Alcoa

Wagerup RSA 10
Baseline Aquatic Fauna Survey
Spring 2022

WRM Wetland Research & Management | PART OF SLR

Technical Report - Final

January 2023

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Aquatic Fauna Survey
Spring 2022

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Final Report
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Frontispiece (top left anti-clockwise to bottom right): Carter's freshwater mussel in Samson Brook site SP012; fyke nets set in the channel of the Harvey River main drain at SP015; Freshwater cobbler and western minnow caught at site SP015.

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EXECUTIVE SUMMARY

Alcoa's Wagerup alumina refinery is located approximately 130 km south of Perth metropolitan area, and 35 km south of the Pinjarra refinery, in the southwest region of Western Australia (WA). The refinery utilises a Residue Storage Area (RSA), located within the lower reaches of the Harvey River catchment. The reaches and tributary streams of the lower Harvey catchment are highly modified into trapezoidal drains, however, these waterways still provide ecological links between the lower reaches and upland forested streams of the Harvey River for aquatic fauna. The Department of Water & Environmental Regulation (DWER) and Environmental Protection Authority (EPA) consider these drains to be ecological systems under the Inland Waters factor, and DWER provide environmental flow from upstream dams to the Harvey River main drain to support downstream ecological values.

To support a proposed expansion of the RSA, Alcoa are undertaking a baseline ecological assessment of the areas to be disturbed. This assessment includes a baseline aquatic fauna survey of creeklines, drains and wetlands adjacent to and downstream of the proposed expansion. The Wagerup RSA 10 Aquatic Fauna Baseline Assessment was successfully completed between 17th – 21st October 2022. Aquatic fauna sampling was conducted at six creekline and three wetland sites in the Wagerup area. The survey included sampling of water quality, zooplankton, macroinvertebrates, fish, and targeted surveys for potential listed species such as freshwater mussel and black-stripe minnow.

The finding of greatest significance to the RSA 10 project was a population of the conservation-listed Carter's freshwater mussels, *Westralunio carteri*, at surface water sampling site SP012, located on Samson Brook, immediately downstream of where Yalup Brook enters Samson Brook. The ecologists captured 200 mussels from along an undercut clay bank over an approximate distance of 20 m. Due to the large numbers of mussels at this location, counting was capped at 200, and the actual size of population is likely to be higher. Smaller populations of mussels were also found at potential exposed site HRDS1, and both reference creekline sites.

Water quality analyte levels recorded from the study area in spring 2022 were generally below or within the Australian and New Zealand default water quality guidelines for the protection of freshwater ecosystems (ANZG 2018), and the Wagerup RSA interim site-specific guideline values (SSGVs) derived in the 2022 hazard analysis. The only analyte to record exceedances at the potential exposed creekline sites, and not the reference sites, was dissolved iron (at sites SP011, SP012 and SP023). The maximum concentration recorded in downstream creekline sites in spring 2022 was 0.73 mg/L at SP011. Currently, the freshwater DGV for iron is under review. Until a DGV is published, the hazard analysis proposed an interim SSGV of 0.56 mg/L for iron based on the 80th percentile of concentrations downstream of the RSAs.

The seasonally-inundated wetland area (a largely cleared, inundated paddock) to the west of the RSAs was sampled due to being identified as potential habitat for the black-stripe minnow, *Galaxiella nigrostriata*, which is listed as Endangered under the EPBC Act. No black-stripe minnows were captured at the three wetland sites sampled in this area. The presence of two common endemic fish species, Western minnow and Western pygmy perch, indicates that this area was likely connected to either Samson Brook or Yalup Brook surface water at some point during the winter months (unlike the black-stripe minnow, these species cannot survive drying, and this wetland area likely dries up during the summer months). In addition to these two native fish species, the wetland area supports at least 43 microinvertebrate and 50 macroinvertebrate taxa, a large number of tadpoles (species not determined), the introduced fish species Eastern gambusia and the introduced crayfish species, the yabby. While no listed conservation-significant aquatic fauna species were recorded in the wetland area, two cladoceran taxa (water fleas) recorded from these sites are likely to be new to science (Dr Russel Shiel, pers. comm., 14th December 2022).

The creekline sites downstream of the RSA10 area support Carter's freshwater mussel, along with at least 122 macroinvertebrate taxa, five native fish species, at least two native crayfish species, two introduced fish species, one introduced crayfish species. Western minnow were the most common fish species, followed by nightfish and western pygmy perch. The native south-western snake-necked turtle was also recorded at potential exposed site HRDS1. The state-listed rakali (Australian water rat, *Hydromys chrysogaster* Priority 4) was not targeted during this survey but was sighted at upstream reference site SPBG1, and is also likely to inhabit aquatic environments downstream of RSA10. A survey targeting rakali in the study area was undertaken by an independent terrestrial ecological consultant (Bamford Consulting Ecologists), therefore, targeted survey effort for rakali was removed from the scope of the aquatic fauna survey (Joel Batten and Ashley Sheardown, Alcoa Wagerup, pers. comm.). Other than the Carter's freshwater mussel and the rakali, none of the fauna species captured or sighted during this survey are conservation-listed at a state or federal level, however, the turtle species is listed as 'near threatened' at the international level, and its status has not been assessed for 20 years.

The dataset generated from this survey forms a good initial baseline against which potential impacts to water quality and aquatic fauna from the proposed expansion can be assessed. Additional baseline water quality data are required to strengthen the dataset to allow derivation of more robust SSGVs.

1 INTRODUCTION

1.1 Background

Alcoa are planning to expand the existing Residue Storage Area (RSA 10) at the Wagerup alumina refinery, approximately 130 km south of Perth metropolitan area, and 35 km south of the Pinjarra refinery, in the southwest region of Western Australia (WA). The development will involve construction of a new storage area RSA 10 (to the south of existing RSA 9) and the development of one or more clay borrow pits to the north of the RSA to provide material to line RSA10 (the Project) (Figure 1).

The Project area is located within the lower reaches of the Harvey River catchment, and encompasses a number of tributaries and drains coming off the escarpment and feeding the lower Harvey catchment (viz. Black Tom, Samson, Yalup, Bancell and Logue brooks). These reaches and tributary streams are highly modified into trapezoidal drains, with varying levels of maintenance. The natural hydrology of the lower Harvey River has been significantly altered since the 1900s by the construction of extensive irrigation and drainage systems for agriculture on the coastal plain. The coastal plain sumplands and drains within the footprint of the proposed and alternative RSA 10 and borrow pit locations were considered highly unlikely to provide significant habitat for conservation-significant aquatic species (WRM 2022a). However, the drains still provide ecological links between the lower reaches and upland forested tributaries of the Harvey River, where conservation significant fauna may reside. The Department of Water & Environmental Regulation (DWER) and Environmental Protection Authority (EPA) consider these drains to be ecological systems under the Inland Waters factor, and DWER provide environmental flow from upstream dams to the Harvey River main drain to support downstream ecological values.

By design, the Wagerup Refinery, including the RSA operates on an efficient closed water circuit with no net discharges of process water or residue to the environment (Alcoa 2017). However, the construction of RSA 10 and the clay borrow pits will require significant earthworks and dewatering to allow the excavation of clay below the water table. The area where the construction of RSA 10 is planned includes former run-off collection pond ROCP1, which was decommissioned in 2017 (Figure 1). ROCP1 stores caustic sand and sediments. A contaminated sites investigation has commenced as of late 2022, focussing on ROCP1 due to suspected leakage caused by potential failure of the liner. Possible pathways by which unplanned water discharge to the nearby sumplands and drainage channels, and ultimately the Harvey River, may occur during the development of RSA 10 were identified. These included:

- Groundwater seepage of residual water from ROCP1 from the weight of the RSA 10 liner construction. Modelling indicates this could flow south-west towards the Yalup Drain, which flows west, then north, into Samson Brook, which then drains to the Harvey River. An underdrain system may be installed to remove this residual water and prevent emissions to groundwater.
- Leakage from the dewatering infrastructure in the RSA, used to lower the groundwater table to limit hydraulic heave on RSA clay liners. This may also drain towards the south-west and Yalup Drain.
- Rainfall resulting in runoff from the RSA structures towards Yalup Drain and potentially the sumplands on the western boundary of the RSA site. However, the RSA has a 100% surface water containment policy and it is expected that stormwater will be controlled under all but the most extreme flood circumstances, when dilution is expected to be high.

To the north-east of the RSA, is a clay borrow pit which is periodically partially or completely dewatered This may result in drawdown of the water table with potential drying/altered hydrology of adjacent aquatic habitats. It is anticipated that all dewater water is re-used on site.

The entire area of the Wagerup Refinery including the RSA 10 proposed location sits within an area mapped as having a moderate to low risk of acid sulfate soils (ASS)[1]. Dewatering and excavation below the water table can cause acidification in ASS soils, if present. Acidification of groundwater may have deleterious effects to aquatic fauna in down gradient ecosystems.

As potential risks to adjacent and downstream aquatic environments through the development of RSA 10 were identified, Wetland Research & Management (WRM) were commissioned to undertake an aquatic fauna survey, including general aquatic ecosystem status/health sampling and targeted field sampling for conservation significant species, to establish baseline condition prior to the proposed RSA 10 development.

1.2 Scope

The scope of works for the RSA 10 baseline aquatic fauna survey, undertaken in October 2022, included:

- General aquatic ecosystem status/health field sampling, including water quality and key aquatic fauna components (microinvertebrate, macroinvertebrate, fish and crayfish),
- Targeted sampling for conservation-significant aquatic/semi-aquatic fauna species *Westralunio carteri* (Carter's freshwater mussel; EPBC Endangered) and *Galaxiella nigrostriata* (Black-stripe minnow; EPBC Endangered),
- Assessment of conservation status of recorded fauna,
- A technical report presenting the results of the survey and an assessment of risks to fauna recorded in downstream receiving environments posed by potential adverse water quality inputs from the RSA 10 development,
- Preparation of an Index of Biodiversity Surveys for Assessments (IBSA) data package in line with 'Instructions – IBSA Data Packages' (EPA 2018).
- Preparation and provision of all field data and spatial data captured in a suitable format (ESRI shapefile, Excel tables, etc.).

[1] Acid Sulfate Soil Risk Map, Swan Coastal Plain (DWER-055) - Datasets - data.wa.gov.au

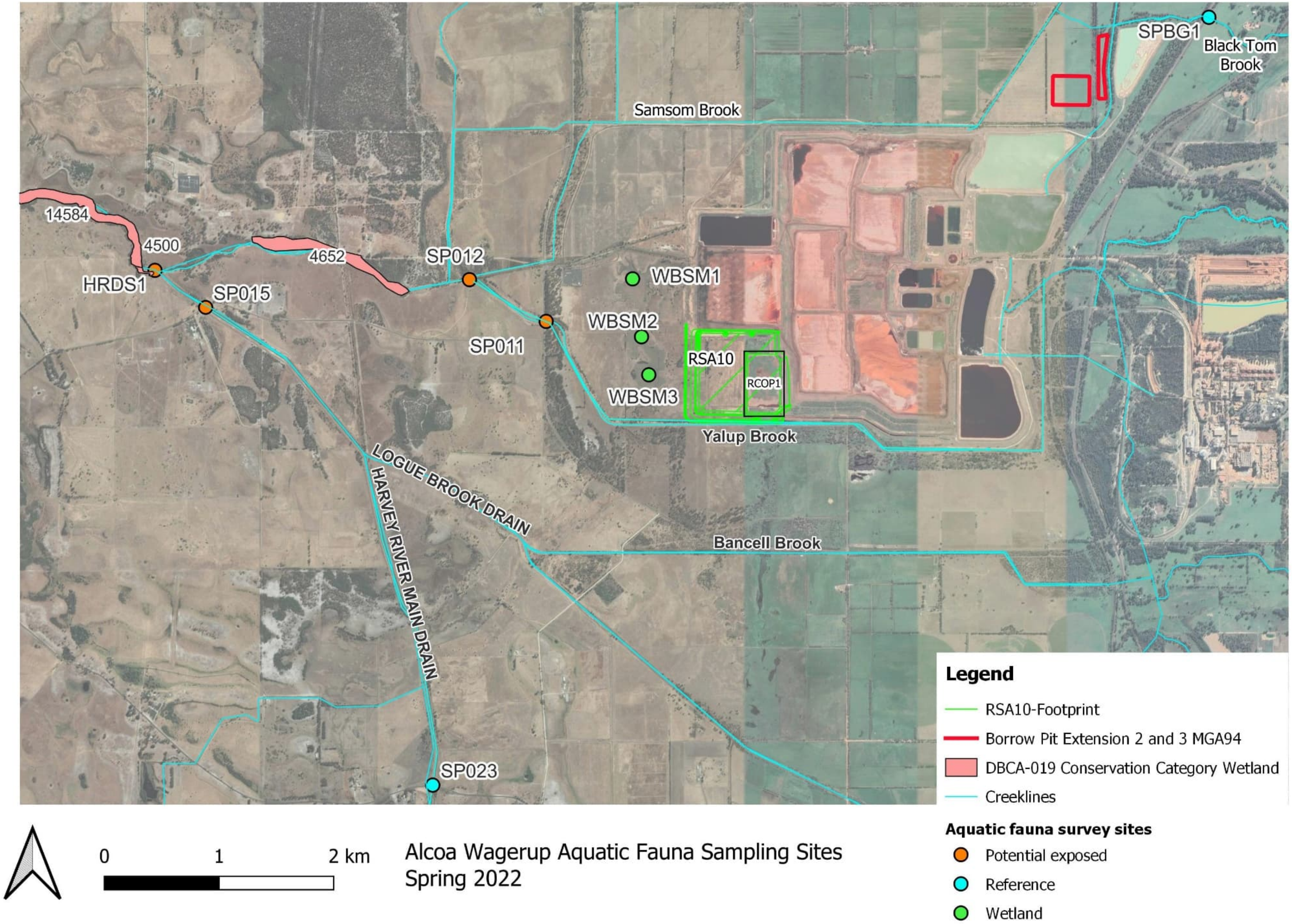


Figure 1. Project area - RSA 10 development footprint, surface water drainange lines, DBCA CCWs and aquatic fauna sampling sites.

2 LEGISLATIVE FRAMEWORK

Aquatic ecosystems and their dependent fauna are protected under a range of State and Federal policies and acts. The Western Australian Environmental Protection Authority's (EPA) environmental objective for *Inland Waters* is to maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected (EPA 2018). Inland Waters are considered to include groundwater systems, wetlands, estuaries, and any river, creek, stream or brook (and its floodplain), including systems that "flow permanently, for part of the year or occasionally, and parts of waterways that have been artificially modified" (EPA 2018). Environmental value is defined under the *Environmental Protection Act 1986* (EP Act) as a beneficial use or an ecosystem health condition. Aquatic fauna and flora and the ecological processes that support them are specifically listed in the Inland Waters Environmental Factor Guideline as one of the ecosystem health values that must be considered as part of the environmental impact assessment process (EPA 2018).

Impacts to the factor Inland Waters can impact the factor *Terrestrial Fauna* which encompasses freshwater fish (EPA 2016). The EPA's objective for the factor Terrestrial Fauna is: "To protect terrestrial fauna so that biological diversity and ecological integrity are maintained" (EPA 2016a).

There are multiple considerations for EIA for the factors Inland Waters and Terrestrial Fauna, however the focus for this desktop review was identifying the aquatic habitats and fauna values that may potentially be affected by the Project, and in particular:

- Threatened fauna species or communities listed as matters of National Environmental Significance (MNES) under the commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and ecosystems that support them;
- Threatened and Priority fauna species or communities listed under the state WA's *Biodiversity Conservation Act 2016* (BC Act), and ecosystems that support them;
- Wetlands of international importance as listed under the Ramsar Convention;
- Wetlands of national importance as listed in the Directory of Important Wetlands in Australia (DIWA);
- Wetlands protected by Environmental Protection Policies (EPP) under Part 3 of the EP Act;
- Conservation Category or Resource Enhancement wetlands as mapped by the Western Australian Department of Biodiversity, Conservation and Attractions (DBCA) *Geomorphic Wetlands of the Swan Coastal Plain* dataset (DBCA-19);
- Wetland types which may be poorly represented in the conservation reserves system;
- Springs and permanent pools which act as refugia;
- Short-range endemic (SRE) aquatic fauna.

Relatively few aquatic species in Western Australia are listed as threatened or endangered under the BC Act or EPBC Act. Aquatic invertebrates in particular, have historically been under-studied. Lack of knowledge of their distributions often precludes aquatic invertebrates for listing as threatened or endangered.

Aquatic fauna is encompassed by the EPA's *Terrestrial Fauna* factor, and their habitat is encompassed by the *Inland Waters* factor. Despite the Environmental Factor relating to *Inland Waters* being updated in 2018 (EPA 2018), there are still no prescriptive guidance statements at the state or Commonwealth level outlining surface water quality and aquatic fauna sampling design and methods. Therefore, the aquatic fauna sampling by WRM-SLR employs methods and general approaches / rationale consistent with the following:

- EPA Technical Guidance: Terrestrial vertebrate fauna surveys for environmental impact assessment (EPA 2020);
- EPA Technical Guidance: Sampling of short-range endemic invertebrate fauna (EPA 2016b);
- the National Monitoring River Health Program (NRHP) Australia River Assessment Scheme (AusRivAS);
- Wetlands of the Swan Coastal Plain: wetland classification on the basis of water quality and invertebrate community data (Davis et al. 1993);
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018), developed as part of the National Water Quality Management Strategy (NWQMS) (Australian Government 2018).

The Department of Biodiversity, Conservation and Attractions (DBCA) *Geomorphic Wetlands of the Swan Coastal Plain* dataset provides information on the location, boundary, geomorphic classification (wetland type) and management category of wetlands on the Swan Coastal Plain (code SWA) according to the Interim Biogeographic Regionalisation for Australia (IBRA) region. This classification is based on their potential ecological, hydrological geomorphological significance, as well as degree of disturbance. Within this dataset, wetlands of the SWA are assigned a geomorphic classification based on hydroperiod and landform (Table 1).

