Government of **Western Australia**
Department of **Water**

Assessment of low-flow thresholds in maintaining ecological health of the Gingin Brook

2010–2011 dry season

Looking after all our water needs

Water*Science*
technical series

Report no. WST 41
July 2012

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Summary

The Gingin Brook is located within Western Australia's Gingin region and is a highly valued water resource for social, economic, cultural and environmental attributes. The brook supports one of the highest diversities of fish found in the state's south-west and includes both rare and endangered taxa. A permanent flow regime is recognised as being essential for the maintenance of all values.

The brook's health is under threat from both local and global anthropogenic activities, including abstraction for stock, domestic and commercial use; the presence of in-stream barriers impeding biotic movement; and climate change. In particular, the stress being applied by a drying climate has increased significantly in recent years and is likely to continue.

These threats have resulted in a number of impacts to the system, most notably lower flows during summer. Annual streamflows in the upper Gingin Brook have declined by 14% – based on a comparison of flows between the 1975–96 period and recent flows between 1997 and 2007.

To protect system values the Department of Water has set a critical low-flow threshold (CLFT) for the Gingin Brook in the *Gingin surface water allocation plan* (DoW 2011b). The CLFT is the flow below which it is predicted an ecological decline will occur. The CLFT was set in the allocation plan as 10 ML/day based on the 98th percentile of streamflow recorded in the brook between 1975 and 2007.

The Department of Water's Water Allocation Branch commissioned the Water Science Branch to assess the suitability of the 10 ML/day threshold, given that development of the threshold did not take into account future climate projections or measure relationships between flow and ecology in the brook.

Streamflow in the Gingin Brook during this study was below the CLFT on four separate occasions: the longest consecutive periods being 41 and 29 days in February and March/April respectively. Although the number and length of consecutive days where flow was below the CLFT have increased significantly compared with previous summer flow regimes, the ecological structure and function of the brook appeared relatively healthy (as assessed by water quantity, habitat availability and biotic assemblages). However, there was evidence to suggest that the brook may be under stress, particularly given observations of surface water disconnection and localised deterioration of water quality.

Given limited temporal data it is difficult to determine whether the current ecological health status is a true indication of a relatively healthy and stable system or a function of system resilience that may rapidly deteriorate if the current flow regime persists (or declines further). Accordingly, this study recommends further assessment in subsequent low-flow years to establish a trend.

Based on the results of this study, daily flows above 10 ML/day are likely to be adequate for maintaining the upper Gingin Brook's ecological health. On the other hand, the results showed that daily flows below 10 ML/day for extended periods of time were placing stress on the system. Surface water disconnection was observed

in February after a period of 41 days below the CLFT (average flow was approximately 8.1 ML/day).

Given the uncertainty in conditions below the existing CLFT, it is recommended a precautionary approach to managing the upper Gingin Brook resource be employed by implementing a daily flow trigger of 8 ML (over two consecutive days). Following this, flows are to be monitored at the Gingin Brook gauging station on a weekly basis during low-flow periods to detect flows below this trigger. A breach in trigger value is recommended to prompt monitoring of the dissolved oxygen in selected river pools (likely refuge areas) to ensure levels are above the concentrations required to sustain aquatic biota. Accordingly, the water quality trigger for dissolved oxygen should be set at 5 mg/L.

Revision of the low-flow trigger is expected in future based on the daily flow (ML) required for maintaining dissolved oxygen levels above 5 mg/L in refuge areas.

1 Introduction

The Gingin Brook is a historically perennial system located approximately 70 km north of Perth. The brook has a strong interaction with groundwater, with summer flows maintained by discharge from seeps and springs (DoW 2011a).

Summer surface water flows are important for preserving the brook's environmental (biodiversity, ecosystem processes), social (recreation, aesthetics), economic (e.g. agriculture) and cultural values (DoW 2011b, c).

Recently summer flows in the Gingin Brook have declined, which is attributed to a reduction in rainfall and associated groundwater discharge (DoW 2011a) and an increase in abstraction for domestic, horticultural and stock purposes (DoW 2011b).

To protect system values the Department of Water set a preliminary critical low-flow threshold (CLFT) for the Gingin Brook in the *Gingin surface water allocation plan* (DoW 2011b). The upper brook's CLFT is a daily flow of not less than 10 ML for more than two consecutive days in a year (DoW 2011b), as recorded at the Gingin Brook gauging station (Figure 1).

The CLFT is a benchmark to monitor the summer flow regime and represents the point at which an unacceptable risk to water users and the environment has arisen. It was determined as the flow exceeded 98% of the time at the Gingin Brook gauging station between 1975 and 2007. This approach assumes that historic flows have been sufficient to protect the ecological values of the brook, and that the CLFT is ecologically relevant.

Recent flows have departed from the long-term average and future streamflows in the Gingin region are predicted to decrease by a further 30% by 2030 under a median climate scenario (CSIRO 2009). It is expected these thresholds will be reached more frequently in a future drier climate. Because of this it is important to validate the CLFT and check it is adequate to detect ecological degradation.

The study described in this report assessed the CLFT's suitability (as defined by hydrological trends) for maintaining the upper Gingin Brook's ecological health (ecosystem services, water chemistry, biotic composition and structure) and environmental values.

1.1 Objectives

The objectives of this study are to:

- investigate the suitability of the existing CLFT in maintaining ecological health in the upper Gingin Brook, with the view to refine it
- identify potential refugia within the brook as sites for future monitoring
- recommend an appropriate management response when the CLFT is reached.

1.2 Background

The Gingin Brook is historically perennial, with groundwater discharge maintaining surface water flow connectivity during the summer months.

A permanent flow regime is recognised as being vital for maintaining the brook's ecological, social and cultural values (Storey & Davies 2002; Strategen & UWA 2005).

Ecological values of the brook include:

- its high diversity of freshwater fish species, many of which are endemic to south-west Western Australia (Morgan et al. 1998, 2000; Storer et al. 2011a)
- it being the most northern extent for three native fish species: the freshwater cobbler (*Tandanus bostocki*), Balston's pygmy perch (*Nannatherina balstoni*) and mud minnow (*Galaxiella munda*) (Morgan et al. 2000)
- the presence of the rare and endangered fish species: both the Balston's pygmy perch and mud minnow have very restricted distributions and have been classified as 'Vulnerable' and 'Restricted' respectively by the Australian Society for Fish Biology (Morgan et al. 1998).

Social and cultural values include aesthetics provided by the town pool, weir and water wheel, naturalness of the brook and riparian vegetation, and Indigenous-significant areas like the Gingin Waugal – which covers the Gingin Brook and its tributaries (Strategen & UWA 2005; DoW 2011a).

Due to increased demand and abstraction of surface water, the brook has recently become disconnected (in terms of surface flows) in some sections, particularly in the Gingin Brook resource unit 3[1] where the bed is disconnected from the groundwater (Tuffs 2010). Long-term trends in streamflow for annual, monthly and daily flows recorded at the Gingin Brook gauging station show a declining trend since the mid-1970s – a trend also reflected in the mean annual rainfall (DoW 2011b, c).

1.3 Approach

Riverine ecosystem structure and function is strongly influenced by the flow regime (Puckridge et al. 1998). A reduction in flow can have a number of impacts on the aquatic environment, which can include:

- *Altered water quality such as increased electrical conductivity, increased diurnal variation in water temperature and decreased dissolved oxygen* (Lake 2003). Ecological consequences can include changes in the distribution and abundance of biota depending on the tolerances of differing species (McNeil & Closs 2007; Miller et al. 2007; Chessman 2003).

[1] For allocation planning purposes the Gingin surface water allocation subarea has been divided into seven resource units (Gingin Brook 1 – 7), see Appendix A.

- *Decreased amount of available habitat through decreased wetted width, depth and flow* (Harvey et al. 2006; Hay 2009). Ecological consequences can include loss of taxa, particularly those with specialised requirements (Bunn & Arthington 2002).
- *Reduced lateral connectivity with the riparian zone and floodplain and reduced longitudinal connectivity affecting the sources and transfer of energy.* Ecological consequences can include an accumulation of organic matter (Boulton & Lake 1992), and changes in biotic community composition due to changes in allochthonous and autochthonous inputs (Reid et al. 2008; Walters & Post 2008).
- *Restricted distribution (migration) of biota between habitats and river reaches* (Bunn & Arthington 2002). Ecological consequences can include the increased importance of refuges in maintaining biotic biodiversity. Hence, sustainability relies on the maintenance of a number of good quality pools as refugia.

In assessing the suitability of low-flow thresholds for maintaining the ecological health of the Gingin Brook, a multiple parameter assessment was chosen that encompassed physical, chemical and biological aspects. This approach was required to account for variability in streamflow and the associated direct, indirect, acute and chronic effects on ecological health.

Note: the health of refugia (as demonstrated by water quality and biotic condition) is a key determinant of low-flow stress and the associated recovery potential of the system (White & Storer 2012).

Fish and crayfish data were collected because biota are sensitive to specific environmental changes; can detect both acute and chronic conditions; and can respond to changes in water quality, hydrology and physical habitat structure (ANZECC & ARMCANZ 2000). For example, biological data (such as recruitment) can indicate system connectivity or habitat quality over recent years, whereas the presence of certain species may provide information on water quality conditions throughout the previous dry season.

Water chemistry, habitat availability and system connectivity were also monitored during the low-flow period to determine specific changes in response to reducing flows.

All data were integrated with the gauged mean daily flow to investigate how flow interacted with the system’s ecology.

1.4 Context

The findings of this study will be used in conjunction with the *Gingin surface water allocation plan* (DoW 2011b) to inform the Department of Water’s decisions on allocation limits and licensing to protect the Gingin Brook water resource. This includes maintaining capacity for water supply to existing users and maintaining sufficient flow to preserve environmental values.

This study focused on the upper Gingin Brook (resource units 1 and 2), which is the area with the greatest intensity of water abstraction.

A separate report addresses the suitability of the Lennard Brook's CLFT (see Galvin & Storer 2011). The Lennard Brook is a surface water allocation subarea within the *Gingin surface water allocation plan* area.

Note: a preliminary environmental water requirement (EWR) study has been conducted for the Gingin and Lennard brooks by Storey and Davies (2002). The department used the preliminary EWRs to establish an understanding of the resource, which was that the Gingin Brook is over allocated (see DoW 2011c for further information).

2 Monitoring locations

This study focused on the upper Gingin Brook (Figure 1), incorporating resource units 1 and 2 as defined in the *Gingin Brook surface water allocation plan* (DoW2011a) (see resource areas map in Appendix A).

Monitoring locations for the Gingin Brook were selected to represent likely refugia; that is, sections of stream that provide habitat and sufficient water quality and quantity to preserve aquatic biota during low-flow periods. Many refugia in the Gingin Brook correspond with in-stream obstructions due to the forced accumulation of biota in these areas (fish barrier effect), the presence of deeper sections of river around obstructions, and the lack of naturally occurring refugia in the system (the brook is a naturally shallow permanent-flowing system that has only recently begun to be at risk from a drying climate). Note: the health of refugia (as demonstrated by water quality and biotic condition) is a key determinant of low-flow stress and the associated recovery potential of the system (White & Storer 2012).

Within the study area the upper Gingin Brook is disconnected by two major in-stream structures that affect flow, biota migration and downstream transport of sediment and organic material. These are the weir at the Gingin Brook gauging station (617058) on Mortimer Road and an artificial waterfall at Cheriton Estate (Figure 1, plates 1 and 2). Note: the Gingin town weir represents a third major obstruction immediately outside (downstream) of the study area (resource unit 3, Appendix A): this prevents in-stream biotic migrations into the upper Gingin Brook. All structures represent a near-complete barrier to upstream movement of native freshwater fish present in the system, with the possible exception of the Mortimer Road weir under high-flow conditions. More work is required to determine whether structures are preventing migration of the Swan River goby (*Pseudogobius olorum*) and south-western goby (*Afurcagobius suppositus*), with populations being observed above the Cheriton Estate weir and Gingin Brook weir respectively.

For the purposes of this study, the upper Gingin Brook has been divided into two reaches (upper and lower, see Figure 1, Table 1) that capture the separate functional biotic regions delineated by obstructions. Assessments have centred on the stream's ecological health above and below the Gingin Brook weir and Cheriton Estate weir obstructions – given they represent sites of biota accumulation and accordingly form refugia in each reach. Note: the artificial pools formed above and below obstructions represented the highest-quality potential refuge areas in the brook in terms of depth (likelihood of permanent water) and habitat diversity.

Specifically, monitoring sites were selected to capture biota moving into likely refuge areas (runs leading into pools); the biota, water chemistry and habitat conditions of the likely refugia (pools); and the impacts of identified obstructions in terms of fish movement, effects on water chemistry and sediment flushing. These requirements resulted in a large spread of sampling locations in the upper reach assessment due to the extended effect of the upstream weir pool. Whakea Road (see Figure 1, Table 1) was the closest access point within the upper reach to assess the system's health immediately upstream of the Cheriton Estate weir pool, as well as the migration of fish into the pool area.

Table 1 Monitoring sites sampled in the Gingin Brook during February to April.

