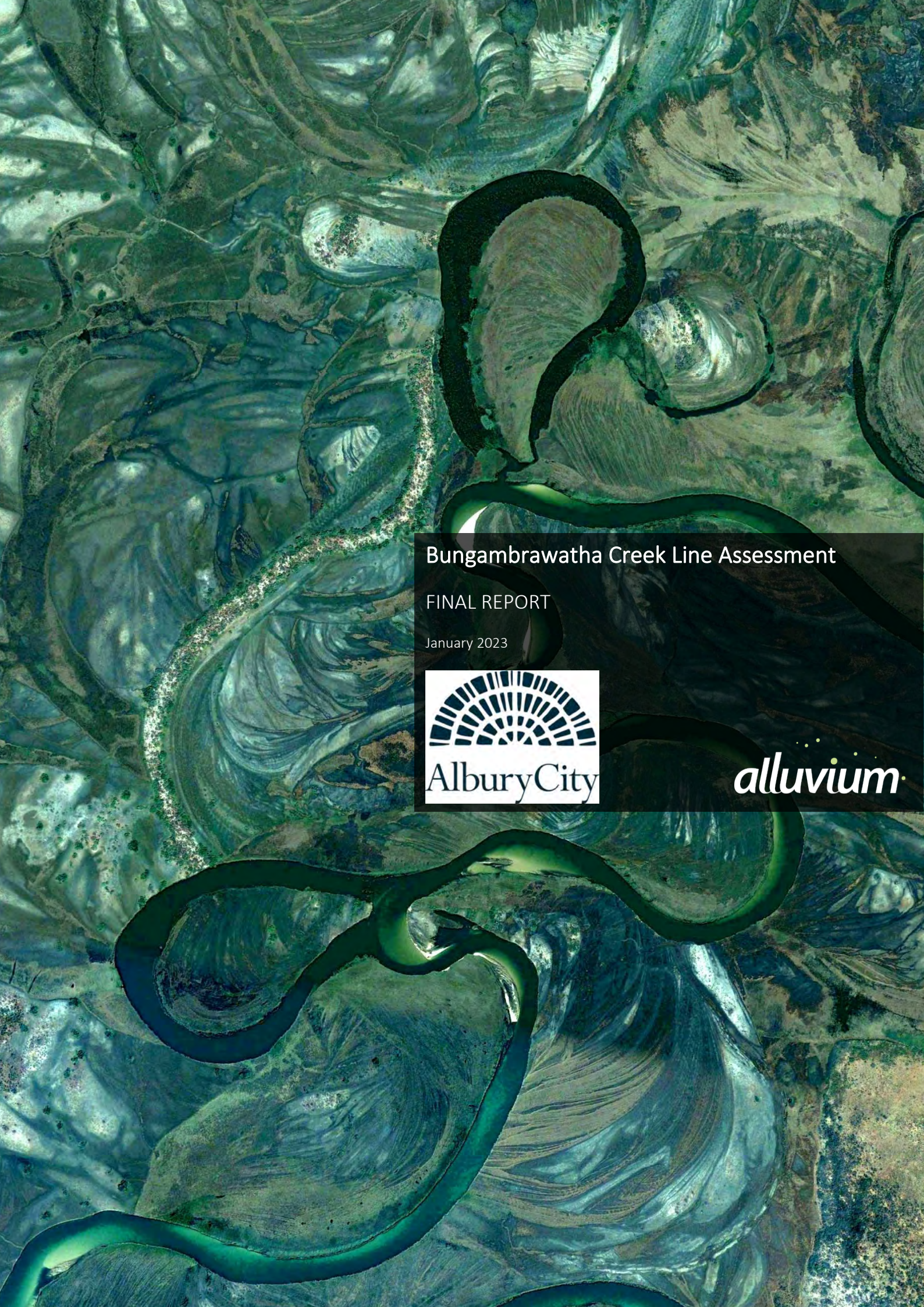

Bungambrawatha Creek Line Assessment

FINAL REPORT

January 2023

Albury City

alluvium

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Vicki Golding. This piece was commissioned by Alluvium and has told our story of water across Country, from catchment to coast, with people from all cultures learning, understanding, sharing stories, walking to and talking at the meeting places as one nation.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for the City of Albury under the contract titled 'Bungambrawatha Creek Line Assessment'.

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Contents

Figures

Tables

1 Introduction

Bungambrawatha Creek flows through the City of Albury, from the headwater streams in the Black Range, through to the AlburyCity CBD where it enters the Murray River. It has a long history of degradation and modification and is now channelised from the Murray River to Oliver Street, Lavington. Council have recognised a need to better manage the unlined reaches of the waterway, and the value that a naturalised concrete channel could bring to the city. This report is the summary of an assessment of the Bungambrawatha Creek line (including reaches of Black Springs and Little Black Springs Creeks), including its unlined and lined sections.

For the purposes of this assessment, Bungambrawatha Creek has been divided into two segments, the unlined sections of the waterway in the north (including parts of Black Springs and Little Black Springs Creeks) and the channelised section from the south of Oliver Street, Lavington. It is the culmination of the technical assessment of the waterway and is the precursor to the Bungambrawatha Creek Action Plan.

1.1 Project Scope

The project has been scoped with two distinct outcomes, outcome one referring to the unlined reaches of waterway, and outcome 2 referring to the lined southern reaches. Owing to the differences in settings and degrees of modification, these are considered as two distinct project outcomes.

Project drivers

Outcome 1

The northern section of Bungambrawatha Creek has a history of disturbance including clearing of vegetation, which has led to significant incision and widening of the waterway channel. It has been modified in some locations and is confined by surrounding private land making management of the waterway difficult. Council seeks to understand the key issues impacting this section of waterway and a pathway to better management.

Outcome 2

The channelised section of the waterway is significantly confined, having been modified to convey water away from the town as efficiently as possible. The channel is currently very space confined, visually unappealing, and offers little to residents other than protection from flooding. Council has recognised the benefit that can come from the naturalisation of this waterway, having recognised this as a possibility in some of their park masterplans, and seek to understand the constraints and opportunities for the waterway along its lined length.

Investigation area

Figure 1 below details the investigation area as it pertains to each individual outcome.

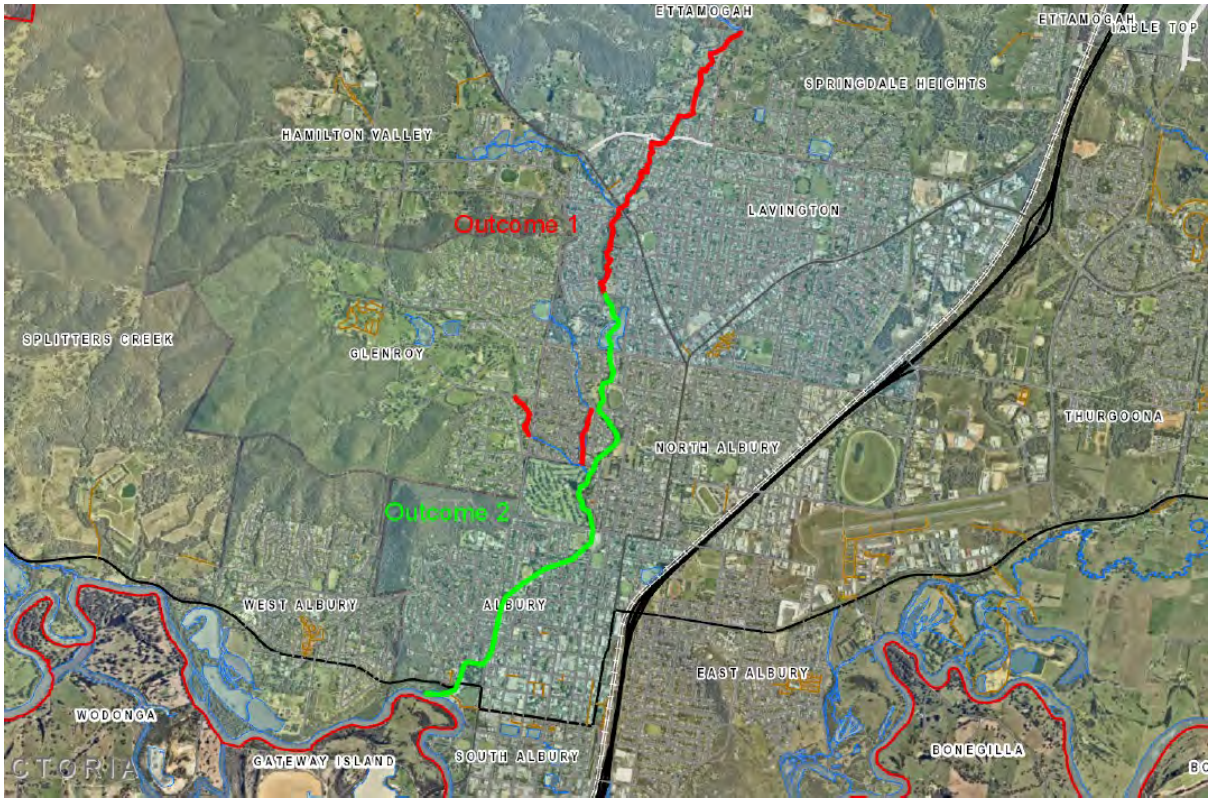
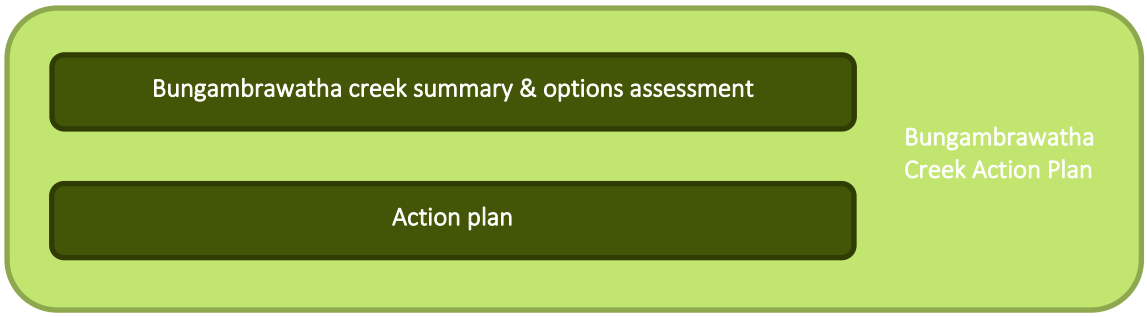


Figure 1. *Study area for the Bungambrawatha Creek assessment*

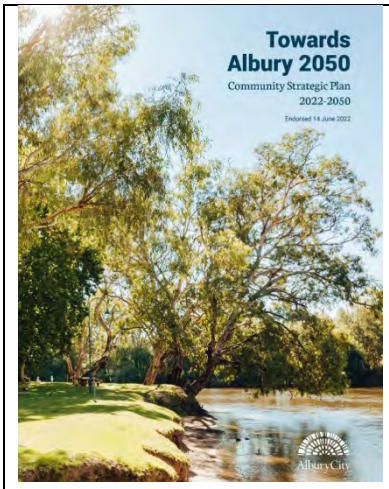
1.2 Approach

The technical assessment is the culmination of a background assessment, field inspections and workshops with Council.



1.3 Policy and Strategy Setting

The enhancement of Bungambrawatha Creek, including the potential for naturalisation, is supported in the City of Albury's strategic plan and policies, as well as local scale master plans. Actions identified in the action plan seek alignment with these outcomes.

 **Towards Albury 2050 Community Strategic Plan**	The Albury Strategic Plan has four key themes, all of which may have linkages to the Bungambrawatha Creek. One of the key themes is '**An enhanced natural environment**', which seeks the following outcomes: 2.1 Albury is a zero emission and climate resilient city 2.2 Albury embraces the cultural heritage of Aboriginal and Torres Strait Islander people 2.3 Albury is a leader in resource management and circular economy 2.4 Albury is a recognised leaser in the protection, conservation and management of our natural assets.
 **Regional Natural Environment Strategy 2020 - 2032**	The two cities, one community (2C1C) have developed the regional natural environment strategy 2020 – 2032 which under the theme of waterways and wetlands calls to "Preserve and improve our waterways, wetlands, aquatic habitats and water quality from local creeks down to the Murray River". It notes actions to: 1. Protect and restore riparian zones, wetlands and aquatic habitats; and, 2. Maintain and improve our water resource (quality and quantity). The theme Liveability expresses that "Our natural places are managed to enhance our well-being and provide connections to nature." Specifically, it identifies actions including: 1. Provide opportunities for everyday connections with nature and waterways; 2. Increase the environmental amenity of our urban parks and steetscapes; and 3. Plan strategically for appropriate recreational use of natural areas.

 Master Plans	The master plans of the Murray River Experience, Fredericks Park, and the Botanic Gardens all express an intent to naturalise, or investigate the naturalisation of, Bungambrawatha Creek.

2 Bungambrawatha Creek – a multi-functional corridor

2.1 Catchment context

The Bungambrawatha Creek catchment (shown in Figure 2) drains the area to the north of Albury including the western portion of the CBD. Major tributaries of Bungambrawatha Creek include Hamilton Valley Creek, Little Black Springs and Black Springs Creeks. The hills to north and west, including the Black Range and Nail Can Hill, are generally lightly to moderately wooded, and dominated by grazing practices. There has been historical land use disturbance from gold mining, and there are numerous actively eroding gullies in the upper catchment.

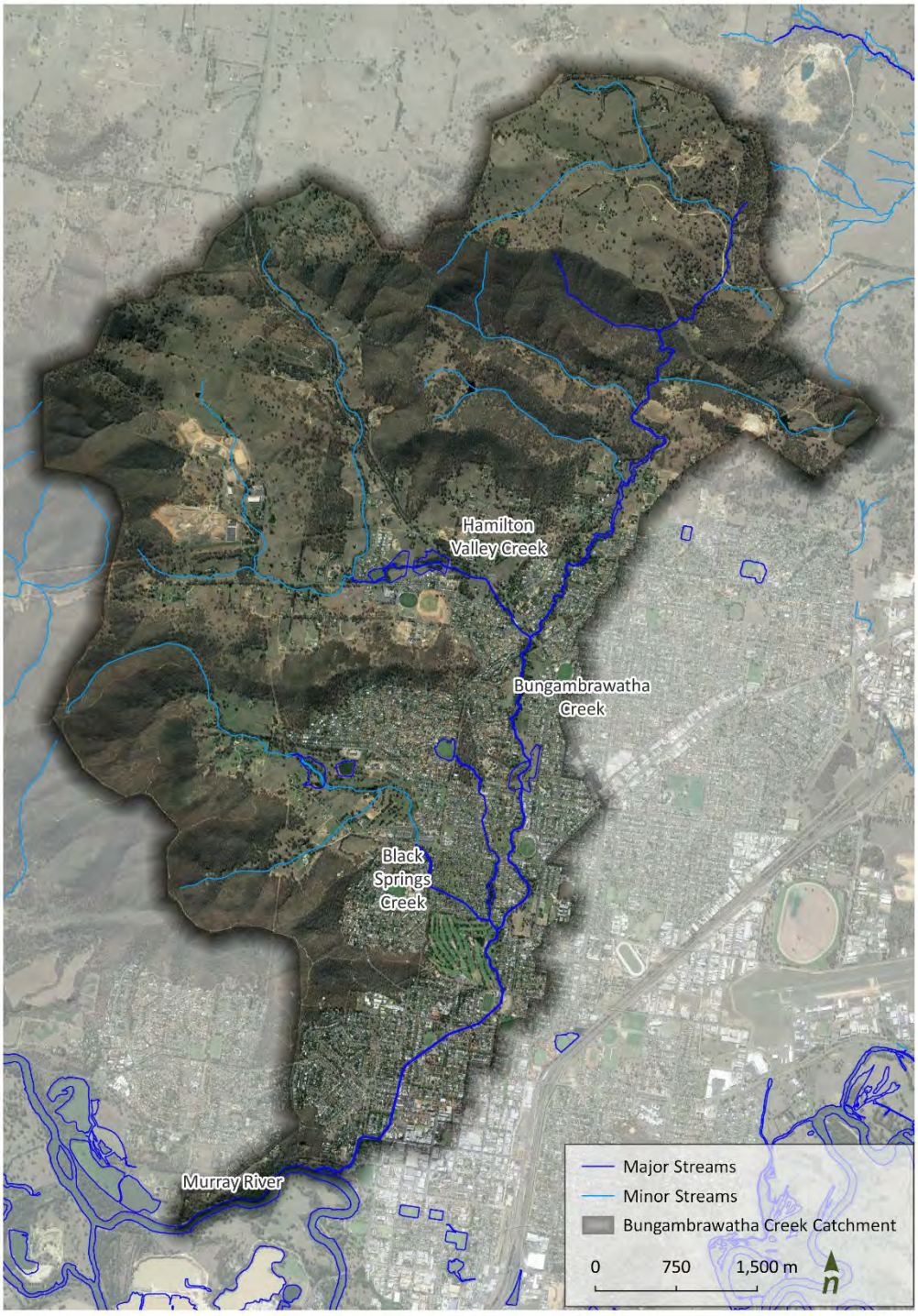


Figure 2. *The Bungambrawatha Creek catchment, waterways and streams.*

Land use

Land uses through the catchment include environmental management zones (encompassing pastoral activities), residential and large lot residential zones. The historical land use change, including clearing for agricultural purposes and urbanisation has changed the nature of runoff within the catchment by increasing the amount and rate of runoff.

Figure 3 below details the existing and future land use within the catchment as zoned in the development control plan.

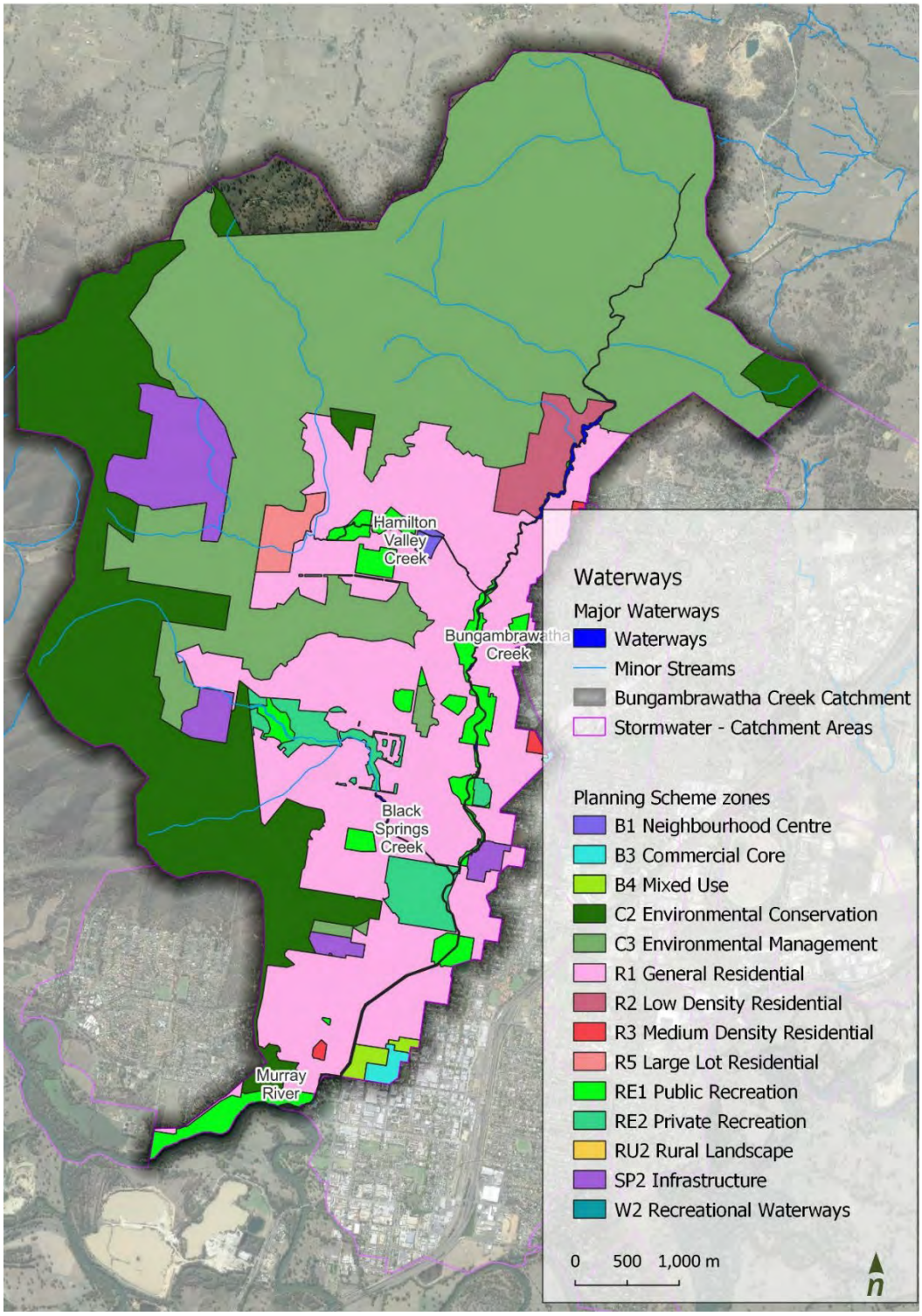


Figure 3. *Land uses of the Bungambrawatha Creek catchment as zoned in the Albury Development Control Plan.*

Historical context

The Wiradjuri, people are the first nations people that occupied the Albury Wodonga area for millennia. The name Bungambrawatha is thought to come from aboriginal etymology meaning *Bun* – Creek that runs only during winter and spring; *bra* meaning white and *watha* meaning hearing (Spennemann, 2015). The Murray River (Millewa River) was a focal point for their lives, as a provider of resources with strong spiritual connection. Bungambrawatha Creek, while not as significant, would have played a similar role in the lives of the Wiradjuri people.

At the time of European settlement, the early settlers would have found Bungambrawatha Creek to be a highly sinuous stream. It flowed through the present-day CBD and the Albury sporting reserve, where it became much like a delta of a series of smaller channels at the confluence with the Murray River (Wooding, Undated). Much of the riparian vegetation was cleared by the early 1900's for agriculture and urban development, and it was successively modified over the course of approximately 150 years. In response to issues of flooding, including as a consequence of upstream dam failure, the waterway was progressively channelised commencing in the 1860's (Wooding, undated). Through the town reach, Bungambrawatha Creek was shifted to the west of its original position and straightened into a highly efficient concrete channel, beginning from the confluence with the Murray River and progressing steadily northward. Figure 4 shows the location of the original waterway in reference to the constructed channel now known as Bungambrawatha Creek.

The upper reaches of the waterway are thought to have been modified from early gold prospecting in the catchment including tributaries and in parts of the waterway themselves. Clearing of vegetation for pastoral activities has resulted in an increase in runoff, which combined with removal of riparian vegetation has led to the incision of the waterway and channel widening.

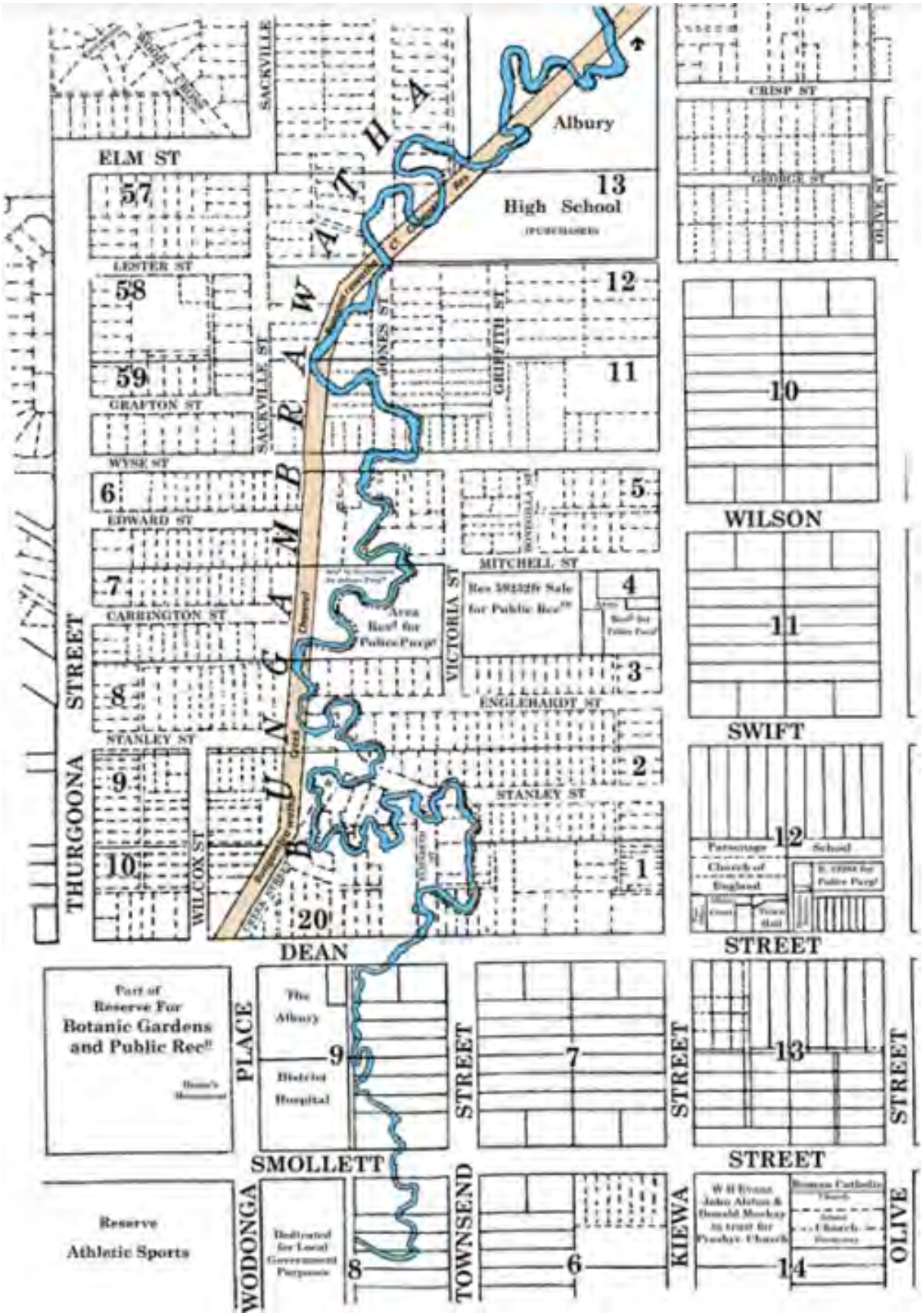


Figure 4. *Historical map of Albury, showing the original location of Bungambrawatha Creek and the modified channel. Source:* (Wooding, Undated)

Geology

The upper reaches of the catchment encompassing the Black Range are part of the Omeo-Albury Metamorphic complex of the upper Ordovician and Silurian periods. The lower hills and valleys of Bungambrawatha Creek consists of fluvial sedimentary deposits of the Quaternary period, which are overlain by recent colluvial deposits (Department of Minerals and Energy, 1979).

Figure 5. *Geological map of the Albury region. O-Ss = Ordovician-silurian Schist, Qrc = Quaternary hillwash scree, Qs = sheparton formation fluvial deposits* **(Department of Minerals and Energy, 1979)**.

Hydrology

Since urbanisation, the hydrology of Bungambrawatha Creek has been greatly modified by the clearing of vegetation and the construction of extensive impervious surfaces including roofs and pavements. Both of these practices have resulted in an increase in runoff, and a subsequent increase in stream power and erosion potential through the waterway. Upstream of the concrete lined section of channel, the waterway exceeds the capacity of the main channel, breaking out into the wider inset floodplain as typically expected of a natural waterway. The 1% AEP flood depth is shown in Figure 6 and Figure 7 below from data supplied by AlburyCity Council. It should be noted that the outputs have been read in WaterRide, and hence the model has not been checked for accuracy and completeness.

Water Quality

Water quality testing of Bungambrawatha Creek has not been undertaken, however based on the land use, assumptions can be made regarding expected water quality. Our field visit was undertaken after a preceding day of heavy rainfall, and it was noted that turbidity was high even in the upper reaches of the corridor, indicating disturbance in the catchment including gully erosion, impact of unsealed roads and disturbance from historical mining and active industry.

The lower corridor is likely to have elevated levels to nutrients such as phosphorus and nitrogen, as well high levels of suspended solids, hydrocarbons and heavy metals, as typically expected in urban waterways. Litter is also a known problem within the waterway. Management of these issues is not readily actioned within the corridor itself. Whilst an online gross pollutant trap crosses the waterway adjacent to the existing Albury pool, it is unlikely to be effective at capturing litter. Because of the large catchment, very high loads of gross pollutants, including organics are swept down the waterway. Water levels in the waterway in response to rain also quickly exceeds the height of the existing trash rack, meaning that most litter simply passes over the top, and it becomes clogged with predominantly leaf litter very quickly, after which it has almost no effectiveness at capturing litter. Such online options are typically ineffective. Given issues with flooding and minimal freeboard between peak flood levels and the top of the channel, flood sensitivity can also be a significant impediment to the construction of online gross pollutant traps that may otherwise be more effective at litter capture.

It is recommended that Council investigate a catchment wide response to the management of water quality, including gross pollutant capture. Managing these issues at source is likely to be the more effective opportunity than online trash racks. Embracing principles of water sensitive urban design can bring many benefits to the environment, as well as contributing to improved amenity, ecology and cooling outcomes for the city. This could include the construction of gross pollutant traps inline in the stormwater network, or the use of blue-green infrastructure such as passively irrigated street trees, raingardens, swales, bioretention basins and constructed wetlands.

Figure 6. *1% AEP flood depth for the critical duration storm - upper Bungambrawatha Creek.*

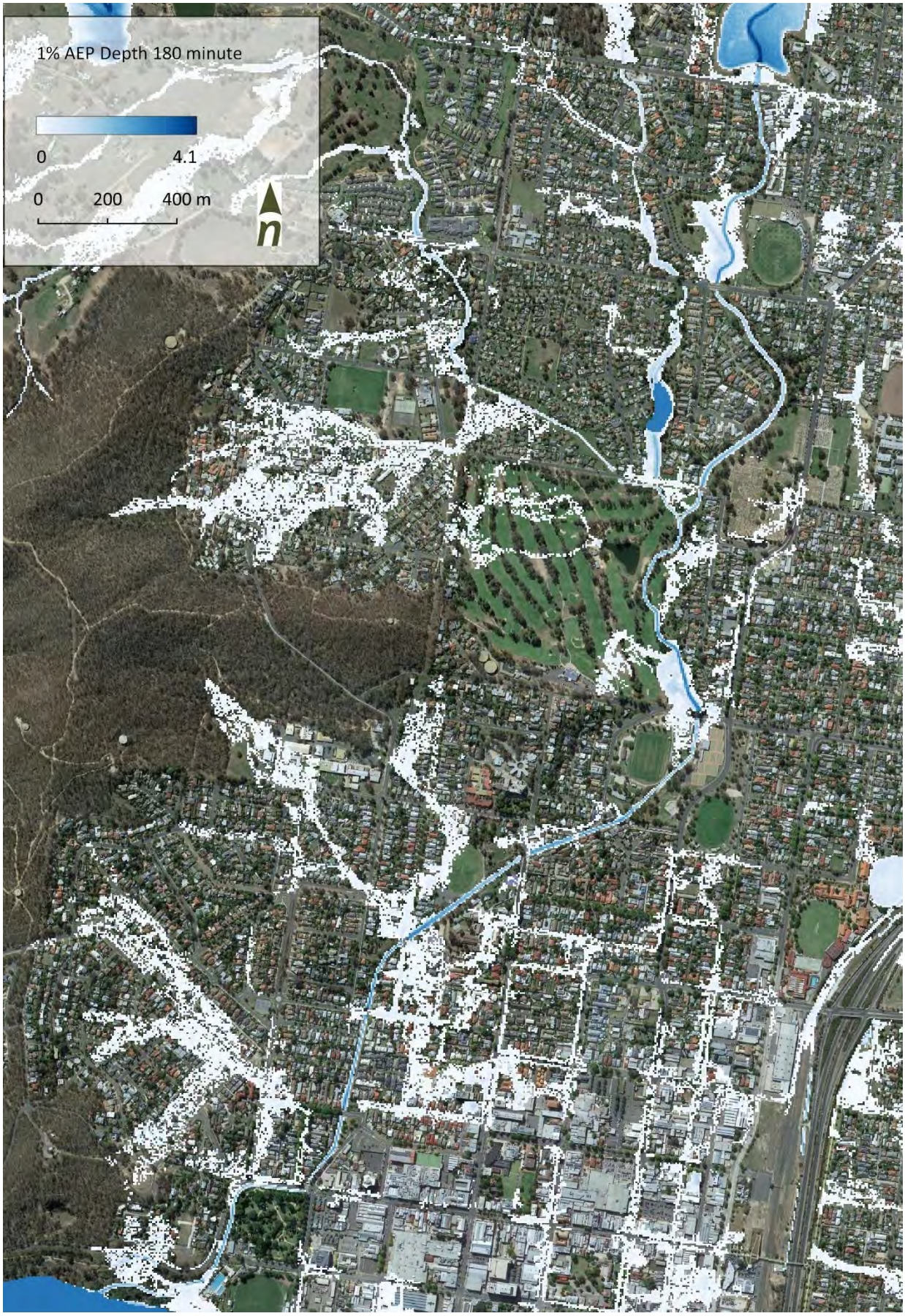


Figure 7. *1% AEP flood depth for the critical storm duration - lower Bungambrawatha Creek*

A number of retarding basins exist throughout the catchment, including in Hamilton Valley Creek (Collins St basin) and on Bungambrawatha Creek itself, upstream of Union Road. These basins assist in preventing flooding of the catchment through the City of Albury. The construction of the existing concrete lined waterway has also served to reduce the extent of flooding by providing a highly efficient drainage network that conveys water very rapidly through the CBD and into the Murray River. The concrete channel contains the majority of flows up to and including the 1% AEP event. However, in events greater than this, modelling shows that the channel capacity is exceeded in proximity to Jones St resulting in flooding through Dean Street near the alignment of the CBD.

