Assessment of the needs of water dependent ecosystems for the Northern Adelaide Plains and Central Adelaide Prescribed Wells Areas

DEW Technical report 2018/03

Government of South Australia
Department for Environment and Water

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Foreword

The Department for Environment and Water (DEW) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, Natural Resources Management Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

John Schutz
CHIEF EXECUTIVE
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Summary

In accordance with Section 164N(4) of the *Natural Resources Management Act 2004* (the Act), before determining the capacity of a prescribed water resource in relation to issuing water use authorisations, the Minister responsible for the administration of the Act must prepare a report assessing the needs of ecosystems that depend on the prescribed resource.

The groundwater resources of the Northern Adelaide Plains (NAP) and Central Adelaide have been prescribed since 1976 and 2007 respectively. In 2009 the AMLR NRM Board decided to prepare a single water allocation plan (Adelaide Plains Water Allocation Plan) covering both prescribed areas, based on evidence that the two areas consisted of connected water resources.

Water resource development in the NAP and Central Adelaide Prescribed Wells Areas (PWAs) extracts water from three different types of aquifers located in the area. Fractured rock aquifers are common in the foothills and western part of the Mount Lofty Ranges which lies within the Central Adelaide PWA: water movement and discharge from these aquifers operate on a local basis and are complex due to the variable nature of the fracture networks. Quaternary aquifers are more commonly associated with the Adelaide Plains: these Quaternary aquifers overlie the deeper Tertiary confined aquifers which yield generally higher quality groundwater.

Groundwater across the NAP and Central Adelaide PWAs is used for a variety of uses. The majority of extraction across the NAP and Central Adelaide PWAs is from the deeper Tertiary confined aquifers, which have higher yields than other aquifers and is generally of higher quality. Additional extraction from the more saline and shallow Quaternary aquifers and from the Fractured Rock aquifers in the hills is common for stock and household use.

Recharge to the fractured rock aquifers is driven by rainfall and stream flow across recharge areas. Recharge to the Tertiary and Quaternary aquifers primarily occurs by stream infiltration and throughflow from fractured rock aquifers associated with the Mount Lofty Ranges. Recharge to the Quaternary aquifers from rainfall is thought to be limited due to the clayey nature of the soils and the lower rainfall on the plains. Fractured rock aquifers discharge at points where the fractures encounter an impermeable layer, or where fractures meet the ground surface, usually in incised river channels or gullies, as well as by lateral flow into the Quaternary and Tertiary aquifers adjacent to the hills. The Quaternary aquifers discharge at locations where the watertable and the land surface intersect, as well as to the sea along the coast. Apart from extraction, discharge from the deeper Tertiary aquifers on the plains is limited to upward leakage into the overlying Quaternary aquifers and diffuse discharge into the offshore marine environment. In the Golden Grove area northeast of Adelaide, Tertiary sand aquifers are exposed at the surface and form an unconfined aquifer, which discharges to the River Torrens.

For the purposes of this report, groundwater dependent ecosystems (GDEs) are considered to be those that can develop wherever groundwater nears the surface or forms a discharge as surface water. For the purposes of the Central Adelaide and NAP PWAs seven types of GDEs are considered relevant (SKM 2012):

- Fractured rock aquifer springs
- Groundwater dependent streams
- Terrestrial vegetation at the base of the hills
- Estuarine GDEs
- Coastal perched aquifer
- Coastal wetlands
- Marine GDEs

Of the seven GDE types relevant for the Central Adelaide and NAP PWAs, three have been identified as being affected by development of water resources across the Adelaide Plains: 1) fractured rock aquifer springs; 2)

groundwater dependent streams; and 3) terrestrial vegetation at the base of the hills. The other four were excluded due to 1) risk to the systems not being considered significant, or 2) insufficient evidence to define an Environmental Water Requirement or because the aquifer was not significantly developed. In addition to this, GDEs along the Gawler, Little Para, Torrens/Karrawirra and Onkaparinga Rivers were not considered as water development risk to these ecosystems are deemed to be managed through policies in the Western Mount Lofty Ranges Water Allocation Plan (WAP).

The highest concentration of GDEs is located in the Mount Lofty Ranges between Anstey's Hill and Coromandel Valley, with relatively few GDEs occurring across the Adelaide Plains. This is mainly due to urbanisation and the low relief of the plains resulting in few areas where groundwater can discharge, compared to the deeply incised ranges exposing outcropping bedrock.

The development of each of the GDEs has been influenced by the availability of water. Based on the different ecological functional groups present in each GDE, EWRs have been developed in order to maintain the ecosystem at a low level of risk, which has been interpreted as 'the water regime required to maintain self-sustaining populations resilient to drought'.

These EWRs have been interpreted in light of groundwater development across the Adelaide Plains to assess the risk to ecosystems dependent on the prescribed resource. The majority of such development occurs from the Tertiary confined aquifers, which have very limited influence on the GDEs in the PWA. The highest level of risk identified is a moderate risk to terrestrial vegetation communities that are potentially dependent on groundwater.

The information in the report provides a basis for the Adelaide and Mount Lofty Ranges (AMLR) Natural Resources Management Board (NRMB) to consider impacts to the environment when preparing the Adelaide Plains Water Allocation Plan, specifically when developing acceptable extraction limits.

1 Introduction

In accordance with Section 164N(4) of the *Natural Resources Management Act 2004* (the Act), before the capacity of a water resource can be determined, the Minister responsible for the administration of the Act must prepare a report to assess the needs of ecosystems that depend on the water resource.

This report outlines the current knowledge of water dependent ecosystems within the Northern Adelaide Plains (NAP) and Central Adelaide Prescribed Wells Areas (PWAs) and is largely based on information contained in previous work by SKM (2011a), Ecological Associates and SKM (2012), and SKM (2012).

1.1 Location and general geology

The Central Adelaide and NAP PWAs comprise the Adelaide Plains and Willunga Basin and extends from beyond the Gawler River in the north (including Kangaroo Flat) to Port Noarlunga and the Onkaparinga River in the south. The area includes the minor catchments of the Western Mount Lofty Ranges that drain west to the sea, such as First through to Sixth Creeks and Brownhill Creek (Figure 1.1).

The Northern Adelaide Plains (NAP) PWA is located immediately north of metropolitan Adelaide and extends from Salisbury to Two Wells and Gawler (and north to include Kangaroo Flat). It incorporates the downstream catchment of the Gawler and Little Para Rivers. The Central Adelaide PWA encompasses the metropolitan area of Adelaide and extends up along the Mount Lofty Ranges to Gawler in the north, across to Outer Harbor and south to Port Noarlunga. The Onkaparinga River forms the boundary between the Central Adelaide and McLaren Vale PWAs.

The Central Adelaide and NAP PWAs exclude catchments which lie substantially east of the western scarp of the ranges including the upper Gawler, Little Para, Torrens, Sturt and Onkaparinga catchments. The environmental water requirements (EWRs) of the majority of these catchments have been determined separately as part of the Western Mount Lofty Ranges Prescribed Water Resources Area (VanLaarhoven and van der Wielen, 2009).

The Central Adelaide and NAP PWAs are bounded by steep terrain in the east, associated with the Mount Lofty Ranges and the Sellicks Hill Range. This region contains steep hills with deeply incised valleys and gorges. Soils are shallow and directly overlie basement rock. The steep terrain grades rapidly to coastal plains in the central and western areas of the PWA. There is little topographic relief on the plains and soils are deep, having formed on unconsolidated sediments. A more undulating landscape is present in the Golden Grove Embayment (north-east of Adelaide) and the Noarlunga Embayment (occupying the southern portion of the Central Adelaide PWA). In these regions, streams are more deeply incised than on the plains.

The geology of the study area comprises sedimentary basins along the coast and plains. The Adelaide Plains are underlain by unconsolidated sediments of the St Vincent Basin which overlie the basement rocks that are exposed in the ranges. The sediments increase in depth with distance from the ranges. They are comprised of Quaternary interbedded sands and clays that are underlain by limestone and sands of Tertiary age (Watt et al, 2017).

Springs, soaks and permanently flowing stream reaches are groundwater dependent ecosystems (GDEs) known to be widespread in the PWAs. The Quaternary aquifers have primary interaction with the ecosystems in the NAP and Central Adelaide PWAs. These aquifers are typically poor yielding and contain brackish groundwater and consequently, have been not been widely developed.

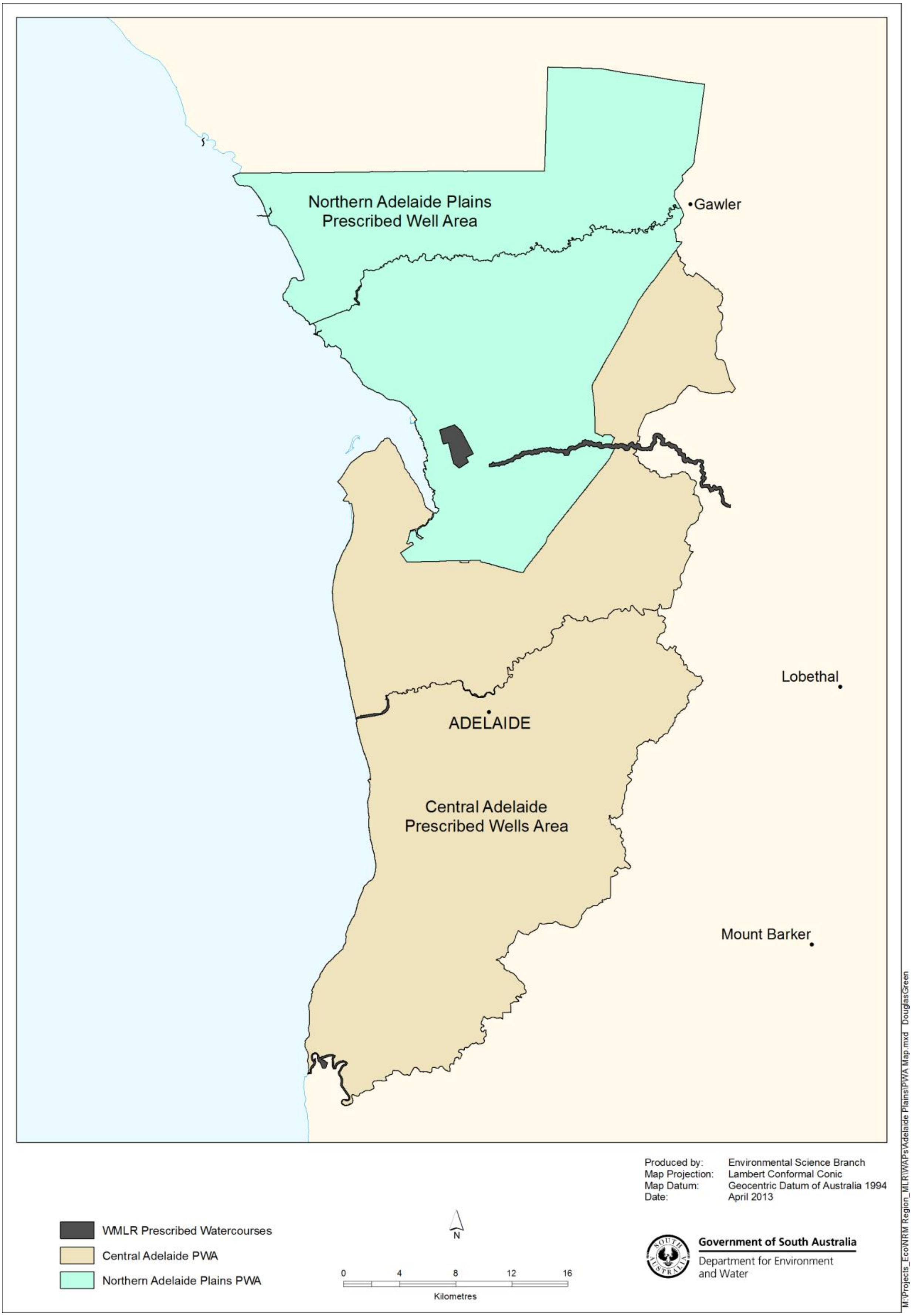


Figure 1.1 Prescribed Wells Areas of the Adelaide Plains, west of the Mount Lofty Ranges

1.2 Management of water in the Central Adelaide and Northern Adelaide Plains PWA

The Adelaide and Mount Lofty Ranges Natural Resources Management Board (the Board) is required, under the Act, to prepare a water allocation plan (WAP) for the Central Adelaide and Northern Adelaide Plains PWAs. The aim of the WAP is to ensure the sustainable use of the available water resources. The groundwater resources of the Adelaide Plains have to date been managed by the Board as two separate entities – the NAP PWA and the Central Adelaide PWA. In October 2009, the Board decided to manage all groundwater resources of the Adelaide Plains through a single WAP (in prep), as research has shown the primary aquifers under the areas are connected (AMLR NRMB, 2011).

The groundwater resource of the NAP was first prescribed in 1976 and in the Central Adelaide, in 2007. The Kangaroo Flat area was prescribed in 2004 and later added to the NAP PWA. The new, combined WAP will review and incorporate the existing NAP WAP and include water allocation policies for the Central Adelaide PWA, which has not yet had a plan developed (AMLR NRMB, 2011).

Groundwater extraction throughout the NAP and Central Adelaide PWAs occur predominantly from the deeper confined Tertiary aquifers, whereas GDEs are predominately reliant upon the shallow watertables and outcropping associated with the Quaternary aquifer and Fractured Rock aquifer. Groundwater extraction from the Tertiary aquifers can only potentially impact GDEs where they outcrop and become unconfined.

In the NAP PWA, the current groundwater allocation is 26,500 ML (not including Kangaroo Flat). Extraction primarily occurs from the T2 Tertiary limestone aquifer (8504 ML in 2014–15, DEWNR 2016b)), followed by the T1 aquifer (3358 ML in 2014–15, DEWNR 2016a) and Quaternary aquifers (approx. 530 ML, DFW, 2010). Groundwater extraction from the Quaternary aquifers is concentrated along the Gawler and Little Para Rivers. Cones of depression and declining groundwater levels have been reported for the Tertiary aquifers, whilst groundwater level trends in the Quaternary aquifers generally have a correlation with rainfall but are mostly stable (DFW 2010). Groundwater flow in the Quaternary aquifers is from east to west with the groundwater typically brackish (~1000–3000 mg/L) and low yielding; thus is used mainly for stock and domestic purposes (DFW 2010).

In the Central Adelaide PWA, the Quaternary sediments provide good supplies for stock and domestic purposes, mainly in the Le Fevre Peninsula and the eastern suburbs. Current extraction from the Quaternary aquifers is estimated at 500 ML/y (DFW, 2010). Groundwater use in the metropolitan area of Adelaide is about 10,000 – 12,000 ML/y with most extractions coming from the confined Tertiary aquifer (T1) (DEWNR 2016c). Groundwater levels in the shallow Quaternary aquifers declined by up to a metre due to below-average rainfall after the 2006 dry winter, however high rainfall in 2010 led to a strong recovery in water levels in some areas (DFW, 2010). Since then, groundwater levels have either stabilised or continued to rise.

Since 2010, there has been no reporting on the Quaternary aquifers in either the NAP or the Central Adelaide PWAs as the levels of use are considered to be low and water levels stable.

