WEST GIPPSLAND CATCHMENT MANAGEMENT AUTHORITY

Thomson River-Rainbow Creek

Waterway Management Plan 2020

West Gippsland
Catchment Management Authority

Acknowledgements

The Thomson Rainbow Waterway Management Plan was co-developed through the collective effort of a number of individuals and organisations, including:

- Project Working Group members: Cr. Carolyn Crossley (Chair), Trevor Astbury, Norm Drew, Beverly Hookey, Merv Whittaker, Phil Taylor, Malcolm Stewart and representatives from Gippsland Water, Wellington Shire Council, Gunaikurnai Land and Waters Aboriginal Corporation, Southern Rural Water and the West Gippsland Catchment Management Authority
- Project Steering Committee members: Southern Rural Water and the West Gippsland Catchment Management Authority
- Project Team: Natural Decisions (Geoff Park and Anna Roberts), Blue Sense Consulting (Michelle Dickson), Professor Ian Rutherfurd, and Water Technology (consulting support)
- Interested community members and landholders who participated in community forums and the supporting studies for this plan.

Acknowledgement of Country

The West Gippsland Catchment Management Authority would like to acknowledge and pay our respects to the Traditional Land Owners of the Thomson – Rainbow Creek area, the Gunaikurnai people. We also recognise the contribution of Aboriginal and Torres Strait Islander people and organisations in land and natural resource management.

Disclaimer

Executive Summary

The Thomson River and Rainbow Creek form part of the Lake Wellington catchment of the Ramsar listed Gippsland Lakes. The waterways flow from Cowwarr Weir through productive agricultural land that forms part of the Macalister Irrigation District. Rainbow Creek is a relatively new waterway in that it formed in the 1950s following a series of flood events on the Thomson River that carved a new flow path (avulsion). The development of Rainbow Creek had a significant impact on the farming communities of Cowwarr and Heyfield districts and changed the way water is managed in the Thomson River and Rainbow Creek following the construction and operation of Cowwarr Weir in 1959.

Current scientific understanding of the system indicates that another avulsion of the Thomson River and Rainbow Creek system is highly likely. This Waterway Management Plan aims to raise community and agency awareness of the risk of another avulsion and the options to address this risk. Implementation of the Plan is intended to manage the risks of an avulsion occurring as well as enhancing the values of the Rainbow Creek and Thomson River.

The Waterway Management Plan was developed using an evidence-based approach, informed by science, modelling, benefit:cost analysis and the knowledge and expertise of local people. Formal governance arrangements were established to provide oversight to the planning process and included a Project Steering Committee and Project Working Group.

The overall vision for this Waterway Management Plan is that the Thomson and Rainbow system is managed to reduce the risk of avulsion and improve waterway health with benefits for agriculture, the community and the Gippsland Lakes.

Objectives were developed by the Project Working Group based on maintaining the productivity of agricultural land and improving amenity, recreation, local natural values and waterway stability.

The benefits and costs of a range of scenarios were assessed and reviewed by the Project Working Group. The scenario selected as the basis for this Plan is to maximise local natural values (riparian) on both the Rainbow Creek and Thomson Rivers and to also minimise the potential damage from a future avulsion. This will be achieved through fencing, willow control and revegetation where required and to reduce the avulsion risk through targeted rock beaching of five identified avulsion 'hotspots', and addressing high-risk instream blockages. This scenario was selected as it is cost-effective, with benefits exceeding costs by almost 80% and it meets the vision and objectives of the WMP.

The initial costs of implementation are approximately $4M, with additional on-going costs of approximately $70,000/year. The costs of implementation represent a significant increase in effort and funding as compared with current programs. The West Gippsland Catchment Management Authority and Southern Rural Water are committed to exploring options to secure funds for implementation informed by the benefit:cost analysis that underpins the Plan.

Contents

1 Introduction

The Thomson River and Rainbow Creek provide essential resources for agriculture, communities and the natural environment. Rainbow Creek was formed in the 1950s through floodplain processes, triggered by floodwaters in the Thomson River that carved a new flow path (avulsion). The avulsion lead to significant loss of agricultural land, liberating hundreds of thousands of tonnes of sediment into the Thomson River and the downstream receiving waters of the Gippsland Lakes. The development of Rainbow Creek had a significant impact on the farming communities of Cowwarr and Heyfield districts. The construction of Cowwarr Weir in 1959 and its operation changed the way water is delivered, providing flow to both the Thomson River and Rainbow Creek. Water from Cowwarr Weir provides significant value to the community by providing an irrigation offtake and expansion of the Macalister Irrigation District.

Without active management of flow at Cowwarr Weir, Rainbow Creek would be the preferred flow path of the Thomson River (see Section 3 for more detail). Current scientific understanding of the system indicates that another avulsion of the Thomson River and Rainbow Creek system is highly likely. Intervention is required to reduce the risk (in the short to medium term) of an avulsion occurring and the subsequent impacts on communities and the environment.

To help reduce the risk of avulsion and maintain the values of the Thomson River and Rainbow Creek the West Gippsland Catchment Management Authority has partnered with the local community and government agencies to develop this Waterway Management Plan (The Plan).

The Plan will guide investment in on-ground actions along the Thomson River and Rainbow Creek and enable actions to support delivery of works and improve knowledge of the waterways and floodplain. The Plan has an emphasis on collaboration between agencies and the community to achieve the priorities that have been identified to best achieve environmental, social and economic benefits.

Figure 1. Project area

1.1 Overview

Understanding catchment and floodplain processes

The Plan provides a strategic approach to reducing the short-term risk of avulsion whilst also aiming to improve the health of the Thomson River and Rainbow Creek. It is supported by a 4-year plan for implementation of on-ground works, maintenance activities and supporting actions.

The Plan provides a consolidated understanding of floodplain and waterway processes operating in the system and the environmental, social and economic values associated with the system. The Plan acknowledges that the long-term risk of avulsion will remain as a result of the catchment setting and floodplain processes but that short-term (1-4 years) and medium term (20-30 years) actions can reduce avulsion risk and improve the overall values of the waterways.

Providing an achievable and cost-effective plan of works

The actions in this plan have been selected using a range of models and decision support tools, the technical advice of scientists and waterway practitioners and the local knowledge of community members. Economic analysis has ensured the benefits and costs associated with implementing the plan have been transparently and consistently assessed in developing a cost-effective program of works.

Involving the community, agencies and technical specialists

The Plan has been developed through a collaborative process that has drawn on the collective knowledge of the local community, agency representatives, technical specialists and waterway planners. Implementation of the Plan will continue the process of sharing knowledge and learning from each other's experience.

It is expected that the Plan will guide Government investment and the activities of agencies as well as the farming community, landholders and interested community groups associated with the Thomson River and Rainbow Creek system. The costs of implementation represent a significant increase in effort and funding as compared with current programs. The West Gippsland Catchment Management Authority and Southern Rural Water are committed to exploring options to secure funds for implementation informed by the benefit:cost analysis that underpins the Plan.

1.2 Scope

The geographic scope of the Plan includes both the Thomson River and Rainbow Creek from Cowwarr Weir to their confluence downstream of Heyfield. It is acknowledged that successful implementation of the Plan will have downstream benefits for both the Thomson River and the Gippsland Lakes. Furthermore, supporting actions and catchment processes upstream of Cowwarr Weir, while outside the direct scope of the Plan, form an important element of an integrated catchment management approach to achieving the benefits of the Plan.

Avulsion risk and waterway health

The Plan addresses the specific risk of another avulsion creating a new flow-path across the floodplain between the Thomson River and Rainbow Creek. It also considers complementary actions required to reduce instream erosion of Rainbow Creek and improve the environmental health of stream banks and the land directly adjacent to the Thomson River and Rainbow Creek (the riparian area).

Amenity and recreation

The Thomson River and Rainbow Creek support community and uses and recreational activities and have important amenity values. Actions to improve amenity and recreation values are not the primary focus of this Plan, however there will be shared benefits from actions to improve overall waterway health. The delivery of the priorities in this Plan will consider ways in which complementary actions to improve the amenity and recreation could be achieved. This might include contractors undertaking works at Rainbow Park (Cowwarr[1]) whilst working on waterway health projects in the local area or using this Plan to help secure funding for complementary works.

Other water and catchment management issues

Irrigation and agricultural management practices

Irrigation water and security of supply of water is an important issue to landholders along the Thomson River and Rainbow Creek. This project has broadly considered the risk of avulsion to the supply of water for irrigators on the Thomson River and Rainbow Creek. Modelling has not considered the specific risks to individual irrigators but has estimated the likely impact on infrastructure and productive agricultural land at a system scale in the case of a future avulsion.

The planning process acknowledges that the practices of agricultural landholders, including irrigation, have the potential to impact on the natural functioning of the floodplain. The inter-relationship between irrigation practices, floodplain management and avulsion risk have not been explored in detail through this project. However, on-farm practices and sustainable irrigation are considered through the Lake Wellington Land and Water Management Plan (2018). Delivery of activities will be coordinated by the WGCMA and Southern Rural Water to avoid any unintended consequences which may arise from differing program objectives.

Urban water supply

The Thomson-Rainbow system provides an important source of drinking water for local communities. Water for the township of Heyfield is sourced from the Thomson River and is treated at the Heyfield Water Treatment Plan (WTP). Actions in this plan to limit stock access to waterways and reduce the risk of avulsion will support water security and improved water quality from the Thomson system.

Environmental flows

The management of flows from Cowwarr weir into the Thomson River and Rainbow Creek considers the water demands of irrigators and Gippsland Water as well as environmental requirements. The management of the flow regime is important to support and maintain the natural values and processes of the Thomson and Rainbow system and is informed by environmental flows studies and an annual planning process. This Plan has not completed a detailed investigation into how the management of environmental flows might support measures to reduce the avulsion risk.

An updated environmental flows investigation is currently underway (through a separate study) and this project will provide updated advice on the flow requirements to support channel form and physical habitat in the Thomson River and Rainbow Creeks.

[1] Rainbow Park is known by a number of alternative local names including: The Waterhole, Waterhole Reserve, The Reserve and Waterhole Lane (Norm Drew pers.[comm]).

