Barwon Water

Boundary Creek, Big Swamp and Surrounding Environment

Remediation and Environmental Protection Plan (REPP)

Submitted: 31 July 2023

Acknowledgements

Barwon Water wishes to acknowledge the contribution of the Boundary Creek and Big Swamp community and stakeholder Remediation Working Group whose valuable insights, local knowledge and passion for the environment helped shape the Remediation and Environmental Protection Plan.

Representatives included Eastern Maar Aboriginal Corporation, Land and Water Resources Otway Catchment (LAWROC), Corangamite Catchment Management Authority, Colac Otway Shire Council, Environment Victoria, Upper Barwon Landcare Network, Boundary Creek landowners, and other interested community members.

Barwon Water also wishes to acknowledge the ongoing contribution of the Boundary Creek and Big Swamp community and stakeholder Remediation Reference Group and their appointed technical experts Dr Darren Baldwin, Associate Professor Vanessa Wong and Professor Richard Bush, who continue to provide valuable feedback during the implementation of the REPP. We would also like to thank Dr Darren Baldwin, Associate Professor Vanessa Wong and Professor Richard Bush for providing independent support to the community and stakeholder Remediation Reference Group.

Version Control

Version	Date	Status	Purpose
1	20 December 2019	For Review	Submitted to Southern Rural Water to satisfy the requirements outlined in the section 78 notice.
2	27 February 2020	Accepted	Revised based on feedback from Southern Rural Water and their Independent Technical Review Panel (ITRP).
3	22 December 2022	Interim Draft for Feedback	Revised to account for any outstanding feedback items and the current 'state of knowledge' pending the outcomes of the ecological risk assessment and paleoenvironmental study. This was submitted to Southern Rural Water for initial feedback and used to engage with the RRG prior to finalisation.
4	31 July 2023	For Acceptance	Revised based on feedback and submitted to Southern Rural Water for review and acceptance.

Executive Summary

In June 2017, Barwon Water acknowledged that the historic management of periodic groundwater pumping activities at the Barwon Downs borefield, that were conducted between 1982 and 2016 to supplement drinking water supplies during dry periods, had led to a reduction in groundwater contribution from the Lower Tertiary Aquifer into Boundary Creek, a tributary of the Barwon River.

This reduction, in conjunction with the changes in land use, Millennium Drought, and the complexities associated with management and regulation of a private on-stream dam that controls flow into the lower reaches of Boundary Creek, resulted in the increased frequency and duration of 'cease to flow' and 'acid flush' events along Boundary Creek and Big Swamp – a wetland that is primary fed by inflows from Boundary Creek.

This was despite meeting the provisions set out in the groundwater extraction licence(s) that were intended to offset the potential impacts from Barwon Water's groundwater pumping activities on Boundary Creek. This drying subsequently resulted in the enhanced oxidation of naturally occurring acid sulfate soils and discharge of acidity and metals that has impacted the condition and function of Big Swamp and the lower reaches of Boundary Creek.

In May 2018 Barwon Water established a community and stakeholder working group to help inform the development of a Remediation Plan to address the impacts caused by Barwon Water's activities. In September 2018, Barwon Water's commitment to undertake remedial works was legally strengthened through the issuing of a Ministerial Notice by Southern Rural Water (SRW) under section 78 of the Water Act. The Boundary Creek, Big Swamp and Surrounding Environment Remediation and Environmental Protection Plan was subsequently submitted to Southern Rural Water (SRW) in December 2019 and subsequently amended to account for Southern Rural Water and ITRP feedback prior to acceptance in February 2020. The objectives of the REPP are twofold:

1. **The Boundary Creek and Big Swamp Remediation Plan** - That outlines the controls and actions that have and will be implemented to:
    - **Ensure** no further harm from Barwon Water's historic groundwater pumping or remediation actions;
    - **Protect** the water quality and ecological values of the Barwon River;
    - **Improve** the water quality and streamflows within Boundary Creek; and
    - **Improve** the ecological values of Big Swamp.
2. **The Surrounding Environment Investigation -** To investigate whether other areas within the regional groundwater system have been impacted by historical management of groundwater extraction activities at the Barwon Downs borefield.

The REPP is a clear statement of Barwon Water's unwavering commitment to improving environmental outcomes and addressing the impacts caused by the historic management of groundwater pumping activities at the Barwon Downs borefield. It also outlines a robust process to undertake further investigations to verify if other areas within the regional groundwater system have been impacted by these activities, and whether any further remediation is required. Noting that the actions and controls implemented as part of the Boundary Creek and Big Swamp Remediation Plan do not aim to address the factors beyond Barwon Water's control and that these will continue to impact on the overarching resilience of the system.

The REPP also outlines Barwon Water's commitment to continuing an open and transparent relationship with community and stakeholder groups, including local environmental/Landcare groups, who contributed to the formation of the REPP and continue to inform its implementation.

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The Boundary Creek, Big Swamp and Surrounding Environment – Remediation and Environmental Protection Plan (REPP) is separated into two sections:

- **Part A** – that presents the details of the REPP and the associated works packages, and
- **Part B** – that contains the technical responses to meet the requirements of the section 78 Ministerial Notice.

The layout and format of each section is outlined in Figure 1.

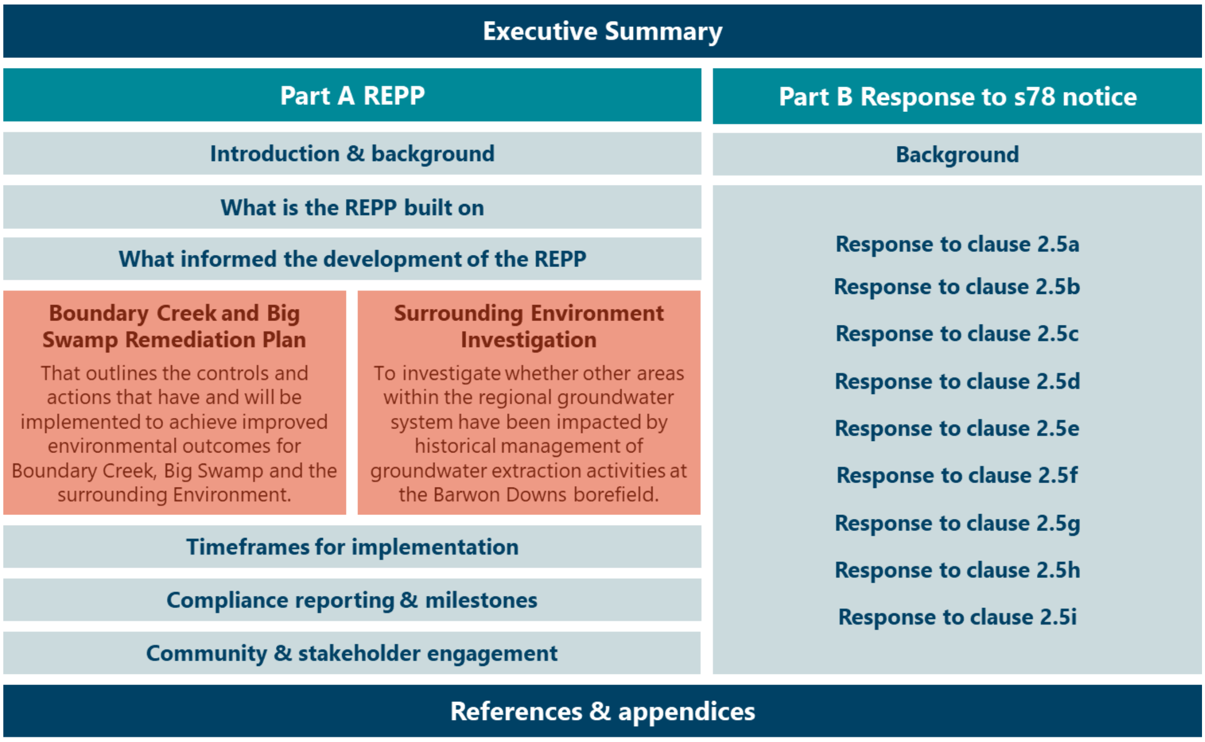

Figure 1 Document overview and structure

Part A – Remediation and Environmental Protection Plan (REPP)

A1 Introduction and background

In response to ongoing water shortages and challenges in meeting demand using conventional water supplies, the Geelong Waterworks and Sewage Trust (now Barwon Water) established the Barwon Downs borefield to access groundwater supplies contained within the Lower Tertiary Aquifer – a predominantly confined aquifer system that is recharged primarily by rainfall infiltration within the Barongarook High recharge zone.

The Barwon Downs borefield was used intermittently to supplement conventional water supplies during dry periods between 1982 and 2016 in accordance with the groundwater extraction licence(s), with pumping primarily occurring between 1982-1983, 1987-1990, 1997-2001, 2005-2010 and 2016. Over the licence period, Barwon Water extracted a total of approximately 119,000 ML from the Barwon Downs borefield before letting the licence expire in 2019.

In June 2017, Barwon Water acknowledged that the historic management of these groundwater pumping activities had led to a reduction in groundwater contribution from the Lower Tertiary Aquifer into Boundary Creek, a tributary of the Barwon River.

This reduction, in conjunction with the changes in land use, Millennium Drought, and the complexities associated with management and regulation of a private on-stream dam that controls flow into the lower reaches of Boundary Creek, resulted in the increased frequency and duration of 'cease to flow' and 'acid flush' events along Boundary Creek and Big Swamp – a wetland that is primary fed by inflows from Boundary Creek.

This was despite meeting the provisions set out in the groundwater extraction licence(s) that were intended to offset the potential impacts from Barwon Water's groundwater pumping activities on Boundary Creek.

This drying subsequently resulted in the enhanced oxidation of naturally occurring acid sulfate soils and discharge of acidity and metals that has impacted the condition and function of Big Swamp and the lower reaches of Boundary Creek.

In May 2018, Barwon Water established a community and stakeholder working group to help inform the development of a Remediation Plan to address the impacts caused by Barwon Water's activities.

In September 2018, Barwon Water's commitment to undertake remedial works was legally strengthened through the issuing of a Ministerial Notice by Southern Rural Water (SRW) under section 78 of the *Water Act*. The Boundary Creek, Big Swamp and Surrounding Environment Remediation and Environmental Protection Plan was subsequently submitted to Southern Rural Water (SRW) in December 2019 and was implemented in February 2020.

In accordance with the section 78 notice, the controls and actions implemented as part of the Boundary Creek and Big Swamp Remediation Plan have been designed to achieve improved environmental outcomes for Boundary Creek, Big Swamp and the Surrounding Environment. Noting that these do not aim to address the factors beyond Barwon Water's control and that these will continue to impact on the overarching resilience of the system.

The selection and assessment of these controls and actions has been guided by an adaptive management approach, which has been conducted in accordance with the endorsed governance framework, involving significant engagement with Southern Rural Water, independent technical experts and community and stakeholder groups.

The REPP also outlines what can practicably be achieved as part of Barwon Water's Remediation Plan and acknowledges that the system will continue to recover over time in response to natural recovery processes if groundwater pumping activities are ceased. Subsequently, the success targets outlined in the REPP focus on establishing remedial end points – i.e., the point at which further intervention by Barwon Water is no longer practicable, thus, meeting the requirements of the section 78 notice and the cessation of the REPP.

A2 What is the REPP built on

This section outlines the roles and responsibilities, vision, objectives, underlying principles and agreed definitions upon which the Boundary Creek, Big Swamp and Surrounding Environment - Remediation and Environmental Protection Plan (REPP) has been developed in response to the requirements of the section 78 Ministerial Notice.

A2.1 Roles and responsibilities

Key stakeholders along with their roles and responsibilities during the development and implementation of the REPP are provided in Table 1 below.

Table 1 Roles and responsibilities

Role	Responsibilities
Barwon Water	Barwon Water, as the recipient of the s78 notice, is responsible for implementing the 'Boundary Creek, Big Swamp and Surrounding Environment – Remediation and Environmental Protection Plan' in accordance with the requirements of the section 78 notice. This includes consultation with Southern Rural Water and their Independent Technical Review Panel (ITRP) and Community Leaders Group (CLG).
Barwon Water's Remediation Reference Group (RRG)	The RRG comprises of local community members, residents / landowners, environmental groups, community groups, Eastern Maar Aboriginal Corporation and department agencies such as the Colac Otway Shire and Corangamite Catchment Management Authority that meet four times a year. The role of this group is to provide oversight and feedback in relation to: • the implementation of the REPP • the delivery of actions within the REPP, including environmental monitoring programs • any proposed changes to the REPP in light of the adaptive management, and

Role	Responsibilities
	• the communications plan for the broader community
Southern Rural Water (SRW)	Southern Rural Water, as issuer of the section 78 Ministerial Notice acting as delegate for the Minister for Water, is accountable for ensuring that Barwon Water is compliant with the directions set out in the section 78 notice. As such, Southern Rural Water's role is to accept or reject controls, actions or targets that Barwon Water may seek to implement or revise during implementation of the REPP.
Southern Rural Water's Independent Technical Review Panel (ITRP)	The ITRP have been appointed by Southern Rural Water to provide independent technical advice for consideration as part of South Rural Water's reviews and/or feedback.
Southern Rural Water's Community Leaders Group (CLG)	The CLG comprises of community members with an interest in the REPP and associated works. The CLG provide input to Southern Rural Water for consideration as part of their reviews and/or feedback to ensure community concerns are addressed and that the controls and actions are commensurate with the community sentiment.
Department of Energy, Environment and Climate Action (DEECA)	DEECA, as the water resource manager for Victoria, will need to be kept informed of progress with implementation of the REPP and as outcomes of the REPP become known. Barwon Water will not seek feedback directly from DEECA regarding implementation of the REPP. Instead, any input from DEECA will be facilitated by Southern Rural Water as the issuer of the section 78 notice.
EPA Victoria	Ensure that appropriate action is being taken to reduce the risks of harm to human health and the environment. While EPA Victoria do not have a formal role in the development or implementation of this REPP, liaison with the EPA is required to ensure the risks or harm to human health and the environment are being adequately addressed and that Barwon Water are following the regulatory approvals process, if and when required. Barwon Water continues to meet with DEECA, Southern Rural Water and EPA representatives every 2 months.

A2.2 Purpose

The Remediation and Environmental Protection Plan (REPP) outlines the controls and actions that have and will be implemented to achieve improved environmental outcomes within the confirmed areas of impact (i.e., where measurable and evidence based scientific methodologies conclude that the historical management of groundwater pumping activities at the Barwon Downs borefield resulted in environmentally significant adverse impacts).

The REPP itself will be delivered under two parallel work packages:

1. **The Boundary Creek and Big Swamp Remediation Plan** - That outlines the controls and actions that have and will be implemented to:
   - **Ensure** no further harm from Barwon Water's historic groundwater pumping or remediation actions;
   - **Protect** the water quality and ecological values of the Barwon River;
   - **Improve** the water quality and streamflows within Boundary Creek, and
   - **Improve** the ecological values of Big Swamp.

2. **The Surrounding Environment Investigation -** To investigate whether other areas within the regional groundwater system have been impacted by the historical management of groundwater extraction activities at the Barwon Downs borefield.

Noting that the REPP does not aim to address the irreversible changes or ongoing stressors that have occurred as a result of changes in land use, surface water harvesting and stream modification activities, or broader groundwater extraction activities beyond Barwon Water's control.

This approach was supported by the community and stakeholder Remediation Reference Group, recognising the need for immediate action to address the confirmed areas of impact within the Boundary Creek catchment and that additional work was required to further investigate the potential impacts within the broader environment to determine if any additional controls and actions are required within these areas. Noting that the cessation of groundwater pumping activities and the ruling out of the Barwon Downs borefield as a future water supply has already occurred. These actions support the recovery and protection of the Lower Tertiary Aquifer more broadly.

A2.3 Principles

This section outlines the fundamental principles (refer Table 2) upon which the Boundary Creek, Big Swamp and Surrounding Environment - Remediation and Environmental Protection Plan (REPP) has been developed in response to the requirements of the section 78 Ministerial Notice (s78 notice).

In this context, a 'principle' is defined as a fundamental idea or rule on which the REPP is founded and explains or controls how remediation will be undertaken to achieve improved environmental outcomes.

Table 2 Underpinning principles

#	Principle	Why is this a principle?
1	No further groundwater extraction from the Barwon Downs Borefield by Barwon Water.	Barwon Water's previous groundwater extraction licence expired on 30 June 2019, with Barwon Water withdrawing our application to extend our extraction licence in 2019. Barwon Water has since ruled out the use of the Barwon Downs borefield as an urban water supply in our Water for our Future Strategy - our next Urban Water Strategy. In addition to this, Barwon Water has also committed to preparing and implementing a

#	Principle	Why is this a principle?
		decommissioning plan for the Barwon Downs borefield production bores which has been included as an action in our 2023-2028 price submission. In addition, the Permissive Consumptive Volume (PCV) prevents any groundwater pumping occurring in the Gerangamete Groundwater Management Area (GMA) other than by three other licensees for dairy wash and irrigation purposes or for maintenance/testing purposes.
2	Support the recovery of groundwater levels within the Lower Tertiary Aquifer (LTA), as intended under the current Permissive Consumptive Volume (PCV) set for the Gerangamete and Gellibrand Groundwater Management Areas.	Barwon Water has ruled out the use of the Barwon Downs borefield as an urban water supply in our Water for our Future Strategy - our next Urban Water Strategy. In addition to this, Barwon Water has also committed to preparing and implementing a decommissioning plan for the Barwon Downs borefield production bores which has been included as an action in our 2023-2028 price submission. Barwon Water fully supports the Victorian Government's reduction in the PCV which will allow for the recovery and ongoing protection of this resource and the ecosystems that rely of this resource. The PCV is a cap set by the Minister for Water that outlines the maximum volume of water that can be allocated for consumptive purposes (not just by Barwon Water) and therefore provides greater protection for this system.
3	Remediation actions which may be required to be carried out by Barwon Water must directly relate to material harm caused by the historic management of groundwater pumping activities at the Barwon Downs borefield.	Barwon Water will consider remediation actions and controls where measurable, and evidence based scientific methodologies conclude that the historical management of groundwater pumping activities at the Barwon Downs borefield resulted in environmentally significant adverse impacts – i.e., material harm to human health or the environment. This will include consideration of the cause, effect and impact linkages associated with a range factors, some of which are beyond Barwon Water's control. Noting that many factors beyond Barwon Water's control have also contributed to the magnitude of the identified impacts. However, these are not within the scope of the section 78 notice or the REPP and require a broader land management response.

#	Principle	Why is this a principle?
		Where potential impacts are identified, further investigations will be undertaken, where required, to better understand these impacts and determine if these are considered to be environmentally significant adverse impacts.
4	Barwon Water highly values its partnerships with Traditional Owners and is committed to working with, and learning from them, to ensure that cultural history and values are considered during the implementation of the REPP.	Waterways are the lifeblood of our land and Traditional Owners have been managing the waterways we all have relied upon for thousands of years. By respecting and understanding the cultures and histories of Aboriginal and Torres Strait Islander peoples within the region, Barwon Water can learn to look at the environment through the eyes of a First Nations person.
5	Barwon Water is committed to continuing an open and transparent relationship with the community and key stakeholders including local environmental groups during the implementation of the REPP.	We want to ensure insights and knowledge of the community, local environmental groups and stakeholders are considered and used help to inform the implementation of the REPP. We also want to build community and stakeholder confidence in the implementation of the REPP. Like the REPP itself, the long-term approach to engagement with the community and stakeholders will adapt as outcomes from the REPP come to hand.
6	The Boundary Creek and Big Swamp Remediation Plan will prioritise actions and controls that minimise the need for active and/or intrusive interventions and enable the system and its ecological values to improve progressively over time. This does not preclude the implementation of engineered interventions if they are deemed to be required.	It was the preference of Barwon Water's community and stakeholder Remediation Reference Group that priority be given to actions and controls that minimise the need for active and/or intrusive interventions and support natural recovery processes. Barwon Water acknowledges that it may take a decade to realise improvements from remedial works, particularly with regard to the acidity loads. However, this needs to be balanced with practicality as required by the section 78 notice, which includes consideration for the environmental implications, costs, risks, and trade-offs associated with implementing active and/or intrusive interventions.
7	The REPP is based on an adaptive management approach.	Barwon Water has adopted the following definition for adaptive management of the REPP: 'a continuous cycle of improvement based on setting goals and priorities, developing strategies, taking action and measuring results, and then feeding the results of monitoring back

#	Principle	Why is this a principle?
		into new goals, priorities, strategies and actions' (Mackay, 2016). An adaptive approach to remediation is considered best practice, where adaptation occurs continuously to improve the REPP's ability to deliver on the vision and objectives. Barwon Water proposes that any improvements made to the REPP in light of the adaptive management approach is put forward and approved by Southern Rural Water as part of the annual reporting process for the s78 notice.
8	Barwon Water and Southern Rural Water will both carry out their relevant statutory obligations and regulatory functions to ensure sufficient flows are passed through the private on-stream dam located on Boundary Creek.	The Boundary Creek catchment has been heavily modified from its original condition. So much so, that surface water flows into the lower reaches of Boundary Creek are controlled by the management and regulation of a private on-stream dam. The management and regulation of this dam has significant implications on both the remediation efforts and the future resilience of the system.

A2.4 Definition of remediation

The words river 'restoration', 'rehabilitation' and 'remediation' are often used interchangeably but have very different definitions with regard to environmental projects, as outlined below:

> **'Restoration**
>
> The ideal restoration project will restore a degraded river to its original condition. This includes restoring the natural range of water quality, sediment and flow regime, channel geometry, native aquatic plants and animals, and adjoining riparian lands. The goal of restoration is an admirable one, but it is important to acknowledge that it is often something to be aspired to, as it will seldom be possible to achieve.
>
> This is because it is often impossible to establish what the 'original' condition was and, secondly, such restoration would mean replicating pre-European inputs and outputs into the system (e.g., water quality and quantity, animals and plants) from upstream, downstream and the riparian zone.
>
> **Rehabilitation**
>
> Although restoration may be impossible, this does not leave a degraded system without hope. By improving the most important aspects of the stream environment, you may create a stream that, although only resembling its original condition, is nevertheless an improvement on the degraded system and often a valuable environment in its own right.
>
> Since restoration is usually impossible, rehabilitation is the more common goal for undertaking projects along rivers.

> **Remediation**
>
> In some cases, even rehabilitation is not possible because of irreversible changes. In such a situation, the original state is no longer an appropriate aim for the system because the system can no longer support that condition. **The aim of remediation is to improve the ecological condition of the stream, but the endpoint of that improvement will not necessarily resemble the original state of the stream.** In fact, it may not be possible to predict what that endpoint will be like.
>
> Understanding that some of the changes in the catchment cannot be reversed (e.g., climate change, land clearing, channelisation and soil chemistry), rehabilitation and restoration are not reasonable and practicable conditions to aim for because inputs from the catchment will never support that original condition.'
>
> (Edgar & Lovett, 2002)

Remediation has been defined in the section 78 notice as 'the controls and actions that could be practicably carried out to achieve improved environmental outcomes for Boundary Creek, Big Swamp and the surrounding environment that has been impacted by groundwater pumping at Barwon Downs'. This definition acknowledges the significant climatic and land use changes that have occurred since European settlement and the presence of naturally occurring acid sulfate soils that were formed in saturated or sedimentary environments (Rabenhorst et al., 2017).

Given these changes, the return of these areas to pre-European conditions is neither practicable nor achievable, thereby ruling out both 'restoration' and 'rehabilitation' efforts. Therefore, remediation actions are aimed at improving the ecological condition and function of the 'confirmed areas of impact', noting that the remedial endpoint is likely to be different to the original condition.

Therefore, without limiting the intent or extent of the s78 notice, the following definition of remediation has been adopted for the REPP to provide further guidance for evaluating the appropriateness and practicality of proposed remediation actions for achieving improved environmental outcomes:

Remediation refers to the controls and actions that could be practicably carried out to improve the ecological condition and function of areas confirmed to have been impacted by the historical management of groundwater pumping activities at the Barwon Downs borefield, noting that this is likely to be different to the original condition due to the extent of change since European settlement.

A2.5 Adaptive management approach

Barwon Water has adopted the following definition of adaptive management for the REPP:

> **'a continuous cycle of improvement based on setting goals and priorities, developing strategies, taking action and measuring results, and then feeding the results of monitoring back into new goals, priorities, strategies and actions'**
>
> (Mackay, 2016).

An adaptive approach to remediation is considered best practice, whereby the REPP can be adapted in response to ongoing monitoring and the current state of knowledge. This approach allows Barwon Water to evaluate how the confirmed areas of impact are responding to interventions and take further action, such as implementation of contingency measures, if and when required, to mitigate against high-risk events, should these persist while the primary remedial actions take effect.

Barwon Water's adaptive management approach is underpinned by:

- **Ongoing community and stakeholder engagement** activities to ensure the remedial goals and success targets are consistent with the community sentiment.
- **An annual review process** whereby minor changes/amendments can be proposed in response to the current state of knowledge as part of the Annual Reporting process.
- **A formal update and review process** whereby Barwon Water or Southern Rural Water as the regulator may propose changes to the REPP and ensure that these are validated and accepted prior to these being published (refer Section A2.6).
- **A robust environmental monitoring program** that has been developed to monitor how the system is responding to the remedial actions and identify whether any additional actions are required.

A2.6 Update and review process

In line with the approved Governance Framework, Figure 2 below outlines:

- The circumstances under which Barwon Water or Southern Rural Water may propose a change to a control, action or target within the REPP, and
- The process by which Southern Rural Water may accept or reject controls, actions or targets proposed by Barwon Water.

In addition to this process, Barwon Water propose to outline any minor changes/amendments as part of the annual reporting process, which is submitted to Southern Rural Water for review and comment prior to being finalised. This will ensure the REPP is reviewed and updated on an annual basis to facilitate the adaptive management approach and ensure the document remains current.

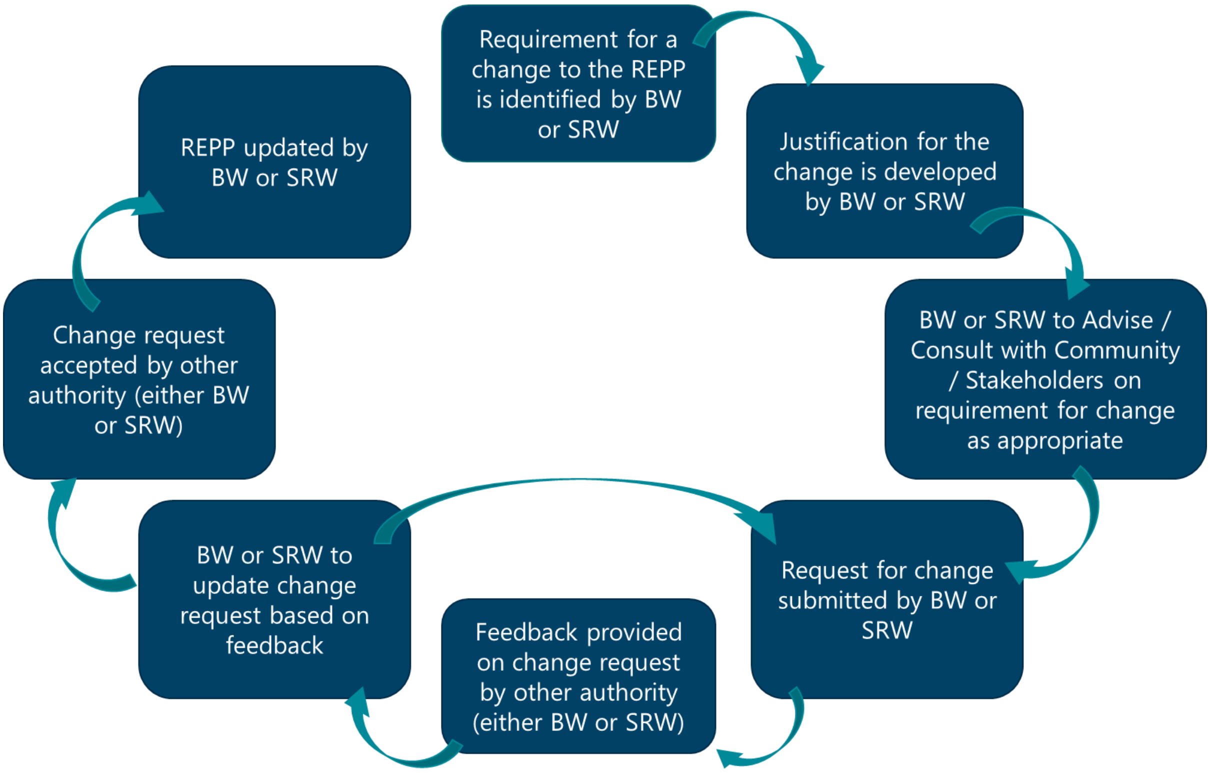

Figure 2 Decision making process for changes within the REPP

A3 What informed the development of the REPP

The approach adopted for development of the Boundary Creek and Big Swamp Remediation Plan was adapted from a nationally recognised 12 step stream rehabilitation planning process developed by the Cooperative Research Centre for Catchment Hydrology that provides guidance on how to conduct a stream rehabilitation – or in this case – a remediation project (LWRRDC & CRCCH, 2000), as shown in Figure 3.

Figure 3 12 step stream rehabilitation/remediation planning process (LWRRDC & CRCCH, 2000)

Throughout the development process, the REPP has also been informed by outcomes from:

- Significant community and stakeholder engagement;
- Environmental monitoring and investigation programs, and
- Groundwater, surface water and geochemical modelling works.

Further information regarding these activities is provided in the following sections.

A3.1 Community and stakeholder engagement

Barwon Water's commitment to continuing an open and transparent relationship with community and stakeholder groups including local environmental/Landcare groups during the implementation of the REPP underpins the development and implementation of this REPP.

In May 2018, the Boundary Creek and Big Swamp Remediation Working Group (RWG) was established to actively engage with Barwon Water in the design and development of a remediation plan for Boundary Creek and Big Swamp.

The working group was made up of representatives from the Corangamite Catchment Management Authority, Colac Otway Shire Council, Traditional Owners, Land and Water Resources Otway

Catchment, Environment Victoria, Upper Barwon Landcare Group, Boundary Creek landowners and other interested community members.

During consultation, the working group was invited to nominate three independent experts to support them in their discussions and translate community views and values into scientific and technical content to ensure these were reflected in any remediation options considered. The three experts nominated by the working group were:

- **Associate Professor Vanessa Wong** (Monash University, Associate Professor, School of Earth Atmosphere and Environment);
- **Professor Richard Bush** (Monash Sustainable Development Institute) (Global Innovation Chair, International Centre for Balanced Land Use Office), and
- **Dr Darren Baldwin** (Independent Consultant) (Principal consultant of Rivers and Wetlands and Adjunct Research Professor at Charles Sturt Universities School of Agricultural, Environmental and Veterinary Sciences).

Ten meetings were held during development of the REPP to consider how best to incorporate the community's vision and values for remediation as well as address any concerns they had about the remediation options.

Prior to submission of the REPP to Southern Rural Water for review and acceptance, the REPP was supported by the Remediation Working Group and their nominated technical experts, subject to the following considerations:

- Desire to see Barwon Water's support for recovery of groundwater levels in the Lower Tertiary Aquifer articulated as a principle;
- Success targets need to be specific and measurable;
- Preference for minimal active treatment interventions unless required to be implemented as a contingency;
- Appropriate contingency measures developed to mitigate any unforeseen impact from the implementation of remedial works for Boundary Creek and Big Swamp, and
- Confirmation of impacts associated with the Surrounding Environment Investigation needs to be based on observable data and field studies to validate the predictions of the regional groundwater model.

Following acceptance of the REPP by Southern Rural Water in February 2020, the Remediation Working Group was rolled into the Remediation Reference Group (RRG) who continue to meet on a quarterly basis to discuss the implementation of the REPP and any changes that are required as part of the adaptive management approach to account for the current state of knowledge. Feedback provided during the quarterly meetings has also been used to inform this revised REPP, with the changes being tested with the Remediation Reference Group prior to submission to Southern Rural Water.

Like the REPP itself, the approach to engagement will be adaptive to suit the needs of the community and stakeholders.

A3.2 Environmental monitoring and investigation works

Since the 2019 and 2020 versions of the REPP, Barwon Water has undertaken a range of environmental monitoring and investigation works to improve the current 'state of knowledge' regarding the impacts to Boundary Creek, Big Swamp and the surrounding environment. In line with the adaptive management approach, the knowledge and understanding obtained from these works has and will continue to be used to inform the REPP revisions.

The REPP itself does not aim to present the details and findings of all the work completed to date. Rather, this document outlines the approach that has been adopted based on these findings.

The technical reports used to inform the development of this REPP are provided on the Your Say website located here: https://www.yoursay.barwonwater.vic.gov.au/boundary-creek

A3.3 Groundwater, surface water and geochemical modelling

A3.3.1 Regional modelling

A numerical groundwater model for the Barwon Downs Graben was initially developed by Barwon Water in 1994 to inform groundwater extraction activities. Since this time, the groundwater model has continued to evolve as more information became available to better inform these activities. In 2016/2017 the regional groundwater model was expanded, re-built and recalibrated to assess potential impacts and risks associated with the future operation of the Barwon Downs borefield to support the licence renewal application (Jacobs, 2018c).

In 2019, the regional groundwater model which considers the following layers was used to assess the magnitude of drawdown and/or baseflow reduction, and identify a number of potentially impacted areas for further monitoring and/or investigation (Jacobs, 2019d):

- Layer 1: Gellibrand Marl;
- Layer 2: Clifton Formation;
- Layer 3: Narrawaturk Marl;
- Layer 4: Dilwyn Formation;
- Layer 5: Pember Mudstone;
- Layer 6: Pebble Point Formation, and
- Layer 7: Basement.

It is noted that based on a comparison between the measured and modelled head response and fluxes during the calibration period, the latest version of the regional groundwater model has a Scaled Root Mean Square (SRMS) error of 4.9%.

This process resulted in the identification and prioritisation of the following potential high-risk areas:

- Boundary Creek between McDonalds Dam and Big Swamp;
- Barwon River (East branch);
- Barwon River (West branch);
- Barwon River (downstream of the confluence with Boundary Creek);

- Gellibrand River and associated groundwater dependent ecosystems;
- Ten Mile Creek;
- Yahoo Creek;
- Groundwater dependent ecosystems west of the Barwon River (near Yeodene), and
- Groundwater dependent ecosystems east of the Barwon River (between Barwon Downs and Yeodene).

While the focus of work to date has been on the Boundary Creek Catchment, given the data gaps and uncertainty in the model, further work to 'ground truth' the findings of the model and determine if Barwon Water's historical management of groundwater pumping activities at the Barwon Downs borefield resulted in any environmentally significant adverse impacts is the focus of the Surrounding Environment Investigation, that is detailed in section A5.

A3.3.2 Modelling of Boundary Creek and Big Swamp

Given the previous environmental monitoring and investigation works undertaken within Boundary Creek and Big Swamp and the identification of the 'confirmed areas of impact', groundwater, surface water and geochemical models have been used throughout the development of this REPP to simulate the Boundary Creek system and predict responses to physical processes such as groundwater and surface water flows, soil chemistry and water quality changes.

Together these models have been used to:

- Identify the key chemical processes responsible for the generation of acid and estimate the current load and concentration of key analytes discharging from the swamp under different flow conditions;
- Predict the impact of surface water flows and influences of localised groundwater levels within Big Swamp, and
- Understand the changes in geochemistry that could result from the implementation of various remediation options.

The outcomes of this work have been instrumental in informing the remedial strategy, assessing the feasibility of different remedial options and informing the design of any active/intrusive remediation actions.

It is noted that given the inherent uncertainty associated with modelling complex environments, and in accordance with feedback received from the community and stakeholder working group and their nominated experts, the findings from this work have been supplemented with additional data and/or field studies.

A3.4 Identification of the 'confirmed areas of impact'

In line with the principles that underpin this REPP (Section A2.3), 'confirmed areas of impact' are defined as those where measurable and evidence based scientific methodologies conclude that the historical management of groundwater pumping activities at the Barwon Downs borefield resulted in environmentally significant adverse impacts – i.e. material harm to human health or the environment.

To help assess this Barwon Water established the following evaluation criteria, which have been used to inform this assessment:

1. Whether there is evidence of borefield related drawdown
2. Whether there is evidence of borefield related reductions in groundwater discharge
3. Whether there is evidence of borefield related adverse water quality changes
4. Whether there is evidence of subsequent ecological impacts

When combined, these allow for a multiple lines of evidence approach with which to interrogate the hydraulic influences, compare these to those caused by climate and other factors (such as licenced surface water extraction and forestry/logging activities) beyond Barwon Water's control and identify any environmentally significant adverse impacts that directly relate to Barwon Water's groundwater pumping activities at the Barwon Downs borefield.

