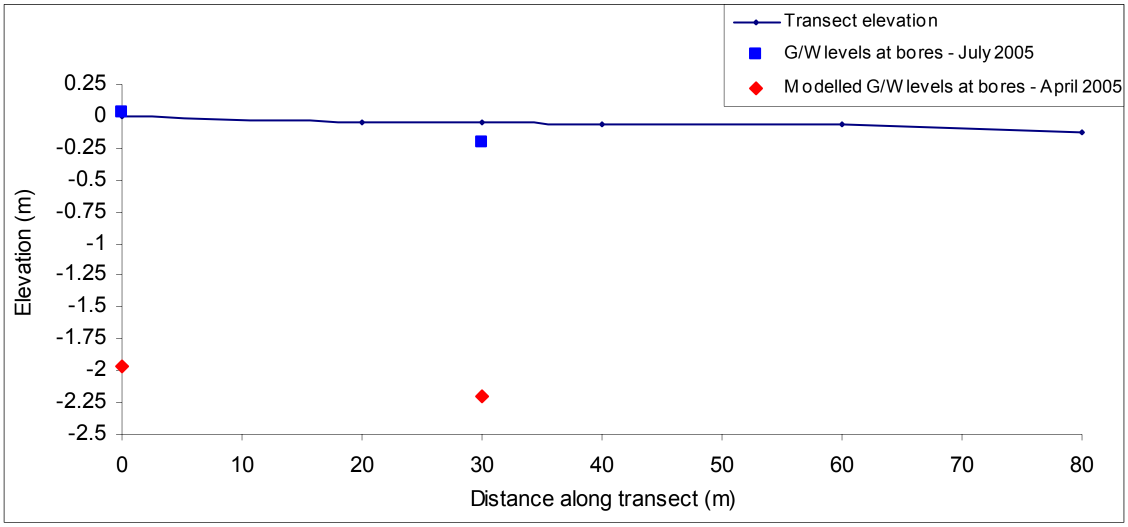


Figure 16: Stewart Rd wetland transect (site 28) showing transect elevation and minimum and maximum groundwater levels 2005.

Poison Gully (wetland 12)

A 40 m transect running west from the roadside across the basin and into the fringing vegetation was established at this site. The piezometer was located near the center of the basin, where the elevational gradient was at its lowest before rising towards the wetland edge and the road. The vegetation across the basin was dominated by tall mixed, shrubland (*T. linearifolia, A. juniperiana* and *Pultenaea reticulata*) with sedge species and emergent *M. preissiana*.

Although some surface water to approximately +0.1 m deep was present in the wetland basin, a depth to groundwater of 0.15 m was measured at the piezometer during July 2005, the modelled autumn depth was 0.45 m (Figure 17).

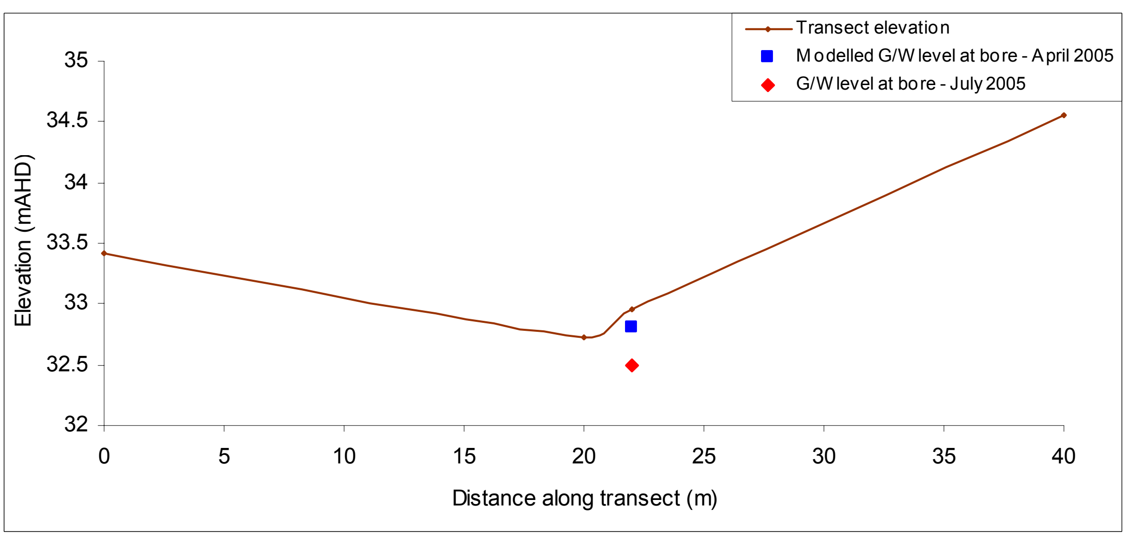


Figure 17: Poison Gully wetland transect (site 31) showing transect elevation and minimum and maximum groundwater levels 2005.

Blackpoint/ Fouracres Rd terrestrial site

The 80 m long transect at this site was established on the opposite side of Blackpoint Rd. from wetland 5. The transect runs west from the roadside through open *E. marginata* woodland as described on p. 5. Although the elevation increased slightly with distance there was little change in vegetation composition and structure. The depth to groundwater measured at the piezometer in July was 4.85 m, the modelled autumn level was 6.64 m (Figure 18).

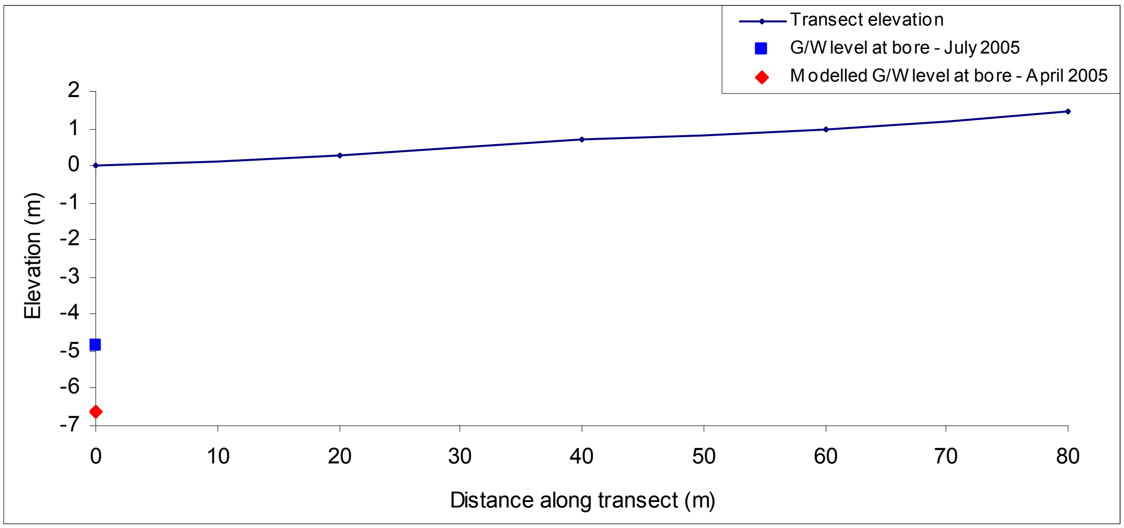


Figure 18: Blackpoint/ Fouracres Rd terrestrial vegetation transect showing transect elevation and minimum and maximum groundwater levels 2005.

Darradup Rd East terrestrial site

This 80m transect was established in the terrestrial vegetation fringing wetland 8Y however, unlike the wetland, vegetation across this transect was not impacted by recent fire. The transect runs west from the wetland edge through open *E. marginata* woodland with *C. calophylla* and *A. fraseriana* as described on p. 5. Although the elevation increased with distance there was little change in vegetation composition and structure. The depth to groundwater measured at the piezometer in July was 0.57 m, the modelled autumn level was 1.57 m (Figure 19).

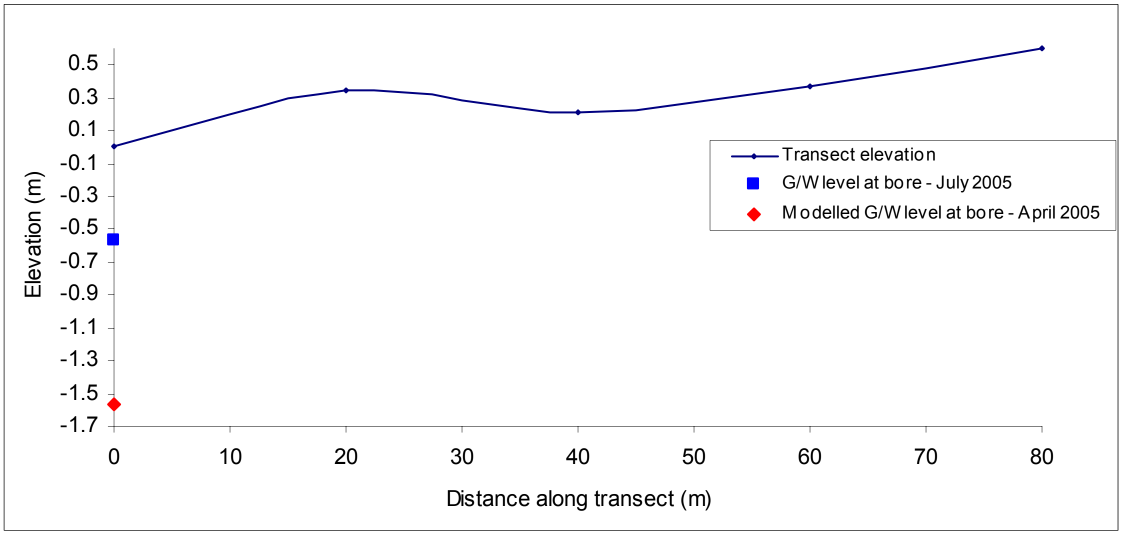


Figure 19: Darradup Rd East terrestrial vegetation transect showing transect elevation and minimum and maximum groundwater levels 2005.

Blackwood River Crossing – Longbottom Rd terrestrial site

The 80 m transect at this site was established in fringing vegetation adjacent to wetland 21. Although the elevation increased with distance there was no change in the vegetation composition from *E. marginata* woodland with *C. calophylla* and *B. littoralis*, as described on p. 6. The depth to groundwater measured at the piezometer in July was 1.40 m, the modelled autumn level was 2.36 m (Figure 20).

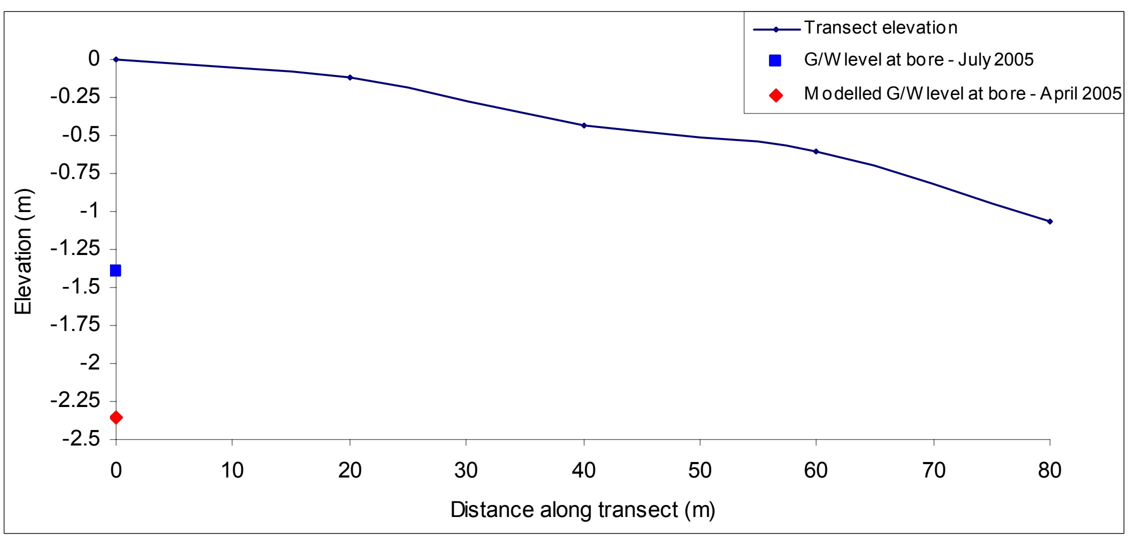


Figure 20: Blackwood River Crossing- Longbottom Rd terrestrial vegetation transect showing transect elevation and minimum and maximum groundwater levels 2005.

Brockman Highway terrestrial site

The transect established at this site ran 80 m from the edge of wetland 10 through fringing *B. littoralis* and wetland shrubs into low open woodland of *E. marginata, C. calophylla* and *B. grandis*, as described on p. 6. The elevation increased with distance and was reflected in a change from an understorey dominated by wetland species to one of terrestrial species only. The depth to groundwater measured at the piezometer in July was 1.10 m, the modelled autumn level was 2.06 m (Figure 21).

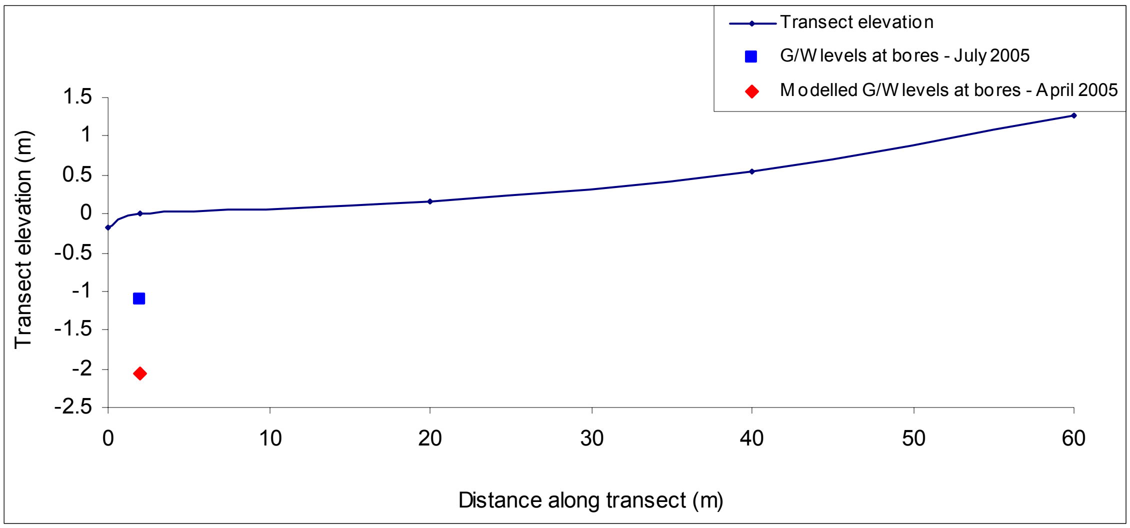


Figure 21: Brockman Highway terrestrial vegetation transect showing transect elevation and minimum and maximum groundwater levels 2005.

Poison Gully terrestrial site

The 80 m transect at this site was established in fringing vegetation adjacent to wetland 12. Although the elevation increased markedly with distance there was little change in species composition and structure, with open *E. marginata*, *B. grandis* and *A. fraseriana* woodland, as described on p. 6., remaining dominant. The depth to groundwater measured at the piezometer in July was 2.11 m, the modelled autumn level was 2.41 m (Figure 22).

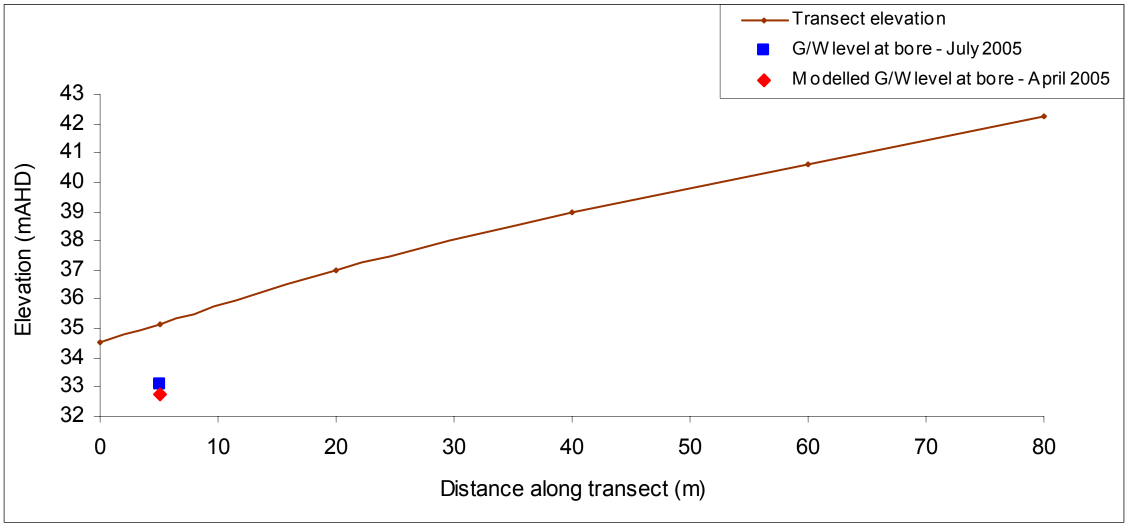


Figure 22: Poison Gully terrestrial vegetation transect showing transect elevations and minimum and maximum groundwater levels 2005.

Stewart Rd (BP20B) terrestrial site

The transect at this site ran 80 m north-west from bore BP20B into closed *E. marginata* woodland, as described on p. 6. There was little change in elevation across the transect which was reflected in the homogeneity in vegetation composition and structure. The depth to groundwater measured at the bore in April 2005 was 4.37 m, the modelled spring level was 2.37 m (Figure 23).

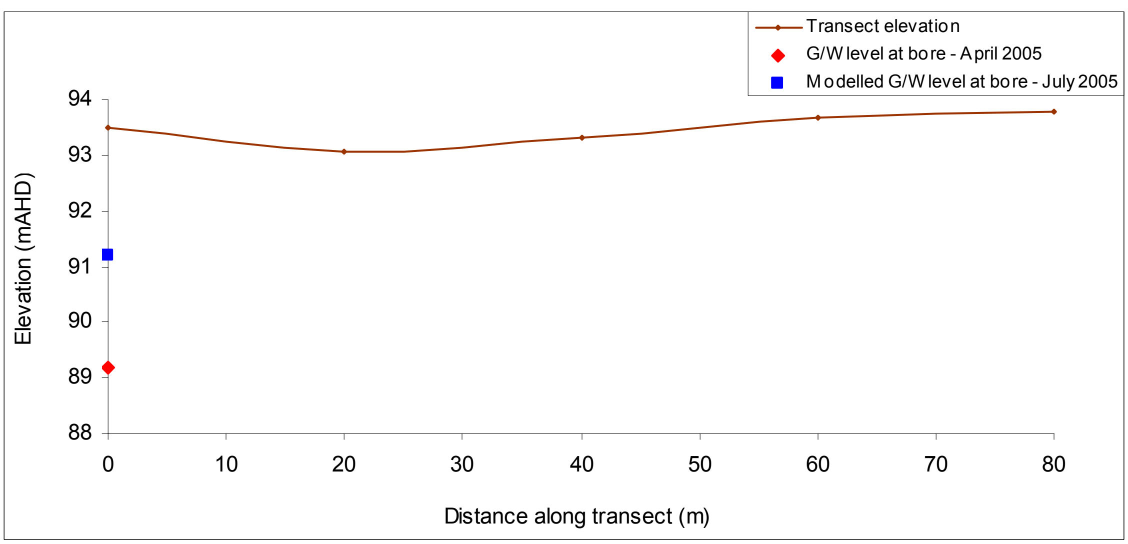


Figure 23: Stewart Rd (BP20B) terrestrial vegetation transect showing transect elevation and minimum and maximum groundwater levels 2005.

Darradup Rd North (BP42B) terrestrial site

The transect at this site ran 80 m south-west from bore BP42B into closed *E. marginata* woodland, with *C. calophylla* and *A. fraseriana*, as described on p. 6. There was little change in elevation across the transect which was reflected in the homogeneity in vegetation composition and structure. The depth to groundwater measured at the bore in April 2005 was 6.27 m, the modelled spring level was 3.82 m (Figure 24).

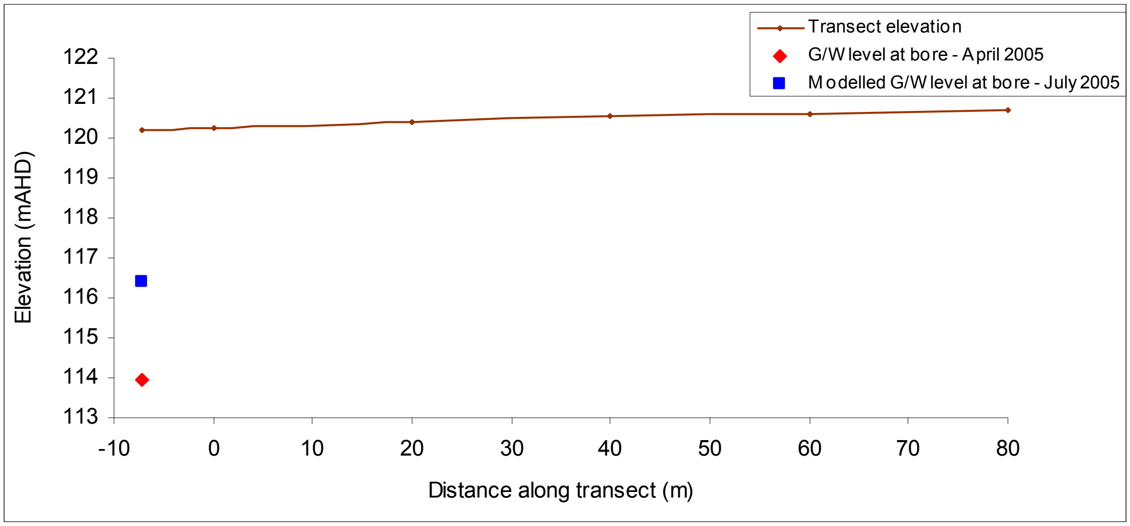


Figure 24: Darradup Rd North (BP42B) terrestrial vegetation transect showing transect elevation and minimum and maximum groundwater levels 2005.

Jack Track (SC8) terrestrial site

The transect at this site ran 80 m north-east from bore SC8 into open *E. marginata* woodland, as described on p. 7. Although there was little change in elevation across the transect, there was some change in understorey composition and structure, with *P. ellipticum* dominant at lower elevations and more xeric species at higher elevation. The depth to groundwater measured at the bore in April 2005 was 5.36 m, the modelled spring level was 3.76 m (Figure 25).

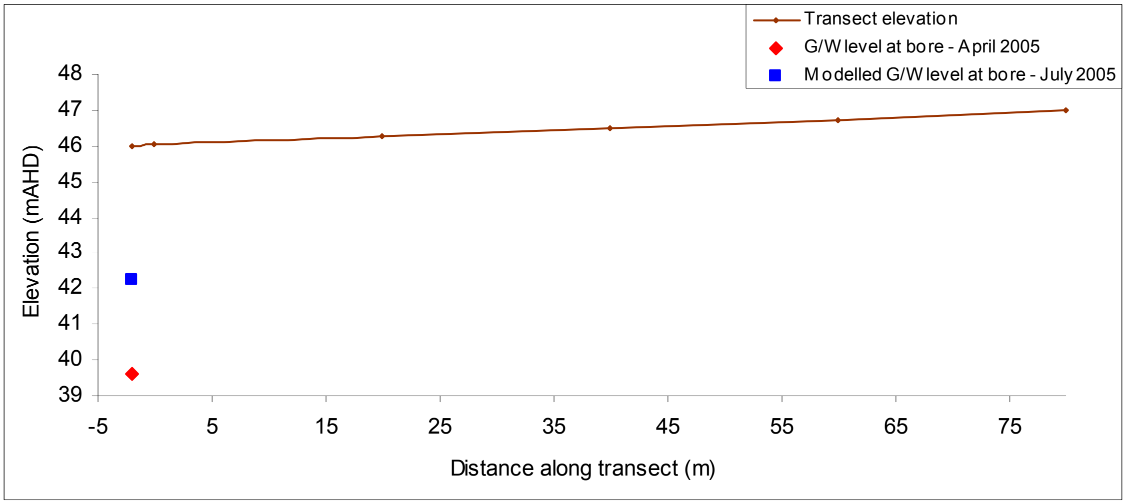


Figure 25: Jack Track (SC8) terrestrial vegetation transect showing transect elevation and minimum and maximum groundwater levels 2005.

Scott Rd – Lake Smith (SC22B) terrestrial site

The 80 m transect at this site ran south from bore SC22B through open *E. marginata* woodland towards a *M. preissiana* woodland, as described on p. 7. This change in vegetation composition reflected the significant change in elevation across the transect. Due to the degree of change in elevation, a piezometer was also installed at the end of the transect. The depth to groundwater measured at bore SC22B in April 2005 was 2.53 m, the modelled spring level was 1.21 m. Depth to groundwater at the piezometer in July 2005 was 0.34, with a modelled autumn level of 1.66 m (Figure 26).

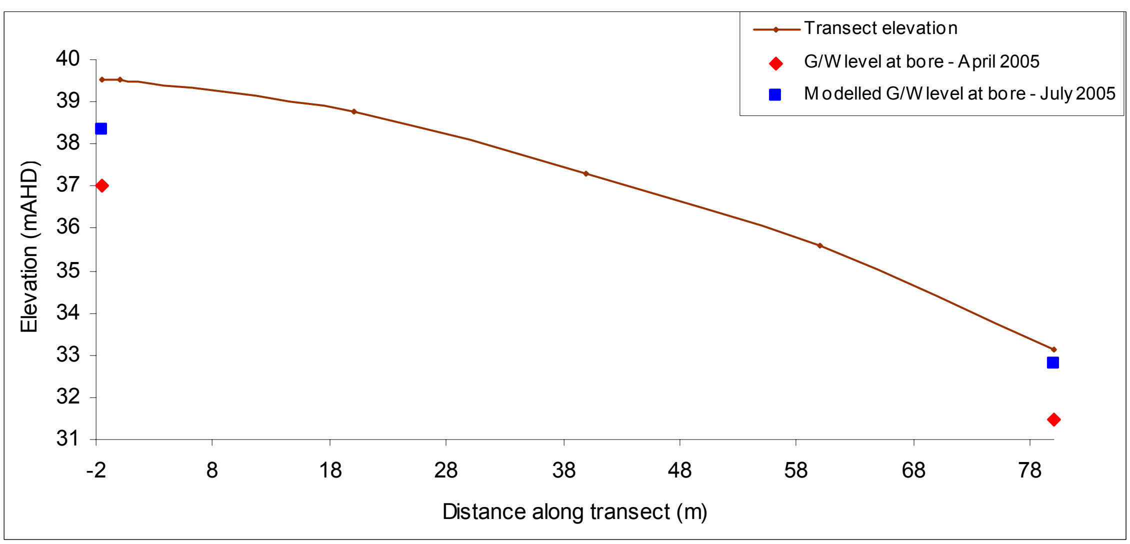


Figure 26: Scott Rd - Lake Smith (SC22B) terrestrial vegetation transect showing transect elevation and minimum and maximum groundwater levels 2005.

Blackwood Rd (bore SC18B) terrestrial site

The transect at this site ran 80 m south-east from bore SC18B into open *E. marginata,* C. *calophylla* woodland as described on p. 7. There was a significant change in elevation across the transect reflected by increased dominance of mesic species in the understorey. The depth to groundwater measured at the bore in April 2005 was 8.95 m, the modelled spring level was 7.16 m (Figure 27).

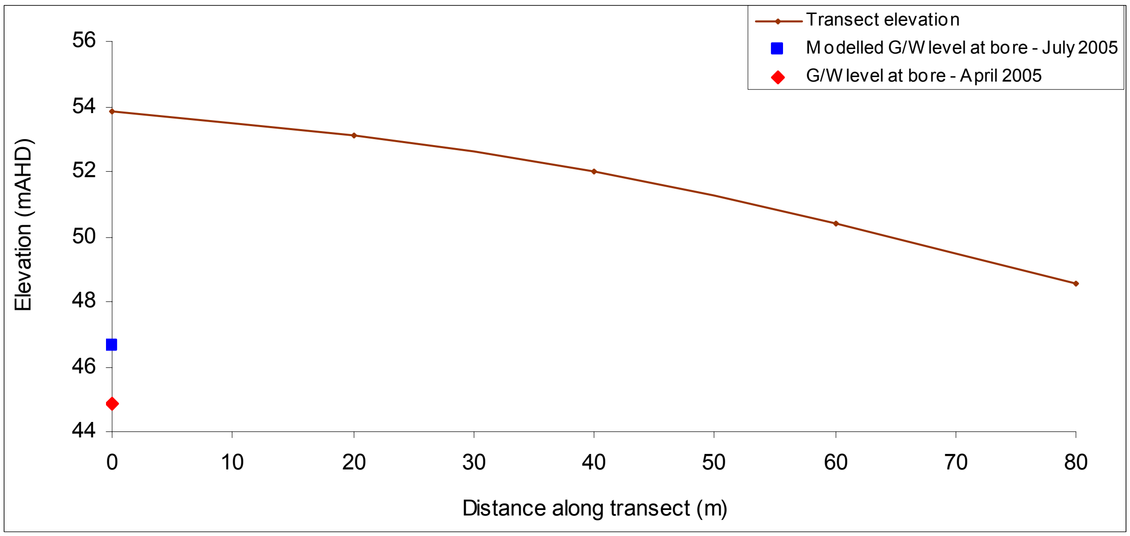


Figure 27: Blackwood Rd (SC18B) terrestrial vegetation transect showing transect elevation and minimum and maximum groundwater levels 2005.

Discussion

The installation of piezometers at the five terrestrial sites not in close proximity to existing bores confirmed that these sites also occurred at depths to groundwater of less than 10 m. However, as with all the newly installed piezometers, groundwater levels were not representative of actual seasonal minimums and maximums necessitating the extrapolation of these levels from a single winter measurement. Ideally, the piezometers should be monitored monthly for a period of no less than two years (preferably much longer) to provide some idea of seasonal fluctuations and possible trends, prior to determination of EWRs. However, prolonged drought across WA coupled with increasing demand on existing water resources, has lead the Water Corporation to bring forward planned development of the S/W Yarragadee groundwater scheme. This, in tun, has put pressure on the DoW and EPA to ensure any proposals are environmentally sustainable. As an end result, groundwater level data could not be collected over an adequate period and the required data was extrapolated from the limited data available.

Further issues arose in relation to the time of year during which the initial fieldwork was undertaken. Piezometers could not be installed to depths adequate to measure summer/ autumn groundwater levels due to 'caving-in' of bore holes on reaching the water table. If monitoring at these locations is to continue it may involve the re-establishment of piezometers at the end of autumn to enable access to depths representing seasonal minimums. Vegetation monitoring could also not be undertaken during winter months as identification of many dominant species, particularly sedge species, requires that they be in flower. Further fieldwork was undertaken in November 2005 and January 2006.

The selection of sites and establishment of piezometers at wetland and terrestrial sites by separate contractors may have been somewhat detrimental to the overall success of the project. As the 'wetland contractors' were unaware of the intended approach of the authors to vegetation monitoring and EWR determination, some piezometers were not located in close proximity to tree species. This reduced the number of wetland trees that could be incorporated into some transects (eg. Stewart Rd – wetland 11, Blackpoint Rd – wetland 3).

Limitations

The following limitations may reduce the accuracy of the approach adopted in this study;

- Groundwater levels at newly installed piezometers were not representative of actual seasonal maximums or minimums which necessitated the extrapolation of these levels from a single measurement.
- Piezometers could not be installed to depths adequate to measure summer/ autumn groundwater levels due to ‘caving-in’ of bore holes on reaching the water table.
- The location of some wetland piezometers reduced the number of wetland trees that could be incorporated in some transects (eg. Stewart Rd – wetland 28, Blackpoint Rd – wetland 3).
- Due to winter flooding the Lake Jasper B site could not be established until summer 2005/06.

Task 3: Management objectives

Background/ Approach

Clear management objectives are essential for the operational management of ecosystems. The very design of a management program is driven by the management objectives as they influence all aspects of management: from the study area, to the identification of management triggers, the design and implementation of a monitoring program, the reporting of outcomes and subsequent response of management within an adaptive management framework. Without a clear statement of objectives, the success or otherwise of any management plan cannot be assessed (Adam, 1998). As stated objectives are often very general or conceptual in nature, the challenge is to translate them into practical targets and performance indicators that can be measured in the field. Furthermore, the management system must be able to detect and correct mistakes before unacceptable damage is done.

Jamieson and O’Boyle (2001) developed a sequential approach to determining management objectives that encourages transparent links between qualitative, conceptual objectives and quantitative, operational objectives, as well as facilitating communication *within* the management system, an important feature for ecosystem-based management where a common set of objectives may be utilised across various sectors (Jamieson & O'Boyle, 2001). As a first step, conceptual objectives are stated in general terms that can be understood by a broad audience. More specific or operational objectives associated with management actions then follow. As an example, a conceptual objective may be ‘to conserve physical and chemical properties’ and related operational objectives for wetlands may be to ‘to conserve water quality’, ‘to conserve sediment properties’ and/or ‘to conserve water column properties’ (Note: there are likely to be more than one operational objective for each conceptual objective). In this way, management objectives reflect the ecological values assigned to an ecosystem (i.e. a wetland may be valued for its water quality and maintenance of ecological processes such as nutrient cycling and soil biogeochemistry).

Identifying the values of an ecosystem is intrinsic to identifying the conceptual and operational objectives of a GDE, and subsequently determining indicators or parameters suitable for use in monitoring. Describing ecological values for well studied and understood ecosystems is relatively straight forward however, baseline surveys are required to identify values of previously unstudied sites. Social and economic objectives should also be considered alongside biological objectives, although are beyond the scope of this project. Using the wetland example from above, water quality values may be associated with chemical condition, nutrients, contaminants and dissolved gases. A generally acceptable performance indicator is the concentration of these in solution. Finally a management trigger is established. This sets specific criteria that cannot be exceeded. Continuing with the wetland example, concentration standards of chemicals can represent criteria that should not be breached. This brief overview of the management process illustrates the importance of defining appropriate management objectives from the beginning: the objectives themselves drive the definition of characteristics describing the biological processes associated with each objective, and guide the choice of indicators and management triggers, which in turn determine management action and the subsequent review of the management program and evaluation of its success or otherwise (Jamieson & O'Boyle, 2001).

Ecological management objectives (EMOs) have been proposed for each terrestrial vegetation criteria site based on the ecological values identified in task 2 (see (Froend et al., 2006) for baseline monitoring results) without consideration of social or economic values (Table 4). EMOs are further restricted to biodiversity values as consideration of values associated with physical and chemical properties and ecosystem processes were beyond the scope of this report. 'Holistic' management objectives are also beyond the scope of this brief and EMOs will remain general as little is known about the ecological values of the criteria sites. Wetland EMOs were proposed in the concurrent wetland mapping and valuation project.

In recognition of historic groundwater use and impacts of climate and land-use changes on phreatophytic vegetation each EMO should be prefaced with the following;

"Recognising the cumulative impacts of abstraction history and long-term climate and land-use change, minimise the contribution of groundwater abstraction to progressive decline in the following ecological values…"

Results

Table 4: Conceptual and operational ecological management objectives and site specific values for terrestrial criteria sites.

Conceptual EMO	Site	Operational EMOs	Site specific values
To maintain biodiversity	Blackpoint/ Fouracres Rd	- to maintain species composition - to maintain species distribution - to maintain species richness - to control species mortality - to maintain species condition and vigour - to maintain community structure	- *Eucalytpus marginata/ Corymbia calophylla/ Banksia grandis* open forest - Overstorey and understorey species distributed evenly across site - High to very high understorey species richness across site - Low mortality - Moderate overstorey health and regeneration - Open forest over shrubland/ herbland
	Darradup Rd East	- to maintain species composition - to maintain species distribution - to maintain species richness - to control species mortality - to maintain species condition and vigour - to maintain community structure	- *E. marginata/ C. calophylla/ A. fraseriana* woodland - Wetland/ terrestrial species co-dominant in understorey in low areas, grading to terrestrial species up slope - High species richness across site - Low mortality - Poor to moderate overstorey health and high regeneration - Woodland over open shrubland
	Blackwood River Crossing	- to maintain species composition - to maintain species distribution - to maintain species richness - to control species mortality - to maintain species condition and vigour - to maintain community structure	- *E. marginata/ C. calophylla* woodland - Overstorey and understorey species distributed evenly across site - High to very high species richness across site - Low mortality - Moderate overstorey health and low regeneration - Woodland over open shrubland
	Brockman Highway	- to maintain species composition - to maintain species distribution - to maintain species richness - to control species mortality - to maintain species condition and vigour - to maintain community structure	- *E. marginata/ C. calophylla/ B. grandis* open forest - Overstorey and understorey species distributed evenly across site - High to very high species richness across site - Low mortality - Moderate to good overstorey health and low regeneration - Open forest over shrubland.
	Poison Gully	- to maintain species composition - to maintain species distribution - to maintain species richness - to control species mortality - to maintain species condition and vigour - to maintain community structure	- *E. marginata/ C. calophylla/ B. grandis* woodland - Wetland/ terrestrial species co-dominant in understorey in low areas, grading to terrestrial species up slope - High to very high species richness across site - Low mortality - Moderate health and low regeneration - Woodland over closed shrubland

	Stewart Rd	- to maintain species composition - to maintain species distribution - to maintain species richness - to control species mortality - to maintain species condition and vigour - to maintain community structure	- *E. marginata/ C. calophylla* closed forest - Terrestrial species distributed evenly across site - High to very high species richness across site - Low mortality - Moderate overstorey health and high regeneration - Closed forest over closed shrubland
	Darradup Rd North	- to maintain species composition - to maintain species distribution - to maintain species richness - to control species mortality - to maintain species condition and vigour - to maintain community structure	- *E. marginata/ C. calophylla* closed forest - Terrestrial overstorey and understorey species distributed evenly across site - High to very high species richness across site - Low mortality - Moderate overstorey health and high regeneration - Closed forest over closed shrubland
	Jack Track	- to maintain species composition - to maintain species distribution - to maintain species richness - to control species mortality - to maintain species condition and vigour - to maintain community structure	- *E. marginata* open woodland - Wetland/ terrestrial species co-dominant in understorey in low areas, grading to terrestrial species up slope - Very high species richness - Low mortality - Moderate to good overstorey health and low regeneration - Open woodland over closed shrubland
	Scott Rd	- to maintain species composition - to maintain species distribution - to maintain species richness - to control species mortality - to maintain species condition and vigour - to maintain community structure	- *E. marginata/ C. calophylla* woodland - Terrestrial species co-dominant in understorey in high areas, grading to wetland species down slope - Low to high species richness - Low mortality - Moderate overstorey health and low regeneration - Woodland over dense shrubland
	Blackpoint Rd	- to maintain species composition - to maintain species distribution - to maintain species richness - to control species mortality - to maintain species condition and vigour - to maintain community structure	- *E. marginata/ C. calophylla* closed forest - Terrestrial overstorey and understorey species distributed evenly across site - Moderate to high species richness - Low mortality - Moderate overstorey health and high regeneration - Closed forest over shrubland

Discussion

Although the values of many wetland sites have been described in previous studies, the setting of ecological management objectives for the phreatophytic vegetation criteria sites was made difficult due to the paucity of information on the ecological nature and values of terrestrial vegetation across much of the study area. There also appears to have been much interest in the values of the Karri (*Eucalyptus diversicolor*) forests of the Pemberton region (Wardell-Johnson & Williams, 2000; Wardell-Johnson, Williams, Mellican, & Annells, 2004), with little attention given to the *E. marginata* woodland of the area.