2 Developing the Plan

2.1 Approach

The development of the Plan involved a structured planning approach undertaken over a twelve month period from December 2018 and December 2019. The approach involved the following inter-related activities (see Figure 2):

- Capturing current knowledge and community values
- Establishing a vision and objectives
- Modelling and technical advice on avulsion risk
- Identifying on-ground works and enabling actions
- Economic analysis of the benefits and costs of alternative management scenarios
- Decision making on preferred scenario for implementation
- Developing a works-plan and arrangements for monitoring, evaluation, reporting and improvement

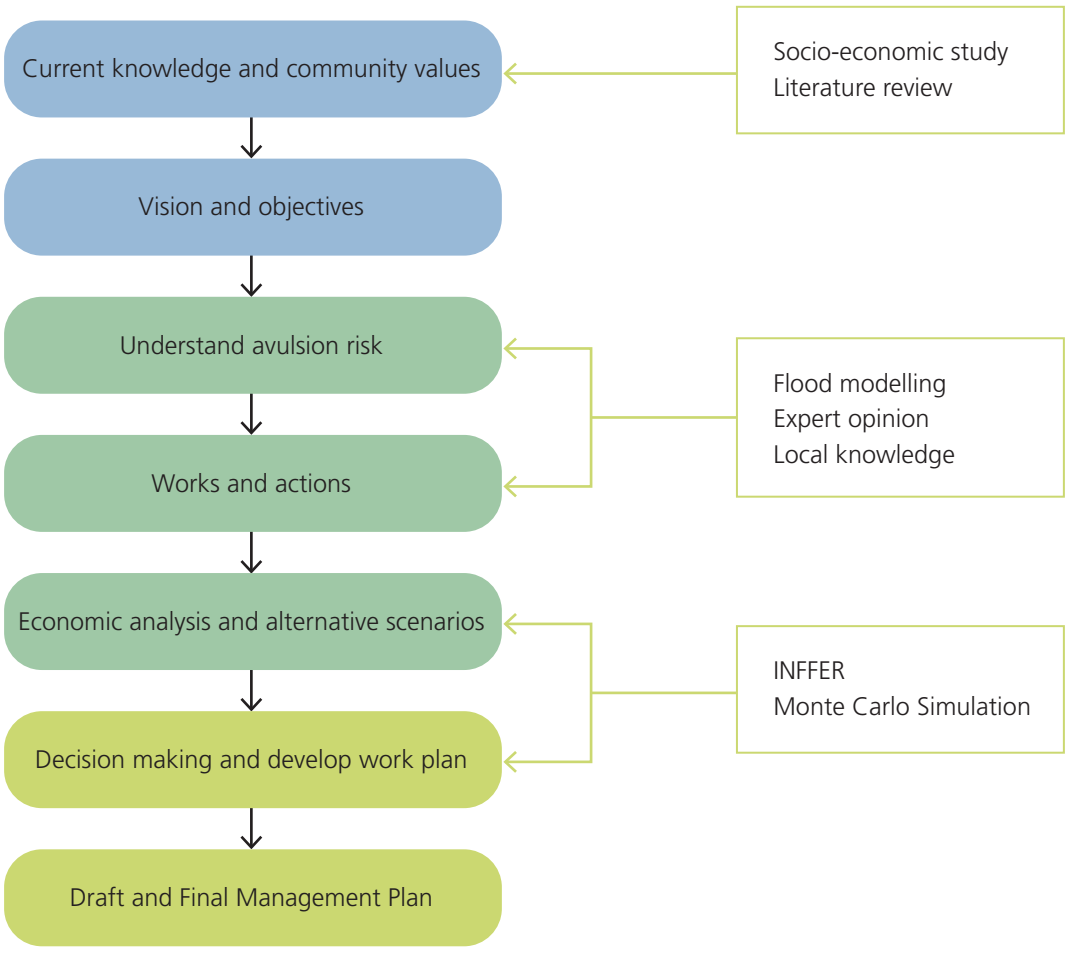

Figure 2. Stages in developing the Thomson River/Rainbow Creek Waterway Management Plan

2.2 Evidence to support decision making

Community views

Consultation with local community members was an important aspect of the collaborative process to develop this Plan. Community views were obtained through two public forums, participation by Project Working Group members and a series of in-depth interviews conducted with 30 local community members, including 25 of the landholders along the Rainbow Creek and Thomson River. The primary aim of the interview process was to gather information, knowledge and perspectives of local community members to inform the Plan. The interview process focussed on exploring the benefits and/or risks of any future management practices for the Thomson/Rainbow System. The results from the interviews were used to confirm the scope of the Plan, to develop the vision and objectives and to identify and assess potential management scenarios. More information on community values and perspectives is documented in Section 3.

Asset inventory

An inventory of assets associated with the Thomson River and Rainbow Creek was compiled to inform the preparation of this Plan. The inventory included information on built assets (e.g. houses, irrigation infrastructure, roads, bridges etc.) and natural assets (waterways, native habitat etc.). The asset inventory was used to understand the location of private and public infrastructure, the extent of past works, condition of waterways and predicted flood extent. This data was used to help quantify the avulsion risk and estimate the costs and benefits from different management scenarios.

Modelling

Scientific and technical modelling was undertaken to support a number of key steps in the development of the Plan. This included:

- Hydrological modelling of water flows under different flood event conditions to identify where potential avulsions may initiate and their subsequent development paths across the floodplain (example of a 1% AEP flood extent (also known as 1 in 100 year) is shown in Figure 3).
- The effect of different waterway management options (e.g. revegetation of riparian zones) and issues (e.g. waterway blockages) on floodplain flows (Water Technology, 2019).
- Analysing the effect of potential avulsion pathways on floodplain and waterway assets, especially productive agricultural land and infrastructure (houses, roads etc.) as a means of assessing avulsion consequences and the effectiveness of treatments to reduce avulsion risk.

The use of flood modelling was a crucial input to the benefit: cost analysis using INFFER (described in the next section).

Benefit: Cost Analysis (INFFER)

The Investment Framework for Environmental Resources (INFFER™) is a structured decision-making process to assess the benefits and costs of making investments in the environment. INFFER (Pannell, et.al, 2012) takes into account all factors that need to be considered in making transparent and robust decisions about the most cost-effective options to manage the environment and natural resources. INFFER uses available and relevant knowledge and information (science, expert judgement and local knowledge) to estimate the benefits and costs of alternative management options.

It is a proven method (published in peer-reviewed scientific and economic journals) and is recognised across Australia and internationally as a state-of-the-art approach to environmental decision-making. INFFER has been used successfully to develop business cases to implement large-scale environmental projects, including waterway management plans.

To support the development of the Plan INFFER was used in a participatory and collaborative process with the Project Working Group to assess the relative cost-effectiveness of alternative implementation options and to identify the preferred option for the Plan itself. Refer to Appendix A for more detailed information about INFFER.

2.3 Governance and community participation

The Plan was developed through a collaborative process, led by the West Gippsland Catchment Management Authority. The Plan incorporates the views and perspectives of community members, landholders and agency representatives. Formal arrangements were established through a Project Steering Committee and Project Working Group (Figure 3). The project team also met with members of the local community including Thomson River and Rainbow Creek landholders at key points across the planning process (see Table 1).

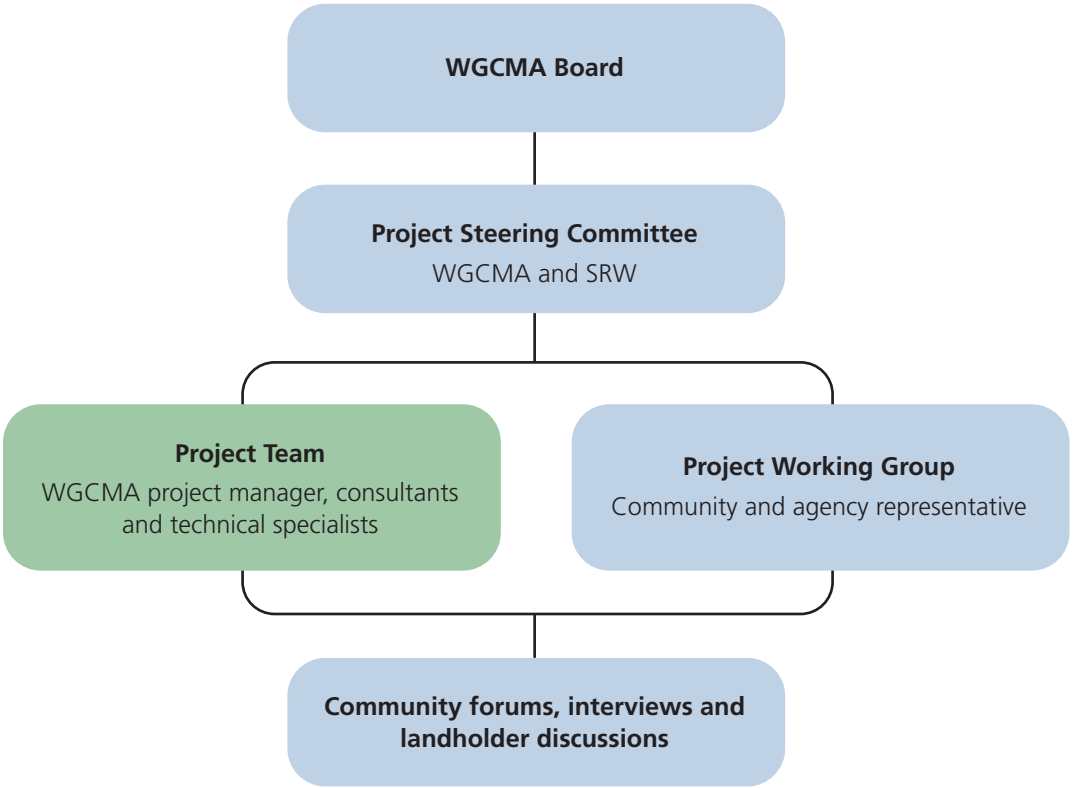

Figure 3. Governance and Engagement Structure for Plan development

Table 1. Governance and community participation arrangements for Plan development

Group	Role	Level of participation
Project Steering Group	• Overall project governance • Review and approval of key milestone documents and draft/ final Waterway Management Plan • Guidance on stakeholder and community consultation	Empower (final decision makers) in terms of the overall deliverables produced by the project team.
Project Working Group	Collaborative input with consultant team to project workshops that informed Plan development • Feedback on proposed method/ approach • Developed and refined the vision and objectives • Input to INFFER analysis and review of results • Input and review of the draft Plan	Collaborate – involved in each aspect of the decision including the development of alternatives, identification of the preferred solution and developing the response to concerns raised by the community.
Thomson River and Rainbow Creek community	Feedback and consultation at key points: • Vision, objectives and options • Preliminary results • Draft Plan	Involved – directly engaged to ensure their aspirations and concerns are heard, understood and responded to.

3 Thomson-Rainbow system

3.1 Overview of the planning area

This Plan focuses on the Thomson River and Rainbow Creek from Cowwarr Weir to the Thomson-Rainbow confluence just downstream of Heyfield (Figure 1). The Thomson-Rainbow system forms part of the mid-Thomson sub-catchment area and is within the Lake Wellington catchment of the Ramsar listed Gippsland Lakes.

Upstream of Cowwarr weir the Thomson River flows from a steep catchment on the Great Dividing Range and emerges at the foothills west of Cowwarr, it then flows through a sediment store known as an 'alluvial fan'. Below Cowwarr Weir the Thomson River flows along the northern boundary of the alluvial fan, whilst Rainbow Creek flows to the South (Zavadil, Moar, & Vietz, 2011). Stony Creek is a tributary of the Thomson River, joining the river approximately 2km downstream of Cowwarr Weir.

The floodplain and agricultural land of the Thomson-Rainbow system is highly productive, forming part of the Macalister Irrigation Area, the largest irrigation district south of the Great Dividing Range (WGCMA, 2014). The communities of Heyfield and Cowwarr have a strong association with the local waterways and rely on them for water supply.

Traditional Owners

The Gunaikurnai are recognised as Traditional Owners over approximately 1.33 million ha in Gippsland – extending east-west from near Warragul to the Snowy River and north-south from the Great Dividing Range to the coast and sea country.

The Gunaikurnai have lived in the valleys, on the fertile plains and up in the mountains of their traditional country for many thousands of years. They see their land (Wurruk), waters (Yarnda), air (Watpootjan) and every living thing as one. All things come from Wurruk, Yarnda and Watpootjan and they are the spiritual life-giving resources, providing the people with resources and forming the basis of their cultural practices. Gunaikurnai culture and identity is embedded in Country. Aboriginal heritage is strong across Gunaikurnai Country, and cultural sites and artefacts can be found along Gunaikurnai songlines, and trade routes, mountain ridges and waterways. They remind the Gunaikurnai about the ways of their ancestors and show their close and continuing connection to Country.

The Gunaikurnai people are actively pursuing their cultural responsibilities to care for country through the management and protection of cultural and natural assets and values within the Thomson-Rainbow planning area.

Development of Rainbow Creek

Community members report that Rainbow Creek previously existed as a series of billabongs on the floodplain. The channel was formed in 1952 through an avulsion during a significant flood event (up to 85,000 ML/day), although prior to this headward erosion was observed at a number of 'knick points' along Rainbow Creek. By 1956 Rainbow Creek was carrying the entire flow that had previously passed along the Thomson River.