Currently there is little commercial groundwater extraction activity within the fractured rock aquifer within the Central Adelaide PWA, with most extraction confined to stock and domestic use. SKM (2010) estimated a total groundwater extraction of 632 ML/y from the fractured rock aquifer within the PWA for non-commercial extraction.

2 Water dependent ecosystems

The Adelaide Plains and western slopes of the Adelaide Hills support a diverse assemblage of flora and fauna despite substantial areas of land clearing and disturbance from urbanisation and agriculture, and are considered to have considerable ecological value (SMK 2010). Important habitats and ecosystems within the PWA include: areas of remnant vegetation; wetlands; permanently flowing streams; dry season pools; and estuarine and marine environments.

In the Adelaide Plains region, these ecosystems primarily interact with the shallow Quaternary aquifers which are typically provide poor yields, or are too saline to be subject to substantial groundwater use (Ecological Associates and SKM, 2012).

Focus GDEs for the determination of EWRs included freshwater discharge sites that are likely to be related to productive aquifers and are potentially threatened by direct groundwater extraction. Less emphasis was given to saline groundwater discharge environments along the coast where groundwater is unlikely to be used and is therefore of less importance to the water allocation planning process.

The highest concentration of GDEs proximal to the PWA occurs in the Mount Lofty Ranges between Ansteys Hill and Coromandel Valley (Ecological Associates and SKM, 2012) (Figure 2.1).

Across the Northern Adelaide Plains and Central Adelaide PWAs, seven GDE types were classified by Ecological Associates and SKM (2012). Those type were:

- Fractured rock springs
- Fractured rock baseflow
- Coastal wetlands
- Coastal perched aquifers
- Estuarine GDEs
- Marine GDEs
- Terrestrial vegetation at the base of the hills

Investigations by Ecological Associates and SKM (2012) indicate that three out of the seven GDEs types listed above had sufficient dependence on the prescribed groundwater resource such that they could be affected by existing/increasing water resource development. These were 1) fractured rock springs; 2) fractured rock baseflow; and 3) terrestrial vegetation at the base of the hills. These three GDE types are described in detail in the following sections.

EWRs were not developed for the other four GDE types due to 1) the aquifer was not subject to substantial use (coastal wetlands; coastal aquifer; estuarine GDEs); or 2) there was not enough information to adequately define an EWR (marine GDEs) (Ecological Associates and SKM, 2012).

Riparian vegetation which may be partially groundwater-dependent along the Gawler, Little Para, Torrens/Karrawirra and Onkaparinga Rivers was not considered as it will be protected by buffer provisions in the Western Mount Lofty Ranges WAP (2013), which controls these four major watercourses across the Adelaide Plains (SKM, 2012). The Western Mount Lofty Ranges WAP requires a buffer for all new groundwater development around all watercourses to protect groundwater driven baseflow. These are considered sufficient protection for the riparian vegetation along the watercourses covered in the Western Mount Lofty Ranges WAP.

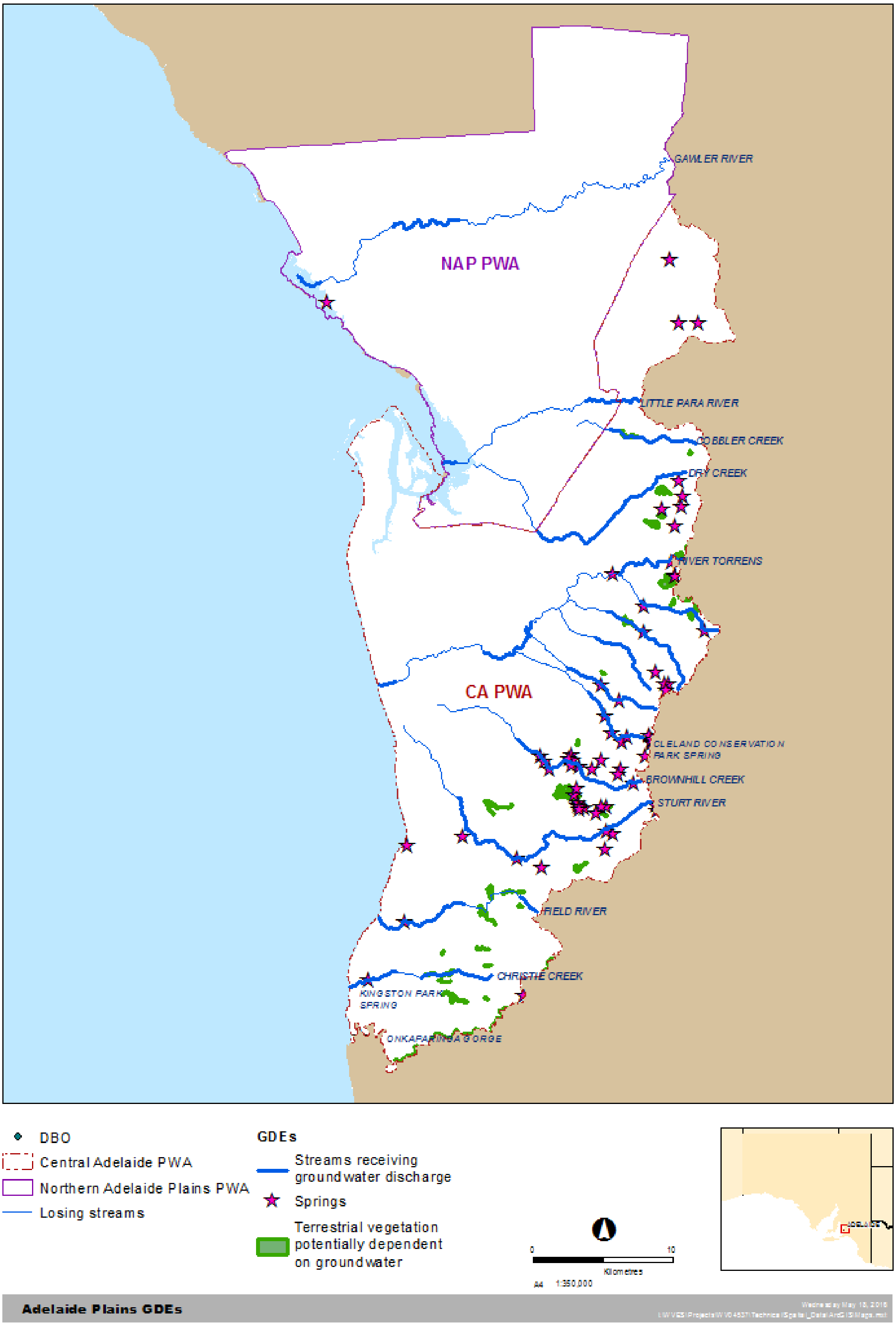


Figure 2.1 Identified GDEs in the Northern and Central Adelaide PWA (From Ecological Associates and SKM, 2012)

2.1 Water dependent flora and fauna

2.1.1 Flora

Functional groups of plants were used to classify the water requirements of streams (Casanova, 2011). Functional groups represent species with similar requirements and tolerances of water levels and flow. Five functional groups are discussed below.

2.1.1.1 Group 1: Perennially saturated, intolerant of flow

Conditions of perennial saturation, but without any significant flow, occur in groundwater seeps in the Mount Lofty Ranges. These conditions are found in Heptinstalls Spring, Eagle Quarry and Harford Spring, all of which are associated with the Stonyfell Quartzite–Basket Range Sandstone contact. The sites are located near the crest of a ridge where there is no significant surface water catchment or drainage lines contributing to wetland hydrology. The saturated soil conditions are sustained entirely by groundwater discharge, supplemented by local rainfall. The absence of drainage features means that flooding is limited to a depth of less than 0.2 m (Ecological Associates and SKM, 2012). These seeps are vegetated by plants adapted to permanently saturated conditions while being intolerant of flow (Table 2.1).

The salinity of threshold of this group of plants is thought to be low (in the order of 200–500 µS/cm EC) (Ecological Associates and SKM, 2012).

Table 2.1 Group 1 plant species

Group 1	
Description	**Example species**
Permanent waterlogging	*Baumea tetragona*
No or shallow (<0.2 m) flooding	*Baumea gunnii*
Intolerant of strong flow	*Gleichenia microphylla* (also occurs on seasonal seeps)
Headwater wetlands and high-order creeks	*Viminaria juncea* *Todea barbara* *Gahnia sieberiana* *Blechnum minus*

2.1.1.2 Group 2: Perennially waterlogged, tolerates flow

Watercourses that receive groundwater discharge are perennially waterlogged and are also typically subject to flow. The plant species in this habitat have adaptations to tolerate flow such as narrow, flexible stems which readily collapse during floods and stabilising root systems. The vegetation is intolerant of drought and consequently has a limited distribution in watercourses where groundwater discharges (Table 2.2). This group includes species that occur in a wide range of salinities ranging from fresh to moderately saline (Ecological Associates and SKM, 2012).

In the PWA these species are found on Brownhill Creek and on the Coats Road tributary.

Table 2.2 Group 2 plant species

Group 2	
Description	**Example species**
Permanent waterlogging Tolerant of stream flow Seasonal flooding related to stream flow, but no sustained standing water	*Acacia provincialis* *Carex appressa* *Cladium procerum* *Carex fascicularis* *Hypolepis rugulosa* *Senecio minimus*

2.1.1.3 Group 3: Perennially saturated, seasonally flooded

Pools and swamps can form along watercourses which receive groundwater discharge. A shallow watertable creates perennially saturated soils and flow, or a seasonally elevated watertable provides seasonal flooding. Flooding can persist for several months and these habitats support species adapted to inundation of up to 0.5 m for some or most of the year (Ecological Associates and SKM, 2012).

In undisturbed areas, *Gahnia sieberiana*, *Leptospermum lanigerum* and *L. continentale* are common. Habitats that have been cleared of native vegetation may be recolonised by *Phragmites australis* and *Typha spp*. This habitat is found in the watercourses flowing out of the ranges, and includes the Brownhill Creek, First Creek, and Second Creek catchments.

The species in this group occur in a wide range of conditions from freshwater (Harding, 2005) to saline marshes (Taylor, 2006) (Table 2.3).

Table 2.3 Group 3 plant species

Group 3	
Description	**Example species**
Permanent waterlogging Shallow (<0.5 m) flooding Weak/low flow (or seeping water)	A) Disturbed areas: *Phragmites australis* *Typha spp.* B) Undisturbed areas: *Gahnia sieberiana* *Leptospermum lanigerum* *Leptospermum continentale* *Baumea tetragona*

2.1.1.4 Group 4: Alternatively waterlogged and drained sites

Groundwater discharge supplements the streamflow created by rainfall runoff, creating more persistent flow. With distance, the influence of groundwater declines as the relatively small contribution of groundwater is lost to evaporation and seepage and rainfall runoff becomes the dominant component. Within this zone, seasonally waterlogged conditions occur. Soils around watercourses are waterlogged while streamflow persists in winter and spring, but dry out in summer and autumn as evaporation rates increase and rainfall becomes more intermittent (Ecological Associates and SKM, 2012).

A wide range of plants are adapted to seasonally waterlogged conditions (Table 2.4). *Eucalyptus camaldulensis* and *Acacia melanoxylon* are tree species that tolerate seasonal waterlogging but occur in well-drained environments as well. Understorey species with similar tolerances include *Carex tereticaulis* and *Chorizandra enodis*.

This group includes species which occur in environments subject to some salinisation. *Chorizandra enodis*, *Cyperus gymnocaulos* and *Lepidosperma laterale* occur in coastal wetlands. However, these species also occur in well-drained environments with low salinities (Ecological Associates and SKM, 2012).

Table 2.4 Group 4 plant species

Group 4	
Description	**Example species**
Alternately waterlogged and drained soils Prolonged flooding rare or absent	*Acacia melanoxylon* *Pteridium esculentum* *Eucalyptus camaldulensis* *Carex tereticaulis* *Chorizandra enodis* *Cyperus gymnocaulos* *Lepidosperma laterale s.str.*

2.1.1.5 Group 5: Shallow watertable below drained soils

A shallow watertable can contribute to the water requirements of deep-rooted vegetation while the overlying soil remains well-drained and supports plants intolerant of waterlogging. Along the Eden–Burnside Fault a shallow aquifer occurs that supports scattered, large *E. camaldulensis* (Table 2.5). The aquifer is recharged by flow across the fault and from streams draining the ranges.

Groundwater dependence of *E. camaldulensis* has been demonstrated at various sites on the River Murray (Thorburn and Walker, 1994), however this species also occurs along watercourses in areas with deep watertables, more than 20 m below the surface, where groundwater dependence is unlikely (Ecological Associates, 2008). These strongly contrasting conditions make it difficult to predict soil and water conditions on the presence of this species, or to estimate tolerance to environmental change (Ecological Associates and SKM, 2012).

E. camaldulensis is moderately tolerant of high salinities with growth affected by salinities as low as 2000 µS/cm EC (Benyon et al., 1999). However, trees tolerate much higher temporary salinities, albeit with severe impacts on canopy cover and growth (Thorburn and Walker, 1994). Gerges (2006) reports groundwater salinities of less than 1500 mg/L occurring in parts of the Q1 aquifer (near First to Fifth Creeks downstream of the Eden–Burnside Fault). As *E. camaldulensis* has adapted to these native groundwater salinities, the EWR can be defined as the maintenance of the historical groundwater salinities.

Table 2.5 Group 5 plant species

Group 4	
Description	**Example species**
Shallow watertable	*Eucalyptus camaldulensis*

2.1.2 Aquatic macroinvertebrates

The aquatic invertebrate fauna of groundwater-fed streams in the Adelaide Plains and Mount Lofty region was characterised by Towns (1985) and has been the subject of both targeted (see Maxwell et al. (2015)) and ongoing investigations (EPA Aquatic Ecosystem Monitoring). The macroinvertebrate fauna exhibit strongly seasonal patterns in composition and life history tied to the intermittent nature of the streams. The macroinvertebrate community undergoes a seasonal shift in composition with the onset of flows with flow-loving species recolonising from perennial flowing rivers, or through eggs laid by terrestrial winged adults. Associated with the onset of flow is changes to stream water quality. Permanent pools are subject to the accumulation of organic matter over low flow periods, which provides for a high biological oxygen demand. Over the cease-to-flow period (summer), high water temperatures reduce oxygen solubility and support higher rates of microbial decay which further reduce dissolved oxygen concentrations. These conditions are alleviated by flushing flows, generally late autumn, which refresh the water and may also remove accumulated organic matter.

The species that exist in the streams of the Adelaide Plains can be broadly classified into two categories: those that require flowing water (found in riffles, runs and cascades) and those with a distinct preference for still or very slow flowing water (found in pond or pool habitats, and slow flowing lowland streams). Within these two broad groups, six different community types were identified by VanLaarhoven and van der Wielen (2009), depending on the type of habitats and the persistence of the flow regime (Table 2.6).

Groundwater discharge makes a strong contribution to two of the six broad community types of macroinvertebrates:

- Flowing water, riffle in reaches with permanent or seasonal flow
- Still water, persistent ponds and pools in reaches with permanent or seasonal flow (Table 2.6).

The cobble/boulder habitats of riffles or the gravel habitats that characterise runs, provide a wide diversity of microhabitats, so that these areas are generally the most diverse communities in stream systems. Cascade species are still present in riffles, living on the upper surfaces of rocks but other taxa present can use other microhabitats. With significant subsurface refuge habitats, most species can survive short periods of no flow (although diversity is highest in permanently flowing streams) (Ecological Associates and SKM, 2012).