Velocities in the channel are very high courtesy of the highly efficient flow mechanism. Velocities in the 20% AEP exceed up to 5m per second in places, and over 7m/sec in the 1% AEP, presenting a significant challenge to the naturalisation of the channel in these highly confined reaches. It should be noted that these are peak velocities, and refined modelling will be required to determine actual velocities and shear stresses through the channel under a modified scenario.

2.2 Social Context

Bungambrawatha Creek has a number of significant recreational facilities immediately adjacent the waterway, including Heathwood Park, Fredericks Park, J.C. King Park, Greenfield Park, and in the lower corridor the Botanic Gardens, community gardens and riverside park.

An off-road cycle network, the Bungambrawatha Creek Trail, connects Urana Road in the north with the Murray River. This is a relatively direct transport route along the waterway corridor, with the exception of a detour away from the creek where it passes through the Albury Golf Club. It is recommended that consideration be given to placing this area under an access easement, with potential maintenance sharing with the Albury Golf Club. The trail's cohesiveness is impeded by a number of road crossings, and an undesirable commute through the carpark of the netball courts. The Smollett Street bridge presents a barrier to the linear connection and requires an awkward deviation away from the channel to cross this road.

Lighting is generally absent from the entire length of the Bungambrawatha corridor. A lighting strategy should be developed that considers appropriate lighting to improve the safety and useability of the corridor, while also considering issues such as the impact of lighting spill and residents and wildlife.

Urban canopy & cooling

The main pedestrian/cycle connection along Bungambrawatha Creek has variable shade cover. In some of the more highly constrained areas there is very minimal vegetation cover. Through some of the parks, specifically Fredericks and Heathwood Parks, vegetation cover along the cycle way is very scant, presenting an opportunity to improve the useability of the cycleway in the warmer months. Detailed mapping of the Bungambrawatha Creek canopy is shown in Figure 8 and Figure 9 below. This mapping can be used to prioritise the shade canopy planting along the Bungambrawatha Creek trail.

Planting should be undertaken in consultation with an arborist, however native species should be selected. Consideration should be taken to ensure that trees are provided ample space to grow and reach full size. This includes making allowances for appropriate soil volume through the use of structural soils or proprietary soil reinforcement products and passive irrigation. Ensuring that vegetation has ample access to water will also reduce the risk of roots spreading and damaging nearby infrastructure like foot or bike paths. Correct species selection will ensure that the tree size and habitat is appropriate, and that potential for root damage is limited.

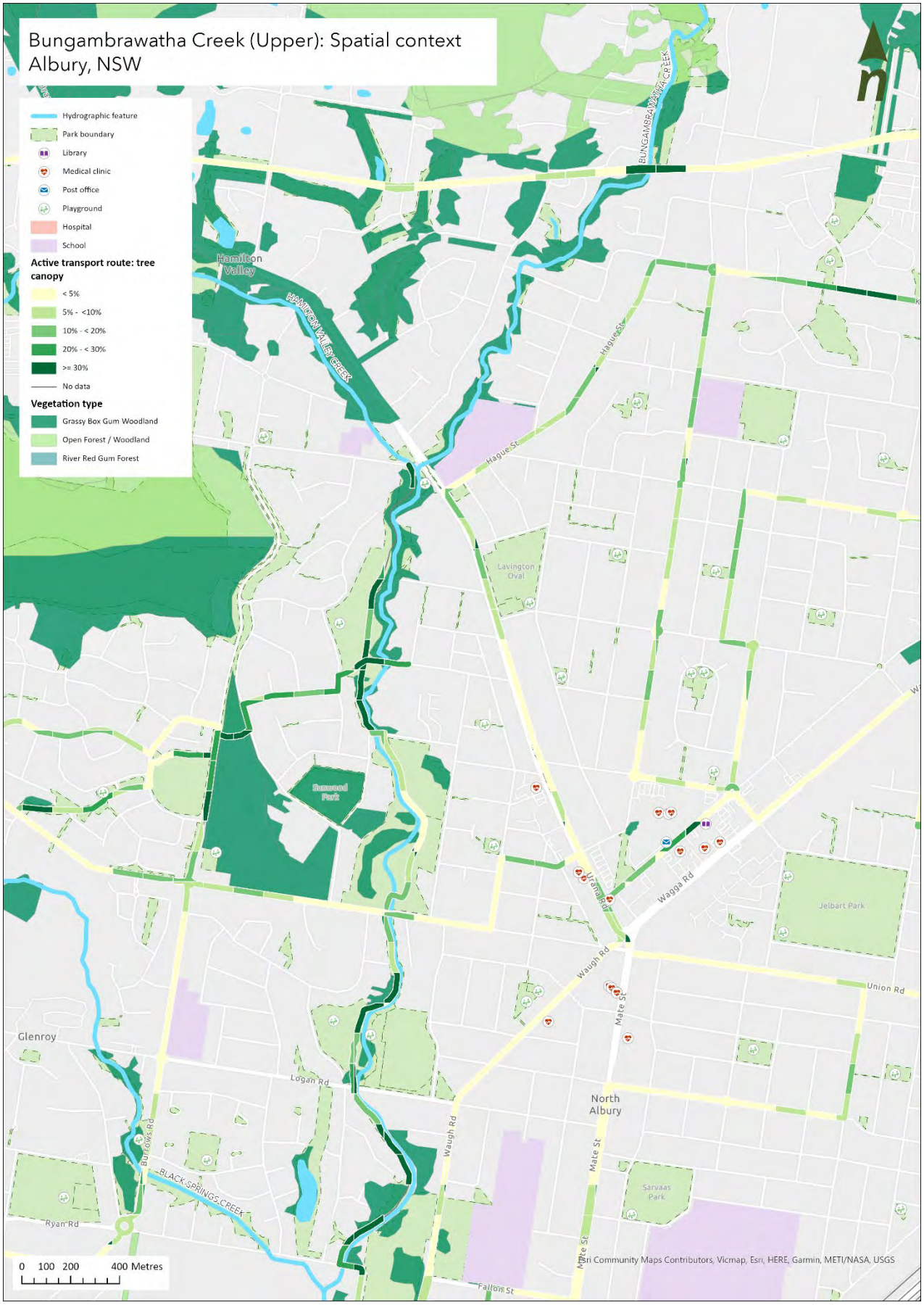


Figure 8. *Urban canopy cover in the upper Bungambrawatha Creek catchment.*

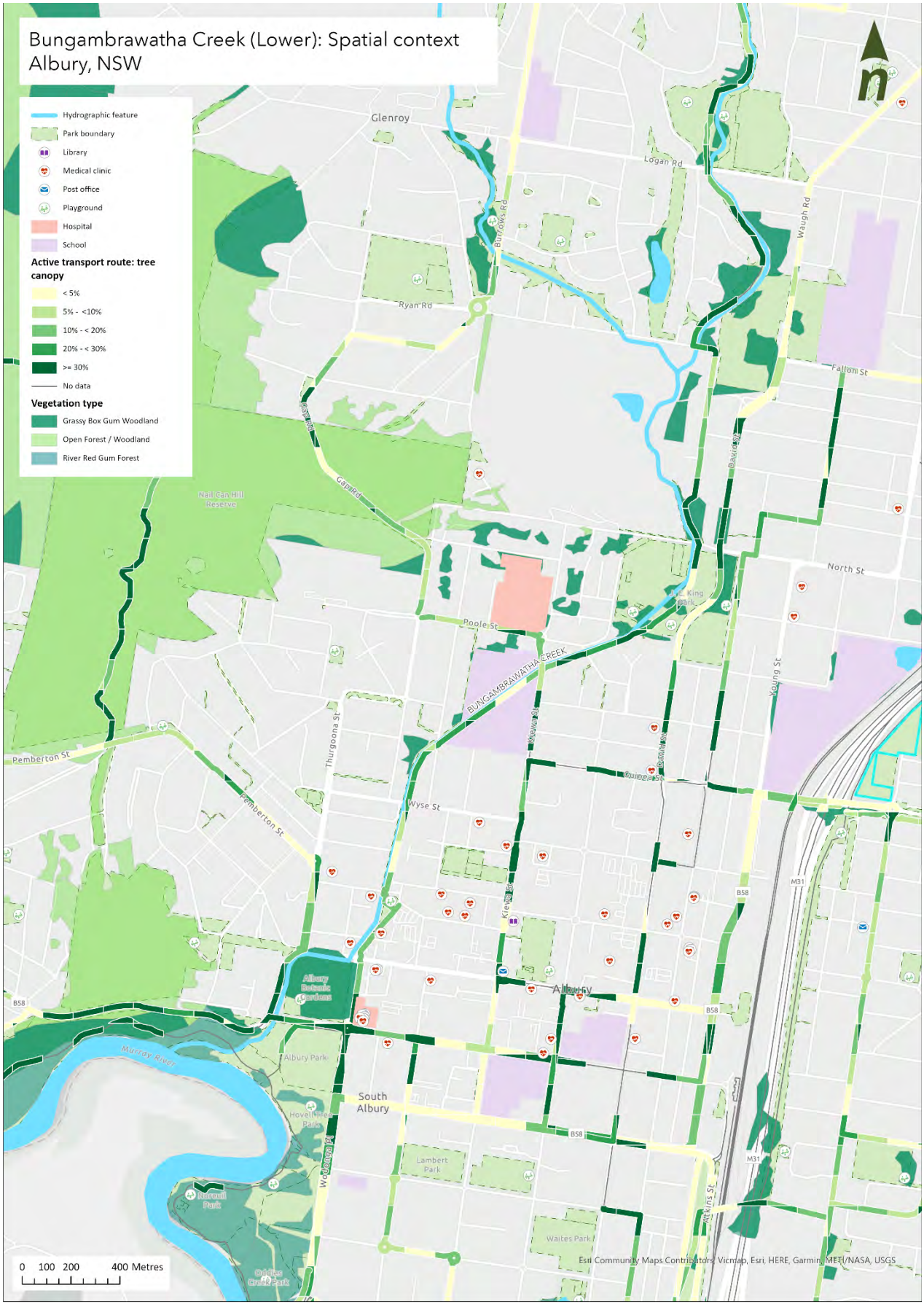


Figure 9. *Urban canopy over active transport routes around lower Bungambrawatha Creek and the Albury CBD.*

2.3 Ecological context

Waterways

Bungambrawatha Creek is one of several lowland creeks in the region including Eight Mile Creek, Splitters Creek and Thurgoona Creek in Albury and House Creek and Middle Creek in Wodonga. There are also a number of small drainage lines that have been dammed to provide water for stock. As with most creeks in the region, settlement was associated with widespread clearing of the land and riparian vegetation that is associated with significant changes in the stream characteristics with increased inputs of sediment and nutrients. The clearing of riparian vegetation was also associated with increased bank erosion and where grazing permitted the spread of aquatic plants. Finally, cleared vegetation provided opportunities for invasive species to colonise creek banks, including willows, thistle, and blackberry.

The urbanisation of Albury-Wodonga has resulted in increased paved and hardstand areas, including the channelisation of Bungambrawatha Creek itself. This increase in catchment imperviousness has changed the flow regime in the catchment, increasing average annual flows and flood magnitude while decreasing the inundation duration and flow attenuation. Urban creeks are subjected to longer periods of cease to flow or base flows which can provide an addition stress on biota. This will often mean that aquatic fauna is reduced to small, short lived invasive species such as mosquito fish, while the macroinvertebrate community is comprised of small generalist species which breed quickly and are tolerant of poor water quality, such as chironomids and worms.

While the changes associated with development have been significant, aquatic ecosystems are resilient due to the fact that they have evolved to deal with a range of disturbances including drought and flood and so there is usually scope to restore both biota and the associated ecosystem services.

In addition to the values of the resident biota within the creek, there is also the function the creek can provide as a corridor linking remnant habitat patches in the landscape.

Vegetation

The riparian zone of Bungambrawatha Creek would be expected to support an overstory comprised of River Red Gum *(Eucalyptus camaldulensis)* in lower reaches (refer to Figure 10 for an example of River Red Gum on floodplain at the Bungambrawatha Creek outfall) with Blakely's Red Gum *(Eucalyptus blakelyi)* more common in upper reaches. The mid-canopy would have been composed of Silver Wattle *(Acacia dealbata)* and shrubs such as River Bottlebrush (*Callistemon sieberi*), and Sweet Bursaria (*Bursaria spinosa*). The ground layer would have included Weeping Grass (*Microlaena stipoides*) and Tussock Grass (*Poa labillardieri*), while aquatic plants would have included Cumbungi *(Typha spp.),* Sedge *(Carex spp.)*, Rushes *(Juncus spp.)* and Reeds *(Phragmites australis),* with Spike-rush (*Eleocharis spp.),* Swamp Wallaby Grass *(Amphibromus fluitans)* and Spiny Mud-grass *(Pseudoraphis spinescens)* being less common.

Figure 10. *Example of Eucalyptus camaldulensis on floodplain at the Bungambrawatha Creek outfall.*

The landscape rising into the hilly surrounds of Bungambrawatha Creek would have predominantly been Grassy White Box Woodland and Box-Gum Woodland which have been listed as an Endangered Ecological Community under the EPBC Act (refer to Threatened species/ecological communities below).

Figure 11. *Example of box gum grassy woodland in the upper catchment, with a moderately disturbed understorey from grazing.*

Threatened species/ecological communities

No listed aquatic species have been identified in Bungambrawatha Creek, although Thurgoona is regarded as a strong-hold for Sloane's Froglet. The species is believed to be associated with wetlands in Box-gum woodland (Knight, 2013) and may occur within the Bungambrawatha Creek catchment owing to similar habitat types.

Three listed species are known to be dependent on riparian habitats, including Squirrel Glider, Barking Owl and Black-chinned Honeyeater (Davidson, 2004). Monitoring of Squirrel Gliders has found that they move around the landscape and at times, riparian habitats are the most commonly used habitat (McWhinney, 2020). Grey Headed Flying-Fox are known to use the creek line as foraging habitat and a Flying-Fox camp is located at Padman Park (edge of Murray river close to confluence of Bungambrawatha Creek and the Murray River).

As noted, the Grassy White Box Woodland and Box-Gum Woodland has been listed as an endangered ecological community mainly due to the extent of clearing with less than 5% remaining in good condition, and much of this occurs in small, isolated patches. This is due to their habitat requirements being the productive agricultural land. The remaining patches are still being lost due to clearing, weed invasion and overgrazing (Department of the Environment and Heritage, 2006).

Other listed species known to frequent the area include:

- Regent Honeyeaters,
- Swift Parrots
- Turquoise Parrot
- Brown Treecreeper
- Diamond Firetail
- Speckled Warbler

- Little Lorikeet
- Purple-crowned Lorikeet

In considering Bungambrawatha Creek's role as a corridor, the linkages between Nail Can Hill and the creek should be included in planning. Nail Can Hill is a regionally significant reserve on the Western side of Albury that supports several listed species including the Pink-tailed Worm Lizard and Crimson Spider Orchid. Perhaps more importantly from a corridor perspective, a wide range of bird species are known to utilise Nail Can Hill, and for whom access to a corridor that would link to both forest remnants North of Albury, the Murray River corridor and Wodonga reserves may be of benefit.

3 Waterway Zones

The investigation area including Bungambrawatha, Black Springs and Little Black Springs Creeks have been divided into management zones based on similar characteristics spanning the physical, environmental and social realms. These management zones will have different management objectives based on what is possible within the corridor in terms of naturalisation or other environmental, social or cultural improvements. The zones are presented in Figure 12 below.

Attachment 1 contains detailed descriptions and photos of each of the Management Zones.

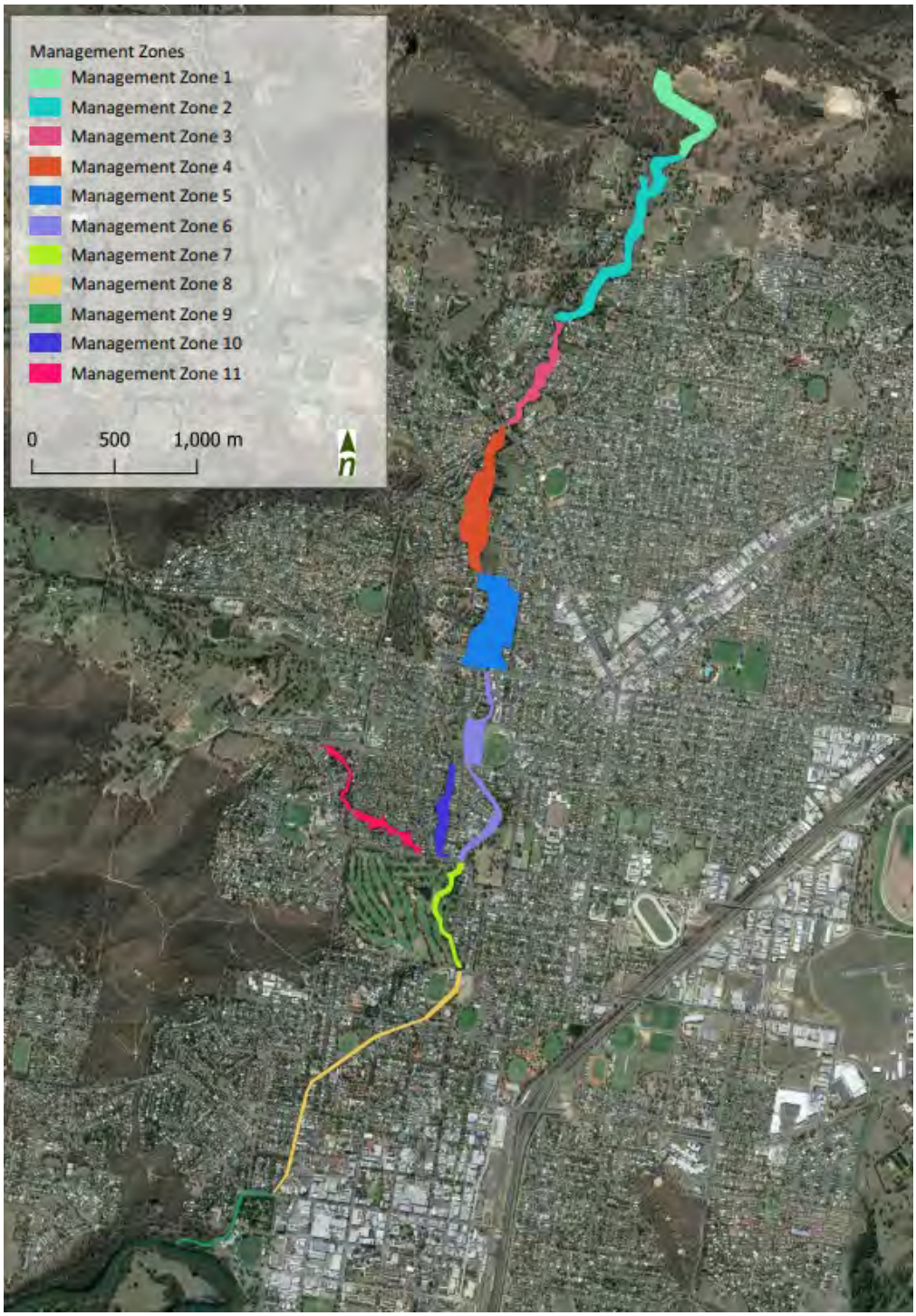


Figure 12. *Waterway management zones.*

3.1 Management Zone 1 – Adjacent upper Prune St

Channel form

Bungambrawatha Creek commences as a valley confined bed rock-controlled waterway. It is a relatively steep reach, and boulders and cobble prevent deepening of the channel. Given the cobbled nature of the stream, limited movement is expected, however some minor movement could occur given the vertical nature of the banks during high magnitude flood events. Evidence exists of historic channel modifications in the form of past mining and bunded areas adjacent to the waterway, where the channel has been excavated and earth placed adjacent to the channel.

Riparian zone

Riparian vegetation is limited to regrowth acacia's, with some weeds apparent. There appears to be occasional access to the waterway by stock, creating localised erosion and waterway degradation.

Land tenure

Crown reserve surrounds the waterway, including road reserve. Surrounding land uses are private, with some conservation land owned by Council adjacent to the crown land.

Open space and connections

Informal access tracks have been formed off Prune Street where informal gathering occurs, and there is some evidence of campfires, suggesting periodic recreational use.

3.2 Management Zone 2 – Laterally migrating channel (private road crossing to Roach St)

Channel form

The channel veers away from Prune St at a relatively consistent grade. There is limited sign of bed incision and channel deepening through the main channel, however some very steep banks are migrating laterally at a rapid rate, as evidenced by numerous fence lines being re-erected at the top of bank (Figure 13). Much of the channel adjustment in this area is historic as indicated by large trees present along some of the eroded channel features, floodplain bars and channel boundaries that would be likely to have formed following initial clearing of the catchment.

Figure 13. *Migrating channel, with movement noted by the location of old fences.*

A notable head cut is migrating upstream in a small headwater tributary flowing into the main arm of Bungambrawtha Creek from the north. Left unchecked, this head cut will likely progress upstream and initiate erosion in private land.

The mid reach of Zone 2 has undergone significant historical erosion, however channel widening no longer appears to be active. This may in part be owing to modifications in the channel to straighten it, as evidenced by a spoil bund left adjacent to the channel. This has resulted in the formation of a small offline wetland.

Limited access was achievable through the downstream reach of Zone 2, however a review of lidar data indicates that significant historical channel deepening and widening has occurred. It is likely that given dense weed infestations through this section that the channel is largely stable in its existing form owing to historical adjustment and dense weed growth.

Riparian zone

The upper reaches of the zone contain remnant, or mature regrowth native vegetation, interspersed with weeds, particularly English Elm and Privet. Most of this vegetation is contained within the macro-channel, including in cut-off meanders and on the banks of historically widened sections of channel.

Land Tenure

Adjoining land is typically freehold, however a significant portion of this land is owned by Council, providing opportunities for recreational access or creek rehabilitation. The land is largely privately owned, however there are some land parcels to the west of Bungambrawatha Creek that have been acquired by Council.

Open space and connections

Council owned parcels could potentially create an open space link connecting Management Zone 2 with Management Zone 1.

3.3 Management Zone 3 - Roach St to Urana Rd

Channel form

Roach Street to Urana Road has been historically cleared and heavily eroded. There appears to have been encroachment of private property into the waterway with fences being built to the channel banks and potential filling of the floodplain. Banks are very steep in some places, however, are generally stable largely owing to the extensive root mass provided by an extensive build-up of debris through the zone.

During January 2022 flooding events, extensive debris build up occurred at the Roach Street culverts, causing flooding to overtop the road and sediment to block the channel outlets.

Riparian zone

The riparian zone is dominated by dense stands of weed, most notably Privet, English Elm, False Acacia and Blackberry. These make access very difficult, however are providing privacy to residents and valuable function of maintaining bank integrity.

Land tenure

The land through this reach is generally freehold, owned by private landholders with some access locations owned by Council.

Open space and connections

There is no existing open space function, however this zone represents one of the major barriers to enabling a continuous linear connection from the Murray River through to the upper reaches of Bungambrawatha Creek.

3.4 Management zone 4 – Urana Road to Oliver Street (encompassing Heathwood Park)

Channel form
The waterway is moderately meandering, and the channel is relatively uniform. There is limited in-stream diversity in the form of pools with a very uniform channel dimension from upstream to downstream through the reach.

Riparian zone
The riparian zone has been well-managed on the Council owned (western) side of the waterway, however Poplar trees and other exotic weeds dominate the eastern waterway. Significant remnant *Eucalyptus camaldulensis* (river red gums) occur along the waterway, and revegetation efforts have resulted in a mid-storey of wattles, tree violets and maturing eucalyptus trees emerging. These are the outcome of community planting by the Friends of Bungambrawatha Creek.

Land tenure
The land on the western zone is largely owned by Council and privately owned on the east.

Open space and connectivity
South of Urana Road, Hamilton Valley Creek joins the Bungambrawatha Creek main arm. This is the upper extent of the Bungambrawatha Creek trail, a formed shared path connecting to the Albury CBD. It is also the beginning of Pioneer and Heathwood Park, a 7.75 Ha of parkland lying west of Bungambrawatha Creek.

The shared path runs between the riparian zone and Heathwood Park, with minimal planting on the western side of the channel. In addition to the formed bikeway, an informal pathway for the more adventurous or those seeking a more intimate connection with nature exists. This dirt track cuts through revegetated riparian areas, having been formed by foot and bicycle traffic over time. Children's cubby houses can be seen in the riparian zone, indicative of informal/nature play experiences being sought.

Heathwood Park is largely a poorly shaded open grassed area that accommodates a dog off-leash area, with a small playground to the west.

Active Maintenance
The reach has been the subject of active debris management with de-snagging of the reach being undertaken post the January 2022 floods.

3.5 Management zone 5 – Oliver Street to Union Rd (encompassing Union Rd retarding basin)

Channel form
South of Oliver Street is the most upstream extent of the concrete channel. The channel concrete lining is generally limited to the base, is unconfined and meanders through the Union Road retarding basin.

Riparian vegetation
There are some remnant trees within the basin, as well as other regenerated species in isolated pockets, particularly on the western side of the channel.

Land tenure
The management zone is entirely owned by Council for the purposes of retarding flood waters.

Open space and connectivity
The bikeway continues through the Union Drive detention basin. The basin floor is generally mown and is used as informal recreation space.

3.6 Management Zone 6 – Union Road to Ryan Road (encompassing Fredericks Park)

Channel form

South of Union Rd the channel corridor is quite confined until it reaches Fredericks Park, maintaining a consistent trapezoidal concrete channel cross section with some sinuosity. The adjacent land opens up into Fredericks Park and terminates at the Albury Golf Club.

Riparian vegetation

There are some significant remnant River Red Gums adjacent the channel. The understorey is typically turf. Some residents have highly manicured gardens extending into the open space. The channel is confined by a fence on the western side of the channel and private property on the east. Maintenance of vegetation largely consists of spraying ground covers between the fence and top of the concrete channel. Through Fredericks Park there are pockets of re-establishing native vegetation, however grassy weeds are prevalent.

Land tenure

Council owns the entirety of the corridor between Union Road and Ryan Road, however this is generally a relatively narrow band with the exception of Fredericks Park.

Open space and connectivity

The shared pathway continues through this zone, passing through Fredericks Park for a reach. The channel is separated from surrounding open space with a chain mail fence, providing a hard barrier and a physical separation from the channel. Whilst this is necessary from a safety perspective, methods should be sought to soften this barrier.

3.7 Management Zone 7 – Albury Golf Club

Channel form

The channel maintains its concrete trapezoidal section through the golf club reach with limited sinuosity.

Riparian vegetation

A scattered overstorey of *Eucalyptus camaldulensis* lies adjacent to the existing channel, remnants of the original floodplain. The understorey is typically poor and highly manicured courtesy of the golf club.

Land tenure

The entire reach is contained within the private ownership of the Albury Golf Course.

Open space and connectivity

Whilst the golf course provides a pleasant environment for golfers, the course presents the only break in the linear stretch of waterway between Urana Road and the Murray River. Cyclists and pedestrians are forced to adhere to the street network in this location before rejoining Bungambrawatha Creek at Ryan Road.

3.8 Management Zone 8 – North Street to Dean Street

Channel form

The concrete channel continues its trapezoidal form to Jones Street, where it gradually transitions to a more V-shaped channel with a side profile of approximately 1 to 2V: 1H. It maintains this profile from Wyse Street through to Dean Street. The section between Jones Street and North Street is nearing a point of requiring significant works, with parts of the channel walls being broken by vegetation, and significant washouts occurring behind the channel walls. Little or no channel sinuosity exists within Zone 8.

Riparian vegetation

Occasional *E. camaldulensis* occur adjacent the channel, many of which are causing the concrete sides of the channel to buckle. Most of the channel is devoid of vegetation and the area between the fence and top of concrete channel, is regularly sprayed for maintenance purposes, leaving it unsightly.

Land tenure
The channel is largely within Council land throughout this reach, however the corridor is very narrow with fences and houses built to the edge of the channel.

Open space and connectivity
The channel provides an effective linear connection through Albury. However it is generally unsightly, and very warm in summer months, limiting its use. To the North are a number of active recreation parks, including J.C. King Park and the Albury Skate Park. Albury High School lies adjacent the channel on Kiewa St, and the Bungambrawtha Community Garden and Gertrude Colquhoun Park straddle Stanley Street on the eastern side of Bungambrawatha Creek.

3.9 Management Zone 9 – Dean Street to the Murray River

Channel form
The channel re-takes its trapezoidal form through this reach. Adjacent to the Council depot there is a trash rack and sediment basin, where the low flows are diverted through the piped network to the Murray River. The sediment basin has a significant drop off on its downstream side. The confluence of Bungambrawatha Creek and the Murray River has recently been reconstructed as a rock-lined outfall to convey high flow events. Between rainfall events this area conveys no vegetation.

Riparian vegetation
To the South of Dean Street and the adjacent channel lies the Albury Botanic Gardens. Vegetation in this area consists of an avenue of English Elms that are slated for removal, as well as a range of other highly manicured gardens. A number of mature Eucalyptus species lie to the west of the channel adjacent to Thurgoona Street, however this is generally not locally indigenous vegetation. On the south side of Smollet Street, persists mature and high quality floodplain vegetation (*Eucalyptus camaldulensis* dominated)

Land tenure
The channel and surrounds are largely in Council ownership and road reserve.

Open space and connectivity
The Botanic Gardens and the new Albury Riverside Precinct. Connectivity is broken by Smollett Street

3.10 Management Zone 10 - Little Black Springs Creek

Channel Form
The channel is concrete lined in the downstream portion, immediately upstream of Ryan Road. A weir has been constructed damming the waterway creating a lacustrine wetland in the middle of the zone, and is natural in the upstream reach to Logan Road.

Riparian vegetation
The waterway is largely devoid of riparian vegetation surrounding the concrete lined section of waterway. The pond has some large remnant River Red Gums, and emergent macrophytes (typically typha) in the wetland. The upstream unlined section of waterway is generally dominated by weeds, particularly Willow and English Elm.

Land tenure
The majority of this corridor is Council owned.

Open space and connectivity
No formal connections exist along the corridor, however there is opportunity to improve the useability of this area as a valued public space.

3.11 Management Zone 11 – Black Springs Creek

Channel Form

Black Springs Creek is concrete lined in the lower section. Upstream of Burrows Road, the channel commences a more natural form, which is largely stable despite likely historical erosion .

Riparian vegetation

The waterway is largely devoid of vegetation through the concrete lined section. The unlined portion of waterway is dominated by weeds, however some remnant trees remain.

Land tenure

The creek is within Council owned land, however the corridor width is very narrow and lined with private property making access poor along the waterway.

Open space and connectivity

Connectivity is poor with no formal pathways, however a number of informal pathways connect the waterway to residential areas and the road network. A community centre exists in an unnamed park between Chenery St and Burrows Road, making this an area for potential improvement in the quality of open space.

4 Waterway Outcomes

Providing an aspirational end state for Bungambrawatha Creek in the form of a vision statement provides an opportunity to provoke thought regarding what is possible, the types of actions required to achieve the vision and provides something against which to measure progress, if qualitatively.

The development of the Bungambrawatha Creek Action Plan has drawn heavily on both our technical assessment of the waterway and review of opportunities and the feedback received from the community through in person and online feedback.

4.1 Community Consultation

Community consultation has been undertaken including with staff from AlburyCity Council and Alluvium. Consultation was undertaken in two in-person events and online between May and June 2022. A range of feedback was received from residents in relation to the waterway, from excitement at the prospect of a naturalised creek, to cautious optimism and great concern. The most common feedback regarded flooding, including how to maintain the flow of water, clean out for access and many other comments that related ultimately to ensuring that the function of a highly efficient drainage system was not compromised.

The concern from the community is unsurprising and warranted. By virtue of its management over the course of the last century, the view of Bungambrawatha Creek as little more than a drainage channel appears to be well entrenched in the minds of the community. Furthermore, through Council's actions in modifying the creek to prevent flooding (disconnecting Bungambrawatha Creek from its floodplain), this view of the creek as a drain has been heavily reinforced by Council's actions over the course of decades. It was widely apparent that the broader community feel that water should be able to 'get away' i.e. drain efficiently, without obstruction, and furthermore that it is Council's responsibility to achieve this outcome given Bungambrawatha Creek's status as a drain (and hence being a part of the stormwater network) rather than a waterway.

There was also notable support for the project from facets of the community, who expressed interest in being involved in improving the quality of the creek through planting days and community events.

Urana Road to Roach Street

There was particular concern relating to flooding in the Urana to Roach Street section of Bungambrawatha Creek, as well as flooding from Hamilton Valley Creek, which is undergoing urban expansion within the catchment. Residents noted that dense and overgrown weeds were a significant issue that needs to be addressed, while the frequency of flooding is anecdotally increasing throughout the catchment. Whilst analysis has not been undertaken to verify this (in light of rainfall intensity/duration), it appears that this may well be the case following upstream development. The upstream extent of Heathwood Park was regularly cited as a pinch point for the channel where water 'cannot get away'. This observation is considered accurate, and the floodplain management strategy has included an option of widening the waterway in this location on the east bank in order to drain the waterway more effectively in acknowledgement of hydraulic behaviour through this area.

