Stage 1 - Scoping Report

Bendigo Creek Huntly Common Reserve

Huntly Common Pty Ltd

10 September 2020

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V02	Report	Lachlan Wilkinson	Ben Hughes	10/09/2020
V01	Report	Julian Martin/Ben Hughes	Ben Hughes	22/07/2020

Project Details

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Document Number	20010373_Huntly Common_R01v02.docx

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CONTENTS

1 INTRODUCTION

This report has been prepared by Water Technology on behalf of Huntly Common Pty Ltd. The report provides preliminary advice relating to the feasibility of modifying/rehabilitating Bendigo Creek associated with the proposed gold reclamation and removal of 19th century mining spoil within the Huntly Streamside Reserve, Huntly.

1.1 Overview

It is understood the proposed Huntly Common propose to remove the historic sludge material deposited over the reserve from early gold mining activities, restore the original topography and rehabilitate the watercourses and surrounding floodplain. The sludge material will be processed off-site.

1.2 Locality

The Huntly Streamside Reserve is situated approximately 1.5km west of Huntly (Figure 1-1). The reserve occupies an area of approximately 1.8km^2 between Leans Road at the upstream extent (south) and Millwood Road at the downstream end (north). The Huntly Streamside Reserve is defined as a Public Conservation and Resource Zone and is freely open to the public by both foot and vehicle access. The neighbouring land is designated Farming Zone. Residential development occupies the land between the Farming Zone and the Huntly township.

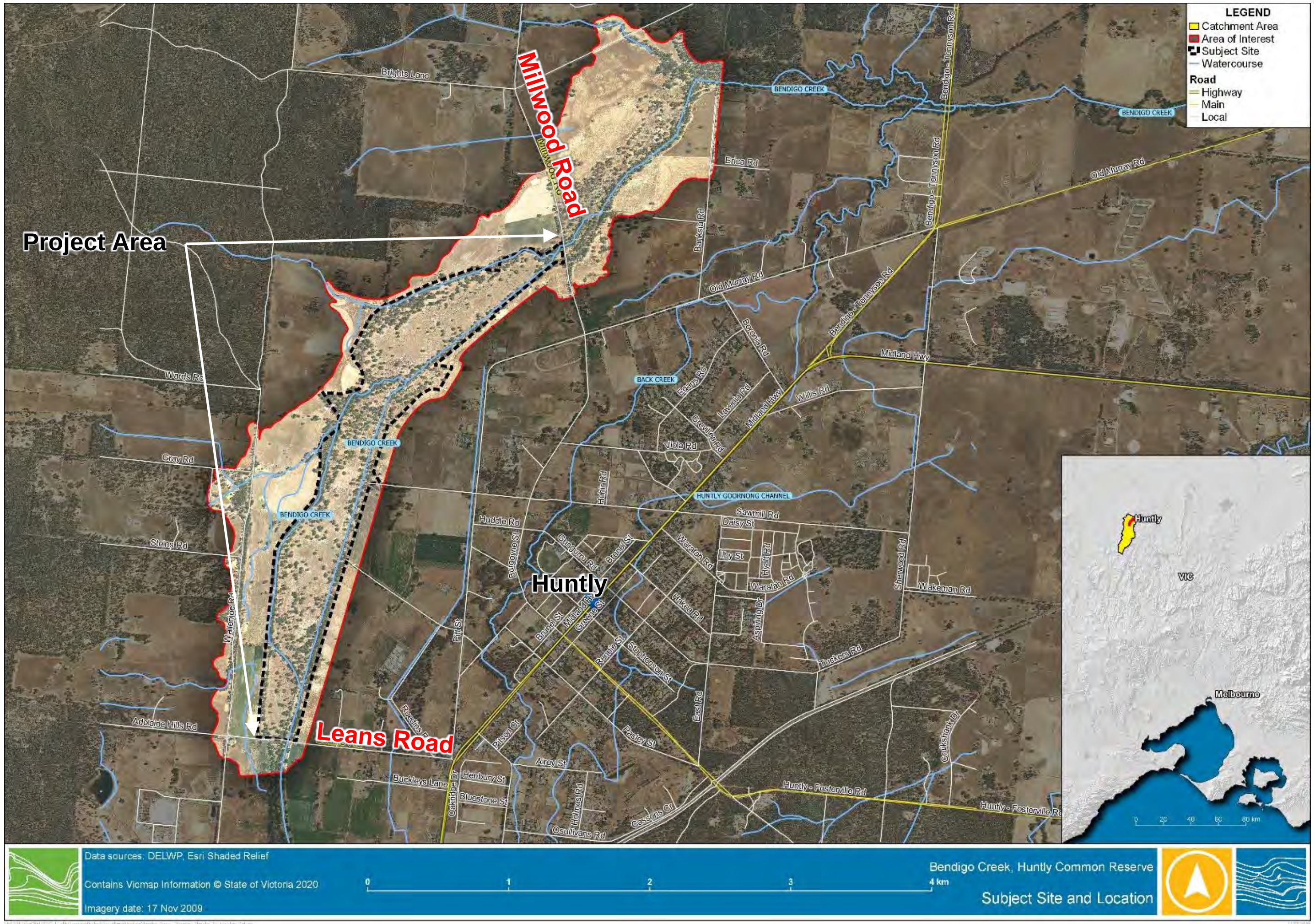

FIGURE 1-1 LOCALITY PLAN

1.3 Project Scope

The aim of this report is to provide surface water and groundwater guidance in relation to the potential modification and rehabilitation of Bendigo Creek associated with the systematic removal of historic mining spoil from the Huntly Streamside Reserve.

Specifically, the scope of this project is considered Stage One of a multi-stage project, leading to the identification of a preferred detailed design arrangement for Bendigo Creek and its surrounding floodplain within the affected Huntly Streamside Reserve. The following summary outlines the broad project stages envisaged to successfully identify the preferred detail design arrangement. Note that the specific tasks may be subject to change depending on the findings of the preceding tasks. It is envisaged that each stage will represent project hold points. It is anticipated that consultation between the project stakeholders and interest groups will be incorporated into the project at key project milestones.

1.3.1 Stage One – Baseline Condition and Scoping Assessment

This stage forms the **current project scope** and broadly comprises the following tasks:

- Identification of a baseline waterway and floodplain condition and function within the nominated project extent.
- Identification of proposed works extent and methods.
- Identification of relevant plans and strategies.
- Identification of design objectives, philosophies and constraints.
- Identification of permit requirements.
- Identification of knowledge gaps and data requirements.

The Baseline Condition and Scoping Assessment was informed by a site assessment undertaken in the 3rd June 2020.

1.3.2 Stage Two – Concept Design Analysis

The Baseline Condition and Scoping Assessment will lead to the identification of design objectives, philosophies and constraints in the selection of a preferred waterway arrangement. With reference to this information in combination with other key outputs derived in Stage One, the Concept Design Analysis stage will generally be inclusive of the following tasks:

- Identification of preferred channel alignments and arrangements. Typically, there is more than one concept design arrangement that is identified and assessed, which inherently results in an iterative design process. Information identified in this task is generally inclusive of:
  - Channel planform location.
  - Floodplain arrangement.
  - Key in-channel features and geometric arrangements (e.g. cross section dimensions, longitudinal slope, inlet and outlet arrangements to surrounding sections of the creek and tributaries.
  - The preparation of plans and maps in relevant software packages.
  - Preliminary material cut and fill and cost estimates.
- Hydraulic modelling to inform the selection of the preferred design arrangement, including an assessment of channel capacity, erosion risk, flood risks.

- An assessment of potential temporary channel and floodplain arrangements to facilitate flows through the works area during the construction stage. This will necessitate preferred channel alignments and arrangements as outlined above.
- The selection of a preferred design arrangement to take to detailed design.
- Identification of knowledge gaps and data requirements required to prepare the detail design.
- Project reporting developed with reference to the permit requirements.

1.3.3 Stage Three – Detail Design Analysis

Upon the selection of a preferred design arrangement, a detailed design shall be prepared. The key project tasks associated with this stage will likely include:

- Hydraulic analysis of the final design arrangement to demonstrate in-channel and floodplain flow characteristics and changes compared to the existing conditions.
- The preparation of design drawings and reporting inclusive of:
  - Drawings of works for inclusion (e.g. river morphology, habitat types and arrangement, infrastructure and public access etc).
  - A description of relevant design elements.
  - Proposed staging and hold points.
  - Cost estimates and works schedules for completion of works with itemised materials including revegetation requirements.
  - Recommendations for future work to inform implementation.
  - A monitoring and maintenance program with recommended monitoring and maintenance methods, including the timing and frequency of monitoring events and maintenance works.

2 PROJECT CONTEXT

2.1 Proposed Reclamation

I It is understood the proposed Huntly Common propose to remove the historic sludge material deposited over the Huntly Streamside Reserve from early gold mining activities, restore the original topography and rehabilitate the watercourses and surrounding floodplain. The sludge material will be processed off-site. The proposed works extent incorporates the Huntly Streamside Reserve between Leans Road at the upstream extent and Millwood Road at the downstream end.

2.2 Re-imagining Bendigo Creek

The Re-imaging Bendigo Creek Plan (Figure 2-1) is a strategic plan that was adopted by the City of Greater Bendigo Council in June 2020 that will be of guidance to the proposed works arrangements. The Draft Plan can be accessed from the City of Greater Bendigo's web site here (https://www.bendigo.vic.gov.au/sites/default/files/2020-06/Reimagining-Bendigo-Creek.pdf).

FIGURE 2-1 REIMAGINING BENDIGO CREEK DRAFT PLAN (CITY OF GREATER BENDIGO, 2020).

The Re-imaging Bendigo Creek Plan aims to:

- Create a single, shared vision and strategic plan for the Creek's future in the interest of Traditional Owners and the Greater Bendigo community.
- Restore the health of Bendigo Creek, including its tributaries and catchment area.

The Plan was developed collaboratively between the City of Greater Bendigo, Dja Dja Wurrung Clans Aboriginal Corporation, Department of Environment, Land, Water and Planning (DELWP), North Central Catchment Management Authority (NCCMA), Coliban Water, Department of Health and Human Services, Goulburn Murray Water, Parks Victoria, and the local community.

The Plan identifies a series of Goals and associated strategies for the Bendigo Creek. These goals and strategies are reproduced in Table 2-1.

TABLE 2-1 GOALS AND STRATEGIES FOR BENDIGO CREEK, REPRODUCED FROM THE REIMAGINGING BENDIGO CREEK DRAFT PLAN (JUNE 2020).

Goal	Strategy
A healthy Bendigo Creek by improving the catchment and creating flood resilient communities	Limit the impact of climate change with water sensitive urban design and traditional ecological knowledge
	Manage flood risk with appropriate infrastructure, landscape treatments and community preparedness
	Restore the aquatic habitat and ecosystem functions of the Creek and tributaries
	Improve how our city landscape relates to the Creek and tributaries
Bendigo Creek forms a continuous and integrated public space network for our community to enjoy and move freely through	Connect places and spaces with a network of accessible public corridors
	Improve the Creek's corridor access
	Increase Creek-based interaction and recreation opportunities
	Create a safe Creek environment for everyone
Bendigo Creek embodies our diverse cultures and is actively cared for by the Community	Empower Dja Dja Wurrung Traditional Owners to practice their Cultural traditions and promote their cultural and spiritual connections to the Creek
	Promote positive community perceptions of the Creek
	Foster community caring for the Creek
	Strengthen the diversity of experiences along the Creek

The Plan subsequently separates Bendigo Creek into four Precincts, where these strategies shall be applied. The project area is encompassed within Precinct Four – Epson to Huntly, which extends from Howard Street Epsom through to the Bendigo – Tennyson Road, Huntly. The Plan specifically lists the following intended Plan outcomes for the Huntly Streamside Reserve following the successful implementation of the creek-wide strategies (summarised Table 2-1):

- The cultural heritage significance of this part of the creek to the Dja Dja Wurrung is respected and strengthened by supporting cultural practice and sharing stories, ceremony and culture through education programs, art and interpretive signs.
- Walking and cycling access is improved to and within the Huntly Streamside Reserve, and its expansive area is used to create an immersive, enriching experience of nature, wildlife, water and Aboriginal cultural heritage.
- The crucial ecological, cultural, educational and recreational functions of the Huntly Streamside Reserve are supported with appropriate joint-management and resourcing.
- Environmental education is supported by interpretive walks and information signs.
- The management of vehicle access is improved.
- Pest plants and animals are being effectively managed.
- A visitor experience plan for Huntly Streamside Reserve has been developed.
- The creek has a chain of ponds and riffles to support wildlife and increase amenity.
- Biolinks / wildlife corridors between the Reserve and the Greater Bendigo National Park and Greater Bendigo Regional Park are protected.

2.3 Stakeholder Authorities and Special Interests Groups

There are numerous stakeholder Authorities and Special interest groups that are relevant to the proposed works and project area. The Re-imaging Bendigo Creek Draft Plan provides a summary of these Authorities and special interest groups. A concise summary of the key stakeholder Authorities and Special interest groups is provided in the following paragraphs and is inclusive of information provided in the Re-imaging Bendigo Creek Plan Draft Plan.

The **Dja Dja Wurrung** are the Traditional Owners of Dja Dja Wurrung Country in central Victoria. One of their key visions is stated as being:

For our lands and waters to be in good condition and actively managed to protect our values and promote the laws, culture and rights of all Dja Dja Wurrung People.

The Dja Dja Wurrung Country Plan 2014 – 2034 (Dja Dja Wurrung, 2014) states that Traditional Aboriginal culture revolved around relationships to the land and water, relationships that hold deep physical, social, environmental, spiritual and cultural significance. Today, the land and its waterways remain central to our cultural identity and aspirations for community and economic development. Our rivers are the veins of Country, and provide food and medicine, and places to camp, hunt, fish, swim and hold ceremonies. They are places that are central to our creation stories, and many of our cultural heritage sites are associated with waterways – burial sites, birthing sites and middens. Our waterways are places that we connect with our ancestors and pass traditional knowledge on to our children and grandchildren.

The Dja Dja Wurrung Country Plan identifies as a goal (Goal 6) to make our upside-down country healthy again. The Plan goes on to state that in the mid-1800s, large deposits of gold were discovered in our Country, enticing flocks of people looking to make their fortune. The miners cut down trees for firewood and building, diverted creeks and rivers and dug holes in the ground, pulling up large volumes of earth. Since that time, mining has been constant in Dja Dja Wurrung Country. This has left a legacy of soil erosion, salinity and toxicity from contaminants such as arsenic and mercury. The country around the goldfields is very sick and a significant program of remediation is required. As custodians of all Dja Dja Wurrung land, we feel a deep responsibility to heal this Country so that it can be healthy and functioning once again.

The **North Central Catchment Management Authority (North Central CMA)** is responsible for co-ordinating integrated catchment management and sustainable land and water use across North Central Victoria, which is inclusive of the project area. The work of the North Central CMA is guided by the Regional Catchment Strategy and North Central Waterways Strategy.

The North Central CMA are the applicable Authority responsible for the assessment of Works on Waterways Application at the subject site. As such, the CMA will require that a Works on Waterways Application be submitted (and subsequently a permit issued) to ensure that the proposed design arrangement does not adversely affect river health.

The Re-imaging Bendigo Creek Plan states that the **City of Greater Bendigo** has a large overall responsibility for managing the waterway which encompasses extensive Creek lands and includes major infrastructure assets. **Parks Victoria** also have a significant land management role and the **Department of Environment, Land Water and Planning** manages several sites also. **Coliban Water** manages significant underground pipelines adjacent to and within the Bendigo Creek. In addition to the previously listed Authorities, **Goulburn Murray Water** and the **Environment Protection Authority** provide regulatory Authority role.