It is noted that the assessment of environmentally significant adverse impacts is site and/or location specific and acknowledges the cumulative effects and interconnectivity of surface water and groundwater resources.

Noting that broader management actions, such as the cessation of groundwater pumping activities and Barwon Water's commitment to develop and implement a decommissioning plan for the Barwon Downs borefield extraction bores are aimed at preventing the potential for any future groundwater pumping related impacts.

A3.5 REPP development timeline

Table 3 summarises the key regulatory mechanisms, technical inputs and community and stakeholder engagement activities that have informed the development of the REPP and associated remedial actions. It is noted that a number of remedial actions are currently under development/review until these are accepted by Southern Rural Water.

An overview of the timeline in relation to the s78 notice and the development of remedial actions is captured in Figure 4.

Table 3 Inputs that informed the development of the REPP

Time	Event
June 2017	<u>Environmental impact caused by historical management of groundwater pumping acknowledged</u> Barwon Water acknowledged publicly that the historic management of groundwater pumping from the Barwon Downs Borefield had environmentally significant impacts in the Boundary Creek catchment.
December 2017	<u>Yeodene (Big) Swamp Study completed</u> A draft technical report was prepared to improve the understanding of chemical and physical processes in and around Big Swamp and on this basis, six possible remediation strategies for Boundary Creek and Big Swamp. This report was finalised in 2018 and shared publicly via the YourSay website.
May 2018	<u>Remediation Working Group established</u> The Remediation Working Group was established to provide input into the development of the Remediation Plan. The Remediation Working Group continue to meet on a quarterly basis to discuss progress against the REPP and obtain feedback on work in progress.

Time	Event
July 2018	Nominated technical experts appointed The Remediation Working Group appointed three independent technical experts to provide technical support in the development of the Boundary Creek and Big Swamp Remediation Plan. The nominated experts continue to provide support to the Remediation Working Group.
September 2018	Section 78 Ministerial Notice issued Barwon Water was issued with a Ministerial Notice under Section 78 of the Water Act 1989. The purpose of the Notice is to ensure that Barwon Water successfully remediates impacts caused by historic groundwater extraction. The section 78 Notice directs Barwon Water to undertake the following requirements: Discontinue extraction, other than for maintenance and emergency response purposes while the assessment is being completed and until all remediation work required under the remediation plan has been completed, and Prepare and implement a remediation and environmental protection plan for Boundary Creek, Big Swamp and the surrounding environment. To facilitate these requirements, the Section 78 notice also required: Submission of a scope of works for developing the Remediation Plan by December 2018; Submission of the Remediation Plan by 20 December 2019; and Implementation of the Remediation Plan by 01 March 2020
December 2018	Scope of works submitted Barwon Water submitted the scope of works which outlined the area covered by the Plan, the environmental values to be included, and the necessary environmental assessments and methodology for how Barwon Water proposed to develop the Plan.
February 2019	Southern Rural Water feedback on scope of works received In early 2019, Southern Rural Water and its Independent Technical Reference Panel reviewed the 'scope of works'. Feedback included: The use of a risk assessment framework to identify and confirm areas for remediation; Broadening out the geographical extent beyond the Boundary Creek catchment; and Broadening the ecological values beyond the emphasis on acid sulfate soils to address all beneficial uses under the State Environmental Protection Policy (Victorian Waters). Data collected will be seasonally variable and vary between years depending on climatic conditions and therefore the setting of indicators and measures of success will be dependent on the periods and seasonality of monitoring Feedback was also received from the Remediation Working Group and their nominated expert panel and was consistent with what was provided from Southern Rural Water.
March 2019	Field program and environmental assessments commenced With approval from Southern Rural Water and support from the Remediation Working Group, Barwon Water initiated: A field program and site-specific environmental assessments to inform the development of the REPP, and

Time	Event
	Completion of additional monitoring as described in the scope of works to improve the conceptual understanding of current system conditions.
April 2019	Community information sessions held Community information sessions were held at Winchelsea, Birregurra and Colac to provide an update on the Remediation Plan to the broader community. Around forty people attended the information sessions with discussion centering on the process for developing the remediation plan, investigating whether there have been impacts in other areas and plans to secure future water supplies.
April 2019	Soil testing and analysis A specialist consultant was engaged to undertake static and kinetic (incubation) testing on the soils/sediments to assess the dominant hydro-geochemical processes occurring within the swamp and how theses might respond to changing hydro-geochemical conditions. Static testing was complete and five soil types were categorized, including: burned, unburned, wet and dry sediment. These soil types underwent further analysis using standard methods according to the national acid sulfate soils identification and laboratory methods manual (Sullivan et al., 2018). Results of the static testing informed the incubation testing by ensuring that the soils used in the incubation tests were representative of Big Swamp. Incubation test samples were sacrificed in a times series of 1, 2, 4, 8, 16, 32, 64, 128 and 200 days to determine if neutralisation of actual and potential acidity is viable via different treatment methods (Cook & Wong, 2020).
July 2019	Revised scope of works submitted Barwon Water submitted a revised scope of works on 31 July 2019 that addressed all feedback received from Southern Rural Water and its Independent Technical Review Panel, as well as the Remediation Working Group and their nominated experts.
October 2019	Southern Rural Water feedback on revised scope of works received After review, Southern Rural Water and its Independent Technical Review Panel considered the scope of works complete conditional to addressing recommendations and feedback through the submission of the Remediation Plan.
October 2019	Community information sessions held Community information sessions were held at Winchelsea and Colac to provide another update on the Remediation Plan to the broader community. Fifteen people attended the information sessions with focus on what would be included in the Remediation Plan and how the field program and environmental assessments were progressing.
February 2020	Southern Rural Water acceptance of the revised REPP Following review of the REPP, Southern Rural Water and its Independent Technical Review Panel (ITRP) accepted the REPP based on the inclusion of a feedback register to inform future amendments.
July 2020	Feedback work plan and governance framework submission & acceptance The feedback work plan outlines the plan for addressing feedback on the REPP. The governance framework outlines the framework to be enacted during implementation of the REPP.

Time	Event
January 2021	Completion of groundwater-surface water modelling The groundwater-surface water model aimed at quantifying the potential effectiveness of different flow regimes and barrier configurations on maintaining saturated conditions within Big Swamp to prevent further oxidation of acid sulfate soils.
July 2021	Completion of technical works to inform remedial actions Following completion of the groundwater-surface water modelling, Barwon Water engaged Jacobs to revise the conceptual site model, assess the potential ecological risks to the Barwon River and assess potential contingency measures.
July 2021	Design of hydraulic barriers and downstream contingency measures The outcomes of the technical works were then used to inform the design of the proposed hydraulic barriers and pH adjustment – flow plant (PAF) to maintain saturation within the swamp and manage the discharge of metals and acidity to the lower reaches of Boundary Creek and the Barwon River.
October 2021	Development of a program outline for upstream treatment trial investigations Following feedback from Southern Rural Water and the ITRP that recommended further investigation of a novel upstream treatment system, Barwon Water developed a program outline to guide these investigations.
November 2021	Receipt of ITRP feedback on technical works and design of hydraulic barriers and downstream contingency measures Following review of the technical and design reports, the Independent Technical Review Panel (ITRP) provided feedback identifying key issues of concern that will need to be addressed prior to Southern Rural Water's acceptance of the proposed design.
January 2022	Upstream treatment trial plan submission Following community and stakeholder engagement, Barwon Water provided a trial plan detailing the proposed approach and methodology in conducting a small-scale field trial of the proposed novel treatment method.
February 2022	Receipt of Southern Rural Water and ITRP feedback on the upstream treatment trial plan Following review of the upstream treatment trial plan, the ITRP provided feedback identifying key issues of concern that would need to be considered as the upstream treatment investigation progresses.
June 2022	Submission of the upstream treatment investigation Following further community and stakeholder engagement, the receipt of feedback on the upstream treatment trial plan and the completion of the upstream treatment laboratory trials, Barwon Water summarised the outcomes and implications of this work on contingency planning measures.
August 2022	Receipt of Southern Rural Water and ITRP feedback on the outcomes and implications of the upstream treatment investigation Following receipt of Southern Rural Water and ITRP feedback, this report was amended and re-issued in November 2022.
December 2022	Submission of the interim revised draft REPP to Southern Rural Water for review and comment

Time	Event

	Following completion of the upstream treatment investigation, the REPP was updated pending the outcomes of the Ecological Risk Assessment and Paleoenvironmental Study to:
	- Take into consideration the feedback received from Southern Rural Water and the Independent Technical Review Panel
	- Account for the additional knowledge and understanding that has been gained since the implementation of the REPP began in March 2020
	- Account for the outcomes of workshops held with the Remediation Reference Group (RRG) on 8 June 2022 and 16 December 2022 that were conducted to:
	    o Check in on vision, objectives and actions outlined in the Remediation Plan;
	    o Discuss the proposed changes to the Remediation Plan and incorporation of previous community and stakeholder feedback, and
	    o Understand the current community sentiment.
	- Simplify and streamline the REPP document as requested by Southern Rural Water whilst still meeting the requirements of the Section 78 Notice
	This provided an opportunity to obtain additional feedback from Southern Rural Water prior to formal submission of the revised REPP.

July 2023	Submission of the following documents to Southern Rural Water for review and acceptance: - Revised REPP - Surrounding Environment Investigation Report, and - Boundary Creek Mobile Downstream Treatment Contingency Measure This also included submission of the Ecological Risk Assessment and Paleoenvironmental Study that underpinned this work.

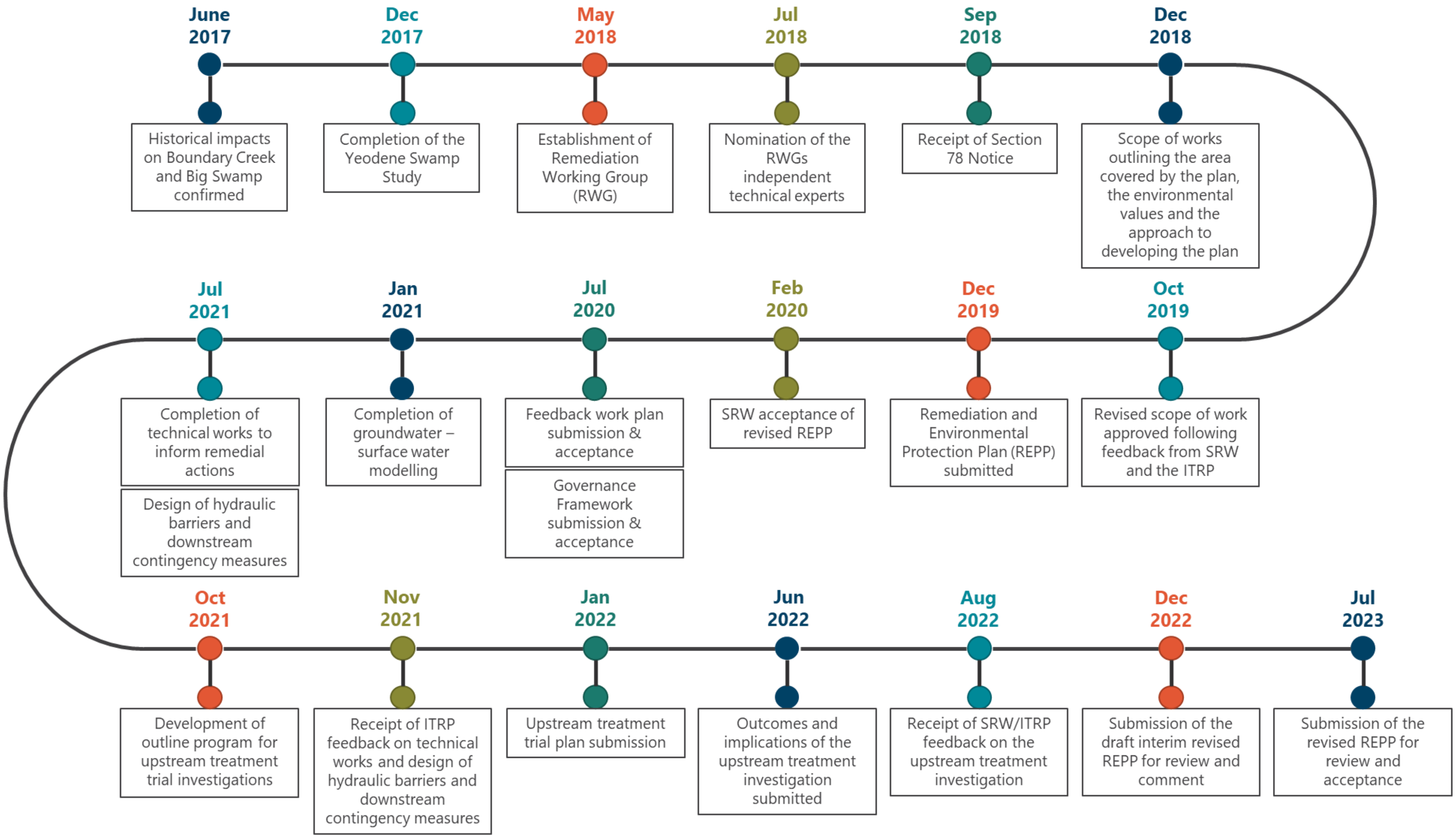

Figure 4 Summary of the REPP development timeline

A4 Boundary Creek and Big Swamp Remediation Plan

A4.1 Overview

Boundary Creek is approximately 19 kilometers long and flows from Barongarook to Yeodene where it joins the Barwon River, approximately 16 kilometers south-east of Colac. The Boundary Creek catchment has been heavily modified from its original condition with historic land clearing, drainage and realignment, and surface water / groundwater harvesting activities changing the hydrology and hydrogeology of the system. The hydrology of Boundary Creek has also been impacted by the construction of a 160ML private on-stream dam, that controls the surface water flows into the lower reaches of Boundary Creek.

Big Swamp (also known as Yeodene Swamp) is a wetland located adjacent to the lower reaches of Boundary Creek, approximately 4 kilometers upstream from the confluence of Boundary Creek and the Barwon River. Big Swamp contains naturally occurring acid sulfate soils that have, in part, been oxidised due to the changes that have occurred within the Boundary Creek catchment, resulting in the discharge of acidity and metals to the lower reaches of Boundary Creek and the Barwon River. While this would have occurred to some degree under natural conditions, groundwater pumping really exacerbated a pre-existing issue, making the issue more severe.

The Boundary Creek and Big Swamp Remediation Plan focuses on remediating the 'confirmed areas of impact' within the Boundary Creek catchment. That is, where the historical management of groundwater pumping activities resulted in material harm to the environment. Noting that this does not aim to address the factors beyond Barwon Water's control and that these will continue to have significant implications on both the remediation efforts and the future resilience of the system.

Based on the works completed to date, the 'confirmed areas of impact' include Reach 2a, 2b, 2c and Reach 3 of Boundary Creek. Despite the primary impacts being realised within Reach 2c and Reach 3 (refer Figure 5).

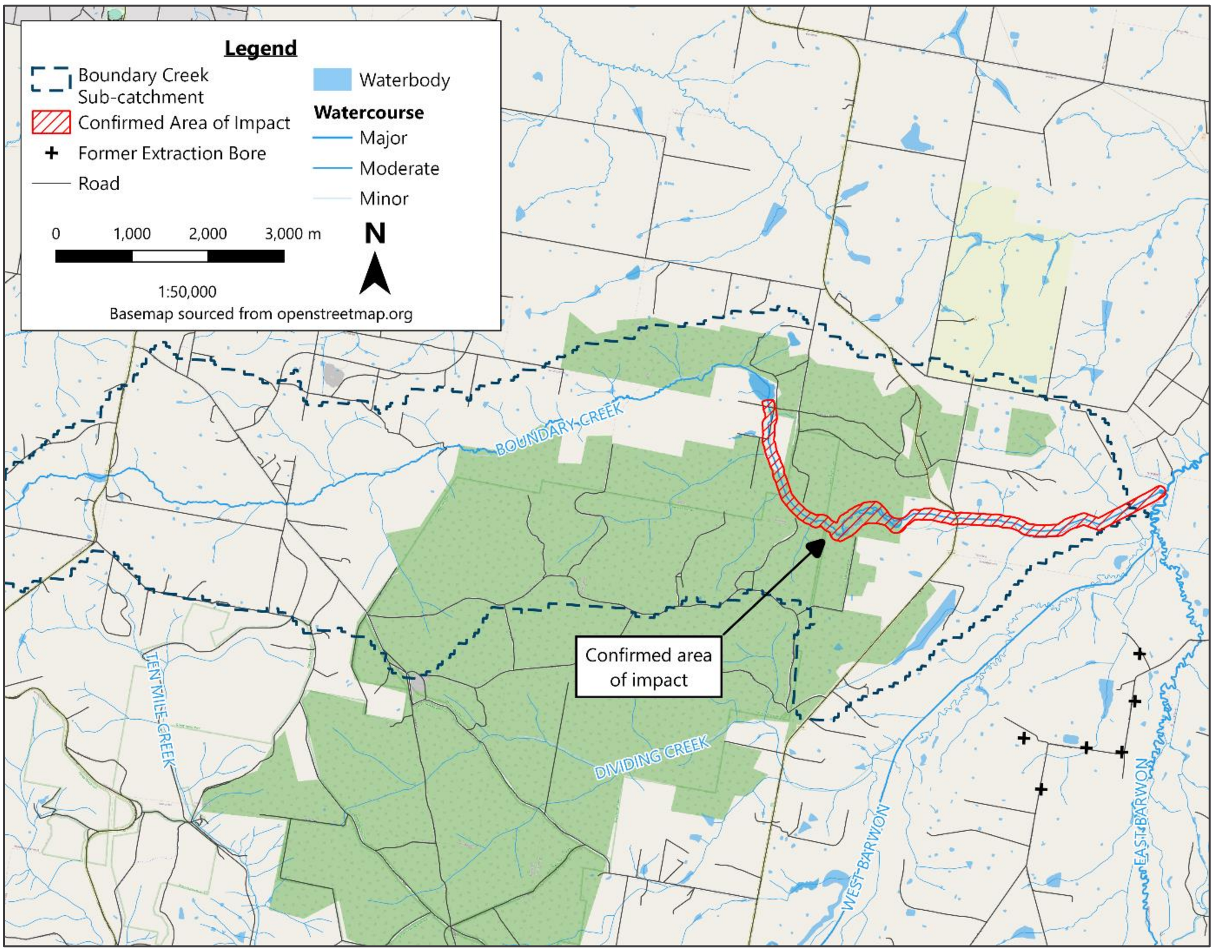

Figure 5 Confirmed areas of impact within the Boundary Creek catchment

A4.2 Why is remediation necessary?

Although many factors (as shown in Figure 6) have contributed to the environmentally significant impacts that have been identified within Reach 2 and Reach 3 of Boundary Creek and Big Swamp, technical works completed to date have identified that Barwon Water's groundwater pumping activities exacerbated these impacts, subsequently resulting in an:

- Increase in the severity of wet – dry cycling and the mobilisation of acidity and metals;
- Increased occurrence of 'cease to flow' and 'acid flush' events;
- Loss of wetland species & stream ecology, and
- Change / loss of soil structure and/or properties.

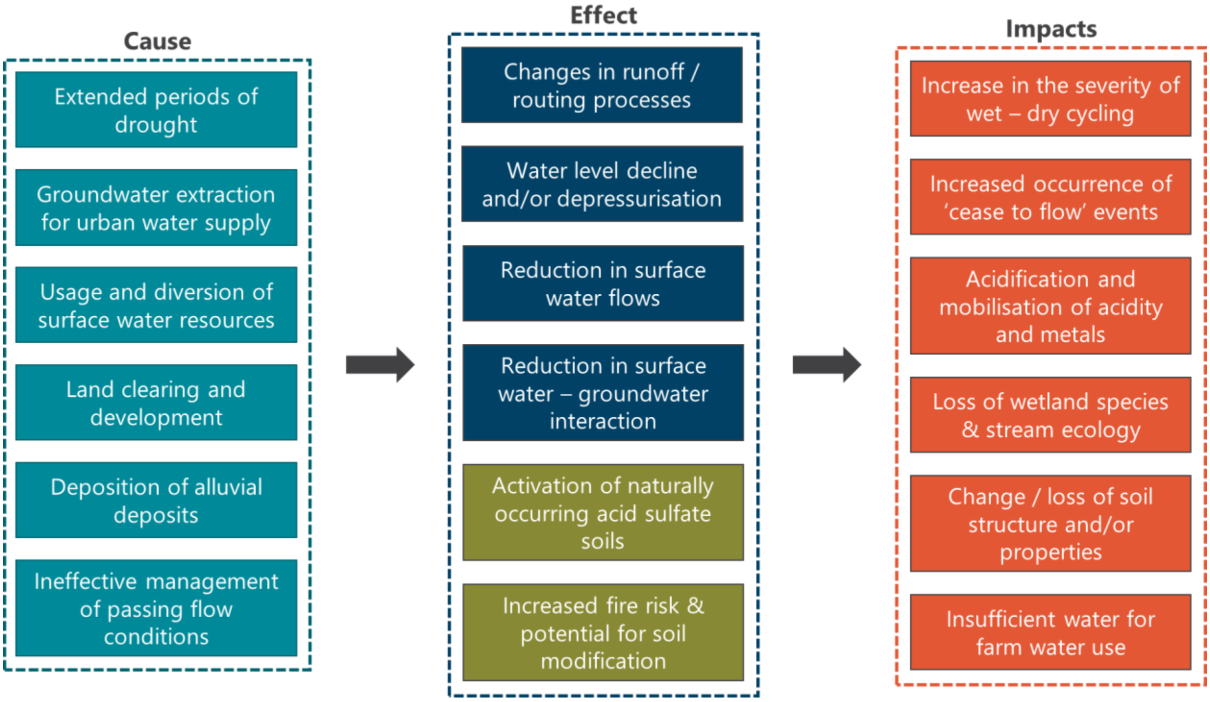

Figure 6 Cause, effect and impact relationships in the Boundary Creek catchment

In line with the section 78 notice, the Boundary Creek and Big Swamp Remediation Plan only addresses the impacts that can be linked to Barwon Water's groundwater pumping activities and does not aim to address the factors beyond Barwon Water's control. These will continue to have significant implications on both the remediation efforts and the future resilience of the system.

A conceptual schematic outlining the key effects and impacts are presented in Figure 7.

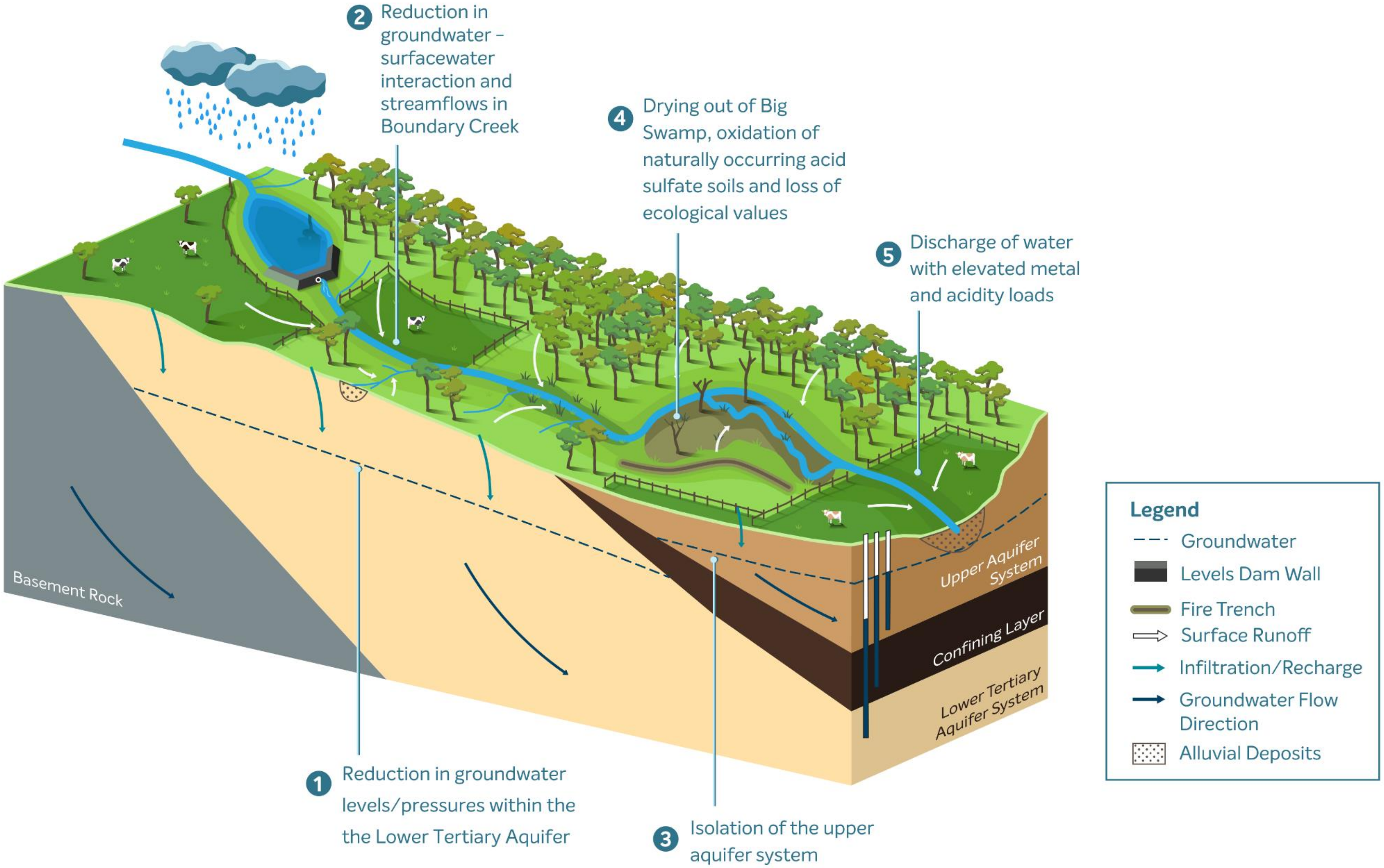

Figure 7 Conceptual schematic of the Boundary Creek catchment under worst case conditions

A4.3 Vision for remediation of Boundary Creek and Big Swamp

Implementation of a practical risk-based remediation strategy that outlines the specific controls and actions that have and will be implemented to:

- **Ensure** no further harm from Barwon Water's historic groundwater pumping or remediation actions;
- **Protect** the water quality and ecological values of the Barwon River;
- **Improve** the water quality and streamflows within Boundary Creek, and
- **Improve** the ecological values of Big Swamp.

A4.4 Objectives for remediation

To assist in realising the project vision, the following remedial objectives have been developed in collaboration with the community and stakeholder working group:

1. Facilitate groundwater level recovery and enable groundwater-surface water interaction to return.
2. Reduce the severity of wet-dry cycling processes and the occurrence of 'acid flush' events in Boundary Creek.
3. Control/manage the risks associated with the oxidation of naturally occurring acid sulfate soils.
4. Preserve/improve the ecological values of Big Swamp and Boundary Creek, and
5. Reduce the fire risk in Big Swamp.

A4.5 Remedial actions for Boundary Creek and Big Swamp

Following a comprehensive review of the remediation options, as outlined in section A8B6, the following remedial actions have been adopted (Table 4), noting that in accordance with the adaptive management approach, these will continue to be informed by the ongoing environmental monitoring activities.

Table 4 Overview and status of adopted remedial actions

Remedial Action	Purpose	Relevant Objectives	Priority	Progress
Cessation of groundwater pumping activities	Allow groundwater levels in the Lower Tertiary Aquifer (LTA) and Upper Aquifer system to recover and enable groundwater-surface water interaction to return	1,2,3,4,5	Short term	Complete and ongoing
Decommissioning of the Barwon Downs extraction bores		1,2,3,4,5	Mid-longer term	Preparations underway

Remedial Action	Purpose	Relevant Objectives	Priority	Progress
Provision of supplementary flows, where required, to maintain flows of at least 0.2 ML/day at the Boundary Creek at Yeodene stream gauge (site 233228)	Minimise wet-dry cycling and the occurrence of cease to flow events, maintain saturation of acid sulfate soils, minimise fire risks and provide suitable conditions for wetland species to recolonise impacted areas. 0.2 ML/day has been set to clearly indicate that flow has been maintained and account for the accuracy limitations (+/- 0.1 ML) of the stream gauge infrastructure at very low flows. As such flows less than 0.1 ML/day are considered to indicate a potential cease to flow event.	1,2,3,4,5	Short term	Complete and ongoing
Prevent the encroachment of dry vegetation classes	Provide suitable conditions for wetland species to recolonise disturbed areas.	4,5	Mid-longer term	Ongoing
Development of risk-based contingency measures to be implemented in the unlikely event that they are required	To minimise the potential for high-risk events, should these persist following the implementation of the primary remedial actions	2,3,4,5	Mid-longer term	In progress

Note:
The water (untreated water) for supplementary flows is sourced from the Colac or Barwon water supply system in accordance with the conditions and limits stipulated in Barwon Water's existing Bulk Entitlements for the Colac and Upper Barwon systems.

A4.6 What does success look like for remediation of Boundary Creek and Big Swamp?

To determine progress against the remedial objectives, a number of success targets, as outlined in Table 5, have been developed in consultation with the Remediation Reference Group and their nominated technical experts. Noting that these have and will continue to be informed by the ongoing monitoring and data collection activities, and the outcomes of various technical works in line with the adaptive management approach.

The success targets have been developed using S.M.A.R.T principles and reflect the point at which further intervention by Barwon Water is no longer practicable or the potential benefits of additional actions do not outweigh the risks. This acknowledges that the natural recovery processes that we are trying to facilitate may take a much longer timeframe (i.e., 10 years or more) and may be impacted by factors beyond Barwon Water's control. This is particularly relevant with respect to the naturally occurring acid sulfate soils that pre-date Barwon Water's activities and have led to acidic conditions prevailing at Big Swamp, to some degree, since the early to mid-Holocene (La Trobe University, 2023).

The success targets also acknowledge the acid sulfate soil hierarchy of controls, published by EPA Victoria, that focus on avoiding/minimising disturbance and/or preventing oxidation over treatment and/or disposal options that may result in material harm to the environment in the absence of other complicating factors.

Consistent with S.M.A.R.T principles, it is important that the success targets are set at a level that is achievable by the controls and actions being implemented and should not be reliant or impacted by factors beyond Barwon Water's control.

While no timelines have been provided as to when these success targets are likely to be achieved due to the number of variables at play, the time-bound element of these success targets aims to ensure that success is not short-lived. Hence this requires the targets to be met for two-consecutive years. Noting that this takes some seasonal variation into account, without attempting to control climatic factors beyond Barwon Water's control. Further justification around each individual target is provided in Table 5 below.

It is noted that when all the success targets have been achieved concurrently, remediation is considered to have been completed and the requirements of the section 78 notice satisfied.

In relation to the specific groundwater level targets, as outlined in Table 6 below, these have been developed based on:

- The historic groundwater level data, topography and connection with Boundary Creek, and
- The reactivity (as indicated by the potential acidity) of the acid sulfate soils within Big Swamp.

Noting that there is still some uncertainty as to whether these can be achieved due to the non-pumping related changes and ongoing stressors that have also occurred within the catchment and may impact on the ability of the system to recover. Similarly, while future climate is an important consideration, these targets do not aim to protect against natural wet-dry cycling processes that are forecast to become more severe in a drier climate. These need to be considered in conjunction with the resource manager and relevant agencies and are beyond the scope of the remediation plan, that aims to address historic groundwater pumping related impacts.

Table 5 Success targets for remediation of Boundary Creek and Big swamp

Remedial Objective	Success Target	Justification	Measurement
Facilitate groundwater level recovery and enable groundwater-surface water interaction to return	Maintain groundwater levels at the levels outlined in Table 6 for a period of 2 consecutive years (Note: targets have been set for both the Lower Tertiary Aquifer and Upper Aquifer systems)	The groundwater levels provided in Table 6 have been set to: 1. Enable the return of groundwater-surface water interaction along Boundary Creek, and 2. Maintain soil moisture within Big Swamp to minimise any further oxidation of acid sulfate soils and fire risks.	Groundwater levels / elevations from routine environmental monitoring works
Reduce the fire risk in Big Swamp			
Reduce the severity of wet-dry cycling processes and the occurrence of 'acid flush' events in Boundary Creek	Supplementary flows have not been required for a period of 2 consecutive years to mitigate against prolonged cease to flow events, where a prolonged cease to flow event is defined as more than 14 days with flow less than 0.1 ML/day at the Boundary Creek at Yeodene stream gauge (site 233228)	Flows less than 0.1 ML/day are within the accuracy limitations of the stream gauge infrastructure and hence, are considered to indicate a potential cease to flow event. Cease to flow events can occur in response to a range of stressors, however the potential for acid flush events increases following a prolonged period of flow cessation. As such, this target aims to minimise the occurrence of prolonged cease to flow events that occurred in Boundary Creek as a result of historical groundwater pumping, and subsequently reduce the severity of wet-dry cycling processes and the occurrence of 'acid flush' events in Boundary Creek.	Telemetered flow measurements (ML/day)

Remedial Objective	Success Target	Justification	Measurement
		The step change decline in pH observed in 1999 at the Boundary Creek at Yeodene stream gauge (site 233228) occurred following a cease to flow event of 30 days. Prior to this, the longest cease to flow event recorded at the Boundary Creek at Yeodene stream gauge (site 233228) was 14 days in 1990. As such, cease to flow periods of up to 14 days are not considered to increase the risk of severe 'acid flush' events or long-term change in pH. This also acknowledges that climate and other catchment scale stressors will continue to impact on the wet-dry cycling processes and could result in the occurrence of cease to flow events post groundwater level recovery in the LTA.	
Control/manage oxidation of naturally occurring acid sulfate soils	Annual pH levels – as indicated by the 25th and 75th percentiles, recorded at the Boundary Creek at Yeodene stream gauge (site 233228) maintained between 5 and 9 pH units for a period of 2 consecutive years*	The Paleoenvironmental study has revealed that species consistent with acidic conditions have been present within Big Swamp historically. This is consistent with the Ecological Risk Assessment that has indicated that these would have existed under pre-pumping conditions due to a range of stressors beyond Barwon Water's control. As such, this target has been set to facilitate the return of desired species and mitigate against potential 'acid flush' events, where pH <5 can result in impacts to aquatic flora and fauna.	Telemetered and spot sampling data

Remedial Objective	Success Target	Justification	Measurement
Preserve/improve the ecological values of Big Swamp and Boundary Creek	The inundation areas within Big Swamp have or have the potential to develop aquatic flora and fauna. This success target applies until the other success targets have been met	The initial vegetation targets were not accepted by SRW and have been revised based on the Paleoenvironmental Study, Ecological Risk Assessment and vegetation monitoring work that indicate the ecological values have and will continue to be impacted by factors beyond Barwon Water's control. Because of this, changes in flora and fauna communities are difficult to attribute to an individual stressor and will continue to adapt to the changing conditions. As such, this target has been set to preserve the wetland areas and facilitate natural recovery processes.	Routine vegetation and macro-invertebrate monitoring

Table 6 Groundwater level targets

Formation	Bore ID	Surface Elevation (m AHD)	Stickup (m)	Top of Casing Elevation (m AHD)	Groundwater Level Target (m bgl)	Groundwater Level Target (m AHD)
Upper Aquifer System	BSBH01	141.86	0.6	142.46	0.7	141.2
	BSBH02	141.75	1.16	142.91	1.2	140.6
	BSBH03	141.74	1.20	142.94	1.6	140.1
	BSBH04	143.36	0.82	144.18	0.6	142.8
	BSBH05	143.08	0.80	143.88	1.0	142.1
	BSBH06	142.90	0.68	143.58	1.0	141.9
	BSBH07	142.49	0.56	143.05	0.4	142.1
	BSBH08	144.62	0.67	145.29	0.4	144.2
	BSBH09	144.36	0.68	145.04	1.5	142.9
	BSBH10	144.32	0.68	145.00	2.0	142.3
	BSBH11	147.09	0.63	147.72	1.5	145.6
	BSBH12	147.20	0.71	147.91	1.2	146.0
	BSBH14	147.66	0.64	148.30	0.3	147.4
	BSBH15	147.42	0.66	148.08	0.3	147.1
	BSBH16	147.98	0.82	148.80	N/A	N/A
	BSBH17	148.11	0.66	148.77	N/A	N/A
	BSBH18	148.72	0.85	149.57	0.3	148.4
Lower Tertiary Aquifer (LTA) System	BSBH13LTA	147.39	0.66	148.046	0.0	147.4
	BSTB1C	144.06	0.78	144.84	0.0	144.1
	YEO19 (109110)	176.56	0.91	177.47	N/A	155.0
	YEO20R (109111)	173.38	0.76	174.14	N/A	155.0
	YEO22 (109113)	179.62	0.61	180.23	N/A	150.0
	YEO37 (109128)	160.43	1.55	161.98	N/A	155.0
	YEO39 (109130)	163.81	1.58	165.39	N/A	160.0
	YEO41 (109132)	208.07	0.07	208.14	N/A	155.0

A conceptualisation of what success remediation looks like is presented in Figure 8.