4.2 Contemporary waterway management paradigm

It is clear that the management of waterways in the City of Albury will continue to be a polarising issue for residents and Council. To resolve this conflict it is recommended that Council consider the development of a clear policy position for waterway management. This should recognise the following:

1. Waterway health is reliant on the provision of a diverse channel form with a healthy riparian community, and with a well connected and frequently engaged floodplain. Healthy waterways contain a range of natural obstructions to flow, including large woody debris that should not be removed owing to their role in maintaining good waterway condition.
2. It is not Council's responsibility to provide improved flood immunity to private property adjacent to the waterway, however the impacts of land use change need to be adequately managed to ensure no worsening.

3. Intervention with natural waterways should be restricted to stabilisation of unstable reaches of waterway, recognizing that some waterway movement is a natural process. Riparian vegetation should remain intact and where weeds are prevalent, revegetation programs should be implemented on Council owned land. 'Cleaning out' of the waterway, including the removal of woody debris, should not constitute a typical maintenance action, with the exception of maintaining conveyance of water through hydraulic structures such as culverts.
4. Waterways have been heavily modified in Albury allowing encroachment of dwellings on the waterways. Established land uses that have been provided with existing flood immunity through the actions of modifying the waterway should continue to be afforded such immunity.

It is important to recognise the legacy of poor land use planning across the country that has allowed development adjacent to creeks and rivers that has allowed the encroachment of property and dwellings within the floodplains of waterways with heartbreaking consequences. Such situations have resulted in tension between environmental preservation (including strong recognition of the human need for healthy waterways) and a call for waterway modification to control the impact of severe weather. It is inevitable that all dwellings can't be protected from flooding, and that appropriate planning, adaptation and resilience measures are the most effective response to such issues. Those most vulnerable dwellings have typically been subject to buy-back schemes.

Whilst Council does not have responsibility for the flooding of natural creeks and rivers, as representatives of the community and lead respondents to disaster situations including flooding, such measures should be applied by AlburyCity. In lieu of undertaking hard infrastructure measures that benefit a few, typically at great cost and incurring a high social, cultural and environmental expense, initiatives such as strategic land acquisition where it is demonstrated that dwellings are at high risk, or resilience measures that encourage the appropriate siting and construction of structures on private property.

4.3 Vision

In conjunction with stakeholders at the City of Albury, the wider community, residents and traditional owners, the following vision has been adopted for the waterway action plan.

"The Bungambrawatha Creek corridor balances the competing interests of this highly constrained and modified area to create a multi-functional space that acts as a community connector, improves biodiversity and waterway condition, practices connection with country, and provides a positive contribution to the lives of those that live and recreate in and adjacent the corridor."

4.4 Objectives

The action plan has been developed with a number of objectives that will be needed to achieve the vision for Bungambrawatha Creek.

Channel form

Bungambrawatha Creek and its tributaries are stable in the unlined sections of the waterway, while opportunities to improve the natural characteristics and amenity of the waterway are explored through the concrete lined reaches.

Floodplain Management

The Bungambrawatha Creek corridor considers stormwater conveyance and resilience to flooding in all aspects of its design and management.

Activation and Connectivity

Bungambrawatha Creek connects the two CBD's and beyond via an active transport network that has appropriate lighting, is safe, cool, shaded, and scenic. The corridor is transformed from an unnoticed waterway to a linear hub of passive and active recreation along its length, connecting CBD's and communities to each other and the waterway.

Amenity
The visual amenity of Bungambrawatha Creek is improved through the enhancement and management of natural values and vegetation that is well integrated with the urban landscape.

Community
The community is connected to Bungambrawatha Creek, actively caring for and valuing the waterway as a place of beauty, biodiversity and recreation.

Water Sensitive Urban Design
Stormwater and the urban flow excess within the waterway is actively managed to improve water quality and waterway health outcomes and to be recognised as a valuable resource to provide alternative water supply for irrigation of adjacent lands.

Ecology
Bungambrawatha Creek is managed as an ecologically functional riparian corridor that provides connectivity and habitat for diverse native aquatic and terrestrial species assemblages.

Infrastructure
Infrastructure is appropriately considered in the Bungambrawatha Creek corridor, and opportunities for co-investment should be investigated.

Maintenance
All proposed activities within the corridor consider at all times the maintenance implications for Council, including cost, human resource requirement, and ability to carry out required maintenance activities.

Cultural Connection
The Wiradjuri people are offered opportunities for self-determination with respect to their role in the management of the Bungambrawatha Creek Corridor with a view to celebrating their ongoing connecting with country and in the management of the corridor that incorporates knowledge of the first nations people.

5 Naturalisation feasibility assessment

The area from Oliver Street to the end of the concrete channel at the Bungambrawatha Creek offer little value to the community outside of flood protection and conveyance. Naturalising this channel has the potential to deliver on the established objectives for Bungambrawatha Creek, and offers a potential pathway to achieve the vision of the plan. This section assesses the potential to naturalise the concrete lined section of Bungambrawatha Creek, including key considerations that deliver on the objectives.

Feasibility is a function of what is practically achievable, cost and benefit. For the purposes of this assessment, it is expected that Council will ultimately determine whether the benefits of naturalisation outweigh the costs, and hence our assessment is focussed on a consideration of determining whether naturalisation is practically achievable in consideration of works required, impacts on flooding, maintenance and an estimate of cost to achieve the outcome.

5.1 What is channel naturalisation?

The concept of channel naturalisation invokes images of pristine waterways where once there was concrete, with vegetation, trees, rocks and streams full of life. While this may indeed be an achievable outcome, it is important to recognise that it is generally not possible to recreate a pristine ecosystem. Channelised waterways typically carry much greater volumes of flow at faster velocities than a natural waterway. In responding to these characteristics, a new channel form is nearly always required that has new objectives for biodiversity, stream health and importantly as a system designed for community interaction and wellbeing. This channel form may be something reminiscent of a natural waterway, such as the recently naturalised Blind Creek, shown in Figure 14, or alternatively it may appear much more like a typical drain with natural waterway characteristics such as the Cheeonggyechen River shown in Figure 15 below. The concept of channel naturalisation has evolved to be considered, in Melbourne Water's terms, waterways reimagined. These reimagined waterways can be considered on a continuous spectrum from a concrete channel to a channel reminiscent of an undisturbed waterway, with many possibilities in between.

Figure 14. *The recently naturalised Blind Creek in Melbourne has many characteristics of a natural waterway, including rocks, grasses and sedges, and large trees (Image: Alluvium)*

Figure 15. *Cheonggyecheon Stream in downtown Seoul, retains characteristics of a drain with a modified profile providing interest and some habitat potential. (Image: https://www.theseoulguide.com/cheonggyecheon-stream/)*

Naturalisation and flooding impact

Naturalisation typically requires the reduction of channel velocity through the lowering of channel grade and an increase in roughness, a measure of friction in the channel caused by rocks, vegetation and other obstructions. These impacts will typically result in an increase in flood level if not adequately managed by providing flooding mitigation (e.g. detention basins to reduce the flow rate) or through an increase in the cross-sectional area of the channel providing more in-channel storage. In highly constrained settings, it may not be possible to add characteristics of natural streams without resulting in an increase in flood levels and adverse impact to private land.

Generally speaking the more 'natural' a waterway is, the higher the roughness value and corresponding flood level increase that can be expected. In many urban waterways the act of channelisation has provided flood immunity to surrounding land uses, allowing them to encroach on the channel and floodplain. This in turn can make increasing the cross-sectional area very difficult, as is the case in Bungambrawatha Creek. In such situations, a novel waterway may be required that has characteristics of a natural system (and corresponding ecological and social benefit) whilst maintaining the conveyance characteristics of the drainage channel. Such versions of naturalisation typically don't contain trees, often retain much of the channel's concrete and use vegetation that is able to withstand high velocities and lie flat under flood, thereby reducing impacts on conveyance. This is a relatively untested approach to naturalisation in Australia.

Biodiversity and amenity

Channel naturalisation of any concrete channel will invariably offer improved ecological outcomes for both aquatic and terrestrial flora and fauna, and offer potential to improve the visual amenity of waterways. The degree of improvement is generally responsive to the amount and type of vegetation provided, with more highly vegetated channels providing higher degree of benefit. However the hydraulic characteristics of the waterway may dictate a channel form with less vegetation or fewer trees. These approaches, while responding to hydraulics, typically have lower social and ecological benefit. However they may still assist in providing improved urban biodiversity and fish passage to upstream habitat, contribute to urban cooling and amenity.

Likewise, the degree of amenity, urban cooling and liveability provided by a naturalised channel is typically proportional to the degree of departure from its drain form.

Maintenance

Maintenance is a key objective of the action plan, and a key operational matter to ensure the objectives of the action plan are achieved in perpetuity. Much like biodiversity and amenity, maintenance effort is typically proportional to the degree of naturalisation i.e channels with lots of trees and vegetation can be managed as natural systems with minimal intervention, while more manicured landscapes or systems not reflective of pre-existing ecosystems require lots of management to maintain them in their desired state.

5.2 Floodplain Management

The ability to naturalise the channel will be dependent on two main factors with respect to flow: 1) the ability to increase the channel roughness without causing flooding impact to private property (causing afllux); and 2) the ability of the modified channel to withstand velocities within the waterway without erosion. Undertaking assessment of these matters is a key factor in determining feasibility and ensuring that the proposed channel form responds to the identified floodplain management objective, "the Bungambrawatha Creek corridor considers conveyance and resilience to flooding in all aspects of its design and management". Typical responses to manage these factors include increasing the cross-sectional area of the channel by extending channel width, and/or increasing bank slope to provide a wider channel base and reducing the slope of the waterway. However in highly constrained settings such as Bungambrawatha Creek this is not always possible.

Flood Depth

The existing design standard for testing the impacts of flooding is typically in consideration of the critical duration storm event for the 1% annual exceedance probability (AEP), which in the case of Bungambrawatha Creek is the 180-minute duration storm. In undertaking flooding assessment, the existing Tuflow model outputs have been extracted from WaterRide, and are shown in Figure 6 and Figure 7 in Section 2.1 - Hydrology.

The flood surface profiles were plotted against the existing surface profile as derived by 2019 LiDAR (light detection and ranging). This has provided an understanding of the amount of freeboard between the existing 1% AEP and the top of the existing concrete channel. Using this information, assessment can be made regarding potential changes that may be made to the channel without impacting the flood level. Flood level data has been extracted at specified cross sections along the channel (locations shown in Figure 18), including all event flows from the 20% AEP to probable maximum flood (PMF). The detailed cross section outputs including flood levels are shown in Appendix 2, while key results for the 1% AEP are presented in Table 1.

This analysis has shown that for much of the channel there is around 0.5 metres of freeboard between the design flood level and top of channel, indicating that there is some capacity to increase roughness within this area. However in some locations the channel is already exceeded, or very close to capacity in the 1% AEP. It has also been identified that in events exceeding the 1% AEP there are some highly vulnerable areas to increased flooding, including within the CBD. Therefore the design premise has been to develop a design that results in no to minimal increase in flood level.

Velocity

One of the regular challenges faced in naturalising channels is the management of high velocity flows. Flow velocity greatly impacts the ability to improve the ecological outcomes of the stream, as aquatic flora and fauna can be stripped away with excessive flow. Vegetated earthen materials capable of supporting plant growth typically only support flow velocities less than 2.5m/sec (from Fischenich, C. 2001). It can be seen from the velocity mapping that velocities are very high as to be expected from this type of channel. They range from around 2.5m/s to over 7 m/s within the channel (refer to Table 1 below) during the 1% AEP storm event. This points to some areas being more suitable for naturalisation than others. It is also important to note that these are typically peak flow velocities that are being experienced in or around about the thalweg (generally where the highest rate of flow is occurring when considering the channel in cross section). These velocities are not uniform across the channel and can be locally much lower at channel boundaries where there is a rougher substrate.

It should be noted that the grid sizing used in the existing model and as extracted from WaterRide has limited the reliability of data, and refined 2D modelling with a fine grid (1 metre) and sub-grid sampling will yield a more accurate assessment. Further, the use of debris deflectors, boulders, and nib walls can help to locally provide pockets of reduced velocity flow. Analysis of the effectiveness of this type of approach to reducing velocities would need to be informed by a 3D hydrodynamic model to understand flows and potential ways to mitigate very high velocity flow.

Channel form

The existing channel has two main cross sectional profiles, shown in Figure 16 and Figure 17. Neither of these profiles have extensive opportunities to increase the cross sectional profile within the bounds of the existing channel footprint.

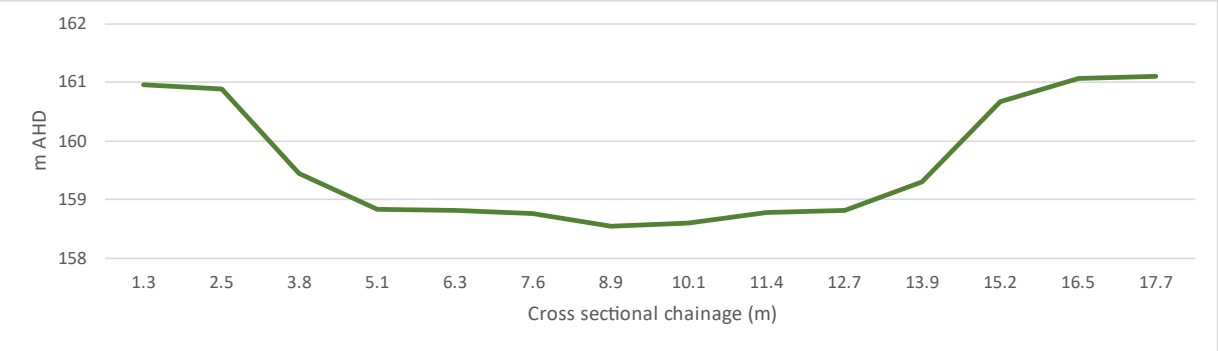


Figure 16. *Typical channel profile south of Dean Street, and between Jones Street and the Union Road retarding basin.*

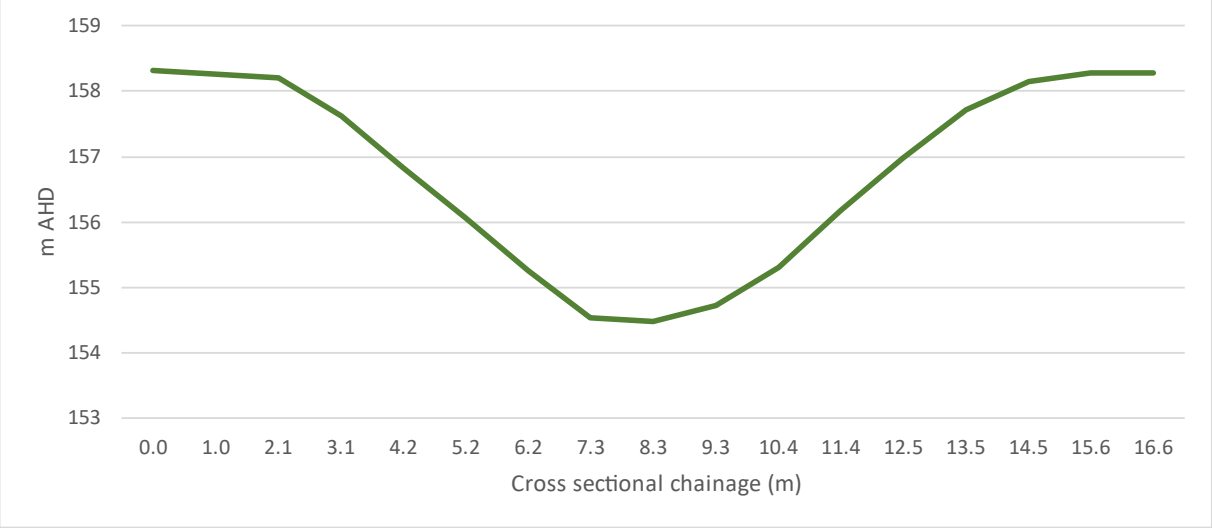


Figure 17. *Typical channel profile between Dean Street and Jones Street.*

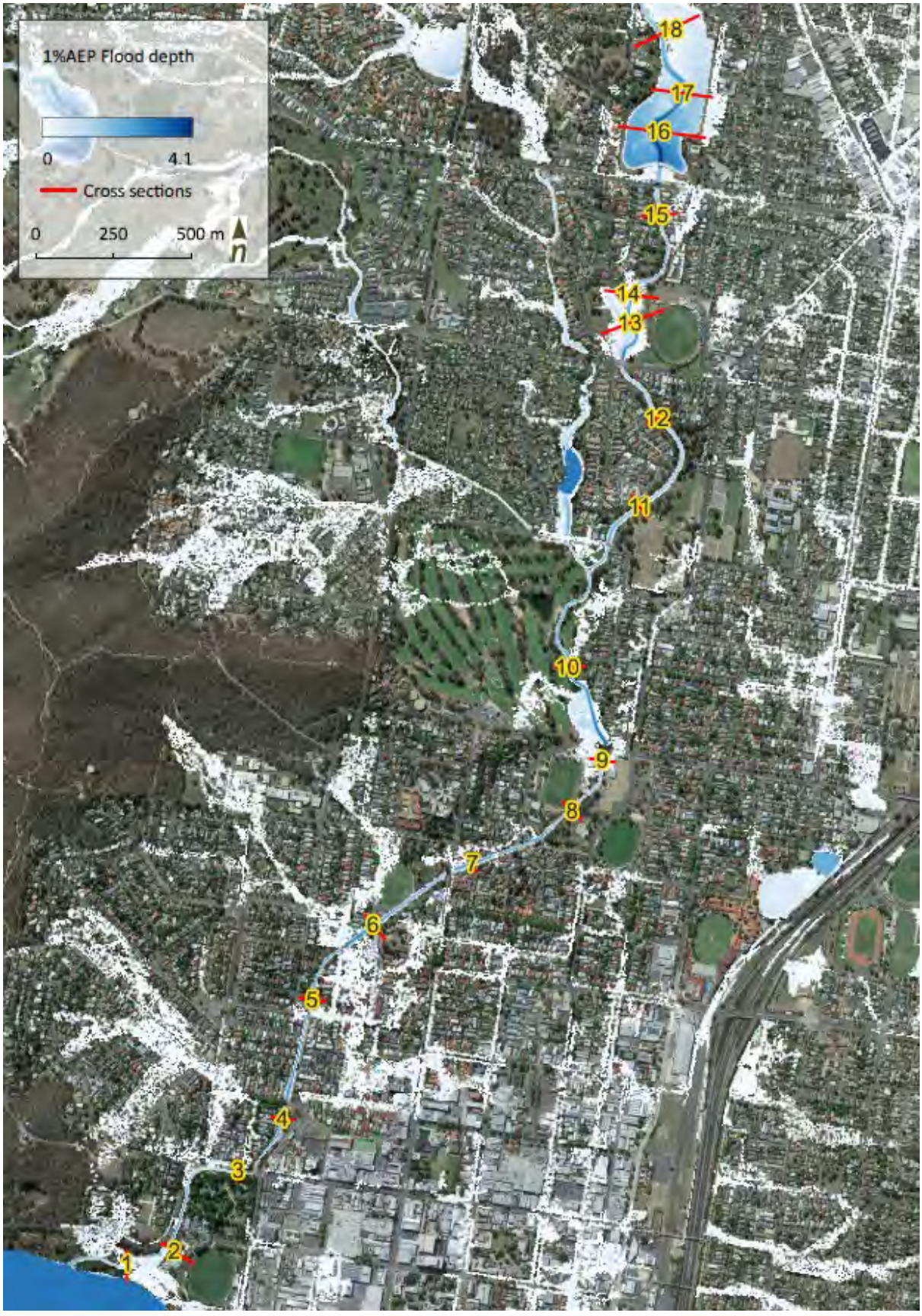


Figure 18. *Modelled flood depth during the 1% AEP, and locations of cross-sectional data for the purposes of flooding analysis.*

Table 1. Available freeboard between the 1% AEP and top of channel at specified channel cross sections.

Management Unit	Cross section	1% AEP level (m AHD)	Top of channel (m AHD)	Freeboard (m)	1% AEP velocity (m/sec)
9	1	150.78	152.59	1.81	6.88
9	2	153.1	153.3	0.2	No data
9	3	153.69	154.22	0.53	7.28
8	4	155.59	156.609	1.019	3.88
8	5	158.82	159.28	0.46	3.64
8	6	160.54	160.79	0.25	4.66
8	7	162.59	162.63	0.04	5.72
8	8	163.85	164.26	0.41	4.21
8	9	164.92	165.702	0.782	5.0
7	10	166.61	167.029	0.419	5.72
6	11	170.12	170.79	0.67	2.67
6	12	171.75	172.504	0.754	3.39
6	13	174.56	174.033	-0.527	5.12
6	14	174.63	174.468	-0.162	No data
6	15	175.8	176.62	0.82	No data
5	16	179.67	180	0.33	1.9
5	17	179.68	179.87	0.19	3.48
5	18	179.89	179.92	0.03	4.9

5.3 Flow regime

One of the key characteristics to consider in the design of waterways is the natural flow regime. Whether a flow is permanent or ephemeral (periodically or seasonally dries out) will dictate the design and ecological considerations for the waterway. In the case of Bungambrawatha Creek, base flows are a consistent feature through the winter months, however in the hot dry summers experienced in the area, the waterway slows to a low trickle and even ceases to flow. In ephemeral urban streams, water quality can decline under low flow conditions and waterways in poor ecological condition can play host to mosquito breeding and algal growth. This can be unsightly, produce odours, as well as causing eutrophication (algal growth leading to oxygen depletion) that kills aquatic life in the waterway.

Even in low flow or intermittently flowing streams these issues can be managed, however they rely heavily on having healthy riparian environments to help filter and shade the water, helping to keep it clean and relatively cool during periods of low flow. This same vegetation helps to provide the necessary habitat for macroinvertebrate and fish species to survive and thrive that predate on macroinvertebrates such as mosquito larvae, thereby keeping their numbers to manageable levels.

While at the early stages of the project consideration was given to simply allowing water to pond through the channel thereby improving longitudinal connectivity to upstream habitats (allowing fish passage), it is considered that any attempt at naturalisation requires vegetation to play a key role to maintain acceptable water quality and condition of the waterway.

5.4 Other constraints

Property boundaries

For much of Bungambrawtha Creek's concreted length the channel is confined laterally by private property, with only sufficient area to accommodate a narrow pathway. This prevents widening of the channel to provide the space to decrease channel velocities and enable the inclusion of natural features.

Existing Vegetation

The channel has been cut into the floodplain around some very large *Eucalyptus camaldulensis* trees. It is understandably the position of Council that these trees are not to be removed and need to be adequately protected through any works. Typical tree protection zones are set at 12 time the diameter of the tree at 1.2 metres above the ground. Many of the trees have diameter that exceeds 2 metres, making a tree protection 24 metres wide. Many of the areas that are not confined by private property are lined with *E. camaldulensis,* making realignment of the channel difficult without removal or damage to the trees.

Infrastructure

Waterways are the low point in the landscape and are not typically developed for residential uses, making them an obvious corridor for utilities infrastructure such as gravity sewerage mains. These mains run along the channel in many locations, further impeding the ability to modify the channel form without requiring substantial realignment of sewer and water infrastructure. While not an insurmountable issue, it can add significant complexity and cost to design and construction of waterway naturalisation projects.

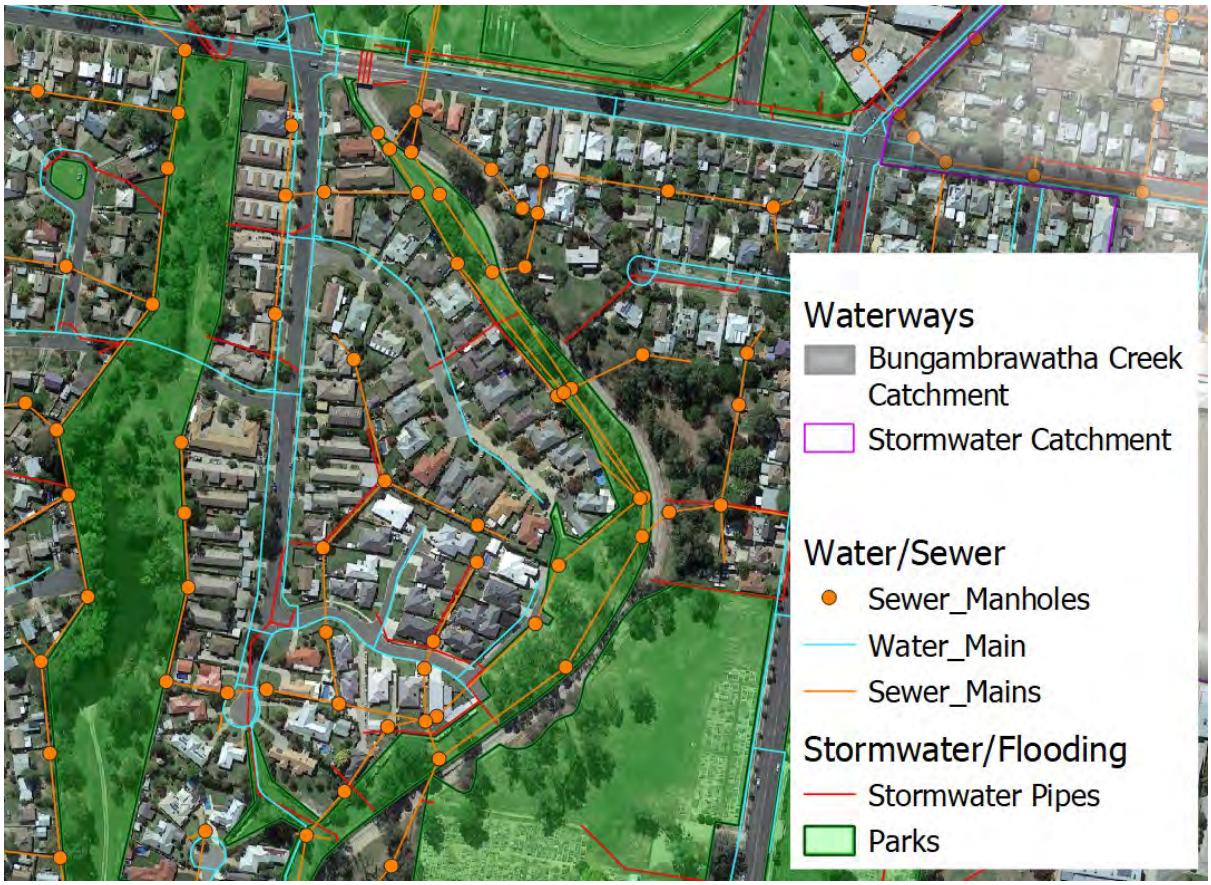


Figure 19. *Map of typical infrastructure surrounding Bungambrawatha Creek*

Conflicting masterplans

The masterplan for J.C. King Park includes the covering of the channel for the provision of additional car parking. This is in direct conflict with the intent for naturalisation of the channel, however given high velocities through the reach, this may be considered an acceptable outcome. However it should be noted that this would be a very expensive and technically challenging proposition.

The Fredericks Park masterplan notes opportunities for naturalisation, however in consideration of many of the above issues this is not possible without a realignment of the channel. This would take up area of park nominated for other purposes such as for dog parks.

Other environmental matters including land contamination and ecological sensitivity have not been considered in this feasibility assessment, and will be important matters to resolve prior to undertaking further design works.

5.5 Feasibility summary

The feasibility of naturalisation of Bungambrawatha Creek responds largely to the physical constraints and ability to deliver on desired objectives. The summary of considerations, including how they relate is detailed below:

Union Road retarding basin

- Within the Union Road retarding basin there is ample capacity to increase the channel cross section, lower grade and reduce velocities to support a channel stabilised with the use of rock and vegetation.

Union Road to Murray River

- The intermittent flow regime, particularly with low and no-flow conditions in warmer months has the potential to cause nuisance algal blooms contrary to the objectives for the action plan. This may be partially offset by provision of vegetated systems that help to improve water quality and shading.
- There is very limited room to gain additional cross-sectional capacity required to offset increased flood levels expected in response to slowing flows or increasing channel roughness through the addition of vegetation. Therefore only vegetation that will not act as a significant impediment on flow may be used (e.g. reeds), and slight excavation may be required to offset this roughness increase as per the typologies shown in section 5.6.
- Velocities in the channel are too high for vegetation alone to prevent erosion. A mix of rock (including structural soil) and vegetation may be able to withstand velocities in some locations, however there is minimal data available to support this and additional modelling and trial would be needed to confirm. Higher resolution modelling may assist in locating areas of lower velocity suited to channel naturalisation.

5.6 Typical naturalisation profiles

In light of the outcomes of the feasibility assessment, a number of typologies have been developed that respond to the principles identified for successful naturalisation, including appropriate vegetation types, soil substrates and the need to generate additional channel capacity. High level cost-estimates have been generated for each of the naturalisation typologies on a unit rate (cost per linear metre of channel of per metre square, as appropriate) basis.

Typology 1: Low flow with inset bench

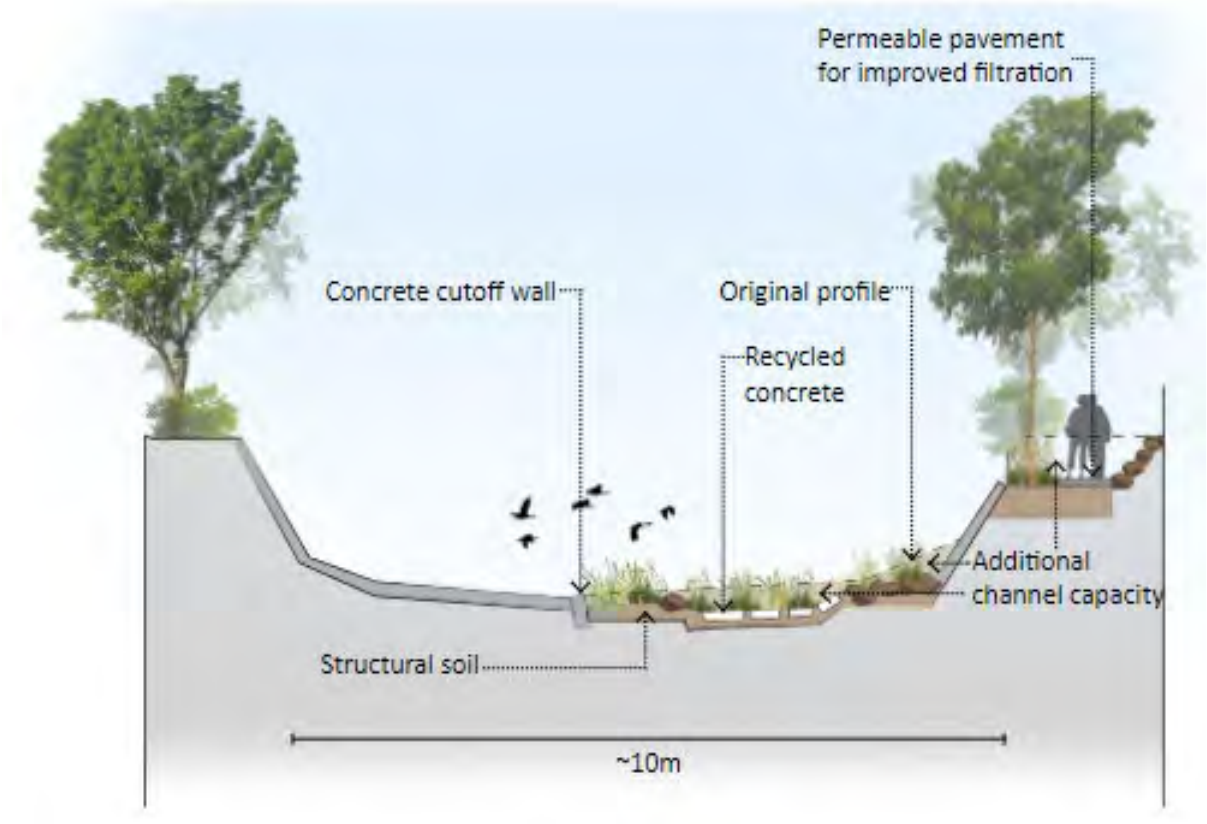


Figure 20. *Typology 1 typical profile, with a low flow channel and inset bench.*

This profile achieves maintenance of the cross-sectional area by cutting down into the channel base, replacing the concrete with structural soils, rocks and vegetation. Vegetation that adds a low roughness (reeds that readily bend over during high flow) should be used as the predominant vegetation. A low flow channel can be provided that utilises salvaged concrete to retain energy embodied in the concrete production process on site, while also eliminating the need to import quarry materials. Such materials would need to be carefully anchored to ensure lift does not occur under high velocity flows. A low flow channel may be provided with a slightly elevated inset floodplain to maximise water quality improvement and infiltration, helping to restore soil moisture in and around the channel. Concrete cut-off walls should be provided at the interface between any naturalised sections and existing concrete to prevent undercutting of the existing channel, which could result in extensive failure of retained portions of the existing form.

