Appendix D

Groundwater Replenishment Scheme Stage 2 Subterranean Fauna Desktop Assessment – Bennelongia Environmental Consultants

Groundwater Replenishment Scheme Stage 2: Subterranean Fauna Desktop Assessment

Prepared for:

Water Corporation

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Final Version

Short-Range Endemics I Subterranean Fauna

Waterbirds I Wetlands

Groundwater Replenishment Scheme Stage 2: Stygofauna Desktop Assessment

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EXECUTIVE SUMMARY

The Water Corporation is proposing to implement an expansion of the Groundwater Replenishment Scheme (Stage 2) including off-site recharge of the confined aquifers. Duplication of the existing Advanced Water Recycling Plant (AWRP) located at the Beenyup Wastewater Treatment Plant (WWTP) and the construction of additional water recharge and conveyance infrastructure will increase the capacity of the project to recharge on average 77 ML/day of recycled water into the Leederville and Yarragadee aquifers. The water will meet drinking water standards prior to being recharged. This report assesses the likelihood of stygofauna being present within the Leederville or Yarragadee aquifers at, or immediately adjacent to, the proposed recharge locations.

Stygofauna are animals that live in groundwater and arid areas of Western Australia are particularly rich in stygofauna. However, knowledge of the subterranean fauna of the Swan Coastal Plain is relatively limited. An unpublished review of stygofauna occurrence in the Gnangara groundwater system suggested that the more frequently recorded groups are copepods, amphipods, syncarids, ostracods and oligochaetes.

Stygofauna may occur in an array of different groundwater habitats including porous, karstic and fractured-rock aquifers, springs and the hyporheos of streams. The groundwater habitats on the Swan Coastal Plain that are likely to support stygofauna include porous alluvium and colluvium, limestone karst, springs and the hyporheos of rivers and streams. In these habitats, both lateral and vertical connectivity of fissures and voids are important for the occurrence of stygofauna. Lateral connectivity enables animals to move about underground, while vertical connectivity through to the surface enables recharge of carbon and nutrients to the stygofauna community. Stygofauna have mostly been recorded in fresh to brackish groundwater but may occur in salinities (expressed as conductivity) of up to 55,000 µS/cm. Irrespective of the prospectivity of the geology, few species and only low numbers of individuals are expected to occur where depth to the watertable is much more than 30 m.

Three regional aquifers occur in the Perth Region: the unconfined superficial aquifer; the confined Leederville aquifer; and the confined Yarragadee aquifer. The superficial aquifer is located close to the surface and is often expressed as wetlands or lakes in low lying areas of land. The Leederville and Yarragadee are mostly confined aquifers that occur much deeper, and are separated from the superficial aquifer and each other by confining materials such as clay and shale. There are small areas north of Perth (and also extensive areas off-shore) where these aquifers come to the surface. Locally, the Mirrabooka aquifer is also used for public supply and was intersected when Bore BNYP 1/07 was drilled in 2007 near near Beenyup and when the pilot hole at the northern recharge site was drilled in 2016.

The geology within the Leederville and Yarragadee aquifers is transmissive and the water is fresh (<500 mg/L TDS); thus both aquifers may provide suitable habitat for stygofauna in this local area where they are unconfined. However, stygofauna are unlikely to occur naturally at the actual point of injection of recycled water, which will be at depths of 140 – 400 m (Leederville) or ~ 1350 m (Yarragadee) and about because levels of carbon and nutrients will be very low. Farther afield, the aquifers quickly become confined with an impermeable layer between the Superficial and the Leederville aquifer (and again between the Leederville and Yarragadee aquifers). In areas where the Leederville and Yarragadee aquifers are confined there is no vertical connectivity with the surface to provide input of carbon and nutrients to the aquifers and stygofauna are very unlikely to occur.

In theory, recharge might have an impact on stygofauna if injection into the underlying Leederville and Yarragadee aquifers leads to upwards movement of the recycled water into the superficial aquifer, where stygofauna are likely to be present. However, owing to mixing of water after injection, it is considered unlikely that there would be any impact on stygofauna in the superficial aquifer from changes in water quality should upward movement of recycled water occur. Furthermore, most species in the Gnangara Mound, where the scheme will operate, appear to have ranges that extend beyond the Mound and the likely extent of any possible water quality changes.

Given that stygofauna are unlikely to occur in the vicinity of reinjection points of recycled water because injection is occurring deep in confined parts of the Leederville and Yarragadee aquifers and that the likelihood of water quality changes in the superficial aquifer appears to very low, no impact on stygofauna conservation values would be expected from Stage 2 of the Groundwater Replenishment Scheme.