The diversity of macroinvertebrates is highest among the permanently flowing riffle-run complexes where water is present throughout the year. The diversity and abundance of plants in permanent ponds and pools ensure a wide range of microhabitats (Ecological Associates and SKM, 2012).

Another element of groundwater contribution to macroinvertebrate habitat, not specified by VanLaarhoven and van der Wielen (2009), is the hyporheos – the fauna that inhabit the flooded interstices of the stream bed that provide a refuge for surface-dwelling invertebrates during periods of low flow (Boulton and Brock, 1999). The hyporheos is maintained by a near-permanent shallow watertable.

Table 2.6 Macroinvertebrate community types relevant to GDEs in the PWA (Ecological Associates & SKM, 2012)

Macroinvertebrate community types	Significance of groundwater discharge
Flowing water	
Flowing water, cascade	Not significant: Flow in cascade habitats is dominated by rainfall runoff.
Flowing water, riffle	Significant: Groundwater discharge can generate perennial flow and contribute to the duration and persistence of flow generated by rainfall-runoff.
Still water, persistent ponds and pools	Significant: Groundwater discharge can maintain permanent pools.
Still water, lowland streams	Not Significant: Lowland streams in the study area are generally losing streams and aquifers do not contribute significantly to flow. Groundwater levels indicate that the watertable is generally well below the stream surface. Permanent pools reported from this area are likely to reflect intermittent inflows from local rainfall runoff.
Still water, temporary pools	Not significant: The hydrology of temporary pools is dominated by runoff.
Still water, floodplain wetlands	Not significant: There is little floodplain development in the upland reaches of watercourses in the study area where groundwater influences hydrology.

2.1.3 Fishes

Given that flow regime determines the physical structure of riverine habitats and provides connectivity between longitudinal and lateral catchment components, native fish are particularly dependent on a wide range of flow regime components. Australia's native fish have evolved to survive within the highly variable and often harsh conditions with Australia's waterways (McNeil et al., 2011a).

None of the fish that occur in the Mount Lofty Ranges, and likely the NAP and Central Adelaide PWAs, are able to survive for periods of time in the absence of surface water and therefore the principal factor influencing fish populations is thought to be the maintenance of aquatic habitats through stream-flow. Given the cyclical desiccation and re-inundation of temporary Australian streams, the presence of permanent pools provide critical refuge habitat over the cease-to-flow period. Flows need to be able to reconnect remnant isolated populations so that fish can re-populate re-inundated reaches. If refuge populations are not available for particular species, then they will remain permanently extinct within that reach. Where refuge populations do exist, groundwater baseflow and small to medium sized flow pulses to stream reaches are very important for maintaining habitat and associated fish species within those reaches (McNeil and Hammer, 2007).

Freshwater flows are also important to estuarine species, for example, a range of these species are known to move into freshwater coastal systems occasionally to take advantage of food and habitat resources, and cleansing their systems of marine parasites intolerant of low salt conditions (McNeil et al., 2009a cited in McNeil et al., 2009).

Ten native fish species have been recorded in the fresh reaches of watercourses in the NAP and Central Adelaide PWAs. Along with this, the watercourses are also known to support four translocated fish species (from the River

Murray) and seven alien fish species (Hammer, 2005b; McNeil et al. 2011a, Appendix). Of these, Common Galaxias, Climbing Galaxias, Mountain Galaxias, and Congolli remain in largely natural aquatic habitats and can be used to interpret the water requirements of groundwater dependent streams. These three species have been split into two groups for determining EWRs: migratory freshwater species and obligate freshwater species. Their presence within the PWA, life cycle and habitat requirements are discussed further below.

2.1.3.1 Migratory freshwater species

Migratory, diadromous species: Species that require migration to and from the sea or estuary as part of their life cycle such as Climbing Galaxias, Congolli, Common Galaxias, Lamprey and Eel.

Climbing Galaxias has a very restricted distribution in the study area. Extant populations are known from Brownhill Creek, south of Adelaide (Hammer, 2005a), the Onkaparinga River at Clarendon, on the southern border of the PWA (Schmarr and McNeil, 2010), from the South Para and the River Torrens/Karrawirra Parri down to the coast (McNeil et al 2010). However, recent sampling has failed to find Climbing Galaxias in Brownhill Creek (Schmarr et al., 2014). Climbing Galaxias are found in deeper pools and shallow fast flowing riffles where there is a permanent flow of cold water, and a high degree of habitat heterogeneity that includes rocks, snags and dense emergent macrophyte growth (McNeil et al. 2011a, b). Climbing Galaxias are also known from the Upper Torrens catchment, in spring-fed pools with similar habitat complexity (Ecological Associates and SKM, 2012).

Climbing Galaxias are generally known to be diadromous with a marine larval phase that involves migration back to freshwater habitats. It is known to substitute the marine environment for lentic (standing) waterbodies like lakes and reservoirs, suggesting larvae and juveniles depend on some form of a pelagic phase. If the Climbing Galaxias in Brownhill Creek are diadromous, juveniles need to negotiate the long stretch of urbanised drains to either reach the sea or the lentic environment of the Patawalonga. This would require connecting flows to be sustained over the migratory periods (Ecological Associates and SKM, 2012).

Climbing Galaxias tends only to be found where Rainbow Trout is absent as the two species are likely to compete for space and food. Hydraulic features within streams that isolate the species are therefore important for the survival of Climbing Galaxias. Permanently flowing riffles can provide habitat too shallow for Rainbow Trout but suitable for Climbing Galaxias (Ecological Associates and SKM, 2012). Similarly, research from Victoria suggests that Brown Trout predation can similarly be restricted under natural flow regimes where summer temperatures become high (Closs and Lake 1996). Permanent pools that are isolated by sills also provide opportunities for Climbing Galaxias to survive in the absence of Rainbow Trout (Ecological Associates and SKM, 2012). However, they can be vulnerable to predation when they accumulate downstream of barriers at such interactions.

Within the area, Common Galaxias are known from the large, flowing pools in the lowland reaches of Sturt Creek, and they are present in all coastal streams, including the minor streams between the River Torrens and the Onkparinga (McNeil et al., 2011a). They are associated with shallow riffles flowing either over rock or through stands of *Typha* (Ecological Associates and SKM, 2012). Elsewhere, this species is more commonly associated with open waters and its restriction to shallow and sheltered habitat probably reflects a retreat to areas from which the larger predators, Trout and Redfin, are excluded. Flows into these habitats are therefore required throughout the year.

Similar to Climbing Galaxias, Common Galaxias appears to be diadromous in the Sturt River and would migrate to the Patawalonga or St Vincent Gulf. Connecting flows are required along the urbanised reaches of the Sturt River to sustain Common Galaxias (Ecological Associates and SKM, 2012).

Both species are tolerant of high salinities in certain circumstances. Common Galaxias has been found in estuaries and watercourses with salinities up to 80,000 µS/cm EC (Morgan et al., 2006). The larvae of Climbing Galaxias tolerate marine salinities. Salinities in the watercourses of the study area are generally less than 1000 µS/cm EC (Hammer, 2005b).

Congolli are widespread in coastal reaches of the system (McNeil and Hammer 2007). This species exhibits male-female separation, with larger females occupying freshwater pools and males occupying downstream saline pools or estuary habitat. Refuge pools have been found to be increasingly important for juveniles despite poor water quality and increasing salinity levels. Key threats to this species include barriers to fish movement and particularly those that impact estuarine linkages, prohibit or reduce flows for female passage to upstream habitats and lowland reaches, such as the Breakout Creek wetland area in the Torrens (McNeil et al., 2011a).

Pouched Lamprey and Short-headed Lamprey exhibit the opposite form of diadromy (anadromy) live in the sea as adults but return to freshwater habitat where they spawn and where larval and juvenile life stages develop and grow before returning to the sea as adults (Potter 1970 cited in McNeil et al. 2009 and McNeil et al 2011a). Key threats for these species predominately relate to barriers to migration, reduction in permanent habitats due to loss of flow and impacts to downstream migration by regulation of high flows. Similarly, the Short-finned Eel has a highly migratory life history, of which little is known, barriers to upstream and downstream movement being a key threat. These three species are all considered to be extremely rare in the Adelaide Plains streams. This is likely due to the barriers to dispersal for adults moving upstream to spawning habitat (McNeil and Hammer 2007).

2.1.3.2 Obligate, freshwater, stream specialist

Obligate freshwater, generalists: Mostly found in association with other species and occupy multiple habitats in a reach; the types of habitats present determine community composition and structure (and therefore water requirements); includes Gudgeon species, numerous species from terminal wetlands and euryhaline species such as Gobies.

Mountain Galaxias are a freshwater fish that tolerates low salinities that are associated with 'freshwater' environments in the Mount Lofty Ranges, up to 1000 µS/cm EC (Hammer, 2005b). They are found in a variety of habitats including small still pools, large deep pools and fast flowing riffles. Sites where Mountain Galaxias are most common have cool, permanent flowing habitat in chains of connected pools. Shade and flowing water are likely to be important in maintaining cool water that the fish require over summer. These fish are widespread in the watercourses of the Mount Lofty Ranges and are common in Brownhill Creek. In the PWA populations are fragmented and restricted to smaller streams and tributaries such as lower Fifth Creek and the main channel of Sixth Creek. They are also known from First, Second and Fourth Creeks and the Sturt River. This species is also present in a small groundwater-fed reach of upper Minno Creek above the Railway Dam (Ecological Associates and SKM, 2012).

Mountain Galaxias tend to be absent from sites where their predators Brown Trout, Rainbow Trout and Redfin are present. Use of available habitat is often limited by the predator species, and Mountain Galaxias are restricted to riffles connecting larger pools or reaches above small barriers that exclude the larger fish. The Mountain Galaxias population in Coats Gully illustrates this situation, where a sill near the junction with the Sturt River appears to exclude the predators from the tributary (Ecological Associates and SKM, 2012). Similar to migratory diadromous species, there can be impacts with sills when large numbers of Mountain Galaxias accumulate downstream of the barrier where they are vulnerable to predation.

These native fish are particularly dependent on baseflows that maintain habitat extent and flows of sufficient discharge to provide low water temperatures and maintain dissolved oxygen concentrations in pools and riffles. Since the introduction of exotic predatory fish, flows that activate sills and riffles have become more important in protecting local populations. Mountain Galaxias are a mobile species within river systems, but the ability to disperse and colonise new habitat is threatened by low baseflows; small and isolated populations are at risk of elimination (Ecological Associates and SKM, 2012).

The Western Blue Spot Goby consistently occurs in low numbers in the estuarine pool on the Onkaparinga River and Lower Torrens River. Whilst this species tolerates broad ranges of salinity, it appears that adults may aggregate in estuaries as a response to freshwater flushes. Key threats relate to reduced quality of estuarine habitat, but flows may also be essential for triggering spawning aggregations. Protection of estuarine habitats and restoration of fish passage at Breakout Creek have been effective in restoring the occupation of this species in that section of the Torrens (McNeil et al., 2011a).

Gudgeon vary in response to flow conditions. Carp Gudgeon appear to prefer the low flow reaches of the lower Torrens, absent in higher flow areas with where predators are present (e.g. Redfin Perch and Trout species). Whilst Flathead Gudgeon are adaptable to all flow conditions, benefitting from both river regulation and degradation. Key threats for this species relate to predator abundance, with habitat complexity and cover remaining important (McNeil et al., 2011a).

2.2 Fractured rock aquifer springs

Springs represent the majority of groundwater discharge sites in the NAP and Central Adelaide PWAs. Fractured rock aquifer springs are defined as localised areas of groundwater discharge from the fractured rock aquifer on hillslopes or at the head of first order watercourses. They receive little inflow from catchment runoff and are not subject to the erosion and deposition processes that influence the structure of watercourses (Ecological Associates and SKM, 2012).

They occur as isolated features where fractures, topography or stratigraphic features promote the discharge of groundwater to the surface. The springs are small in extent and consequently often provide a specialised plant habitat for species with a very restricted distribution. The springs therefore support a high proportion of rare and threatened plant species, and generally have a very high conservation value.

Figure 2.2 illustrates the potential distribution of springs based on the extent of the outcropping fractured rock aquifer. Known springs are largely confined to the outcropping basement of the Mount Lofty Ranges, with a high density reported in the vicinity of Stoneyfell Quartzite.

A number of springs are associated with the outcropping Stonyfell Quartzite between Cleland Conservation Park and Eagle Quarry. The quartzite, which caps the range, is underlain by the relatively impermeable Basket Range Sandstone and Woolshed Flat Shale. The Stonyfell Quartzite, near Mount Lofty, hosts a perched aquifer above the Woolshed Flat Shale (Stewart and Green, 2010). Springs in this region tend to occur at the contact between the Stonyfell Quartzite and underlying strata, suggesting the change in permeability is causing groundwater to discharge at the surface. Significant springs include Heptinstalls, Wilsons Bog, Chinamans Bog, Harford Spring and Eagle Quarry, each of which support species threatened at a state and national level (Ecological Associates and SKM, 2012) (Table 2.7).

Fractures which outcrop low in the landscape in relation to the watertable will tend to be more persistent, while springs positioned at or near the watertable will flow seasonally where the watertable is high (late winter–spring). Fractures also drain the unsaturated zone and can discharge over several weeks after a period of rainfall without being connected to a regional aquifer. In all cases, the greater duration and reliability of saturated soil conditions will influence the plant communities present and their habitat values.

In the Adelaide Plains region, these springs are largely associated with the upper reaches of streams on the downward slope of the ranges. Some coastal spring occurrences have also been reported.

The threat of current groundwater use to fractured rock aquifer springs is likely to be low as there is little development of groundwater resources in aquifers maintaining these systems. However, there may be sites where local groundwater use in close proximity to springs, even if small, can affect spring hydrology.