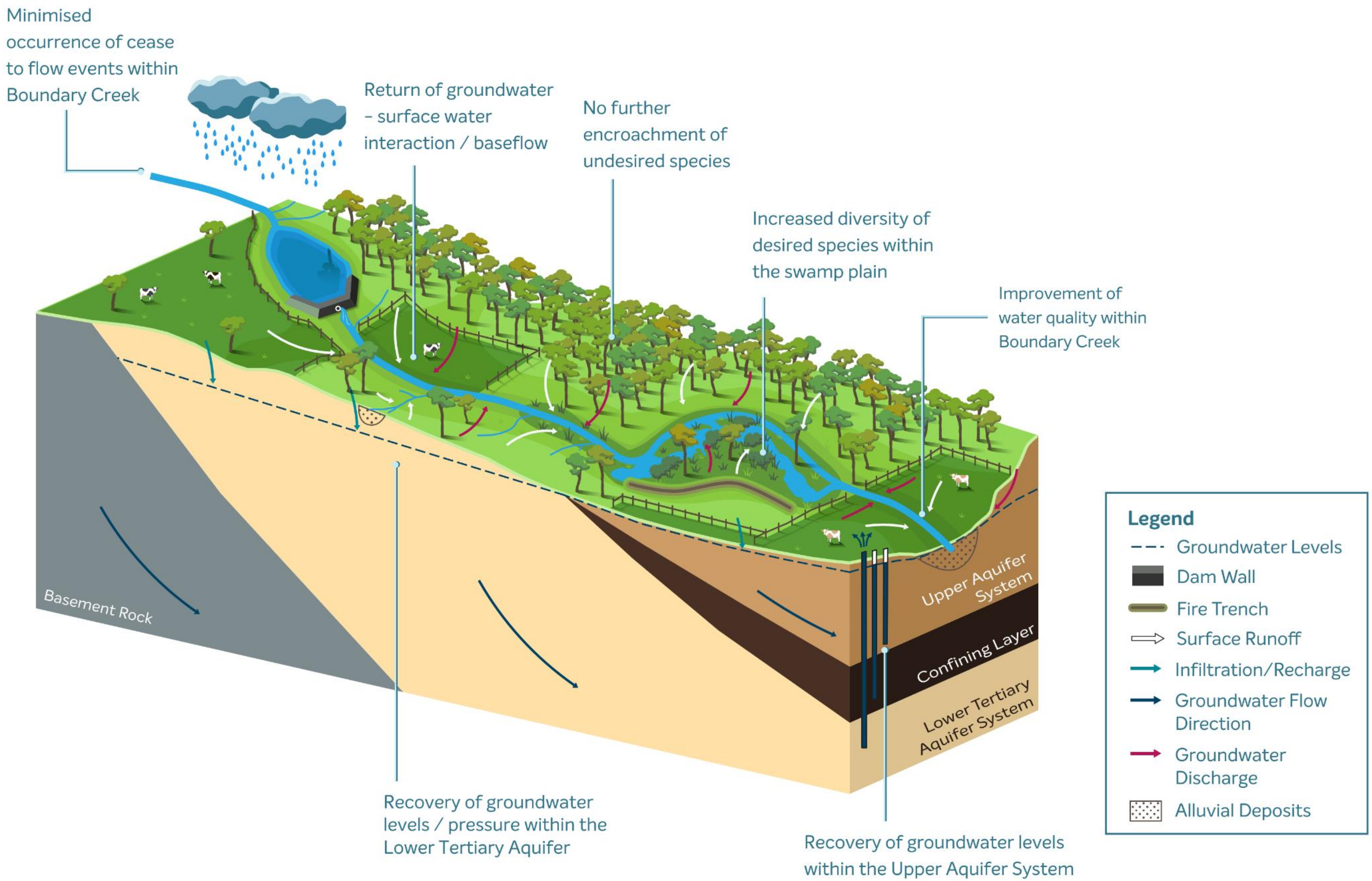

Figure 8 Conceptual schematic of what successful remediation looks like

A4.7 Progress against the remediation success targets

The remediation actions that have been undertaken as part of the REPP to facilitate the natural recovery process to date, have resulted in the following:

- Ongoing recovery of the Lower Tertiary Aquifer, with groundwater levels in the central portions of the aquifer nearing pre-pumping levels;
- Recovery and maintenance of soil moisture within Big Swamp's upper aquifer system and subsequent decrease in the severity of wet-dry cycling processes and the potential for acid flush / fish kill events in the Barwon River;
- Improvements in the water quality within the lower reaches of Boundary Creek and Big Swamp compared to worst case conditions. Noting that these have and will continue to be impacted by the naturally occurring acid sulfate soils into the future;
- Improvements in the ability for Barwon Water to ensure that our supplementary flows are passed through the private on-stream dam, and
- Continued recolonisation of the wetland with desired species since the 2010 fires and ongoing stabilisation of these species towards a 'new normal'.

A4.8 Environmental monitoring

An adaptive approach to remediation is considered best practice, whereby the Remediation Plan can be adapted in response to ongoing data collection activities and measured changes. This approach allows Barwon Water to evaluate how systems are responding to interventions and take further action, such as implementation of contingency measures, in the unlikely event they are required.

Fundamental to an adaptive management approach is establishing an effective monitoring and assessment program to enable ongoing assessment of:

- Compliance against the requirements set out in the s78 notice;
- Progress towards meeting the vision, objectives and success targets;
- Any unforeseen changes in environmental conditions, and
- Any unexpected high-risk conditions that require immediate management via the implementation of a contingency measure.

The data obtained from these works will be used to inform the Quarterly Updates and the Annual Report, that will outline any changes required to the Remediation Plan based on this data. In addition to this, the data collected as part of these works will be used to:

- Refine, update and calibrate models and/or the conceptual understanding;
- Determine if and when additional remedial actions and/or contingency measures are required;
- Evaluate the effectiveness of remedial actions, and/or
- Determine the need or otherwise for the implementation of contingency measures.

The environmental monitoring program for the Boundary Creek and Big Swamp Remediation Plan is provided in Appendix A. It is envisioned that this will be updated on an annual basis, as required, as part of the annual reporting process. This will include consideration for the need for further monitoring assets and/or investigation works, or refinement of the existing monitoring program.

A4.9 Contingency measures

While the remedial actions focus on addressing the environmentally significant adverse impacts resulting from the historical management of Barwon Water's groundwater pumping activities at the Barwon Downs borefield, the development of contingency measures focuses on minimising the potential for high-risk events, should these persist following the implementation of the primary remedial actions. As such, these are last resort controls and in line with feedback provided by the Remediation Reference Group should only be implemented if the benefits outweigh the risks associated with more intrusive actions. Noting that the remediation actions may take time for improvements to be realised. As such, contingency measures are designed to support the primary remedial actions and focus on managing the short-term, rather than long-term risks.

Based on the identified risks (refer to section B8), the following risk-based contingency approach (Table 7) has been developed in collaboration with the community and stakeholder working group and their nominated experts. Noting that in all cases, additional approvals in addition to those from Southern Rural Water (e.g., CCMA, Colac Otway Shire, EMAC and EPA Victoria) may be required prior to these being implemented on the ground. Once approved by Southern Rural Water, the timeline for obtaining these additional approvals is likely to range between 6 and 12 months, depending on the complexity of the contingency measure.

Table 7 also outlines the trigger(s) for the implementation of specific contingency measures. Where appropriate, multiple and/or tiered triggers have been developed to ensure the management actions are commensurate with the risks and, where possible, avoid further harm to the environment.

As a minimum, the implementation of contingency measures will be assessed as part of the annual reporting process, with routine reviews of monitoring data and SCADA/telemetry alarms used, where possible, to prompt the need for a detailed assessment of conditions.

Table 7 Risk-based contingency approach

Contingency approach	Contingency measure	Trigger(s)	Justification
Minimise the potential for acid-related fish kill events in the Barwon River	Mobile downstream treatment system (pending revised design)	**Planning Trigger**: Streamflows at gauge site 233228 are less than 0.1 ML/day for greater than 6 weeks → staff notified to verify flows, conduct pre-operational checks and liaise with chemical supplier. **Mobilisation Trigger**: Streamflows at gauge site 233228 have been less than 0.1 ML/day for greater than 3 months, **and** greater than 40mm rainfall is forecast within 5 days **or** streamflows at gauge site 233228 have since increased above 0.5 ML/day. **Dosing Trigger**: pH readings less than 5 at gauge sites 233276 **and** less than 4 at gauge site 233228 are confirmed via field readings **and** Boundary Creek is contributing greater than 35% of flows into the Barwon River (based on flow measurements from gauge sites 233228 and 233233). **Cease Treatment Trigger**: pH readings upstream of the dosing plant are greater than 5 or Boundary Creek is contributing less than 35% of flows into the Barwon River.	Hydrogeochemical modelling work (Jacobs, 2021) indicates that the potential for fish kill events in the Barwon River occurs during first flush events: a. Following an extended period of flow cessation in Boundary Creek (>4 months) when acidity and metals have accumulated in the unsaturated zone, **and** b. When flows from Boundary Creek represent >40% of those in the Barwon River. Outside these times, the potential for fish kill events is low.
Reduce the severity of wet-dry cycling processes	**Tier 1**: Water diversion barriers (e.g., straw bales or similar)	Water levels within Big Swamps upper aquifer system cannot be sustained in an average rainfall year (when rainfall is at or above the median).	Boundary Creek is a highly modified ecosystem. Many of these modifications pre-date Barwon Water's groundwater pumping activities and have changed the

Contingency approach	Contingency measure	Trigger(s)	Justification
	Tier 2: Adjustment of existing drainage lines / channels	Water levels within Big Swamps upper aquifer system cannot be sustained during a wet year (when rainfall is above the median).	hydrology of the system. These factors continue to provide a barrier to the remedial works and continue to impact the future resilience of the system. As such, this action focusses on distributing flows more effectively, rather than implementing intrusive actions to re-engineer the hydrology of Big Swamp.
Improve the condition and function of Big Swamp	**Tier 1**: Removal of dry vegetation classes and/or undesired species from the swamp plain	Water level targets have been met, but vegetation monitoring indicates that undesired species are providing a barrier to achieving improved environmental outcomes within Big Swamp.	In line with the s78 notice, Barwon Water's actions and controls aim to achieve improved environmental outcomes – not to return the swamp to a previous state. As such, addition actions will only be undertaken if these are providing a barrier to achieving improved environmental outcomes. This acknowledges that minimising further impacts is the key and that even with these actions the ecological communities may not respond as intended.
	Tier 2: Revegetation of areas with low species diversity with desired species (mesic specialist lifeforms)	Water level targets have been met, but vegetation monitoring indicates that despite the presence of suitable conditions, desired species are unable to naturally recolonize the swamp plain.	

A5 Surrounding Environment Investigation

A5.1 Overview

The Surrounding Environment Investigation considers the whole extent of the Lower Tertiary Aquifer (480 km^2) and aims to determine whether the historical management of Barwon Water's groundwater pumping activities resulted in any other unintended environmentally significant adverse impacts within the broader environment, in addition to those already confirmed within Big Swamp and the lower reaches of Boundary Creek. Should environmentally significant adverse impacts be identified, additional remedial actions will be considered to address these impacts. Noting that Barwon Water have already committed to decommissioning the Barwon Down borefield extraction bores to ensure no further extraction of groundwater from the Barwon Downs Borefield. This action will have positive impacts on the entire aquifer system by ensuring that the natural recovery processes that are already occurring within the broader environment continue.

As a starting point, the regional groundwater model was used to identify the areas where groundwater pumping activities within the Lower Tertiary Aquifer may result in impacts to surface water features based on a systematic risk assessment framework (Jacobs, 2019d). This work was also used to determine where further investigation(s) was required to fill the identified data gaps and provide sufficient data to 'ground truth' the findings of the systematic risk assessment.

The outcomes of this work identified the following eight areas outside of the Boundary Creek catchment, where further monitoring and/or investigation was required, as shown in Figure 9, to better inform the impact assessment:

- Barwon River (East branch);
- Barwon River (West branch);
- Barwon River (downstream of the confluence with Boundary Creek);
- Gellibrand River and associated groundwater dependent ecosystems;
- Ten Mile Creek;
- Yahoo Creek;
- Groundwater dependent ecosystems west of the Barwon River (near Yeodene), and
- Groundwater dependent ecosystems east of the Barwon River (between Barwon Downs and Yeodene).

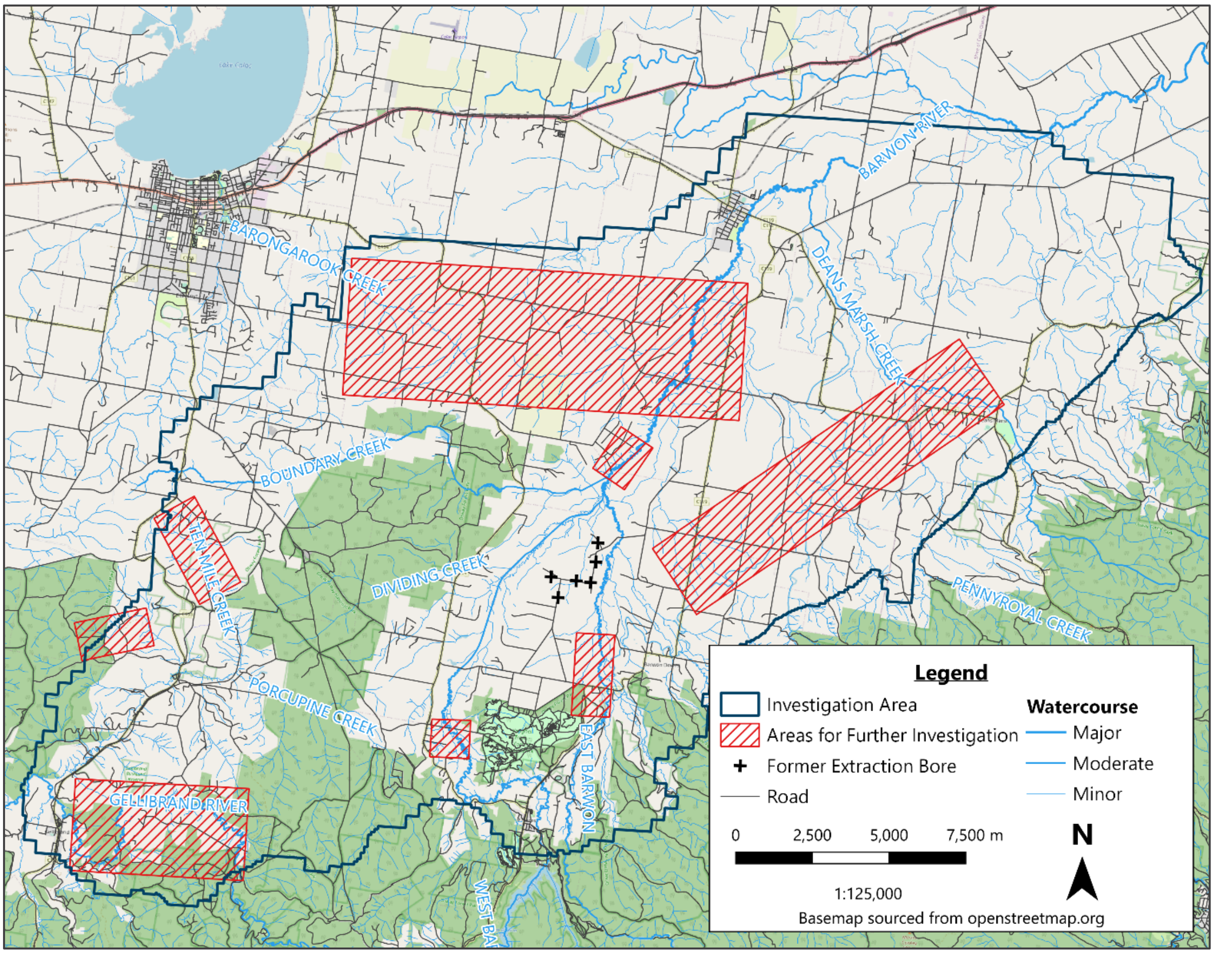

Figure 9 Areas identified for further investigation

A5.2 Scope of the Surrounding Environment Investigation

The Surrounding Environment Investigation process, as outlined in Figure 10, was develop to:

- Test the underlying assumptions of the regional groundwater model that was used to conduct the systematic risk assessment;
- 'Ground truth' the findings of the model to confirm or otherwise potential groundwater pumping related impacts, and
- Determine if Barwon Water's historical management of groundwater pumping activities at the Barwon Downs borefield resulted in any environmentally significant adverse impacts.

Further detail regarding the scope of the investigation is provided below.

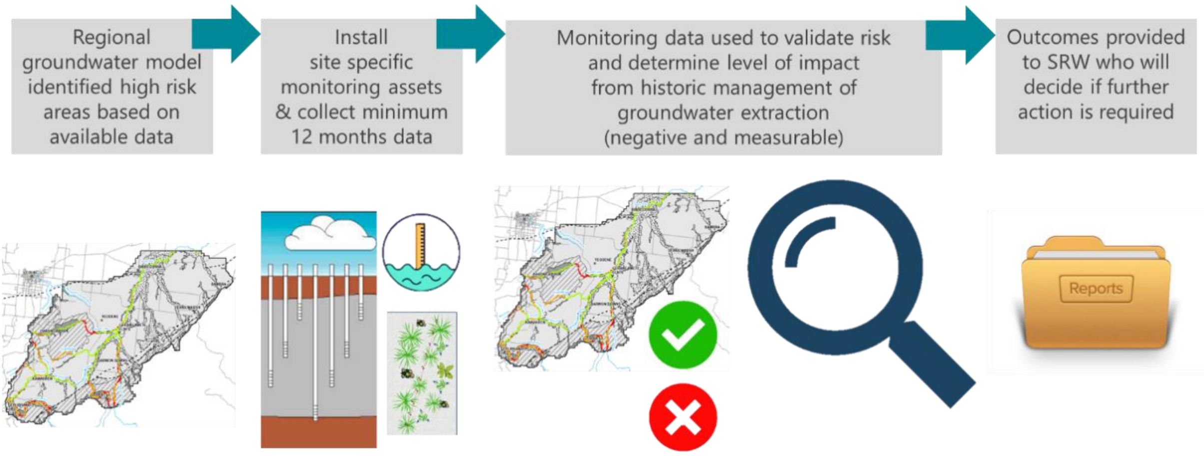

Figure 10 Process overview for the Surrounding Environment Investigation

A5.2.1 Data gathering

Acknowledging the data gaps and uncertainty in the model, the initial focus of the surrounding environment investigation was to gather sufficient data and understanding to fill these data gaps and provide sufficient data to 'ground truth' the findings of the systematic risk assessment and better inform the impact assessment. The actions undertaken to achieve this are outlined in Table 8 below.

Table 8 Summary of data gathering activities undertaken to inform the Surrounding Environment Investigation

Item	Description	Purpose	Reference Documents
1	Installation of 21 additional groundwater monitoring bores	To better understand the connectivity or otherwise between the Lower Tertiary Aquifer, overlying geological units and surface water features	Jacobs, 2022
2	Development and re-instatement of 3 existing groundwater monitoring bores		Jacobs, 2022
3	Installation of 5 additional stream gauges (noting that one was subsequently removed under landholder direction having initially been given approval for installation)		N/A
4	Completion of additional vegetation monitoring within areas where the model suggested potential impacts to groundwater dependant ecosystems, where present	To determine the presence of any groundwater dependant ecosystems within the modelled high-risk areas	Eco Logical, 2020
5	Review of potential groundwater dependant ecosystems within the Barwon Downs region to better the impact assessment process	To identify groundwater dependant ecosystems within the Barwon Downs region	Eco Logical, 2022

A5.2.2 Impact Assessment

A5.2.2.1 Phase 1 – Completion of a hydrogeological assessment

Following completion of the data gathering activities, the outcomes from this work will be used to conduct a Hydrogeological Assessment in general accordance with EPA Victoria Publication 668 of each of the modelled high-risk areas.

These will be broken down by sub-catchment, where relevant, and include:

- Review of existing reports and information;
- Desktop review of publicly available information relating to the environmental setting, geology, hydrogeology, hydrology, rainfall including community gathered and climate, groundwater dependent ecosystems and acid sulfate soils;
- Completion of a site inspection to ground truth the findings of the desktop review and interviews with knowledgeable landholders;
- Development of a conceptual site model;
- Identification of water features that are potentially susceptible to low flow impacts from grounding pumping activities within the Lower Tertiary Aquifer;
- Apportionment of likely flow impact from historic groundwater pumping activities as opposed to other factors and identification of confirmed areas of impact;
- Overview of changes and/or improvements since cessation of groundwater pumping activities, and
- Consultation with relevant stakeholders, including presenting and testing the assumptions in the conceptual site model and inclusion of feedback from the RRG nominated experts.

Refer to the Surrounding Environment Investigation Report (Barwon Water, 2023a) for the outcomes of this work.

A5.2.2.2 Phase 2 – Completion of targeted investigations, as required

Where Phase 1 works identify potential environmentally significant adverse impacts or data gaps, additional works will be undertaken to fill the data gaps and help determine whether any additional remediation actions are required.

This may include flora and fauna assessments, additional acid sulfate soil sampling and/or isotopic analysis to better constrain the connectivity or otherwise between the groundwater and surface water systems.

A5.2.2.3 Phase 3 – Completion of additional modelling, as appropriate, to suitably ascertain the potential groundwater pumping related impacts, if any

Where either Phase 1 or Phase 2 works cannot suitably ascertain the potential groundwater pumping related impacts associated with the groundwater pumping activities undertaken at the Barwon Downs borefield, the data collected and reviewed as part of these works will be used to inform further modelling work, as appropriate.

The need, or otherwise for this level of detail will be informed by the earlier phases and reflects the community and stakeholder groups preference to base this investigation on actual data rather than modelling.

A5.3 Confirming areas of impact

Should the surrounding environment investigation reveal that Barwon Water's historical management of groundwater pumping activities at the Barwon Downs borefield resulted in environmentally significant adverse impacts within the broader environment, the need for additional remedial actions will be considered.

Should additional remedial actions be practicable, a remediation plan similar to that of Boundary Creek and Big Swamp will need to be developed for the impacted areas. This will be guided by the outcomes of the surrounding environment investigation.

A5.4 Climate resilience modelling

Following completion of Phase 1 and Phase 2 of the impact assessment, as required, Barwon Water will look to either update the regional groundwater model or create a purpose-built model to track recovery and test what may happen under future climate scenarios. This will be used to:

1. Determine if recovery is enough to prevent any further degradation under future drought conditions, or
2. Determine what impacts we can expect to see under future drought conditions even in the absence of groundwater pumping activities.

A6 Timeframes for implementation

High level timeframes for implementation of the Boundary Creek, Big Swamp and Surrounding Environment - Remediation and Environmental Protection Plan are outlined in Figure 11 (over-leaf).

While the timeframes presented in Figure 11 only extend until the end of 2024, Barwon Water acknowledges that it may take a number of years to meet all of the Boundary Creek and Big Swamp remediation success targets and that the number and nature of remedial actions or contingency measures may change in response to the environmental monitoring data and any further technical works. However, this needs to be balanced with practicality as is required under the section 78 notice, along with the environmental implications, costs, risks and trade-offs associated with implementing remedial actions that may alter the condition or intrinsic value of the swamp.

Beyond implementation, regular assessment of monitoring results against the success targets and triggers for the implementation of contingency measures will continue until successful remediation has been achieved.

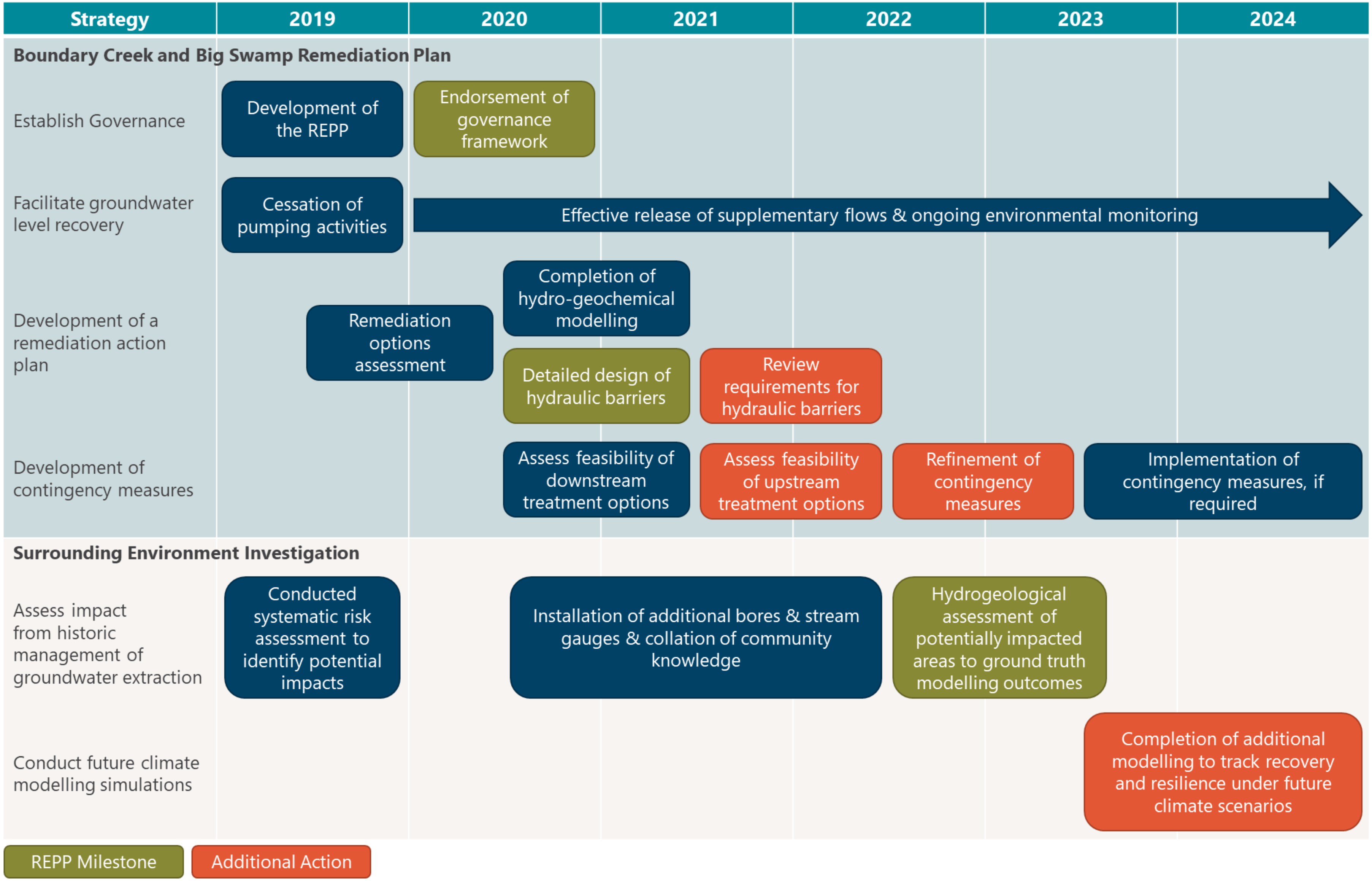

Figure 11 Timeframes for implementation of the REPP

A7 Compliance reporting and milestones

A7.1 Reporting schedule

In line with the accepted Governance Framework and s78 notice, Barwon Water will submit quarterly progress updates to Southern Rural Water throughout the duration of the REPP. These will occur in March, June, September and December of each year and be submitted to Southern Rural Water within 14 days from the end of the reporting period. It is noted that the quarterly reports do not require review and acceptance by Southern Rural Water. However, feedback can be provided to Barwon Water for inclusion in subsequent quarterly updates.

In addition to this, an annual report will be submitted at the end of September that will require review and acceptance by Southern Rural Water prior to finalisation. To facilitate this, Barwon Water will provide the draft annual report to Southern Rural Water for review and comment at least 14 days prior to the September submission date (being 30th September). As part of the annual reporting process, Barwon Water propose that any improvements made to the REPP in light of the adaptive management approach is put forward and approved by Southern Rural Water through the annual reporting process. The intent of this process is to ensure that the details in the REPP remain current and that the REPP can respond to changes in the hydraulic regime and environmental condition that are expected to occur as a result of the remedial actions.

The quarterly and annual reports will also be made publicly available via the Your Say website located here: https://www.yoursay.barwonwater.vic.gov.au/boundary-creek

It is noted that once all of the success targets outlined in this REPP have been met and any further actions required as part of the surrounding environment investigation are complete, remediation is deemed to have been completed to the extent practicable, thus, meeting the requirements of the section 78 notice and the cessation of the REPP and associated reporting requirements.

A7.2 Milestones

In addition to the reporting requirements, Table 9 outlines the progress against the milestones that have been developed in accordance with the section 78 notice.

Table 9 REPP milestones

Milestone	Timeframe	Status
Submission of the proposed Boundary Creek, Big Swamp and Surrounding Environment – Remediation and Environmental Protection Plan to Southern Rural Water. Southern Rural Water to review and provide feedback on requirement changes.	20 December 2019	Complete
Finalisation of the Boundary Creek, Big Swamp and Surrounding Environment – Remediation and Environmental Protection Plan, including any changes required by Southern Rural Water	1 March 2020	Complete

Milestone	Timeframe	Status
Endorsement of a governance framework clearly outlining roles and responsibilities of stakeholders involved in the REPP, a decision-making process to determine how revisions to the REPP in the form of controls or actions are accepted or rejected and how controls and actions are implemented. Southern Rural Water to accept the governance framework.	By 31 July 2020	Complete
Submission of detailed design of the hydraulic barriers outlining proposed controls or actions and any revisions to success measures/targets. Southern Rural Water to accept the detailed design, including proposed actions, controls, and success measures/targets.	01 July 2021	Complete
Submission of the Surrounding Environment investigation to Southern Rural Water for review and acceptance. Should any further work be identified, this will be outlined for consideration by Southern Rural Water to determine if further remedial works are required.	31 July 2023	Complete
Submission of the climate resilience modelling work to Southern Rural Water	31 December 2024	On track
Barwon Water to provide progress updates on a quarterly basis and publish there on the Your Say website.	Quarterly	Complete and ongoing
Barwon Water to submit an Annual Report to Southern Rural Water. Once accepted this Annual Report is to be published on the Your Say website	Annually	Complete and ongoing

A8 Community and stakeholder engagement

Barwon Water's community and stakeholder Remediation Reference Group (RRG), continues to meet on a quarterly basis to discuss the implementation of the REPP and any changes that are required as part of the adaptive management approach to account for the current state of knowledge.

In addition to this, Barwon Water is committed to keeping the broader community informed. We will continue to share updates via the dedicated Boundary Creek & Big Swamp web page on our Your Say website, media releases, social media and community information sessions.

Barwon Water will also continue to engage with Southern Rural Water and DEECA.

Like the REPP itself, the approach to engagement will be adaptive to suit the needs of the community and stakeholders (refer Figure 12).

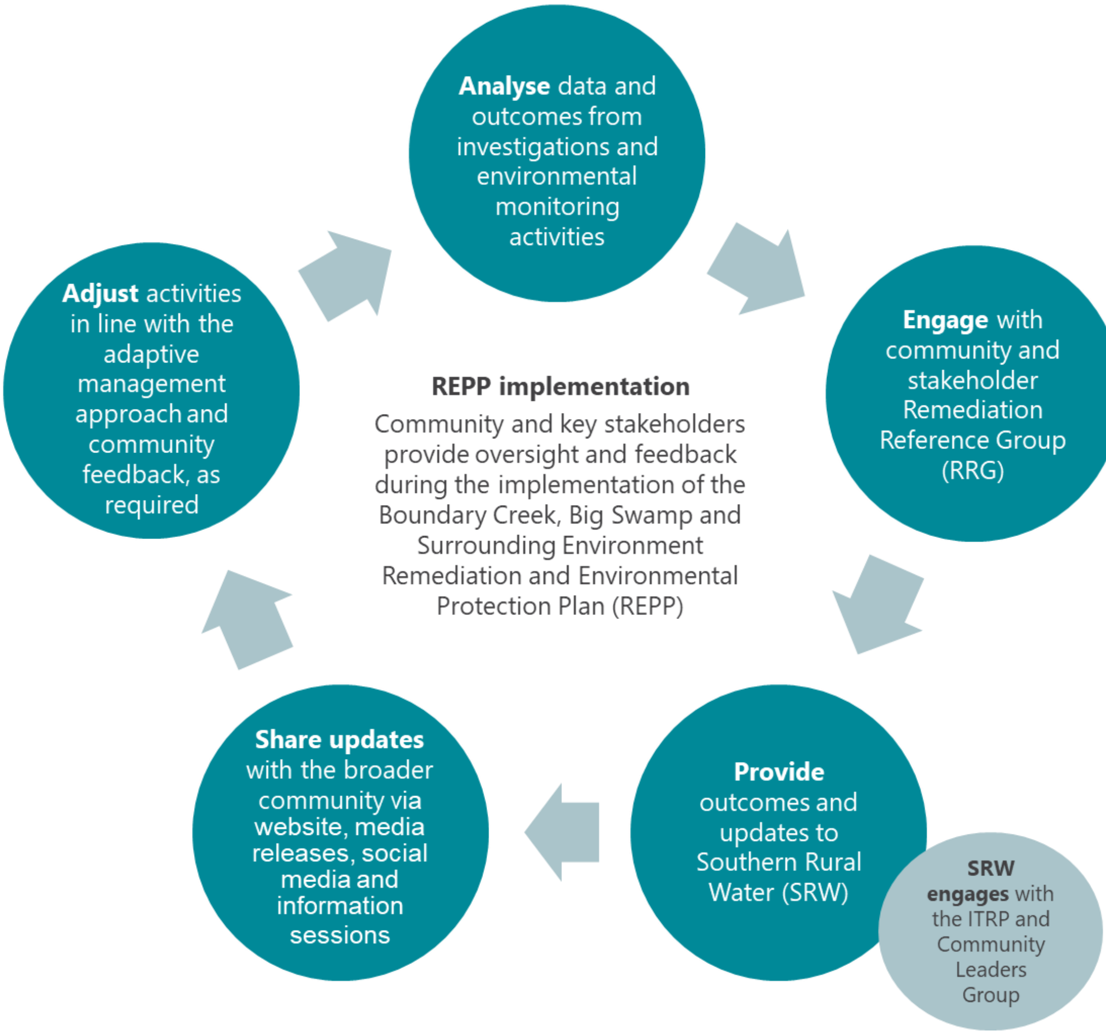

Figure 12 General community and stakeholder engagement process

Part B - Technical Response to s78 notice

B1 Background

On 11 September 2018, Southern Rural Water as a delegate for the Minister for Water, issued a notice (under section 78 of the Water Act, 1989 (Vic)) requiring Barwon Water to:

a) Continue no groundwater extraction, other than for maintenance and emergency response;
b) Prepare a plan for the remediation of Boundary Creek, Big Swamp and the surrounding environment impacted by groundwater pumping at Barwon Downs, and
c) Describe the environmental outcomes for the waterways to be achieved by the remediation plan.

This was issued on the basis "that a process or activity which is being/or has been carried out at the property has caused measurable negative environmental impact on Boundary Creek, Big Swamp and the surrounding environment".