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1. INTRODUCTION

The Water Corporation is proposing to implement an expansion of the Groundwater Replenishment Scheme (Stage 2) including off-site recharge of the confined aquifers from which scheme water is drawn. Duplication of the existing Advanced Water Recycling Plant (AWRP) located at the Beenyup Wastewater Treatment Plant (WWTP) and the construction of additional water recharge and conveyance infrastructure will increase the capacity of the scheme to recharge into the Leederville and Yarragadee aquifers, on average, 77 ML/day of recycled water. The recycled water will meet drinking water standards.

Recharge of the confined aquifers in specific locations (Figure 1) has potential ecological benefits in aiding the recovery of some sensitive wetlands and groundwater dependent ecosystems (GDEs). The proposed recharge locations have been placed where increase in pressure within the deep aquifer as a result of injecting recycled water will result in upwards water pressure from the deeper aquifers to the superficial aquifer.

This report assesses the likelihood of stygofauna being present within the Leederville or Yarragadee aquifers at, or immediately adjacent to, the proposed recharge locations. It also examines the likelihood of recharge affecting stygofauna in the superficial aquifer but does not consider in detail whether stygofauna communities that may occur near the recharge sites. It takes account of:

- Pre-existing datasets and relevant reference materials;
- Information on the current understanding of aquifers within the Perth Metropolitan area (including conceptual models);
- Site-specific geological data derived from a pilot hole at the proposed northern recharge site; and
- The consultant's experience regarding the likely distribution of stygofauna within the confined aquifers of the Perth Metropolitan area.

2. OVERVIEW OF PERTH'S MAJOR AQUIFERS

Three regional aquifers occur in the Perth Region in the vicinity of the proposed recharge sites. These are the:

- unconfined superficial aquifer;
- confined Leederville aquifer; and
- confined Yarragadee aquifer.

The superficial aquifer is located relatively close to the ground surface and is often expressed as wetlands or lakes in low-lying parts of the landscape. The Leederville and Yarragadee aquifers are confined aquifers that occur much deeper, and are separated from the superficial aquifer and each other by confining materials such as siltstone and shale (Figure 2). Locally, the Mirrabooka aquifer is also used for public supply (Commander 2003) and was intersected when Bore BNYP 1/07 was drilled in 2007, and when the pilot hole at the northern recharge site was drilled in 2016, in addition to the three aforementioned aquifers (Rockwater 2008). Thus, the Mirrabooka aquifer is also described in this report.

2.1 Superficial Aquifer

The superficial aquifer is a complex, unconfined multilayered aquifer which extends throughout the Swan Coastal Plain, west of Gingin and the Darling Scarps. It supports a mix of ephemeral, seasonal and perennial wetlands, and in areas of urban development with shallow water tables much of it has