Table 1. Summary of wetland geomorphic classification as outlined by the DBCA's Geomorphic Wetlands of the Swan Coastal Plain dataset.

Hydroperiod	Landform				
	Basin	Channel	Flat	Slope	Highland
Permanent inundation	Lake	River	-	-	-
Seasonal inundation	Sumpland	Creek	Floodplain	-	-
Intermittent inundation	Playa	Wadi	Barlkarra	-	-
Seasonal waterlogging	Dampland	Trough	Palusplain	Paluslope	Palusmont

Wetlands of the SWA are also assigned one of three wetland management categories to broadly reflect their conservation value, which are summarised as follows:

1. Conservation Category Wetlands (CCW) – wetlands that support a high level of ecological attributes and functions (generally having intact vegetation and natural hydrological processes), or that have a reasonable level of functionality and are representative of wetland types that are rare or poorly protected.
2. Resource Enhancement Wetlands (REW) – wetlands that have been modified (degraded) but still support substantial ecological attributes (wetland dependant vegetation covering more than 10%) and functions (hydrological properties that support wetland dependent vegetation and associated fauna), and have some potential to be restored to the Conservation management category. Typically, such wetlands still support some elements of the original native vegetation, and hydrological function.
3. Multiple Use Wetlands (MUW) – wetlands that are assessed as possessing few remaining ecological attributes and functions. While such wetlands can still play an important role in regional or landscape ecosystem management, including water management, they are considered to have low intrinsic ecological value. Typically, they have very little or no native vegetation remaining (less than 10%).

The DBCA is also custodian of the *Consanguineous Wetlands Suites* dataset. Consanguineous wetlands suites are areas containing a group of wetlands that are considered to have common or interrelated features, based on geomorphic setting, origin and water maintenance. Assessment of these groups provide a regional perspective on natural wetland groups, and can also be used to determine if certain individual wetland types are rare or unusual within consanguineous suites, and are therefore of greater conservation value.

The DBCA provides methodological guidance on evaluating the conservation significance of SWA wetlands in their 2017 document *A methodology for the evaluation of wetlands on the Swan Coastal Plain, Western Australia,* while the Western Australian Planning Commission's most recent (October 2021) document, *Guideline for the Determination of Wetland Buffer Requirements* (Draft) (WAPC 2005), outlines how to identify an appropriate buffer between wetlands and adjacent landuses in order to enhance or maintain their significant attributes and values. In general, WAPC (2005) recommends a minimum of 50 m separation distance from surrounding landuse in order to protect their attributes and values. Accurately defining wetland boundary/function area are key considerations outlined in both of these documents. Definition of wetland boundaries and foreshore areas can also inform any requirement for licences under the *Rights in Water and Irrigation Act 1914* (RIWI Act) to interfere or obstruct the bed and banks of a wetland or watercourse.

3 STUDY AREA

The study area for the Spring 2022 Wagerup RSA 10 Aquatic Fauna Survey comprised the Project area and the surface water sampling locations detailed in Figure 1. The study area is located on the Pinjarra Plain, in the south-eastern margin of the Swan Coastal Plain, and in the Perth sub-region (SWA02) of the Swan Coastal Plain Interim Biogeographic Regionalisation of Australia (SWA IBRA) region as defined by the Department of Water and Environmental Regulation (DWER).

3.1 Climate

The study area experiences a Mediterranean climate of hot, dry summers and cool, wet winters. The major drainage catchment is the Pinjarra-Waroona-Harvey Drainage Catchment which receives an average annual rainfall of 850mm (1981 - 2021; BOM 2022). Typically, highest rainfall occurs between May and September (highest average monthly rainfall in July - 159 mm), and lowest rainfall occurs between October and April (lowest monthly average in December - 13 mm) (Figure 2). Rainfall recorded in July and August 2022 was approximately 20% above the long-term average. However, rainfall recorded in September and October, in the lead up the Spring 2022 survey in mid-October, was approximately 50% below the long-term average.

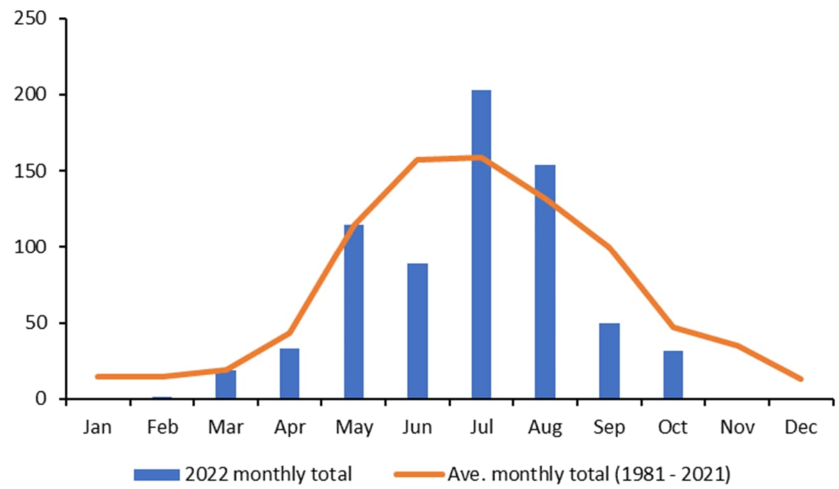


Figure 2. Total monthly rainfall recorded at Bureau of Meteorology station 9894 (Wagerup Refinery) in 2022, compared to the long-term average (1981 to 2021).

3.2 Surface water hydrology

The study area is located within the lower Harvey River catchment and is surrounded by agricultural lands. The majority of natural watercourses and wetlands in the catchment are highly modified by vegetation clearing and by drains constructed for winter flood relief and irrigation in the early 1900's (Streamtec 2000, Environ 2005). Many of the natural seasonal and perennial wetlands were drained, while riverine flats and riparian vegetation were preferentially cleared for agriculture, and are some of the most heavily cleared and degraded habitats in the catchment. Vegetation clearing and drain construction has significantly altered the hydrology of the catchment. Runoff from the catchment is considered to be much greater than under pre-European conditions (by an estimated 300% for the lower Harvey sub-catchment) (Environ 2005), though reduced rainfall due to climate change has reduced catchment runoff and streamflow by up to 40% since the 1970s.

Surface water flows into the refinery area from the east, via North and South Yalup brooks, and from the north, via Samson Brook South Drain and Black Tom Brook through the Wagerup Diversion Drain (Figure

1). Two dams on South Yalup Brook (Upper and Lower South Yalup dams) are used for refinery supply. A pipehead dam on North Yalup Brook diverts a small amount of water into Upper South Yalup Dam to supplement supply. Any surplus yield from these dams eventually flows into the Diversion Drain. The Diversion Drain diverts water from South Samson Drain (SSD) through the Detention Pond area and around to the south, of the existing RSA including the proposed RSA 10 site, before reconnecting with SSD to the west of the existing RSAs. The SSD runs along the northern boundary of the existing RSAs, around the alternative RSA 10 location, and converges with the Diversion Drain and Samson North Drain (SND), and then the Harvey Main Drain approximately 3.5 km west of the Project (Figure 1). Bancell Brook Drain and Logue Brook Drain lie to the south of the refinery. WRM (2022a) found strong historic[2] seasonality in water levels in SSD, corresponding to rainfall, with low levels in summer (minimum monthly average 0.09 m) and high levels in winter (maximum monthly average 0.35 m). Seasonality was far less pronounced for surface water levels in SND, with monthly averages ranging from 0.27 m (April) to 0.48 m (October), presumably due to environmental/irrigation releases. The volume of surface water in the Samson Brook drains can vary by orders of magnitude depending on a number of factors, including, rainfall, agricultural irrigation demands during summer and associated environmental releases/compensation flows from upper dams on the Darling Scarp, i.e., Samson Brook Dam (12 km ENE), Drakesbrook Weir (6.5 km NE) and Waroona Dam (9.3 km NE).

Under conditions of the refinery lease, run-off from residue and the refinery areas must be strictly controlled to prevent contamination of adjacent streams and downstream receiving systems (Alcoa 2017). The understanding is that the water management systems are designed to cope with extreme rainfall events (e.g., cyclonic) to ensure surface runoff and discharge is contained. All dewatering and runoff water from Project construction area are expected to be captured and retained on-site as process water.

3.3 Groundwater hydrology

Groundwater in the Project area flows generally in a westerly direction and south-westerly through the proposed RSA 10 site. Groundwater levels are highly seasonal, and shallow groundwater and surface water are thought to be connected (Environ 2005). Groundwater discharges to the surface at a number of points both within and immediately west of the existing residue area (Nield 2000). Previous investigations by Alcoa have determined that expanded pumping of shallow groundwater in the area is highly undesirable, as the associated decline in water levels has the potential to accelerate seepage from existing residue areas and impact on other nearby users (Environ 2005). The understanding for the current Project is that the cone of depression associated with any groundwater drawdown due to dewatering for construction, will be highly localised.

A potential risk identified by Alcoa is the mobilisation of contaminants from the decommissioned ROCP1 during construction and operation of RSA 10 in the vicinity of the ROCP1 site (Figure 1). If not managed, leachate (if any) may potentially reach the Diversion Drain that flows along the southern perimeter of the proposed RSA 10 site.

3.4 Significant aquatic fauna habitats

The desktop review (WRM 2022a) found no Conservation Category (CCW) or Resource Enhancement (REW) wetlands, as listed under Geomorphic Wetlands, Swan Coastal Plain (DBCA-019), within the Project area. The drains in and around the Project area are all classified as Multiple Use Wetlands (MUWs) and are predominantly farmland used for grazing livestock. Downstream and to the west of the study area/Project area, there are four CCWs and five REWs. The CCWs on Samson Brook (wetland UFI 4652) and on the Harvey River (wetlands UFI 4500 and UFI 14584) are the nearest significant aquatic fauna habitats downgradient of the Project area (Figure 1).

[2] DWER ceased monitoring water levels in SSD in 1990 and SND in 2007.

In general, CCWs are categorised on the basis of having “a reasonable level of functionality and are representative of wetland types that are rare or poorly protected”, while REWs are categorised as “degraded, but still supporting substantial ecological attributes and functions” (DBCA 2020). However, current management categories for the CCWs and REWs in the vicinity of the Project appear to be based solely on the 1996 report, Wetlands of the Swan Coastal Plain Volume 2B Wetland Mapping, Classification and Evaluation: Wetland Atlas (Hill et al. 1996). The literature search did not find any recent field surveys confirming the current ecological condition of these wetlands.

3.5 Conservation-significant aquatic fauna

WRM (2021) identified two aquatic fauna species listed under the EPBC Act that had been recorded within 50 km of the Project prior to the Spring 2022 survey:

- *Westralunio carteri* Iredale, 1934 (Carter’s freshwater mussel).
- *Galaxiella nigrostriata* Shipway, 1953 (black-stripe minnow, blackstriped dwarf minnow).

Carter’s freshwater mussel, *W. carteri*, (“CFM”; Plate 1) is listed as Vulnerable on the IUCN Red List (IUCN 2019), nationally under the EPBC Act and at state level under the BC Act (DBCA 2021). Nearest records to the Project were for Logue Brook Drain at the junction of Trotter Road (~1 km south) and at the junction of Brockman Road (~2 km south). *W. carteri* have also recently been recorded from degraded coastal plain reaches of Samson Brook, immediately east of SW Highway, 3 km NNE of the Project area (WRM 2020, 2021). There are no records of these mussels within the Project area. However, based on their nearby occurrence and known habitat preferences, there is moderate to high likelihood of *W. carteri* occurring in the Project area. Further information about CFM biology is provided in section 5.5.1.

The species preferentially occurs in slower flowing perennial waters where sediments are stable and soft enough to allow the species to burrow (< 10 cm depth) (DWER 2021). However, *W. carteri* also occurs in lentic (still water) waters including large water supply dams and on-stream farm dams (DWER 2021). The species is vulnerable to prolonged drying and cannot withstand exposure for longer than five days without moist sediments and shade. When allowed to burrow or if shaded, mussels can survive at least 62 days out of water (Lymbery et al. 2021). Aerial imagery (Landgate SLIP imagery online) indicates suitable habitat may exist in vegetated sections of the Diversion Drain downstream of Browns Farm borrow pit, and in Samson Brook South Drain downstream of the alternative RSA 10 location.

The black-stripe, or blackstriped dwarf minnow, *Galaxiella nigrostriata*, is currently listed as Endangered nationally under the EPBC Act and at state level under the BC Act (DBCA 2021). This species is endemic to southwest WA and rare throughout its distribution. Given the recent and past records of *G. nigrostriata* in highly disturbed, seasonal wetlands on the coastal plain (Morgan et al. 1998, Allen et al. 2002, WRM 2019), it is considered possible *G. nigrostriata* may occur in similar sumpland habitats within and around the Project area (Table 5).

The black-stripe minnow is restricted to shallow, tannin-stained, seasonal and ephemeral pools, with limited connectivity to other waterbodies (Morgan & Gill 2000, Galeotti 2013). Its main distribution lies within 100 km of the coast, between Albany and Augusta, with isolated populations known from further north, including Lake Chandala (Gingin), Melaleuca Park (Perth), wetlands at Kemerton (Bunbury) (Morgan et al. 1998, Allen et al. 2002) and wetlands to the south of the project area, surrounding Bunbury airport and at Gelorup (WRM 2019). Aerial imagery (Landgate SLIP imagery online) indicates suitable habitat may exist in sumplands adjacent the western boundary of the proposed RSA 10 location, and ~1.2 km SW of the Project area, upstream of the confluence of Logue Brook Drain and Harvey River Main Drain.

Black-stripe minnow are capable of aestivating in cool moist soils to survive dry periods and will appear in pools within hours following first rains. Interestingly, the species does not have any specific anatomical, physiological, or behavioural adaptations to aid aestivation, and presumably survives within moist soils or crayfish burrows that contain water through the dry summer-autumn season. Breeding occurs in spring (May to October) when seasonal habitats are typically inundated. Most fish only live for one year, dying shortly after spawning. It is thought that the populations in the SWA IBRA region are remnants of a once wider distribution (Morgan et al. 1998), suggesting that the loss of habitat caused by urban and rural development during the previous hundred years has had a significant impact on this species.

No other aquatic fauna species listed under the EPBC Act were identified as likely to occur in the vicinity of the study area or Project area. This was based on the fact that there are no records within 50 km, and suitable habitats are highly unlikely to occur within or around the study/Project area.

3.5.1 Other protected fauna

The study/Project area is also within the known distribution of one WA-state Priority species (WRM 2022), the rakali, or Australian water rat, *Hydromys chrysogaster* Priority 4 (Near Threatened, DBCA 2021). Literature and database searches returned recent records of rakali within 10 km of the Project area. Though rakali have been observed in irrigation channels and farm dams, it is unlikely that the Project area provides suitable habitat for these semi-aquatic mammals as there is little riparian vegetation or root material for them to shelter and burrow in. However, it is considered highly likely that Rakali occur downstream in Samson Brook, Harvey River and nearby Logue Brook Drain, where there is remnant riparian vegetation. A survey targeting rakali in the study area was undertaken by an independent terrestrial ecological consultant (Bamford Consulting Ecologists), therefore, targeted survey effort for rakali was removed from the scope of the aquatic fauna survey (Joel Batten and Ashley Sheardown, Alcoa Wagerup, pers. comm.).

4 METHODS

This study was conducted under Department of Primary Industries and Regional Development (DPIRD) Fisheries Licence EXEM 3407, and DBCA fauna taking (scientific or other purposes) licence BA27000735 and an Authorisation to take or disturb threatened species (TFA) 2223-0096. As a condition of these licences, taxa lists and reports are required to be submitted to DPIRD and DBCA.

Sampling was conducted over five consecutive days, 17th – 21st October 2022.

Aquatic fauna sampling by WRM is consistent with methodology used by others in similar surveys across Australia (i.e., Cheal et al. 1993, Storey et al. 1993, Edward et al. 1994), including the sampling of wetlands of the Swan Coastal Plain (SCP) by Murdoch University (Davis et al. 1993) and the National Monitoring River Health Initiative (Department of Environment Sport and Territories et al. 1994).

4.1 Sampling Sites

Sampling for water quality and aquatic fauna was conducted at the following site locations (Figure 1):

a) Potentially exposed creekline sites downgradient of RSA 10 (4): SP011 (Yalup Brook), SP012 (Samson Brook), SP015 (Harvey River) and a site downstream of Samson Brook confluence with Harvey River (HRDS1).
b) Reference creekline sites upgradient of Wagerup Refinery, RSA and Borrow Pits (2): SPBG1 (Black Tom Brook) and SP023 (Harvey River).
c) Black stripe minnow targeted wetland sites: three sites located in the seasonally-inundated wetland to the west of the RSAs.

Photographs of sites are provided in Appendix 1.

Table 2. Site locations for the 2022 survey. Coordinates are provided in UTM datum MGA94, zone 50.

Site	Date sampled	Easting	Northing	Habitat type	Category	Max channel width (m)	Max water depth (m)
WBSM1	19-10-2022	393234	6358610	Wetland	Potential exposed	2	0.5
WBSM2	19-10-2022	393250	6358033	Wetland	Potential exposed	1.5	0.5
WBSM3	19-10-2022	393309	6357760	Wetland	Potential exposed	1.2	0.5
SP011	17-10-2022	392488	6358158	Creekline	Potential exposed	2	1
SP012	17-10-2022	391815	6358516	Creekline	Potential exposed	4	0.6
SP015	18-10-2022	389517	6358248	Creekline	Potential exposed	3	1.2
HRDS1	18-10-2022	389071	6358566	Creekline	Potential exposed	3.5	1.5
SP023	20-10-2022	391543	6354126	Creekline	Reference	5	0.6
SPBG1	18-10-2022	398241	6360860	Creekline	Reference	1.5	0.5

4.2 Sampling Methods

4.2.1 Water Quality

Surface water quality sampling was conducted at all sites. Methods included *in situ* measurement of pH, redox potential, dissolved oxygen (DO) and water temperature using calibrated hand-held field meters, and gulp samples for major component analysis by a NATA accredited laboratory. The suite of parameters for laboratory analysis included electrical conductivity (EC; µS/cm), turbidity (NTU), total dissolved solids (TDS), alkalinity, hardness, major ions (Ca, Cl, HCO_3, K, Mg, Na, SO_4), SiO_2, nitrogen (TN, N-NH_3, N-NO^3, N-NO_2), phosphorus (TP, P-SR), total suspended solids, and dissolved metals (Ag, Al, As, Ba, Cd, Co, Cr, Cu, Hg, Mg, Mn, Mo, Ni, Pb, Se, U, V Zn). Laboratory analyses was conducted by ChemCentre WA, Bentley

(NATA accredited). Units of measure and limits of reporting were suitable for comparison against ANZG (2018) guidelines for protection of 95% of freshwater species.