Reach	Site	Latitude	Longitude
Upper	Whakea Road	31.3125°S	115.9233°E
	Downstream Cheriton Estate weir	31.3278°S	115.9162°E
Lower	Gingin Brook gauging station on Mortimer Road	31.3446°S	115.91761°E

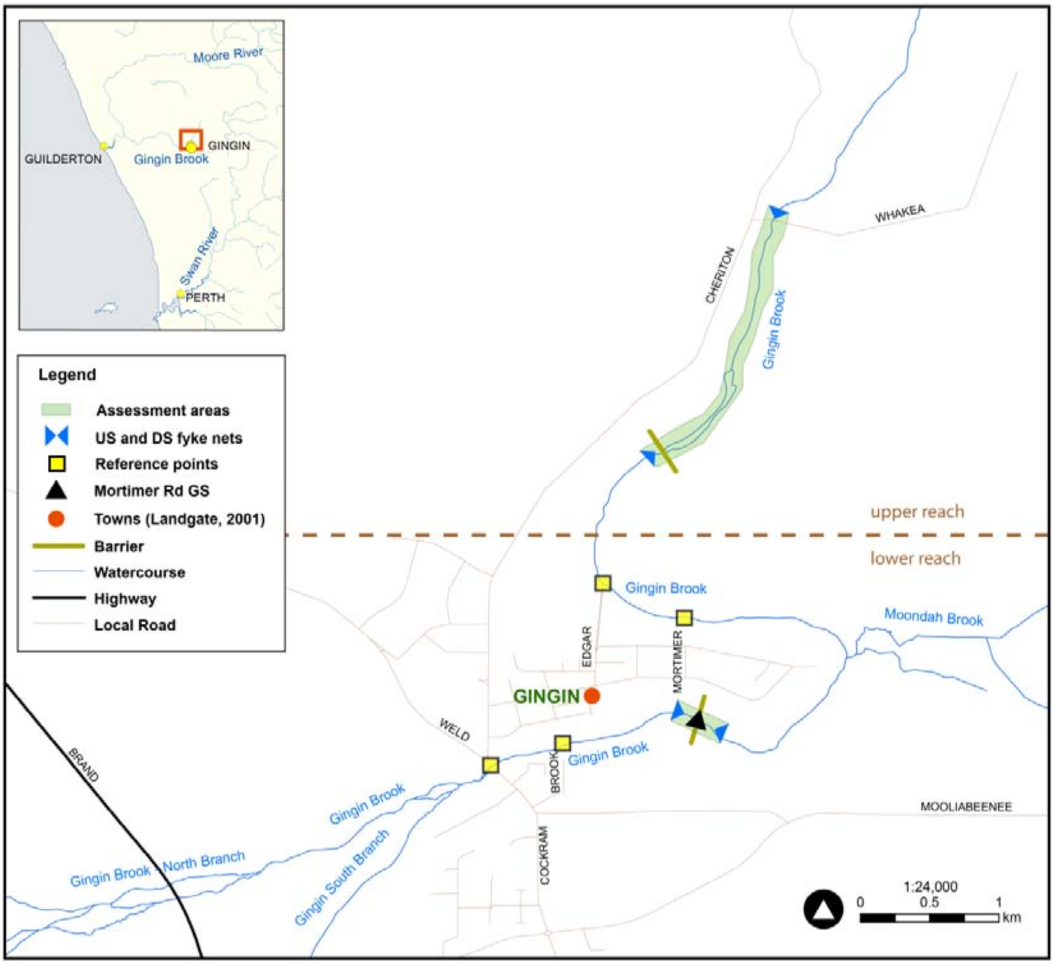


Figure 1 Study sites, in-stream barriers and gauging stations located on the upper Gingin Brook (US – upstream, DS – downstream, GS – gauging station).

Plate 1 Gingin Brook weir on Mortimer Road

Plate 2 Cheriton Estate weir

3 Assessment method

Data on flow, stream connectivity, water chemistry, biota and habitat were collected to ascertain flow-ecology relationships for the Gingin Brook and used to evaluate the existing CLFT's suitability for maintaining ecological health. Data were collected through field sampling conducted monthly in February (21–22 upper reach, 23–24 lower reach), March (23–24 upper reach, 21–22 lower reach) and April (20–21 upper reach, 18–19 lower reach) and continuous measurements from water chemistry dataloggers and flow gauging data. Monitoring schedules are explained further in the sections below.

3.1 Hydrology

Water levels and flows were monitored at the Gingin Brook gauging station (617058) between December and April and at several reference points established at each site.

Gauged data were collected to assess summer flows leading up to and throughout the study period. The reference point measurements for flow and depth were taken on each field sampling occasion using a Global™ flow probe and a 1 m ruler respectively to allow direct comparison against water quality and biota records. These were used to correlate flow at reference points to gauged flow to identify critical flows to meet environmental thresholds such as depth and dissolved oxygen concentration.

3.2 Stream connectivity

Stream connectivity incorporates longitudinal surface water flow, fish movement and lateral connectivity.

As introduced in Section 2, longitudinal connectivity in terms of biotic movement is significantly impaired in the Gingin Brook. To quantify the degree of impact under low-flow conditions, longitudinal connectivity was assessed at several locations:

1. Each of the major obstructions previously highlighted for the upper Gingin Brook (Cheriton Estate weir and Gingin Brook gauging station weir, see Figure 1) were assessed using the Department of Water barrier assessment method (Storer et al. 2010a, b) – see field sheets provided in Appendix B. Assessments determined the extent to which each fish species present in the Gingin Brook would be able to negotiate the structures.

2. A number of additional reference points, typically at road crossings, were assessed each month over the study period (see Figure 1). At each point the presence of flow and water depth was recorded. This was included to observe the connectivity of baseflow between major obstructions.

3. Photo points were also set up at each of the four study sites. These were specifically targeted at observing the impact of flow change on water depth,

wetted area, channel features and available fish habitat (habitat inundation). Photos were taken monthly (Appendix D). Note: this assessed a combination of longitudinal and lateral connectivity (the latter being the linkages between habitats within the streamline, such as connection between pools and draping riparian vegetation or undercut banks).

3.3 Water chemistry

Water quality loggers were employed to examine the relationship between changes in flow and water chemistry under low-flow conditions.

A single multi-parameter water quality datalogger (Manta™ 2) was deployed downstream of the Gingin Brook gauging station at Mortimer Road (lower reach) for the duration of the study period (February to April). Dissolved oxygen, temperature, pH, specific conductivity and turbidity were recorded at 10-minute intervals. Data were downloaded and the equipment cleaned each month.

Dissolved oxygen and water temperature were also monitored at the upper reach sites over the 24-hour field assessment period in February, March and April (10-minute intervals). This was done to examine localised water chemistry changes for comparability with biological information collected at each site. Data were collected using YSI 5739 oxygen/temperature probes attached to TPS WP-82Y dissolved-oxygen temperature loggers. Probes were placed into a PVC housing along with a small recirculating pump to ensure continual water movement over the probes' polarographic membranes. Calibration was conducted before initial deployment and at re-deployment after each field assessment.

Note: dissolved oxgen levels and temperature assessments in the upper reach were initially monitored in the pool upstream of Cheriton Estate weir during the February sampling period. This was done to evaluate whether the weir pool was acting as a refuge. As the results indicated the pool was not a suitable refuge for native fish, dissolved oxygen monitoring in subsequent field sampling events was undertaken at both Whakea Road and below the Cheriton Estate weir.

Weather conditions (e.g. rainfall, cloud cover, wind) and water depth were also recorded to aid interpretation of temperature and dissolved oxygen data.

In situ spot readings and vertical depth profiling of dissolved oxygen, water temperature, specific conductivity and pH were recorded at several locations at each site to assess the effect of low flow on the general water quality throughout the site. Measurements were made using a Hydrolab Quanta multi-probe.

3.4 Fish and crayfish

Fish and freshwater crayfish were monitored to examine the relationship between changes in flow and fish abundance and diversity under low-flow conditions.

Fish and crayfish sampling was undertaken monthly between February and April. Two dual-winged fyke nets (rectangle mouth, opening 75 cm high and 105 cm wide, 3 mm mesh) were deployed over 24 hours on each sampling occasion: one placed on the upstream end of the sampling area and the other on the downstream end to capture fish migration into the study area. At the Gingin Brook gauging station site (lower reach) this equated to approximately 100 m distance between the upstream and downstream fykes; however, at the upper reach site – due to the large weir pool and access issues (previously described in Section 2) – the upstream fyke was deployed at Whakea Road (approximately 2 km upstream of the Cheriton Estate weir) and the downstream fyke was deployed approximately 100 m below the Cheriton Estate weir. Fykes were placed near the centre of the stream channel with wings extending across the entire width of the stream. All fykes were set with a ball float at the end to enable surface access for air-breathing by-catch.

Five large and five small box traps (baited with chicken pellets) were also deployed within the 100 m section of the streamline delineated by fyke nets. Traps were left for 24 hours before retrieval. All in-stream habitat types present at each site were sampled to maximise collection of the full complement of fish and freshwater crayfish species present in the system.

Note: trapping at the Cheriton Estate weir site in February targeted assessment of the upstream weir pool. This was done to evaluate whether the weir pool was acting as a refuge. As the results indicated the pool was not a suitable refuge for native fish, trapping in subsequent field sampling events was moved to Whakea Road and below the Cheriton Estate weir.

Collected fish and crayfish were identified to species and assigned to a size class category (Appendix B). The following information was also recorded: evidence of reproduction; observations relating to their health and condition (i.e. staining, parasites, disease and injury); length of smallest-sized gravid individual; and length of largest individual. All native fish and crayfish were returned live to the water.

Additional sampling

Fish fauna were also sampled in the deep pool directly below the Gingin Brook gauging station at Mortimer Road in February and April to assess if fish were congregating below the weir and using the pool as a refuge. The pool was not sampled in March because high water levels and fallen tree trunks prevented access (conditions were caused by a storm on February 28). A single fyke net with one central wing was placed in the centre of the pool with the wing extended perpendicular to the stream bank. The fyke was deployed for a 24-hour period.

3.5 Additional environmental data

At each site detailed information was collected on aquatic habitat condition (e.g. woody debris, substrate characterisation, macrophytes); catchment condition (e.g. land use, impact of cattle, sources of pollution); physical form (e.g. erosion, channel form); riparian vegetation (e.g. width, presence of weeds, vegetative cover); and fish passage (barrier assessments). These assessments are taken directly from the South-west Index of River Condition (SWIRC) protocol developed by the Department of Water (Storer et al. 2011a, b). See Appendix B for the SWIRC river health assessment field sheets used.

These data were used to characterise the habitat conditions in the brook and provide a general indication of the condition of the reach and catchment. Data were used for the interpretation of results and, as such, have only been referred to in support of observations made about water chemistry and fish/crayfish assemblage.

4 Results

4.1 Hydrology

Streamflow in the Gingin Brook during the 2011 dry season was below the CLFT of 10 ML/day for a large proportion of January and February 2011 (leading into the sampling period for the project). Rainfall events in late February subsequently increased the streamflow above 10 ML/day for a period of approximately 10 days, however flows returned to levels below the CLFT between March 10 and April 7 (Figure 2). During the sampling period for the project (February 21 to April 21) flow in the brook ranged from 9.20 to 12.84 ML/day. The lowest flows were recorded in January to early February – with flows ranging between 5.9 and 11.5 ML/day.

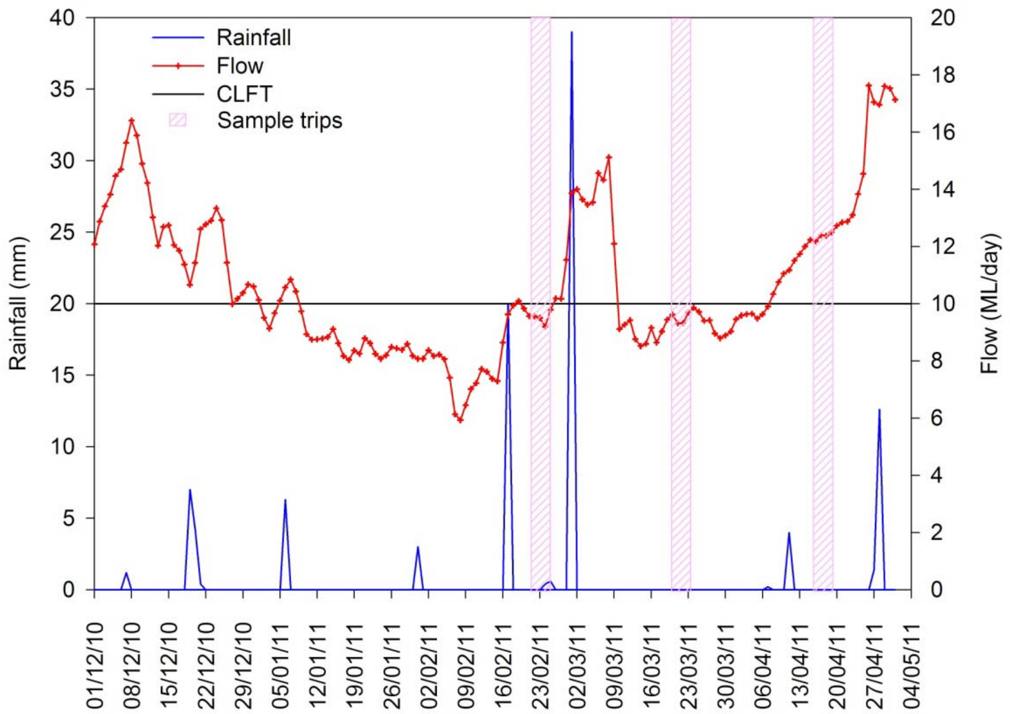


Figure 2 Gingin Brook – daily flow from Gingin Brook gauging station (617058) and daily rainfall from the Gingin meteorological station (009018) between December and April 2011. Pink shading indicates field sampling occasions.

The number of days where streamflow was recorded below the CLFT in 2011 (80 days, 53% of the time) has almost doubled since 2010, more than tripled since 2008 (Table 2) and before this (1975–2007) had reached the 10 ML/day threshold 1 to 2% of the time (DoW 2011c). Accordingly, the period where flows have been below the CLFT has also increased significantly in 2011: before 2011 low-flow breaches were typically confined to January and February, compared with breaches recorded from January through to April in 2011. The number of consecutive days where flow was recorded below the CLFT has also more than doubled in 2011 compared with the previous three years (Table 2).

Table 2 Maximum and minimum flows and number of consecutive days below the critical low-flow threshold

	2007		2008		2009		2010		2011	
	Dec–Mar	**Dec–Apr**	**Dec–Mar**	**Dec–Apr**	**Dec–Mar**	**Dec–Apr**	**Dec–Mar**	**Dec–Apr**	**Dec–Mar**	**Dec–Apr**
Maximum flow	23.6	35.0	21.6	27.6	21.9	21.9	20.1	20.1	16.4	17.6
Minimum flow	11.9	11.9	6.4	6.4	7.3	7.3	7.1	7.1	5.9	5.9
Total days where flow is <=10 ML/day	0	0	24	24	34	34	42	42	73	80
Number of consecutive days <=10 ML/day	n/a	n/a	18		9		12		41	41 & 29*

* This includes two separate extended periods of flows below 10 ML/day: these were 41 consecutive days between January and February and 29 consecutive days between March and April.

4.2 System connectivity

No disconnection in surface water flow was recorded within the Gingin Brook study area between December 2010 and April 2011 (Appendix D). However, in late February, before a large rainfall event on the 28th, surface flow ceased immediately downstream of the study area (upstream of Weld Road in the centre of Gingin town site, see Figure 1). Flows at the gauging station were below the CLFT for 41 consecutive days before this observation, ranging between 5.9 and 10.1 ML/day (average 8.4 ML/day) (Figure 2). It is unknown how long the brook was disconnected, but connectivity was restored soon after the rainfall event. The rainfall resulted in an increase in streamflow to approximately 14 ML/day (at the gauging station for seven days, see Figure 2).

No obvious diminished lateral connectivity was observed during this period based on water level and flow data collected at reference points or through observations of aquatic habitat at the study sites (see site photos in Appendix D).

Fish movement, with the exception of the disconnection at Weld Road, was unaffected by the low-flow conditions experienced throughout the study period (outside of the permanent barriers to fish movement identified in Section 2).

