WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Final Report

Green Lake Waterway Action Plan

Wimmera Catchment Management Authority

19 March 2024

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Project Details

Project Name	Green Lake Waterway Action Plan
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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present.

By Maurice Goolagong 2023

EXECUTIVE SUMMARY

Water Technology, in collaboration with Lloyd Environmental, was commissioned by the Wimmera Catchment Management Authority (CMA) to develop a Waterway Action Plan (WAP) for the Green Lake catchment, which is situated 12 km southeast of Horsham.

Waterway Action Plans provide a technical and financial basis for the implementation of works and initiatives on waterways by government and its partners. The waterway action planning process includes a review of environmental, social, cultural and economic values, and threats to these values, along a particular waterway. This information is strengthened by community experience and knowledge gathered through community consultation during the project.

The project area includes Green Lake and its catchment. Green Lake is an off-stream reservoir situated on Crown land, immediately south of the Western Highway. It was formerly a wetland, then modified in 1933 to hold water for irrigation purposes. However, its use as a water storage has been made obsolete through the construction of the Wimmera Mallee Pipeline. The lake incorporates a natural catchment area of approximately 50 km^2. When full, Green Lake holds 5,350 ML and has a maximum depth of approximately 3.5 m.

There are two main tributaries (Diggers Creek and Mibus Creek) that generally flow in a northerly direction and meet just before entering the southern edge of Green Lake. The lake can also receive flows from the Toolondo Channel via the Green Lake Inlet Channel and Diggers Creek.

This Waterway Management Plan has been prepared to ultimately guide the most appropriate waterway management actions across the project area. The Plan provides a technical strategic blueprint for the implementation of works and initiatives on the relevant waterways.

Specifically, the Plan seeks to:

- Identify reach wide and site-specific values and issues across the project area, including bed and bank instability, riparian vegetation condition, stock access (i.e. fencing presence and condition) and weed infestations.
- Identification of prioritised management actions (using a cost/benefit analysis and agreed risk management approach), to:
  - Improve environmental, social, and recreational values of the lake.
  - Improve water quality and reducing the frequency of blue green algae outbreaks in the lake.

This Waterway Action Plan process and involved the following key stages:

1. Project Scoping and Initiation,
2. Stakeholder and Community Engagement,
3. Site Assessment,
4. Preparation of the Draft Waterway Action Plan (this report),
5. Following review, report findings back to the stakeholders and community,
6. Incorporate final feedback and finalise the Plan.

Objectives for the future management of the Green Lake and tributaries were developed with Wimmera CMA, stakeholders and the community during consultation. The primary objective of the project is to develop appropriate actions to reduce the incidence of blue-green algal (BGA) blooms within Green Lake. Many of the key actions to achieve this primary objective provide additional benefits to waterway health, water quality and

habitat improvement. Ultimately, a reduction in BGA blooms will increase the social, health, economic and environmental values of Green Lake.

Key Management Principles have been identified and described to assist the Wimmera CMA to plan and implement river health projects, mitigate risks and improve the environmental condition of the Green Lake and its tributaries. Key Management Principles are:

- Vegetation establishment:
  - Riparian vegetation along tributaries and the lake surrounds,
  - Water quality treatment wetlands, and
  - Lake fringing reed beds.
- Riparian fencing for stock management
- Weed management.
- Structural intervention to manage bank erosion:
  - Rock armouring, and
  - Log revetment.

Prioritised recommendations for management were developed with consideration of:

- The project objectives,
- The threats and values present within the project area,
- The reach delineation, and.
- Stakeholder and community input.

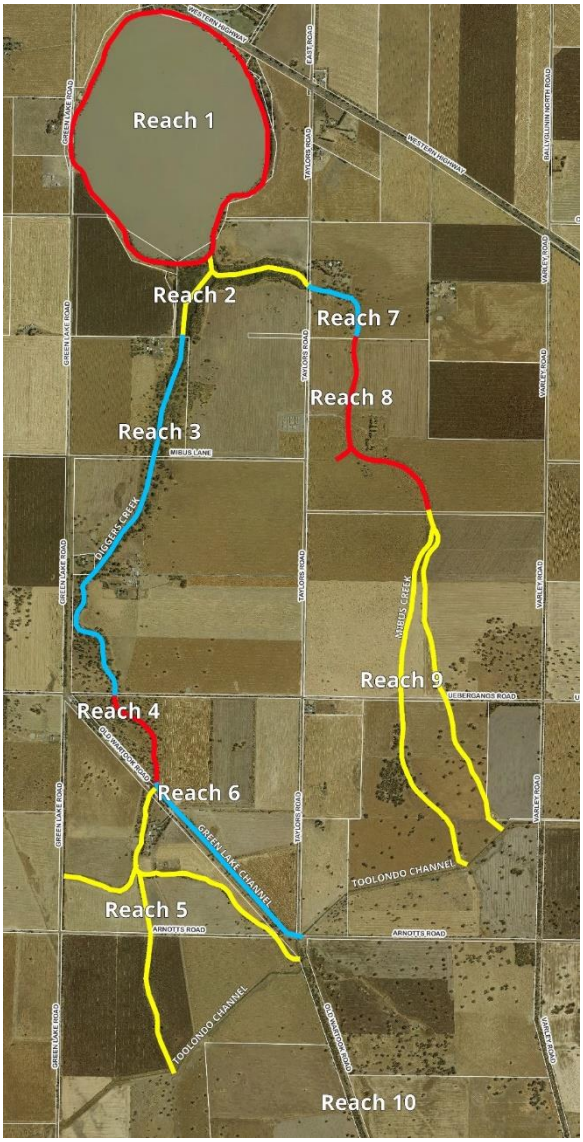
Recommended priorities for the management of the stream network across the project area have been developed based on the following rationale:

- **The highest priority (priority A) is given to those actions**:
  - That have the potential to reduce the incidence of Blue-Green Algal blooms within Green Lake. Ultimately, a reduction in Blue-Green Algal blooms will increase the social, health, economic and environmental values of Green Lake.
- **The second highest priority (Priority B) is given to those actions**:
  - That improves the general riparian condition of the waterways within the project area.

The project area has been divided into 10 Reaches that have similar attributes and condition. Each reach has been described and complemented with photos showing indicative condition and points of interest.

Fifteen management actions have been documented across all 10 reaches. These actions have been mapped and described with reference to the project reach and the rationale for implementing the action. A summary of the management actions proposed is as follows:

- Reach 1, Green Lake:
  - Fringing reed bed establishment
  - Carp control
  - Weed management (Cape Broom and Bridal Creeper)
- Reach 2, Diggers Creek and Mibus Creek confluence:
  - Create a wetland treatment area
- Reach 3, Diggers Creek downstream of Bungalally Bushland Reserve
  - Erosion management
  - Riparian vegetation establishment/enhancement
- Reach 4, Diggers Creek within Bungalally Bushland Reserve
  - Weed management (Horehound)
- Reach 5, Diggers Creek Bungalally Bushland Reserve upstream to Toolondo Channel
  - Support landholders existing revegetation
- Reach 6, Green Lake Channel
  - Develop a wetland treatment area
  - Upgrade the remainder of the damaged concrete lined channel and drop structure
- Reaches 7, 8 & 9, Mibus Creek downstream end
  - Riparian vegetation establishment/enhancement (fencing and revegetation)
- Reach 10, drainage lines upstream of Toolondo Channel
  - Opportunistically fence and revegetate drainage lines
- All Reaches
  - Land management plan, and a water quality / sediment monitoring plan and analysis
  - Consultation to help minimise fertilizer and pesticide use



CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

Water Technology, in collaboration with Lloyd Environmental, was commissioned by the Wimmera Catchment Management Authority (CMA) to develop a Waterway Action Plan (WAP) for the Green Lake catchment, which is situated 12 km southeast of Horsham.

Waterway Action Plans provide a technical and financial basis for the implementation of works and initiatives on waterways by government and its partners. The waterway action planning process includes a review of environmental, social, cultural and economic values, and threats to these values, along a particular waterway. This information is strengthened by community experience and knowledge gathered through community consultation during the project.

> *Effective waterway management requires a coordinated and collaborative effort across the project area, with appropriate information to guide environmentally sensitive action and a continued investment of funds and time to achieve the desired outcome of an improvement in waterway condition.*

1.1 Project Area

The project area includes Green Lake and its catchment. Green Lake is an off-stream reservoir situated on Crown land, immediately south of the Western Highway. It was formerly a wetland, then modified in 1933 to hold water for irrigation purposes. However, its use as a water storage has been made obsolete through the construction of the Wimmera Mallee Pipeline. The lake incorporates a natural catchment area of approximately 50 km^2. When full, Green Lake holds 5,350 ML and has a maximum depth of approximately 3.5 m.

There are two main tributaries (Diggers Creek and Mibus Creek) that generally flow in a northerly direction and meet just before entering the southern edge of Green Lake. The lake can also receive flows from the Toolondo Channel via the Green Lake Inlet Channel and Diggers Creek.

Figure 1-1 shows the location of Green Lake, the approximate catchment extent and its location relative to Horsham. A more detailed description of the lake and tributaries is provided in Section 4 – Catchment Overview.

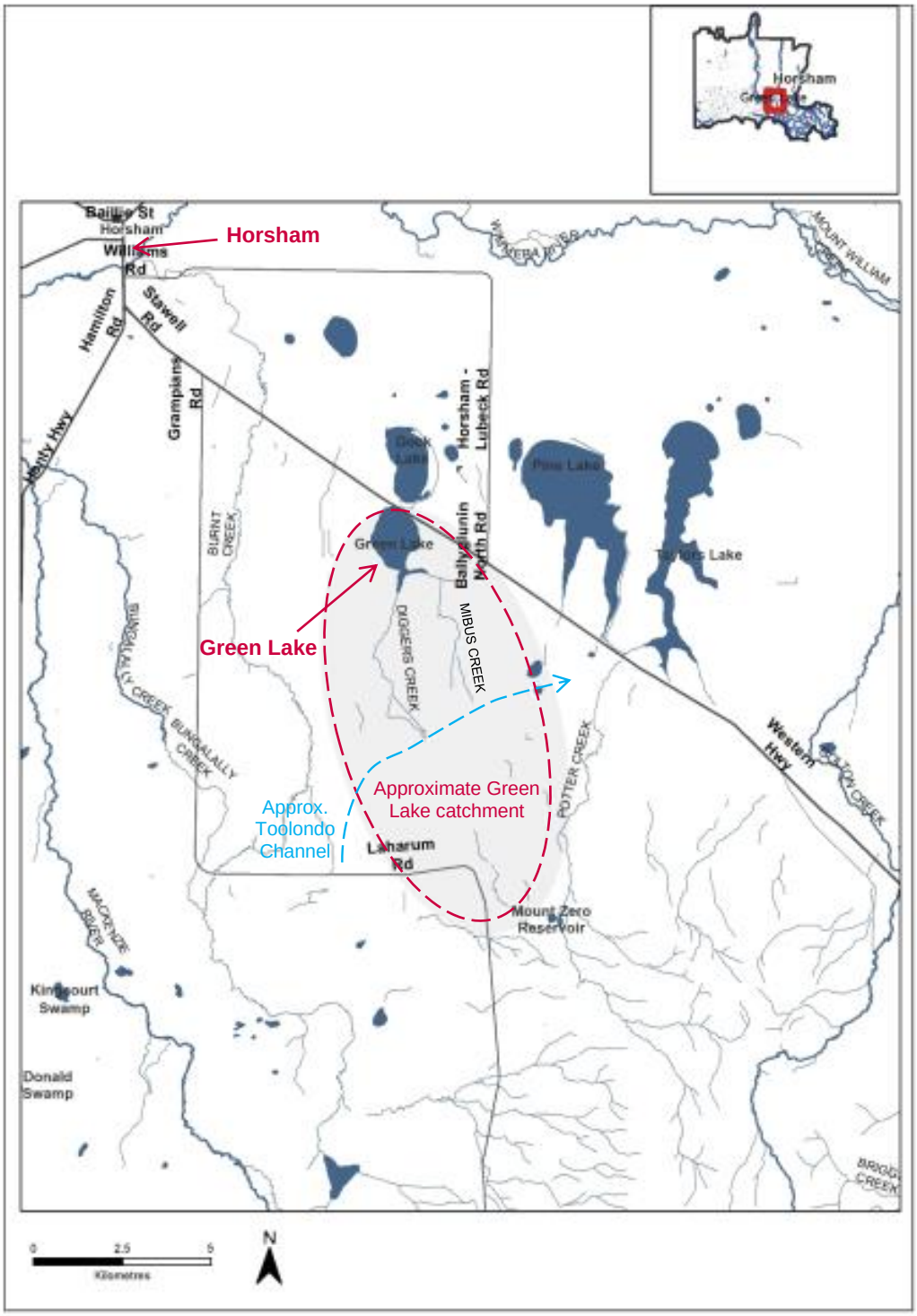


Figure 1-1 Green Lake and catchment locality plan

1.2 Waterway Action Plan Objectives

This Waterway Management Plan has been prepared to ultimately guide the most appropriate waterway management actions across the project area. The Plan provides a technical strategic blueprint for the implementation of works and initiatives on the relevant waterways.

Specifically, the Plan seeks to:

- Identify reach wide and site-specific values and issues across the project area, including bed and bank instability, riparian vegetation condition, stock access (i.e. fencing presence and condition) and weed infestations.
- Identification of prioritised management actions (using a cost/benefit analysis and agreed risk management approach), to:
  - Improve environmental, social, and recreational values of the lake.
  - Improve water quality and reducing the frequency of blue green algae outbreaks in the lake.