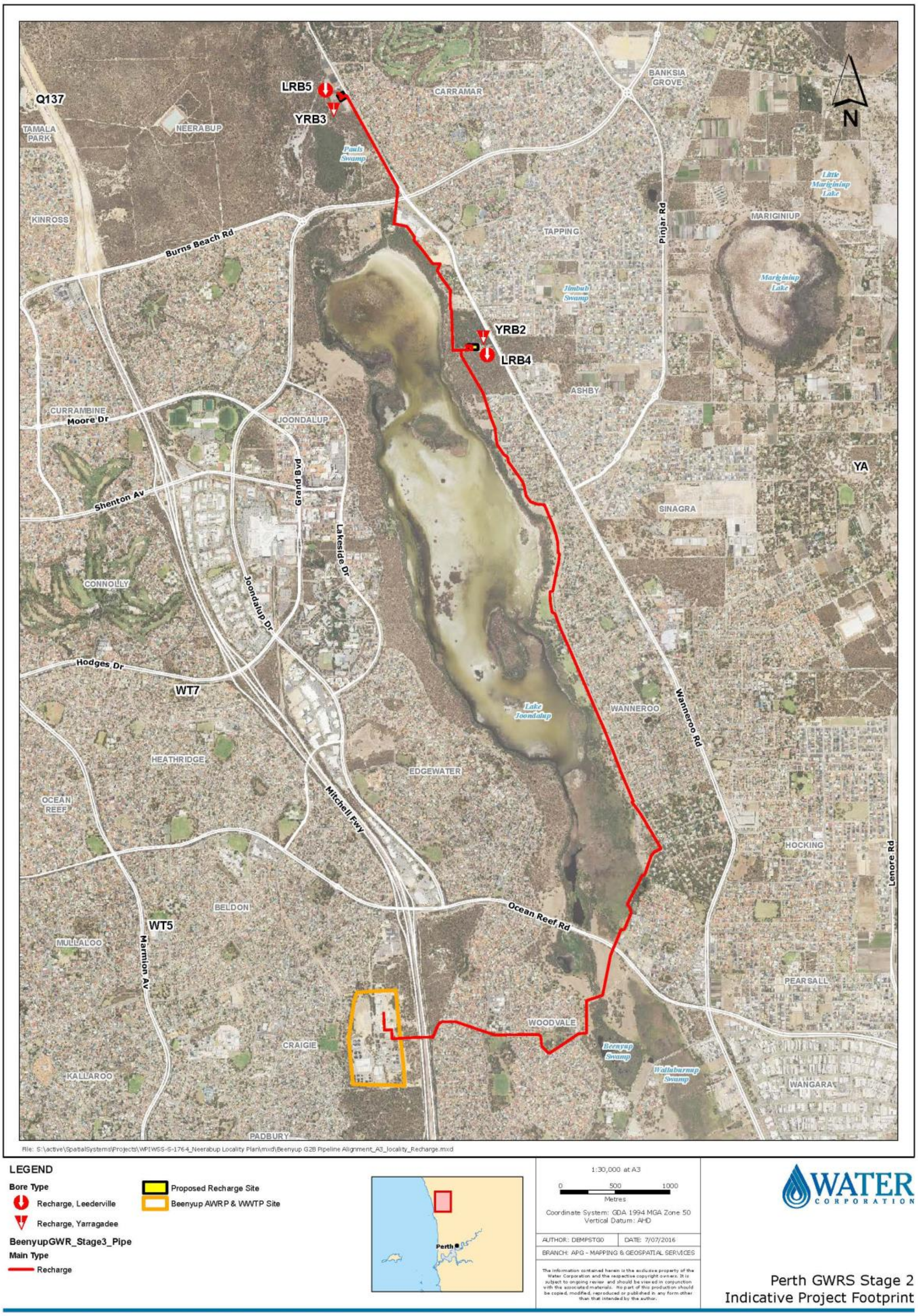

Figure 1. Perth GWRS Stage 2 Indicative Project Footprint.

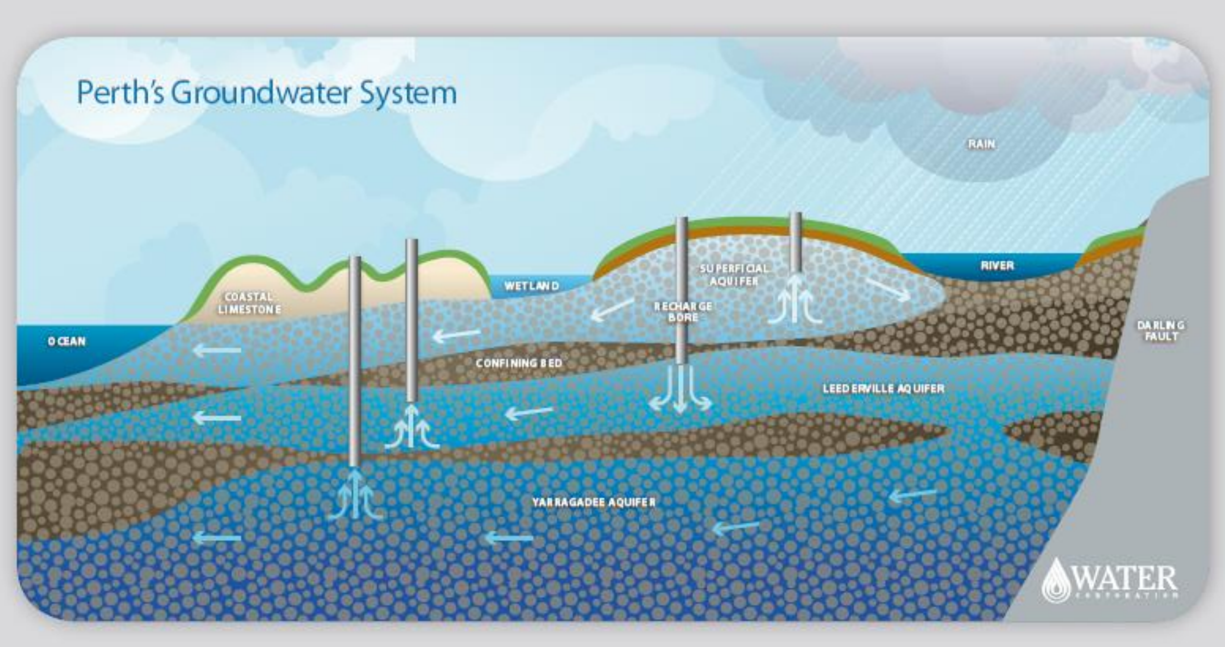

Figure 2. Schematic diagram of Perth's groundwater system (Water Corporation).