4.3 Water quality – dissolved oxygen

No continuous dissolved oxygen data were reported for the lower reach between February and March due to equipment malfunction (oxygen decreasing to zero within the first few days after three separate deployments). Although the cause of the equipment error is unconfirmed, it may be attributed to clogging of the sensor by suspended particles in the system. An optical sensor was used for dissolved oxygen measurement, which although preferable to a membrane sensor (given durability for long-term monitoring), can be affected if it comes in contact with either algae or a chemical oxidising agent. Given the rapid decline in oxygen levels and lack of recovery, the latter would be the most likely cause of the problems experienced. This is supported by large amounts of silt and organic matter observed within the system.

Dissolved oxygen data recorded during April at the lower site (Figure 3) ranged between 6 and 7 mg/L, with the exception of a short-term rapid decrease in dissolved oxygen to below 3 mg/L observed at midday on April 18. This could be attributed to suspended materials in the system temporarily affecting the sensor as a result of cattle crossing the brook upstream (cattle access to the brook was observed immediately upstream of the loggers).

In situ spot measurements of dissolved oxygen showed levels being generally maintained at around 6 mg/L during the study period. In April, however, dissolved oxygen levels in the pool upstream of the Gingin Brook weir were between 5.55 mg/L at the surface and 4.65 mg/L at the bottom. Flows at this time were at their highest – approximately 12 ML/day (Figure 2).

Dissolved oxygen levels within the pool upstream of the Cheriton Estate weir (measured in February) were below the environmental threshold of 5 mg/L during the night, which is known to cause stress to aquatic fauna (ANZECC & ARMCANZ 2000; Hunt & Christiansen 2000; Koehn & O'Connor 1990). The night time minima was around 4 mg/L (Figure 4). The pool also displayed the largest diurnal range of 4.35 mg/L, which is relatively high and demonstrates that algal production and respiration are dominating the oxygen dynamics in the pool. Dissolved oxygen levels at the Whakea Road site in March were below the environmental threshold of 5 mg/L for most of the day, with levels stabilising around 4 mg/L (Figure 4). In April the dissolved oxygen at Whakea Road increased, with a night time minima of approximately 6.3 mg/L and daytime maxima of 9.8 mg/L. The brook below the Cheriton Estate weir remained well oxygenated, with concentrations being maintained between 6.5 and 7.9 mg/L during March and between 8.1 and 9.1 mg/L in April (Figure 4).

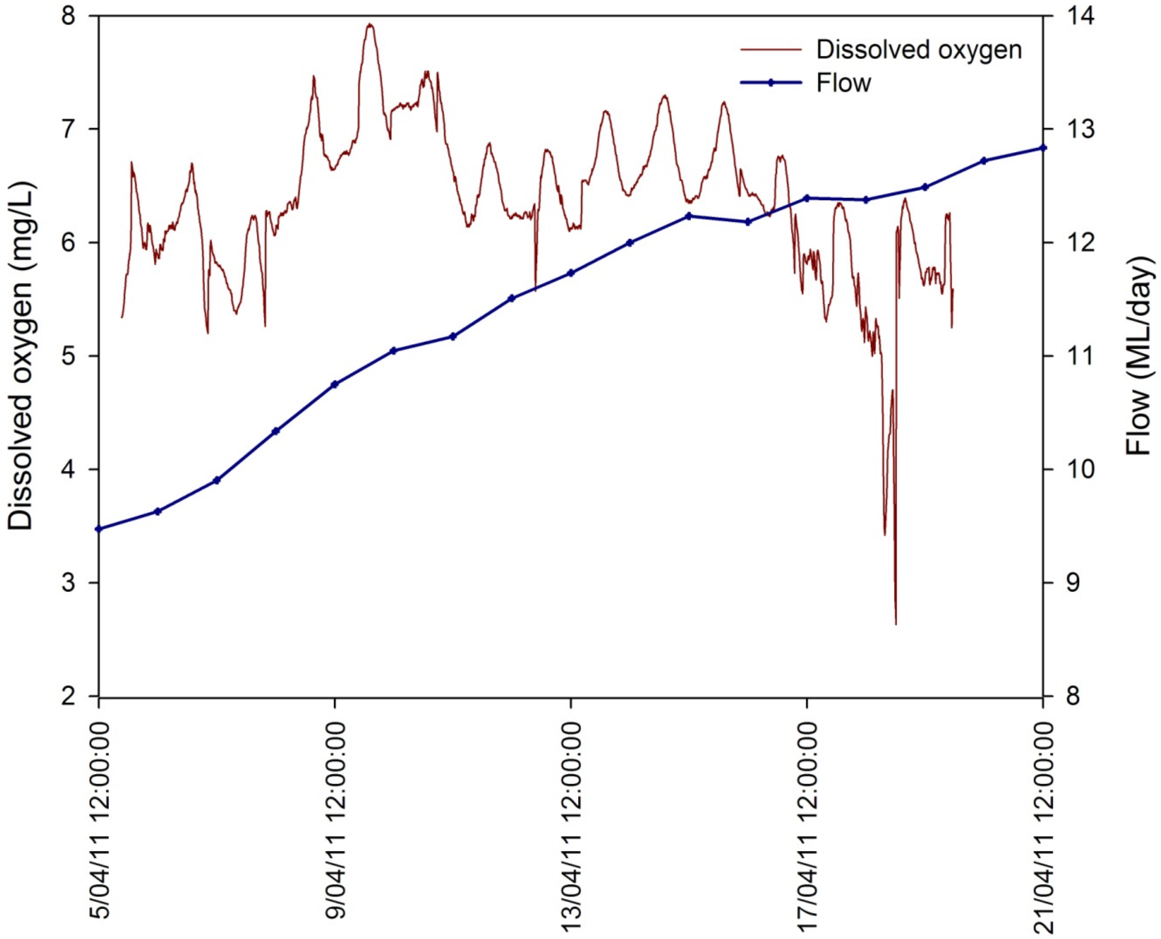


Figure 3 Dissolved oxygen in the lower reach of the Gingin Brook relative to gauged flow at Gingin Brook gauging station. The decline in dissolved oxygen seen on 18 April is likely due to equipment failure.

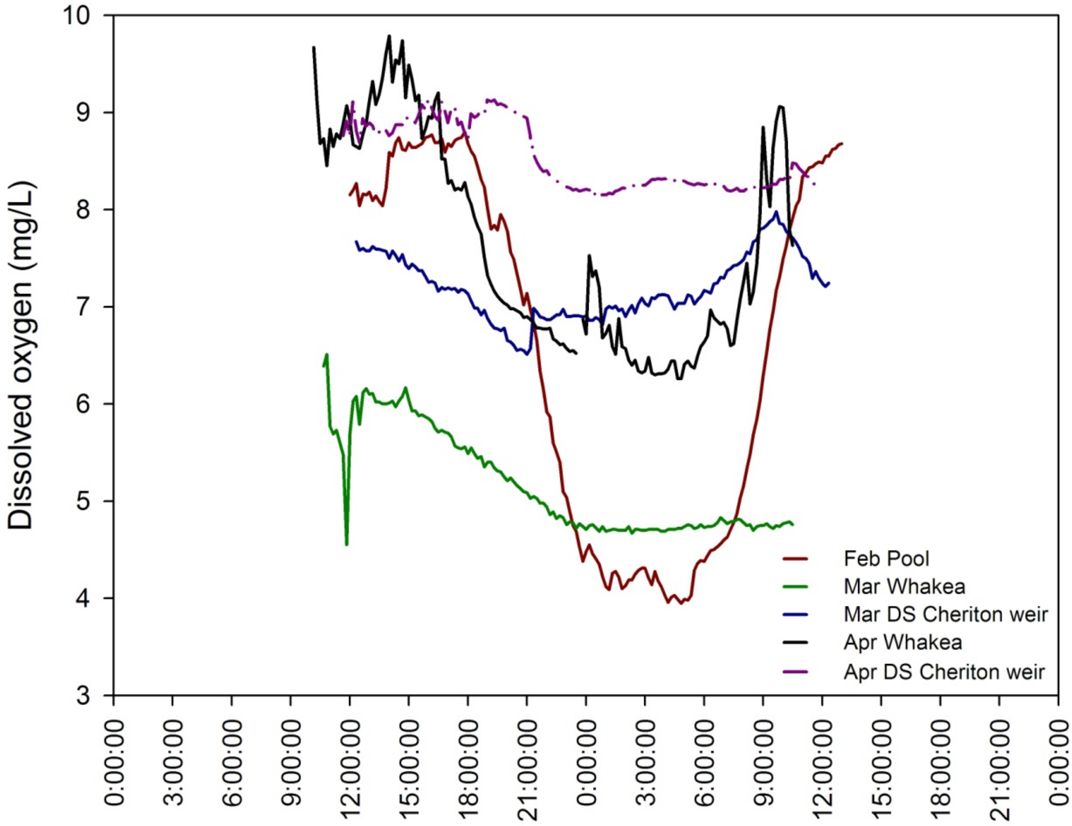


Figure 4 Diel dissolved oxygen in the upper reach on the Gingin Brook.

4.4 Other water quality variables

The Gingin Brook's electrical conductivity (measured at the lower reach site) was between 0.41 and 0.74 m^S/cm during the study period (Figure 8, Appendix C). While this is within the freshwater range (0–1 m^S/cm) (ANZECC & ARMCANZ 2000), pulses of increased salt content were recorded in February and March after large rainfall events. In April electrical conductivity showed a gradual increase coinciding with increasing daily flows to the system (Figure 8, Appendix C).

The pH of the brook was between 6 and 7 for the study period (Figure 9, Appendix C) which is within optimal ranges for south-west systems (ANZECC & ARMCANZ 2000).

Equipment failure resulted in erroneous results for turbidity and thus no data have been presented. Visual observations of turbidity revealed relatively low levels during February when flows were low, but levels increased significantly towards the end of the study period. High turbidity was observed in the pools below the Gingin Brook weir due to organic matter and silt being suspended as a result of turbulence.

4.5 Fish and crayfish assemblages

A total of six native fish, two native crayfish and one introduced species (mosquitofish, *Gambusia holbrooki*) were recorded in the Gingin Brook at both sites during the study period. Native species collected were freshwater cobbler (*Tandanus bostocki*), western pygmy perch (*Nannoperca vittata;* formerly *Edelia vittata*), nightfish (*Bostockia porosa*), western minnow (*Galaxias occidentalis*), Swan River goby (*Pseudogobius olorum*) and south-western goby (*Afurcagobius suppositus*). Freshwater crayfish collected were gilgie (*Cherax quinquecarinatus*) and marron (*Cherax caiini*).

Freshwater cobbler was the most abundant fish species collected on all sampling occasions at both sites on the Gingin Brook. In February, March and April 85% of the freshwater cobbler were travelling upstream. However, only a few individuals were recorded in April in the upper reach. Over the entire study period a total of 438 individuals were collected. Most of these were captured below barriers – with 74% and 90% of the catch being recorded in the pool below the Gingin Brook weir (Figure 5) and in the run downstream of the Cheriton Estate weir (Figure 5) respectively. The population of freshwater cobbler in the brook appears to be recruiting successfully, as suggested by a wide size range of individuals captured, including juveniles (<100 mm TL) (Figure 7).

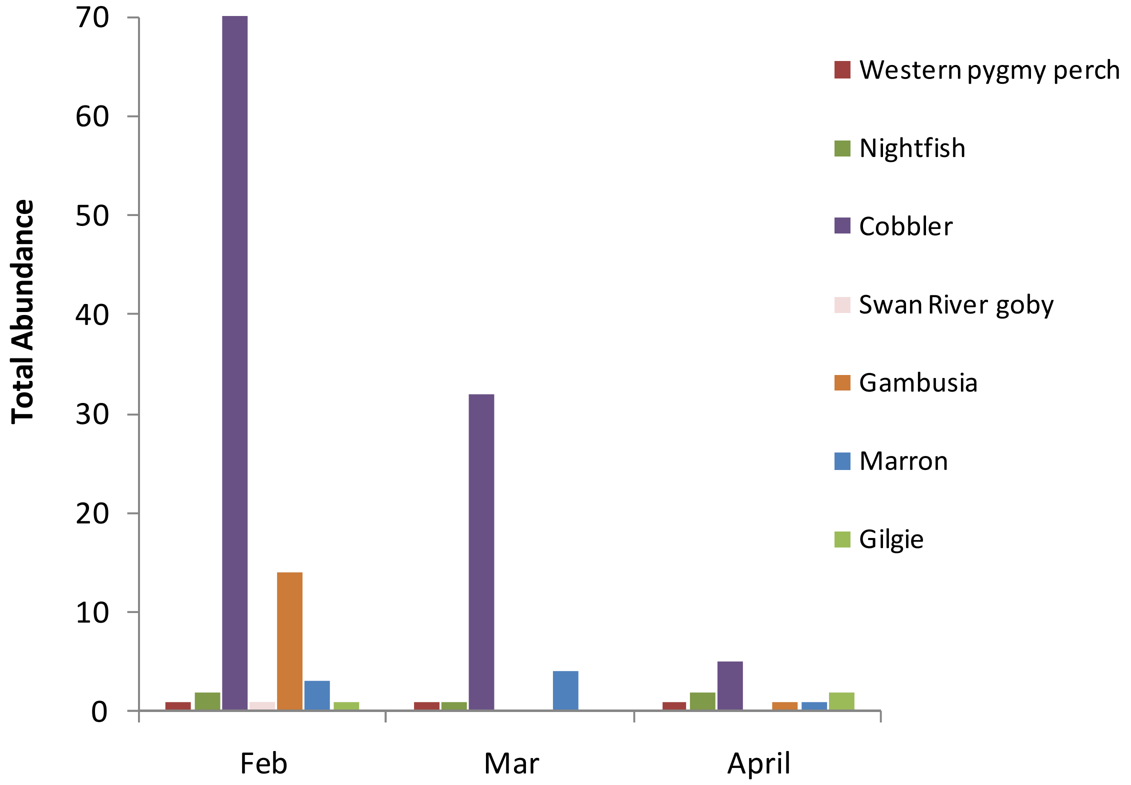
Western pygmy perch, western minnow and nightfish were found at both sites, being typically more abundant in the lower reach (figures 5 and 6). Numbers and size class distribution (Figure 7) of these three species support the existence of viable, sustaining populations.

Mosquitofish were only recorded in the pool above and the run below the Cheriton Estate weir. They were mainly observed in the slower-flowing areas of the brook.

Gilgie and marron were collected at both sites throughout the study period. Marron were more abundant in the lower reach, which is likely due to the presence of more complex permanent habitat (specifically deeper pools).