2 PROJECT APPROACH

The tasks below were undertaken in the development of the Green Lake Waterway Action Plan.

This Waterway Action Plan process and involved the following key stages:

1. **Project Scoping and Initiation**. This stage involved:

   a. An inception meeting with the Wimmera CMA to confirm the scope and aims of the Waterway Action Plan and requirements of the CMA.

   b. A review of relevant data and documentation with a focus on information pertaining to the history, management, condition, values and threats across the project area. The review assisted the selection of field assessment locations to ensure that the field work was undertaken on an informed basis.

2. **Stakeholder Engagement.** Stakeholder engagement was an important component of the project as it gave the project team a broader understanding of the history of the catchment, as well as local issues, perspectives and priorities for management.

   A range of stakeholders were involved in the development of the WAP. These included:

   - Wimmera CMA
   - Local landholders and community
   - Department of Environment, Land, Water and Planning (DELWP)
   - Grampians Wimmera Mallee Water (GWMWater)
   - West Vic Business
   - Green Lake Action Group
   - Horsham Rural City Council.
   - Horsham Yacht Club.

   Key stakeholder engagement events were an agency meeting and a community meeting on the 16th August 2023, prior to the field inspections. The purpose of these meetings was to introduce the project , discuss the stakeholders and community's values and perceived threats to those values, and to identify areas to be targeted for further field investigation.

3. **Site Assessment**. This stage involved:

   a. Undertaking targeted field assessments based on the background research and through consultation.

   b. Identification of the values, issues and opportunities present across the project area with reference to current best practice actions.

   During the field inspections we met with a number of landholders. This consultation allowed for the transfer of information pertaining to the Waterway Action Plan between landholders, the project team and the CMA. Specifically, the meeting was used to:

   - Communicate the Waterway Action Plan objectives and process.
   - Gain an appreciation of the catchment wide and property level issues perceived by landholders.
   - Gain an appreciation of individual landholders willingness to undertake activities to improve stream health (e.g. fencing and revegetation).

4. **Preparation of the Draft Waterway Action Plan**. The development of the Waterway Action Plan drew upon existing background information, investigations, relevant strategies and policies and a knowledge of the current condition of the project area gained through the targeted field assessments. Appropriate management strategies and actions were subsequently developed to address the key threats to values in the reach to produce the Waterway Action Plan for the project area.

3 POLICY, PLANNING AND MANAGEMENT CONTEXT

The following section summarises key policy documents that are relevant to the Green Lake Waterway Action Plan.

3.1 The Wimmera Regional Catchment Strategy 2021-2027 (WCMA 2021)

The Wimmera Regional Catchment Strategy (RCS) 2021 -2027 is the overarching strategy for integrated catchment management for the Wimmera. It has been developed in consultation with First Nations people (Barengi Gadjin Land Aboriginal Corporation and Eastern Maar Aboriginal Corporation) and key stakeholders from across the region to determine the environmental/ social outcomes to improve the overall health and longevity of the Wimmera catchment.

The document is broken down into the key regions of the Wimmera catchment including: Hindmarsh, Horsham, Upper catchment, West Wimmera and Yarriambiack and Buloke Creek catchments with a focuses on four key themes within each of these subcatchment areas:

- Water.
- Land.
- Biodiversity.
- Community.

The documents provide social, environmental, and economical targets to be met within the next 26 years which will have beneficial outcomes to the catchment's overall health. To ensure that these targets are met, there are key indicators which need to be re-assessed at key hold points of 6, 20 and 26 years. These targets are centred around improvements to the catchment including:

- hydrological connectivity of wetlands and storages.
- waterway heath.
- ecological functionality.
- community participation.
- Revegetation and weed management.
- Groundwater management.

The document details that Green Lake is located within the Horsham sub-catchment and is one of the key storages/wetlands of the area which has both social and environmental importance to the community and tourists that use the lake.

An assessment of Green Lake's current conditions indicates the changes in the hydrological regime are key factors in the deterioration of health of the Lake. These changes are furthered exacerbated by other factors such as agricultural practices which reduce the amount of moisture in the catchment and more frequent extended dry periods. It is these factors which directly influence the likelihood of blue green algae event, due to blue green algae thriving in stagnant and polluted water.

Furthermore, the document details how these is a direct link between the recreation value of the lake and how this has changed over time depending on the health of the lake. A survey of recreational users indicates the value of participation decreased in the blue green algae event, i.e., only ~2000 participants in 2019/20 in a blue green algal event versus 10,0000 participants in 2016/17 when the lake was clear of blue green algae.

3.2 Wimmera Waterway Strategy (2014)

The *Wimmera Waterway Strategy* (the Strategy) set a vision for the management of waterways across the Wimmera region until 2022 (Wimmera CMA, 2014). A new Strategy is currently under development which is likely to build on this vision.

The Strategy is integrated with the Wimmera Regional Catchment Strategy and works on an asset-based approach. This approach identifies areas with significant values and threats to those values. This allows for priority setting to target investment (Wimmera CMA, 2014).

The goals for the existing Wimmera Waterway Strategy are as follows:

- maintaining and improving the values and condition of waterways that have formally recognised significance
- improved connectivity and condition along priority wetland systems and riparian corridors
- improved water quality in priority areas for; water supply, environmental condition and recreation
- waterways with high social, cultural and economic values are maintained in a state that continues to support those values in line with climatic conditions (Wimmera CMA, 2014).

Green Lake is listed as a priority wetland due to the following values:

- Environment: High value bird community
- Social/Cultural: Valued for sightseeing, picnics, barbeques, game hunting, boating, swimming and fishing.
- Significant Aboriginal cultural heritage values

Threats to Green Lake include degraded water quality and altered hydrology.

Key management outcome targets and activities in the Strategy specific to Green Lake are listed in Table 3-1.

Table 3-1 Targets and activities for Green Lake (Wimmera Waterway Strategy 2014)

Management outcome target	Management activity / output	Quantity	Lead agency / partners
No decrease in Index of Wetland Condition (IWC) Water properties sub-index score	HO MA 38. Establish riparian management agreements (upstream Green/Dock Lakes). Undertake riparian management and invasive fauna management activities for upstream priority waterways.	2 km (10 ha)	CMA, landholders

3.3 Water for Victoria: Water Plan (2016)

Water for Victoria: Water Plan (Water Plan) (DELWP, 2016) is the Victorian Government's strategic plan for management of water resources. It aims to manage Victoria's water to support a healthy environment, a prosperous economy and thriving communities. It particularly recognises:

- The role that that water plays in communities, and seeks to make the most of water, including for agriculture, the environment, Aboriginal communities and recreation.

Water Plan includes an implementation plan and 69 actions. The following actions are relevant to the WAP:

- Action 3.3 Invest in integrated catchment management.
- Action 3.4 Provide long-term investment to improve waterway health.
- Action 3.8 Support community partnerships and citizen science.
- Action 3.9 Improve knowledge and information about waterways and catchments.
- Action 6.1 Recognise Aboriginal values and objectives of water.
- Action 7.1 Include recreational values in water and waterway planning (DELWP, 2016).

3.4 Growing What Is Good Country Plan: Voices of the Wotjobaluk Nations (2017)

The *Growing What Is Good Country Plan: Voices of the Wotjobaluk Nations* (2017) outlines the history of Aboriginal occupation in the Wimmera and sets out a vision, goals, priorities and actions for Wotjobaluk Country. The priorities are:

- more time on Wotjobaluk Country.
- strengthening Wotjobaluk culture and language.
- education and rewarding jobs for Wotjobaluk people.
- stronger partnerships.
- caring for our country (Barengi Gadjin Land Council, 2017).

3.5 Storage Management Rules for the Wimmera-Mallee System Headworks (GWMW 2016) and Water Quality

Green Lake is an off-stream (recreational) lake with a small natural catchment. The primary purpose is to safeguard the water quality of Taylors Lake and its surrounding assets by diverting a portion of the lower quality water from the Burnt Creek (Toolondo) channel (GWMW 2016). Along with the main function of Green Lake, it also provides recreation for the community, which is highly valued due to its accessibility and proximity to Horsham.

The lower headworks form an integrated subsystem of the broader Wimmera - Mallee system headworks. For reference, shows how the reservoirs and Wimmera Inlet Channel are linked together relative to other headworks assets.

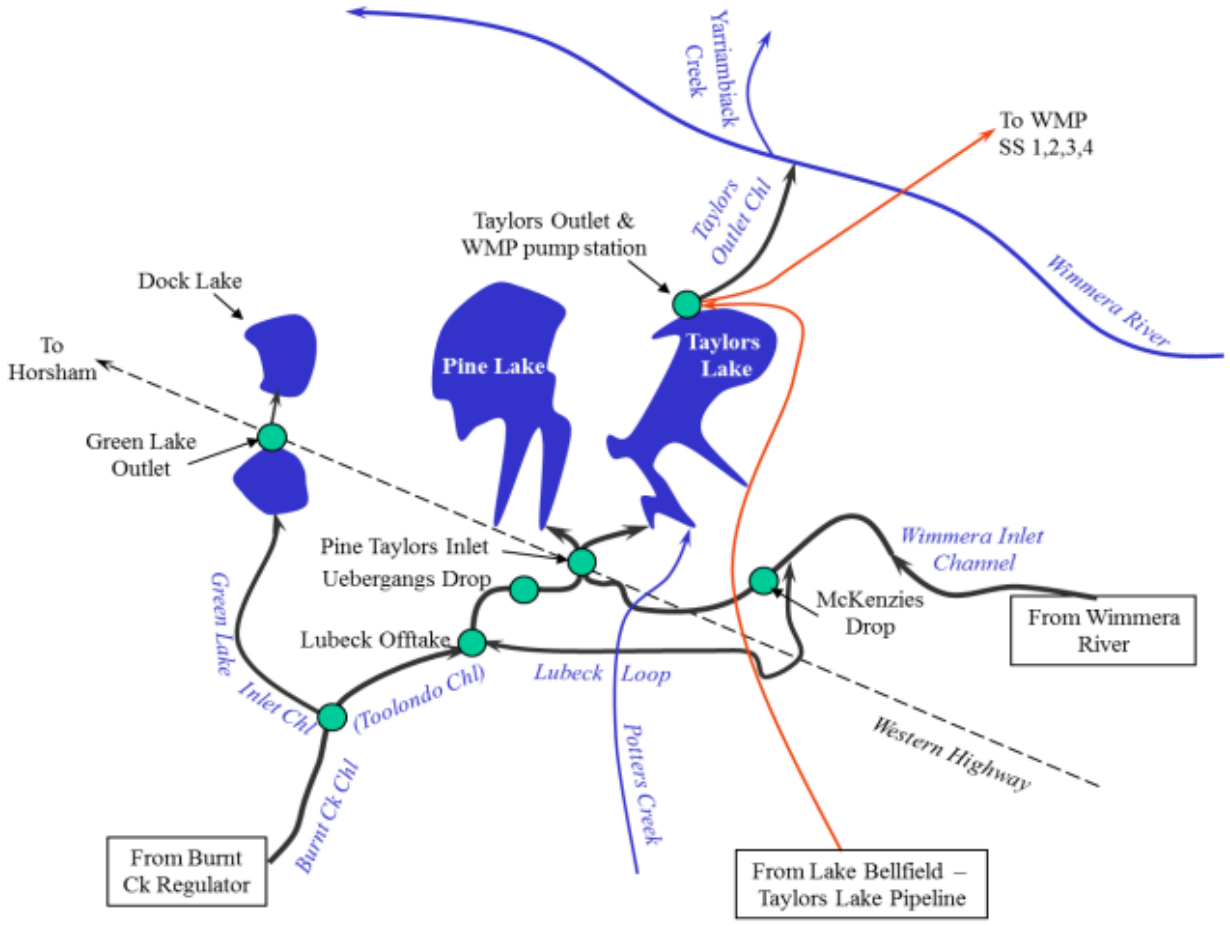


Figure 3-1 Schematic of Lower Headworks showing location of Taylors, Wimmera Inlet Channel and other reservoirs (GWMW 2016)

Due to its main function of protecting water quality in Taylors Lake, water held in Green Lake cannot be used to calculate water allocations for entitlement holders. The volume of water that may be contained in Green Lake cannot be guaranteed at any time.

The primary sources of water diverted into Green Lake are the poorer quality waters resulting from:

- Transfers from upstream reservoirs to Taylors Lake via the Rocklands, Toolondo, Burnt Creek and Moora channels, up to 500 ML/yr.
- Channel pickup flows via the Rocklands, Toolondo, Burnt Creek and Moora channels.
- Natural runoff from its own catchment.

Water diverted into Green Lake from secondary sources mainly consists of lower-quality water resulting from flood pre-releases or spills from upstream reservoirs. This source of water plays a crucial role in supporting the waterways within the Wimmera and Glenelg catchments. However, to divert such water down the Green Lake Channel, it must either be of poor quality or exceed the needs of the waterways, necessitating advice from the Storage Manager to the Storage Manager Reference Group.

Although no water quality monitoring has been done on Green Lake, there is a likely chance that there is an increase in salinisation from the Glenelg catchments, due to the Rocklands Reservoir contributing to salinisation of downstream sites (SKM 2003).

The selective harvesting of poorer quality water into Green Lake may increase the risk of algal blooms, of which it has a history. As flushing water through the lake is not a practical strategy (due to its high outlet) to manage algal blooms, the Storage Manager:

- Continually monitors the level of nutrients and algal cell counts.
- Engages in public awareness activities.
- Establishes warning alerts and signage when blooms occur.