In addition to the high-level requirements outlined above, clause 2.5 of this notice required "the preparation and submission of a plan to Southern Rural Water that details:

a) A description of the current environmental conditions of Boundary Creek, Big Swamp and the surrounding environment;
b) An outline and risk assessment of the processes/activities on the Property which may impact on Boundary Creek, Big Swamp and the surrounding environment;
c) A range of controls and actions that could be practicably carried out to protect and improve the condition of Boundary Creek, Big Swamp and the surrounding environment, including reasonable targets and/or measures of success to be adopted for the purposes of the implementation plan;
d) A comprehensive risk assessment of proposed controls and actions documented in c);
e) The controls and actions to be implemented, including reasonable targets and/or measures of success to be adopted for the purposes of the implementation of the Plan;
f) A monitoring program to check the controls and actions documented in e);
g) Contingency measures designed to address any issues identified from monitoring results;
h) A schedule of timeframes by which the controls and actions documented in e) will be carried out, and
i) A reporting schedule, whereby Barwon Water will provide a minimum of quarterly updates to Southern Rural Water which report on the progress of the Plan, as well as an Annual Report. The Annual Report must be submitted to Southern Rural Water and made publicly available by 30 September each year".

The following sections provide a response to each of these requirements.

B2 Clause 2.5a: A description of the current environmental conditions of Boundary Creek, Big Swamp and the surrounding environment

This section provides a synthesis of the technical data and analysis that was undertaken to inform the REPP. This section is not intended to provide an exhaustive description of the methods, results and findings associated with all technical works, but rather draws on the key findings and outcomes of the technical works completed to provide a description of the "current environmental conditions of Boundary Creek, Big Swamp and the surrounding environment" as required by Clause 2.5a.

The objective of this section is to synthesize a sound understanding of the Boundary Creek system in such a way that can inform the Boundary Creek and Big Swamp Remediation Plan. Full details of the methods and results of technical works undertaken as part of this program can be found in the technical reports provided on the Your Say website located here: https://www.yoursay.barwonwater.vic.gov.au/boundary-creek

B2.1 Regional climatic conditions

The historic distribution of rainfall across the Otway's and Barwon Downs region is shown in Figure 13 and Figure 14 below. Accordingly, this illustrates an average annual rainfall of between 1,000 and 2,000 mm/yr throughout the southern Otway Ranges. These rates are consistent with some of the wettest areas in Victoria, with areas inland of these areas reporting average annual rainfall of <1,000 mm/yr.

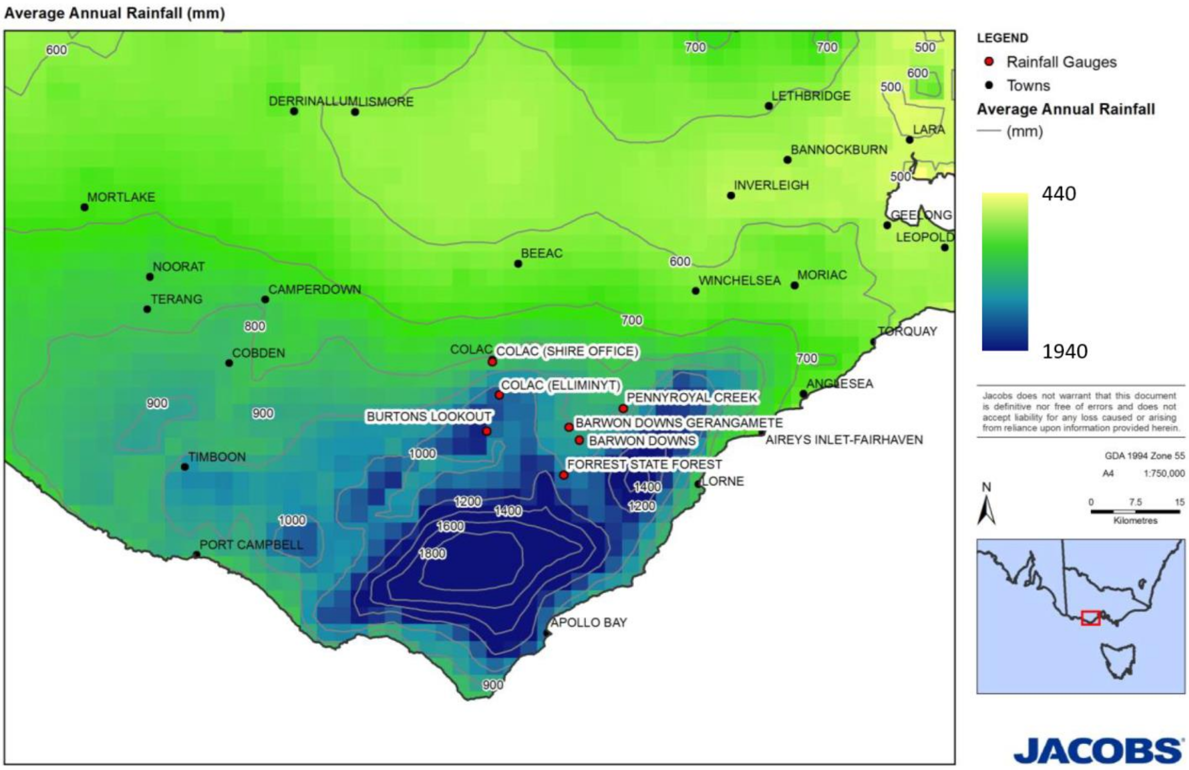

Figure 13 Spatial trends in average annual rainfall in Victoria based on 1960-1991, 30-year period. Data sourced from the Bureau of Meteorology (2010)

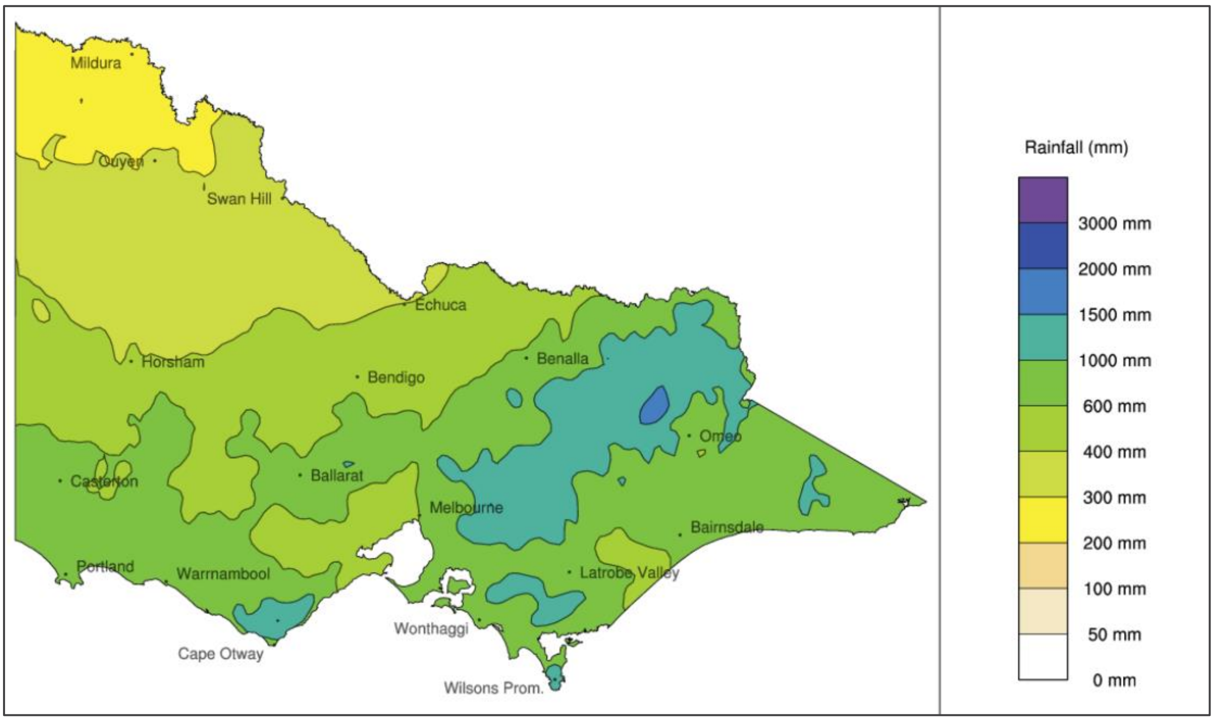

Figure 14 Spatial trends in average annual rainfall in Victoria based on 1981-2010, 30-year period. Data sourced from the Bureau of Meteorology (2020)

B2.2 Local climatic conditions

Following review of the available rainfall records, three Bureau of Meteorology rainfall monitoring stations (Forrest State Forest (Station #90040), Barwon Downs (Station #090004) and Gellibrand River Forestry (Station #90040)), one WMIS rainfall monitoring station (Agroforestry Site (Station #233250)) and five community-based rainfall monitoring stations were reviewed. The location and average annual rainfall recorded at each of these stations in presented on Figure 15.

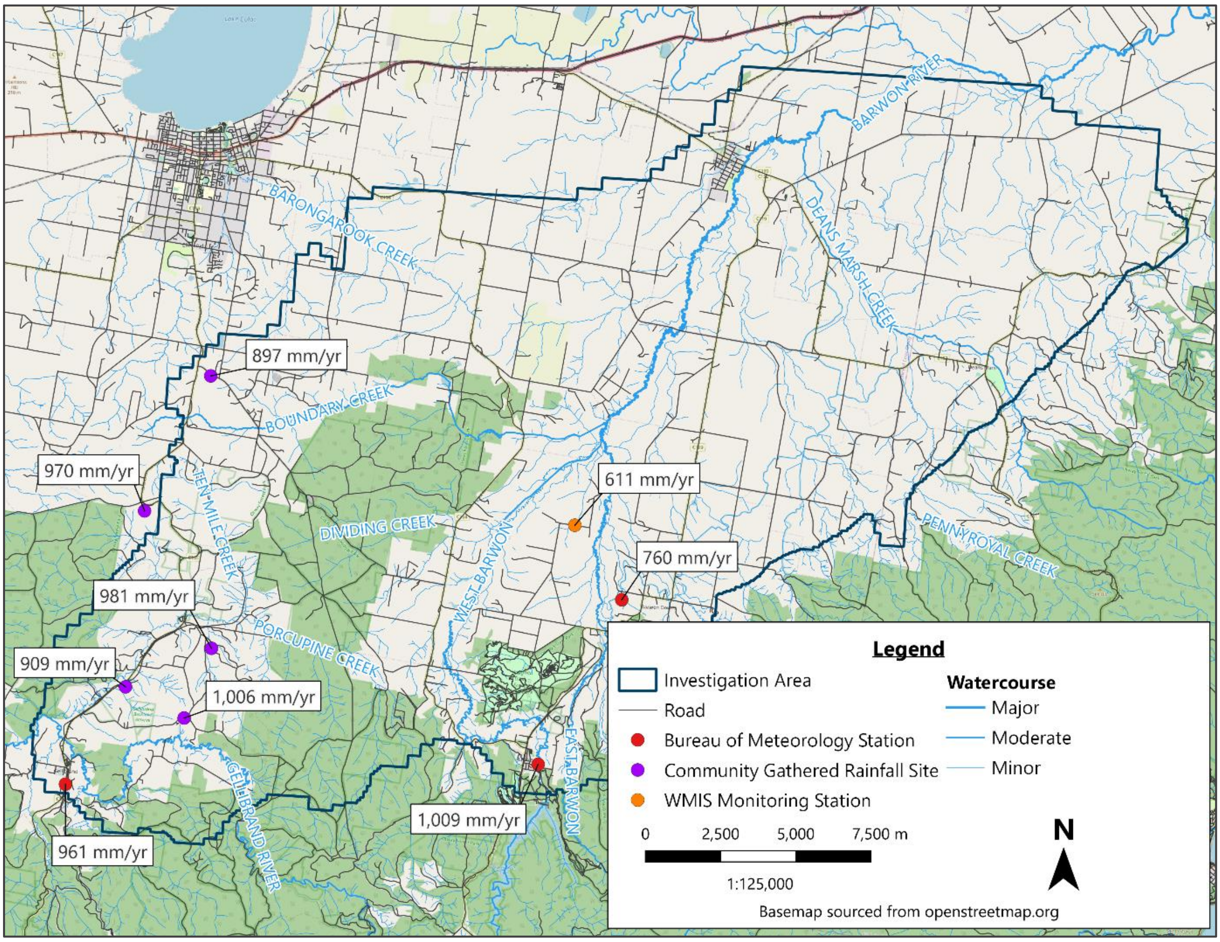

Figure 15 Boundary Creek, Big Swamp and surrounding environment average annual rainfall

When broken down by year, the combined dataset indicates an average mean rainfall for the region of 918 mm/yr, with the 5-year moving average reflecting the variability in the average annual rainfall data over time (Figure 16).

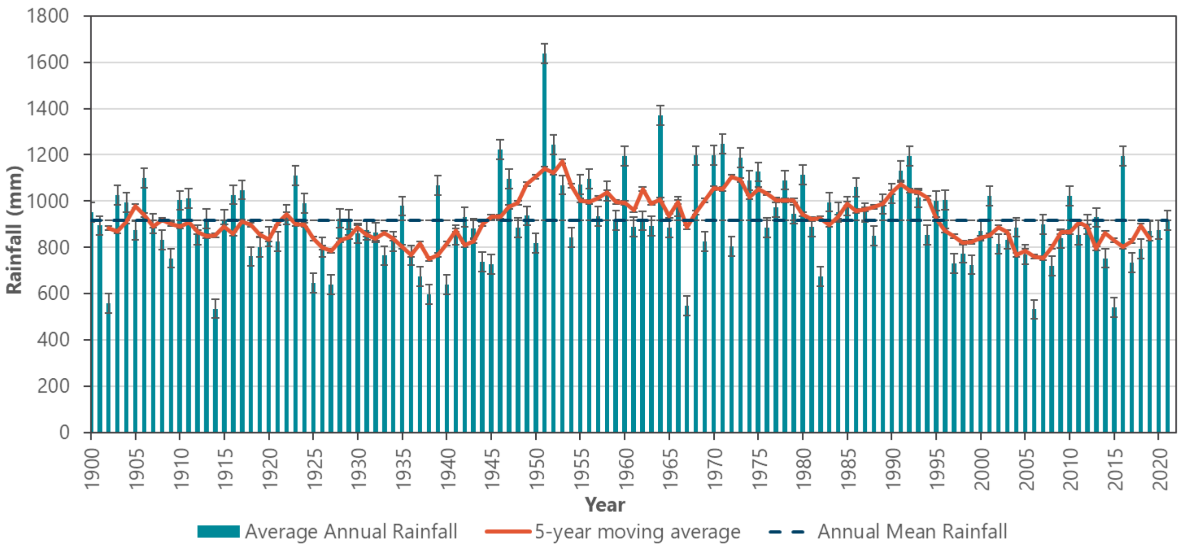

Figure 16 Average annual rainfall statistics for the Barwon Downs region

The Accumulative Monthly Residual Rainfall graph presented in Figure 17 plots the accumulated monthly deficit or surplus rainfall at a particular time, relative to the historical mean monthly rainfall for each station. This highlights periods of below average rainfall conditions (e.g., drought) as declining trends and periods of above average rainfall as rising trends.

As can be seen in Figure 17, periods of below average rainfall were recorded at all rainfall monitoring stations during the recorded historical drought periods, despite the combined average annual rainfall values within the region remaining above 500 mm/yr (Figure 16).

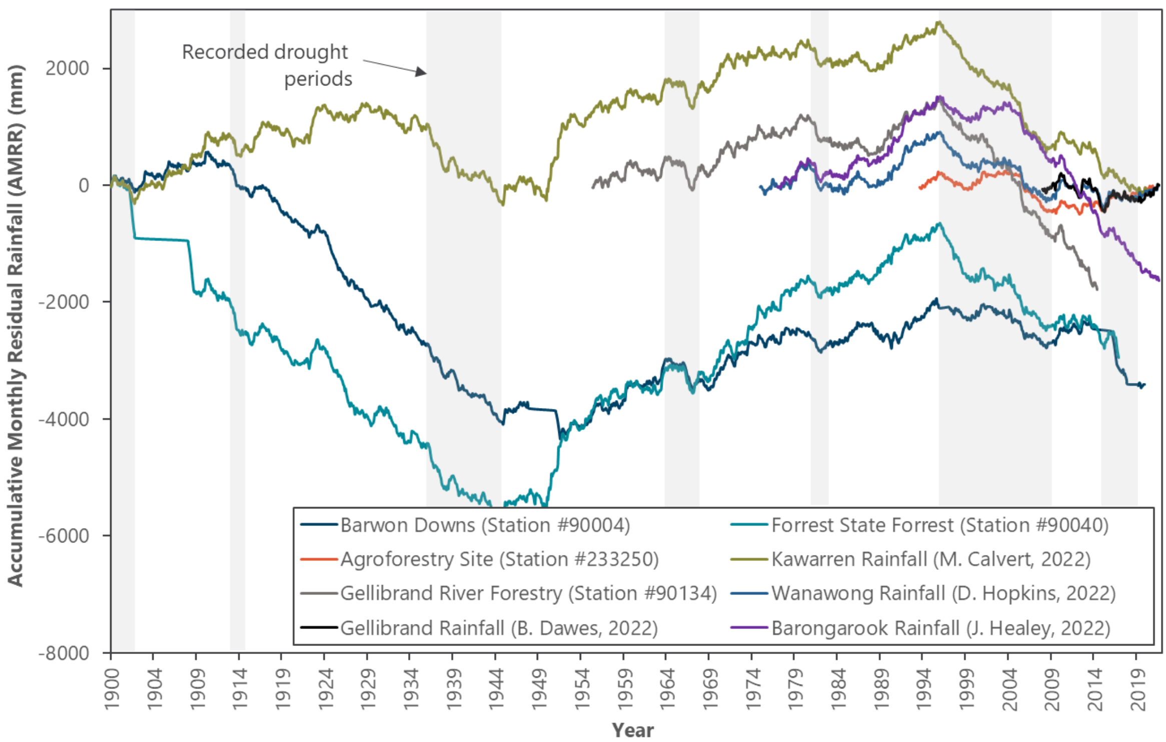

Figure 17 Accumulative Monthly Residual Rainfall (AMRR) for 1900 – 2020

The recorded rainfall deficiencies during the millennium drought, which occurred between 1997 and 2009, also coincides with an elevated annual pan evaporation, between 90 and 319 mm/yr greater than the average annual evaporation rate of 1,300 mm/yr (Figure 18). This reflects a 7 to 25% increase in evaporation rates during this time.

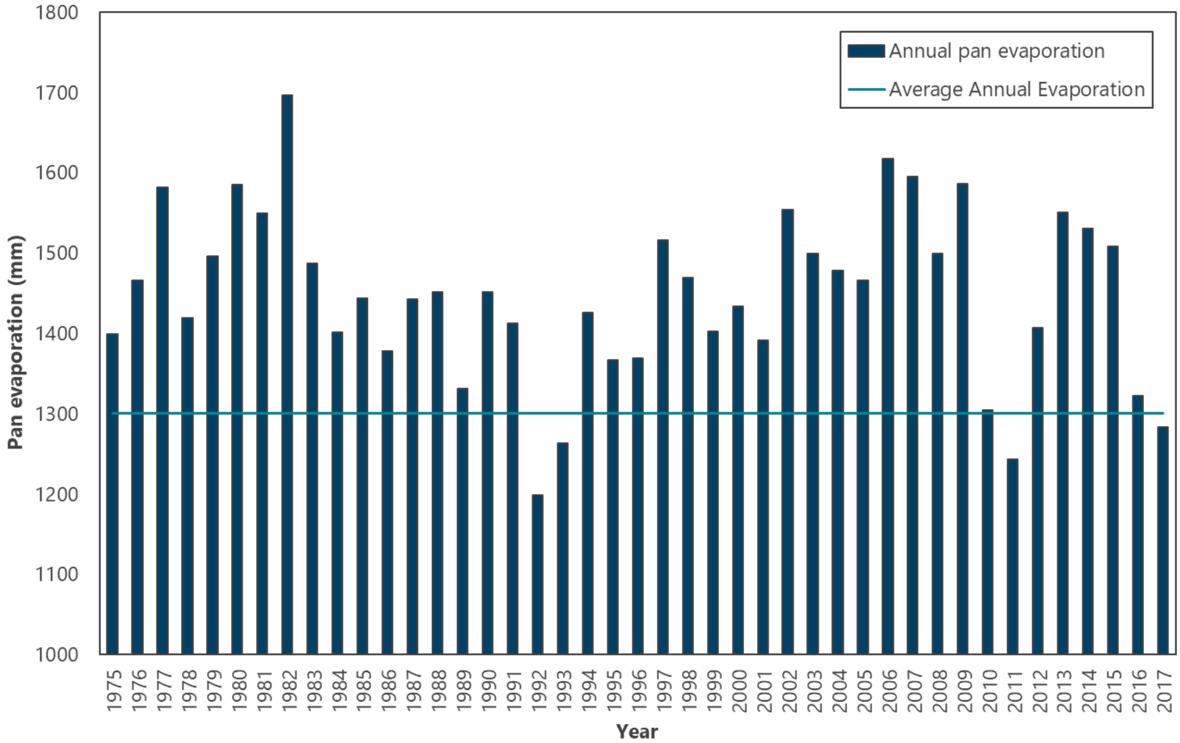

Figure 18 Victorian Annual Pan Evaporation Rates from 1975 – 2017 (BoM, 2022)

B2.3 Hydrological setting

As outlined in section A5.1, the Surrounding Environment Investigation considers the whole extent of the Lower Tertiary Aquifer, with an extent of approximately 480 km^2 (refer to Figure 19). The investigation area extends across two surface water catchments, the Barwon River catchment and the Otway Coast catchment (refer to Figure 19). Surface water features of regional importance within these catchments are the Barwon River and the Gellibrand River. In addition to this, a number of smaller rivers, streams and/or channels that feed into these larger waterbodies may also be important in their own right – in the same way as Boundary Creek.

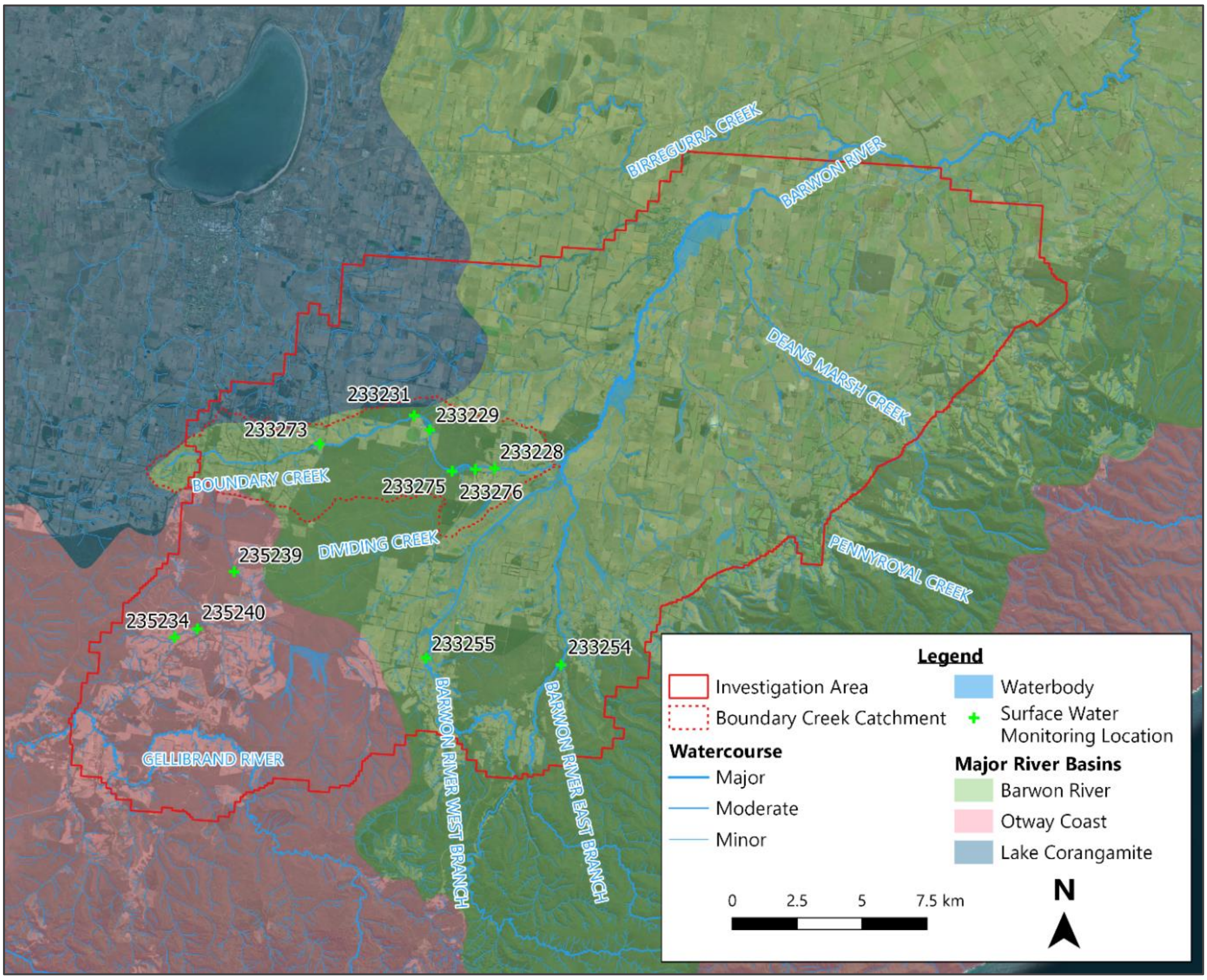

Figure 19 Surface water catchments within the surrounding environment investigation area

Being a tributary of the Barwon River, the Boundary Creek catchment forms part of the Barwon River catchment. Boundary Creek is approximately 19 kilometers long and flows from Barongarook to Yeodene where it joins the Barwon River, approximately 16 kilometers south-east of Colac. The hydrology of Boundary Creek has also been impacted by the construction of a 160ML private on-stream dam, that controls the surface water flows into the lower reaches of Boundary Creek.

Big Swamp (also known as Yeodene Swamp) is a wetland located adjacent to the lower reaches of Boundary Creek, approximately 4 kilometers upstream from the confluence of Boundary Creek and the Barwon River. Big Swamp contains naturally occurring acid sulfate soils that have, in part, been oxidised due to the changes that have occurred within the Boundary Creek catchment, resulting in the discharge of acidity and metals to the lower reaches of Boundary Creek and the Barwon River. While this would have occurred to some degree under natural conditions, groundwater pumping really exacerbated a pre-existing issue, making the issue more severe.

B2.4 History of the Boundary Creek catchment

The Boundary Creek catchment has been highly modified over the last century as a result of:

- European settlement and associated changes in land use as illustrated in Figure 20 which illustrates the distribution of different vegetation classes prior to and following European settlement (DELWP, 2017). Further to this, land use changes claimed about 800 acres (Jennings, 2008) of low-lying land for agricultural production and required the removal of large sections of low land forest and grassy woodlands as shown in Figure 20. Much of the lower reach of Boundary Creek was cleared over the last century to support agriculture and farming practices;

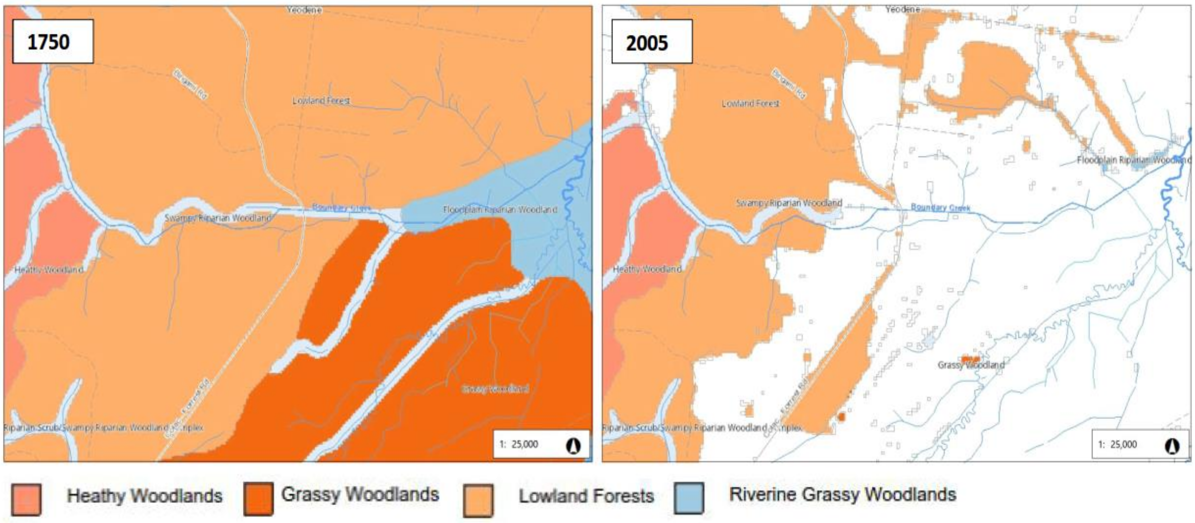

Figure 20 Ecological Vegetation Class mapping of the Boundary Creek catchment in 1750 and 2005 (DELWP, 2017)

- Land clearing activities and channelisation/drainage of Boundary Creek for agricultural and farming purposes;
- Surface water harvesting activities, including the construction of a 160 ML private on-stream dam along Boundary Creek in 1979 and a number of private diverters and farm dams which collect rainfall before it reaches the creek;
- Groundwater extraction activities which were used intermittently to supplement urban water supplies between 1982 and 2016;
- Surface water extraction activities by adjacent landholders with existing water rights;
- Fires which occurred in 1997, 1998 and 2006 as a result of the drying out of the swamp;
- The excavation of a fire trench along the southern side of Big Swamp in 2006 to mitigate fire risks, and
- Significant changes in long-term climatic conditions that have resulted in widespread streamflow reductions of 20-40% across the state (DLWP, 2020) and a minimum 30% reduction of streamflow in some parts of the Otway's.

These activities have resulted in significant changes to the catchment, some of which are permanent and irreversible, that have significantly altered the natural hydrological flow regime, rainfall-runoff processes and streamflows. A timeline outlining the key changes that are likely to have impacted on the ecological values of the catchment are provided in Figure 21.

It is also noted that since 2003, supplementary flows have been released by Barwon Water, where required, into the headwaters of Boundary Creek upstream of stream gauge 233273 to offset the potential baseflow reduction that was identified as a potential side effect of the groundwater extraction activities. Noting that this requirement was later adopted as a condition under Barwon Water's former groundwater extraction licence that was issued in November 2006. Following expiry of this licence, Barwon Water have continued to release supplementary flows, where required, to minimise the occurrence of cease to flow and acid flush events in Reach 2 of Boundary Creek.

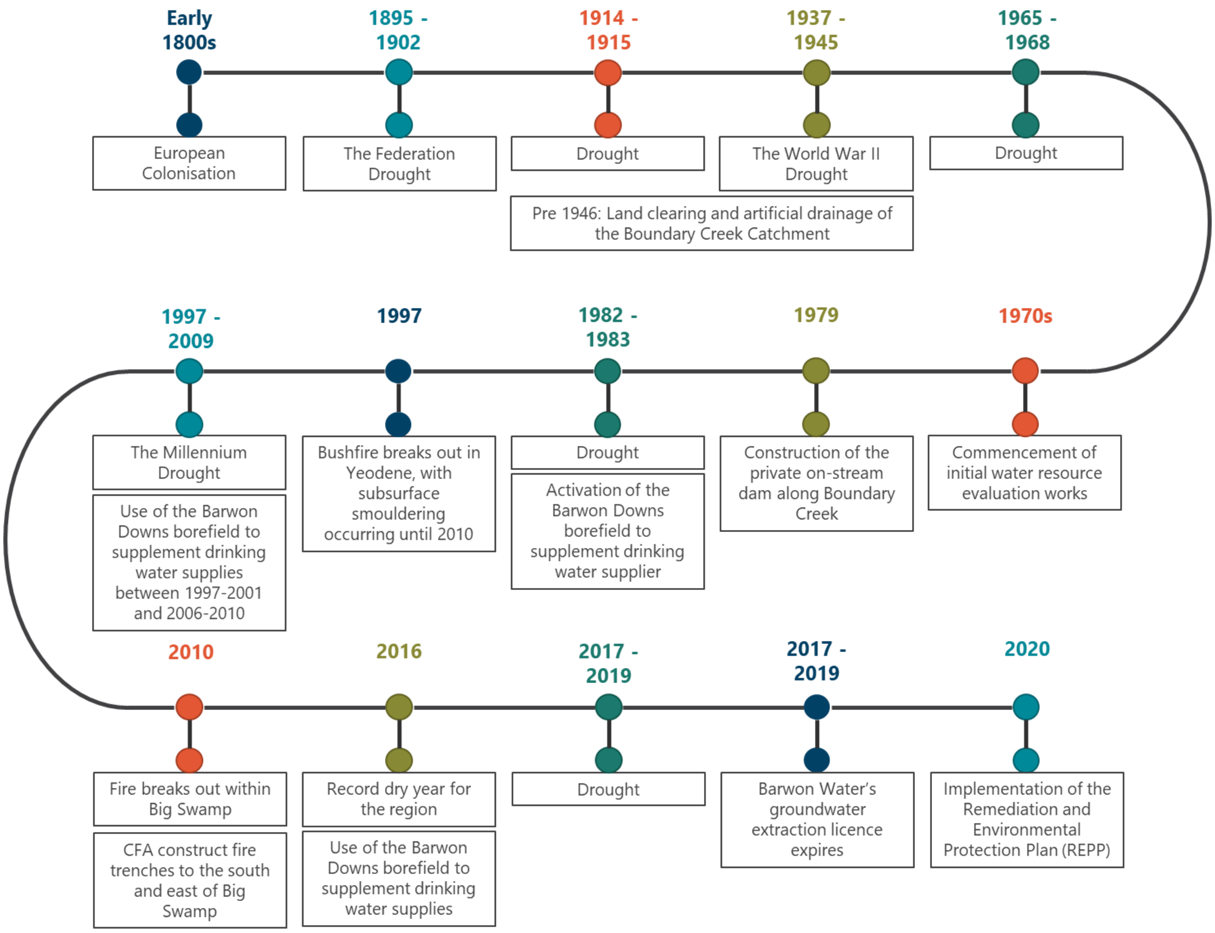

Figure 21 Overview of changes in the Boundary Creek catchment

B2.5 Geological setting

The study area is located within the Barwon Downs Graben, which extends from the Gellibrand Saddle to the Birregurra Monocline and is bounded to the south by the Bambra Fault and the Otway Ranges (Petrides & Cartwright, 2006). The Barwon Downs Graben has been heavily shaped by numerous depositional and tectonic events and contains a range of Mesozoic and Cainozoic sediments (Petrides & Cartwright, 2006).

Based on a review of the Geological Survey of Victoria's Colac 1:50,000 geological layers (refer Figure 22), the Australian Stratigraphic Units Database (https://asud.ga.gov.au/) and previous investigations (i.e. Dahlhaus et al, 2002, HydroTechnology, 1994, Petrides & Cartwright, 2006 and Tickell et al., 1991), the main geological units within the region are outlined in their depositional order from newest to oldest in Table 10 below.