Two estuarine species, the south-western goby and Swan River goby, were recorded in very low abundance upstream of the Gingin Brook gauging station weir and in the pool upstream of the Cheriton Estate weir respectively.

Upper reach



Lower reach

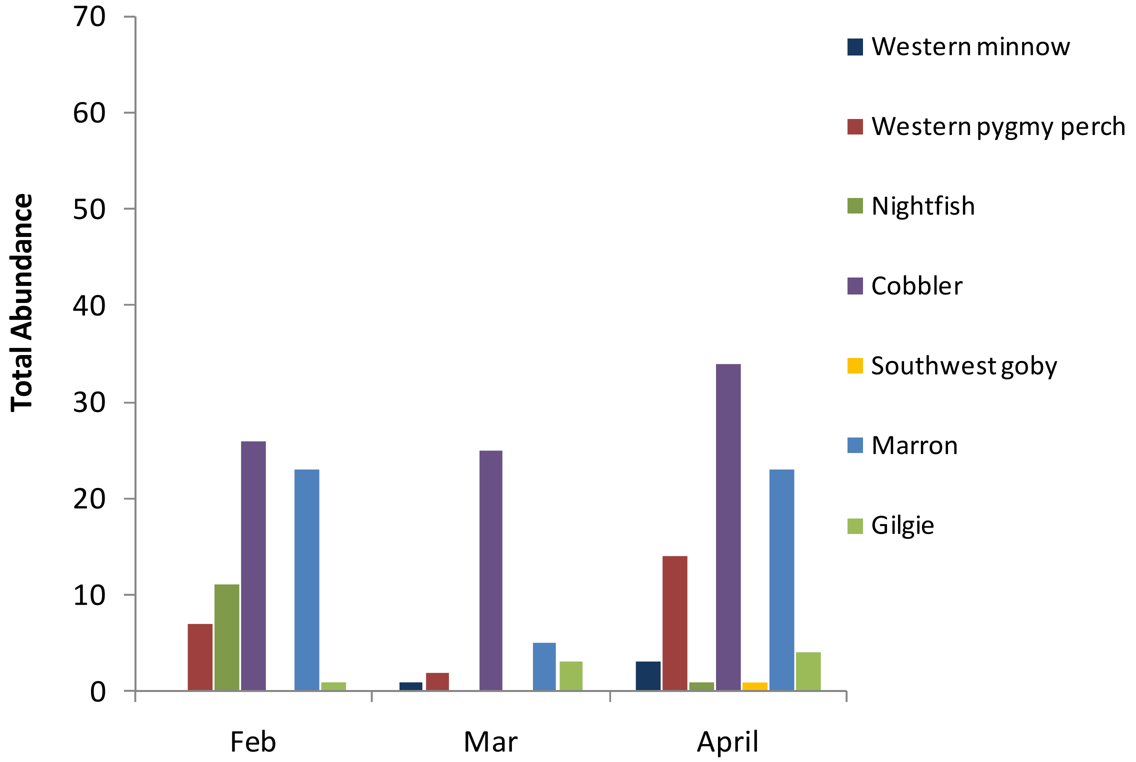


Figure 5 Fish fauna assemblage at the upper and lower reaches on the Gingin Brook.

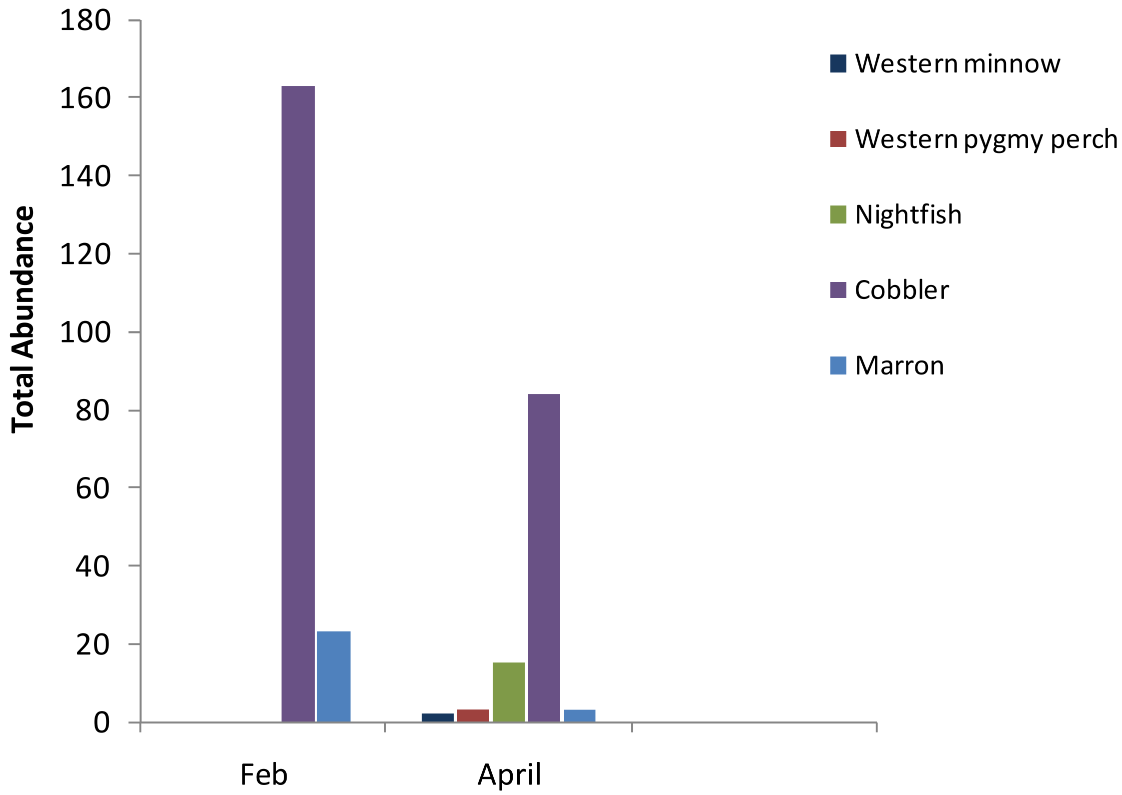


Figure 6 Fish fauna assemblage in the pool below Gingin Brook gauging station weir at Mortimer Road (lower reach).

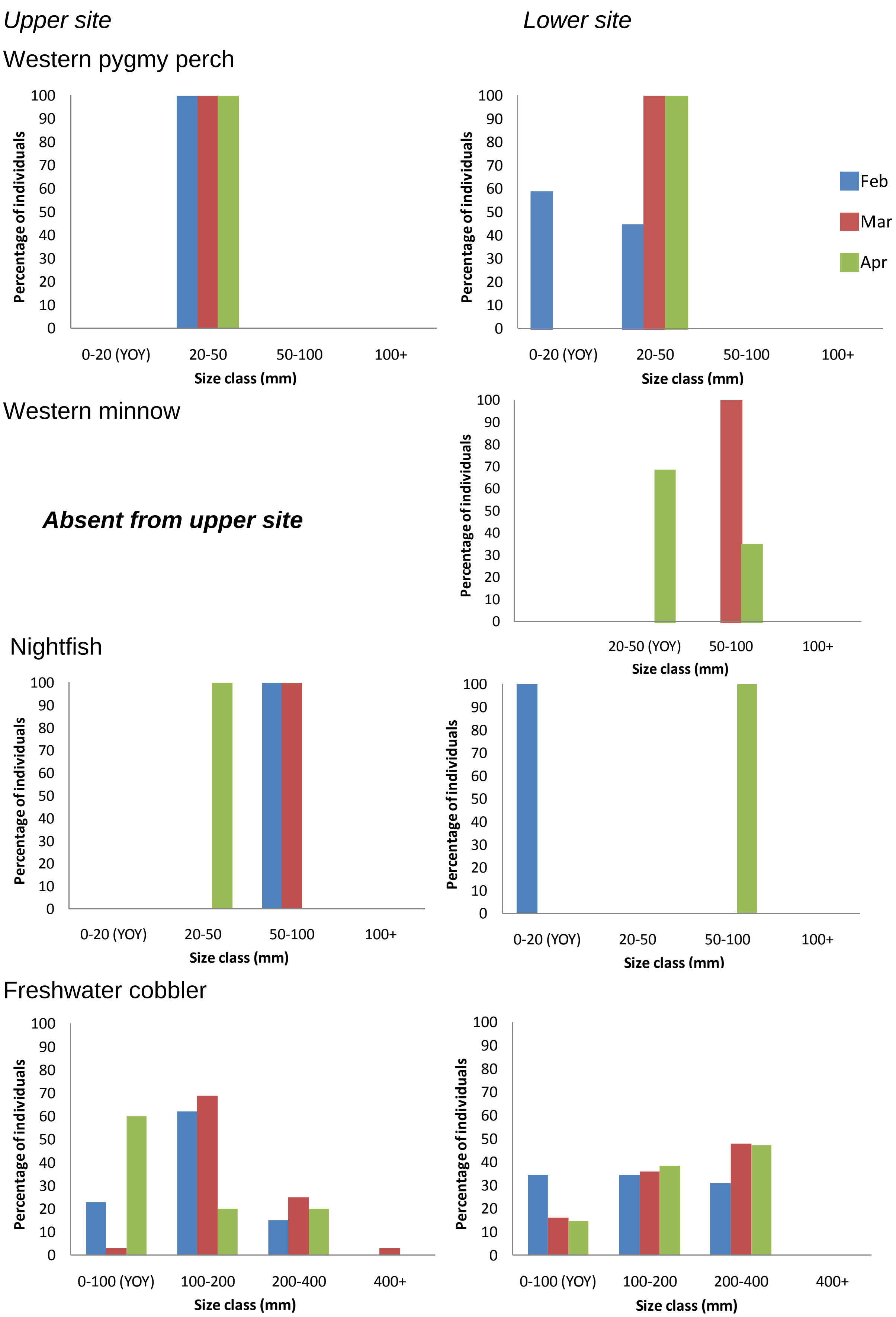


Figure 7 Size class frequency distributions for the freshwater fish in Gingin Brook (YOY – young of year).

4.6 Additional observations

The Gingin Brook's catchment has been extensively cleared for agriculture, horticulture and urban development – resulting in much of the vegetation being completely lost or degraded. The riparian vegetation of the upper and lower reaches assessed in this study is restricted to a narrow corridor (approximately 20 to 50 m width) along the brook. The overstorey vegetation is largely intact and dominated by *Melaleuca rhaphiophylla* and *Eucalyptus rudis*. The understorey is severely impacted by weed invasion and stock access. In some places the riparian vegetation is only partially fenced or not fenced at all, allowing cows and sheep to access the brook. Signs of bank damage and grazed understorey were evident at both reaches, particularly at Whakea Road.

In addition to stock access and weed invasion, siltation in the Gingin Brook was also identified as a key issue. Large amounts of fine silt and organic matter were observed in deeper slower-flowing areas of the brook, particularly upstream of the major obstructions referred to in Section 2. For example, accumulation of materials upstream of the weir associated with the Gingin Brook gauging station at Mortimer Road was approximately 60 cm in depth, recorded in February 2011. The deposits observed in February were largely removed by April, demonstrating the system's ability to flush (given flows recorded during this study).

The in-stream habitat at Whakea Road is characterised by draping emergent macrophytes and large areas of the submerged macrophyte (*Triglochin procerum*). Some areas of bare ground exist on the edge of the brook due to cattle crossings. The biological substrate consists of detrital material (leaf, twigs, branches) and moderate amounts of large woody debris.

The habitat downstream of the Cheriton Estate weir is more degraded compared with Whakea Road: the in-stream vegetation is virtually absent with only small clumps of emergent macrophytes present and no submerged macrophytes. Large woody debris and detrital material is also sparse in the system. Above the Cheriton Estate weir, the pool is filled in with large amounts of silt and organic matter. In places the silt/organic matter was more than 1 m deep. Surface water above the silt/organic layer was shallow at approximately 30 cm deep. Emergent vegetation was present around the edges of the pool, providing some habitat for biota.

The lower reach consists of runs and pools located above and below the Gingin Brook weir and below the concrete spillway (located approximately 60 m downstream from the weir). The in-stream vegetation is virtually absent with only small clumps of emergent macrophytes present and no submerged macrophytes. The brook contains much large woody debris and has a good cover of detrital material.

5 Discussion

The south-west of Western Australia is experiencing an uncharacteristically dry climate, with winter rainfall significantly lower than the long-term average (DoW 2011c). Streamflows have subsequently reduced. This situation is expected to continue (or decline further) in the coming years (CSIRO 2009).

This study has been conducted in response to these conditions: it assesses the suitability of the CLFT within the upper Gingin Brook for maintaining ecological health – in terms of both adequacy of the current flow regime and likely conditions if flows were to continue, or be further reduced, in the future.

5.1 Adequacy of existing flow regime in maintaining the ecological health of the upper Gingin Brook

A CLFT designed to provide sufficient streamflow to protect environmental values has been established for the Gingin Brook. During the 2010–11 dry season (December–April) flow in the upper Gingin Brook fell below this threshold on four separate occasions. The longest periods below the CLFT were 41 consecutive days between 9 January and 18 February (leading into the ecological field assessment component of this study) and 29 consecutive days between 10 March and 7 April. The lowest flow recorded during the dry season period was 5.9 ML/day on 8 February. Despite the recorded breaches in the existing CLFT, this study's results suggest the Gingin Brook is in relatively good ecological condition under the current flow regime. This is demonstrated through the general maintenance of lateral/longitudinal connectivity, in-stream habitat, water quality, biodiversity and biota condition in the sampling sites (which represented likely refugia).

As introduced above, the longitudinal connectivity of surface water was generally maintained throughout the study period, with flows also sufficient to maintain inundation of a representative spread of aquatic habitat. Disconnection of surface water was observed once during the study – at Weld Road (immediately below the study area, Figure 1) – but as no obvious biotic impacts were observed it appears this extent of disconnect does not produce adverse effects on system health. Hence flows above the CLFT (10 ML/day), representing an increase in flows from that recorded in this study, appear to be adequate to maintain system connectivity longitudinally (between barriers) and maintain habitat inundation. This will be discussed further in Section 5.2.

Water quality through the study period was generally maintained within acceptable levels for aquatic biota, based on available relevant guidelines (encompassing ANZECC & ARMCANZ 2000; Hunt & Christiansen 2000; Koehn & O'Connor 1990). However, based on observations of temporary and/or localised deterioration in water quality within the study region and a number of gross environmental observations (e.g. build-up of organic material and system disconnection), several concerns have been raised about the brook's future health if low-flow conditions persist. These conditions will be discussed in Section 5.2.