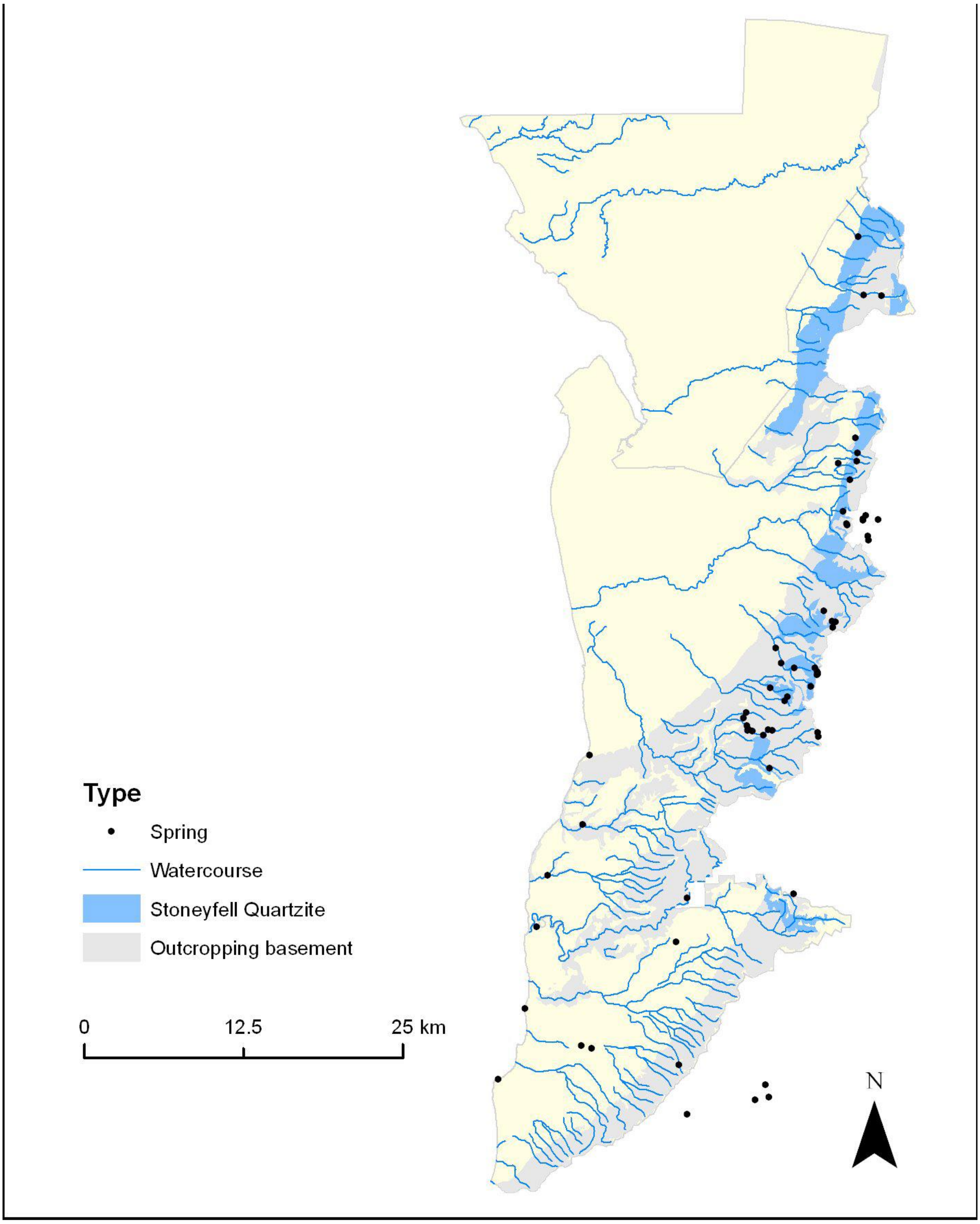
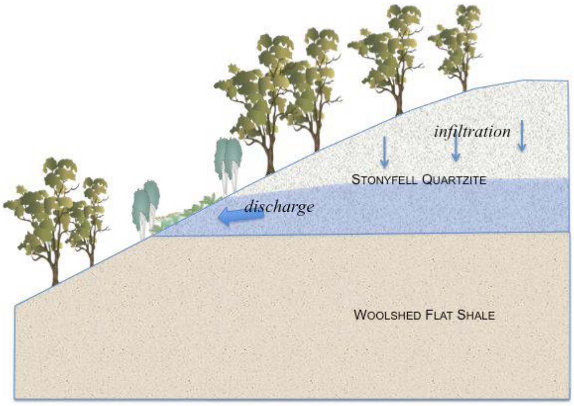


Figure 2.2 The extent of outcropping basement (in general) and Stoneyfell Quartzite (in particular) as a guide to the potential distribution of springs in the PWAs (From Ecological Associates and SKM, 2012)

Table 2.7 Conceptual hydrogeological model of fractured rock spring discharge and example sites (Ecological Associates and SKM, 2012)

	Example sites	Description
	Heptinstalls Spring	Heptinstalls Spring is a permanent soak at the head of a first order tributary of First Creek near the crest of Mount Lofty Ranges. The wetland vegetation contrasts strongly with the surrounding *Eucalyptus obliqua* woodland and supports a range of species dependent on permanent waterlogging including *Gleichenia microphylla*, *Leptospermum lanigerum*, *L. continentale* and *Baumea tetragona*.
	Eagle Quarry	Wetland at the head of a first order tributary of Brownhill Creek (Ellis Creek) that supports *Leptospermum lanigerum*, *Blechnum minus* and *Gleichenia microphylla*.
	Harford Spring	Wetland at the head of a first order tributary of First Creek near Reynolds Drive, Crafers
	Horsnell Gully	Deeply incised first-order watercourses in Horsnell Gully Conservation Park receive groundwater discharge that supports wetland vegetation including *Blechnum nudum*. B. *minus* and *Todea barbara*.
	Joseph Fisher Picnic Area	Localised damp area on the lower slopes of the Minno Creek gully that supports a stand of *Phragmites australis* within a *Eucalyptus obliqua* woodland.
Photo: Hepinstalls Spring		

2.2.1 Ecology

The water regimes created by fractured rock aquifer springs vary in relation to the amount of discharge of the spring, and proximity to the spring. Springs on hillsides at Coats Gully, Wilsons Bog and Heptinstalls Spring become progressively wetter at lower parts of the slope, and there is a corresponding change in plant communities and fauna habitat along this gradient (Ecological Associates and SKM, 2012).

The upper fringe of the spring is most likely to be near the watertable and will therefore experience seasonal waterlogging as the watertable rises and falls on a seasonal basis. This area tends to support terrestrial species that tolerate, or benefit from, waterlogging but which also occur outside the influence of groundwater. Overstorey vegetation includes *Acacia melanoxylon*, *Eucalyptus obliqua* or *E. viminalis* and the understorey will include species such as *Baumea juncea*, *Poa umbricola*, *Lepidosperma semiteres*, *Lindsaea linearis* and *Pteridium esculentum*. These conditions can occur at the fringes of wetlands and watercourses and this plant assemblage is not exclusively associated with groundwater discharge (Ecological Associates and SKM, 2012).

Lower slopes of hillside springs are perennially saturated and have deeper, sometimes peaty, soils. These conditions only occur in locations of groundwater discharge and therefore support a plant assemblage that occurs in small, isolated patches and supports many species of conservation significance. The fern *Gleichenia microphylla* tends to replace *Pteridium esculentum* and is associated with *Goodenia ovata*, *Derwentia derwentiana* and *Juncus subsecundus*. The tree fern *Todea barbara* can occur, particularly in areas sheltered from the sun. Trees do not persist into these areas and the shrubs *Leptospermum continentale* and *L. lanigerum* (in the wetter areas) become the dominant overstorey species (Ecological Associates and SKM, 2012).

Water may pool in the lower slopes creating conditions of perennial inundation and seasonal inundation that supports a third plant assemblage. *Gahnia sieberiana* or *Leptospermum lanigerum* may be present as the dominant overstorey species, but a more open form may also be present, dominated by *Gleichenia microphylla*, *Blechnum minus*, *B. wattsii* and *B. nudum*. A range of other herbs and sedge-form species occur, such as *Baumea tetragona* and *Baumea gunii* (Ecological Associates and SKM, 2012).

In degraded areas, where native vegetation has been cleared, springs in the fractured rock aquifer will be recolonised by the native species *Phragmites australis* or *Typha domingensis*, or a range of exotic species including Blackberry and Periwinkle.

Todea barbara is generally only known from perennially damp areas with deep soils that are usually found in the floor of gullies in the highest rainfall areas of the Mount Lofty Ranges. However, a small population is known near Montacute high on a hillside, but in a location that is sheltered from direct sunlight for most of the day by a southerly aspect.

There are few fauna that are exclusively associated with fractured rock aquifer springs, but a number of species are require the sort of dense, damp conditions that springs provide. Swamp Rats and Bandicoots both favour dense vegetation cover and soft soil for digging. A number of bird species benefit from the dense shrubby vegetation including Scrubwren, Heathwren and Southern Emu-wren (Mount Lofty Ranges subspecies). Damp areas can support a high density of insects which attract swallows and martins. Dense vegetation can provide shelter for the cryptic Lewin's Rail (Ecological Associates and SKM, 2012).

As isolated springs are not connected to watercourses and do not generally pond water, they do not provide significant habitat for native fish.

2.2.2 Functional groups

Functional groups relate to water dependent flora and fauna groups described in Section 3.1 above.

2.2.2.1 Flora

Group 1: Perennially saturated, intolerant of flow

Group 3: Perennially saturated, seasonally flooded

2.2.2.2 Aquatic macroinvertebrates

Still water, persistent ponds and pools

2.2.2.3 Fishes

None present

2.2.3 Groundwater dependence

Given that many of the springs have small surface catchment areas and consequently receive limited input from surface runoff, groundwater is likely to provide a substantial proportion of their water requirements.

Groundwater may support these ecosystems in several different ways, depending on the site. The functions of groundwater, listed in order of decreasing groundwater contribution, are:

- Maintenance of inundation (permanent or seasonal)
- Maintenance of waterlogged conditions (permanent or seasonal)
- Provision of shallow watertables that phreatophytic vegetation can access.

There is significant variability in springs throughout the PWA and the nature of groundwater dependency will vary, but as a minimum groundwater will maintain waterlogged conditions and support phreatophytic vegetation in fringing areas (Ecological Associates and SKM, 2012).

The primary aspect of groundwater in supporting the ecology at the site is the depth of the watertable. This controls the extent and persistence of waterlogging and inundation. The springs are also dependent on the rate at which water is supplied to the site (i.e. groundwater flux) to sustain evapotranspiration and any throughflow. The rate of groundwater supply is controlled by the hydraulic gradient into the spring.

2.3 Groundwater dependent streams

Few stream reaches were reported to have perennial flow sustained by groundwater discharge. Most notable were the streams of the Brownhill Creek catchment, First Creek, Second Creek and the Ironbank tributary of Sturt River (Ecological Associates and SKM, 2012).

Groundwater dependent streams occur in the Mount Lofty Ranges where springs contribute to streamflow or where the stream bed intersects the watertable. They include the groundwater discharge point as well as the watercourse downstream where the influence of groundwater persists. Groundwater influences the stream hydrology by contributing to the persistence or permanence of pools, flowing reaches and waterlogged channel beds.

Groundwater contributions to stream hydrology are important in maintaining native fish populations in the study area. The majority of native fish species occur in reaches that are strongly influenced by groundwater and depend on permanent pools and riffles to maintain populations and escape predators. Perennial pools and flowing reaches also contribute to macroinvertebrate diversity and supports specialised native plants (Ecological Associates and SKM, 2012).

The threat of current groundwater use to groundwater dependent streams is likely to be low as there is little use of groundwater from the fractured rock aquifer in the study area which has generally step terrain. However, there may be localised areas of groundwater use in close proximity to groundwater dependent streams that potentially have an effect.

The only stream GDE reported for the NAP region was the downstream reach of the Gawler River. Watercourse GDEs, like spring GDEs, are concentrated in the upper stream reaches associated with the Central Adelaide region (Ecological Associates and SKM, 2012).

Historically, soaks have been recorded along the River Torrens and were most likely maintained by bank recharge from the river (Shanahan et al., 2010). Groundwater data indicate the potential for discharge from the Quaternary aquifer to the Gawler River between Gawler and Virginia. In this reach, the watertable is within 10 m of the surface and potentially contributes to streamflow and the water requirements of deep-rooted vegetation such as *Eucalyptus camaldulensis*.

Baseflow and permanent pools have also been identified on watercourses on the Adelaide Plains in aerial videography by the Department of Water, Land and Biodiversity Conservation in 2003. However, reported groundwater levels are generally too low to suggest that watercourses are groundwater dependent and it is most likely that permanent pools are sustained by local intermittent rainfall events and bank recharge (Ecological Associates and SKM, 2012) (Figure 2.3).

The distribution of groundwater dependent stream GDEs is presented in Figure 2.2 and is based on a stream-aquifer connectivity analysis undertaken by SKM (2011a).

Gaining streams are reported mostly from the incised landscape of the Mount Lofty Ranges with losing and variably gaining-losing streams dominant on the plain (i.e. Gawler and Little Para Rivers). Baseflow and dry season pools are identified on the plain, but generally with a lower level of confidence. An exception is the reach of the Gawler River between Gawler and Virginia where a high level of confidence is assigned to the groundwater interaction. Permanent pools may indicate isolated areas where the streambed intersects the Quaternary aquifer. Native diadromous (inland/marine) fish species are known to exist within the Gawler River catchment. Pools are likely to act as important ecological 'stepping stones' for migration to and from the lower reaches of the catchment (DFW 2010b).

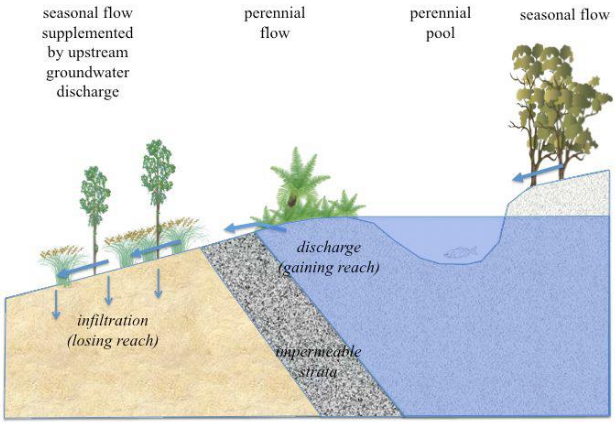
Overall, it can be concluded that groundwater interactions with watercourses occur predominantly in the Mount Lofty Ranges and that watercourses on the plains are typically losing streams.

Watercourses may receive groundwater from isolated locations, such as fractured rock aquifer springs which discharge to the slopes in or near watercourses. This frequently occurs in first or second order watercourses with steep gradients (Table 8). Outcropping fractures or outcropping strata which direct groundwater to the surface provide a point source of groundwater which contributes to stream flow. Isolated areas of discharge occur in First Creek at Wilsons Bog, Chinamans Bog, Harford Spring and Waterfall Gully Reserve (among other locations) and contribute to persistent, but not perennial, flow in First Creek to the foot of the ranges. Similarly, in Minno Creek upstream of the Railway Dam in Belair National Park, a series of isolated springs contribute to flow (Ecological Associates and SKM, 2012).

Discharge may also occur along a reach of a watercourse, and this occurs where a stream channel intersects the watertable. The evidence for this is strongest when streams are deeply incised into the surrounding landscape and is interpreted to occur between steep spurs in the two northerly-flowing streams in Horsnell Gully Conservation Park and in Coats Gully in Ironbank.

Where the watertable is close to the surface, groundwater may contribute to the water requirement of riparian vegetation, even if groundwater does not always discharge to the surface. Groundwater is within 10 m of the surface for part of the reach between Gawler and Virginia. *Eucalyptus camaldulensis* growing along the river may meet part of their water requirement from groundwater. The discharge of groundwater to the surface at this location may only be intermittent (Ecological Associates and SKM, 2012).