3.6 Green Lake Recreational Precinct Vision (Village Well 2022)

The Green Lake Recreational Precinct Vision was developed to underpin the potential redevelopment of the Green Lake and Horsham Yacht Club into a community and business venue. Driven by West Vic Business, stakeholders were engaged through a site walk and workshop to collectively develop the vision. The key recommendations developed through this process include:

- Redevelop and extend the Yacht Club into a mixed-use facility - including a business hub and café.
- Maximise accessibility within the precinct - including improving pedestrian access, installing a lake loop recreational path with boardwalk connections to key nature watching locations, mapping ‘nature priority zones’ and upgrading boat ramp facilities.
- Upgrade the foreshore for recreational use.
- Explore future camping.

4 CATCHMENT OVERVIEW

This section provides an overview of the Green Lake Catchment project area, informed through both the desktop review and field inspection. For the purpose of description and land management, Green Lake and the main waterways were divided into reaches based on existing conditions or features as shown in Figure 4-1.

4.1 Green Lake land tenure and current management

Green Lake was appropriated under the Water Act, 1989 by GWMWater's predecessor organisation the State Rivers and Water Supply Commission. As it has always been a popular lake for recreational activities, there has been various committees of management since the late 1960's. The committee of management for Green Lake does not currently exist. Horsham Rural City Council and the local committee of management members currently manage Green Lake under an informal arrangement. GWMWater currently wishes to formalise this arrangement by delegating management of the Green Lake Reserve to Horsham Rural City Council under section 122B of the Water Act, 1989.

4.2 Catchment land use and tenure

A review of Vicmap Crown Land Tenure (DEECA 2023) website indicates that there is Crown land encompassing Green Lake, Diggers Creek up to Mibus Lane, and approximately 300 m of the most downstream extent of Mibus Creek (see the unshaded areas on Figure 4-1). This Crown tenure is mostly Water Authority Reserve (Water Production) and Water Frontage Licence (Primary Production). The Bungalally Bushland Reserve also surrounds Diggers Creek immediately downstream of Old Wartook Road (see the yellow shaded Nature Reserve in Figure 4-1).

Outside of these reserves, the remainder of the tributaries flow through freehold land, with landuse mostly mapped as cropping and, to a lesser extent, mixed farming and grazing (Figure 4-1).

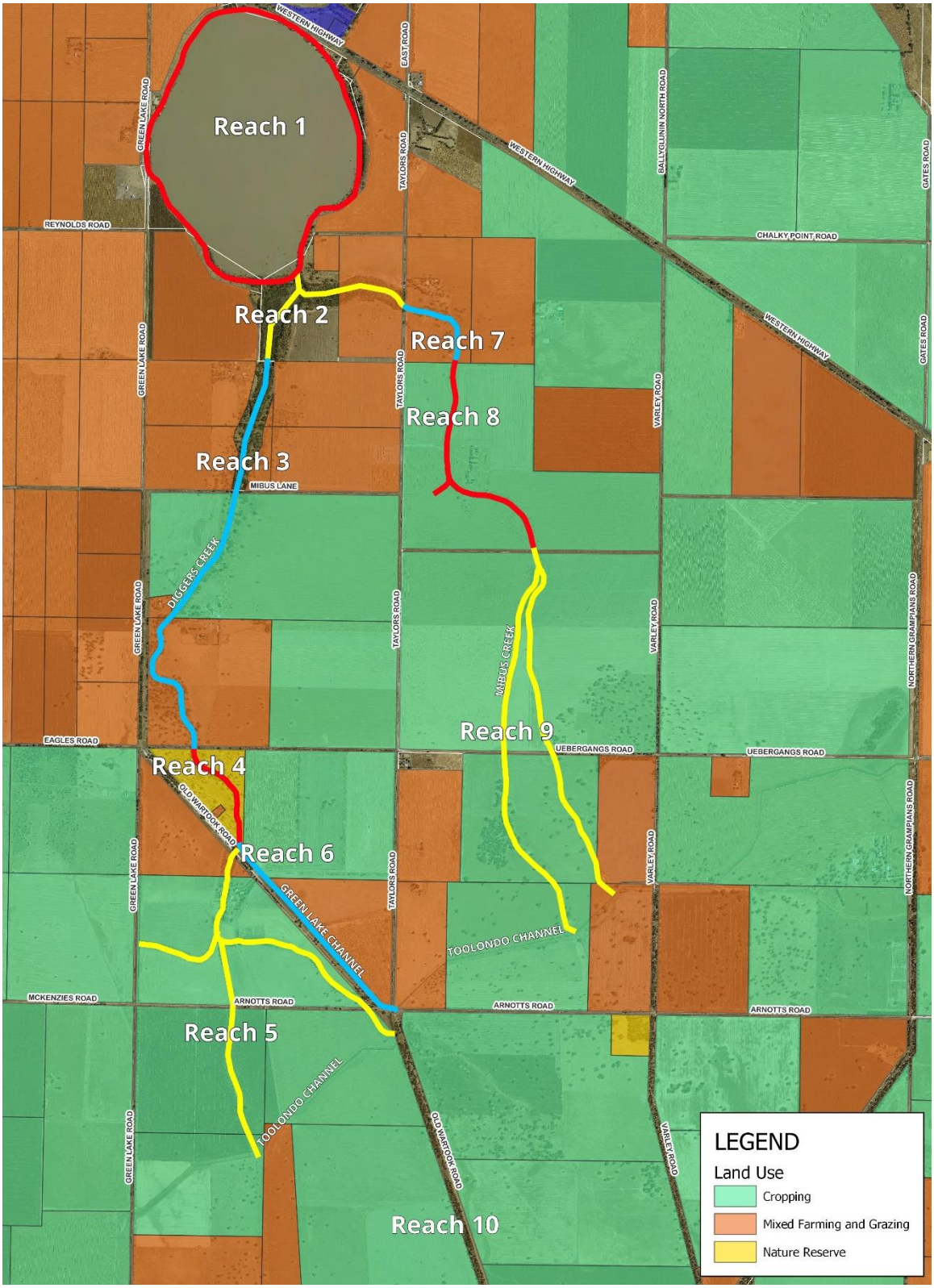


Figure 4-1 Landuse mapping

4.3 Flora and fauna

4.3.1 Vegetation communities

The DEECA website *NatureKit* (DEECA 2023a) was accessed to determine the bioregion, modelled ecological vegetation class (EVC) and bioregional conservation status (BCS) for the project area.

4.3.1.1 Pre-1750s Mapping

Pre-1750s EVC Mapping indicates that EVC 636 Brackish Lake Aggregate would have been the dominate vegetation class for Green Lake, as well as the dominate vegetation class for the surrounding lakes, indicating that Green Lake and surrounding lakes have been predominantly saline. And other vegetation in the surrounding areas is likely to be EVC 803 Plains Woodland (indicated by the orange shading), EVC 640 Creekline Sedgy Woodland (indicated by blue shading) and EVC 652 Lunette Woodland (indicated by yellow shading) (Figure 4-2). Another vegetation class in the surrounding area is Pre-1750s EVC 991 Water body – salt.

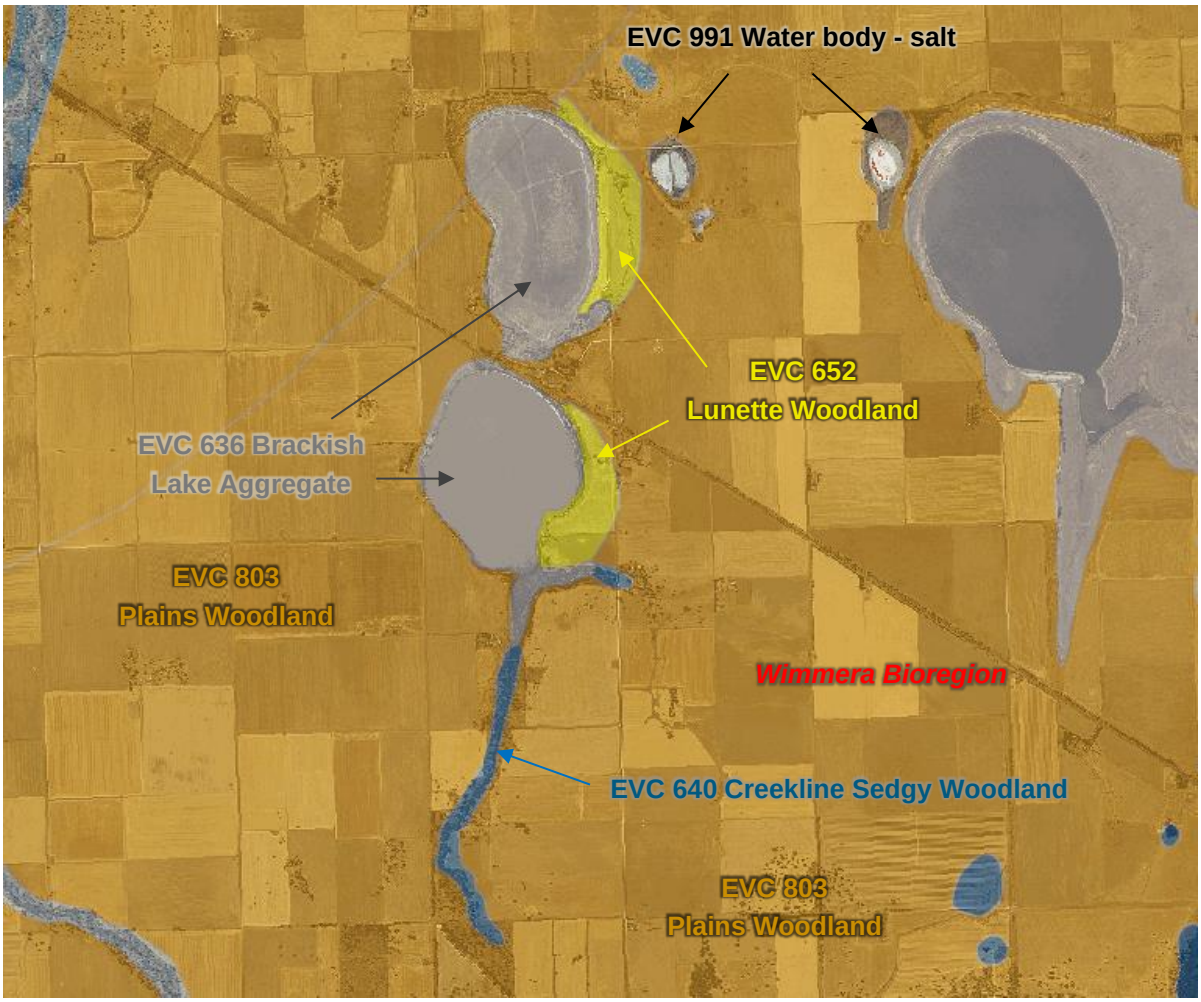


Figure 4-2 Pre-1750s EVC Mapping of Green Lake and surrounding EVCs (DEECA 2023a)

4.3.1.2 Current EVC Mapping

The main current vegetation class located within the subject site is also the EVC 636 Brackish Lake Aggregate, which represents a generalised label for wetlands occurring within a given ecological context. A list of identifiable components within this aggregate is listed below, where an on-site visit will determine the appropriate EVC of the subject site.

- EVC 13 Brackish Sedgeland
- EVC 656 Brackish Wetland

Any vegetation in the surrounding areas is likely to be EVC 803 Plains Woodland (indicated by the orange shading), EVC 640 Creekline Sedgy Woodland (indicated by blue shading) and EVC 652 Lunette Woodland (indicated by yellow shading) (Figure 4-3), similar to that of the pre-1750s EVC mapping.

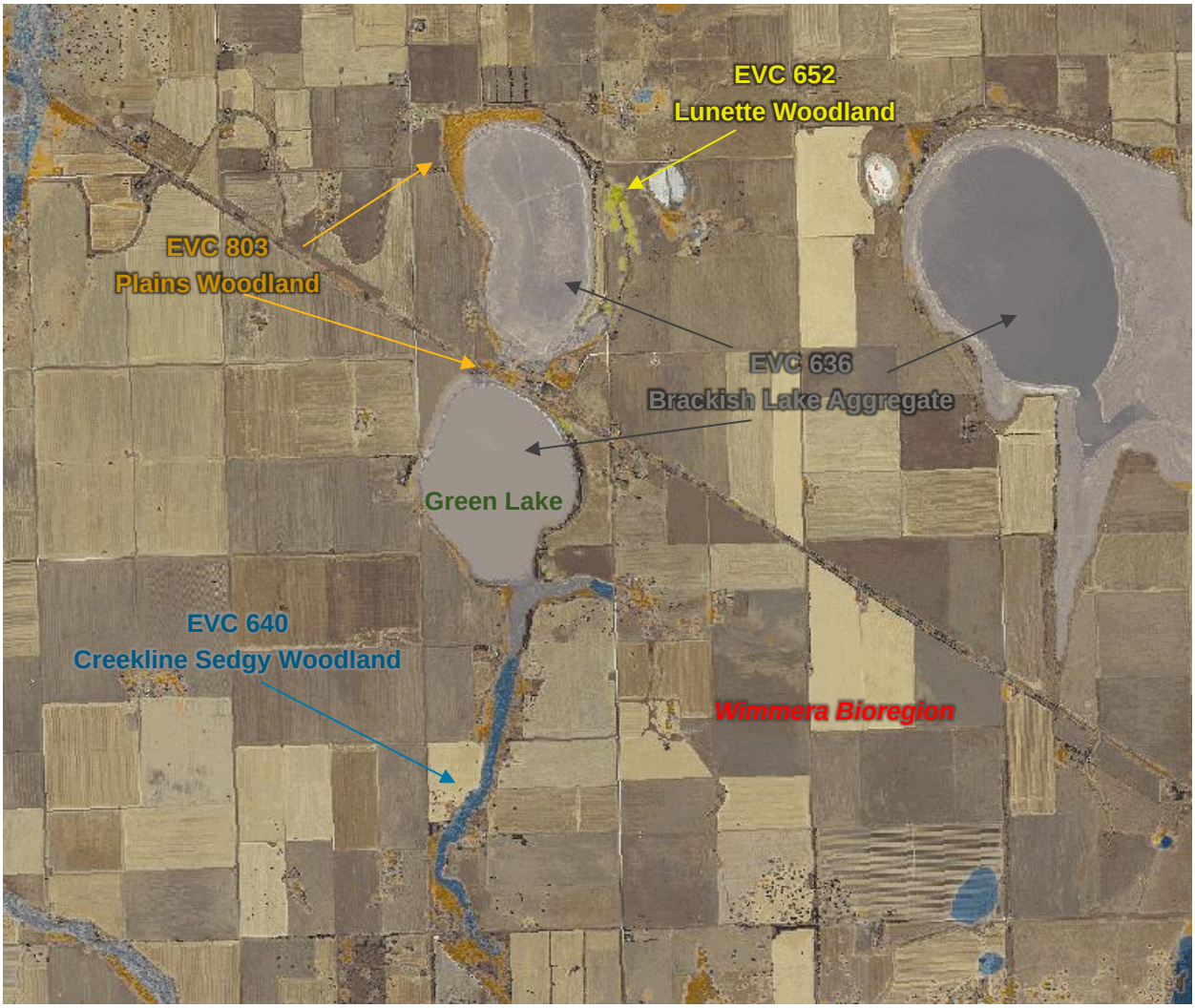


Figure 4-3 2005 EVC Mapping of Green Lake and surrounding EVCs (DEECA 2023a)

4.3.2 Victorian Biodiversity Atlas (Flora and Fauna)

A review of the Victorian Biodiversity Atlas (VBA) records contained within *NatureKit* showed that 25 flora and fauna records had been previously registered within a 5 km radius of Green Lake from 01/01/2000 to today, 10 of those being threatened species. Table 4-1 summarises the recorded species.