Importantly, the Re-imaging Bendigo Creek Plan acknowledges that there are several community groups, including the **Northern Bendigo Landcare Group** that have an active interest and role in caring for the Creek (Figure 2-2).

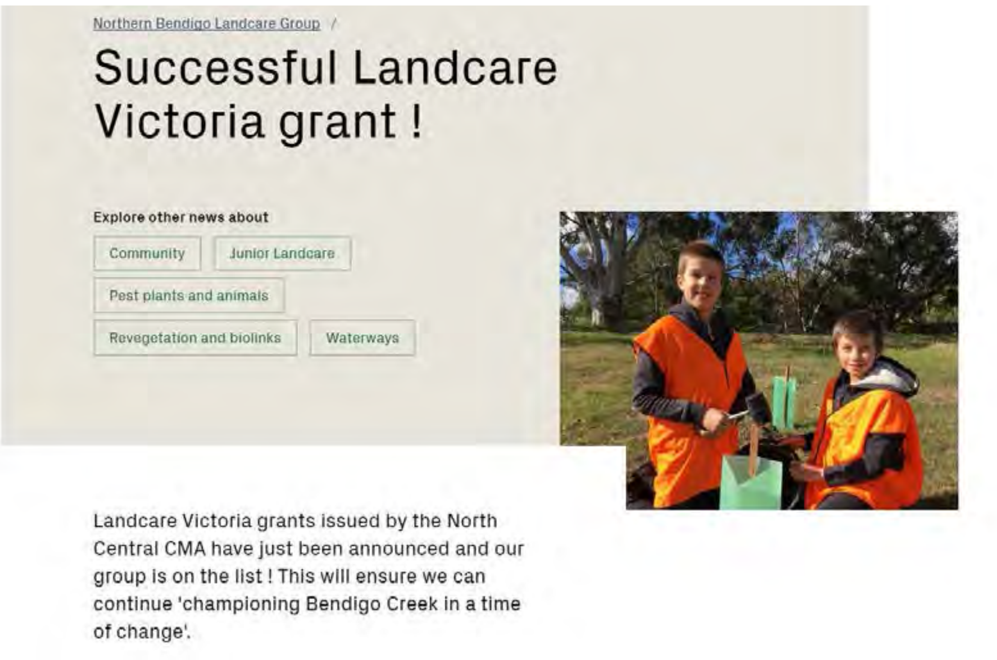

FIGURE 2-2 THE NORTHERN BENDIGO LANDCARE GROUP ARE AN EXAMPLE OF AN ACTIVE COMMUNITY GROUP ALONG BENDIGO CREEK IN HUNTLY. SOURCE: HTTPS://WWW.LANDCAREVIC.ORG.AU/GROUPS/NORTHCENTRAL/NORTHERN-BENDIGO/SUCCESSFUL-LANDCARE-VICTORIA-GRANT/.

3 REACH CONDITION

3.1 Site Arrangement

The proposed extraction extent occupies an area of approximately 1.8km^2 within the Reserve, between Leans Road at the upstream extent and Millwood Road at the downstream end. There are three primary channels that enter the Reserve at the upstream end (Leans Road), which form part of the Bendigo Creek channel network within the project area. Each of the channels pass through a concrete culvert beneath Leans Road and have been artificially channelised both within and surrounding the Huntly Streamside Reserve. The channel network is summarised as follows (Figure 3-4 and Figure 3-2):

- The primary Bendigo Creek channel is a straight, artificially constructed channel that has been positioned against the eastern edge of the Huntly Streamside Reserve. The channel extends for approximately 4.2km in length between Leans Road at the upstream extent and Millwood Road at the downstream end. This channel conveys low flows in Bendigo Creek.
- An artificial levee is positioned a short distance back from the eastern bank of Bendigo Creek. The levee, constructed of mine tailings, was installed to provide flood protection to the eastern side of the creek, including the Huntly township.
- A secondary channel, incorporating a higher channel invert and smaller channel dimensions exists on the western side of the primary Bendigo Creek channel. This secondary channel runs parallel with, and approximately 40m from the primary channel for approximately 500m downstream of Leans Road. The channel subsequently changes direction towards western side of the Streamside Reserve where it enters the third channel, situated against the western edge of the Streamside Reserve.
- The third channel is positioned against the western boundary of the Streamside Reserve. The channel extends for approximately three kilometres in length, before entering the Bendigo Creek primary channel. This channel receives inflows from the local catchments/tributaries on the western side of the creek. A pipe outlet was observed on the bank face. The outlet appears to discharge flows from a dam on the western side of the channel, a short distance downstream of Leans Road.
- A small tributary stream, originating within the Greater Bendigo National Park, enters the Reserve from the western side towards the downstream end of the reach. This tributary subsequently joins Bendigo Creek approximately 140m upstream of Millwood Road.

FIGURE 3-1 SITE LAYOUT.

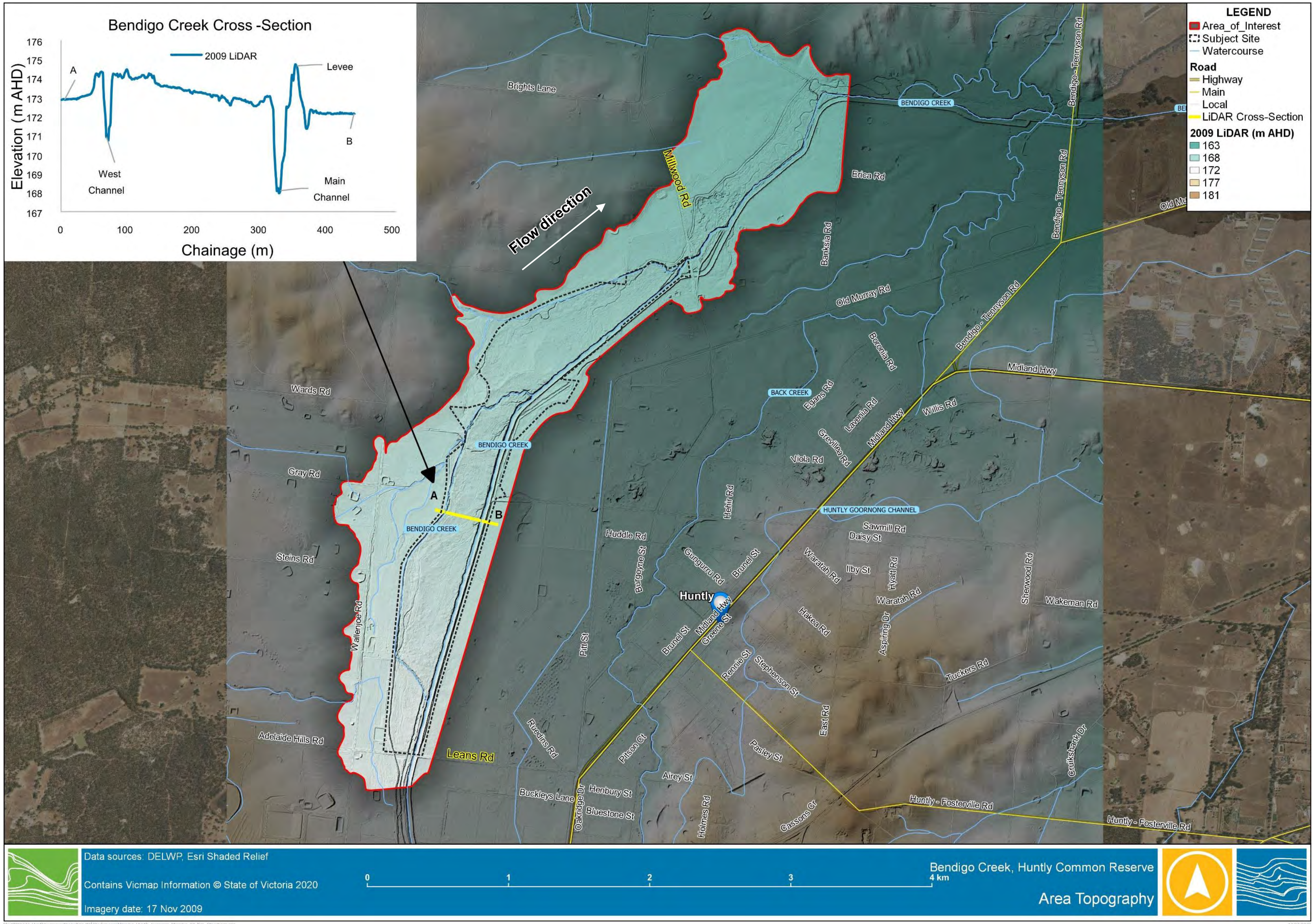

FIGURE 3-2 LIDAR IMAGE OF THE SUBJECT REACH.

3.2 Geomorphic Overview

The Bendigo Creek catchment originates in the Big Hill Range south of Kangaroo Flat. Both Bendigo Creek and its tributaries flow in a northerly direction through the Central Business District of Bendigo and its surrounds, adjoining residential, commercial, industrial and open space areas. The creek continues to flow in a northerly direction towards Huntly where it transitions into a rural landscape. Bendigo Creek eventually merges with Myers Creek and Mount Hope Creek. Mount Hope Creek subsequently flows into Kow Swamp.

3.2.1 Pre-European Condition

Prior to European settlement Bendigo Creek (within and surrounding Bendigo) is believed to have been a Chain-of-Ponds watercourse. That is, the creek form comprised a series of discrete swamp ponds separated by swampy depressions where a channel was either typically absent or poorly defined. The Reimagining Bendigo Creek, Issues and Opportunities Report (July, 2019) describes that through both Indigenous and European observations, that Bendigo Creek consisted of a connected and meandering chain of clear pools, varying in depth and some of which are likely to have included permanent water. A sketch map, drawn by a miner William Sandbach (reproduced in Figure 3-3) provides an insight into the physical form of Bendigo Creek, prior to widespread disturbance associated with historic mining and settlement. Due to anthropogenic influences such as land clearing and channelisation, Chain-of-Ponds watercourses are now quite rare in the south-east Australian landscape.

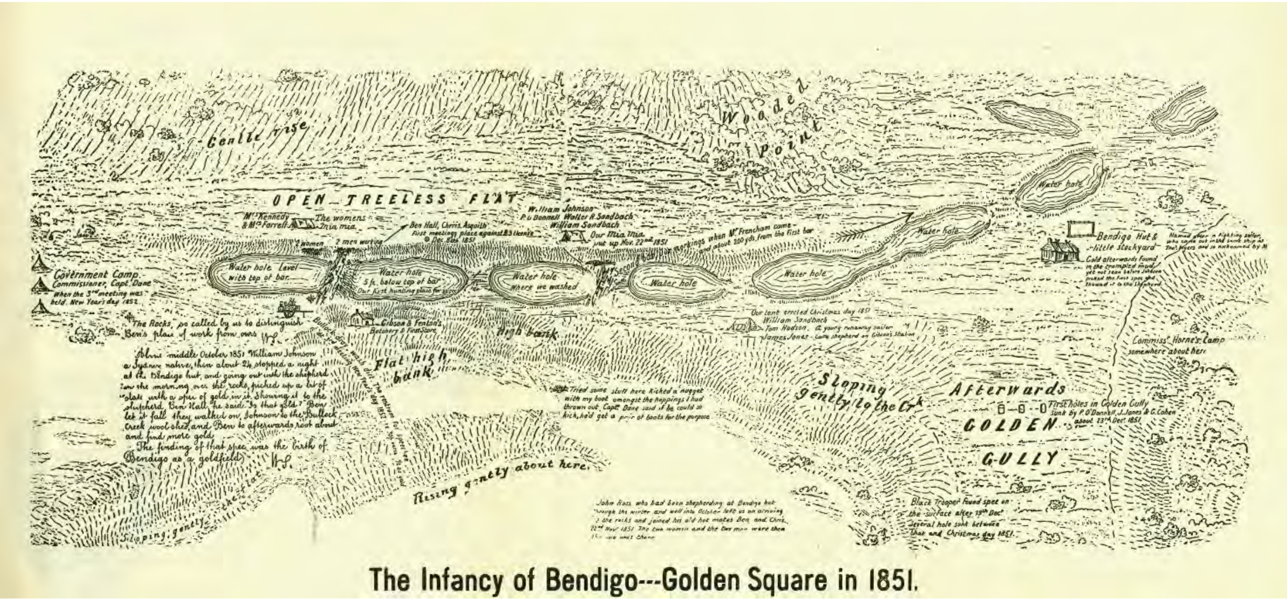

FIGURE 3-3 HAND DRAWN MAP OF BENDIGO CREEK, SKETCHED BY WILLIAM SANDBACH (CULTURE VICTORIA, 2018).

3.2.2 Post European Influences

Bendigo Creek has been subject to substantial physical, ecological and hydrological changes following European settlement. The Reimagining Bendigo Creek, Issues and Opportunities Report (July, 2019) provides a succinct summary of the timeline of the key events that influenced these changes. A short description of these changes, with reference to the impacts to Bendigo Creek are summarised below.

- **Gold Mining** commenced within the Bendigo Creek catchment area in 1851. These works involved alluvial mining, puddling, broadscale excavation and sluicing. These works completely altered the catchment characteristics through:
  - Physical changes to Bendigo Creek and the tributary watercourses.
  - Removal of native vegetation.
  - The liberation of large volumes of sediment into downstream reaches.
  - Changes to the catchment hydrology.
- **Urbanisation and creek channelisation**. The on-going requirement to manage sediment (commonly referred to as sludge or tailings) liberated from mining activities, combined with development (e.g. roads, houses, buildings etc.) led to the artificial channelisation of Bendigo Creek, which commenced in approximately 1859. In its current form, Bendigo Creek has been substantially modified by channel deepening, widening and concrete or stone lining, forming a constructed drain for much of its length through Bendigo. Whilst the vast quantities of sediment liberated through mining activities have now ceased, the impacts associated with mining deposition (sludge) in downstream reaches, urbanisation and channelisation remain.

  Urbanisation has a number of impacts on stream processes, in particular by altering the flow characteristics within a stream. These impacts include:
  - The clearance of native vegetation across the catchment area and subsequent construction of largely impermeable infrastructure such as roads and houses, leading to an increase in the volume of run-off that enters the stream.
  - The time of concentration of the catchment (the time it takes the catchment to reach peak run-off during a rainfall event) decreases, resulting in a more rapid rise in water levels and higher peak flows. This is exacerbated by the hydraulically efficient straight, concrete and stone lined sections of waterway.

  Urbanisation of the Bendigo Creek catchment has likely increased run-off volume to the waterway. This change can potentially lead to degradation (incision/erosion) of the stream bed. This channel adjustment occurs to accommodate the increased peak flows within the channel. Evidence of channel incision is present within the project area.

  Urbanisation is also likely to have altered sediment supply to the reach, in turn altering the rate and trajectory of bed degradation. Historically, sediment inputs into Bendigo Creek increased due to mining, the removal of vegetation and urbanisation. However in the longer term (and post mining), an increase in impervious surface areas leads to a reduction in the available sediment that may be eroded from a catchment and thus, urban streams will experience a decrease in sediment loads (Wolman, Dawdy, Ferguson and Sucking, cited in Niezgoda and Johnson, 2005).

3.2.3 Observed Geomorphic Processes

Active erosion processes are evident within the project area. Most of these processes are influenced by the channelisation of the creek, the post European influences outlined in Section 3.2.2 and the absence of a continuous riparian vegetation corridor. An overview of each relevant erosion process is given in the following sections.