Landholders recall this period as traumatic for the local community. Those on the Thomson River lost access to water for irrigation, whilst many landholders on the Rainbow Creek had their property cut in two by the newly formed channel, resulting in the loss of land and access to property. In the years following the formation of the channel, private landholders constructed bridges and crossings to try and maintain access to their land.

Cowwarr Weir was constructed in 1957 to divert flow back into the Thomson River and manage the split of flows between the Thomson River and Rainbow Creek. While subsequent floods continued to impact on the bed and banks of Rainbow Creek, a major flood in 1978 caused significant erosion and damage along the Rainbow Creek and was the catalyst for a major program of waterway rehabilitation works.

Works undertaken in response to the 1978 floods were undertaken using the best available knowledge and understanding of waterway management principles at that time. Important elements of the recovery program, such as grade-control structures and concrete groynes were designed to manage flows and reduce erosion and continue to play a positive role. It was acknowledged however, that some actions, for example the large scale planting of willows, while appropriate for the time would not have been done with the benefit of hindsight.

The development of the Rainbow Creek avulsion has been documented in various studies including Brizga (1990), Brizga and Finlayson (1990) and Erskine et al. (1990). A study by Alluvium in 2011, (Zavadil et al 2011) gives a synthesis of this work and provides a contemporary understanding of the avulsion risk in the Thomson/Rainbow system. Consultation undertaken for this Plan has provided additional local context to the technical understanding of the development of Rainbow Creek. A conceptual overview of the system is shown below (Figure 4) while a chronological summary is provided in Table 2.

Table 2. Development of Rainbow Creek (summarised from Zavadil et. al 2011: and Park and Dickson 2019)

Year	Event
1891	Newspaper reports on the large flood in 1891 drew attention to considerable damage on the floodplain near Cowwarr, along with other reports of severe erosion under the rail bridge which would later span Rainbow Creek.
1950s	The current Rainbow Creek exists as a series of billabongs. Landholders observe headward erosion in the current upper reach of the Rainbow Creek, during a series of large rain events.
1952	During the major flood of June 1952, the new channel was cut by floodwater. Although the channel was blocked by farmers after the June 1952 flood, another flood in December 1952 removed the barrier and completed the avulsion.
1955	Local reports suggest that by 1955 a well-defined continuous channel had been established.
1956	The base flow from the Thomson River is captured by Rainbow Creek, resulting in a massive reduction in flow in the Thomson River. Cowwarr Weir was constructed in 1957 to divert irrigation flows down the Thomson River and control the flow split between the Thomson River and Rainbow Creek.
1960s	Landholders observe topsoil falling into Rainbow Creek as the channel develops.
	Landholders recall the period from the 1960s and mid 1970s as being relatively dry with no major floods.
1975 – 1976	The first of several substantial flood relief allocations for Rainbow Creek was made by the government.

Table 2. Development of Rainbow Creek (summarised from Zavadil et. al 2011: and Park and Dickson 2019) *continued...*

Year	Event
1978	Landholders recall the 1978 flood as significant, driven by rainfall in the Aberfeldy catchment. This event caused significant erosion and loss of topsoil along Rainbow Creek. Records at the Thomson River, upstream of Cowwarr Weir gauge recorded flows of up to 66,100 ML/day and modelling suggests that the peak flows reached somewhere between 90-100,000 ML /day (Arrowsmith, Russell, & Laws, 2011).
1978 – 1980s	Effects of the 1978 flood on the Rainbow Creek channel were substantial enough to secure one million dollars for channel stabilisation works (erosion control). Works included the use of around 36,000 concrete blocks, installation of grade-control structures, plus fencing and revegetation including native trees and willows. The works (undertaken by the Thomson River Improvement Trust) following the 1978 flood were seen have been very successful in controlling erosion and improving the overall environmental and aesthetic values of the waterway.
2006 – 2007	Extensive bushfires across the upper Thomson River catchment (Dec 06 – Jan 07), followed by flooding in June – July 07. The 2007 floods are reported by the community as the last 'big flood'. The peak modelled flow at the Thomson River, upstream of Cowwarr Weir gauge was estimated to be 73,700 ML/day (Arrowsmith, Russell, & Laws, 2011). Whilst some damage was reported on the Rainbow from this flood event, the Creek was viewed by many landholders to have 'held up well'. Repairs to Cowwarr Weir undertaken in 2007 (banks and bed reinforcement downstream). An estimated 50,000 m^3 of sediment (silt and shingle) removed from behind Cowwarr Weir following June – July 2007 flooding – restoring the original design profile for the upstream pool.
Since 2007	The WGCMA has worked with a number of landholders along the Rainbow Creek and Thomson River to undertake riparian improvements works, including fencing and revegetation, willow management and weed control.

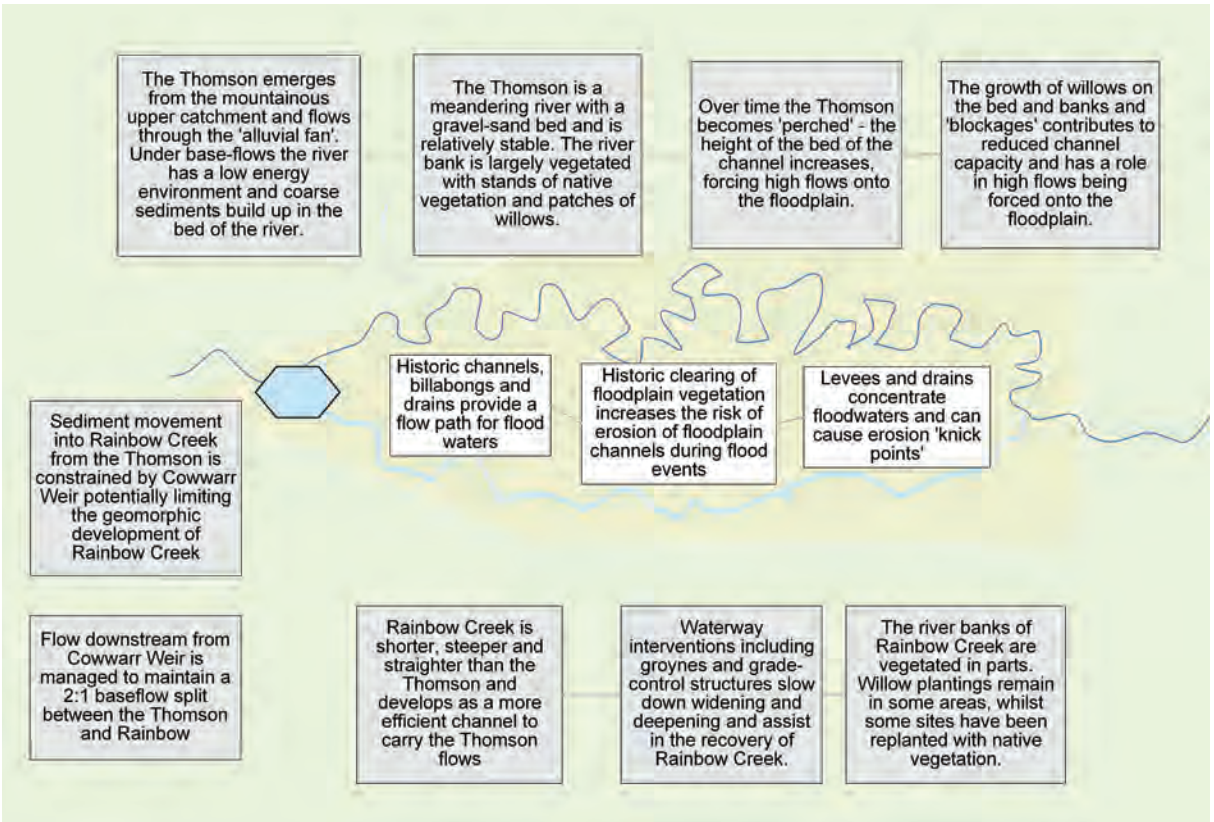

Figure 4. Conceptual overview of avulsion development on the Thomson River and Rainbow Creek

Community perspectives on the formation of Rainbow Creek were collected through interviews and consultation for the Plan. A selection of views and recollections are included below.

Community perspectives on the development of Rainbow Creek

I can remember family stories of how the channel formed – it took until the 60s for the creek to really form, before then it was swampy and flowed across land for quite a few years. The channel was much narrower in the past. (Rainbow Creek landholder).

Before Rainbow Creek formed a lot of the country was swampy and lagoons (1930s map), when Rainbow Creek cut through it drained and became more productive. (Thomson River landholder).

The formation of the creek has been a game changer, was all dryland farming previously but now there is access to irrigation water, which makes the land more valuable and production. (Community interest).

1978 flood saw the creek move a lot – erosion of outside bends, then the river improvement trust came through a did a lot of works. Hasn't changed that much since. (Rainbow Creek landholder).

Big changes after the '78 flood i.e. movement of outside bend in '78. Big program of work in 78-81, groynes, grade control structures that have helped keep the river from laterally moving (Other).

There have been two big floods since 1991. Flood after Black Saturday was very significant – it left lots of large woody debris across the floodplain and did quite a bit of damage. 80 – 90,000 ML/day can move down the creek in a big flood. (Rainbow Creek landholder).

After the creek cut through it was completely erratic, lots of movement of sediment.

People tried to put willows in to slow the flow, but the river can't be controlled and the willows only partly worked. In the 60s and 70s it was drier and the changes were slower. Concrete blocks and grade controls worked well but it did straighten the bends. (Rainbow Creek landholder).

We don't get the water that we used to … the climate has totally changed. (Community interest).

3.2 Community views and perspectives

As part of the early stages of plan development extensive consultation was undertaken with community members and landholders. The focus of the stakeholder consultation was on local perspectives, in particular those of landholders on Rainbow Creek (and the Thomson River) and people with community interests, such as local residents and others with long term historical knowledge of Rainbow Creek and the broader Thomson River catchment context.

The consultation covered the following matters:

- Landholder profile, farm area, how long they have lived/farmed in the area, farm scale assets, enterprise and land use.
- Knowledge and experiences with the creek – values/threats, flow and geomorphic changes, vegetation changes, flooding history.
- Perceptions of the future risk and consequences of large scale rainfall and flooding.
- Views on future management options.

30 people were interviewed (the majority face-to-face) and the detailed results were reported and used to inform the planning process (Park and Dickson, 2019).

Values and community uses

The Thomson River and Rainbow Creek system supports a range of values and community uses. During consultation, the water resources associated with the waterways were highlighted as a particularly important value. Water is especially valued in supporting irrigated agricultural production and the supply of potable water for domestic use. Other important values of the waterways included amenity and recreation with biodiversity and habitat also significant.

Secure water supplies are essential for the viability of irrigated agriculture and to support townships and industry. There are 18,000ML of entitlements in the Thomson-Rainbow system (SRW, undated). Within the planning area Gippsland Water supplies more than 850 domestic customers with water from the Thomson River via the Heyfield Water Treatment Plan. Gippsland Water is also planning in the future to supply a further 400 customers on the Coongulla-Glenmaggie system from the Heyfield WTP (F. Pfeil pers. comm and Gippsland Water, 2017).

Waterways in the planning area support six native species of migratory fish that need to move between the sea and freshwater environments to complete their life cycles. The system provides important habitat for the Australian grayling, which is listed as a threatened species in Victoria. The composition and condition of native vegetation along stream banks varies, the Thomson River has more extensive tracts of vegetation than the Rainbow. In many places vegetation is degraded due to stock access and widespread weed invasion (VEWH, 2019). Water for Environment is managed to support fish, vegetation, channel form and invertebrates in the Thomson/Rainbow system (VEWH, 2019).

The Thomson River and Rainbow Creek system supports a range of recreational uses and the waterways form an important part of the landscape character. Community members and visitors access waterways and streamside areas for canoeing, walking and relaxation, whilst the Gippsland Plains Rail Trail crosses through the planning area and provides glimpses of the waterways and floodplain environments. Rainbow Park in the township of Cowwarr provides open space and directly adjoins Rainbow Creek.