For stressors, such as conductivity, pH, dissolved oxygen, temperature and turbidity, which typically display naturally high variability, ANZG (2018) recommend the use of local default guideline values (GVs; Appendix 2) where available, or development of site-specific GVs (SSGVs). The recently finalised Wagerup RSA Hazard Analysis (WRM 2022b) proposed a suite of interim SSGVs, developed in accordance with ANZG (2018). These SSGVs are “interim” as more data are needed to improve the confidence in these SSGVs to protect at least 95% of aquatic fauna from potential harm in the event of any unplanned releases of contaminated water to surrounding environments. The interim SSGVs have been applied for the current report and are provided in Appendix 2.

4.2.2 Aquatic Habitat Evaluation and Characterisation

Qualitative visual observations of habitat characteristics were made at all sites sampled, to assist in interpreting any patterns in species assemblages. WRM have standard worksheets for this task so that recordings between sites and seasons remain as comparable as possible. Habitat characteristics recorded included percent cover by inorganic sediment, submerged macrophyte, floating macrophyte, emergent macrophyte, algae, large woody debris, detritus, roots and trailing vegetation. Details of substrate composition were also recorded and included percent cover by bedrock, boulders, cobbles, pebbles, gravel, sand, silt and clay. General observations regarding the condition of wetland habitat and disturbance were made, with site photographs taken.

4.2.3 Fish and Crayfish

All sites were sampled for fish and crayfish. A range of sampling methods were used in order to maximise the number of fish and crayfish caught at each site. Methods included electrofishing, box traps, fyke nets, and visual observation. Box traps comprised of up to five large traps (21 x 47 x 60 cm, 3 mm mesh, mesh slit opening) and five small traps (26 x 26 x 46 cm, 20 mm mesh, 50 mm diam. opening), each baited with a mixture of cat biscuits and chicken pellets. Two fyke nets comprising a double 10 m leader/wing (7 mm mesh, 1.5 m drop) and a 5 m hooped net (75 cm diam. semi-circular opening, 10 mm mesh) were also set at each creekline site overnight, one facing upstream and the other facing downstream, to capture fauna moving upstream/downstream. A floating fauna platform was placed at the cod-end (closest to the bank) to provide an air space for any freshwater turtles or water rats, if present.

Targeted sampling for black-stripe minnows, *Galaxiella nigrostriata* (EPBC Endangered), was undertaken in wetland (sumpland) habitats (3 sites) to the west of the RSAs. The most effective method for surveying conservation listed minnow species is fyke nets and dip netting. At least three fyke nets, comprising two double wings fyke nets and one single wing (a 5.5 m leader/wing and a 3 m hoop) fyke net, were set at each wetland site overnight. A floating fauna platform was placed at the cod-end (closest to the bank) to provide an air space for any freshwater turtles or water rats, if present.

All species were identified in the field, measured by standard length[3] (SL mm, for fish) or carapace length (CL mm, for crayfish) and then released alive. Any introduced species collected (e.g., mosquitofish *Gambusia holbrooki*) were recorded, and euthanised humanely on site in an ice slurry in an esky. Fish nomenclature followed that of Allen et al. (2002).

[3] Standard length (SL) = tip of the snout to the posterior end of the last vertebra (i.e., this measurement excludes the length of the caudal fin). Carapace length (CL) = anterior tip of the rostrum to the posterior median edge of the carapace.

4.2.4 Carter's freshwater mussel targeted sampling

Targeted searching for mussels was undertaken in the inundated channel area of creekline sites, over a distance of approximately 50 m in channel length, targeting preferred habitat (i.e., underneath shading structure such as along undercut banks). In order to establish the presence of mussels in the search area, a range of methods were used, including visual observations for shells, manual hand sorting through benthic sediments, and the gentle use of mussel rakes and wire baskets where water depth allowed. The total number of mussels captured at each site was recorded. All mussels were gently returned alive to the site of capture. These targeted survey methods for CFM followed that of Klunzinger et al. (2012) and the *Technical Guidance – Terrestrial vertebrate fauna surveys for environmental impact assessment* (EPA, 2020).

4.2.5 Aquatic macroinvertebrates

A 250 µm Freshwater Biological Association (FBA) 'D' frame style dip net was used to selectively collect benthic macroinvertebrates at all wetland and creekline sites, and involved kick-sweep sampling over an equivalent 50 m x 0.3 m area within each site in order to provide a semi-quantitative measure of richness and abundance. All mesohabitats at a site were sampled, including trailing riparian vegetation, woody debris, open water column and benthic sediments, with the aim of maximising the number of species recorded. Each sample was washed through a 250 µm sieve to remove fine sediment, with any large coarse material (i.e., leaves, roots etc.), carefully washed in the sieve to remove attached fauna and discarded. Samples were then transferred to a 1L polypropylene container and preserved in 70% ethanol for laboratory enumeration and identification.

In the laboratory, each sample was sorted into different size fractions (1 mm, 500 µm and 250 µm) by washing through a series of sieves. Each size fraction was then sorted under high-power microscope to remove a maximum of 40 specimens of each family (or sub-family for Chironomidae). All specimens were identified to the lowest taxonomic level practicable (typically species or genus) and enumerated to $\log_{10}$ scale abundance per sample for all fractions combined (i.e., 1 = 1 individual, 2 = 2 - 10 individuals, 3 = 11 - 100 individuals, 4 = 101 - 1,000 individuals, etc.). In-house expertise was used to identify invertebrate taxa using available published keys and through reference to the established voucher collections held by WRM. Taxa that could not be identified to species level generally were assigned a voucher number and lodged in the WRM voucher collection.

4.2.6 Microinvertebrates (zooplankton)

Microinvertebrates were only sampled at the wetland sites, as the majority of aquatic microinvertebrate species have a preference for still-water or low-flow waterbodies. One composite microinvertebrate sample was collected from each wetland site, by gentle sweeping with a 53 µm mesh plankton net over an approximate total distance of 20 m of open water. Care was taken not to disturb the benthos (bottom sediments) during sampling. Samples were preserved in ethanol in the field, and sent to Dr Russell Shiel for processing. Dr Shiel is a world authority on microfauna, with extensive experience in fauna survey and impact assessment across Australasia, including the south-west of Western Australia.

In the laboratory, microinvertebrate samples were processed by identifying the first 200 individuals encountered in an agitated sample decanted into a 125 mm^2 gridded plastic tray, with the tray then scanned for additional missed taxa also taken to species, and recorded as 'present'. Specimens were identified to the lowest taxon possible, i.e., species or morphotypes. Where specific names could not be assigned, vouchers were established. These vouchers are held by Dr Shiel.

4.3 Data Analysis

All data collected were entered into Excel spreadsheets. Other data generated as part of the project included:

- an IBSA data package in line with 'Instructions – IBSA Data Packages' (EPA 2021);
- all field data and spatial data captured in a suitable format (GIS shapefiles, Excel spreadsheets, etc.).

4.3.1 Assessment of Conservation Status of Fauna

Conservation significant species were identified as those:

- listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act),
- listed under the WA *Biodiversity Conservation Act 2016* (BC Act) as Threatened or Priority species, as listed on the DBCA Threatened and Priority Fauna List (DBCA 2021),
- listed as Near Threatened, Vulnerable, Endangered or Critically Endangered on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2021),
- listed on the Australian Society for Fish Biology Conservation List (ASFB 2018), and/or
- potential or known short range endemic (SRE) freshwater invertebrate species, that have naturally small distributions of less than 10,000 km^2 (after Harvey 2002), as described by the EPA (2016c) for the purposes of environmental impact assessment.

4.4 Survey limitations

Table 3 below summarises the potential limitations and constraints affecting the Alcoa Wagerup RSA 10 aquatic fauna survey.

Table 3. Survey limitations.

Aspect	Constraint?	Comment
Competency	No	The survey was conducted by two aquatic ecologists with prior experience in both general and targeted fauna surveys in South West Western Australia aquatic ecosystems. The combined number of years' experience in aquatic ecology held by the personnel is 11 years. Both personnel hold university-level degrees in biological sciences. The survey was conducted under a Fauna Taking (Biological Assessment) Licence and an Authorisation to Take or Disturb Threatened Species issued by DBCA on the 5th October 2022.
Scope	No	The scope was prepared by Alcoa and WRM-SLR, informed by the consultants knowledge of previous, similar assessments and limited to areas downgradient of the proposed RSA location and reference sites outside the potential impact area. The scope is considered sufficient to characterise the current ecological condition of aquatic environments downgradient of RSA 10.
Fauna detected if present in the survey area	Minor	It was not feasible to sample the entire area that may be affected by the proposed RSA, therefore seven sites representative of habitat areas and locations present in downgradient areas were selected and targeted for sampling to maximise species detection. Rare species with low abundance may not have been detected. A desktop assessment was conducted prior to the survey to identify all fauna likely to be present in the survey area.
Sources of information	No	The previous desktop assessment collated the previous findings in the region as presented in publicly available reports and databases.
The proportion of the task achieved and further work	No	The surveys were completed adequately, carried out to a sufficient level with respect to the scope.
Timing/weather/season/cycle	No	Surveys were carried out in favourable conditions. Timing of the survey was not a limitation for the survey.
Disturbances	No	There were no disturbances that affected the survey.

Aspect	Constraint?	Comment
Intensity (in retrospect was the intensity adequate)	No	Based on the results the survey intensity is considered adequate to have met the scope.
Completeness (e.g., was relevant area fully surveyed)	Minor	It was not feasible for the entire area of possible habitat within the survey area to be sampled for aquatic fauna. Areas of representative habitat were selected and targeted to maximise species detection.
Resources	No	The resources made available to the survey were sufficient.
Remoteness and/or access problems	No	There were no barriers to accessing the selected survey sites.

5 RESULTS AND DISCUSSION

5.1 Water quality

Water quality analyte levels recorded from the study area in spring 2022 were generally below or within the ANZG (2018) DGVs and Wagerup RSA interim SSGVs (Table 4). In general, analytes which recorded exceedances of SSGVs and/or DGVs at potential exposed sites downgradient of RSA 10 also recorded exceedances at one or both upgradient reference sites. Examples of this included:

- Alkalinity, which exceeded the SSGV in the potential exposed wetland sites and at both creekline reference sites
- Dissolved copper, which exceeded the SSGV in the potential exposed creekline sites (except for SP011) and at both creekline reference sites,
- EC, which exceeded the SSGV and/or the DGV at all sites,
- Na, which exceeded the SSGV at one wetland site, the two Harvey River potential exposed creekline sites, and the Harvey River reference site,
- N-total, which exceeded the SSGV at all wetland sites, and above the DGV at creekline sites (both potential exposed and reference),
- P-total, which exceeded the DGV, but not the SSGV, at all sites except SPBG1, and
- Dissolved vanadium, which exceeded the SSGV at the two Harvey River potential exposed creekline sites, and the Harvey River reference site.

The only analyte to record exceedances at the potential exposed creekline sites, and not the reference sites, was dissolved iron (at SP011, SP012 and SP023). While iron is an essential trace element for both plants and animals, acute toxicity to aquatic insects has been reported (Warnick & Bell 1969, ANZG 2018). Currently, the freshwater DGV for iron is under review. Until a DGV is published, WRM (2022) proposed an interim SSGV of 0.56 mg/L for iron based on the 80th percentile of concentrations downstream of the RSAs. The maximum concentration recorded in downstream creekline sites in spring 2022 was 0.73 mg/L at SP011.

Table 4. Water quality recorded at the aquatic fauna survey sites in spring 2022, compared with the Wagerup RSA interim SSGVs (WRM 2022b) and ANZG (2018) DGVs. Recorded values which exceeded (or fell outside the range of) the ANZG DGV are highlighted pale orange, and values which exceeded (or fell outside the range of) the Wagerup RSA interim SSGVs are highlighted yellow.

Analyte		**ANZG (2018)**	**Interim SSGV**	**Potential exposed**							**Reference**	
				Wetland			**Creekline**				**Creekline**	
		95% TV		**WBSM1**	**WBSM2**	**WBSM3**	**SP011**	**SP012**	**SP015**	**HRDS1**	**SP023**	**SPGB1**
Al (pH>6.5)	T	0.055	**0.055**	0.009	<0.005	0.008	0.008	0.015	0.12	0.11	0.12	0.009
Alkalinity (as $CaCO_3$)		np	**63**	85	67	43	46	52	42	46	68	75
As-total	T	np	**np**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	T	0.94	**np**	0.011	0.018	0.023	0.038	0.039	0.045	0.046	0.044	0.054
Ca	E	np	**np**	24	20.3	8.4	8.1	9.1	12.8	14.3	15.9	17.5
Cd	T, H	0.0002	**0.0002**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cl (chloride)	E	np	**np**	215	170	67	106	122	167	188	190	110
CO_3	E	np	**np**	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cr (VI)	T	0.001	**np**	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cr-total	T	np	**0.001**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cu	T	0.0014	**0.0028**	0.0011	0.008	0.0008	0.0009	0.0064	0.0017	0.0054	0.0085	0.0031
DO-field (% sat)		85-120	**85-120**	97	119.6	65.5	48.7	60.4	126.2	122.6	122.2	94.1
EC (uS/cm)	E	300	**616**	866	690	312	443	500	679	765	815	563
F	T, F	2.4	**2.4**	0.13	0.13	0.11	0.09	0.09	0.08	0.08	0.1	0.06
Fe	T, F	np	**0.56**	0.1	0.1	0.17	0.73	0.71	0.54	0.59	0.48	0.16
Hardness (as $CaCO_3$)		np	**np**	190	150	68	57	66	100	120	110	96
HCO_3	E	np	**np**	104	82	53	57	63	51	56	82	91
Hg-inorganic	T, B	0.00006	**0.00006**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
K	E	np	**np**	3.5	2.4	4.1	1.1	1	3.2	3.1	5.4	2
Mg	E	np	**np**	32.4	25.2	11.4	9.1	10.5	17.1	19.3	16.4	12.8
Mn	T	1.9	**1.9**	0.0052	0.0052	0.018	0.01	0.021	0.014	0.021	0.039	0.063
Mo	T, M	0.073	**0.073**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Na	E	np	**78.4**	88.7	66.6	32.4	61.3	70.3	87.6	97.2	108	68
Ni	T, H	0.011	**0.011**	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$N\text{-}NH_3$	T	0.9	**0.9**	0.01	0.02	0.03	<0.01	<0.01	<0.01	0.03	<0.01	0.02
$N\text{-}NO_x$ (eutrophication)		0.15	**0.15**	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.04	<0.01	0.22
$N\text{-}NO_2$		np	**np**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NO_3	T, N	9.3	**9.3**	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.18	<0.04	0.97
N-total (eutrophication)		0.3	**1.66**	2	2	2	0.79	0.79	0.67	0.59	0.9	0.38
FRP (eutrophication)		0.04	**0.054**	<0.01	<0.01	0.02	0.01	0.02	<0.01	<0.01	0.02	<0.01
P-total (eutrophication)		0.01	**0.166**	0.079	0.13	0.096	0.16	0.12	0.087	0.058	0.084	0.01
Pb	T, H	0.0034	**0.0034**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0002	0.0002	<0.0001
pH-field (H^+)		6.5 - 8.0	**6.5 - 8.0**	7.26	7.16	6.92	6.83	7.09	7.62	7.51	8.4	7.74

Analyte		ANZG (2018) 95% TV	Interim SSGV	Potential exposed							Reference	
				Wetland			Creekline				Creekline	
				WBSM1	WBSM2	WBSM3	SP011	SP012	SP015	HRDS1	SP023	SPGB1
Redox (mV)		np	**np**	-8.5	-4.7	13.9	-17.7	2.5	-28.2	-23.4	-74	-36.6
Sb	T	0.009	**0.009**	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Se-total	T, B	0.005	**0.005**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO_4	E	np	**np**	18.5	18.3	12.7	12.9	14.6	38.1	38.9	45.7	37
TDS		np	**np**	480	380	170	240	280	370	420	450	310
Temperature-field (ºC)		np	**np**	22.7	23.1	22.8	21.2	21.9	22.5	21.9	20.9	17.9
Turbidity-field (NTU)	ID	20	**20**	4.4	2.1	2.6	4.4	5.3	19	12	15	2.6
U	T	0.005	**0.005**	0.0004	0.0002	<0.0001	<0.0001	<0.0001	0.0003	0.0003	0.0005	0.0001
V	T	0.0006	**0.001**	0.0004	0.0002	0.0003	0.0005	0.0007	0.0012	0.0012	0.0015	0.0001
Zn	T, H	0.008	**0.008**	0.003	0.004	0.003	0.004	0.004	0.007	0.006	0.007	0.003

Notes:

B = ANZG (2018) 99% species protection level TV recommended due to the ability of these metals to bioaccumulate. However, laboratory analysis of mercury for routine screening is only achievable to 0.0001 mg/L Hg-inorganic or 0.00005 mg/L Hg-total: the latter by persulphate digestion on low salinity samples.

E = Conductivity (EC) and associated ions (e.g., Ca, Mg, SO_4) will vary depending on flow; values higher than the preliminary GV may occur naturally in seasonal sites during the drying phase if water levels are reduced due to evapo-concentration.