The fish fauna of the Gingin Brook are diverse on a south-west Western Australian scale, with a total of six native species recorded during the low-flow period, five of which are endemic to the region. All species expected to occur in the brook were collected with the exception of rare taxa; that is, the mud minnow (*Galaxiella munda*) and Balston's pygmy perch (*Nanatherina balstoni*) (Morgan et al. 2000; Beatty & Morgan 2004). The mud minnow and Balston's pygmy perch have been classified as 'Restricted' and 'Vulnerable' respectively by the Australian Society for Fish Biology. This result is not surprising given the likelihood of capturing these species is low: both species are generally extremely rare within their distribution range and are typically found in tributaries and ephemeral pools not sampled in this study. However, Morgan et al. (2000) suggest these species could be in decline as a result of habitat degradation.

During this study freshwater cobbler were abundant and the data supports a viable population, including successful recruitment indicated by many individuals <100 mm TL (juveniles) (figures 5, 6 and 7). Based on numbers caught in fyke nets, small groups of freshwater cobbler appear to be migrating upstream predominantly during February and March, with only a few individuals in April. Given that reproductive condition was not advanced it is likely that migrations are due to food and/or habitat selection. This trend is consistent with observations from the adjacent Lennard Brook, with a peak in migration around February (Galvin & Storer 2011). Note: a previous assessment of the Gingin Brook during spring detected what is believed to be the peak upstream migration period for spawning in this system, with approximately 300 adult freshwater cobbler (in advanced reproductive condition) captured in fykes over 24 hours (data collected through Storer et al. 2011a). This is almost 1000% more individuals caught than in this present study. The presence of in-steam barriers in the Gingin Brook does appear to be an impediment to freshwater cobbler (and other native fish) due to most of the catch being below the barriers. Yet under the current flow regime this does not seem to be affecting population dynamics. Therefore it appears that freshwater cobbler have adapted to the impediments to migration and that current flow conditions are sufficient to sustain populations – at least in the short term.

Western minnow, western pygmy perch and nightfish were present in both reaches but typically in lower abundances compared with data on other south-west systems (data collected through Storer et al. 2011a). Low abundance in these systems may be due to natural variation (e.g. seasonal migration patterns) or could indicate a reduced carrying capacity, possibly due to limited food resources and/or habitat associated with reduced range due to lower flows. Further, as freshwater cobbler will predate on small native fish (Morgan et al. 1998), congregations of species in refuge pools may increase the predatory advantage of freshwater cobbler and thus reduce numbers of prey species. Both adults and juveniles (young of the year) of each species were captured, indicating that the populations of these species are reproducing and likely to be sustainable under the current flow conditions. More work is required to elucidate the cause of the low abundances collected.

In general, the refugia assessed within the upper Gingin Brook appeared to be in sufficient health to maintain ecological function under the low-flow conditions experienced during the study period. This is demonstrated through the maintenance of water quality and the biological conditions tested. Under the current summer flow regime the refugia pools assessed are isolated from each other via in-stream barriers (most significantly the Cheriton Estate weir and Gingin Brook gauging station weir on Mortimer Road). While these barriers create an impediment to fish movement they also provide an important source of oxygenation under the altered system dynamics (turbulence caused by water fall). However, these structures have an additional and more concerning effect on system function (compared with impediments to fish passage) through increasing the accumulation of organic matter and silt in slow-flowing deposition areas above the weirs. This accumulation has the potential to clog upstream habitat and can result in oxygen levels deteriorating in the pools (due to bacterial breakdown of organic material), making them unsuitable as habitat for biota under a low-flow regime. The impact of sediment/organic material build-up is a function of the flushing capabilities of winter flows, and this capability was seen at the Gingin Brook gauging station weir site, with much of the accumulated material from behind the weir washed away during a storm in late February. However, flushing has been less successful in the pool above Cheriton Estate weir, where the benthic environment is dominated by fine silt and organic matter (surface water depth approximately 30 cm over the flocculent sediment). This helps explain why the biotic assemblage of the pool largely comprises mosquitofish (*Gambusia holbrooki*) and only one Swan River goby and one marron. In a declining flow environment the ability for the system to move materials downstream is at risk and should be monitored.

The results of this study indicate the system is resilient to periods below the threshold (<10 ML/day for greater than two days). However, several concerns were identified that may affect the current CLFT's suitability in future, particularly when flows are below the threshold for extended periods (see Section 5.2).

5.2 Sustainability of ecological health if current flow conditions persist

This study detected a number of signs that the system's health may be threatened if the current flow regime persists, or if flows decline further. Issues identified were disconnection of surface flow within the brook near the Gingin town site, low dissolved oxygen at Whakea Road and in pools upstream of the weirs, the potential for increases in the system's electrical conductivity, and accumulation of organic material and sediment behind the weirs (and associated problems previously discussed). All of these issues have the potential to negatively affect system health and reduce confidence in the ability of refuge pools to sustain viable biotic populations over the drier summer months. These issues are discussed below.

Surface water connectivity is essential to maintaining biotic populations and hence the Gingin Brook's ecological health. Fish, crustaceans and other biota need to move within a system to gain access to habitat and food, complete lifecycles and maintain population dynamics and genetic diversity (Norton & Storer in press). Loss of connectivity can result in isolation of populations, failed recruitment and local extinction of fish species (Fairfull & Witheridge 2003; Bunn and Arthington 2002). The Gingin Brook is already disconnected in several places by in-stream barriers that prevent the upstream movement of most native fish (with the possible exception of the goby species which were recorded above the weirs). Under the current flow regime additional disconnection of surface water flow was observed immediately below the study area (at Weld Road) in February after an extended period (41 days) of flows below the CLFT. This is particularly important for the Gingin Brook because during low-flow periods freshwater cobbler depend on permanent flows to provide adequate passage to and from areas with suitable habitat for spawning (Beatty et al. 2006). In addition, the separation of pools due to surface water disconnection can lead to declines in populations of small native fish due to predation by freshwater cobbler (if disconnection occurs for long periods of time).

Given no obvious impacts on the recruitment of native fish species were observed within this study, it appears that fish populations are either self-sustaining within each river section (divided by the barriers) and/or via periodic seeding from upstream reaches (young of the year travelling downstream over barriers). Winter flows are also likely to be adequate for fish passage only over the Gingin Brook gauging station weir. However, if low-flow conditions persist or worsen the level of surface water disconnection may not be sustainable.

Adequate water quality is also vital to sustain the Gingin Brook's ecological health. Significant deposits of organic material and silt observed within the system have the potential to adversely affect both water quality and habitat availability – a situation caused by increased erosion due to land use practices and restricted flushing of the system due to lower winter flows and the presence of in-stream barriers. The primary concern about water quality stemming from increased organic load is the potential for oxygen depletion (bacterial load associated with mobilisation of organic deposits), particularly in areas of accumulation (behind in-stream obstructions). These conditions are currently occurring above the Gingin Brook gauging station weir where *in situ* measurements showed dissolved oxygen levels decreased from 5.5 at the surface to 4.6 mg/L at depth in April, which is below levels known to cause stress to aquatic fauna (5 mg/L, ANZECC & ARMCANZ 2000; Hunt & Christiansen 2000; Koehn & O'Connor, 1990). Oxygen levels were also a concern at the Whakea Road site in March and in the upstream pool at Cheriton Estate weir in February. During this study there were no obvious signs of stress to the aquatic biota observed under these dissolved oxygen conditions.

The high organic loads to the Gingin Brook are likely to be via runoff from the cleared catchment, which is used for cattle grazing and intensive horticulture. In addition, a large proportion of the brook is not fenced off, which allows cattle to access the brook – degrading the banks and resulting in erosion. In addition, due to reduced flows, the brook is no longer receiving the volume of water historically supplied and thus the oxygenation function and other benefits from this 'replenishing' water are not being provided.

As introduced above, adequate water quality, particularly in the refuge pools, is essential to maintaining the brook's health. If flows continue at the current regime, or reduce further, issues such as the build-up of organic material discussed above may result in the pools deteriorating and possibly a loss of species. Note: deposition areas, which can produce localised reduction in dissolved oxygen, are naturally not uncommon, but appear uncharacteristic to the Gingin Brook considering extent.

Electrical conductivity within the Gingin Brook remained relatively fresh with the exception of small increases after large rainfall events. This indicates the potential for inputs of salt via runoff from the surrounding cleared catchment. However, given the levels recorded this is not a major concern for the brook at this time. Towards the end of the study period (April) there was an increasing trend in electrical conductivity observed, which coincided with rising streamflow and a decrease in pH from 6.4 to 6.0. Given no rainfall was observed during this period it is unlikely this trend relates to the input of salt from runoff. It is more likely that the increase is associated with groundwater discharge contributing to the surface water flow (e.g. through reduced evaporation and atmospheric pressure changes). Anecdotal evidence supports this, with landholders observing increases in the streamflow independent of rainfall during March and April (E. Wedge and L. Carvell pers. comm.).

Significant changes in the electrical conductivity should be monitored if low flows continue, given freshwater fish are sensitive to changes in salinity. Beatty et al. (2008) suggest the western pygmy perch is particularly susceptible to changes in salinity during certain parts of its life history.

Based on this study's results it is difficult to predict whether a subsequent year of similar low flows (or a further reduction in flow) will produce impacts to the fish populations and ecological health of the upper Gingin Brook. It is suggested that low flows and the effects on biota and ecology be routinely monitored in future low-flow years.

5.3 Management of the CLFT

The overall objective of this study was to assess the existing CLFT's suitability for maintaining the upper Gingin Brook's ecological health and environmental values.

In the current flow regime the brook's ecological health was relatively good despite the total number of days and length of consecutive periods when flow was below the CLFT having greatly increased compared with previous years. However, there were signs the brook may be under stress given observations such as surface water disconnection and localised deterioration in water quality. In saying this, it appears the system has resilience to low-flow conditions given that fish diversity, population structure and water quality in refuge areas have been maintained. The sustainability of the brook's ecological health is difficult to predict if current flow conditions persist or flows reduce further – supporting the need for ecological trend data.

Based on this study's results, daily flows above 10 ML are likely to be adequate for maintaining the upper Gingin Brook's ecological health. The results also suggest that daily flows below 10 ML for extended periods are placing stress on the system in maintaining ecological health. In particular, this study identified surface water disconnection after a period of 41 days in February when the average flow was approximately 8.1 ML/day. Given the uncertainty in conditions below the existing CLFT, adopting a precautionary approach is recommended for managing the upper Gingin Brook resource by implementing a daily flow trigger of 8 ML (over two consecutive days). In addition, flows are to be monitored at the Gingin Brook gauging station on a weekly basis during low-flow periods to detect flows below this trigger. A breach in the trigger value is recommended to prompt monitoring of the dissolved oxygen in selected river pools (likely refuge areas) to ensure levels are above the concentrations required to sustain aquatic biota. Accordingly, the water quality trigger for dissolved oxygen should be set at 5 mg/L.

Revision of the low-flow trigger is expected in future based on the daily flow (ML) required to maintain dissolved oxygen levels above 5 mg/L in refuge areas.

A response strategy to a breach in prescribed threshold has been provided in Appendix E.

5.4 Recommendations

1. Replace existing CLFT with a precautionary flow trigger value of 8 ML/day recorded over two consecutive days (monitored at the Gingin Brook gauging station). Breach of this trigger could initiate a monitoring response to determine whether flows below this level are impacting system health, with a focus on assessing dissolved oxygen levels at selected sampling sites.

   It is recommended that dissolved oxygen levels below 5 mg/L elicit a more comprehensive ecological assessment (including biological response), with the specific response to be determined by a meeting of staff from the region and the Water Allocation and Water Science branches.

   Dissolved oxygen levels above 5 mg/L at flows below 8 ML/day should result in a redesignation of the flow trigger: the new trigger value derived should be based on sufficient flow to maintain dissolved oxygen above 5 mg/L (incorporating diurnal fluctuation).

   A detailed response strategy following breach of the precautionary flow trigger is provided in Appendix E.

2. Maintain regular monitoring of the daily flow at the Gingin Brook gauging station (617058) to identify when flows are below the trigger.

3. Protection of the refuge areas is important for maintaining the Gingin Brook's ecological health. Consideration should thus be given to restricting surface water and groundwater abstraction near refugia and encouraging surface water users to abstract water from the brook during the winter high flows to reduce the reliance on summer flow.

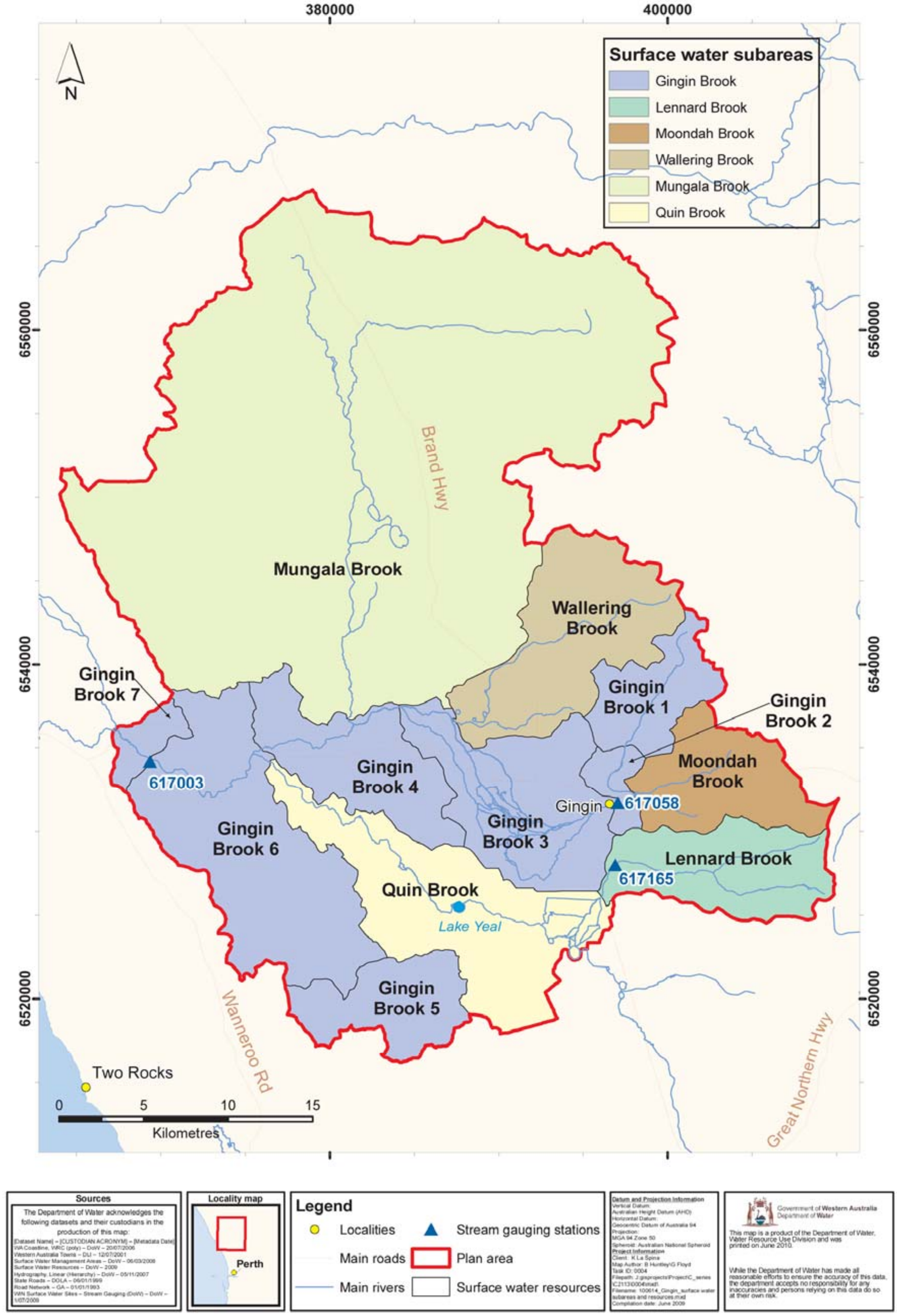
5.5 Knowledge gaps and management priorities

Based on the results of this study, a number of knowledge gaps and management actions were identified as areas for future investigation for enhancing our ability to better manage and maintain or improve the Gingin Brook's ecological health. These include:

1. Assessment of connectivity of surface water in terms of fish movement. This should also include an in-stream barrier assessment.
2. Maintenance of refuge areas is critical to the long-term sustainability of the Gingin Brook. Consideration should be given to involving local catchment groups to implement management actions to protect key refuge areas (assessment of key refugia in the system is required).
3. Monitoring of inorganic and organic sediment levels above and below in-stream barriers to evaluate whether system flushing is adequate to maintain water quality and habitat.