High level cost estimate per linear metre (channel works only) for typology 1: $1,475

Bikeway modifications (option)

To help provide additional flood storage and improve the quality of the bikeway, the level of the existing bikeway could be lowered where not impacting mature trees. This would involve retaining structures to be provided immediately adjacent to private property, but allows for improved shading over the pathway and waterway, as well as improved infiltration into garden beds to be planted adjacent to the active transport path. Used in conjunction with improved soil volume and passive irrigation, tree vigour and size can be maximized. Under this scenario, the existing fence would be moved to sit on top of the concrete retaining structures and gardens between the fence and pathway, reducing the existing zone that is unable to be maintained except through application of herbicides.

Typology 2: Inline pond

In order to improve aquatic habitat and visual amenity through the waterway, there may be opportunities to construct ponds at set intervals. These areas provide habitat and respite for fish moving between the Murray River and the unlined sections of Bungambrawatha Creek.

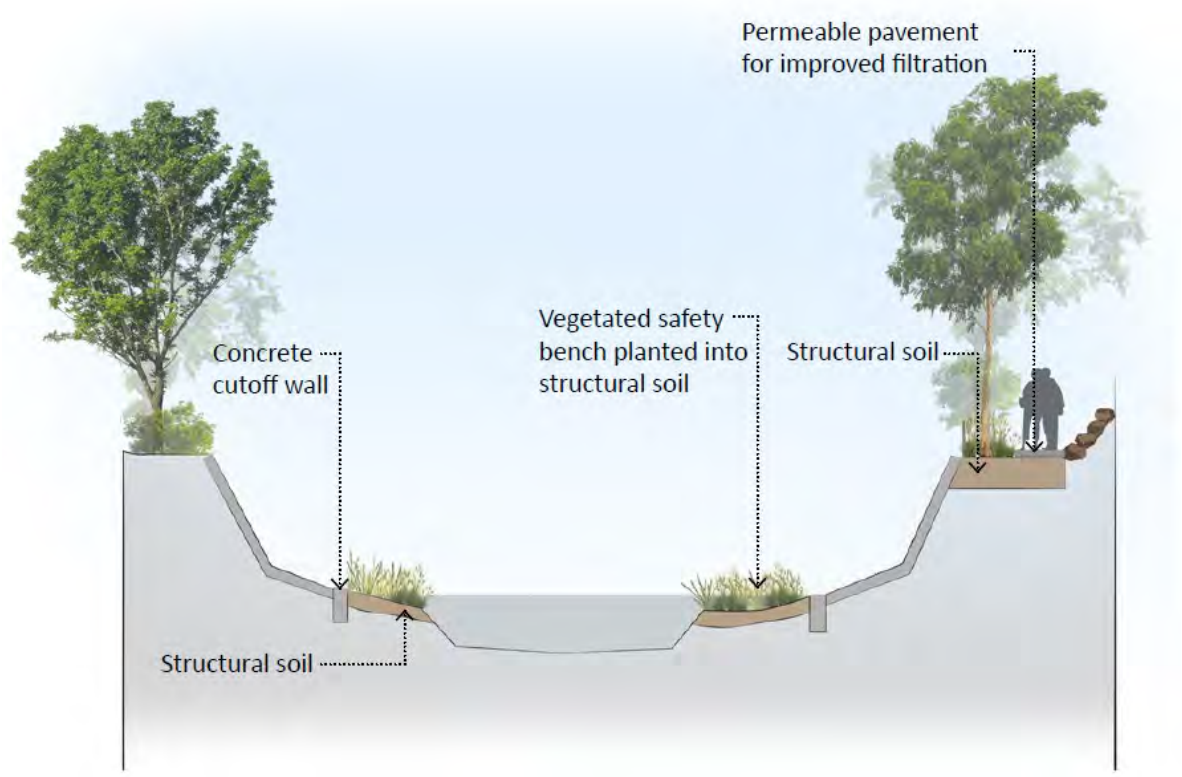


Figure 21. *Typical section of a pond constructed in the base of the channel.*

As with other profiles, the pond would be cut into the base of the channel providing some increase in cross-sectional area of the channel. The pond would have macrophyte benching for safety should people gain access to the channel, as well as providing opportunity for water quality improvement and habitat availability. All soil to be planted into would need to be structural soils consisting of a mix of gravel/ small rock and topsoil to withstand high velocities during the vegetation establishment period. The pond depth should be a minimum of 1.5 metres to prevent dry out during periods of low flow, maintaining their role as habitat refuge.

High level cost estimate per linear metre (channel works only) for typology 2: $3,100

Typology 3: elevated ponding and reed beds

Typology three attempts to reduce cutting of the channel, and instead focuses on the construction of nib walls across the channel that encourage water to pond across the concrete. This would be coupled with the addition of elevated planting beds to provide aesthetic improvement. The key consideration of this approach is that it results in lost cross-sectional capacity and should therefore be coupled with approaches such as that detailed in Typology 1, including reducing the level of the active transport pathway to allow this area to be used in flood conveyance.

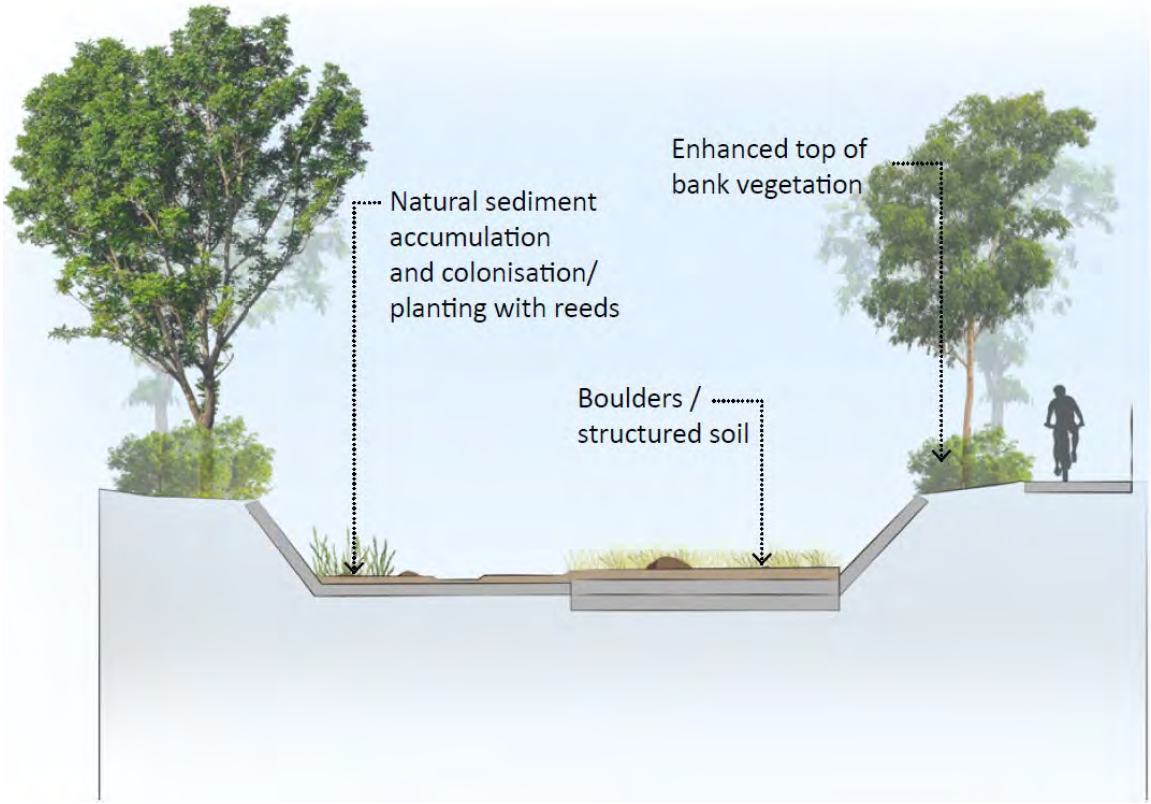


Figure 22. *Elevated nib walls and planting beds to reduce interference with channel concrete and risking channel integrity.*

Concrete nib walls would be constructed in the channel under this scenario. This would encourage the natural deposition of soil behind these structures, which could be actively planted or natural colonised with vegetation, obscuring the view of the concrete channel. The elevated reed beds would provide a dry bed that would need to be supported with concrete edging to ensure soil does not wash away. To improve infiltration of water and connection with in situ soils, the concrete channel may be cut and removed or cored in the location of planting beds.

High level cost estimate per linear metre (channel works only) for typology 3: $1,050

Typology 4: terraced channel

This typology applies to the reach through Jones Street to Dean Street, and is shown indicatively in Figure 23 The channel is V-shaped and is typically between 3 – 4 metres deep (refer to Figure 17). The cross-sectional channel grade is between 1:1 and 1:2, providing opportunity to remove the channel sides and provide terraces within the channel.

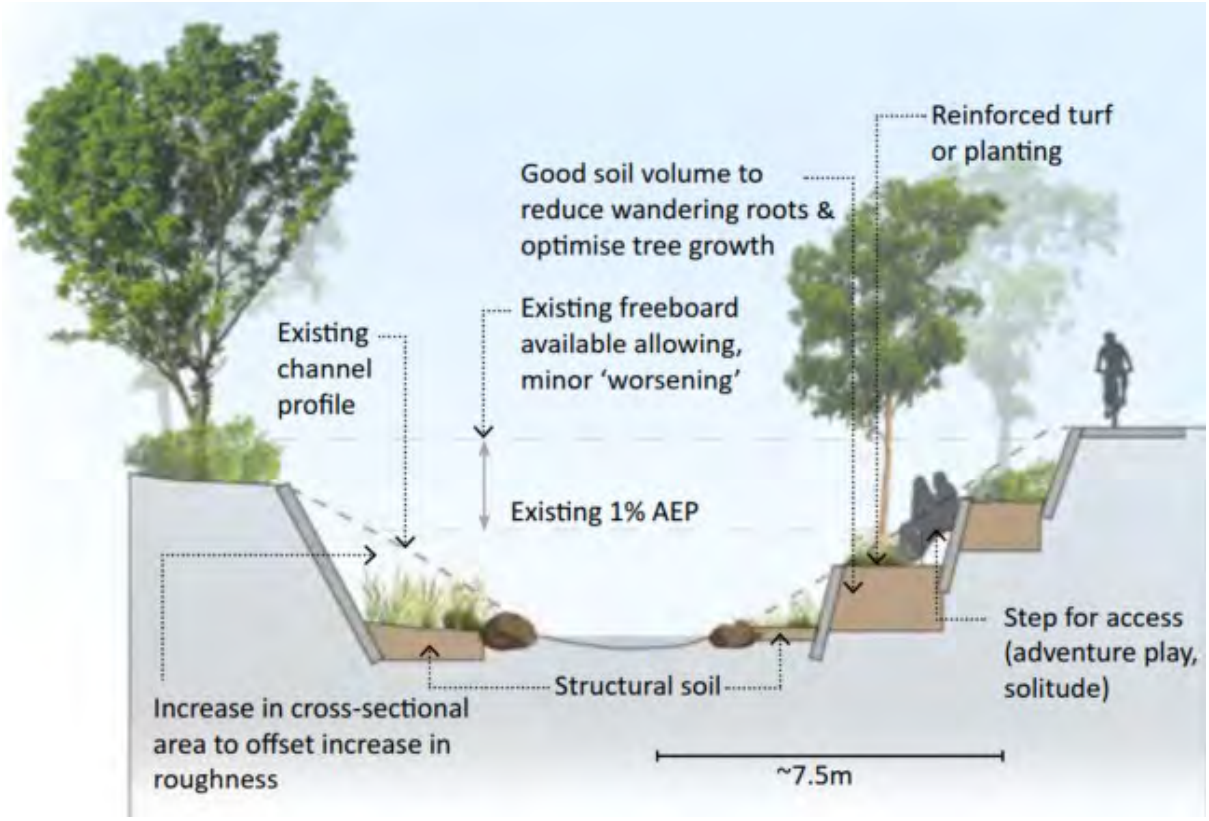


Figure 23. *Typology 4 includes a terraced portion of the channel.*

Terraces can improve access to the channel, as well as increasing the available area for vegetated treatments to improve aesthetics and shading over the channel and bike path. Given constrained space, it's proposed that individual walls would be constructed with either pre-cast panels or formed concrete, minimizing the width taken up with block walls (a cheaper alternative), maximizing the vegetated area and providing a consistent aesthetic with the areas of retained channel. It should be noted that modifications to the western side of the channel (to the left of Figure 23) would provide additional flood storage, ecological and water quality benefit as well as greening and cooling, however the construction of walls required to facilitate this outcome will incur a significant expense. Therefore this can be considered an optional outcome to be considered with further cost-benefit analysis.

High level cost estimate per linear metre (channel works only): $5,900

Typology 5: cantilevered path and terracing

Cantilevering a pathway over the channel (as shown in Figure 24) provides an opportunity to improve the standard of pedestrian connection along Bungambrawatha Creek, particularly in high profile locations such as around Dean Street and the Botanic Gardens. Increased width of the pathway will help to improve safety through zones 8 and 9, where the path is most constrained by private property and the channel. It will also allowing improved path width and opportunities for additional landscaping and shade planting. There are opportunities through the botanic gardens adjacent to the avenue of English Elms to widen the channel and provide terraces down to a naturalised channel (consistent with typology 1, 2 or 3).

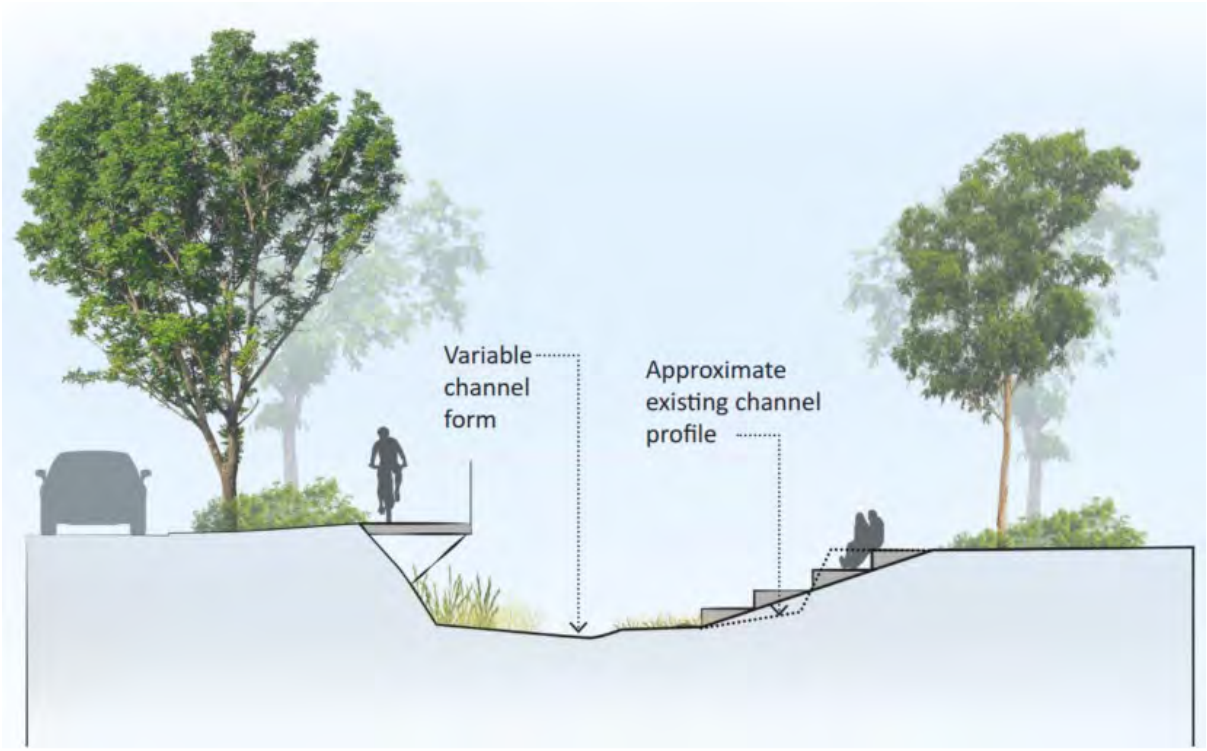


Figure 24. *Typology 5 including cantilevered pathway, laid back and terraced bank.*

Typology 6: Retarding basin naturalisation

There is ample opportunity to undertake naturalisation of the Union Road retarding basin, including reinstating a low velocity section of creek by re-engaging the floodplain and increasing the sinuosity of the channel. This has the greatest potential to improve in-stream ecology post-construction, with opportunities to improve riparian vegetation extent and structure without being limited by flooding in terms of negative afflux impacts and high velocity flows. Naturalisation of the main channel can also be coupled with improved connectivity of a floodplain with potential for offline ephemeral habitat and/or water quality improvement wetlands to be constructed. With a lower velocity environment and lower grade separation, this typology has the greatest potential for improved interaction with the community and engagement through the naturalisation process.

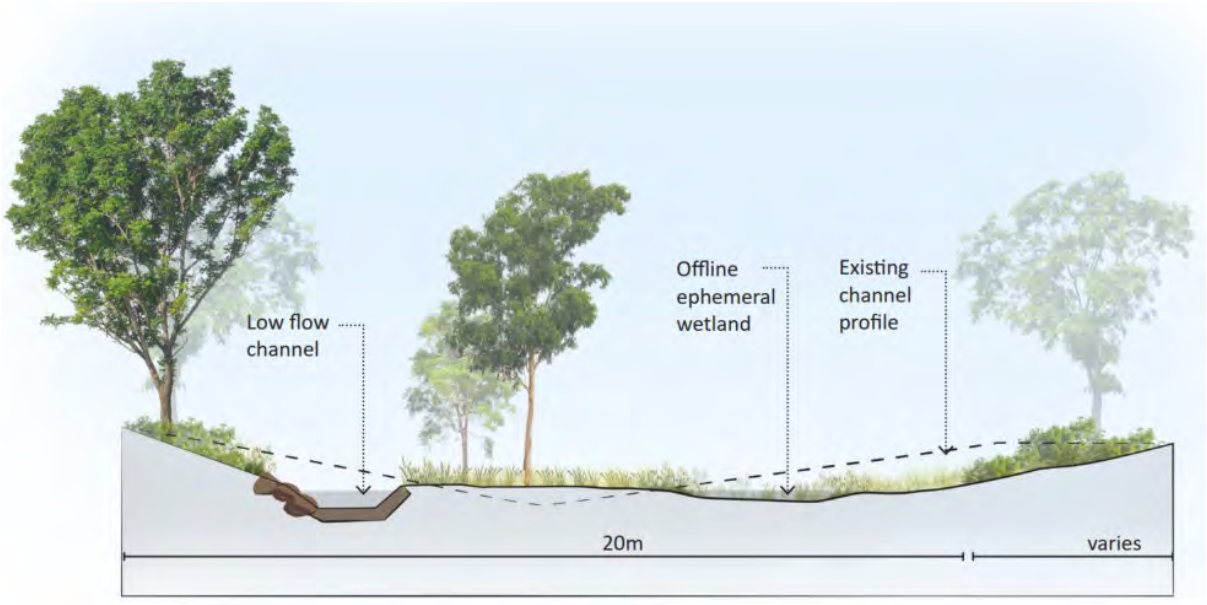


Figure 25. *Typology 6, opportunity for a naturalised waterway and extended floodplain with ephemeral wetlands.*

High level cost estimate linear metre - $5000 (assuming 25m width of channel works)

6 Actions

In conjunction with the AlburyCity staff, the following actions have been determined as options to be considered by Council in the coming years and decades to improve the management of Bungambrawatha Creek, and deliver on the objectives of the plan.

The Action plan, including the location of proposed actions is included in Appendix 3.

Table 2. List of potential actions for the improved management of Bungambrawatha Creek.

Action no.	Description	Consequence of no action	Cost Low (<$20K) Moderate ($20K - $50K) High ($50K - $200K) Major Capital (>$200K)	Priority
Management Zone 1				
1.1	Undertake weed removal and revegetation of the waterway and inset floodplains to remove weeds and reinstate a native species assemblage	Weeds dominate and native plants are outcompeted	Moderate	Short
1.2	Continue to promote the exclusion of stock access from the waterway	Ongoing degradation of channel and poor water quality	Low	Short
1.3	Formalise access locations to prevent unauthorised activities	Access tracks become further eroded and cause sediment to enter waterways	Moderate	Short
1.4	Monitor potential erosive impacts on outer bend of waterway on Prune Street	Outer bank erosion cuts into Prune Street cutting off access	Low	Medium
1.5	Potential for informal walking track adjacent the creek with potential for seating and interpretive signage at the end of trail.	Poor community access to waterway	Moderate	Long
Management Zone 2				
2.1	Undertake weed removal and revegetation on Council owned land	Weeds dominate and native plants are outcompeted	Moderate	Short
2.2	Collaborate with landholders to undertake weed control and revegetation	Weeds dominate, outcompeting native species and become source of weed seed to downstream waterway	Low	Medium
2.3	Stabilise undercut bank to prevent further migration and significant contribution of sediments downstream	High rate of sediment input downstream and loss of Council and private land	High	Long
2.4	Stabilise large headcut in tributary contained within Council land	High rate of sediment input downstream and loss of Council land	Moderate	Long
2.5	Construction of offline wetland area (existing low lying area), potential removal of bund deposited from creek channelisation. Slow water, capture debris upstream of Roach Street	Potential deepening and widening of existing channel, highly efficient conveyance	High	Long

Action no.	Description	Consequence of no action	Cost Low (<$20K) Moderate ($20K - $50K) High ($50K - $200K) Major Capital (>$200K)	Priority
2.6	Debris management at key locations, specifically upstream of Roach St. Access ramp for easy removal of built-up debris	Flooding continues and debris is difficult to remove	High	Medium
Management Zone 3				
3.1	Management of scour at dwelling to west of upstream stormwater culvert (Roach St) and maintenance access to culvert	Erosion from culverts results in loss of private property (small lot), no access	High	Short
3.2	Develop MOU and partnership with school to improve waterway and aid access for maintenance works along creek line	Weeds continue to dominate and worsen flooding	Low	Medium
3.3	Carryout weed control and revegetation on Council land	Weeds dominate and remain as a source of weed seed downstream	Moderate	Short
3.4	Engage with Lavington Public School to educate and empower to improve waterway	Significant landholder not engaged in waterway improvement	Low	Medium
3.5	Compliance to investigate instances of unlawful activities (fill, dumping, structures etc) in the corridor resulting in exacerbation of flooding	Future flood debris and worsening caused by potential unlawful works	Low	Medium
Management Zone 3a Hamilton Valley Creek				
3a.1	Investigate impact of Hamilton Valley flooding on Urana to Roach St residents, including understanding the cumulative impact of development and increased flow on downstream waterway.	BAU development results in more frequent flooding and increased erosion potential of waterways	Moderate	Short
3a.2	Investigate existing capacity of Collins St basins, potential for outlet modification to improve flood defence for downstream	Downstream residents continue to flood and increased flood frequency following development	Moderate	Medium
3a.3	Development compliance required on existing development erosion and sediment control and construction phase detention	Continued mass sediment export	Low	Medium
3a.4	Partner with landholders adjacent to Hamilton Valley Creek to control erosion immediately upstream of the confluence, providing resilience to future land use change	Ongoing deepening and widening of Hamilton Valley Creek	High	Medium

Action no.	Description	Consequence of no action	Cost Low (<$20K) Moderate ($20K - $50K) High ($50K - $200K) Major Capital (>$200K)	Priority
3a.5	Investigate existing controls on development, including building, flood mitigation (detention) and WSUD on new developments	BAU results in further downstream flooding and water quality issues	Low	Medium
Management Zone 4				
4.1	Reestablish a Friends of Bungambrawatha Creek to continue planting and maintenance activities	Friends of Bungambrawatha ceases to operate and Council becomes responsible for all improvements and maintenance	Low	Short
4.2	Collaborate with landholders to undertake weed control and revegetation	Weeds continue to dominate and worsen flooding	Low	Ongoing
4.3	Shade planting to provide improved useability of bike corridor	Bike corridor is not used in warmer months with continued reliance on vehicular transport	Low	Medium
4.4	Opportunity for constructed wetland to provide stormwater quality treatment in Heathwood Park, potential flood improvement	Ongoing poor water quality	Major capital	Long
4.5	Maintenance access to Oliver St culverts	Inability to clean blockages and prevent flooding	High	Medium
Management Zone 5				
5.1	Opportunity for full naturalisation of RB including reinstating the original creek line	Underutilised area persists providing one dimensional outcome (flood mitigation)	Major capital	Medium
5.2	Inclusion of water quality treatment/habitat wetlands	Low habitat availability and poor water quality	Major capital	Medium
5.3	Weed control and revegetation on Council land	Weeds slowly come to dominate existing vegetation patches	Moderate	Ongoing
5.4	Informal kickabout spaces to be provided	informal access provides benefit to limited number of people	Low	Medium
5.5	Investigate opportunity to enhance capacity and assist in detention to alleviate potential CBD flooding issues	CBD remains highly vulnerable to high magnitude flood	Major capital	Medium

Action no.	Description	Consequence of no action	Cost Low (<$20K) Moderate ($20K - $50K) High ($50K - $200K) Major Capital (>$200K)	Priority
5.6	Potential for multi-use open space areas	Minimal activation and use of the RB by the community	Major capital	Long
5.7	Union Road masterplan	Poorly integrated infrastructure	Low	Medium
Management Zone 6				
6.1	Improve riparian vegetation maintenance adjacent to channel	Increased weed invasion and degradation of native vegetation	Moderate	Short
6.2	Opportunity for species that will hang over the channel sides to disguise concrete	Channel sides and top of bank remain unsightly	Low	Medium
6.3	Improve fences adjacent to channel	Continues to be unsightly	High	Medium
6.4	Investigate opportunities to improve maintenance of vegetation between fence and channel to remove reliance on spraying	Accumulation of herbicide, soils die and only support weeds	Low	Medium
6.5	Opportunity to direct channel through naturalised low flow path	Channel diversity and habitat potential remains low	Major capital	Long
6.6	Investigate opportunity for roughened channel base, drown out concrete base, introduce rock/structural rock and reed planting, ponds	No fish passage, water quality improvement or improved urban outcome	Major capital	Long
6.7	Investigate opportunity for offline wetlands/habitat ponds	Poor connectivity to floodplain, no infiltration and groundwater recharge	Major capital	Long
6.8	Lighting to be investigated to improve safety / activation	Unsafe pathways, and poor utilisation	High	Medium
Management Zone 7				
7.1	Engage with Albury Golf Club to consider stormwater capture and re-use, reconfiguration of existing ponds for stormwater quality improvement wetlands/habitat wetlands and continuity of public access	Broken Bungambrawatha link, wasted opportunity for improved water management	Low	Short

Action no.	Description	Consequence of no action	Cost Low (<$20K) Moderate ($20K - $50K) High ($50K - $200K) Major Capital (>$200K)	Priority
Management Zone 8				
8.1	Consider opportunities to remove the main pedestrian thoroughfare from the netball court carpark	Pedestrians still contending with traffic, potentially unsafe connection	High	Long
8.2	New bridge crossing connecting skate park precinct with playing fields	Missed opportunity for improved activation/use of community infrastructure	High	Medium
8.3	Understorey revegetation, scattered planting of new *E. camaldulensis* (River Red Gum)	Low habitat value, no succeeding vegetation in the event of camaldulensis death	Moderate	Medium
8.4	Interpretation opportunity for old creek line location	Poor understanding about Bungambrawatha Creek and its natural form, and the significance of modification	Low	Medium
8.5	Improve creek side planting including landform modification to provide more room for trees, open up channel	Confined channel with no flood capacity beyond 1% AEP, minimal room for active transport and improved shading	Major capital	Long
8.6	In stream structures to cover the base of the waterway with water, disguise extent of concrete and introduce reed bed planting for wildlife habitat	channel remains ugly and one-dimensional (flood conveyance function only)	Major capital	Long
8.7	Provide open pools where possible to improve fish habitat options/improve amenity and prevent anti-social activity	fish connection not possible, motorcycles continue to drive up and down channel	Major capital	Long
8.8	Terrace to waterway in high profile locations where unconstrained by mature vegetation	Unactivated channel serves limited value	Major capital	Long
8.9	Investigate activation of the western bank with community gardens or go-slow path	western side continues to be treated as residents' backyards and private access points, potential conflict between cyclists and pedestrians on main active transport route.	Moderate - High	Medium

Action no.	Description	Consequence of no action	Cost Low (<$20K) Moderate ($20K - $50K) High ($50K - $200K) Major Capital (>$200K)	Priority
8.10	Planting in school yard to improve shade over bikeway (engage with Albury High)	No shade and low active transport use	Low	Short
8.11	Explore opportunities for activation, including public art in channel and adjacent to the channel where space allows	Channel remains, bare, ugly and of limited use	Low	Short
8.12	Channel renewal, including opportunities for passively irrigated street trees with ample soil volume to provide shade	At end of life, channel is replaced in existing state	High - Major Capital	Medium
8.13	Improve fencing to improve aesthetics and sense of public space	fencing continues to be ugly and creates a barrier to the waterway, reinforcing perceptions as conveyance only asset	Moderate	Ongoing
8.14	Cantilever deck structure over channel to improve ability to enhance landscaping and provide room for trees in the corridor	Tight area to accommodate planting, improved urban ecology and active transport	High - Major Capital	Long
Management Zone 9				
9.1	Improve pedestrian/active transport around Botanic Gardens	Management Zone 9 remains barrier to continuous connection to Riverside park with poor pedestrian connection		Medium
9.1.1	Option 1 Cantilever deck on north and west side to provide wider movement network		Major Capital	
9.1.2	Option 2 Remove car parking on Dean St to widen pathway, including improved planting		Major Capital	
9.2	Formalise pathway through the trees on western side of the channel to ensure all-weather suitability	Pedestrians pushed onto narrow road verge in poor weather	High	Medium
9.3	Provide four way (X bridge) pedestrian movement under Smollett St bridge	Pedestrians have a big diversion to cross Smollett St where there are no pedestrian crossing facilities	High - Major Capital	Medium

Action no.	Description	Consequence of no action	Cost Low (<$20K) Moderate ($20K - $50K) High ($50K - $200K) Major Capital (>$200K)	Priority
9.4	Remove 'sediment trap' and gross pollutant trap adjacent Council depot to reinstate fish passage into naturalise sections of waterway & disconnect low flow diversion	sediment trap is ineffective and remains as fish barrier (if upstream habitat provided)	Major capital	Medium
9.5	Stabilise erosion of bank at confluence with the Murray River	Continued erosion, sediment transport and risk to mature vegetation	Moderate	Long
Management Zone 10				
10.1	Improve streamside vegetation/weed removal	Weeds continue to colonise and dominate	Moderate	Ongoing
10.2	Improve visual permeability into corridor to discourage anti-social behaviour	Anti-social behaviour continues	Moderate	Medium
10.3	Opportunity for pedestrian link connecting Solander St east and west	Informal path remains as current crossing	Moderate	Medium
10.4	Collaborate with community group to manage the corridor, increase activity and public surveillance	Anti-social behaviour continues	Low	Medium
10.5	Community gathering facility	Area remains underutilised and forgotten	Moderate	Long
Management Zone 11 - Black Springs Creek				
11.1	Investigate naturalisation of concrete channel	Corridor retains singular functionality	Moderate	Medium
11.2	Weed removal and revegetation of natural section of waterway	Weed expansion and domination, flooding worsening from very dense weeds	High	Ongoing
11.3	Improve visual permeability into the waterway adjacent community hall	No view to waterway, disconnect remains	Moderate	Medium
11.4	Connectivity - investigate a path Burrows Rd to Ryan Rd	No connection or activation	Low	Medium
11.5	Explore opportunities for partnerships with traditional owners and aboriginal groups to activate and manage open space	limited cultural connection with waterway	Low	Medium
Citywide				
	Partner with representatives of the Wiradjuri people to facilitate self-determination of their role in respect to the management and representation of culture in the Bungambrawatha Creek corridor.	The opportunity to advance reconciliation, celebrate culture and improve management that considers traditional owner knowledge is lost.	Low	High

Action no.	Description	Consequence of no action	Cost Low (<$20K) Moderate ($20K - $50K) High ($50K - $200K) Major Capital (>$200K)	Priority
	Develop a works program for the implementation of the action plan	Actions identified aren't funded through Council's operational and capital expenditure programs.	High	Ongoing
	Undertake high resolution stormwater modelling of the channel to investigate ability to undertake naturalisation in accordance with the proposed typologies.	Channel continues to play single function of flood conveyance without broader community benefit.	Moderate	High
	Develop a catchment stormwater quality improvement plan including opportunities for gross pollutant capture	Provide distributed assets to improve the quality of stormwater runoff and provide improved benefit to the community through greener and cooler streets.	Moderate - High	High
	Review Council policies, procedures and guidelines relating to waterway management, to provide greater clarity around waterway responsibilities for Council staff and residents	Council continues to reactively and inconsistently respond to community requests for action regarding creek condition.	Low	High
	Opportunistic land acquisition to improve linear connectivity of the waterway and minimize flooding risk, particularly through management zone 3	The corridor continues to have an incomplete connection and flood impacts private property	Major Capital	Low
	Develop a lighting strategy for the Bungambrawatha Creek Corridor, being cognisant of lighting spill and impact on residents and native fauna.	Underutilised pathways and safety risk (Crime prevention through environmental design (CPTED) considerations)	Low	High

7 Advancing the Action Plan

The action plan has been developed on an understanding of the physical, ecological, social and cultural characteristics of the Bungambrawatha Creek Catchment. It provides a set of actions that can help to achieve the objectives and vision for Bungambrawatha Creek, and should be considered as a blueprint for the future management of the waterway. The action plan should not be considered a static document, instead it can be revisited as new information comes to light, new stakeholders are engaged, and as Council and community aspirations change over time. The full action plan is included in Attachment 1.