been drained (Halse 1989). The sediments which constitute the superficial aquifer range from predominantly clayey (Guildford Clay) in the east adjacent to the Darling Fault, through a sandy succession (Bassendean Sand and Gnangara Sand) in the central coastal plain area, to sand and limestone (Safety Bay Sand, Becher Sand and Tamala Limestone) within the coastal belt. The superficial aquifer has a maximum thickness of about 70 m, but average thicknesses of 45 and 20 m in the northern and southern Perth Region respectively (Davidson 1995).

Groundwater recharge occurs mostly from winter rainfall and is highest in the central and western parts of the coastal plain where the superficial formations are sandy and runoff is minimal. Seasonal water table fluctuations range from less than 0.5 m in the Tamala Limestone, 1-1.5 m in the Bassendean Sand and 3 m in the Guildford Clay, reflecting transmissivity of the sediments (Commander 2003).

The groundwater salinity is less than 250 mg/L in the Gnangara and Jandakot Mounds and typically rises to 600–800 mg/L along the coast (Davidson, 1995). Pockets of high salinity occur in groundwater discharge areas (Maddington, Serpentine Flats). Lakes Coogee, Cooloongup and Walyungup in coastal areas south of Perth are fed by groundwater and are saline.

2.2 Mirrabooka aquifer

The Mirrabooka aquifer is a semi-confined, or locally confined, aquifer that exists only in the northern Perth area. It is a predominantly sandy, major semi-confined aquifer and comprises the Poison Hill Greensand, Gingin Chalk, Molecap Greensand, and Mirrabooka Member. The extent of the Mirrabooka aquifer is quite widespread in the northern Perth area, where it is in hydraulic continuity with the superficial aquifer (Davidson 2005).

Groundwater from the Mirrabooka aquifer ranges in salinity from 130 to 350 mg/L TDS. The lowest salinity water is generally found in the recharge area and at the top of the aquifer, where it is in direct hydraulic contact with the groundwater in the superficial aquifer.

2.3 Leederville aquifer

The Leederville Aquifer is located between the superficial aquifer and the Yarragadee aquifer. While smaller than the Perth Yarragadee, it is still very large and in some areas it connects with the surface.

The Leederville aquifer is a major confined aquifer spanning the Perth Region. It overlaps the Darling Fault south of the Dandaragan Plateau and extends both north and south of the area. This aquifer is present beneath the entire coastal plain except near the Swan Estuary, where it has been eroded out prior to deposition of the Kings Park Formation, and in the southeast corner where the superficial formations rest directly on the Cattamarra Coal Measures. The Leederville aquifer is a multilayer groundwater-flow system consisting of discontinuous interbedded sandstones, siltstones and shales of the Henley Sandstone Member (Osborne Formation) and the Wanneroo and Mariginiup Members (Leederville Formation) (Davidson 2005).

The Leederville aquifer has a maximum thickness of more than 550 m in the Yanchep Syncline. In the northern part of the Swan Syncline and in the Wanneroo area it is about 500 and 400 m thick, respectively. Across the Pinjar Anticline the aquifer has a minimum thickness of about 50 m. South of Perth, the Leederville aquifer ranges in thickness from about 50 m in the southeast to about 300 m in the Jandakot area.

Groundwater salinity is less than 500 mg/L north of the Swan River and in areas near the Darling Scarp to the south east. The salinity exceeds 1,000 mg/L around the contact with the Kings Park Formation; in the eastern Swan Valley, the Kwinana Rockingham area, Serpentine, and in the Maddington area (where it is greater than 3,000 mg/L) (Davidson 2005).

The aquifer is unconfined at natural recharge locations where it directly underlies the superficial aquifer, but over short distances it becomes confined by discontinuous interbedding of siltstone and shale (Davidson 2005).