3.2.3.1 Bed Level Lowering

Commonly, bed level lowering (incision) occurs through a process called head-cut migration (or knickpoint regression) and is a common response to the artificial channelisation of a watercourse. Head-cut migration presents as an abrupt change in channel slope, similar to small waterfalls or cascades within the channel

(Schumm, 1977) (Figure 3-4). A small plunge pool may be present at the base of the head-cut due to the higher energy of falling water. This is particularly common in steeper channels.

Head-cut erosion occurs in an upstream direction. In general, after a head-cut forms, it will continue to migrate upstream until it reaches either the head of the catchment or a solid barrier (e.g. a rock bar, road crossing). That is, without physical intervention within the watercourse, the head-cut will continue to migrate, and the watercourse will continue to deepen and subsequently cause channel widening (Booth, 1990). This has the potential to impact on infrastructure that is aligned with the current bed elevation.

As channels deepen, the water flowing into the watercourse from overland flow paths (tributaries or concentrated runoff) must fall greater distances into the watercourse. This creates a break in slope and leads to the formation of a head-cut into the floodplain (Figure 3-5). Head-cuts can retreat into the floodplain rapidly, particularly during high rainfall events. This process, commonly referred to as alluvial gullying, will continue to erode into the floodplain until it meets an erosional barrier (e.g. erosion resistant substrate such as bedrock).

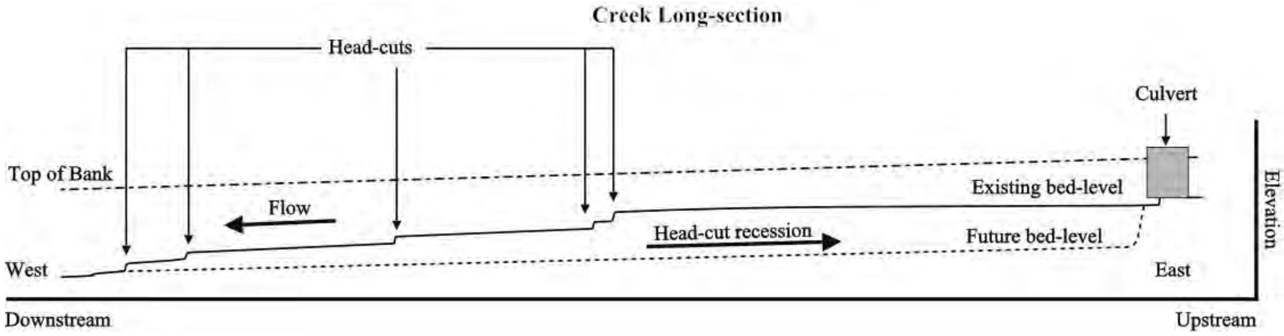

FIGURE 3-4 CONCEPTUAL DIAGRAM OF KNICKPOINT RECESSION SHOWING HEAD-CUTS MOVING UPSTREAM.

Bed level lowering is a means by which a stream channel reduces its bed slope and thus its erosive power. Over time, it is expected that the channel network will reach a state of quasi-equilibrium. Schumm *et al*. (1984) derived a model of channel evolution relating to incised streams (Figure 3-6). According to this model, many of the reaches inspected along the primary channel are typically at Stage 3 and 4 of this evolutionary cycle, whereby the channel is subject to bed deepening and associated channel widening (Stage 3) or aggradation and widening (Stage 4). The model suggests that over time (decades to centuries) the channel is expected to form a modified channel shape and reattain bed and bank stability. It is also expected that the inset floodplains formed within the macro channel will capture and retain sediments transported by the stream from upstream reaches (Stages 4 and 5 in Figure 3-6).

FIGURE 3-5 AN EXAMPLE OF A HEAD-CUT OCCURING INTO THE FLOODPLAIN IN RESPONSE TO DEEPENING WITHIN THE TRUNK STREAM.

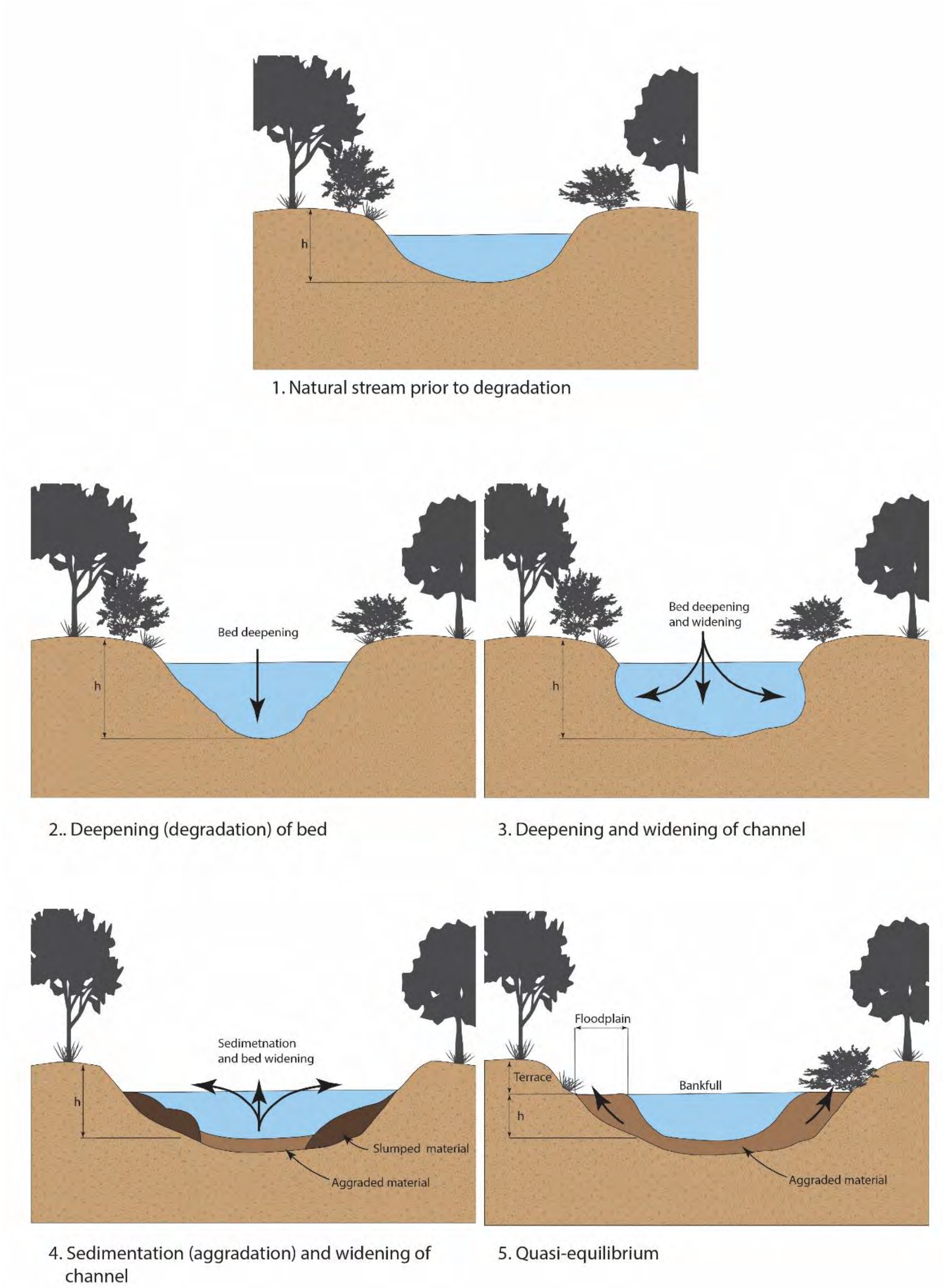

FIGURE 3-6 THE EVOLUTION OF AN INCISED CHANNEL DEVELOPED BY SCHUMM *ET AL.* (1984).

3.2.3.2 Channel Widening and Enlargement

Channel enlargement primarily occurs through bed level lowering, a process in which the bed-level is lowered through erosion (Section 3.2.3.1). This can occur for many reasons and can have several effects on bank stability, in-stream geomorphic diversity and floodplain hydrology. It is almost always accompanied by channel widening as the steepening banks collapse (Figure 3-7). Hence, bed level lowering combined with channel widening results in the enlargement of the overall channel area. As a consequence of the increased channel capacity within this reach, flow events of considerable magnitude remain in-channel, resulting in increased hydraulic forces (stream powers and shear stresses) that are expended as erosive energy on the channel bed and banks.

FIGURE 3-7 DOWNSTREAM VIEW OF BENDIGO CREEK WHERE CHANNEL WIDENING HAS OCCURRED.

3.2.3.3 Bank Erosion

Bank erosion can occur in response to several different processes and can present in a variety of forms. Toe erosion of banks, particularly on the outside of meander bends (meander extension), was a commonly observed form of bank erosion and is occurring in response to channelisation, whereby the stream channel attempts to reduce its bed slope and thus its erosive power (Section 3.2.3.1) and Figure 3-8.

Erosion of this sort is also often associated with a lack of riparian vegetation to stabilise the bank. The toe of the bank is gradually (or episodically) eroded until the bank is vertical or undercut and the bank subsequently collapses under its own weight. Erosion on the outside of meander bends is a natural process of gradual channel planform change. Erosion is expected at the outside of bends, as it is an area in increased flow velocity. Likewise, deposition is expected on the inside of the bend, as it is an area of reduced flow velocity.

FIGURE 3-8 DOWNSTREAM VIEW OF BENDIGO CREEK DEMONSTRATING MEANDER EXTENSION, OCCURING IN RESPONSE TO CHANNELISATION, WHERE THE CREEK ATTEMPTS TO REDUCE ITS EROSIVE POWER BY DECREASING ITS BED SLOPE.

3.2.4 Current Condition

In its current form, Bendigo Creek and its associated channel network within the Huntly Streamside Reserve is a highly modified waterway environment. The primary channel course exists as a straight channel constructed against the eastern boundary of the Reserve. Bank erosion is common throughout the length of the creek, largely occurring in response to the artificial channelisation and in accordance with the processes outlined in Section 3.2.3. In some sections the bank erosion is occurring into the constructed levee on the eastern side of the channel.

Several sedimentary layers are evident within the creek bank profile (Figure 3-9). The orange basal sediment layer represents the pre-European floodplain level and the upper greyish/yellow sediment layer, comprising fine sand having been widely deposited across the floodplain surface from historic mining activities upstream. Visually, the upper sediment layer extends to approximately 2m in thickness above the pre-European floodplain level and comprises less cohesive sediments. The upper sediment layer is therefore likely to be comparatively more erodible than the basal sediment layer.

There is evidence of past erosion control works within Bendigo Creek through the presence of a failed pile field structure and a rock chute situated approximately 1.5km downstream of Leans Road (Figure 3-10). Whilst the rock chute is in poor condition, it still provides a form of longitudinal bed control.

The stream bed contains a moderately poor bed morphology due to the historic bed deepening processes. Observed in-stream features included shallow pools, bars, riffles benches and ledges. It is important to note, that whilst the current bed morphology and aquatic habitat diversity is relatively poor, it still retains some value and function for aquatic habitat flora and fauna. Furthermore, in the long term, the bed morphology and aquatic habitat diversity is likely to improve as the channel system tries to re-attain bed and bank stability by reducing its bed slope through meander migration (Section 3.2.3.2).

Like the primary Bendigo Creek channel course, the remaining channels within the Reserve have been artificially constructed through the historic floodplain deposits. Whilst these channels have deepened and likely widened in response to the artificial channelisation, the contemporary bank erosion is less common in these channels compared to the primary Bendigo Creek channel course.

FIGURE 3-9 THE DISTINCT FLOODPLAIN DEPOSITS ASSOCIATED WITH HISTORIC MINING OVERLYING THE PRE-EUROPEAN FLOODPLAIN LEVEL. NOTE THE LEVEE A SHORT DISTANCE BEHIND THE CHANNEL.

FIGURE 3-10 DOWNSTREAM VIEW OF THE ROCK CHUTE. WHILST IN POOR CONDITION THE STRUCTURE PROVIDES LONGITUDINAL BED GRADIENT CONTROL.

3.2.5 Summary

A summary of the geomorphic condition, trajectory and potential management implications for Bendigo Creek within the Huntly Streamside Reserve is provided in the following dot points:

- Prior to European settlement Bendigo Creek (within and surrounding Bendigo) is believed to have been a Chain-of-Ponds watercourse. That is, the creek form comprised a series of discrete swamp ponds separated by swampy depressions where a channel was either typically absent or poorly defined.
- In its current form, Bendigo Creek and its associated channel network within the Huntly Streamside Reserve is highly modified waterway environment.
- Several active erosion processes are evident within the project area. Most of these processes are influenced by the channelisation of the creek, the post European influences outlined in Section 3.2.2 and the absence of a continuous riparian vegetation corridor.
- Bed and bank erosion is likely to continue to occur within Bendigo Creek, in accordance with the model of channel evolution relating to incised streams identified by Schumm *et al*. (1984). This process is likely to take decades to centuries before the creek reaches a state of quasi- equilibrium.
- As a consequence of the historic channelisation, bed deepening and channel widening, the primary Bendigo Creek channel has over-enlarged. Therefore, this reach is likely to have a large proportion of

large flow event energy expended as erosive power in-channel, further contributing to potential channel instabilities.

- The stream bed within each of the channel networks contains a moderately poor bed morphology due to the historic bed deepening processes. Whilst the current bed morphology and aquatic habitat diversity is relatively poor, it still retains some value and function for aquatic habitat flora and fauna. Furthermore, in the long term, the bed morphology and aquatic habitat diversity is likely to improve as the channel system tries to re-attain bed and bank stability by reducing its bed slope through meander migration.

3.3 Environmental Condition

3.3.1 Overview

The Huntly Streamside Reserve is part of a vegetated corridor in a largely cleared floodplain landscape. It is in close proximity to the Greater Bendigo National Park, Bendigo Regional Park, the Whipstick Nature Conservation Reserve and other areas of public land that support remnant native vegetation (Figure 3-11). Habitat linkages such as this are important flora and fauna habitats and provide ecological connectivity from one vegetated area to another, allow freedom of movement for fauna and flora species, help to maintain and improve genetic diversity and provide refuges for species near urban developments or under climate change.

The Reimagining Bendigo Creek Plan (City of Greater Bendigo, 2020) acknowledges that the Huntly Streamside Reserve is the largest contiguous conservation area on the Creek and is home to a comparatively rich diversity of native and indigenous plants, as well as native frogs, fish, birds, mammals and reptiles (City of Greater Bendigo 2020).

This Scoping Report has not included a detailed Flora and Fauna assessment. We understand that Ecology Australia has completed a field study: 'Huntly Streamside Reserve - Bendigo Creek Mining Licences (MIN5515 and MIN5512) - Flora and Fauna Assessment (Ecology Australia 2020).