Appendices

Appendix A — Surface water allocation subareas and surface water resources



Appendix B — SWIRC river health assessment field sheets

Date ______________ Site code ______________

Government of Western Australia
Department of Water

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
COVER SHEET

SITE CODE ______________

SWMA ______________

RIVER SYSTEM ______________

RIVER/STREAM NAME ______________

SITE NAME ______________

DATE ______________ COC ______________ SAMPLE NUMBER ______________

NAME OF SAMPLERS ______________

NOT ASSESSED IN FIELD

ALTITUDE ______ (m) SLOPE ______ (m/km) DFS ______ (km) STREAM ORDER ______ (km)

NEAREST RAINFALL STATION ______ (name) DISTANCE AWAY ______ km AVERAGE ANNUAL RAINFALL ______ (mm)

FLOW PATTERN CATEGORY ______________ DISCHARGE CATEGORY ______ (mm)

ORDER OF SAMPLING – DAY 1

1. Take water quality samples: grab followed by in-situ
2. Collect macroinvertebrates
3. Deploy water quality loggers. *Note: after loggers have been deployed only enter river downstream.*
4. Process macroinvertebrate sample
5. Deploy fish/crayfish traps and fyke nets
6. Site photos (important to capture conditions on first day as factors such as water level and flow can change rapidly)
7. Field sheets (if time permits)

ORDER OF SAMPLING – DAY 2

1. Collect fish/crayfish traps and fyke nets
2. Collect water quality loggers: after 25 hours (144 logged measurements)
3. Complete field sheets
4. Complete site photos: fill-in checklist below.

Photo checklist

[ ] Upstream and downstream photos; taken at the top, middle and bottom of the 100m sampling site (6 photos total)
[ ] Representative site photos
[ ] Macroinvertebrate sampling area
[ ] Representative video taken
[ ] Canopy shots (taken from edge of stream of both sides – representative of density of canopy throughout site)

Acronyms
LB: Left Bank, **RB:** Right Bank

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Date ________________ Site code ________________

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Department of Water

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS

GPS DATUM ________________

LONGITUDE (°E) or EASTING ________________

LATITUDE (°S) or NORTHING ________________

MAP NAME and YEAR OF PUBLICATION ________________ SCALE ________________

PAGE REFERENCE OR MAP NUMBER ________________

ACCESS DETAILS ________________

____

____

____

PROPERTY OWNER ________________

PHONE NUMBER ________________

ADDRESS ________________

NOTIFY BEFORE EACH VISIT [ ] Yes [ ] No PERMISSION REQUIRED [ ] Yes [ ] No

KEY REQUIRED [ ] Yes [ ] No KEY NUMBER / AVAILABLE FROM ________________

ACCESS MAP – SKETCH ROUTE BELOW OR ATTACH MAP TO BACK OF FIELD SHEET

Include flow direction, site location, roads, crossings, north arrow, distances and landmarks.

MAP ATTACHED ☐

Version 12 - November 2009

Page 2 of 19

Date ______________ Site code ______________

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SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
GENERAL SITE ASSESSMENT – 100m sampling site

Artists name ______________________

LONGITUDINAL DIAGRAM (AERIAL VIEW)

Essential features	Legend
Flow direction	→ → →
Loggers	(L)
Macroinvertebrate sample	(M)
Water quality sample	(W)
Fyke nets	▶ or ◀
North arrow	↑ N

Possible features	DIY legend	*Possible features*	DIY legend
Macrophyte habitat		Vegetation type A: ________	
Large trees		Vegetation type B: ________	
Woody debris		Vegetation type C: ________	
Riffles			
Sandbars/sediment deposits			
Significant erosion			
Natural or artificial barriers			

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Date ______________   Site code ______________

Government of Western Australia
Department of Water

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
GENERAL SITE ASSESSMENT – 100m sampling site

CROSS SECTION DIAGRAM

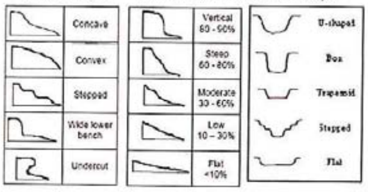
Representative of sampling region (where high variability exists draw two cross-sections).

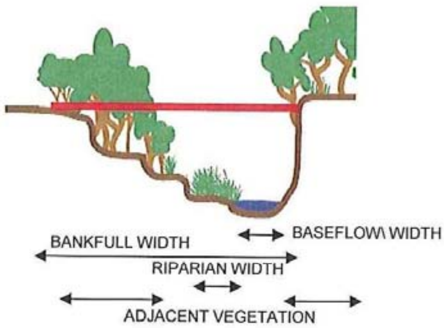
Suggested information to include on cross section diagram above

- Bank shape (see below)
- Bank slope (see below)
- Channel shape (see below)
- Base-flow and bank-full width (m)
- Streamside and adjacent vegetation width and structure
- Presence of bars, benches, toes

Circle diagrams below

Bank Shape   Bank slope   Channel shape





STREAM WIDTH MEASURMENTS

	Top	Middle	Bottom
Bankfull width (m)	______	______	______
Current water width (m)	______	______	______

Water width compared to base-flow (circle)				
No flow dry isolated	Low < low water mark	Moderate Equal to base-flow	High > high water mark	Flood

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Date ________________ Site code ________________

Government of Western Australia
Department of Water

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
AQUATIC HABITAT ASSESSMENT – 100m sampling site

STREAM HABITAT DIVERSITY

Habitat area	%
Channel (Includes woody debris)	
Macrophytes	
Riffle	
Pool	
Total	100

Macrophyte types	%
Emergent	
Submerged	
Floating	
Total	100

Large woody debris ☐ present ☐ absent (Size relative to 'un-impacted' conditions for specific area)	
Diversity (circle)	Abundance (circle) *
Wood of similar size	Sparse (few pieces)
2-3 different sizes	Moderate *
Variety of sizes	Dense (throughout most of site)

* A few sections of moderate density or low density across most of site

Bank vegetation draped in water ** (percentage of bank length)	

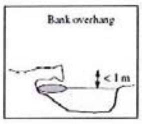
*Note: section relates to habitat (not shading). ** Dead vegetation not included*

Roots overhanging and draped in water			
None	Limited	Moderate	Extensive
Overhanging banks			
None	Limited	Moderate	Extensive

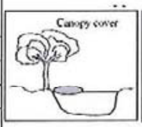
Limited = 1-10% of bank length, Moderate = 11-50%, Extensive >50% of bank.

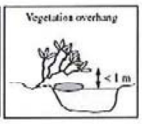
Flow (circle)
Uniform flow (e.g. drain)
Moderately varied flow
Varied flow (eg eddies, backwaters, fast, slow)

Depth (circle)
Uniform depth (eg drain)
Moderately varied depth
Varied depths



Stream shading	Percentage of bank length		Average distance from bank (m) **Average stream width** ________ m	
	LB	RB	LB	RB
Tree cover #				
Shrub overhang				
Grass overhang (rushes/sedges)				





Note: density of canopy will be determined from canopy photographs; therefore only total area should be assessed.

Physical substrate DIVERSITY	Increasing complexity (circle one number)
Mainly bedrock or artificial substrate	1 2 3 4 5
Silt or sand or a mixture of silt and sand	6 7 8 9 10
Mainly sand with some pebbles &/or boulders	11 12 13 14 15
Mix of boulders, pebbles & sand etc	16 17 18 19 20

Note: increasing complexity or density are not a direct indication of health (i.e. boulders are not expected at all sites)

Biological substrate DENSITY *Tip: try breaking site into sub-sections (i.e. 10 x 10m sections for a 100m sampling site), to estimate cover*	Increasing density (circle one number)
<10% of substrate cover	0 1 2 3 4 5
11-30%	6 7 8 9 10
31-60%	11 12 13 4 15
>60%	16 17 18 19 20

Biological substrate DIVERSITY (circle)				
leaves	twigs	branches	detritus *	Epiphytes

* *Detritus relates to undifferentiated organic material*

Sediment deposition	None or minor	Not obvious	Obvious

Type (sand/silt): ______________________________

WATER AND SEDIMENT

Circle the appropriate description under each category.

Water odours	*Water Oils*	*Turbidity*	*Tannin staining* *	*Algae in water column*	*Algae on substrate*	*Plume***	*Sediment oils*	*Sediment odours*
Normal/None	None	Clear	Clear	0%	0%	Small	Absent	Normal/None
Anaerobic	Slick	Slight	Slight	1 to 10%	1 to 10%	Moderate	Light	Sewage
Sewage	Sheen	Turbid	Light tea	11 to 50%	11 to 50%	Large	Moderate	Petroleum
Petroleum	Globs	Opaque	Dark tea	51 to 75%	51 to 75%		Profuse	Chemical
Chemical	Flecks		Black	> 75%	> 75%			Anaerobic

* tannin staining can be confused when combined with systems containing fine suspended sediment (if problematic assess from filtered water sample)
** relates to amount of fine sediment generated and time take to settle (i.e. a large plume may extend for a meter diameter and remain suspended for 5 seconds or more)

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SW-WA RIVER HEALTH ASSESSMENT – FIELD SHEETS
PHYSICAL FORM/CATCHMENT IMPACT ASSESSMENT – 100m sampling site

BANKS AND PHYSICAL FORM

AMOUNT of erosion *Length of bank affected (%)*		
0 to 5%	LB	RB
>5 to 20%	LB	RB
21 to 50%	LB	RB
> 50%	LB	RB

SEVERITY of erosion, and bank stability	Circle	
Severe: LITTLE TO NO STRUCTURAL INTEGRITY Banks are predominantly bare. Significant sections of erosion (undercutting/slumping) on both outside bends and straight stretches (sediment deposits in river). Exposed roots obvious (where applicable), with significant loss of vegetation in eroding areas. Channel shape, bank shape and depth likely to change in near future.	LB	RB
High: POOR STRUCTURAL INTEGRITY Evidence of bank instability (undercutting/slumping); with signs of soil loss from banks, and possibly areas of sedimentation (i.e. sandbars or toes) and scouring. Some exposed roots (where applicable), with loss of vegetation in eroding areas. Erosion typically around outside bends.	LB	RB
Low-Moderate: GOOD STRUCTURAL INTEGRITY Banks relatively stable – exposed and superficially eroding bank (erosion doesn't penetrate deeply into bank wall) or stabilised by only exotic grasses. Little likelihood of significant change to channel/bank shape, depth or loss of bank material in near future.	LB	RB
Minor: EXCELLENT STRUCTURAL INTEGRITY Banks stable and mostly intact (minor slumping, undercutting or bare banks expected naturally): stabilised by vegetation or bedrock.	LB	RB

Factors affecting bank stability	Circle	
Feral animals	LB	RB
Livestock access (if yes, compete table below)	LB	RB
Human access	LB	RB
Cleared vegetation	LB	RB
Runoff		
Irrigation draw-down		
Flow and waves		
Culvert, bridge, dam		
Drain pipes	LB	RB
Other (specify)		

Stabilisation works Yes ☐ No ☐		
Choose one or more	Circle	
Rock wall protection	LB	RB
Bank matting	LB	RB
Logs/planks strapped to bank	LB	RB
Concrete lining	LB	RB
Revegetation plantings	LB	RB
Fenced human access (deterrent)	LB	RB
Fenced livestock access	LB	RB
Fenced stock watering points	LB	RB
Other (specify)	LB	RB

Indicate livestock types ________________________________ & indicate their impact (major or minor) for each category below.

CATEGORY	MINOR	Tick box	MAJOR	Tick box
Vegetation damage	Only small patches of vegetation grazed		Most groundcover vegetation grazed.	
Bank damage	Isolated areas (1 or 2) of livestock damage		Near continuous livestock damage to stream	
Pugging	Isolated (1or 2) areas of pugging		Extensive pugging along the stream length	
Manure	≤2 significant manure deposits per site		>2 significant manure deposits per site	
Tracks	≤1 track per site		>1 track per site	

POLLUTION SOURCES

Local point source pollution		*None evident* ☐
Potential	Obvious	Indicate type/s:
Within site	Within site	
Upstream	Upstream	
Downstream	Downstream	

Local non-point source pollution		*None evident* ☐
Potential	Obvious	Indicate type/s:
Within site	Within site	
Upstream	Upstream	
Downstream	Downstream	

LANDUSE AT SITE - WITHIN 50m FROM EDGE OF STREAM

Circle all applicable for each bank

LB	Conservation	Remnant vegetation	Water Catchment	State Forest	Aboriginal Reserve	Vacant Crown Land	Agriculture	Pastoralism	Tourism	Mining	Industrial	Urban
RB	Conservation	Remnant vegetation	Water Catchment	State Forest	Aboriginal Reserve	Vacant Crown Land	Agriculture	Pastoralism	Tourism	Mining	Industrial	Urban

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SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
VEGETATION ASSESSMENT - 100m sampling site

RIPARIAN VEGETATION

Riparian zone = a clear distinction in vegetation type between water dependant and non-water-dependent vegetation

Riparian zone ABSENT ☐ >>>> Due to: **human impact** ☐ **natural feature (eg bedrock)** ☐ **fire/flood...** ☐ **unknown** ☐

Riparian zone PRESENT ☐ [complete rest of box]

Indicate riparian layers PRESENT*?	circle			**Width of riparian zone** Left bank ______m Right bank ______m
Ground layer (i.e. sedges, rushes)	yes	no	reduced	**Dominant riparian species** (if unknown write: refer to photographs):
Shrub layer (woody)	yes	no	reduced	
Tree layer	yes	no	reduced	

* this refers to the presence of riparian species (intactness is incorporated below). Note: if only 1 or 2 shrubs remain (for example) circle 'no'.