Table 2.8 Conceptual hydrogeological model of a groundwater dependent stream and example sites (Ecological Associates & SKM, 2012)

	Example sites	Description
	First Creek catchment	First Creek catchment receives groundwater discharge in the headwaters of the catchment from a number of springs including Wilsons Bog and Chinamans Bog. Groundwater fed baseflow contributes to perennial flow in the upper reaches of the catchment and contributes to sustained, but not perennial, flow in Waterfall Gully. Supports Mountain Galaxias.
	Second Creek catchment	Slapes Gully is the narrow gorge Second Creek passes through just before discharging to the plain. Slapes Gully has perennial flow which extends to Michael Perry Reserve in Burnside. The baseflow maintains pools and riffles in the reserve which provide habitat for Mountain Galaxias.
 Photo: Wilsons Bog	Brownhill Creek catchment	Localised springs and reaches of perennial baseflow are recorded throughout the catchment including the lower reaches of Brownhill Creek. The catchment supports one of only two populations of climbing galaxias in the study area. The first and second order tributaries are steep with shallow alluvium but the main creek on the valley floor has rather deeper channel alluvium.
	Coats Gully, Ironbank	A tributary flowing 1.5 km from Coat Road to Sturt River near Pole Road features permanent flow. Creek flows through deeply incised bedrock with a narrow corridor of channel alluvium featuring permanent pools separated by riffles. Supports Mountain Galaxias.
	Minno Creek, Belair National Park	The upper reaches of Minno Creek are perennially waterlogged and provide trickle flow. Vegetation has been modified by clearance and replacement by exotic species but remnants. Supports Mountain Galaxias. Channel gradient is relatively low and channel alluvium is deeper than other examples.
	Gawler River	Shallow groundwater beneath the stream channel may contribute to the water requirements of riparian *Eucalyptus camaldulensis.*

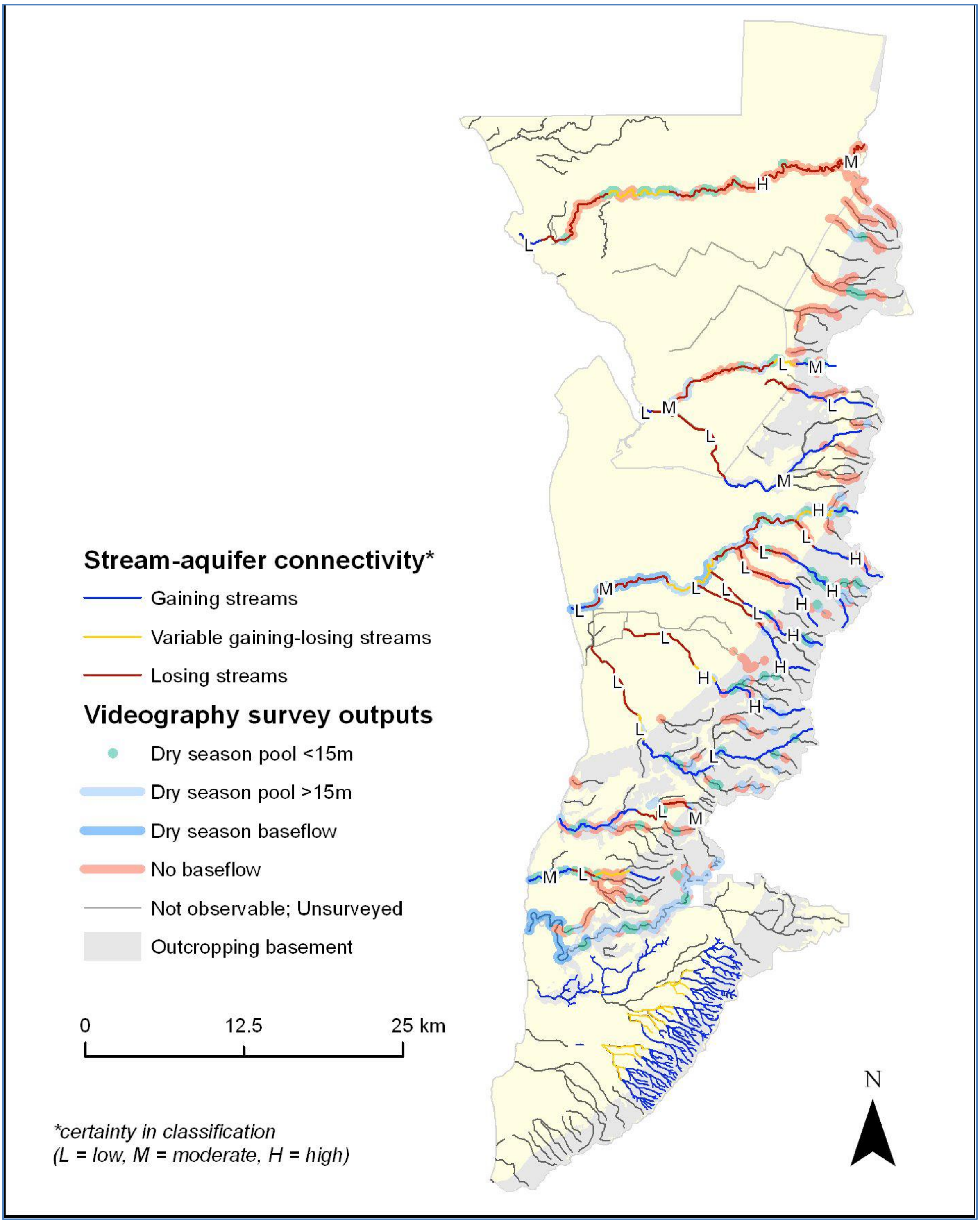


Figure 2.3 **Classification of the groundwater dependence of streams within the PWAs (From Ecological Associates and SKM, 2012).**

2.3.1 Ecology

Watercourses in the Mount Lofty Ranges tend to be deeply incised with steep gradients. The alluvium in the stream channel tends to be shallow and underlain directly by bedrock. This alluvium stores water from catchment runoff and groundwater flow and is a storage that supports vegetation and maintains pools between flow events.

Fractured rock aquifer baseflow streams tend to have an open channel, which is periodically disturbed by high flows. Fast-growing, colonising species such as *Phragmites australis* and *Typha domingensis* may establish in this zone between major disturbances. Stream flow will erode pools, creating structural diversity and providing a variety of depths and flow environments. Pools may support semi-emergent and aquatic species such as *Triglochin procerum* or *Haloragis brownii* and riffles may support low growing, flow-resistant species such as *Isolepis fluitans* (Ecological Associates and SKM, 2012).

Benches adjacent to the primary channel will support species which depend on permanent waterlogging but are well-anchored, with strong root systems that tolerate flow. Streams with persistent or perennial baseflow will support *Acacia provincialis*, *Leptospermum lanigerum*, *Carex appressa*, *Gahnia sieberiana*, *Cladium procerum* and *Pteridium esculentum*. Where an established population is present, *Gleichenia microphylla* and *Hypolepis rugulosa* readily recolonise damp areas after disturbance. Streams with seasonally waterlogged benches will support species more tolerant of dry conditions such as *Carex tereticaulis*, *Juncus pallidus* and *Cyperus appressa*. *Eucalyptus camaldulensis* is more likely to be present as the dominant overstorey species.

The persistent flow created by groundwater discharge is important for maintaining the depth and extent of pools, which are required by native fish and macroinvertebrates. Discharge must be sufficient to replace losses to seepage and evaporation to maintain pools through periods without runoff events. Under natural conditions deep permanent pools would have supported many species now considered rare, including Congolli, Climbing and Mountain Galaxias as well as a diverse macroinvertebrate community. With the introduction of Brown Trout and Rainbow Trout, Mountain and Climbing Galaxias are restricted to pools that are too small for these larger predators, or to reaches protected by barriers to alien fish dispersal (e.g. rocky cascades) (Hammer, 2005b). They tend to occur in pools less than 0.3 m deep but with a surface area of more than 2 m^2. Pools this small are vulnerable to drying out in summer and autumn, so sustained groundwater-fed baseflow is critical to the survival of these species (Ecological Associates and SKM, 2012).

Baseflows contribute to the magnitude and duration of riffle flows which connect pools. Riffle flows enable fish to disperse to new pools, which reduces the vulnerability of local populations to disturbances at any one site. Dispersal is particularly important for Climbing Galaxias which is an anadromous species. Found only in Brownhill Creek within the PWA, Climbing Galaxias migrates downstream to spawn, at least to the Patawalonga but possibly to Gulf St Vincent (Hammer, 2005b). Since the introduction of Brown Trout and Rainbow Trout, riffles have become important habitat for native Galaxias fish. Populations survive throughout the year if there is access to riffles. Shallow riffles are a barrier to the movement of Brown and Rainbow Trout, and the presence of Mountain Galaxias but not Trout in Coats Gully, is attributed to the riffles that isolate the tributary from the Sturt River (Ecological Associates and SKM, 2012). Riffle flows are also important for macroinvertebrate communities as there is a whole group of species that only occur in the riffle habitat.

The perennially damp soil and dense understorey vegetation provides habitat for similar birds and mammals as for fractured rock aquifer springs.

2.3.2 Functional groups

Functional groups relate to water dependent flora and fauna groups described in Section 3.1 above.

2.3.2.1 Flora

Group 2: Perennially waterlogged, tolerates flow

Group 3: Perennially saturated, seasonally flooded

Group 4: Alternately waterlogged and drained sites

2.3.2.2 *Aquatic macroinvertebrates*

Flowing water, riffle

Still water, persistent ponds and pools

2.3.2.3 *Fishes*

Migratory freshwater species (e.g. Climbing Galaxias, Common Galaxias)

Obligate, freshwater stream specialist (e.g. Mountain Galaxias)

2.3.3 Groundwater dependence

Depending on the site, groundwater may support these ecosystems in several different ways. The functions of groundwater are listed in order of decreasing groundwater contribution:

- Maintenance of permanent flow
- Maintenance of permanent pools
- Maintenance of waterlogged conditions within the riparian zone
- Provision of shallow watertables that phreatophytic vegetation can access within the riparian zone.

If, at a particular site, the groundwater contribution is such that permanent flow is maintained, then it follows that the remaining functions will also be provided (Ecological Associates and SKM, 2012).

There is significant variability among the streams of the PWA and the level of groundwater contribution. There are a few stream reaches where permanent flows are maintained. At other sites, only permanent pools, waterlogged conditions or shallow watertables may be maintained by groundwater. The application of EWRs can be tailored to reflect the variability in streams of the Adelaide Plains.

2.4 Terrestrial vegetation at the base of the Adelaide Hills

Watercourses draining the Mount Lofty Ranges cross a steep scarp where the Eden–Burnside Fault marks the commencement of the Adelaide Plains. Alluvial fans have formed at the foot of the ranges where material eroded from the catchments in the ranges are deposited as streams lose power on the lower gradient Adelaide Plains. Alluvial fans are evident at the base of the ranges where Brownhill Creek, First Creek, Second Creek and other tributaries enter the plains (Ecological Associates and SKM, 2012) (Figure 2.4 and Figure 2.5).

These Quaternary sediments contain the shallow Quaternary (Q1) aquifer which is recharged by stream flow from the catchments to the east as well as groundwater throughflow from the fractured rock aquifer across the Eden-Burnside Fault. The aquatic habitat and vegetation in these areas have been extensively modified through the development of the eastern suburbs, but support significant stands of *Eucalyptus camaldulensis*. Historically, a stand of *Leptospermum lanigerum*, which depends on permanent waterlogging was known from Brownhill Creek in Mitcham, and this probably represents reliance on shallow groundwater within this system.

Shallow groundwater in the Quaternary aquifer at the base of the hills between Yatala Vale and Springfield is coincident with a population of large *E. camaldulensis*. This species is known to make use of groundwater when available, and this region is interpreted to represent a GDE.

Groundwater may contribute to the water requirements of these trees by providing elevated soil moisture in the capillary zone above the watertable or providing tree roots with water directly from the saturated zone. Trees are likely to also access rain infiltration above the watertable, but groundwater is likely to supplement tree growth, increasing productivity and growth rates, and thereby tree habitat value (Ecological Associates and SKM, 2012).

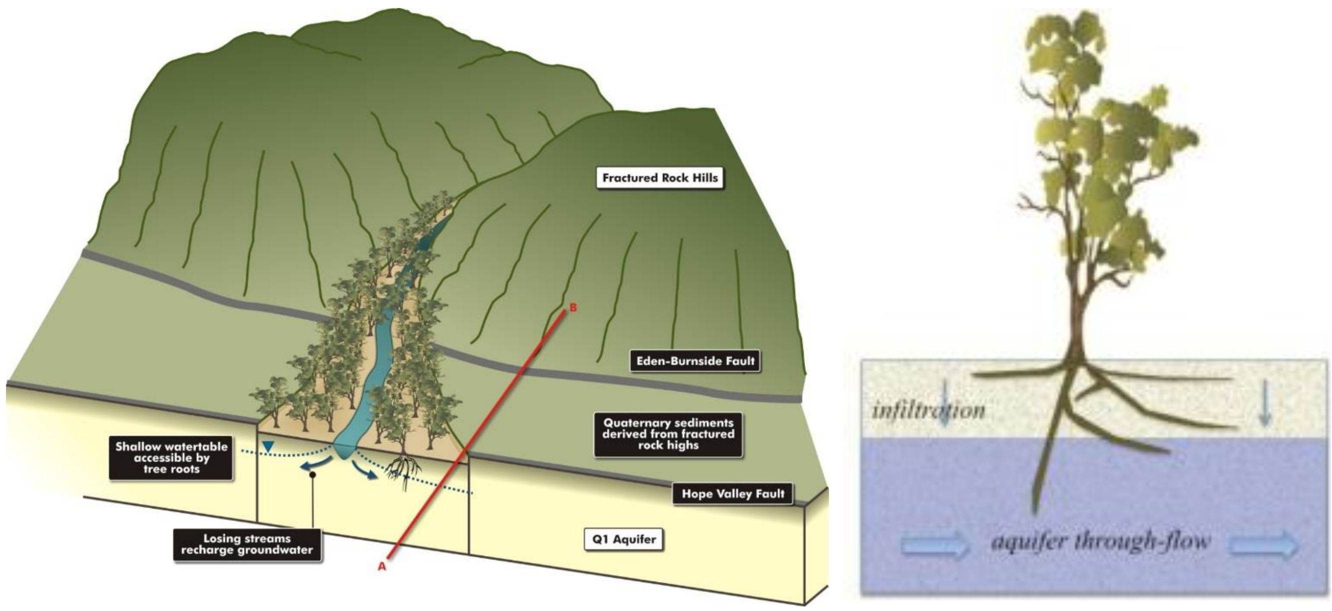
The threat of current groundwater use to terrestrial vegetation at the base of the hills is likely to be moderate. There has been increasing use of groundwater from domestic bores on the Adelaide Plains and groundwater levels have been shown to decline in response to dry years (DEWNR 2016a&b). Groundwater monitoring data from the shallow aquifer in this region is very sparse and this threat assessment can only be made with a low level of confidence.

Ecosystem interactions are predicted to occur on the western side of the Eden–Burnside fault in the region shown in Figure 2.5. The shallow aquifer in this region receives groundwater throughflow across the fault as well as recharge from streams as they reach the alluvial fans at the base of the range. The principal ecosystem component in this region is the large *E. camaldulensis* trees. These are not mapped as urban areas are not included in native vegetation mapping and in any case exist mainly as scattered trees (Ecological Associates and SKM, 2012).

The level of confidence that groundwater contributes to the water requirements of these trees in this region is moderate: i.e. while it can be confidently predicted that shallow groundwater is present and it is known that the species *E. camaldulensis* utilises groundwater when available:

- There is no empirical evidence of groundwater use by trees in this region
- The distribution of *E. camaldulensis* has not been mapped
- Groundwater level data in the shallow aquifer is very limited.