Table 10 Summary of relevant stratigraphic units

Formation	Stratigraphic Group	Description	Age (Ma)
Quaternary Alluvium	Quaternary Sediments	Channel and flood plain alluvium consisting of gravel, sand and silt; variably sorted; generally unconsolidated	< 3
Sandringham Sandstone	Sandringham Sandstone	Sandy silt, fine sandstone, sandy conglomerate to pebbly sandstone, clayey sand, clayey gravel, carbonaceous band including plant fossils; lag deposit including variable to highly rounded pebbles; horizontal and swaley cross-lamination; burrows.	2.5 - 23
Gellibrand Marl	Heytesbury Group	Marine shelf deposits: clay, marl and worm-burrowed calcarenite, fine to medium grained quartz and detrital calcareous fossil fragments in clay matrix, moderately sorted, massive to well bedded	7 - 34
Clifton Formation		Shallow marine deposits: medium to coarse grained calcarenite of bryozoan and shell fragments in quartz sand matrix, moderately sorted, thin to medium bedded	5 - 34
Older Volcanics	Yaugher Volcanic Group	Olivine basalt, tuff, microgabbro, minor sedimentary rocks	23 - 28
Demons Bluff Formation	Demons Bluff Group	Carbonaceous pyritic silt to fine sand, clay, and clayey sand; contains occasional shelly fossils and glauconite	23 - 56
Narrawaturk Marl	Nirranda Group	Calcareous mudstone, minor thin calcarenite beds: locally carbonaceous and burrowed, locally abundant glauconite pellets and polished quartz sand, foraminifers, bryozoans, brachiopods and molluscs; open marine (below storm wave base) deposits	28 - 41
Mepunga Formation		Shallow to nearshore marine sandstone and shale	34 - 48
Dilwyn Formation	Wangerrip Group	Composed mainly of dark brown, carbonaceous sandy clay and silt, interbedded with fine- to medium-grained, clean to clayey sand, with minor coarse sand and gravel	41 - 56
Pember Mudstone		Carbonaceous, micaceous, pyritic silty clay to clayey silt, and minor fine sand	56 - 66
Pebble Point Formation		Quartz sand, minor clay: micaceous, fine-grained, friable, generally massive; minor planar cross-bedding; minor gravel, minor	59 - 66

Formation	Stratigraphic Group	Description	Age (Ma)
		volcanic and metamorphic lithic cobbles and pebbles; near shore, shallow marine deposits	
Eumeralla Formation	Otway Group	Fluvial volcaniclastic arkosic sandstone, mudstone, minor black coal, sandstone and conglomerate	100 - ~150

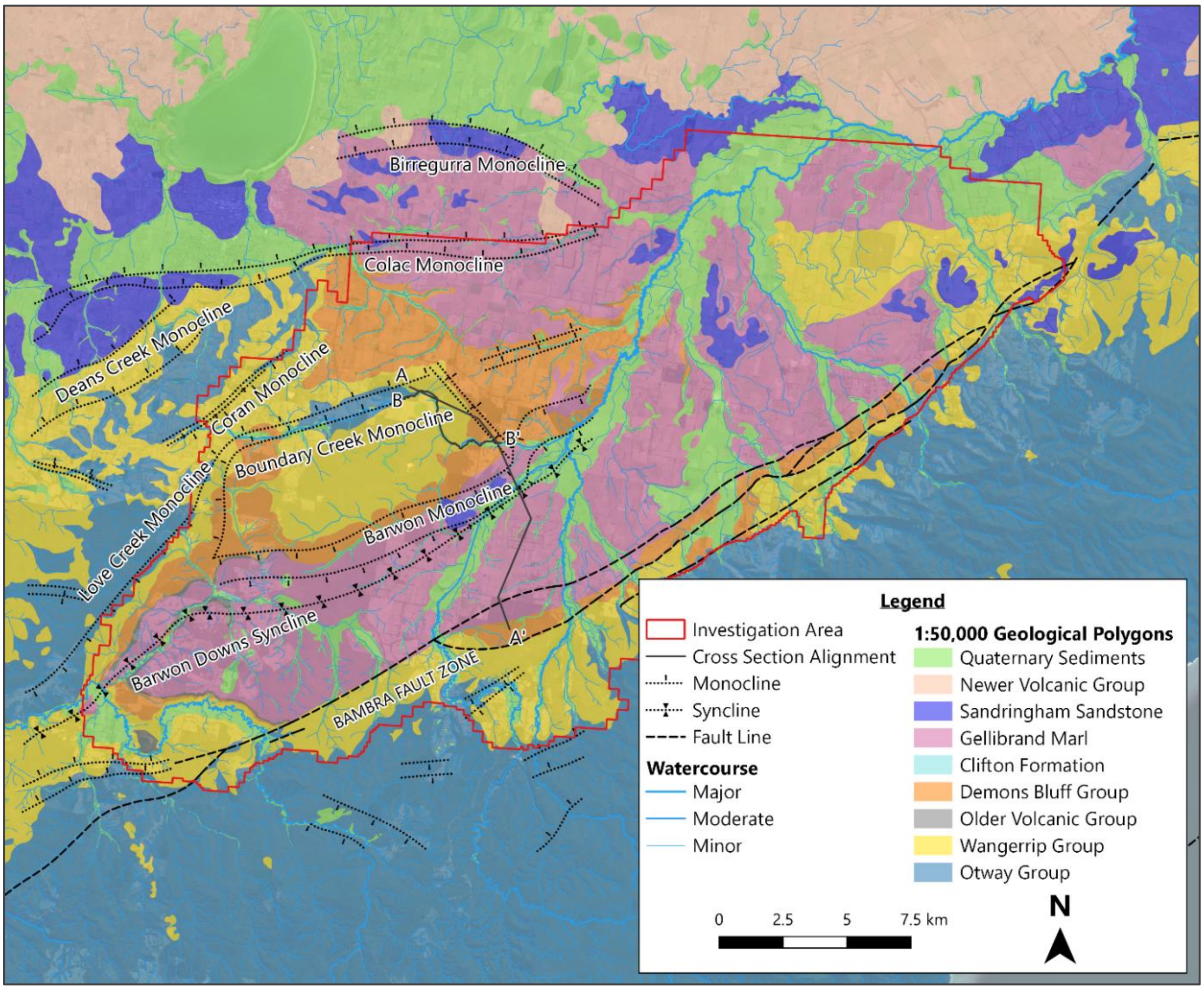

Figure 22 1:50,000 Geological Map (Layers obtained from the Victorian Spatial Datamart with geological structures sourced from Geological Survey of Victoria's Colac 1:50,000 geological map sheet)

B2.6 Hydrogeological setting

B2.6.1 General

Based on previous investigations undertaken within the Barwon Downs Graben, the geological units presented in Table 10 above can be grouped into the following hydrogeological units (refer Table 11). Noting that given the Gellibrand Marl is the uppermost geological unit across much of the Graben and forms part of the local groundwater flow system (CCMA, 2002), this is considered to form part of the upper aquifer system rather than being a regional surficial aquitard. This is supported by the monitoring data that suggest groundwater – surface water interaction does occur between the Quaternary Alluvium and the marls.

Table 11 Summary of hydrogeological units

Interpreted Hydrogeological Unit	Geological Formation(s)	Hydrogeological Setting
Upper Aquifer System	Quaternary Alluvium	The Quaternary Alluvium consists of unconsolidated sediments deposited in and adjacent to rivers/streams. This is expected to be hydraulically connected to the underlying materials and contribute to groundwater-surface water interaction.
	Sandringham Sandstone	Where they occur the Sandringham Sandstone deposits are understood to be hydraulically connected to the overlying Quaternary Alluvium and underlying Gellibrand Marl system and contribute to groundwater-surface water interaction.
	Gellibrand Marl & Clifton Formation	The Gellibrand Marl is the uppermost geological unit across much of the graben and contains the watertable. Given its importance in the local groundwater flow system (CCMA, 2002) this unit is considered to be in direct hydraulic connection with the overlying sediments and in this case is expected to act as a minor aquifer. Noting that this may also be confined at depth, consistent with this unit generally being considered more of an aquitard.
	Older Volcanics	Older volcanics outcrop in select areas within the Kawarren sub-basement namely around Love Creek and the Gellibrand River. Depending on the fracturing and weathering profile, this may help to transmit and/or restrict groundwater flow.
Confining Layer	Demons Bluff Group & Narrawaturk Marl	The Demons Bluff Group and the Narrawaturk Marl, which are generally comprised of low permeability sediments, are considered to be the primary confining units within the Barwon Downs Graben, thus separating the Upper Aquifer system from the Lower Tertiary Aquifer.
Lower Tertiary Aquifer System	Mepunga Formation, Dilwyn Formation, Pember Mudstone and Pebble Point Formation	The Lower Tertiary Aquifer System is a predominantly sand-based aquifer system that is confined by the overlying low permeability units. While the Lower Tertiary Aquifer system is comprised of multiple

Interpreted Hydrogeological Unit	Geological Formation(s)	Hydrogeological Setting
		geological units, these are generally considered to be in direct hydraulic connection. As such, these units form a multi-layered aquifer system that exhibits different characteristics depending on the individual units. This is considered to be the primary regional aquifer system and was the groundwater source for the Barwon Downs Borefield. The Lower Tertiary Aquifer is recharged by direct infiltration where these sediments outcrop on the Barongarook High.
Basement	Otway Group	The Basement rock which is understood to have low primary porosity and hydraulic conductivity is considered to be a poor aquifer system.

The structural relationship between these units along alignment A-A' presented in Figure 22 is shown in Figure 23.

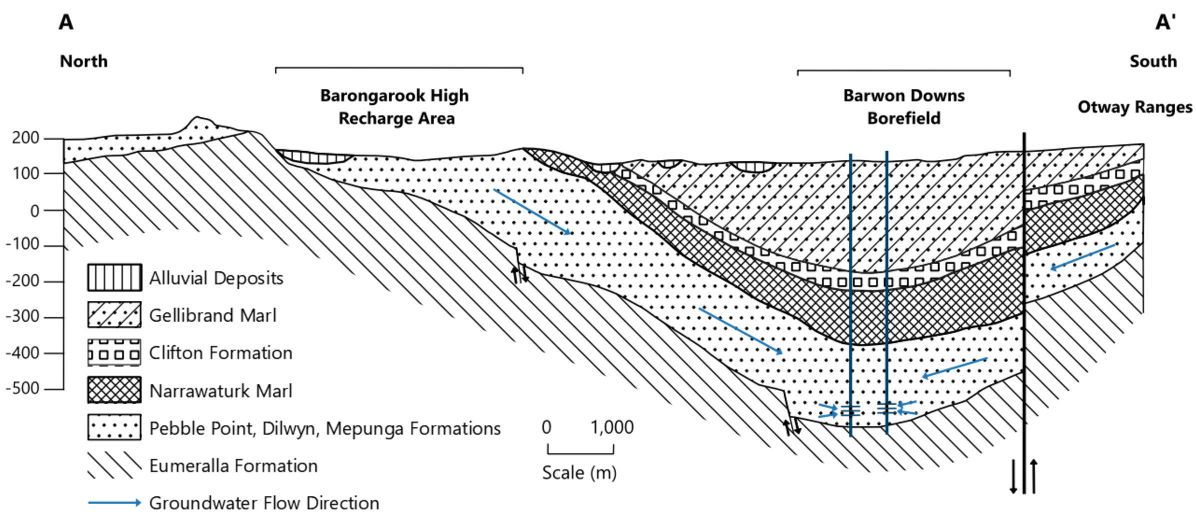

Figure 23 Regional hydrogeological cross section (adapted from Petrides & Cartwright, 2006)

B2.6.2 Boundary Creek Catchment

The different reaches of Boundary Creek have been defined by surface water features, underlying hydrogeology, hydrology and operational considerations as described below and presented in Figure 24:

Reach 1 – This is the upper reach of Boundary Creek commencing near the township of Barongarook and flowing east towards a private on-stream dam (160 ML capacity) located in Yeodene. Supplementary flows by Barwon Water are released into a small tributary that joins Boundary Creek in Reach 1, upstream of the dam. This reach can be further divided into two sub-reaches as follows:

- **Reach 1a**, represents the section of the creek from Barongarook to ~500 m upstream of the private on-stream dam. The Quaternary Sediments within this reach are predominantly underlain by outcropping bedrock comprised of impermeable Paleozoic sandstone, siltstone and mudstone. The Quaternary Sediments within this reach are expected to receive a minor contribution of upward vertical flow from the underlying basement rock, and
- **Reach 1b**, represents the section from Reach 1a through to the downstream end of the private on-stream dam. Approximately 50% of this reach has been heavily modified by the construction of the private on-stream dam with only the upper ~500 m stretch being consistent with its historical condition. The Quaternary Sediments within this reach are underlain by the Lower Tertiary Aquifer (LTA) system. This reach is within the groundwater recharge zone and is classified as a losing stream.

Reach 2 – Represents the portion of Boundary Creek between the outlet of the private on-stream dam and the downstream end of Big Swamp. This reach can also be further broken down into 3 sub-reaches based on the nature of the streambed, the vegetation classes and underlying geological units, as follows:

- **Reach 2a**, represents a likely artificial channelised section immediately downstream of the private on-stream dam. The Quaternary Sediments within this reach are underlain by the Lower Tertiary Aquifer (LTA) system. Historically, this portion of the stream was likely a gaining stream that received rejected recharge/baseflow from the Lower Tertiary Aquifer system. The hydrogeological regime within this reach is likely to have also been influenced by the presence of the private on-stream dam;
- **Reach 2b**, represents a densely vegetated and marshy low-land area known as the 'damplands', located upstream of Big Swamp. This reach is characterised by highly braided flow pathways and waterlogged conditions. Similar to Reach 2a, the Quaternary Sediments within this reach are underlain by the Lower Tertiary Aquifer (LTA) system. Historically, this portion of the stream was likely a gaining stream that received rejected recharge/baseflow from the Lower Tertiary Aquifer system, and
- **Reach 2c**, represents the area from the end of Reach 2b to the downstream end of Big Swamp where the Boundary Creek and Big Swamp flow paths meet. The Alluvial Sediments within this reach are between 1.5 and 6 m thick and are underlain by the Demons Bluff Formation and/or the Narrawaturk Marl that is confined at depth, thus confining the Lower Tertiary Aquifer and minimising the connectivity between the Upper Aquifer and Lower Tertiary Aquifer systems. This reach is considered to have relied on throughflow and groundwater – surface water interaction with the Upper Aquifer system to sustain streamflows during dry periods.

Reach 3- Represents the channelised portion of Boundary Creek from the downstream end of Big Swamp to the confluence of Boundary Creek and the Barwon River. This section has been heavily modified to support agricultural activities, with the Quaternary Sediments within this reach being underlain by the Gellibrand Marl, Demons Bluff Formation and/or Narrawaturk Marl that is confined at depth, thus confining the Lower Tertiary Aquifer and minimising the connectivity between the Upper Aquifer and Lower Tertiary Aquifer systems. This reach also receives groundwater discharge from the Upper Aquifer system.

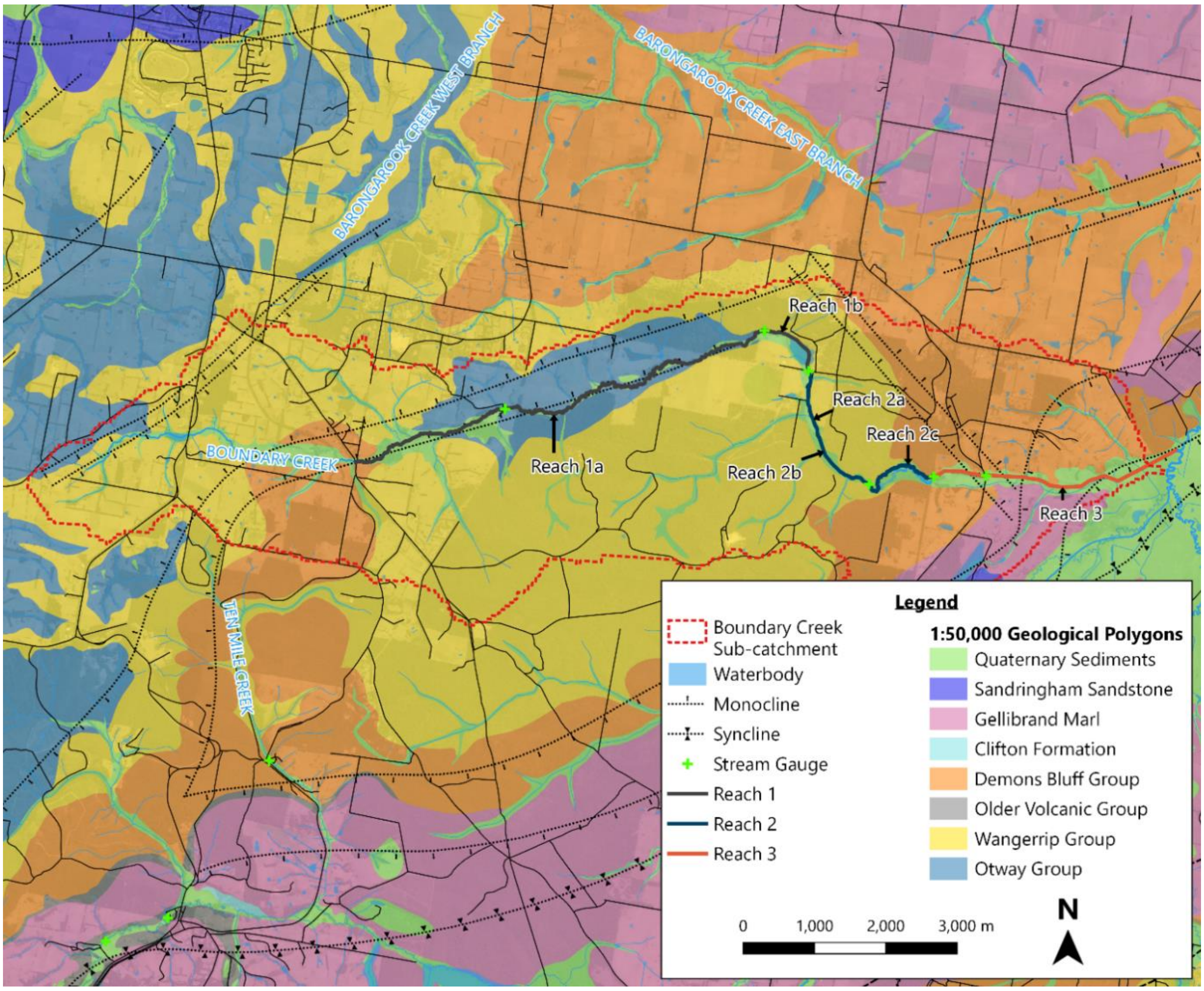

Figure 24 Simplified geology and hydrology of the Boundary Creek catchment

Based on the investigations undertaken to date, Reach 1a of Boundary Creek is expected to be sustained primarily by rainfall-runoff processes and receives low volumes of inflow from the Basement Aquifer that underlies a large proportion of this reach (Jacobs, 2018b). Reach 1b of Boundary Creek is considered to have been a neutral to weakly loosing stream historically. The limited groundwater - surface water interaction in this reach is supported by the streamflow monitoring data from surface water gauging stations 233273 and 233231 that show flows do not consistently increase or decrease in Reach 1b, as would be expected for a highly gaining or losing system.

Based on the lithology and groundwater and surface water elevations within Reach 2a and 2b of Boundary Creek, these reaches would have historically received baseflow/rejected recharge from the Lower Tertiary Aquifer system. This would have supplemented the overall surface water flows and helped to buffer the system during dry periods.

Reach 2c of Boundary Creek is not in direct hydraulic connection with the Lower Tertiary Aquifer system due to the presence of the regional confining layer. In addition to runoff, this reach receives both inflow from Reach 2 and groundwater discharge from the Upper Aquifer system. This is supported by the hydrographs from nested bores BSTB1C/BSTB1A and BSBH13LTA/BSBH15 installed in the eastern and western portions of the swamp respectively (refer Figure 25 and Figure 26).

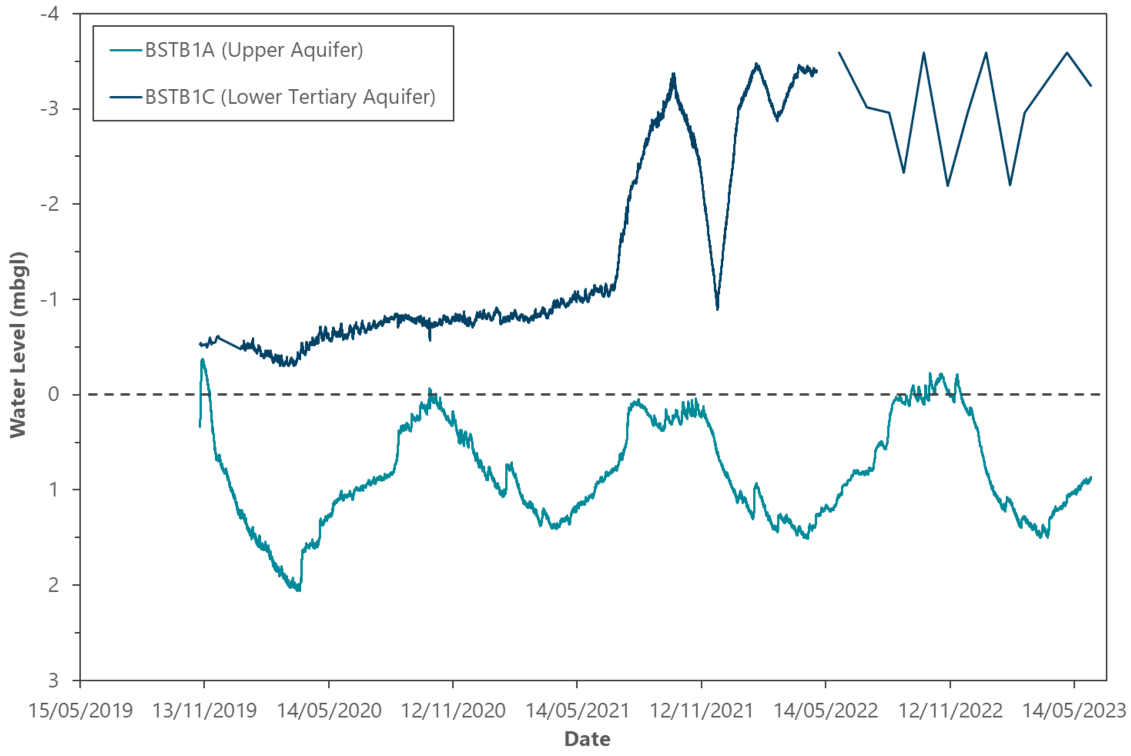

Figure 25 Groundwater levels in the eastern portion of the swamp. Note that the absence of data for BSTB1C after April 2022 is due to the logger being removed due to leakage associated with re-pressurisation of the LTA and headwork's modifications undertaken in April 2022

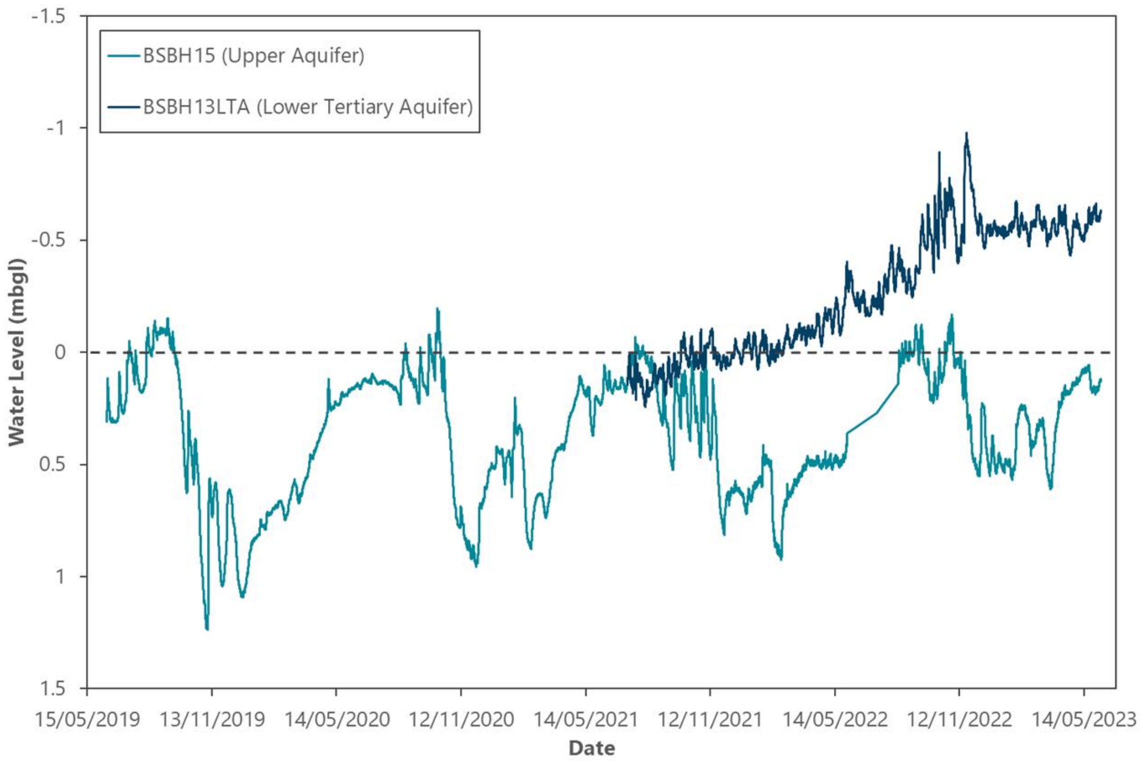

Figure 26 Groundwater levels in the western portion of the swamp. Note that the logger from BSBH15 was found to be missing on 14 July 2022 and was replaced on 15 August 2022

B2.7 Acid sulfate soils

B2.7.1 Regional occurrence of acid sulfate soils

Until relatively recently, the distribution of acid sulfate soils in Australia was believed to be constrained to predominantly coastal areas as a result of historic sea levels and the saturated conditions required to form acid sulfate soils. In contrast, the understanding of inland acid sulfate soils in Australia has only developed since 1990, mainly in response to extensive drying of wetlands and river systems during the Millennium Drought (Glover, 2014). During this period, reductions in groundwater and/or surface water levels has led to the historically saturated acid sulfate soils within these wetlands and river systems being exposed or drying out, thus allowing the oxidation of sulfidic sediments and the subsequent generation of acid (Fitzpatrick et al., 2008).

Today, the distribution of acid sulfate soils in Australia are relatively well understood, with National mapping outlining the probability of occurrence available (Fitzpatrick et al., 2011). However, the majority of research on inland acid sulfate soils in Victoria has focused on those in the Murray River Basin (e.g., Hall et al., 2006; Lamontagne et al., 2004; Fitzpatrick et al., 2008). To improve on this understanding, Glover (2014) focused on assessing the distribution of inland acid sulfate soils that may occur over a regional scale within the Corangamite Catchment. Sampling and analysis of soils were undertaken in five areas including Boundary Creek, Anglesea River, Porcupine Creek, Pennyroyal Creek and Bambra Wetlands. Noting that this did not aim to identify the anthropogenic factors that may have contributed to the oxidation of these sediments.

Within these areas, Glover (2014) found that seasonal fluctuations in the water table, due to variability in rainfall and temperature resulted in the loss of anaerobic conditions at the top of the soil profile. As such, it was asserted that seasonal drying of sediments in these areas was responsible for the partial oxidation of sulfides in the upper soil profile, which ranged between 0.3 and 1.5 m below ground surface.

The regional occurrence of acid sulfate soils was also identified as part of the Barwon Downs Stage 1 Field Works (Jacobs, 2015) and Barwon Downs Hydrogeological Study (Jacobs, 2017a) that looked at identifying and assessing areas with potential Acid Sulfate Soils. It is also important to note that while the alluvial sediments appear to be more reactive, the clays associated with the Demons Bluff and Gellibrand Marl formations that underlie the alluvial sediments are also in many cases potential acid sulfate soils given these were deposited in a marine environment and subject to waterlogged conditions.

B2.7.2 Big Swamp acid sulfate soils

The occurrence of acid sulfate soils within Big Swamp has been well documented. This includes initial characterisation by Graham and Lancaster (2007) and subsequent work by Glover (2014), Jacobs (2017a), Cook and Wong (2020) and Jacobs (2019c) and finally Jacobs (2022). These studies have identified the occurrence of both sulfuric and sulfidic material, yielding concentrations of net acidity in excess of 20%S in some samples. The neutralising (buffering) capacity of the Big Swamp sediments is also considered to be limited (GHD, 2019).

As part of soil sampling and laboratory analysis of acid sulfate soils within Big Swamp, characterization of the concentration of sulfides and acidity in the soil profile was undertaken. At a high level, trends in the concentration of both existing and potential acidity with depth have been illustrated in Figure 27 below. While such trends are spatially variable, this illustrates the elevated concentrations of existing acidity are relatively high (>0.5 %) in the upper 2 m of the soil profile within the swamp. Conversely, the potential acidity concentrations are comparatively low (0.1 %S) in the upper 0.5 m of the soil profile but increase significantly at depth (>2 %S below 1.5 m depth). It is also important to note that the increase in potential acidity with depth indicates that the sediments below 1 m have the potential to generate significant additional acidity should these become exposed to oxidising conditions.

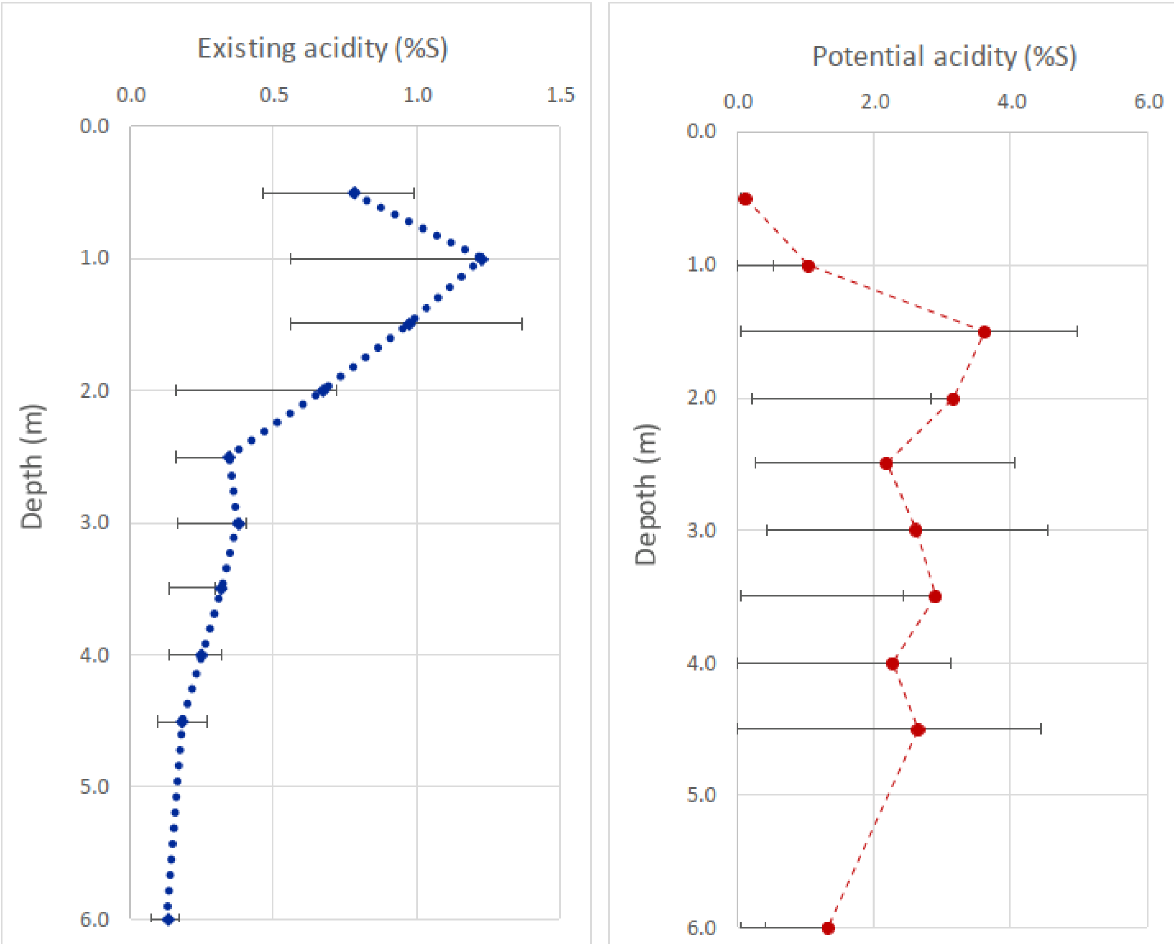

Figure 27 Average, 25th and 75th percentile (shown as error bars) of existing and potential acidity with depth (aggregates from 0.5 m intervals) (Jacobs, 2019c)

The distribution of potential acidity across the swamp was also investigated during the Big Swamp groundwater monitoring bore installation works (Jacobs, 2019c) and subsequent research (Cook and Wong, 2020) to assess potential remedial actions and help inform the groundwater level targets presented in section 0. The outcomes of this laboratory work are presented in Table 12.

Table 12 Potential acidity concentrations vs depth

<table>
<tr><th rowspan="2">Depth (m)</th><th colspan="17">Potential Acidity (%S)</th></tr>
<tr><th>BH01</th><th>BH02</th><th>BH03</th><th>BH04</th><th>BH05</th><th>BH06</th><th>BH07</th><th>BH08</th><th>BH09</th><th>BH10</th><th>BH11</th><th>BH12</th><th>BH14</th><th>BH15</th><th>BH16</th><th>BH17</th><th>BH18</th></tr>
<tr><td>0.00</td><td rowspan="4">0.03</td><td rowspan="8">0.03</td><td rowspan="8">0.02</td><td rowspan="12">0.02</td><td rowspan="4">0.09</td><td rowspan="4">0.12</td><td rowspan="8">0.07</td><td rowspan="3">0.02</td><td rowspan="15">0.17</td><td rowspan="4">0.02</td><td rowspan="6">0.01</td><td rowspan="10">0.02</td><td rowspan="3">0.11</td><td rowspan="4">0.08</td><td rowspan="2">0.06</td><td rowspan="2">0.03</td><td rowspan="4">0.08</td></tr>
<tr><td>0.05</td></tr>
<tr><td>0.10</td><td rowspan="8">0.04</td><td rowspan="12">0.01</td></tr>
<tr><td>0.15</td><td rowspan="5">0.09</td><td rowspan="11">2.11</td></tr>
<tr><td>0.20</td><td rowspan="4">0.02</td><td rowspan="4">0.04</td><td rowspan="4">0.14</td><td rowspan="8">0.04</td><td rowspan="6">1.47</td><td rowspan="12">10.39</td></tr>
<tr><td>0.25</td></tr>
<tr><td>0.30</td><td rowspan="14">0.01</td></tr>
<tr><td>0.35</td></tr>
<tr><td>0.40</td><td rowspan="6">0.02</td><td rowspan="8">0.03</td><td rowspan="8">0.02</td><td rowspan="4">0.06</td><td rowspan="2">0.07</td><td rowspan="9">0.63</td><td rowspan="12">3.04</td></tr>
<tr><td>0.45</td></tr>
<tr><td>0.50</td><td rowspan="10">0.10</td><td rowspan="10">0.10</td><td rowspan="10">3.45</td><td rowspan="10">0.01</td></tr>
<tr><td>0.55</td></tr>
<tr><td>0.60</td><td rowspan="4">0.52</td><td rowspan="8">0.30</td><td rowspan="8">0.10</td></tr>
<tr><td>0.65</td></tr>
<tr><td>0.70</td><td rowspan="6">0.44</td><td rowspan="6">0.38</td><td rowspan="6">0.00</td></tr>
<tr><td>0.75</td><td rowspan="5">0.04</td></tr>
<tr><td>0.80</td><td rowspan="4">0.11</td><td rowspan="4">0.03</td><td rowspan="4">6.79</td><td rowspan="4">11.99</td></tr>
<tr><td>0.85</td><td rowspan="3">3.17</td></tr>
<tr><td>0.90</td></tr>
<tr><td>0.95</td></tr>
</table>

<table>
<tr><th rowspan="2">Depth (m)</th><th colspan="17">Potential Acidity (%S)</th></tr>
<tr><th>BH01</th><th>BH02</th><th>BH03</th><th>BH04</th><th>BH05</th><th>BH06</th><th>BH07</th><th>BH08</th><th>BH09</th><th>BH10</th><th>BH11</th><th>BH12</th><th>BH14</th><th>BH15</th><th>BH16</th><th>BH17</th><th>BH18</th></tr>
<tr><td>1.00</td><td rowspan="10">2.71</td><td rowspan="4"></td><td rowspan="4"></td><td rowspan="10"></td><td rowspan="10">0.30</td><td rowspan="10">0.80</td><td rowspan="10"></td><td rowspan="10">17.55</td><td rowspan="4"></td><td rowspan="10"></td><td rowspan="10">0.09</td><td rowspan="4"></td><td rowspan="10">11.76</td><td rowspan="10">13.31</td><td rowspan="10">0.00</td><td rowspan="7"></td><td rowspan="4"></td></tr>
<tr><td>1.05</td></tr>
<tr><td>1.10</td></tr>
<tr><td>1.15</td></tr>
<tr><td>1.20</td><td rowspan="8">0.89</td><td rowspan="8">0.03</td><td rowspan="6">0.03</td><td rowspan="8">1.12</td><td rowspan="8">19.92</td></tr>
<tr><td>1.25</td></tr>
<tr><td>1.30</td></tr>
<tr><td>1.35</td><td rowspan="5">0.00</td></tr>
<tr><td>1.40</td></tr>
<tr><td>1.45</td></tr>
<tr><td>1.50</td><td rowspan="11">0.47</td><td rowspan="11">15.70</td><td rowspan="11">2.88</td><td rowspan="11">2.85</td><td rowspan="11">3.98</td><td rowspan="11">0.18</td><td rowspan="6">0.78</td><td rowspan="11">0.16</td><td rowspan="6">2.51</td><td rowspan="11">0.70</td><td rowspan="11">20.77</td><td rowspan="11">0.00</td></tr>
<tr><td>1.55</td></tr>
<tr><td>1.60</td><td rowspan="9">0.96</td><td rowspan="9">0.46</td><td rowspan="9">1.33</td><td rowspan="9">0.01</td><td rowspan="9">0.82</td></tr>
<tr><td>1.65</td></tr>
<tr><td>1.70</td></tr>
<tr><td>1.75</td></tr>
<tr><td>1.80</td><td rowspan="5">5.73</td><td rowspan="5">2.16</td></tr>
<tr><td>1.85</td></tr>
<tr><td>1.90</td></tr>
<tr><td>1.95</td></tr>
<tr><td>2.00</td></tr>
</table>

Note: The cells have been colour coded as follows:

<0.03 %S
0.03-0.3 %S
>0.3 %S

Overall, the oxidation of the naturally occurring acid sulfate soils contained within Big Swamp has led to the generation of significant acidity. As reported in the hydro-geochemical modelling report (Barwon Water, 2021b), the mass of acidity within the swamp can be broken down into three key sources:

- Soil acidity that is estimated at 3,900 tonnes $CaCO_3$ equivalent;
- Groundwater acidity that is estimated at 126 tonnes of $CaCO_3$ equivalent, and
- Pore water acidity that is estimated at 11 tonnes $CaCO_3$ equivalent.