STREAMSIDE ZONE VEGETATION (FIRST 10m) - NATIVE AND EXOTIC VEGETATION

Percentage cover	0%		1 - 10%		10 to 50%		50 - 75%		> 75%	
	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
Bare ground (not bedrock)										
Ground cover/grasses/sedges/rushes										
Shrubs (woody, multi-stem)*										
Trees < 10m										
Trees > 10m										

*Shrubs include Blackberry, Tea trees

STREAMSIDE ZONE VEGETATION (FIRST 10m) - EXOTIC VEGETATION

Proportion (%) of exotic vegetation in each vegetation layer	0%		1 - 10%		10 to 50%		50 - 75%		> 75%	
	LB	RB	LB	RB	LB	RB	LB	RB	LB	RB
Ground cover/grasses/sedges/rushes										
Shrubs (woody, multi-stem)*										
Trees < 10m										
Trees > 10m										

STREAMSIDE ZONE VEGETATION (FIRST 10m) - NATIVE WOODY VEGETATION

Recruitment evidence	*Recruitment type*	*Extent of recruitment*	*Recruitment health*
None	Trees	Limited	Poor
Natural	Shrubs	Moderate	Moderate
Planted	Both	Abundant	Healthy

ADJACENT ZONE VEGETATION (10 to 100m)

Tick box for the DOMINANT feature in each zone	10 to 50m		50 to 100m		100m +	
	LB	RB	LB	RB	LB	RB
Minimal vegetation Typical of areas of urban development / industry / mining						
Weeds/Grasses May have a few scattered trees (typical of agriculture)						
Remnant vegetation Mostly native trees and/or shrubs (may have exotic understorey).						
Forest Native trees, shrubs and understorey. Few or no exotics.						
Plantations **Type:** ______________________						
Other (describe)						

COMMENTS (VEGETATION IN ADJACENT ZONE): ______________________________

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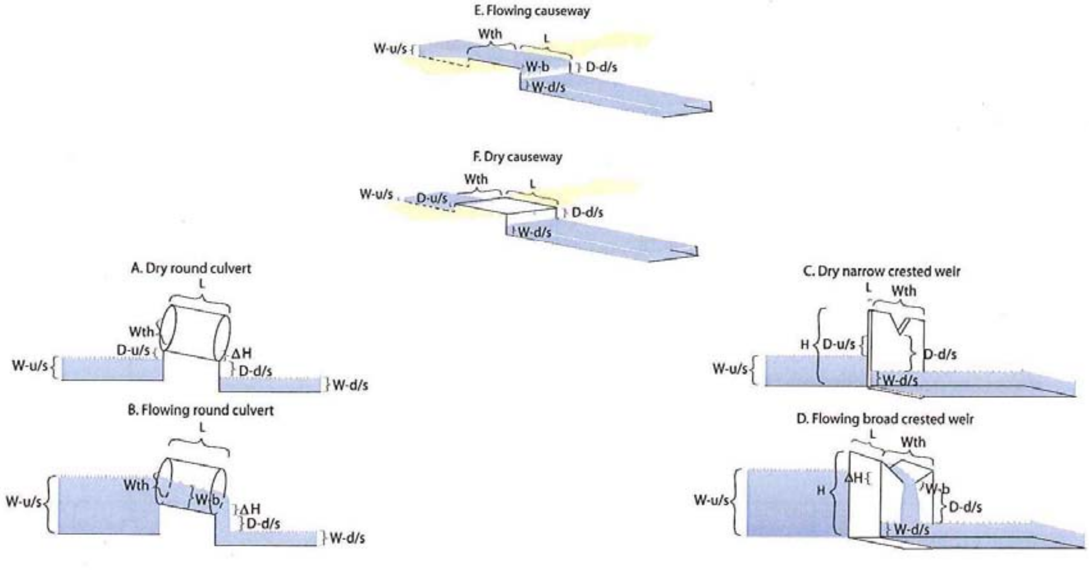
SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
BARRIER ASSESSMENT - 100m sampling site

NATURAL AND ARTIFICIAL BARRIERS IN 100m SITE

No barriers ☐

Description		Barrier 1	Barrier 2	Barrier 3
	Type of Barrier – artificial (see bottom of page for types) or natural			
	Longitude or Northing			
	Latitude or Easting			
	Tick when photo taken			
L	Length (longitudinal) (m)			
ΔH	Height difference across barrier (m)			
Wth	Width or diameter (cross-section) (m)			
H	Height (m)			
W – b	Water depth across barrier (m)			
D – d/s	Downstream drop (bottom of barrier to water) (m)			
W – d/s	Water depth – downstream (m)			
D – u/s	Upstream drop (bottom of barrier to water) (m)			
W – u/s	Water depth – upstream (m)			
	Blockage – overgrowth or sedimentation % cross-sectional area			
	Flow over barrier (either measure or describe)			
	Structure material (e.g. concrete, timber, steel, plastic, loose rock)			
	If culvert, number or pipes or boxes			
	Barrier floods at flow condition (extremely high, high, medium, low flows)			

Note: Not all of the above measurements will apply to natural barriers.



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SW-WA RIVER HEALTH ASSESSMENT – FIELD SHEETS
100m sampling site

NATURAL OR ARTIFICIAL BARRIERS OUTSIDE 100m SITE

Artificial barriers outside 100m site (upstream or downstream)		Circle
Unknown	None	Yes (see below)
Description and distance from site (if time, assess as per previous page).		

Natural barriers outside 100m site (upstream or downstream)		Circle
Unknown	None	Yes (see below)
Description and distance from site (if time, assess as per previous page).		

CHANNELISATION

Signs of channelisation	No ☐	Yes ☐ (describe below)

Note whether channelisation is due:

1. **Direct causes**: deepening and straightening by humans to increase water flow (e.g. to reduce flooding), or
2. **Indirect causes:** deepened systems with more vertical banks due to bank erosion and bed scouring; a result of increased flows from changes such as catchment clearing or hydrological modifications.

WATER VELOCITY (FLOW) ACROSS 100m SAMPLE SITE

Flow information is recorded on the Macroinvertebrate Sampling Sheet and WQ 2 Sheet, if neither is being used for this assessment use space provided below.

Meter or Method used ____________________________ units ________ Velocity____________

WEATHER CONDITIONS

Rain in past week	Tick box
Yes	
No	
If known, mm	

Cloud cover	%
Day 1	
Day 2	

Rain	Tick box
Day 1	Yes ☐ No ☐
Day 2	Yes ☐ No ☐

Weather comments ____

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SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
WATER QUALITY 1: GRAB AND IN-SITU SAMPLES

Recorders name ______________________

PRE - INSTRUMENT CALIBRATION

Instrument Type ______________________ Instrument Number ______________________

Pre – field calibration	Electrical Conductivity (mS/cm)	pH 7	pH 10	Dissolved Oxygen (% sat)	Salinity	Temperature
Pre reading						
Post reading						

NOTE: In most cases salinity and temperature are not calibrated prior to use.

Circle:

Conductivity units	uncomp	comp (25°C)	
Conductivity setting	fresh	salt	none
Salinity setting	2311	Other (indicate):	
Electrical conductivity calibration solution used	1.413 mS/cm	Other (indicate):	
Dissolves oxygen calibrated to	100% sat. in air	Other (indicate):	

Barometric pressure from BOM (if required) for DO calibration

Full state: 1900 955 366
Coastal: 1900 969 902

_________ hPa ______ mmHg
(mmHg = hPa x 0.7502)

GRAB WATER QUALITY

Water quality samples taken

Date ______________ Time ______________

Sample number ______________ COC ______________

IN-SUTU WATER QUALITY

	Date	Time (24 hrs)	Salinity (ppt)	pH	Dissolved oxygen (mg/L)	Dissolved Oxygen (% sat)	Electrical Conductivity (mS/cm)	Temperature (°C)	Add any others here	
Surface										
Bottom										

Note: Usually only surface water samples are taken.

POST - INSTRUMENT CALIBRATION

Post – field calibration	Electrical Conductivity (mS/cm)	pH 7	pH 10	Dissolved Oxygen (% sat)	Salinity	Temperature (°C)
Pre reading						
Post reading						

NOTE: In most cases pH 10 does not require post calibration. Dissolved oxygen is only checked, not post calibrated

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SW-WA FARWH – FIELD SHEETS
WATER QUALITY 2: DIEL DISSOLVED OXYGEN AND TEMPERATURE

Recorders name ______________________

PRE-DEPLOYMENT MEASUREMENTS

Deployment date ______________ Deployment time ______________

Probe Letter	Pump Number	Field air calibration			Water readings (mg/L)	Pump running (yes or no)	Water depth to first inlet hole (cm)	Actual water depth (m)
		Pre-cal (mg/L)	Span (%)	Post-cal (mg/L)				

LOCATION OF LOGGERS

Circle one each category (except for in-stream vegetation)

Location in stream	In main flow	Off main flow	Other (describe)	
Angle loggers deployed	90° (vertical)	45 to 90°	< 45°	
Canopy cover over loggers	0%	10 to 50%	50% to 80%	100%
In-stream vegetation* (tick all applicable)	None	Emergent	Submerged	Floating
Density of in-stream, vegetation*	N/A	Sparse	Medium	Dense
Density of algae in water column*	None	Sparse	Medium	Dense
Riffles/cascades (upstream of loggers)**	None		If yes __________ m upstream	

* within 1m from loggers. ** within 50m from loggers

Notes ____

WATER VELOCITY (FLOW) AT LOGGER SITE

Meter or Method used ____________________ units ________ Velocity__________

POST DEPLOYMENT MEASUREMENTS

Retrieval date __________ Retrieval time __________

Probe Letter	Pump running	Condition of HOUSING	Condition of MEMBRANE		Water reading (mg/L)	Air reading (mg/L)
	No Slow Fast	Clean Slightly dirty Very dirty	Clean Slightly dirty Very dirty	Bubbles No bubbles		
	No Slow Fast	Clean Slightly dirty Very dirty	Clean Slightly dirty Very dirty	Bubbles No bubbles		

Weather observations in past 24 hours and/or any noticeable changes to site or loggers ______________________
____
____

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SW-WA FARWH – FIELD SHEETS
WATER QUALITY 3: MULTI PARAMETER LOGGING

Recorders name ____________________________

PRE-DEPLOYMENT INSTRUMENT CALIBRATION

Instrument Type ______________________ Logger Number _______________ Handpiece Number _______________

Pre – field Calibration	Salinity	pH 7	pH 10	Dissolved Oxygen (% sat)	Electrical Conductivity (mS/cm)	Temperature (°C)
Reading						
Calibrated to						

NOTE: In most cases salinity and temperature are not calibrated prior to use.

Barometric pressure from BOM (if required) for DO calibration

Full state: 1900 955 366
Coastal: 1900 969 902

_________ hPa ______ mmHg
(mmHg = hPa x 0.7502)

LOGGING INFORMATION

Deployment date ________________ Deployment time ________________

Parameters set to log (tick)

[ ] Dissolved Oxygen [ ] Temperature [ ] Electrical conductivity
[ ] pH [ ] Turbidity [ ] Other ________________

Loggers set to record every ___________________ mins for ___________________ days / hours (circle)

LOCATION OF LOGGERS

Circle one option for each category (except for in-stream vegetation)

Location in stream	In main flow	Off main flow	Other (describe)	
Angle loggers deployed	90° (vertical)	45 to 90°	< 45°	
Canopy cover over loggers	0%	10 to 50%	50% to 80%	100%
In-stream vegetation* (tick all applicable)	None	Emergent	Submerged	Floating
Density of in-stream, vegetation*	N/A	Sparse	Medium	Dense
Density of algae in water column*	None	Sparse	Medium	Dense
Riffles/cascades (upstream of loggers)**	None		If yes ______________ m upstream	

* within 1m from loggers. ** within 50m from loggers

Notes ____

WATER VELOCITY (FLOW) AT LOGGER SITE

Meter or Method used ______________________ units ________ Velocity ______________

LOGGER REMOVAL

Logger removal date ___________ Logger removal time ___________

Weather observations in past 24 hours and/or any noticeable changes to site or loggers ______________________________
____

Post – field Calibration	Salinity	pH 7	pH 10	DO%	Electrical Conductivity (mS/cm)	Temperature (°C)
Reading						
Calibrated to						

NOTE: In most cases pH 10 does not require post calibration. Dissolved oxygen is only checked, not post calibrated

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SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
FISH AND CRAYFISH

Recorders name ____________________ Date traps deployed ____________________

☐ (tick) Local Fisheries WA officer called (1800 815 507) up to one day prior (need permit number, car registration and samplers names)

TRAP SETTING – BOX TRAPS

Trap #	Small trap (S) or Large trap (L)	Left bank (LB) Right bank (RB) or Centre (C)	Water Depth (cm)	Describe location of trap e.g. in woody debris, under log, amongst emergent macrophytes, in full sun, % shaded, under overhanging vegetation, amongst tree roots.

TRAP SETTING – FYKE NETS

TYPE		Water Depth (cm)	% stream width *	Comments e.g. fyke in eddy, gaps between wings and bank or river bottom
Dome (D) or Rectangle (R)	Upstream (US) or Downstream DS)			

*If both wings are fully extended to edge of bank this would be 100%. If spaces exist between wings and bank or between wings and surface of water (due to depth), estimate coverage and provide explanation of set-up.