The values that have been identified and on which the management objectives are based, are restricted to those identified during transect scale assessments and do not consider values at a regional scale. For example, if a geographically restricted complex occurred in proximity to the transect without occurring within it, the values of the complex would not be considered. Values were also based entirely on vegetation with no consideration given to fauna values or to social or economic values.

Finally, little information exists on hydrological and land-use changes. This DoWs not permit consideration of historic changes in ecological values, which may result in significant values being overlooked if disturbances (eg. fire, logging) have recently changed the physical appearance of sites and thus influencing the visual assessment of site values.

Limitations

There are a number of impediments to setting ecological management objectives for phreatophytic vegetation criteria sites in the study area. These are;

- Ecological values of criteria sites are largely unknown.
- Insufficient information on hydrological and land-use changes DoWs not permit consideration of historic changes in ecological values.
- Values are generally restricted to a transect scale assessment and do not consider values at a regional scale eg. vegetation of a geographically restricted complex.
- Values are based entirely on vegetation with no consideration given to fauna or other ecological components of GDEs.

Task 4: Determination of ecological water requirements

Water regimes considered necessary to achieve the ecological management objectives for both terrestrial vegetation and wetland criteria sites were determined and described as ranges in annual maximum depths to groundwater.

Water regimes of selected species

Approach

Wetland vegetation

To determine EWRs for wetland vegetation historic water level data are generally related to the current distribution of wetland species to determine the water regimes under which the vegetation established. However, as there was little to no historic hydrological data for wetland criteria sites, current groundwater levels were compared to known eco-hydrological ranges of key wetland species as determined across the South West of WA (Froend, Loomes et al., 2004; Loomes, 2000) (Appendix 4). The existing database of species water levels is updated periodically to incorporate ranges measured at previously unstudied sites and ranges re-assessed at sites monitored regularly. Therefore the ranges of common SW species, as presented in this report, include those measured at criteria sites during this study.

This data is presented in a series of figures (Figures 28 to 51) which illustrate the current water level range of each key species at a specific site in comparison to mean and absolute ranges calculated across South West wetlands.

In the field, this entailed the measurement of elevational ranges of key species at each site for comparisons to water levels taken at the piezometers/ bores/ staff gauge. As current water levels were not representative of autumn lows or spring peaks, hydrological data from nearby monitoring bores (where available) were assessed to determine the likely range in seasonal water levels at each site (see p. 13 for explanation of approach adopted to extrapolate minimum and maximum 2005 groundwater levels).

Terrestrial vegetation

To determine EWRs for terrestrial vegetation, historic groundwater levels are also generally considered. However, as historic data were limited to one or two samples per year for only a short period, current groundwater levels were related to the current distribution of species to determine the water regimes the vegetation experienced in 2005. Current groundwater levels were then compared to water requirements of dominant species as described in the literature and as determined across study sites, including wetlands (Appendix 5). To achieve this, hydrological ranges of key species were determined at each site and a mean and total water depth range calculated for the study area. In the field, this entailed the measurement of elevational ranges of key species at each site for comparisons to water levels taken at the piezometers. Due to the nature of the soils across the study area (lateritic), it was not be possible to install piezometers that reach the groundwater table at all sites However, as five of the proposed terrestrial sites are in close proximity to existing groundwater monitoring bores (within 10 m), piezometers were not required at these sites.

Results

Lake Jasper - South (wetland 1)

The water depth range experienced in 2005 across the Lake Jasper Sth transect by two of the three identified wetland species, *Melaleuca preissiana* and *Banksia littoralis*, were drier than the SW mean and total ranges (Figure 28). *Lepidosperma longitudinale*, however occurred within both its SW mean and total ranges.

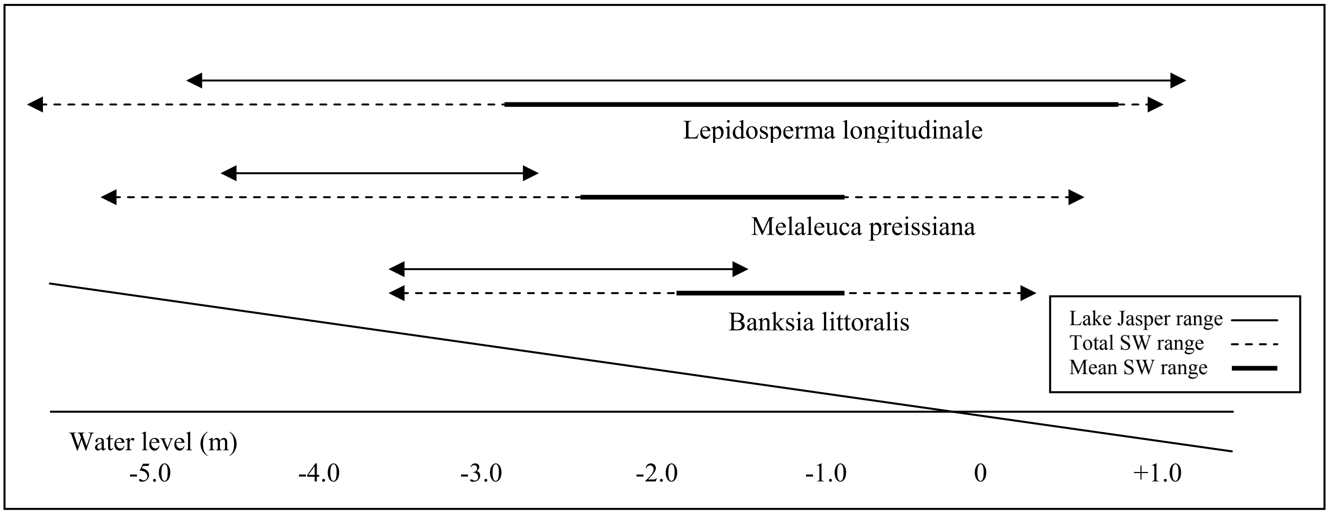


Figure 28: Water depth ranges experienced by wetland species at Lake Jasper South (wetland 1) in 2005 compared to total and mean ranges across SW wetlands.

Lake Jasper – East

The water depth range experienced in 2005 by all identified wetland species, *M. preissiana, B. littoralis, P. reticulata, Baumea articulata* and *B. juncea*, across the Lake Jasper East transect (Figure 29) were wetter than their SW mean ranges. The absolute maximum depth experienced by three species, B. articulata, B. juncea and M. preissiana at this site represent the wettest conditions experienced across the SW.

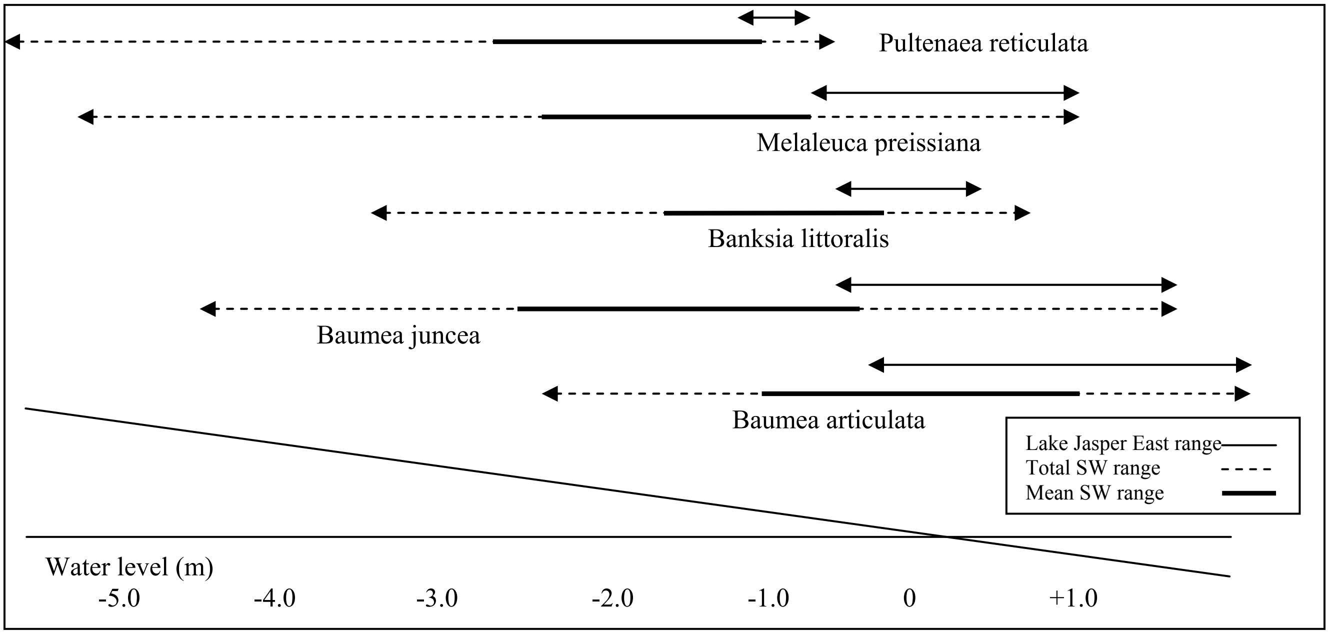


Figure 29: Water depth ranges experienced by wetland species at Lake Jasper East in 2005 compared to total and mean ranges across SW wetlands.

Jangardaup Rd (wetland 2)

The water depth ranges experienced in 2005 across the Jangaradup Rd (wetland 2) transect by two identified wetland species, *Pericalymma ellipticum* and *M. preissiana,* were beyond their SW means but well within total ranges (Figure 30).

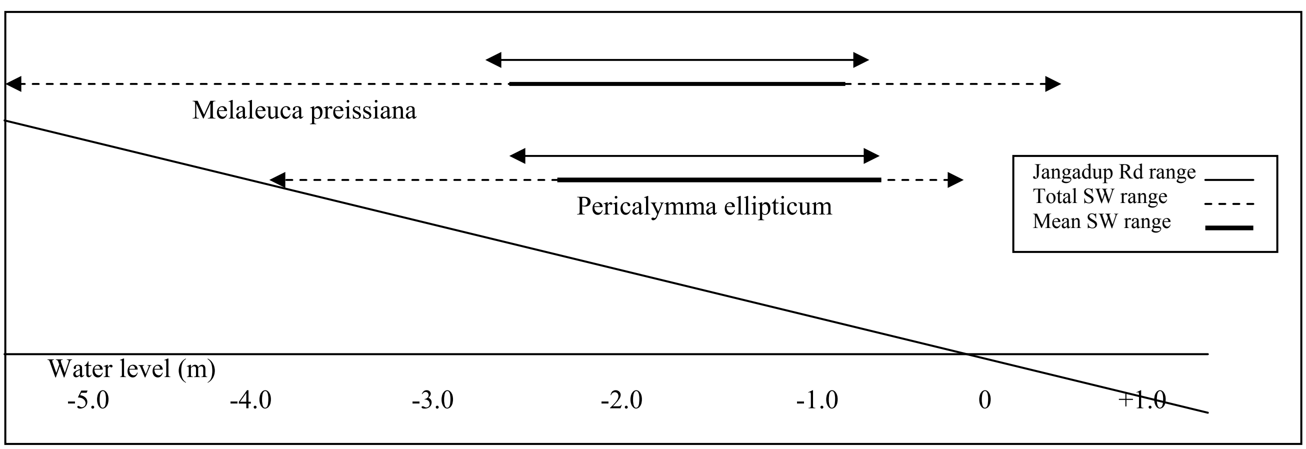


Figure 30: Water depth ranges experienced by wetland species at Jangardup Rd (wetland 2) in 2005 compared to total and mean ranges across SW wetlands.

Blackpoint Rd (wetland 3)

The water depth range experienced in 2005 across the Blackpoint Rd transect by *P. ellipitcum* was wetter than the SW mean and encapsulated its wettest depth (Figure 31).

M. preissiana also occurred beyond the wetter end of its mean SW range, but was within its total range.

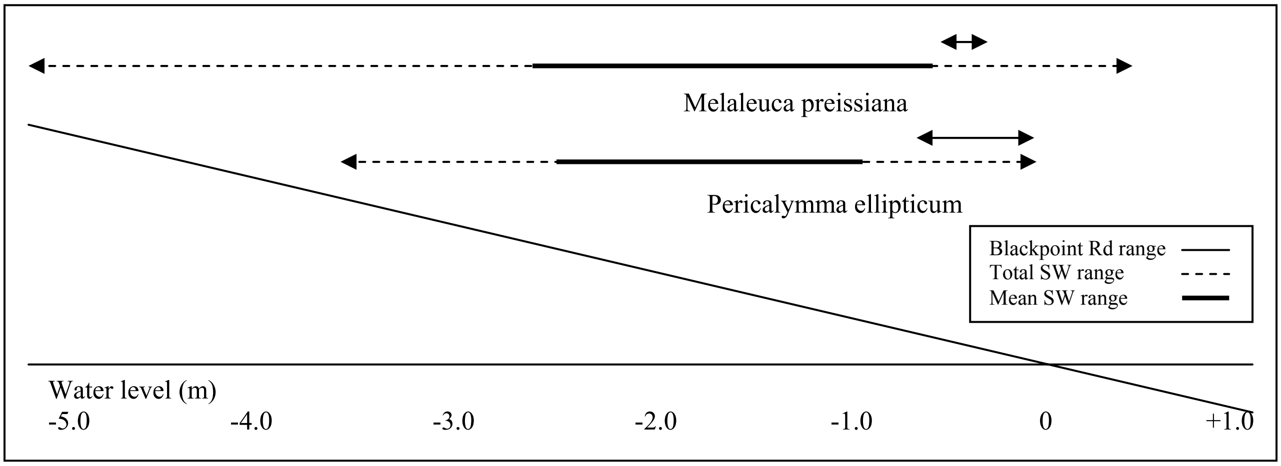


Figure 31: Water depth ranges experienced by wetland species at Blackpoint Rd (wetland 3) in 2005 compared to total and mean ranges across SW wetlands.

Pneumonia Rd (wetland 4)

The water depth ranges experienced in 2005 across the Pneumonia Rd transect by *M. preissiana* and *P. ellipitcum* were within their total SW range, with *P. ellipitcum* also occurring beyond the wetter end of its mean SW range (Figure 32).

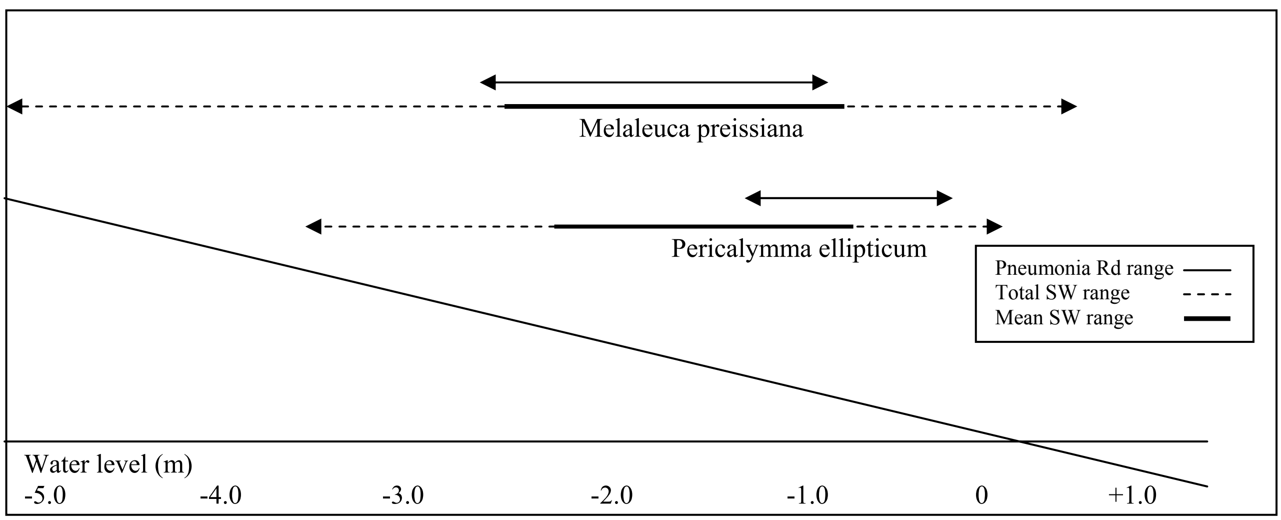


Figure 32: Water depth ranges experienced by wetland species at Pneumonia Rd (wetland 4) in 2005 compared to total and mean ranges across SW wetlands.

Blackpoint/ Fouracres Rd (wetland 5)

The water depth ranges experienced in 2005 across the Blackpoint/ Fouracres Rd transect by *M. preissiana* was within its mean and total SW ranges (Figure 33). *P. ellipitcum* occurred beyond both ends of its mean yet remained within its absolute range.

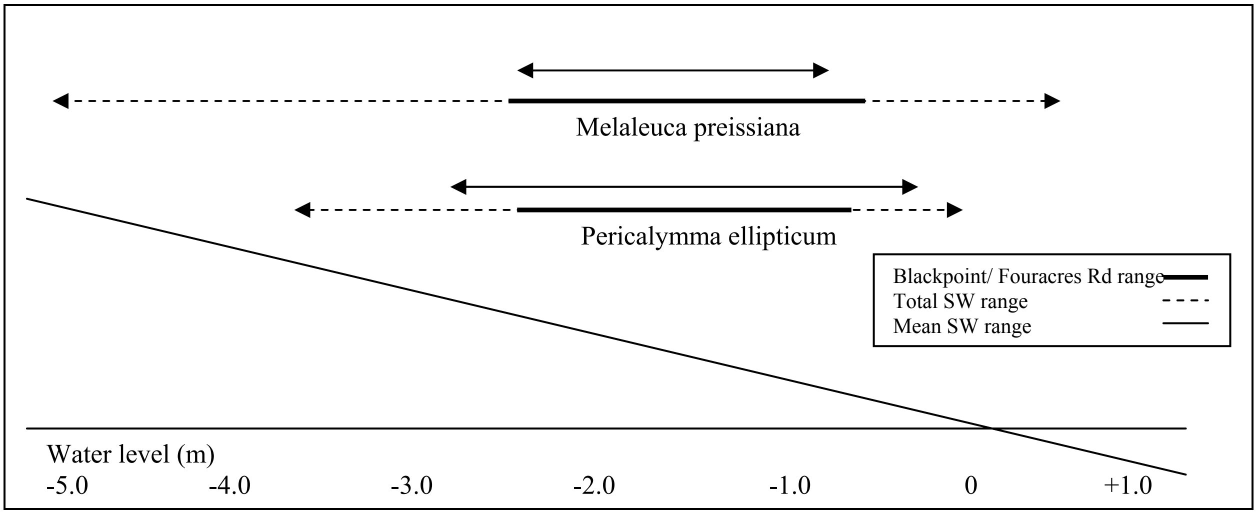


Figure 33: Water depth ranges experienced by wetland species at Blackpoint/ Fouracres Rd (wetland 5) in 2005 compared to total and mean ranges across SW wetlands.

Blackpoint Rd (wetland 6)

The water depth range experienced in 2005 across the Blackpoint Rd (wetland 6) transect by *M. rhaphiophylla* was within both its SW mean and total ranges (Figure 34). *B. littoralis* however, occurred beyond the wetter end of mean range but with its total.

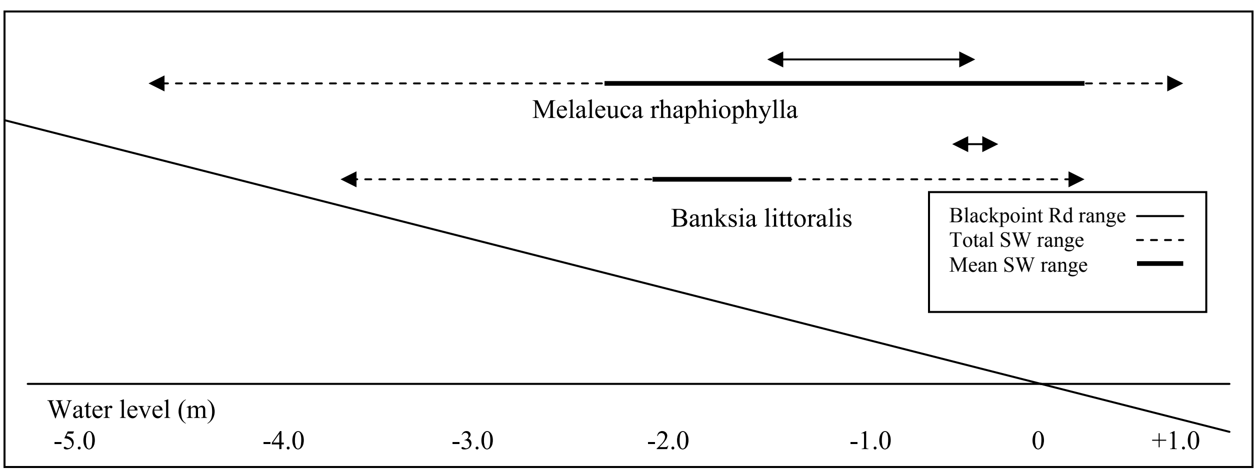


Figure 34: Water depth ranges experienced by wetland species at Blackpoint Rd (wetland 6) in 2005 compared to total and mean ranges across SW wetlands.

Blackpoint Rd (site 7)

The water depth ranges experienced in 2005 across the Blackpoint Rd (wetland 7) transect by *M. preissiana* and *L. longitudinale* were within both there mean and total SW ranges (Figure 35). The range of *B. littoralis* however, was beyond the wet end of its SW mean, but within its total range.

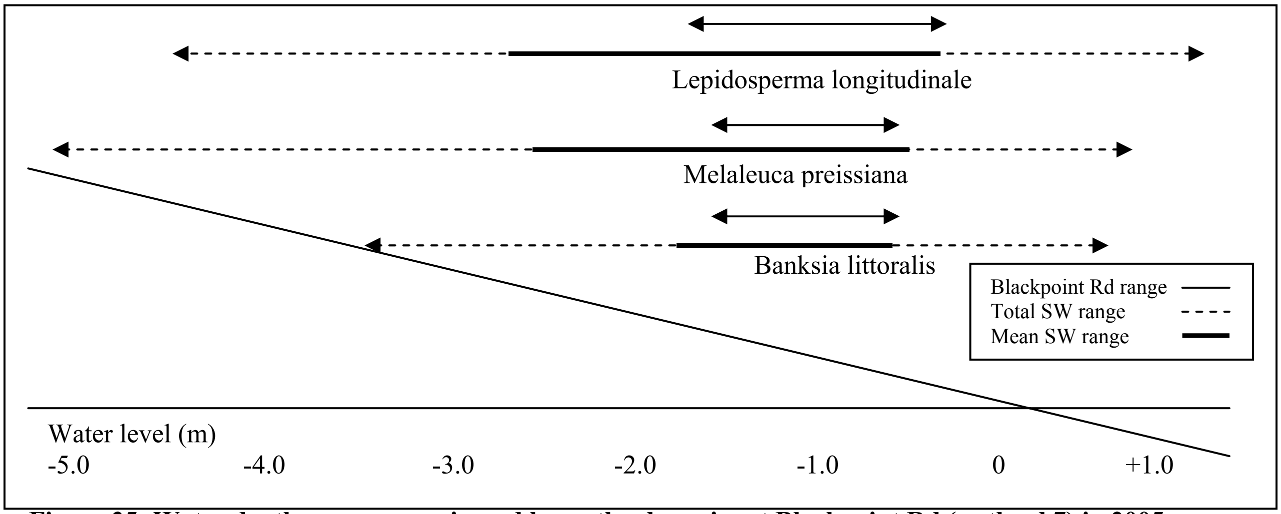


Figure 35: Water depth ranges experienced by wetland species at Blackpoint Rd (wetland 7) in 2005 compared to total and mean ranges across SW wetlands.

Darradup Rd (wetland 8Y)

The water depth ranges experienced in 2005 across the Darradup Rd (wetland 13Y) transect by *M. preissiana* and *Hypocalymma angustifolium* extended beyond the wet end of their SW means (Figure 36). However, while *M. preissiana* remained within its SW total, *H. angustifolium* experienced wetter conditions than its total SW range.

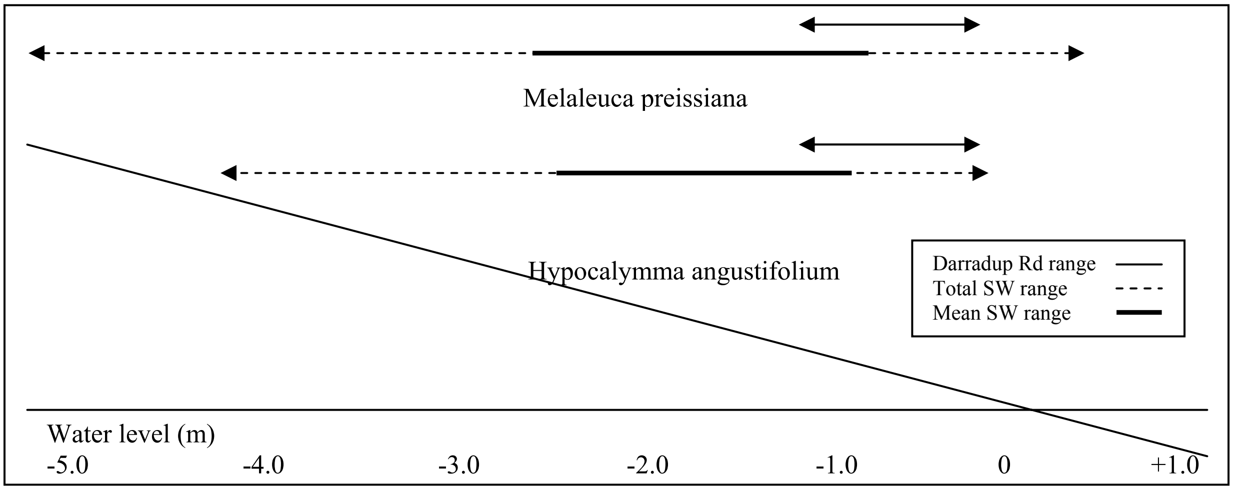


Figure 36: Water depth ranges experienced by wetland species at Darradup Rd (wetland 13Y) in 2005 compared to total and mean ranges across SW wetlands.

Darradup Rd (wetland 8X)

The water depth range experienced in 2005 across the Darradup Rd (wetland 13B) transect by single identified wetland species, *M. preissiana*, was beyond the wet end of its SW mean, but within the species total range (Figure 37).

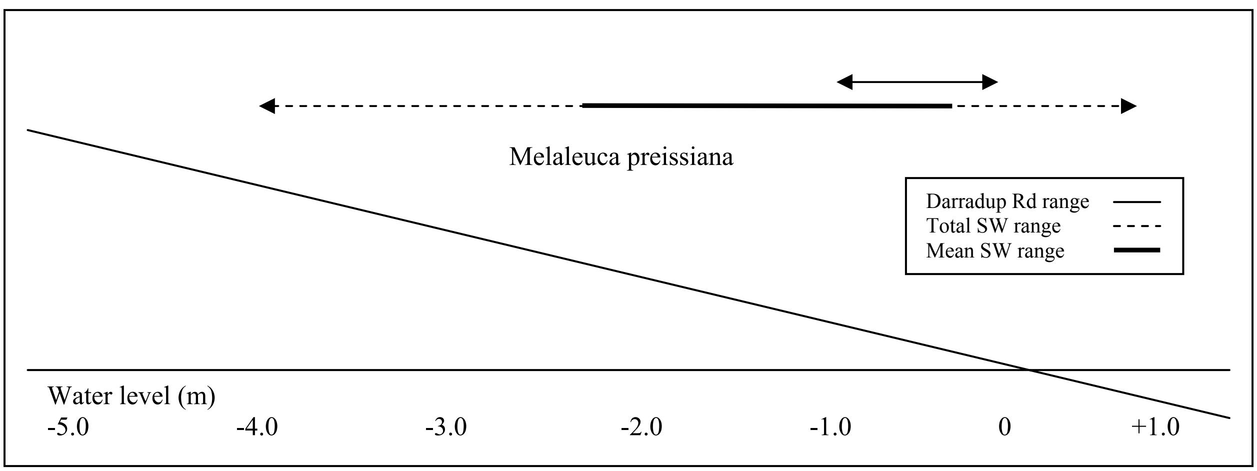


Figure 37: Water depth ranges experienced by wetland species at Darradup Rd (wetland 13B) in 2005 compared to total and mean ranges across SW wetlands.

Blackwood River Crossing – Longbottom Rd (wetland 9)

The water depth range experienced in 2005 across the Blackwood River Crossing transect by two of the three identified wetland species, *B. littoralis* and *P. ellipitcum*, extended beyond the wet end of their mean SW ranges whilst remaining within their total ranges (Figure 38). The range of *M. preissiana* at this site was within both its SW mean and total ranges.

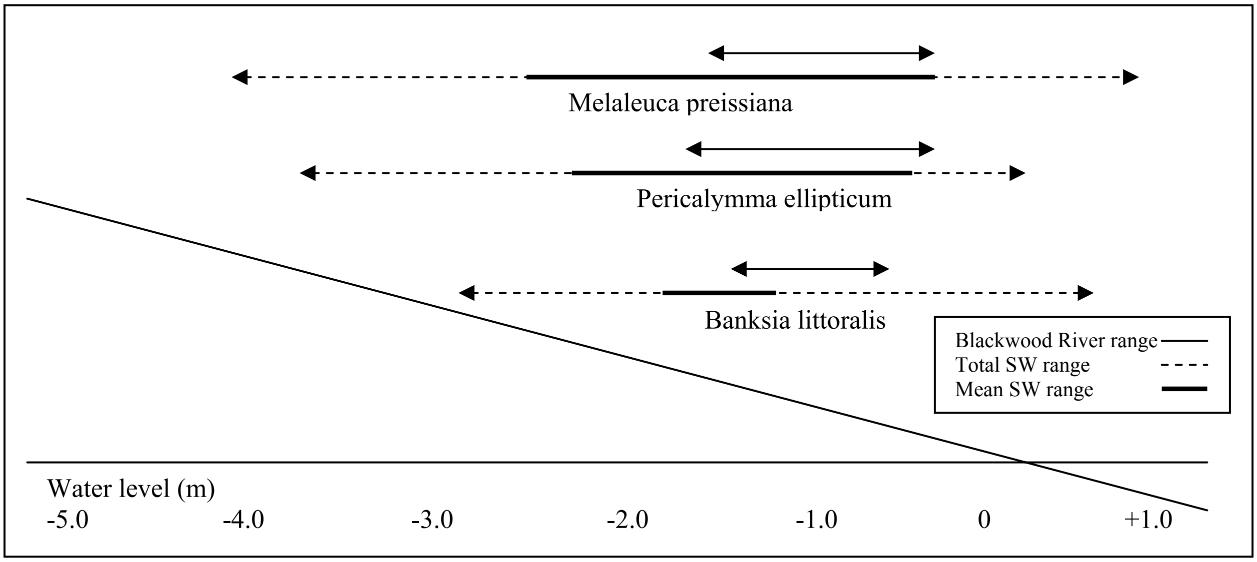


Figure 38: Water depth ranges experienced by wetland species at Blackwood River Crossing (wetland 21) in 2005 compared to total and mean ranges across SW wetlands.

Brockman Highway - Milyeanup (wetland 10)

The water depth range experienced in 2005 across the Brockman Highway - Milyeanup transect by the single identified wetland species, *Eucalyptus rudis*, was within both the species mean and total SW ranges (Figure 39).

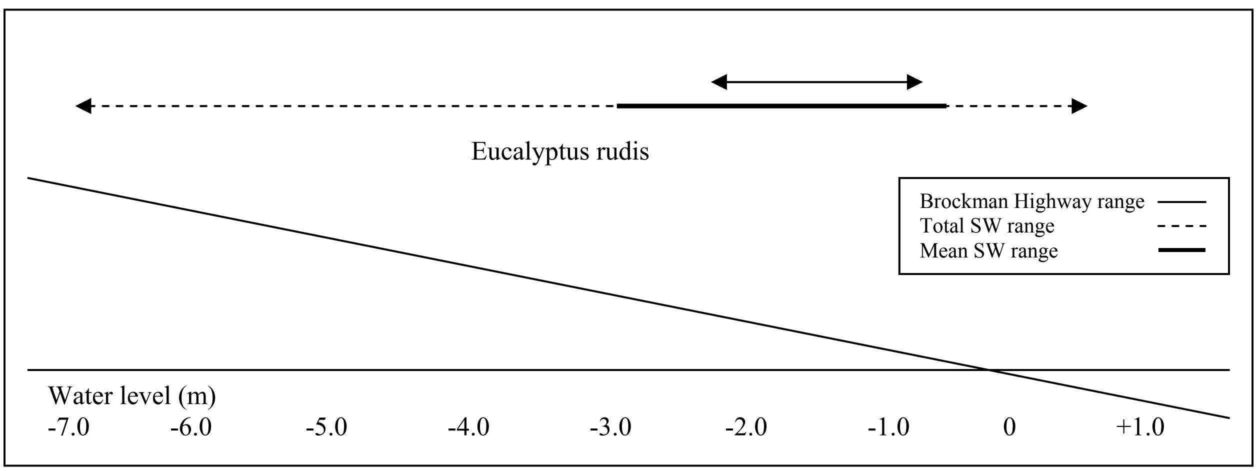


Figure 39: Water depth ranges experienced by wetland species at Brockman Highway - Milyeanup (wetland 22) in 2005 compared to total and mean ranges across SW wetlands.

Stewart Highway (wetland 11)

The water depth ranges experienced in 2005 across the Stewart Highway transect by the three identified wetland species, *B. littoralis, P. ellipitcum* and *M. preissiana*, extended beyond the wet end of their mean SW ranges whilst remaining within their total ranges (Figure 40).

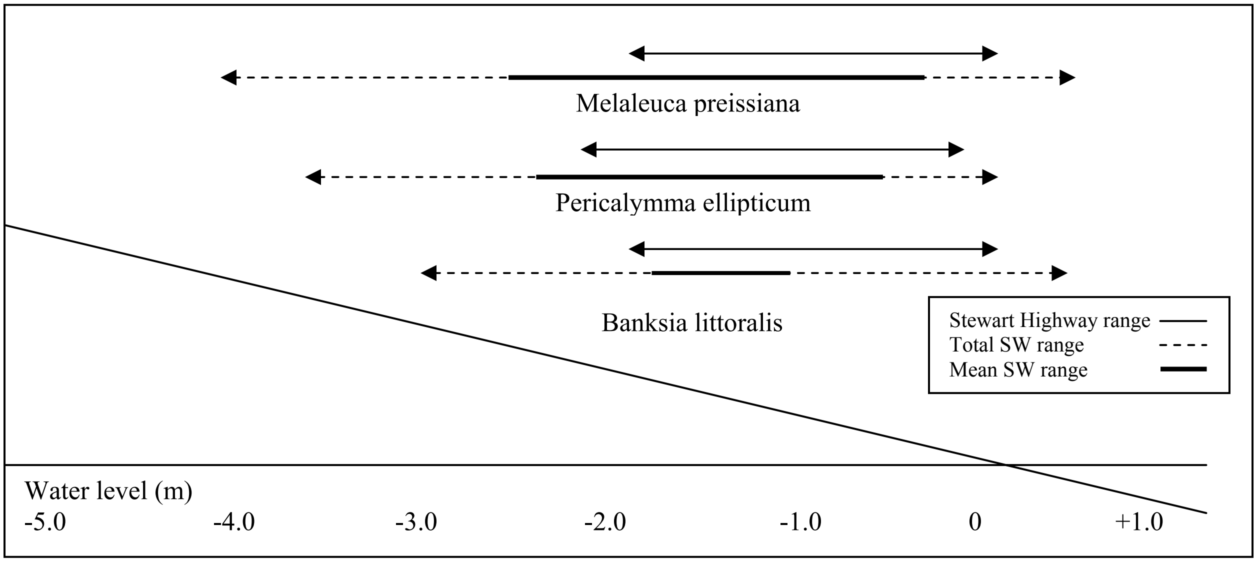


Figure 40: Water depth ranges experienced by wetland species at Stewart Highway (wetland 22) in 2005 compared to total and mean ranges across SW wetlands.

Poison Gully (wetland 12)

The water depth ranges experienced in 2005 across the Poison Gully transect by *M. preissiana* extended beyond the wet end of its SW mean range, but remained within its total (Figure 41). The range of *Pultenaea reticulata* however, extended beyond the dry end of its SW mean towards the end of its total range.