3.3 Management issues and the risk of avulsion

Management issues

The consultation process identified a range of views on waterway management issues which are summarised in Table 3. There are a number of key issues associated with the current state and management of Rainbow Creek and the Thomson River, with the predominant issues being; erosion and bed degradation, native species (e.g. wattles) impeding flow, weed invasion and willow management. Consistent themes emerged in the identification of issues but there was by no means overall agreement on the importance of all issues. For example, while willows and their impact on flows was seen as a major concern by many interviewees, some respondents valued the willows for aesthetic and functional values.

Table 3: Summary of management issues identified during community consultation.

Issue	Number of responses	Comment
Bank erosion and bed degradation	9	A complex issue that is understood quite differently by different people. Linked to a number of other issues (e.g. willow, flow impedance, wombat impacts etc.).
Native species (e.g. wattles) impeding flow	8	Largely related to native species growing in the bed and on the banks, where in some cases they are viewed as 'blockages' to water flow.
Weed invasion	7	On-going management of weeds was seen as an important future management action.
Willows	6	As per native species willows growing into the stream viewed as blockages and a risk for flooding.
Uncontrolled public access	4	Vandalism, litter etc.
Grey water from Cowwarr township	4	Run-off/infiltration of poorly functioning septic systems.
Aesthetics	3	Especially in key public access locations such as Cowwarr Park.
Native fauna (wombats)	3	Tunnelling in banks causing erosion.
Lack of agency coordination/ communication	3	Lack of clarity about the roles and responsibilities of relevant organisations. Sometimes not notified about changes in flow (environmental flows or other flows).
Carp	3	Impact on bank stability and water quality.
Uncontrolled stock access to waterway	3	Acknowledgement that a significant % of the Thomson River and Rainbow Creek has been fenced and revegetated over recent years.
Agricultural run-off	2	
Levee banks and land forming altering flows	2	Concerns that some levee banks and land-forming has occurred without permission.
Pest animals (foxes, rabbits)	1	
Habitat quality and quantity	1	

Avulsion Risk

Under 'natural conditions' and without the establishment of the Cowwarr Weir in the mid-1950s, the course of the Thomson River would have been abandoned, with the entire flow directed down Rainbow Creek.

The establishment of the weir now allows for control of the flow, and release of water is split between the Rainbow Creek and the Thomson River as described below.

- The flow split is in the order of 2:1 in favour of the Thomson River up to an inflow of around 500 ML/d, at which point a by-wash channel is opened to deliver more flow to the Thomson River.
- When inflows to Cowwarr Weir reach around 1000 ML/d the floodgates into Rainbow Creek are usually opened and the majority of flood flow is then carried by Rainbow Creek.
- Depending on the flood event, operators can sometimes maintain the 2:1 flow split (beyond inflows of 1000 ML/d) in favour of the Thomson River, but usually the flow split will end up being either 1:1 or 2:1 in favour of Rainbow Creek for these large events (Zavadil, Moar, & Vietz, 2011).

The management of flows down the Thomson River and Rainbow Creek, and the interception of sediments within Cowwarr Weir have artificially disrupted the "natural" waterway processes. As a result, there is an ongoing likelihood of another avulsion event occurring in the Rainbow/Thomson system over coming decades. Expert opinion indicates that the likelihood of another avulsion is not merely possible; it is inevitable, at some future time as the system evolves. It is understood that development of such an avulsion event is most likely under a moderate (1:5 to 1:20) flood event. In the case that there is no management intervention the probability of an avulsion in the next 100 years is very close to 100% (I. Rutherfurd pers. comm.).

Figure 5 below shows the location of the most likely initiation points for a future avulsion and the paths that would be created by a 'new' course. However, it is important to note that once one of the avulsion paths happen, this relieves the pressure on the system and the other paths will not form (i.e. there will only be one avulsion pathway). These are described in Table 4; in order of decreasing likelihood (i.e. path 1 is the most likely and 5 is the least likely). The location of avulsion initiation points and subsequent avulsion pathways has been identified through examination of available flood modelling (Water Technology, 2019) by Professor Ian Rutherfurd from the University of Melbourne (a member of the project team).

Table 4: Overview of the probability of an avulsion along identified pathways
(Note that the likelihood of an avulsion occurring along one of these pathways is assumed to = 1)

Avulsion pathway	Description	Relative probability of occurrence	Probability of occurrence (in next 100 years)
1	Thomson River – downstream of Cowwarr-Seaton Road	Most likely – this pathway has the most active channel formation	0.50
2	Thomson River – downstream of Stony Creek confluence		0.25
3	Rainbow Creek – downstream of Cowwarr township		0.10
4	Rainbow Creek – between Cowwarr Weir and Cowwarr		0.10
5	Rainbow Creek – Coghlan's Lane	Least likely	0.05

It is important to note that while these locations and paths are deemed to be the most likely based on currently available information, the exact location and timing of a future avulsion is uncertain. Despite the uncertainties the results from the modelling and expert advice does provide a basis upon which to estimate both the costs of an avulsion and the benefits of management actions that can be implemented to reduce the likelihood of an avulsion occurring.

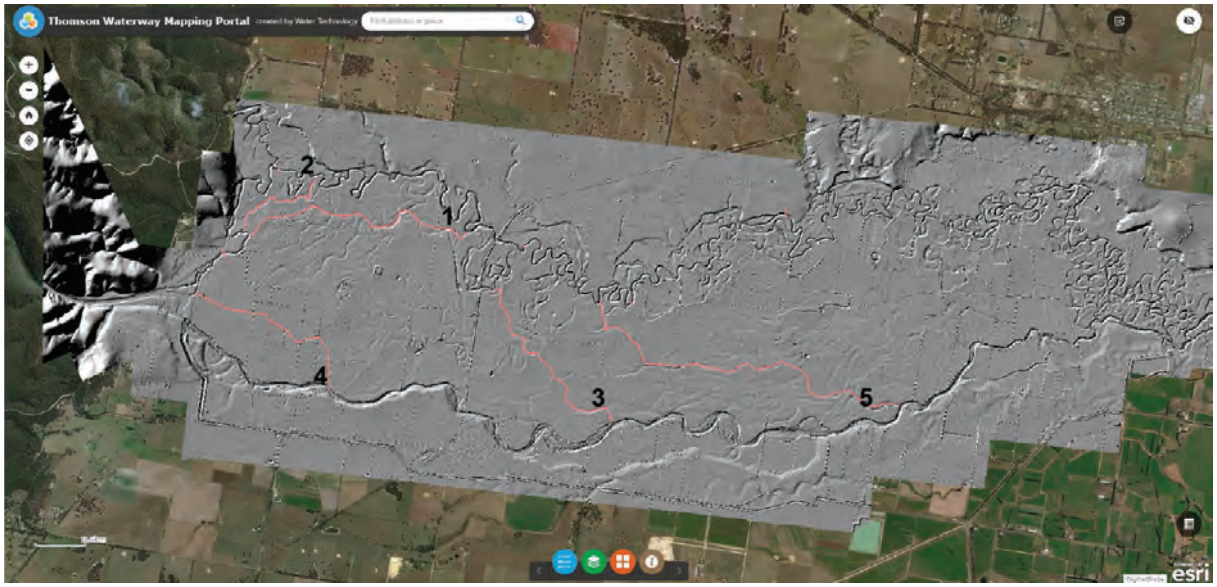

Figure 5: Overview map of Thomson River and Rainbow Creek with LIDAR imagery showing modelled possible avulsion initiation points and pathways *[Note: The location of avulsion initiation points and pathways are not definitive, they are indicative only, based on available modelling and technical understanding of waterway behaviour, a range of other scenarios are possible due to the range of factors that influence avulsion processes]*

The consequences of an avulsion event involve costs in terms of asset damage (e.g. irrigation infrastructure, houses), loss of agricultural land/soil and potential loss of access to water resources for Thomson and Rainbow Creek landholders, as well community dislocation and downstream impacts on the Gippsland Lakes. It is also possible (in theory and perhaps in practice) that there could be benefits to some landholders (such as an additional water resource or waterway views).

During the consultation process, community members reported widely different views about future avulsion risk. A small number of people felt that the likelihood of a future avulsion was certain, while a correspondingly small number held the exact opposite opinion. For many respondents, generally more recent arrivals to the district, the likelihood and potential consequences of a future avulsion was largely unknown and that the consultation process has raised their awareness of the risk.

Various management actions are available to address and minimise the risks associated with a future avulsion and these are assessed later in the Plan. An important point to note, based on both scientific understanding and local knowledge and expertise, is that avulsions typically don't 'happen overnight'. For this reasons, it will be important to undertake regular monitoring and assessment of floodplain evolution (especially at the identified 'hotspots') to detect any changes as a result of flood events as a step towards a rapid response. Monitoring and observations by local landholders and the community combined with technical assessment and the use of remote sensing technology (e.g. LIDAR) are essential elements of a future monitoring program.

3.4 Management arrangements

A range of organisations together with the community and local landholders have important roles that relate to the implementation of this Plan. Most of the identified works are located on or adjacent to private land and the participation and agreement of landholders will be critical to the Plan. As such the Plan has a high emphasis on landholder engagement and community consultation.

The West Gippsland Catchment Management Authority is responsible for waterway and floodplain management. Southern Rural Water, Wellington Shire Council and Gippsland Water all have roles in the management of land and water resources associated with the planning area.

The Gunaikurnai Land and Waters Aboriginal Corporation are a Recognised Aboriginal Party. GLaWAC are the primary guardians, keepers and knowledge holders of Aboriginal cultural heritage in the planning area and have responsibilities under the Aboriginal heritage Act (2006).

Further information on organisational responsibilities is set out in Table 5.

Table 5. Government agencies involved in the Thomson River and Rainbow Creek Waterway Management Plan

Organisation	Responsibilities
Southern Rural Water	Water corporations in Victoria are established under the Water Act 1989 and provide a range of water services to customers within their service areas. Southern Rural Water provides a combination of irrigation services, domestic and stock services, bulk water supply services in the region. SRW is responsible for the operation of Cowwarr Weir and has an operational role in environmental water management.
Wellington Shire Council	Wellington Shire Council is involved in the management of the Thomson River and Rainbow Creek through its role as responsible planning authority, manager of stormwater drainage and onsite domestic wastewater systems, user of integrated water systems, land manager, emergency management, and supporter of community groups.
West Gippsland Catchment Management Authority	The WGCMA is responsible for developing and implementing a Regional Waterway Strategy that accounts for community needs relating to the use and values of waterways. It has the following functions with respect to this Plan: • Carries out works and activities in accordance with the Regional Waterway Strategy to maintain or improve the values of waterways. • Manages the bed and banks of waterways through licensing works on waterways, and implementing works such as erosion control, fish passage and habitat enhancement. • Is responsible for aspects of floodplain management, including flood modelling, mapping and strategy development and providing advice on development applications for land prone to flooding. • Undertakes projects throughout the catchment in partnership with landholders to improve waterway health. • Undertakes regional plans and management of environmental water including the delivery of water held in environmental entitlements.
Gunaikurnai Land and Waters Aboriginal Corporation	Gunaikurnai Land and Waters Aboriginal Corporation (GLaWAC) represents the Traditional Owners from the Brataualung, Brayakaulung, Brabralung, Krauatungalung and Tatungalung family clans, who were recognised in the Native Title Consent Determination, made under the *Traditional Owner Settlement Act 2010*, the first such agreement under that Act. GLaWAC Is the Prescribed Body Corporate (PBC) for the Gunaikurnai people and claim area, as outlined in the agreement, providing joint management of 10 parks and reserves within the State. GLaWAC is the Registered Aboriginal Party for the Gunaikurnai claim area, as decided by the Victorian Aboriginal Heritage Council under the *Aboriginal Heritage Act, 2006*. GLaWAC have responsibilities related to native title, cultural heritage, joint management and economic development.