It is noted that given the natural occurrence and distribution of these acid sulfate soils, evidence of historic acidic conditions (as indicated by La Trobe, 2023), and the improvement in ecological conditions since worst case conditions, treatment of these soils is not considered to be practicable. Therefore, in accordance with the EPA Victoria (2009) hierarchy for management, the adopted remedial strategy focuses on minimising any further disturbance and/or oxidation.

As such, the water level targets that have been set as part of the Boundary Creek and Big Swamp Remediation Plan (section A4) are based on the potential acidity results presented in Table 12, and aim to maintain water levels above the 1 %S horizon, where this can be achieved. It is noted that water level targets below the 1 %S horizon will still minimise the amount of acidity that can be generated due to this assisting to maintain moisture in the overlying soils. Noting that the final groundwater level targets also factor in the maintenance of soil moisture due to capillary fringe processes.

It is also noted that the existing acidity is expected to reduce over time as these are gradually flushed from the system as water levels/moisture recover, thus, reducing the net acidity loads within the swamp. This is supported by sampling work undertaken in 2023 that indicated actual acidity reductions of 43, 28 and 31 % in the Eastern, Central and Western portions of the swamp respectively when compared to the 2019 results.

B2.8 Surface water flows and quality

Streamflow gauging along Boundary Creek has occurred since 1979, albeit in some cases intermittently due to the removal and re-instatement of select gauging stations, with the number of analytes monitored and gauging stations increasing over time. Today, the Boundary Creek surface water monitoring network comprises six (6) stream gauges. A summary of their individual monitoring record is provided in Table 13 below.

Table 13 Status of surface water flow gauges on Boundary Creek

Gauge	Description	Parameters	Record length
233273	Boundary Creek at Barongarook	Flow, water level, temperature, EC	June 2014 to present
233231	Boundary Creek Upstream McDonald's Dam	Flow, water level	December 1989 to February 1994 and June 2014 to present
		Temperature, EC	June 2014 to present

Gauge	Description	Parameters	Record length
233229	Boundary Creek Downstream Macdonald's Dam	Flow, water level	December 1989 to February 1994 and June 2014 to present
		Temperature, EC, pH	June 2014 to present
233275	Boundary Creek Upstream Big Swamp	Flow, water level, pH, temperature, EC	June 2019 to present
		Analytical data	August 2019 to present
233276	Boundary Creek Downstream Big Swamp	Flow, water level, pH, EC	June 2019 to present
		Humidity, air temperature, wind direction, wind velocity, barometric pressure, solar radiation intensity	August 2019 to present
		Analytical data	August 2019 to present
233228	Boundary Creek at Yeodene	Mean daily flow	June 1979 to March 1985
		Flow, water level, spot pH data	March 1985 to present
		Temperature, EC, pH	June 2014 to present
		Analytical data	August 2019 to present

Works to date have confirmed that the historical management of groundwater pumping activities at the Barwon Downs borefield was the primary cause in the reduction of groundwater contribution to Reach 2 of Boundary Creek. This reduction, in conjunction with the changes in land use, Millennium Drought, and the complexities associated with management and regulation of a private on-stream dam that controls flow into the lower reaches of Boundary Creek, resulted in the increased frequency and duration of 'cease to flow' and 'acid flush' events along Boundary Creek and Big Swamp. This was despite meeting the provisions set out in the groundwater extraction licence(s) that were intended to offset the potential impacts from Barwon Water's groundwater pumping activities on Boundary Creek. This drying subsequently resulted in the enhanced oxidation of naturally occurring acid sulfate soils and discharge of acidity and metals that has impacted the condition and function of the lower reaches of Boundary Creek and Big Swamp.

A summary of the surface water flow and quality statistics prior to the identification of groundwater pumping related impacts, worst case conditions and current conditions are shown in Table 14.

Table 14 Boundary Creek surface water quality and quality statistics

Site	Measure	Prior to environmentally significant adverse impacts (pre-1990)		During worst case groundwater conditions (2010 – 2019)			Current (2020 – 2022)		
		Flow (ML/day)	pH	Flow (ML/day)	pH	EC (µS/cm)	Flow (ML/day)	pH	EC (µS/cm)
233275	Min	-	-	0.2	5.9	380	0	5.3	163
	25th Percentile	-	-	1.8	6.5	435	1.0	6.4	348
	50th Percentile	-	-	5.7	6.8	470	2.4	6.8	394
	75th Percentile	-	-	13.3	7.0	500	8.7	7.1	439
	Max	-	-	41.6	7.7	575	63.6	7.8	658
	Average	-	-	8.7	6.8	467	6.9	6.7	394
233276	Min	-	-	0.1	3.3	321	0	3.2	218
	25th Percentile	-	-	1.5	3.5	538	0.8	4.2	413
	50th Percentile	-	-	5	3.6	662	2.6	5.4	537
	75th Percentile	-	-	11	3.7	828	9.0	5.9	689
	Max	-	-	64	4.4	1012	92.5	7.2	1361
	Average	-	-	8.5	3.6	680	8.1	5.1	592
233228	Min	0.0	4.7	0.0	2.8	222	0.0	2.7	86
	25th Percentile	1.8	6.1	0.0	3.5	676	1.2	3.9	512
	50th Percentile	4	6.5	1.1	3.7	799	4.6	4.5	638
	75th Percentile	12.3	6.7	5.8	3.9	979	11.1	5.4	780
	Max	340.3	7.8	484.3	6.9	3199	258.6	6.5	1829
	Average	11.2	6.4	6.8	3.8	876	11.9	4.7	651

As shown in Figure 28, the relative difference in streamflow's between the various stream gauges is highly variable, with Boundary Creek at Yeodene (station 233228) recording the highest monthly average flow. This is due to station 233228 being situated within a topographic low that receives surface water inflow (that includes a component of groundwater discharge from the Lower Tertiary Aquifer), stormwater runoff and to some degree groundwater discharge from the Upper Aquifer system. This is supported by the significantly reduced streamflows at this location during dryer periods (i.e., when additional inputs are minimal).

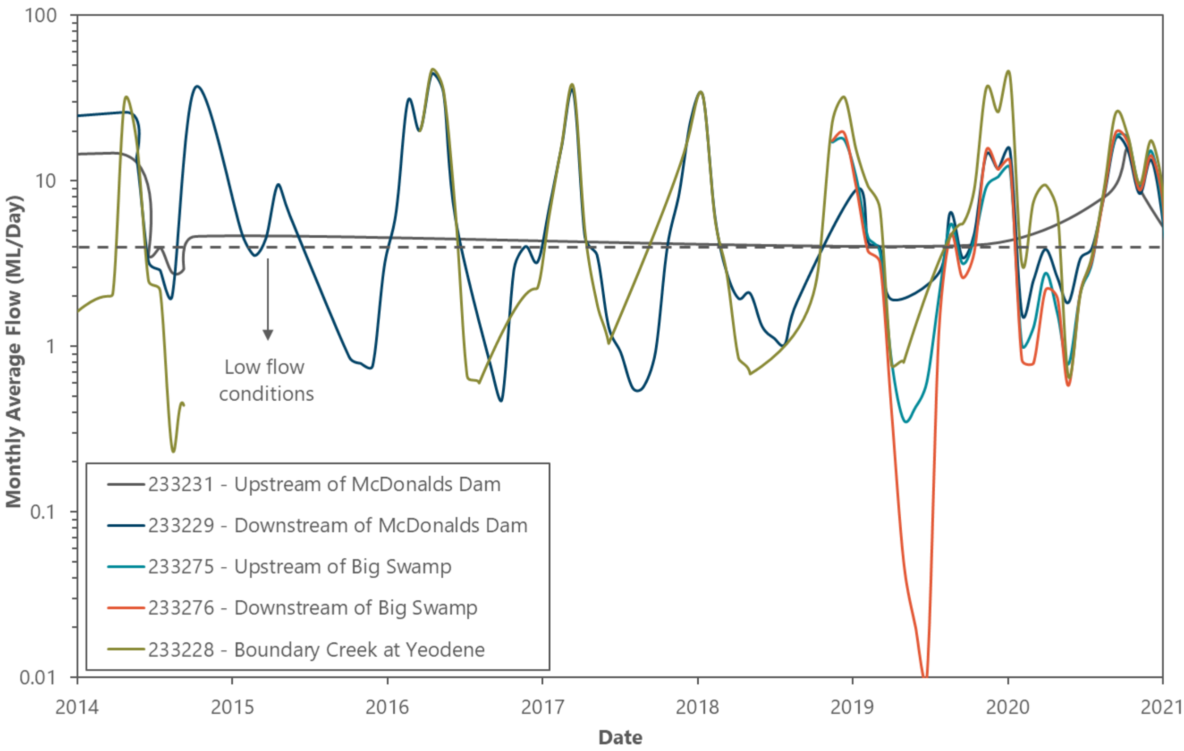

Figure 28 Boundary Creek monthly average flow data between 2014 and 2021 (Data obtained from DELWP, 2022)

The real-time monitoring and analytical data are also reviewed and summarized as part of the annual reporting process.

B2.9 Geochemistry

Geochemical laboratory analysis of sediments collected from Big Swamp has been undertaken by Cook & Wong (2020) of Monash University. In this work, the acid sulfate soils were subject to a variety of treatments to assess the dominant hydro-geochemical processes occurring within the swamp and how these might respond to different remedial actions.

In this work, initial static testing was undertaken to characterise the soils and analyse for acid sulfate soil indicators in accordance with Sullivan et al. (2018). The 5 soil categories were as follows:

- Soil 1 - Deep reduced, medium organic carbon (OC, most common) - medium pH (~4), high net acidity, ~20% OC;
- Soil 2 - Deep reduced, low OC - medium pH, %OC <5%, low net acidity;
- Soil 3 - Burned surface - Red soil, %OC variable (<10%), low net acidity;
- Soil 4 - Surface oxidised medium OC - Very low pH (~2), 20%OC; and

- Soil 5 - Surface oxidised high OC - Very low pH (~2), 40-50% OC.

The results of this work revealed that while the data was quite heterogeneous, the results are consistent with previous interpretations, i.e., that the highest actual acidity occurs in the surface sediments, with soil categories reporting average actual acidity concentrations between 100 and 830 mol H+/t (Table 16). The data also revealed that there is a large store of potential acidity contained within the soil profile, reporting average potential acidity concentrations between 34 and 3,500 mol H+/t, which can lead to further acidification if these acid sulfate soils are not managed appropriately.

Table 15 Summary of key geochemical characteristics of different soil types (Cook and Wong, 2020)

Soil ID	Organic Carbon		pH		Potential Acidity		Actual Acidity	
	%	St dev	pH Units	St dev	mol H^{+}/t	St dev	mol H^{+}/t	St dev
Soil 1	22	6	4.1	0.2	3300	2700	220	100
Soil 2	2	1.5	4.1	0.3	61	100	100	70
Soil 3	4	2.5	4.3	0.5	34	36	160	80
Soil 4	22	5.1	2.8	0.1	1300	1800	830	360
Soil 5	44	7.4	2.8	0.4	3500	3800	490	230

Samples from these various soil categories were then selected for incubation trials to assess potential soil treatments to neutralize this acidity. The incubation trials were conducted in 160 ml serum vials that were purged with Argon gas to simulate the anoxic conditions that would occur upon inundating the swamp. Each of the samples was then sacrificed in a time series of 1, 2, 4, 8, 16, 32, 64, 128 and 200 days, with the overlying water and headspace being sampled at each point.

The results from this testing revealed the unsaturated sediments had the potential to undertake iron reduction following inundation, with estimates suggesting this would be sufficient to neutralise the local actual acidity concentrations within 1-2 years. It was noted however, that this reaction still produces mobile potential acidity in the form of dissolved iron, which would then generate acidity upon contact with oxygen and that the longer-term immobilisation of acidity would require sulfate reduction reactions to take place. Given the sulfate concentrations, the chances of this occurring in the short-medium term are slim.

In conjunction with the above laboratory test work, a series of geochemical models were run using the thermodynamic equilibrium model (MINTEQ), to assess the geochemical processes occurring within the swamp and how these might change over time and with the implementation of management strategies (GHD, 2019). The findings from this work suggested that the oxidation of pyrite minerals were the primary acid source minerals, and that the oxidation of reduced Fe^{2+} as forecast by the incubation experiments, was not occurring at this time. However, more recent sampling from the swamps upper aquifer system suggests that iron reduction processes may be occurring when conditions are suitable (Barwon Water, 2022c).

Based on the findings of this work, the major hydro-geochemical and acid generating processes occurring within Big Swamp and Boundary Creek can be summarised by Figure 29 below. Noting that this does not include the iron reduction processes that may also be occurring when conditions are suitable.

It further shows that the infiltration and reduction of iron from Fe^{3+} to Fe^{2+} upon inundation or infiltration into the groundwater system may remove acidity from the system, however upon subsequent discharge, this may re-oxidise and lead to secondary acidification further downstream of the swamp. The re-oxidation of Fe^{2+} may however be limited if residence times under reducing conditions are sufficient to result in adsorption within the sediment profile.

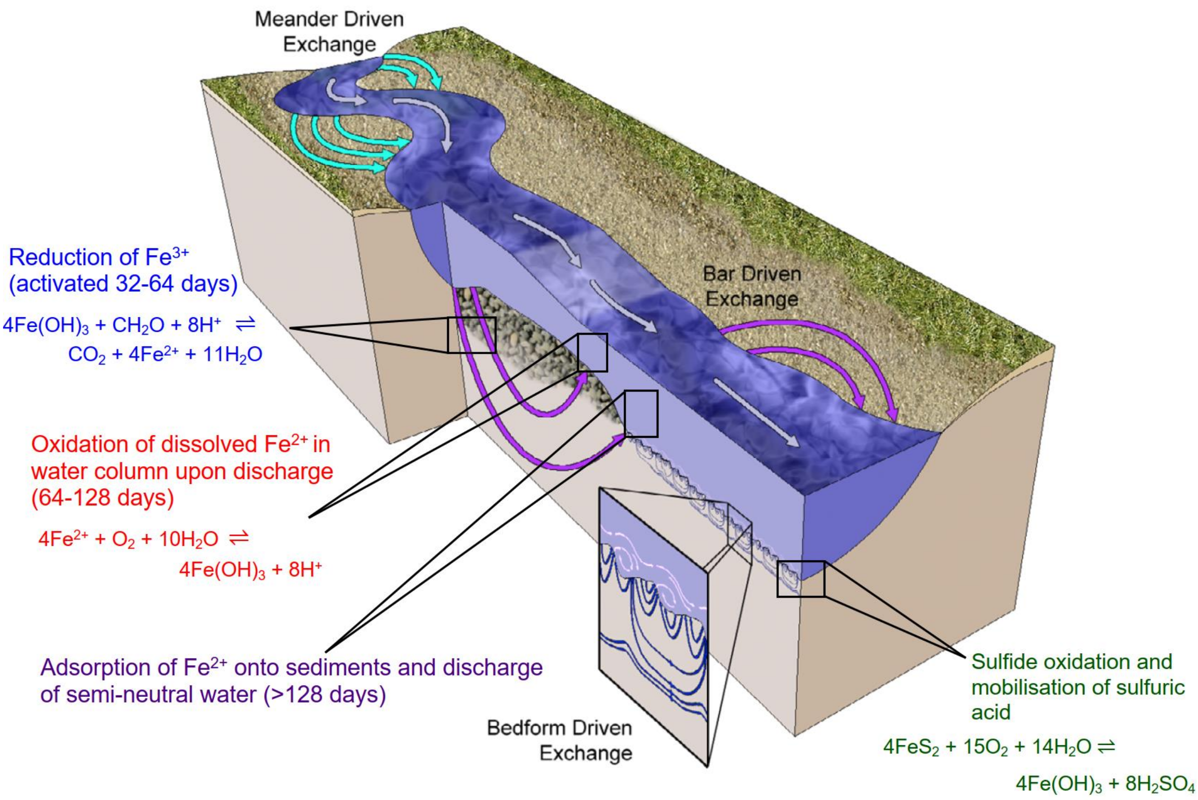

Figure 29: Major hydro-geochemical and acid generating processes occurring within Big Swamp (adapted from Stonedahl et al, 2010)

B2.10 Ecological condition of Big Swamp

B2.10.1 Vegetation community

In 2019 Eco Logical Australia (ELA) were engaged by Barwon Water to undertake a vegetation assessment of Big Swamp (Eco Logical, 2019). The outcomes of this work determined that historically the swamp is likely to have supported a diverse wetland ecosystem comprised of four distinct vegetation associations:

1. A low scrub community through the central and northern sections of the swamp plain which was likely to have been an association of the Riparian Fern Scrub vegetation community. It would have been tolerant of frequent or prolonged inundation and saturated soil conditions. As a result, sedges and rushes were likely to have been dominant in the understory.

2. A tall scrub at the western end of the swamp plain and fringing the swamp plain. This is likely to have been an association of the Riparian Fern Scrub vegetation community which is differentiated from the above community due to less frequent or less prolonged periods of inundation and moist rather than saturated soil conditions. It is likely that ferns were dominant throughout this association.

3. A highly variable, low riparian woodland along the main channels around the northern edge and eastern parts of the swamp. Swamp Gum is likely to have been the dominant canopy species, however the community would have included other Eucalypts tolerant of wet conditions as well as a high diversity of understory shrubs, ferns, sedges, rushes and herbs.

4. A damp woodland fringing the swamp plain and areas of riparian woodland, primarily along the southern edge and across much of the eastern third of the swamp outside the influence of existing channels. This varied woodland would have supported a range of tall Eucalypts as co-dominants in an open canopy, over a dense understory tree / shrub layer.

In addition to the dominant associations listed above, ELA (2019) reported that there would have also been small pockets of unique vegetation communities throughout the swamp that persisted due to a combination of local conditions. An example of this is a small patch of Wet Verge Sedgeland which was identified at the western end of the swamp during their recent field surveys.

ELA (2019) also noted that from as early as the 1800s, the swamp has been affected by changing land and water use as vegetation clearance and agricultural practices expanded across the region. This activity has continued to the current day, with the extraction of groundwater from the Lower Tertiary Aquifer, reductions in surface water flows into the swamp and fires within the swamp serving as additional pressures on the system.

These cumulative effects have resulted in significant changes to vegetation over the past 20 years, including almost complete loss of vegetation cover across the swamp due to fire, substantially altering the structure of the vegetation communities throughout. Subsequent declines in soil structure appears to have also resulted in increased erosion of the swamp plain which may have been driven by large, seasonal surface flow events concentrating flows into a primary channel that now bisects the swamp plain.

Whilst there is likely to have been a gradual shift in community structure and composition since European settlement, and even prior due to decadal shifts in climate, ELA's assessment is that the last 30 years has seen significant changes to the vegetation of the Swamp.

During this assessment, the post-pumping vegetation communities following a period of recovery were identified as follows to help monitor the continued recovery and the condition and function of the swamp during remediation (refer Figure 30):

- **Riparian Fern Scrub (EVC A120)** was recorded throughout much of the swamp plain in the western and central sections of the Swamp. The majority of the EVC has been significantly modified by fire resulting in the loss of much of the original ground layer vegetation. The most heavily affected areas are now dominated by Prickly Tea-tree (Leptospermum continentale) or Scented Paperbark (Melaleuca squarrosa) with occasional patches of Austral Bracken (Pteridium esculentum) and/or Red-fruit Saw-sedge (Gahnia sieberiana). More intact patches occur in the far west of the study area in areas apparently less affected by fire, supporting a diverse ground layer dominated by various sedges such as Tall Sedge (Carex appressa) and Tassel Sedge (Carex fascicularis). Areas closer to the main channel in the north of the site contained a braided system of channels and supported a higher cover of sedges and ferns, including additional species such as Spreading Rope-rush (Empodisma minus) and Scrambling Coral-fern (Gleichenia microphylla);

- **Swampy Riparian Woodland (EVC 83)** was recorded along the main channel and adjacent terraces of Boundary Creek and shared a broad ecotone with the adjacent Riparian Fern Scrub. This vegetation contained a scattered tree layer, dominated by Swamp Gum (Eucalyptus ovata), Brooker's Gum (Eucalyptus brookeriana) and Manna Gum (Eucalyptus viminalis), often over a secondary tree layer. In elevated sections with limited inundation a variety of ground, scrambling and tree ferns were common. The creek channel supported a range of aquatic and semi-aquatic forbs and sedges;
- **Wet Verge Sedgeland (EVC 932)** was recorded at the western end of the swamp in a small patch adjacent to the main channel. The patch shared floristic affinities with the adjacent Riparian Fern Scrub, but woody species were mostly absent, and the vegetation was dominated by relatively dense Tall Sedge and Tassel Sedge. Associated species included White Purselane (Montia australasica), Common Spike-sedge (Eleocharis acuta), Rushes (Juncus spp.) and Slender Knotweed (Persicaria decipiens);
- **Damp Sands Herb-rich Woodland (EVC 3)** was recorded on the lower slopes to the south and east of the swamp plain. This community was dominated by young Swamp Gum with a very species-poor understorey containing Austral Bracken and Red-fruit Saw-sedge. Whilst this community has been described as Damp Sands Herb-rich Woodland due to its current structural and floristic characteristics (which is likely a result of recent fires and changes in hydrology), this vegetation is considered to represent a derived state of the Swamp Gum (Eucalyptus ovata) Forest described by Carr and Muir (1994), and
- **Lowland Forest (EVC 16)** was recorded on the slopes surrounding Big Swamp, upslope from areas historically effected by waterlogging or inundation. This floristically diverse community was dominated by Messmate Stringybark (Eucalyptus obliqua) and Manna Gum with a high cover of Austral Bracken. Prominent shrubs included Silver Banksia (Banksia marginata), Prickly Moses (Acacia verticillata) and Sweet Bursaria (Bursaria spinosa).

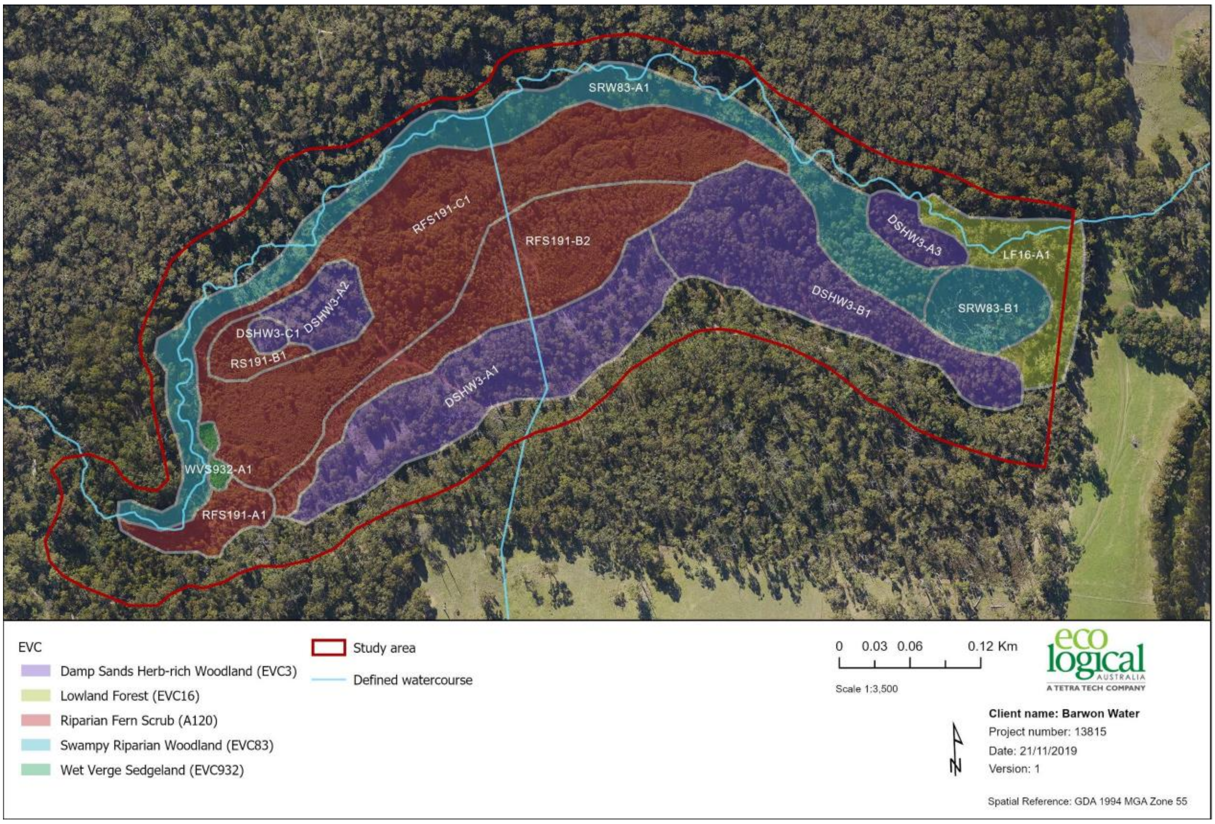

Figure 30 Baseline vegetation communities observed in Big Swamp (ELA 2019)

Further information regarding the historic relationship between water and vegetation, the hydrological conditions required to support these species and additional information used to inform the remediation plan can be found in the ELA report provided on the Your Say website located here: https://www.yoursay.barwonwater.vic.gov.au/boundary-creek

B2.10.2 Macroinvertebrate community

Since 2019, macroinvertebrate sampling along Boundary Creek and the Barwon River have been undertaken biannually in autumn and spring to provide an overview of the ecological condition of Boundary Creek and the upper Barwon River and the impact, if any, of Boundary Creek and Big Swamp on the Barwon River.

The findings to date indicate that whilst the water quality and macroinvertebrate communities within the lower reaches of Boundary Creek are still being impacted by Big Swamp, these are of very limited downstream effect given the water quality and macroinvertebrate communities within the Barwon River is in very good condition at a number of sites downstream of the Boundary Creek confluence.

Further to this, additional work undertaken in 2022 indicates that 'Boundary Creek is in very good condition upstream of Big Swamp and appears to be in a good position to provide recolonization via drift or aerial dispersal to the downstream wetlands and waterways provided water quality can be improved' (Austral Research and Consulting, 2022). This is also supported by the improvements in macroinvertebrate communities downstream of Big Swamp over the past three years.

These reports can be found on the Your Say website located here: https://www.yoursay.barwonwater.vic.gov.au/boundary-creek

B2.10.3 Site-specific ecological values

As part of the Ecological Risk Assessment completed by Nation Partners in 2023, the relevant ecological values for Big Swamp, Boundary Creek (Reach 2c and 3) and the Barwon River (downstream of the Boundary Creek confluence) based on the stressor characteristics, ecosystem and receptor characteristics, management goals, stakeholder input and policies or precedents were considered to be:

1. Natural soil saturation within Big Swamp is supported such that species diversity and abundance of swamp vegetation communities are able to be sustained, and
2. Natural water quality within Boundary Creek (Reach 2c and 3) is supported such that abundance and diversity of aquatic communities (including those within receiving environments (e.g., the Barwon River)) are not impacted.

Refer to the ERA located on the Your Say website for further information:
https://www.yoursay.barwonwater.vic.gov.au/boundary-creek

B2.10.4 Ecological Risk Assessment

The Ecological Risk Assessment completed by Nation Partners in 2023 reports '*The presence of increased acidity and metals concentrations in surface water discharging from Big Swamp into Boundary Creek are considered to be posing a high risk to ecological receptors in Reach 2c and Reach 3. However, the available data indicates that the presence of metals and acidity in water discharging from Boundary Creek into Barwon River is not increasing the risk profile of the Barwon River. The presence of metals in the Barwon River catchment is resulting in a moderate risk based on screening against guideline values, however the biological indicators in the Barwon River indicate a minor risk. These risk outcomes are the same for sample locations both upstream and downstream of the Boundary Creek confluence.*'

This report also outlines that these risk outcomes need to be considered in the context of the significant stressors that remain within the catchment, and that ecological impacts resulting from groundwater pumping cannot be uncoupled from the impacts from other stressors (Nation Partners, 2023)

Refer to the ERA located on the Your Say website for further information:
https://www.yoursay.barwonwater.vic.gov.au/boundary-creek

B3 Clause 2.5b: An outline and risk assessment of the processes/activities on the Property which may impact on Boundary Creek, Big Swamp and the surrounding environment (including, but not limited to hydrogeology, hydrology and soil chemistry)

In 2018, Barwon Water conducted a risk assessment to determine the potential impacts and risks from future operation of the Barwon Downs borefield (Jacobs, 2018e) to inform Barwon Water's groundwater licence renewal application. The outcomes of this work revealed that groundwater levels within the Lower Tertiary Aquifer will be lower than pre-pumping levels as long as the borefield is operational and that a range of triggers/actions would need to be in place to manage the potential risks from future operation of the borefield. This meant that the ability to extract groundwater for urban water supplies was dependent on whether groundwater levels were above the trigger levels and therefore this could not be sufficiently relied upon to supplement urban water supplies in times of need.

Based on this and the environmentally significant adverse impacts that had already occurred within Reach 2 and 3 of Boundary Creek, in 2019 Barwon Water withdrew our application to extend the groundwater extraction licence and has since ruled out the use of the Barwon Downs borefield as a source of urban water supply in our Water for our Future Strategy - our next Urban Water Strategy. In addition to this, Barwon Water has also committed to preparing and implementing a decommissioning plan for the Barwon Downs borefield production bores which has been included as an action in our 2023-2028 price submission.

Because of this, there can be no further impacts from Barwon Water's groundwater pumping activities at the Barwon Downs borefield with groundwater levels within the central portion of the graben recording substantial recovery and the return of artesian conditions since the cessation of groundwater pumping activities in 2016. It is noted that potential risks associated with remedial actions and/or contingency measures may exist. These were considered as part of the Remediation Options Assessment (refer to Section B4) and will continue to be considered as part of the design of contingency measures and the adaptive management approach.

B4 Clause 2.5c: A range of controls and actions that could be practicably carried out to protect and improve the condition of Boundary Creek and Big Swamp and the surrounding environment, including reasonable targets and/or measures of success to be adopted for the purposes of the implementation of the Plan

This section details the results of a Remediation Options Assessment (ROA) that was undertaken to identify what controls and actions could be practicably carried out to address the identified environmentally significant adverse impacts caused by the historic management of groundwater pumping activities at the Barwon Downs borefield.

The adopted remediation options assessment framework (Figure 31) was informed by the nationally recognised 12-step stream rehabilitation planning process developed by the Cooperative Research Centre for Catchment Hydrology that provides guidance on how to conduct a stream rehabilitation – or in this case – a remediation project (LWRRDC & CRCCH, 2000), and included the following engagement and consultation activities:

- Engagement with the Remediation Working Group and their nominated technical experts via quarterly reference group meeting;
- Liaison with Southern Rural Water and their independent technical review panel;
- Completion of a technical workshop with members from the community and stakeholder group, two of their appointed technical experts, technical specialists and a range of consultants providing advice on surface water, groundwater, ecology, geochemistry and remediation, and
- Completion of further technical discussions with Southern Rural Water and their independent technical review panel.

It is noted that in line with the adaptive management approach, the remedial strategy will continue to be adapted based on the additional knowledge and understanding gained since the implementation of the REPP.

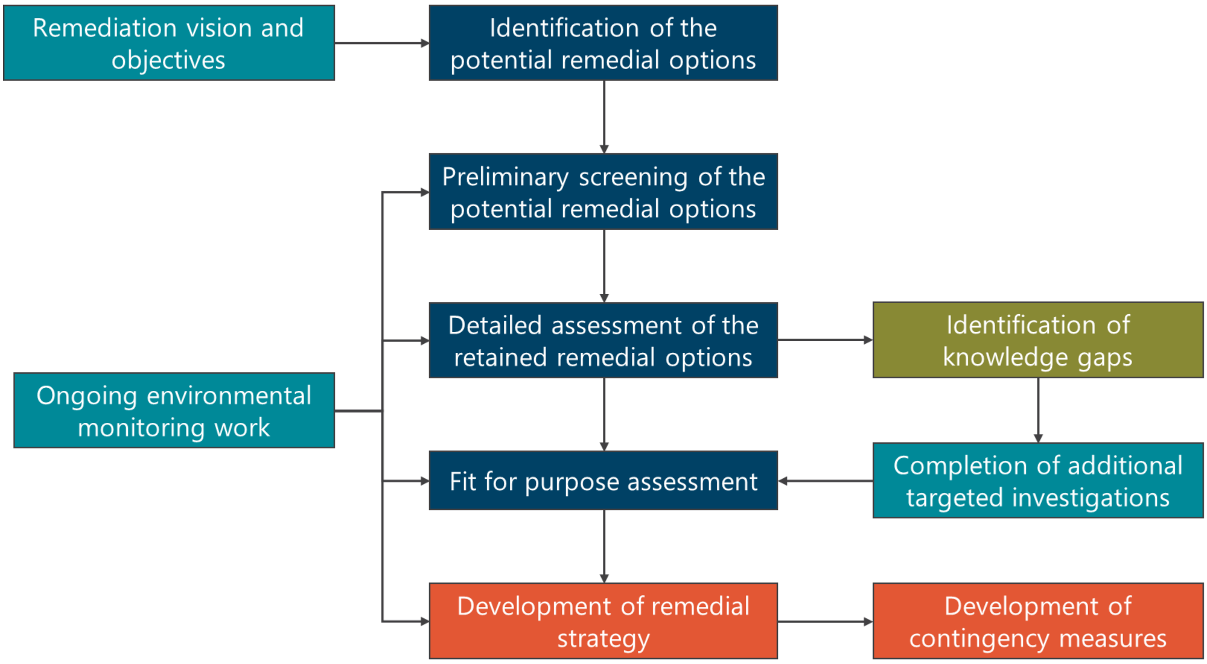

Figure 31 Remediation options assessment framework

B4.1 Identification of the potential remedial options

An initial review of the potential remedial options was completed as part of the Yeodene Swamp Study (Jacobs, 2018a). This was later expanded on as part of the Remediation Options Assessment that was completed in 2019 (CDM Smith, 2019) and continues to be revisited, where required, to account for further discussion and feedback from the community and stakeholder Remediation Reference Group, Southern Rural Water and the Independent Technical Review Panel (ITRP).

The outcomes of this work identified 18 potential remedial options for further assessment as part of the preliminary screening process. These are discussed in greater detail below.

B4.2 Preliminary screening of the potential remedial options

The preliminary screening of the potential remedial options involved a qualitative assessment process that was undertaken to refine the number of potential remediation options and restrict more detailed and site-specific assessment to those that may be applicable to the site.

Table 16 presents a summary of the 18 remediation options identified for preliminary screening and provides the following information:

- The underlying principle of the remediation option;
- A high-level description of possible implementation at the site;
- Advantages and disadvantages of the remediation option, and
- A discussion on key issues related to implementation including technical, logistical and regulatory/community considerations.