2.4 Yarragadee aquifer

The Yarragadee aquifer is a major confined aquifer, located below the Leederville aquifer and underlying the entire Perth Region and extending to the north and south within the Perth Basin. It is a multilayer aquifer, more than 2,000 m thick, consisting of interbedded sandstones, siltstones and shales of the Gage Formation, Parmelia Formation, Yarragadee Formation and Cattamarra Coal Measures. Over most of the area, the Yarragadee Formation is the major component of the aquifer, but in the northeastern and southern areas, the Parmelia Formation and the Cattamarra Coal Measures are, respectively, the major components. Only about the upper 500 m of the aquifer have been investigated by drilling (Davidson 2005).

Groundwater flow is from the north, with the addition of recharge in a comparatively small area in the north of the Gnangara Mound by leakage through the Wanneroo Member of the Leederville Formation. This recharge is low in salinity, less than 500 mg/L, and flows southwards to cross the coast between City Beach and Whitfords. Groundwater elsewhere in the aquifer is brackish, reaching over 3,000 mg/L in the Swan Valley.

3. PROJECT SITE: HYDRO-STRATIGRAPHIC SUMMARY

The results from drilling at a site near to the proposed northern reinjection location is described below and summarised in Table 1. It provides a good overview of the depths of the aquifers and geological layers.

Closest to the surface is the superficial aquifer, which is 46 m thick and consists of unconsolidated Bassendean Sand consisting of fine to coarse-grained quartz. Below this, the Mirrabooka aquifer occurs at a depth of 46 m and 108 m. It includes the Osbourne Formation and Henley Sandstone. The Osbourne Formation is comprised of two layers, an overlying sand layer comprised of fine to very coarse grained quartz and an underlying layer of sandstone that is weakly consolidated.

The Leederville Formation, which lies below the Mirrabooka aquifer, extends from 108 – 474 m and contains an upper siltstone and mudstone aquitard layer (a layer that separates aquifers and partially disconnects the flow of water) and lower sandstone and siltstone aquifer layer, both within the Wanneroo Member. Below these layers, there is approximately 30 m of siltstone and shale aquitard (in the Mariginiup Member).

The Leederville and Yarragadee Formations are separated by a 300 m thick siltstone and shale aquiclude (a layer that separates aquifers where there is zero flow) in the South Perth Shale. The Yarragadee Formation itself consists of a deep sandstone aquifer.

Groundwater salinity in the superficial and Mirrabooka aquifer in the vicinity of the drilling site is fresh and less than 500 mg/L TDS. Groundwater salinity gradually increases from about 250 mg/L at the top to about 800 mg/L TDS at the base of the Leederville aquifer.

Table 1. Hydro-Stratigraphic summary.

Average Depth (m)		Description	Stratigraphic Unit	Hydrogeology
From	To			
0	46	SAND: fine to coarse grained quartz	Bassendean Sand	Superficial
UNCOMFORMITY				
46	71	SAND: grey to pale green, fine to very course quartz with minor green staining (glauconite)	Osborne Formation	Mirrabooka Aquifer
71	81.5	SANDSTONE: greyish brown, fine to very course grained, poorly sorted, weakly consolidated		
81.5	108	SANDSTONE: grey very fine to very course grained with occasional granules, with minor clay	Henley Sandstone	
UNCOMFORMITY				
108	117	SILTSTONE: Dark grey, moderately to well consolidated, interbedded with fine to course grained sand	Leederville Formation	Wanneroo Member (Aquitard)
117	140	SILTSTONE, MUDSTONE: Dark grey to black, very well consolidate, interbedded with fine to medium grained quartz sandstone		
140	178	SANSTONE: Grey to dark grey, fine to coarse grain with some siltstone and clays.		Wanneroo Member (Aquifer)
178*	404*	SANDSTONE/SILTSTONE: fine to coarse grained quartz with some siltstone and shale beds.		
404*	474*	SILTSTONE AND SHALE		Mariginiup Member (Aquitard/Seal)
474*	776*	SILTSTONE AND SHALE	South Perth Shale	Aquiclude
>776*		SANDSTONE: light grey to grey, interbedded fine to medium grained well sorted quartz with fine to coarse grained poorly sorted beds. Few siltstone/shale beds. Garnet and heavy minerals occur throughout.	Yarragadee Formation	Yarragadee (Aquifer)

*Depths taken from PRAMS3.5 and interpretation from Beenyup lithology.

4. HYDROGEOLOGICAL MODELLING OF THE GWS

Hydrogeological modelling of the effects of GWR Stage 1 and Stage 2 which includes recharge and subsequent abstraction from new and existing assets for the Integrated Water Supply System (IWSS) was undertaken by Water Corporation in 2016. The assessment compares the net effect on the three main aquifers of the Gnangara groundwater system of recharge and abstraction of GWR Stage 1 and Stage 2 against the currently licenced IWSS Baseline abstraction plan. These effects were modelled over 30 years and Option 17 for GWR Stage 2 provides the preferred distribution of impacts relative to site specific environmental sensitivity and provides an operationally feasible option in terms of water quality, site access and IWSS capacity (see Water Corporation 2016).