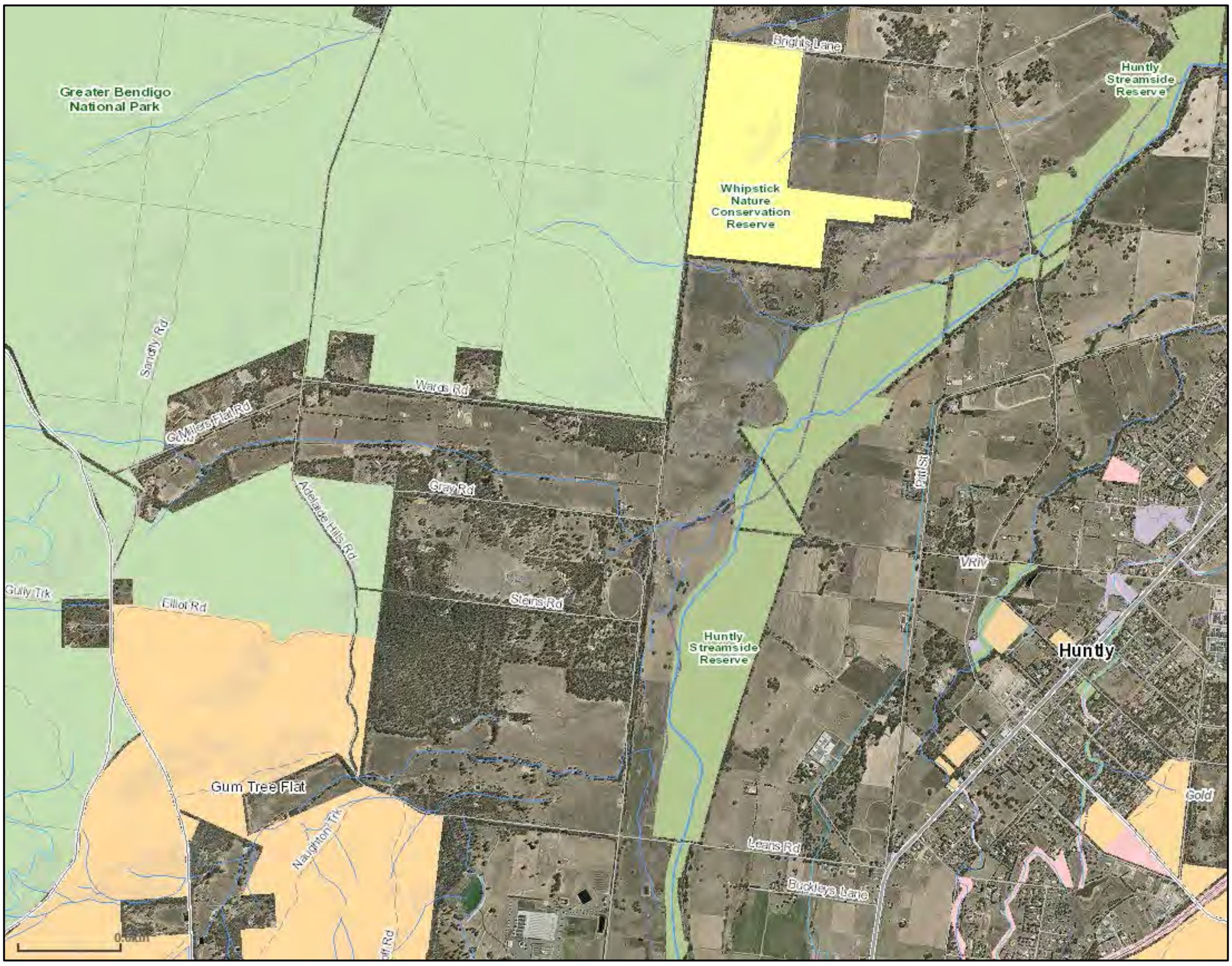

FIGURE 3-11 PUBLIC LAND SUPPORTING REMNANT VEGETATION WITHIN THE VICINITY OF THE HUNTLY STREAMSIDE RESERVE

3.3.2 Bioregion and Ecological Vegetation Class

Victoria's native vegetation is mapped and described by bioregion and Ecological Vegetation Class (EVC). Bioregions are a landscape-scale classification which uses attributes such as climate, geomorphology, geology, soils and vegetation, to map areas with similar environmental features (DELWP, 2020a). EVCs are the standard unit for categorising vegetation types in Victoria. EVCs are described through a combination of floristics, lifeforms, ecological characteristics and fidelity to particular environmental attributes (DELWP 2020a). The entire state of Victoria has been mapped by EVC at two timeframes, pre-1750 (pre-European settlement) and 2005 (DELWP, 2020a).

The combination of EVC and bioregion is used to determine the bioregional conservation status of an EVC. This is a measure of the current extent and quality of each EVC, when compared to pre-1750 extent and condition (DELWP, 2020a). The relevant bioregion, EVC and bioregional conservation status of the EVC/s present on site are considered as part of any development application that has the potential to impact on native vegetation.

Most of the site is located in the Victorian Riverina Bioregion (with a small portion of the site on the western side situated in the Goldfields Bioregion). The mapped EVC at the site is predominately EVC 68 Creekline

Grassy Woodland (CGW) (in both the 1750 and 2005 EVC mapping). A small portion of the site, along the western boundary, is classified as EVC 175 Grassy Woodland (GW) (DELWP, 2020b) (Figure 3-12).

Creekline Grassy Woodland is described as a Eucalypt-dominated woodland to 15 m tall with occasional scattered shrub layer over a mostly grassy/sedgy to herbaceous ground-layer. It occurs on low-gradient ephemeral to intermittent drainage lines, typically on fertile colluvial/alluvial soils, on a wide range of suitably fertile geological substrates. These minor drainage lines can include a range of graminoid (grasses, sedges, rushes) and herbaceous species tolerant of waterlogged soils, and are presumed to have sometimes resembled a linear wetland or system of interconnected small ponds (DELWP, 2020a). Creekline Grassy Woodland is classified as an Endangered EVC in the Victorian Riverina and in the Goldfields Bioregions (DELWP, 2020a).

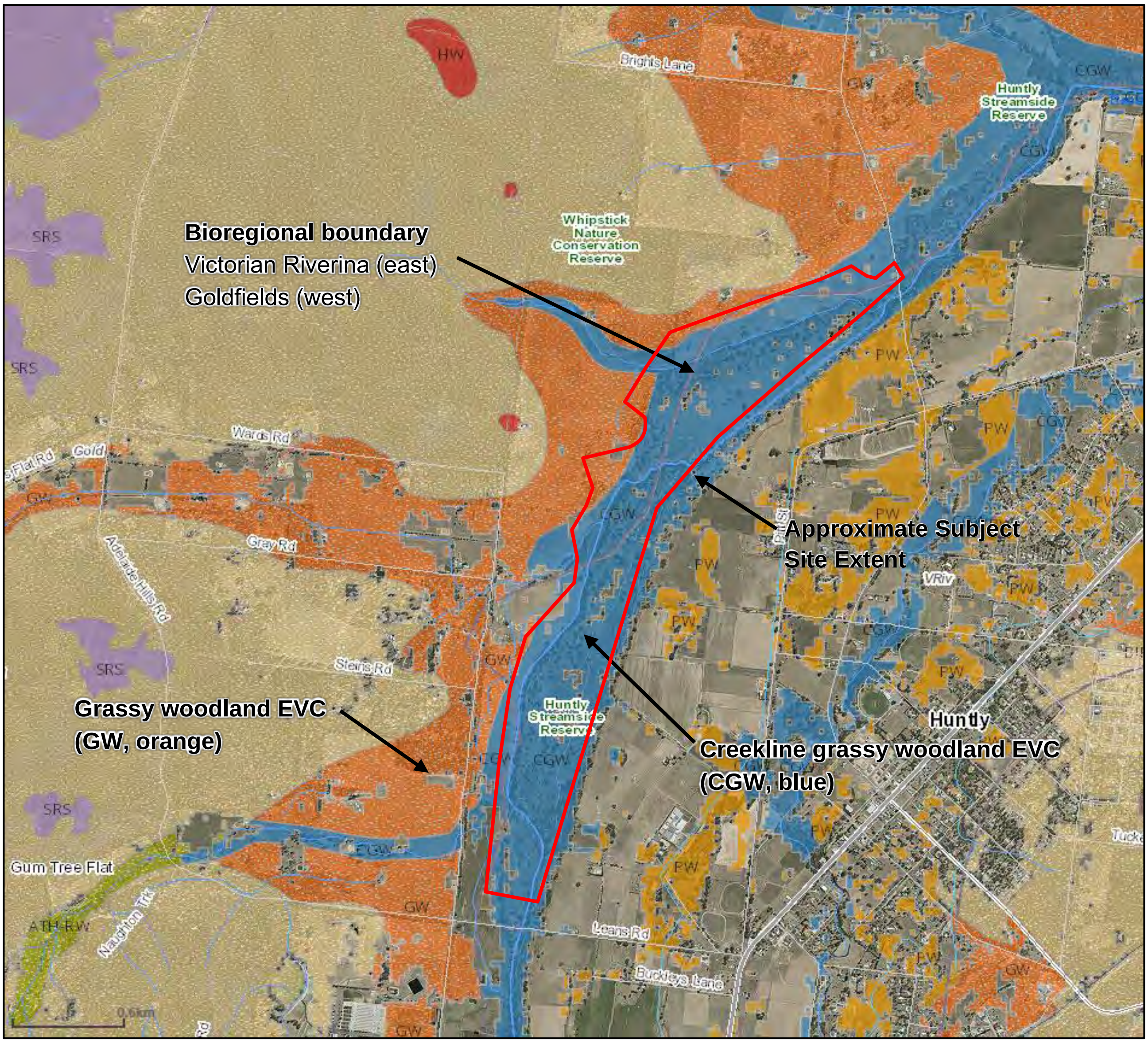

FIGURE 3-12 BIOREGION AND EVCS (2005) (SOURCE: DELWP 2020B)

3.3.2.1 Threatened species

A review of the Victorian Biodiversity Atlas (VBA) records showed that no flora or fauna surveys have been registered within the project area (DELWP 2020b). It is difficult to ascertain the presence or absence of threatened species, communities or habitats on site without a comprehensive, field-based, targeted survey. However, several threatened species are reported to have been recorded near the Bendigo Creek Biolink, Huntly project which includes the Whirrakee Wattle Biolink (Whipstick to Bendigo Creek) and the Huntly Streamside Reserve Biolink (Creekline Grassy Woodland Community, Bendigo Ck) (SWIFT, 2020).

3.3.2.2 Vegetation Condition

A rapid, preliminary inspection of the site on 22nd May 2020 indicated that many environmental values are present on the site today. However, these are significantly diminished from what would have been present prior to European settlement. This is largely due to diminished native vegetation species diversity and cover. This has occurred due to historical vegetation clearance, the deposition of sediment from upstream mining ('sludge'), channel straightening, weed invasion and the impacts of pest animals such as rabbits.

The native vegetation present on site shows affinities with EVC 68 Creekline Grassy Woodland. The overstorey is dominated by River Red Gum trees (*Eucalyptus camaldulensis),* particularly along stream margins or in wet depressions, with Yellow Box (*Eucalyptus melliodora)* and Grey Box (*Eucalyptus microcarpa*) present further off-stream or on higher ground.

Some of the River Red Gum trees on site are classified as 'Large Old Trees' for this EVC as they exceed 80 cm in diameter at breast height (DBH, measured at 1.3 m above the ground). There are several trees on site which exceed 130 cm DBH (e.g. 138 cm, 140 cm and 167 cm DBH). These trees are located near the entrance to the reserve on Leans Road. Large old trees such as these often bear hollows and provide habitat for birds, arboreal mammals and other fauna species. They are a source of seed, as well as fallen timber and organic litter for ground dwelling fauna and invertebrates (Figure 3-13).

The native understorey vegetation on site generally consists of scattered patches of juvenile River Red Gums and native grasses such as Wallaby Grasses (*Rytidosperma* spp.), Spear grasses (*Austrostipa* spp.) and Common Wheat grass (*Anthosachne scabra*) (Figure 3-14). A few wattles (*Acacia* sp.) were observed along the banks of the main Bendigo Creek channel on site. Native sedges, rushes and reeds were also observed in the bed and on the banks of this channel.

FIGURE 3-13 LARGE RIVER RED GUM

FIGURE 3-14 MIXED AGE RIVER RED GUMS, WITH WEEDS SOURSOB AND SPINY RUSH ON THE FLOODPLAIN

3.3.3 Threats

The primary threat to the native vegetation condition at the site is the presence of weeds. Weeds along the banks of the waterways at the site include Peppercorn trees (*Schinus molle)*, Soursob (*Oxalis pes capre*) and Spiny Rush (*Juncus acutus*) while young Willows (*Salix* sp.) and Ash (*Fraxinus* sp.) trees were observed in the Bendigo Creek channel (Figure 3-14 to Figure 3-17). Spiny Rush is also present in great numbers in some areas of the floodplain, along with Capeweed (*Arctotheca calendula*), Horehound (*Marrubium vulgare*) and scattered shrubs such as Sweet Briar rose (*Rosa rubiginosa*) and African Boxthorn (*Lycium ferocissimum*). Exotic grasses such as Wild Oat (*Avena fatua*) and Great Brome (*Bromus diandrus*) are also present at the site.

FIGURE 3-15 PEPPERCORN TREE ON THE BANK OF THE CHANNEL

FIGURE 3-16 SOURSOB COVERING THE BANKS OF THE CHANNEL ON THE WESTERN SIDE OF THE SITE

FIGURE 3-17 WILLOWS AND ASH IN THE MAIN CHANNEL

Several of these weeds are declared noxious weeds in Victoria under the Catchment and Land Protection (CaLP) *Act 1994*. These include:

- **Regionally Controlled Weeds** – are classified as weeds that exist in the North Central CMA region and are usually widespread. Continued control measures are required to prevent further spread to clean land. Control is the responsibility of both public and private land managers on their land and VIC Roads on Declared Roads under the Victorian Transport Act 1983. Weeds observed at the site that are listed under this classification include:
  - Spiny Rush.
  - Horehound.
  - Sweet Briar.
  - African Boxthorn.
- **Restricted Weeds** – are classified as weeds that seriously threaten primary production, Crown Land, the environment or community health in another State or Territory and have the potential to spread into and within Victoria. If sold or traded in Victoria there would be an unacceptable risk of it spreading within Victoria and to other states and territories. There is no requirement for land managers to control restricted weeds on their property. However, they cannot be traded or transported within Victoria. Weeds observed at the site that are listed under this classification include:
  - Sour sob.
  - Crack willow.

Crack Willow is also classified as a **Weed of National Significance** (WONS). WONS require coordinated action across all states and territories to reduce their impact on Australia's productive capacity and natural ecosystems. WONS are determined according to invasiveness, impact, potential to spread and socioeconomic and environmental values. It is the responsibility of land managers (both public and private) to control WONS.

Other threats to the vegetation condition at the site include:

- Impacts from rabbits such as scratchings, warrens and grazing.
- Excavated areas around the roots of trees where people have been digging (grubbing) for bardi grubs for fishing bait.
- Damage from recreational vehicles.
- Bank erosion in the main channel may also limit the establishment of native vegetation.

3.3.3.1 Active Environmental Management

It was also evident during the site inspection that works have been undertaken to improve the ecological values on site. These works include significant revegetation of parts of the floodplain and riparian corridor (particularly at the southern end of the reserve), the installation of nest boxes and rabbit exclosure fences.

While the land is managed by Parks Victoria, the Northern Bendigo Landcare Group is also active in the management of the reserve and two local public schools use the Creek as part of their environmental education programs (City of Greater Bendigo 2020).

As of February 2017, the Landcare group had installed 50 nest boxes with a range of designs to suit different species including: Brush-tailed Phascogale, Sugar Glider, Pardalote, Ducks, Lorikeets, Brown Treecreeper, Owlet-nightjar and Microbats. Monitoring has found at least one of each type of box has been used by all these except for Lorikeet, Brown Treecreeper and Owlet -nightjar (SWIFT 2020). Other activities include community plantings, weed & rabbit control, educational activities and nest box monitoring. Northern Bendigo Landcare Group has the support of Parks Victoria, local primary schools, Bendigo TAFE Conservation & Land Management and other community groups (SWIFT 2020) (Figure 3-18 to Figure 3-21).