Figure 2.4 Schematic representation of terrestrial vegetation at the base of the hills (Ecological Associates & SKM, 2012)



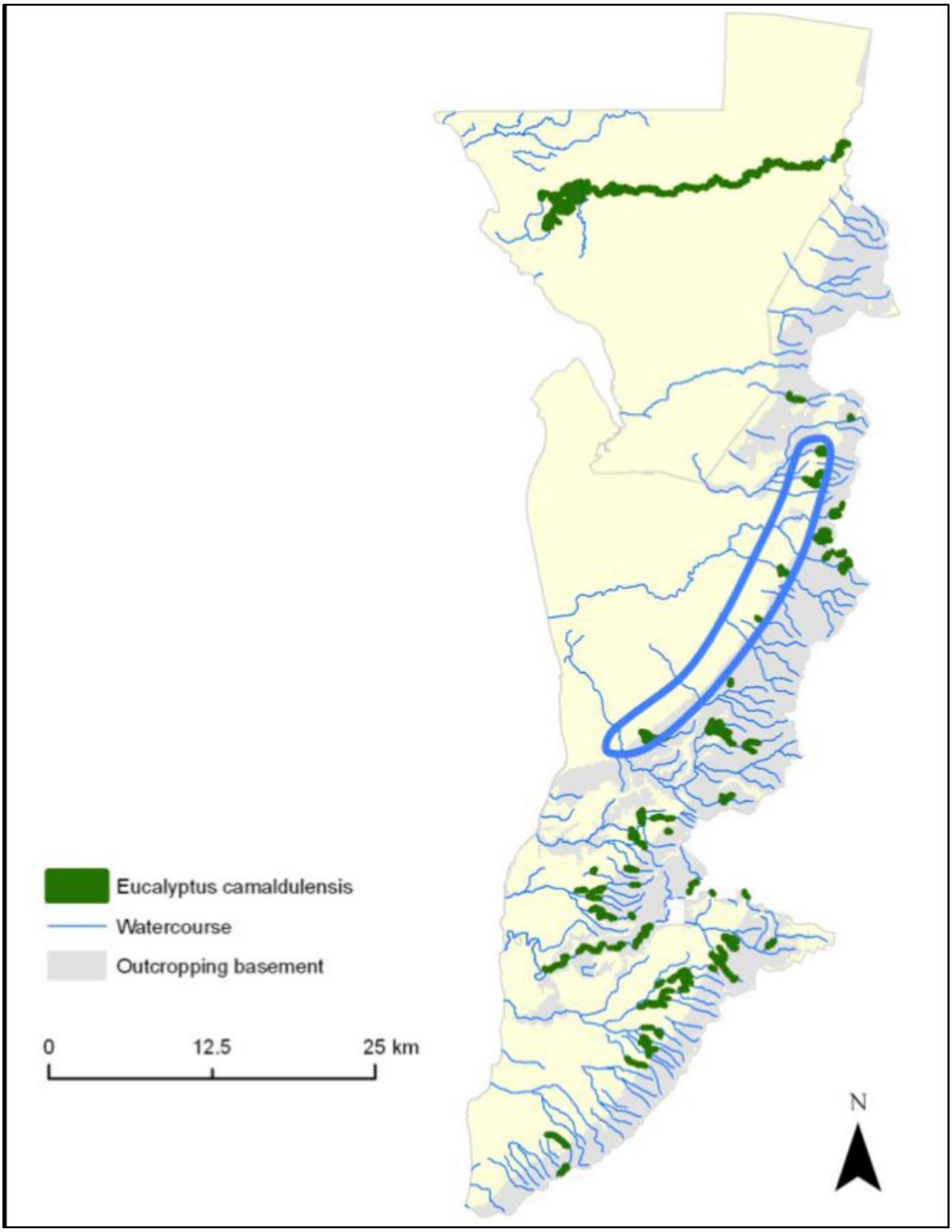


Figure 2.5 **Suggested area of terrestrial vegetation at the base of the hills likely to be dependent on the discharge of groundwater (circled in blue) (Ecological Associates and SKM, 2012)**

2.4.1 Ecology

The plains along the foot of the range have been modified extensively, initially for agriculture and later for urban development. While there is little evidence of extant GDEs, springs have been previously described in this region, i.e. a perennial spring at Burnside formed where "a gravel bed resting on a subsoil of clay" discharged to the surface and supported *Stylidium despectum*, *Cyperus tenellus*, *Crassula decumbens*, *Juncus caespiticius* and *Isolepis cernua* (Ecological Associates and SKM, 2012).

The most widespread indicators of ecosystem dependence on groundwater are *Eucalyptus camaldulensis*. This species occurs predominantly along watercourses which provide water to support growth over spring and summer. However, at the base of the ranges they are distributed outside watercourses, suggesting that shallow groundwater is available to support their growth.

E. camaldulensis are important habitat trees in the urban landscape. They support a range of vertebrate fauna by providing nesting and sheltering habitat in hollows, fissures and bark for bats, birds, possums and reptiles. Insects that feed on nectar, pollen, leaves and decaying organic matter provide prey for insectivorous birds, bats and reptiles.

There is little other information to characterise this ecosystem. There are records of plants that depend on perennial waterlogging at other locations at the foot of the ranges, specifically *Leptospermum continentale* and *Leptospermum lanigerum* at Greenglades Council Reserve at Paradise (Kraehenbuehl, 1996) and *L. lanigerum* on Brownhill Creek downstream of Old Belair Road (Ecological Associates and SKM, 2012).

2.4.2 Functional groups

Functional groups relate to water dependent flora and fauna groups described in Section 3.1 above.

2.4.2.1 Flora

Group 5: Shallow watertable below drained soils

2.4.2.2 Aquatic macroinvertebrates

None present

2.4.2.3 Fishes

None present

2.4.3 Groundwater dependence

Groundwater supports these ecosystems by providing a shallow watertable that roots can access, such that the vegetation is able to maintain photosynthesis in summer when soil moisture stores are depleted. To support this ecological function the groundwater regime must be maintained at depths that are accessible to plant roots and be of a tolerable salinity (Ecological Associates and SKM, 2012).

The EWR is defined based on the needs of *Eucalyptus camaldulensis* as it is the key species within this GDE type. *E. camaldulensis* is known to be able to access groundwater from deep within the soil profile. White et al., (2000) reported root water uptake from the capillary fringe at 6 m below the ground surface in the Western Australian wheatbelt, and Horner et al., (2009) reports that root water uptake from a watertable at 15 m deep in the Barmah-Millewa Forest, Victoria. It is probable that even greater rooting depths can be attained in the absence of soil physical or chemical constraints. Despite their ability to access groundwater from depth and their drought tolerance, *E. camaldulensis* can be sensitive to changes in groundwater level. Horner et al. (2009) showed a high incidence of tree mortality within high density stands of the Barmah–Millewa Forest that coincided with a watertable decline of 0.25 m/y between 1998 and 2007. In this regard, the EWR for *E. camaldulensis* is based on a rate of change of the watertable as opposed to a fixed groundwater level (Ecological Associates and SKM, 2012).

Historical groundwater data provides a benchmark for the derivation of EWRs of this GDE group. Given that the *E. camaldulensis* at Hazelwood Park have adapted to these conditions and were resilient during the recent drought, the EWR could be defined by rate of decline in groundwater levels that occurred over the period (March 2006 to March 2010). That is, the recovered (spring) groundwater levels need to be maintained near the long-term average and the summer groundwater levels must not decline by more than that evident during 2006 to 2010 (Ecological Associates and SKM, 2012).

3 Environmental water requirements

Environmental water requirements (EWRs) are defined as "the water regime needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk" (DWLBC 2006). Ecosystem requirements include both the local influence of underground water and the influence on receiving environments downstream.

The water requirements of GDEs must be considered in the water allocation plan (WAP) where they are potentially impacted by use of the groundwater resource. The importance of GDE types for the determination of EWRs was determined in Ecological Associates and SKM (2012). Based on the classification of GDEs and their recorded occurrence within the NAP and Central Adelaide PWAs, there is a requirement to determine EWRs for the following GDEs:

- Fractured rock aquifer springs
- Groundwater dependent streams
- Terrestrial vegetation at the base of the hills.

The following GDEs are associated with the Adelaide Plain PWA but are not considered to be required to have EWRs determined for them for reasons stated:

- Estuarine GDEs – the associated aquifer is poorly defined, localised, ephemeral and not subject to groundwater extraction.
- Coastal perched aquifer – the associated aquifer is poorly defined, localised, ephemeral and not subject to groundwater extraction.
- Coastal wetlands – the associated aquifer is saline and not subject to groundwater extraction.
- Marine GDEs – the hydrogeology and ecology of these GDEs is poorly known and EWRs cannot be evaluated using existing information.

EWRs for the three focus GDE groups outlined above, together with water dependent flora and fauna, are described in detail in the sections below.

3.1 Water dependent flora and fauna

3.1.1 Flora

3.1.1.1 Group 1: Perennially saturated, intolerant of flow

This group of flora species requires perennial waterlogging and shallow flooding to support its ecological functions (Table 3.1). This translates to watertables at or above the ground surface throughout the year.

Table 3.1 Group 1 groundwater requirements (Ecological Associates & SKM (2012)

Season	Ecological functions	Hydrological objective	Groundwater requirements
Winter	Plant growth and survival	Continuous shallow flooding, 0 to 0.2 m	Watertable above the ground surface
Spring	Asexual reproduction and growth	Continuous shallow flooding, 0 to 0.2 m	Watertable above the ground surface
Summer	Germination and growth	Waterlogged	Watertable at or above the ground surface
Autumn	Plant growth and survival	Waterlogged	Watertable at or above the ground surface

3.1.1.2 Group 2: Perennially waterlogged, tolerates flow

This group of flora species requires damp to waterlogged stream beds to support its ecological functions (Table 3.2). This translates to watertables at or above the ground surface throughout the year.

Table 3.2 Group 2 groundwater requirements (Ecological Associates & SKM (2012)

Season	Ecological functions	Hydrological objective	Groundwater requirements
Winter	Plant growth and survival.	Waterlogged stream bed. Ready transmission of flow from rainfall events.	Watertable above the ground surface
Spring	Asexual reproduction. Growth, flowering and fruit maturation.	Waterlogged stream bed. Ready transmission of flow from rainfall events.	Watertable above the ground surface
Summer	Seed set, germination and growth. Adult plant growth and survival.	Damp stream bed. Ready transmission of flow from rainfall events.	Watertable at or above the ground surface
Autumn	Adult plant growth and survival. Juvenile plant maturation.	Damp stream bed. Ready transmission of flow from rainfall events.	Watertable at or above the ground surface

3.1.1.3 Group 3: Perennially saturated, seasonally flooded

This group of flora species requires continuous flooding (up to 0.5 m) to support its ecological functions (Table 3.3). This translates to watertables at or above the ground surface throughout the year.

Table 3.3 Group 3 groundwater requirements (Ecological Associates & SKM (2012)

Season	Ecological functions	Hydrological objective	Groundwater requirements
Winter	Plant growth and survival.	Continuous flooding up to 0.5 m	Watertable above the ground surface
Spring	Asexual reproduction. Growth, flowering and fruit maturation.	Continuous flooding up to 0.5 m	Watertable above the ground surface
Summer	Seed set, germination and growth. Adult plant growth and survival.	Continuous flooding up to 0.5 m or receding to 0 m.	Watertable at or above the ground surface
Autumn	Adult plant growth and survival. Juvenile plant maturation.	Continuous flooding up to 0.5 m or receding to 0 m.	Watertable at or above the ground surface

3.1.1.4 Group 4: Alternately waterlogged and drained sites

This group of flora species requires continuous flow or persistent baseflow to support its ecological functions (Table 3.4). This translates to receiving groundwater discharge through winter–spring and shallow watertables throughout summer–autumn.

Table 3.4 Group 4 groundwater requirements (Ecological Associates & SKM (2012)

Season	Ecological functions	Hydrological objective	Groundwater requirements
Winter	Plant growth and survival.	Continuous flow	Groundwater discharge to watercourse upstream
Spring	Asexual reproduction. Growth, flowering and fruit maturation.	Continuous flow	Groundwater discharge to watercourse upstream
Summer	Seed set, germination and growth. Adult plant growth and survival.	Persistent baseflow	Shallow watertable upstream readily transmits flow in summer rainfall runoff events
Autumn	Adult plant growth and survival. Juvenile plant maturation.	Persistent baseflow	Shallow watertable upstream readily transmits flow in autumn rainfall runoff events

3.1.1.5 Group 5: Shallow watertable below drained soils

This group of flora species requires high soil moisture in the root zone to support its ecological functions (Table 3.5). This translates to requiring shallow watertables throughout the year.

Table 3.5 Group 5 groundwater requirements (Ecological Associates & SKM (2012)

Season	Ecological functions	Hydrological objective	Groundwater requirements
Winter	Tree growth. Germination and juvenile growth.	Very high soil moisture in the root zone.	Shallow watertable
Spring	Tree growth.	Very high soil moisture in the root zone.	Shallow watertable

Season	Ecological functions	Hydrological objective	Groundwater requirements
	Flowering and fruit maturation.		
Summer	Flowering, fruit maturation and seed set. Adult plant growth and survival.	Well drained surface zone above deeper zone of high soil moisture.	Shallow watertable
Autumn	Adult plant growth and survival. Germination and juvenile growth.	Well drained surface zone above deeper zone of high soil moisture.	Shallow watertable

3.1.2 Aquatic macroinvertebrates

Groundwater discharge to surface waters supports two important ecological functions for aquatic macroinvertebrates: it contributes to the persistence of aquatic habitat; and it provides the connecting flows that allow fauna to disperse and colonise new areas.

The groundwater conditions that contribute to these processes can, in general, be defined by the presence of the watertable at or near the surface or the discharge of groundwater to the surface (Table 3.6).

Table 3.6 Groundwater conditions to support macroinvertebrate ecological functions (Ecological Associates & SKM (2012)

Habitat component	Ecological functions	Groundwater requirements
Permanent pools	Maintain persistent aquatic habitat conditions	Watertable at or near the surface throughout the year
Perennial riffles	Allow movement to recolonise vacant habitats	Watertable at or near the surface throughout the year
Persistent pools	Maintain persistent aquatic habitat conditions	Groundwater discharge to the watercourse upstream of the site throughout the year
Persistent riffles	Allow movement to recolonise vacant habitats	Groundwater discharge to the watercourse upstream of the site throughout the year
Shallow groundwater	Maintain hyporheos. Provide refuge for predominantly surface-dwelling macroinvertebrates	Watertable at or near the surface throughout the year
Permanent pools	Maintain persistent aquatic habitat conditions	Watertable at or near the surface throughout the year

3.1.3 Fishes

Groundwater discharge to streams helps to maintain baseflow, pool depths and wetted channel area. This in turn helps to provide riffle and pool habitat to support fish species as well as beneficial water quality.