4 Vision and objectives

The vision for the Plan (below) recognises the wide range of aspirations for the Thomson -Rainbow system including agriculture, water supply, amenity, recreation, local natural values, waterway stability and downstream benefits.

> The Thomson and Rainbow system is managed to reduce the risk of avulsion and improve waterway health with benefits for agriculture, the community and the Gippsland Lakes.

Supporting the vision is a set of objectives developed by the Project Working Group (Table 6). The objectives form the basis of the decision-making process for the Plan and informed the identification of works and actions and the benefit: cost analysis.

Objectives are related to the values the community has for the Thomson-Rainbow system. Achieving the objectives will require sustained effort through the implementation of the Plan and through other complementary programs.

It is important to note that the preferred implementation scenario has not considered flow management in detail and only a limited range of actions have been included to improve recreational use. Further work will be required through other programs in order to achieve the objectives C1 and D3). This is reflected in the objectives and outcomes, whereby a set of primary objectives and intermediate outcomes have been identified as the primary focus for this Plan through development of a Program Logic (Figure 7).

Table 6. Objectives of the Thomson-Rainbow Waterway Management Plan

Theme	Objective
A: Agricultural uses	A1 Maintain current agricultural productivity and infrastructure (to reduce avulsion risk).
B: Amenity	B1 Riparian vegetation provides improved visual amenity and contributes to community use.
C: Recreation	C1 Enhance recreation use at key sites on Rainbow Creek (e.g. Rainbow Park).
D: Local natural values	D1 Rainbow Creek and Thomson River are fenced to manage stock and revegetated with appropriate indigenous species . D2 Rainbow Creek and Thomson River are 'willow free'[2]. D3 Ensure flow regimes maintain natural values.
E: Waterway stability and downstream benefits	E1 Rainbow Creek and Thomson River are managed to enhance waterway stability, reduce floodplain and bank erosion, and reduce sediment transport (locally and downstream). E2 Risk of damage to built and natural assets from waterway instability is significantly reduced.

[2] It was recognised during plan development that a staged approach would be required to achieving this objective and that a small number of landholders value the local role played by willows on their properties. The plan then seeks to achieve this objective through specific site based consultation and landholder agreement.

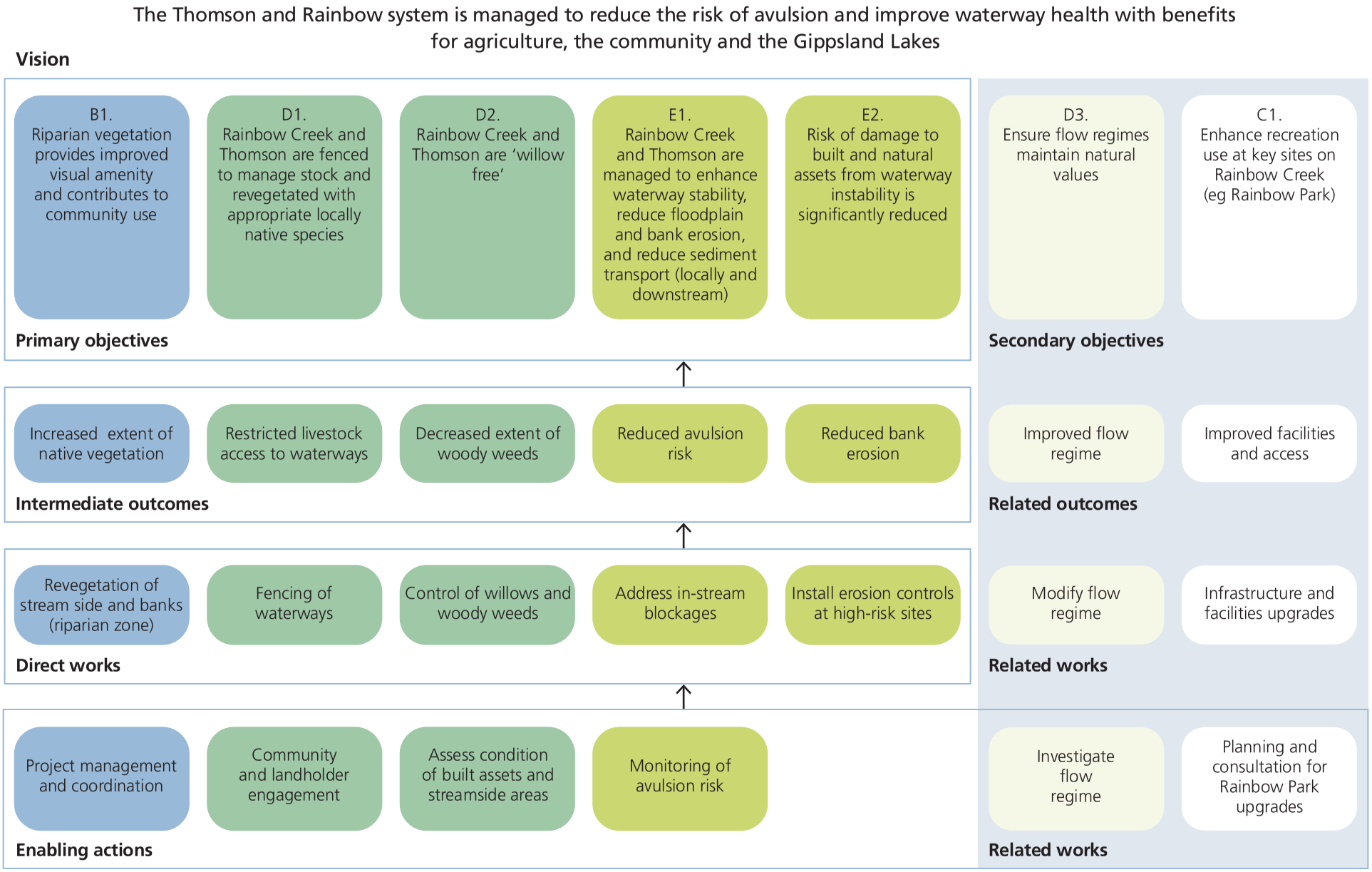

Figure 7. Program logic for the Thomson Rainbow Waterway Management Plan *(Note: The avulsion risk reduction element of Objective A1 is met through Objective E2)*

5 Works and actions

As described in the West Gippsland Waterway Management Strategy (WGCMA 2014), healthy waterways depend on the condition of riparian land and in particular native vegetation on riparian land provides a range of functions including:

- filters run-off (sediments, nutrients and pathogens) from overland flow, improving water quality,
- helps stabilise banks and reduces erosion, reducing the risk of damage during high flows and floods,
- provides shade and helps regulate water temperature,
- provides a supply of organic matter including large wood to the waterway,
- provides habitat for fauna species including as a refuge from drought, flood and fire, and
- provides a store of carbon.

A suite of direct works and actions (e.g. fencing and revegetation) along with enabling actions have been identified to address the key issues identified during consultation and to support the realisation of the vision and objectives of the Plan.

The works and actions described here build on a legacy of past waterway management works, especially those undertaken following the 1978 floods involving significant rehabilitation activities (concrete groynes, grade control structures and revegetation) and in more recent years by the West Gippsland CMA and local landholders involving waterway fencing, revegetation, willow management and weed control. Importantly they also reflect the knowledge of likely avulsion pathways based on scientific knowledge and modelling.

A key focus of the Plan is to build on the existing riparian values associated with the Thomson River and Rainbow Creek and improve them over time through a comprehensive and integrated program of direct works and enabling actions. These activities will be coupled with specific and targeted actions to reduce the risk of avulsion to realise the vision and objectives of the Plan.

The major types of works and actions are described below, with further specific details in sections 7 and 8 of this document.

5.1 Fencing and revegetation of waterways

Fencing to control stock access to waterways is a key strategy to improving waterway health. For best results it is recommended that fencing is combined with revegetation, using local indigenous plants, to enhance the quality and extent of riparian land.

At present a significant portion of the Thomson River has been fenced to manage stock access and the majority of these areas have been successfully revegetated with native species. Significantly less of the Rainbow Creek has been fenced and revegetated to date, however, a number of recent projects have been completed and serve as excellent template for future actions.

During consultation and with advice from the Project Working Group it was clear there is strong support to fence and revegetate the entire lengths of both waterways in cooperation with landholders, acknowledging that the design and implementation of specific project sites will require detailed consultation and agreement to support maximum achievement of this objective.

Successful implementation of riparian fencing and revegetation projects requires careful site preparation, especially to minimise the impact of weed competition (willows and other woody weeds as well as other exotic non-woody species), in addition to optimising soil and moisture conditions for successful indigenous plant establishment. The WGCMA in their role as caretakers of waterway health have well developed standards and procedures for the design and implementation of fencing and revegetation programs, which also acknowledge the importance of local knowledge and landholder consultation.

5.2 Control of willows and woody weeds

Weeds directly threaten native vegetation condition and extent for numerous waterways across the region and indirectly impact on the habitat of fauna that use waterways. Exotic species such as willows were historically planted along waterways for erosion control and aesthetic purposes. The spread of these species over time has degraded riparian land and pose a significant challenge for riparian restoration programs.

Willows have been a component of the Thomson River and Rainbow Creek systems for many decades and were actively planted as part of recovery works. Since that time willows have spread along both waterways and become a problem in terms of spread and degradation of riparian values. As noted earlier the planting of willows is no longer regarded as appropriate for managing and enhancing waterways in Victoria. It was clear during consultation that while removal and management of willows was a key plan objective this would be costly, that it would require a staged approach (in conjunction with fencing and revegetation) and that it would require careful consultation with all landholders. Furthermore, it was reinforced that ongoing maintenance would be required to maintain the benefits generated by the initial investment in willow and woody weed control.

5.3 Erosion control measures

The Rainbow Creek, as a newly formed waterway has experienced significant large-scale and localised erosion during its development since the mind 1950s. The last major erosion event occurred in 1978 and this is well remembered by some in the local community. The effect of this event in widening the channel of the waterway and sediment deposition remains clearly visible.

Since that time there has continued to be localised erosion effects at a number of sites along Rainbow Creek – these are in addition to the avulsion hotpots discussed earlier. During plan implementation it will be important to identify opportunities to explore how treatment options[3] (e.g. rock beaching, battering and targeted planting) can be used in a complementary way with larger scale fencing, revegetation and willow management works to stabilise priority sites of localised erosion.

In contrast, the Thomson River is a much more stable waterway than Rainbow Creek with little active erosion along its length, although a small number of sites of local concern were identified during consultation and plan development. These sites are recommended for detailed assessment and treatment (if justified) in consultation with relevant landholders.

Avulsion hotspots

As described earlier five avulsion hotspots were identified during plan development, two on the Thomson River and three on the Rainbow Creek. Each of these sites was identified through analysis of mapping and modelling work and then subject to a field inspection to confirm the characteristics of each site and appropriate treatment options. This information has been used to inform costings for the Plan but will require more detailed assessment and design work prior to treatment. In each case it is likely that varying quantities of rock beaching will be required at the 'head cut' of each of the five potential avulsion initiation points to significantly reduce the risk of an avulsion occurring. Up-stream of each site there is potential to further reduce the avulsion risk through the establishment of vegetated easements along each pathway. Installation of rock beaching and pathway treatments will need to be discussed and negotiated with the respective landholders in each case.

[3] Including maintenance of previous treatment works such as grade-control structures and rock beaching.

5.4 In-stream blockages

During consultation with the Project Working Group, concerns were raised about blockages within the Thomson River, caused by log jams during floods, would drive the development of an avulsion. Flood modelling of management intervention scenarios highlighted that complete (top of bank) in-stream blockages in the upper sections of the Thomson River (between Cowwarr Weir and old railway crossing) may lead to increased intensity of localised flooding, resulting in more flows through potential avulsion pathways. Increased flows through these pathways have the potential to amplify the scouring of the pathways and avulsion development.