LIST FISH/CRAYFISH SPECIES OBSERVED BUT NOT CAUGHT

____

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Date ________________ Site code ________________

Government of Western Australia
Department of Water

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
FISH AND CRAYFISH

Recorders name ________________________ Date traps collected ________________________

TRAP COLLECTION

Trap #		Size class (mm)					Evidence of Reproduction*	Comments (for example) • staining, parasites, disease, injury • smallest size gravid individual • size of largest individual
	Fish	0-20	20 - 50	50 - 100	100 +	Other	none	
	Crayfish	0-20	20 - 50	50 - 76	76 - 100	100+	✓ (few)	
	Large fish	0-100	100-200	200-400	400+	Other	✓✓ (many)	***Note size of marron over 76mm***

**Evidence of reproductive condition includes gravid females &/or characteristic colours*

Legend
WM = Western Minnow, **TM** = Trout Minnow, **BSM** = Black-stripe Minnow, **NF** = Nightfish, **WPP** = Western Pygmy Perch, **BPP** = Balstons Pygmy Perch, **SWG** = South West Goby, **SRG** = Swan River Goby, **COB** = Cobbler, **JOL** = Jollytail, **GAM** = Gambusia, **1SPOT** = One spot live bearer, **WH** = Western Hardy Head, **ELONG** = Elongata, **BB** = Black Bream, **RP** = Redfin Perch, **RT** = Rainbow Trout, **BT** = Brown Trout, **MM** = Mud Minnow, **GIL** = Gilgie, **GH** = Hybrid Gilgie, **MAR** = Marron, **HMAR** = Hairy Marron, **K** = Koonac, **KX** = Koonac sp X, **Y** = Yabbie, **FS** = Freshwater Shrimp.

Large fish include: cobbler, trout, redfin, lamprey.

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[additional sheets provided in field kit; explaining disparity in page numbers]

Date ________________ Site code ________________ Government of Western Australia Department of Water

SW-WA RIVER HEALTH ASSESSMENT - FIELD SHEETS
MACROINVERTEBRATES: AUSRIVAS FIELD SHEET

Recorders name ____________________________

DATE SAMPLE TAKEN ______________________ TIME SAMPLE TAKEN ______________________

COLLECTED BY ______________________ PICKED BY ________________ AND ________________

HABITAT ______________________ % OF 100 m reach ______________________

SAMPLE NUMBER ______________________ COC NUMBER ______________________

SAMPLING CONDITIONS [ ] good [ ] average [ ] poor

PICKING CONDITIONS [ ] good [ ] average [ ] poor

BREAKDOWN OF 10m SAMPLING AREA

Mineral Substrate	%	Habitat surface area	%	*Density (circle) (1= sparse, 5 = dense)*
Bedrock		Mineral substrate		
Boulders (>256mm or scorer ball)		Emergent macrophyte		1 2 3 4 5
Cobble (64 to 256mm or cricket to soccer ball		Submerged macrophyte		1 2 3 4 5
Pebble (16 to 64mm or 5c piece to cricket ball)		Floating macrophyte		1 2 3 4 5
Gravel (4 to 16mm or raw sugar to 5c piece)		Detritus		1 2 3 4 5
Sand (1 to 4mm)		Algal Cover		1 2 3 4 5
Silt (<1mm)		Riparian veg draped in water		
Clay		Other (e.g. woody debris)		
Total	100%	Total (may be > 100%)		

DEPTH

Depth macroinvertebrate sample taken (circle) <25cm <50cm <100cm < 200cm > 200cm

WATER VELOCITY (FLOW) AT MACROINVERTEBRATE SITE

Meter or Method used ______________________ units ________ Max velocity ______________ Min velocity ____________

BOX SUB-SAMPLER TALLY

Number of cells picked ______________

Number of cells in box ______________

Total number of macroinvertebrates picked ______________

Comments (if any)

____

____

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Appendix C — Water quality graphs

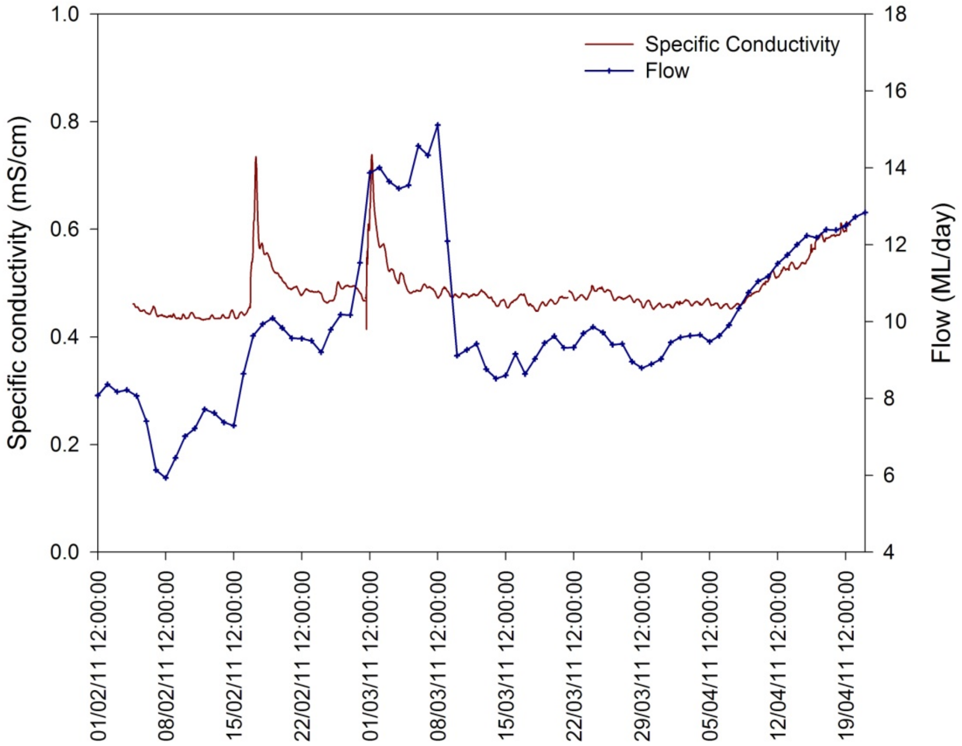

Figure 8 Specific conductivity monitored over the study period at the lower reach on the Gingin Brook.

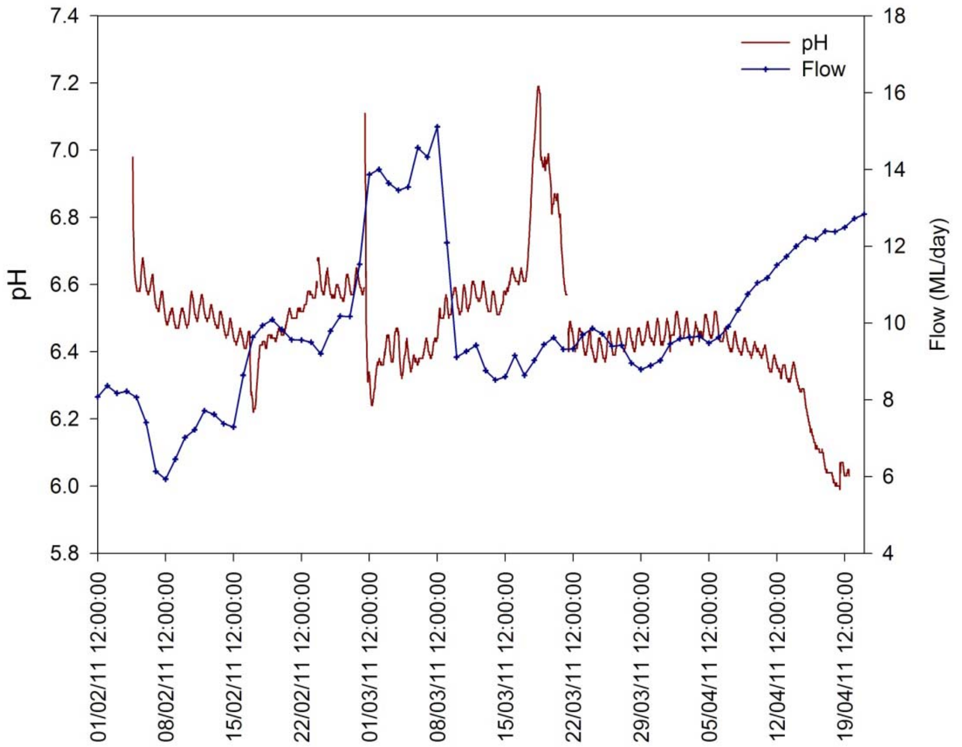

Figure 9 pH monitored over the study period at the lower reach on the Gingin Brook.

Appendix D — Photo points

1. Whakea Road

2. Pool upstream Cheriton Estate weir

February

March

April

Figure 10 Photo points 1 and 2 taken at Whakea Road and the pool upstream of Cheriton Estate weir in the upper reach of the Gingin Brook.

3. Downstream Cheriton Estate weir

February

No photo taken

March

April

Figure 11 Photo point 3 taken at the run downstream of Cheriton Estate weir in the upper reach of the Gingin Brook.

1. Gauging station weir

2. Upstream of concrete spillway

February

March

April

Figure 12 Photo points 1 and 2 taken at the Gingin Brook gauging station and upstream of the concrete spillway (downstream of Gingin Brook gauging station weir) in the lower reach of the Gingin Brook.

3. 20 m downstream of concrete spillway

3a. looking upstream

3b. looking downstream

February

March

April

Figure 13 Photo points 3a and 3b taken at approximately 20 m downstream of concrete spillway (downstream of Gingin Brook gauging station weir) on the lower reach of Gingin Brook.

Appendix E — Strategic response during low flows

Response strategy for breach of low-flow trigger in the Gingin Brook

During low-flow periods (typically December to April) flow data should be monitored weekly to detect whether flows are below the low-flow trigger value of 8 ML/day for two consecutive days. Flows are to be monitored at the Gingin Brook gauging station (617058, telemetered site).

When the low-flow trigger is breached, regional staff are required to monitor dissolved oxygen in predetermined areas (outlined in Table 3), following the monitoring protocols outlined below, and additional information collected (Table 4) to be used for interpretation.

Monitoring is designed to be a rapid, cost-efficient approach to track dissolved oxygen concentrations and to elicit a more comprehensive response only if levels fall below 5 mg/L. Subsequent action is to be determined by a meeting of staff from the region and the Water Allocation and Water Science branches.

The low-flow trigger may be revised in future based on data collected on the relationship between the daily flow (ML) and dissolved oxygen.

Table 3 Assessment sites for dissolved oxygen monitoring.

Monitoring site	Depth profile locations	Coordinates	Access
Whakea Road, L89 Whakea Road, Ginginup	Depth profile in deepest section of the brook.	31.3125°S 115.9233°E	Contact landholder for access: Eddie Wedge 9575 2206
Pool upstream of Cheriton Estate Weir, L50 Cheriton Road, Ginginup	Depth profile in front of double culvert	31.3278°S 115.9162°E	Contact landholder for access: Robyn Lang 0427 511 985
Gingin Brook gauging station, 68 Robinson Street, Gingin	Depth profile in pool upstream of weir and pool ~10 m upstream of spillway	31.3445°S 115.9176°E	Contact landholder for access to book below the weir: Len Carvell 9575 1186

Dissolved oxygen monitoring protocol

Ideally the measurement of dissolved oxygen level should be over a 24-hour period to capture diurnal fluctuations; however, spot measurements can be used so long as the expected daily fluctuations are considered. Hence spot measurements should be conducted in the early morning or late afternoon (the former being most important if phytoplankton and/or macrophytes are abundant) to capture the minima dissolved oxygen concentrations.

If using a hand-held water quality probe take depth profile measurements (surface to 10 cm above the substrate) at 10 cm intervals. Measure dissolved oxygen in at least in two different locations within each site, preferably in the deepest areas.

If using a water quality datalogger, ensure that the probe is placed at least 10 cm below the water's surface. Set the instrument to log data every 10 minutes. Ideally the equipment should be deployed in the morning and collected the next day after at least 25 hours have lapsed.

Refer to the field sampling guidelines (DoW 2009) for detailed information on how to take *in situ* dissolved oxygen measurements. Water Science staff can help set up of datalogging equipment. Both hand-held water quality instruments and water quality dataloggers can be borrowed from Water Science if required

Table 4 Locations for assessment of system connectivity.

Site	Measurement	Trigger and response
Edgar St Mortimer Rd Brook St Weld Rd Assessment sites	Check water depth and note whether the Gingin Brook is flowing	If surface water is disconnected, check dissolved oxygen in the remaining waterbody. Record level of disconnection with photographs and note percent and type of aquatic habitat exposed. If dissolved oxygen levels are below 5 mg/L, convene a meeting with staff from the region and the Water Allocation and Water Science branches for subsequent actions.

Shortened forms

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
CLFT	critical low-flow threshold
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DOW	Department of Water
EWR	environmental water requirement
SWIRC	South-west Index of River Condition

Glossary

Abstraction	The permanent or temporary withdrawal of water from any source of supply, so that it is no longer part of the resources of the locality.
Barrier assessment	The measurement and classification of barriers in rivers that prevent fish migration. Barriers can be physical such as dams and weirs, or chemical such as pollutants entering a waterway.
Baseflow	The component of streamflow supplied by groundwater discharge.
Climate change	A change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.
Discharge	The water that moves from the groundwater to the ground surface or above, such as a spring. This includes water that seeps onto the ground surface, evaporation from unsaturated soil, and water extracted from groundwater by plants (evapotranspiration) or engineering works (groundwater pumping).
Ecological health	Symptoms of an ecosystem's ability to perform nature's functions, affected by anthropogenic disturbance such as pollution and development of habitat and food sources.
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.
Ecological water requirements	The water regime needed to maintain the ecological values (including assets, functions and processes) of water-dependent ecosystems at a low level of risk.
Flow regime	A description of the variation of the flow rate over time.
Refugia	Sections of a stream that provide habitat and sufficient water quality and quantity to preserve aquatic biota during low-flow periods.
Spring	A spring is where water naturally rises to and flows over the surface of land.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Water quality	The physical, chemical and biological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and/or to any human need or purpose.

Volumes of water

One litre 1 litre 1 litre (L)

One thousand litres 1000 litres 1 kilolitre (kL)

One million litres 1 000 000 litres 1 Megalitre (ML)

One thousand million litres 1 000 000 000 litres 1 Gigalitre (GL)

Data sources

The maps in this publication were produced by the Department of Water with the intent that they be used as illustrations in this report *Assessment of low flow thresholds in maintaining ecological health of the Gingin Brook*. While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, it accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

The Department of Water acknowledges the following datasets and their custodians in the production of the maps:

Dataset Name	Custodian acronym	Metadata year
Hydrography, linear (hierarchy)	DOW	2007
Hydrography Linear (course scale) (Global Map Data Australia 1M)	GA	2001
Road centrelines	Landgate	2010
Western Australian towns	Landgate	2001
WA Coastline	DOW	2006
Water Information Network sites	DOW	2006

The maps have been produced using the following data and projection information:

Vertical Datum: AHD (Australian Height Datum)

Horizontal Datum: GDA 94 (Geocentric Datum of Australia 1994)

Projection System: GDA 94 (Geocentric Datum of Australia 1994)

Original ArcMap documents (*.mxd):
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