Table 16 Preliminary assessment of the identified potential remedial options (adapted from Jacobs, 2018a, CDM Smith 2019, CDM Smith 2022 and Earth Systems 2022)

ID	Technology	Principle	Site Implementation	Advantages	Disadvantages	Key Issues
O1	Monitored Natural Attenuation	Limit further intervention	This is a slightly modified version of the original 'do nothing' option presented in the Yeodene Swamp Study (Jacobs, 2018). During the first technical workshop, it was agreed that a true 'do nothing' approach should reflect historical conditions and management practises at the site, which include the following: • Supplementary flow not passed entirely at McDonalds Dam • Continued presence of existing drainage channels across Big Swamp • Water users along Reach 3 of Boundary Creek unable to access water allocation during periods of 'no flow' Unlikely recovery of groundwater levels in the LTA aquifer to pre-pumping conditions in the short term (i.e., 5 years)	• Lowest financial cost	• High socio-environmental cost • Relies on natural recovery processes, which may take time (i.e., many years)	• Does not satisfy notice requirements
O2	Water retention / flow enhancement	Limit further intervention Prevent (further) oxidation of acid sulfate soils	This option focuses on minimising further oxidation of acid sulfate soils by: • The cessation of groundwater pumping activities at the Barwon Downs borefield to facilitate groundwater level recovery • The use of supplementary flows, where required, to minimise wet-dry cycling and offset the groundwater pumping-related impacts as was intended by the previous extraction licence conditions • Preventing water diversion and/or drainage from the swamp • Construction of a water pipeline to provide water to existing users along Reach 3 of Boundary Creek (note this has already been completed)	• Low financial cost • Removes the cause of the impacts (i.e., groundwater extraction) • Provides an alternative water source for those with existing water rights • Provides a buffer to ongoing climatic stressors • Promotes natural recovery processes	• High socio-environmental cost • Improvements may take time (i.e., many years) • Does not address the metal and acidity issues	• It is unlikely that these measures alone will meet all of the project objectives • This option focuses on removing key stressors and enhancing the systems natural ability to rebound
O3	Direct treatment of soils with neutralising agents (wetland liming)	Treatment to neutralise acidity (soil and water)	This option envisages spreading of agricultural lime (or other suitable neutralising agent) over all or a part of Big Swamp to neutralise acidity of the upper soil profile as wells as increasing pH and alkalinity of the water leaving Big Swamp and discharging into Boundary Creek. Once the areas requiring treatment and the treatment rate (expressed as mass of neutralising agent per unit area) have been evaluated, a variety of implementation methods are possible, including terrestrial applications and aerial methods.	• Effective duration longer compared to in-stream liming methods; in some cases, effects last 10 to 20 years • Lower amount of aluminium is exported to streams. May have less aluminium precipitate on stream bottom compared to other stream liming methods	• Clearing of vegetation for construction of access tracks in case of terrestrial application over the entire swamp area • Impacts of the neutralising agent on the terrestrial and aquatic ecosystems affected by the treatment • Grain diameter of the neutralising agent must be evaluated to minimise potential for downstream transport during high rainfall events, which may cause uneven coverage of the treatment area	• Terrestrial applications (i.e., using truck mounted equipment, pressure hose for slurry applications or manual spreading) are likely to be challenging because of access constraints and soft consistency of the soil across Big Swamp • Aerial application by helicopter is likely to overcome some of the logistical constraints related to terrestrial applications, however, will incur increased costs

ID	Technology	Principle	Site Implementation	Advantages	Disadvantages	Key Issues
					• Metal precipitation in Boundary Creek associated with increased surface water pH.	• This technology is generally more effective when application of the neutralising agent is targeted at water discharge areas (i.e., areas of high groundwater levels during periods of high rainfall) compared to uniform application over the entire swamp area • Requires less frequent application • Because dissolution and penetration of the neutralising agent is associated with rainfall (amongst other factors), this method is generally less suitable for dry and severely acidified environments
O4	Oxic (aerobic) limestone drain (OLD)	Treatment to neutralise acidity (water)	This option involves the construction of an open drain channel filled with limestone (or other suitable material) downstream of Big Swamp to improve the quality of Boundary Creek water (i.e., increase pH/alkalinity and decrease dissolved metals concentration). Key design parameters of OLDs are mass and size of the limestone aggregate, slope of the drain and water residence time (in the range of several hours). The slope of the drain is inversely proportional to residence time, however higher slopes increase OLDs' efficiencies by limiting the potential for metal precipitation on the surface of the aggregate (armouring). Armouring reduces limestone pore space and surface area, decreasing the limestone dissolution rate and acid neutralising capacity.	• Low cost • Simple implementation	• Armouring of the alkaline materials caused by metal precipitation has the potential to be detrimental to the efficiency and longevity of the limestone drain • Ongoing maintenance is required to ensure treatment efficiency is maintained over time • Depending on the quality (i.e., pH, metal and anion/cation concentrations) of the water leaving the OLD, a settling pond may be required to collect precipitates prior to discharge	• Construction of an OLD (and potentially settling pond) with adequate slope and residence time to treat Boundary Creek water is likely to impact on the following: – Hydrological and hydrogeological regime of Boundary Creek (Reach 2/Reach 3) and Big Swamp. – Amenity and natural environment of Big Swamp and Reach 3 of Boundary Creek.
O5	Dilution of acidic discharge	Dilution of existing acidity (water)	This option involves the provision and release of additional water volumes to improve water quality in Boundary Creek. Implementation of this option will require construction of dedicated infrastructure and identification of a sustainable water source that can supply water into the future (this option does not address generation of acidity in Big Swamp, which will continue). The Yeodene Swamp Study (Jacobs, 2018) assumes that the additional water volumes will be delivered through McDonalds Dam. However, to increase effectiveness and	• Relatively simple implementation	• Requires large volumes of water • Increased erosion as a result of increased flows • Potential to have significant impacts on the Delivering of significant volumes of additional water is likely to have significant impacts on the hydrology, hydrogeology and natural environments	• Does not remove the source of the acidity and can mask new issues • The water volumes required to achieve dilution of acidic discharge are not available in the region and could potentially trigger water management issues in other parts of Victoria

ID	Technology	Principle	Site Implementation	Advantages	Disadvantages	Key Issues
			minimise potential side effects to natural environments downstream of the release point, the additional water volumes could also be delivered further downstream (i.e., in the upper reaches of Reach 3 of Boundary Creek).		downstream of the delivery point, which will require detailed assessment to support detailed design and implementation of this option.	
O6	Water flow diversion and Big Swamp isolation	Reduce metal and acidity loads	This option would involve isolating and by-passing Big Swamp (i.e., the source of acidity) to reduce the acidity inputs to Reach 3 of Boundary Creek. Implementation of this option would require building a channel so that water flowing into Boundary Creek does not disperse into Big Swamp, as well as construction of a series of impermeable structures to prevent groundwater within the alluvial swamp sediments to discharge into Reach 3 of Boundary Creek. Additional water retention structures may be also required to minimise risks of acid flushes from Big Swamp into Reach 3 of Boundary Creek.	• This option could be effective in improving water quality in Boundary Creek by breaking the source, pathway, receptor linkages between the source (Big Swamp) and downstream environments	• This option is likely to have significant impacts on the hydrology, hydrogeology and natural environments of Boundary Creek (Reach /Reach 3) and Big Swamp, which will require detailed assessment to support detailed design and implementation of this option. • Implementation of this option, in the absence of other measures, has the potential to worsen the intensity of 'acid flushes' associated with wet-dry cycling. In addition, dryer conditions across Big Swamp will increase fire risks.	• This option is likely to severely impact on the existing condition of Big Swamp, which is likely to dry out further and continue to generate acidity. It is therefore considered that this option is unlikely to gain stakeholder's approval unless: – A water retention system and artificial water recharge are implemented to prevent wet-dry cycling and minimise ongoing oxidation of ASS – It is demonstrated to be the only alternative to manage the metals and acidity loads within the lower reaches of Boundary Creek and the Barwon River; – The community agrees that Boundary Creek and Barwon River are of higher value compared to Big Swamp.
O7	Managed groundwater levels and flooding	Prevent (further) oxidisation of ASS	This option involves the flooding of Big Swamp to prevent the ongoing oxidation of ASS and create permanently waterlogged areas where microbially mediated iron reducing and sulfate reducing reactions have the potential to increase alkalinity, raise pH and remove dissolved metals by precipitation. For sulfate reduction reactions to occur, the following conditions must be realised in the re-flooded portions of Big Swamp: • Maintenance of anaerobic conditions • Presence of a bioavailable organic carbon source (electron donor) • pH between 5 and 8	• Relatively low cost • Minimise further oxidation • Reversal of iron sulfides oxidation processes • Barrier installation is a proven technology and can be supported by adequate modelling • Promotes swampy vegetation assemblages to recolonise	• The delivery of supplementary flow to maintain waterlogged conditions and higher groundwater levels will result in increased surface water flow in Big Swamp, which has the potential to enhance mobilisation and downstream transport of acidification by-products accumulated in near-surface sediments • Preliminary results from laboratory incubation work from Monash University and GHD geochemical modelling	• Prevents the ongoing oxidation of ASS contained within the swamp • May future proof the system from future droughts • Groundwater and surface water modelling are required to assist in assessment of the following technical aspects associated with this option: – additional water volumes to be delivered to Big Swamp to achieve the required minimum groundwater levels

ID	Technology	Principle	Site Implementation	Advantages	Disadvantages	Key Issues
			• Presence of sulfate and low concentrations of competing electron acceptors such as nitrate (NO_3^-), manganese (Mn^{4+}) and ferric iron (Fe^{3+}). Implementation of this option envisages the following steps: • construction of water retention structures (likely to be located at the downstream side of Big Swamp) to realise a permanent water coverage across a significant portion of Big Swamp • infilling of existing drainage channels across Big Swamp to assist with water retention • supply of additional water volumes to achieve the required permanent water coverage • supply of additional organic carbon source (and potentially sulfate) in case of deficiencies of these elements in the natural environment.		suggest that there is a risk that the soluble ferrous iron generated under reducing conditions will not precipitate in Big Swamp and will be transported downstream in Boundary Creek • Change in vegetation assemblages and visual amenity due to the retreat or die-back following inundation	– extent and location of the water retention structures required to maintain groundwater at the desired levels – potential impacts to hydrological, hydrogeological and hydrogeochemical regime of Boundary Creek and Big Swamp
O8	Ex-situ remediation and/or disposal of acid sulfate soils	Treatment to neutralise acidity (soil)	This option involves the excavation and removal of acid sulfate soils (ASS) from within Big Swamp, which are treated (or disposed of) according to EPA Victoria ASS management guidelines. Construction of access tracks and significant removal of vegetation will be required to implement this option. The excavation is likely to be progressed as separate cells to minimise potential exposure of non-oxidised sediments to oxygen. Following removal of the oxidised sediments, lime would be added at the base of the excavations to neutralise potential future acidity generation and then the excavation would be backfilled with suitable imported fill material. After remediation and backfilling, the site would be landscaped and revegetated to resemble the original character of Big Swamp.	• Could effectively remove the primary source of acidity • The extent of excavation areas could be minimised by developing a high-resolution characterisation of the spatial extent of oxidised sediments within Big Swamp, so that a more targeted approach can be developed	• The soft consistency of the soil across Big Swamp is likely to pose significant logistical constraints to implementation of this option • Irrespective of the extent of excavations, implementation of this option will severely impact on the natural environment of Big Swamp and the hydrological/ hydrogeological regime of Boundary Creek • This option is likely to have significant environmental impacts and may limit the remedial goals. However, removal of acid generating sediments within Big Swamp is likely to be an effective solution to reduce acidity loads within and downstream of the swamp • Based on a comparison of aerial images captured since 2010 (when the majority of Big Swamp vegetation was severely affected by a fire), it appears that low lying vegetation would re-establish	• This option is the least preferred approach based on EPA Victoria's ASS management hierarchy • It is considered that this option is unlikely to gain stakeholders approval, **unless**: – It is demonstrated that removal of oxidised sediments is the only alternative to manage acid discharges to Boundary Creek and Barwon River – The community agrees that Boundary Creek and Barwon River are of higher value compared to Big Swamp – Remediation of Big Swamp to a satisfactory 'engineered endpoint' as opposed to rehabilitation to some of its original values is an acceptable outcome for the project

ID	Technology	Principle	Site Implementation	Advantages	Disadvantages	Key Issues
					within 3 to 5 years after re-planting	
O9	In-situ treatment of acid sulfate soils	Treatment to neutralise acidity (soil)	This option involves the use of a large diameter (one to three metres) hollow-flight auger fitted with special mixing 'paddles' (or other suitable device) to achieve mixing of a neutralising agent with the oxidised sediments in Big Swamp. Construction of access tracks and significant removal of vegetation will be required to implement this option. Following treatment of the oxidised sediments, the disturbed sections of Big Swamp will require to be rehabilitated through landscaping and planting of vegetation.	• Compared to surface liming, this option has the potential to achieve effectively neutralise the oxidised ASS sediments at depth • The extent of treatment areas could be minimised by developing a high-resolution characterisation of the spatial extent of oxidised sediments within Big Swamp, so that a more targeted approach can be developed	• The soft consistency of the soil across Big Swamp is likely to pose significant logistical constraints to implementation of this options • This option is likely to have significant environmental impacts and may limit the remedial goals. However, removal of acid generating sediments within Big Swamp is likely to be an effective solution to reduce acidity loads within and downstream of the swamp	• If applied on a large scale, this option will severely impact on the natural environment of Big Swamp • It is considered that this option is unlikely to gain stakeholders approval, **unless**: – It is demonstrated that removal of oxidised sediments is the only alternative to manage acid discharges to Boundary Creek and Barwon River – The community agrees that Boundary Creek and Barwon River are of higher value compared to Big Swamp – Remediation of Big Swamp to a satisfactory 'engineered endpoint' as opposed to rehabilitation to some of its original values is an acceptable outcome for the project
O10	Alkaline slurry injection	Prevent (further) oxidation of acid sulfate soils and treatment to neutralise acidity (soil)	This option involves injecting a slurry composed of alkaline and impermeable materials to minimise oxygen infiltration and neutralise acidity. The depth of application would be typically to the top of the unoxidized ASS in Big Swamp. Construction of access tracks and significant removal of vegetation will be required to implement this option. Following treatment of the oxidised sediments, the disturbed sections of Big Swamp will require rehabilitation through landscaping and planting of vegetation.	• Compared to surface liming, this option has the potential to achieve effective neutralisation of oxidised ASS sediments at depth • The extent of treatment areas could be minimised by developing a high-resolution characterisation of the spatial extent of oxidised sediments within Big Swamp, so that a more targeted approach can be developed	• This option is likely to have significant environmental impacts and may limit the remedial goals. However, removal of acid generating sediments within Big Swamp is likely to be an effective solution to reduce acidity loads within and downstream of the swamp Additionally, soil heterogeneity could limit the ability to achieve uniform distribution of the injected amendments	• If applied on a large scale, this option will severely impact on the natural environment of Big Swamp • It is considered that this option is unlikely to gain stakeholders approval, **unless**: – It is demonstrated that removal of oxidised sediments is the only alternative to manage acid discharges to Boundary Creek and Barwon River – The community agrees that Boundary Creek and Barwon River are of higher value compared to Big Swamp

ID	Technology	Principle	Site Implementation	Advantages	Disadvantages	Key Issues
						– Remediation of Big Swamp to a satisfactory 'engineered endpoint' as opposed to rehabilitation to some of its original values is an acceptable outcome for the project
O11	In-stream limestone sand	Treatment to neutralise acidity (water)	This option involves the placement of limestone sand (or another suitable neutralising agent) directly in the streambed of Boundary Creek. The sand is carried into the stream during high flow periods where it dissolves releasing alkalinity and increasing pH.	• No maintenance, simple, and relatively inexpensive	• Water quality improvement may be inconsistent • Effectiveness diminishes with time • Limestone sand must be applied repeatedly, usually at least once per year • Metals such as Al and Fe are likely to precipitate downstream of the application point because of the increased pH • Provides no benefit to Big Swamp	• Unlikely to be effective, considering the limited flow and gentle slopes of Boundary Creek, limiting the potential for downstream transport of the neutralising sand.
O12	Water Treatment	Use of physical, biological and chemical processes to improve water quality. In this case to neutralise acidity (water)	Current water treatment technologies can be categorised as either 'active' or 'passive', depending on the nature of the treatment system. The intent of water treatment in this instance is to lower the total acidity by raising the pH and lowering the concentration of dissolved metals. Based on the site conditions, there are two potential approaches: 1. The use of fixed plant to pump and treat the acidity, or 2. In-situ approaches that conduct treatment within or adjacent to the affected water body. Depending on the system configuration and design parameters, precipitation of metals could be achieved in a settling pond or above ground clarifiers rather than allowing to settle within the swamp and/or creek	• Ability to manage high acidity loads, high flows and variability in acid loads • Achieve virtually any water quality targets • Can be engineered to suite a particular situation • Commercially proven	• Can have high capital and ongoing costs. • Infrastructure requirements (power, water, access roads, etc.). • Potential to generate sludges and/or by-products that require management • Potential acquisition of land to site and operate system • Potential environmental impacts associated with noise, amenity, overdosing and changes in geochemistry • Provides no benefit to Big Swamp	• Water treatment systems are considered to be a useful tool in managing the metal and acidity loads. However, these systems will not address the issues associated with wet-dry cycling and groundwater level decline. • In-situ options have the potential to negatively impact the environmental values of the swamp • Potential treatment technologies would need to be carefully reviewed and the design of any system approved by Southern Rural Water and other relevant parties prior to implementation
O13	Limestone diversion wells	Treatment to neutralise acidity (water)	This option envisages that a portion of the flow in Boundary Creek downstream of Big Swamp is diverted into a series of limestone-filled wells to increase alkalinity/pH and precipitate metals. Following treatment, the flow is diverted back into Boundary Creek.	• Typical pH increases are about ½ to 2 units during average flows • Multiple diversion wells can be installed to increase effectiveness	• Typically, this option is suitable for treating small flows and likely to fail in cases when a stream has a variety of flow regimes during the year	• Similar to the above, this option will not address the source of the impacts (i.e., acid sulfate soils). As such, this is considered to be more

ID	Technology	Principle	Site Implementation	Advantages	Disadvantages	Key Issues
					• High maintenance (weekly to biweekly) is required • Metals such as Al and Fe are likely to precipitate downstream of the application point because of the increased pH	of a contingency measure than a remedial option • Unlikely to be suitable based on-site conditions
O14	Anoxic limestone drains (ALD) and settling pond	Treatment to neutralise acidity (water)	This option envisages construction of a buried drain lined with impermeable material, filled with limestone (or other suitable neutralising agent) and covered by impermeable materials. The water seeping downstream of Big Swamp is diverted into the limestone (to maintain saturated conditions and anoxic conditions) where dissolution of the limestone increases alkalinity and pH. Low oxygen conditions in the ALD would prevent precipitation of metals and armouring issues. The water leaving the ALD is then directed into an aerobic settling stage where metals are precipitated and removed from the water. Removal of metal precipitates (sludges) is required at periodic intervals.	• Increases efficiency of other treatment types. For example, anoxic limestone drains can be used to pre-treat water prior to entering a wetland system. • ALDs can also be used as a post-treatment system to add additional alkalinity.	• Water pre-treatment may be required prior to the ALD to remove dissolved oxygen and generate reducing conditions to promote conversion of ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}) • The infrastructure required for precipitation and settling of metals (i.e., settling tank, engineered section of Boundary Creek or settling pond) is likely to impact on the natural environment • Anoxic conditions within the drain are likely to reduce issues associated with iron armouring of alkaline materials • Variable alkalinity output • Effluent pH difficult to maintain over time • Treatment effluent has low oxidised metal concentrations (aluminium and ferrous iron) and low dissolved oxygen	• Similar to the above, this option will not address the source of the impacts (i.e., acid sulfate soils). As such, this is considered to be more of a contingency measure than a remedial option • If applied on a large scale, this option will severely impact on the natural environment of Big Swamp • Water with elevated concentrations of Al (i.e., >25 mg/L) will form floc in the ALD, progressively reducing its permeability and efficiency.
O15	Constructed aerobic wetland	Treatment to neutralise acidity (water)	Construction of an aerobic wetland to remove metals by oxidation and hydrolysis.	• Relatively inexpensive • Lower maintenance than active treatment systems • Can improve amenity	• Metal removal efficiencies vary because pH is seldom constant • pH decreases as metals are removed • Potential acquisition of land to site and operate system • Requires a large land mass • Relatively limited lifespan (15-25 years) due to substrate saturation	• Unlikely to be suitable based on-site conditions • This option is generally suited to slightly alkaline environments, with a pH greater than 5.5 and low to moderate concentrations of metals.

ID	Technology	Principle	Site Implementation	Advantages	Disadvantages	Key Issues
O16	RAPS (reducing and alkalinity producing systems)	Treatment to neutralise acidity (water)	Construction of a vertical flow anaerobic wetland to increase alkalinity, raise pH and remove metals by precipitation of insoluble hydroxides, carbonates and sulfides. The anaerobic wetland comprises an organic-rich substrate at the top, a layer of limestone at the bottom and a drainage system. The wetland is constructed within a watertight basin and water flowing from the top across the organic layer and the limestone layer is collected by the drainage system and released into an aerobic settling pond. Alkalinity is generated by microbial process in the organic layer (if sulfate is available) and through dissolution of the limestone. An aeration and settling stage may be required prior to discharge to increase oxygen and promote precipitation of residual dissolved metals.	• Area required for RAPS is relatively small compared to other passive systems • Treat poorer quality water compared to passive systems	• Drainage system limited by high concentrations of aluminium and ferric iron • Noxious odour (hydrogen sulfide) produced in vicinity of the system • Risk of people or animal drowning	• Unlikely to be suitable based on-site conditions • The construction of an anaerobic wetland is likely to impact on the natural environment of Big Swamp and Reach 3.
O17	Permeable reactive barriers (PRBs)	Treatment to neutralise acidity (groundwater)	Construction of permeable reactive barriers in Big Swamp (perpendicular to groundwater flow direction) to intercept and treat acidic groundwater.	• Relatively low maintenance and installation costs • Ability to treat a range of contaminants	• Construction of a permeable reactive barrier is likely to impact on the natural environment of Big Swamp • Potential for clogging • Requires periodic removal and replenishment of barrier material • Overall effectiveness will depend on size (length and depth)	• This option while addressing the groundwater acidity does not address the source of the impacts (i.e., acid sulfate soils). As such, this is considered to be more of a contingency measure than a remedial option • Groundwater modelling results indicate that groundwater discharges into Reach 3 of Boundary Creek account for only a small proportion of the total surface water flow (i.e., less than 0.3 ML/d), and therefore groundwater transport does not significantly contribute to the acidity loads within Reach 3 of Boundary Creek. As such, the effectiveness of this option is limited unless the proportion of groundwater contribution significantly increases
O18	Managed Aquifer Recharge (MAR)	Injection or infiltration of water into the groundwater system to facilitate	Managed aquifer recharge can be achieved using two approaches: 1. The use of injection bores or artificial recharge ponds to increase the rate of aquifer recovery, or	• Increases the rate of aquifer recovery • Decreases the time taken for the aquifer to re-pressurise • Can be both passive or active and utilise natural processes	• Can have significant construction and operational costs depending on the infrastructure • May require additional volumes of water that are not	• Passive recharge is currently occurring due to the supplementary flow releases and hydrogeological conditions

ID	Technology	Principle	Site Implementation	Advantages	Disadvantages	Key Issues
		groundwater level recovery	2. By enhancing or supplementing the natural infiltration processes which may occur within the recharge zone This could include the capture and infiltration of rainwater and/or stormwater, the use of recycled water or alternate water sources or the release of supplementary flows in the upper reaches of Boundary Creek that function as a losing stream.		currently accounted for and may present an unacceptable water security risk • Can lead to changes in the hydrogeological regime and/or lead to potential impacts • Long lead and implementation timeframes (up to 10 years)	• Groundwater levels within the LTA are already recovering due to the cessation of groundwater pumping activities. • MAR will have a limited capacity to increase water levels within the Upper Aquifer system given the shallow groundwater levels within the swamp and • Additional water sources to facilitate further recharge are currently not available • Active recharge systems would require the construction of specific infrastructure for the purpose of delivering, treating and injecting water and come with significant ongoing operational and maintenance costs, not to mention the potential for further harm if not managed correctly

Based on the information presented in Table 16, the following remediation options were not carried forward for detailed assessment:

- **O1 - Monitored Natural Attenuation**: The main reasons for removing this remediation option are that this would not lead to any improvements in the short-term and may take many years for improvements to be realized. This option would also fail to meet the requirements of the Section 78 Notice;
- **O2 - Water retention / flow enhancement**: This option comprises the implementation of various actions that have already been implemented to prevent any further impacts, particularly given Barwon Water's commitment to developing and implementing a decommissioning plan for the Barwon Downs borefield production bores as part of our 2023-2028 Price Submission. Consideration of additional water retention / flow enhancement actions will be considered as part of the contingency planning process;
- **O4 - Oxic (aerobic) limestone drain (OLD)**: This option was removed because the concentrations of iron and aluminium in the water requiring treatment are outside of the recommended range for this technology to be suitable. Armouring of the limestone aggregate caused by metal precipitates is likely to impact on the long-term effectiveness of the OLD. The relatively gentle slopes of the site do not provide favourable conditions for installing the OLD with the recommended 20% gradient that is indicated as one of the main design factors to limit the severity of armouring issues. In addition, an OLD constructed in accordance with the recommended design water retention time of 3 hours, will require approximately 310 m3 of limestone aggregate (assuming a porosity of 40%) for each ML/d of water requiring treatment, equivalent to an open channel 5 m wide, 1 m deep and 60 m long. It is considered that such a structure will impact on the visual amenity of the area downstream of Big Swamp;
- **O5 - Dilution of acidic discharge**: This option is removed because of the large water volumes (estimated by Jacobs in the range of 60-250 ML/d depending on flow conditions) required to achieve effective dilution of acidity and acidity impacts in Boundary Creek. It is considered that sourcing and delivery of such volumes of dilution water would be impracticable, unlikely to be accepted by the authority (dilution for management of contamination is usually considered an unacceptable management practice by EPA Victoria) and a risk of impacting on water availability in other parts of Victoria;
- **O6 - Water flow diversion and Big Swamp isolation**: This option is removed because of the technical challenges associated with providing an effective hydraulic barrier to prevent acidic discharges from Big Swamp to the surrounding receiving environments and the additional impacts to Big Swamp caused by further declines of surface water and groundwater water levels that are likely to eventuate as a result of decreased inflows into the swamp. The progressive acidification of Big Swamp and the drier environment caused by hydraulic isolation will also increase fire risk and potential for episodic and high intensity 'acid flushes' in case the integrity of the barrier is compromised during high rainfall events. It is also unlikely that this option would gain regulatory approval and/or community support;
- **O10 – Alkaline slurry injection**: This option is removed because a generally equivalent option (soil mixing) has been retained for detailed assessment. Soil mixing was retained over slurry injection because it is considered to be easier to implement in consideration of the high liming rates required to neutralise ASS in Big Swamp, the low hydraulic conductivity of the majority of

the alluvium sediments in Big Swamp and the potential for preferential pathways to affect homogeneity of treatment;

- **O11 - In-stream limestone sand**: This option has been removed because during periods of low flow the limestone sand is unlikely to be transported downstream in Boundary Creek, resulting in low consistency of this technology in managing water quality impacts. In addition, a generally equivalent option (active treatment) has been retained for detailed assessment which has the advantage of providing more consistent outcomes in terms of treatment efficient and water quality results;
- **O13 - Limestone diversion wells**: This option has been removed because the high concentrations of iron and aluminum in the water requiring treatment are outside of the recommended range for this technology to be suitable. In addition, limestone diversion wells require a very high O&M intensity (i.e., weekly) to maintain system efficiency and replacement of the limestone aggregate;
- **O14 - Anoxic limestone drain (ALD) and settling pond**: This option has been removed because the concentrations of iron and aluminum in the water requiring treatment are outside of the recommended range for this technology to be suitable. In addition, the high retention times required for effective limestone dissolution (in the range of 13 hours) generally require construction of large structures. For example, an ALD designed to treat 4 ML/d of impacted water would typically be 1.5 m deep (1 m of limestone and 0.5 m of impermeable cover), 5 m wide and 1,000 m long (assuming limestone porosity of 40%). It is considered that construction and ongoing maintenance of such a structure downstream of Big Swamp would be impracticable, and
- **O18 – Managed Aquifer Recharge (MAR)**: This option has been removed because the Lower Tertiary Aquifer is naturally recharging following the cessation of groundwater pumping activities and the provision of supplementary flows to maintain flows in Boundary Creek. Further to this, any artificial enhancements would be of little long-term value given the cost of constructing and operating such a scheme, particularly given the lack of additional water volumes and mechanisms for delivering significant volumes of water for the purpose of artificial recharge without impacting on water security.

The following remediation options were retained for detailed assessment:

- O3 - Direct treatment of soils with neutralizing agents (wetland liming);
- O7 - Flooding of Big Swamp and managed groundwater levels;
- O8 - Ex-situ remediation and/or disposal of acid sulfate soils;
- O9 - In-situ treatment of acid sulfate soils;
- O12 – Water treatment;
- O15 - Constructed aerobic wetland. This technology would not treat impacted water from Big Swamp, however, is has been retained because it could be uses as a final step of a treatment train including other remediation options;
- O16 – RAPS (reducing and alkalinity producing systems, and
- O17 – Permeable Reactive Barriers (PRBs) – noting that these were initially ruled out due to the proportion of groundwater discharge to Big Swamp. However, were reassessed in 2022 due to the observed improvements.

B4.3 Detailed assessment

B4.3.1 Assessment framework

As outlined in the Remediation Options Assessment (CDM Smith, 2019) and the subsequent PRB assessment (CDM Smith, 2022), the following steps were performed to support the detailed assessment of the retained remediation options:

- Development of a high-level concept design for each retained option, using a range of site-specific data or general assumptions;
- Estimate of relative cost of each technology using publicly available data and software (AMDTreat v5.0.2 Plus) developed by the Pennsylvania Department of Environmental Protection, the West Virginia Department of Environmental Protection, the U.S. Geological Survey's (USGS) and the Office of Surface Mining Reclamation and Enforcement (OSMRE);
- Liaison with other technical consultants working on the project (Jacobs, GHD and Monash University) to obtain site-specific information on expected design requirements, performances and risks associated with each remediation option;
- Review application of national and international guidance for selection of suitable project-specific categories for the assessment of each option. The following set of six categories was considered to enable a broad assessment of the various facets associated with each option:
    - Effectiveness;
    - Implementability;
    - Cost;
    - Stakeholders;
    - Timing, and
    - Sustainability.

- Development of indicators for each category to assist with ranking the merits of each option. Ranking ranged from 1 (low/least preferable) to 5 (high/most preferable), according to the general guidelines provided in Table 17;
- Development of a weighting system to allow prioritisation of more categories that were considered more important for the project;
- Discussion on the proposed categories, indicators and weighting system as part of the 10 October 2019 workshop and the 23 October 2019 RWG meeting so that feedback from technical and community stakeholders could be incorporated in the ROA framework;
- Ranking of the indicators and calculating normalised scores for each category to remove the effect of different numbers of indicators defined for each category (i.e., all the categories have the same weight regardless of number of indicators), and
- The normalised scores for each option were then weighted and summed to assist with identifying preferred options for the site. Various permutations using different weights were performed to account for feedback from the community and for sensitivity analysis.

Table 17 Ranking Guidelines (CDM Smith, 2022)

Category	Description	Ranking Criteria		
		1	3	5
Effectiveness	Assessment of the degree to which the technology will achieve the remediation objectives, considering the nature and extent of the contaminants and the site-specific geological and hydrogeological settings	Technology has not been proven and demonstrated at scale or is unable to meet remediation objectives. Site specific conditions preventing or limiting effectiveness.	Proven effectiveness and within recommended ranges for chemicals to be treated. Pilot scale trials may be required to demonstrate applicability and develop detailed design.	Proven effectiveness and within recommended ranges for chemicals to be treated. Pilot scale trials not likely to be required prior to demonstrate effectiveness and develop design criteria.
Implementatbility	Practical considerations associated with the logistics of designing, constructing, operating, maintaining, monitoring and decommissioning the technology at the site	Complex engineering and design, large footprint (>2 ha), restricted access high level of administrative controls, high level of operation, maintenance, and monitoring, difficult to decommission	Moderate level of engineering design required, feasible to construct, moderate level of operation, maintenance and monitoring required, feasible to decommission	Proven technology with standard design, standard construction techniques, moderate level of operation, maintenance and monitoring required, feasible to decommission
Cost	Relative cost of implementing the technology for a nominal 10-year timeframe	Fixed costs > $5 M Ongoing costs > $100k/yr	Fixed cost $1 to $5 M Ongoing costs $50k/yr to $100/yr	Fixed costs < $1 M Ongoing costs < $50k/yr
Stakeholders	Likelihood of regulatory and community approval.	Unlikely to meet regulatory or stakeholder approval.	Standard level of permitting required and aligned with stakeholder's expectations.	Minimal permitting requirements and strongly supported by the community.
Timing	The envisaged timeframe required for the technology to meet the selected clean-up objectives	More than 2-years for design and construction. More than 5 years to realise relevant project objectives. No source reduction, long treatment timeframes (>50 years) envisaged.	Between 1 and 2-years implementation time. Between 1 and 5 years to realise relevant project objectives. Some potential for source reduction potentially leading to shorter treatment timeframes (between 10 and 50 years).	Less than 1-year implementation time. Less than 1 year to realise relevant project objectives. Substantial source reduction and short treatment timeframes (less than 10 years).
Sustainability	Includes consideration such as remediation hierarchy, use of resources, emissions and impacts on future generations.	High use of resources (chemical or natural), landfill space. High and/or non-recoverable impacts on the natural environment	Moderate use of resources (chemical or natural), landfill space. Moderate impacts on the natural environment, likely to be recoverable.	Low use of resources (chemical or natural), landfill space. Low impacts on the natural environment.

B4.3.2 Conceptual design of the retained remedial options

To help inform this assessment, the remediation options assessment also included the development of concept designs for the retained remedial options (CDM Smith, 2019 and CDM Smith, 2022).

These concept designs were developed based on the following considerations:

- Review of the principle of operation of the selected remediation option;
- Envisaged approach for implementation approach;
- Assessment of expected technology performance;
- Inputs from groundwater/surface water and geochemical modelling works by Monash University, Jacobs and GHD (where relevant);
- Estimate of relative costs for technology implementation, and
- Assessment of the technology ability to meet the project objectives.

B4.3.3 Technology scoring, ranking and weighting

Finally, each of the retained remedial options were then ranked using the criteria provided in section B4.3.1. The outcomes of this assessment are provided in Table 18:

Finally, these scores were then weighted based on the outcomes of the technical options workshops as follows:

- Technical = 40%;
- Logistical = 10%;
- Financial = 10%;
- Stakeholders = 30%;
- Timing = 5%, and
- Sustainability = 5%.

The results of this assessment are provided in Table 18. However, it is noted that this does not account for the 'do no harm' principal that focuses on preventing any unintended impacts that may occur as a result of implementing specific remediation actions. This was common theme that came through during our Remediation Reference Group meetings and has since been incorporated into the plan.

Table 18 Technology scoring of the retained remediation options (adapted from CDM Smith, 2019 and CDM Smith 2022)

Indicators	Direct treatment of soils with neutralizing agents (wetland liming)	In-situ treatment of acid sulfate soils	Ex-situ treatment of acid sulfate soils	Constructed aerobic wetlands	RAPS (reducing and alkalinity producing systems)	Water Treatment	Managed groundwater levels and flooding	Permeable Reactive Barriers (PRBs)
Effectiveness	3.0	2.8	2.8	2.3	3.0	3.5	3.0	1.0
Implementability	4.0	3.0	3.3	3.3	2.5	2.8	4.5	5.0
Cost	4.0	3.0	2.7	3.7	1.7	2.7	3.3	3.0
Stakeholders	3.4	2.6	2.4	3.6	3.0	3.8	4.0	3.0
Timing	3.7	2.0	2.0	2.0	3.0	3.3	3.0	3.0
Sustainability	4.5	2.8	2.5	3.8	2.5	2.5	4.3	5.0
Total unweighted score	22.6	16.2	15.7	18.7	15.7	18.6	22.1	20.0
Unweighted ranking	**1**	**6**	**8**	**4**	**7**	**5**	**2**	**3**
Total weighted score	20.6	16.4	16.0	17.9	16.8	20.3	21.3	15
Weighted ranking	**2**	**6**	**7**	**4**	**5**	**3**	**1**	**8**

B4.3.4 Ability to meet project objectives

To assist in further assessment of each of the retained remedial options, an assessment of the ability of each technology to meet the project objectives (as outlined in section A4.4) was undertaken.

The results of this assessment are provided in Table 19, noting that only the following two options achieved an overall ranking greater than low:

- Managed groundwater levels and flooding, and
- Water treatment.

Previous work (CDM Smith, 2019 and Barwon Water, 2021b) also identified a number of potential detrimental side effects associated with the implementation of the potential remedial actions, particularly those involving active treatment.