7.1 Next Steps

There are a number of actions to take forward to achieve the long-term vision for Bungambrawatha Creek. These actions are as follows:

1. **Develop a works program for the implementation of the actions developed for the Bungambrawatha Creek Action Plan.**

The works plan should respond to Council's recognised objectives for Bungambrawatha Creek, and should be prioritized against Council's wider strategic objectives outlined in their corporate documents. This may involve the development of business cases and cost-benefit analysis to determine the appropriateness of the expenditure, including consideration of non-market benefits. The program should be considered in light of the need for asset rehabilitation along the channel, at which time more costly interventions such as naturalisation or cantilevered pathways may become more cost-effective.

2. **Undertake high resolution hydraulic modelling of the channel to investigate naturalisation in accordance with the proposed typologies.**

Refining the model resolution will be necessary to improve understanding of flow characteristics within the Bungambrawatha Creek channel, including improved understanding of channel velocity and shear stress. The potential of in-stream structures to create localised areas of lower velocity may require the development of a 3D model to provide a more accurate understanding of turbulence reactions to these structures.

3. **Develop a consistent policy position for the management of waterways across the city, including Bungambrawatha Creek.**

This would provide greater clarity for both Council staff and residents to provide consistent responses to requests for management intervention in the waterway.

4. **Undertake pilot projects for channel naturalisation to test potentially viable interventions in low risk locations.**

The channel velocities are very high, warranting advanced modelling and trial of different approaches to naturalisation prior to large-scale investment in outcomes.

5. **Develop a catchment stormwater quality improvement plan, including opportunities for gross pollutant capture.**

Long-term management of Bungambrawatha Creek and the receiving waterways requires a holistic consideration of runoff and the pollutants that enter the waterway from land-based sources. A stormwater quality improvement plan identify opportunities for alternative water resources, improved amenity and greening of the broader catchment area.

8 Creek line assessment summary

The Bungambrawatha Creek line assessment has been undertaken in response to a recognised need from AlburyCity Council to better manage the waterway. The assessment and subsequent action plan serves as a roadmap to achieve the vision for Bungambrawatha Creek, *"The Bungambrawatha Creek corridor balances the competing interests of this highly constrained and modified area to create a multi-functional space that acts as a community connector, improves biodiversity and waterway condition, practices connection with country, and provides a positive contribution to the lives of those that live and recreate in and adjacent the corridor."*

The action plan has been developed through consultation with Council stakeholders and the broader Albury Community. Like many urban waterways, Bungambrawatha Creek is required to perform many functions, from ecological corridor, flood conveyor to social connector. There are inherent tensions in achieving these outcomes, reflected in wide-ranging views from the community regarding their aspirations for the future of Bungambrawatha Creek.

The feasibility for naturalisation has been tested in light of the existing hydrological and hydraulic characteristics of the waterway. It has been found that the combination of the channel being at or near capacity and with high velocities that naturalisation is likely to be very difficult. Based on velocity data alone, it would be conventionally considered as unsuitable for channel naturalisation. However, based on our experience it is suggested that with higher resolution hydraulic models, some modification with ecological and amenity improvement may be possible in defined reaches. Further detail will be required to adequately test the best areas available for this type of treatment, and Council will need to consider the return on investment in monetary and non-monetary terms.

The assessment and action plan has set a vision and objectives for the Bungambrawatha Creek that reflects the multiple outcomes expected by the community and stakeholders within the corridor. The action plan developed can guide Council in improving the waterway, meeting community expectations and aspirations, as well as ensuring that management occurs in a coordinated and consistent manner.

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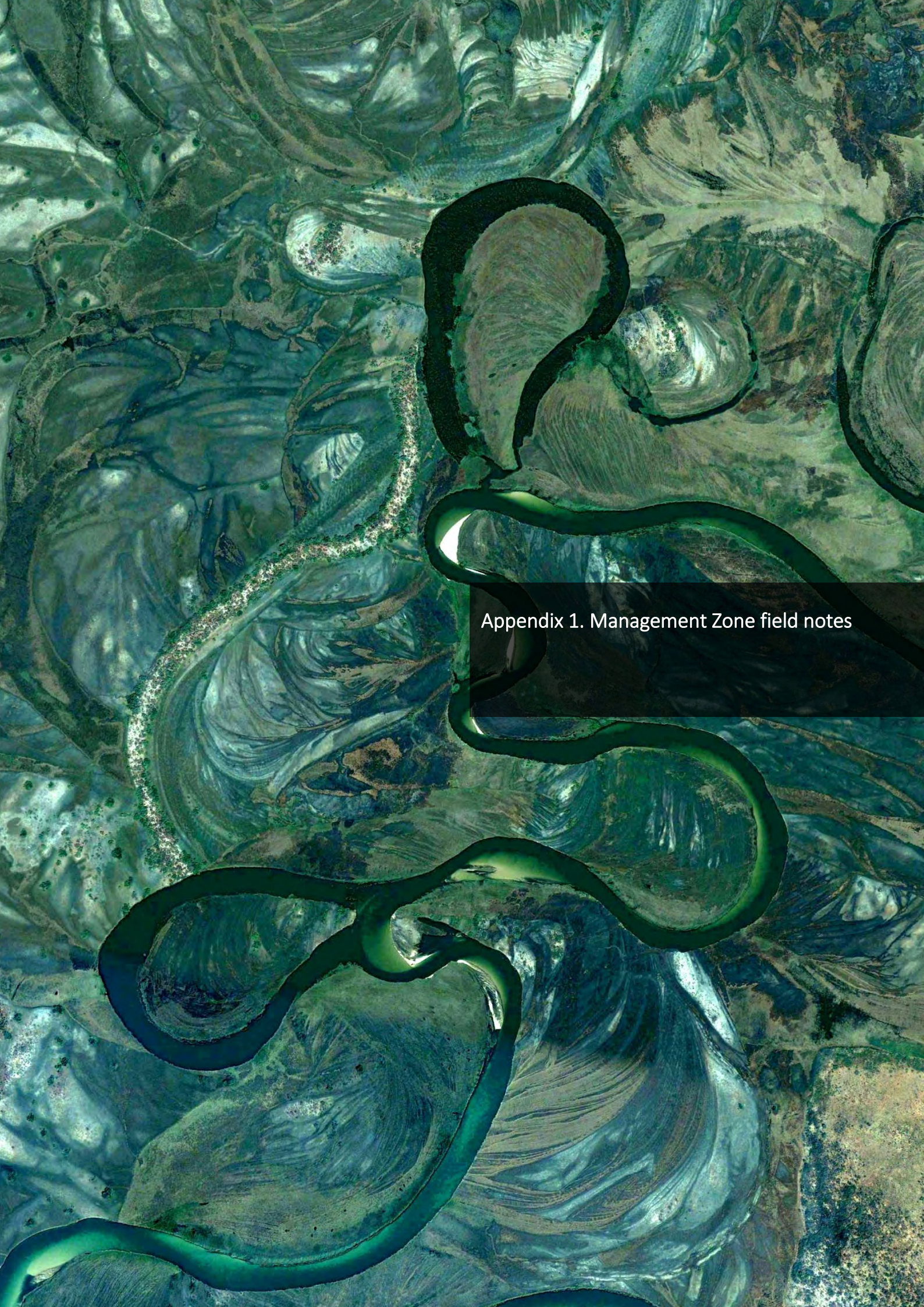

Appendix 1. Management Zone field notes

Management Zones

Management Zone 1

Management Zone 2

Property Boundaries

0 25 50 m

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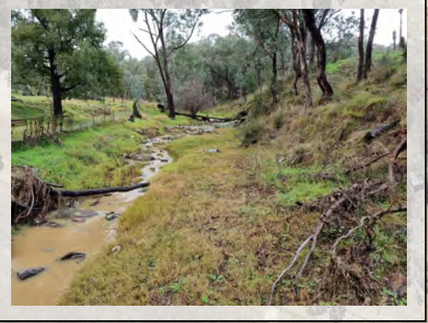
Good upstream channel condition



Formalise controlled access to prevent

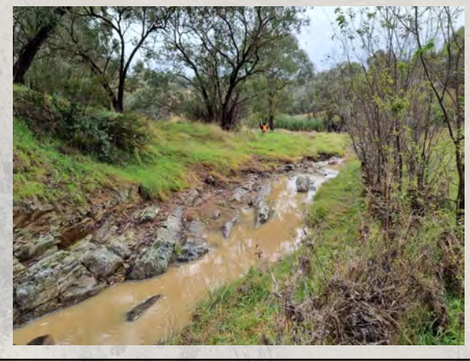
Uncontrolled vehicle access and evidence of recreational use (fire rings)

Recreational 4WD access

Revegetation of inset floodplains to prevent lateral channel migration

Channel modifications and soil desposits apparent

Bedrock controlled system with limited stream widening. Regrowth vegetation and including weeds and natives in floodplain.

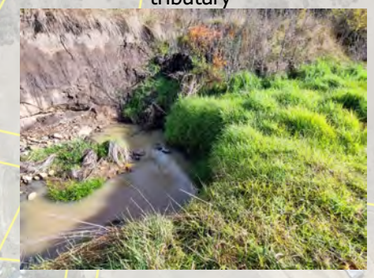


Uniform channel potentially formed by modification. Bedrock controlled system, small risk of lateral migration threatening Prune St

Management Zones
Management Zone 1
Management Zone 2
Property Boundaries
0 50 100 m
n

Historical meander that has been cut off through incision

Active headcut progressing upstream of tributary



Active lateral migration as indicated by sequence of new fences. Significant sediment contributor

Limited public access, despite being Council owned land

Undercutting and channel migration

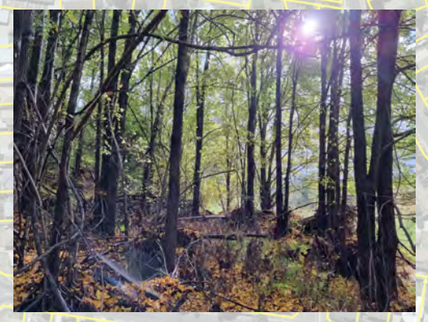
Meander cutoff has been artificially constructed, isolating inset floodplain.

Modified low flow channel cut into broader floodplain

Offline wetland has formed from placement of spoil adjacent to channel from cut low flow. Despite being visually eroded, these vertical banks appear to be generally stable.

Roach St was cut off during January 2022 flooding with significant sediment accumulation.

Dense infestations of english elm



Management Zones
Management Zone 2
Management Zone 3
Management Zone 4
Property Boundaries
0 50 100 m
n

Weed and exotic species dominant around the waterway corridor. Historic erosion is largely being held in check by weedy root mass. Encroachment of private property on the waterway channel.

Private property encroaches on the waterway channel throughout the corridor.

Landholder partnerships for weed removal and planting

Partnership for improvement of corridor with school

No pedestrian connectivity in the Urana to Roach St section of Bungambrawatha Creek.

Management Zones
Management Zone 3
Management Zone 4
Management Zone 5
Property Boundaries
0 50 100 m
n

Hamilton Valley Creek

Dog off leash area

Weed and exotic species dominated western bank in private land

Informal pathway worn through use

Lack of western shade to shared path

Avenue of shade planting to the west of shared path

Heathwood Park

Community revegetation

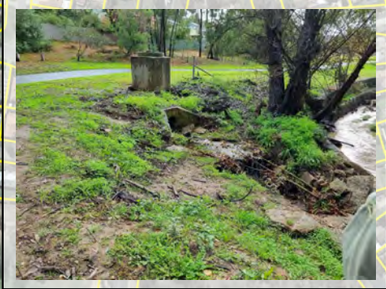
Maintain and extend community planting

Constructed wetland opportunity

Pedestrian connection to Heathwood Park

Gabion bank stabilisation

Stormwater outlet erosion



Management Zones
Management Zone 4
Management Zone 5
Management Zone 6
Property Boundaries
0 25 50 m
n

Existing paddocks are Council owned but currently leased for grazing (horses).

The basin is currently being used for informal recreational, including a soccer pitch.

Basin outlet structure

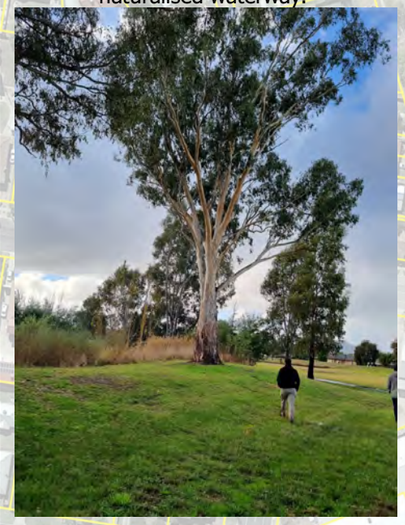
Weed control and revegetation through basin floor and cut embankments only

Union Road retarding basin

historical creek location showing how it meandered through existing vegetation.

No planting to basin bund to prevent structural failure

Remnant vegetation persists in the basin, providing an opportunity to complement a naturalised waterway.



The low flow is cut into the base of the basin, providing some opportunity to further increase flood storage through the basin.

Opportunities for constructed wetlands & channel naturalisation

Retarding basin outlet to Union Road culverts

Management Zones
- Management Zone 5
- Management Zone 6
- Management Zone 7
- Management Zone 10
- Management Zone 11
- Property Boundaries

0 50 100 m

N

Further embellishment is planned for Frederick Park in line with the Masterplan. This will use most available open space for alternative waterway/wetland features.

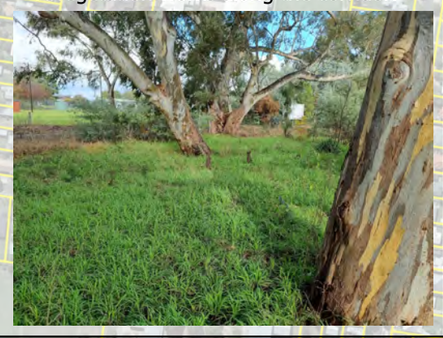
Looking North to Union Road. A narrow corridor is confined with unattractive star picket fencing adjacent to the channel. Channel side vegetation is typically maintained through chemical spraying, however some regrowth vegetation exists.

Grass swale draining Frederick Park

Frederick Park (the Turtle Park)

Looking south with Frederick park to the east.

Some parts of Bungambrawatha Creek through Frederick Park have patches of grassy woodland, a potential template for revegetation works along the corridor.



View east to the cemetery with vegetation adjacent to the channel showing evidence of persistent herbicide application. Unattractive fences line the west of the channel.

Original surveyed line of Bungambrawatha Creek

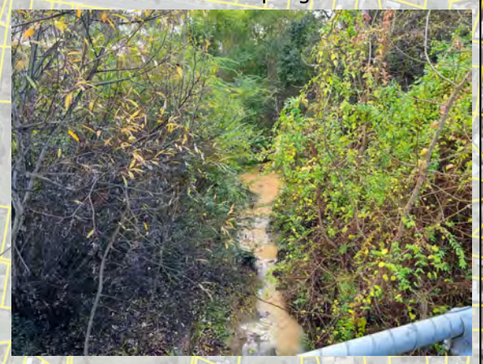
Management Zones
- Management Zone 6
- Management Zone 7
- Management Zone 8
- Management Zone 9
- Management Zone 10
- Management Zone 11
- Property Boundaries

0 75 150 m

n

Community centre

Dense weed cover dominates through the natural section of Black Springs Creek



Informal pedestrian paths from heavily pedestrian traffic. Weeds are prevalent through Little Black Springs Creek.

25 year old community plantings

Black Springs Creek

Little Black Springs Creek

Online lake with ungrated field inlet pit and overflow weir

Albury Ce

Informal paths connecting to Black Springs Creek through box gum.

Albury Commercial Golf Club

No public access through golf course

The golf course contains one of the most laterally unconfined sections of Bungambrawatha Creek.

Channelised section of Black Springs Creek

Management Zones
Management Zone 7
Management Zone 8
Management Zone 9
Property Boundaries
0 100 200 m
n

Existing pedestrian bridge is not ideally placed to adequately link Greenflield and J.C. King Park

The bikeway passes through the netball court car park in this location

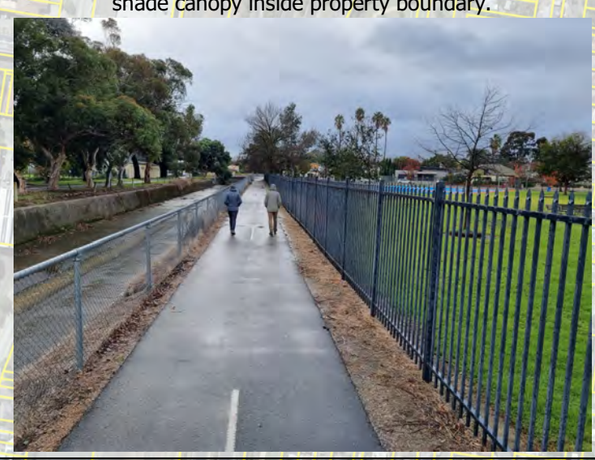
The corridor is highly confined by private property and the presence of existing mature vegetation. However the channel is damaged in places.

Highly confined channel with poor visual surveillance, and minimal vegetation canopy. Solid fences address the waterway corridor.

The channel has appoximately 1:1 batters through the central Albury length. Remants of an earlier channel remain in proximity to the CBD.

The channel typically has informal access on its western side, with the bikeway on the east.

Albury High, dissected by the channel, has potential to improve shade canopy inside property boundary.



Community garden

Greenfield Park

J.C. King Park

Albury High School

Management Zones

Management Zone 9

Property Boundaries

0 25 50 m

n

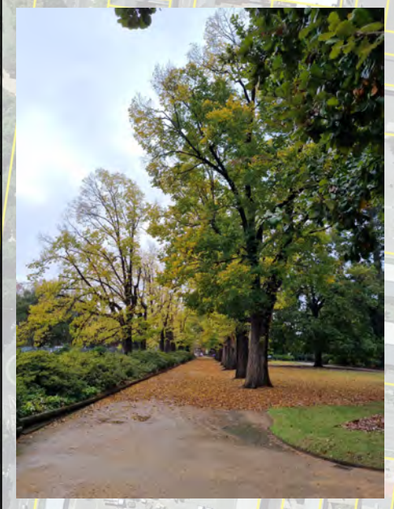
A narrow kerbisde footpath pushes most people onto this informal path when going around the Botanic Gardens (a requirement after hours)

The channel adjacent is currently highly confined, however the removal of English Elms offers potential to siden the waterway.

The Smollet Street bridge is an obstruction to continous pedestrian connectivity in the corridor, and requires an awkward and unsafe crossing to continue downstream to the riverside park.

Albury Botanic Gardens

The avenue of English Elms in the Albury botanic gardens are in decline and slated for removal.

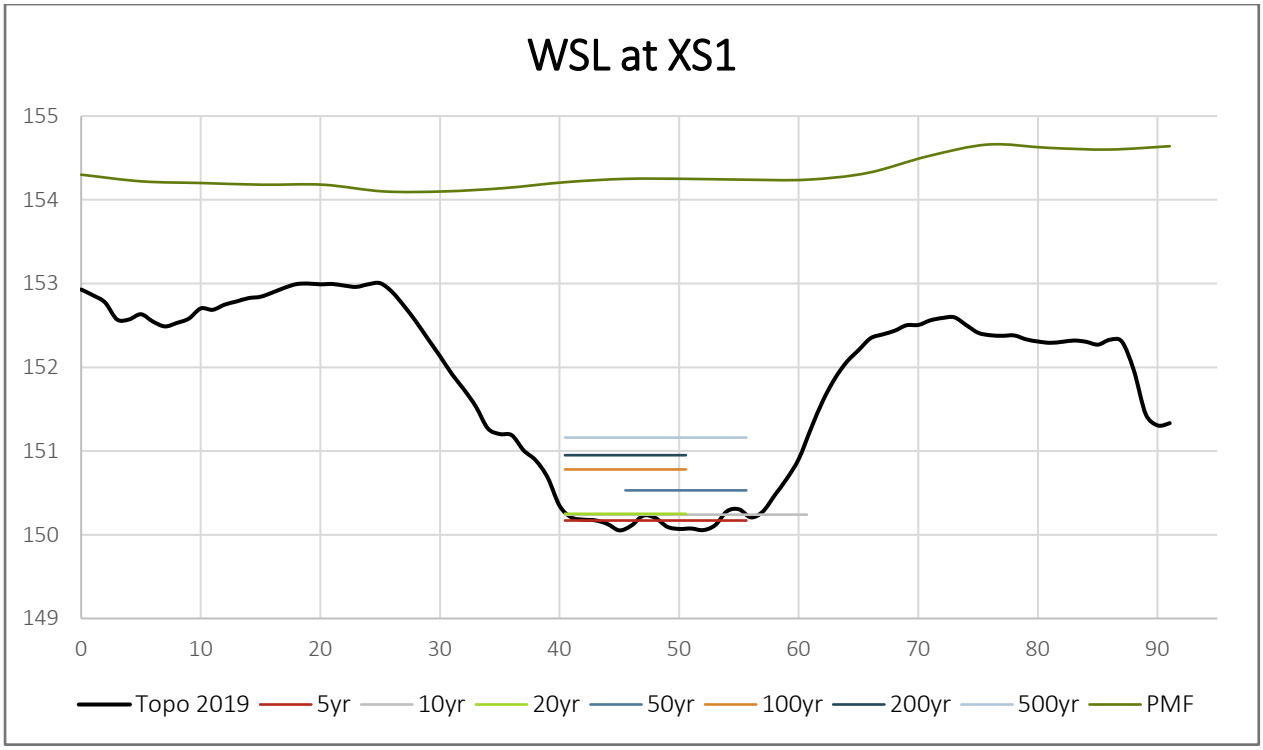


The Bungambrawtha Creek outfall to the Murray River has recently been constructed as a rock-lined channel.

A sediment trap adjacent the Council depot is likely to be of minimal effectiveness. Low flows are directed to the river via pipe.

Tje trash rack is likely to offer minimal effectiveness in any flow and is causing an obstruction when blocked.

Appendix 2. Channel cross sections and water surface level (WSL)