Management of high risk in-stream blockages within this area is required. However, the presence of large wood within a waterway is critical for aquatic habitat and nutrient cycles. As such, management actions must be assessed on a case-by-case situation.

5.5 Rainbow Park[4]

Rainbow Park, located in Cowwarr, is an important local community asset, providing public open space for recreation and is located directly adjacent to Rainbow Creek. Management responsibility for the area lies with Wellington Shire Council. Implementation of the proposed waterway management works in the Plan would include the banks and streamside area of the reserve. It is outside the scope of the Plan to recommend additional development and improvement works for Rainbow Park. Issues raised through this planning process, in particular removal of the ageing cypress trees and amenity improvements, will complement the work outlined in this Plan and will be subject to ongoing dialogue between the local community and Wellington Shire Council.

5.6 Community engagement

Active community engagement and consultation has been a feature of developing the Plan. The Project Working Group (with a majority of local community members and landholders) has shaped the direction and priorities for implementation and a number of community forums were held to inform the wider community of the project at key stages.

Successful implementation of the Plan will be underpinned by a continued communication and engagement effort with local landholders, other community members and all those with an interest in the Thomson River and Rainbow Creek.

5.7 Investigations and condition assessments

A number of specific investigation and assessment activities have been identified during the development of the plan. These are described briefly below.

Assessment of grade control structures

Approximately seven grade control structures were established in Rainbow Creek following the damaging 1978 flood event. These structures have been very successful as an element of river stabilisation works in moderating erosion but are at risk of failure (Zavadil, Moar, & Vietz, 2011).

It will be important to undertake a detailed assessment of the current condition of these structures and an assessment of their future role as part of the overall restoration of the waterway. This assessment may reveal the need to allocate additional resources for repair of existing structures and/or the need for installation of additional structures.

[4] Rainbow Park is known by a number of alternative local names including: The Waterhole, Waterhole Reserve, The Reserve and Waterhole Lane (Norm Drew pers.[comm]).

Assessment of stream side and banks (riparian areas)

Prior to undertaking fencing, revegetation and weed control works it is recommended that a detailed field based assessment be undertaken to inform the development of the detailed works program. The assessment should:

- Assess the condition of existing fences.
- Assess the state of historical and more recent revegetation activities with respect to success rate, weed load and function.
- Identify local issues such as erosion impacts on waterway stability or infrastructure.

This assessment will also provide an opportunity to re-engage with landholders along both waterways and provide a foundation for negotiating future projects.

Investigation of water regime and flow management

This project has not explored the relationship between typical river flows in the Thomson River and Rainbow Creek with instream processes and avulsion risk in detail. There is a need to further investigate flow regime, instream processes and the potential to manage the avulsion risk. A current project to investigate the environmental flows in the Thomson has recently been initiated by the WGCMA. The findings of this study will complement the findings and implementation of the Plan through improved understanding of the relationship between current and future flow regimes and the plan objectives.

6 Results of benefit: cost analysis

This section describes the results of the benefit: costs analysis (BCA) that was used to assess the merit of a range of management scenarios that were considered as a means of identifying the preferred implementation option for the Plan. The BCA was undertaken using Investment Framework for Environmental Resources (INFFER) and associated sensitivity analysis, including the use of a Monte Carlo approach to explore the effect of actions to minimise avulsion risk and damage (see section 2.2.4 and Appendix 1 for more detail).

6.1 Current situation and 'Business as Usual'

Understanding the benefits and costs of different management scenarios required a clear description of the current situation for the Thomson-Rainbow system, in terms of both the current extent of works (e.g. % of waterways that are currently fenced and revegetated, % of waterways impacted by willows etc.) as well as future plans under a 'Business as Usual' (BAU) approach to waterway management over the time frame for the analysis (assumed to be 20 years). The BAU is defined as what is expected to happen over the next 20 years in the absence of this Plan.

The benefits and costs of the scenarios described below are estimated as the 'difference' between the scenario and BAU. Table 7 provides a summary, for each of the relevant works and actions, both the current status and what is assumed will happen under BAU.

Table 7: Summary of works and actions for inclusion in INFFER assessment – current status and what is assumed under Business as Usual (next 20 years)

Works and actions	Current status	**Business as Usual** (what is predicted to happen over the next 20 years without this Plan)
Fencing to exclude/ manage stock	Rainbow Creek – total length is 15 km of which 2 km (both sides) is of sufficient standard. 0.5 km in Cowwarr doesn't require fencing – 12.5km requires replacement or new fencing (25 km in total). Thomson River – total length is 30 km of which 25 km is of sufficient standard. 5 km (both sides) requires new fencing.	Low to nil level of new works.
Revegetation with locally native species	Rainbow Creek – as for fencing, however, 0.5 km in Cowwarr will require revegetation. Thomson River – as for fencing.	Low to nil level of new works. Follow up maintenance of recent revegetation projects (replanting/ weed control) undertaken only.
Willow management	Rainbow Creek – 25% of waterway has been completed to an acceptable standard. Thomson River – 5 km of treatment required.	Minimal effort at whole of waterway scale – some local works may occur.
Weed management	Rainbow Creek: weed load varies along reach Very Low (15%), Low (25%), Moderate (25%), High (25%), Very High (10%). Thomson River – similar to Rainbow Creek but only maintenance required for 25 km of 30 km length.	Minimal effort apart from follow up on recent revegetation sites.

Table 7: Summary of works and actions for inclusion in INFFER assessment – current status and what is assumed under Business as Usual (next 20 years) *continued...*

Works and actions	Current status	Business as Usual (what is predicted to happen over the next 20 years without this Plan)
Grade control structures	Rainbow Creek – 7 structures in varying condition/effectiveness. Requires on site assessment. Thomson River – Not applicable.	No action on existing grade control structures – allowed to gradually deteriorate.
Avulsion risk management at hot spots	Rock beaching at existing nick point 'hot spots' – three on Rainbow Creek and two on Thomson River.	No action.
Avulsion risk management – fencing and revegetation	Installation of stock control fencing +/- revegetation along potential avulsion pathways.	No action.
Localised erosion management	Treatment of existing areas of localised erosion (rock beaching) along the main stem of Rainbow Creek and/or Thomson River as required.	Minimal effort at whole of waterway scale – some local works may occur.

6.2 Benefits and Costs

The implementation of this Plan is designed to generate benefits for the Thomson River and Rainbow Creek and the communities that utilise these significant waterway assets for the values they provide. As outlined earlier, the Plan also aims to reduce the likelihood and consequences of a future avulsion, which produces benefits in terms of reduced economic and social damage to agriculture and local communities.

Three main benefit types were identified in the development of this Plan:

1. Environmental asset improvement – enhancement of the environmental values such as riparian extent and condition, waterway connectivity and improved habitat for threatened and non-threatened species.
2. Reduced consequences of an avulsion – preventing or reducing the consequences of an avulsion will avoid incurring costs associated with avulsion damage (e.g. loss of high value agricultural land and infrastructure, public assets such as roads, bridges, culverts etc. as well as social and community impacts).
3. Other benefits – it is anticipated that there will be additional benefits, for example recreation and improved amenity associated with implementation of this Plan.

Realising the benefits incurs costs, for example, those costs associated with fencing and revegetation to improve waterway health as well as costs incurred to reduce the impact of a future avulsion, such as rock beaching.

As for the benefits, the costs are assessed as additional to what would be incurred under a BAU situation.

6.3 Scenarios assessed

A set of scenarios were identified by the project team and then further developed and approved by the Project Working Group. The purpose of examining a range of different scenarios was to compare the extent to which different options met the range of objectives and expectations of stakeholders and to identify the most-cost effective option for implementation. In taking this approach it was acknowledged

that resources for funding the implementation of the Plan were not unlimited. With this in mind, it was prudent and informative to include some scenarios that may not address avulsion risk (2a,b,c, d and 3) for comparative purposes.

Each scenario was costed and then assessed in terms of their benefits and costs (relative to BAU).

Table 8 describes the scenarios that were assessed in developing the Plan, along with a summary of the benefits and works associated with each scenario.

Table 9 shows the benefit:cost ratio (BCR) and costs of each scenario and indicates whether the scenario reduces the avulsion risk.

The preferred implementation option for the Plan, is one that supports the vision and objectives and is a cost-effective investment.

Table 8: Summary of the benefits and works required for each scenario assessed

Scenario	Description	Benefits			Direct works included in scenario[5]
		Environmental improvement	Reduced consequences of avulsion	Other (e.g. recreation, improved amenity)	
1 Combined (actions to maximise natural and amenity values and reduce avulsion)	Combines 2a, 3 and 4b – all actions for Rainbow Creek and Thomson River	●●●	●●●	●●	Riparian fencing, willow management and revegetation on both waterways. Rock beaching and vegetated easements on freehold land at 5 high-risk avulsion hotspots.
2a Maximise local natural values (riparian) – Rainbow/ Thomson	100% effort on both Rainbow Creek and Thomson (fencing, willow control, revegetation)	●●●	○	●●	Riparian fencing, willow management and revegetation on both waterways.
2b Maximise local natural values (riparian) – Rainbow	100% effort on Rainbow Creek only (fencing, willow control, revegetation)	●●	○	●●	Riparian fencing, willow management and revegetation on Rainbow Creek only.
2c Sub-maximum local natural values (riparian) – Rainbow/ Thomson	75% effort on both Rainbow and Thomson (fencing, willow control, revegetation)	●●	○	●●	Riparian fencing, willow management and revegetation on both waterways.
2d Sub-maximum local natural values (riparian) – Rainbow	75% effort on Rainbow Creek only (fencing, willow control, revegetation)	●	○	●●	Riparian fencing, willow management and revegetation on Rainbow Creek only.

Table 8: Summary of the benefits and works required for each scenario assessed *continued...*

Scenario	Description	Benefits			Direct works included in scenario[5]
		Environmental improvement	Reduced consequences of avulsion	Other (e.g. recreation, improved amenity)	
3 Maximise recreation and local amenity – Rainbow	Targeted riparian works and infrastructure at Rainbow Park	●	○	●	Riparian fencing, willow management and revegetation at Rainbow Park in Cowwarr.
4a Reduce avulsion risk – beaching	Targeted rock beaching of avulsion 'hotspots"	○	●●	○	Installation of rock beaching on freehold land at 5 high-risk avulsion 'hotspots'.
4b Reduce avulsion risk – beaching plus fencing and revegetation	As for 4a plus fenced and revegetation along potential pathways	○	●●●	○	Installation of rock beaching and avulsion pathway fencing/revegetation on freehold land associated with the 5 high-risk avulsion 'hotspots'.
5 Preferred implementation option for WMP (actions to maximise natural and reduce avulsion risk)	2a plus 4a – 100% effort on both Rainbow Creek and Thomson (fencing, willow control, revegetation) plus targeted rock beaching of avulsion 'hotspots"	●●●	●●	●●	Riparian fencing, willow management and revegetation on both waterways.

Codes:

●●● significant benefit above BAU

●● moderate benefit above BAU

● minor benefit above BAU),

○ no or negligible benefit

[5] Supporting works including project management, coordination of on-ground works, investigations and community engagement are detailed for each scenario

6.4 Results

The scenarios (Table 8) were assessed in terms of benefits and costs, with the results presented in Table 9.

Scenario 5 was selected as the preferred implementation option for the WMP. The rationale for selection of this option is:

- The benefit:cost ration (BCR of 1.79). indicates that it is cost effective and that the benefits are close to 80% more than the costs.
- This scenario maximises the overall environmental benefits and while not treating the risk and consequences of an avulsion to the same extent as Scenario 4b, it is significantly more cost-effective than this scenario with a high likelihood of gaining local landholder and community acceptance. Revegetation along avulsion pathways (as in Scenario 4b) involves taking land out of production and needing to reconfigure paddocks.
- The overall level of up-front costs and on-going maintenance costs are thought to be commensurate with the levels of funding likely to be made available for significant waterway management projects.