Table 4-1 Summary of Victorian Biodiversity Atlas records in the vicinity of Green Lake

Scientific Name	Common Name	FFG status	EPBC status	In area
FAUNA				
Anseranas semipalmata	Magpie Goose	Vulnerable	-	+
Antigone rubicunda	Brolga	Endangered	-	
Ardea alba	Great Egret	-	-	
Ardea alba modesta	Eastern Great Egret	Vulnerable	-	+
Aythya australis	Hardhead	Vulnerable	-	+
Biziura lobata	Musk Duck	Vulnerable	-	+
Calidris ferruginea	Curlew Sandpiper	Critically Endangered	Critically Endangered	
Calidris subminuta	Long-toed Stint	-	-	
Chlidonias hybrida	Whiskered Tern	-	-	
Circus assimilis	Spotted Harrier	-	-	
Egretta garzetta	Little Egret	Vulnerable	-	
Falco subniger	Black Falcon	Endangered	-	
Haliaeetus leucogaster	White-bellied Sea-Eagle	Vulnerable	-	Sen
Hydroprogne caspia	Caspian Tern	Vulnerable	-	
Litoria raniformis	Growling Grass Frog	Vulnerable	Vulnerable	+
Oxyura australis	Blue-billed Duck	Vulnerable	-	
Phalacrocorax varius	Pied Cormorant	-	-	
Platalea regia	Royal Spoonbill	-	-	
Spatula rhynchotis	Australasian Shoveler	Vulnerable	-	
Stictonetta naevosa	Freckled Duck	Endangered	-	
Tringa nebularia	Common Greenshank	Endangered	-	
Tringa stagnatilis	Marsh Sandpiper	Endangered	-	
FLORA				
Convolvulus angustissimus subsp. *omnigracilis*	Slender Bindweed	-	-	
Melaleuca armillaris subsp. *armillaris*	Giant Honey-myrtle	Endangered	-	
Corymbia maculata	Spotted Gum	Vulnerable	-	

+ - Recorded within Green Lake/Diggers Creek, Sen – Green Lake is a sensitive habitat

Most of the recorded fauna species are waterbirds or aquatic birds that live on or around water. The vulnerable frog species also relies on permanent water bodies. This emphasises the importance of the Green Lake system as fauna habitat.

5 CONSULTATION AND FIELD INSPECTION RESULTS

Stakeholder and Community consultation was conducted on the 16th August 2023 by Water Technology staff Julian Martin (Waterway Engineer) and Jamie Kaye (Ecologist). The consultation occurred at the Wimmera CMA office in Horsham (Stakeholders), and at the Horsham Yacht Club on Green Lake (Community) (Figure 5-1).

Figure 5-1 Community consultation at the Yacht Club and landholder consultation in the field

The common themes to come out of the consultation process was:

- Green Lake is viewed as an important regional asset combining social, tourism and recreational values.
- There is a strong desire from the community to build upon these existing values and there was general cooperation and commitment from the stakeholders and community to achieve this.
- Blue Green Algae is viewed as the major threat to Green Lake and to values associated with the lake.

Field inspection and continued consultation with landholders occurred on the following two days across the Green Lake Catchment. The lake margin was assessed at a number of locations and the full length of Diggers Creek up to the Toolondo Channel was traversed. The Green Lake Channel was viewed including the concrete lined lower section which has since been partially replaced with rock work. Mibus Creek was inspected at targeted locations including an area that was recently fenced and revegetated. Upstream of the Toolondo Channel, Diggers Creek and Mibus Creek, are ill-defined and meander across a very flat landscape. This upper catchment was viewed from road reserves.

Informed by consultation and field inspections, Green Lake and the main waterways were divided into reaches based on existing conditions or features. The project area was divided into 10 Reaches as shown in Figure 5-2.

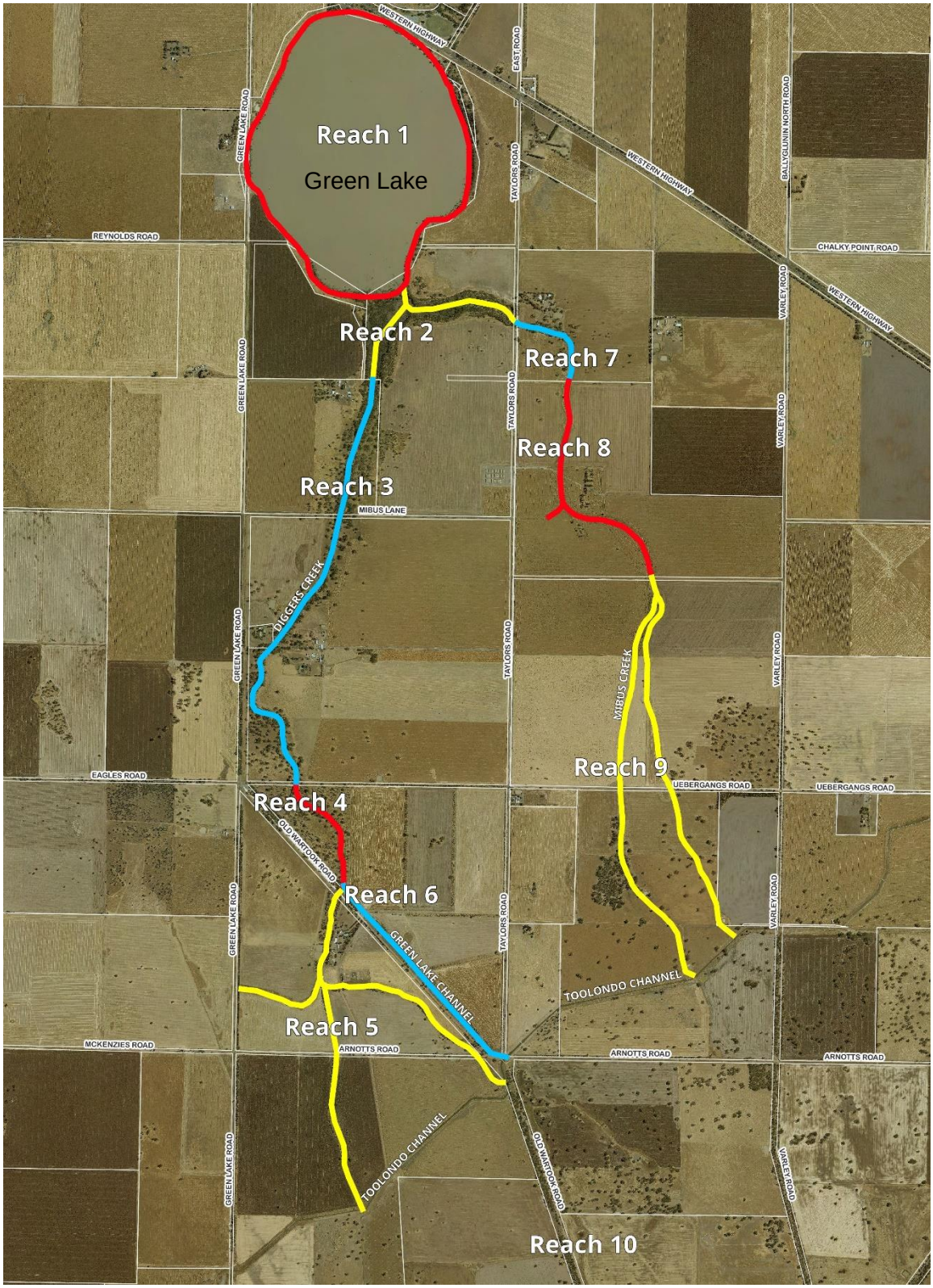


Figure 5-2 Project area Reach map

A description and indicative photographs for each reach is provided in the following sub-sections.

5.1 Reach 1 - Green Lake

This project reach encompasses the margins of Green Lake, which has a length of approximately 5 km, and encompasses an area of approximately 1.5 km^2. This reach can be further divided into two main areas: the northeastern shoreline adjacent to the lunette sand hill, and the remainder of the lake margin.

Lunettes are crescent shaped aeolian deposits of fine sediment located on the eastern (or lee) side of lake beds or playas in semi-arid areas of southern Australia (VRO 2023a). The north eastern lunette margin has a mostly gentle sloping sandy shoreline, with a high lunette sandy ridge behind (Figure 5-3).

Figure 5-3 Gentle sloping sandy lake margin adjacent to the lunette

The recreational precinct is located along the northern half of the lunette and accommodates the Horsham Yacht Club (Figure 5-4), Green Lake Recreation Area, Green Lake Rest area and associated boat ramps.

Figure 5-4 Foreshore infrastructure includes the Yacht Club (left) and the main boat ramp (right)

River Red-gum's dominate the margins of the lake adjacent to the lunette where they have regular, if not continuous, access to water within the lake sands. The lunette vegetation is highly disturbed, particularly around the Recreational Precinct between the Horsham Yacht Club and the Boat Ramp. The lunette vegetation has been impacted by the development and exotic species often dominate the precinct, including exotic Radiata Pine trees (Figure 5-5). Native Cypress Pines and wattles were observed along the lunette south of the Yacht Club. The invasive weed Bridal Creeper was also observed in patches across the lunette behind and south of the Yacht Club.

Figure 5-5 Pines dominate the lunette within recreational precinct (left), River Red-gum and wattles dominate the lake margin adjacent to a mostly cleared lunette (right)

The lake margin away from the lunette (e.g., along the western, southern and southeastern edges) are characterised by a steep drop-off, typically about 3-5 m high). It is presumed the lakebed slowly deepens from the toe of the bank and wattles were often observed growing out into the water for a distance up to 10 m. Note that Green Lake was almost full (92% full) at the time of assessment. It is likely that the lakebed inside the wattle and eucalypt regrowth stays saturated for extended periods preventing further expansion of woody vegetation (terrestrialisation) into the lake. It is also likely that this woody vegetation growing in the water at the edge of the lake (as shown in Figure 5-3 & Figure 5-6) would drown if water levels were maintained above 90% for extended periods (i.e. > 1 year).

Figure 5-6 Steep edged margins on the western (left) and northwestern (right) sides of the lake

Green Lake forms part of the 'Horsham Lakes lunette clusters' landform unit. "*This low depositional complex unit is part of the Northern Riverine Plains. These swamps/swales/playa and lunette complexes of Quaternary sediments occur as depressions within the fan material of the older alluvial plain. Site drainage is slow to very slow but moderately well drained on the lunettes. Soils are sodic yellow, brown and grey texture contrast soils (Sodosols) with grey cracking clay soils (Vertosols), with sodic red contrast soils also found on the lunettes*." (VRO 2023b). What we see on these side walls (banks) of the lake (Figure 5-7) is the exposed older alluvial plain clays. These clays are dispersive and the bank shows signs of undercutting, likely due to wave action from wind and boat wash, and subsequent collapse. Blocks of collapsed bank material are evident at the toe of the bank. This dispersive bank material is a likely contributor to Green Lake's milky water appearance.

Figure 5-7 Western side wall of Green Lake showing sodic older alluvial plain material

5.2 Reach 2 - Green Lake Entry Wetland

Prior to undertaking the field inspection, the area where the creeklines converge before entering the lake, was identified as an area with potential to create a vegetated wetland zone for the purposes of water treatment (Figure 5-8). This area of interest was viewed with landholders and the potential for using this area as a water quality treatment wetland was discussed. The approximate area of potential wetland improvement is shown in Figure 5-8.