WSL at XS1
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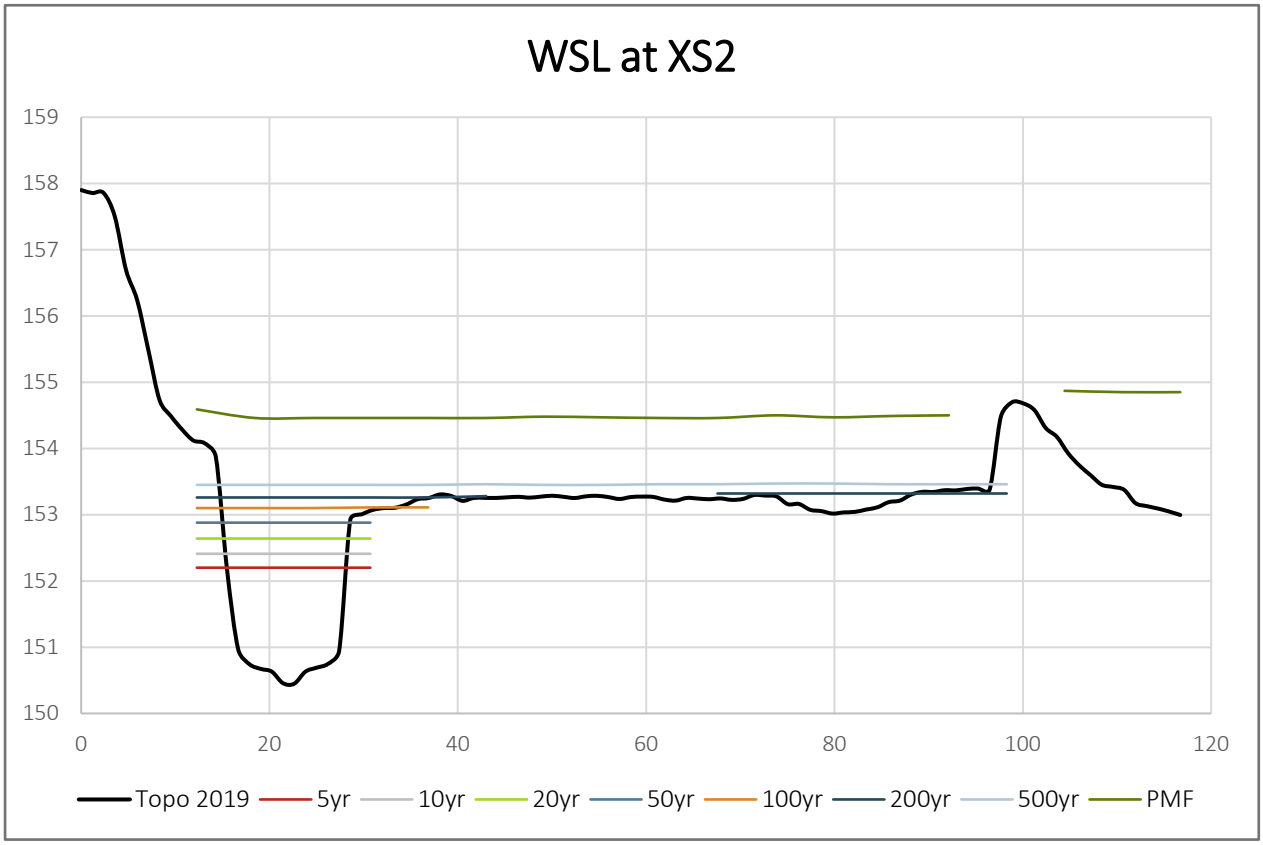
WSL at XS2
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Topo 2019
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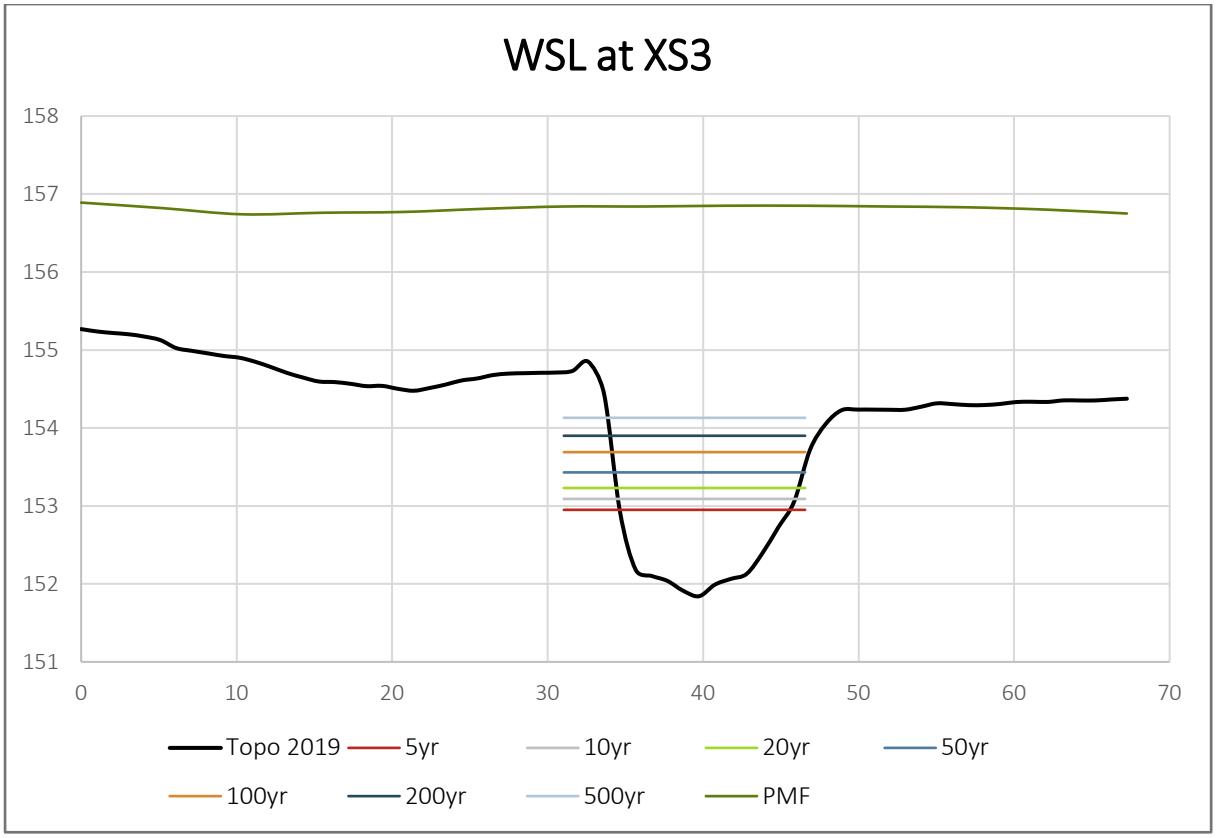
WSL at XS3
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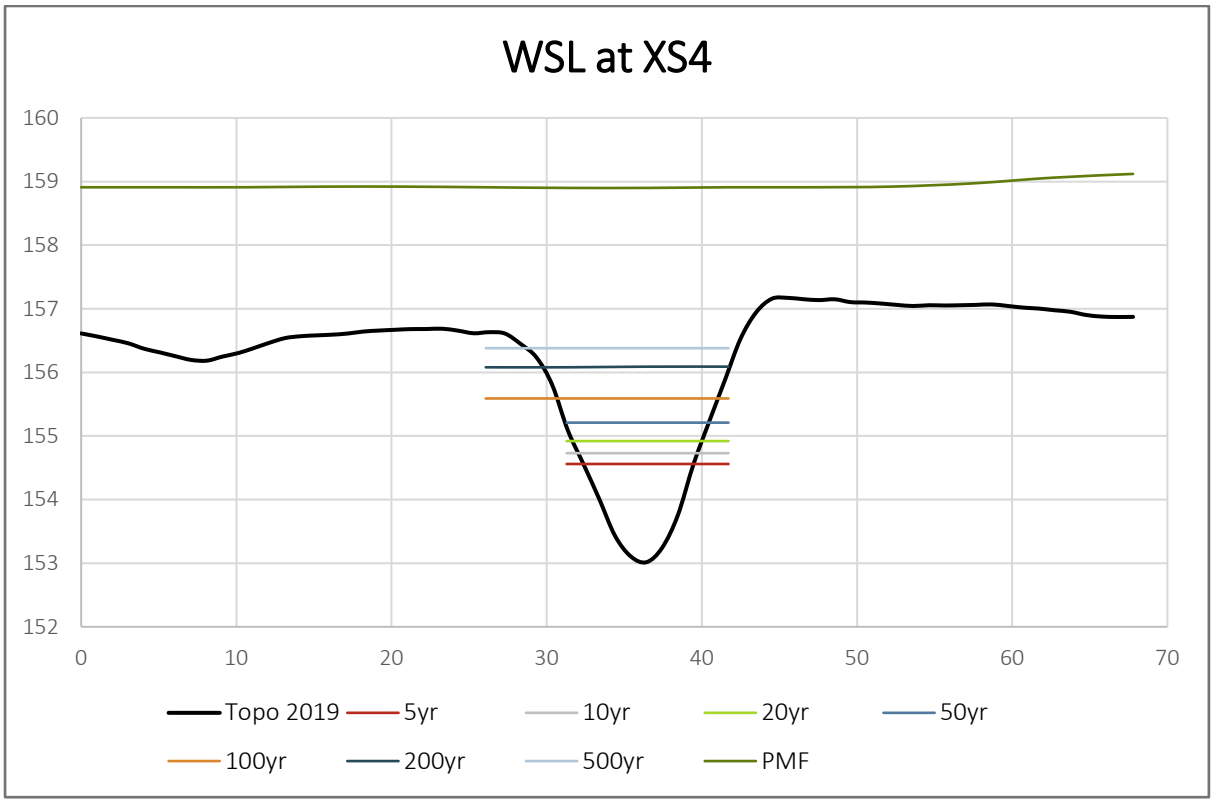
WSL at XS4
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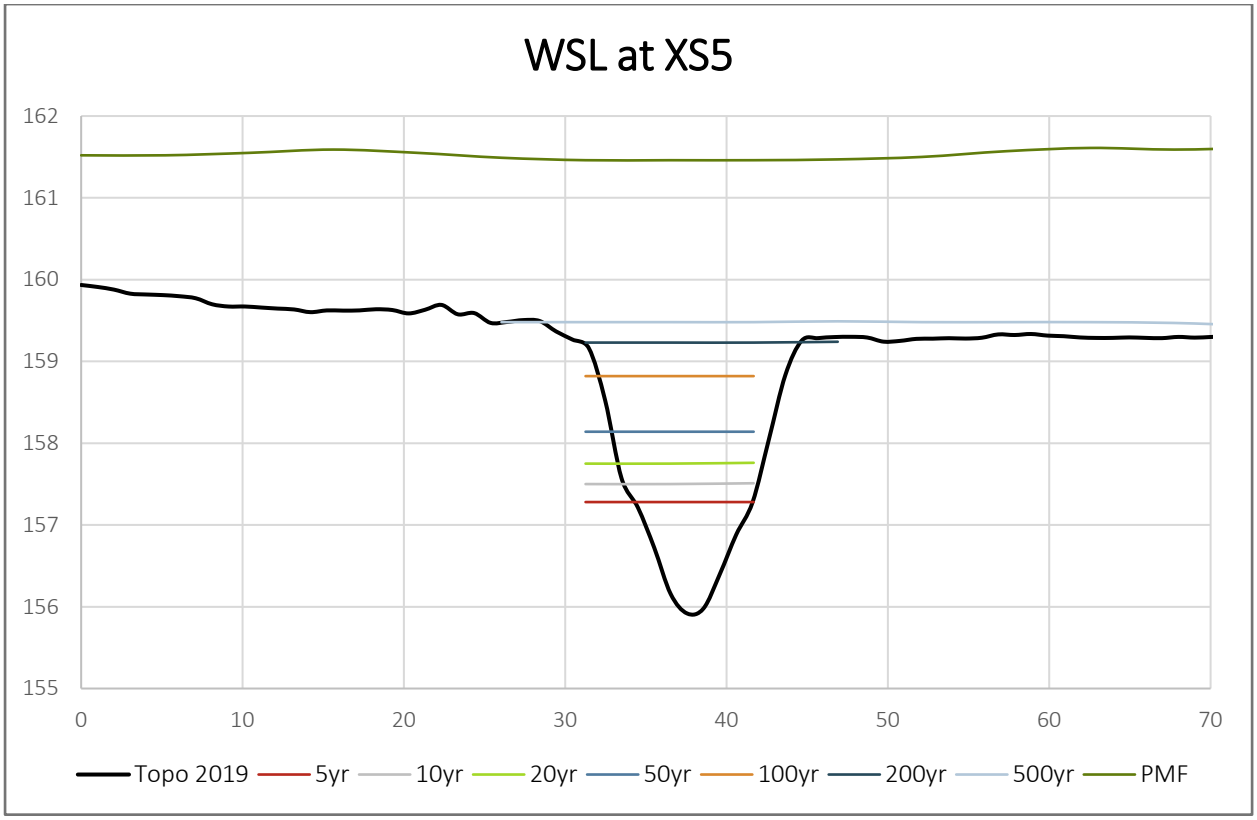
WSL at XS5
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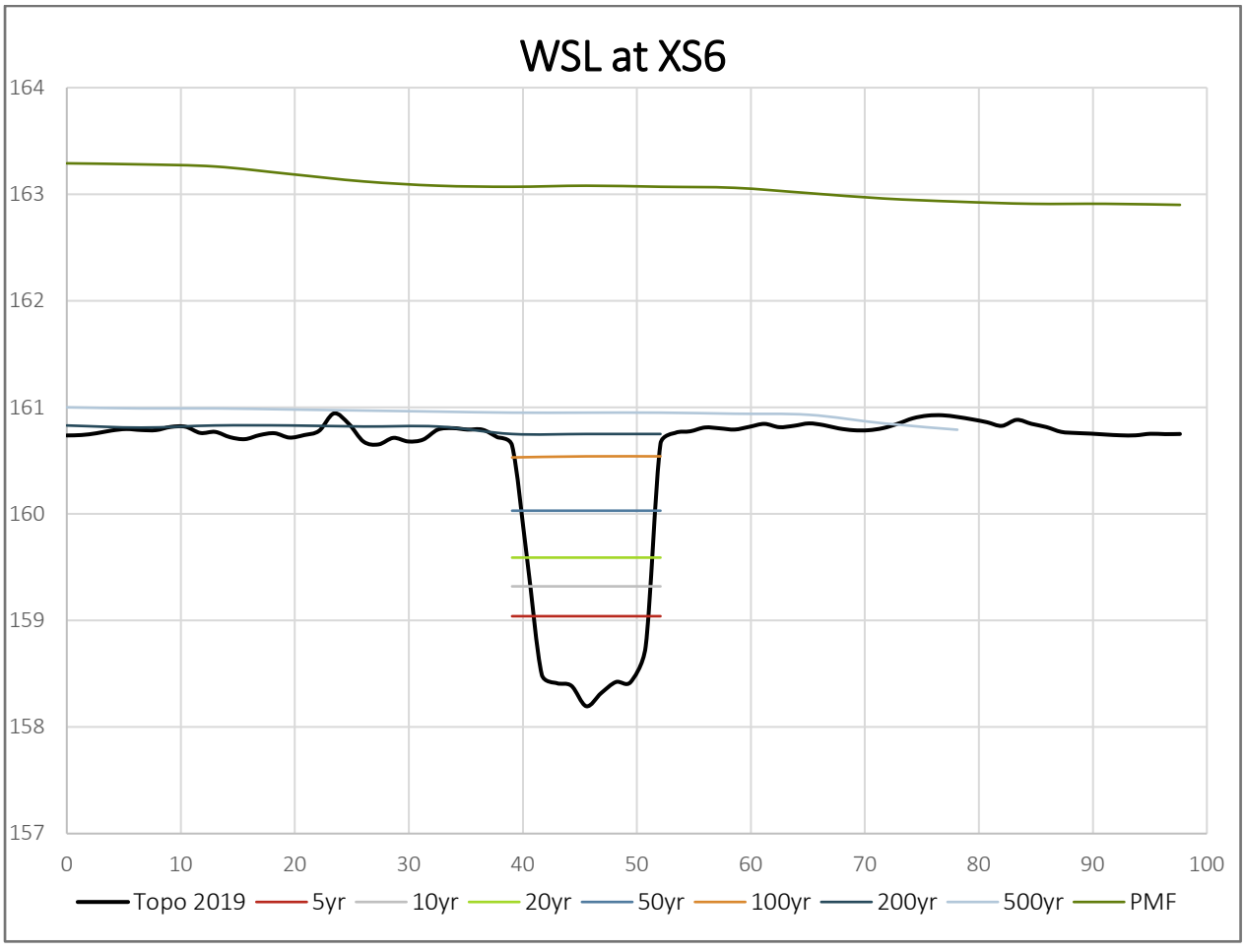
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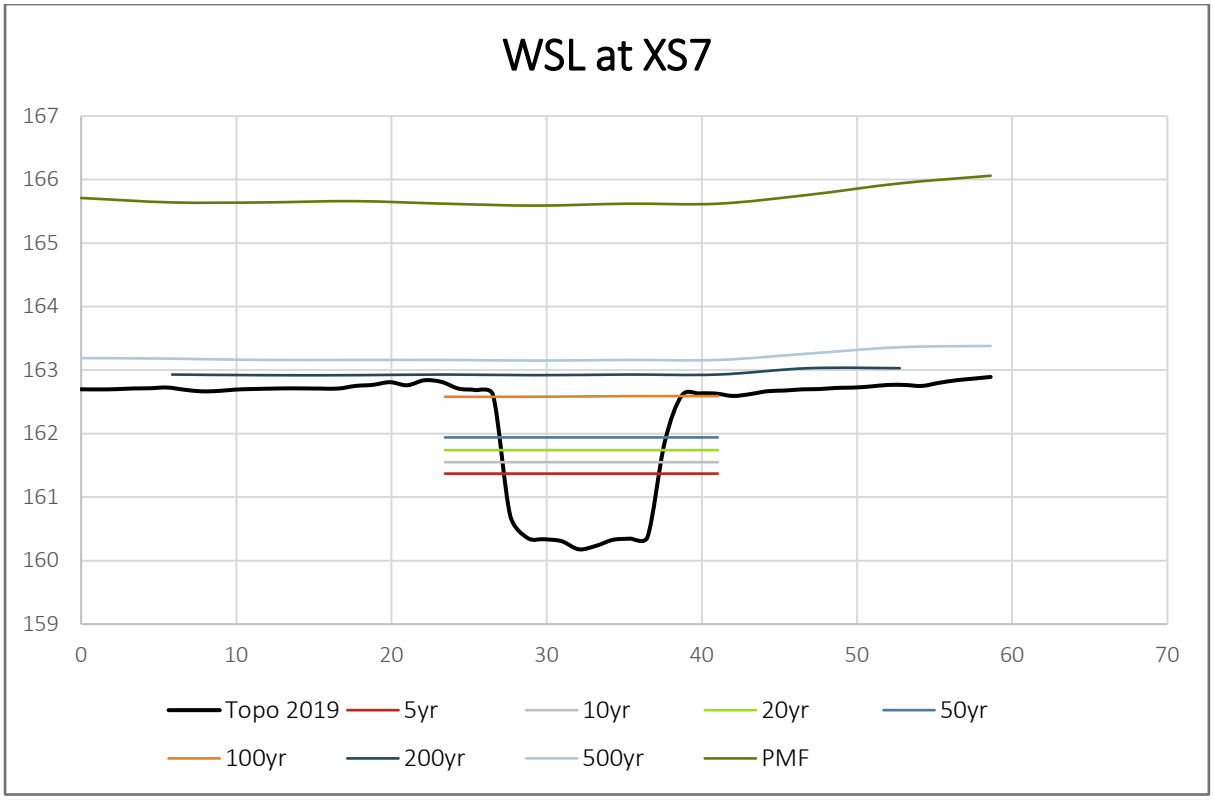
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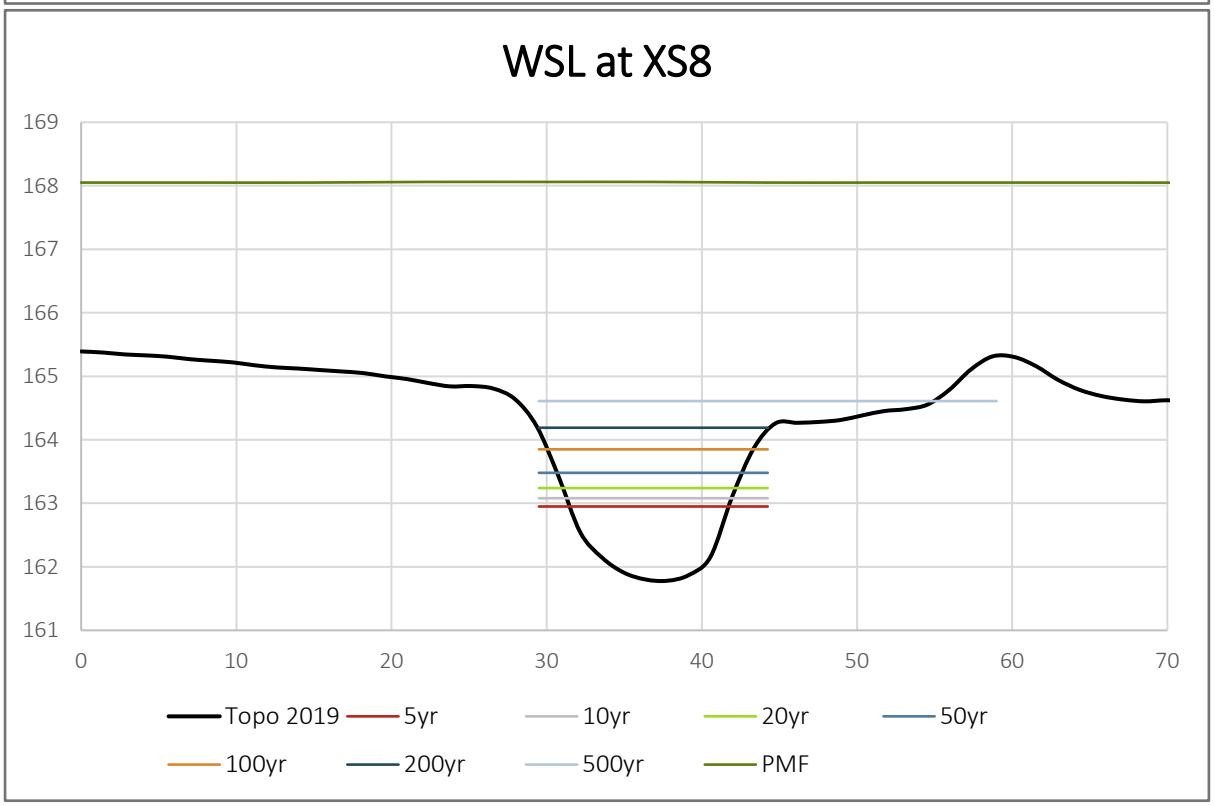
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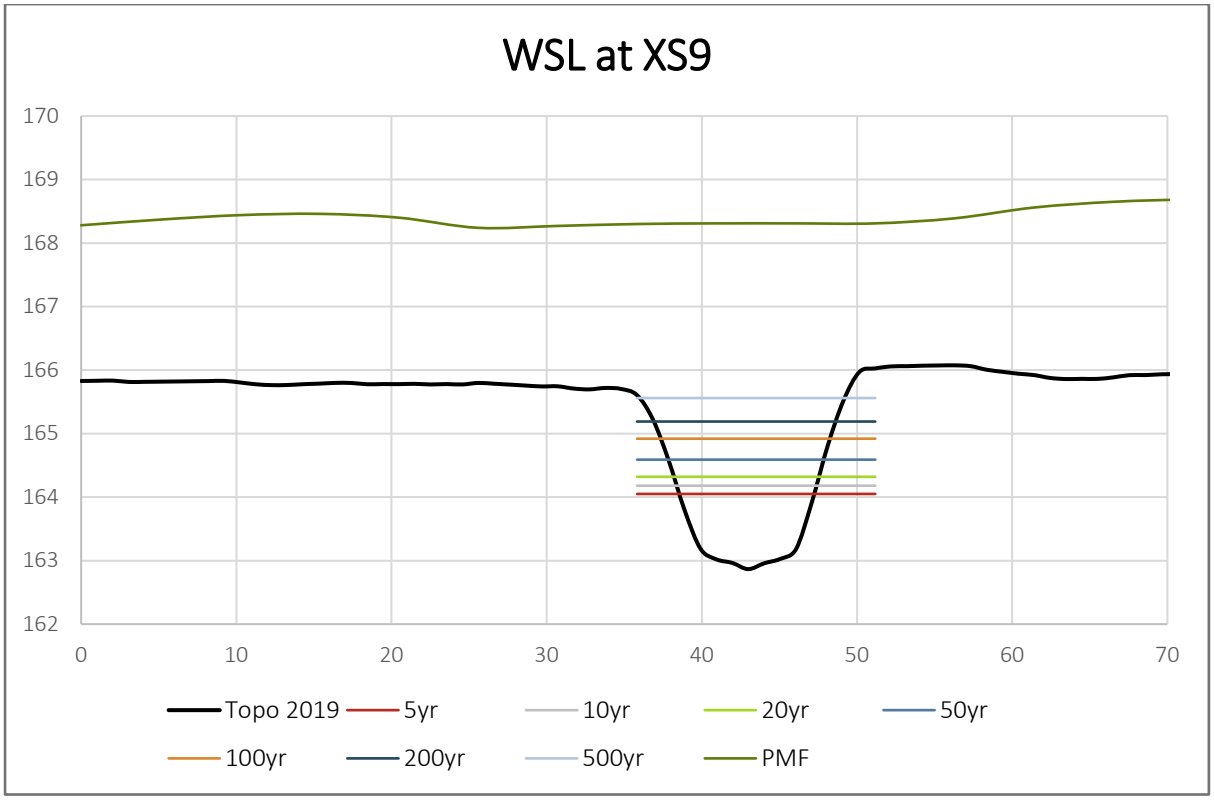
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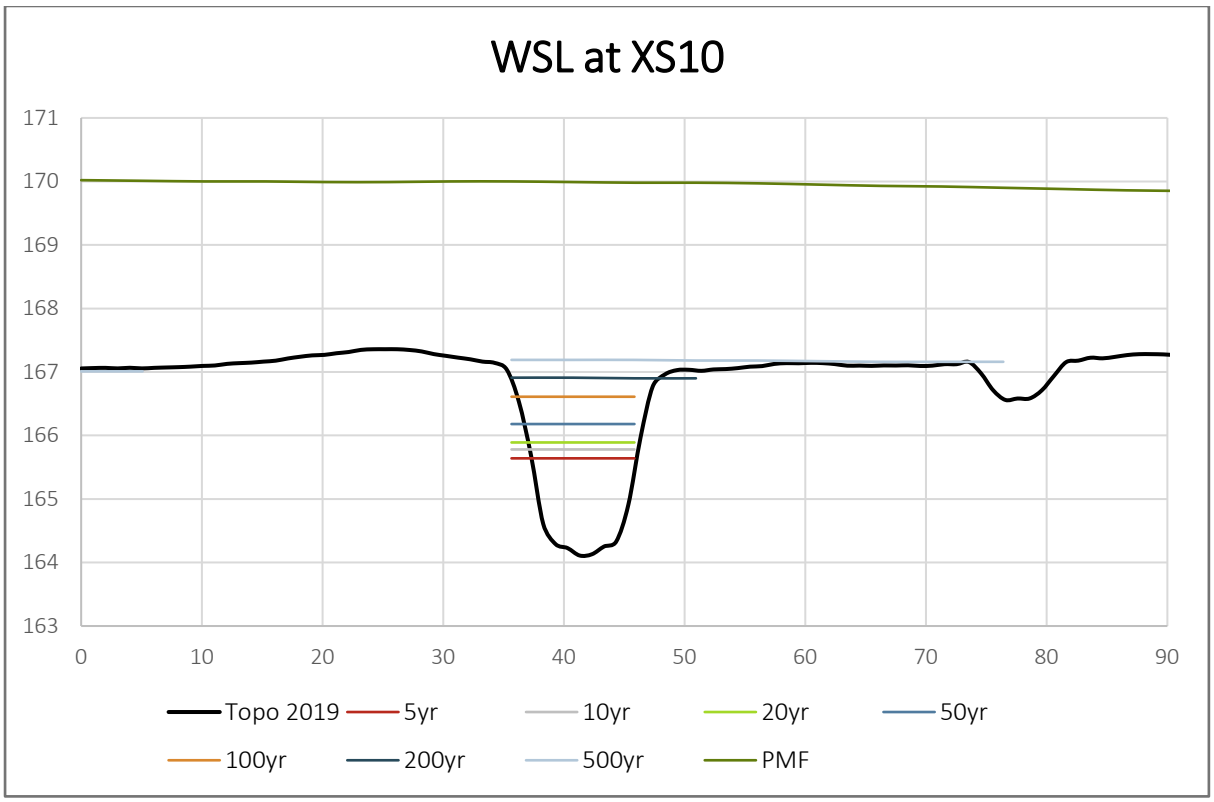
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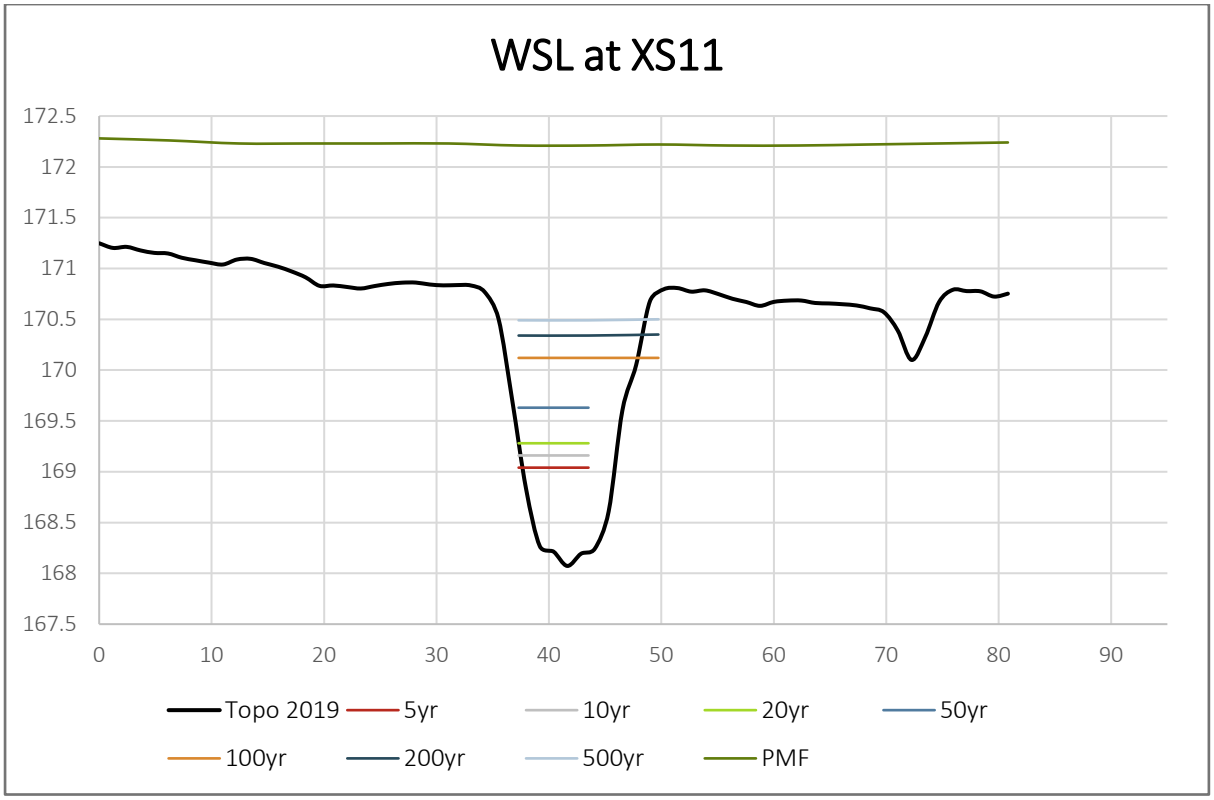
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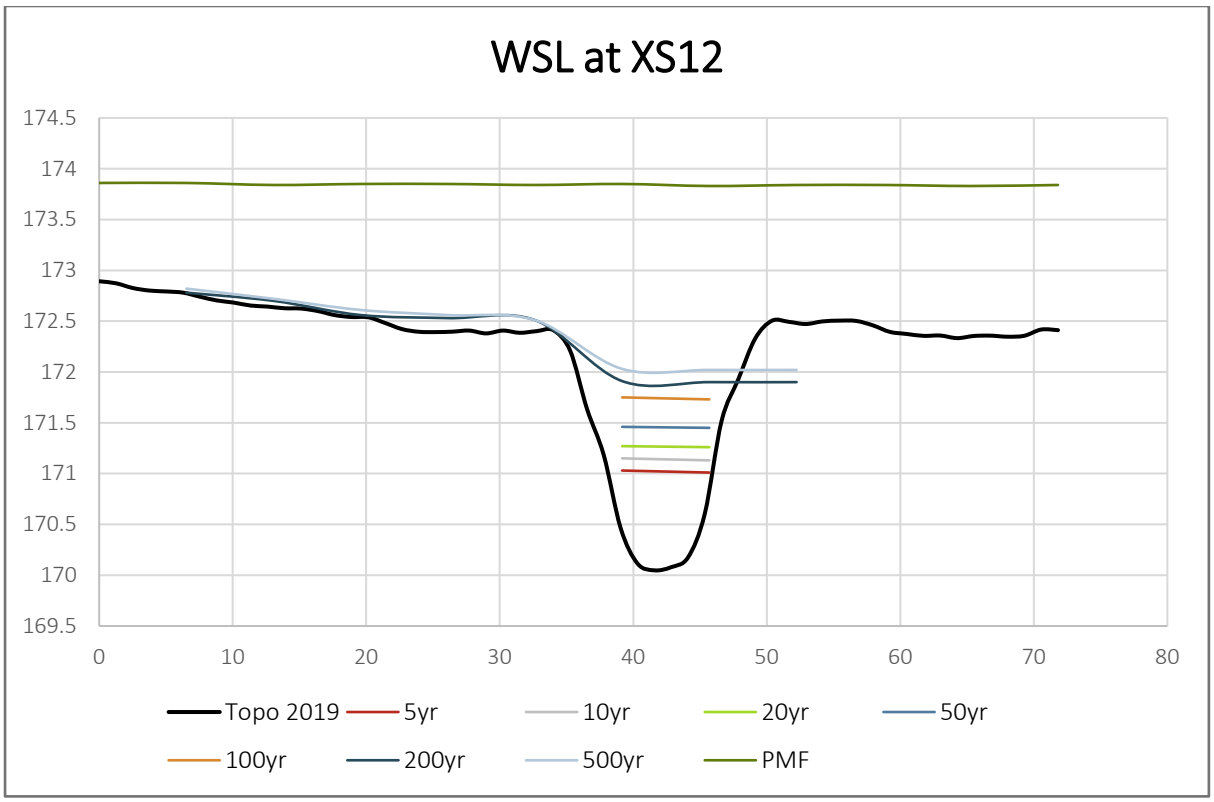
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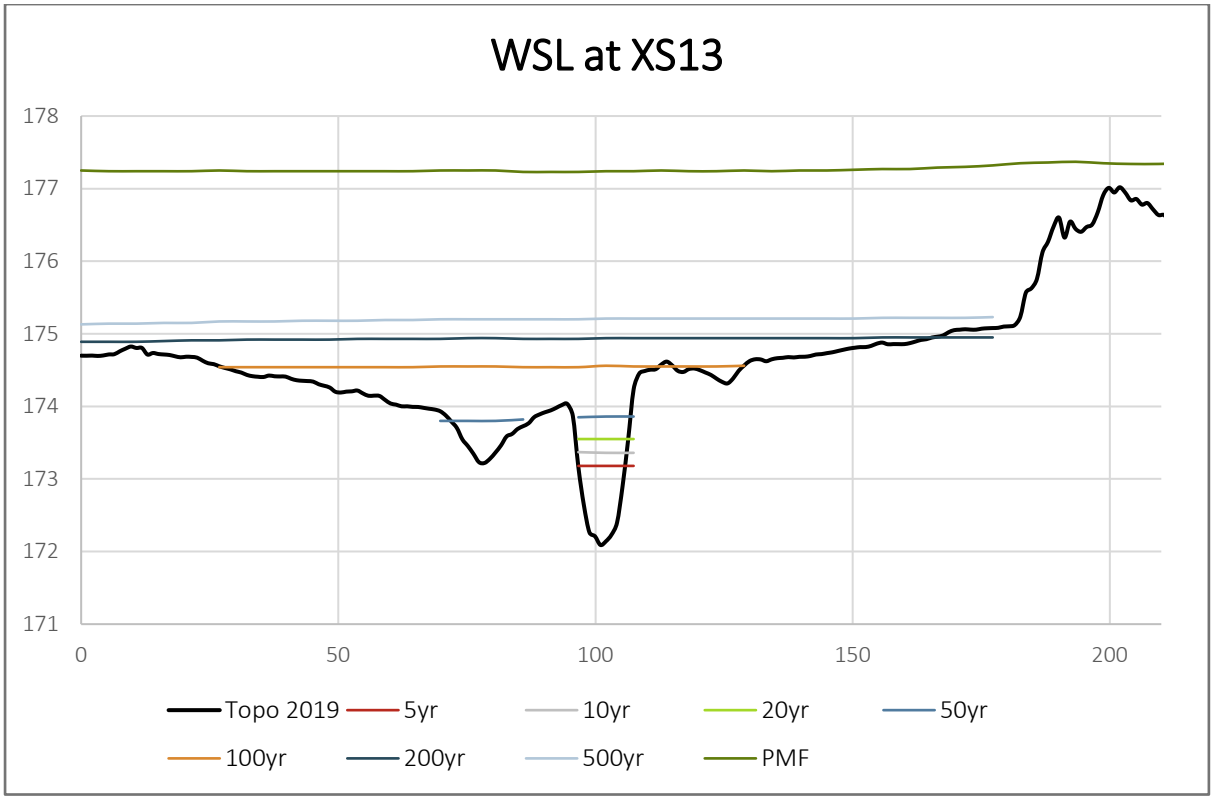
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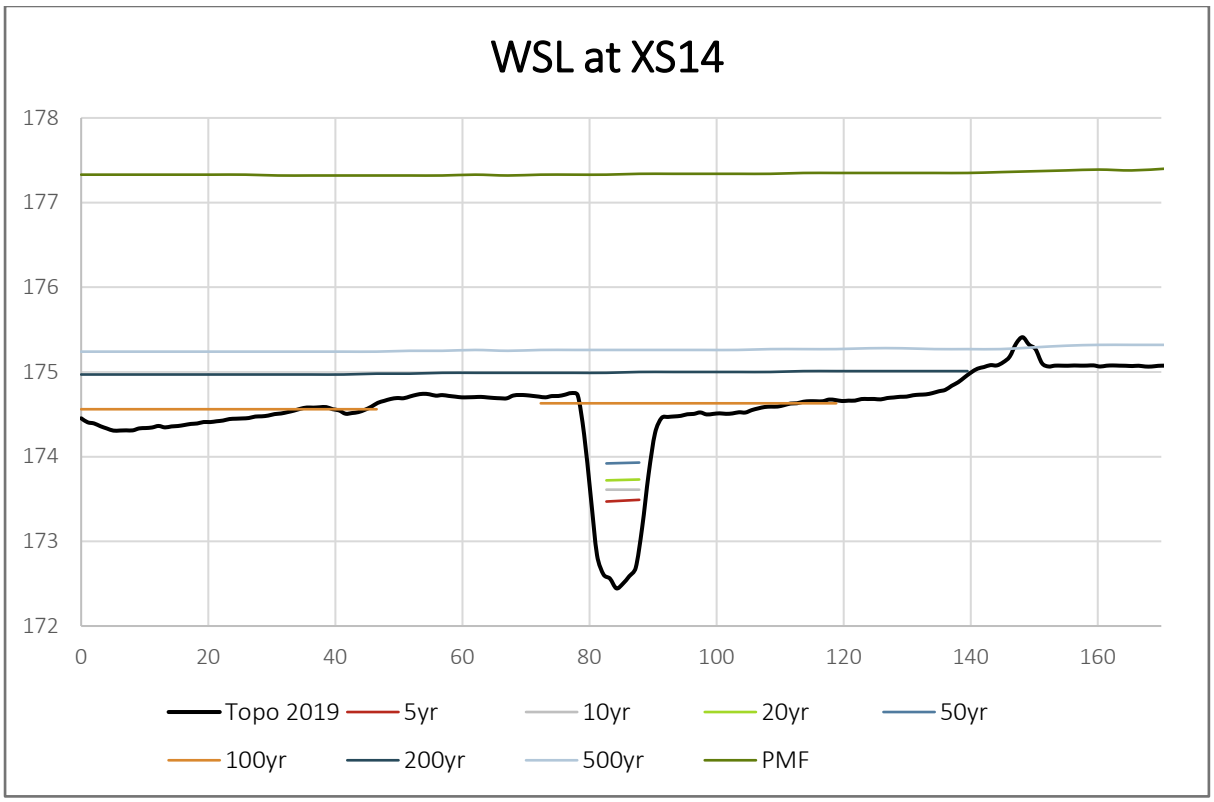
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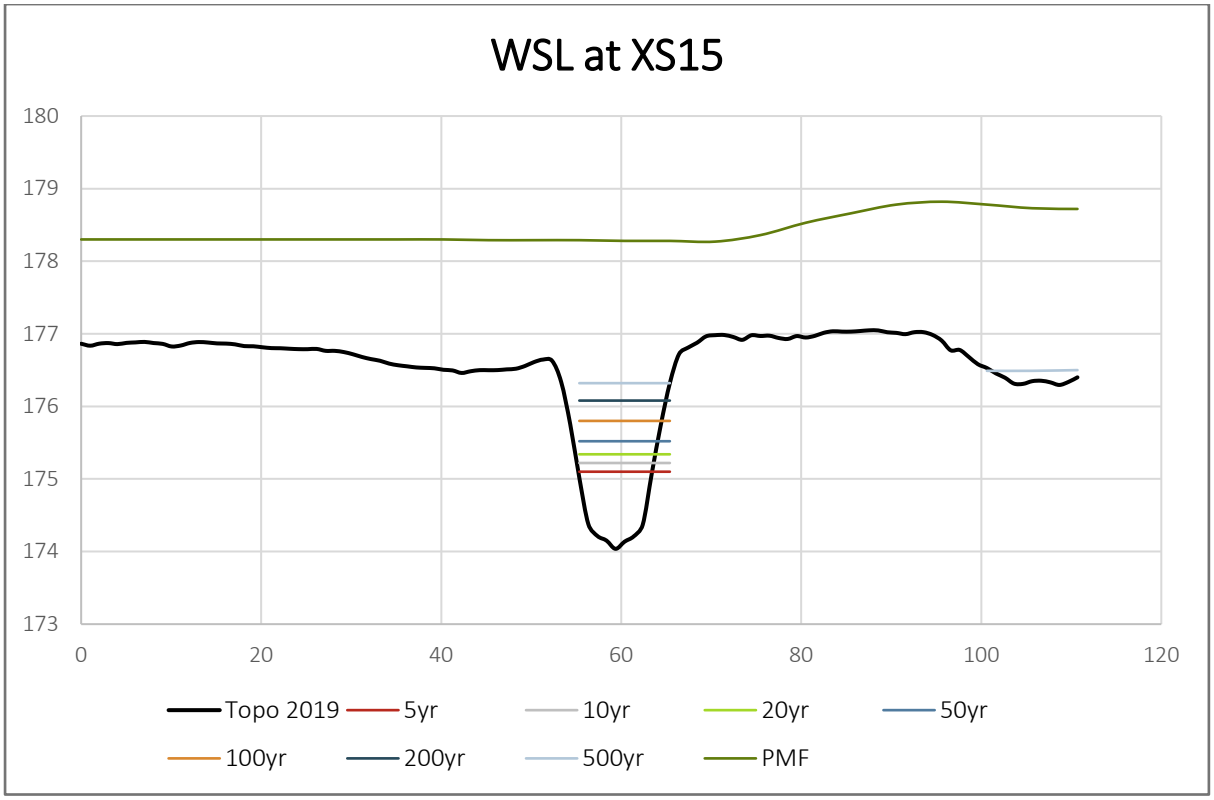
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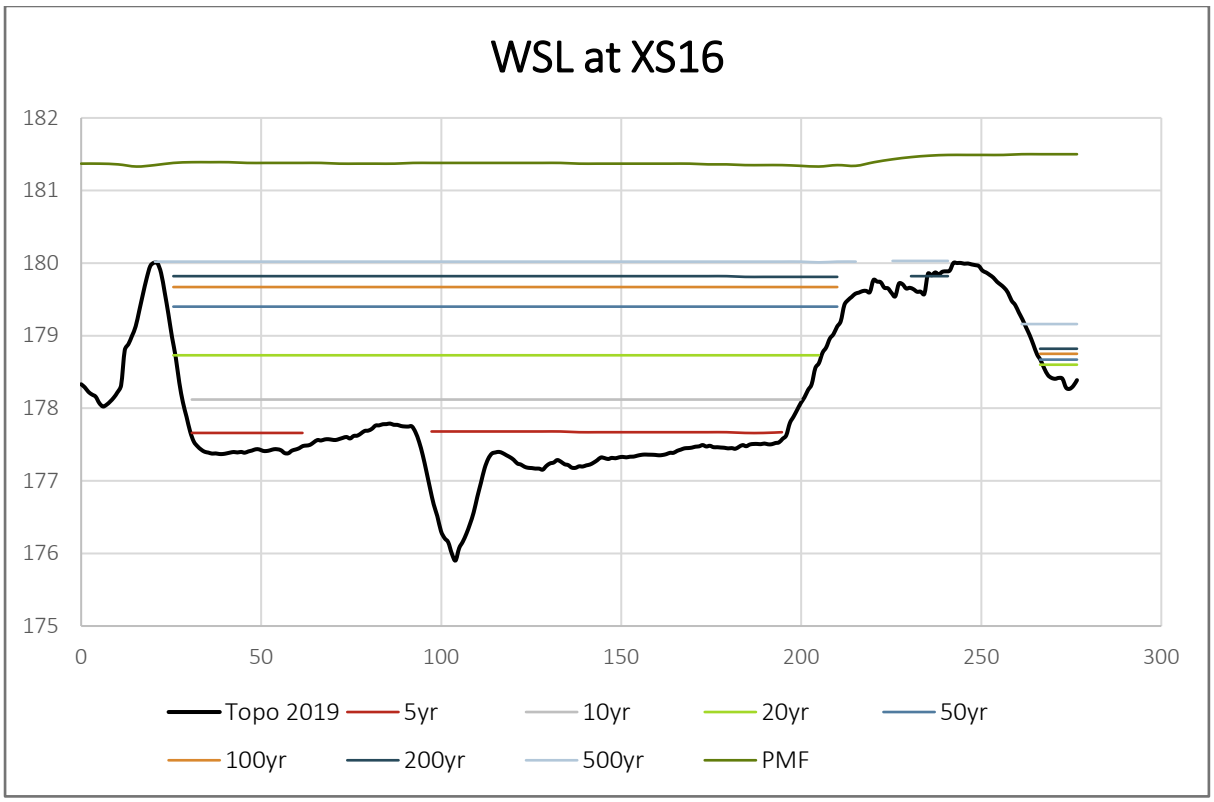
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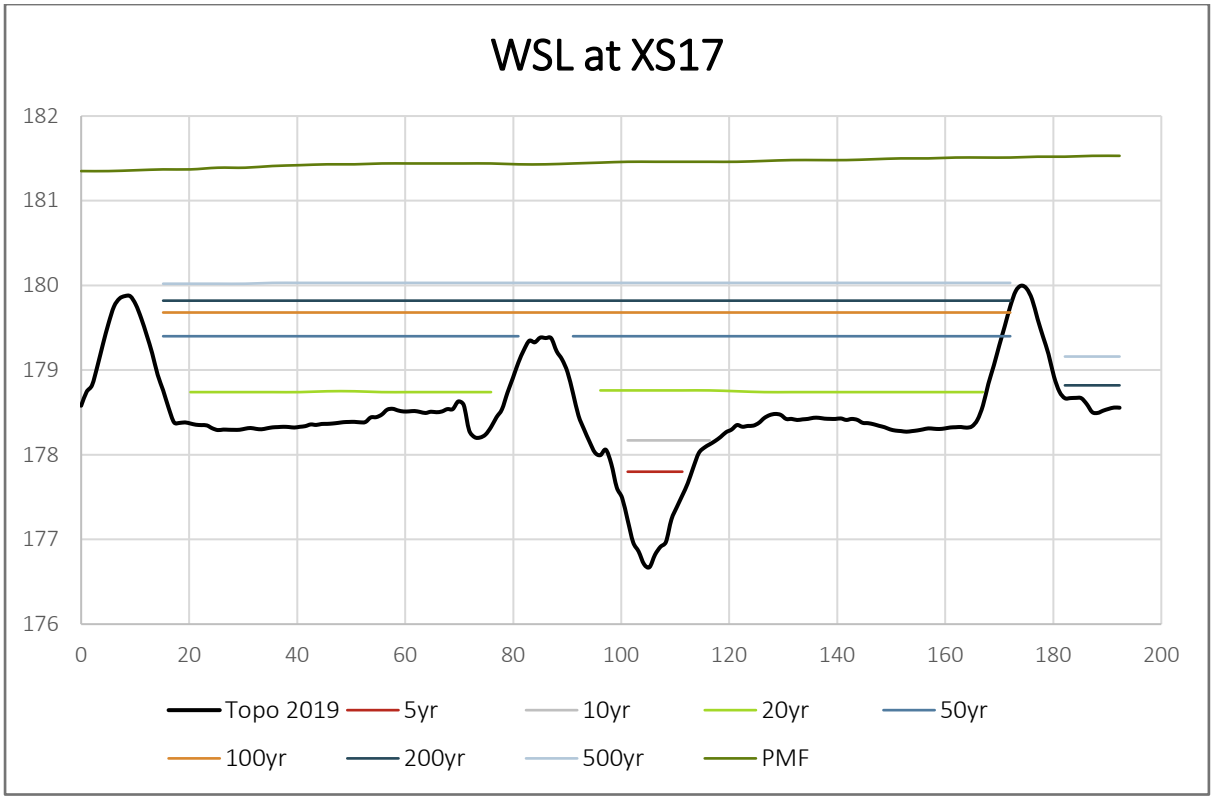
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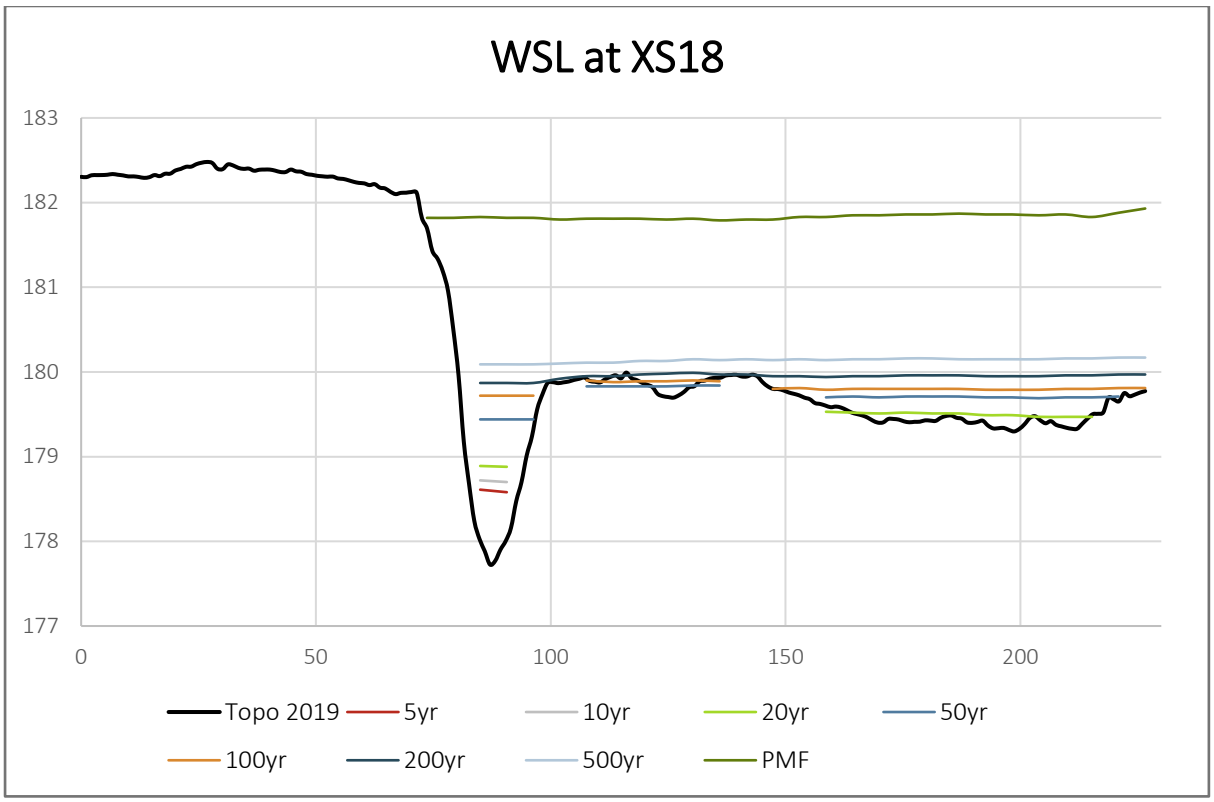
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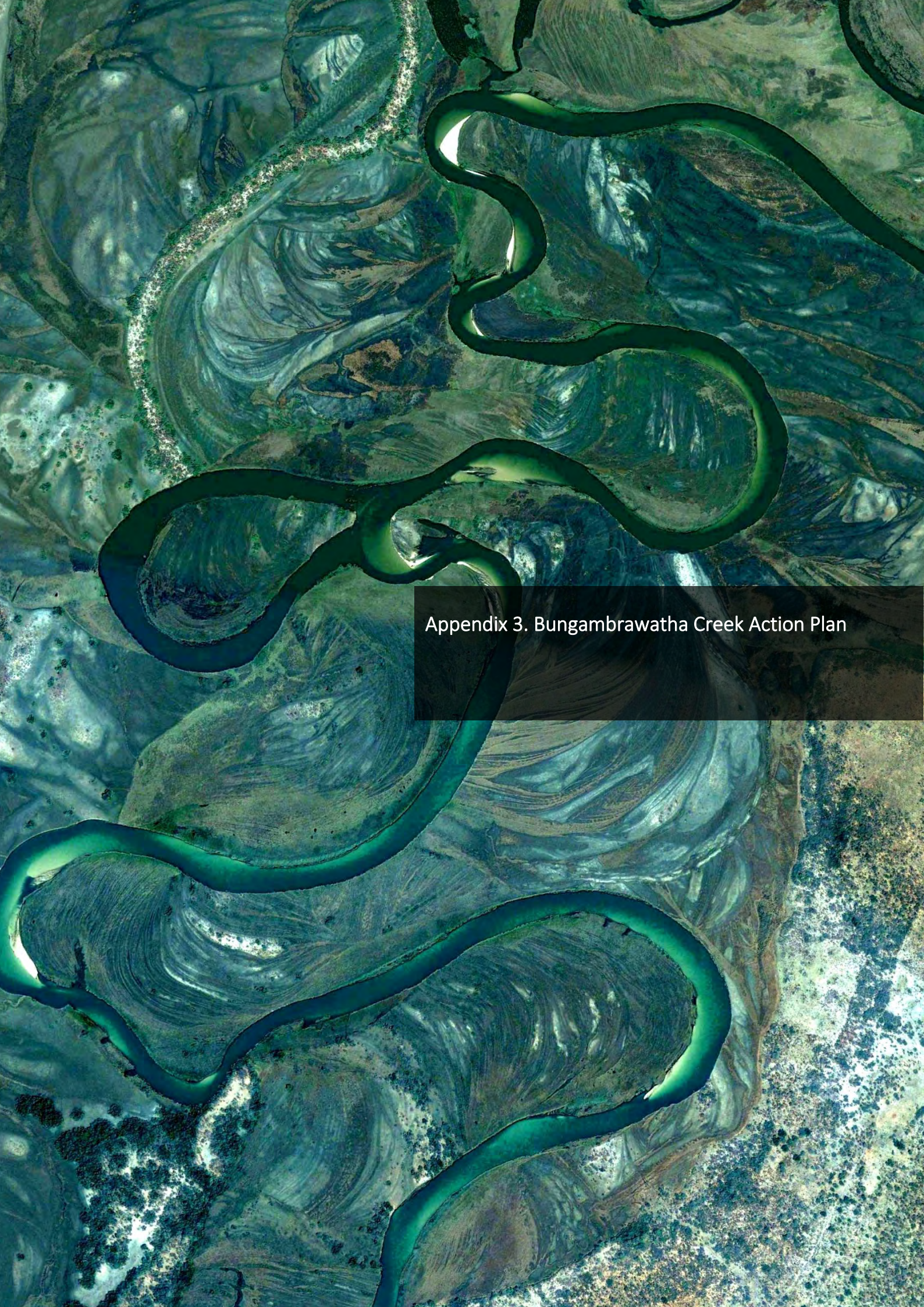