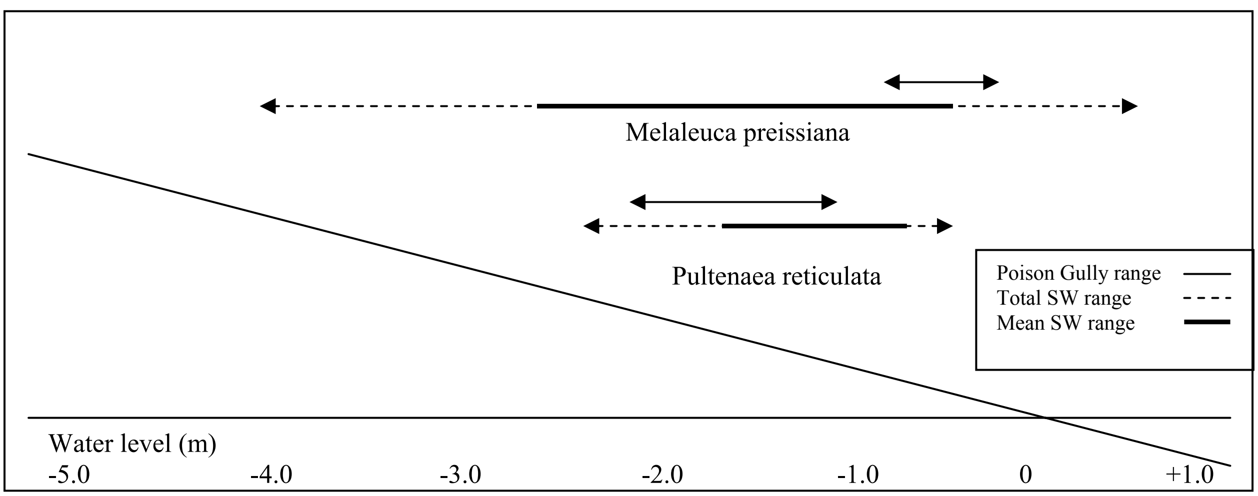


Figure 41: Water depth ranges experienced by wetland species at Poison Gully (wetland 31) in 2005 compared to total and mean ranges across SW wetlands.

Blackpoint/ Fouracres Rd terrestrial

The water depth ranges experienced in 2005 across the Blackpoint/ Fouracres Rd terrestrial transect by *Taxandria parviceps* and *Astartea juniperiana* extended beyond the dry end of their study area mean while remaining within their total ranges (Figure 42). While occurring towards the dry end of their study area mean ranges, *Banksia grandis* and *E. marginata* were within their total water depth ranges.

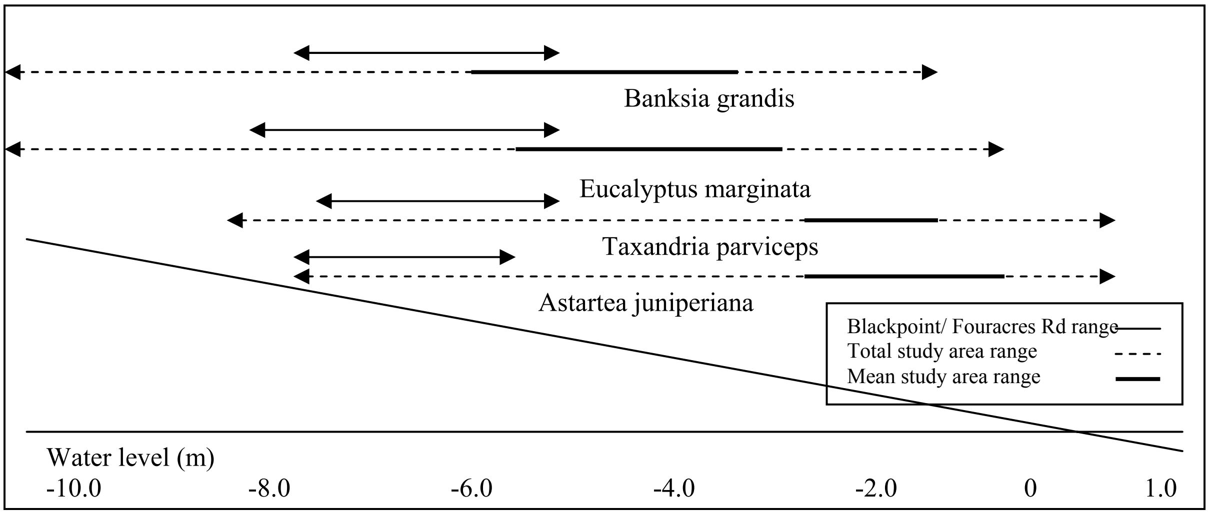


Figure 42: Water depth ranges experienced by wetland species at Blackpoint/ Fouracres Rd terrestrial site in 2005 compared to total and mean ranges across study area sites.

Darradup Rd East terrestrial

The water depth ranges experienced in 2005 across the Darradup Rd East terrestrial transect by *E. marginata, Allocasuarina fraseriana* and *Corymbia calophylla* extended beyond the wet end of their study area means while remaining within total ranges. (Figure 43).

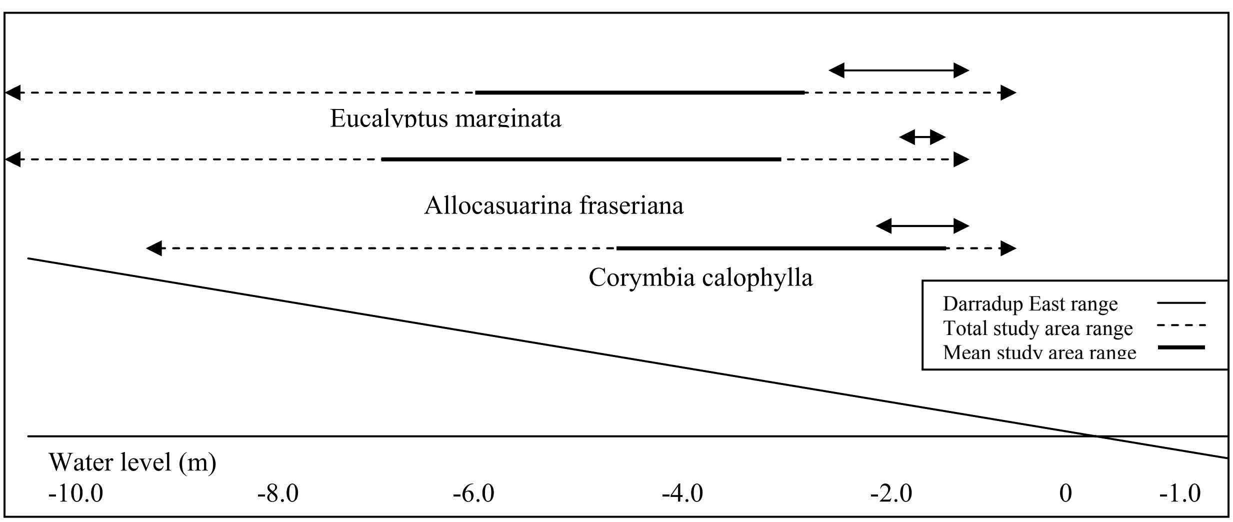


Figure 43: Water depth ranges experienced by wetland species at Darradup Rd terrestrial site in 2005 compared to total and mean ranges across study area sites.

Blackwood River Crossing – Longbottom Rd terrestrial

The water depth range experienced in 2005 across the Blackwood River Crossing terrestrial transect by *E. marginata* extended beyond the wet end of its study area mean while remaining within its total range (Figure 44). While extending beyond the wet end of their study area mean ranges, *T. parviceps* and *Corymbia calophylla* were within their total water depth ranges.

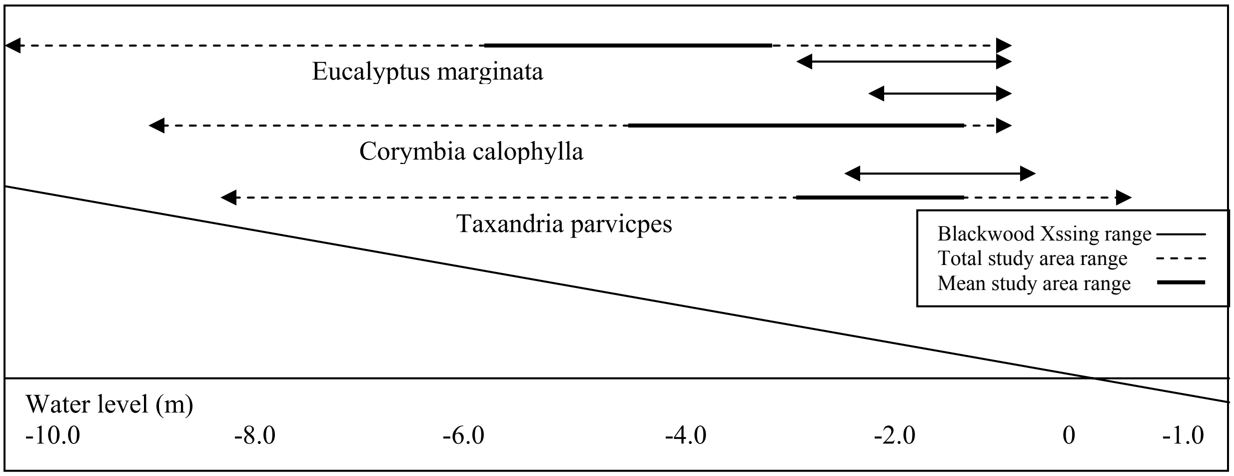


Figure 44: Water depth ranges experienced by wetland species at Blackwood River Crossing terrestrial site in 2005 compared to total and mean ranges across study area sites.

Brockman Highway - Milyeanup terrestrial

The water depth ranges experienced in 2005 across the Brockman Highway - Milyeanup terrestrial transect by *E. marginata* and *Banksia grandis* were beyond the wet end of their study area means while remaining within their total ranges (Figure 45). The range of *C. calophylla* fell largely within its mean water depth range, albeit closer to the wet end of its total range.

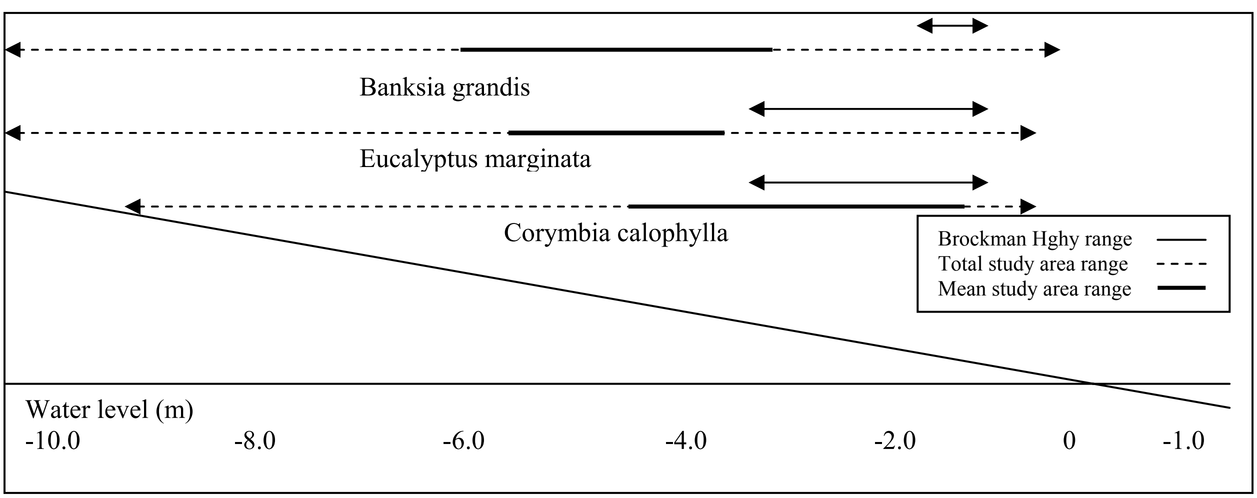


Figure 45: Water depth ranges experienced by wetland species at Brockman Highway - Milyeanup terrestrial site in 2005 compared to total and mean ranges across study area sites.

Poison Gully terrestrial

The water depth ranges experienced in 2005 across the Poison Gully terrestrial transect by *E. marginata*, *B. grandis* and *A. fraseriana* extended well beyond the dry end of their mean ranges incorporating the driest conditions of all study sites (Figure 46). Only *E. marginata* experienced conditions wetter than its mean study site range.

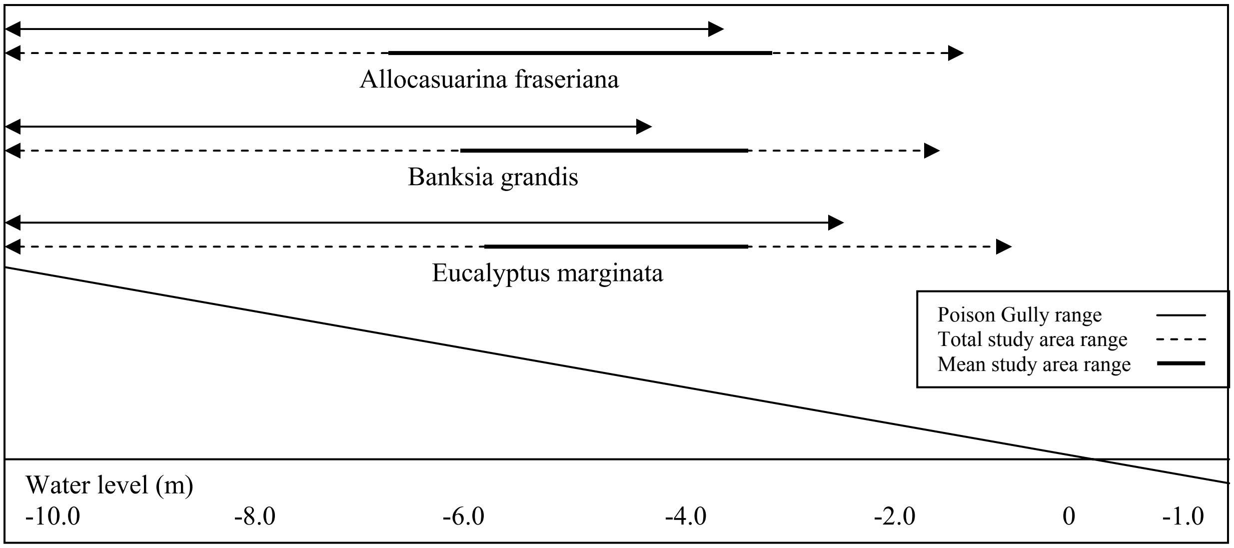


Figure 46: Water depth ranges experienced by wetland species at Poison Gully terrestrial site in 2005 compared to total and mean ranges across study area sites.

Stewart Rd terrestrial

The water depth ranges experienced in 2005 across the Stewart Rd terrestrial transect by *E. marginata* and *C. calophylla* were towards the wet end of their study site mean and total ranges (Figure 47). *T. parviceps* fell towards the dry end of its mean range, but within its total range.

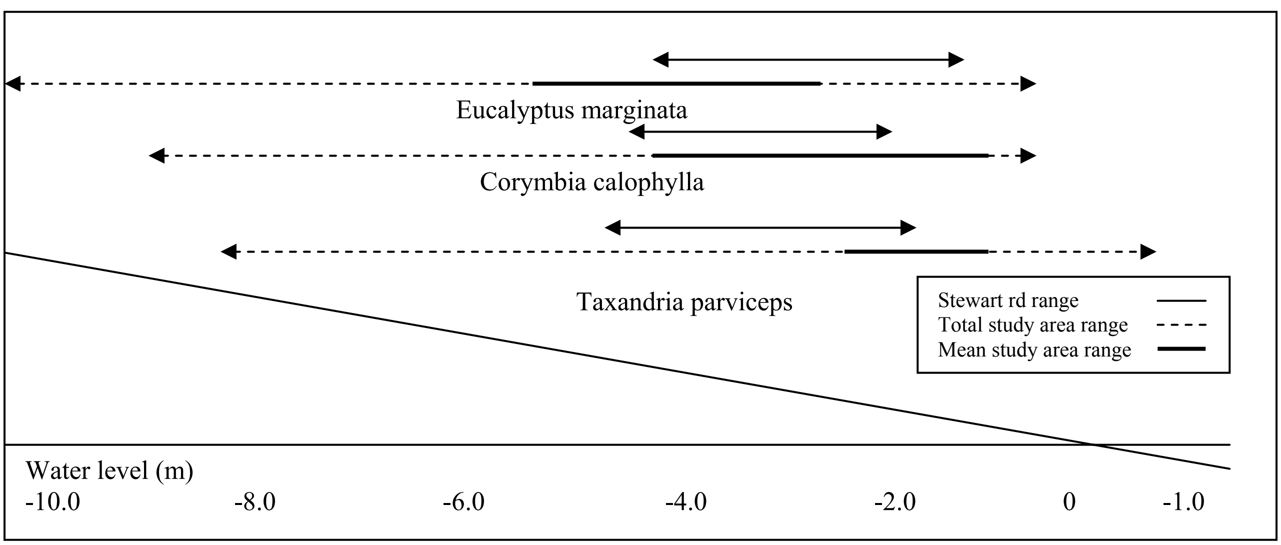


Figure 47: Water depth ranges experienced by wetland species at Stewart Rd terrestrial site in 2005 compared to total and mean ranges across study area sites.

Darradup Rd North terrestrial

The water depth range experienced in 2005 across the Darradup Rd North terrestrial transect by *A. juniperiana* was drier than the species mean study site range falling towards the dry end of its total range (Figure 48). The range of *E. marginata* also fell towards the dry end of its mean range, but was well within the total study site range.

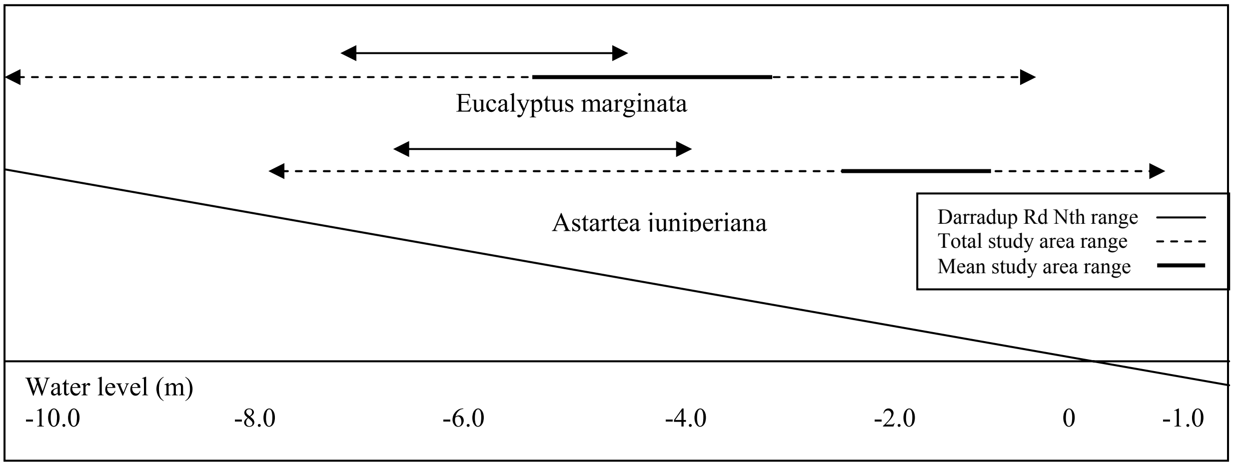


Figure 48: Water depth ranges experienced by wetland species at Darradup Rd North terrestrial site in 2005 compared to total and mean ranges across study area sites.

Jack Track terrestrial

The water depth range experienced in 2005 across the Jack Track terrestrial transect by *A. fraseriana* was very similar to the species mean study area range (Figure 49). The range of *E. marginata* fell towards the dry end of its mean range yet remained well within its study area total range.

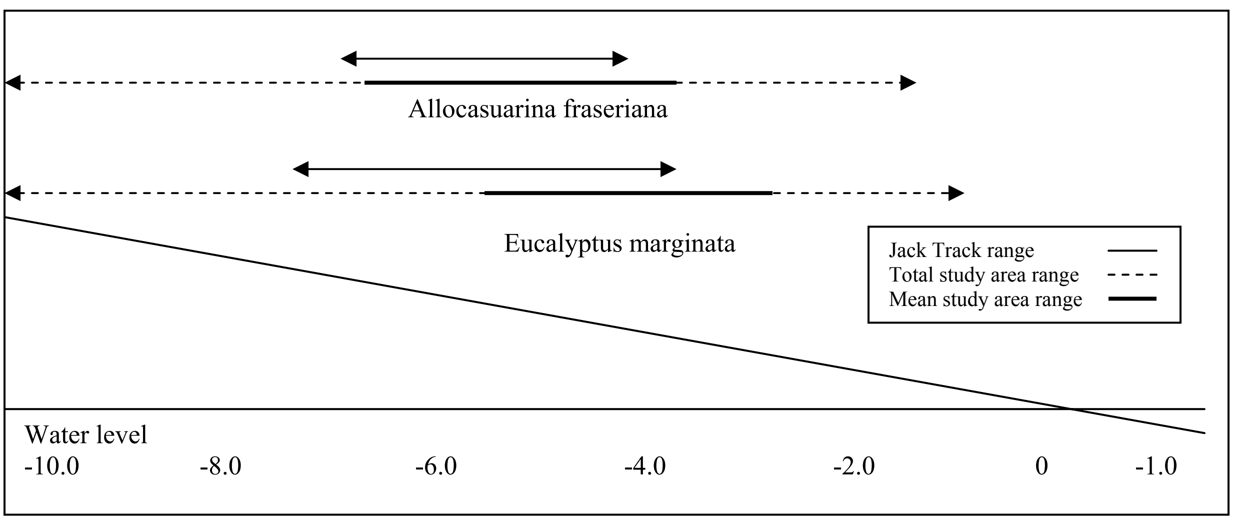


Figure 49: Water depth ranges experienced by wetland species at Jack Track terrestrial site in 2005 compared to total and mean ranges across study area sites.

Scott Rd terrestrial

The water depth range experienced in 2005 across the Scott Rd terrestrial transect by *E. marginata* fell towards the wet end of the species mean and total study areas ranges (Figure 50). The range of *Agonis flexuosa* also occurred towards the wet end of its mean range and incorporated the wettest conditions experienced by the species across the study area.

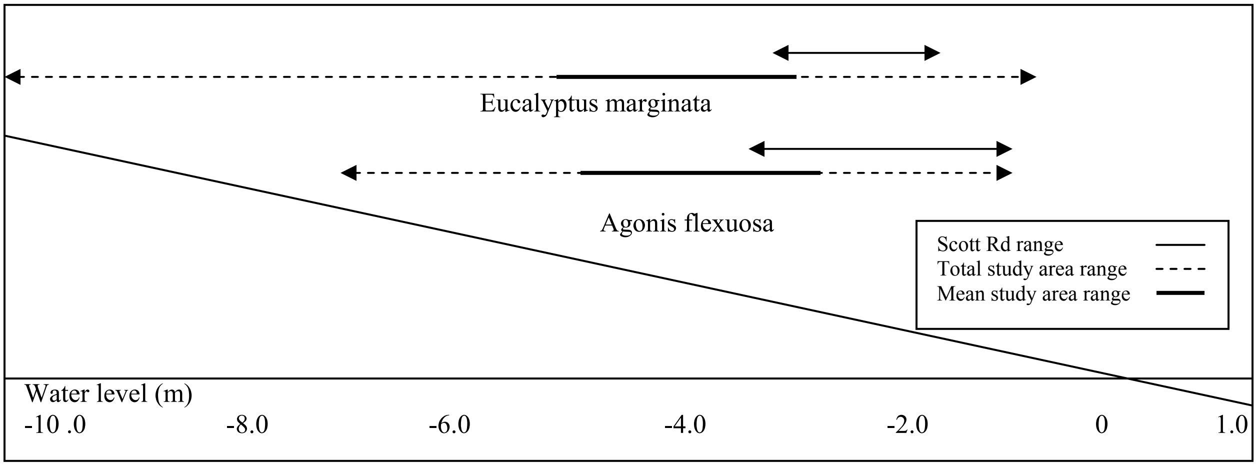


Figure 50: Water depth ranges experienced by wetland species at Scott Rd terrestrial site in 2005 compared to total and mean ranges across study area sites.

Blackpoint Rd terrestrial

The water depth range experienced in 2005 across the Blackpoint Rd terrestrial transect by all study species fell towards the dry end of their total study area ranges, with the exception of *B. grandis* which occurred towards the wetter end of its mean and total ranges (Figure 51). *E. marginata* and *A. flexousa* occurred beyond their mean ranges, while the ranges of *T. parviceps* and *C. calophylla* incorporated the dry end of their means.

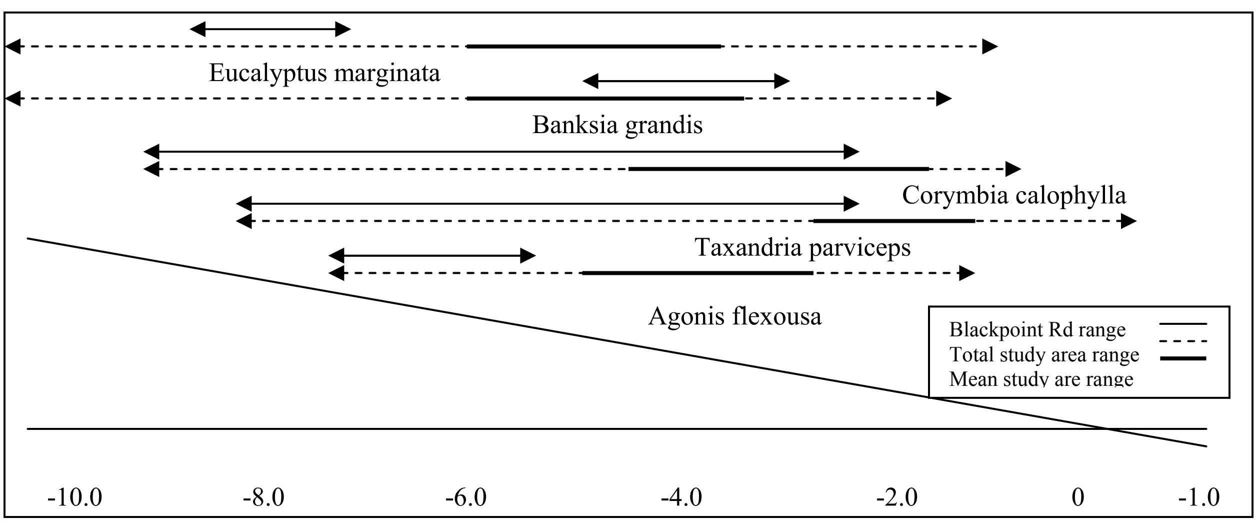


Figure 51: Water depth ranges experienced by wetland species at Blackpoint Rd terrestrial site in 2005 compared to total and mean ranges across study area sites.

Ecological Water Requirements

Background/ Approach

Wetland Vegetation EWRs

Ideally wetland EWRs should consider the requirements of all ecological components in the system including fauna and sediments. However, the paucity of information available on the ecology and values of wetlands in the study area, with the possible exception of Lake Jasper, necessitates the setting of EWRs based solely on wetland vegetation water requirements.

There are a number of components of the water regime that influence wetland vegetation (Roberts, Young, & Marston, 2000). The season of flooding or highest groundwater levels determines the climatic variables, such as day length and temperature that persist during periods of greatest water availability (Roberts et al., 2000). The combination of climatic variables and water availability a species requires will determine when it grows and reproduces (Roberts et al., 2000). The rate at which surface water rises is important as a rapid increase in depth will not allow emergent species to grow quickly enough to stay above the water (Brock & Casanova, 1997), while the rate of groundwater decline will influence which species can tolerate loss of connectivity to sub-surface water sources. The frequency of flooding/ wetting or drought and the interval between these episodes are also important for growth and reproduction. For example, the seeds of some species may become unviable if dry for too long a period, while other species may require lengthy dry periods to germinate and establish (Roberts et al., 2000).

For the purposes of this report, the depth to groundwater is considered the most important component of the water regime. The impact of depth on vegetation is dependent on the size and growth form of a species. Large species can grow above the water and/ or access groundwater due to more extensive root systems, while smaller plants may drown and/ or be unable to access groundwater (Roberts et al., 2000). A strong relationship therefore exists between the distribution, growth and reproduction of wetland vegetation and the depth of ground/ surface water (Brownlow, Sparrow, & Ganf, 1994; Froend & McComb, 1994; Mountford & Chapman, 1993; Neilsen & Chick, 1997).

In this section EWRs are presented as a scale of maximum depth to groundwater levels (DTGs) or minimum surface water levels (minimum summer/ autumn levels), as measured at the piezometer/ bore/ staff gauge. In the first instance this was been achieved through consideration of eco-hydrological ranges of key species common to the South West of WA (refer to Task 3) and their current (2005) distribution at each criteria wetland.

Specifically, a species mean maximum SW DTG (m) was subtracted from both its lower (L) and upper (U) elevational range (m or mAHD) at a site to provide a range of maximum DTGs (U max DTG and L max DTG) required to maintain that species at that specific criteria site. For example, *Banksia littoralis* occurred between elevations of 39.4 and 39.56 mAHD at the Lake Jasper East transect. Subtracting its SW mean maximum DTG (1.82 m) from these elevations, gives a range of 37.58 to 37.74 mAHD (Figure 52).

A range in maximum DTGs rather than a single level as generally applied provides managers with greater scope for managing an ecological system within the context of climate and landuse changes not related to groundwater abstraction.

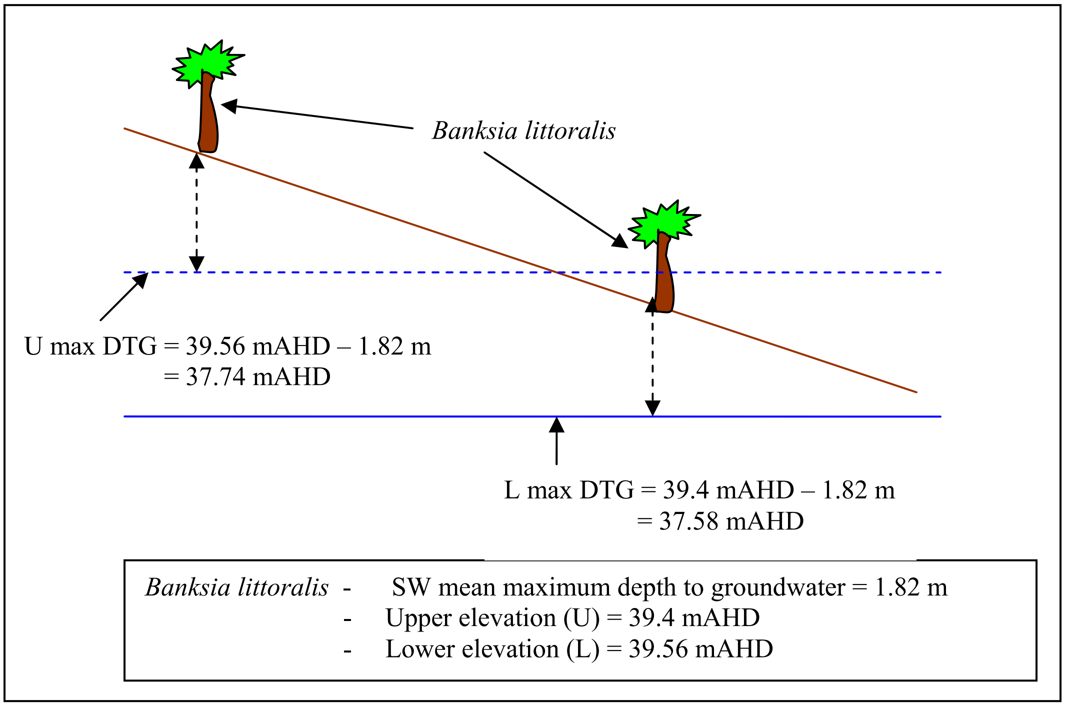


Figure 52: Example diagram showing approach to EWR (max DTG) determination as applied to wetland and terrestrial vegetation in this study.

A maximum DTG range was calculated for all common wetland species (see Appendices 3, 4 and 5) and the range of the most vulnerable species (ie. the species with the 'smallest' DTG) and least vulnerable species (ie. species with 'greatest' DTG) compared to the current (2005) minimum and maximum DTG at the site. For verification, identified greatest allowed depth to groundwater (maximum or max DTG) were then compared to current water level ranges experienced by common species at each site. Where applicable recommended max DTG were re-assessed to better represent current ranges. Figure 53 provides an example of the EWR figures presented in the results section.

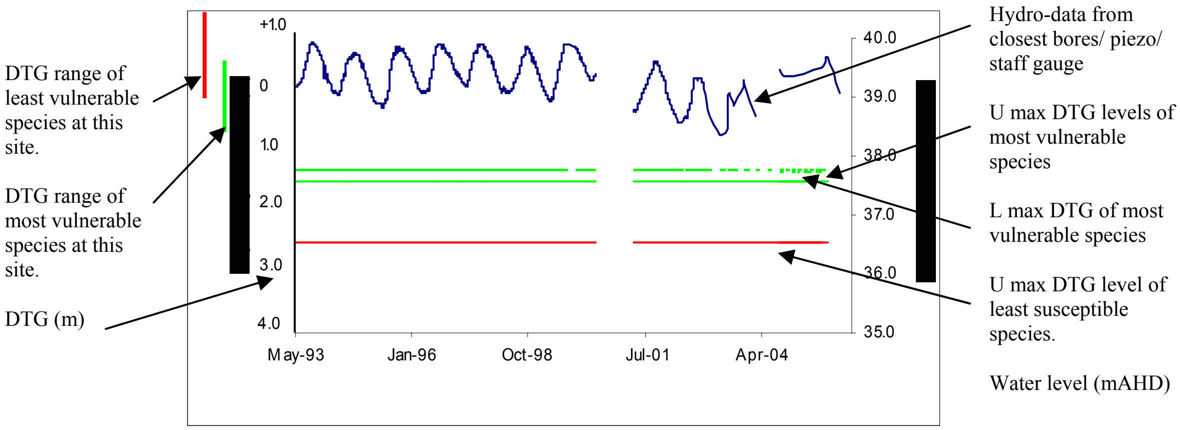


Figure 53: Example EWR figure with descriptions of key elements.

The max DTG range required by the most vulnerable species represents a range of summer/ autumn minimum groundwater levels considered necessary to maintain that species, and therefore all other less vulnerable species, at a low level of risk. The L max DTG of the least vulnerable species, is considered necessary to maintain only that species at the site at a low level of risk. At this DTG all other species are at a higher level of risk.

The only exceptions to this approach were Lake Jasper south, where longer term hydrological data were available and were compared to species minimum water level ranges and Lake Jasper East, where surface water levels were considered. The entire water level range of both the most and least vulnerable species were also considered.

Terrestrial EWRs

All terrestrial sites supported *Eucalyptus marginata* (jarrah) with *Corymbia calophylla* (marri) also prevalent at the majority of sites. Research on water relations and rooting patterns has shown *E. marginata* to be less capable of extracting soil water than *C. calophylla* and *B. grandis* (Crombie, Tippett, & Hill, 1988) and to derive the majority of its summer water supply from underlying clay horizons (Carbon, Bartle, Murray, & Macpherson, 1980). However, it has also been found that although tap roots of *E. marginata* may extend to a depth of 20-30 m (Crombie, 1992) water is extracted from shallower water sources in preference to deeper soils (Crombie, 1997). This suggests that in areas of shallow groundwater (<10 m) *E. marginata* are likely to use this source in preference to soil moisture and possibly water held in underlying clays, although the clay horizon may mitigate impacts of groundwater level decline. For the purposes of this report it is assumed that *E. marginata, C. calophylla, B. grandis* and *A. fraseriana* currently access the shallow groundwater available to them at all terrestrial sites.

Terrestrial ecosystem criteria site EWRs were also based on the requirements of vegetation due to the paucity of information on other ecological components. The approach described above for wetland vegetation EWRs was applied. Although a small number of wetland species (*Astartea juniperiana, Taxandria parviceps, Pericalymma* *ellipitcum, Lepidosperma longitudinale*) occurred at some terrestrial sites, and were included in the initial EWR assessment, they were excluded from the final EWR determination process as their water level requirements reflected those of a wetland system. It is probable that individuals of these species access soil water from underlying clays noted during piezometer/ bore installation at terrestrial sites (Appendix 2) rather than from the actual groundwater table.

Results

Lake Jasper (wetland 1)

To maintain the most vulnerable of the dominant wetland species recorded at the Lake Jasper South transect (*Taxandria parviceps*) at a low level of risk following the recommended approach, a minimum groundwater level (upper maximum DTG) of between 40.76 mAHD and 39.0 mAHD (lower maximum DTG) may be required (Figure 54). If the minimum groundwater level falls below 39.0 mAHD this species may not be maintained at this site. A minimum groundwater level range of 39.0 mAHD and 36.64 mAHD (lower maximum DTG) may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A groundwater level below 36.64 mAHD may be insufficient to maintain any dominant species at a low level of risk.

The upper maximum DTG (U max DTG) of the most vulnerable species largely exceeded actual groundwater levels measured at SC21B, 10 m from the transect (Figure 54). The lower maximum DTG (L max DTG) however, was very similar to existing minimum levels (38.93 mAHD), while the L max DTG of the least vulnerable species was 2.5 m below current groundwater levels. The existing water level ranges of the most and least vulnerable species fell within or very close to the recommended max DTGs however, a recommended groundwater level of 38.5 mAHD should meet the requirements of the most vulnerable species while allowing for some change in current levels. It is further recommended that groundwater levels persist no longer than two years below these minimum levels. It must be noted that these groundwater level ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species.