The development of off-site recharge options has determined the balance of planned recharge between the Leederville and Yarragadee aquifers. This balance has evolved into the proposed recharge of 14 GL/year through a mix of two Leederville bores delivering 4 GL/year each and two Yarragadee bores delivering 3 GL/year each (Water Corporation 2016).

It is anticipated that an increase in pressure in the Leederville aquifer can help to reverse the historic de-pressurisation of the Leederville aquifer and decrease, or reverse, the existing downward vertical hydraulic gradient between the superficial and Leederville aquifers in some areas. Where the Leederville aquifer is unconfined, a significant change in vertical gradient can provide a mechanism to aid recovery of groundwater levels in the superficial aquifer. However, at the recharge sites in the Leederville aquifer some confinement of that aquifer is required to prevent the direct vertical movement of recharge water into the superficial aquifer where aquatic ecosystems might be impacted. Consequently Leederville recharge locations have been selected based on sites near where a confining layer (Wanneroo Member) pinches out to provide maximum pressure benefit but prevent direct vertical flux to the superficial aquifer (Water Corporation 2016).

5. OVERVIEW OF STYGOFAUNA AND PREFERRED HABITATS

5.1 Stygofauna

Stygofauna are animals that live in groundwater and arid Western Australia appears to be particularly rich in stygofauna. Nearly all stygofauna are invertebrates, mostly crustaceans, although stygofaunal fish have been found on around Exmouth Cape (e.g. Whitely 1945). Various terminologies have been applied to describe the relationship between stygofaunal species and groundwater. The most common scheme is that stygoxenes are surface species that use groundwater facultatively, stygophiles are species with most life stages completed in groundwater or some populations entirely dependent on groundwater, and stygobionts are obligate users of groundwater throughout their life cycle. In this document, however, all species using groundwater will be referred to as stygofauna. In general, stygofauna are characterised by the loss of eyes and skin pigmentation and the development of a vermiform body shape and more elongated appendages than surface relatives, although some species retain reduced eyes and not all have a vermiform shape.

The main concentrations of stygofauna in Western Australia appear to be in the Pilbara (Eberhard et al. 2005a, Halse et al. 2014) and the Yilgarn (Cooper et al. 2007) but they have also been found in the Kimberley (Hancock & Bennison 2005), Nullarbor and south-western Australia in lower abundance. Historically, intensive study of stygofauna in Western Australia began at Cape Range (Knott 1993) and then expanded to Barrow Island and the Pilbara before the Yilgarn was explored (see Humphreys

2001). There has been less survey effort in the South-West than in central and northern Western Australia.

A high proportion of stygofauna have restricted distributions (Gibert and Deharveng, 2002). According to Eberhard et al. (2009), about 70 % of Pilbara stygofauna species are likely to be short range endemics (SREs) as defined by Harvey (2002), with many of them having much smaller ranges than Harvey's criterion of 10,000 km^2. Species with restricted ranges are vulnerable to extinction following habitat destruction or environmental changes (Ponder and Colgan 2002; Fontaine et al. 2007).

5.1.1 Stygofauna of the Swan Coastal Plain

Knowledge of the subterranean fauna of the Swan Coastal Plain is relatively limited. An unpublished review of stygofauna occurrence in the Gnangara groundwater system suggested that the more frequently recorded groups are copepods, amphipods, syncarids, ostracods and oligochaetes (Bennelongia 2008).

More recently, Bennelongia has conducted monitoring in shallow bores at Kensington, with 59 samples collected from 12 bores over three years to 2015. Twenty-one species were collected and of these, at least 13 are true stygofauna including six copepods, three syncarids, three oligochaetes and one aphanoneuran species. The assemblage is typical of that found in alluvial/colluvial aquifers and is similar in higher-level taxonomic composition to the assemblages found in eastern Australian alluvial aquifers (Hancock and Boulton 2008). All of the species were collected at very low abundance.

The Western Australian Museum has undertaken ad-hoc stygofauna surveys of the subterranean fauna of the Swan Coastal Plain. Both unconfined (superficial) and confined (Leederville, Yarragadee) aquifers have been sampled. The surveys also revealed that stygofauna occur within the superficial aquifer but species richness is low. There were only 24 records of 11 species from a moderately extensive sampling program (Table 2) (Bennelongia 2008). The occurrence of stygofauna in the confined aquifers has not been confirmed.