F = ANZG (2018) state the DGVs for F and Fe are under review and recommend use of a site-specific GV where background levels are higher than the DGV. Interim guideline values for fluoride (mg/L) in freshwaters have been proposed as 3.4 mg/L for 90% species protection, 2.4 mg/L for 95% species protection, 1.4 mg/L for 99% species protection (R. van dam, pers. com).

H = GV should be modified for water hardness at the time of sampling using the default algorithms in Tables 3.4.3 and 3.4.4 of ANZG (2018). Note, worldwide literature reports the default hardness modified trigger value (HMTV) for Cu may not be sufficient to protect key sensitive species (see Markich et al. 2005, USEPA 2007), so an **HMTV for Cu is not recommended here**.

ID = Insufficient baseline data to derive SSGV, ANZG (2018) DGV applied.

N = ANZG DGV for NO_3 as a toxicant is soon to be revised to around 9.3 mg/L NO_3 (i.e., 2.1 mg/L N-NO_3); to convert nitrate-nitrogen (N-NO_3) to nitrate (NO_3), multiply by 4.43.

NA = Not analysed

np = Not provided.

T = Toxicant.

5.2 Habitat

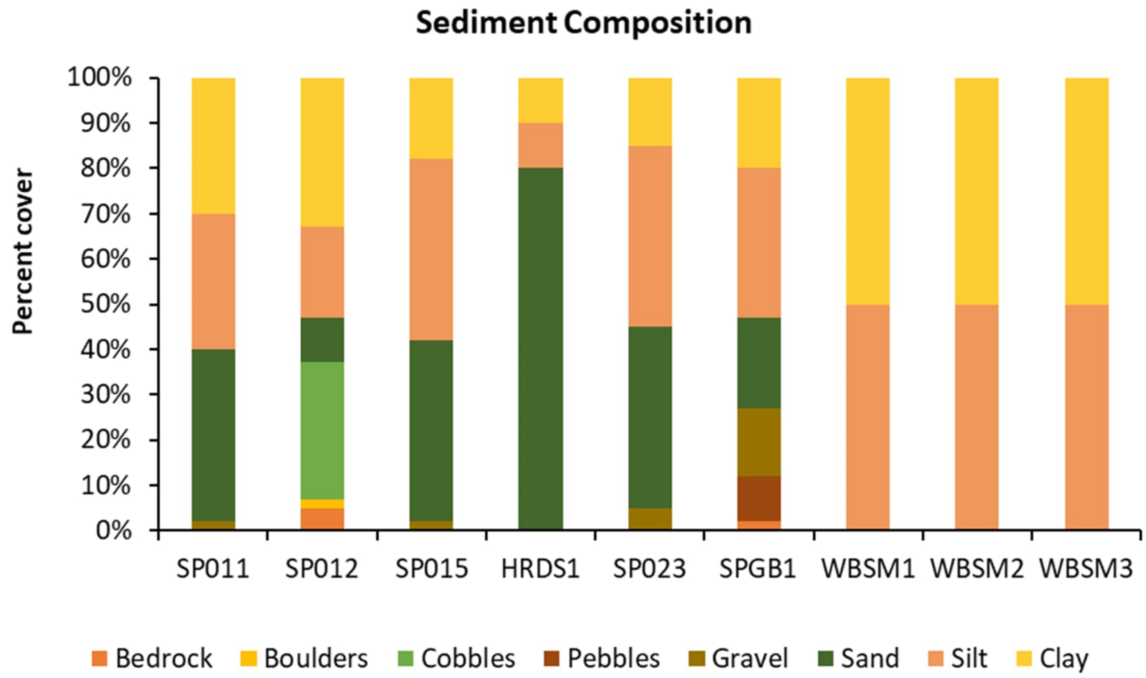
The condition of aquatic fauna habitat in the study area has previously been described as "degraded" or "erosion-prone" (Streamtec 2000, WRM 2022a). Vegetation in and around Samson Brook, Yalup Brook and Harvey River, with its associated habitat for aquatic fauna, has been heavily cleared for rural development, and channelisation of brooks and rivers has resulted in a loss of almost all riparian vegetation. Channelisation was also evident throughout the inundated grassy wetland area (see photos in Appendix 1). Visual habitat assessments undertaken at each site during the spring 2022 survey found introduced grasses and annuals dominated the littoral and riparian zones of both the wetland and creekline sites, with limited overstory canopy tree species present, occasionally as isolated stands (Photo 1). The exceptions were reference site SPBG1, where mature paperbark/redgum trees and an understory of shrubs and sedges were the main vegetation features, rather than grass (Photo 2) and wetland site WBSM3, where a stand of flooded paperbarks was present in the inundated grassy paddock (Photo 3).

The benthic sediment of all sites was dominated by fine sand and/or clay silt (Figure 3). Larger sediment sizes were observed at SP012, including some bedrock/boulders and cobbles in a riffle zone (Photo 1), and at SPBG1, including some pebble/gravel cover. In-stream/inundated organic habitat was dominated by grass, emergent sedges (Cyperaceae sp.), coarse particulate organic matter and the occasional stand of bullrush (*Typha* sp.). A breakdown of habitat type composition for each site is provided in Figure 3. Very little algal growth was observed, despite the concentrations of nutrients N-total and P-total exceeding the ANZG (2018) eutrophication DGVs (see Table 4).

Photo 1. Riffle habitat and grass/sedge bank vegetation at SP012.

Photo 2. Riparian vegetation at reference site SPBG1.

Photo 3. Remnant flooded paperbarks and inundated grass paddock at WSBM3.



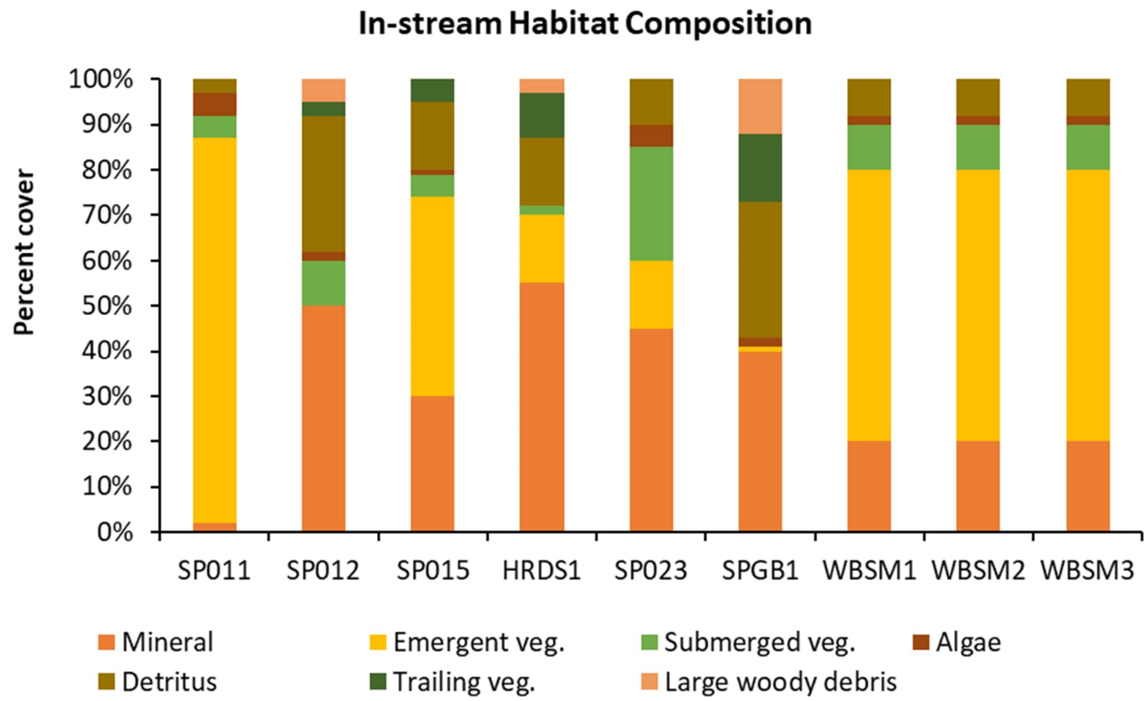


Figure 3. Percent cover of different sediment particle sizes and in-stream habitat type compositions recorded from the Wagerup aquatic fauna survey sites in October 2022. Refer to Figure 1 for site locations.

5.3 Microinvertebrates (zooplankton)

Microinvertebrate sampling was conducted at the three wetland sites surveyed for black-stripe minnows. The creekline sites were not sampled for microinvertebrates as the majority of microinvertebrate species have a preference for still-water or low-flow waterbodies.

A total of 43 microinvertebrate taxa were recorded from the three wetland sites[4] sampled in October 2022 (Appendix 3). Taxa richness was similar between WSBF1 and WSBF2, but was 50% higher at WSBF3. Microinvertebrates comprised 47% of all invertebrate taxa (i.e., microinvertebrates and macroinvertebrates) recorded for the wetland area. This supports the findings of Halse et al. (2002) that microinvertebrates typically constitute around 45% of the total aquatic invertebrate fauna in Australian wetlands. This indicates that the wetland area, although largely cleared, channelised and adjacent to the existing RSA area, still supports a robust aquatic microinvertebrate assemblage.

Table 5. Summary of higher-order microinvertebrate taxa composition from the study area. Refer to Appendix 3 for full taxa list.

Microinvertebrates		Number of Taxa		
Scientific name	**Common name**	**WSBF1**	**WSBF2**	**WSBF3**
Protista	Protists	0	2	2
Rotifera	Rotifers	3	4	12
Cladocera	Water fleas	6	5	6
Copepoda	Copepods	5	6	7
Ostracoda	Seed shrimp	6	4	3
	Taxa richness:	20	21	30

Approximately 56% of the microinvertebrate species recorded were present at only one of the wetland sites, while 21% were present at all three sites. Rotifera were the most diverse group of microinvertebrates present in the study area, with 16 taxa, dominated by the families Lecanidae and Euchlanidae. The next most diverse groups were Cladocera and Copepoda, represented by 12 and 7 taxa respectively (Appendix 3).

One of the few other studies of wetlands is that by Pusey and Edwards (1990), who surveyed micro-crustacea (copepods, ostracods & cladocerans) at eight relatively undisturbed, seasonal wetlands on peat flats in the Warren (WAR) IBRA region, on the south coast. Pusey and Edwards (1990) recorded similar micro-crustacea species richness to that recorded for the Wagerup wetland area; i.e. between one and six species of Ostracoda, three to four species of Copepoda and two to five species of Cladocera. Identification of other taxonomic groups such as Rotifera and Protista that typically dominate south-west microinvertebrate communities, was not undertaken as part of the study by Pusey and Edwards (1990).

5.3.1 Microinvertebrate Species of Conservation Significance

None of the microinvertebrate species recorded from the Wagerup wetlands are formally listed as conservation significant, or likely rare or restricted in distribution. The majority were common, ubiquitous species, with distributions extending throughout Australasia or the world (i.e., cosmopolitan species).

[4] The creekline sites were not sampled for microinvertebrates as the majority of microinvertebrate species have a preference for still-water or low-flow waterbodies.

5.3.2 Microinvertebrate Species of Scientific Interest

Two cladoceran species of scientific interest were recorded from the wetland area. Numerous specimens of an undescribed *Macrothrix* species were collected from all three wetland sites (Photo 4). Dr Shiel had previously examined a single specimen of this undescribed species from DBCA sampling of a wetland in Drummond Nature Reserve, in the Wheatbelt region of Western Australia, in 2004. These specimens have been retained by Dr Shiel for possible DNA barcoding and formal description.

Photo 4. The undescribed *Macrothrix* species recorded from Wagerup area wetland sites.

The second cladoceran of scientific interest was *Ovalona* cf. *pulchella* (Photo 5). The notation "cf." indicates that a specimen is morphologically close to, but exhibits slight differences from, a known described species. The Wagerup specimens of this cladoceran have a greater number of denticles (bristle-like structures) along their abdomen compared to *O. pulchella*. *O. pulchella* is an Australian-endemic species (Sinev 2015). Specimens have been sent to international cladoceran expert Dr Artem Sinev at Moscow State University for further examination.

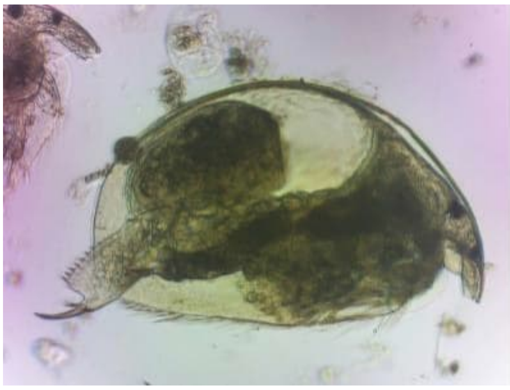


Photo 5. *Ovalona* cf. *pulchella* recorded from Wagerup area wetland sites.

The fact that the two cladocerans described above were collected from wetland area may be new to scientific knowledge does not necessarily mean they rare or restricted in distribution and therefore of conservation significance. It is not uncommon or unexpected to find species that are new to science or new records for WA due to the low level of research conducted on freshwater invertebrates. It is probable that these species are more widely distributed in comparable habitats throughout Australia but have yet to be recorded (Dr Russel Shiel, pers. comm.).

5.4 Macroinvertebrates

A total of 135 macroinvertebrate taxa were recorded from the nine sites sampled in October 2022, including 96 taxa from the four potential exposed creekline sites, 76 taxa from the reference creekline sites, and 50 taxa from the three wetland sites (Table 6, Appendix 4). In this context, "taxa" includes groups which could not be identified to species level, due to unresolved taxonomy and/or immaturity of specimens. Therefore, the total macroinvertebrate taxa richness is likely greater than reported here.

Between site variability in taxa richness was relatively high, ranging from 27 at WSBM1 to 51 at SPBG1 (Figure 4, Appendix 4). Taxa richness levels and community composition at the potential exposed creekline sites (SP011, SP012, SP015 and HRDS1) were generally comparable to the creekline reference sites (SP023 and SPBG1). Taxa richness was lower at potentially exposed site SP012 on Samson Brook downstream of Yalup Brook (31 taxa), compared to the other potential exposed sites (range 43 to 51). However, the site on Yalup Brook closest to the RSAs, SP011, recorded the highest taxa richness (50 taxa) of the four potential exposed sites. SP011 recorded higher diversity among the Coleoptera (beetles) and Hemiptera (true bugs) taxonomic groups compared to all other creekline sites. This may be related to the greater coverage of in-stream emergent macrophytes in the channel at SP011 compared to the other creekline sites sampled (see Figure 3 in section 5.2, photos in Appendix 1). Macrophytes provide habitat for macroinvertebrates (i.e., shelter, food), and sites with greater cover and complexity of macrophytes tend to have greater macroinvertebrate diversity than sites with lower cover or simpler macrophyte communities (Wolters et al. 2018). The macrophyte stand at SP011 is also likely to be providing biofiltration (removal of nutrients and metals from the water column through plant uptake) and protection from flood washout to the aquatic fauna community. SP012 had lower percent coverage of emergent and submerged macrophytes compared to the other potential exposed creekline sites (see Figure 3 in section 5.2, photos in Appendix 1).

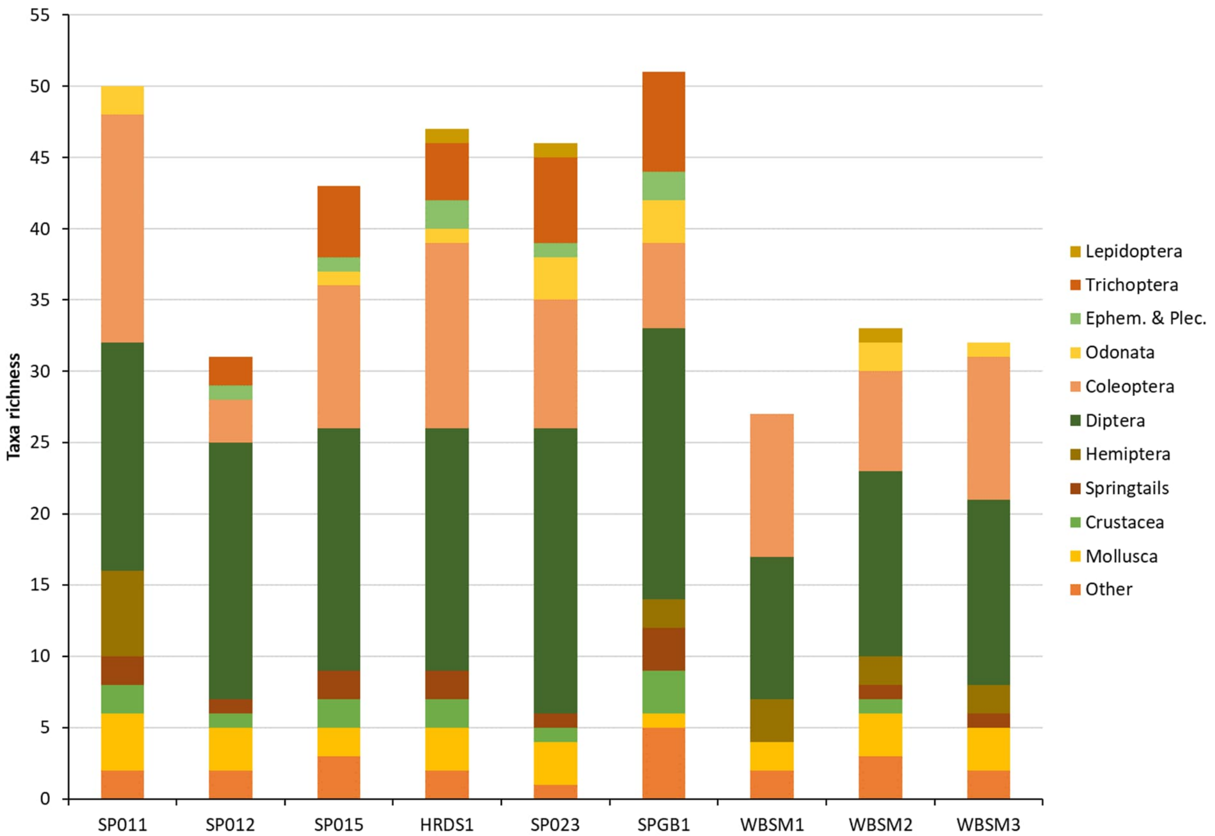


Figure 4. Total macroinvertebrate taxa richness and composition recorded from the Wagerup aquatic fauna survey sites in October 2022. Refer to Figure 1 for site locations.