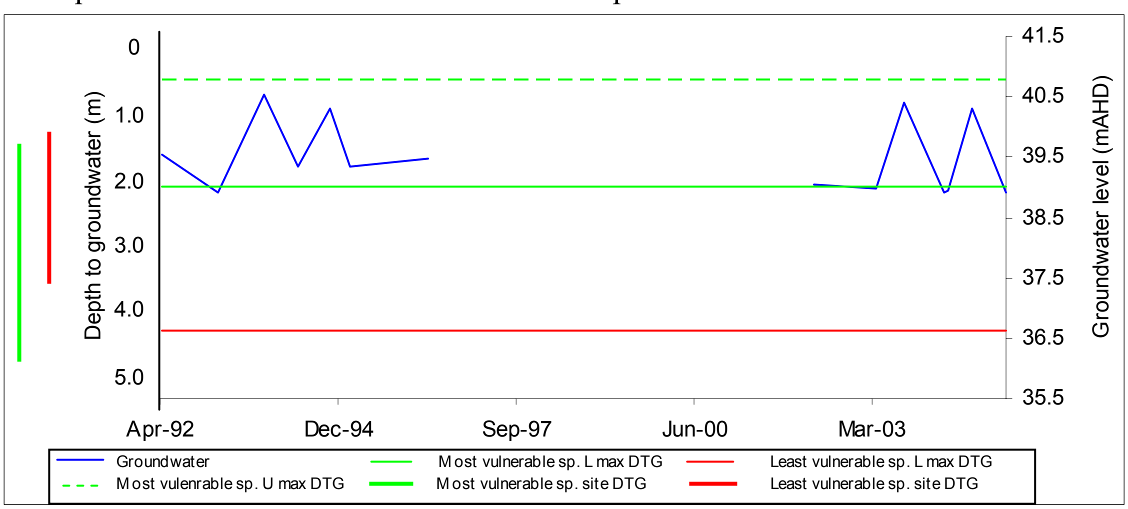


Figure 54: Groundwater levels at Lake Jasper South transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

To maintain the most vulnerable of the dominant wetland species recorded at the Lake Jasper East transect (*Banksia littoralis*) at a low level of risk following the recommended approach, a minimum groundwater level (upper maximum DTG) of between 37.74 mAHD and 37.58 mAHD (lower maximum DTG) may be required (Figure 55). If the minimum groundwater level falls below 37.58 mAHD this species may not be maintained at this site. A minimum groundwater level range of 37.58 mAHD and 36.54 mAHD (lower maximum DTG) may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A groundwater level below 36.54 mAHD may be insufficient to maintain any dominant species at a low level of risk.

All minimum groundwater levels identified following the above approach fell well below existing surface water levels at Lake Jasper (April min 2005 - 39.06 mAHD) and existing water level ranges of the most and least vulnerable species. It is therefore recommended that an autumn minimum surface water level not fall below 38.5 mAHD, a level more representative of current requirements. It is further recommended that surface water levels persist no longer than two years below this minimum level. A minimum spring peak surface water level should also be considered. As a large proportion of the *Baumea articulata* at this site is inundated at a water level of 39.0 mAHD, this level should meet the requirements of the species and reduce the likelihood of its encroachment into the wetland.

It must be noted that these groundwater level ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. Due to the extremely high ecological values of Lake Jasper, it is recommended that further research be undertaken on requirements of macroinvertebrates, vertebrates and wetland sediments before a final EWR is determined.

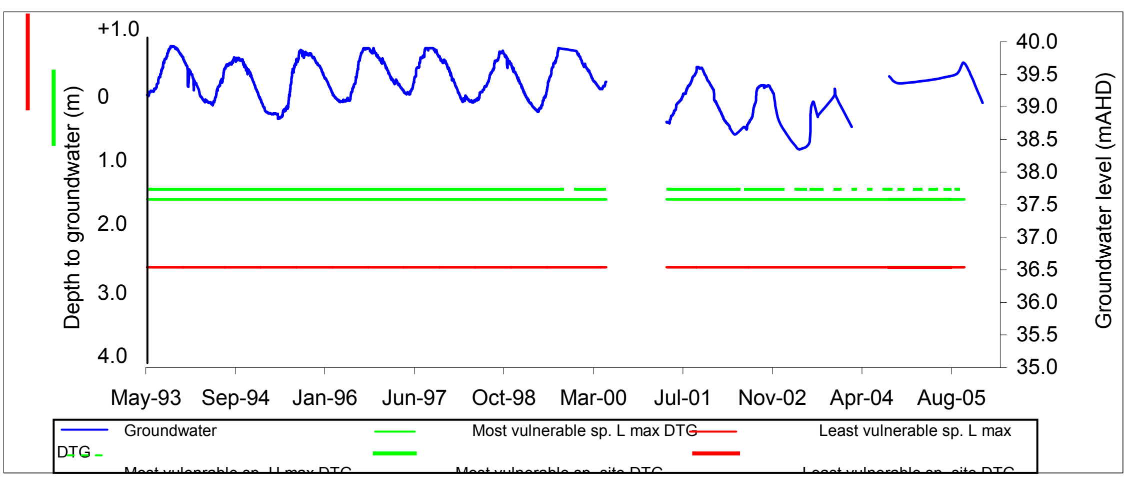


Figure 55: Surface water levels at Lake Jasper East transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Jangardup Rd (wetland 2)

To maintain the most vulnerable of the dominant wetland species recorded at the Jangardup Rd transect (*Melaleuca preissiana*) at a low level of risk following the recommended approach, a max DTG of between 1.8 m and 1.95 m may be required (Figure 56). If the groundwater level falls below 1.95 m this species may not be maintained at this site. A max DTG range of 1.95 m to 2.42 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.42 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.85 m.

The recommended max DTG of the most and least vulnerable species and their existing water level ranges at Jangardup Rd were closely related. Therefore, considering the uncertainty regarding depth to groundwater and absence of water level monitoring a max DTG of 2.0 m should maintain wetland vegetation at this site. It is further recommended that groundwater levels persist no longer than two years below these minimum levels. It must however, be noted that these max DTG ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species.

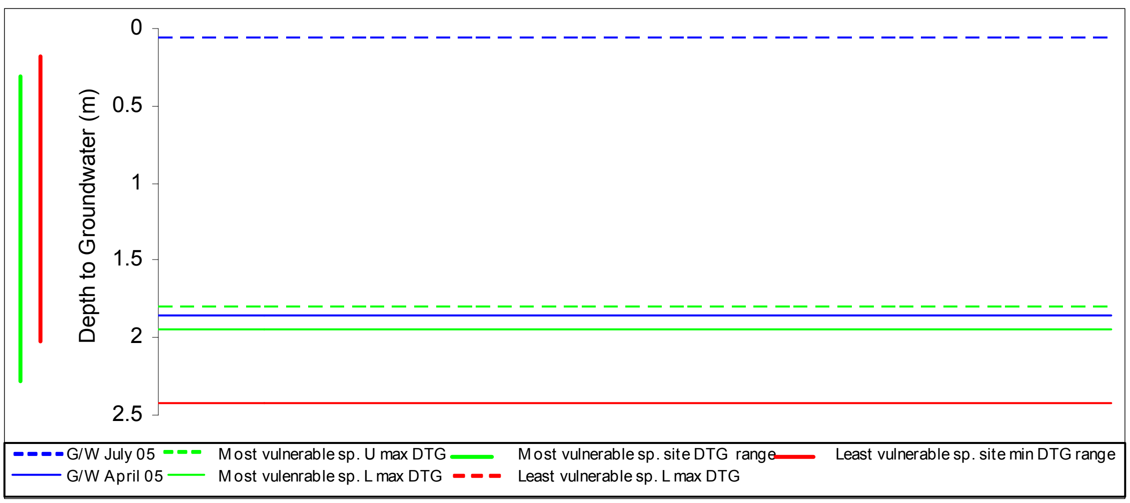


Figure 56: Groundwater levels at the Jangardup Rd wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Blackpoint Rd (wetland 3)

To maintain the most vulnerable of the dominant wetland species recorded at the Blackpoint Rd transect (*Melaleuca preissiana*) at a low level of risk following the recommended approach, a max DTG of between 1.88 m and 2.04 m may be required (Figure 57). If the max DTG falls below 2.04 m this species may not be maintained at this site. A max DTG range of 2.04 m to 2.42 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.42 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.74 m.

The identified max DTG of the most and least vulnerable species fell below their existing water level ranges at the Blackpoint Rd wetland. However, as the max DTG of the most vulnerable species is only 0.14 m below the 2005 minimum groundwater level, this level should meet the requirements of wetland vegetation at the site. It is further recommended that groundwater levels persist no longer than two years below this minimum level. It must be noted that these max DTG ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species.

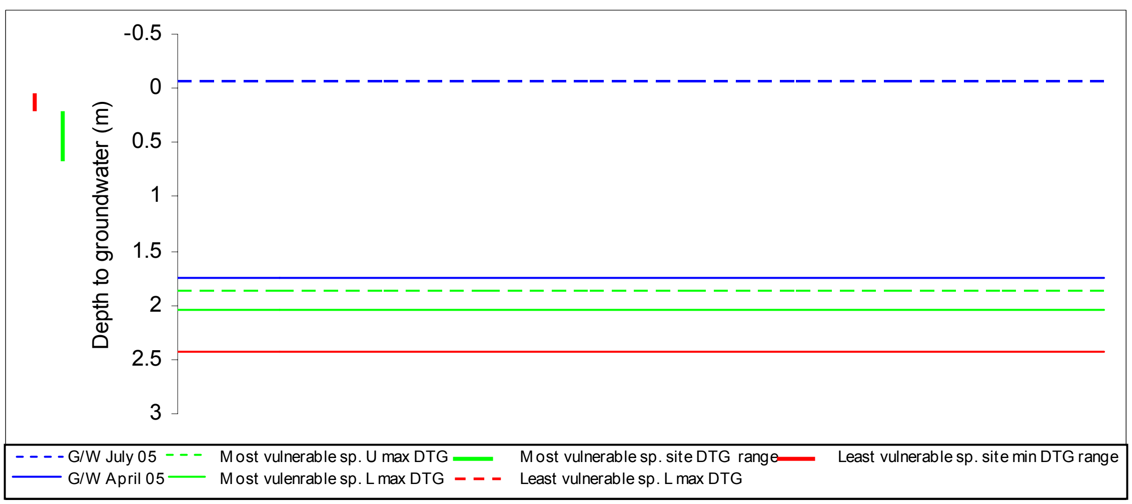


Figure 57: Groundwater levels at Blackpoint Rd wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Pneumonia Rd (wetland 4)

To maintain the most vulnerable of the dominant wetland species recorded at the Pneumonia Rd transect (*Melaleuca preissiana*) at a low level of risk following the recommended approach, a max DTG of between 2.31 m and 2.55 m may be required (Figure 58). If the max DTG falls below 2.55 m this species may not be maintained at this site. A max DTG range of 2.55 m to 2.63 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.63 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.51 m.

The identified max DTG of the most and least vulnerable species fell below their existing water level ranges at the Pneumonia Rd wetland. This may be due to the number of unidentified species, recorded at the site and the potential that these had higher water level requirements than identified species. Therefore, also considering the uncertainty regarding depth to groundwater and absence of water level monitoring a max DTG of 2.31 m should maintain wetland vegetation at this site It must be noted that these minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. It is further recommended that groundwater levels persist no longer than two years below this minimum level.

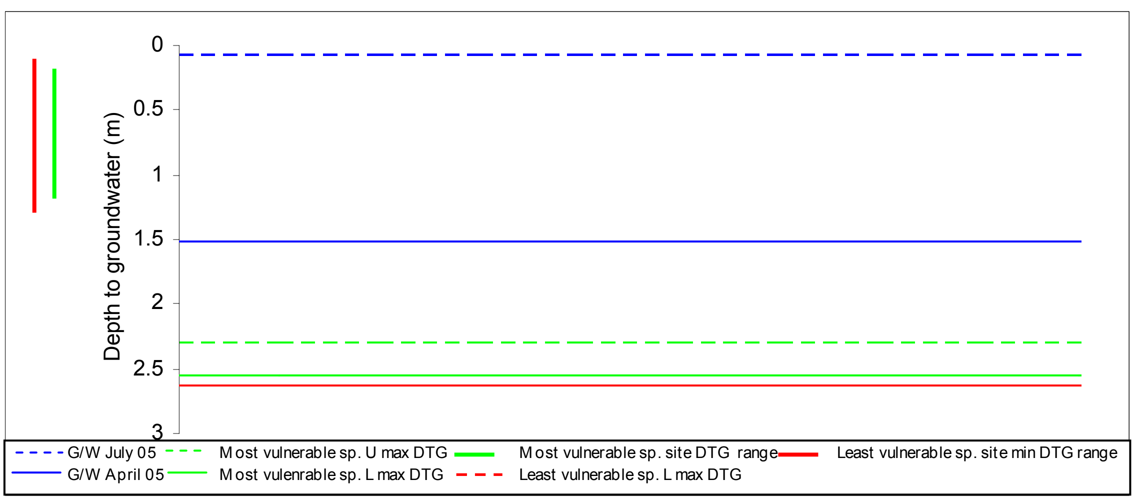


Figure 58: Groundwater levels at Pneumonia Rd wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Blackpoint/ Fouracres Rd (wetland 5)

To maintain the most vulnerable of the dominant wetland species recorded at the Blackpoint/ Fouracres Rd transect (*Taxandria parviceps*) at a low level of risk following the recommended approach, a max DTG of between 2.45 m and 3.36 m may be required (Figure 59). If the DTG falls below 3.36 m this species may not be maintained at this site. A max DTG range of 3.36 m to 3.45 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 3.45 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 3.11 m.

The L max DTG of the most vulnerable species (3.36 m) fell close to the max DTG of all wetland species identified at this wetland. Although this represents a maximum groundwater level decline of 0.25m from 2005 levels, a max DTG between 2.45 m and 3.36 m is recommended. It must be noted however, that minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. It is further recommended that groundwater levels persist no longer than two years below these minimum levels.

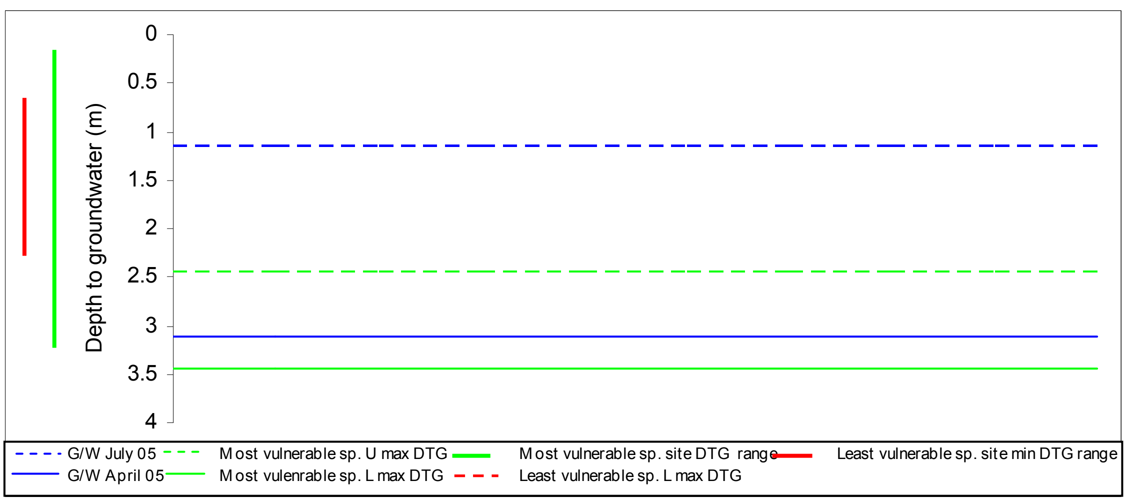


Figure 59: Groundwater levels at Blackpoint/ Fouracres Rd wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Blackpoint Rd -dunes (wetland 6)

To maintain the most vulnerable of the dominant wetland species recorded at the Blackpoint Rd transect (*Banksia littoralis*) at a low level of risk following the recommended approach, a max DTG of between 2.12 m and 2.18 m may be required (Figure 60). If the max DTG falls below 2.18 m this species may not be maintained at this site. A max DTG range of 2.18 m to 2.82 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.82 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.34 m.

The identified max DTG of the most and least vulnerable species fell well below their existing water level ranges at the Blackpoint Rd wetland and current groundwater levels. This may be due to the number of unidentified species, specifically sedges, recorded at the site and the potential that these had higher water level requirements than identified species. Therefore, after consideration of this, the uncertainty regarding depth to groundwater and absence of water level monitoring a max DTG of 1.6 m is recommended as this should maintain wetland vegetation at this site. It is further recommended that groundwater levels persist no longer than two years below these minimum levels.

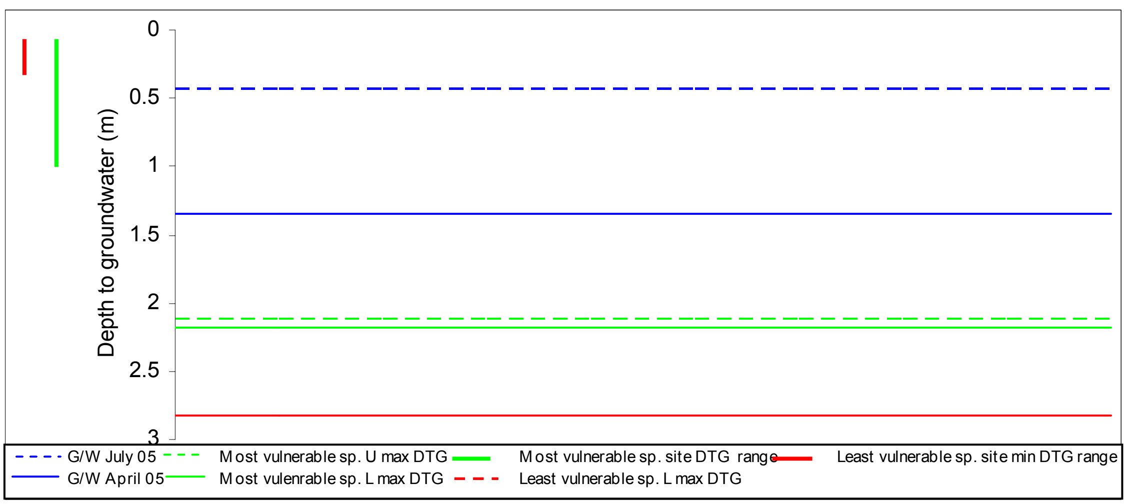


Figure 60: Groundwater levels at Blackpoint Rd base of dunes wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Blackpoint Rd (wetland 7)

To maintain the most vulnerable of the dominant wetland species recorded at the Blackpoint Rd transect (*Banksia littoralis*) at a low level of risk following the recommended approach, a max DTG of between 1.7 m and 1.86 m may be required (Figure 61). If the max DTG falls below 1.86 m this species may not be maintained at this site. A max DTG range of 1.86 m to 2.49 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.49 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.53 m.

The identified max DTG of the most and least vulnerable species fell slightly below their existing water level ranges and current groundwater levels at this site. Although the U max DTG (1.78 m) represents a maximum groundwater level decline of 0.25m from 2005 levels, this level should meet the requirements of wetland vegetation at this site. It must be noted that these minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. It is further recommended that groundwater levels persist no longer than two years below these minimum levels.

Figure 61: Groundwater levels at Blackpoint Rd dunes wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Darradup Rd East (wetland 8Y)

To maintain the most vulnerable of the dominant wetland species recorded at the Darradup Rd East transect (*Melaleuca preissiana*) at a low level of risk following the recommended approach, a max DTG of between 2.28 m and 2.58 m may be required (Figure 62). If the max DTG falls below 2.28 m this species may not be maintained at this site. A max DTG range of 2.58 m to 2.61 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.61 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.05 m.

The identified max DTG of the most and least vulnerable species fell well below their existing water level ranges and current groundwater levels at the Darradup Rd East wetland. This may be due to recent fires and possible changes in species composition and distribution across the site as well as a potential rise in water levels. It must be noted that these minimum water ranges also only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. Therefore, after consideration of this, the uncertainty regarding depth to groundwater and absence of water level monitoring a max DTG of 1.3 m is recommended as this should maintain wetland vegetation at this site. It is further recommended that groundwater levels persist no longer than two years below these minimum levels.

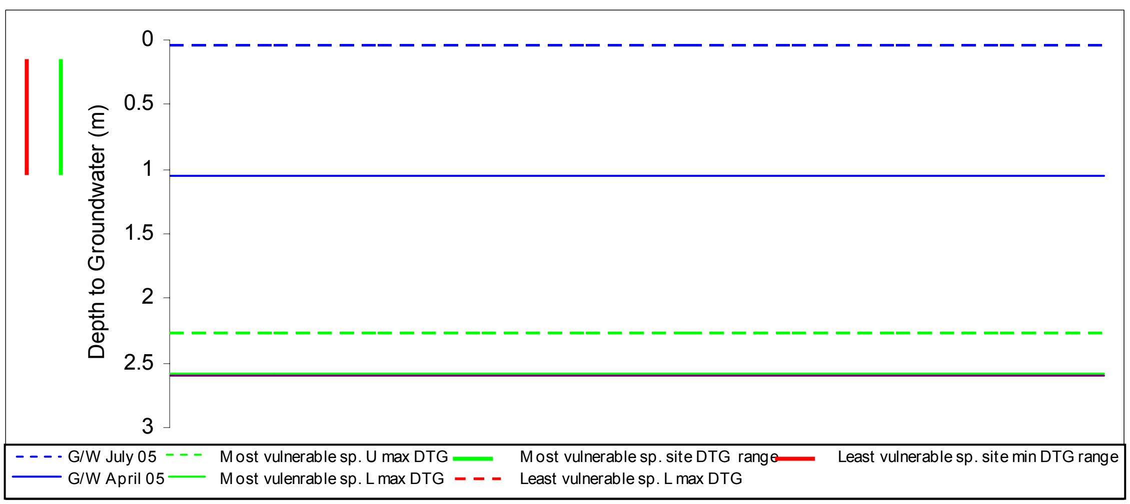


Figure 62: Groundwater levels at Darradup Rd East wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red line). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Darradup Rd West (wetland 8x)

To maintain the most vulnerable of the dominant wetland species recorded at the Darradup Rd West transect (*Astartea juniperiana*) at a low level of risk following the recommended approach, a max DTG of between 2.42 m and 2.59 m may be required (Figure 63). If the max DTG falls below 2.59 m this species may not be maintained at this site. A max DTG range of 2.59 m to 2.62 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.62 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.05 m.

The identified max DTG of the most and least vulnerable species fell well below their existing water level ranges and current groundwater levels at the Darradup Rd West wetland. This may be due to the number of unidentified species, specifically sedges, recorded at the site and the potential that these had higher water level requirements than identified species. These minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. Therefore, after consideration of this, the uncertainty regarding depth to groundwater and absence of water level monitoring a max DTG of 1.3 m is recommended as this should maintain wetland vegetation at this site It is further recommended that groundwater levels persist no longer than two years below these minimum levels.

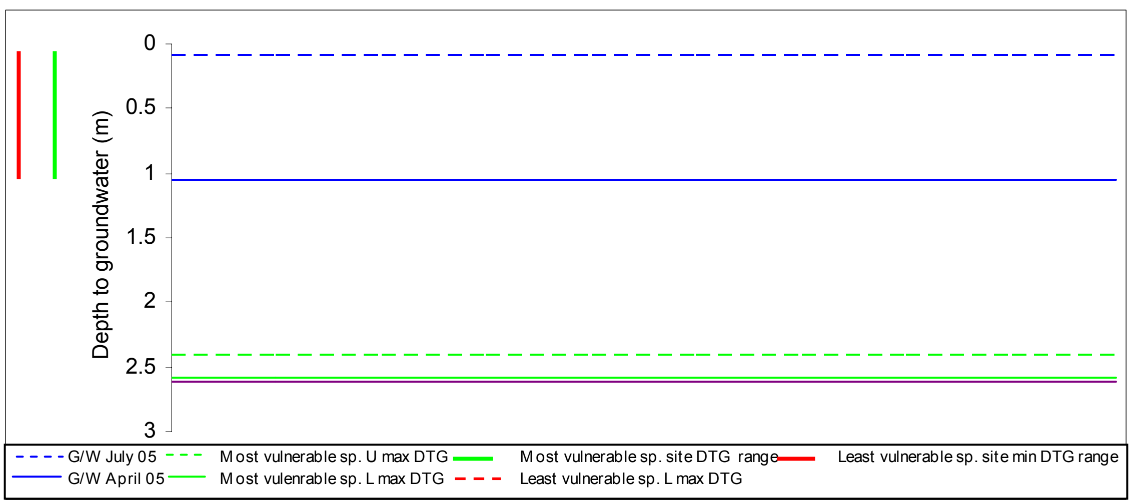


Figure 63: Groundwater levels at Darradup Rd West wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red line). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Blackwood River Crossing – Longbottom Rd (wetland 9)

To maintain the most vulnerable of the dominant wetland species recorded at the Blackwood River Crossing transect (*Banksia littoralis*) at a low level of risk following the recommended approach, a max DTG of 1.7 m may be required (Figure 64). If the max DTG falls below this, this species may not be maintained at this site. A max DTG range of 1.7 m to 2.47 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.47 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.4 m.

The identified max DTG of the most and least vulnerable species fell slightly below their existing water level ranges and current groundwater levels at the Blackwood River Crossing wetland. However, as the max DTG of the most vulnerable species is only 0.3 m below the 2005 minimum groundwater level, this level should meet the requirements of wetland vegetation at the site. It must be noted that these max DTG ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. It is further recommended that groundwater levels persist no longer than two years below this minimum level.

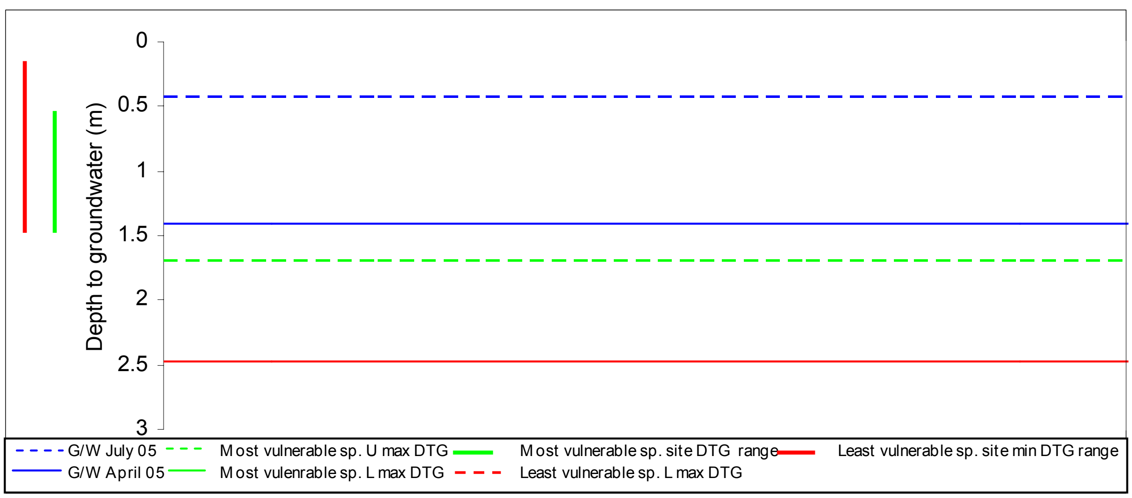


Figure 64: Groundwater levels (blue lines) at Blackwood River Crossing wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Brockman Highway - Milyeanup (wetland 10)

To maintain the most vulnerable of the dominant wetland species recorded at the Brockman Highway transect (*Taxandria parvicpes*) at a low level of risk following the recommended approach, a max DTG of between 0.37 m and 2.83 m may be required (Figure 65). If the max DTG falls below 2.83 m this species may not be maintained at this site. A max DTG level range of 2.83 m to 2.86 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.86 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.02 m.

The identified U max DTG of the most vulnerable species fell well within its existing water level range and current groundwater levels at the Blackwood River Crossing wetland. A max DTG between 0.37 m and 2.83 m should therefore be sufficient to maintain wetland vegetation at this site. It must be noted however, that these max DTG ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species, specifically the large number of sedges recorded at this site. Therefore, after consideration of this, the uncertainty regarding depth to groundwater and absence of water level monitoring a max DTG of 1.0 m is recommended. It is further recommended that groundwater levels persist no longer than two years below this minimum level.

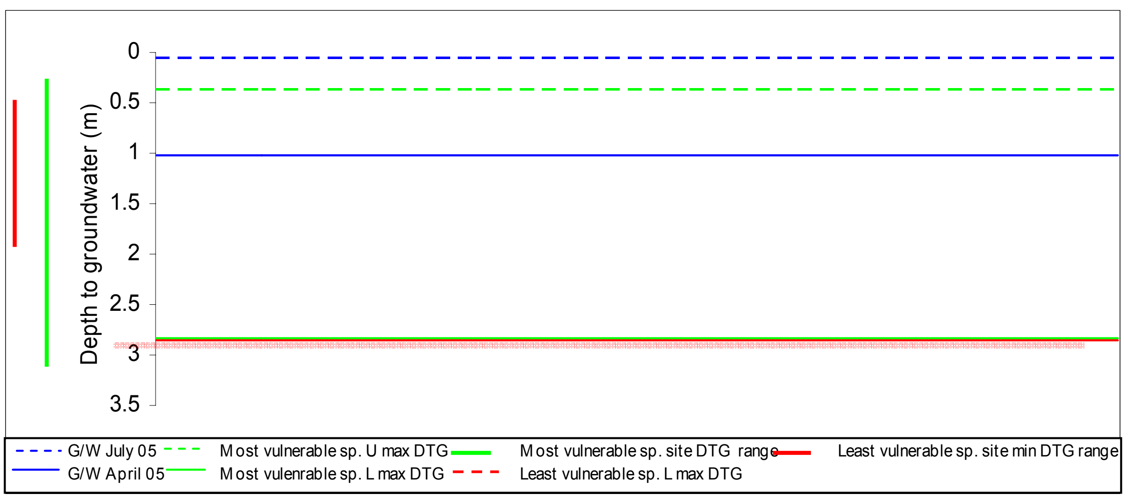


Figure 65: Groundwater levels (blue lines) at Brockman Highway wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Stewart Rd (wetland 11)

To maintain the most vulnerable of the dominant wetland species recorded at the Stewart Rd transect (*Banksia littoralis*) at a low level of risk following the recommended approach, a max DTG of 1.72 m may be required (Figure 66). If the max DTG falls below 1.72 m this species may not be maintained at this site. A max DTG of 2.48 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.48 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.97 m.

The identified max DTG of the most vulnerable species fell well within its existing water level range and current groundwater levels at the Blackwood River Crossing wetland, with the L max DTG of the least vulnerable species also within current groundwater levels. A max DTG between 1.72 m and 2.48 m should therefore be sufficient to maintain wetland vegetation at this site. It must be noted however, that these max DTG ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. Therefore, after consideration of this, the uncertainty regarding depth to groundwater and absence of water level monitoring a max DTG of 1.50 m is recommended as this should maintain wetland vegetation at this site. It is further recommended that groundwater levels persist no longer than two years below this minimum level.

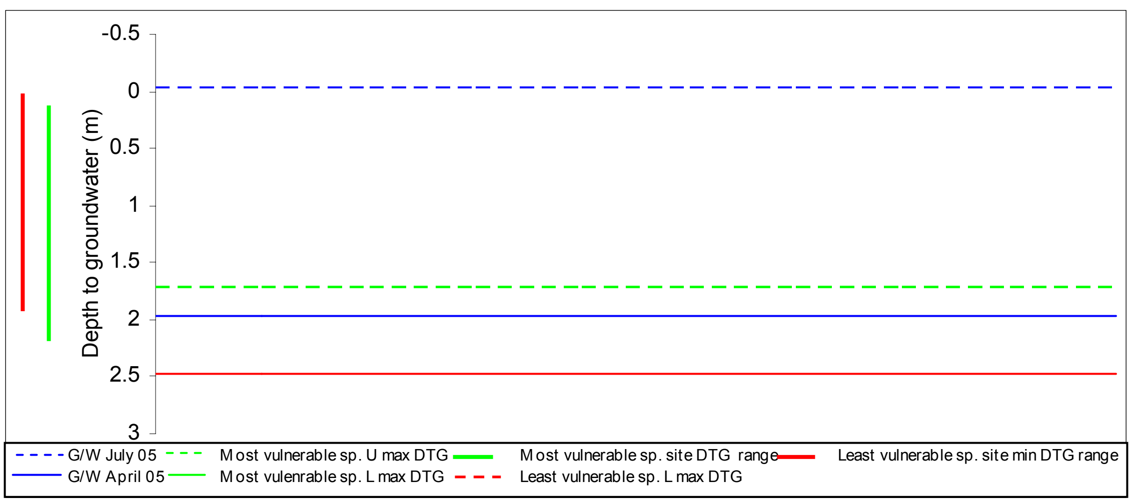


Figure 66: Groundwater levels (blue lines) at Stewart Rd wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Poison Gully (wetland 12)

To maintain the most and vulnerable of the dominant wetland species recorded at the Poison Gully transect (*Pultenaea reticulata*) at a low level of risk following the recommended approach, a max DTG of between 0.95 m and 1.55 m may be required (Figure 67). If the max DTG falls below 1.55 m this species may not be maintained at this site. A max DTG range of 1.55 m to 2.3 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 2.3 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 0.45m.

The identified max DTG of the most and least vulnerable species fell below current groundwater levels at the Poison Gully wetland. However, the current water level range of the most vulnerable species fell close to its recommended max DTG. A max DTG between 0.95 m and 1.55 m should therefore be sufficient to maintain wetland vegetation at this site. It must be noted however, that these max DTG ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species, specifically sedges. Therefore, after consideration of this, the uncertainty regarding depth to groundwater and absence of water level monitoring a max DTG of 0.75 m is recommended. It is further recommended that groundwater levels persist no longer than two years below this minimum level.

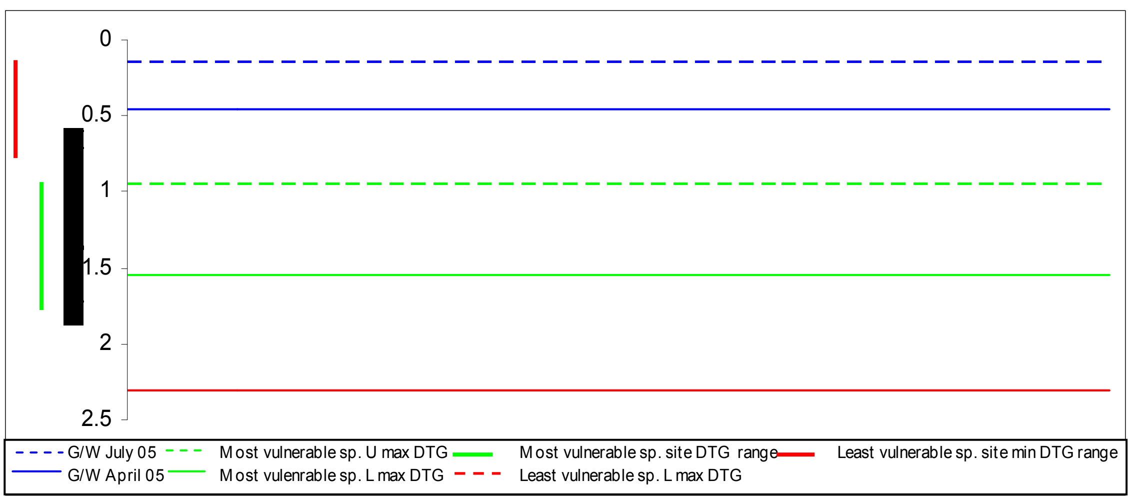


Figure 67: Groundwater levels (blue lines) at Poison Gully wetland transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Blackpoint/ Fouracres Rd terrestrial

To maintain the most vulnerable of the dominant terrestrial species recorded at the Blackpoint/ Fouracres Rd terrestrial transect (*Eucalyptus marginata*) at a low level of risk following the recommended approach, a max DTG of between 4.24 m and 5.68 m may be required (Figure 68). If the max DTG falls below 5.68 m this species may not be maintained at this site. A max DTG range of 5.68 m to 5.96 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 5.96 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 6.64 m.

The identified U max DTG of the most vulnerable species fell within its existing water level range and above current groundwater levels at the Blackpoint/ Fouracres Rd terrestrial site, while its L max DTG and the U max DTG of the least vulnerable species were within current groundwater levels and water level ranges. Current groundwater levels therefore should therefore be sufficient to maintain terrestrial vegetation at this site. However, it must be noted that these max DTG ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. As the water requirements of terrestrial species of the area are largely unknown, it is difficult to be more specific about EWRs at this site. However, applying the 'rule of thumb' drawdown magnitude for terrestrial species at 6-10 m DTG a max decline of 1.75 m from 2005 max DTG is recommended (8.39 m DTG). It is further recommended that groundwater levels persist no longer than two years below this minimum level.

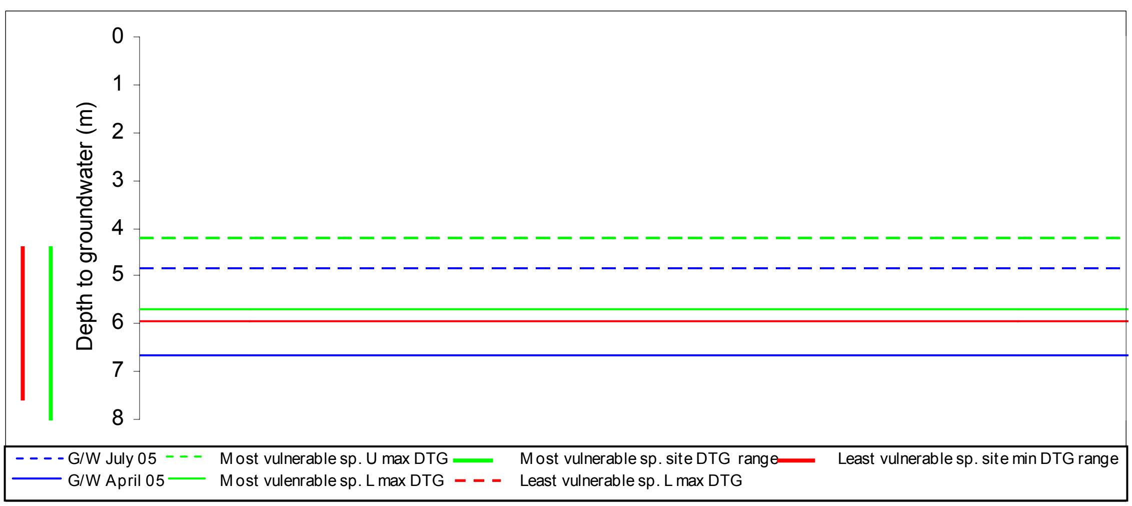


Figure 68: Groundwater levels (blue lines) at Blackpoint/ Fouracres Rd terrestrial transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Darradup Rd East terrestrial

To maintain the most vulnerable of the dominant terrestrial species recorded at the Darradup Rd East terrestrial transect (*Corymbia calophylla*) at a low level of risk following the recommended approach, a max DTG of between 4.04 m and 4.44 m may be required (Figure 69). If the max DTG falls below 4.44 m this species may not be maintained at this site. A max DTG range of 4.44 m to 6.31 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 6.31 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 1.57 m.