Other sampling along the Swan Coastal Plain has been undertaken around the Yanchep area by Brenton Knott of the University of Western Australia, who has taken hundreds of samples to find only copepods, amphipods and a few ostracods (pers. comm. 2008). Results of other studies in the South-West are similar to those of the Museum and University, providing added confidence that the area does not support stygofauna communities as diverse as those in arid areas. Schmidt (2005) found relatively few species in groundwater associated with Marbling Brook on the eastern edge of the Darling Scarp in the Chittering catchment, 60 km north-east of Perth. The total yield from seven groundwater bores sampled 12 times was about 21 species, with most being copepods (Table 3). All animals collected were very small, with the exception of two species of amphipod, and only two of the 21 species were considered to be stygobionts. Other animals are either known, or likely to be, widespread. Another moderately diverse fauna was found on the eastern side of the Harvey Estuary, where 18 species were collected from 19 samples. All but four of the species were known to have a wider distribution than the study area (Bennelongia 2009).

With few stygobionts and extensive aquifers systems, few species on the Swan Coastal Plain would be expected to have highly restricted distributions. This has been confirmed when Swan Coastal Plain species have identified by morphological studies, with most stygobionts appearing to be wide-ranging. For example, the copepod *Kinnecaris eberhardi* has been recorded from both the Leeuwin-Naturaliste and Yanchep karsts (Tang and Knott, 2009). However, not all groups show this pattern, and regional endemism has been recorded in the worm fauna, with two congeneric species known only from Leeuwin-Naturaliste and Nambung north of Perth, respectively (Pinder *et al.* 2006). It should also be noted that taxonomic concepts are primarily based on morphology and no genetic studies have been carried out to test for cryptic speciation.

Table 2. Results of sampling in bores by the Western Australian Museum on the Swan Coastal Plain within the rectangle defined by 31° 30'S 115° 30'E and 32° 12'S 116° 00'E. Note that the number of stygobionts is uncertain but likely to be few. Data supplied by W.F. Humphreys

Taxon	No. records	Comments
Protozoa		
'Paramecium'	1	
Rotifera		
rotifer	1	few rotifers other than bdelloids are stygobionts
Oligochaeta		
Antarctodrilus WA3	1	
Enchytraeidae spp	1	usually widespread
Crustacea		
Ostracoda		
ostracod	5	prob. 2 species
Cyclopoida		
Paracyclops fimbriatus	7	=*P. chiltoni*, widespread surface species
cyclopoid	1	2nd species of cyclopoid
Harpacticoida		
harpacticoid	2	
Syncarida		
Bathynellidae	1	bathynellids usually stygobionts
Decapoda		
shrimp	1	atyid?
crustacea larvae	3	Order unknown but perhaps decapods

Table 3. Results of sampling seven groundwater bores 12 times for stygofauna at Marbling Brook (Schmidt, 2005)

Higher Taxon	No. bores present	Comments
Nematoda	6	
Oligochaeta	6	
Ostracoda	2	1+ species of candonid
Copepoda	5	4+ species of cyclopoid, 5+ of harpacticoid
Syncarida	2	2 secies, 1 bathynellid, 1 parabathynellid
Amphipoda	4	2+ species
Acariformes	6	5+ species, 4+ oribatids

5.2 Stygofauna Habitat

Stygofauna occur in an array of different groundwater habitats including porous, karstic and fractured-rock aquifers, springs and the hyporheos of streams (Eberhard *et al*. 2005). Calcrete and alluvium are typically considered to be productive habitats for stygofauna, although mafic volcanics support rich stygofauna communities compared with the moderate abundance of communities in banded iron formation (Halse *et al*. 2014). The groundwater habitats on the Swan Coastal Plain that are likely to support stygofauna includee porous alluvium and colluvium, limestone karst, springs and the hyporheos of rivers and streams.

In these habitats, both lateral and vertical connectivity of fissures and voids are important for the occurrence of stygofauna. Lateral connectivity enables animals to move about underground, while vertical connectivity through to the surface enables recharge of carbon and nutrients to the stygofauna community. There is a clear correlation between transmissivity of an aquifer and its suitability for stygofauna.

Stygofauna have mostly been recorded in fresh to brackish groundwater but may occur in salinities (expressed as conductivity) of up to 55,000 µS/cm (ca. 35,000 mg/L) (Watts and Humphreys 2006; Schulz *et al*. 2013). Apart from salinity, the physicochemical tolerance of stygofauna to different groundwater parameters, especially in the Pilbara, has been poorly defined (see Halse *et al.* 2014).