FIGURE 3-18 REVEGETATION ON THE FLOODPLAIN

FIGURE 3-19 NESTBOX IN A EUCALYPT

FIGURE 3-20 RABBIT EXCLOSURE FENCE AND OLDER REVEGETATION AT THE SOUTHERN END OF THE SITE

FIGURE 3-21 RABBIT EXCLOSURE CONTAINING NATIVE GRASSES

3.4 Flood Behaviour

3.4.1 Overview

A combination of site visit observations, review of the Bendigo Urban Flood Study (Water Technology, 2013) results and a new flood model developed as part of this project has been used to gain an understanding of flood behaviour at and surrounding the proposed extraction area. Modelling completed as part of this project was based on the TUFLOW model developed during the Bendigo Urban Flood Study; however, it had a reduced model extent (from Leans Road to Banksia Road), a finer grid resolution to provide more detail of the site and updated crossing arrangement at Leans Roads. Changes to the model have resulted in some inconsistencies between the results. Further details on the model development, validation and comparison of the new model results with the Bendigo Urban Flood Study model are provided in Appendix 1-1.

Modelling was completed using 1% Average Exceedance Probability (AEP) flows determined during the Bendigo Urban Flood Study, two scenarios were modelled:

- Existing conditions.
- Preliminary assumed mined and rehabilitated conditions.

3.4.2 Existing conditions

The existing floodplain flow characteristics are complex due to a number of anthropogenic landform changes that have occurred at and surrounding the site. The major anthropogenic landform features influencing flood behaviour are:

- The presences of the roads that run perpendicular to the direction of flow such as Millwood and Leans Roads.
- The presence of levees and spoil mounds/windrows.

Existing site inundation can be described as follows:

- Upstream of Leans Road, flood flow along Bendigo Creek is split between three adjacent channels and along the western portion of the floodplain. Most floodplain flow is conveyed within the western floodplain.
- Three culverts and a floodway control the flow of floodwater through Leans Road.
- Overland flow on the western floodplain is largely outside of the subject site. Flow that enters the site is largely contained within the three channels running through the reserve.
- Flow along the western floodplain and the flow within the channels converge approximately 2.5km downstream of Leans Road (near cross section ‘c’ in Figure 3-22). Downstream of this point much of the site is inundated in the 1% AEP event.
- Upstream of Millwood Road the water levels within and adjacent to the primary channel are up to 800-900mm higher than on the western floodplain. This phenomenon is shown in the water surface profiles in Figure 3-22 (cross sections ‘e’). This is caused by a spoil mound/windrow that runs to the east and parallel to Bendigo Creek.
- The levee that runs along the eastern bank of the primary channel prevents flow from entering the eastern floodplain. The levee typically has two metres of freeboard with the freeboard reducing to one metre at the downstream end of the site.

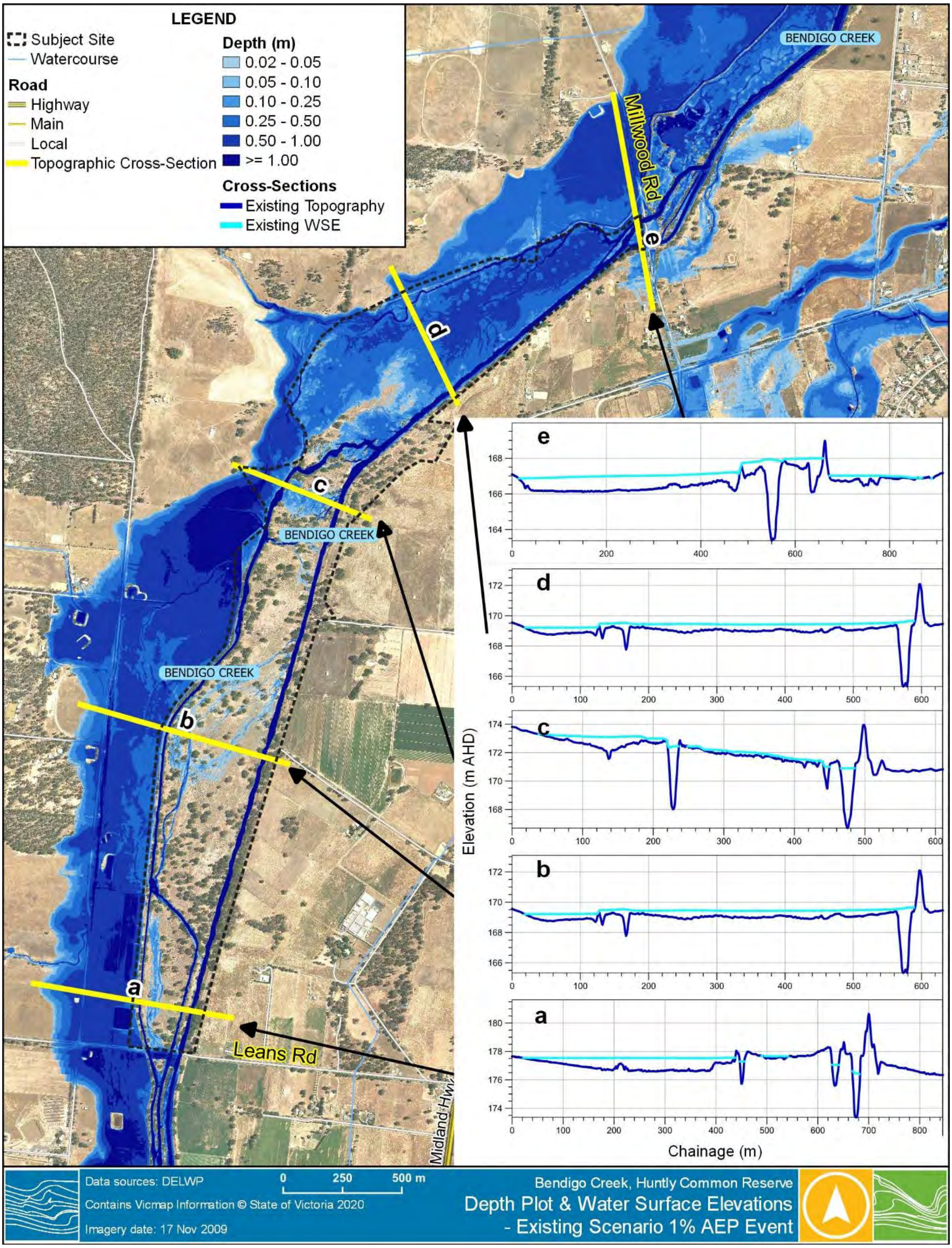

FIGURE 3-22 EXISTING CONDTIONS FLOODING (CURRENT STUDY)

3.4.3 Preliminary Post Reclamation Scenario

As described in Section 2.1, proposed reclamation works will involve lowering the landform to near pre-European levels. Bore data provided by JBS&G enabled the project team to establish a post reclamation topography within the area proposed to be disturbed. It is noted that this approach is crude and will only provide an approximate representation of the mined and rehabilitated landform. This surface has been modelled to give a high-level indication of changes in flood behaviour (positive or negative) compared to the existing scenario and used to inform the proposed reclamation approach and understand risks associated with the works. Significant refinement of active and post reclamation landforms is recommended to better understand changes in flood behaviour.

The comparison of flood extent and depth between the existing and mined and rehabilitated topographies has been undertaken using the 1% AEP event. The lower mined surface increases flood flow conveyance and storage. This results in a change of flood behaviour at and surrounding the subject site. A summary of this comparison is provided in the following points and shown in Figure 3-23:

- There is generally a reduction in flood levels across the floodplain (5mm -100mm) particularly on the western flow path between Leans road and “cross-section d” (see Figure 3-23).
- There is an overall reduction in flood extent outside of the project area particularly near Millwood Road.
- Approximately 50m upstream of Millwood Road flood level increase by between 10mm and 500mm. This increase in flood levels is likely to be associated with the localised lowering of a spoil mound/windrow in the centre of the floodplain. It is anticipated that if this feature is retained then localised increases in flood levels will not occur. This should be investigated further in subsequent stages.

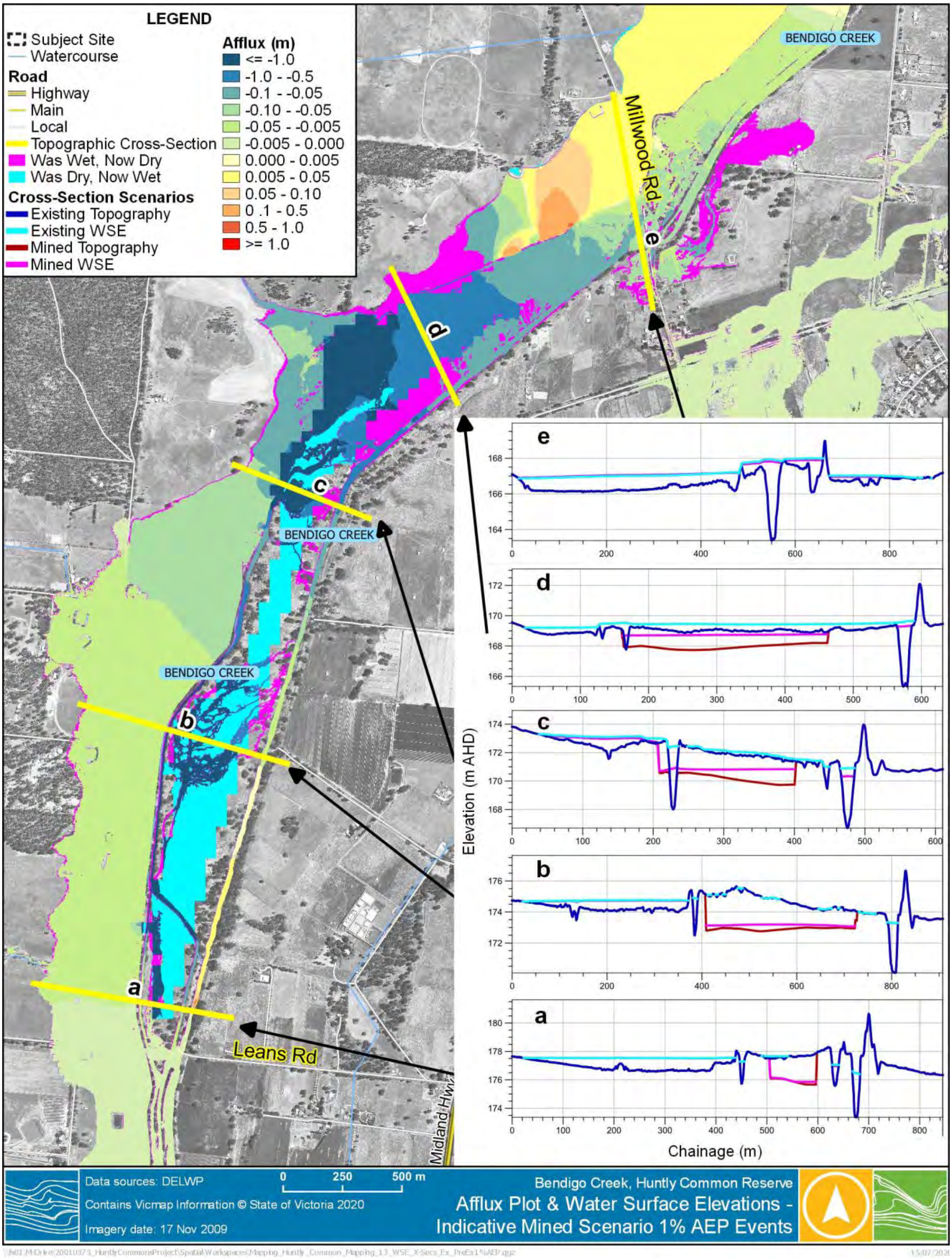

FIGURE 3-23 CHANGES IN FLOOD LEVELS POST RECLAMATION (INDICTIVE ONLY)

3.5 Hydrogeological Setting

3.5.1 Overview

The Victorian Groundwater Management Framework consists of groundwater catchments, groundwater management areas (GMAs) and water supply protection areas (WSPAs). Collectively these are known as groundwater management units. The Huntly Streamside Reserve is located within the Campaspe Groundwater Basin, near the boundary with the Loddon Groundwater Basin (Figure 3-24 and Figure 3-25). The site is not located within a Groundwater Management Area (GMA) or a Water Supply Protection Area (WSPA) (Figure 3-25). The Mid Loddon GMA to the west and the Lower Campaspe Valley WSPA to the east of the site are the nearest regulated groundwater resources.

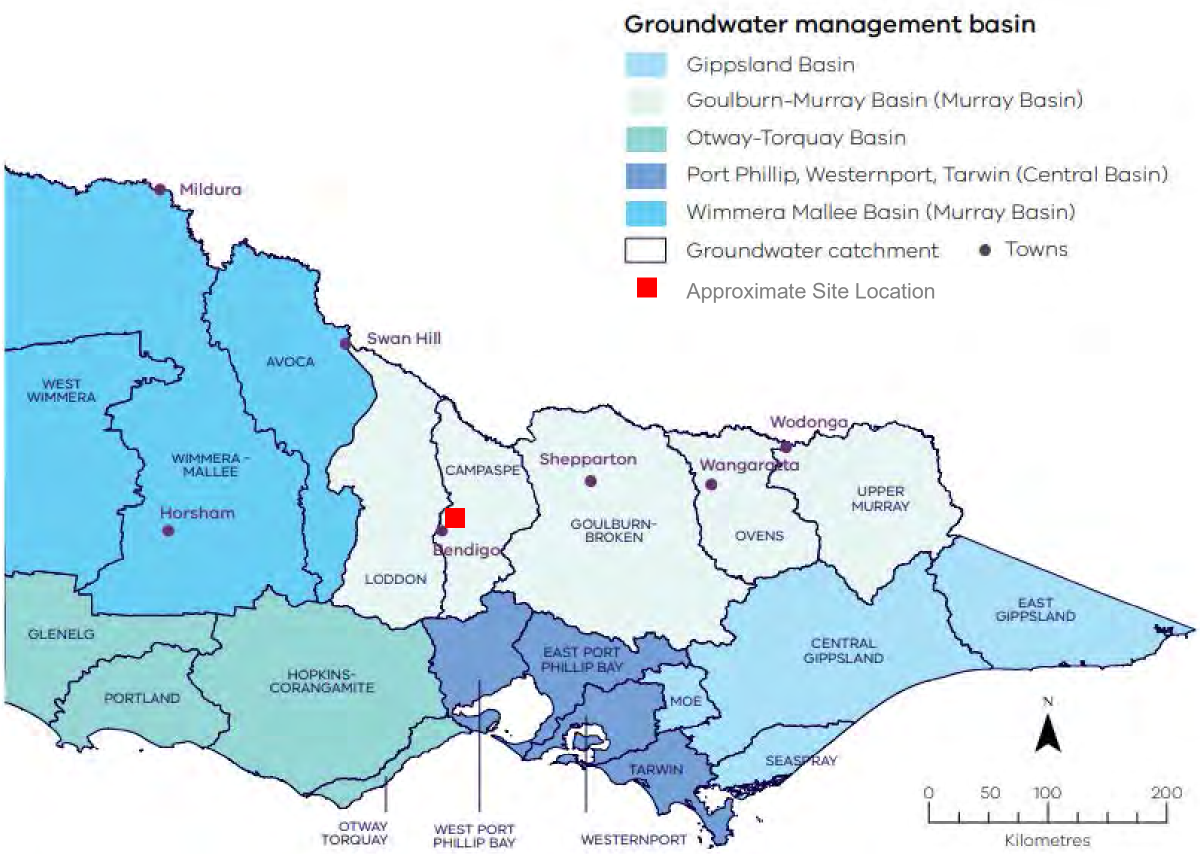

FIGURE 3-24 GROUNDWATER MANAGEMNT BASINS (DELWP 2019))