The identified max DTG of the most and least vulnerable species fell well below their existing water level ranges and current groundwater levels at the Darradup Rd East terrestrial site. This may be due to the number of unidentified species recorded at the site and the potential that these had higher water level requirements than identified species. These minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. As the water requirements of terrestrial species of the area are largely unknown, it is difficult to be more specific about EWRs at this site. However, applying the 'rule of thumb' drawdown magnitude for terrestrial species at 0-3 m DTG a max decline of 0.75 m from 2005 max DTG is recommended (2.32 m DTG). It is further recommended that groundwater levels persist no longer than two years below this minimum level.

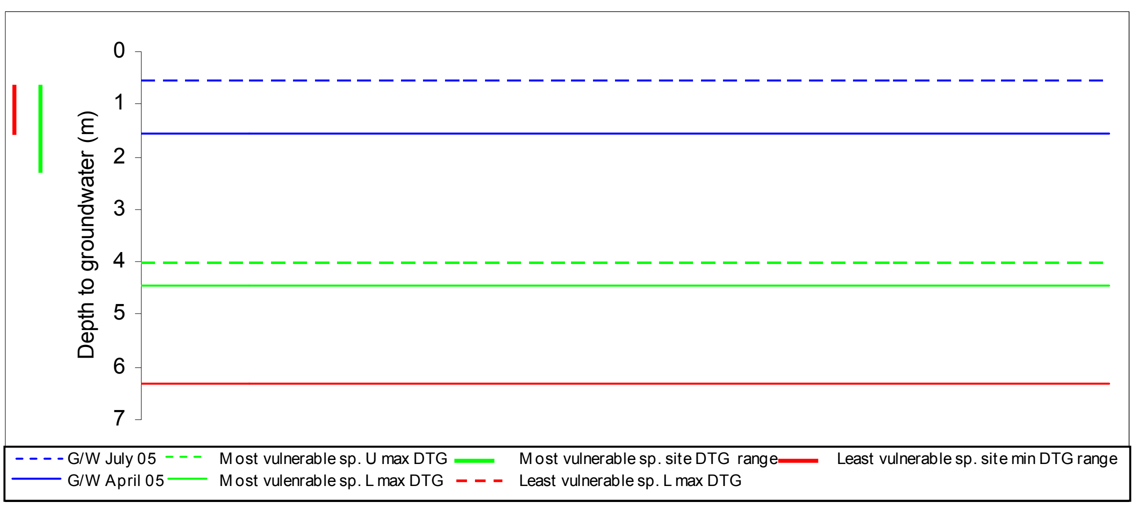


Figure 69: Groundwater levels (blue lines) at Darradup Rd East terrestrial transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Blackwood River Crossing – Longbottom Rd terrestrial

To maintain the most vulnerable of the dominant terrestrial species recorded at the Blackwood River Crossing terrestrial transect (*Corymbia calophylla*) at a low level of risk following the recommended approach, a max DTG of between 3.69 m and 4.64 m may be required (Figure 70). If the max DTG level falls below 4.64 m this species may not be maintained at this site. A max DTG range of 4.64 m to 6.75 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 6.75 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 2.36 m.

The identified max DTG of the most and least vulnerable species fell well below their existing water level ranges and current groundwater levels at the Blackwood River Crossing terrestrial site. This may be due to the number of unidentified species recorded at the site and the potential that these had higher water level requirements than identified species. These minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. As the water requirements of terrestrial species of the area are largely unknown, it is difficult to be more specific about EWRs at this site. However, applying the ‘rule of thumb’ drawdown magnitude for terrestrial species at 0-3 m DTG a max decline of 0.75 m from 2005 max DTG is recommended (3.11 m DTG). It is further recommended that groundwater levels persist no longer than two years below this minimum level.

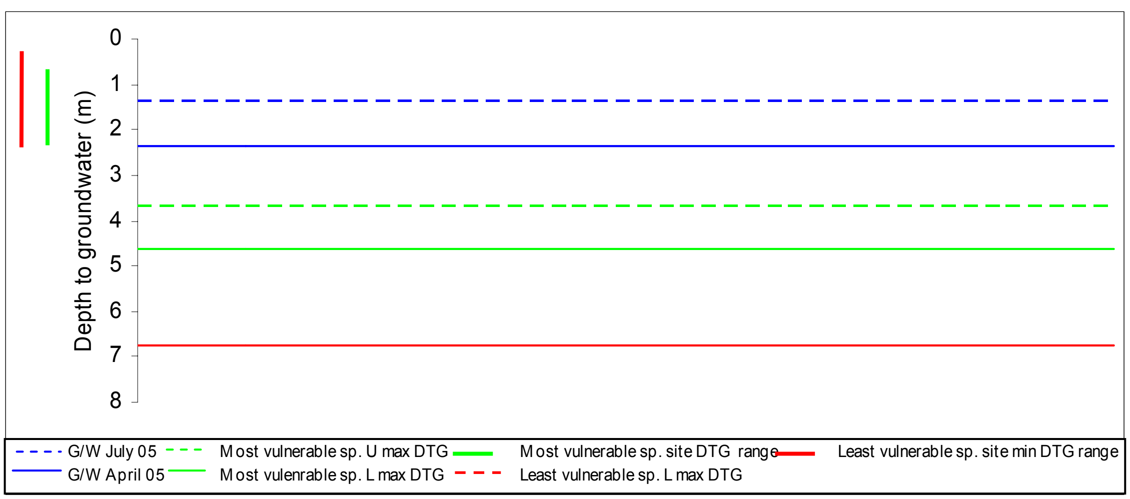


Figure 70: Groundwater levels (blue lines) at Blackwood River Crossing terrestrial transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Poison Gully terrestrial

To maintain the most vulnerable of the dominant terrestrial species recorded at the Poison Gully terrestrial transect (*Allocasuarina fraseriana*) at a low level of risk following the recommended approach, a max DTG of between 1.67 m and 2.45 m may be required (Figure 71). If the max DTG falls below 2.45 m this species may not be maintained at this site. A max DTG range of 2.45 m to 5.68 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 5.68 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 2.41 m.

The identified U max DTG of the most vulnerable species was above current groundwater levels and its existing water level range at the Poison Gully terrestrial site, while its L max DTG fell within groundwater levels and above its existing water level range. The U max DTG of the least vulnerable species was below current groundwater levels but well within its existing water level range. A max DTG between 2.45 m and 5.68 m should therefore be sufficient to maintain terrestrial vegetation at this site. It must be noted however, that these max DTG ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. As the water requirements of terrestrial species of the area are largely unknown, it is difficult to be more specific about EWRs at this site. However, applying the 'rule of thumb' drawdown magnitude for terrestrial species at 0-3 m DTG a max decline of 0.75 m from 2005 max DTG is recommended (3.16 m DTG). It is further recommended that groundwater levels persist no longer than two years below this minimum level.

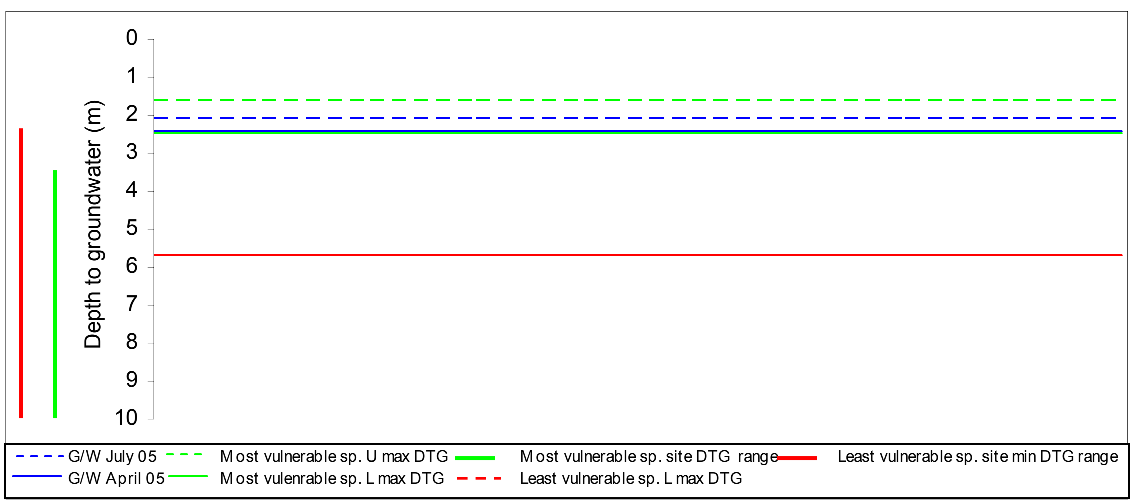


Figure 71: Groundwater levels (blue lines) at Poison Gully terrestrial transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Brockman Highway - Milyeanup terrestrial

To maintain the most vulnerable of the dominant terrestrial species recorded at the Brockman Highway- Milyeanup terrestrial transect (*Corymbia calophylla*) at a low level of risk following the recommended approach, a max DTG of between 3.37 m and 4.47 m may be required (Figure 72). If the max DTG falls below 4.47 m this species may not be maintained at this site. A max DTG range of 4.47 m to 6.13 m may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A max DTG below 6.13 m may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled maximum depth to groundwater at this site was 2.06 m.

The identified max DTG of the most and least vulnerable species fell below their existing water level ranges and current groundwater levels at the Brockman Highway terrestrial site. This may be due to the number of unidentified species recorded at the site and the potential that these had higher water level requirements than identified species. Minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. As the water requirements of terrestrial species of the area are largely unknown, it is difficult to be more specific about EWRs at this site. However, applying the 'rule of thumb' drawdown magnitude for terrestrial species at 0-3 m DTG a max decline of 0.75 m from 2005 max DTG is recommended (2.81 m DTG). It is further recommended that groundwater levels persist no longer than two years below this minimum level.

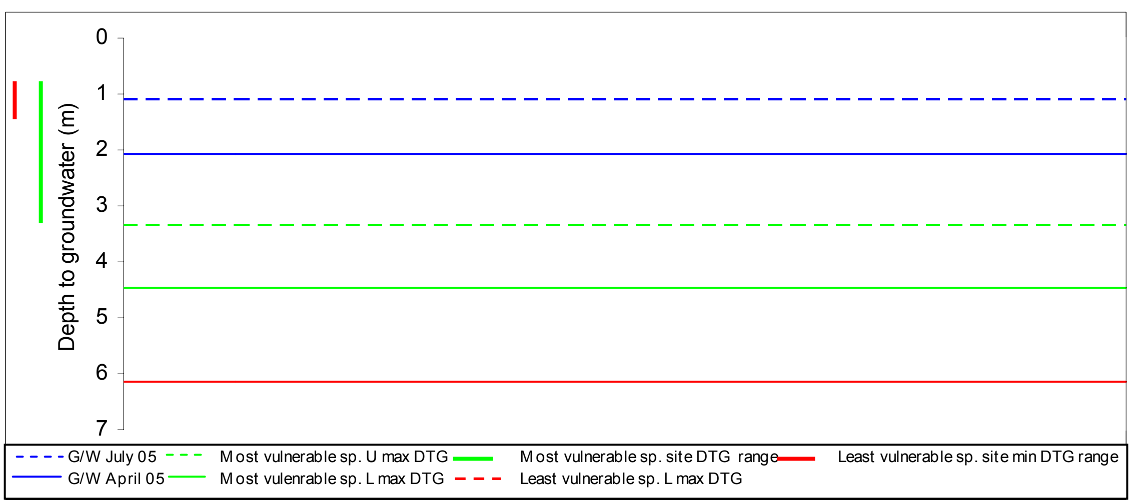


Figure 72: Groundwater levels (blue lines) at Brockman Highway terrestrial transect and interim summer/ autumn minimum EWRs, expressed as a range in maximum DTG levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Stewart Rd terrestrial (BP20B)

To maintain the most vulnerable of the dominant terrestrial species recorded at the Stewart Rd terrestrial transect (*Corymbia calophylla*) at a low level of risk following the recommended approach, a groundwater level of between 89.06 mAHD and 88.81 mAHD may be required (Figure 73). If the groundwater level falls below 88.81 mAHD this species may not be maintained at this site. A minimum groundwater level range of 88.81 mAHD to 87.37 mAHD may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A minimum groundwater level below 87.37 mAHD may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled minimum groundwater level at this site was 88.86 mAHD.

The max DTG range of the most vulnerable species fell within the current groundwater level at the Stewart Rd terrestrial site but below its existing water level range. The max DTG range of the least vulnerable species fell mostly below current groundwater levels and its existing water level range. This may be due to the number of unidentified species recorded at the site and the potential that these had higher water level requirements than identified species. Minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. As the water requirements of terrestrial species of the area are largely unknown, it is difficult to be more specific about EWRs at this site. However, applying the 'rule of thumb' drawdown magnitude for terrestrial species at 3-6 m DTG a max decline of 1.0 m from 2005 max DTG is recommended (87.86 mAHD). It is further recommended that groundwater levels persist no longer than two years below this minimum level.

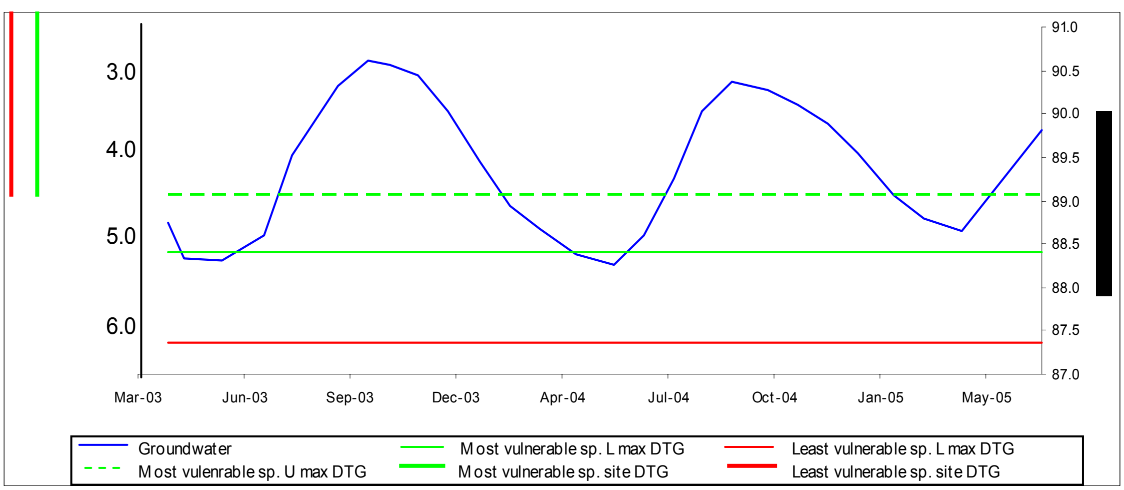


Figure 73: Groundwater levels at Stewart Rd terrestrial transect and interim summer/ autumn minimum EWRs, expressed as a range in max DTG (m) and minimum groundwater (mAHD) levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Darradup Rd North terrestrial (BP42B)

To maintain the most vulnerable of the dominant terrestrial species recorded at the Darradup Rd Nth terrestrial transect (*Corymbia calophylla*) at a low level of risk following the recommended approach, a minimum groundwater level of between 115.96 mAHD and 115.56 mAHD may be required (Figure 74). If the groundwater level falls below 115.56 mAHD this species may not be maintained at this site. A minimum groundwater level range of 115.56 mAHD to 114.52 mAHD may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A minimum groundwater level below 114.52 mAHD may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled minimum groundwater level at this site was 113.93 mAHD.

The identified max DTG of the most and least vulnerable species fell within current groundwater levels but slightly higher than the species existing water level ranges at the Darradup Rd terrestrial site. Current max DTG should meet the requirements of terrestrial vegetation at this site. However, it is must be remembered that the minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. As the water requirements of terrestrial species of the area are largely unknown, it is difficult to be more specific about EWRs at this site. However, applying the 'rule of thumb' drawdown magnitude for terrestrial species at 6-10 m DTG a max decline of 1.75 m from 2005 max DTG is recommended (112.18 mAHD). It is further recommended that groundwater levels persist no longer than two years below this minimum level.

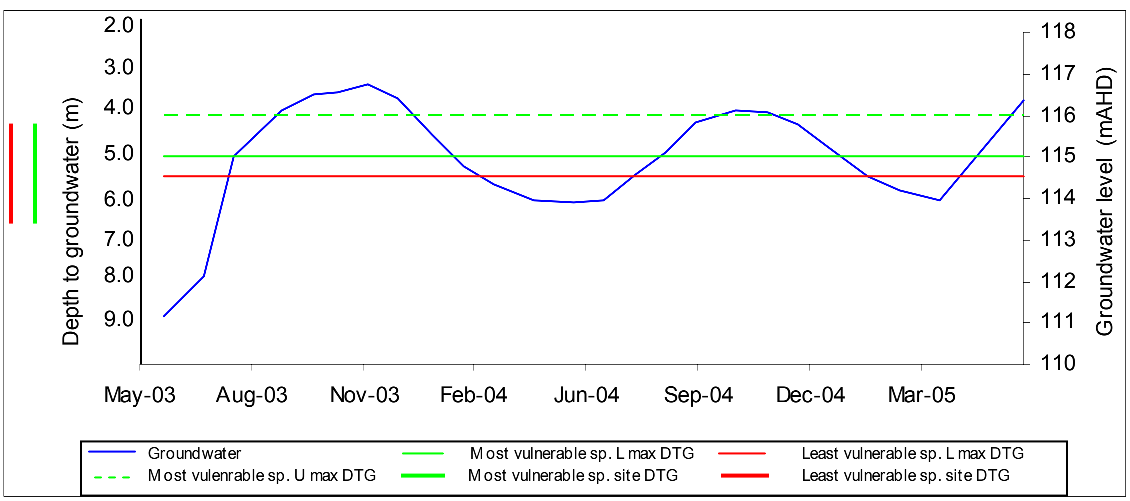


Figure 74: Groundwater levels at Darradup Rd North terrestrial transect and interim summer/ autumn minimum EWRs, expressed as a range in max DTG (m) and minimum groundwater (mAHD) levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Jack Track terrestrial site (SC8)

To maintain the most vulnerable of the dominant terrestrial species recorded at the Jack Track terrestrial transect (*Eucalyptus marginata*) at a low level of risk following the recommended approach, a minimum groundwater level of between 41.3 mAHD and 40.42 mAHD may be required (Figure 75). If the groundwater level falls below 40.42 mAHD this species may not be maintained at this site. A minimum groundwater level range of 40.42 mAHD to 39.65 mAHD may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A minimum groundwater level below 39.65 mAHD may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled minimum groundwater level at this site was 40.624 mAHD.

The identified max DTG of the most vulnerable species fell within current groundwater levels and the species existing water level ranges at the Jack Track terrestrial site. A max DTG of between 41.3 mAHD and 40.42 mAHD should therefore meet the requirements of terrestrial vegetation at this site. However, it is must be remembered that the minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. As the water requirements of terrestrial species of the area are largely unknown, it is difficult to be more specific about EWRs at this site. However, applying the 'rule of thumb' drawdown magnitude for terrestrial species at 3-6 m DTG a max decline of 1.0 m from 2005 max DTG is recommended (39.624 mAHD). It is further recommended that groundwater levels persist no longer than two years below this minimum level.

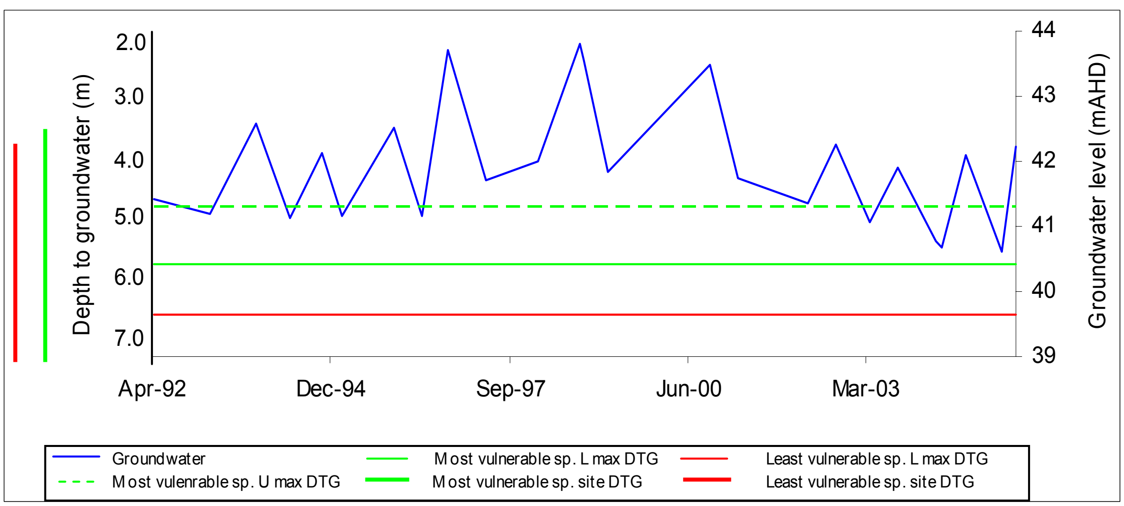


Figure 75: Groundwater levels at Jack Track terrestrial transect and interim summer/ autumn minimum EWRs, expressed as a range in max DTG (m) and minimum groundwater (mAHD) levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Scott Rd terrestrial site (SC22B)

To maintain the most vulnerable of the dominant species recorded at the Stewart Rd terrestrial transect (*Pericalymma ellipticum*) at a low level of risk following the recommended approach, a minimum groundwater level of between 37.09 mAHD and 36.93 mAHD may be required (Figure 76). If the groundwater level falls below 36.93 mAHD this species may not be maintained at this site. A minimum groundwater level range of 36.93 mAHD to 33.82 mAHD may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A minimum groundwater level below 33.82 mAHD may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled minimum groundwater level at this site was 36.93 mAHD.

The identified max DTG of the most vulnerable species fell within current groundwater levels and the species existing water level ranges at the Scott Rd terrestrial site. A max DTG of between 37.09 mAHD and 36.93 mAHD should therefore meet the requirements of terrestrial vegetation at this site. However, it is must be remembered that the minimum water ranges only consider the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. As the water requirements of terrestrial species of the area are largely unknown, it is difficult to be more specific about EWRs at this site. However, applying the 'rule of thumb' drawdown magnitude for terrestrial species at 0-3 m DTG a max decline of 0.75 m from 2005 max DTG is recommended (35.93 mAHD). It is further recommended that groundwater levels persist no longer than two years below this minimum level.

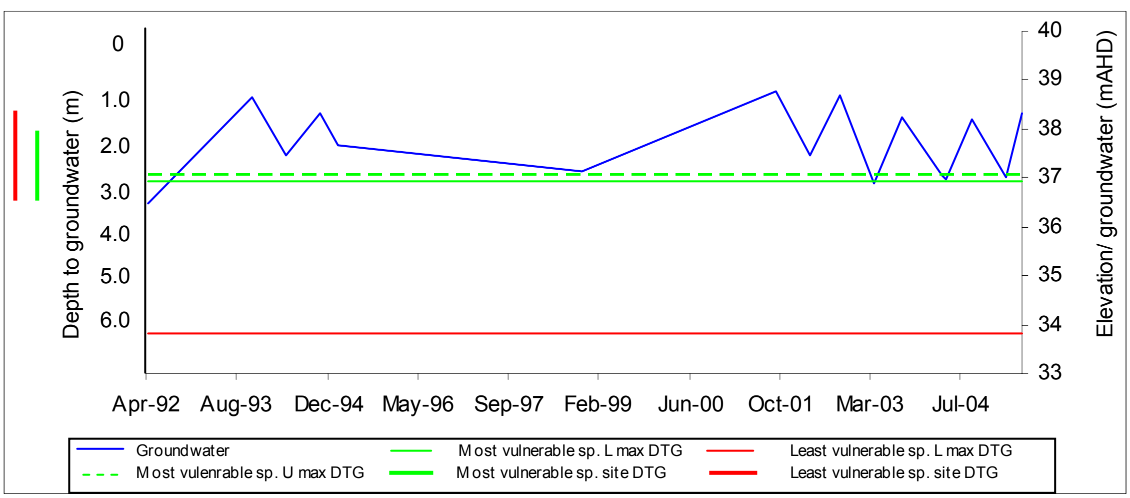


Figure 76: Groundwater levels at Scott Rd terrestrial transect and interim summer/ autumn minimum EWRs, expressed as a range in max DTG (m) and minimum groundwater (mAHD) levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Blackpoint Rd terrestrial (SC18B)

To maintain the most vulnerable of the dominant terrestrial species recorded at the Blackpoint Rd terrestrial transect (*Corymbia calophylla*) at a low level of risk following the recommended approach, a minimum groundwater level of between 49.06 mAHD and 43.94 mAHD may be required (Figure 77). If the groundwater level falls below 43.94 mAHD this species may not be maintained at this site. A minimum groundwater level range of 43.94 mAHD to 43.24 mAHD may be required to maintain at least one of the dominant species at a low level of risk (the upper and lower levels being defined by the most vulnerable and least vulnerable species respectively). A minimum groundwater level below 43.24 mAHD may be insufficient to maintain any dominant species at a low level of risk. The current (2005) actual/ modelled minimum groundwater level at this site was 44.418 mAHD.

The U max DTG of the most vulnerable species fell above the current groundwater levels at the Blackpoint Rd terrestrial site yet below the upper end of its existing water level range. The L max DTG of both the most and least vulnerable species fell below current groundwater levels and species ranges. Minimum water ranges only considers the dominant species (as estimated by projected foliage cover) at the site and may not meet the requirements of uncommon or unidentified species. As the water requirements of terrestrial species of the area are largely unknown, it is difficult to be more specific about EWRs at this site. However, applying the 'rule of thumb' drawdown magnitude for terrestrial species at 6-10 m DTG a max decline of 1.75 m from 2005 max DTG is recommended (42.69 mAHD). It is further recommended that groundwater levels persist no longer than two years below this minimum level.

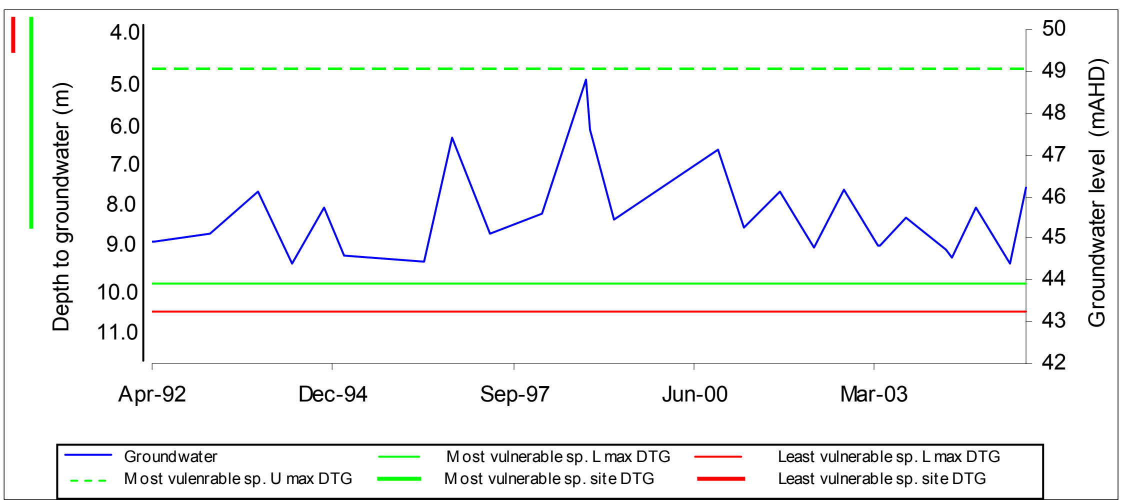


Figure 77: Groundwater levels at Blackpoint Rd terrestrial transect and interim summer/ autumn minimum EWRs, expressed as a range in max DTG (m) and minimum groundwater (mAHD) levels required to maintain the most vulnerable identified species at a low level of risk (green lines) and as a range required to maintain at least 1 species at a low level of risk (red lines). Vertical lines represent the current DTG range experienced by the most (green) and least (red) vulnerable species at the site.

Discussion

The approach applied in this section of the study represents a relatively quick and inexpensive method of determining EWRs for phreatophytic vegetation. It has proven useful as a first pass or interim approach in previously unstudied areas where resource management authorities require data for modelling of potential impacts of new water use developments. However, there are a number of issues that may reduce the accuracy of the approach and should be considered before final resource management decisions are made.

Although previous studies (Loomes, 2000; Loomes & Froend, 2001) have determined the hydrological ranges for key wetland species across the Swan Coastal Plain, little work has been undertaken on vegetation species of south-west wetlands and Jarrah woodlands. This necessitated the establishment of water level ranges for many species based on their occurrences at only a small number of sites. The absence of long-term hydrological data from the majority of sites also led to ranges being based on only 1 year of data. Ideally up to 20 years of data is required for long lived tree species, with 5 years more appropriate for shrub and sedge species (Froend, Farrell, Wilkins, Wilson, & McComb, 1993).

As terrestrial tree species such as *E. marginata* and *C. calophylla* are considered capable of accessing groundwater to depths of up to 30 m, it was unsure how appropriate this approach was to determining hydrological ranges. However, as the aim of the study was to determine ranges at the study sites only, the approach should be considered adequate.

Site specific conditions such as underlying geology and soil Stratigraphy also influence groundwater usage and dependency of phreatophytic vegetation. Possible water sources of terrestrial vegetation are soil water and groundwater directly recharged by precipitation (Freeze & Cherry, 1979). Deep-rooted species with a dimorphic root structure have a large root capture zone and are therefore capable of using (if available) unsaturated soil moisture (both shallow and at depth) and groundwater, either derived from the capillary fringe of directly from the watertable. In clay soils soil particles and pores are small and water held by matric forces which DoWs not drain freely (Freeze & Cherry, 1979). Clay soils are therefore able to store large amounts of water, which is available to plants where root length and density are suitable. Sandy soils, in contrast have larger particles and pores which drain freely and store less water (Freeze & Cherry, 1979). Bore logs available from the study area and prepared during piezometer installation indicates both sand and clay soils occur across the area, with sandy soils often underlain by clay and/ or silt layers. Although it is probable that both terrestrial and wetland vegetation has access to water held in the clay layers and possibly also from other water sources, this factor was not considered during the EWR process.

The method of extrapolating groundwater levels from a single measurement at a piezometer/ bore across the transect represents a trade-off between the time required to install multiple piezometers at each site and the accuracy of the estimated water level. Ideally piezometers should be located at 10 m intervals to fully represent the dynamic nature of water tables. However, time constraints rendered this approach inefficient.

EWRs were also described only as simplified minimum water depths without recognition of other hydrological variables important to the ecology of the system; duration, timing and rate of seasonal flooding/drying and the episodicity of extreme flooding/drying events. The potential future influences of climate change were also not considered.

As previously stated EWRs should consider the requirements of all ecological components in the system including fauna. However, the paucity of information available on the ecology and values of terrestrial vegetation and wetlands in the study area, with the possible exception of Lake Jasper, necessitates the setting of EWRs based solely on vegetation water requirements.

Limitations

The following limitations may reduce the accuracy of the approach;

- Little data on water regime requirements (hydrological ranges) of many species particularly terrestrial species.
- Absence of long-term hydrological data reduces accuracy of historic water regimes.
- Assumptions made that groundwater levels run level from the bore across the transect
- Site Stratigraphy may influence soil water retention.
- EWRs simplified to range in minimum water depths without recognition of other hydrological variables important to the ecology of the system; duration, timing and rate of seasonal flooding/drying and the episodicity of extreme flooding/drying events.
- Consideration of water requirements of only one component of a GDE; eg. determining EWRs of a whole wetland based on wetland vegetation requirements alone.
- No differentiation between water sources (eg. vegetation may be accessing groundwater, meteoric water and/or soil moisture).

Task 5: Description of possible impacts due to water level decline

Background/ Approach

Altered water regimes demonstrate the importance of water levels to vegetation (Wheeler, 1999). As each species is adapted to a specific water level range, or, any change in water levels can ultimately affect its distribution. Long-term persistent changes can cause a shift in community composition and structure as species better adapted to the new conditions become established (Harding, 1993). Lowering water tables can result in the loss of species intolerant of drying and their gradual replacement by species with drier hydrological requirements (Keddy & Reznicek, 1986; Moore & Keddy, 1988). Changed climatic patterns and human activities such as groundwater abstraction are the main causes of declining water levels in Australia (Balla, 1994; Froend et al., 1993).

Wetland vegetation

Due to their larger size, longer life-span and more expansive root systems, trees are often more tolerant and respond more slowly to changes in water levels than other species (Balla, 1994; Jenik, 1990). Sedges and rushes with vegetative parts emerging from seasonal fresh water (Semeniuk, 1987), respond much quicker to altered water regimes than trees and many other perennial wetland species (Froend et al., 1993). Not only are they lost to declining water tables, like many species they are also affected by rising (McComb & Lake, 1990; ter Heerdt & Drost, 1994). Increased groundwater levels can result from climatic changes as well as increased runoff from urban areas and the removal of native vegetation (Balla, 1994).

Emergent macrophytes generally respond to decreasing water depths in two ways (van der Valk, 1994). Firstly, if levels rise quickly, they may be lost due to drowning if they do not have enough leaf area above the water surface to allow respiration (van der Valk, 1994). Secondly, if the water rises more gradually they may respond by migrating upslope to more suitable (Froend & McComb, 1994; van der Valk, 1994). Migration downslope will occur in response to lower water levels (Froend & McComb, 1994; ter Heerdt & Drost, 1994).

The distribution and composition of perennial wetland shrubs, herbs and ferns are also influenced by water level gradients (Harding, 1993). These species generally tolerate lower depths of inundation for shorter periods than trees and emergent macrophytes and are often more prominent as fringing species (Keddy & Reznicek, 1986). However, changed water regimes will affect these species in a similar fashion to the emergent macrophytes as they are either lost or migrate to more suitable water levels (Keddy & Reznicek, 1986).

Terrestrial vegetation

Phreatophytic terrestrial vegetation may respond to groundwater drawdown at three different levels; individual, population or community. At the population level changes in abundance can be described in terms of reduction in canopy cover, loss of mature plants, increase in mortality rates, reduced seedlings establishment and shift in distribution towards a shallower depth to groundwater (Froend, Loomes, & Zencich, 2002).

As species more vulnerable to prolonged dry periods become locally extinct, the diversity and composition of a phreatophytic terrestrial vegetation community changes. In severe cases, diversity may be significantly reduced, and comprise drought tolerant xerophytic species only. Under conditions of moderate drawdown, replacement of mesophytic species with xerophytes (compositional dynamics) will offset any potential reductions in diversity. Upon death of drought intolerant species, spatial niches may become available to weed species colonisation. Such weed species would possess drought tolerance/avoidance mechanisms that facilitate establishment, reproduction and persistence within the community.

The possible impacts that may occur at each terrestrial vegetation and wetland criteria site under an agreed range of water level decline scenarios are discussed in this section. This follows an approach developed by Froend *et al.*(2002), later refined in Froend *et al* (2004) and Froend and Loomes (2005), that uses a matrix of conservation values, historic water level decline and current depth to groundwater to identify areas of greatest susceptibility to groundwater decline. In this study predicted water level changes are then considered to determine the risk of impact to each criteria site under 6 modelled drawdown scenarios provided by the DoW (scenario 1 -3: maximum drawdown/ change in water level for sites after the 30 years for 3 different scenarios (current license entitlements, regional growth, Water Corporation + regional growth); scenario 4-6: as above incorporating climate change). Comment is then made on the possible impacts to vegetation species composition, distribution, richness and/or health.

Susceptibility

The susceptibility of a GDE to future water regime changes is directly influenced by historic water level changes and current depth to groundwater. These factors are considered important as it is unlikely for any ecosystem to evolve in the presence of groundwater without having some reliance on it. It is further suggested that if the availability of groundwater is reduced or its quality altered, these ecosystems would respond in some way regardless of their degree of dependence. If a GDE has experienced historic declines in groundwater levels it may be more susceptible to further declines than other systems. Conversely, historic groundwater rises may buffer future declines.

Conservation values require special consideration when determining the level of protection afforded to GDEs. It is difficult to apply a standard approach to the rating of conservation values for GDEs, especially when trying to differentiate between the importance of international, national and regional conservation classifications. For example, a highly modified wetland may be recognised as an internationally important water-bird habitat under the Ramsar Convention but little regional significance due to its altered nature, whereas a wetlands supporting a vegetation community that is unusual within a specific region, may have regional conservation values, but be of little international importance. Existing impacts may include clearing for agricultural uses, fire, invasion by exotics (flora and/or fauna), dieback, timber harvesting, water pollution, climatic changes and vehicular or human traffic. Although there is a need to consider social and community values, public concern will generally be restricted to iconic GDEs such as large wetlands. Therefore it may be prudent to default to formally assessed conservation values and include identified community values where they are known.

Rating of susceptibility for use in the matrix should be based on the premise that the most vulnerable GDEs are those in areas of shallow groundwater that are already under pressure (stress, impact etc) from historic drawdown. Current depth to groundwater for wetlands and terrestrial vegetation has been rated based on phreatophytic vegetation categories (0-3m, 3-6m, 6-10m and >10m) (Froend & Zencich, 2001), with the shallowest depths the most susceptible. Depths were based on modeling or actual water depths from monitoring bores/ piezometers.

Long-term hydrological data from groundwater monitoring bores allows assessment of past water regimes. These data can provide comprehensive information on mean groundwater depths, seasonal and long-term changes in groundwater levels (magnitude), duration and rate of water level rise and/or decline and the seasonality of peak and low levels. Of most significance to ecosystem integrity are the mean annual depth to groundwater and magnitude, rate and duration of decline (or rise). Long-term data was not available for many sites in the current study.

In the current project susceptibility was determined for individual wetlands and areas of terrestrial vegetation using conservation values, current depths to groundwater (autumn minimum 2005) and the historic water level changes (2003/04-2005). The first stage in determining level of susceptibility was to give all GDEs a conservation value. Conservation value is scored between 1-4 (lowest value to highest value), based on categories as described below (Table 5) (Froend & Loomes, 2004b).

Table 5: Conservation value scores.