Irrespective of the prospectivity of the geology, few species and only low numbers of individuals are expected to occur where depth to the water table is much more than 30 m (Halse *et al.* 2014). Similarly few species will occur at large depths below the water table because of the attenuation of carbon and nutrient inputs with depth, so that productivity is reliant on chemosynthesis (Porter *et al*. 2009)

6. LIKELIHOOD OF IMPACT ON STYGOFAUNA

The geology within the Leederville and Yarragadee Aquifers is likely to be suitably transmissive for stygofauna and the water is fresh (<500 mg/L TDS), so that it might be considered to provide suitable habitat for stygofauna. Injection of recharge water is proposed to occur at depths of 140 m – 400 m and ~1350 m (Rockwater 2008), so that it is unlikely stygofauna will occur in the zone of recharge owing to the presence of confining layers and the attenuation of carbon and nutrient inputs with depth. Accordingly, there is unlikely to be any conservation impact on stygofauna as a direct consequence of recharge.

There might, theoretically, be an impact on stygofauna if recharge of the underlying Leederville and Yarragadee Aquifers led to upwards movement of recharged water into the superficial aquifer, where stygofauna are likely to be present. In this regard, it should be noted that recycled water is required to meet only drinking water guidelines (Water Corporation 2015), which are less stringent than ecological guidelines for parameters such as nitrogen (ANZEEC 2000). With that caveat and without detailed analysis of water flows, mixing and likely realised water quality after injection, it is considered unlikely that there will actually be an impact on stygofauna for four reasons:

- The salinity of groundwater in all aquifers and the recharge water has similar magnitude (approximately 250 – 500 mg/L in the superficial aquifer on the Gnangara Mound, 150 – 350 in the Mirrabooka aquifer, <500 in the Leederville aquifer, <500 in the Yarragadee aquifer and <600 in recharge) (Davidson 1995).
- The Leederville recharge locations have been selected such that they are where the Wanneroo Member pinches out to provide maximum pressure benefit but prevent direct vertical flux to the superficial aquifer.
- Aquatic invertebrate species in south-western Australia, including stygofauna species, have evolved in a relatively saline landscape and have relatively high salinity tolerances. The differences in salinity levels in the different aquifers and recharge water are unlikely to be ecologically meaningful below 600 mg/L (Pinder *et al*. 2005).
- Most species occurring in the superficial aquifer are likely to be relatively widespread at the scale of water management operations (about 13 km). It is likely that most stygofauna species with restricted distributions occur in association with landscape features, such as the Yanchep caves, approximately 20 km north of the scheme (Jasinska and Knott 2000), rather than in more hydrogeologically uniform parts of the Swan Coastal Plain. For example, Tang and Knott (2009) recorded 14 groundwater copepod species from the Gnangara Mound, of which only two species were restricted to the Mound: *Eucyclops edytea* which occurs in springs and caves, and *Paranitocrella bastiani* which occurs only in caves.

7. SUMMARY AND CONCLUSIONS

The Water Corporation is proposing to implement an expansion of the Groundwater Replenishment Scheme (Stage 2) including off-site recharge of the confined aquifers. Water is proposed to be reinjected to the Leederville or Yarragadee aquifers where the superficial aquifer is disconnected from the deeper aquifers, but close enough to where the deeper aquifers are unconfined and this report assesses the likelihood of stygofauna being present at, or immediately adjacent to, the proposed recharge locations.

Reinjection to the aquifer is proposed to occur at depths of 140 m – 400 m and ~1,350 m. The density of stygofauna is usually inversely proportional to depth because carbon and nutrient inputs decline with depth. In theory, there might be an impact on stygofauna if recharge of the underlying Leederville and Yarragadee aquifers leads to upwards movement of recycled water into the superficial aquifer where stygofauna are likely to occur. In practice, however, owing to mixing of recycled water with surrounding aquifer water after injection, it is considered unlikely that there will be any changes in water quality that are sufficient to impact on stygofauna in the superficial aquifer. Furthermore, most species in the Gnangara Mound, where the scheme will operate, appear to have ranges that extend beyond the Mound and any possible extent of water quality changes.

Given that stygofauna are unlikely to occur in the vicinity of reinjection points of recycled water because injection is occurring deep in confined parts of the Leederville and Yarragadee aquifers and that the likelihood of water quality changes in the superficial aquifer appears to very low, no impact on stygofauna conservation values would be expected from Stage 2 of the Groundwater Replenishment Scheme.

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