The remaining scenarios are not preferred for the following reasons:

- Scenario 1 is significantly less cost-effective (BCR of 1.46) than the preferred implementation option (BCR of 1.79). The overall up-front costs are approximately $500K greater and while the BCR is still favourable it is likely to be much less acceptable to local landholders and the community as it requires the establishment of large scale vegetated floodplain easements associated with avulsion hotspots. This assumption can be tested through implementation of the plan.
- Scenarios 2a, 2b, 2c and 2d are all cost effective (BCR>1) and provide significant waterway health and environmental benefits but do not treat the risk and potential consequences of a future avulsion. For this reason they do not satisfy the vision and objectives of the WMP.
- Scenario 3 which is targeted at local waterway and amenity improvement at Rainbow Creek is not cost-effective and does not address the avulsion risk.
- Scenarios 4a and 4b provide benefits in terms of reducing the risks and consequences of a future avulsion but do not provide any waterway health benefits, at least for the Rainbow Creek and Thomson River, although they may well provide significant downstream benefits for the Gippsland Lakes by reducing large scale sediment and nutrient inputs. Furthermore, Scenario 4b is not cost-effective when the risks associated with landholder adoption and socio-politics are included as a result of this option requiring fencing and revegetation and floodplain easements associated with avulsion hotspots on freehold land.

Table 9: Results of Benefit Cost analysis

Scenario	Cost ($M) Upfront over 4 years / (annual maintenance cost)	Benefit: Cost ratio	Reduced consequence of avulsion	Comment
1 Combined (actions to maximise natural and amenity values and reduce avulsion)	4.562 (0.098)	1.46	✓	High BCR
2a Maximise local natural values (riparian) – Rainbow/Thomson	3.624 (0.052)	1.82	✗	Highest BCR
2b Maximise local natural values (riparian) – Rainbow	2.078 (0.025)	1.66	✗	High BCR
2c Sub-maximum local natural values (riparian) – Rainbow/Thomson	2.737 (0.041)	1.70	✗	High BCR
2d Sub-maximum local natural values (riparian) – Rainbow	1.577 (0.021)	1.63	✗	High BCR
3 Maximise recreation and local amenity – Rainbow	0.213 (0.013)	0.84	✗	Recreation benefits not quantified however they are estimated to be very small and not likely to change BCR
4a Reduce avulsion risk – beaching only	0.314 (0.017)	1.48	✓	High BCR both with and without inclusion of risks
4b Reduce avulsion risk – beaching plus fencing and revegetation	1.037 (0.049)	0.40	✓	BCR <1 due to risks (e.g. landholder adoption, socio-politics) associated with works
5 Preferred implementation option for WMP (2a + 4a)	4.031 (0.068)	1.79	✓	High BCR – this scenario addresses the vision and objectives of the plan

7 Work program

This section describes the works and actions that will guide implementation of the Thomson-Rainbow Waterway Management Plan. The Plan includes works for both the Thomson River and Rainbow Creek as well as enabling actions, such as investigations, awareness raising, research and monitoring. The work program is based on scenario 5, the preferred implementation option that was identified by the Project Working Group and endorsed by the Project Steering Group.

In choosing where to allocate resources, decision-makers will consider available budgets, community interests and values and risks to public and private assets.

Recommended actions have been assessed and prioritised based on:

- How well they help to meet the objectives of the Plan
- Their relative costs and benefits
- Their likely adoption by landholders

The Plan's work plan was co-developed with the Project Working Group comprising representatives of regional authorities, local government, community representatives and affected landholders. As noted earlier in the Plan the costs of implementation represent a significant increase in effort and funding as compared with current programs. The West Gippsland Catchment Management Authority and Southern Rural Water are committed to exploring options to secure funds for implementation informed by the benefit:cost analysis that underpins the Plan.

7.1 Overview

The WGCMA will be responsible for leading implementation of the Plan in its role as the regional waterway manager. The Plan will also guide the activities of the community and other organisations. Partnerships with private landholders and the participation of the local community are critical to the success of the Plan, with much of the required work identified to take place on land that is private land. Landholder participation will be facilitated through one-on-one discussions with WGCMA staff and the delivery of agreed works formalised through landholder agreements where required.

Formal community participation will continue through the implementation of this Plan. In addition, the WGCMA will also work closely with SRW, Gippsland Water and Wellington Shire Council to coordinate the delivery of the works and enabling actions with other programs occurring in the planning area.

7.2 Direct works and enabling actions

The direct works and actions and quantities were derived from the benefit:cost analysis results described in Section 6 as they relate to the preferred implementation option (scenario 5) Direct works are required across both the Thomson River (Table 10) and Rainbow Creek (Table 11).

Table 10. Thomson River direct works program

Management Action	Description	Quantity	Lead agency
Fencing to control stock access	5 km of fencing required on each side of waterway to enable control of stock access to the bed and banks (average 10 metre setback).	10km fencing	WGCMA
Revegetation of stream-side and banks	Establishment of locally indigenous native trees and understorey.	15 ha revegetation	WGCMA
Off-stream watering	Enable stock access to water resources when excluded from waterway.	10 troughs and pipes	WGCMA
Willow removal	Includes site preparation for planting as well as willow control. Includes provision for willow control at Cowwarr Weir*	15 ha of willow and pest plant control	WGCMA *SRW
Initial maintenance of newly planted areas	Undertaken annually for the two years following planting (includes some replants and weed control).	15 ha	WGCMA
Annual maintenance program for erosion, weeds and vegetation	Where required – treatment of waterway erosion and riparian weeds (e.g. blackberry, periwinkle) to promote natural recruitment and viability of planted areas.	90 ha (22.5 ha/yr) over four years and then ongoing as required to maintain benefits/values	WGCMA
Rock beaching – avulsion hotspots	Installation of rock beaching to (detailed design and engineering required for each site) prevent erosion of head cut sites.	2 sites	WGCMA
In-stream blockages – removal/management	Where required – sites will be assessed and treated on a case-by-case basis in consultation with landholders.	As required	WGCMA

Table 11. Rainbow Creek direct works program

Management Action	Description	Quantity	Lead agency
Fencing to control stock access	12.5 km fencing required on each side of the waterway to enable control of stock access to the bed and banks (average 10 metre setback).	25 km fencing	WGCMA
Revegetation of stream-side and banks	Establishment of locally indigenous native trees and understorey.	37.5 ha revegetation	WGCMA
Off-stream watering	Enable stock access to water resources when excluded from waterway.	20 troughs and associated pipes	WGCMA
Willow removal	Includes site preparation for planting as well as willow control.	37.5 ha	WGCMA
Initial maintenance of newly planted areas	Undertaken annually for the two years following planting (includes some replants and weed control).	50 ha	WGCMA
Annual maintenance program for erosion, weeds and vegetation	Where required – treatment of waterway erosion and riparian weeds (e.g. blackberry, periwinkle) to promote natural recruitment and viability of planted areas.	45 ha (11.25 ha /yr) over 4 yrs and then ongoing as required to maintain benefits/values	WGCMA
Rock beaching – avulsion hotspots	Installation of rock beaching to (detailed design and engineering required for each site) prevent erosion of head cut sites.	3 sites	WGCMA
Rainbow Park[6] amenity works	These works have not been quantified or costed. Consultation between the Cowwarr community and Wellington Shire is required to explore preferred options.	TBA	Wellington Shire Council

[6] Rainbow Park is known by a number of alternative local names including: The Waterhole, Waterhole Reserve, The Reserve and Waterhole Lane (Norm Drew pers.comm.). It is recommended that the PWG advise on the agreed name for inclusion in the final plan.

In addition to the direct on-ground works and actions, a range of enabling activities is required to enable implementation of the Plan. Table 12 includes actions for project management, community engagement, monitoring and additional investigations as quantified in the benefit:cost analysis.

Table 12. Enabling actions program

Management Action	Description	Quantity	Lead agency
Project management	Coordination of project planning, reporting and community engagement.		WGCMA
On-ground works delivery coordination	Coordination of fencing, revegetation and willow/weed control, including landholder liaison and management of contractors.	1.6 FTE per year for four years	WGCMA
Avulsion risk monitoring	CMA inspections, landholder observations, photo-point monitoring, drone survey, LIDAR.	Conducted on a regular (annual) basis and after all moderate/major flood events *LIDAR every 5-10 years*	WGCMA
Community engagement	Annual community forums and communications activities.		WGCMA
Grade control structure assessment	Inspection and detailed assessment of existing structures to inform development of works plan.		WGCMA
Riparian assessment – fencing, weed load, willows	Detailed assessment required to inform works plan.		WGCMA
Investigate flow regime, instream processes and the potential to manage the avulsion risk	Collaboration with storage operator.		WGCMA

8 Monitoring, evaluation and reporting

Monitoring, evaluation and reporting arrangements will help improve confidence in the Thomson-Rainbow Creek Waterway Management Plan and embed learning and improvement in its delivery.

The monitoring, evaluation and reporting arrangements for the Thomson-Rainbow Waterway Management Plan includes:

- The program logic underpinning the works, actions, outcomes and objectives
- Key evaluation questions
- An overview of the processes for evaluation, reporting, learning and improvement.

A separate detailed MER plan is also in development so that evaluation of the works and actions can occur. This detailed plan will include measures, indicators and monitoring requirements to track progress towards the outcomes, test the assumptions in the program logic and understand the effectiveness of interventions. The WGCMA is responsible for leading this process and the working group will participate in evaluation and reporting processes.

8.1 Program logic

Program logic is an approach to planning (commonly used in natural resource management) that uses a diagram to demonstrate the rationale for a program and express how change is expected to occur.

The program logic (Figure 7) provides the rationale for how the Project will achieve the Intermediate Outcomes and Objectives. It describes how the direct works and enabling actions are expected to collectively contribute to either maintaining or improving the environmental condition of waterways and thereby continue to support environmental, economic, social and cultural values.

Table 13 provide a list of the key assumptions associated with the program logic and the level of the program logic to which they relate. Management responses to address the risk associated with assumptions will be further developed upon finalisation of the Plan.

Table 13. Assumptions underpinning the primary objectives in the Program Logic

Assumptions and external factors
Intermediate Outcomes resulting in achievement of Objectives
The outcomes from direct works are at a sufficient scale to manage the risk to built and natural assets from waterway instability.
There is a positive relationship between increased native vegetation along the Thomson River and Rainbow Creek and improved visual amenity.
Willow infestations can be effectively controlled and maintained to achieve 'willow free' status.
The positive influences of management outcomes are greater than negative influences from external factors (e.g. extreme events, climate change, invasive species).

Table 13. Assumptions underpinning the primary objectives in the Program Logic *continued...*

Assumptions and external factors
Direct works leading to Intermediate Outcomes
Erosion controls including armouring and beaching will reduce bank erosion at identified nick-points and will contribute to improved waterway stability and a reduced avulsion risk.
Removing blockages and maintaining an open channel will contribute to an overall reduced avulsion risk.
Enabling actions
Regular monitoring and modelling of avulsion risk will improve confidence in direct works.
Regular inspection and maintenance of grade control structures will improve channel stability along Rainbow Creek.
The majority of landholders along the Thomson River and Rainbow Creek are willing and able to participate in direct works.
Foundational activities
Modelling and expert opinion has correctly identified the mostly likely avulsion pathways for the Thomson River and Rainbow Creek.
Appropriate funding and agreements are secured to deliver planned outputs.