Conservation value category	Score
Ecosystem with international, national or regional conservation values (legislated) that has little evidence of alteration from surrounding land-use practices.	4
Ecosystem with international, national or regional conservation values (legislated) that has evidence of low to moderate impacts from surrounding land-use practices.	3
Ecosystem that has not been assessed for conservation values or is poorly understood, and that has evidence of low to moderate impacts from surrounding land-use.	2
Ecosystem with no recognised conservation values that has been moderately to severely degraded by surrounding land-use patterns	1

The second stage in determining level of susceptibility was to consider the current (autumn minimum 2005) depth to groundwater. The scores for current depth to groundwater are those outlined by Froend, Loomes & Zencich (2002) (Table 6).

Table 6: Wetland and terrestrial vegetation depth to groundwater scores.

Depth to groundwater (2005) category	Score
0-3m	4
3-6m	3
6-10m	2
>10m	1

The third stage was to determine the historic groundwater level change using the scoring system outlined by Welker Environmental Consultancy (2002). Changes in water levels score from 1-5 (no change or increase to severe change) depending on depth to groundwater category and the degree of water level change (Figures 78a-d). Hydrodata from the monitored WRC or WC bore nearest to each site were used. Due to the absence of long-term data the period examined for historic groundwater change was 2003-2005 for all sites with the exception of Poison Gully as data from the nearest bore, BP51C was only available from 2004-2005.

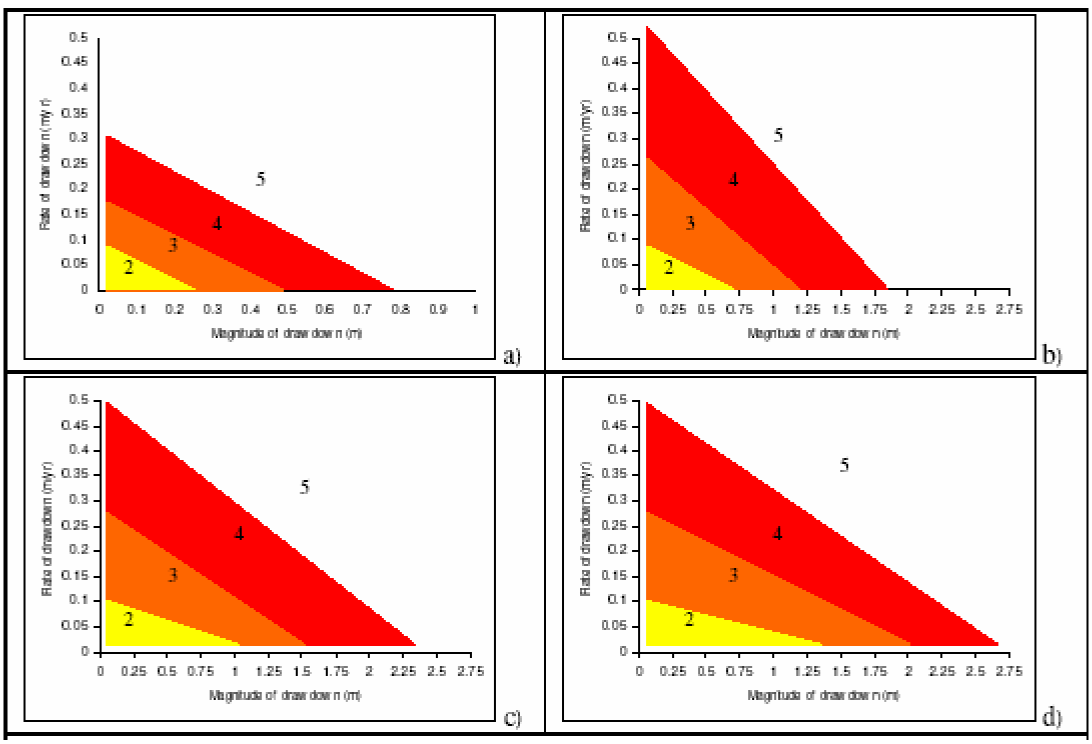


Figure 78: a-d: Historic water level change and ROI scores for a) wetlands, b) terrestrial vegetation 0-3m, c) terrestrial vegetation 3-6m, d) terrestrial vegetation 6-10m to groundwater.

The third stage was to determine the susceptibility score. This was achieved by adding the scores for conservation value, current depth to groundwater and historic groundwater level change together with lower numbers representing the highest susceptibility. Finally, GDEs are ranked by level of susceptibility to allow identification of those ecosystems that may require the most stringent management.

Risk of impact

In this step GDE susceptibility to impact was related to changes in groundwater levels (modelled under six different drawdown scenarios over a 30 year period) to describe the possible risk of impact (ROI) to each criteria site[1]. Changes in water levels scored 1-5 (no change or increase to severe change) depending on depth to groundwater category and the degree of water level change (Figures 78a-d). These values were then added to the susceptibility score (Table 7) to achieve a ROI score (Table 8). Risk of impact was expressed as; (4-7) not significant, (8-11) moderate, (12-15) high and (16-18) severe. Risks of impact over 1 and 2 years were not determined due to an artifice of the groundwater model that shows as an unrealistic change in groundwater levels over the first year. Impacts after 20 and 30 years were also not determined as current understanding of vegetation response to water level change DoWs not extend to these time periods. As modelled drawdown was not available for the Lake Jasper East transect, groundwater level changes modelled at the southern transect were applied. The scenarios, as modelled by DoW, were as follows.

1. Current entitlement - current use plus water that has been licensed for but which is not yet being used.
2. Regional growth - current entitlement plus and extraction amount that has been cited as fulfilling regional growth needs.
3. Water Corporation (WC) - current entitlement plus regional growth plus Water Corporation.
4. 90% current entitlement - reduction in recharge to mimic climate change under scenario 1.
5. 90% regional growth - reduction in recharge to mimic climate change under scenario 2.
6. 90% Water Corporation - reduction in recharge to mimic climate change under scenario 3.

Possible response of phreatophytic wetland and terrestrial vegetation to modelled drawdown

In this section comment is made on the possible response of vegetation at criteria sites to predicted drawdown. Given the current level of understanding of groundwater dependence of phreatophytic vegetation of the study area it is not possible to make accurate predictions of the degree of change in vegetation composition, diversity and health that may occur. However, some comment can be provided for wetland criteria sites based on observed responses of species common to both the study area and the Perth region. Only generic comments can be made on possible responses of terrestrial

[1] * Since this assessment was undertaken, a local model was constructed for the eastern Scott Coastal Plain/southern Blackwood Plateau area, which better takes into account the 'rejected recharge' or winter ponding of water that occurs on the plain. Results from the local model indicate that drawdowns in the model domain (which encompasses most of the criteria sites discussed in this report), are likely to be substantially less than what has been predicted by the SWAMS model.

vegetation to drawdown as the response of key species to drawdown are largely unstudied. Hydrographs showing the modeled water level changes for each site under the 6 drawdown scenarios are provided for reference.

Results

Susceptibility scores and rankings are presented in Table 7. The sites most susceptible to further drawdown are the terrestrial GDEs in the 0-3 m depth to groundwater category at Darradup Rd east, Brockman Highway and Blackwood River Crossing. Wetland sites at Lake Jasper, Blackpoint Rd dunes, Blackpoint Rd base of dunes, Darradup Rd east and west, Blackwood River Crossing and Brockman Highway, all within the 0-3 m depth to groundwater category and the terrestrial GDE at Jack Track, within the 3-6m category are the next most susceptible. The remaining wetlands and terrestrial sites at Blackpoint/ Fouracres Rd, Poison Gully, Scott Rd and Blackpoint Rd follow, with terrestrial sites at Stewart Rd and Darradup Rd north the least susceptible to further drawdown.

Risk of impact (ROI) scores (Tables 8 and 9) suggest that none of the criteria sites are at a ‘not significant’ or ‘severe’ risk of impact under any of the 6 drawdown scenarios over 5, 10 and 15 year periods. The following sites are at a ‘high’ risk of impact under all scenarios over all time periods; wetlands at Lake Jasper South, Blackpoint Rd dunes and base of dunes, and terrestrial sites at Darradup Rd east, Brockman Highway and Blackwood River Crossing. Wetlands at Blackpoint Rd and Blackpoint Fouracres Rd and the terrestrial site at Jack Track and are at a ‘high’ level of risk under the majority of scenarios over most time periods and a ‘moderate’ level of risk for the remainder. At a ‘moderate’ level of risk for the majority of time periods are the wetland at Pneumonia Rd and terrestrial sites at Blackpoint/ Fouracres Rd, Poison Gully and Scott Rd. Wetlands at Stewart Rd and Poison Gully are at ‘high’ and ‘moderate’ levels of risk over an equal number of time periods/ scenarios. The remaining sites, wetlands at Jangardup Rd, Darradup Rd East and West, Blackwood River Crossing and Brockman Highway and terrestrial GDEs at Stewart Rd, Darradup Rd north and Blackpoint Rd, are at a ‘moderate’ risk of impact under all 6 drawdown scenarios over 5, 10 and 15 year periods.

Table 7: Susceptibility of vegetation at wetland and terrestrial criteria sites to future drawdown determined through a matrix of conservation values, current depth to groundwater and historic water level change.

GDE	A. Conservation value	B. Current min. (2005) DTGW score	C. Historic water level change (03-05) score	D. Susceptibility (A+B+C)	E. Susceptibility ranking
Wetlands					
Lake Jasper Sth	4	4	2	10	=4
Lake Jasper Est	4	4	2	10	=4
Jangardup Rd	3	4	2	9	=12
Blackpoint Rd	4	4	1	9	=12
Pneumonia Rd	4	4	1	9	=12
Blackpoint/ Fouracres Rd	4	3	2	9	=12
Blackpoint Rd – dunes	4	4	2	10	=4
Blackpoint Rd – base of dunes	4	4	2	10	=4
Darradup Rd east	4	4	2	10	=4
Darradup Rd west	4	4	2	10	=4
Blackwood River Crossing	4	4	2	10	=4
Brockman Highway	4	4	2	10	=4
Stewart Rd	4	4	1	9	=12
Poison Gully	4	4	1	9	=12
Terrestrial sites					
Blackpoint/ Fouracres Rd	4	2	3	9	=12
Darradup Rd east	4	4	3	11	=1
Blackwood River Crossing	4	4	3	11	=1
Brockman Highway	4	4	3	11	=1
Poison Gully	4	4	1	9	=12
Stewart Rd	4	3	1	8	22
Darradup Rd north	4	2	1	7	23
Jack Track	4	3	3	10	=4
Scott Rd	4	4	1	9	=12
Blackpoint Rd	4	2	3	9	=12

Table 8: Risk of impact to vegetation at wetland and terrestrial criteria sites under 6 modelled drawdown scenarios.

GDE	Scenario	Predicted water level change scores			Susceptibility score	Risk of impact scores		
		5	**10**	**15**		**5**	**10**	**15**
Wetlands								
Lake Jasper Sth	**1**	2	2	2	10	12	12	12
	2	2	2	2		12	12	12
	3	2	2	2		12	12	12
	4	3	3	3		13	13	13
	5	3	3	3		13	13	13
	6	3	3	4		13	13	14
Lake Jasper Est	**1**	2	2	2	10	12	12	12
	2	2	2	2		12	12	12
	3	2	2	2		12	12	12
	4	3	3	3		13	13	13
	5	3	3	3		13	13	13
	6	3	3	4		13	13	14
Jangardup Rd	**1**	2	2	2	9	11	11	11
	2	2	2	2		11	11	11
	3	2	2	2		11	11	11
	4	2	2	2		11	11	11
	5	2	2	2		11	11	11
	6	2	2	2		11	11	11
Blackpoint Rd	**1**	2	2	3	9	11	11	12
	2	1	1	2		10	10	11
	3	2	3	5		11	12	14
	4	3	4	5		12	13	14
	5	2	3	4		11	12	13
	6	3	5	5		12	14	14
Pneumonia Rd	**1**	1	1	2	9	10	10	11
	2	1	1	2		10	10	11
	3	1	2	3		10	11	12
	4	1	2	2		10	11	11

GDE	Scenario	Predicted water level change scores			Susceptibility score	Risk of impact scores		
		5	**10**	**15**		**5**	**10**	**15**
	5	1	2	2		10	11	11
	6	1	3	4		10	12	13
Blackpoint/ Fouracres Rd	**1**	2	2	3	9	11	11	12
	2	1	1	2		10	10	11
	3	2	4	5		11	13	14
	4	2	4	5		11	13	14
	5	2	3	4		11	12	13
	6	3	5	5		12	14	14
Blackpoint Rd – dunes	**1**	2	2	2	10	12	12	12
	2	2	2	2		12	12	12
	3	2	2	3		12	12	13
	4	3	3	3		13	13	13
	5	3	3	4		13	13	14
	6	3	4	4		13	14	14
Blackpoint Rd – base of dunes	**1**	2	2	2	10	12	12	12
	2	2	2	3		12	12	13
	3	2	2	3		12	12	13
	4	3	3	3		13	13	13
	5	3	4	4		13	14	14
	6	3	4	4		13	14	14
Darradup Rd east	**1**	1	1	1	10	11	11	11
	2	1	1	1		11	11	11
	3	1	1	1		11	11	11
	4	1	1	1		11	11	11
	5	1	1	1		11	11	11
	6	1	1	1		11	11	11
Darradup Rd west	**1**	1	1	1	10	11	11	11
	2	1	1	1		11	11	11
	3	1	1	1		11	11	11
	4	1	1	1		11	11	11
	5	1	1	1		11	11	11

GDE	**Scenario**	**Predicted water level change scores**			**Susceptibility score**	**Risk of impact scores**		
		5	**10**	**15**		**5**	**10**	**15**
	6	1	1	1		11	11	11
Blackwood River Crossing	**1**	1	1	1	10	11	11	11
	2	1	1	1		11	11	11
	3	1	1	1		11	11	11
	4	1	1	1		11	11	11
	5	1	1	1		11	11	11
	6	1	1	1		11	11	11
Brockman Highway	**1**	1	1	1	10	11	11	11
	2	1	1	1		11	11	11
	3	1	1	1		11	11	11
	4	1	1	1		11	11	11
	5	1	1	1		11	11	11
	6	1	1	1		11	11	11
Stewart Rd	**1**	2	2	2	9	11	11	11
	2	2	2	2		11	11	11
	3	2	2	2		11	11	11
	4	3	3	3		12	12	12
	5	3	3	3		12	12	12
	6	3	3	3		12	12	12
Poison Gully	**1**	1	2	2	9	10	11	11
	2	1	1	2		10	10	11
	3	3	4	5		12	13	14
	4	2	3	3		11	12	12
	5	2	2	3		11	11	12
	6	4	5	5		13	14	14
Terrestrial sites								
Blackpoint/ Fouracres Rd	**1**	1	2	2	9	10	11	11
	2	1	1	2		10	10	11
	3	2	3	3		11	12	12
	4	2	3	2		11	12	11
	5	2	2	2		11	11	11
	6	2	2	3		11	11	12

GDE	Scenario	Predicted water level change scores			Susceptibility score	Risk of impact scores		
		5	**10**	**15**		**5**	**10**	**15**
Darradup Rd east	**1**	1	1	1	11	12	12	12
	2	1	1	1		12	12	12
	3	1	1	1		12	12	12
	4	1	1	1		12	12	12
	5	1	1	1		12	12	12
	6	1	1	1		12	12	12
Blackwood River Crossing	**1**	1	1	1	11	12	12	12
	2	1	1	1		12	12	12
	3	1	1	1		12	12	12
	4	1	1	1		12	12	12
	5	1	1	1		12	12	12
	6	1	1	1		12	12	12
Brockman Highway	**1**	1	1	1	11	12	12	12
	2	1	1	1		12	12	12
	3	1	1	1		12	12	12
	4	1	1	1		12	12	12
	5	1	1	1		12	12	12
	6	1	1	1		12	12	12
Poison Gully	**1**	1	2	2	9	10	11	11
	2	1	1	2		10	10	11
	3	2	3	3		11	12	12
	4	2	2	2		11	11	11
	5	2	2	2		11	11	11
	6	3	3	3		12	12	12
Stewart Rd	**1**	2	2	2	8	10	10	10
	2	2	2	2		10	10	10
	3	2	2	2		10	10	10
	4	2	2	2		10	10	10
	5	2	2	2		10	10	10
	6	2	2	2		10	10	10

GDE	Scenario	Predicted water level change scores			Susceptibility score	Risk of impact scores		
		5	**10**	**15**		**5**	**10**	**15**
Darradup Rd north	**1**	1	1	1	7	8	8	8
	2	1	1	1		8	8	8
	3	1	1	1		8	8	9
	4	1	1	2		8	8	9
	5	1	1	2		8	8	9
	6	1	1	2				
Jack Track	**1**	1	2	2	10	11	12	12
	2	1	2	2		11	12	12
	3	1	2	2		11	12	12
	4	2	2	2		12	12	12
	5	1	2	2		11	12	12
	6	2	2	3		12	12	13
Scott Rd	**1**	2	2	2	9	11	11	11
	2	2	2	2		11	11	11
	3	2	2	2		11	11	11
	4	2	2	2		11	11	11
	5	2	2	2		11	11	11
	6	2	3	2		11	12	11
Blackpoint Rd	**1**	1	1	1	9	10	10	10
	2	1	1	1		10	10	10
	3	1	1	2		10	10	11
	4	1	1	2		10	10	11
	5	1	1	2		10	10	11
	6	1	2	2		10	11	11

Table 9: Risk of impact (ROI) rating and possible consequences for terrestrial and wetland vegetation

ROI rating	Consequence for terrestrial vegetation structure/distribution	Consequence for wetland vegetation structure/distribution
Not significant	No significant* change in distribution of terrestrial phreatophytic species (not measurable over 20 years).	No significant* change in distribution of species.
Moderate	Some evidence of changing distribution of species, encroachment of more drought tolerant species into areas previously dominated by less drought tolerant species.	Some evidence of changing distribution of species, with disturbance and/or drying allowing establishment of exotic species.
High	Measurable change in the demographics of some species (affect on population distribution), with encroachment of more drought tolerant species into areas previously dominated by less drought tolerant species.	Signs of contraction of wetland through changing demographics of more than one species, with terrestrialisation and encroachment of xeric species into wetland areas.
Severe	Overstorey and understorey decline and/or loss of species from ecosystem. Greater than 50% reduction in abundance of dominant species and/or significant change in dominant populations and/or disturbance allowing establishment of exotic species.	Greater than 50% reduction in abundance of dominant species and/or significant change in dominant populations (possibly complete drying out of wetland basin, reduction in period of inundation), with terrestrialisation through encroachment of xeric species into wetland areas.

Possible impacts to vegetation

Wetlands

Lake Jasper

The hydrograph of modeled water level changes (Figure 79) at Lake Jasper under the drawdown scenarios shows a sharp decline over the first year (model artifice) followed by a rapid rise over year 2. Under scenarios 1 to 3 there is then a gradual increase for 16 years followed by a decline to year 30. Under scenarios 4-6, there is a gradual incline to year 8, followed a decline to year 30. Water levels are consistently lower under scenarios 4-6. Water levels at the end of years 5, 10 and 15 are lower than at the beginning of year 1 (current use) (Table 8). Due to ecosystem dynamics there is likely to be some change in species diversity and richness and community structure across both the monitoring transects at Lake Jasper over time as there is a high risk of impact to changes in ecosystem values from predicted drawdown. Areas of surface water may decrease across the wetland, leading to the contraction in the current ranges of more mesic species reliant on the high moisture conditions (eg. *Baumea articulata, B. juncea* on eastern transect).

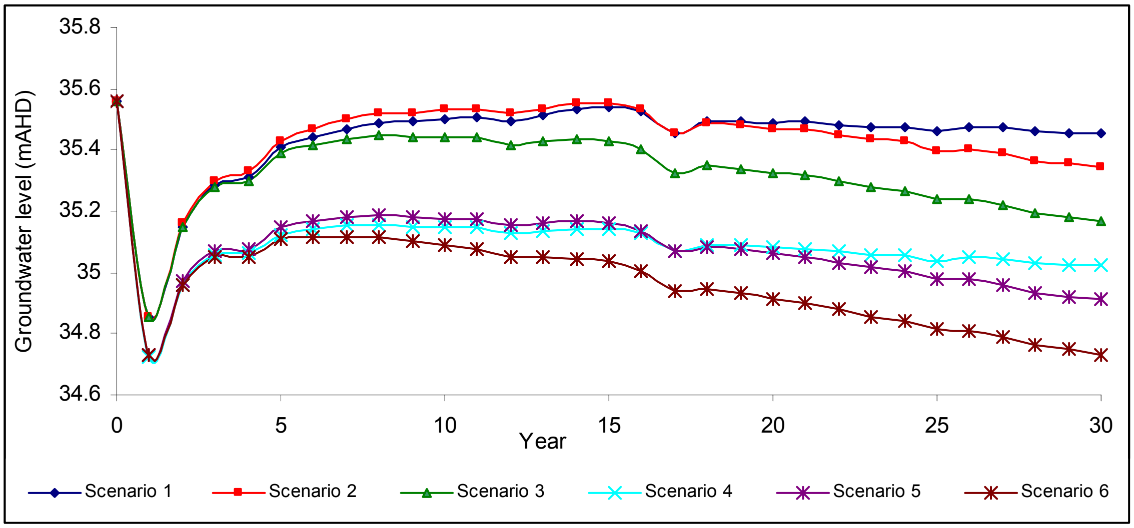


Figure 79: Groundwater level change at Lake Jasper modelled under 6 drawdown scenarios.

Jangardup Rd

The hydrograph of modeled water level changes (Figure 80) at Jangardup Rd under all drawdown scenarios shows a sharp decline over the first year (model artifice) followed by a rapid rise over years 2 – 5. A more gradual rise then occurs to year 11 after which time water levels remain relatively stable to the end of year 30. Water levels are consistently lower under scenarios 4-6. At the end of years 5, 10 and 15 all groundwater levels are lower than at the beginning of year 1 (Table 8). Due to ecosystem dynamics there is likely to be some change in species diversity and richness and community structure across the monitoring transect at this site over time however, there is only a moderate risk of impact to changes in ecosystem values from predicted drawdown.

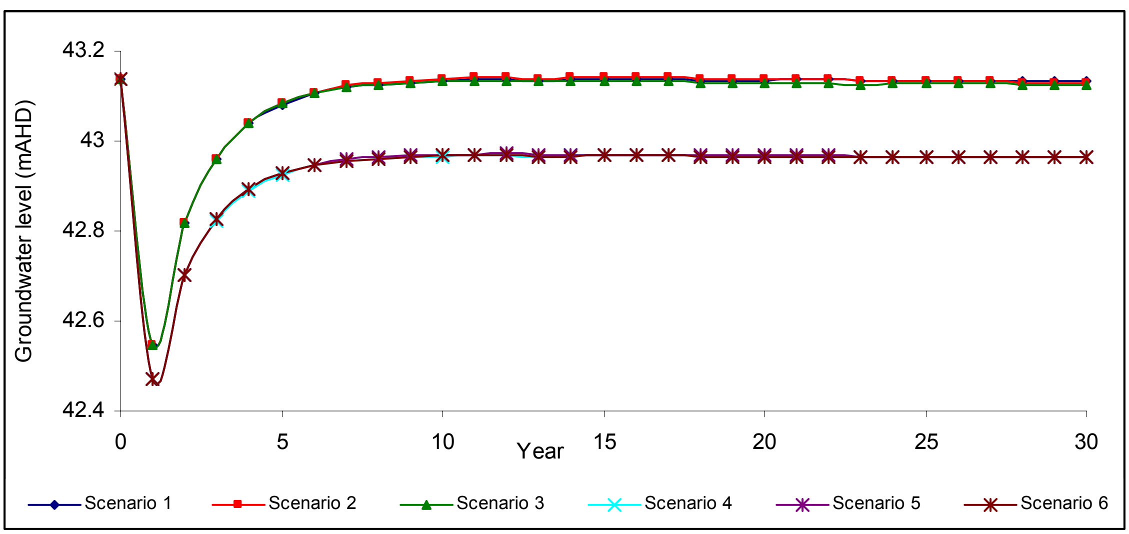


Figure 80: Groundwater level change at the Jangardup Rd wetland site modelled under 6 drawdown scenarios.

Blackpoint Rd

The hydrograph of modeled water level changes (Figure 81) at Blackpoint Rd under all drawdown scenarios shows a rise over year 1 followed by a decrease to the end of year 30. As a result water levels at the end of years 5, 10 and 15 are lower than at the beginning of year 1, under all scenarios with the exception of years 5 and 10 under scenario 2. Despite this, the site is at moderate to high risk of impact (Table 8). Under periods/ scenarios of moderate risk of impact to the end of year 15 there may be some change in the current distribution and/or health of mesic species fringing the wetland as water availability declines (eg. *Taxandria parviceps*, *Melaleuca preissiana*). Under high risk of impact areas of surface water may decrease, leading to the contraction in the current ranges of more mesic species reliant on the high moisture conditions (eg. wetland sedges).

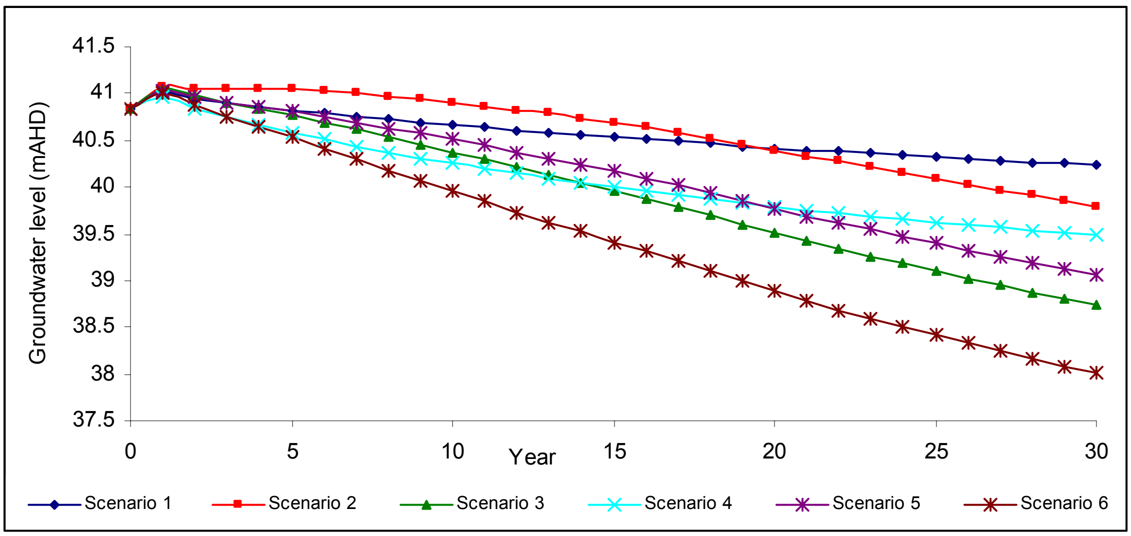


Figure 81: Groundwater level change at the Blackpoint Rd wetland site modelled under 6 drawdown scenarios.

Pneumonia Rd

The hydrograph of modeled water level changes (Figure 82) at Pneumonia Rd under all drawdown scenarios shows a rapid increase over year 1, followed by a decline to the end of year 30. As a result water levels at the end of year 5 are higher than current levels under all scenarios and after year 10 under scenarios 1and 2. Despite this, the site is at moderate to high risk of impact (Table 8). Under periods/ scenarios of moderate risk of impact up to the end of year 15 (Table 8) there may be some change in the current distribution and/ or health of mesic species fringing the wetland as water availability declines (eg. *Banksia littoralis, Melaleuca preissiana*). Under high risk of impact areas of surface water may decrease, leading to the contraction in the current ranges of more mesic species reliant on the high moisture conditions (eg. wetland sedges).

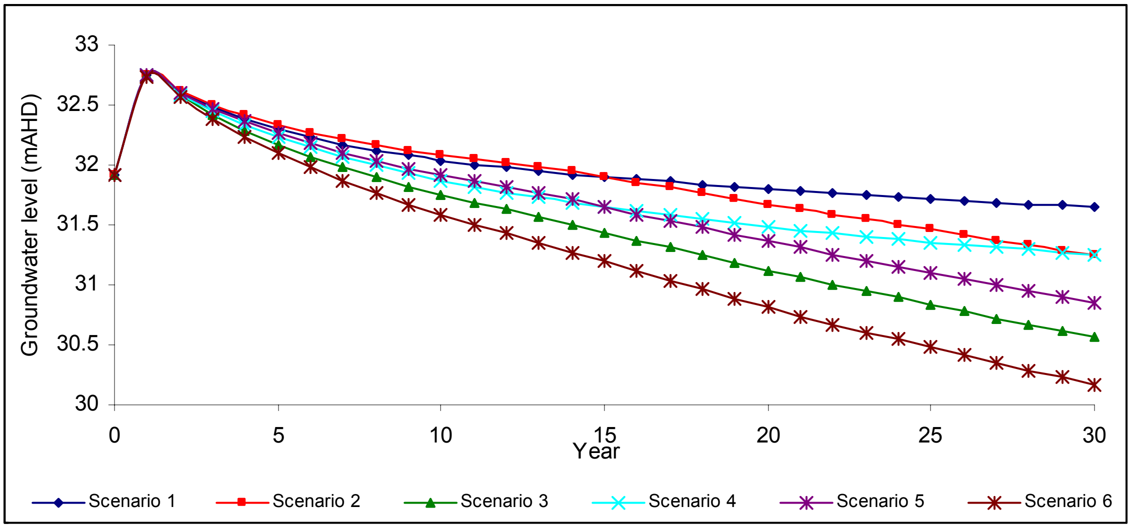


Figure 82: Groundwater level change at the Pneumonia Rd wetland site modelled under 6 drawdown scenarios.

Blackpoint/ Fouracres Rd

The hydrograph of modeled water level changes (Figure 83) at Blackpoint/ Fouracres Rd shows an increase over year 1 under all drawdown scenarios. All levels then fall to the end of year 30 with the exception of scenario 2 under which levels rise to the end of year 5 before falling to the end of year 30. As a result water levels at the end of years 5, 10 and 15 are lower than current. The site is at moderate or high risk of impact under all scenarios. Under periods/ scenarios of moderate risk of impact up to the end of year 15 (Table 8) there may be some change in the current distribution and/or health of mesic species fringing the wetland as water availability declines (eg. *Calothamnus lateralis, Melaleuca preissiana*). Under high risk of impact areas of surface water may decrease, leading to the contraction in the current ranges of more mesic species reliant on the high moisture conditions (eg. wetland sedges).

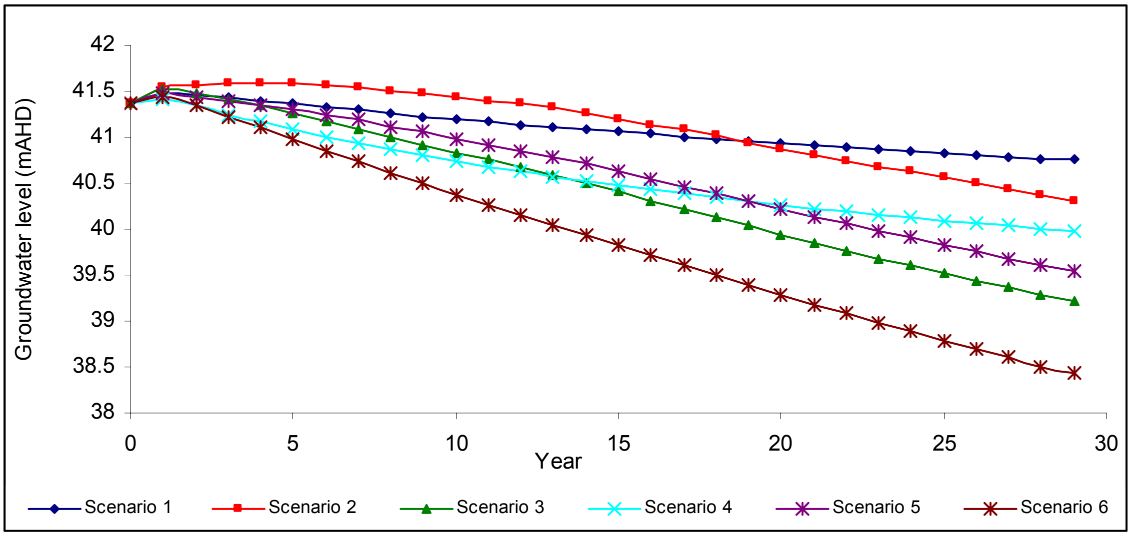


Figure 83: Groundwater level change at the Blackpoint/ Fouracres Rd wetland site modelled under 6 drawdown scenarios.

Blackpoint Rd – dunes

The hydrograph of modeled water level changes (Figure 84) at Blackpoint Rd dunes under all drawdown scenarios shows a decrease over year 1, followed by an increase to the end of year 3, decrease over year 4 and another increase to end of year 6. After this time, under scenarios 1 and 4, levels increase to year 15 before falling gradually to the end of year 30. Under scenarios 2 and 5 levels decrease to the end of year 12 then increase to year 15 before falling to year 30. Levels generally fall to the end of year 30 under the remaining scenarios. As a result water levels are lower at the end of years 5, 10 and 15 under all scenarios and are at a high risk of impact (Table 8). At this level of risk it is possible that the current ranges of mesic species reliant on the high moisture conditions (eg. wetland sedges) may contract. There may also be some change in the current distribution and/or health of mesic species as water availability declines

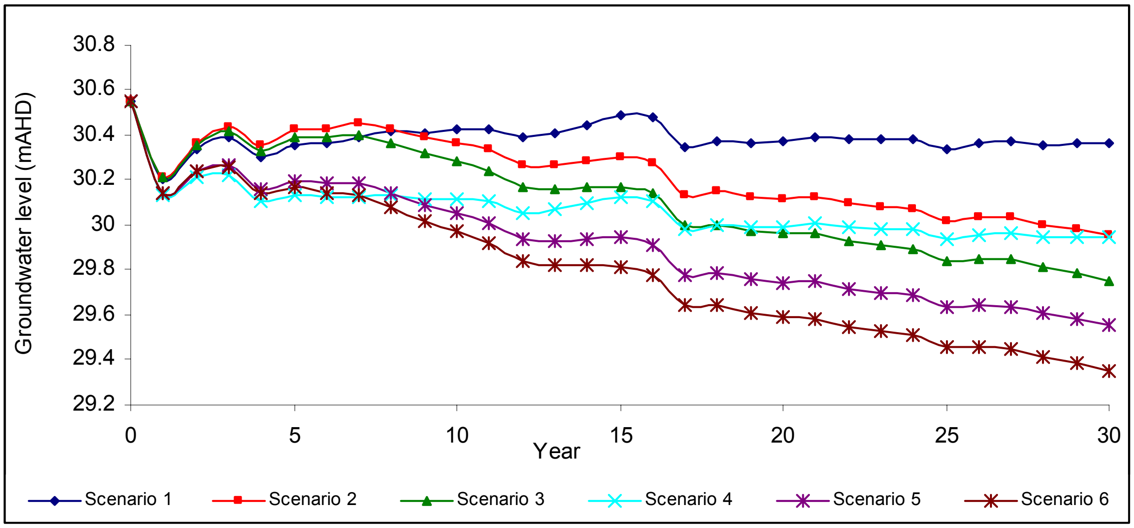


Figure 84: Groundwater level change at the Blackpoint Rd - dunes wetland site modelled under 6 drawdown scenarios.

Blackpoint Rd base of dunes

The hydrograph of modeled water level changes (Figure 85) at Blackpoint Rd base of dunes shows the same trends as those described above for Blackpoint Rd dunes. The site is therefore under high risk of impact under all periods/ scenarios.

Under high risk of impact areas of surface water may decrease, leading to the contraction in the current ranges of more mesic species reliant on the high moisture conditions (eg. wetland sedges). There may also be some change in the current distribution and/or health of mesic species as water availability declines (eg. *Melaleuca rhaphiophylla*).

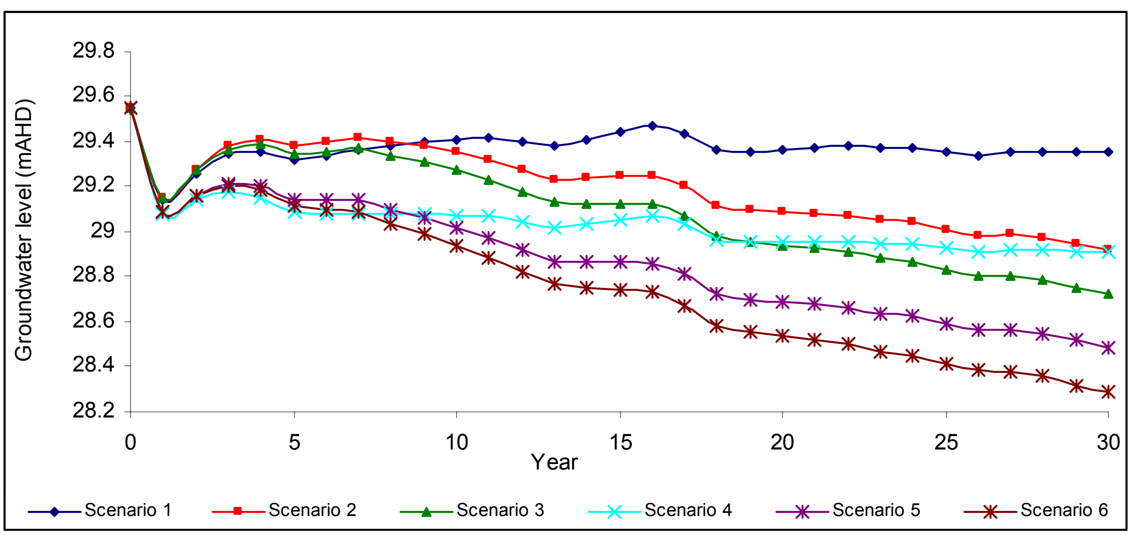


Figure 85: Groundwater level change at the Blackpoint Rd – base of dunes wetland site modelled under 6 drawdown scenarios.

Darradup Rd East

The hydrograph of modeled water level changes (Figure 86) at Darradup Rd east under all drawdown scenarios shows an increase after year 1, followed by a decrease to the end of year 30. However, water levels at the end of years 5, 10 and 15 are higher than at the beginning of year 1. All periods/ scenarios indicate moderate risk of impact up to the end of year 15 (Table 8). At this level of risk there may be some change in the current distribution and/or health of mesic species fringing the wetland as water availability declines.