Appendix 3. Bungambrawatha Creek Action Plan

Bungambrawatha Creek - Action Plan

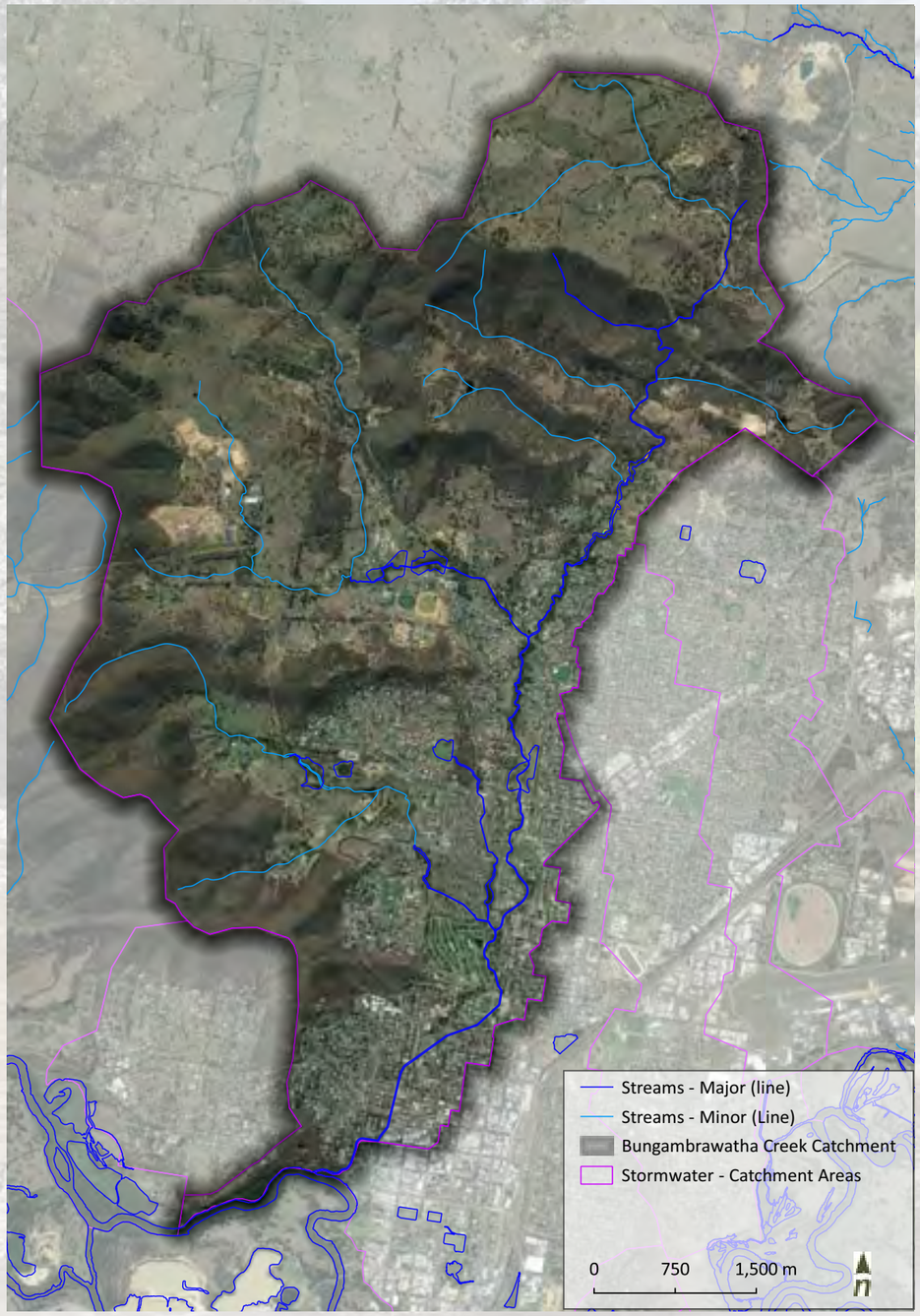
a multi-functional corridor

Vision

"The Bungambrawatha Creek corridor balances the competing interests of this highly constrained and modified area to create a multi-functional space that acts as a community connector, improves biodiversity and waterway condition, practices connection with country, and provides a positive contribution to the lives of those that live and recreate in and adjacent to the corridor."

Originating in the Black Range to the north of the city, Bungambrawatha Creek flows through the Albury City CBD to its confluence with the Murray River. The creek flows through the traditional lands of the Wiradjuri people, taking it's name, Bungambrawatha, from the name given to the area by the traditional owners, meaning 'Homeland'. The catchment is over 40km² in area, encompassing the major tributaries of Hamilton Valley Creek, Little Black Springs and Black Springs Creeks. The waterway has been channelised over the course of the last century in what has until relatively recently been considered best engineering practice.

This action plan has been developed in recognition of a need to better manage the waterway and to improve its environmental and social value. The actions in the action plan respond to the needs of the community identified through consultation, a technical assessment of flooding, and the ecological, physical and social values of the waterway.



AlburyCity

Objectives

Floodplain Management
The Bungambrawatha Creek corridor considers stormwater conveyance and resilience to flooding in all aspects of its design and management.

Activation and Connectivity
Bungambrawatha Creek connects the two CBDs and beyond via an active transport network that has appropriate lighting, is safe, cool, shaded, and scenic. The corridor is transformed from an unnoticed waterway to a linear hub of passive and active recreation along its length, connecting CBDs and communities to each other and the waterway.

Amenity
The visual amenity of Bungambrawatha Creek is improved through the enhancement and management of natural values and vegetation that is well integrated with the urban landscape.

Community
The community is connected to Bungambrawatha Creek, actively caring for and valuing the waterway as a place of beauty, biodiversity and recreation.

Water Sensitive Urban Design
Stormwater and excess urban flow within the waterway is actively managed to improve water quality and waterway health outcomes and to be recognized as a valuable resource to provide alternative water supply for irrigation of adjacent lands.

Ecology
Bungambrawatha Creek is an ecologically functional riparian corridor that provides connectivity and habitat for diverse native aquatic and terrestrial species assemblages.

Infrastructure
Infrastructure is appropriately considered in the Bungambrawatha Creek corridor, and opportunities for co-investment should be investigated.

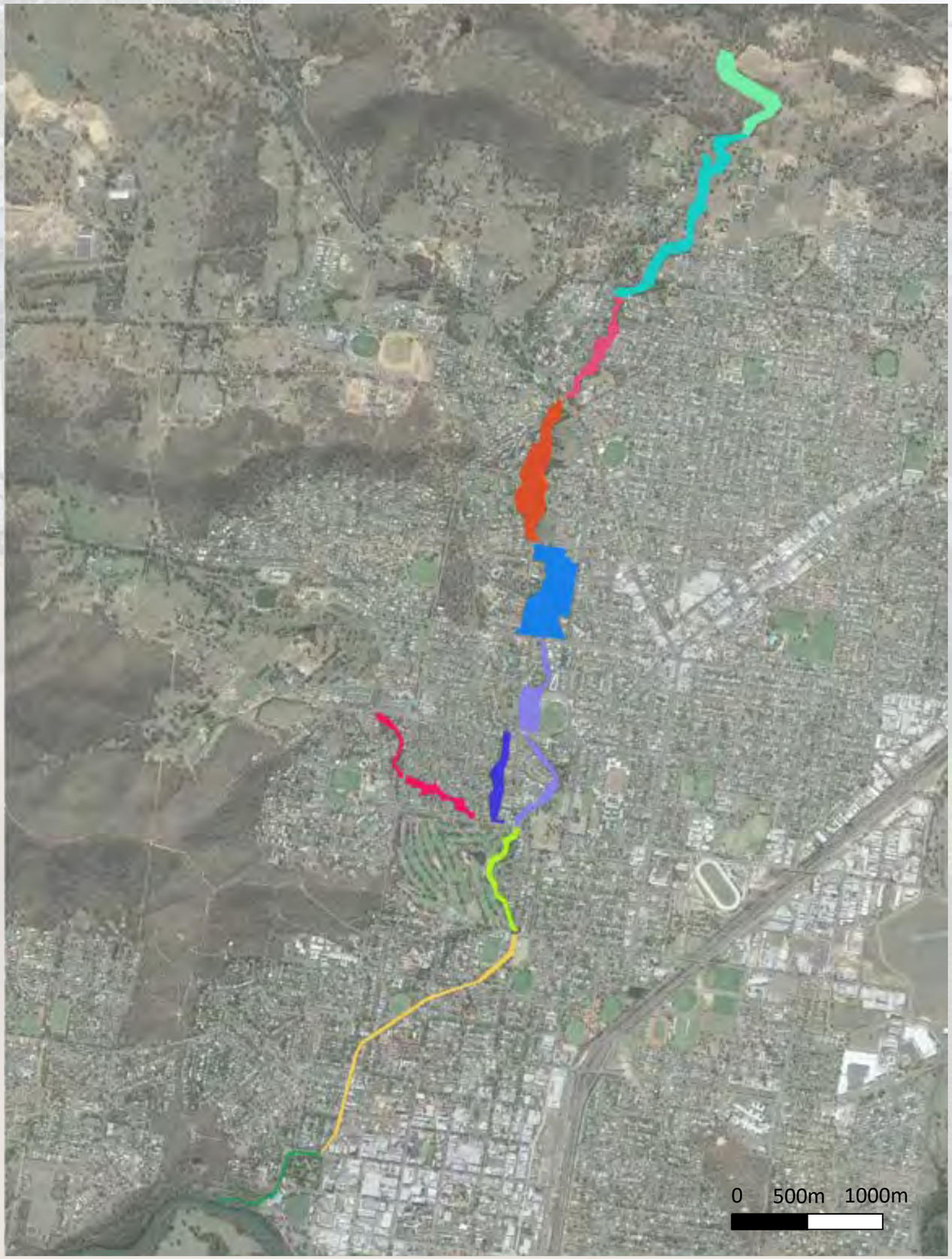
Maintenance
All proposed activities within the corridor consider at all times the maintenance implications for Council, including cost, human resource requirement, safety and ability to carry out required maintenance activities.

Cultural Connection
To be developed with Traditional Owners
Possible objective: The Bungambrawatha Creek corridor allows an opportunity for the Traditional Owners to connect with country as a living expression of their culture.

Channel form
Bungambrawatha Creek and its tributaries are stable in the unlined sections of the waterway, while opportunities to improve the natural characteristics and amenity of the waterway are explored through the concrete lined reaches.

Management Zones

- Management Zone 1
- Management Zone 2
- Management Zone 3
- Management Zone 4
- Management Zone 5
- Management Zone 6
- Management Zone 7
- Management Zone 8
- Management Zone 9
- Management Zone 10
- Management Zone 11



Management Zone 1

Located in the mid to upper reaches of Bungambrawatha Creek, management zone 1 is relatively stable, despite historical disturbance and ongoing grazing access. Surrounding rural vegetation is characteristic of grassy box gum and typically grazed. Crown land surrounds the creek, which is used for informal recreation, and the zone is surrounded by privately and Council-owned parcels of land.

Key outcomes for the zone are to improve site **ecology**, monitor **channel form**, and improve **activation and connectivity**

Actions

Ecology

1. Weed management, revegetation and stock exclusion
2. Formalise access to prevent unauthorised activities

Activation and Connectivity

3. Bungambrawatha Creek Trail established with potential seating and interpretive signage points

Channel form

4. Monitor outer bend of waterway

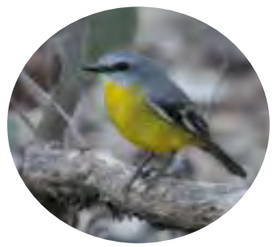


Image of Eastern Yellow Robin
Photo source: Matthew Lincoln

Management Zone 2

The waterway in this reach has been subject to historical deepening and widening, and some channel migration continues with steep embankments being undercut by the waterway in upper reaches. Vegetation is a mix of quality remnant overstorey with grassy understorey, and some areas dominated by weeds including Privet and English Elm. The surrounding freehold land is a mix of Council and privately owned. Objectives for this reach revolve around improved ecology, stabilisation and maintainability.

Key outcomes include improving **ecology**, **channel form** and maintenance infrastructure

Actions

Ecology

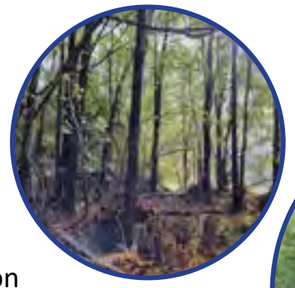
1. Weed management and revegetation
2. Offline ephemeral wetland
3. Collaborate with landholders to undertake weed removal and revegetation
4. Undertake weed removal and revegetation on Council land

Channel form

5. Bank stabilisation
6. Headcut stabilisation
7. Toe of bank protection
8. Bund removal

Infrastructure

9. Improved maintenance accessibility



Management Zone 3

The waterway in this zone has been historically eroded, however is now largely stabilised by dense stands of exotic vegetation. Flooding is a significant concern of local residents who are regularly impacted by flood waters in the reach. Key outcomes sought for the zone are improved **ecology**, **channel form** and **community connection** to the waterway.

Actions

Ecology

1. Staged weed removal and revegetation on Council land
2. Collaborate with landholders to undertake weed removal and revegetation

Maintenance

3. Scour protection & maintenance access

Community connection

4. Develop MOU and partnership with school to improve waterway and aid access for maintenance works along creek line
5. Work with community to ensure no unlawful activities (dumping and filling in and adjacent waterway) that exacerbates flooding

Hamilton Valley Creek

Floodplain management

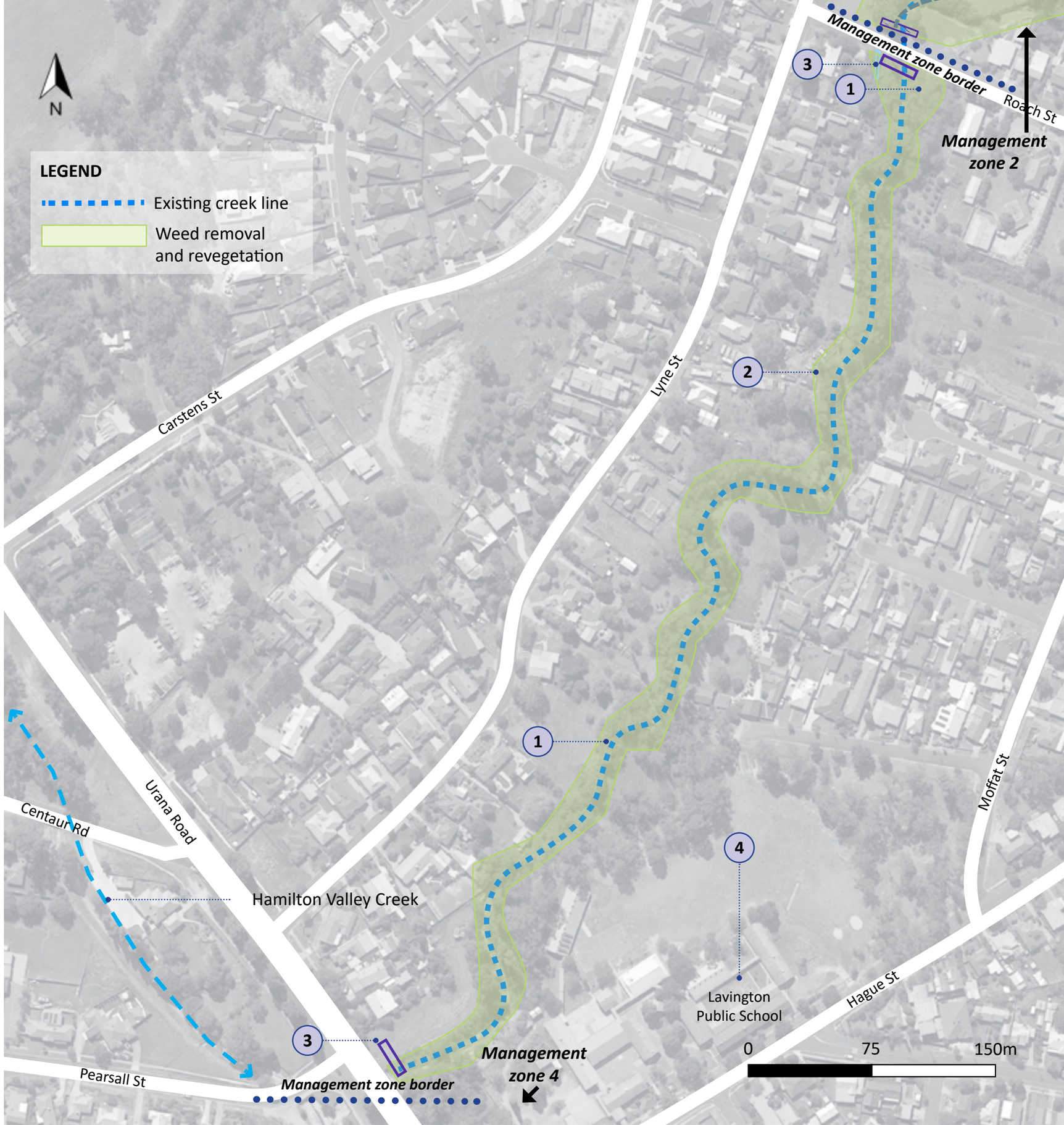
5. Investigate cumulative impact of development on flooding on Bungambrawatha Creek
6. Investigate improved performance of Collins St Basin for flood retardation

Water sensitive urban design

7. Development compliance for flooding, WSUD and erosion control
8. Erosion and sediment control compliance

Community connection

9. Collaborate with landholders to improve waterway stability and improve Council access to the creek for maintenance



Management Zone 4

This zone encompasses Heathwood Park, and is immediately downstream of the confluence of Bungambrawatha Creek with Hamilton Valley Creek. Riparian vegetation on the west bank within Heathwood Park is in good condition, having benefited from community revegetation effort, whilst on the east bank quality remnant trees (River Red Gums) remain, but exotic species dominate in private land. The Bungambrawatha Creek trail commences at Urana Road, and has poor shade coverage through Heathwood Park.

Key outcomes for the zone are to enhance **ecology**, improve the **amenity** of Heathwood Park and useability of the shared path (**activation and connectivity**) through the provision of shade trees and explore opportunities for **water sensitive urban design** for water quality and amenity improvement.

Actions

Ecology

1. Ongoing weed management and revegetation as required
2. Re-establish a Friends of Bungambrawatha Creek to maintain and extend community planting
3. Collaborate with landholders for weed removal and revegetation

Amenity

4. Overstory planting to create shaded pathway

Water sensitive urban design

5. Constructed wetland

Maintenance

6. Maintenance access

All objectives

7. Heathwood Park masterplan to ensure integrate ed and planned out-comes.

Management Zone 5

The Union Road retarding basin dominates this zone, playing an important flood retardation role that protects the Albury City centre from flooding. It is the first section of concrete lined channel, which meanders through remnant vegetation.

Key outcomes are to improve **ecology** and **channel form** through naturalisation, provide improved **activation and connectivity** and investigate enhancements to infrastructure performance.