Figure 5-8 Green Lake creekline entry wetland and surrounds (Google Earth Image 2023)

This area has potential for the creation of a well vegetated wetland to help capture sediment and nutrient from the creek inflows prior to entering the lake. A treatment wetland might be created by installing a weir structure that would provide the ability to control the water level and inundation duration. The concept would not involve damming and elevating water level, but installing a weir structure that could maintain water longer to support aquatic/emergent native vegetation, which in turn provides the filtering and nutrient stripping that would help to reduce the likelihood of blue-green algae blooms. The main outlet between the creeks and Green Lake is a relatively narrow passage less than 15 m (Figure 5-9).

Figure 5-9 Creekline/wetland entry point to Green Lake showing potential weir location

The water level was relatively high at the time of the field inspection. It was difficult to get a clear understanding of the weir location and potential size. Similarly, the extent of inundation and number of trees that might be affected by a more continuous water level/inundation could not be determined. Observing the number of live trees observed sitting in the water at the time of inspection (Figure 5-10) suggests that the high water level (92% full) does not occur frequently, or that the water naturally draws down relatively quickly thereby preventing drowning.

Figure 5-10 View up the Mibus Ck arm (left) and the Diggers Ck arm (right)

This potential wetland area requires further investigation to determine feasibility of the concept.

5.3 Reach 3 – Lower Diggers Creek

This reach extends from the upstream inundation extent of the potential wetland to Bungalally Bushland Reserve. The creek is approximately 5-7 m wide and 1.2-1.5 m deep and the native vegetation was confirmed as having affinities with EVC 640 Creekline Sedgy Woodland with River Red-gums being the dominant tree canopy over native rushes, sedges and a variety of grass species (Figure 5-11). Yellow box were also observed, mostly slightly higher on the floodplain. Grazing pressure around the creekline, particularly in the downstream half of this reach, was light, allowing a diversity of ground layer species to remain. However, natural recruitment of woody species was scarce to absent, suggesting grazing or macropod browsing is limiting regeneration. The shrub understorey, which is naturally quite sparse, was virtually absent.

Figure 5-11 Typical Diggers Creek channel within Reach 3

Several discrete bank erosion sites were observed within this reach, which are primarily located on outside bends with very little woody riparian vegetation capable of assisting channel stability (Figure 5-12). These erosion sites have the potential to contribute on-going sediment and nutrients into the Diggers Creek and Green Lake system. Notably, this reach also comprised a section of floodplain erosion associated earthworks undertaken several decades ago. A secondary flow path has formed as a result of the primary channel having been blocked. This has subsequently led to a new channel being eroded that likely now acts as the primary flow path. On-going erosion at this location is contributing both sediment and nutrients into downstream reaches. Concrete rubble has been placed in the floodplain channel, however this is having limited benefit to managing the erosion (Figure 5-12).

Figure 5-12 Erosion sites including a deepening meander cutoff (left), and outside bend migration (right)

Towards the upstream end of this reach a small fixed-crest weir was observed. This is an old structure which was in disrepair, being outflanked on both ends. Despite being damaged the weir was holding water to crest height and providing pool habitat upstream and potential refuge for aquatic life.

Figure 5-13 Small weir and weir pool

5.4 Reach 4 – Diggers Creek, Bungalally Bushland Reserve

This reach is through land reserved for flora and fauna. At the time of inspection there were no domestic animals grazing the property and there was a distinct increase in native vegetation species diversity and structure. Natural recruitment of native woody species was relatively abundant and the creek channel was

stable, with well vegetated banks and bedrock outcropping in the base of the channel. Instream habitat diversity was evident with fringing and aquatic species present, overhanging vegetation, pools, and riffles (Figure 5-14). Frogs were heard calling from the pools with abundant fringing vegetation.

Figure 5-14 Pool with fringing and emergent native vegetation providing important habitats for aquatic life

Despite the well vegetated and ungrazed channel, filamentous algae was observed in the bed of the creek. The presence of algae suggests high nutrient loads within Diggers Creek. The algae was evident on the outcropping rock bar, so its presence may be due to having a stable substrate on which to attach. This might explain why this filamentous algae was not observed in the sandy bed stream reaches downstream. The highly invasive weed Horehound *Marrubium vulgare* was observed within the reserve (Figure 5-15). This listed environmental weed can disperse rapidly and should be controlled.

Figure 5-15 Algae on rock bar instream (left) and Horehound weed (right)

5.5 Reach 5 – Upper Diggers Creek

This reach includes Diggers Creek and at least two tributaries upstream of Old Wartook Road. All waterways on the upper Diggers Creek from the Old Wartook Road to the Toolondo Channel have been revegetated with native trees and shrubs (Figure 5-16). The channel size is much reduced as this reach is not receiving the water from the Toolondo Channel and is bypassed by the Green Lake Channel (Reach 6).

Figure 5-16 20-year-old plantings on Diggers Ck (left) and recent revegetation on a tributary (right)

There are no known erosion issued in this reach, however, Diggers Creek passes over Arnotts Road (effectively a ford) and becomes impassable in very wet conditions (Figure 5-17). It is understood that funds have been committed to provide a new culvert at this location. Despite no fish being recorded in this section of creek, the proposed culvert should be made wildlife friendly. This might be achieved with use of an inverted box culvert with steel mesh over the top to allow light in and encourage fish and other fauna to travel through the culvert unimpeded.

Figure 5-17 Arnotts Road crossing of Diggers Ck (left), looking up the ill-defined Diggers Ck from Arnotts Road (right)

5.6 Reach 6 – Green Lake Channel

The Green Lake Channel receives water from the Toolondo Channel via a penstock gated structure (Figure 5-18) and delivers it into the natural Diggers Creek alignment. The channel is mostly straight, running parallel with Old Wartook Road, and is approximately 1.4 km long in total. It is an earthen channel from the gate until the final 250 m, where it becomes a rocked and concrete lined channel (the remaining concrete lined channel is in disrepair), before plunging over a drop structure (approximately 1 m high) as it meets the natural Diggers Creek.

Figure 5-18 Offtake penstock gate and earthen channel immediately downstream.

The upstream 1.15 km earthen section of the channel is relatively flat and contains some native plants, including water ribbons *Cycnogeton* sp., however, the regular 'cleaning out' of the channel appears to limit aquatic vegetation colonisation of the channel. This section of channel may provide opportunity for the creation of a sediment pond and linear treatment wetland as there is ample open space along the southern side of the channel. This opportunity is further discussed in Section 7.

Figure 5-19 Earthen section of channel (left), open space along the southern edge of the channel

The upstream half of the concrete lined section has recently been removed and replaced with rockwork (Figure 5-20). A larger capacity culvert has also been installed at the upstream end of the rockwork. It is for reference prior to meeting presumed this downstream section of the channel is steeper as it transitions down to the drop structure and Diggers Creek, and therefore requires engineered bed and bank stability.

Figure 5-20 Upper concrete lined section of channel, before and after replacement with rockwork

5.7 Reach 7 – Lower Mibus Creek

The lower Mibus Creek reach extends upstream from Taylors Road for a distance of approximately 1 km. This reach is unfenced and meanders through an open paddock with scattered mature trees on or near the tree line. There is no evidence of tree recruitment and woody understorey is absent. Cultivation of the surrounding paddocks extends relatively close to the top of bank (i.e., <10 m).

Figure 5-21 Looking upstream from Taylors Rd (left), looking downstream from upstream end of Reach 7 (right)

5.8 Reach 8 – Middle Mibus Creek

This reach has been separated from the reaches upstream and downstream as it is in the one landholding and has been fenced and recently revegetated within the downstream half. The meandering creekline has been broadly fenced to an overall width mostly between 15-50 m (Figure 5-22). The revegetation is relatively young and includes trees, shrubs and ground cover species. At the time of assessment there was thick ground layer grasses providing an effective buffer to help capture sediments and nutrients from adjoining paddocks. The stream channel itself was also becoming denser with vegetation and forming pools, soaks and riffle zones. Native rushes and herbs were identified naturally recruiting along the creek margin.

Figure 5-22 Looking into fenced creekline from paddock (left), view along creek within fenced area (right)

5.9 Reach 9 – Upper Mibus Creek

This reach traverses very flat country downstream of the Toolondo Channel. This reach includes two channels that converge just before the downstream end and much of the channel length has been straightened, or rather, the country is so flat that small drains have been cut. As the photographs in Figure 5-23 suggest, most of this reach is devoid of trees and the channel is very small. Grazing is unrestricted from the channel and cultivation is likely to occur in close proximity to the channel (i.e., within metres).

Figure 5-23 View from Uebergangs Road, south/upstream (left), north/downstream (right)

5.10 Reach 10 - Upstream of Toolondo Channel

The Toolondo Channel acts like a levee across the entire catchment. All water draining north-eastward from the upper catchment needs to converge and pass through one of the numerous channel syphons in order to drain to Diggers Creek or Mibus Creek. The main channel observed during field inspection was Diggers Creek where situated within the Old Wartook Road reserve (Figure 5-24). Few of these channels were observed during field inspection, however, aerial imagery suggests very shallow ill-defined drainage lines, or small cut channels exist within this reach/area. There are scattered trees within this area however woody vegetation does not line the drainage lines. None of these drainage lines appear to be fenced and therefore stock grazing is unrestricted.

Figure 5-24 Defined creekline adjacent to Old Wartook Rd (left), ill-defined creek within paddock showing wet area (right)

6 MANAGEMENT OBJECTIVES

Objectives for the future management of the Green Lake and tributaries were developed with Wimmera CMA, stakeholders and the community during consultation. The primary objective of the project is to develop appropriate actions to reduce the incidence of blue-green algal (BGA) blooms within Green Lake. Many of the key actions to achieve this primary objective provide additional benefits to waterway health, water quality and habitat improvement. Ultimately, a reduction in BGA blooms will increase the social, health, economic and environmental values of Green Lake.

6.1 Blue-Green Alae

Cyanobacteria, commonly known as blue-green algae (BGA), are a recurring natural component of aquatic ecosystems in Victoria, including streams, lakes, estuaries, and the sea. While these microorganisms are typically not visible in the water due to their small size, they can rapidly multiply, forming visible blooms on the water's surface. These blooms are often triggered by factors such as nutrient levels, low inflow, reduced storage capacity, and warm weather conditions. Blooms can manifest in various unsightly colours, ranging from dark green to yellowish-brown, and develop a paint-like consistency when drying out, often accompanied by a pungent odour.

Green Lake, located at the end of a stream system and characterized as a terminal lake, is particularly susceptible to BGA blooms. In such terminal water bodies, sediments carrying nutrients can accumulate in the lake bed. During dry periods, when reflooding or when oxygen levels are low, these sediments release nutrients into the water column, further exacerbating the problem.

One of the primary concerns with high BGA populations in water bodies is the potential production of toxins, which can have adverse effects on human health, animals, birds, livestock, and the environment. To address this issue, water corporations and local waterway managers in Victoria actively monitor blue-green algae through regular sampling and testing. When BGA blooms occur, actions are taken based on the intended use of the water body and the characteristics of the bloom. In many cases, affected water bodies are temporarily closed to human activities and recreation until the blooms subside.

6.2 Drivers of BGA blooms

There are multiple drivers of cyanobacterial (BGA) blooms which include:

- Nutrient Pollution.
- Increased Water Temperature.
- Stagnation and Calm Conditions.
- Low Water Flow.
- Sedimentation.

Nutrient Pollution: Excessive input of nutrients, particularly nitrogen and phosphorus, from sources such as agriculture (or in other areas, urban runoff, sewage discharge), and cleared land can promote the growth of cyanobacteria. These nutrients act as fertilizers for the algae, leading to overgrowth and the formation of blooms.

Increased Water Temperature: Cyanobacteria thrive in warm water, and elevated water temperatures can accelerate their growth and reproduction. Climate change can contribute to higher water temperatures, making it conducive for cyanobacterial blooms but vegetation clearance over time has reduced shading and also leads to higher temperatures experienced by water bodies.

Stagnation and Calm Conditions: Stagnant or slow-moving water bodies provide a conducive environment for blue-green algae to accumulate and form blooms. Calm conditions allow the algae to stay near the surface, where they can access light and nutrients more easily.

Low Water Flow: Reduced water flow, such as in terminal water bodies or reservoirs, can contribute to the development of blue-green algal blooms. Low flow reduces the flushing of nutrients and algae out of the system.

Sedimentation: Sediments settle to the lakebed and store nutrients, and when disturbed, or activated (such as under low oxygen conditions), they can release these nutrients, driving algal growth. Activities like construction, dredging, or erosion can contribute to sediment disturbance and nutrient release. Riparian vegetation upstream binds the sediments in the creek banks and prevents run-off from cleared or disturb areas. Aquatic vegetation (emergent or submerged) will compete with algae for the nutrients as well as bind the sediments, preventing erosion and entrainment into the water column.

Collectively these drivers can result in stressors and impacts upon aquatic ecosystem biodiversity as well as on animal and human health. Figure 6-1 shows how nutrient pollution, warm water temperature, and stagnant conditions can lead to potential ecological and human health impacts of BGA blooms.