8.2 Monitoring

Monitoring of on-ground change will be a crucial element of plan implementation and will feed directly into evaluation and reporting processes. A detailed monitoring plan, including the establishment of a baseline, will be developed to encompass:

- The behaviour and development of avulsion knick-points and floodplain pathways. This will be done on an annual basis and following any major flood events.
- Progress in the implementation of on-ground works (fencing, revegetation, willow management, weed control) and the effect on key indicators of riparian and landscape health).
- Socio-economic indicators, including changes in values and attitudes towards the Thomson River and Rainbow Creek as a result of plan implementation.

8.3 Evaluation and reporting

Evaluation of the Plan will include an assessment of the extent to which the activities have been delivered and the outcomes and objectives have been achieved. It will also address the assumptions in the program logic and provide for learning and improvement. Evaluation and reporting will take place at three time-scales (annual, mid-term and final). Annual review processes will alignment with the requirements of funding organisations and will focus on effectiveness and implementation progress, whilst the mid-term and final evaluations will consider all evaluation categories.

Evaluation questions have been adopted from an existing state-wide MER framework and address the following five categories (DSE, 2012) and are summarised in Table 14.

Table 14: Summary of evaluation criteria and key evaluation questions

Evaluation criteria	Key Evaluation Questions
Impact *Achievement of outcomes and changes to resource condition*	• To what extent has progress been made towards the intermediate outcomes and objectives of the Plan? • What progress would have been made anyway, in the absence of the Plan? • What, if any, unanticipated positive or negative changes or other outcomes have resulted from the Plan?
Appropriateness *Addressing the needs of beneficiaries and against best practice*	• To what extent were the approaches to communication and engagement successful in ensuring implementation of the Plan? • To what extent were governance and risk management practices undertaken throughout implementation of the Plan? • To what extent was implementation updated in response to new knowledge, information or changed circumstances?
Effectiveness *Implementation progress and achievements*	• To what extent have the direct works and enabling actions been delivered? • What factors impacted on the effectiveness of project implementation?
Efficiency *Value or return from investment*	• To what extent did the project implementation attain the best value out of available resources?
Legacy *After the activity/program ends*	• To what extent are there arrangements in place for the ongoing management and resourcing of the long-term outcomes from the Plan?

8.4 Learning and improvement

This Plan will adopt a systematic process for learning and improvement. This will be incorporated into the annual review process by documenting lessons learned from implementation, identifying new knowledge from research and investigations and identifying opportunities for improvement. Monitoring and evaluation will also help to address uncertainties in the Program Logic and over time this will inform future planning processes.

Some of the mechanisms that will be used for learning and improvement are:

- Undertaking a site assessment prior to implementation of on-ground works to determine feasibility of planned action
- Reallocation of funds in the instance of extreme events (e.g. flood and fire).
- Changing the location or type of intervention in response to new information about avulsion risks.
- Modifying project design in response to landholder feedback.
- Incorporating changes to flow management based on the outcomes of investigations and consultation with the community.

Ongoing project management will incorporate regular meetings with project staff and key stakeholders to exchange new knowledge and information, which will provide the mechanism for regular reflection of progress and the need for change.

9 References

Arrowsmith, C., Russell, K., & Laws, S. (2011). *Thomson River Flood Study Hydrological and Hydarulics analysis*. Water Technology for the West Gippsland Catchment Management Authority.

Australian Government. (2009). *Developing and Using Program Logic, a user guide*. Department of Environment, Water, Heritage and the Arts and Department of Agriculture, FIsheries and Forestry.

Brizga, S.O. (1990). River channel changes in Gippsland, Victoria. *Unpublished PhD Thesis*. The University of Melbourne.

Brizga, S.O and Finlayson, B.L (1990). *Channel avulsion and river metamorphosis: The case of the Thomson River, Victoria, Australia*. Earth Surface Processes and Landforms, 15: 391 – 404.

DSE. (2012). *Monitoring, evaluation and reporting framework for Land, water and biodiversity*. Department of Sustainability and Environment.

Erskine, B.F., Rutherfurd, I.D. and Tilleard, J.W. (1990). *Fluvial geomorphology of tributaries to the Gippsland Lakes*. Report by Ian Drummond and Associates Pty Ltd to the Department of Conservation and Environment, Victoria.

Gippsland Water. (2017). *Gippsland Water. Urban Water Supply Strategy. 2017*. Gippsland Water.

Pannell, D.J., Roberts, A.M., Park, G., Alexander, J., Curatolo, A. and Marsh, S. (2012). *Integrated assessment of public investment in land-use change to protect environmental assets in Australia*, Land Use Policy 29(2): 377-387.

Park, G and Dickson, M. (2019) *Rainbow Creek Thomson River Stakeholder Consultation Report*. Prepared for the West Gippsland Catchment Management Authority.

VEWH. (2019). *Seasonal Watering Plan 2019-20*. Victorian Environmental Water Holder.

WGCMA. (2014). *West Gippsland Waterway Strategy 2014-2022*. West Gippsland Catchment Management Authority.

Water Technology (2019). Modelling of avulsion risk. Unpublished model outputs for the West Gippsland Catchment Management Authority.

WGCMA. (2019). Monitoring, Evaluation and Reporting Plan for the Rivers 2040 – Thomson River Project. West Gippsland Catchment Management Authority.

WGCMA, (2017) *Lake Wellington Land and Water Management Plan*. West Gippsland Catchment Management Authority.

Zavadil, E., Moar, D., & Vietz, G. (2011). *Fluvial Geomorphology of the Thomson River.* Prepared by Alluvium consulting for the West Gippsland Catchment Management Authority.

10 Glossary

CMA	Catchment Management Authority
DELWP	Department of Environment, Land, Water and Planning
EPA	Environment Protection Authority
GLaWAC	Gunaikurnai Land and Water Aboriginal Corporation, the Registered Aboriginal Party for Traditional Owners in the Thomson Rainbow catchment
INFFER	Investment Framework for Environmental Resources
KEQ	Key evaluation questions
MERI	Monitoring, Evaluation, Reporting and Improvement
MID	Macalister Irrigation District
SRW	Southern Rural Water
WGCMA	West Gippsland Catchment Management Authority

Appendix A: INFFER

INFFER (Investment Framework for Environmental Resources) is an approach, based on the principles of benefit: cost analysis, to developing, assessing and prioritising activities and projects aimed at addressing environmental issues. It is designed to help managers achieve the most valuable environmental outcomes with the available resources.

The framework integrates information on: asset significance, threats, project goal, works and actions, time lags, effectiveness of works, risk factors (practice change, technical feasibility, socio-politics, long-term funding), spin-offs, quality of information and key information gaps (Figure 1).

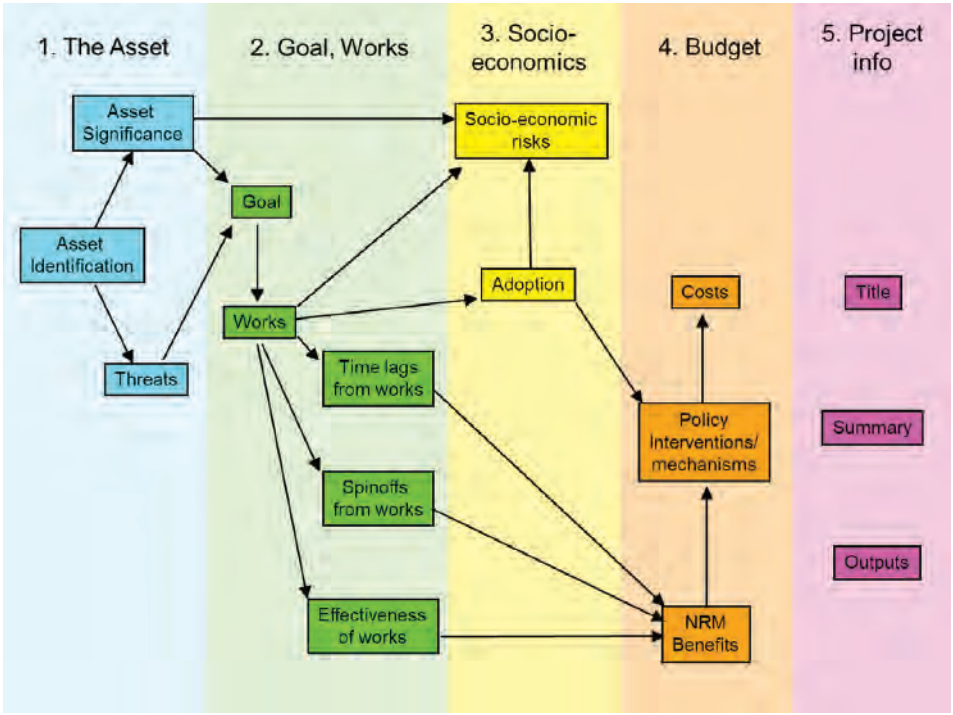

Figure 1: INFFER Logic and information requirements

A key output of the INFFER analysis is the calculation of a Benefit: Cost Ratio (BCR) for each scenario assessed. The equation for the BCR is shown below.

$$BCR = \frac{(V \times W \times A \times B \times F \times G \times DF \times 20)}{(C+PV\,(M+E) \times G)}$$

The variables that feed into calculation of the Benefit: Cost Ratio are mostly specified as proportions, and are included in the Index multiplicatively. They are described below in Table 15. Further information on INFFER can be accessed at www.inffer.com.au.

Table 15: Overview of INFFER information requirements used to estimate Benefit: Cost ratios of scenarios

Parameter value	Description	Comment
V	Value of the asset	The ecological, economic and social value of the asset using the INFFER Asset scoring system.
W	Impact of works	The overall impact (effectiveness) of works expressed as a proportional change in asset value, with and without projects works and actions.
F	Technical feasibility risk	The probability that the benefits aren't realised due to technical factors.
A	Likelihood of adoption	The probability that works and actions on private land and/or relevant to behavioural change by private citizens will be adopted.
B	Likelihood of adverse adoption	The probability that actions will be undertaken by landholders and/or private citizens (over and above current practice) that lead to environmental damage.
P	Socio-political risk	The probability that the benefits aren't realised due to administrative, institutional or political factors.
G	Long-term funding risk	The probability that long-term funding required for ongoing maintenance actions is not made available.
DFB	Discount factor function for benefits, which depends on L	A 5% discount rate will be used.
L	Lag until benefits occur (years)	The minimum length of time (in years) for the majority of benefits to be realised.
C	Short-term cost of project	The initial up-front costs required for project implementation.
PV	Present value function	Applied to both maintenance and compliance costs.
M	Maintenance costs	Annual cost of maintaining outcomes from the project in the longer term.
E	Compliance costs	Cost to private citizens, if the project involves enforcement of regulations.

Estimating the benefits and costs associated with avulsion risk

As described earlier while the relative probabilities of an avulsion occurring along one of the five identified pathways have been estimated it is not possible to determine when an avulsion might occur, for example it may happen in Year 1, Year 20 or Year 100. Furthermore, if an avulsion occurs (predicted as almost certain at some stage in the next 100 years) the probability of a future avulsion immediately decreases to almost zero.

To cater for these scenarios a Monte Carlo simulation was used to generate a probability distribution of avulsion events that might occur along each of the possible pathways and the benefits (in terms of reduced damage) and costs from the interventions described in scenarios 4a (rock beaching) and 4b (rock beaching plus fencing and revegetation of easements) were then included in the INFFER analysis.

Flood flow in Rainbow Creek spilling into hole near Boundary Allots 1 and W4 Sec N Toongabbie South. See TC7821

1952

Traralgon Office
16 Hotham Street, Traralgon VIC 3844
T: 1300 094 262 | F: 03 5175 7899

Leongatha Office
Corner Young & Bair Streets, Leongatha VIC 3953
T: 1300 094 262 | F: 03 5662 5569

Correspondence
PO Box 1374, Traralgon 3844

Email
westgippy@wgcma.vic.gov.au

www.wgcma.vic.gov.au

West Gippsland
Catchment Management Authority