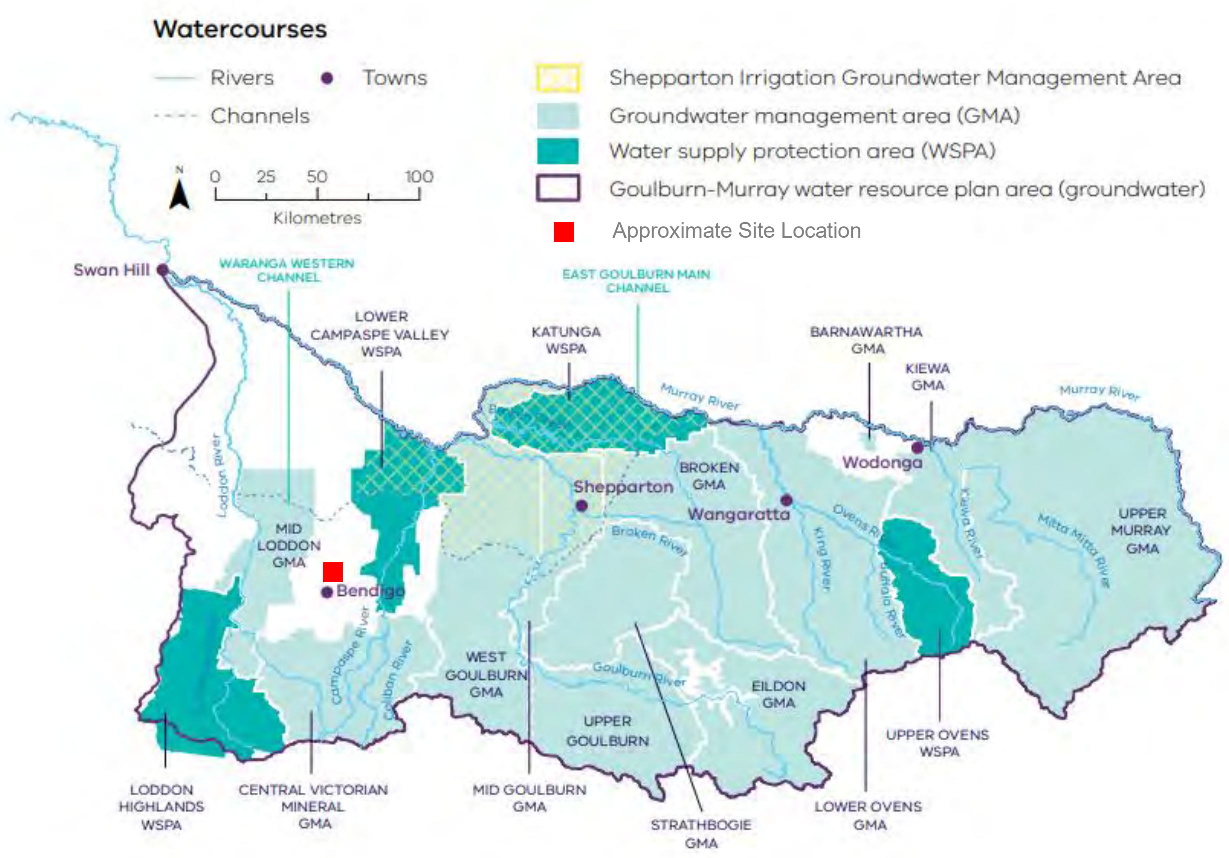

FIGURE 3-25 GROUNDWATER MANAGEMENT AREAS AND WATER SUPPLY PROTECTION AREAS (DELWP 2019)

3.5.2 Geology

Geological units in the study area consist of the Shepparton Formation (Nws), Parilla Sand Formation (Nxp), Calivil Formation (Nwc) and the Castlemaine Group (Oc) (the corresponding geological codes are shown spatially in Figure 3-26). The surface geology for the site has been extracted from the Huntly 1:50,000 geological map sheet (Figure 3-26).

The Shepparton Formation (Nws) is characterised by prior stream deposits and minor alluvium consisting of unconsolidated to poorly consolidated mottled variegated clay, silty clay with lenses of polymictic, coarse to fine sand and gravel. The Shepparton Formation forms an extensive flat alluvial floodplain within the study area. The Parilla Sand and Calivil Formation sit conformably below the Shepparton Formation and outcrop in isolated areas on the margins of the floodplain (Figure 3-26). The Parilla Sand consists of non-marine fine to medium-grained sand deposited in aeolian, lacustrine and fluvial environments while the Calivil Formation is a river valley deposit with interbedded clay, silty clay, silt and subangular to subrounded fine to coarse-grained quartz sand.

The older Ordivician Castlemaine Group, charactered by marine turbiditic sandstone, siltstone, mudstone, black shale and minor granule conglomerate is the most extensive geological unit in the study area. The Castlemaine Group outcrops outside of the floodplain and sits unconformably below the alluvial deposits within the floodplain (Figure 3-26).

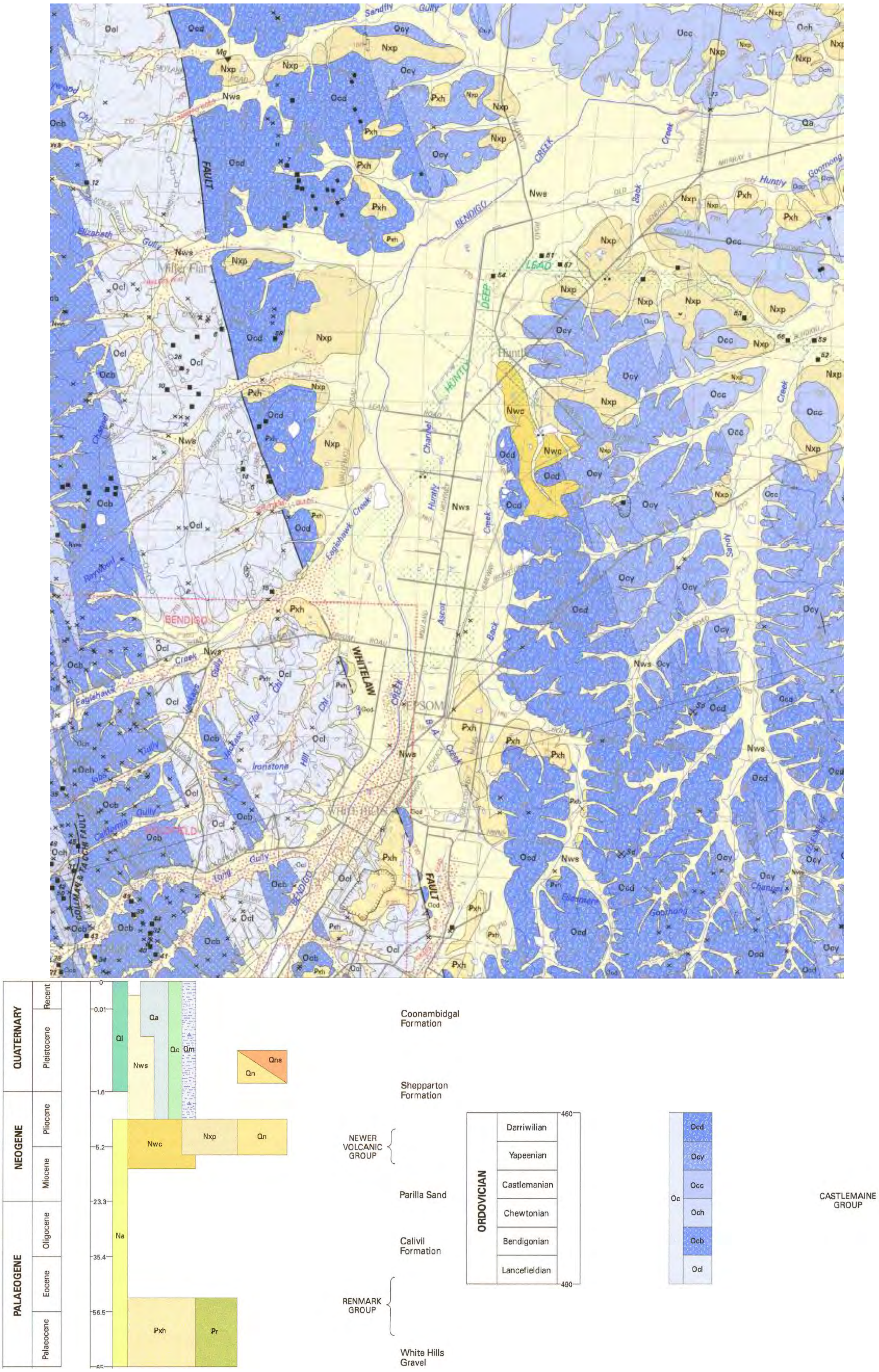

FIGURE 3-26 EXTRACT FROM HUNTLY 1:50,000 GEOLOGICAL MAP SHEET (PARENZAN ET AL., 2001)

3.5.3 Hydrogeology

3.5.3.1 Aquifers and Aquitards

Aquifers in the study area comprise the sedimentary aquifers associated with the channel deposits of the Shepparton Formation (Nws), Parilla Sand Formation (Nxp) and Calivil Formation (Nwc), and the underlying and adjacent Castlemaine Group fractured rock aquifer.

There is limited drill hole information in the vicinity of the project area to characterise the depth of the alluvial sediments and their degree of saturation. The depth to basement layer from Visualising Victoria's Groundwater platform (VVG) suggests that the alluvial fill in the Huntly Streamside Reserve area is in the order of 10 m thick. It is noted that this data has been generated by extrapolation between limited data points, but this thickness is used as a guide in the absence of site-specific data.

Groundwater in the Castlemaine Group fractured rock aquifer is contained within the fractures and cracks within the rocks. The fractured rock aquifer is reported to be relatively impermeable with low yields, however, in areas of strong fracturing higher yields are possible (SRW, 2009).

3.5.3.2 Groundwater Flow

There is little groundwater level data available for the Huntly Streamside Reserve area, with the closest available readings derived from wells located around one kilometre upstream along Bendigo Creek. Data from these wells suggest that groundwater is shallow, often within 2 m of the surface. There is limited data from which to estimate groundwater levels and flow direction within the proposed extraction area. It is expected that groundwater in the alluvial aquifer follows the general northly drainage direction of Bendigo Creek.

Groundwater flow in the regional Castlemaine aquifer is unknown, and there is limited data available from which to interpret flow directions. Historic underground mining in the Bendigo area has been reported to have caused regional drawdown in localised areas, however, since underground mining ceased in Bendigo in 2011, levels are reported to be increasing (DELWP, 2018). The main underground working areas are located around 7 km southwest of Huntly Streamside Reserve project area.

3.5.3.3 Groundwater Quality

There are very few groundwater wells in the area from which to characterise groundwater quality. Well 67742 located 1.2 km east of the proposed extraction area recorded a salinity of 16,000 µS/cm in 1990 while well 67739 located 1.7 km northeast of the extraction area recorded a salinity of 1,200 µS/cm in 1985. Interpretation of the borelogs and screened intervals suggest that well 67742 is completed in the Castlemaine Group fractured rock aquifer while well 67739 is completed in one of the sedimentary aquifers. The groundwater quality conditions below the proposed extraction area are currently unknown.

Groundwater quality testing as a part of the Bendigo Groundwater Project found that groundwater in the regional fractured rock aquifer has elevated levels of salt, arsenic, heavy metals and hydrogen sulphide (DELWP, 2018). The abandoned mine workings are located around 7 km southwest of the Huntly Streamside Reserve and are completed in the regional fractured rock aquifer system.

3.5.4 Groundwater Receptors

3.5.4.1 Groundwater Wells and Licenced Use

To investigate the location of existing groundwater users in the project area, groundwater well data was accessed from the Victorian Water Measurement Information System (WMIS) on 22 June 2020. The spatial search was conducted to include wells within 2 km of the nominal extraction area as illustrated in Figure 3-27.

Available well depths are also shown and indicate that the majority of wells, including those wells within two kilometres of the subject reach are greater than 10 m deep.

The majority of wells within this area are used for stock and domestic purposes with the other main purposes including investigation and observation. The purpose description for each of the 16 existing groundwater wells located within 2 km of the proposed excavation area is provided in Table 3-1.

The site is not located within a groundwater management area and there are no known licenced groundwater users within the area. Drawdown impacts to existing groundwater wells as a result of the proposed excavation are not envisaged due to the limited depth of the excavation. This assumption requires validation through installation of observation wells within and adjacent the proposed excavation area to establish the depth to groundwater. It is understood that groundwater is being considered as a water source to support site operations. Impacts and licensing requirements as a result of groundwater extraction have not been assessed as a part of this study.

TABLE 3-1 GROUNDWATER WELLS BY PURPOSE WITHIN 2 KM OF THE NOMINAL EXTRACTION AREA

Purpose Description	Number of wells with 2 km
Domestic and Stock	5
Groundwater Investigation	4
Observation, Dryland Salinity Bore Network	3
Domestic	1
Stock, Domestic	1
Commercial	1
Not Known	1
Total	**16**

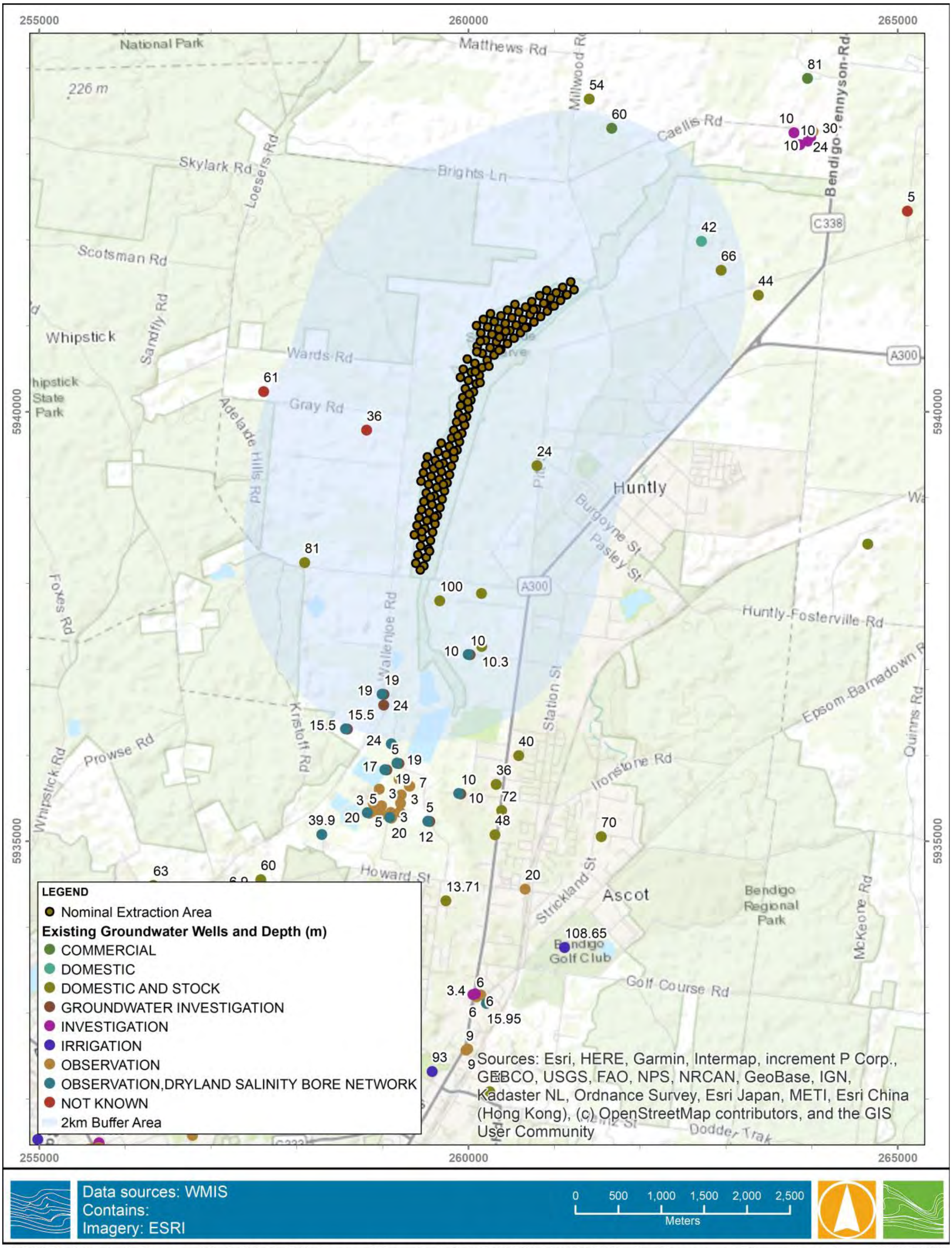

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FIGURE 3-27 EXISTING GROUNDWATER WELLS BY PURPOSE AND DEPTH

3.5.4.2 Groundwater Dependent Ecosystems

Some ecosystems rely on groundwater to meet ecological water requirements, and as such may be sensitive to changes in the natural groundwater regime. These ecosystems are defined as Groundwater Dependent Ecosystems (GDEs). The Australian GDE Atlas published by the National Water Commission (2012) provides locations of potential GDEs based on broad scale analysis, existing data sets and remote sensing. GDEs are broadly categorised into the following types.