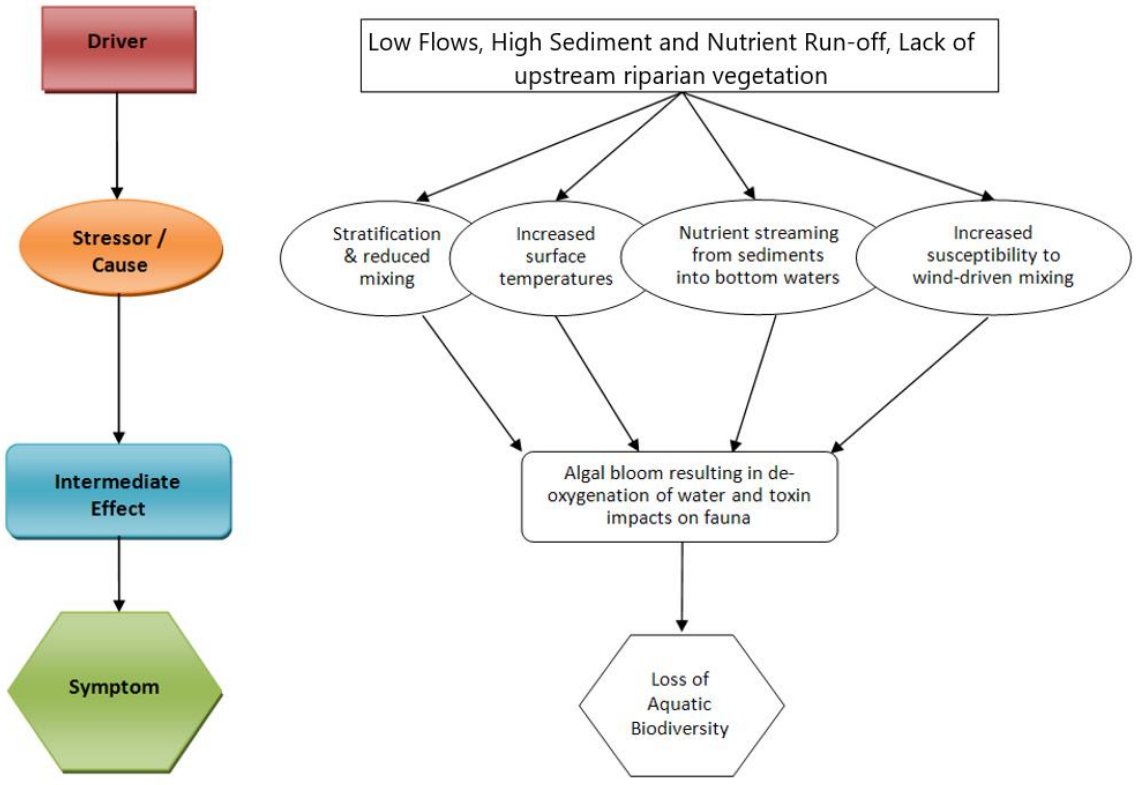


Figure 6-1 Potential ecological and human health impacts of BGA blooms

7 KEY MANAGEMENT PRINCIPLES

These management principles will assist the Wimmera CMA to plan and implement river health projects, mitigate risks and improve the environmental condition of the Green Lake and its tributaries. It is important to acknowledge that most on-ground projects will involve a combination of management strategies to manage a particular threat(s) and to achieve a desired outcome.

The following on ground management techniques are considered most appropriate to achieve the objectives detailed in Section 6.

7.1 Water quality monitoring to identify high nutrient sources

Section 6.2 describes the drivers of blue-green algae (BGA) and states that excessive input of nutrients, particularly nitrogen and phosphorus, promotes the growth of cyanobacteria. These nutrients act as fertilizers for the algae, leading to overgrowth and the formation of blooms.

If minimising nutrient input to Green Lake is a key action to reduce the likelihood of BGA blooms, then it is important to identify the areas or flows that deliver the highest nutrient loads to the lake. It is also important to understand the in situ nutrient loads within the lake bed. Understanding where the highest nutrient loads are originating helps to best target investment in activities to reduce BGA outbreaks (see Section 8.3). Monitoring and analysis of water quality within the tributaries, and sediments within the Lake, is therefore recommended. Water delivered from the Toolondo Channel, particularly the 'first flush', should also be monitored for nutrients. Green Lake might be better off nutrient wise without the first flush water from the Toolondo Channel.

To further understand the likelihood and triggers for BGA outbreaks, it is recommended that Lake water levels, water delivery (and source e.g. Rocklands Reservoir, Moora Moora Reservoir, Lake Wartook) and water quality results are analysed concurrently. It has been suggested that the supply of additional water to the lake from Moora Moora Reservoir / Lake Wartook, as occurred in 2021 / 2022, may have prevented BGA blooms that summer (B. Dunn, personal communication, February 22, 2024).

7.2 Vegetation establishment

Healthy riparian zones are essential for maintaining healthy ecosystems and economic productivity along waterways. Vegetation establishment is a key technique for meeting the objectives for water quality improvements in Green Lake. The benefits of vegetation within context of the Green Lake Waterway Action Plan include:

- improving vegetation and habitat connectivity
- improving aquatic and terrestrial ecology values of a waterway/waterbody
- improving in-channel geomorphic diversity
- improving lake water quality and reducing the likelihood or BGA blooms.

In context of waterway health more broadly, the benefits of vegetation include:

- assisting channel and lake bank stability, and reducing rates of channel change
- increasing stream roughness and reducing instream velocities
- reducing sediment transport capacity throughout the stream network
- reducing erosion, and sedimentation/turbidity within the lake.

7.2.1 Riparian revegetation

Revegetation is used to improve waterway health where the riparian corridor lacks remnant vegetation and seed bank may be absent. It can also be implemented on lake margins to reduce wave impacts, capture sediments and nutrients and provide habitats for fauna. In time, revegetation will also provide a source of instream logs and branches, which in turn provides complex habitat such as pools, positively influencing aquatic biodiversity. Revegetation works are typically complemented by stock exclusion (or controlled grazing) and weed management.

Strategic revegetation programs are recommended throughout the Green Lake project area to improve:

- the waterway health of the Green Lake tributaries.
- vegetation quality and structure.
- landscape connectivity.
- water quality in both the tributary and Green Lake.

The revegetation should comprise a suitable mixture of species with consideration of the relevant EVCs, namely:

- Creekline Sedgy Woodland.
- Lunette Woodland.
- Plains Woodland.

A comprehensive revegetation program should aim to plant native species on the bank face, top of bank and beyond the top of bank for as wide as can be accommodated. The revegetation area should extend as far off stream as practical, **typically a minimum of ten metres** beyond top of bank.

Denser plantings are generally encouraged on the bank face and on outside bends. Additional revegetation recommendations include:

- A vegetation survey in an adjoining or nearby stream system with riparian vegetation will assist identification of the most appropriate native species. Take note of where particular species occur in relation to the river channel (e.g., lower bank, mid bank, upper bank or floodplain).
- Preferably a range of species should be used, including trees, shrubs and ground covers (as appropriate for the EVC and climate change predictions).
- If overstorey trees are already present, reduce or eliminate the number of trees planted.
- Utilise and protect natural recruitment of native species wherever present. These plants will have the greatest prospect for survival.
- Prior to planting seedlings, reduce weed cover as much as possible from the planting area. Ideally, one full year of weed control should occur before planting.
- Avoid ripping soils in riparian areas that may be subject to flooding.
- Soil preparation, the aim is to create good tilth (loose friable soil) in which to plant your seedlings.
- Newly planted seedlings may need protection from browsing or trampling from domestic or native animals.
- Gently water new plants with a few litres of water over the first year of their life.

The Wimmera CMA website contains further information, including relevant links to determine appropriate species selection (https://wcma.vic.gov.au/native-vegetation).

Riparian vegetation widths should be determined on an individual property/works site basis as part of the appropriate planning process taking into consideration:

- the works type proposed for the site.
- ongoing management issues (e.g., weed spraying access).
- interaction of floodplain and channel landforms.
- property size and layout.
- estimated meander migration direction and rate / estimated erosion rate (note: erosion is scarce in these tributary streams, and erosion rates are low).
- ecological benefits.
- existing infrastructure.
- land planning issues.
- stock access and watering.
- existing remnant vegetation.
- riparian corridor links.

7.2.2 Water quality treatment wetlands

Treatment wetlands simply involve the slow passing of water through densely established native aquatic or semi-aquatic vegetation. Particulate matter, nutrients, and toxicants are removed through:

- enhanced sedimentation of particles.
- adsorption (attachment) of particles to soil and organic matter and subsequent storage in the wetland substrate.
- nitrification/denitrification and volatilisation converting nutrients and toxicants to gaseous forms.
- uptake (absorption) by vegetation (Kadlec *et al.* 2000).

The construction/development of a treatment wetland on the main Green Lake tributaries would help to improve the quality of water entering the lake and reduce the likelihood of BGA blooms.

7.2.3 Lake fringing reed beds

Establishing reedbeds (e.g., Phragmites and other emergent species to encourage diversity) around the lake margins has multiple benefits. They form excellent aquatic fauna habitat when inundated and at all water levels, are the preferred habitat for reed warbler birds and other cryptic water birds, so they will increase the biodiversity and hence resilience of the ecosystem. They protect the bank from wind and wave erosion, and filter water running into the Lake, reducing sediment and nutrient loads, and ultimately BGA blooms. They have an extensive underground root network that binds the soils to the lake bed but also removes nutrients from the sediments. The leaf litter from these reeds also forms an organic layer which can help prevent erosion and promote aquatic life, such as invertebrates. A resilient ecosystem is more easily able to bounce back after impacts from natural or human-induced events.

7.3 Riparian fencing (stock management)

Fencing is the most common approach to control stock in the riparian zone. Fencing may be employed where stock exclusion will protect and/or enhance the riparian zone. This approach applies to numerous sections of waterway within the Green Lake project area, where a healthy riparian zone (including remnant vegetation) is already present and a seed source for future natural recruitment is available. Stock exclusion can improve a

riparian zone through natural regeneration and stream bank stability. Fencing also has the potential to improve the riparian zone in areas where existing vegetation is grazed and the density is declining. Complementary revegetation may be beneficial several years after the installation of fencing, to fill in gaps not already occupied through natural recruitment.

Guidelines for the riparian vegetation in flood-prone areas have been prepared by the Victorian Department of Environment, Land, Water and Planning.

7.4 Weed management

Weed management involves the management (control or eradication) of all weeds deemed to have a negative influence on environmental health. Invasive weeds such as Horehound, Bridal Creeper and Cape Broom were observed in the project area. Without intervention these invasive weed species will continue to colonise the Lake margin and riparian areas. A weed management program targeting the highly invasive environmental weeds is strongly recommended.

7.5 Structural intervention

Occasionally, structural works may be required to address specific threats to waterway health or other environmental or structural assets. In these instances, specialist design advice should generally be sought to ensure the intended works consider the relevant waterway processes and account for the necessary design considerations.

In the planning stage of a project aimed at managing erosion, it is important to assess the implications associated with not undertaking structural works. **In many circumstances, erosion processes are most effectively managed in the long term through vegetation establishment and stock exclusion.**

The following on ground management techniques are considered most appropriate to manage the observed bank erosion in the Green Lake Catchment.

7.5.1 Rock Armouring

Rock armouring (also known as rock rip rap) involves the placement of quarried, angular rock against a stream bank or bed to prevent erosion (Figure 7-1). The rock acts as physical barrier that separates the flowing water from the in-situ material. The rock is graded and placed to a design thickness to ensure that it forms an interlocking mass. Rock armouring is also commonly utilised in the protection of infrastructure such as bridges, culverts, and drains. Rock armouring is relatively costly if undertaken on a large scale. As such, the use of rock armouring should be targeted.

In context of the project area, rock armouring of the banks in isolation will not address the bed degradation processes (as opposed to rock chutes or timber drop structures). However, rock armouring is considered an effective management technique to provide erosion protection at and surrounding roadside/trackside culverts and drains and to protect infrastructure threatened by bank erosion.

Figure 7-1 Rock beaching installed on the Ovens River at Wangaratta aimed at protecting an existing levee.

7.5.2 Log Revetment

Log revetment (also known as timber brushing) involves the placement of timber on a stream bank with the objective of preventing bank erosion over the short to medium term (Figure 7-2). The revetment typically extends into the bed of the stream to deal with scouring of the bed and is held onto the bank with either timber piles or cables that are anchored to stakes or piles at the top of the bank. A gravel filter layer or filter fabric can be placed under the revetment to prevent flow permeating the timber from eroding the bank material behind. Stock management and revegetation are often undertaken to complement the log revetment. Log revetments typically have a design life of approximately 10-15 years (depending on the timber used) in which revegetation should be established on and surrounding the bank. Hence, as the revetment fails the vegetation will colonise the area to provide some ongoing bank stability. In providing only interim stability to the bank the brushing has the important effect of, unlike hard engineering works (e.g. rock revetment), not locking sections of the planform of the river in position for the long term (Water Technology 2010). Once the structure fails the logs remain instream and provide habitat value.

Figure 7-2 Log revetment on the Murray River (sourced from Soil Conservation Service).

8 RECOMMENDATIONS FOR MANAGEMENT

8.1 Overview

This section details priorities and recommendations for the management of the stream network across the Green Lake catchment. The priorities and recommendations for management have been developed with consideration of:

- The project objectives.
- The threats and values present within the project area.
- The reach delineation (outlined in Section 4).
- Stakeholder and community input.

8.2 Prioritisation

Recommended priorities for the management of the stream network across the project area have been developed based on the following rationale:

- **The highest priority (priority A) is given to those actions**:
  - That have the potential to reduce the incidence of Blue-Green Algal blooms within Green Lake. Ultimately, a reduction in Blue-Green Algal blooms will increase the social, health, economic and environmental values of Green Lake.
- **The second highest priority (Priority B) is given to those actions**:
  - That improves the general riparian condition of the waterways within the project area.

8.3 Management and Mitigation of Blue Green Algae Blooms

8.3.1 General Management Practices

Several management practices can reduce the frequency, extent, and duration of BGA blooms. Effective management focuses on addressing the key drivers of BGA blooms, including nutrient pollution, warm water temperature, and stagnant conditions. Understanding these drivers is essential for implementing effective mitigation strategies.