Singletons[5] constituted a relatively high proportion (41%) of all macroinvertebrates recorded from the study area. A high proportion of singletons is quite common in seasonal and permanent freshwater systems in WA (see Pinder et al. 2005), due to the high turnover of species as natural succession progresses during the cycle of wetland/creekline filling and drying. The most common taxa in survey area samples were the beetles *Berosus approximans and Paracymus pygmaeus*, biting midge larvae Ceratopogoninae spp., non-biting midge pupae (Chironomidae spp.) and larvae *Chironomus* aff. *alternans*, *Corynoneura* sp., *Procladius paludicola*, *Rheotanytarsus underwoodi* and *Tanytarsus* sp., blackfly larvae Simuliidae spp., the amphipod *Perthia acutitelson,* the snail *Physa acuta*, the limpet *Ferrissia petterdi*, and segmented worms (Oligochaeta species). Insecta were the dominant group, as is common in most lentic and lotic waters across WA, with Diptera and Coleoptera the best represented taxa (Table 6).

Table 6. Summary of higher-order macroinvertebrate taxa composition from the study area. *n* = number of sites sampled. Refer Appendix 4 for full taxa list.

Macroinvertebrates		Creekline Potential Exposed	Creekline Reference	Potential Exposed Wetland	Total
Scientific name	**Common name**	***(n = 4)***	***(n = 2)***	***(n = 3)***	***(n = 9)***
Platyhelminthes	Flatworms	2	1	0	2
Nematoda	Roundworms	0	1	0	1
Mollusca	Freshwater bivalves & snails	5	3	4	9
Annelida	Aquatic worms & leeches	2	2	1	3
Notostraca	Shield shrimp	0	0	1	1
Malacostraca	Amphipods & Isopods	2	2	0	3
Decapoda	Shrimp & Crayfish	1	1	0	2
Acarina	Water mites	1	1	2	2
Collembola	Springtails	3	3	1	3
Hemiptera	True Bugs	6	2	3	7
Coleoptera	Aquatic beetles	24	13	14	34
Diptera	Two-winged flies	33	30	21	46
Odonata	Dragonflies & damselflies	4	4	2	6
Ephemeroptera	Mayflies	2	1	0	2
Plecoptera	Stoneflies	0	1	0	1
Lepidoptera	Moth larvae	1	1	1	2
Trichoptera	Caddisflies	6	10	0	11
		92	**76**	**50**	**135**

5.4.1 Macroinvertebrate Species of Conservation Significance

The majority of macroinvertebrate taxa recorded were common, ubiquitous species, with distributions extending across south-western Australia, Australasia, and the world (i.e., cosmopolitan species). No conservation significant macroinvertebrate species were recorded during the surveys. The earlier literature review (WRM 2022b) found no invertebrate species (other than Carter's freshwater mussel) listed under the EPBC or BC Act, or SRE aquatic invertebrates, were likely to occur in the vicinity of the Project area. This was based on the fact that there are no records within 50 km, and suitable habitats are highly unlikely to occur within or around the Project area.

5.4.2 Macroinvertebrate Species of Scientific Interest

Fourteen south-west WA endemics were recorded in the macroinvertebrate samples, including the bivalve *Sphaerium kendricki*, amphipod *Perthia acutitelson*, glass shrimp *Palaemonetes australis*, freshwater crayfish *Cherax quinquecarinatus*, aquatic beetles *Limbodessus inornatus*, *L. shuckardii*,

[5] Taxa recorded from only one location

Sternopriscus browni and *S. marginatus*, the non-biting midge *Rheotanytarsus underwoodi*, the damselfly *Austrolestes aleison*, the dragonfly *Austroaeschna anacantha*, the caddisflies *Taschorema pallescens* and *Maydenoptila baynesi* and the stonefly *Newmanoperla exigua*.

Pennifold (2018), under the direction of DBCA, developed a protocol for assessing how many freshwater invertebrates from the entire south-west of WA (a broad area defined as west of a line between Shark Bay and Cape Arid) may be candidates for listing on the WA Priority Fauna list, and provided an overview on a selection of those species for listing. None of the macroinveterbate species recorded during the Wagerup aquatic fauna survey are on the Pennifold (2018) list of candidates for listing.

5.5 Fish, crayfish and mussels

The spring 2022 survey found the wetland and creekline sites downgradient of the Wagerup RSAs supported at least five native fish species, at least two native crayfish species, one native freshwater mussel species, two introduced fish species and one introduced crayfish species (Table 7). Western minnow were the most common native fish species (980 specimens captured), followed by nightfish (601) and Western pygmy perch (510). All of the species captured are widespread throughout the south west WA region, and all of the native species captured are endemic to this region.

Fauna abundance and richness was generally lower in the wetland sites compared to the creekline sites. The greatest species richness was recorded at Samson Brook site SP012 (potential exposed) and the Harvey River site SP023 (reference). Nine species were recorded at both of these sites. Eight of these species were present at both sites, with a single western hardyhead recorded at SP023 only, and gilgies recorded at SP012, but not at SP023. Gilgies were also recorded at SP011 and SPBG1.

Reference creekline site SPBG1 recorded the lowest diversity of the creekline sites. This may be due to the smaller channel size and width compared to the other creekline sites, however, the abundance of fauna at this site (mostly western minnow) was comparable to the other creekline sites. SP011 recorded the lowest abundance of all creekline sites, and lower diversity compared to the other potential exposed creekline sites. This site does not hold water over the summer months, therefore, species that require permanent water (i.e., CFM, marron, and cobbler) are less likely to occur there, which most likely influences the lower diversity recorded at this site.

Of the two conservation-significant fauna species targeted in this survey, only CFM were found in the study area. CFM are discussed further in section 5.5.1 below. Black-stripe minnows are known to occur in habitat similar to the study area wetland sites within 40 km of the RSAs (the closest known population is in the Kemerton Nature Reserve, 20 km north of Bunbury), however, none were captured in the study area in spring 2022. There has been a considerable decline in the number of known extant populations and the geographical distribution of the black-stripe minnow, largely due to climate change and habitat loss (Ogston et al. 2016). There are four remnant populations known to occur on the Swan Coastal Plain (WRM 2019). Galeotti et al. (2010) suggest that other remnant populations may still exist, with many undiscovered suitable habitats located on private property. However, it is unlikely that black-stripe minnows are present in the study area wetlands and remain undetected following the spring 2022 survey, as the same methods WRM (2019) used to successfully detect them in the Bunbury area were used in this survey. The presence of two common endemic fish species, Western minnow and Western pygmy perch, in the study area wetland sites indicates that this area was likely connected to either Samson Brook or Yalup Brook surface water at some point during the winter months. Unlike the black-stripe minnow, these species cannot survive drying, and this wetland area likely dries during the summer months. In addition to these two native fish species, the wetland sites supported a large number of tadpoles (species not determined), the introduced fish species Eastern gambusia and the introduced crayfish species, the yabby.

Table 7. Fish, crayfish and mussel species recorded at the aquatic fauna survey sites in spring 2022.

		Potential Exposed - Wetlands			Potential Exposed - Creekline				Reference - Creekline		
Fauna group / species name	**Common name**	**WBSM1**	**WBSM2**	**WBSM3**	**SP011**	**SP012**	**SP015**	**HRDS1**	**SP023**	**SPGB1**	**Total**
Mollusca (mussels)											
Westralunio carteri	Carter's freshwater mussel^^					200		1	4	10	215
Crustacea (crayfish)											
Cherax quinquecarinatus	Gilgie				15	5				11	31
Cherax cainii	Smooth marron					1	1		1		3
Cherax destructor	Common yabby^^	1	2			12	2	3	2		22
Osteichthyes (bony fish)											
Tandanus bostocki	Freshwater cobbler						8	5			13
Bostokia porosa	Nightfish				41	16	261	99	158	26	601
Pseudogobius olorum	Western blue-spot goby				6	5	15	27	2		55
Leptatherina wallacei	Western hardyhead								1		1
Galaxias occidentalis	Western minnow	71	12	13	13	81	96	210	92	392	980
Nannoperca vittata	Western pygmy perch	12	1		1	8	227	136	125		510
Cyprinus carpio	Common carp **				7						7
Gambusia holbrooki	Mosquitofish **	1				2	19	83	19		124
Total abundance		*85*	*15*	*13*	*83*	*330*	*629*	*564*	*404*	*439*	***2562***
Total species richness		*4*	*3*	*1*	*6*	*9*	*8*	*8*	*9*	*4*	*12*

^^ = conservation-listed species
** = exotic species

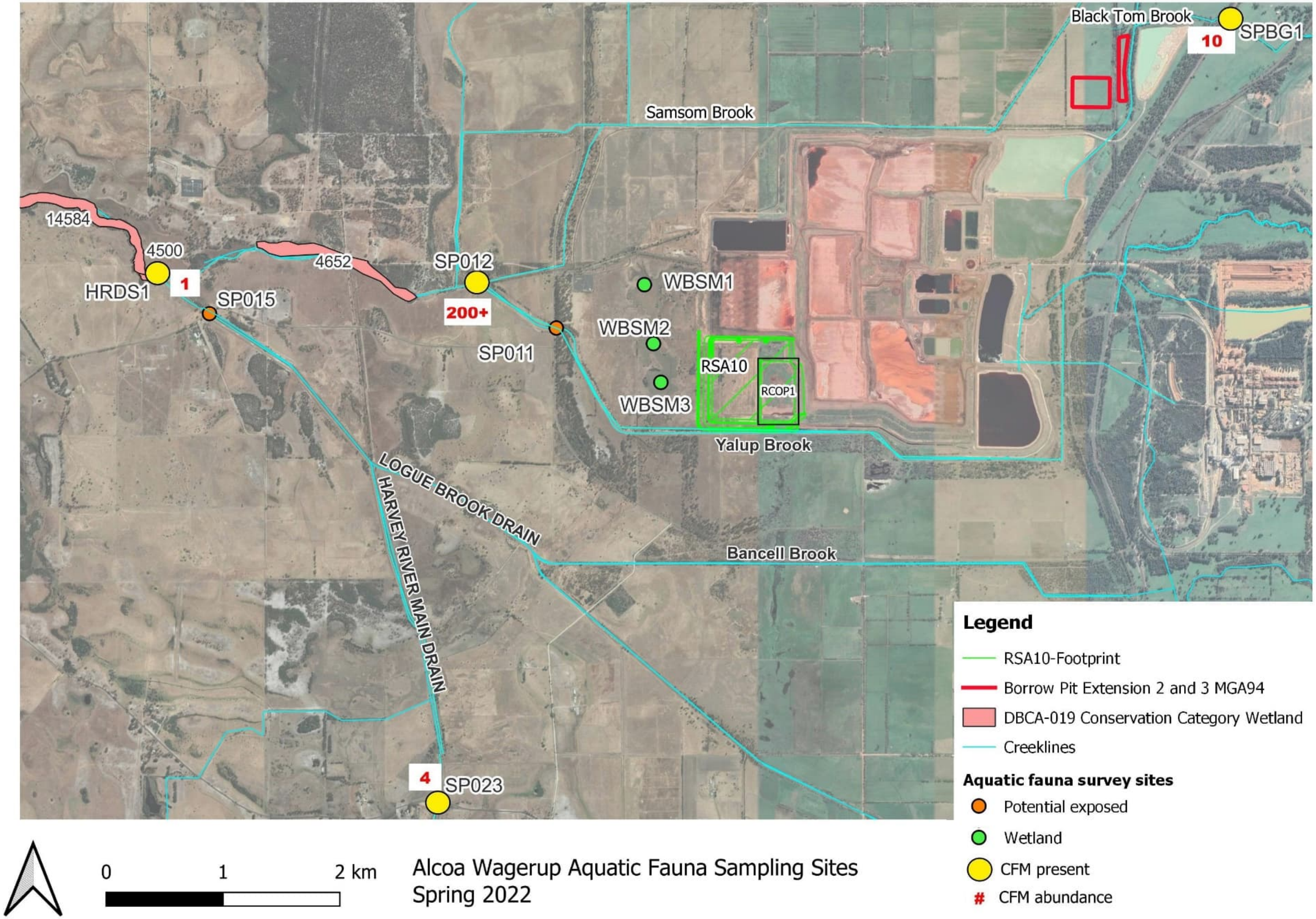


Figure 5. Carter's freshwater mussel presence and abundance – Wagerup RSA10 study area.

5.5.1 Carter's freshwater mussel – EPBC Act protected matter

A location map indicating where mussels were found in the study area is provided in Figure 5. The finding of greatest significance to the RSA 10 project was the large population of CFM at surface water sampling site SP012 (Table 7, Figure 5). SP012 is located on Samson Brook, immediately downstream of where Yalup Brook enters Samson Brook. Two hundred mussels were captured from along an undercut clay bank over an approximate distance of 20 m. This is a relatively high density of mussels for a south-west creekline. Due to the large numbers of mussels at this location, counting was capped at 200, and the actual size of population is likely to be much higher. Smaller populations of mussels were also found at potential exposed site HRDS1, and both reference creekline sites. It is likely mussels also occur in suitable areas of habitat along the creekline between SP012 and HRDS1.

<u>CFM conservation status, distribution, and biology</u>

CFM is listed as a Vulnerable threatened species under the *Biodiversity Conservation Act 2016* (state, Western Australia), the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth) and the ICUN Redlist of Threatened Species 2020 (International). The current distribution of CFM is limited to within 50-100 km of the coast from Gingin Brook in the north, to the Kent River and Waychinicup River along the southern coast (Klunzinger and Walker 2014, Klunzinger et al. 2015). However, a recently published study by Kunzinger et al. (2022) has undertaken morphological and genetic analysis of CFM across the south-west and determined there are additional species/subspecies present. CFM is restricted to western coastal drainages south of Perth, with those on the southwest and south coast described as a different species, split into two subspecies; those along the south coast and those in the very south-west corner around Margaret River. This paper therefore greatly reduces the known range of CFM to western flowing drainages off the Darling Scarp, and by inference increases its level of threat. CFM occurs in greatest abundance in slower flowing permanent/semi-permanent stream and riverine habitats with stable sediments and low salinity, living two thirds to almost fully buried in sand and finer sediment (Klunzinger et al. 2010, Klunzinger 2012). Klunzinger (2012) only found CFM in perennial (permanent/semi-permanent) stream and riverine habitats, and dehydration exposure experiments demonstrated CFM cannot survive prolonged drying (i.e., 76% mortality occurring under experimental conditions, within five days of exposure to dry conditions in sand filled bath tubs). CFM also occurs in lentic (still water) waters including large water supply dams and on-stream farm dams (Klunzinger et al. 2015, DWER 2022). The species is vulnerable to prolonged drying and cannot withstand exposure for longer than five days without moist sediments and shade (Lymbery et al. 2021). CFM require perennial streams or shallow pools or damp mud to retreat to during low water levels and drought, but may survive in seasonally-flowing creeks if the period of zero flow is sufficiently short, and/or there are residual pools or low lying area that remain damp/wet.

Freshwater mussels (Bivalvia: Unionoida) are a keystone species in freshwater ecosystems due to their filter-feeding ability, the important role they play in nutrient cycling and bio-deposition, as well as the structural habitat and the food source they provide for other organisms (Klunzinger et al. 2014, Vaughn and Hakenkamp 2001, Spooner and Vaughn 2008). Despite their immense importance, a number of freshwater mussel species remain endangered throughout the world, with a multitude of threats influencing their persistence and survival (Klunzinger and Walker 2014).

The CFM lifecycle involves an obligate parasitic 'larval' stage, known as glochidia, which attach to host fish for several weeks to complete their development (Bauer and Wächtler 2001, Strayer 2008, Klunzinger et al. 2012). The glochidia aids with the distribution of this species, with individuals being dispersed by migrating fish. CFM is a long-lived species, becoming sexually mature within 6 years at approximately 27 mm shell length, and living for at least 50 years (Klunzinger et al. 2014; Figure 6). Despite this known information, there is a distinct knowledge gap with respect to the ecology of CFM, thereby confounding conservation efforts and status of the species, whilst emphasizing the protection of any known/new populations of the species (Klunzinger et al. 2015).

CFM is currently under threat across south-western Australia due to secondary salinisation, loss of suitable host species, nutrient pollution, habitat loss, water extraction, as well as sedimentation resulting in increased turbidity. Reservoir dewatering and declining rainfall also appear to have had a negative effect on populations (Klunzinger et al. 2012). Secondary threats are trampling by cattle, changes in water quality and possible loss of suitable host fishes for larval stages (glochidia). Confirmed native host species for glochidia are freshwater cobbler, western minnows, western pygmy perch, nightfish, Swan River goby and southwestern goby, and exotic gambusia and one-spot livebearer (Klunzinger et al. 2012, 2015). Barriers to upstream movement of fish may therefore also restrict gene flow between mussel populations, limit upstream-downstream recruitment of CFM, restrict distributions and prevent recolonisation. As well as weirs and dams, barriers include low flow regimes that make natural barriers (waterfalls, riffle zones) impassable for fish. CFM are filter feeders and are vulnerable to water pollutants and sedimentation. Burial by deep loose sands and silts will also kill CFM. CFM also appear intolerant of average salinity levels > 1,500 mg/L (~3,000 µS/cm; Klunzinger et al. 2012). Klunzinger et al. (2015) speculated that the species extent of occurrence (EOO) had declined by 49% in less than 50 years, due primarily to secondary salination, and emphasised the importance of habitat protection where the species persists. The former range for this species extended from Moore River in the north to King George Sound in the south and inland to the Avon River (Klunzinger & Walker 2014, Klunzinger et al. 2015), but now needs to be revised (Klunzinger et al. 2022).