- Aquatic ecosystems that rely on the surface expression of groundwater; this includes surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs.
- Terrestrial ecosystems that rely on the subsurface presence of groundwater; this includes all vegetation ecosystems.
- Subterranean ecosystems; this includes cave and aquifer ecosystems.

Terrestrial and aquatic GDEs in the Huntly Streamside Reserve area as defined in the Australian GDE Atlas are illustrated in Figure 3-28. The data suggests that the floodplain consists of terrestrial ecosystems which have a high potential of being supported by groundwater. Similarly, Bendigo Creek is defined as an aquatic GDE with high potential of being supported by groundwater.

It is noted that the assessment is based on broad scale analysis of existing data sets and remote sensing. Site specific assessment is required to further ascertain the level of reliance these ecosystems may have on groundwater and their ecological value.

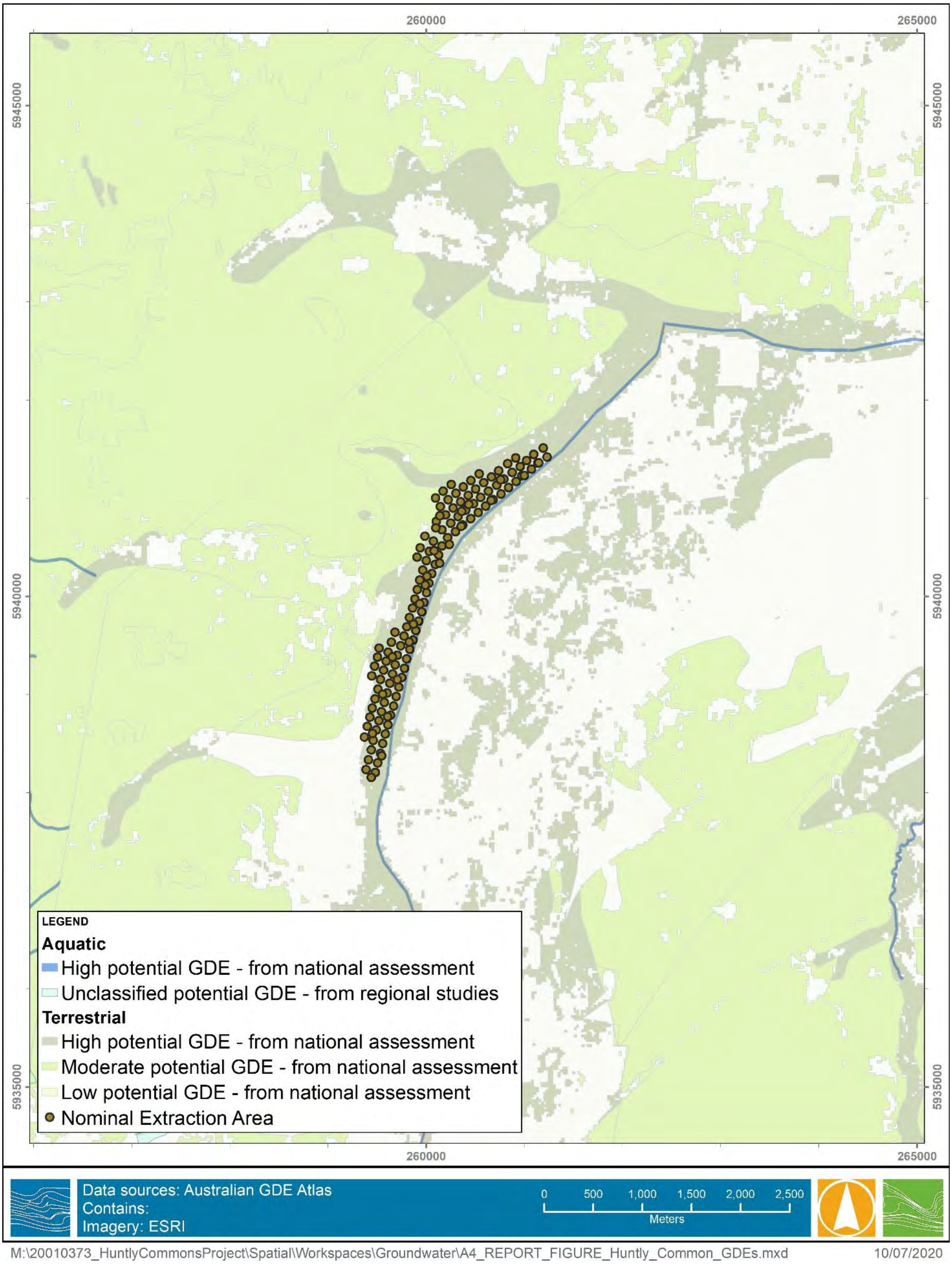

FIGURE 3-28 GROUNDWATER DEPENDENT ECOSYSTEMS (AUSTRALIAN GDE ATLAS)

3.5.4.3 Beneficial Use

According to the Victorian Environmental Protection Authority (EPA), a beneficial use is a use to the environment, or a segment of the environment which is conductive to public benefit, welfare, safety, health or aesthetic enjoyment and which requires protection from the effects of waste discharges. Total Dissolved Solids (TDS) is used as the primary indicator for segment definition as the salinity of groundwater affects what it can be used for and it has proven to be an effective way to classify groundwater for beneficial uses. For the purposes of this schedule 'Total Dissolved Solids' is a measure of salinity. Other water quality parameters such as metals and nutrients may also influence the beneficial use category for groundwater.

Visualising Victoria's Groundwater platform (VVG) provides a spatial layer of TDS for the watertable aquifer which has been used to provide a high level screening of potential beneficial uses. Based on this data, groundwater salinity falls in the 3,501 to 13,000 mg/L range south and east of Huntly and in the 13,001 to 200,000 mg/L range north of Huntly (Figure 3-29). It is noted that this data has been generated by extrapolation between limited data points. Site specific data is required to verify the actual beneficial use. Other water quality parameters such as metals should be included in this assessment given the site history.

The beneficial uses of the groundwater at the site are provided in Table 3-2.

TABLE 3-2 BENIFICIAL USES FOR GROUNDWATER (SEPP 2018). BENEFICIAL USES OF THE GROUNDWATER AT THE SITE ARE HIGHLIGHTED IN BLUE.

BENEFICIAL USE	SEGMENT (TDS mg/L)						
	A1 (0-600)	A2 (601-1,200)	B (1,201-3,100)	C (3,101-5,400)	D (5,401-7,100)	E (7,101-10,000)	F (>10,001)
Water dependent ecosystems and species	✓	✓	✓	✓	✓	✓	✓
Potable water supply (desirable)	✓						
Potable water supply (acceptable)		✓					
Potable mineral water supply	✓	✓	✓	✓			
Agriculture and irrigation (irrigation)	✓	✓	✓				
Agriculture and irrigation (stock watering)	✓	✓	✓	✓	✓	✓	
Industrial and commercial	✓	✓	✓	✓	✓		
Water-based recreation (primary contact recreation)	✓	✓	✓	✓	✓	✓	✓
Traditional Owner cultural values	✓	✓	✓	✓	✓	✓	✓
Cultural and spiritual values	✓	✓	✓	✓	✓	✓	✓
Buildings and structures	✓	✓	✓	✓	✓	✓	✓
Geothermal properties	✓	✓	✓	✓	✓	✓	✓

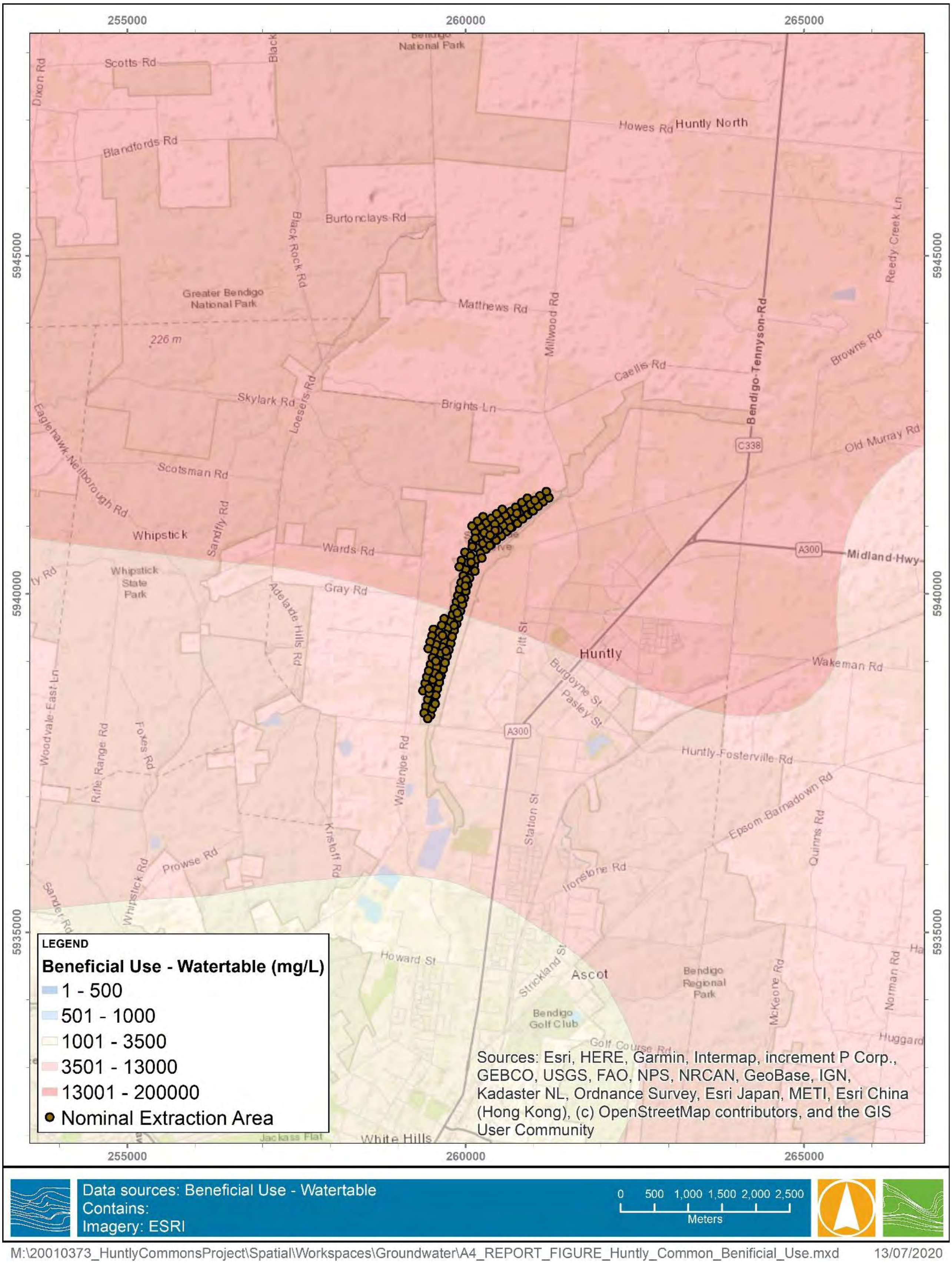

FIGURE 3-29 BENEFICIAL WATER USE ZONES

4 DISCUSSION

4.1 Overview

Huntly Common Pty Ltd propose to rehabilitate Bendigo Creek within the Huntly Streamside Reserve. The rehabilitation will involve the remove the historic sludge material deposited over the reserve from early gold mining activities, restoration of the original topography and rehabilitation of the watercourses and surrounding floodplain. The sludge material will be processed off-site. While the removal of the mining spoil will result in some short-term impacts at the site, this provides an opportunity to rehabilitate a large section of Bendigo Creek and its floodplain. The rehabilitation works have the potential to significantly improve the ecological, cultural and social value of the reach.

This section summaries preliminary design advice around the feasibility of rehabilitating Bendigo Creek within the Huntly Streamside Reserve following the proposed reclamation activities.

4.2 Key Waterway Design Considerations

To achieve the relevant objectives of the proposed reclamation activities, the construction of a modified channel arrangement is necessary. The reconstruction of a new channel has the potential to cause several waterway and on-going management issues. As such, there are several key design considerations associated with channel construction/modification. These key design considerations include:

- The stream length and hydraulic capacity of the new channel relative to the existing channel.
- Loss of established environmental values and functions of the existing waterway.
- Long term channel stability and flood behaviour.
- The entry and exit points of the new channel.

For the rehabilitation to be successful, it must be aligned with the broader goals, strategies and outcomes identified in the Re-imaging Bendigo Creek Plan and the The Dja Dja Wurrung Country Plan 2014 – 2034 (Dja Dja Wurrung, 2014). The key relevant outcomes for the Huntly Streamside Reserve identified in the Re-imaging Bendigo Creek Plan are:

- The creek has a chain of ponds and riffles to support wildlife and increase amenity.
- Biolinks / wildlife corridors between the Reserve and the Greater Bendigo National Park and Greater Bendigo Regional Park are protected.
- Pest plants and animals are being effectively managed.

In addition, The Dja Dja Wurrung Country Plan identifies as a goal (Goal 6) to make our upside-down country healthy again. The remaining goals, strategies and outcomes are presented in Section 2.2. In addition to the key outcomes, the following guiding principles for the reclamation and rehabilitation the Huntly Streamside Reserve have been developed:

- It is not possible to return Bendigo Creek to its unique pre-European Chain of Ponds condition. However, it is possible to use the Chain of Ponds stream type as a model for rehabilitating Bendigo Creek within the Reserve.
- The project should aim to strike a balance between environmental, cultural and social objectives, working within available funding arrangements.
- The project will involve multiple stakeholders working in partnership to achieve positive outcomes.