Nutrients can be controlled by:

- Limiting run-off from agricultural runoff, road stormwater and other sources.
- Promote responsible fertilizer and pesticide use in agriculture.
- Employ best management practices (BMPs) to reduce erosion and nutrient runoff from construction sites.
- Establish vegetated buffer strips along the inflow streams and areas where overland water flow into the Lake. Vegetated buffer strips help to filter runoff, trapping nutrients and preventing them from entering the waterway or lake.
- Control erosion along the banks by planting native vegetation in buffer strips can absorb excess nutrients and stabilize the soil.

Sediment control can be affected via the same mechanisms as nutrients but also:

- Controlling sediment inflows upstream through watershed management, such as revegetation in all upstream riparian zones.

- Develop comprehensive watershed management plans to address nutrient sources across the entire watershed.
- Planting instream and lakebed aquatic vegetation to bind sediment and prevent its spread and disturbance.
- Control carp numbers to prevent bioturbation of sediments.
- Fencing to prevent stock access and reduction of vegetated areas.
- Restore water regime and wetland function in the upstream inflow area where Diggers Creek and Mibus Creek spreads out and flows into Green Lake.

Water temperature can be ameliorated by planting locally native large trees around the Lake margins and tributary streams to create shading. Some vegetation exists already but gaps exist and other trees are senescing or not the best species. These trees will only provide limited shading due to the size of the waterbody, however, they may also provide woody debris (in time) which will add leaves, sticks and snags which will provide tannins and local shading.

Public education and outreach through:

- Education of the public, including farmers, residents, and businesses, about the impacts of nutrient pollution and the importance of reducing it.
- Promote responsible water use, within the catchment to maximise flows into the system.
- Research and adaptive management will drive new information for the system.
- Support research into local water bodies and their specific drivers of algal blooms to tailor management strategies.
- Continuously adapt management practices based on the latest scientific understanding.

It's important to note that managing BGA blooms often requires a holistic and long-term approach. Combining multiple strategies, such as nutrient reduction, sediment management, flow management, and public awareness, is usually the most effective way to address the problem and reduce the impact of algal blooms in water bodies.

8.3.2 Chemical control of BGA

Chemical methods for BGA control are fraught with difficulties and should be avoided. The chemicals which are effective against BGA also are highly toxic to many forms of aquatic life, and the EPA prevent their use in natural systems. Even if there were no off target, effects the sudden death of the algal mass can cause a deoxygenation event which would kill all gill-breathing organisms and create conditions where more nutrients would stream into the water column and create conditions for algal spores store in the sediment to germinate and multiple. Further, on death, the algal cells release all their toxins in the water body and this would have negative effects on fish, invertebrates, and mammals. Still further, these toxins would also affect humans recreating on the lake or any form of use for some time.

8.3.3 Carp

Carp control is especially important in shallow lakes and turbid lakes. The are very effective herbivores and prevent aquatic plants from establishing and converting plant material (which only slowly releases nutrients when it dies), to being processed in the carp's alimentary canal into forms of nutrients that are readily taken up by algae, thereby stimulating more BGA and other algal blooms. Their feeding methods tend to roil the water and send sediment into the water column where the nutrients dissolve and become available for algal growth immediately. The sediment then is suspended in the water column and stops light penetrating which further weakens the vegetation and advantages BGA over green algae and aquatic vegetation.

A single carp of 4kg in weight can have up to 1 million eggs, and at 6kg females may have 3 million eggs, and also these large individuals are the ones which have the most impact on aquatic vegetation and sediment disturbance. Therefore, controlling these large individuals is an effective method to prevent impacts. Fishing techniques such as community-led Carp musters (where the competition is on for the largest individuals or greatest weight of catch). There are some community-led carp fishing using spiral traps in South Australia which have also been effective in reducing fish density. Further, electrofishing is a selective mechanism where large carp can be targeted and removed, and reducing the density of the carp also reduces the many impacts the species has on our wetlands and lakes. A carp control plan, when comprehensively implemented can have an effect over time. In Tasmania, carp have been effectively removed from two lakes by selective fishing, capturing spawning aggregations, meshing off suitable breeding habitat in the lake shallows, and leading to inbreeding which has ultimately meant a significant reduction in reproductive fitness and almost complete eradication of the species.

The carp collected in these programs are often sought after by fertilizer companies that process the fish into fish food or fertilizer for plants.

The wetlands that could be enhanced to treat incoming water quality are likely to be very effective, and while carp may be able to colonise, the system will dry from time to time and this will reduce the carp populations, especially if it is dried every few years and water is not left in the wetland for more than 5-6 years in a row (however, this would be detrimental to the vegetation as well).

8.4 Fencing and revegetation

Using aerial photo interpretation, and advice and observations during field inspections, the fencing status of Diggers Creek, Mibus Creek, and major tributaries was mapped. Figure 8-1 shows the status of fencing as follows:

- **Absent** – the creekline has no fencing and is potentially exposed to grazing stock.
- **Absent, not required** – this is where the creek is unfenced but stock are not likely to graze these sections of creek i.e., the creekline is within a nature reserve that is not grazed by stock, or in a road reserve which is also unlikely to be grazed.
- **Present, effective** – Fencing is present and in good condition to control stock access as required.
- **Present, with revegetation** – these creeklines have been fenced and revegetated.

This mapping clearly indicates the sections of creekline where fencing is absent (red lines) and where fencing and revegetation could be implemented to improve stream health including water quality.

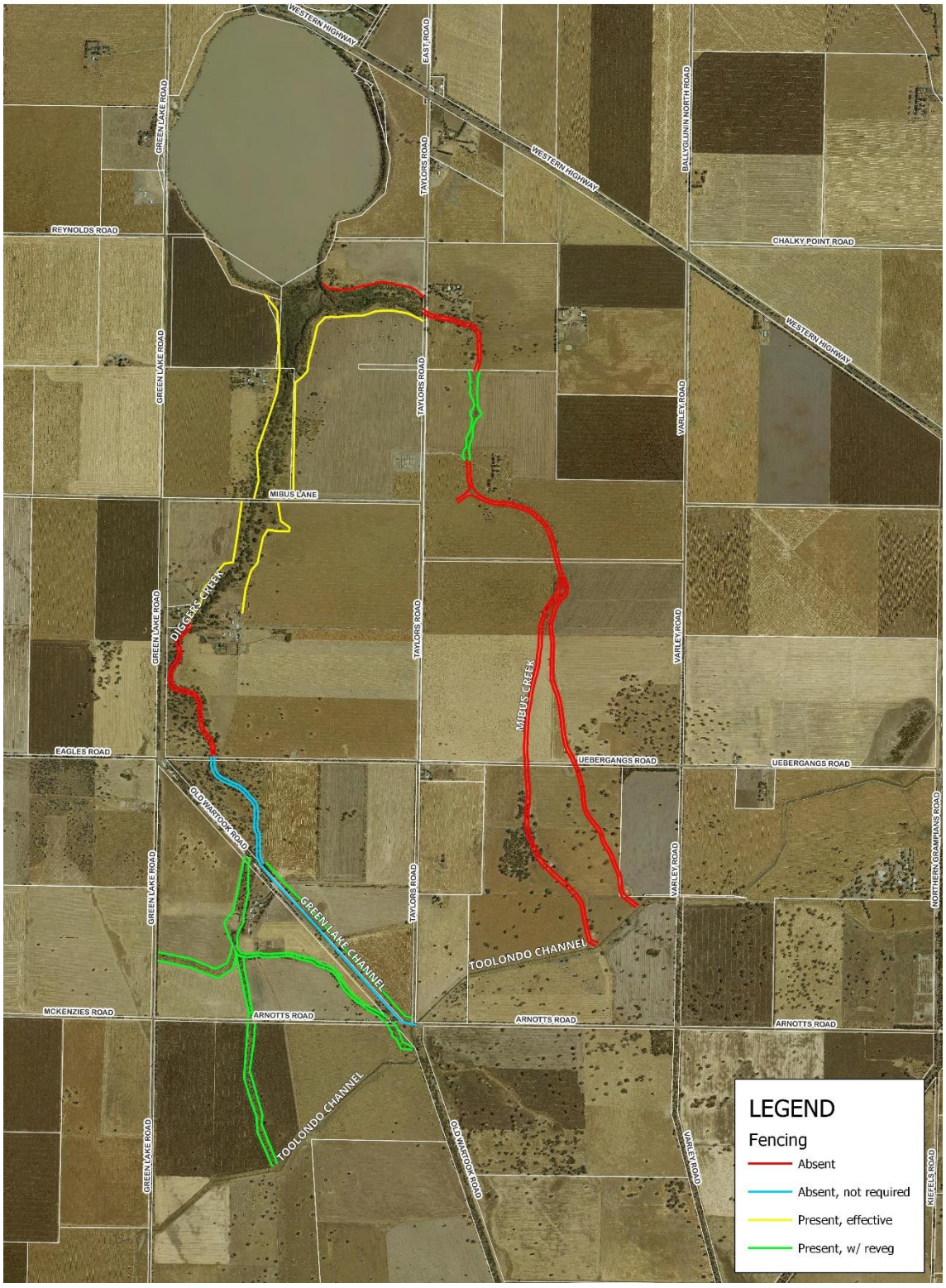


Figure 8-1 Existing fencing status along Diggers Creek and Mibus Creek

Following a review of opportunities to improve stream health, in particular water quality to reduce the likelihood of BGA blooms, areas were identified for fencing and revegetation. Figure 8-2 shows sections of creekline, and margins of Green Lake, that are recommended for revegetation. Of course, landowner buy-in and

willingness to protect and manage these revegetation areas needs to be negotiated. The implementation of revegetation in priority areas will require landholder willingness to actively support and participate in actions to enhance their creek frontage and ultimately improve the water quality of Green Lake.

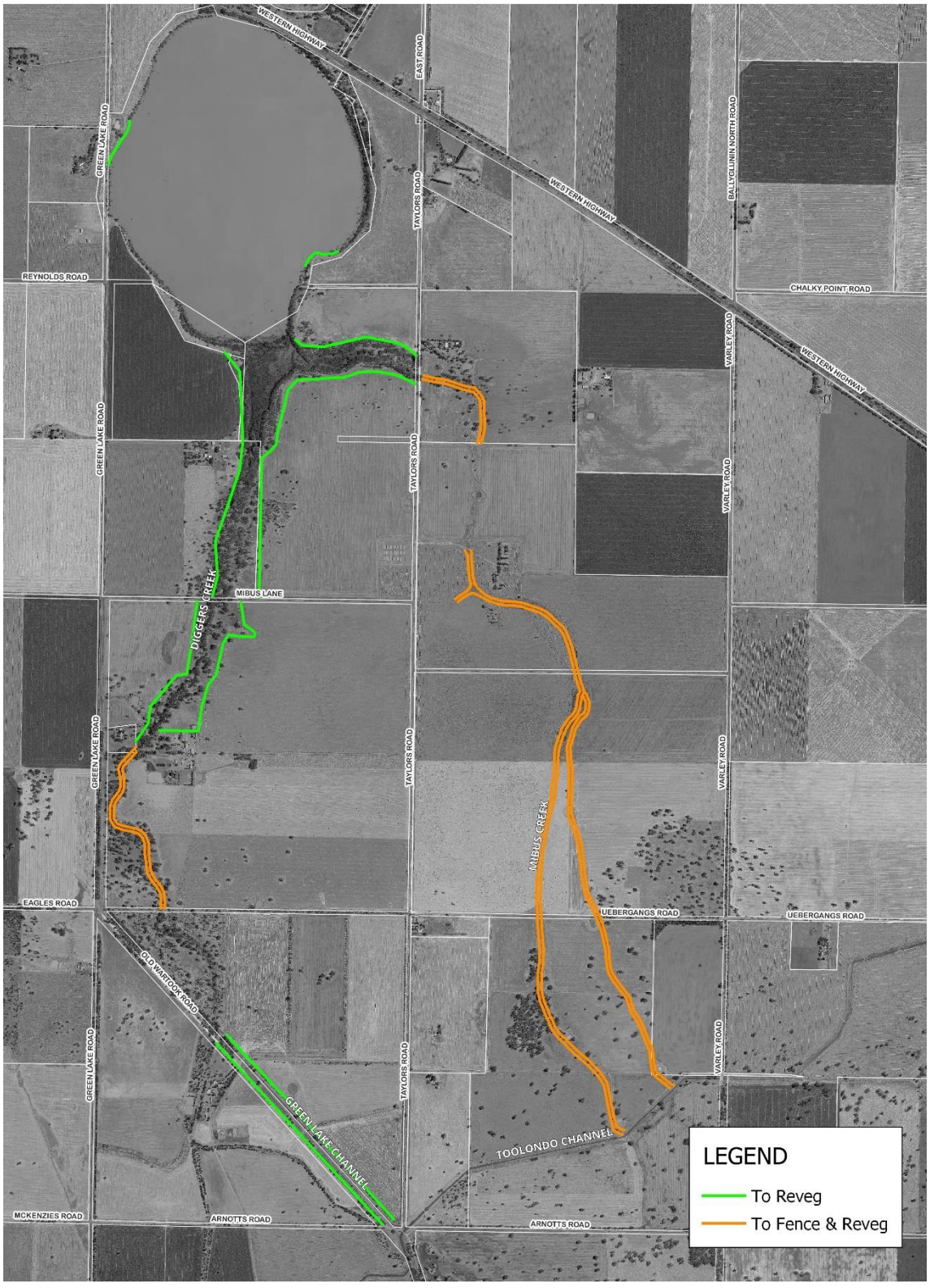


Figure 8-2 Recommended fencing and revegetation

9 SUMMARY OF MANAGEMENT ACTIONS FOR THE GREEN LAKE CATCHMENT

A summary of recommended management actions is provided in map form (Figure 9-1) and summarised in a table (Table 9-1).