Table 3.7 Groundwater requirements linked to stream flow components to support fish species (Ecological Associates & SKM (2012)

Flow season	Flow component	Ecological functions	Relevant species	Groundwater requirements
Low flow season	Low flow	Maintain pool depth and flow across riffles as habitat as refuge habitat	Climbing Galaxias Common Galaxias Mountain Galaxias Gudgeon species Congolli	Groundwater discharge to maintain baseflow
		Discharge sufficient to maintain low water temperatures and oxygenated conditions	Climbing Galaxias Common Galaxias Mountain Galaxias Gudgeon species Congoli	Groundwater discharge to maintain baseflow
	High flow	Scour pools to export organic matter and prevent de-oxygenation	Climbing Galaxias Common Galaxias Mountain Galaxias Gudgeon species Congoli	Groundwater discharge to maintain pool volumes and wetted channel to increase channel response to catchment runoff
		Reconnect pools to support dispersal to new habitats	Climbing Galaxias Common Galaxias Mountain Galaxias Gudgeon species Congolli	Groundwater discharge to maintain pool volumes and wetted channel to increase channel response to catchment runoff
High flow season	Low flow	Maintain pool depth and flow across riffles as habitat as refuge habitat	Climbing Galaxias Common Galaxias Mountain Galaxias Gudgeon species Congolli	Groundwater discharge to maintain baseflow
	High flow	Provide connecting flow to the sea to permit downstream migration of larvae and upstream migration of juveniles	Climbing Galaxias Common Galaxias Gudgeon species Congolli Lamprey Shortfin Eel	Groundwater discharge to maintain pool volumes and wetted channel to increase channel response to catchment runoff

3.2 Fractured rock aquifer springs

The proposed EWR for fractured rock aquifer springs is:

"*the adjacent groundwater levels must be above the pool level (where permanent inundation occurs), above the base of the bog (where permanently waterlogged conditions are located), or above the rooting depth of phreatophytic vegetation (where shallow watertables are required) to maintain permanent inundation where currently permanent,* *seasonal inundation where currently seasonal or ephemeral where currently ephemeral*" (Ecological Associates and SKM, 2012).

The influence of groundwater on vegetation declines with increasing distance from the spring. The edges of these sites support vegetation that depends on deeper groundwater than described above. It is assumed that by specifying groundwater discharge to the surface, the fringing vegetation will necessarily be protected. This assumption should be tested when groundwater impacts on ecosystems are being evaluated (Ecological Associates and SKM, 2012).

3.2.1 Threat assessment

The sensitivity of groundwater conditions to pumping is likely to be high given the small hydrogeological capture zones and the limited storage associated with fractured rock aquifers. A small capture zone is indicative of a small water budget, and the limited storage means that watertables tend to be drawn down more acutely in such settings. Given the dependence of these ecosystems is linked to the watertable and the rate of groundwater discharge, the ecosystems are considered to be sensitive to pumping if initiated.

The current level of groundwater pumping in the vicinity of springs in the Mount Lofty area is limited. A spring water bottling plant captures natural spring discharge and some domestic extraction occurs to the south of the Mount Lofty summit, along the ridge towards Crafers. However, there is no pumping in the immediate vicinity of these sites (i.e. within their hydrogeological capture zones) (Ecological Associates and SKM, 2012).

3.2.1.1 Consequences of groundwater change

A reduction in groundwater levels will affect fractured rock aquifer springs by reducing the rate of groundwater discharge and the surface area of the wetland that is affected by inundation, waterlogging or shallow groundwater. Wetland plant communities will contract to the remaining waterlogged parts of the site and terrestrial plants will colonise the wetland fringes.

The perennially saturated, non-flowing, freshwater conditions provided by fractured rock aquifer springs have a very limited occurrence in the Mount Lofty Ranges and therefore support specialised, endemic plant species. Consequently, the wetlands support many species that are rare or endangered such as *Drosera binata* (State Rare status), *Thelymitra circumsepta* (State Endangered status) and *Schizaea fistulosa* (State Vulnerable status).

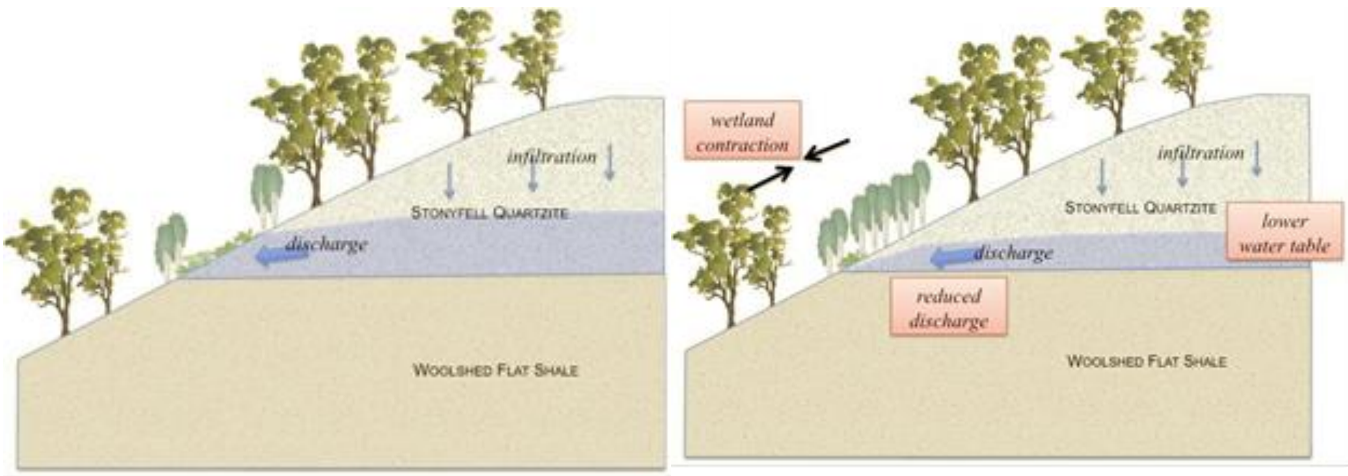


Figure 3.1 Consequences of lower watertables for fractured rock aquifer springs (Ecological Associates & SKM, 2012)

Even minor changes to the groundwater environment of fractured rock aquifer springs can have significant consequences for species distribution and persistence (Figure 3.1).

3.3 Groundwater dependent streams

The baseflow separation data from the historical stream flow record can be used as a benchmark to quantify EWRs on a catchment scale. Recognising that low flows are critical for the maintenance of GDEs, the EWRs can be defined in terms of low flow requirements. For instance, the EWR for First Creek specifies that flows need to be maintained above 1 ML/month at Gauge #5040517. Similarly, the EWR for Brownhill Creek suggest flows are required at least 90 % of the time at Gauge #5040901 (Ecological Associates and SKM, 2012).

The use of gauging data is appropriate for a catchment, but further detail is required that links the ecology of the stream to the flow regime. For instance, the EWR for Brownhill Creek specifies (in addition to the flow requirements listed above) that permanent flows and permanent pools need to be maintained in sections of the stream where Climbing Galaxias have been identified.

Where the ecology depends on waterlogged conditions or shallow watertables, the EWR can be defined in terms of groundwater levels. To maintain waterlogged conditions, a minimum groundwater level is defined by the capillary fringe of the watertable below land surface. To maintain the accessibility of groundwater for phreatophytic vegetation, the EWR is defined by a groundwater level that roots can access (i.e. a maximum depth and/or rate of change) (Ecological Associates and SKM, 2012).

The proposed EWR for groundwater dependent streams is based on suggestions from Ecological Associates and SKM, (2012), where*" a reach defined as gaining, the environmental water requirement is*:

- *The baseflow component of streamflow must be sufficient to maintain permanent flow (where identified) or a minimum number of no flow days (where flow is seasonal); and,*
- *The adjacent groundwater levels must be above the stream/pool level (where permanent flow/pools are located), above the base of the stream (where permanently waterlogged conditions are located), or within access of the roots of phreatophytic vegetation (where shallow watertables are required)".*

3.3.1 Threat assessment

The groundwater catchments associated with fractured rock baseflow are significantly larger than for fractured rock spring discharge. Local pumping will have an acute and immediate impact on springs, whereas the impacts to baseflow from pumping will be spread over a greater area. Any pumping within the groundwater catchment will impact baseflow, but the timeframe between pumping and the impact to streamflow will vary with the distance from the stream. As such, total extraction as opposed to the location of extraction is of more significance to fractured rock baseflow (Ecological Associates and SKM, 2012).

Currently there is little commercial groundwater extraction activity within the fractured rock aquifer, with most extraction confined to stock and domestic use. SKM (2010) estimated a total groundwater extraction of 632 ML/y from the fractured rock aquifer within the PWA for non-commercial extraction.

3.3.1.1 Consequences of groundwater change

A reduction in groundwater levels will affect groundwater fed watercourses by reducing the persistent or perennial hydrological influences of groundwater discharge and increasing the intermittent and seasonal influences of rainfall runoff (Ecological Associates and SKM, 2012).

Groundwater-fed pools would become shallower, more vulnerable to poor water quality and more prone to drying out in summer or during droughts. A reduction in the persistence of pools would threaten the survival of native fish populations and will alter the structure of macroinvertebrate communities (Figure 3.1).

Reaches where groundwater maintains saturated conditions or perennial flow would contract, reducing the habitat available for plants dependent on waterlogging. The extent of reaches that provide perennial flowing riffles would contract, reducing an important habitat component for Climbing, Mountain and Common Galaxias (Ecological Associates and SKM, 2012).

Losing reaches downstream of groundwater discharge sites will be affected by a reduction in the persistence of flow. The seasonal availability of aquatic habitat will decrease, providing fewer or shorter opportunities for macroinvertebrates, frogs and fish to complete their life-cycles. Plant species tolerant of seasonal flow are likely to become more abundant.

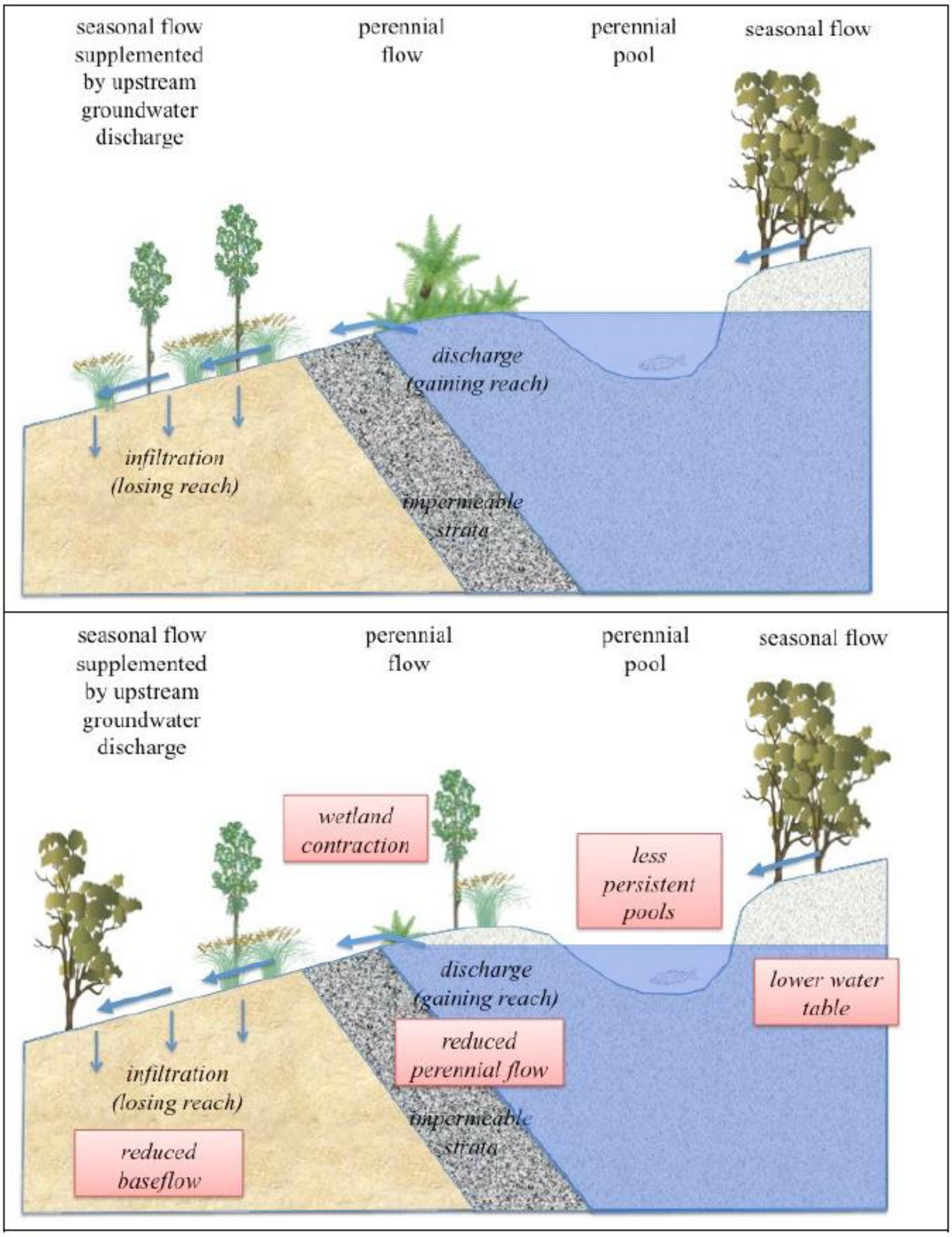


Figure 3.2 Consequences of lower watertables for groundwater dependent streams (Ecological Associates and SKM, 2012)

3.4 Terrestrial vegetation at the base of the hills

The proposed EWR for terrestrial vegetation at the base of the hills is:

- Maintenance of the long-term average recovered (spring) groundwater levels
- Summer groundwater levels must not decline by more than the rate of change from 2006 to 2010 as measured a nearby observation bore that was not influenced by groundwater use over this period.

3.4.1 Threat assessment

In this part of the St Vincent Basin, the presence of faults creates strong hydraulic connection between the deeper, more productive Tertiary aquifers and the shallow Quaternary aquifers that host the watertable. Extraction from any aquifer in this region may impact the watertable, but that which occurs from the shallow Quaternary aquifer will have the most significant impact.

Domestic water users take water from backyard bores tapping into the Quaternary aquifers. Since 1990, about 2600 backyard bores have been drilled into these aquifers on the Adelaide Plain and 2000 are thought to be operational. These bores have low rates of extraction of less than 3 L/s (Barnett et al., 2010).

In contrast to the fractured rock aquifers, extraction from the sedimentary aquifers has more diffuse impacts that occur over a longer timeframe. Because storage is limited in a fractured rock setting, extraction can result in sharp groundwater level declines over a small area of influence near the point of extraction. In the region-wide sedimentary aquifers, particularly the deeper Tertiary aquifers, storage is high and groundwater level declines resulting from extraction will be less significant but will occur over a greater area of influence (Ecological Associates and SKM, 2012).

It is unlikely that groundwater extraction activities in the vicinity of these GDEs will impact the salinity of the groundwater. In certain settings, extraction can cause the upward or lateral migration of high salinity groundwater. However at this location, the salinity of underlying and surrounding layers is typically less than 1500 mg/L (Gerges, 2006) and does not constitute a threat.

Recharge processes will also play a major role in influencing groundwater levels, particularly as this is a major recharge zone for the sedimentary aquifers. Changes in rainfall and streamflow are likely to exert significant influence on the depth of the watertable (Ecological Associates and SKM, 2012).

3.4.1.1 Consequences of groundwater change

A reduction in groundwater levels will affect the productivity and health of vegetation dependent on the watertable. The most likely species to be affected will be *Eucalyptus camaldulensis*.

The water requirements of *E. camaldulensis* are likely to be met by a combination of rainfall infiltration, capillary rise of water from the watertable and direct access to water in the saturated zone of the aquifer (Ecological Associates and SKM, 2012).