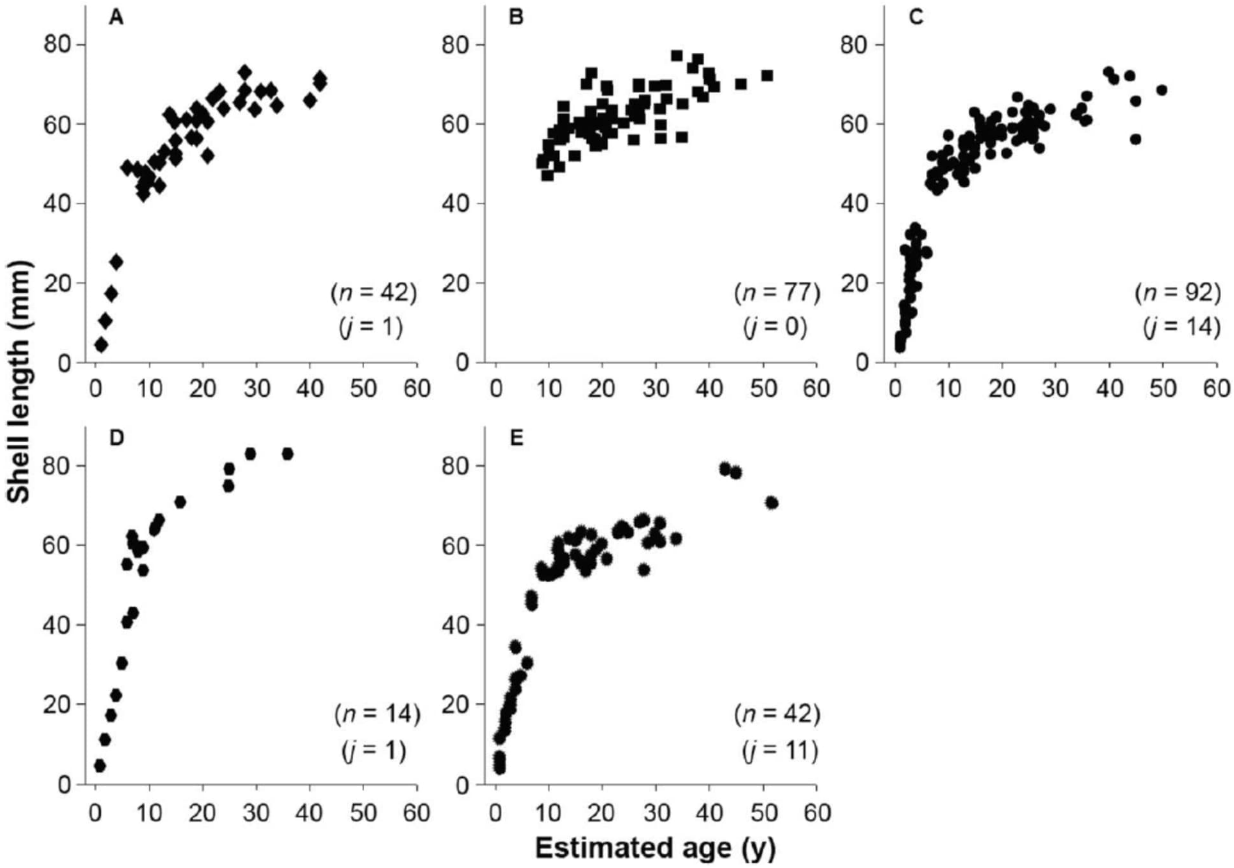


Figure 6. Carter's freshwater mussel age-at-length measurements from Klunzinger et al. (2014); age-at-length measurements for CFM at Bennett Brook (A), Brunswick River (B), Collie River (C), Serpentine River at Dog Hill (D), and Serpentine River at Horse Drink (E).

5.6 Other vertebrate fauna

The literature review (WRM 2022a) found the Wagerup study area is within the known distribution of the rakali, or Australian water rat, *Hydromys chrysogaster* Priority 4 (Near Threatened, DBCA 2021). A survey targeting rakali in the study area was undertaken by an independent terrestrial ecological consultant (Bamford Consulting Ecologists), therefore, targeted survey effort for rakali were not included in the October 2022 aquatic fauna survey. However, one rakali was briefly sighted during this survey at upstream reference site SPBG1, during early morning net/trap retrieval.

A native South-western snake-necked turtle (*Chelodina oblonga*, synonymous with *Chelodina colliei*) was captured in a fyke net at potential exposed site HRDS1. This species is endemic to the south-west of Western Australia, inhabiting both permanent and seasonal waterbodies in fresh and saline systems. In seasonal waterbodies, *C. oblonga* over-summer by burrowing into moist bottom sediments, or by travelling long distances to reach permanent water. Where permanent water is available, *C. oblonga* may nest twice during the breeding season, i.e., in September-October and again in December-January. In seasonal systems, nesting typically only occurs during spring. Nesting sites are usually located in sandy soils, some distance away from waterbodies. Tadpoles, fish, and aquatic invertebrates constitute a large part of their diet. *C. oblonga* is not listed at state or federal level, however, it is currently listed as 'near threatened' by the IUCN, and its status has not been assessed for 20 years (DWER 2022). Threats to local populations may include injury by traffic when crossing roads to reach nesting habitat, predation by foxes, fencing that blocks migrations, illegal fishing by humans, and destruction of natural habitat.

6 PROJECT-SPECIFIC RISKS TO AQUATIC FAUNA

Four potential RSA 10 project specific risks to aquatic fauna present in downgradient environments have been identified:

1. Leaching or runoff transporting contaminated water from ROCP1.
2. Exposure of acid sulfate soils.
3. Unplanned dewatering discharge to Yalup Brook.
4. Sediment transport via stormwater runoff.

Should any of these unplanned events occur, depending on the time of year and efficacy of management responses, aquatic fauna in downstream/adjacent environments may be at risk. The mechanisms of potential impact to aquatic fauna include sedimentation (increased turbidity of water, smothering of fauna and infilling of habitat) and exposure to potential toxic contaminants and elevated salinity transported in surface or ground water from the RSA 10 site and haul road construction areas. The aquatic fauna of greatest significance and most at-risk of impact, should these events occur, is the large population of EPBC-listed Vulnerable CFM at SP012 in Samson Brook, immediately downstream of the confluence with Yalup Brook, approximately 3 km downstream of RSA 10 and ROCP1, and populations assumed to occur in suitable habitat further downstream. CFM, as filter-feeding organisms, are vulnerable to bioaccumulation of metals (e.g., copper, iron and zinc) within their tissues, as well as smothering during sedimentation events. CFM are also sensitive to salinisation. The 80th percentile for electrical conductivity (a measure of salinity) in Guildford formation groundwater below RSA 10 was 4112 µS/cm, and the calculated 80th percentile for salinity was 1.39 g L, which approaches the acute salinity tolerance limit (LD^{50}) of CFM of 1.6–3.0 g L (Klunzinger et al. 2012). The other non-listed aquatic fauna (i.e., fish and crayfish species listed in Table 7, microinvertebrates listed in Appendix 3 and macroinvertebrates listed in Appendix 4) occupying the potential receiving environment are also likely to have varying levels (largely undocumented) of vulnerability to salinity, potential contaminant of concern (PCOCs) and sedimentation.

The south-western corner of the RSA, where the construction of RSA 10 is planned, includes former run-off collection pond ROCP1, which was decommissioned in 2017 (see Figure 1). ROCP1 stores caustic sand and sediments. At the time of this report, a contaminated sites investigation was being conducted, focussing on ROCP1, due to suspected leakage caused by potential failure of the liner. As ROCP1 is located adjacent to Yalup Brook drain in an area where the underlying aquifer is close to ground level, leakage from this site has a high potential of entering the adjacent low-value aquatic environment, and may also be transported downstream to higher value aquatic habitats (i.e., Samson Brook, where the substantial population of CFM was found, approximately 3 km downstream of ROCP1).

The entire area of the Wagerup Refinery including the RSA sits within an area mapped as having a moderate to low risk of acid sulfate soils (ASS)[6]. Dewatering and excavation below the water table can cause acidification in ASS, if present. Acidification of groundwater may have deleterious effects to aquatic fauna in downgradient ecosystems either through direct effects of acidity, or mobilisation of metals under reduced pH. At the time of this report, Alcoa were investigating the extent of ASS in the RSA 10 area.

The Wagerup refinery has been designed to operate an efficient closed water circuit, with losses from steam and evaporation, made up by the collection of all refinery surface water run-off, harvesting fresh surface water flows, and the purchase of make-up water from licenced bores, when required (Alcoa 2017). The Alcoa Wagerup Refinery Long Term Residue Management Strategy (LTRMS) 2017 also describes how the contamination of stormwater is prevented, and that the RSA has a 100% surface water containment policy. Potential failures of RSA 10 dewatering infrastructure resulting in leakages are expected to be contained according to this policy through precautionary measures implemented by Alcoa, and prevented from entering downgradient aquatic environments.

[6] Acid Sulfate Soil Risk Map, Swan Coastal Plain (DWER-055) - Datasets - data.wa.gov.au

A hazard analysis (HA) for potential unplanned inputs to aquatic environments from the RSA was conducted in early 2022, based on data available at the time (WRM 2022b). The aim of the HA was to identify potential contaminants of concern in RSA ground and surface water, and document the current condition of water quality in streams both upstream, adjacent to, and downstream of the RSA. The HA proposed a set of site-specific guideline values that are intended to be used to monitor and assess the condition of aquatic environments downstream of the RSA in future, with the goal of preventing deterioration in water quality that may be attributable to RSA operations.

7 SUMMARY AND CONCLUSIONS

The Wagerup RSA 10 Aquatic Fauna Baseline Assessment was successfully completed between 17th – 21st October 2022. Aquatic fauna sampling was conducted at six creekline and three wetland sites in the Wagerup area. The finding of greatest significance to the RSA 10 project was the large population of Carter's freshwater mussels, *Westralunio carteri*, at surface water sampling site SP012. SP012 is located on Samson Brook, immediately downstream of where Yalup Brook enters Samson Brook. The ecologists captured 200 mussels from along an undercut clay bank over an approximate distance of 20 m. Due to the large numbers of mussels at this location, counting was capped at 200, and the actual size of population is likely to be much higher. Smaller populations of mussels were also found at potential exposed site HRDS1, and both reference creekline sites. It is likely CFM occur along the length of the creekline, where there is suitable habitat, between sites SP012 and HRDS1.

Water quality analyte levels recorded from the study area in spring 2022 were generally below or within the ANZG (2018) DGVs and Wagerup RSA interim SSGVs derived in the 2022 hazard analysis. The only analyte to record exceedances at the potential exposed creekline sites, and not the reference sites, was dissolved iron (at sites SP011, SP012 and SP023). The maximum concentration recorded in downstream creekline sites in spring 2022 was 0.73 mg/L at SP011. Currently, the freshwater DGV for iron is under review. Until a DGV is published, the hazard analysis proposed an interim SSGV of 0.56 mg/L for iron based on the 80th percentile of concentrations downstream of the RSAs.

The wetland area (a largely cleared, inundated paddock) to the west of the residue storage areas was sampled due to being identified as potential habitat for the black-stripe minnow, *Galaxiella nigrostriata*, which is listed as Endangered under the EPBC Act. No black-stripe minnows were captured at the three wetland sites sampled in this area. The presence of two common endemic fish species, Western minnow and Western pygmy perch, indicates that this area was likely connected to either Samson Brook or Yalup Brook surface water at some point during the winter months (unlike the black-stripe minnow, these species cannot survive drying, and this wetland area likely dries up during the summer months). In addition to these two native fish species, the wetland area supports at least 43 microinvertebrate and 50 macroinvertebrate taxa, a large number of tadpoles, the introduced fish species Eastern gambusia and the introduced crayfish species, the yabby. While no listed conservation-significant aquatic fauna species were recorded in the wetland area, two cladoceran taxa (water fleas) recorded from these sites are likely to be new to science (Dr Russel Shiel, pers. comm., 14th December 2022).

The creekline sites downstream of the RSA10 area support Carter's freshwater mussel, along with at least 122 macroinvertebrate taxa, five native fish species, at least two native crayfish species, two introduced fish species, one introduced crayfish species. Western minnow were the most common fish species, followed by nightfish and western pygmy perch. The native south-western snake-necked turtle was also recorded at potential exposed site HRDS1. The state-listed rakali (Australian water rat, *Hydromys chrysogaster* Priority 4) was not targeted during this survey but was sighted at upstream reference site SPBG1, and is also likely to inhabit aquatic environments downstream of RSA10. Other than the Carter's freshwater mussel and the rakali, none of the fauna species captured or sighted during this survey are conservation-listed at a state or federal level, however, the turtle species is listed as 'near threatened' at the international level, and its status has not been assessed for 20 years.

This dataset forms a good initial baseline against which potential impacts to water quality and aquatic fauna from the proposed expansion can be assessed. Additional baseline water quality data are required to strengthen the dataset to allow derivation of more robust site-specific guideline values.

8 REFERENCES

Alcoa (2017) Wagerup Alumina Refinery Long Term Residue Management Strategy.

Allen GR, Midgley SH, Allen M (2003) *Field Guide to the Freshwater Fishes of Australia.* Western Australian Museum, Perth WA.

ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australia and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand. Paper No. 4. Canberra. http://www.deh.gov.au/water/quality/nwqms/index.html

ANZG (2018) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

ASFB (2018) Conservation status of Australian Fishes. Australian Society for Fish Biology Newsletter 46: 142-144.

Australian Government (2018) Charter: National Water Quality Management Strategy, Department of Agriculture and Water Resources, Canberra, March. CC BY 3.0.

Bauer G and Wächtler K (2001) *Ecology and evolution of the freshwater mussels Unionoida.* Springer-Verlag, New York.

Beatty S, Morgan D, Rashnavadi M, Lymbery A (2011). Salinity tolerances of endemic freshwater fishes of south-western Australia: Implications for conservation in a biodiversity hotspot. *Marine and Freshwater Research* 62: 91-100. 10.1071/MF10100.

BOM (2022) Bureau of Meteorology Climate Data Online. http://www.bom.gov.au/climate/data/.

Bunn S, Davies P (1992) Community structure of the macroinvertebrate fauna and water quality of a saline river system in south-western Australia. *Hydrobiologia* 248, 143–160. doi:10.1007/BF00006082

Canadian Council of Ministers of the Environment (2002) Canadian water quality guidelines for the protection of aquatic life: Inorganic fluorides. In: *Canadian environmental quality guidelines*, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Cheal F, Davis J, Growns J, Bradley J, Whittles F (1993) The influence of sampling method on the classification of wetland macroinvertebrate communities. *Hydrobiologia* 257: 47-56.

Davis J, Rosich R, Bradley J, Growns J, Schmidt L, Cheal F (1993) Wetlands of the Swan Coastal Plain Volume 6: Wetland Classification on the Basis of Water Quality and Invertebrate Community Data. Water Authority of Western Australia, January 1993.

DBCA (2021) Threatened and priority fauna list. Department of Biodiversity, Conservation and Attractions, Species and Communities Branch, Parks and Wildlife Service. https://www.dpaw.wa.gov.au/plants-and-animals/threatened-species-and-communities/threatened-animals.

Department of Environment and Conservation (2011) Wagerup 2009 Air Quality Study, Department of Environment and Conservation, Perth, Western Australia. https://www.der.wa.gov.au/images/documents/your-environment/air/publications/Wagerup_2009_Air_Quality_Study_Report.pdf

Department of Environment Sport and Territories, Land and Water Resources – Research and Development Corporation, Commonwealth Environment Protection Authority (1994) National River Processes and Management Program: Monitoring River Health Initiative. River Bioassessment Manual Version 1.0. February 1994.

DWER (2021) Healthy Rivers South West website. Department of Water and Environmental Regulation http://rivers.dwer.wa.gov.au. Accessed 22nd September 2021.

Edward DHD, Gazey P, Davies PM (1994) Invertebrate community structure related to physico-chemical parameters of permanent lakes of the south coast of Western Australia. *Journal of the Royal Society of Western Australia* 77: 51-63.

Environ (2005) Water Supply Study Wagerup Refinery Unit 3. Report prepared for Alcoa World Alumina Australia by Environ Australia Pty Ltd. 4th of April 2005.

EPA (2016a) Environmental Factor Guideline: Terrestrial Fauna. Environmental Protection Authority, Western Australia. 13 December 2016.

EPA (2016b) Technical Guide: Sampling methods for Subterranean fauna. Environmental Protection Authority. December 2016.

EPA (2016c) Technical Guide: Sampling of short range endemic invertebrate fauna. Environmental Protection Authority. December 2016.

EPA (2018) Environmental Factor Guideline: Inland Waters. Environmental Protection Authority, Western Australia. 27 June 2018.

EPA (2020). Technical Guidance – Terrestrial vertebrate fauna surveys for environmental impact assessment, EPA, Western Australia. June 2020.

EPA (2021). Instructions - IBSA Data Packages. 15 November 2021.

Galeotti D, McCullough C & Lund M (2010). Black-stripe minnow *Galaxiella nigrostriata* (Shipway 1953) (Pisces: Galaxiidae), a review and discussion. Journal of the Royal Society of Western Australia. 93. 13-20.

Galeotti DM (2013) Metapopulation theory explains black-stripe minnow (Pisces: Galaxiidae, *Galaxiella nigrostriata)* distribution in seasonal wetlands in south-western Western Australia. https://ro.ecu.edu.au/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1709&context=theses. Accessed 15th September 2021.

Halse SA, Cale DJ, Jasinska EJ, Shiel RJ (2002) Monitoring change in aquatic invertebrate biodiversity: sample size, faunal elements and analytical methods. *Aquatic Ecology* 36: 395-410.

Harvey MS (2002) Short-range endemism among the Australian fauna: some examples from nonmarine environments. *Invertebrate Systematics* 16:555 - 570

Hill AL, Semeniuk CA, Semeniuk V, Del Marco A (1996) Wetlands of the Swan Coastal Plain Volume 2B Wetland Mapping, Classification and Evaluation: Wetland Atlas. Water and Rivers Commission, and the Department of Environmental Protection, Perth, Western Australia.