Figure 9-1 shows the project area reaches and the proposed management action locations. These actions are described in Table 9-1 and include:

- A reference to the project reach.
- The rationale for implementing the action.
- The action Priority level (A or B) as defined in Section 8.2.

Note that some actions are not specifically mapped but described in the rationale. For example:

- Carp Control – these many and varied activities can occur within Green Lake, shallow breeding areas, and around hydraulic controls.
- Reach 10 drainage line fencing and revegetation - these ill-defined waterways could be identified, broadly fenced and revegetated to improve water quality.

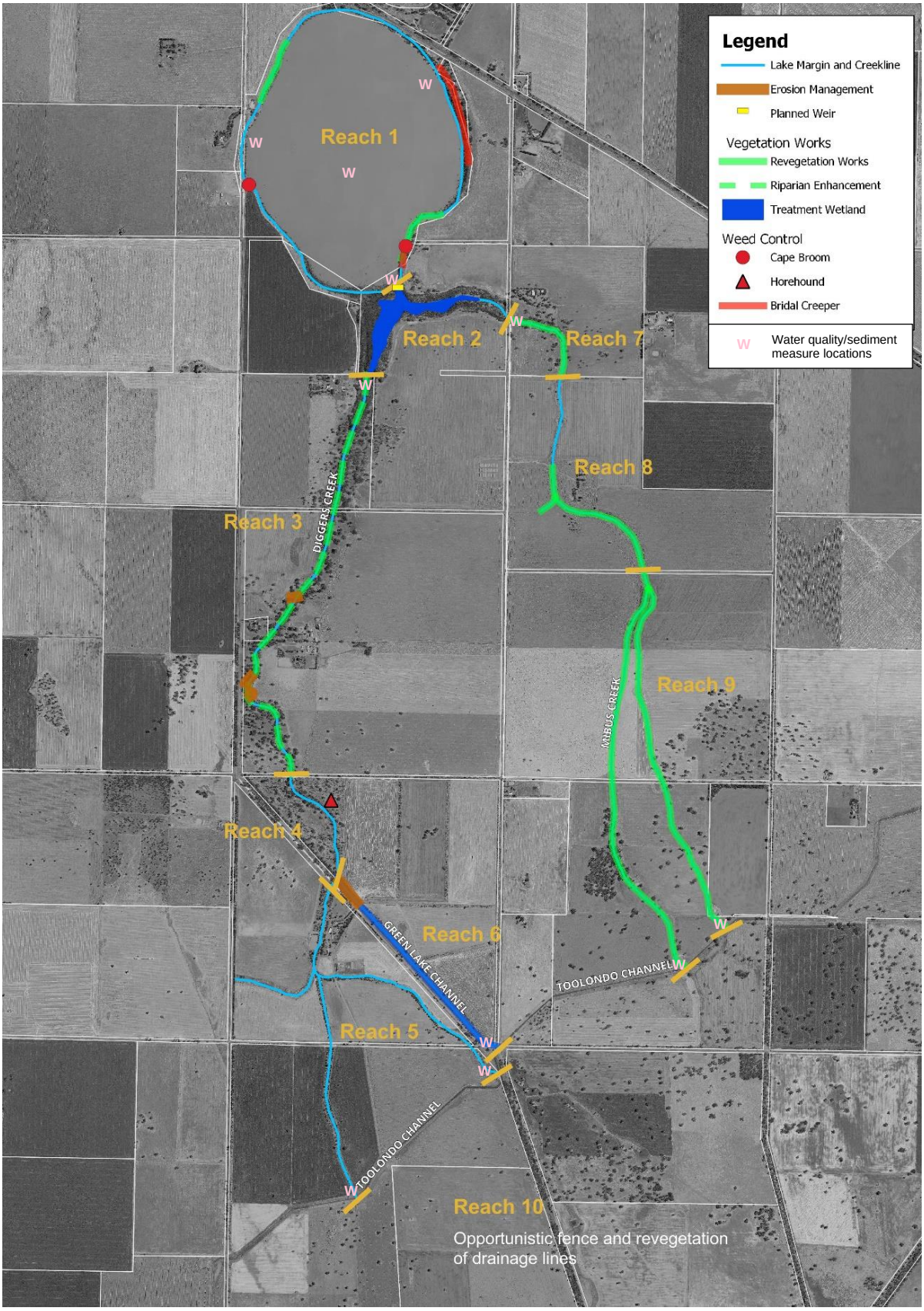


Figure 9-1 Recommended action locations

Table 9-1 Management Action Table

Reach	Management Action	Rationale	Priority
Reach 1 (Green Lake)	Fringing Reed Bed Establishment	Managing erosion on the lake margins through the establishment of fringing reed beds at strategic locations aimed at: ■ Absorbing excess nutrients. ■ Managing existing erosion along the lake margins. Specific locations identified for fringing reed bed establishment includes: ■ The eastern side of the lake, north of the old tip road (accessed off Taylors Road). ■ The western side of the lake, adjoining the old quarry accessed via Green Lake Road.	A
	Carp Control	Control carp numbers to prevent bioturbation of sediments. Specific actions to be considered include: ■ Installation of carp separation cages on existing wetland / road crossing controls (e.g., culverts). ■ Promotion of community event targeting fishing of carp (e.g. a carp muster) through local community groups including the Horsham Angling Club. ■ Targeted electrofishing. ■ Installation of exclusion screens in shallow carp breeding areas.	A

Reach	Management Action	Rationale	Priority
	Weed Management (Cape Broom and Bridal Creeper)	Two listed environmental weed species (White *et al.* 2018) were observed around Green Lake: ■ Cape Broom, *Genista monspessulana*, was observed adjacent to the quarry on the western shore, and another patch was observed on the southeastern margin immediately south of the tip road. It is inevitable that there are more patches of this woody weed around the lake as the field assessment did not circumnavigate the lake. The seeds from this species can remain viable for decades and therefore ongoing control will be required. There was evidence of control activities on the western shoreline. ■ Bridal Creeper, *Asparagus asparagoides,* was observed along the Lunette, south from the recreation precinct, and just south of the old tip road.	B
Reach 2 (Diggers Creek and Mibus Creek confluence)	Wetland treatment area	(See Section 5.2 for additional detail, map and images within Reach 2) Creation of a vegetated wetland zone for the purposes of water treatment through limiting nutrient inputs into Green Lake. Specific design elements of this action include: ■ Mapping the bathymetry of the backwater wetland area to inform the elevation level of the weir sill and guide the revegetation planting zones within the wetland. ■ Installing a weir structure that would regulate water level and inundation duration aimed at supporting aquatic/emergent native vegetation establishment and maintenance. ■ Revegetate if/as required to the modelled hydrological change following installation of the weir.	A

Reach	Management Action	Rationale	Priority
Reach 3 (Diggers Creek)	Erosion Management	Undertake erosion management works at discrete locations of active bank erosion aimed at reducing sediment and nutrient inputs. Specific locations include: ■ Active bank erosion sites (two). ■ Floodplain erosion (avulsion) feature. Note that specialist expertise may need to be sought to determine the most appropriate works at this location.	A
	Riparian vegetation establishment/enhancement.	Establishing vegetation and supplementing existing vegetation along the channel and floodplain areas aimed at filtering runoff, trapping sediment and nutrients and preventing them from entering the lake.	A
Reach 4 (Diggers Creek)	Weed Management (Horehound)	The highly invasive weed Horehound *Marrubium vulgare* was observed within the Bungalally Bushland Reserve. This listed environmental weed can disperse rapidly and should be controlled.	B
Reach 5 (Diggers Creek)	None, however, landholder support (e.g., weed control, top up revegetation or plant/fence maintenance) is likely to be appreciated.	Diggers Creek and the two main tributaries/drains have already been revegetated.	B
Reach 6 (Green Lake Channel)	Wetland treatment area	Creation of a vegetated wetland zone within the Green Lake Channel between the Toolondo Channel and the rock lined outfall into Diggers Creek for the purposes of water treatment through limiting nutrient inputs into Green Lake. Specific design elements of this action include: ■ Establishing dense emergent vegetation within the channel, or enlarging the channel to include broad vegetated treatment wetlands. Vegetated channels and wetlands help to filter runoff, trapping nutrients and preventing them from entering the waterway or lake. ■ Dense emergent vegetation, such as Common Reed *Phragmites australis*, may need to be periodically harvested to more effectively remove nutrients from the system.	A

Reach	Management Action	Rationale	Priority
	Remainder of concrete lined channel and drop structure	The existing concrete lined channel is planned for removal as funds become available. Remove the remaining damaged concrete lined channel and drop structure and replace with rock work and rock chute to deliver water to the invert of Diggers Creek.	B
Reach 7 (Mibus Creek)	Riparian vegetation establishment/enhancement (fencing and revegetation).	Establishing vegetation and supplementing existing vegetation along the channel and floodplain areas aimed at filtering runoff, trapping sediment and nutrients and preventing them from entering the lake. Fencing will be required to manage stock access.	A
Reach 8 (Mibus Creek) southern/upstream unfenced section	Riparian vegetation establishment/enhancement (fencing and revegetation).	Establishing vegetation and supplementing existing vegetation along the channel and floodplain areas aimed at filtering runoff, trapping sediment and nutrients and preventing them from entering the lake. Fencing will be required to manage stock access.	A
Reach 9 (Mibus Creek)	Riparian vegetation establishment/enhancement (fencing and revegetation).	Establishing vegetation and supplementing existing vegetation along the channel and floodplain areas aimed at filtering runoff, trapping sediment and nutrients and preventing them from entering the lake. Fencing will be required to manage stock access.	A

Reach	Management Action	Rationale	Priority
All Reaches	Land Management and Water Quality / Sediment Monitoring Program.	Develop a comprehensive watershed management plan for the contributing catchment area to address nutrient sources across the entire watershed. Design and implement a monitoring program to inform and prioritise actions to improve water quality to Green Lake. This program and analysis might include: ■ Sample and analyse Green Lake bed (centre of lake) and eroding bank sediments (western shoreline) to determine nutrient loads (see Figure 9-1 for locations). ■ Undertake periodic (e.g. autumn and/or spring) and event based (e.g. during/post flooding or water delivery from Toolondo Channel) water quality assessments including Nitrogen, Phosphorus, Turbidity, pH, Electrical Conductivity, Turbidity and Dissolved Oxygen. Sampling should be undertaken at the following locations (see Figure 9-1): - Green Lake, at the lake inlet and on the opposite side of the Lake e.g. 10m offshore, near the Yacht Club but away from boat/people movements. - Downstream end of Diggers Creek (d/s end of Reach 3) and downstream end of Mibus Creek (d/s end of Reach 7). - Upstream end of Diggers Creek (u/s ends of Reach 5) and upstream ends of Mibus Creek (u/s ends of Reach 9). - Upstream end of the Green Lake Channel (u/s end of Reach 6). ■ Analyse results to determine the areas or flows that are delivering the highest nutrient loads. Target appropriate actions upstream to reduce nutrients, or plan treatment options (e.g. treatment wetlands) downstream of these locations.	A
	Consultation	Promote responsible fertilizer and pesticide use in agriculture to landholders across the catchment area and surrounds.	A

10 REFERENCES

Barengi Gadjin Land Council (BGLC) (2020), *Barengi Gadjin Land Council* https://www.bglc.com.au/ a website accessed 28 September 2023.

Department of Energy, Environment and Climate Action (DEECA 2023), Vicmap Crown Land Tenure website accessed October 2023, https://www.land.vic.gov.au/maps-and-spatial/spatial-data/vicmap-catalogue/vicmap-crown-land-tenure

Department of Energy, Environment and Climate Action (DEECA 2023a), *NatureKit*, https://maps2.biodiversity.vic.gov.au/Html5viewer/index.html?viewer=NatureKit, website accessed October 2023.

Department of Environment, Land, Water and Planning (DELWP) (2016), *Water for Victoria: Water Plan.* Victorian Department of Environment, Land, Water and Planning. Melbourne.

White, M., Cheal, D., Carr, G. W., Adair, R., Blood, K. and Meagher, D. (2018), *Advisory list of environmental weeds in Victoria*. Arthur Rylah Institute for Environmental Research Technical Report Series No. 287. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

GWMWater (GWMW 2016), *Storage Management Rules for the Wimmera-Mallee System Headworks*, version 2.02

Kadlec, RH, Knight, RL, Vymazal, J, Brix, H, Cooper, P & Haberl, R (2000), *Constructed wetlands for pollution control: processes, performance, design and operation*, IWA Publishing, London.

Sinclair Knight Merz (SKM 2003), Stressed rivers project – Environmental flows study, Glenelg River System, report for the Glenelg Hopkins Catchment Management Authority.

Victorian Resources Online (VRO) (2013a), Soil Glossary H-R, https://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/gloss_hr#lunettes , website accessed October 2023

Victorian Resources Online (VRO) (2013b), Soil/Landform Unit – Horsham Lakes lunette clusters, https://vro.agriculture.vic.gov.au/dpi/vro/wimregn.nsf/pages/soil_landform_horsham_lake_clusters, website accessed October 2023

Village Well (2022), *Green Lake Recreational Precinct Plan*, Place Vision for West Vic Business.

Wimmera Catchment Management Authority (WCMA) (2021), *Wimmera Regional Catchment Strategy 2021-2027*. Wimmera Catchment Management Authority, Horsham

Wimmera Catchment Management Authority (WCMA) (2014), *Wimmera Waterway Strategy.* Wimmera CMA. Horsham, Victoria.

https://vro.agriculture.vic.gov.au/dpi/vro/wimregn.nsf/pages/soil_landform_horsham_lake_clusters,

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