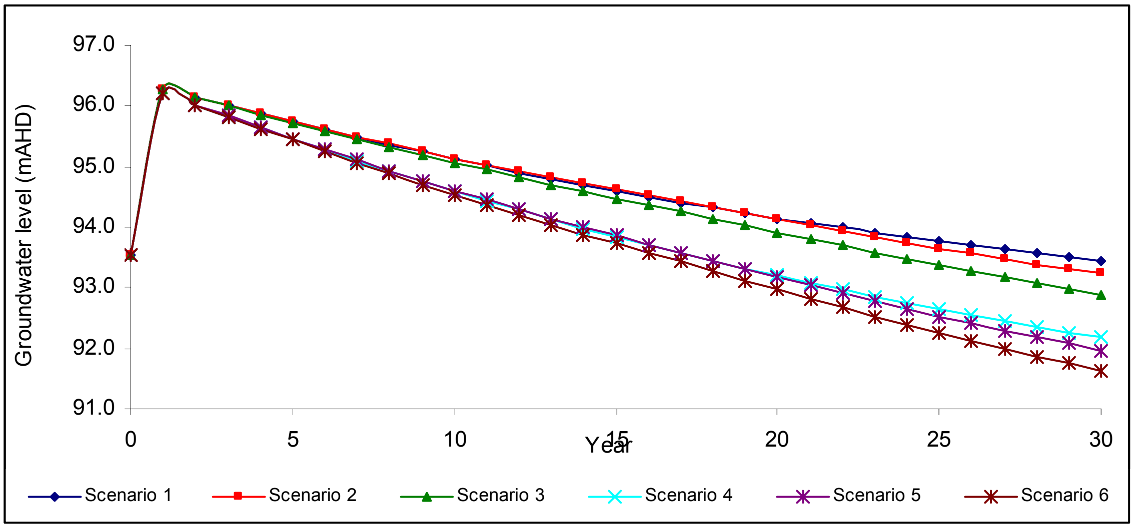


Figure 86: Groundwater level change at the Darradup Rd East wetland site modelled under 6 drawdown scenarios.

Darradup Rd west

The hydrograph of modeled water level changes (Figure 87) at Darradup Rd west under all drawdown scenarios shows the same trend as Darradup Rd east however, the increase after year 1 is much greater. Water levels at the end of years 5, 10 and 15 are higher than at the beginning of year 1. All periods/ scenarios indicate moderate risk of impact up to the end of year 15 (Table 8). At this level of risk there may be some change in the current distribution and/or health of mesic species fringing the wetland as water availability declines.

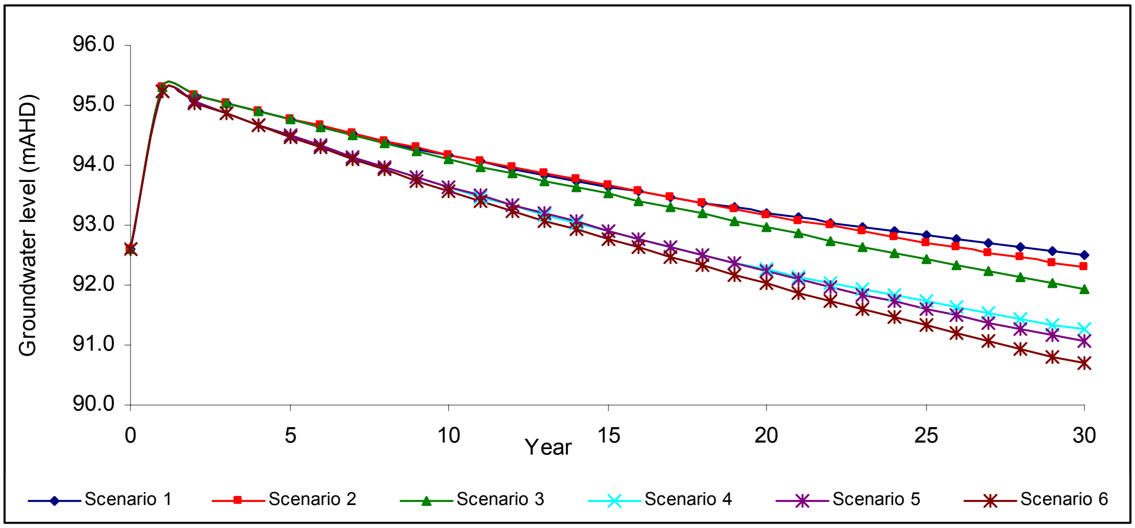


Figure 87: Groundwater level change at the Darradup Rd West wetland site modelled under 6 drawdown scenarios.

Blackwood River Crossing

The hydrograph of modeled water level changes (Figure 88) at Blackwood River Crossing under all drawdown scenarios shows an increase at the end of year 1 followed by decline to the end of year 30. However, water levels at the end of years 5, 10 and 15 are higher than at the beginning of year 1. All periods/ scenarios indicate moderate risk of impact up to the end of year 15 (Table 8). At this level of risk there may be some change in the current distribution and/or health of mesic species fringing the wetland as water availability declines.

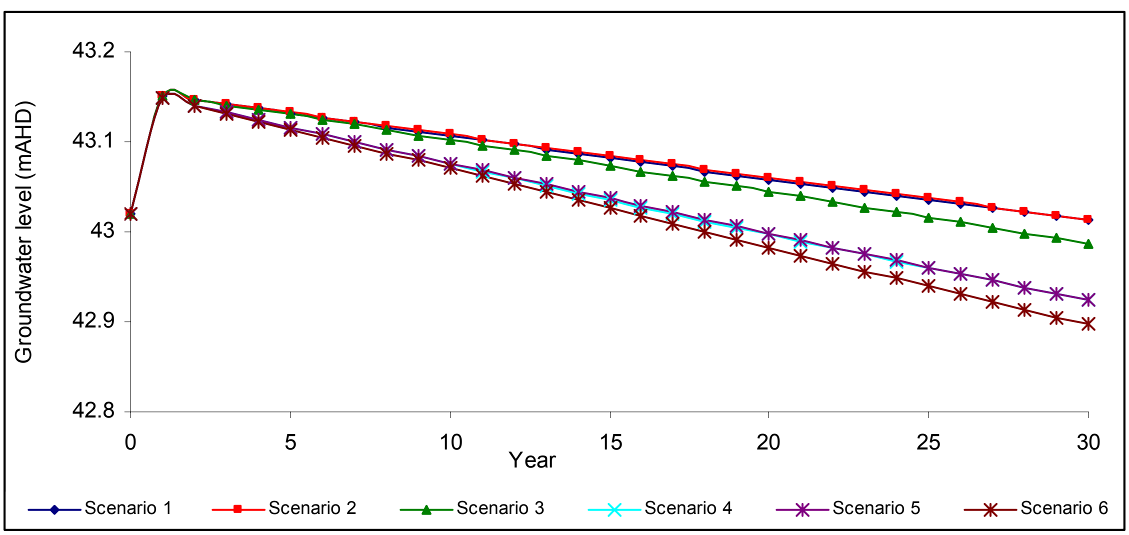


Figure 88: Groundwater level change at the Blackwood River Crossing wetland site modelled under 6 drawdown scenarios.

Brockman Highway

The hydrograph of modeled water level changes (Figure 89) at Brockman Highway under all drawdown scenarios shows an increase at the end of year 1 followed by decline to the end of year 30. However, water levels at the end of years 5, 10 and 15 are higher than at the beginning of year 1. All periods/ scenarios indicate moderate risk of impact up to the end of year 15 (Table 8). At this level of risk there may be some change in the current distribution and/or health of mesic species fringing the wetland as water availability declines.

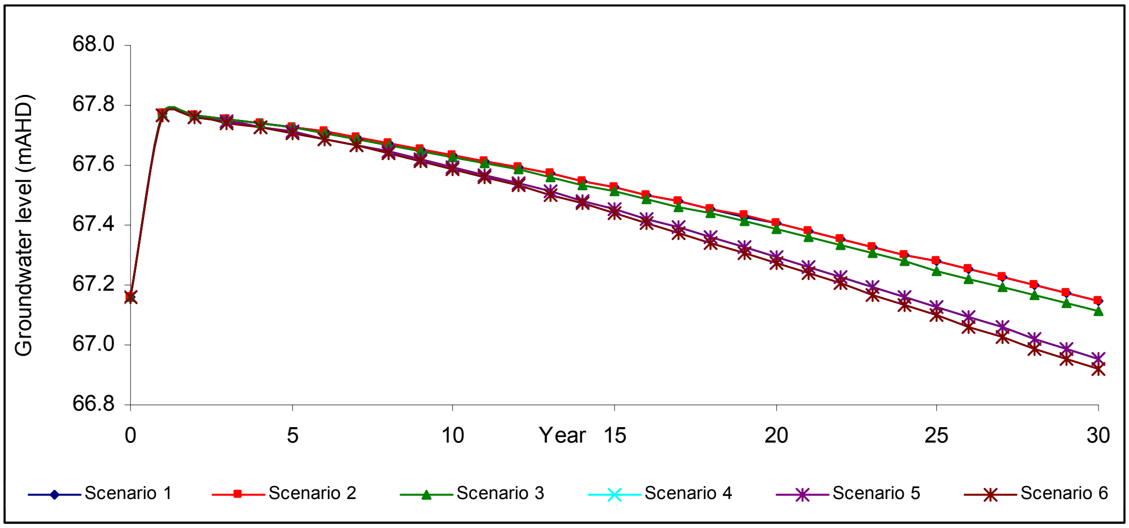


Figure 89: Groundwater level change at the Brockman Highway wetland site modelled under 6 drawdown scenarios.

Stewart Rd

The hydrograph of modeled water level changes (Figure 90) at Stewart Rd under all drawdown scenarios shows a decrease at the end of year 1. This is followed by a gradual increase to the end of year 30 under scenarios 1-3 and a decline under scenarios 4-6. Water levels are therefore higher at the end of years 5, 10 and 15 under scenarios 1-3 and lower under scenarios 4-6. The site is at moderate risk of impact under scenarios 1-3 and high under 4-6. Under periods/ scenarios of moderate risk of impact up to the end of year 15 (Table 8) there may be some change in the current distribution and/or health of mesic species fringing the wetland as water availability declines (eg. *Banksia littoralis, Melaleuca preissiana*). Under high risk of impact areas of surface water may decrease, leading to the contraction in the current ranges of more mesic species reliant on the high moisture conditions (eg. wetland sedges).

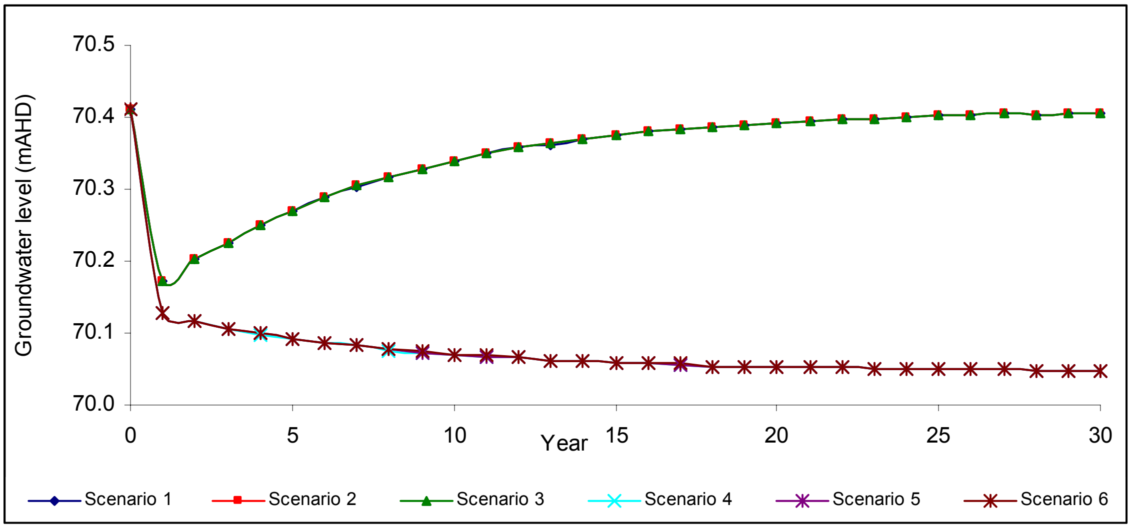


Figure 90: Groundwater level change at the Stewart Rd wetland site modelled under 6 drawdown scenarios.

Poison Gully

The hydrograph of modeled water level changes (Figure 91) at Poison Gully shows an increase over year 1 under all drawdown scenarios. All levels then fall to the end of year 30 with the exception of scenario 2 under which levels rise to the end of year 5 before falling to the end of year 30. As a result water levels at the end of years 5, 10 and 15 are lower than current under all periods/ scenarios with the exception of scenario 1 after years 5 and 10 and scenario 2 after year 10. The site is at moderate or high risk of impact under all scenarios. Under periods/ scenarios of moderate risk of impact up to the end of year 15 (Table 8) there may be some change in the current distribution and/or health of mesic species fringing the wetland as water availability declines (eg. *Melaleuca preissiana*). Under high risk of impact areas of surface water may decrease, leading to the contraction in the current ranges of more mesic species reliant on the high moisture conditions (eg. wetland sedges).

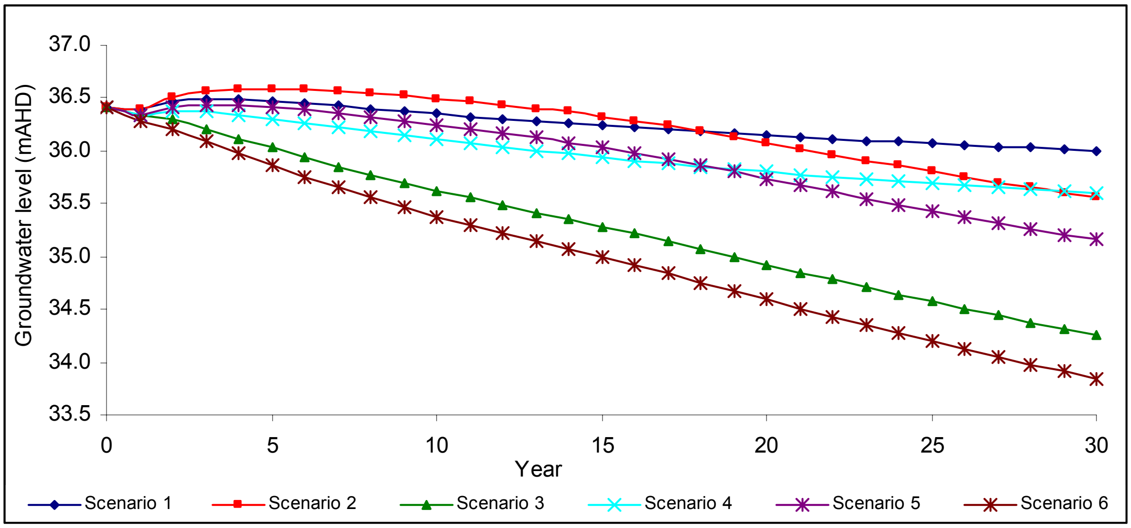


Figure 91: Groundwater level change at the Poison Gully wetland site modelled under 6 drawdown scenarios.

Terrestrial sites

Blackpoint/ Fouracres Rd

The hydrograph of modeled water level changes (Figure 92) at Blackpoint/ Fouracres shows an increase over year 1 under all drawdown scenarios. All levels then fall to the end of year 30 with the exception of scenario 2 under which levels rise to the end of year 5 before falling to the end of year 30. As a result water levels at the end of years 5, 10 and 15 are lower than current under all periods/ scenarios with the exception of scenario 1 after years 5 and 10 and scenario 2 after year 10. The site is at moderate or high risk of impact under all scenarios. Under periods/ scenarios of moderate risk of impact up to the end of year 10 (Table 8) there may be some change in the current distribution and/or health of some species as groundwater availability declines. Under high risk of impact there may be a contraction in the current ranges of phreatophytic vegetation and encroachment of more xeric species.

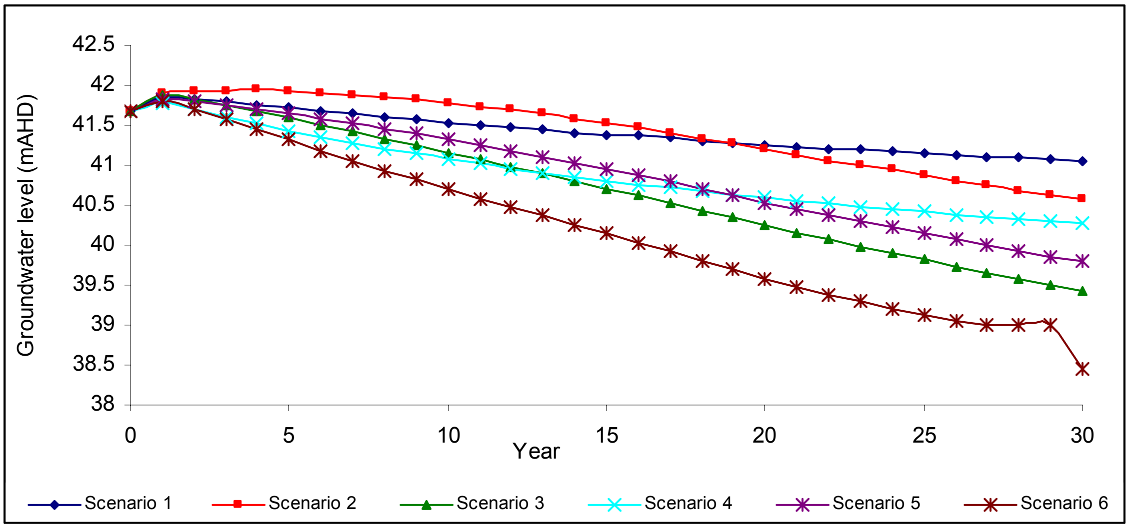


Figure 92: Groundwater level change at the Blackpoint/ Fouracres Rd terrestrial site modelled under 6 drawdown scenarios.

Darradup Rd east

The hydrograph of modeled water level changes (Figure 93) at Darradup Rd east shows an increase after year 1 under all drawdown scenarios, followed by a decrease to the end of year 30. However, water levels at the end of years 5, 10 and 15 are higher than at the beginning of year 1. Despite this, all periods/ scenarios indicate high risk of impact up to the end of year 15 (Table 8). At this level of risk there may be a contraction in the current ranges of phreatophytic vegetation and encroachment of more xeric species. There may also be may be some change in the current distribution and/or health of some species as groundwater availability declines.

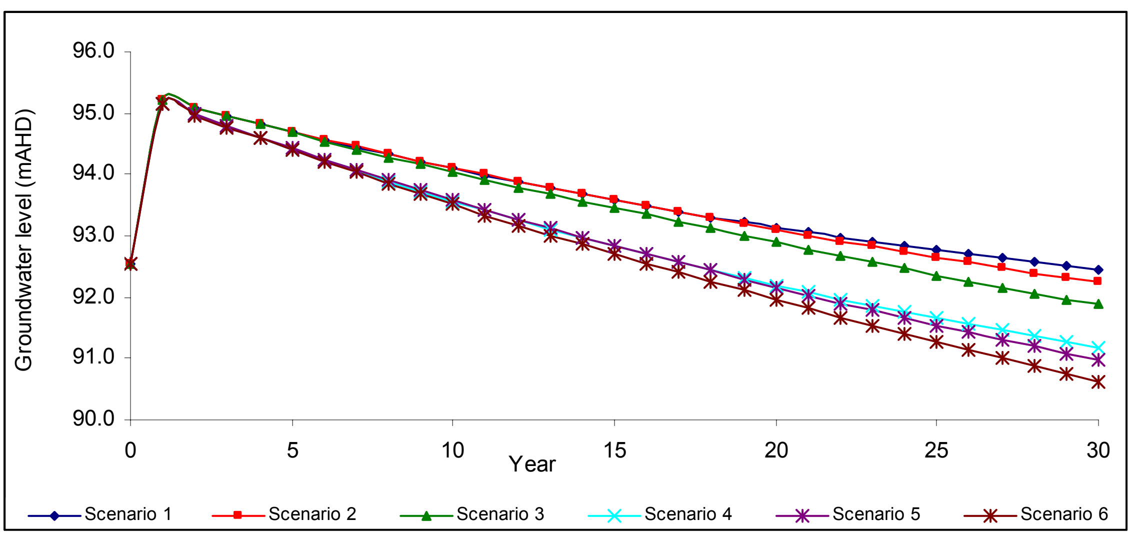


Figure 93: Groundwater level change at the Darradup Rd East terrestrial site modelled under 6 drawdown scenarios.

Blackwood River Crossing

The hydrograph of modeled water level changes (Figure 94) at Blackwood River Crossing shows an increase after year 1 under all drawdown scenarios, followed by a decrease to the end of year 30. However, water levels at the end of years 5, 10 and 15 are higher than at the beginning of year 1. Despite this, all periods/ scenarios indicate high risk of impact up to the end of year 15 (Table 8). At this level of risk there may be a contraction in the current ranges of phreatophytic vegetation and encroachment of more xeric species. There may also be may be some change in the current distribution and/or health of some species as groundwater availability declines.

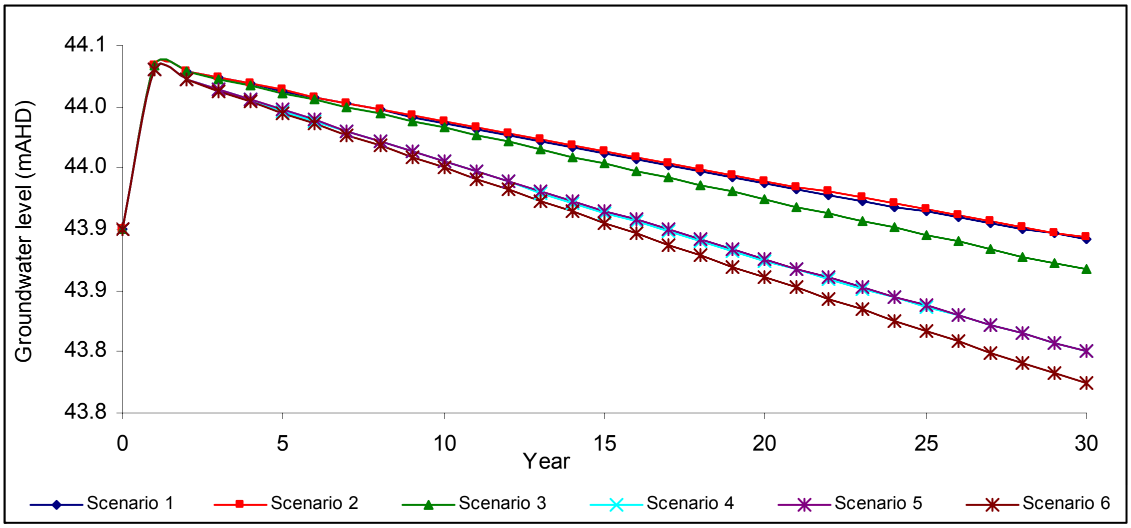


Figure 94: Groundwater level change at the Blackwood River Crossing terrestrial site modelled under 6 drawdown scenarios.

Brockman Highway

The hydrograph of modeled water level changes (Figure 95) at Brockman Highway shows an increase after year 1 under all drawdown scenarios, followed by a decrease to the end of year 30. However, water levels at the end of years 5, 10 and 15 are higher than at the beginning of year 1. Despite this, all periods/ scenarios indicate high risk of impact up to the end of year 15 (Table 8). At this level of risk there may be a contraction in the current ranges of phreatophytic vegetation and encroachment of more xeric species. There may also be may be some change in the current distribution and/or health of some species as groundwater availability declines.

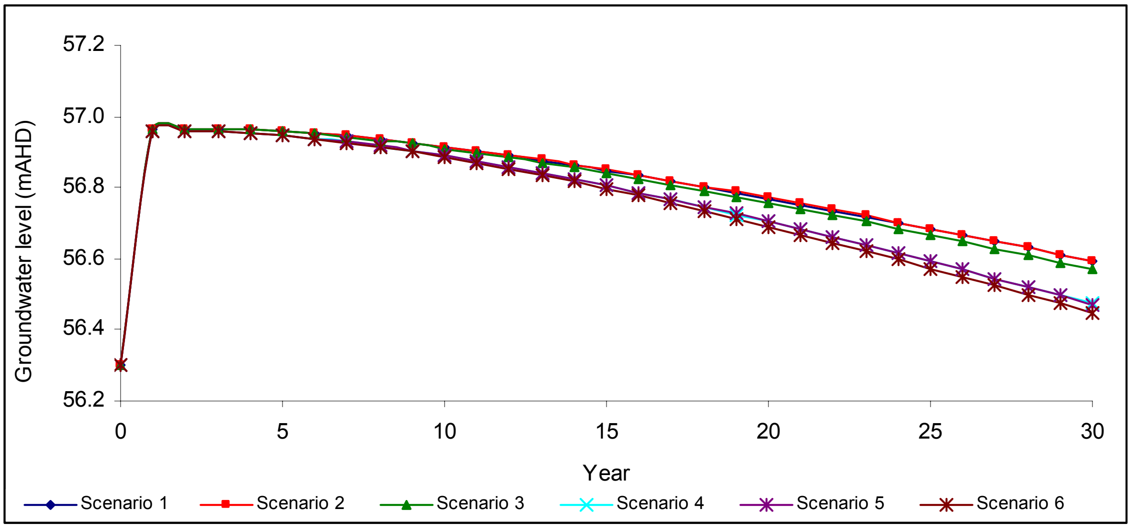


Figure 95: Groundwater level change at the Brockman Highway terrestrial site modelled under 6 drawdown scenarios.

Poison Gully

The hydrograph of modeled water level changes (Figure 96) at Poison Gully shows an increase over year 1 under all drawdown scenarios. All levels then fall to the end of year 30 with the exception of scenario 2 under which levels rise to the end of year 5 before falling to the end of year 30. As a result water levels at the end of years 5, 10 and 15 are lower than current under all periods/ scenarios with the exception of scenario 1 after years 5 and 10 and scenario 2 after year 10. The site is at moderate or high risk of impact under all scenarios (Table 8). Under moderate risk there may be some change in the current distribution and/or health of some species as groundwater availability declines. Under high risk of impact there may be a contraction in the current ranges of phreatophytic vegetation and encroachment of more xeric species.

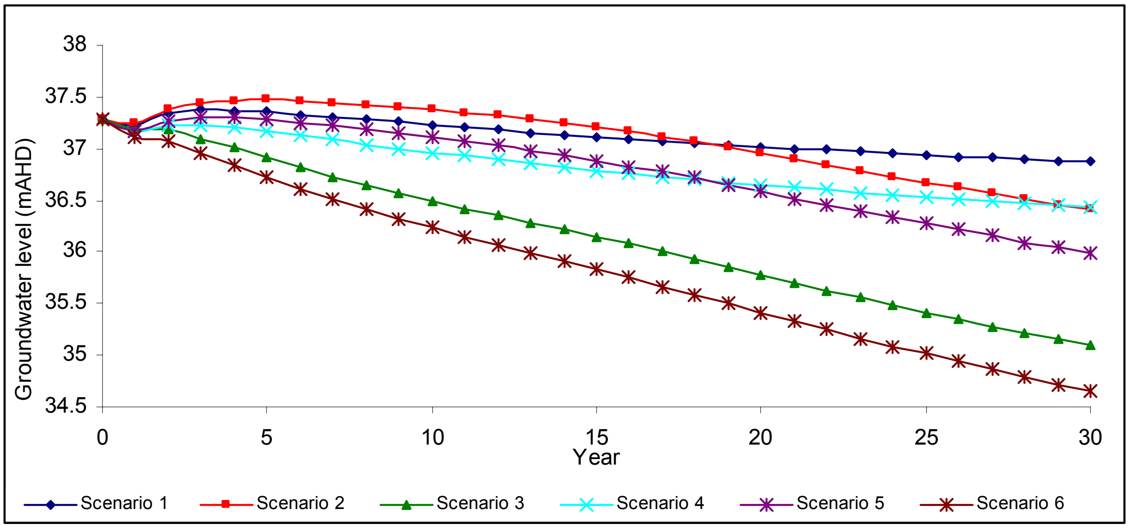


Figure 96: Groundwater level change at the Poison Gully terrestrial site modelled under 6 drawdown scenarios.

Stewart Rd

The hydrograph of modeled water level changes (Figure 97) at Stewart Rd shows a decrease at the end of year 1 under all drawdown scenarios, followed by an increase to the end of year 30 under scenarios 1-3 and a gradual decline under scenarios 4-6. Despite this, all water levels are lower at the end of years 5, 10 and 15 than current levels. The site is at moderate risk of impact under all scenarios (Table 8). Under this level of risk there may be some change in the current distribution and/or health of some species as groundwater availability declines.

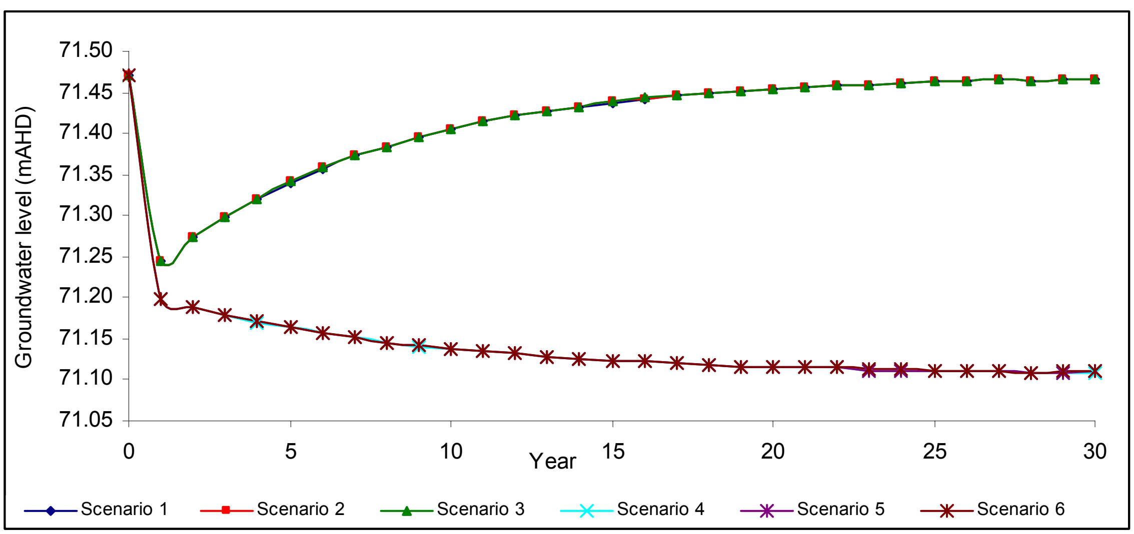


Figure 97: Groundwater level change at the Stewart Rd terrestrial site modelled under 6 drawdown scenarios.

Darradup Rd north

The hydrograph of modeled water level changes (Figure 98) at Darradup Rd north shows an increase after year 1 under all drawdown scenarios, followed by a decrease to the end of year 30. However, water levels are higher than at the beginning of year 1 under all periods/ scenarios with the exception of scenarios 4-6 at the end of year 15. The site is at moderate risk of impact under all scenarios (Table 8). Under this level of risk there may be some change in the current distribution and/or health of some species as groundwater availability declines.

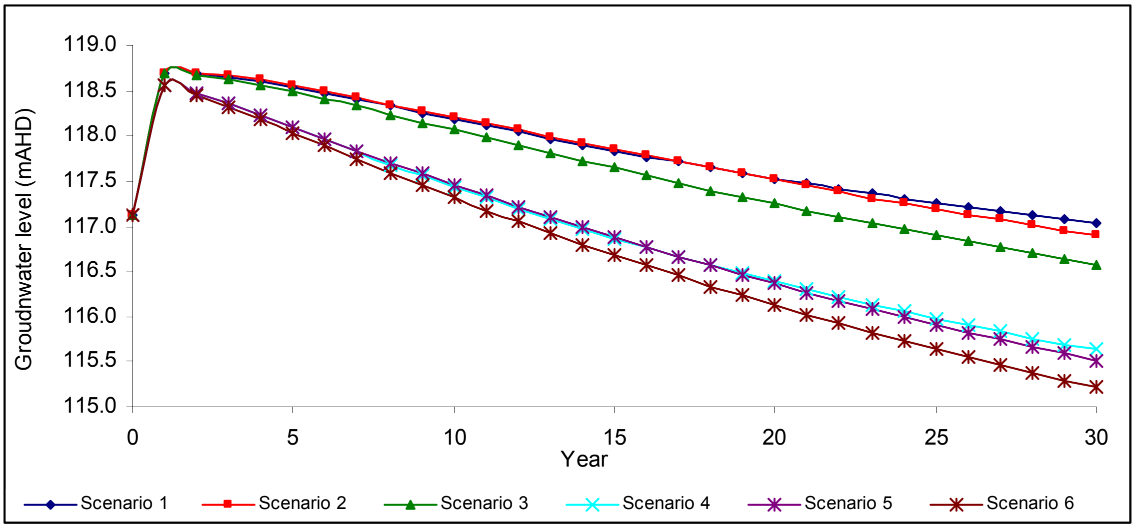


Figure 98: Groundwater level change at the Darradup Rd North terrestrial site modelled under 6 drawdown scenarios.

Jack Track

The hydrograph of modeled water level changes (Figure 99) at Jack Track shows an increase after year 1 under all drawdown scenarios. Levels then decline to the end of year 30 under all scenarios with the exception of scenario 2 under which levels continue to increase to the end of year 3 before falling to the end of year 30. Water levels are lower than at the beginning of year 1 under all periods/ scenarios with the exception of scenarios 1, 2, 3 and 5 at the end of year 5. The site is at moderate or high risk of impact under all scenarios (Table 8). Under moderate risk there may be some change in the current distribution and/or health of some species as groundwater availability declines. Under high risk of impact there may be a contraction in the current ranges of phreatophytic vegetation and encroachment of more xeric species.

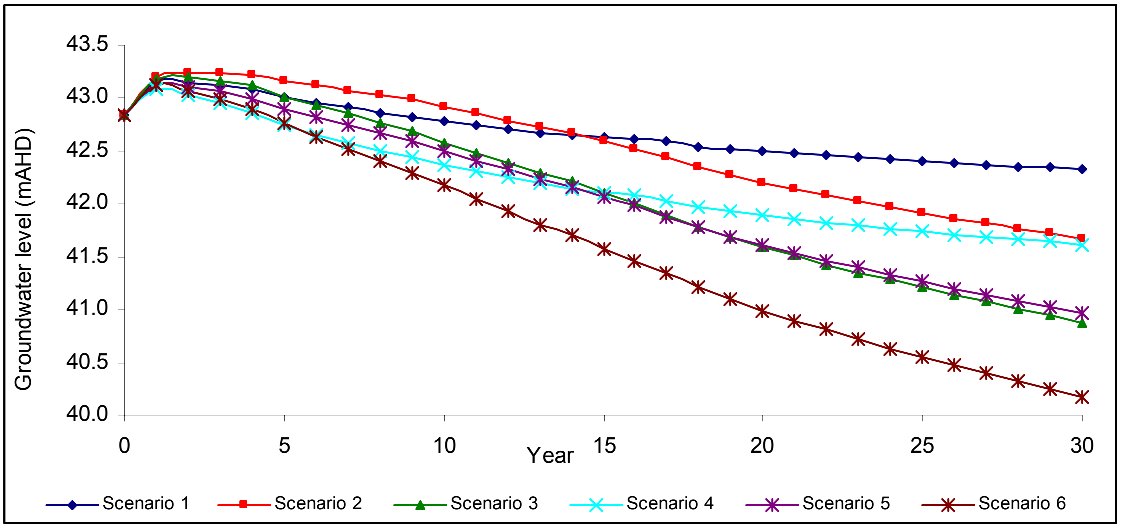


Figure 99: Groundwater level change at the Jack Track terrestrial site modelled under 6 drawdown scenarios.

Scott Rd

The hydrograph of modeled water level changes (Figure 100) at Scott Rd shows an increase to the end of year 11 followed by a decline to year 30 under drawdown scenarios 1 and 2. Under scenario 3 levels increase to year 9 before falling to year 30, under scenarios 4 and 5 there is an increase to year 5 before the decline, while level decline after year 1 under scenario 6. However, water levels are lower at the end of years 5, 10 and 15 than at the start of year 1. The site is at moderate or high risk of impact under all scenarios (Table 8). Under moderate risk there may be some change in the current distribution and/or health of some species as groundwater availability declines. Under high risk of impact there may be a contraction in the current ranges of phreatophytic vegetation and encroachment of more xeric species.

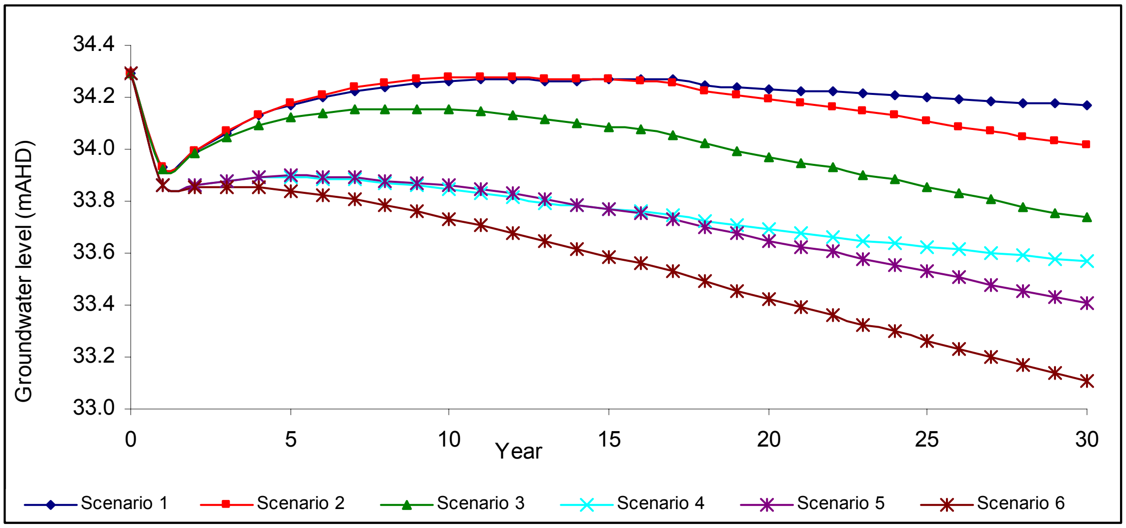


Figure 100: Groundwater level change at the Scott Rd terrestrial site modelled under 6 drawdown scenarios.