IUCN (2021) IUCN Red List of Threatened Species. Version 2019.3. www.iucnredlist.org. Accessed 15th September 2021.

Klunzinger MW, Beatty SJ, and Lymbery A (2010) Acute salinity tolerance of the freshwater mussel *Westralunio carteri* iredale, 1934 of south-west Western Australia. *Tropical Natural History* Suppl. 3: 112.

Klunzinger MW, Strebel D, Beatty SJ, Morgan DL and Lymbery AJ (2011). Baseline assessment of freshwater mussel populations within the urban waterways renewal project.

Klunzinger MW (2012) Ecology, life history and conservation status of *Westralunio carteri* Iredale 1934, an endemic freshwater mussel of south-western Australia. PHD Thesis. Murdoch University, Perth Western Australia.

Klunzinger MW, Beatty SJ, Morgan DL., Lymbery AJ, Pinder AM, and Cale DJ (2012) Distribution of Westralunio carteri iredale 1934 (Bivalvia: Unionoida: Hyriidae) on the south coast of Southwestern Australia, including new records of the species. *Journal of the Royal Society of Western Australia*, 95(2), 77–81.

Klunzinger MW, Beatty SJ, Morgan DL, Lymbery AJ, and Haag WR (2014) Age and Growth in the Australian Freshwater Mussel, *Westralunio carteri*, with an Evaluation of the Fluorochrome Calcein for Validating the Assumption of Annulus Formation. *Freshwater Science*, 33(4), 1127–1135. https://doi.org/10.1086/677815.

Klunzinger MW and Walker KF (2014) *Westralunio carteri* . The IUCN Red List of Threatened Species 2014: e.T23073A58526341. http://dx.doi.org/10.2305/IUCN.UK.2014-3.RLTS.T23073A58526341.en. Downloaded on 11 December 2019.

Klunzinger MW, Beatty SJ, Morgan DL, Pinder AM, and Lymbery AJ (2015) Range decline and conservation status of *Westralunio carteri* Iredale, 1934 (Bivalvia:Hyriidae) from south-western Australia. *Australian Journal of Zoology*, 63(2), 127–135. https://doi.org/10.1071/ZO15002.

Klunzinger MW, Whisson C, Zieritz A, Benson JA, Stewart BA & Kirkendale L (2022) Integrated taxonomy reveals new threatened freshwater mussels (Bivalvia: Hyriidae: *Westralunio*) from southwestern Australia. *Sci Rep,* 12, 20385. https://doi.org/10.1038/s41598-022-24767-5

Lymbery A, Le M, Lymbery S, Klunzinger M, Beatty S, Morgan D (2021) Burrowing behaviour protects a threatened freshwater mussel in drying rivers. *Hydrobiologia* 848 (12-13): 3141-3152. 10.1007/s10750-020-04268-0.

Markich SJ, Batley GE, Stauber JL, Rogers NJ, Apte SC, Hyne RV, Bowles KC, Wilde KL, Creighton NM (2005) Hardness corrections for copper are inappropriate for protecting sensitive freshwater biota. *Chemosphere* 60: 1-8.

Morgan DL, Gill HS (2000) Fish associations within the different inland habitats of lower south-western Australia. *Records of the Western Australian Museum* 20: 31-37.

Morgan DL, Gill HS, Potter IC (1998) Distribution, identification and biology of freshwater fishes in south-western Australia. Records of the Western Australian Museum. No. 56. http://museum.wa.gov.au/sites/default/files/1.%20Morgan,%20Gill,%20Potter%20.pdf.

Nield (2000) Alcoa World Alumina Australia, Wagerup Refinery, Review of Impacts on Waters. Unpublished report by Nield Consulting Pty Ltd. March 2000 (*cited in Streamtec 2000*).

Ogston G, Beatty S, Morgan D, Pusey B, Lymbery A (2016) Living on burrowed time: Aestivating fishes in south-western Australia face extinction due to climate change. *Biological Conservation* 195: 235-244.

Pennifold M (2018) Identifying Priority Species Within the South-western Australian Aquatic Invertebrate Fauna. Department of Biodiversity, Conservation and Attractions, Perth. Available from: https://library.dbca.wa.gov.au/static/FullTextFiles/072273.pdf.

Pinder AM, Halse SA, McRae JM, Shiel RJ (2005) Occurrence of aquatic invertebrates of the wheatbelt region of Western Australia in relation to salinity. *Hydrobiologia* 543: 1-24.

Pusey BJ, Edward DH (1990) Limnology of the southern acid peat flats, South-western Australia. *Journal of the Royal Society of Western Australia* 73 (2): 29-46.

Sinev A (2015). Revision of the pulchella-group of *Alona s. lato* leads to its translocation to *Ovalona* Van Damme et Dumont, 2008 (Branchiopoda: Anomopoda: Chydoridae). *Zootaxa* 4044 (4):

Spooner D and Vaughn CC (2008) A trait-based approach to species' roles in stream ecosystems: climate change, community structure, and material cycling. *Oecologia* (Berlin), 158, 307–317.

Storey AW, Halse SA, Shiel RJ (1993) Aquatic invertebrate fauna of the Two Peoples Bay area, southwestern Australia. *Journal of the Royal Society of Western Australia* 76: 25-32.

Strayer DL (2008) *Freshwater mussel ecology: a multifactor approach to distribution and abundance*. University of California Press, Berkley.

Streamtec (2000) Wagerup Refinery: Yalup Brook and Samson Brook Environmental Water Requirements. Report ST 07/00. Unpubl. report to the Alcoa World Alumina - Australia by Streamtec Pty Ltd.

US EPA (2007) Aquatic Life Ambient Freshwater Quality Criteria – Copper. U.S. Environmental Protection Agency, Office of Water and Office of Science and Technology, Washington DC. 2007 Revision.

Vaughn CC and Hakenkamp CC (2001) The functional role of burrowing bivalves in freshwater ecosystems. *Freshwater Biology,* 46, 1431–1446.

Western Australian Planning Commission (WAPC) (2005) Guideline for determination of wetland buffer requirements. Western Australian Planning Commission, Perth, Western Australia.

Warnick SL, Bell HL (1969) The acute toxicity of some heavy metals to different species of aquatic insects. *Journal of the Water Pollution Control Federation* 4, 280-284.

Wolters JW, Verdonschot RCM, Schoelynck J, Verdonschot PFM, Meire P (2018) The role of macrophyte structural complexity and water flow velocity in determining the epiphytic macroinvertebrate community composition in a lowland stream. *Hydrobiologia* 806: 157–173. https://doi.org/10.1007/s10750-017-3353-6

WRM (2019) Bunbury Outer Ring Road Northern and Central Investigation Area: Targeted Conservation Significant Aquatic Fauna Survey 2018. Unpublished report by Wetland Research & Management to BORR Team. April 2019.

WRM (2020) Samson Brook Ecological Condition Assessment 2019/2020. Unpublished report by Wetland Research & Management to the Water Corporation, Leederville. June 2020.

WRM (2021) Samson Brook Ecological Condition Assessment 2020/21. Unpublished report by Wetland Research & Management to the Water Corporation, Leederville. September 2021.

WRM (2022a) Aquatic Fauna Desktop Review for Wagerup RSA 10. Final Report to Alcoa of Australia by Wetland Research & Management, 5 January 2022.

WRM (2022b) Wagerup Residue Storage Area Water Quality Hazard Analysis for Potential Inputs to Aquatic Environments, 2022. Unpublished Report to Alcoa of Australia by Wetland Research & Management, November 2022.

APPENDICES

Appendix 1. Site photographs – Spring 2022

WSBM1

WSBM2

WSBM3

SP011

SP012

SP015

HRDS1

SP023

SPBG1

Appendix 2. ANZG (2018) default guideline values and Wagerup RSA SSGVs (WRM 2022b)

Table A2-1. Default guideline values for physical and chemical stressors for south-west Australia for slightly disturbed ecosystems (Chl *a* = chlorophyll *a*, TP = total phosphorus; FRP = filterable reactive phosphorus; TN = total nitrogen; NOx = total nitrates/nitrites; NH3 = NH4+ = ammonium, DO = dissolved oxygen).

Ecosystem type		Chl *a*	TP	FRP	TN	NO_x	NH_4^+	DO (% saturation)[i]		pH	
		(μg L^{-1})	(μg P L^{-1})	(μg P L^{-1})	(μg N L^{-1})	(μg N L^{-1})	(μg N L^{-1})	Lower limit	Upper limit	Lower limit	Upper limit
Upland river[f]		na[a]	20	10	450	200	60	90	na	6.5	8.0
Lowland river[f]		3–5	65	40	1200	150	80	80	120	6.5	8.0
Freshwater lakes & reservoirs		3–5	10	5	350	10	10	90	no data	6.5	8.0
Wetlands[d]		30	60	30	1500	100	40	90	120	7.0[e]	8.5[e]
Estuaries		3	30	5	750	45	40	90	110	7.5	8.5
Marine[g,h]	Inshore[c]	0.7	20[b]	5[b]	230	5	5	90	na	8.0	8.4
	Offshore	0.3[b]	20[b]	5	230	5	5	90	na	8.2	8.2

na = not applicable

a = monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers — values for periphyton biomass (mg Chl *a* m^{-2}) to be developed;

b = summer (low rainfall) values, values higher in winter for Chl *a* (1.0 μgL^{-1}), TP (40 μg P L^{-1}), FRP (10 μg P L^{-1});

c = inshore waters defined as coastal lagoons (excluding estuaries) and embayments and waters less than 20 metres depth;

d = elevated nutrient concentrations in highly coloured wetlands (gilven >52 $g_{440}m^{-1}$) do not appear to stimulate algal growth;

e = in highly coloured wetlands (gilven >52 $g_{440}m^{-1}$) pH typically ranges 4.5–6.5;

f = all values derived during base river flow conditions not storm events;

g = nutrient concentrations alone are poor indicators of marine trophic status;

h = these trigger values are generic and therefore do not necessarily apply in all circumstances e.g. for some unprotected coastlines, such as Albany and Geographe Bay, it may be more appropriate to use offshore values for inshore waters;

i = dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability (see Section 3.3.3.2).

Table A2-2. Range of default guideline values for salinity and turbidity for the protection of aquatic ecosystems, applicable to slightly disturbed ecosystems in south-west Australia.

Ecosystem type	Salinity (μScm^{-1})	Explanatory notes
Upland & lowland rivers	120–300	Conductivity in upland streams will vary depending upon catchment geology. Values at the lower end of the range are typically found in upland rivers, with higher values found in lowland rivers. Lower conductivity values are often observed following seasonal rainfall.
Lakes, reservoirs & wetlands	300–1500	Values at the lower end of the range are observed during seasonal rainfall events. Values even higher than 1500 μScm^{-1} are often found in saltwater lakes and marshes. Wetlands typically have conductivity values in the range 500–1500 μScm^{-1} over winter. Higher values (>3000 μScm^{-1}) are often measured in wetlands in summer due to evaporative water loss.
	Turbidity (NTU)	
Upland & lowland rivers	10–20	Turbidity and SPM are highly variable and dependent on seasonal rainfall runoff. These values representative of base river flow in lowland rivers.
Lakes, reservoirs & wetlands	10–100	Most deep lakes and reservoirs have low turbidity. However, shallow lakes and reservoirs may have higher turbidity naturally due to wind-induced resuspension of sediments. Lakes and reservoirs in catchments with highly dispersible soils will have high turbidity. Wetlands vary greatly in turbidity depending upon the general condition of the catchment or river system draining into the wetland and to the water level in the wetland.
Estuarine & marine	1–2	Turbidity is not a very useful indicator in estuarine and marine waters. A more appropriate measure for WA coastal waters is light attenuation coefficient. Light attenuation coefficients (log_{10}) of 0.05–0.08 m^{-1} are indicative of unmodified offshore waters and 0.09–0.13 m^{-1} for unmodified inshore waters, depending on exposure. Light attenuation coefficients (log_{10}) for unmodified estuaries typically range 0.3–1.0 m^{-1}, although more elevated values can be associated with increased particulate loading or humic rich waters following seasonal rainfall events.

Table A2-3. Guideline values for toxicants at alternative levels of protection (mg/L).

	Trigger values for freshwater			
	Level of protection (% species) in mg/L			
Compound	*99%*	*95%*	*90%*	*80%*
METALS & METALLOIDS				
Aluminium pH > 6.5	0.027	0.055	0.08	0.15
Aluminium pH < 6.5	ID	ID	ID	ID
Antimony	ID	0.009	ID	ID
Arsenic (As III)	0.001	0.024	0.094	0.36
Arsenic (As IV)	0.0009	0.013	0.042	0.14
Boron [R]	0.34	0.94	1.5	2.5
Cadmium	0.00006	0.0002	0.0004	0.0008
Cobalt	ID	ID	ID	ID
Chromium (Cr III) [R]	0.00016	0.00031	ID	ID
Chromium (Cr VI)	0.00001	0.001	0.006	0.04
Copper	0.001	0.0014	0.0018	0.0025
Iron [R]	0.43	0.7	ID	ID
Manganese	0.0012	0.0019	2.5	3.6
Molybdenum	ID	0.034	ID	ID
Mercury	0.00006	0.0006	0.0019	0.0054
Nickel	0.008	0.011	0.013	0.017
Lead	0.001	0.0034	0.0056	0.0094
Selenium (Se total)	0.005	0.011	0.018	0.034
Selenium (Se IV)	ID	ID	ID	ID
Uranium	ID	0.005	ID	ID
Vanadium	ID	0.0006	ID	ID
Zinc	0.0024	0.008	0.015	0.031
NON-METALLIC INORGANICS				
Ammonia [R]	0.32	0.9	1.43	2.3
Nitrate [R]	1.1	2.1	3.1	5.4

Note: several new (proposed) toxicant default guideline values are soon to be released and are denoted as [R].

Table A2-4. Interim site-specific water quality guidelines for Wagerup RSA, together with ANZG (2018) default 95% GVs, and 80%ile values (and 20%ile values for pH) from adjacent and downstream surface water (i.e., current background condition) datasets. All values are mg/L unless otherwise indicated. **Refer footnotes.**

Greater than or equal to the ANZG (2018) DGV for protection of 95% of freshwater species.

Proposed SSGV is equal to the ANZG (2018) DGV for protection of 95% of freshwater species.

Proposed SSGV is greater than the ANZG (2018) DGV for protection of 95% of freshwater species, or a DGV has not yet been published.

Analyte		ANZG (2018)	Upstream RSA	Adjacent RSA	Downstream RSA	Interim SSGV
		95% TV	80%ile	80%ile	80%ile	
Al (pH>6.5)	T	0.055	0.044	0.038	0.04	**0.055**
Alkalinity (as $CaCO_3$)		np	68.4	120	63	**63**
As-total	T	np	<0.001	<0.001	<0.001	**np**
B	T	0.94	0.03	0.04	0.04	**np**
Ca	E	np	17	40.8	18.8	**np**
Cd	T, H	0.0002	<0.0001	<0.0001	<0.0001	**0.0002**
Cl (chloride)	E	np	142	206	140	**np**
CO_3	E	np	<1	<1	<1	**np**
Cr (VI)	T	0.001	np	np	np	**np**
Cr-total	T	np	<0.001	<0.001	<0.001	**0.001**
Cu	T	0.0014	0.002	0.002	0.0028	**0.0028**
DO-field (% sat)		85-120	np	np	np	**85-120**
EC (uS/cm)	E	300	755	952	616	**616**
F	T, F	2.4	0.12	0.3	0.1	**2.4**
Fe	T, F	np	0.63	1.08	0.56	**0.56**
Hardness (as $CaCO_3$)		np	102	226	118	**np**
HCO_3	E	np	59.8	218	130	**np**
Hg-inorganic	T, B	0.00006	<0.00005	<0.00005	<0.00005	**0.00006**
K	E	np	5.5	4.2	3.8	**np**
Mg	E	np	15.2	31.2	17	**np**
Mn	T	1.9	0.03	0.128	0.05	**1.9**
Mo	T, M	0.073	<0.001	0.002	<0.001	**0.073**
Na	E	np	77	120	78.4	**78.4**
Ni	T, H	0.011	<0.001	0.001	<0.001	**0.011**
$N\text{-}NH_3$	T	0.9	0.038	0.033	0.028	**0.9**
$N\text{-}NH_4$ (eutrophication)		0.01	np	np	np	**np**
$N\text{-}NO_x$ (eutrophication)		0.15	0.32	0.01	0.12	**0.15**
NO_2		np	0.052	0.01	0.01	**np**
NO_3	T, N	9.3	1.4	0.01	0.85	**9.3**
N-total (eutrophication)		0.3	2	1.8	1.66	**1.66**
FRP (eutrophication)		0.04	0.083	0.073	0.054	**0.054**
P-total (eutrophication)		0.01	0.184	0.23	0.166	**0.166**
Pb	T, H	0.0034	<0.001	<0.001	<0.001	**0.0034**
pH-field (H^+)		6.5-8.0	7.7 7 (20%ile)	7.2 6.7 (20%ile)	7.3 6.9 (20%ile)	**6.5 - 8.0**
Redox (mV)		np	264	275	266	**np**
Sb	T	0.009	<0.001	<0.001	<0.001	**0.009**
Se-total	T, B	0.005	<0.001	<0.001	<0.001	**0.005**
SO_4	E	np	32.2	65	30	**np**
TDS		np	386	700	408	**np**
Temperature-field (°C)		np	23.2	18.2	23.2	**np**
Turbidity-field (NTU)	ID	20	np	np	11.7	**20**
U	T	0.005	<0.0005	0.0033	<0.0005	**0.005**
V	T	0.0006	0.002	0.003	0.001	**0.001**
Zn	T, H	0.008	0.002	0.004	0.005	**0.008**

Notes:

B = ANZG (2018) 99% species protection level TV recommended due to the ability of these metals to bioaccumulate. However, laboratory analysis of mercury for routine screening is only achievable to 0.0001 mg/L Hg-inorganic or 0.00005 mg/L Hg-total; the latter by persulphate digestion on low salinity samples.