Actions

Ecology

1. Investigate channel naturalisation aligning with typology 6
2. Offline ephemeral wetlands for improved habitat opportunities
3. Weed control and revegetation on Council land

Floodplain management

4. Opportunity to increase retarding basin capacity to reduce downstream flooding

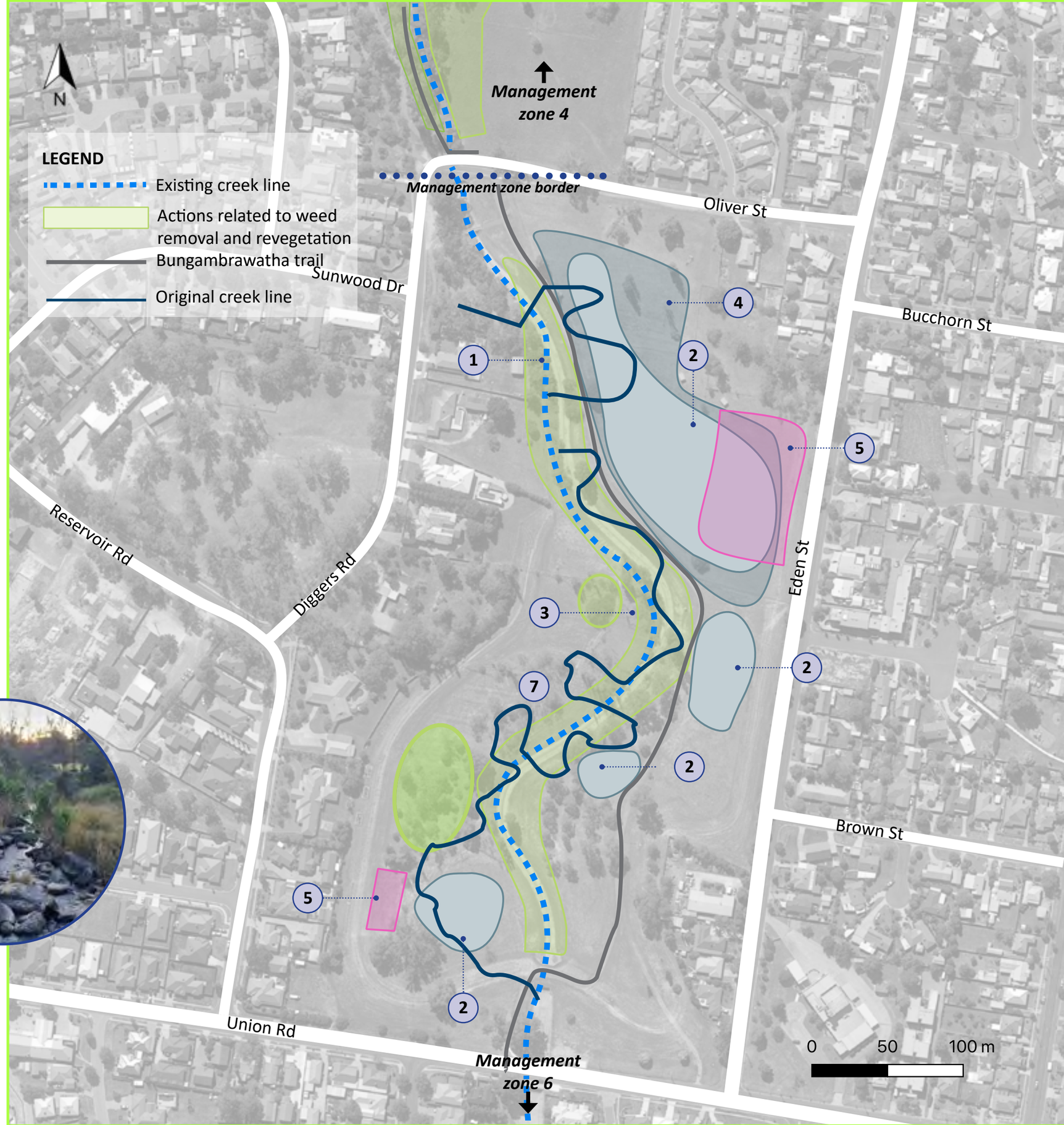
Activation and connectivity

5. Investigate multi-use open space areas
6. Informal kickabout spaces provided

All objectives

7. Union Road basin masterplan

Greenfield Park (sports field)
Photo source: AlburyCity website



Management Zone 6

Encompassing Frederick Park, this zone is concrete lined. Some areas of remnant River Red Gums line the waterway with areas of quality grassy understorey, particularly through Frederick Park. The Bungambrawatha Creek trail generally has good shade cover, and while in a tightly confined corridor (excepting Frederick Park) has a reasonable linear corridor.

Zone intent is to investigate naturalisation opportunities improving **channel form** and improved **ecology** and **amenity** through improved channel-side vegetation management and by adopting **water sensitive urban design.**

Actions

Ecology

1. Weed management and revegetation
2. Low flow directed to naturalised channel
3. Offline ephemeral wetlands for improved habitat opportunities

Water sensitive urban design

4. Swale planting to improve water quality and habitat diversity

Amenity

5. Shade planting
6. Improve channel side typology including weed spraying reduction, revegetation and more attractive fences
7. Lighting to pathway

Channel form

Investigate naturalisation in accordance with typology 1, 2 and 3

8.

Management Zone 6 cont. & 10

Management zone 10 encompasses Little Black Springs Creek. The southern section is concrete lined, whilst the northern section has been dammed, creating a pond. Remnant vegetation occurs adjacent to the pond, however weeds are a notable feature of the zone.

Key management outcomes are to improve the **ecology** of Little Black Springs Creek and **activation** and **connectivity** through the zone.

Actions

Ecology

1. Weed removal and revegetation

Activation and connectivity

2. Formalise path
3. Historic creek line interpretation
4. Improve visual permeability of corridor to discourage anti-socail behaviours.

Amenity

5. Improve channel side typology including weed spraying reduction, revegetation and more attractive fences

Community connection

6. Collaborate with community to manage the corridor, increase activation and public surveillance
7. Activate open space providing community gathering opportunities

Channel form

8. Investigate naturalisation in accordance with typology 1, 2 and 3

The Memory Line is a 2.7 km long band of ryecorn grass that marked the original course of Clear Paddock Creek in suburban Fairfield, Sydney.

Photo credits: Ian Hobbs Media

Management Zone 7

This zone is in the private ownership of the Albury Golf Club. It is the only discontinuous section of the Bungambrawatha Creek Trail that does not run alongside the waterway. Whilst concrete lined, remnant river red gums remain through the zone.

Outcomes sought are to explore ongoing opportunities for **activation and connectivity** and **water sensitive urban design**.

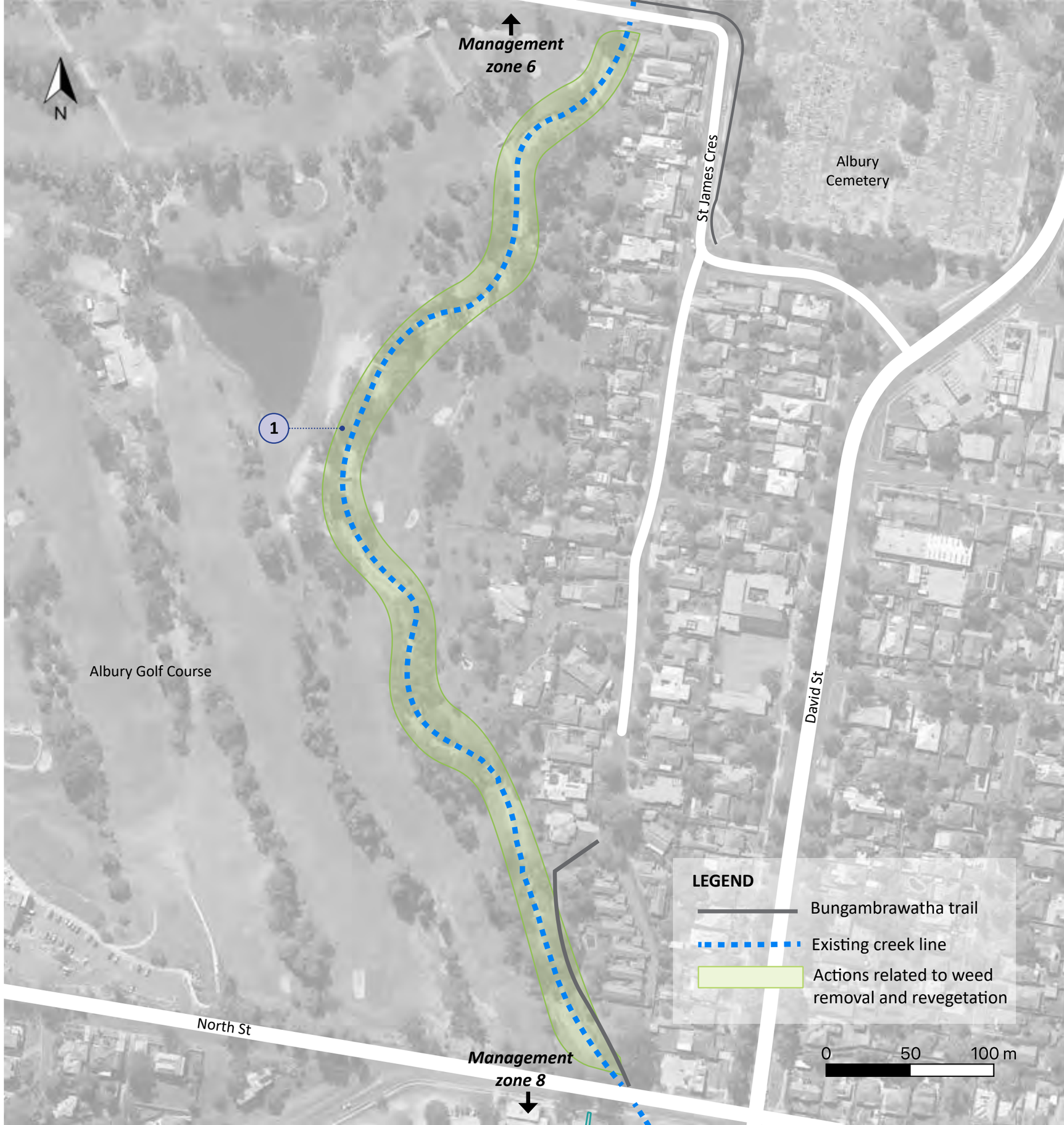
Actions

Water sensitive urban design

1. Engage golf club with a view to exploring opportunities for water sensitive urban design and integrated water management

Activation and connectivity

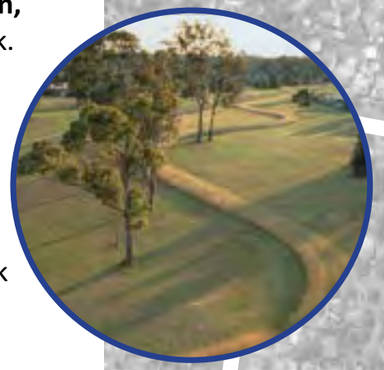
2. Engage with golf club to explore opportunities for improved activation and connectivity through the club grounds.



Management Zone 8

This is the most confined zone of Bungambrawatha Creek, characterised by a highly built up area with a very narrow corridor. The Bungambrawatha Creek trail is squeezed between the channel and property boundaries, with minimal shade cover. Occasional remnant vegetation remains, and there is need for channel renewal courtesy of wash outs behind the wall.

The key outcomes for the zone are to improve **activation, connectivity** and **amenity** along Bungambrawatha creek. Opportunities for improved **ecology** and **channel form** through naturalisation should be investigated further.



Actions

Activation & Connectivity

1. Investigate activation of the western bank with community gardens or go-slow path
2. Incorporate pedestrian bridge
3. Historic creek line interpretation
4. School partnership for shade planting
5. Shade planting over main shared-use path including exploration of opportunities to make room for more trees
6. Explore opportunities for activation, including public art in and adjacent the channel
7. Improve aesthetics of fencing
8. Cantilever deck structure for pathway, allowing additional room to provide landscaping and large trees for shade in shade planting location
9. Consider options to remove pathway from wi-tin the netball courts carpark

Channel form

10. Investigate channel naturalisation in accordance with typology 1 and 2
11. Investigate channel naturalisation in accordance with typology 4

Management Zone 9

One of the most highly visible sections of Bungambrawatha Creek, the channel runs adjacent to the Botanic Gardens before entering the Murray River at the recently constructed Bungambrawatha Creek outfall. Surrounding vegetation ranges from formal plantings associated with the Botanic Gardens to remnant river red gum floodplain vegetation adjacent to confluence with the Murray River.

Key outcomes for the zone are to improve **activation and connectivity** to the Murray River, improve stormwater **infrastructure** and investigate **channel form** improvements including bank stabilization and naturalisation.

Actions

Activation and connection

1. Cantilevered pathway in accordance with typology 5 or remove Dean Street Parking and widen pedestrian pathway
2. Formalise existing pathway
3. Pedestrian bridge under existing Smollett Street bridge
4. English elm removal and terracing in accordance with typology 5

Infrastructure

5. Sediment trap removal to allow fish passage

Channel works

6. Investigate naturalisation in accordance with typology 5 to enhance interface with botanic gardens
7. Bank stabilisation

Management Zone 11

This zone includes Black Springs Creek. The upstream portion of the creek is dominated by dense weed growth, which also acts as a visual screen to the waterway. The downstream portion has a concrete lined low flow channel, with minimal surrounding vegetation.

Key outcomes sought for Black Springs Creek are improved **ecological condition, community and cultural connection,** and **activation and connectivity** of the corridor.

Actions

Ecology

1. Staged weed removal and revegetation
2. Investigate naturalisation

Community

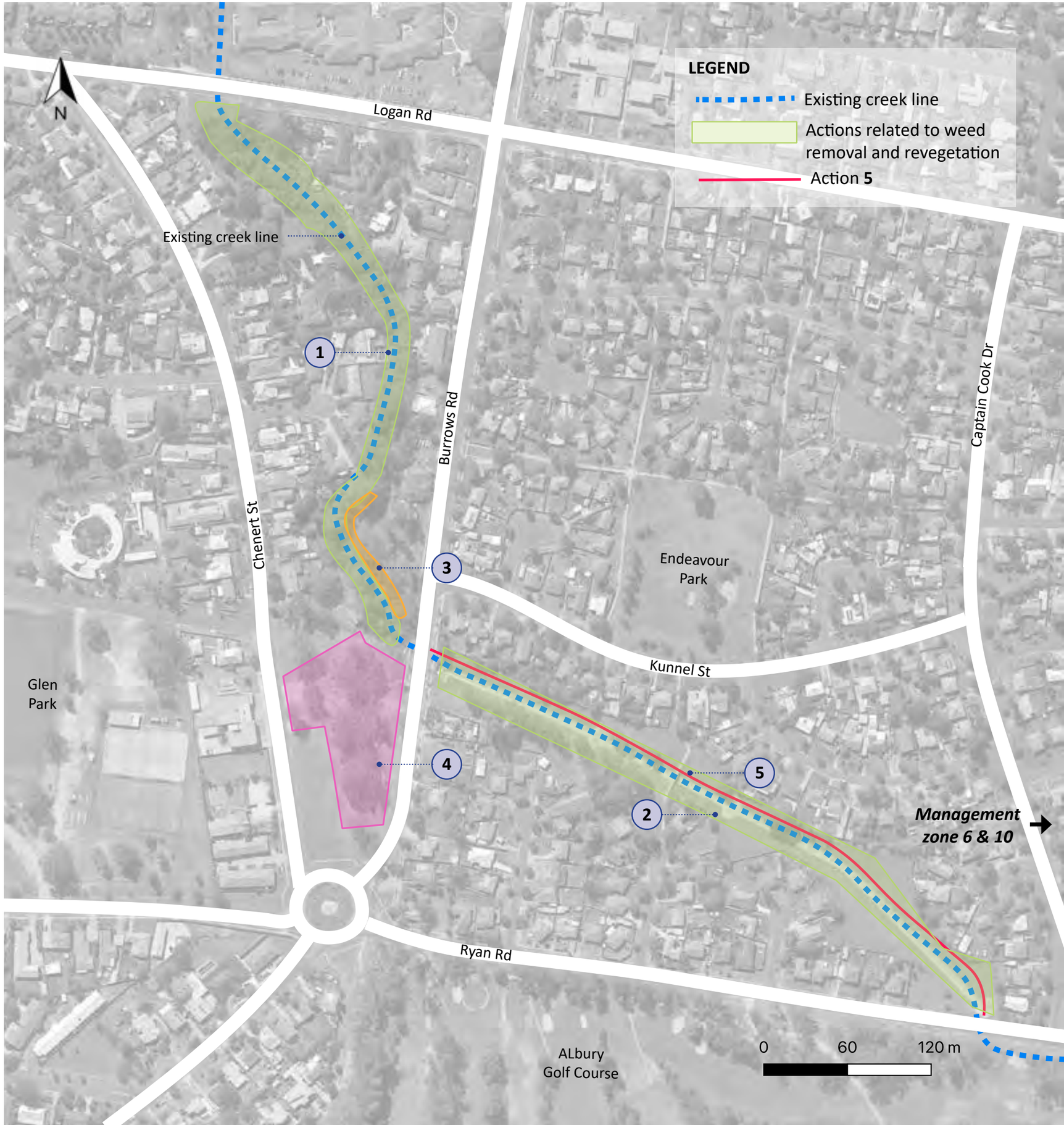
3. Improve visual permeability into the waterway adjacent to community hall

Cultural connection

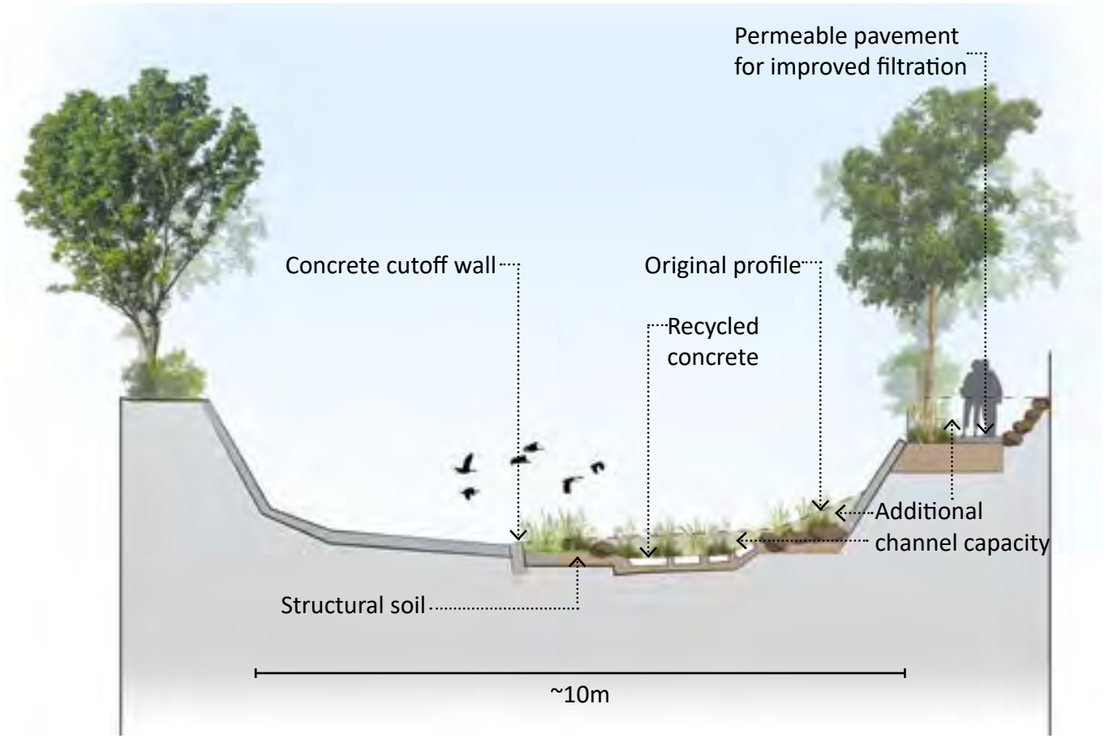
4. Explore opportunities for partnerships with traditional owners and aboriginal groups to activate and manage open space

Activation and connection

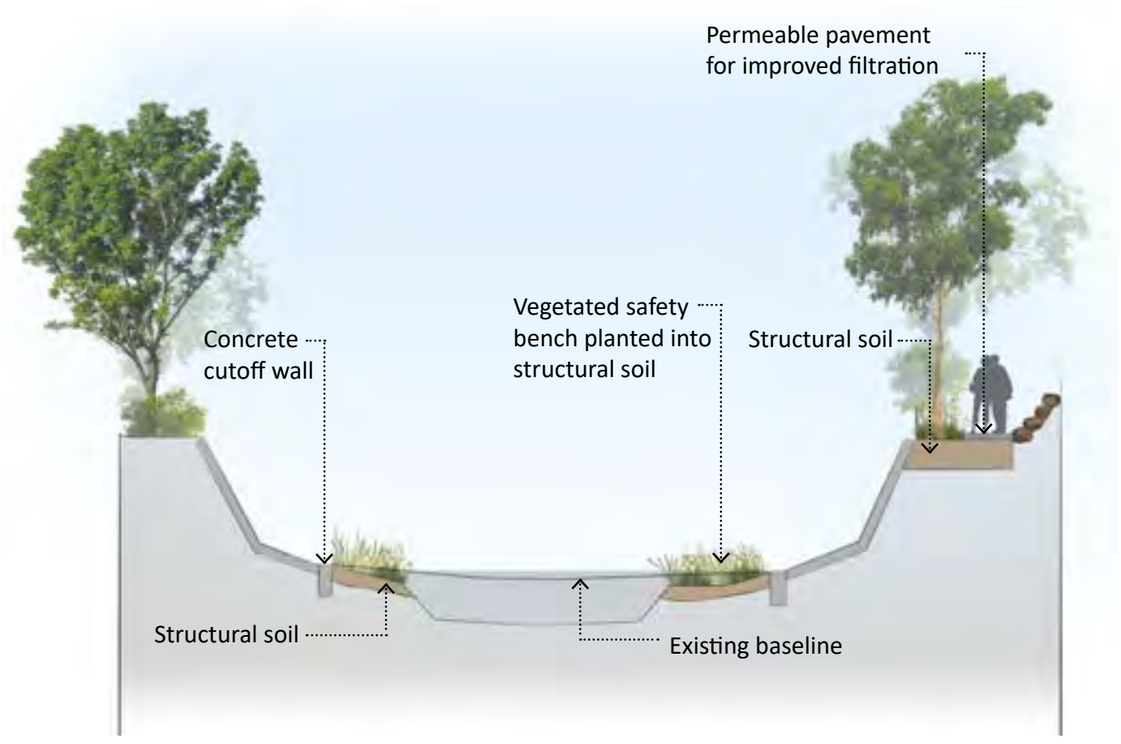
5. Investigate pedestrian connection between Burrows and Ryan Road



Creek Typologies

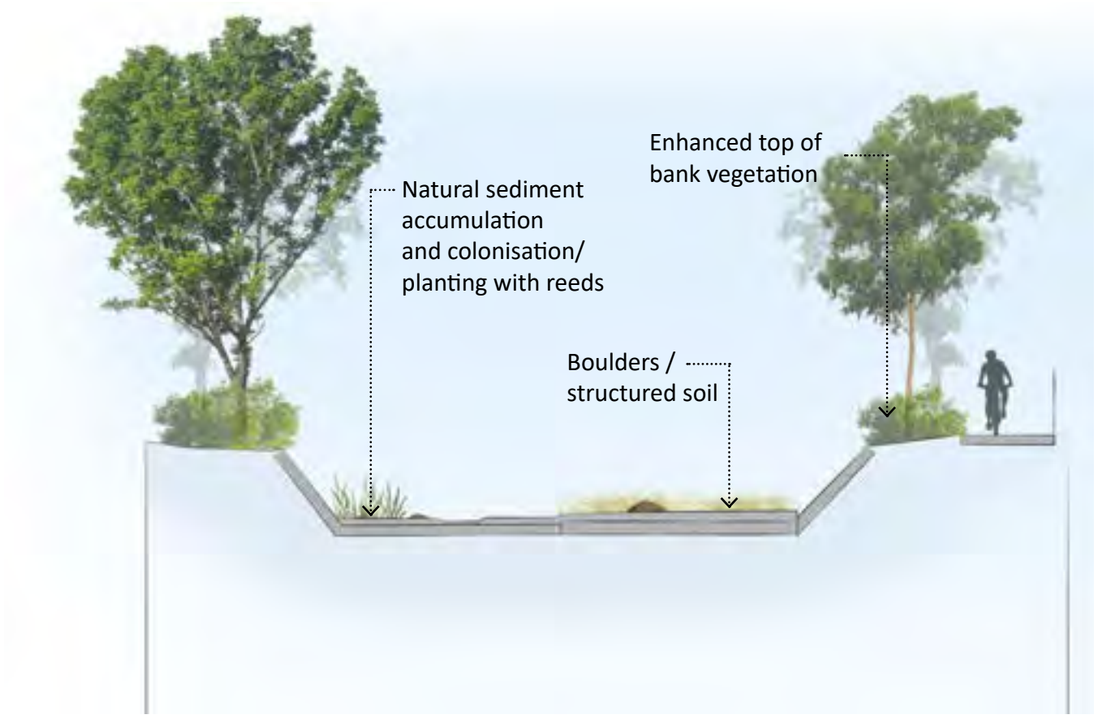


Typology1: Low flow with inset bench channel section

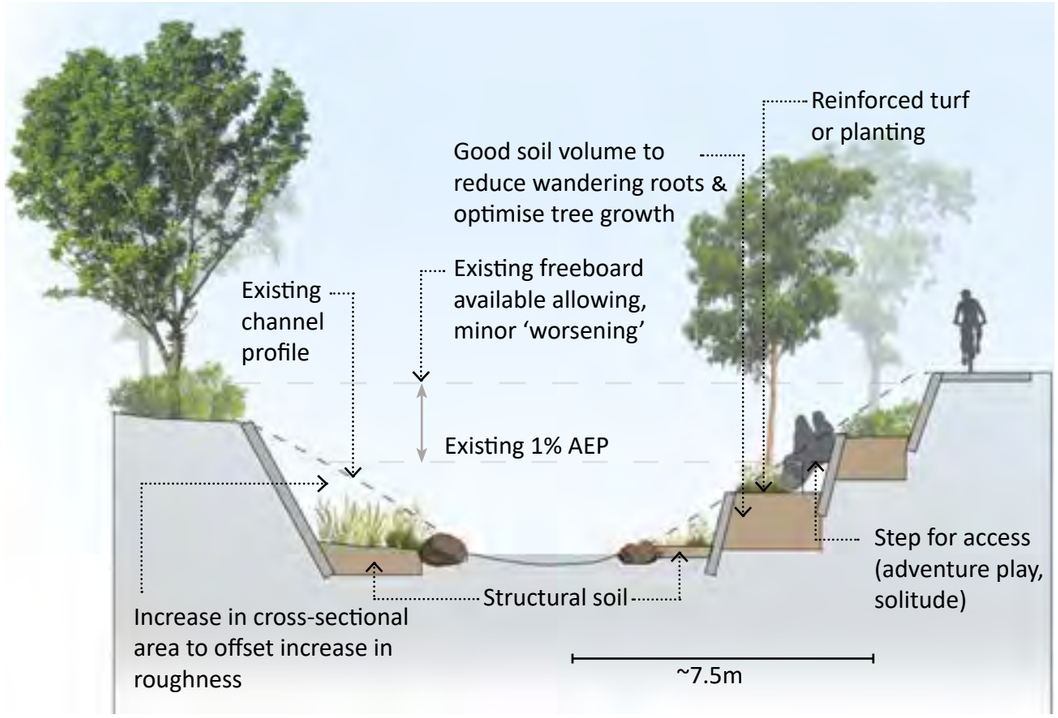


Typology 2: Pond section

Creek Typologies

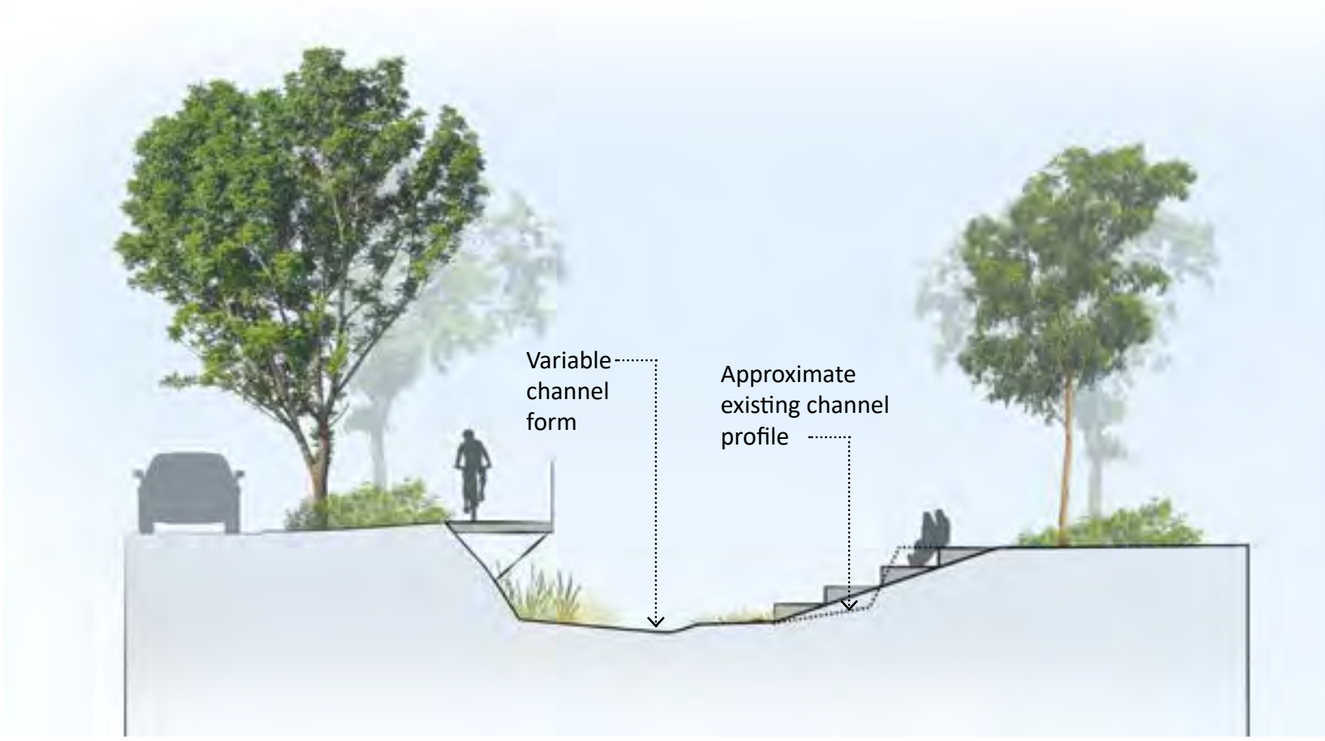


Typology 3: Lighter touch

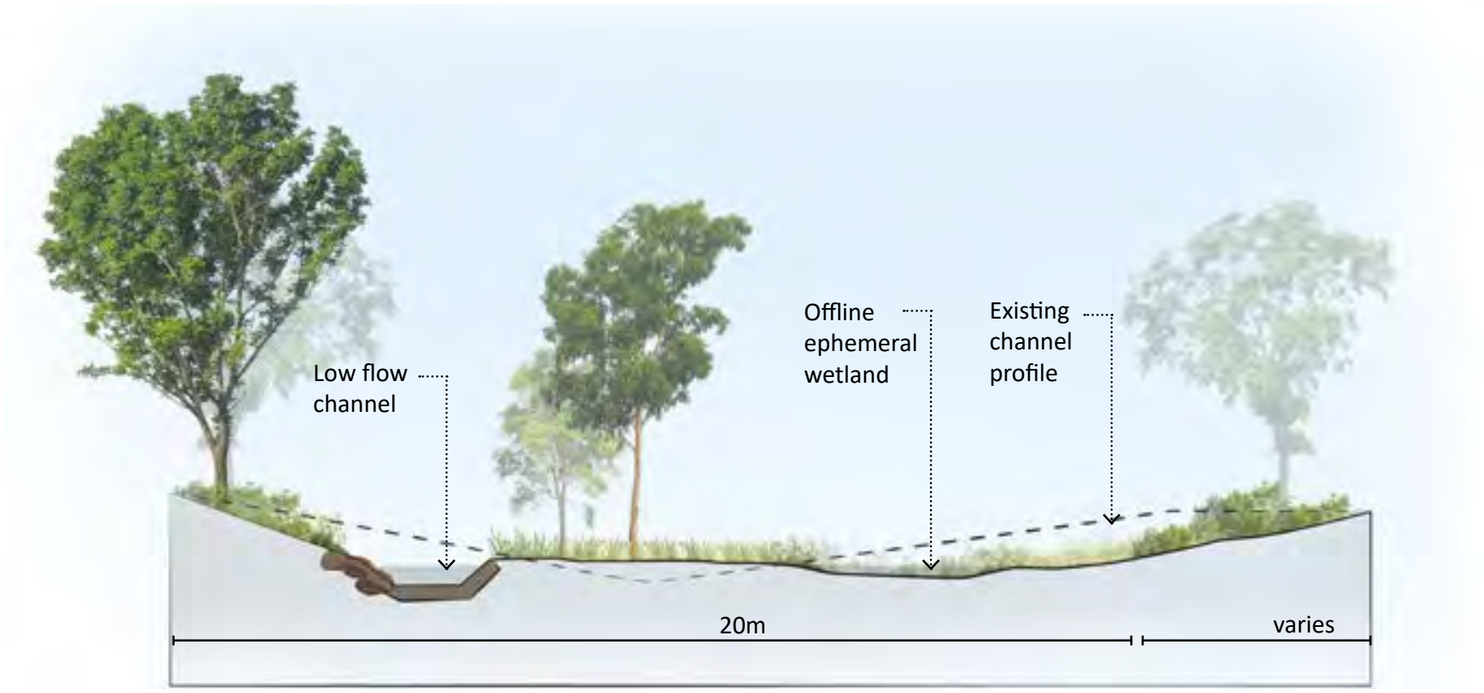


Typology 4: Terraced steppers

Creek Typologies



Typology 5: Cantilevered pathway



Typology 6: Retention Basis Section

Next Steps..

1. Partner with representatives of the Wiradjuri people to facilitate self-determination of their role in respect to the management and representation of culture in the Bungambrawatha Creek corridor.

2. Develop a works program for the implementation of the actions developed for the Bungambrawatha Creek Action Plan.

3. Undertake high revsolution hydraulic model to test the impact of naturalisation on flooding and to investigate ways to provide a stable channel form.

4. Develop a consistent policy position for the management of waterways across the city, including Bungambrawatha Creek.

5. Undertake pilot projects for ‘naturalisation’ to test potential viable forms in low risk locations.

6. Broader catchment stormwater quality improvement plan including opportunties for gross pollutant capture.

7. Consider opportunities for opportunistic land acquisition to improve corridor connecitvity and mitigate flood risk.