Blackpoint Rd

The hydrograph of modeled water level changes (Figure 101) at Blackwood Rd shows an increase over year 1 followed by a decrease to the end of year 30 under all drawdown scenarios. However, water levels at the end of year 5 are higher than year 1 under all scenarios, after year 10 under scenarios 1-5 and after year 15 under scenarios 1 and 2. The site is at moderate risk of impact under all scenarios (Table 8). Under this level of risk there may be some change in the current distribution and/or health of some species as groundwater availability declines.

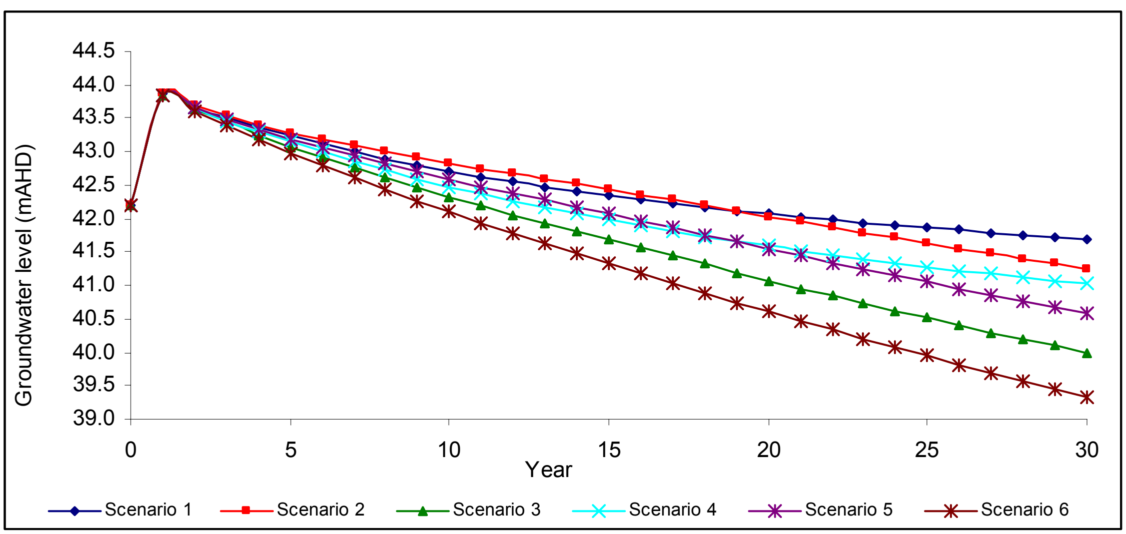


Figure 101: Groundwater level change at the Blackpoint Rd terrestrial site modelled under 6 drawdown scenarios.

Discussion

This approach has been applied during a number of studies across the south-west of Western Australia (Froend & Loomes, 2004a; Froend, Loomes et al., 2004; Froend, Loomes, & Lam, 2002; Froend, Loomes, & Zencich, 2002) and has proven to be a relatively quick and inexpensive desk-top method to describe the risk of impact to GDEs from groundwater drawdown and the potential response to altered water regimes. However, there are a number of issues that may reduce the accuracy of the approach and should be considered before final resource management decisions are made.

The uncertainties associated with groundwater modelling are significant especially in a project such as this where the monitoring bore network is relatively sparse compared to those in more developed areas of the state. As drawdown was modelled at a regional scale[2], with cells that cover or that are associated with criteria sites, drawdown values were averaged. Drawdown therefore was not relevant to a specific piezometers/ bores/ staff gauge. This necessitated the use of the depth to groundwater category approach rather than predicting the response of site specific vegetation to changes in groundwater levels at the actual site. Direct comparisons to EWRs were therefore not possible.

As monitoring at many bores has only been undertaken in the short-term, long-term historic groundwater data were often not available. This restricted the ability to assess the cumulative effects of past and predicted groundwater level change on dependent vegetation. The absence of long-term vegetation data meant that past change in vegetation vigour could not be taken into account when predicted future potential impacts.

Although the response of common wetland species to groundwater drawdown have been described in previous studies there has been little work undertaken to describe the response of less common wetland species and species common to Jarrah woodlands. As a result only generic comments regarding the possible response at a community level could be made for the majority of sites.

Site specific conditions such as underlying geology and soil Stratigraphy also influence groundwater usage and dependency of phreatophytic vegetation. Bore logs available from the study area and prepared during piezometer installation indicate both sand and clay soils occur across the area, with sandy soils often underlain by clay and/ or silt layers. Although it is probable that both terrestrial and wetland vegetation has access to water held in the clay layers and possibly also from other water sources, this factor was not considered when describing risk of impact and possible response to drawdown. The

[2] * Since this assessment was undertaken, a local model was constructed for the eastern Scott Coastal Plain/southern Blackwood Plateau area, which better takes into account the 'rejected recharge' or winter ponding of water that occurs on the plain. Results from the local model indicate that drawdowns in the model domain (which encompasses most of the criteria sites discussed in this report), are likely to be substantially less than what has been predicted by the SWAMS model.

influence of other factors including logging, fire and dieback may also have a bearing on the response of groundwater dependent vegetation to drawdown.

Limitations

There are a number of limitations to this approach that may influence the accuracy of predicted responses;

- Little available data on response of species to groundwater decline, especially terrestrial species.
- Where historic groundwater data is not available cumulative effects of past and predicted groundwater level change can not be considered.
- No long-term vegetation data.
- Variations in site conditions.
- Influence of disturbance eg. fire, dieback.
- Drawdown modelled at a regional scale, with cells that cover or are associated with criteria sites averaged. Drawdown therefore not relevant to specific piezometers/ bores/ staff gauges necessitating use of depth to groundwater category approach rather than response of site specific vegetation to change in groundwater. Direct comparisons to EWRs therefore not possible.

Appendices

Appendix 1: Photos of wetland and terrestrial sites

Wetlands


A)


B)


C)


D)

Figure 1: Lake Jasper South (site 1); A) Looking east along transect from plot A; B) Large *M. preissiana* in plot C: C) Looking east from monitoring bores SC21A and B to start of transect; D) Lake Jasper East looking west from plot towards wetland basin; E) Lake Jasper East looking west from plot A across *B. articulata.*

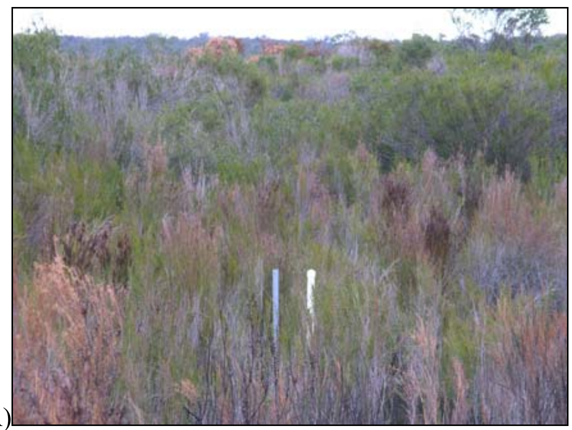
A)


Figure 2: Jangardup Rd (site 2); A) Looking east from bore along transect

A)

B)


C)  D) 

Figure 3: Blackpoint Rd (site 3) Looking northwest towards transect; B) Looking west from plot B along transect; C) Looking east from plot B; D) Looking west from plot C.

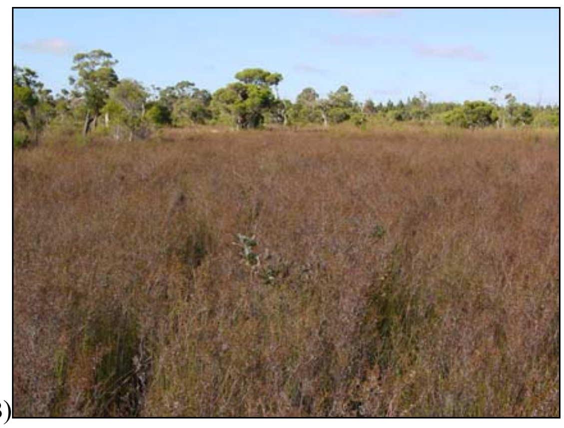
A)  B) 

Figure 4: Pneumonia Rd; A) Looking northeast along transect; B) Looking southwest across wetland.

A)  B) 

Figure 5: Blackpoint Rd/ Fouracres Rd. (site 5A); A) Looking east from bore (dry) along transect; B) Looking north-east from bore towards wetland edge

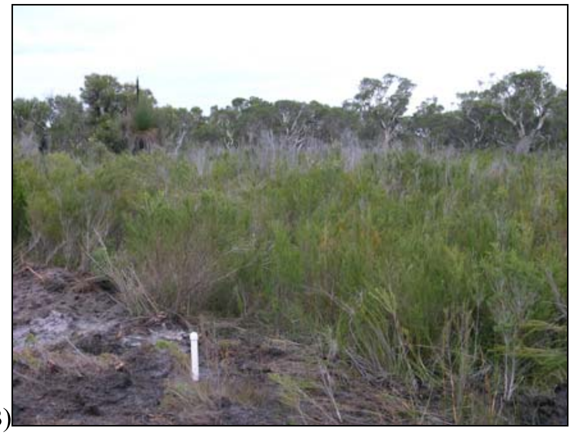
A) 
B) 

Figure 6: Blackpoint Rd – base of dunes (site 6); A) Looking west from plot B along transect; B) Looking west from bore towards wetland edge.

A) 
B) 
C) 

Figure 7: Blackpoint Rd – in dunes (site 7); A) Looking west from roadside to bore; B) Looking north-west from plot B along transect; C) Looking north-west from bore.

A)  B) 

Figure 8: Darradup Rd east (site 13Y); A) Looking north from bore along transect; B) Looking south-west from terrestrial site towards transect.

A)  B) 

C) 

Figure 9: Darradup Rd west (site 13B); A) Looking south from plot B along transect; B) Looking west from transect across wetland; C) Looking north from plot B along transect.

A) 

B) 

Figure 10: Blackwood River Crossing – Longbottom Rd (site 21); A) Looking south-west along transect towards the bore; B) Looking south towards the terrestrial vegetation.

A) 

B) 

C) 

Figure 11: Brockman Highway - Milyeanup (site 22); A) Looking north-east across the wetland to the terrestrial site; B) Bore at site 22; C) Looking south-east from the wetland fringe.

A)  B) 

Figure 12: Stewart Rd (site 28); A) Looking south-west from the road verge across the wetland; B) Looking across the wetland towards the terrestrial vegetation.

A)  B) 

Figure 13: Poison Gully (site 31); A) Looking south-east from the road verge across the wetland; B) Looking south-west.

Terrestrial

A)  B) 

Figure 14: Blackpoint Rd/ Fouracres Rd; A) Looking west from the bore along the transect; B) Looking east across Blackpoint Rd towards site 5A.

A)  B) 

Figure 15: Darradup Rd east; A) Looking north-east from the bore along the transect; B) Looking south-west from the bore towards site 13Y.

Figure 16: Blackwood River crossing – Longbottom Rd. Looking east along transect.

A)  B) 

Figure 17: Brockman Highway - Milyeanup; A) Looking south along transect; B) Looking north along transect into wetland.

A)  B) 

C) 

Figure 18: Poison Gully; A) Looking east into wetland from terrestrial bore; B) Looking west along transect; C) Looking south from road towards bore

A)  B) 

Figure 19: Stewart Rd (BP20B); A) Bores 20A and B; B) Looking north from bores across transect.

A) 

B) 

C) 

Figure 20: Darradup Rd North (BP42B); A) Bores BP42A and B; B) Looking south-west along transect from bore; C) Looking north-east towards bore.

A) 

B) 

C)  D) 

Figure 21: Jack Track (SC8); A) Bores SC8A and B; B) Looking north-east from bore along transect; B) Looking south-west along transect towards bore; D) Looking north-west from transect.

A)  B) 

Figure 22: Scott Rd (SC22B); A) Looking south from bores SC21A and B; B) Looking south along transect.

A)  B) 

Figure 23: Blackpoint Rd (SC18B); A) Looking south-east along transect from bores; B) Looking north-west along transect.

Appendix 2: Stratigraphy of piezometers / monitoring bores at terrestrial and wetland criteria sites (where available).

Bore/ site	Depth	Stratigraphy
SC8A – 60930032 Jack Track	0-3.0	Sand. Brown, fine to gravel sized, poorly sorted, sub-angular to sub-rounded quartz with some organic matter near top, minor feldspar, blue/purple tinted quartz, abundant brown iron/organic coating on grains (coffee rock).
	3.0-9.0	Clayey sand. Pale brown/cream, fine to gravel sized, poorly sorted, sub-angular to sub-rounded quartz sand with abundant off-white/cream clay (kaolin) with minor blue/purple tinted quartz, brown iron stained grains, trace of fine grained heavy minerals, some rounded pebbles at base.
	9.0-12.0	Sandy clay. Pale brown/cream clay with common fine to gravel sized quartz sand.
SC22A – 60830006 Near Lake Smith	0-1.0	Sand. White, fine to coarse grained, poorly sorted, sub-angular to sub-rounded quartz sand.
	1.0-3.0	Sand. White, fine to coarse grained, dominantly medium grained, moderately sorted, rounded quartz sand.
	3.0-4.0	Coffee rock. Dark brown, fine to coarse grained, poorly sorted, sub-angular to sub-rounded quartz sand with organic/iron-oxide matrix, trace fine grained heavy minerals.
	4.0-12.0	Silt. Light grey, grey and pale brown silt, cream coloured at the top, common coal at base.
Bore 2 - Near Lake Smith	0-0.25	Sand. Dark grey. Coarse. High organic matter content.
	0.25-0.5	Sand / clay. Brown. Fine grained. High organic matter content.
	0.5	Cap rock.
BP42B – 60910304 Darradup Rd North	0-1.0	Silt / gravel. Moderate brown (5yr 4/4), silcrete and ironstone gravels, very coarse grained, angular to sub-angular, poorly sorted, loamy and silty.
	1.0-2.0	Gravel / silt. Dark reddish brown (10r 3/4), very coarse to pebble sized (gravels up to 50mm diameter), angular to sub-angular, poorly sorted, extremely weathered.
	2.0-3.0	Silt / gravel. Moderate reddish brown (10r 4/6), as per 0-1m.
	3.0-4.0	Clay / sand. Dark yellowish orange (10yr 6/6) to light bluish grey (5b 7/1), moderate plasticity, firm clay with very fine to fine grained, sub-rounded, moderately sorted quartz sands, mottled.
	4.0-5.0	Clay. Yellowish grey (5y 8/1), medium dark grey (n4) and dark yellowish orange (10yr 6/6), moderate plasticity, firm.
	5.0-6.0	Clay. Greyish black (n2), moderate to high plasticity, stiff, carbonaceous with pale yellowish brown (10yr 6/2), low plasticity, soft, silty clay.
	6.0-7.0	Clay. Olive grey (5y 4/1), high plasticity, stiff clay.
	7.0-8.0	Clay. Dark grey (n3), high plasticity, stiff, carbonaceous, weakly micaceous.
	8.0-11.0	Clay. Greyish black (n2), as per 7-8m.
	11.0-12.0	Clay. Medium dark grey (n4), moderate plasticity, soft, micaceous.
Darradup Rd site 13Y	0-0.5	Sand. Black, coarse grained. High organic material content.
	0.5-1.0	Sand. Grey, coarse grained.
Poison Gully	0-0.25	Sand. Dark grey, coarse grained. Some organic material.
	0.25-0.5	Sand. Grey/white, coarse grained.
	0.5-1.0	Sand. Orange, medium grained.
	1.0-1.5	Sand. Cream, medium grained.
Blackpoint/	0-1.0	Sand. Orange, coarse grained.

Fouracres Rd	1.0-2.5	Clay. Orange. Moderate plasticity. Fine grained. Highly sticky-firm
	2.5-3.0	Clay. Orange. Moderate plasticity. Fine grained. Moderately sticky-firm. Mottled.
	3.0-4.0	Clay. White. Fine grained. Moderate plasticity. Sticky-firm.
	4.0-5.0	Clay. White. Coarse grained. Moderate plasticity. Sticky.
	5.0-6.0	Clay. White. Fine grained. Sticky, silty. High plasticity.
Blackwood River Crossing-Longbottom Rd	0-0.25	Sand. Grey. Coarse grained.
	0.25-1.25	Sand. Orange. Coarse grained.
	1.25-1.5	Sand. Orange. Coarse grained. Some rounded gravel at base.
	1.5 1.75	Clay. Cream. Rounded gravel more prevalent.
Brockman Highway - Milyeanup	0-1.0	Sand. Grey / brown. Coarse grained.
	1.0-1.7	Clay / sand. Cream. Sticky. High plasticity.
BP20A - Stewart Rd	0-2.0	Laterite / sand. Pale reddish brown (10r 5/4), weakly calcreted 1-2m, sand fine grained sub-angular quartz.
	2.0-3.0	Silt / clay. Moderate reddish orange (10r 6/6), clay soft.
	3.0-5.0	Clay. Light grey (n7), soft.
	5.0-6.0	Sand / clay. Medium light grey (n6), fine to medium grained sub-angular to sub-rounded quartz, clay soft.
SC18B - 60830001 Blackpoint Rd	0-9.0	Silt; light brown near surface, off-white to pale grey silt with fine to coarse, very coarse and gravel sized quartz sand, ironstained near base, light brown shale at base.
	9.0-12.0	Sand; brown, fine to gravel sized, dominantly very coarse grained, moderately to poorly sorted, sub-angular to sub-rounded quartz sand with common brown ironstained grains and minor purple tinted quartz, some pale grey/white and red silt in part.
SC21A – 60830004 Lake Jasper south (W)	0-4.0	Sand. Grey brown to brown, fine to coarse grained, poorly sorted, sub-rounded to rounded quartz sand with some organic material, brown stained grains near base.
	4.0-5.0	Sand and peat. Brown, fine to coarse grained, poorly sorted, sub-rounded to rounded quartz sand with abundant brown peat, some organic material.
	5.0-9.0	Sand. Dark grey brown, fine to coarse grained, poorly sorted, sub-rounded to rounded quartz sand with some brown organic/iron matrix.
	9.0-12.0	Silt. Dark brown, carbonaceous silt.
	12.0-19.0	Sand and silty sand. Grey brown, medium and fine to course grained, well to moderately sorted, sub-angular to rounded quartz sand with abundant brown stained grains, trace fine to medium grained heavy minerals and garnet, abundant brown organic silt in parts.
Darradup Rd East (site 13Y)	0-0.1	Sand. Black. Coarse grained. High organic matter content.
	0.1-1.5	Sand. Grey. Coarse grained.

Appendix 3: Vegetation water depth range assessment raw data

GDE type/ Site	Species	Range along transect (m)	Elevational range across transect (m/ mAHD)	Water depth range (m)
Wetland				
Lake Jasper Sth (site 1a)	*Melaleuca preissiana*	20.0 to 70.0	42.64 to 42.67	-2.51 to -4.28
	Banksia littoralis	2.2 to 43.0	41.5 to 42.1	-1.37 to -3.71
	Agonis flexuosa	1.0 to 42.0	41.4 to 42.05	-1.27 to -3.66
	Lepidosperma gladiatum	0 to 5.0	41.45 to 41.5	-1.32 to -3.11
	Lepidosperma longitudinale	0 to 80.0	41.45 to 42.64	-1.32 to -4.25
	Taxandria parviceps	0 to 100.0	41.45 to 43.21	-1.32 to -4.82
	Centella sp.	0 to 15.4	41.45 to 41.6	-1.32 to -3.21
Lake Jasper Est (site 1b)	*Melaleuca preissiana*	23.0 to 35.3	39.18 to 39.55	0.43 to -0.74
	Baumea articulata	-15.0 to 22.4	37.74 to 39.1	1.87 to -0.29
	Baumea juncea	-0 to 26.6	37.84 to 39.28	1.77 to -0.47
	Banksia littoralis	30.0 to 35.0	39.4 to 39.56	0.21 to -0.75
	Pultenaea reticulata	45.0 to 65.0	39.74 to 39.8	-0.13 to -0.99
Jangardup Rd (site 2)	*Pericalymma ellipticum*	16.5 to 80.0	0.19 to 0.56	-0.25 to -2.35
	Melaleuca preissiana	62.5 to 78.8	0.35 to 0.5	-0.41 to -2.29
	Astartea juniperina	0 to 14.0	0 to 0.18	-0.06 to -1.97
	Anarthria scabra	0 to 15.0	0 to 0.19	-0.06 to -1.98
Black Point Rd (site 3)	*Melaleuca preissiana*	13.5 to 78.0	0.26 to 0.42	-0.21 to -0.37
	Taxandria parviceps	15.0 to 80.0	0.27 to 0.45	-0.22 to -0.4
	Pericalymma ellipticum	0 to 80.0	0 to 0.45	0.05 to -0.4
	Astartea juniperina	0 to 8.0	0 to 0.15	0.05 to -0.1
Pneumonia Rd (site 4)	*Pericalymma ellipticum*	0 to 80.0	0 to -0.27	-0.08 to -1.24
	Melaleuca preissiana	0.5 to 52.4	-0.01 to -0.25	-0.07 to -1.26
	Taxandria linearifolia	10.0 to 70.0	-0.05 to -0.23	-0.03 to -1.28
Jangardup Rd (Blackpoint/ Fouracres Rd (Site 5)	*Melaleuca preissiana*	34.0 to 76.0	-0.70 to -0.95	-2.41 to -0.79
	Taxandria parviceps	0 to 80.0	0 to -1.0	-3.11 to -0.16
	Pericalymma ellipticum	22.0 to 80.0	-0.48 to -1.0	-2.63 to -0.16
Blackpoint Rd – base of dunes (site 6)	*Melaleuca rhaphiophylla*	20.3 to 80.0	-0.16 to -0.37	-1.18 to -0.07
	Astartea juniperina	0 to 75.0	0 to -0.36	-0.44 to -0.08
	Taxandria parviceps	0 to 80.0	0 to -0.37	-0.44 to -0.07
	Banksia littoralis	55.0 to 78.0	-0.3 to -0.36	-0.14 to -0.08
Blackpoint Rd – dunes (site 7)	*Melaleuca preissiana*	1.9 to 80.0	-0.02 to 0.02	-0.61 to -1.55
	Astartea juniperina	1.6 to 80.0	-0.015 to 0.02	-0.615 to -1.55
	Taxandria parviceps	1.6 to 57.8	-0.015 to -0.04	-0.615 to -1.61
	Banksia littoralis	56.0 to 84.0	-0.04 to 0.04	-0.59 to -1.53
	Beaufortia sparsa	69.0 only	-0.01	-0.62 to -1.54
	Melaleuca sp.	10.0 to 80.0	-0.02 to 0.02	-0.61 to -1.55
	Lepidosperma longitudinale	60.0 to 80.0	-0.03 to 0.02	-0.6 to -1.55
Darradup Rd east (site 13Y)	*Hypocalymma angustifolium*	0 to 80.0	0 to -0.07	-0.05 to -1.06
	Melaleuca preissiana	2.0 to 80.0	0.02 to -0.07	-0.07 to -1.06
	Pericalymma ellipticum	0 to 80.0	0 to -0.07	-0.05 to -1.06
	Taxandria parviceps	12.9 to 66.7	0.06 to -0.06	-0.11 to -0.99
	Astartea juniperina	26.2 to 80.0	0.03 to -0.07	-0.08 to -1.06

Darradup Rd west (site 13B)	*Melaleuca preissiana*	7.0 to 64.0	0.03 to -0.13	-1.071 to -0.06
	Taxandria parviceps	0 to 80.0	0 to -0.17	-1.068 to -0.1
	Astartea juniperina	0 to 80.0	0 to -0.17	-1.068 to -0.1
Blackwood River Crossing – Longbottom Rd (site 21)	*Melaleuca preissiana*	0 to 120.0	0.14 to -0.11	-1.54 to -0.33
	Pericalymma ellipticum	0 to 120.0	0.14 to -0.11	-1.54 to -0.33
	Banksia littoralis	93.0 only	0.12	-1.52 to -0.56
Brockman Highway - Milyeanup (site 22)	*Taxandria parviceps*	0 to 60.0	-0.38 to 2.08	0.32 to -3.10
	Astartea juniperina	8.0 to 54.0	-0.38 to 1.55	0.32 to -2.57
	Lepidosperma tetraquetrum	6.5 to 15.0	0.55 to -0.19	-1.58 to 0.13
	Eucalyptus rudis	0 to 8.0	1.04 to 0.4	-2.06 to -0.46
Stewart Rd causeway (site 28)	*Pericalymma ellipitcum*	0 to 80.0	0 to -0.12	0.03 to -2.2
	Melaleuca preissiana	10.0 to 73.0 (off transect)	-0.02 to -0.05	0.01 to -1.92
	Banksia littoralis	12.0 only	0.1	0.02 to -1.98
Poison Gully (site 31)	*Melaleuca preissiana*	0 to 22.0	0.46 to 0	-0.91 to -0.15
	Astartea juniperina	0 to 15.0	0.46 to -0.01	-0.91 to -0.16
	Pultenaea reticulata	35.0 to 40.0	1.01 to 1.61	-1.16 to -2.06
	Taxandria linearifolia	0 to 35.0	0.46 to 1.01	-0.91 to -1.16
	Sedges (inc. *Lepidosperma tetraquetrum*)	0 to 34.0	0.46 to 1.0	-0.91 to -1.15
Terrestrial				
Jangardup Rd (Blackpoint/ Fouracres Rd	*Eucalyptus marginata*	0 to 80.0	0 to 1.44	-4.85 to -8.08
	Banksia grandis	0 to 68.0	0 to 1.2	-4.85 to -7.84
	Astartea juniperina	34.0 to 56.0	0.6 to 0.9	-5.41 to -7.73
	Taxandria parviceps	12.0 to 45.0	0.2 to 0.75	-5.05 to -7.39
Darradup Rd east (site 13Y)	*Eucalyptus marginata*	0.5 to 80.0	0.01 to 0.6	-0.58 to -2.17
	Allocasuarina fraseriana	8.0 to 50.0	0.19 to 0.28	-0.76 to -1.85
	Banksia ilicifolia	10.0 only	0.17	-0.74 to -1.74
	Corymbia calophylla	39.0 to 80.0	0.2 to 0.6	-0.78 to -2.17
Blackwood River Crossing – Longbottom Rd	*Eucalyptus marginata*	0 to 80.0	0 to -1.07	-2.36 to -0.33
	Corymbia calophylla	0 to 75.0	0 to -0.95	-2.36 to -0.45
	Taxandria parviceps	2.0 to 79.0	-0.02 to -1.05	-2.34 to -0.35
Poison Gully	*Pultenaea reticulata*	10.0 to 77.0	0 to 4.09	-2.34 to -6.72
	Eucalyptus marginata	10.0 to 80.0	0 to 7.67	-2.34 to -10.3
	Banksia grandis	17.0 to 80.0	2.19 to 7.67	-4.52 to -10.3
	Xylomelum occidentale	14.0 to 60.0	0.39 to 6.07	-2.72 to -8.7
	Allocasuarina fraseriana	51.0 to 80.0	1.45 to 7.67	-3.77 to -10.3
Brockman Highway - Milyeanup	*Eucalyptus marginata*	0 to 60.0	-0.17 to 1.27	-0.93 to -3.33
	Banksia grandis	0 to 15.0	-0.17 to 0.1	-0.93 to -1.37
	Xylomelum occidentale	9.0 to 47.0	0.01 to 0.8	-1.11 to -2.86
	Corymbia calophylla	0 to 60	-0.17 to 1.27	-0.93 to -3.33
Stewart Rd (BP20B)	*Eucalyptus marginata*	0 to 80.0	93.05 to 93.77	-1.85 to -4.57
	Corymbia calophylla	6.0 to 78.0	93.05 to 93.7	-1.85 to -4.5
	Taxandria parviceps	10.0 to 79.5	93.05 to 93.75	-1.85 to -4.55
Darradup Rd Nth (BP42B)	*Eucalyptus marginata*	0 to 80.0	120.2 to 120.7	-4.32 to -6.77
	Astartea juniperina	7.4 to 72.0	120.4 to 120.7	-4.12 to -6.77
	Corymbia calophylla	5.0 to 76.0	120.2 to 120.6	-4.32 to -6.67
Jack Track (SC8)	*Eucalyptus marginata*	9.4 to 80.0	46.1 to 46.98	-3.88 to -7.36
	Pericalymma ellipticum	0 to 79.0	45.99 to 46.9	-3.77 to -7.28
	Allocasuarina fraseriana	18.0 to 80.0	46.15 to 46.98	-3.93 to -7.36

Scott Rd – Lake Smith (SC22B)	*Eucalyptus marginata*	1.5 to 8.0	39.5 to 39.4	-1.4 to -2.95
	Agonis flexuosa	1.0 to 37.0	35.63 to 37.5	-1.2 to -3.3
	Nutysia floribunda	4.0 to 17.0	39.5 to 39.0	-1.45 to -3.2
	Pericalymma ellipticum	10.0 only	39.15	-1.8 to -3.0
	Lepidosperma longitudinale.	0 to 80.0	39.55 to 33.13	-2.65 to -0.34
	Melaleuca preissiana	60.0 to 70.0	35.6 to 34.39	-2.7 to -0.69
Blackpoint Rd (SC18B)	*Eucalyptus marginata*	2.0 to 74.0	53.75 to 53.6	-8.88 to -6.94
	Corymbia calophylla	4.8 to 80.0	53.7 to 48.58	-8.83 to -1.92
	Taxandria parviceps	23.6 to 78.0	53.05 to 48.9	-8.18 to -2.24
	Banksia grandis	74.0 only	49.2	-4.33 to -2.54
	Agonis flexuosa	38.0 only	52.2	-7.33 to -5.54

Appendix 4: Water depth ranges experienced by (Loomes, 2000) phreatophytic species common to the Swan Coastal Plain and study sites. SW mean and absolute ranges incorporate SW Yarragadee and Swan Coastal Plain ranges.

Species	Site	Water depth range (m)	
		Maximum	**Minimum**
Melaleuca preissiana	Lake Jasper (site 1)	-2.51	-4.28
	Jangardup Rd (site 2)	-0.41	-2.29
	Blackpoint Rd (site 3)	-0.21	-0.37
	Pneumonia Rd (site 4)	-0.73	-1.26
	Blackpoint/ Fouracres Rd (site 5)	-0.79	-2.41
	Blackpoint Rd (site 7)	-0.61	-1.55
	Darradup Rd (site 13Y)	-0.07	-1.06
	Darradup Rd (site 13B)	-0.06	-1.07
	Blackwood Crossing - Longbottom Rd (site 21)	-0.33	-1.54
	Stewart Rd Causeway (site 28)	0.01	-1.92
	Poison Gully (site 31)	-0.15	-0.91
	Scott Rd – Lake Smith (SC22B)	-0.69	-2.7
	SW Mean range	**-0.70**	**-2.30**
	SW Absolute range	**0.4**	**-5.04**
Melaleuca rhaphiophylla	Blackpoint Rd (site 6)	-0.07	-1.18
	SW Mean range	**0.07**	**-2.12**
	SW Absolute range	**1.03**	**-4.49**
Banksia littoralis	Lake Jasper (site 1)	-1.37	-3.71
	Blackpoint Rd (site 6)	-0.08	-0.14
	Blackpoint Rd (site 7)	-0.59	-1.53
	Blackwood Crossing - Longbottom Rd (site 21)	-0.56	-1.52
	Stewart Rd Causeway (site 28)	0.02	-1.98
	SW Mean range	**-0.44**	**-1.82**
	SW Absolute range	**0.3**	**-3.71**
Banksia ilicifolia	Darradup Rd east (terrestrial)	-0.74	-1.74
	SW Mean range	**-1.56**	**-2.59**
	SW Absolute range	**-0.46**	**-3.99**
Eucalyptus rudis	Brockman Highway - Milyeanup (site 22)	-0.46	-2.06
	SW Mean range	**-0.69**	**-3.19**
	SW Absolute range	**1.03**	**-6.44**
Pericalymma ellipticum	Jangardup Rd (site 2)	-0.25	-2.35
	Black Point Rd (site 3)	0.05	-0.4
	Pneumonia Rd (site 4)	-0.08	-1.24
	Blackpoint/ Fouracres Rd (site 5)	-0.16	-2.63
	Darradup Rd east (terrestrial)	-0.05	-1.06
	Blackwood Crossing - Longbottom Rd (site 21)	-0.33	-1.54
	Stewart Rd Causeway (site 28)	0.03	-2.2
	Jack Track (SC8)	-3.77	-7.28
	Scott Rd – Lake Smith (SC22B)	-1.8	-3.0
	SW Mean range	**-0.78**	**-2.36**
	SW Absolute range	**0.05**	**-3.53**
Hypocalymma angustifolium	Darradup Rd (site 13Y)	-0.05	-1.06
	SW Mean range	**-1.01**	**-2.51**
	SW Absolute range	**-0.05**	**-4.08**

Pultenaea reticulata	Poison Gully (site 31)	-1.16	-2.06
	Poison Gully (terrestrial)	-2.34	-6.72
	SW Mean range	**-1.01**	**-2.56**
	SW Absolute range	**-0.43**	**-6.72**
Lepidosperma longitudinale	Lake Jasper South (site 1)	-1.32	-4.25
	Blackpoint Rd (site 7)	-0.6	-1.55
	Scott Rd – Lake Smith (SC22B)	-0.34	-2.65
	SW Mean range	**-0.24**	**-2.5**
	SW Absolute range	**0.72**	**-4.25**
Baumea articulata	Lake Jasper East	1.87	-0.29
	SW Mean range	**0.30**	**-1.20**
	SW Absolute range	**1.87**	**-2.63**
Baumea juncea	Lake Jasper East	1.77	-0.47
	SW Mean range	**-0.33**	**-2.53**
	SW Absolute range	**1.77**	**-4.64**

Appendix 5: Water depth ranges experienced by previously unstudied phreatophytic species common to study sites.

Species	**Site**	**Water depth range (m)**	
		Maximum	**Minimum**
Taxandria parviceps	Lake Jasper (site 1)	-1.32	-4.82
	Blackpoint Rd (site 3)	-0.22	-0.4
	Pneumonia Rd (site 4)	-0.03	-1.28
	Blackpoint/ Fouracres Rd (site 5)	-0.16	-3.11
	Blackpoint Rd (site 6)	-0.07	-0.44
	Blackpoint Rd (site 7)	-0.61	-1.61
	Darradup Rd (site 13Y)	-0.11	-0.99
	Darradup Rd (site 13B)	-0.1	-1.07
	Brockman Highway - Milyeanup (site 22)	0.32	-3.1
	Poison Gully (site 31)	-0.91	-1.61
	Blackpoint/ Fouracres Rd (terrestrial)	-5.05	-7.39
	Blackwood Crossing - Longbottom Rd (terrestrial)	-0.35	-2.34
	Stewart Rd (BP20B)	-1.85	-4.55
	Blackpoint Rd (SC18B)	-2.24	-8.18
	Mean SW range	**-0.91**	**-2.45**
	Absolute SW range	**0.32**	**-8.18**
Astartea juniperina	Jangardup Rd (site 2)	-0.06	-1.97
	Blackpoint Rd (site 3)	0.05	-0.1
	Blackpoint Rd (site 6)	-0.08	-0.44
	Blackpoint Rd (site 7)	-0.62	-1.55
	Darradup Rd (site 13Y)	-0.08	-1.06
	Darradup Rd (site 13B)	-0.1	-1.07
	Brockman Highway - Milyeanup (site 22)	0.32	-2.57
	Poison Gully (site 31)	-0.16	-0.91
	Blackpoint/ Fouracres Rd (terrestrial)	-5.41	-7.73
	Darradup Rd Nth (BP42B)	-4.02	-6.77
	Mean SW range	**-1.02**	**-2.42**
	Absolute SW range	**0.32**	**-7.73**
Eucalyptus marginata	Blackpoint/ Fouracres Rd (terrestrial)	-4.85	-8.08
	Darradup Rd east (terrestrial)	-0.58	-2.17
	Blackwood Crossing - Longbottom Rd (terrestrial)	-0.33	-2.36
	Poison Gully (terrestrial)	-2.34	-10.3
	Brockman Highway - Milyeanup (terrestrial)	-0.93	-3.33
	Stewart Rd (BP20B)	-1.85	-4.57
	Darradup Rd Nth (BP42B)	-4.32	-6.77
	Jack Track (SC8)	-3.88	-7.36
	Scott Rd – Lake Smith (SC22B)	-1.4	-2.95
	Blackpoint Rd (SC18B)	-6.94	-8.88
	Mean SW range	**-2.74**	**-5.68**
	Absolute SW range	**-0.33**	**-10.3**
Corymbia calophylla	Darradup Rd east (terrestrial)	-0.78	-2.17
	Blackwood Crossing - Longbottom Rd (terrestrial)	-0.45	-2.36
	Brockman Highway - Milyeanup (terrestrial)	-0.93	-3.33
	Stewart Rd (BP20B)	-1.85	-4.5
	Blackpoint Rd (SC18B)	-1.92	-8.83
	Darrdaup Rd nth (BP42B)	-4.42	-6.77
	Mean SW range	**1.71**	**-4.64**
	Absolute SW range	**-0.45**	**-8.83**

Banksia grandis	Blackpoint/ Fouracres Rd (terrestrial)	-4.85	-7.84
	Poison Gully (terrestrial)	-4.52	-10.3
	Brockman Highway - Milyeanup (terrestrial)	-0.93	-1.37
	Blackpoint Rd (SC18B)	-2.54	-4.33
	Mean SW range	**-3.21**	**-5.96**
	Absolute SW range	**-0.93**	**-10.3**
Agonis flexuosa	Lake Jasper (site 1)	-1.27	-3.66
	Scott Rd – Lake Smith (SC22B)	-1.2	-3.3
	Blackpoint Rd (SC18B)	-5.54	-7.33
	Mean SW range	**-2.67**	**-4.76**
	Absolute SW range	**-1.2**	**-7.33**
Allocasuaria fraseriana	Darradup Rd east (terrestrial)	-0.76	-1.85
	Poison Gully (terrestrial)	-3.77	-10.3
	Jack Track (SC8)	-3.93	-7.36
	Mean SW range	**-2.82**	**-6.50**
	Absolute SW range	**-0.76**	**-10.3**

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