E = Conductivity (EC) and associated ions (e.g., Ca, Mg, SO_4) will vary depending on flow; values higher than the preliminary GV may occur naturally in seasonal sites during the drying phase if water levels are reduced due to evapo-concentration.

F = ANZG (2018) state the DGVs for F and Fe are under review and recommend use of a site-specific GV where background levels are higher than the DGV. Interim guideline values for fluoride (mg/L) in freshwaters have been proposed as 3.4 mg/L for 90% species protection, 2.4 mg/L for 95% species protection, 1.4 mg/L for 99% species protection (R. van dam, pers. com).

H = GV should be modified for water hardness at the time of sampling using the default algorithms in Tables 3.4.3 and 3.4.4 of ANZG (2018). Note, worldwide literature now report default hardness modified trigger value (HMTV) for Cu may not be sufficient to protect key sensitive species (see Markich et al. 2005, USEPA 2014), so an **HMTV for Cu is not recommended here**.

ID = Insufficient baseline data to derive SSGV, ANZG (2018) DGV applied.

N = ANZG DGV for NO_3 as a toxicant is soon to be revised to around 9.3 mg/L NO_3 (i.e., 2.1 mg/L N-NO_3); to convert nitrate-nitrogen (N-NO_3) to nitrate (NO_3), multiply by 4.43.

np = Not provided.

T = Toxicant.

Appendix 3. Microinvertebrate taxa

Values are log10 abundance categories, where 1 = 1 individual, 2 = 2-10 individuals, 3 = 11-100, 4 = 101-1000, and so on.

Phylum/Class/Order	Family	Lowest taxon	WBSM1	WBSM2	WBSM3	Known distribution
PROTISTA						
Rhizopoda	Arcellidae	*Arcella discoides*	0	3	4	Cosmopolitan
		Arcella megastoma	0	3	3	Cosmopolitan
ROTIFERA						
Belloidea		indet. bdelloid [med]	0	3	0	Indeterminate - immature specimens
Monogononta	Asplanchnidae	*Asplanchna brightwellii*	3	0	0	Cosmopolitan
		Asplanchnopus multiceps	0	0	3	Cosmopolitan
	Brachionidae	*Keratella procurva*	3	0	0	
	Euchlanidae	*Euchlanis dilatata larga*	0	4	4	Cosmopolitan (likely)
		Euchlanis sp.	3	0	0	
	Lecanidae	*Lecane bulla s.l.*	0	4	3	This is a species complex and individual distributions are unknown
		Lecane hamata	0	0	3	Cosmopolitan
		Lecane luna	0	0	4	Cosmopolitan
		Lecane spp.	0	4	3	
	Lepadellidae	*Lepadella discoidea*	0	0	3	Cosmopolitan
		Lepadella triptera	0	0	3	Cosmopolitan
	Mytilinidae	*Mytilina ventralis*	0	0	4	Cosmopolitan
	Testudinellidae	*Testudinella patina*	0	0	3	Cosmopolitan
	Trichocercidae	*Trichocerca elongata s.l.*	0	0	3	Cosmopolitan (likely)
		Trichocerca obtusidens	0	0	3	Europe, South-East Asia & Australia - rarely collected from Western Australia
ARTHROPODA						
Cladocera	Chydoridae	*Alona intermedia*	3	0	0	Cosmopolitan (likely)
		Armatalona macrocopa	0	3	0	Australia & New Zealand
		Coronatella cf. rectangula	4	0	0	Indeterminate - genus needs revision for Australia.
		Chydorus cf. sphaericus	0	0	3	Indeterminate - genus needs revision for Australia.
		Dunhevedia crassa	3	0	0	Cosmopolitan (likely)
		Ovalona cf. pulchella	0	5	5	Indeterminate - potentially an undescribed/new species. Specimens have been sent to an international expert for further examination.
		Pleuroxus inermis	3	0	0	Cosmopolitan (likely)
	Daphnidae	*Ceriodaphnia* sp.	0	3	0	Indeterminate
		Simocephalus acutirostratus	3	0	3	South-East Asia & Australia
		Simocephalus gibbosus	3	3	0	Cosmopolitan (likely)
	Macrotrichidae	*Macrothrix* n.sp.	3	3	3	Undescribed species. Previously collected from Drummond Nature Reserve (DPAW 2004).
	Moinidae	*Moina micrura*	0	0	3	Australia (possibly)
Copepoda						
Calanoida	Centropagidae	*Boeckella robusta maxima*	0	0	3	Western Australian endemic
		Boeckella triarticulata	3	3	3	Australasia, Mongolia & Italy
		Calamoecia lucasi	0	3	3	Australasia
Cyclopoida		Cyclopoida sp. (copepodites)	5	5	5	Indeterminate - immature specimens

		Cyclopoida sp. (nauplii)	6	5	5	Indeterminate - immature specimens
	Cyclopidae	*Mesocyclops brooksi*	3	4	4	Western Australian endemic
		Microcyclops varicans	4	4	3	Cosmopolitan (likely)
Ostracoda		Ostracoda spp. (imm./dam.)	4	0	0	Indeterminate - immature specimens
	Cyprididae	Cyprididae spp. (imm./dam.)	3	0	0	Indeterminate - immature specimens
		Bennelongia sp.	3	3	3	Indeterminate - immature specimens
		Cypretta sp.	3	3	4	Indeterminate - immature specimens
		Ilyocypris sp.	1	3	3	Indeterminate - immature specimens
		Platycypris sp.	3	3	0	Indeterminate - immature specimens
		Taxa richness	21	21	29	

Appendix 4. Macroinvertebrate taxa

Values are log10 abundance categories, where 1 = 1 individual, 2 = 2-10 individuals, 3 = 11-100, 4 = 101-1000, and so on.

Phylum/Class/Order	Family	Lowest taxon	SP011	SP012	SP015	HRDS1	SP023	SPGB1	WBSM1	WBSM2	WBSM3
PLATYHELMINTHES											
Rhabditophora		Turbellaria spp.	0	0	2	0	0	2	0	0	0
Temnocephalida											
	Temnocephalidae	Temnocephalidae spp.	0	2	0	0	0	0	0	0	0
NEMATODA		Nematoda spp.	0	0	0	0	0	4	0	0	0
MOLLUSCA											
Bivalvia											
Veneroida											
	Sphaeriidae	*Sphaerium kendricki*	0	0	0	0	2	0	0	0	0
Gastropoda											
Hygrophila											
	Lymnaeidae	Lymnaeidae spp. (imm./dam.)	0	0	0	0	0	0	0	4	0
		Bullastra lessoni	0	0	0	0	0	0	1	2	2
		Pseudosuccinea columella	0	0	0	1	0	0	0	0	0
	Physidae	*Physa acuta*	4	2	3	4	4	1	0	0	0
	Planorbidae	*Bayardella* spp.	4	2	0	0	0	0	0	0	0
		Ferrissia petterdi	3	3	2	1	2	0	0	0	1
		Glyptophysa spp.	4	0	0	0	0	0	0	0	0
		Leichhardtia spp.	0	0	0	0	0	0	3	3	3
ANNELIDA											
Hirudinida		Hirudinea sp.	0	0	1	0	0	0	0	0	0
Rhynchobdellida	**Glossiphoniidae**	Glossiphoniidae sp.	0	0	0	0	0	1	0	0	0
Oligochaeta		Oligochaeta spp.	4	4	3	2	3	4	3	3	3
ARTHROPODA											
Arachnida											
		Acarina spp.	3	0	0	2	0	0	3	3	3
Sarcoptiformes		Oribatida spp.	0	0	0	0	0	3	0	1	0
Branchiopoda											
Notostraca	**Triopsidae**	*Lepidurus apus viridus*	0	0	0	0	0	0	0	1	0
Malacostraca											
Amphipoda											
	Chiltoniidae	*Austrochiltonia subtenuis*	0	0	0	0	0	3	0	0	0
	Perthiidae	*Perthia acutitelson*	3	3	3	2	3	4	0	0	0
Isopoda											

	Amphisopidae	Amphisopidae spp.	2	0	0	0	0	0	0	0	0
Decapoda											
	Palaemonidae	*Palaemonetes australis*	0	0	2	2	0	0	0	0	0
	Parastacidae	*Cherax quinquecarinatus*	0	0	0	0	0	2	0	0	0
Collembola											
Entomobryomorpha		Entomobryoidea spp.	2	2	1	2	1	2	0	1	1
Poduromorpha		Poduroidea spp.	0	0	1	2	0	3	0	0	0
Symphypleona		Symphypleona spp.	1	0	0	0	0	2	0	0	0
Insecta											
Coleoptera											
	Dytiscidae	*Allodessus bistrigatus*	2	0	0	0	0	0	0	0	0
		Antiporus femoralis	1	0	0	0	0	0	0	0	0
		Bidessini spp. (L)	2	0	0	0	0	0	1	2	2
		Hyphydrus spp. (L)	0	0	0	1	1	0	0	0	0
		Lancetes lanceolatus	0	0	0	1	1	0	0	0	0
		Limbodessus inornatus	3	0	0	2	0	0	2	0	1
		Limbodessus shuckardii	2	0	0	2	0	0	2	0	1
		Megaporus howitti	3	0	2	0	0	0	0	0	0
		Megaporus sp. (L)	0	0	0	0	0	0	2	2	2
		Onychohydrus spp. (L)	0	0	0	0	1	0	0	0	2
		Platynectes spp. (L)	2	1	0	0	1	4	0	0	0
		Rhantus spp. (L)	0	0	0	0	0	0	0	2	2
		Rhantus suturalis	2	0	1	1	0	0	0	0	0
		Sternopriscus browni	0	0	0	0	0	0	0	1	0
		Sternopriscus marginatus	0	0	0	0	0	2	0	0	0
		Sternopriscus multimaculatus	0	0	1	0	0	0	0	0	0
		Sternopriscus spp. (L)	0	0	0	0	0	3	0	0	0
	Gyrinidae	*Aulonogyrus strigosus*	0	0	3	3	2	2	0	0	0
		Aulonogyrus strigosus (L)	0	0	2	2	2	0	0	0	0
	Hydrochidae	*Hydrochus* spp.	2	0	1	0	0	0	0	0	0
	Hydrophilidae	*Berosus approximans*	3	1	1	2	2	0	3	3	3
		Berosus spp. (L)	3	0	0	2	2	0	3	3	0
		Enochrus elongatulus	3	0	0	1	0	0	0	0	0
		Enochrus eyrensis	0	0	1	0	0	0	1	0	0
		Enochrus spp. (L)	2	0	0	0	0	0	0	0	0
		Helochares spp. (L)	0	0	0	0	0	2	0	0	0
		Hydrophilus spp. (L)	0	0	0	0	0	0	2	0	0
		Limnoxenus spp. (L)	2	0	0	0	0	0	3	2	4
		Paracymus pygmaeus	3	2	2	3	1	0	2	0	1

		Paracymus spp. (L)	2	0	0	0	0	0	0	0	0
	Scirtidae	Scirtidae sp. (L)	0	0	0	0	0	1	0	0	0
	Staphylinidae	Staphylinidae sp.	0	0	0	1	0	0	0	0	0
	Hydraenidae	Ochthebius spp.	0	0	1	1	0	0	0	0	0
	Curculionidae	Curculionidae sp.	0	0	0	0	0	0	0	0	1
Diptera	**Dolichopodidae**	Dolichopodidae spp.	2	0	0	0	0	0	2	0	0
	Empididae	Empididae spp.	0	0	0	0	0	2	0	0	0
	Stratiomyidae	Stratiomyidae sp.	0	0	0	1	0	0	0	0	0
	Tabanidae	Tabanidae spp.	0	0	0	0	0	0	0	2	0
	Ceratopogonidae	Ceratopogonidae spp. (P)	0	1	1	2	0	2	0	0	0
		Ceratopogoninae spp.	0	2	2	2	2	1	1	2	1
		Dasyheleinae spp.	0	3	0	0	0	0	0	1	0
	Chironomidae										
	Chironominae										
	Chironomini	Chironomidae spp. (P)	3	2	3	3	3	4	0	2	2
		Chironomus aff. alternans	3	3	3	2	0	4	0	0	2
		Cryptochironomus griseidorsum	0	0	1	0	2	0	0	0	0
		Dicrotendipes sp. (V47)	0	3	1	2	2	0	0	0	0
		Kiefferulus intertinctus	0	0	0	0	2	0	0	0	0
		Chironomus tepperi	4	0	0	0	0	0	0	0	0
		Cladopelma curtivalva	0	2	0	0	3	0	0	0	0
		Polypedilum nubifer	0	0	0	0	2	0	0	0	0
		Polypedilum (Pentapedilum) leei	0	0	0	0	0	3	0	0	0
		Parachironomus sp. (V74)	0	0	2	0	0	0	0	0	0
	Tanytarsini	*Tanytarsus sp.*	0	0	0	0	0	3	0	0	0
		Rheotanytarsus underwoodi	4	3	2	2	3	4	2	0	0
		Tanytarsus sp. (V6)	3	2	2	2	3	0	0	1	0
		Cladotanytarsus sp. (VSC12)	0	0	0	1	2	0	0	0	0
	Orthocladiinae	*Cricotopus parbicinctus*	0	0	0	0	0	4	0	0	0
		Thienemanniella sp. (V19)	0	3	4	4	3	4	0	0	0
		Limnophyes vestitus(V41)	0	0	0	0	0	0	0	0	3
		Paralimnophyes pullulus (V42)	3	2	0	3	2	3	0	0	0
		Corynoneura sp. (V49)	4	3	2	0	2	0	4	4	4
		Cricotopus albitarsis	0	3	2	0	3	0	0	0	0
		Nanocladius sp. (VCD7)	0	0	0	2	0	0	0	0	2
	Tanypodinae	*Paramerina ?levidensis*	3	0	2	0	2	4	2	0	0
		Procladius villosimanus	0	3	0	0	2	0	0	0	0
		Ablabesmyia notabilis	0	0	0	0	1	0	0	0	0

		Procladius paludicola	1	2	2	2	3	3	0	0	0
	Culicidae	Culicidae spp. (P)	2	0	0	0	0	0	3	2	2
		Anopheles spp.	2	0	0	0	0	0	4	3	3
		Culex spp.	4	0	0	0	0	0	2	3	1
	Simuliidae	Simuliidae spp.	1	4	2	3	4	3	0	0	0
		Simuliidae spp. (P)	0	0	1	2	2	2	0	0	0
	Thaumaleidae	Thaumaleidae sp.	0	0	0	0	0	2	0	0	0
	Tipulidae	Tipulidae spp.	0	2	0	1	0	3	1	0	0
	Cecidomyiidae	Cecidomyiidae spp.	0	0	0	0	0	0	0	2	0
	Scatopsidae	Scatopsidae spp.	2	0	0	0	0	0	0	0	0
	Sciomyzidae	Sciomyzidae spp.	2	0	0	0	0	0	0	0	0
	Psychodidae	Psychodidae spp.	0	1	2	0	0	3	0	2	2
	Ephydridae	Ephydridae spp.	0	0	0	1	0	0	3	2	2
		Ephydridae sp. (P)	0	0	0	0	0	0	0	0	1
	Muscidae	Muscidae spp.	0	0	0	0	0	2	0	2	2
Odonata											
	Zygoptera	Zygoptera spp. (imm./dam.)	0	0	0	0	2	1	0	0	0
	Lestidae	*Austrolestes ?aleison*	1	0	0	0	0	0	0	2	2
	Anispotera	Anisoptera spp. (imm./dam.)	1	0	0	0	3	2	0	1	0
	Telephlebiidae	*Austroaeschna anacantha*	0	0	0	0	0	2	0	0	0
	Libellulidae	*Orthetrum caledonicum*	0	0	0	1	2	0	0	0	0
	Corduliidae	*Hemicordulia tau*	0	0	1	0	0	0	0	0	0
Trichoptera		Trichoptera spp. (imm./dam.)	0	0	0	0	0	2	0	0	0
	Ecnomidae	*Ecnomus* spp.	0	0	3	2	3	2	0	0	0
	Hydrobiosidae	*Taschorema pallescens*	0	0	0	0	0	2	0	0	0
	Hydropsychidae	*Cheumatopsyche sp. AV2*	0	3	2	2	3	3	0	0	0
	Hydroptilidae	*Maydenoptila baynesi*	0	0	0	0	0	3	0	0	0
	Leptoceridae	Leptoceridae spp. (imm./dam.)	0	0	2	0	3	3	0	0	0
		Notalina sp. AV15	0	0	0	0	0	2	0	0	0
		Notalina spira	0	0	0	0	1	0	0	0	0
		Oecetis sp.	0	1	2	1	3	0	0	0	0
		Triplectides australis	0	0	0	3	1	0	0	0	0
		Triplectides ciuskus seductus	0	0	1	0	0	0	0	0	0
Ephemeroptera											
	Caenidae	*Tasmanocoenis tillyardi*	0	2	4	4	4	4	0	0	0
	Leptophlebiidae	Leptophlebiidae sp. (imm./dam.)	0	0	0	1	0	0	0	0	0
Hemiptera											
	Veliidae	*Microvelia oceanica*	1	0	0	0	0	0	0	0	0
		Nesidovelia peramoena	0	0	0	0	0	2	0	0	0

		Veliidae spp.	2	0	0	0	0	2	0	0	0
	Corixoidea	Corixoidea spp. (imm./dam.)	1	0	0	0	0	0	1	0	2
	Micronectidae	*Micronecta robusta*	1	0	0	0	0	0	0	0	0
	Notonectidae	*Anisops* spp.	1	0	0	0	0	0	3	2	0
		Notonectidae spp. (imm./dam.)	2	0	0	0	0	0	3	3	3
Lepidoptera											
	Crambidae	Acentropinae spp. (imm./dam.)	0	0	0	1	0	0	0	2	0
		Parapoynx sp.	0	0	0	0	3	0	0	0	0
Plecoptera											
	Gripopterygidae	*Newmanoperla exigua*	0	0	0	0	0	1	0	0	0
		Total richness	**50**	**31**	**43**	**47**	**46**	**51**	**27**	**33**	**32**