A lower watertable reduces the availability of groundwater and trees will become more dependent on the less persistent, less abundant and less reliable water provided by rainfall infiltration. This is likely to lead to slower growth in trees and reduced productivity of leaves, flowers, nectar and wood. Trees will become less resilient to drought possibly leading to dieback or death.

4 Conclusion

Three GDE types in the NAP and Central Adelaide PWAs were considered relevant to the development of the Adelaide Plains WAP:

- Fractured rock aquifer springs
- Groundwater dependent streams
- Terrestrial vegetation at the base of the hills.

These ecosystems are associated with shallow groundwater or the discharge of groundwater to the surface from aquifers that are subject to use. Table 4.1 summarises the occurrence, surface and groundwater dependence, current level of groundwater use, current level of threat and recommended EWRs for the GDEs of the Adelaide Plains (as described by Ecological Associates and SKM, 2012).

Table 4.1 GDEs of the NAP and Central Adelaide PWAs (Ecological Associates and SKM 2012)

GDE type	Occurrence within the NAP and Central Adelaide PWAs	Surface water dependence	Groundwater dependence	Level of current groundwater use	Level of threat of current groundwater use	Proposed EWR
Fractured rock springs	Numerous examples found in the Mount Lofty Ranges. A number of important springs are associated with the outcropping Stonyfell Quartzite between Cleland Conservation Park and Eagle Quarry. Significant springs include Heptinstalls, Wilsons Bog, Chinamans Bog Harford and Eagle Quarry, each of which support species threatened at a state and national level.	Receive limited inflow from surface runoff.	Groundwater is likely to provide a substantial proportion of their water supplies.	The current level of groundwater pumping in the vicinity of springs in the Mount Lofty area is limited.	The threat of current groundwater use to fractured rock aquifer springs is **not likely to be significant** as the level of groundwater development of groundwater resources in aquifers maintaining these systems is relatively low relative to recharge (e.g. estimated to be around 1700 ML/y in 2010 across groundwater subregions 1 and 2 (SKM 2011b, Figure 3)). However there may be sites where local groundwater use is in close proximity to springs and baseflow fed streams, even if small, affects spring and stream hydrology. The level of threat may change depending on the volumes granted. SKM (2011b) indicates that available hydrographs do not indicate widespread groundwater level decline and that a conservative	The proposed EWR for fractured rock aquifer springs is: • The adjacent groundwater levels must be above the pool level (where permanent inundation occurs), above the base of the bog (where permanently waterlogged conditions are located), or above the rooting depth of phreatophytic vegetation (where shallow watertables are required).

GDE type	Occurrence within the NAP and Central Adelaide PWAs	Surface water dependence	Groundwater dependence	Level of current groundwater use	Level of threat of current groundwater use	Proposed EWR
					approach to management in the fractured rock areas is to set the sustainable diversion limit to be equal to current use until more information becomes available regarding rates of recharge and discharge in these areas.	
Groundwater dependent streams	Numerous examples found in the Mount Lofty Ranges. Example sites include First Creek, Slapes Gully, Brownhill Creek, Coats Gully, Minno Creek and Gawler River.	Receive substantial catchment inflow.	Groundwater contributes to baseflow. There is significant variability among the streams of the study area and the level of groundwater contribution.	Currently there is little commercial groundwater extraction activity within fractured rock aquifer, with most extraction limited to stock and domestic use.	The threat of current groundwater use to groundwater dependent streams is likely to be **low**, given little use of groundwater from fractured rock aquifer in the study area. There may however be localised areas of groundwater use in close proximity to groundwater dependent streams that have an effect.	The proposed EWR for groundwater dependent streams is: • The baseflow component of streamflow must be sufficient to maintain permanent flow (where identified) or a minimum number of no flow days (where flow is seasonal). • The adjacent groundwater levels must be above the stream/pool level (where permanent flow/pools are located), above the base of the stream

GDE type	Occurrence within the NAP and Central Adelaide PWAs	Surface water dependence	Groundwater dependence	Level of current groundwater use	Level of threat of current groundwater use	Proposed EWR
						(where permanently waterlogged conditions are located), or within access of the roots of phreatophytic vegetation (where shallow watertables are required).
Terrestrial vegetation potentially dependent on groundwater	Ecosystem interactions are predicted to occur on the western side of the Eden-Burnside fault in the region	Changes in rainfall and streamflow are likely to exert significant influence on the depth of the watertable.	Directly dependent on groundwater.	Domestic water users take water from the Quaternary aquifers. Since 1990 about 2600 backyard bores have been drilled into these aquifers on the Adelaide Plain and 2000 are thought to be operational with an estimated total use of about 500 ML per year.	The threat of current groundwater use to terrestrial vegetation at the base of the hills is likely to be **moderate**. There has been an increased use of groundwater from domestic bores on the Adelaide Plains, which has resulted in a decline in groundwater levels in the shallow aquifer in some areas. Groundwater monitoring data from the shallow aquifer in this region is very sparse and this threat assessment can only be made with a low level of confidence.	The proposed EWR for terrestrial vegetation at the base of the hills is: • Maintenance of the long-term average recovered (spring) groundwater levels. • Summer groundwater levels not to decline by more than the rate of change from 2006 to 2010.

5 Glossary

Aquatic ecosystem — The stream channel, lake or estuary bed, water and/or biotic communities and the habitat features that occur therein

Aquatic habitat — Environments characterised by the presence of standing or flowing water

Aquifer — An underground layer of rock or sediment that holds water and allows water to percolate through

Aquifer, confined — Aquifer in which the upper surface is impervious and the water is held at greater than atmospheric pressure; water in a penetrating well will rise above the surface of the aquifer

Aquifer, unconfined — Aquifer in which the upper surface has free connection to the ground surface and the water surface is at atmospheric pressure

Aquitard — A layer in the geological profile that separates two aquifers and restricts the flow between them

Baseflow — The water in a stream that results from groundwater discharge to the stream; often maintains flows during seasonal dry periods and has important ecological functions

Basin — The area drained by a major river and its tributaries

Bore — See 'well'

Buffer zone — A neutral area that separates and minimises interactions between zones whose management objectives are significantly different or in conflict (e.g. a vegetated riparian zone can act as a buffer to protect the water quality and streams from adjacent land uses)

Catchment — That area of land determined by topographic features within which rainfall will contribute to run-off at a particular point

DEW – Department for Environment and Water

DEWNR — Department of Environment, Water and Natural Resources (Government of South Australia)

Diadromous – A group of fish that move between the marine and freshwater environment, usually to breed. There are two categories of diadromous fishes, catadromous and anadromous . Catadromous fishes hatch or are born in marine habitats, but migrate to freshwater areas where they spend the majority of their lives growing and maturing. As adults they return to the sea to spawn.

Diversity — The distribution and abundance of different kinds of plant and animal species and communities in a specified area

Ecological processes — All biological, physical or chemical processes that maintain an ecosystem

Ecological values — The habitats, natural ecological processes and biodiversity of ecosystems

Ecology — The study of the relationships between living organisms and their environment

Ecosystem — Any system in which there is an interdependence upon, and interaction between, living organisms and their immediate physical, chemical and biological environment

Endangered species — (1) Any species in danger of extinction throughout all or a significant portion of its range

Endemic — A plant or animal restricted to a certain locality or region

Environmental water requirements — The water regimes needed to sustain the ecological values of aquatic ecosystems, including their processes and biological diversity, at a low level of risk

Ephemeral streams or wetlands — Those streams or wetlands that usually contain water only on an occasional basis after rainfall events. Many arid zone streams and wetlands are ephemeral.

Estuaries — Semi-enclosed water bodies at the lower end of a freshwater stream that are subject to marine, freshwater and terrestrial influences, and experience periodic fluctuations and gradients in salinity

Floodplain — Of a watercourse means: (1) floodplain (if any) of the watercourse identified in a catchment water management plan or a local water management plan; adopted under the Act; or (2) where (1) does not apply — the floodplain (if any) of the watercourse identified in a development plan under the Development (SA) Act 1993; or (3) where neither (1) nor (2) applies — the land adjoining the watercourse that is periodically subject to flooding from the watercourse

Flow regime — The character of the timing and amount of flow in a stream

Gaining reach/stream – A section of watercourse that gains water from the underlying groundwater resulting in a increase in flow along the watercourse.

Groundwater — Water occurring naturally below ground level or water pumped, diverted and released into a well for storage underground; see also 'underground water'

Habitat — The natural place or type of site in which an animal or plant, or communities of plants and animals, live

Hydrogeology — The study of groundwater, which includes its occurrence, recharge and discharge processes and the properties of aquifers; see also 'hydrology'

Hydrology — The study of the characteristics, occurrence, movement and utilisation of water on and below the Earth's surface and within its atmosphere; see also 'hydrogeology'

Hyphoreos - the assemblage of organisms which inhabits the hyporheic zone

Licence — A licence to take water in accordance with the Act; see also 'water licence'

Losing reach/stream – A section of a watercourse that loses water to the underlying groundwater table, resulting in a reduction in flow along the watercourse.

Macro-invertebrates — Aquatic invertebrates visible to the naked eye including insects, crustaceans, molluscs and worms that inhabit a river channel, pond, lake, wetland or ocean

Monitoring — (1) The repeated measurement of parameters to assess the current status and changes over time of the parameters measured (2) Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, animals and other living things

NAP — Northern Adelaide Plains

Native species — Any animal and plant species originally in Australia; see also 'indigenous species'

Natural resources — Soil, water resources, geological features and landscapes, native vegetation, native animals and other native organisms, ecosystems

Pelagic - Any water in a sea or lake that is neither close to the bottom nor near the shore

Perennial streams — Permanently inundated surface stream courses. Surface water flows throughout the year except in years of infrequent drought.

Permeability — A measure of the ease with which water flows through an aquifer or aquitard, measured in m2/d

Phreatophytic vegetation — Vegetation that exists in a climate more arid than its normal range by virtue of its access to groundwater

Population — (1) For the purposes of natural resources planning, the set of individuals of the same species that occurs within the natural resource of interest. (2) An aggregate of interbreeding individuals of a biological species within a specified location

Prescribed watercourse — A watercourse declared to be a prescribed watercourse under the Act

Prescribed water resource — A water resource declared by the Governor to be prescribed under the Act and includes underground water to which access is obtained by prescribed wells. Prescription of a water resource requires that future management of the resource be regulated via a licensing system.

Prescribed well — A well declared to be a prescribed well under the Act

PWA — Prescribed Wells Area

Recharge area — The area of land from which water from the surface (rainfall, streamflow, irrigation, etc.) infiltrates into an aquifer. See also artificial recharge, natural recharge

Riparian — Of, pertaining to, or situated or dwelling on the bank of a river or other water body

Riverine habitat — All wetlands and deep-water habitats within a channel, with two exceptions — wetlands dominated by trees, shrubs, persistent emergent mosses or lichens, and habitats with water that contains ocean-derived salt in excess of 0.5 parts per thousand

Stormwater — Run-off in an urban area

Surface water — (a) water flowing over land (except in a watercourse), (i) after having fallen as rain or hail or having precipitated in any another manner, (ii) or after rising to the surface naturally from underground; (b) water of the kind referred to in paragraph (a) that has been collected in a dam or reservoir

Sustainability — The ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time

Taxa — General term for a group identified by taxonomy, which is the science of describing, naming and classifying organisms

Tertiary aquifer — A term used to describe a water-bearing rock formation deposited in the Tertiary geological period (1–70 million years ago)

Threatened species — Any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range

Transmissivity (T) — A parameter indicating the ease of groundwater flow through a metre width of aquifer section

Tributary — A river or creek that flows into a larger river

Underground water (groundwater) — Water occurring naturally below ground level or water pumped, diverted or released into a well for storage underground

Water allocation — (1) In respect of a water licence means the quantity of water that the licensee is entitled to take and use pursuant to the licence. (2) In respect of water taken pursuant to an authorisation under s.11 means the maximum quantity of water that can be taken and used pursuant to the authorisation

WAP — Water Allocation Plan; a plan prepared by a CWMB or water resources planning committee and adopted by the Minister in accordance with the Act

Watercourse — A river, creek or other natural watercourse (whether modified or not) and includes: a dam or reservoir that collects water flowing in a watercourse; a lake through which water flows; a channel (but not a channel declared by regulation to be excluded from the this definition) into which the water of a watercourse has been diverted; and part of a watercourse

Water dependent ecosystems — Those parts of the environment, the species composition and natural ecological processes, that are determined by the permanent or temporary presence of flowing or standing water, above or below ground; the in-stream areas of rivers, riparian vegetation, springs, wetlands, floodplains, estuaries and lakes are all water-dependent ecosystems

Well — (1) An opening in the ground excavated for the purpose of obtaining access to underground water. (2) An opening in the ground excavated for some other purpose but that gives access to underground water. (3) A natural opening in the ground that gives access to underground water

Wetlands — Defined by the Act as a swamp or marsh and includes any land that is seasonally inundated with water. This definition encompasses a number of concepts that are more specifically described in the definition used in the Ramsar Convention on Wetlands of International Importance. This describes wetlands as areas of permanent or periodic to intermittent inundation, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed six metres.

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7 Appendix

Adelaide Plains Fish Species and Functional Groups

Functional group	Species	Scientific name	National Conservation Status	State Conservation Status	Record Type Adelaide Plains
D	Pouched Lamprey	*Geotria australis*		EN	1
D	Short-headed Lamprey	*Mordacia mordax*		EN	1
Fw	Freshwater Catfish	*Tandanus tandanus*		P, V	3*
D	Short-finned Eel	*Anguillla australis*		R	2
D	Climbing Galaxias	*Galaxias brevipinnis*		V	1
D	Common Galaxias	*Galaxias maculatus*			3
Fs	Mountain Galaxias 1	*Galaxias olidus*		R	3
Fg	Murray rainbowfish	*Melanotaenia fluviatilis*		R	3*
Fg	Smallmouth Hardyhead	*Atherinosoma microstoma*			2
D	Congolli	*Pseudaphritis urvillii*		R	3
Fg	Carp Gudgeon	*Hypseleotris sp.*			3*
Fg	Flathead Gudgeon	*Philypnodon grandiceps*			3
Fg	Dwarf Flathead Gudgeon	*Philypnodon sp. 1*		R	1*
Fg	Western bluespot goby	*Pseudogobius olorum*			1
Ex	Common Carp	*Cyprinus carpio*			3
Ex	Tench	*Tinca tinca*			1
Ex	Rainbow Trout	*Oncorhynchus mykiss*			?
Ex	Brown Trout	*Salmo trutta*			?

Ex	Brook Trout	*Salvelinus fontinalis*			?
Ex	Gambusia	*Gambusia holbrooki*			3
Ex	Redfin Perch	*Perca fluviatilis*			

Source: McNeil and Hammer 2007; McNeil et al 2011

Functional group: D = diadromous; Fs = obligate freshwater, stream specialist; Fw = obligate freshwater, wetland specialist; Fg = obligate freshwater, generalist; Fp = obligate freshwater, potamodromous generalist; Ex = exotic.

Conservation status: National (Nat.): VU=Vulnerable (EPBC Act 1999); State: P = protected (Fisheries Act 1982), E = Endangered, V = Vulnerable, R = Rare (DEH 2004).

Record type: 1 = verified records, limited in number; 2 = species present but no recent records; 3 = recent records at a few or more locations; 0 = presumed to exist based on unverified records or nearby records plus suitable habitat; * = translocated; ? = unknown if native or translocated (or both).