Table 19 Ability to meet project objectives (adapted from CDM Smith, 2019 and CDM Smith 2022)

Remedial Objectives	**Remediation Options**							
	Direct treatment of soils with neutralizing agents (wetland liming)	**Managed groundwater levels and flooding**	**Ex-situ remediation and/or disposal of acid sulfate soils**	**In-situ treatment of acid sulfate soils**	**Water treatment**	**Constructed aerobic wetlands**	**RAPS (reducing and alkalinity producing systems)**	**Permeable Reactive Barriers (PRBs)**
Facilitate groundwater level recovery and enable groundwater-surface water interaction to return	No effect	Medium to high	No effect	No effect	No effect	No effect	No effect	No effect
Reduce the severity of wet-dry cycling processes and the occurrence of 'acid flush' events in Boundary Creek	No effect	High	No effect	No effect	No effect	No effect	No effect	No effect
Control/manage the risks associated with the oxidation of naturally occurring acid sulfate soils	Low to medium	Low to medium	Low to medium	Low to medium	High	Low to medium	Medium to high	Low
Preserve / improve ecological values of Big Swamp and Boundary Creek	Not known	Medium to high	Not known	Not known	No effect	No effect	No effect	Low
Reduce the fire risk in Big Swamp	No effect	Medium to high	No effect	No effect	No effect	No effect	No effect	No effect
Overall Ranking	**Low**	**Medium to high**	**Low**	**Low**	**Low to medium**	**Low**	**Low**	**Low**

B4.3.5 Preferred remedial strategy

Based on the findings of the detailed assessment, the ability of the potential remedial actions to meet the project objectives and the principles that underpin this REPP, managed groundwater levels and flooding was adopted as the preferred remedial strategy.

This strategy focuses on facilitating natural recovery processes, while minimising the need for active and/or intrusive interventions that may lead to further harm to the environment. Noting that this does not preclude the implementation of engineered interventions as a last resort if they are deemed to be required.

A number of other remedial options were also considered as potential contingency measures, or supportive actions that could be implemented in conjunction with the preferred remedial strategy to manage the acidity loads within Big Swamp and Boundary Creek (CMD Smith, 2019 and Barwon Water, 2021b). These included:

- Manual chemical application within Big Swamp;
- Construction of hydraulic barriers;
- Construction of a lime bed;
- Construction of a chemical dosing system;
- Construction of an in-stream dosing system, or
- Construction of permeable reactive barriers.

Noting that a number of these have since proven not to be feasible within Big Swamp as the potential benefits do not outweigh the potential risks associated with implementing intrusive interventions such as these in a complex environment with sensitive ecological receptors. Further information regarding the adopted risk-based contingency approach can be found in Section A4.9).

B4.4 Development of reasonable targets and/or measures of success

To determine progress against the remedial objectives, a number of success targets, as outlined in Table 5, have been developed in consultation with the Remediation Reference Group and their nominated technical experts. Noting that these have and will continue to be informed by the ongoing monitoring and data collection activities, and the outcomes of various technical works in line with the adaptive management approach.

Refer to Section 0 for further information.

B5 Clause 2.5d: A comprehensive risk assessment of proposed controls and actions documented in c);

An initial risk assessment of each of the potential remedial options was undertaken as part of the Remediation Options Assessment (CDM Smith, 2019).

More detailed risk assessments have also been completed for the upstream and downstream treatment options (Barwon Water, 2021b and Barwon Water, 2022b) as part of the contingency planning process.

Further works are currently underway to better constrain the risks under the current state to help inform the development of suitable triggers for the implementation of contingency measures. This is required to better understand the potential risks that may result from the implementation of different contingency measures.

B6 Clause 2.5e: The controls and actions to be implemented, including reasonable targets and/or measures of success to be adopted for the purposes of the implementation of the Plan

Refer to the Boundary Creek and Big Swamp Remediation Plan outlined in Section A4.

B7 Clause 2.5f: A monitoring program to check the controls and actions documented in e);

Barwon Water has adopted the following definition of adaptive management for the REPP:

> ‘a continuous cycle of improvement based on setting goals and priorities, developing strategies, taking action and measuring results, and then feeding the results of monitoring back into new goals, priorities, strategies and actions’
>
> (Mackay, 2016)

An adaptive approach to remediation is considered best practice, whereby the remediation plan can be adapted to observed changes. This approach positions Barwon Water to 'watch' through a monitoring and assessment program to evaluate if systems are responding to interventions 'and act' if further action like contingency measures are required.

Barwon Water proposes that the environmental monitoring program outlined in Appendix A be implemented to inform the REPP and continuously review the effectiveness of the controls and actions for remediation of Boundary Creek and Big Swamp.

It is noted that since the previous version of the REPP, sediment and vegetation monitoring has been refined based on the outcomes of the initial sampling works.

B8 Clause 2.5g: Contingency measures designed to address any issues identified from monitoring results

While the remedial actions focus on addressing the environmentally significant adverse impacts resulting from the historical management of groundwater pumping activities at the Barwon Downs borefield, the development of contingency measures focuses on minimising the potential for high-risk events, should these persist following the implementation of the primary remedial actions. Noting that it may take time for improvements from the implementation of remedial actions to be realised. As such, contingency measures are designed to support the primary remedial actions and focus on managing the short-term, rather than long-term risks.

Based on the current 'state of knowledge' these include:

- Potential for acid-related fish kill events;
- Extreme wet-dry cycling, and
- Vegetation encroachment and/or dieback.

B8.1 Potential for acid-related fish kill events

Based on a review of the potential remedial options (CDM Smith, 2019, CDM Smith, 2022 and Barwon Water, 2021b), two potential approaches were considered to neutralise the pH and control the metal and acidity loads discharging from Big Swamp should this continue to present a risk to Big Swamp, Boundary Creek or the Barwon River:

- **Downstream treatment** where a water treatment system is located along Boundary Creek downstream of Big Swamp to manage the metal and acidity loads emanating from Big Swamp, and
- **Upstream treatment** where a water treatment system is located within Big Swamp to address the metal and acidity loads at the source.

Further works undertaken since the implementation of this REPP to further refine the potential contingency options have focused on:

- The design and development of a sodium hydroxide-based dosing plant that is envisaged to be situated immediately downstream of Big Swamp, and
- Investigating the potential application of a semi-passive caustic magnesia-based treatment system within Big Swamp

However, based on the findings of the Upstream Treatment Investigation (Barwon Water, 2022a), Barwon Water has since ruled out the use of the semi-passive caustic magnesia-based treatment system.

It is noted that while an initial design of a permanent sodium hydroxide-based pH Adjustment – Flow plant was submitted to Southern Rural Water on 31 July 2021, this has not yet been accepted by Southern Rural Water. As such, based on the findings of the Upstream Treatment Investigation (Barwon Water, 2022a) Barwon Water have now revised the design to focus on a mobile downstream treatment system that could be deployed as a last resort, in the unlikely event it is required (Barwon Water, 2023b). This aims to address a number of the risks and challenges raised by Southern Rural Water and the ITRP with regard to the permanent downstream dosing plant and minimise the need for active and/or intrusive interventions, where possible.

Refer to section A4.9 for further information regarding the adopted risk-based contingency approach and associated triggers.

B8.2 Extreme wet-dry cycling

Should the existing remedial actions not be sufficient in preventing the extreme wet-dry cycling that resulted in oxidation of acid sulfate soils, the following contingency measures could be implemented to prevent dewatering of the swamp and improve the flow distribution through the swamp:

- Straw bales or other similar, less intrusive water diversion barriers
- Adjustment to existing drainage lines
- Flow enhancement options, or
- Revegetation

As the design/arrangement of these contingency measures will need to be informed by the conditions within the swamp at that time, the exact nature of these measures cannot currently be ascertained. The needs and design/arrangement of these measures will continue to be reviewed in line with the adaptive management approach, and if required, will be based on the conditions at that time.

Refer to section A4.9 for further information regarding the adopted risk-based contingency approach and associated triggers. Additional actions and/or controls would only be considered after these options had been exhausted.

B8.3 Vegetation encroachment and/or dieback

While remedial actions are already underway to prevent the encroachment of dry vegetation classes and encourage the return of desirable species, manual removal and/or revegetation may be required as a last resort if the anticipated improvements are not realized through natural recovery processes.

This may include:

- Removal of dry vegetation classes and/or undesired species from the swamp plain to encourage understory recovery and desired species to re-populate;
- Slashing of bracken and dense lower vegetation to provide recruitment space and opportunity, or
- Revegetation of areas with low species diversity with desired species (mesic specialist lifeforms)

Refer to section A4.9 for further information regarding the adopted risk-based contingency approach and associated triggers. Noting that the removal of undesired species or the planting of desired species may also lead to unintended consequences, and these would only be successful if suitable conditions are maintained within Big Swamp.

B9 Clause 2.5h: a schedule of timeframes by which the controls and actions documented in e) will be carried out

Refer to section A6 of this REPP.

B10 Clause 2.5i: a reporting schedule, whereby Barwon Water will provide a minimum of quarterly updates to SRW which report on the progress of the Plan, as well as an Annual Report. The Annual Report must be submitted to SRW and made publicly available by 30 September each year

Refer to section A7 of this REPP.

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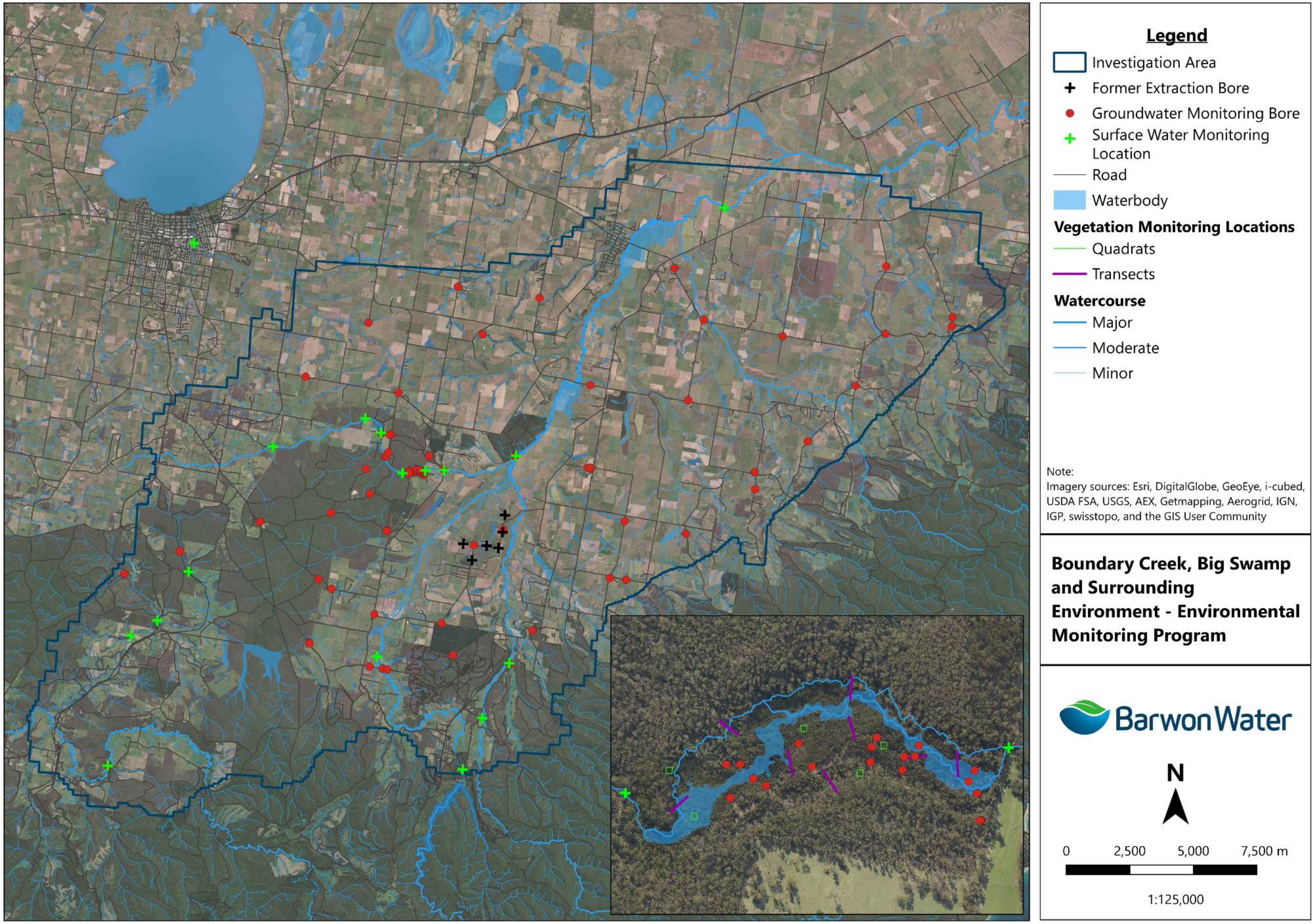
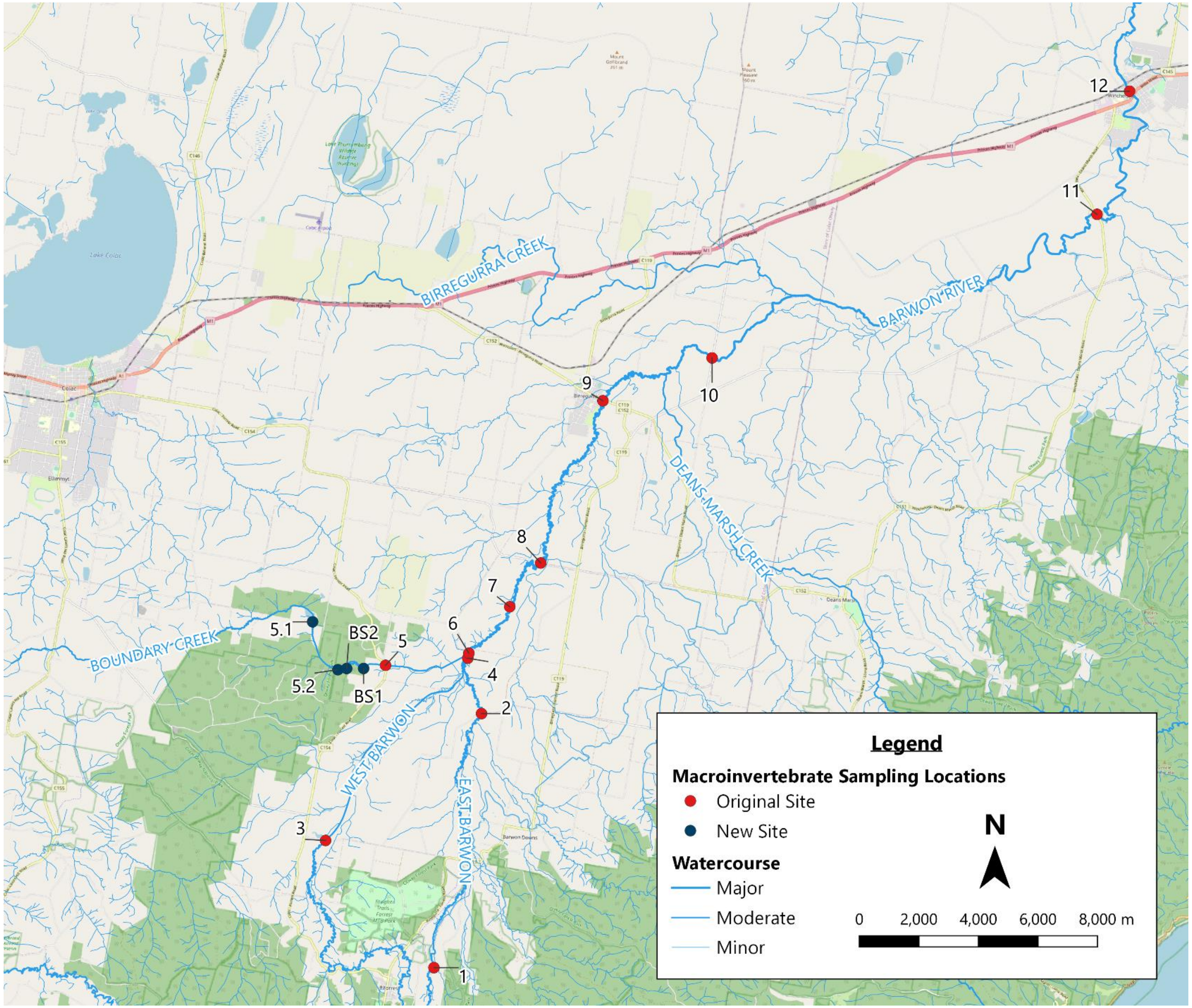
Appendix A – Environmental Monitoring Program

Monitoring Type	Monitoring Unit/Description	Monitoring Locations	Physical Parameters	Chemical Parameters	Frequency
Boundary Creek and Big Swamp Remediation Plan					
Surface Water Monitoring	Boundary Creek Stream Gauges	233273, 233231	Water level (m), flow (ML/day), temperature (°C), electrical conductivity (µS/cm)	N/A	15-minute intervals via remote sensing
		233229, 233275, 233228, 233233	Water level (m), flow (ML/day), pH, temperature (°C), electrical conductivity (µS/cm)		
		233276	Water level (m), flow (ML/day), pH, electrical conductivity (µS/cm)		
		233275, 233276, 233228, 233233	Water level (m), dissolved oxygen (DO), temperature (°C), electrical conductivity (µS/cm), pH, turbidity (NTU)	pH, alkalinity, acidity, total dissolved solids (TDS), metals, major cations and anions, nutrients, biochemical oxygen demand (BOD), chemical oxygen demand (COD)	Monthly
	Barwon River and Boundary Creek Monitoring Locations	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	Dissolved oxygen (DO), temperature (°C), electrical conductivity (µS/cm), pH, turbidity (NTU)	Alkalinity	Biannual (autumn and spring) or as recommended pending outcomes of monitoring

Groundwater Monitoring	Upper Aquifer System	BSBH01, BSBH02, BSBH03, BSBH04, BSBH05, BSBH06, BSBH07, BSBH08, BSBH09, BSBH10, BSBH11, BSBH12, BSBH14, BSBH15, BSBH16, BSBH17, BSBH18, BSTB1A	Standing water level Standing water level (SWL), dissolved Oxygen (DO), temperature (°C), electrical conductivity (µS/cm), pH, turbidity (NTU)	N/A pH, alkalinity, acidity, total dissolved solids (TDS), metals, major cations and anions, nutrients, biochemical oxygen demand (BOD), chemical oxygen demand (COD	Hourly using water level loggers Quarterly
	Confining Layer	BSTB1B			
	Lower Tertiary Aquifer System	BSBH13LTA, BSTB1C			
		YEO19, YEO20R, YEO22, YEO37, YEO39, YEO41	Standing water level (SWL)	N/A	Quarterly
Macro-invertebrate Sampling	Barwon River and Boundary Creek Monitoring Locations	1, 2, 3, 4, 5, 5.1, 5.2, 6, 7, 8, 9, 10, 11, 12, BS1, BS2	Biotic indices	N/A	Biannual (autumn and spring)
Vegetation Monitoring	Quadrats	Q1, Q2, Q3, Q4, Q5	Vegetation condition, distribution and diversity	N/A	Every 2 years or as recommended pending outcomes of monitoring
	Transects	T1, T2, T3, T4, T5, T6, T7, T8			
Surrounding Environment Investigation					
Surface Water Monitoring	Stream Gauges	233224, 233245, 233254, 233255, 233268, 234211, 235231, 235234, 235239, 235240 & Boundary Creek stream gauges outlined above	Water level, flow (ML/day), pH, electrical conductivity (µS/cm)	N/A	15-minute via remote sensing

Groundwater Monitoring	Upper Aquifer System	BCBH01, BCBH02, BRBH01, BRBH02, DMBH01V, DMBH02V, EBBH02, GRBH02, NYBH01, NYBH02, PCBH01V, PCBH02V, WBBH02	Standing water level (SWL)	N/A	Hourly using water level loggers
	Lower Tertiary Aquifer System	108898, 108899, 108917, EBBH01, GRBH01, TMCBH01, TMCBH02, WBBH01, YCBH01, YCBH02	Standing water level (SWL)	N/A	Hourly using water level loggers
Routine Residual Drawdown Monitoring					
Groundwater Monitoring	Clifton Formation	G18, G19, M22	Standing water level (SWL)	N/A	Quarterly
	Mepunga Formation	G20, G25, G28, M25, M27, M28, M29, W9, Y40, YEO21, YEO44	Standing water level (SWL)	N/A	Quarterly
	Dilwyn Formation	BA54, BA56, BA57, BA58, BD3, G11, G14, G17, G22, G24, M30, M31, W7, Y41, YEO20R, YEO37, YEO38, YEO39, YEO40R, YEO42, YYG217, YYG218, YYG221	Standing water level (SWL)	N/A	Quarterly
	Pebble Point Formation	BK69, E68, G13, G21, G23, M24, YEO19, YEO22, YEO23, YEO41	Standing water level (SWL)	N/A	Quarterly


Legend
Investigation Area
Former Extraction Bore
Groundwater Monitoring Bore
Surface Water Monitoring Location
Road
Waterbody
Vegetation Monitoring Locations
Quadrats
Transects
Watercourse
Major
Moderate
Minor
Note:
Imagery sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Boundary Creek, Big Swamp and Surrounding Environment - Environmental Monitoring Program
Barwon Water
N
0
2,500
5,000
7,500 m
1:125,000


BIRREGURRA CREEK
BARWON RIVER
DEANS MARSH CREEK
BOUNDARY CREEK
WEST BARWON
EAST BARWON
12
11
10
9
8
7
6
5
5.1
5.2
BS1
BS2
4
3
2
1
Legend
Macroinvertebrate Sampling Locations
Original Site
New Site
Watercourse
Major
Moderate
Minor
N
0
2,000
4,000
6,000
8,000 m

Appendix B – Bore Construction Details

Site Code	Alternate Name	State ID	Date Drilled	Easting (MGA Zone 55)	Northing (MGA Zone 55)	Monitoring Unit	Well Diameter	Screened From (m bgl)	Screened To (m bgl)	Well Base (m bgl)	Surface Elevation (mAHD)	Top of Bore (or gauge if artesian) (mAHD)	Bore Stickup (m)	Hydraulic Conductivity (m/day)
108898		108898	15/10/1981	201569.5	5731360.2	Dilwyn	102	46	52	62		82.67	0.17	
108899		108899	6/05/1981	201585.1	5731347.6	Dilwyn	102	26	32	34		82.58	1.06	
108917		108917	1/01/1981	201565.4	5731343.1	Dilwyn	50	14	15	15		82.54	0.31	
BA54	47771	47771	17/10/1985	227073	5744376	Dilwyn Formation		235.2	240.3	247.3	157.27	158.37	1.1	
BA56	47773	47773	13/08/1986	228799	5746690	Dilwyn Formation		143.3	146.4	153.4	167.45	168.04	0.59	
BA57	47774	47774	4/12/1987	229843	5748798	Dilwyn Formation		135.9	139	146.1	155.26	156.41	1.15	
BA58	47775	47775	1/06/1988	225815	5748439	Dilwyn Formation		284.2	287.2	301.3	157.02	158.51	1.49	
BCBH01	Bore 14		11/04/2021	209500.5	5747911.8	Upper Aquifer System	50	20	23	23.5	174.9	175.56	0.66	
BCBH02	Bore 15		11/04/2021	209501.1	5747912.3	Upper Aquifer System	50	11	14	14.5	174.92	175.57	0.65	
BD3	48249	48249	5/07/1968	216736	5736238	Dilwyn Formation		61.3	68	68	180.32	180.76	0.44	
BK69	48001	48001	8/10/1986	205755.6	5739813.8	Pebble Point Formation		27	33	43	248.16	248.68	0.52	
BRBH01	Bore 6		8/04/2021	215608.2	5743050.5	Upper Aquifer System	50	26.5	29.5	30	118.93	120.03	1.1	
BRBH02	Bore 7		8/04/2021	215608.2	5743051.1	Upper Aquifer System	50	2	5	5.5	118.91	119.59	0.68	
BSBH_TB1A	TB01a / BSTB1A		14/05/2014	212070.4	5742075.1	Upper Aquifer System	50	8.7	11.7	12.9	144.04	144.58	0.54	0.16
BSBH_TB1B	TB01b / BSTB1B		28/05/2015	212068.7	5742075.0	Narrawaturk Marl	50	17.5	19	19	144.06	144.67	0.61	
BSBH_TB1C	TB01c / BSTB1C		28/05/2015	212066.5	5742075.0	Lower Tertiary Aquifer	50	33	36	36.5	144.06	144.84	0.78	
BSBH01	BH01		17/04/2019	212055.8	5742138.5	Upper Aquifer System	50	2	5	6	141.86	142.46	0.6	0.22
BSBH02	BH02		7/05/2019	212034.0	5742165.3	Upper Aquifer System	26	2.2	3.7	3.7	141.75	142.91	1.16	0.11
BSBH03	BH03		7/05/2019	212046.8	5742192.2	Upper Aquifer System	26	2.5	4	4	141.74	142.94	1.2	0.03
BSBH04	BH04		23/04/2019	211875.9	5742182.4	Upper Aquifer System	50	2	5	6	143.37	144.19	0.82	0.09
BSBH05	BH05		18/04/2019	211878.5	5742213.3	Upper Aquifer System	50	2	5	6	143.08	143.88	0.8	0.06
BSBH06	BH06		18/04/2019	211903.7	5742216.0	Upper Aquifer System	50	1.9	4.9	5.9	142.9	143.58	0.68	1.51
BSBH07	BH07		17/04/2019	211911.5	5742242.8	Upper Aquifer System	50	2	5	6	142.49	143.05	0.56	0.02
BSBH08	BH08		25/04/2019	211799.6	5742195.7	Upper Aquifer System	50	1.9	4.9	5.9	144.62	145.29	0.67	0.1
BSBH09	BH09		24/04/2019	211799.9	5742231.6	Upper Aquifer System	50	2	5	6	144.36	145.04	0.68	1.31
BSBH10	BH10		24/04/2019	211811.0	5742254.8	Upper Aquifer System	50	2	5	6	144.32	145	0.68	1.3
BSBH11	BH11		8/05/2019	211662.7	5742176.2	Upper Aquifer System	50	2	5	6	147.09	147.72	0.63	0.35
BSBH12	BH12		9/05/2019	211627.9	5742228.7	Upper Aquifer System	26	1.9	3.4	3.4	147.2	147.91	0.71	0.82
BSBH13LTA	Bore 1		9/04/2021	211527.3	5742138.2	Lower Tertiary Aquifer	80	26.5	29.5	30	147.39	148.05	0.66	
BSBH14	BH14		25/04/2019	211557.4	5742124.3	Upper Aquifer System	50	2	5	6	147.66	148.3	0.64	0.13
BSBH15	BH15		26/04/2019	211526.0	5742139.2	Upper Aquifer System	50	2	5	6	147.42	148.08	0.66	0.16

Site Code	Alternate Name	State ID	Date Drilled	Easting (MGA Zone 55)	Northing (MGA Zone 55)	Monitoring Unit	Well Diameter	Screened From (m bgl)	Screened To (m bgl)	Well Base (m bgl)	Surface Elevation (mAHD)	Top of Bore (or gauge if artesian) (mAHD)	Bore Stickup (m)	Hydraulic Conductivity (m/day)
BSBH16	BH16		7/05/2019	211493.5	5742170.6	Upper Aquifer System	50	2	5	6	147.98	148.8	0.82	1.79
BSBH17	BH17		6/05/2019	211460.3	5742167.9	Upper Aquifer System	50	1.9	4.9	5.9	148.11	148.77	0.66	0.05
BSBH18	BH18		23/03/2019	211474.9	5742089.9	Upper Aquifer System	50	1.5	3	3.6	148.72	149.57	0.85	1.46
DMBH01V	Bore 18		10/03/2021	219643.9	5738495.5	Upper Aquifer System	50	12.5	15.5	16.5	165.21	165.9	0.69	
DMBH02V	Bore 19		10/03/2021	219645.6	5738494.7	Upper Aquifer System	50	5	8	8	165.28	165.96	0.68	
E68	62578	62578	28/08/1986	207175	5745629	Pebble Point Formation		59	77	85	228.17	229.01	0.84	
EBBH01	Bore 2		2/06/2022	215936.7	5734858.1	Lower Tertiary Aquifer	50	16.3	19.3	20	141.49	142.4	0.85	
EBBH02	Bore 3		6/06/2022	215937.7	5734859.4	Upper Aquifer System	50	6	9	10	141.5	142.49	0.92	
G11	64227	64227	14/08/1972	207999.6	5735190.1	Dilwyn / Pebble Point Formation		421.2	445	421.2	156.58	157.36	0.78	
G12	64228	64228	10/12/1972	208017.1	5735149.6	Dilwyn Formation		362.7	378	362.7	158.04	158.96	0.92	
G13	64229	64229	10/08/1973	214219.2	5739437.6	Pebble Point Formation		515.7	542	515.7	140.18	141.20	1.02	
G14	64230	64230	3/02/1977	215330.4	5740135.9	Dilwyn / Pebble Point Formation					140.26	140.76	0.5	
G17	64233	64233	26/08/1980	210762.9	5739801.8	Dilwyn Formation		148.9	154	160.5	171.53	172.34	0.81	
G18	64234	64234	17/11/1982	2153147.8	5740048.9	Clifton Formation		247	253	253	141.11	141.89	0.78	
G19	64235	64235	6/07/1983	208737.7	5737358.8	Clifton Formation		167.7	173.9	188	170.3	170.72	0.42	0.54
G20	64236	64236	13/07/1983	213147.3	5736286.5	Mepunga Formation		348.3	371.5	380	164.15	164.78	0.63	
G21	64237	64237	26/03/1985	210487.6	5736471.2	Pebble Point Formation		400.7	406.5	420.5	146.09	146.84	0.75	
G22	64238	64238	21/05/1985	209999	5741195	Dilwyn Formation		70	87.4	98.7	179.02	179.63	0.61	
G23	64239	64239	12/06/1986	208524.7	5740347.4	Pebble Point Formation		70	73.1	86.3	232.34	233.03	0.69	
G24	64240	64240	28/08/1986	210758.2	5739783.2	Dilwyn Formation		229.3	235.7	245.1	171.57	172.52	0.95	
G25	64241	64241	3/10/1986	213678.0	5735071.0	Mepunga Formation		142.9	146	153.1	175.86	176.44	0.58	
G28	64244	64244	3/06/1987	208192.6	5737705.7	Mepunga Formation		238.4	241.5	248.6	204.03	204.67	0.64	
GRBH01	Bore 8		23/03/2021	200404.2	5729821.4	Lower Tertiary Aquifer	50	10	13	13.5	76.24	76.92	0.69	
GRBH02	Bores 9		23/03/2021	200404.2	5729821.4	Upper Aquifer System	50	2	5	5.5	76.24	76.93	0.69	
M22	82838	82838	18/01/1973	218619	5742767	Clifton Formation					159.16	159.69	0.53	
M24	82840	82840	3/04/1973	218489	5742779	Pebble Point Formation		576.7	595	595	155.97	156.79	0.82	
M25	82841	82841	18/05/1973	218576	5742770	Mepunga Formation		460.3	466	466	158.37	159.13	0.76	
M27	82843	82843	4/09/1985	220080	5740764	Mepunga Formation		370	375.1	383.3	141.65	142.9	1.25	
M28	82844	82844	29/11/1984	218385	5746032	Mepunga Formation		134.1	140.3	134.1	127.55	128.73	1.18	
M29	82845	82845	10/12/1985	222522	5740428	Mepunga Formation		74.5	93.2	100	177.69	178.33	0.64	
M30	82846	82846	24/03/1986	225126	5742359	Dilwyn Formation		59.5	62.6	70	202.67	202.87	0.2	

Site Code	Alternate Name	State ID	Date Drilled	Easting (MGA Zone 55)	Northing (MGA Zone 55)	Monitoring Unit	Well Diameter	Screened From (m bgl)	Screened To (m bgl)	Well Base (m bgl)	Surface Elevation (mAHD)	Top of Bore (or gauge if artesian) (mAHD)	Bore Stickup (m)	Hydraulic Conductivity (m/day)
M31	82847	82847	10/04/1986	220288	5738471	Dilwyn Formation		27.6	53.4	61	173.95	174.61	0.66	
NYBH01	Bore 16		26/03/2021	214026.4	5747747.4	Upper Aquifer System	50	26.5	29.5	30	173.98	174.67	0.69	
NYBH02	Bore 17		26/03/2021	214025.6	5747746.9	Upper Aquifer System	50	3	6	6.5	174.03	174.74	0.7	
PCBH01V	Bore 20		18/03/2021	225063.3	5743027.9	Upper Aquifer System	50	26.6	29.6	30.1	161.48	162.09	0.61	
PCBH02V	Bore 21		18/03/2021	225063.3	5743028.0	Upper Aquifer System	50	4.5	7.5	7.7	161.48	162.09	0.61	
TMCBH01	Bore 10		31/03/2021	202686.3	5738451.3	Lower Tertiary Aquifer	50	26.7	29.7	30.2	159.55	160.29	0.74	
TMCBH02	Bore 11		31/03/2021	202686.6	5738452.0	Lower Tertiary Aquifer	50	7	10	10.5	159.56	160.21	0.65	
W4	102865	102865	20/03/1972	222674.3	5748887.4	Pebble Point Formation					119.99	120.25	0.26	
W7	102868	102868	9/04/1984	221400	5750847	Dilwyn Formation		449	459	473.8	120.77	121.18	0.41	
W9	102869	102869	19/09/1984	222268	5745680	Mepunga Formation		418	424	427	143.79	144.46	0.67	
WBBH01	Bore 4		13/04/2021	210956.6	5734348.7	Lower Tertiary Aquifer	50	15	18	18.5	141.62	142.19	0.58	
WBBH02	Bore 5		13/04/2021	210957.2	5734348.6	Upper Aquifer System	50	2	5	5.5	141.62	142.16	0.53	
Y40	108915	108915	6/04/1987	210432	5734393	Mepunga Formation		123.9	127	134	156.1	157.02	0.92	
Y41			2006	211131.7	5734330.4	Dilwyn Formation					141.93	142.58	0.65	
YCBH01	Bore 12		28/03/2021	200561.0	5737420.7	Lower Tertiary Aquifer	50	26.5	29.5	30	143.28	143.93	0.66	
YCBH02	Bore 13		28/03/2021	200560.2	5737420.0	Lower Tertiary Aquifer	50	11.5	14.5	15	143.29	143.95	0.66	
YEO19	109110	109110	27/10/1980	210675	5743580	Pebble Point Formation		67.4	76.7	98.4	176.56	177.47	0.91	
YEO20R	109111	109111	1/06/2017	210618.4	5743570.5	Dilwyn Formation	100	19.8 31.8	25.8 40.8	41	173.38	174.14	0.76	
YEO21	109112	109112	9/12/1983	212815.0	5742350.8	Mepunga Formation		54	59	59	137.39	137.79	0.4	
YEO22	109113	109113	29/05/1984	212231.0	5742825.8	Pebble Point Formation		198.9	231	270.6	179.16	179.69	0.53	
YEO23	109114	109114	15/11/1984	212933	5749559	Pebble Point Formation					163.48	164.44	0.96	
YEO37	109128	109128	1/01/1970	210508.5	5742696.4	Dilwyn Formation		20	28	30	158.92	159.01	0.09	
YEO38	109129	109129	1/01/1970	210542.1	5742717.0	Dilwyn Formation		12	18	20	163.68	164.61	0.93	
YEO39	109130	109130	1/01/1970	210290.1	5743587.0	Dilwyn Formation		8	15.5	17.5	162.46	163.19	0.73	0.009
YEO40R	109131	109131	1/06/2006	210614	5742866	Dilwyn Formation						165.703		
YEO41	109132	109132	5/05/1986	209779.8	5742159.3	Pebble Point Formation		106.2	109.3	123	206.98	208.16	1.18	
YEO42	109133	109133	20/06/1986	210858.4	5745236.6	Dilwyn Formation		79	82.1	91.1	210.13	210.82	0.69	
YEO44	109135	109135	7/08/1986	216168.6	5749323.1	Mepunga Formation		152.4	155.5	162.5	175.24	175.22	-0.02	
YYG217	107716	107716	27/10/1987	232437	5749265	Dilwyn Formation		97	100.8	107	190.91	191.81	0.9	
YYG218	107717	107717	19/11/1987	232440	5749622	Dilwyn Formation		174.9	177.9	192.5	190.47	191.86	1.39	
YYG221	107720	107720	25/03/1988	229704	5751452	Dilwyn Formation		132	135	142	132.7	134.11	1.41	