- The works should be staged so that rehabilitation activities such as revegetation and the installation of habitat can commence soon after a particular area has been disturbed. This will help to reduce erosion, improve soil stability and increase habitat and aesthetic values on site.
- The environmental outcomes will improve on the current condition of the creek and floodplain through increased complexity in the stream habitat for native fauna.
- The riparian vegetation corridor shall use indigenous species or those listed in the relevant EVC for revegetation works.
- The works shall have no adverse impacts on flood levels and velocities for neighbouring properties.
- Where trees are required to be cleared, the wood from these trees should be installed as fauna habitat in the channel, on the banks and on the floodplain.
- The reclamation and subsequent rehabilitation of the creek and floodplain will require the removal of large trees. The existing large trees (e.g. greater than 80cm DBH) and patches of remnant vegetation provide an important value and function. Retention of these shall:
  - Provide valuable fauna habitat.
  - Be a potential seed source for future germination of River Red Gums.
  - Maintain some of the aesthetic values of the site.
  - Demonstrate that efforts have been made to ‘avoid’ and ‘minimise’ vegetation losses under the *Guidelines for the removal, destruction or lopping of native vegetation* (DELWP 2017).

A preferred concept design arrangement for Bendigo Creek between Lean Road and Millwood Road will be informed and analysed in subsequent project stages. The concept design arrangement will be informed through the project objectives, guiding principles, design requirements and stakeholder input. From this, a set of design criteria will be developed for the constructed waterway and rehabilitated floodplain. Design criteria are likely to include specification of some or all the following variables as agreed with the relevant stakeholder authorities:

- Target vegetation condition.
- Density of in-stream timber.
- Meander wavelength and sinuosity.
- Stream bed form.
- Channel and floodplain roughness coefficients commensurate with the above.
- Bed grade.
- Channel width and depth.
- Changes to flood impacts.

Further advice on suitable ranges for each of these design criteria can be sought from the Technical Guidelines for Waterway Management (DSE 2007).

The concept design arrangements for the waterway design will include the following details:

1. Identification of a preferred channel location.
2. Identification of a preferred cross section, long section and channel arrangement, based on the key criteria and stakeholder objectives outlined above.
3. Details relating to the entry and exit points of the new Bendigo Creek channel. This will need to consider:

a. That the floodplain within Huntly Streamside Reserve will be lower than the surrounding floodplain. This has the potential to see Huntly Streamside Reserve become inundated for longer time periods of time during flood events.

b. Post works flood behaviour. The rehabilitation of the creek and surrounding floodplain has the potential to re-engage the surrounding floodplain and away from freehold land where it currently inundates.

c. The presence of the Leans Road and Millwood Road and the associated culvert and floodway arrangements and how flow will be captured from and directed to the existing infrastructure.

d. It is likely that the existing channel will need to transition to the designed channel over a distance. This may mean that is it not possible to mine right up to Leans Road and Millwood Road.

4. Identify stable tributary entry points locations and arrangements.

5. Vegetation establishment requirements.

6. Mitigation measures/considerations to account for the proposed reclamation activities/impacts. It is envisaged that this will feed into a detailed Works Plan. This will need to consider:

a. That there may be isolated areas where gold is not present in the spoil at the site. This may result in an uneven removal of sediment and undulating floodplain surface.

b. How the flow will be maintained though the site during the works period. It is likely that the existing channel will need to be retained until the active reclamation phase is completed.

c. How floodwaters will be managed at the site during the operation phase. It is likely that a series of levees will be required to divert floodwaters away from the active works site and potentially the lowered floodplain surface.

d. Management of the liberation of toxic materials e.g. mercury contained in mine tailings, into the waterway and surrounding environment.

The detailed work plan will need to be submitted for environmental assessment by Earth Resources Regulation and other agencies including Parks Victoria, Goulburn Murray Water, EPA and the City of Greater Bendigo.

e. Existing flora and fauna values and function:

i. A comprehensive flora and fauna survey should be undertaken to confirm the presence/absence of threatened species, communities or habitats on site. The survey should target those species and habitats that are listed by the Australian Government (*Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and those listed by the Victorian Government (*Flora and Fauna Guarantee Act 1988*, the Victorian Flora and Fauna Advisory Lists and the *Flora and Fauna Guarantee Amendment Act 2019*. This survey should include the following areas:

A. The floodplain.

B. The streambanks and in channel areas, particularly to determine the flora and fauna values in the channel, to inform the design of the new waterway and rehabilitation/decommissioning of the existing channels on site.

ii. The survey above, or a separate survey, will also be required to quantify the vegetation on site, potential losses and offsets required as part of a planning permit to remove, lop or destroy native vegetation.

iii. Develop a pest plant and animal management program. This should include:

A. A thorough weed management program should be developed as part of the project planning. Particular focus should be on Spiny Rush and other species which are listed under Victorian legislation and have the potential to spread rapidly on site or spread to processing areas as part of the proposed works.

B. A strategy to manage pest animals on site should also be developed as part of the project. Effective management of pest animals such as rabbits will be crucial to the success of the rehabilitation of the site.

f. Potential groundwater related risks including:

i. Intersection of shallow groundwater.

ii. Enhanced or reduced groundwater recharge as a result of changes to surface topography.

iii. Mobilisation of chemicals of concern to the water table during and following operation (active reclamation through to closure).

iv. Exposing potential acid sulphate soils.

At this stage, it is difficult to assess these risks as a result of the limited groundwater level and water quality information available within the extraction area.

g. The order in which the sediment is removed from the site. The hydraulic modelling suggests that in its current form, there are large parts of the proposed reclamation extent that a free from flood inundation during the 1% Average Exceedance Probability (AEP) flows. It is recommended that works operate in the areas outside of the 1% AEP flows during the months/seasons when flooding is most likely. In addition, it is considered best to work perpendicular to the direction of flow and begin removing sediment from the upstream section of the site first.

4.3 Vegetation Permit Requirements

4.3.1 Overview

Ecology Australia has completed a field study: 'Huntly Streamside Reserve - Bendigo Creek Mining Licences (MIN5515 and MIN5512) - Flora and Fauna Assessment (Ecology Australia 2020). This Scoping Report has not included a review of the Flora and Fauna Assessment, however the following information has been prepared to guide likely vegetation permit requirements.

4.3.2 Victoria's Planning Scheme

A planning permit is required to remove, destroy or lop native vegetation, including dead native vegetation under Clause 52.17 of all Victorian Planning Schemes. The purpose of this clause is to ensure that there is no net loss to biodiversity as a result of the removal, destruction or lopping of native vegetation. The state planning provisions are established under the *Victorian Planning and Environment Act 1987*.

4.3.3 Guidelines for the Removal, Destruction and Lopping of Native Vegetation

Clause 52.17 is implemented through the *Guidelines for the removal, destruction or lopping of native vegetation* (DELWP 2017) (the Guidelines). The Guidelines outline the following three step approach to manage the removal, destruction or lopping of native vegetation to minimise land and water degradation:

1. Avoid the removal, destruction or lopping of native vegetation.
2. Minimise impacts from the removal, destruction or lopping of native vegetation that cannot be avoided.

3. Provide an offset to compensate for the biodiversity impact if a permit is granted to remove, destroy or lop native vegetation.

All applications for a permit to remove, lop or destroy native vegetation must describe and quantify the vegetation to be lost and *include an avoid and minimise statement.* The statement describes any efforts to avoid the removal of native vegetation and minimise the impacts on the biodiversity and other values of native vegetation, and how these efforts focus on areas of native vegetation that have the most value.

4.3.4 Offsets

If the removal of native vegetation is approved, an offset to compensate for the impacts to biodiversity must be secured. There are two types of offsets:

- A species offset is required when the removal of native vegetation has a significant impact on habitat for a rare or threatened species.
- A general offset is required when the removal of native vegetation does not have a significant impact on habitat for a rare or threatened species.

Offsets are described as either first or third party:

- First party offsets are on land owned by the holder of a permit to remove native vegetation. First party offsets are used to meet landowners' own offset requirements.
- Third party offsets are on land owned by another party. Permit holders can purchase native vegetation credits from other landowners to meet their offset requirements (DELWP 2017).

4.4 Floodplain Hydraulics

4.4.1 Overview

As the floodplain management authority, the North Central CMA will require a flood risk report to demonstrate that the proposed design arrangement associated with the creek and its surrounding floodplain will not adversely impact on any neighbouring properties or infrastructure.

Flood mapping has been previously developed for the project area (summarised in Section 3.3). However, changes to the Bendigo Creek channel and its surrounding floodplain surface will also result in changes to the floodplain hydraulics, making the existing information inaccurate. A new flood model and hydraulic analysis will be required to:

- Quantify the changes to existing and design conditions.
- Contribute to the identification of any flooding or erosion issues and design requirements.

Specific considerations associated with the hydraulic analysis are outlined in the following points:

- The culverts and floodway at Leans Road and Millwood Road are major hydraulic controls that will influence how flows enter and leave the site. It is critical that these structures are accurately represented in the hydraulic model. It is recommended that these structures are surveyed some that they can be accurately represented in the hydraulic model.
- Any concept designs that will result in changes to the creek and floodplain topography should be modelled to test the likely impact on flood levels. Flood modelling results can then provide feedback into the design to ensure no adverse impact on neighbouring properties or surrounding infrastructure.

- The concept design should be modelled to identify areas that will be exposed to high hydraulic forces. These areas may require further design analysis which might conclude that hard engineering (e.g. rock armouring) is required.

4.4.2 Hydrogeology

The following recommendation are made to progress the groundwater impact assessment for the project:

- Installation of six groundwater monitoring wells at the locations provided in Figure 4-1. The six locations have been selected to provide sufficient coverage to evaluate the depth to groundwater and baseline water quality in the project area. The monitoring wells will target the alluvial aquifer and drilling depths are expected to be in the order of 10 m. Drilling methods will need to account for unconsolidated sands, silts and clay. It is recommended that the wells are installed as 50 mm observation wells with lockable steel standpipes.
- Groundwater quality sampling is recommended at each of the six wells to characterise the water quality in the alluvial aquifer. Laboratory analysis to include Total Dissolved Solids (TDS), Electrical Conductivity (EC), pH, major cations and anions, and total and dissolved metals.
- Monthly groundwater level monitoring should be undertaken to ascertain seasonal groundwater level variations. Once the seasonal range is established, monitoring can be reduced to quarterly.
- Groundwater quality monitoring should be conducted quarterly for the first year and reduced to annually thereafter.
- The assessment should also include screening for Acid Sulphate Soils and other soil contaminants that may be mobilised during or after operations.
- Following completion of the field based groundwater investigation, the hydrogeological conceptualisation of the site should be updated, and the risk assessment completed based on the newly acquired data.

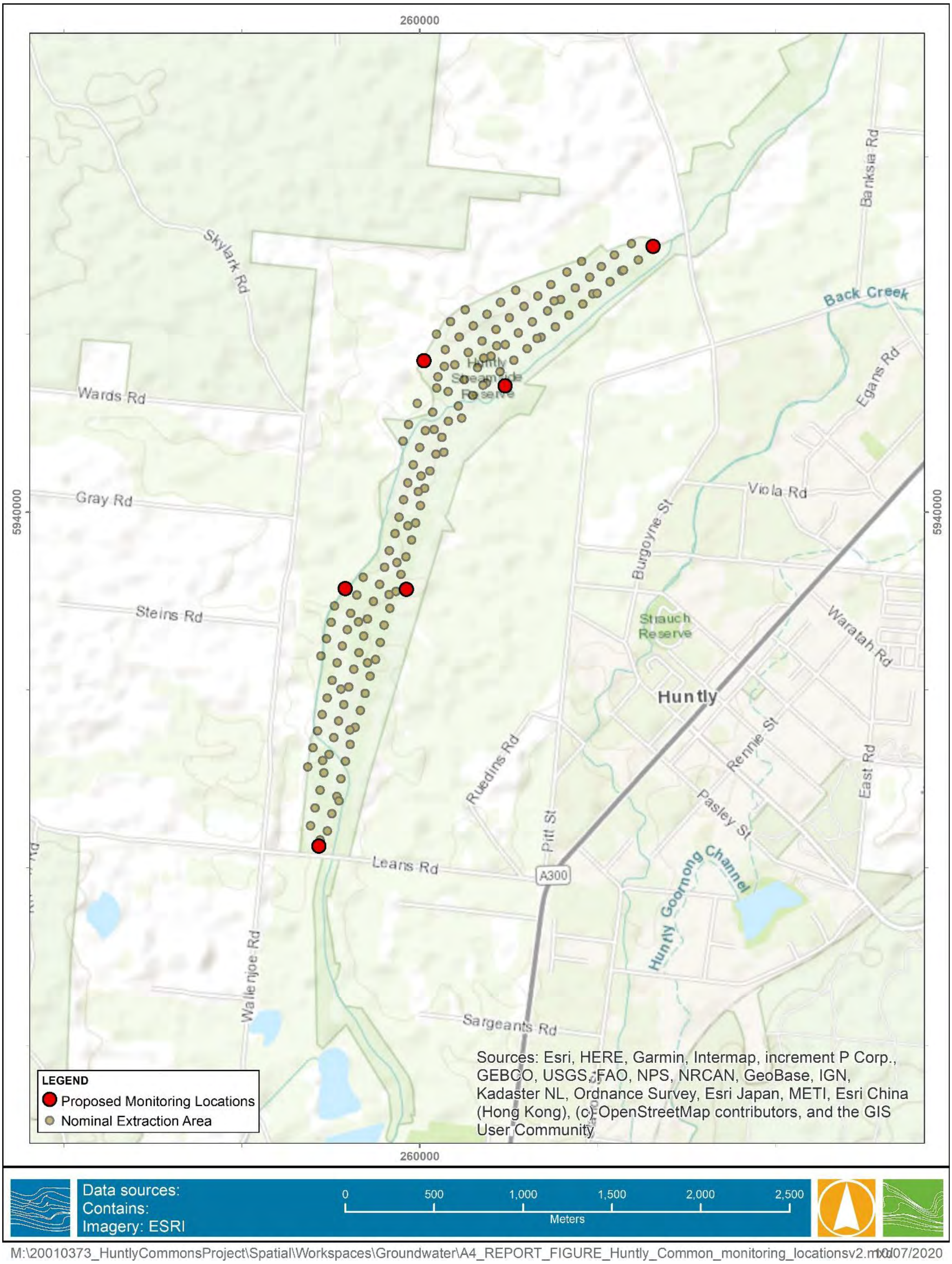

FIGURE 4-1 PROPOSED MONITORING WELL LOCATIONS

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FLOOD MODELLING METHOD

1-2 TUFLOW model Detail

As discussed in Section 3.4, flood modelling was used to understand the implications of modifying the floodplain through reclamation activities. The TUFLOW model was informed by the Bendigo Urban Flood Study (2013) and informally validated checked against the Epsom Ascot Huntly Floodplain Management Study.

Bendigo Urban Flood Study

Water Technology was commissioned by the North Central Catchment Management Authority (NCCMA) in conjunction with the City of Greater Bendigo (CoGB) to undertake the Bendigo Urban Flood Study (2013). This study involved detailed hydrological and hydraulic modelling for Bendigo's urban areas and its outskirts, including Bendigo Creek and its major tributaries and the overland flow paths.

Within the area of interest for this study the Bendigo Urban Flood Study model (2013 model) was schematised with one-dimensional channels to represent the major flow path through the Huntly Commons (including structures) and a two-dimensional domain for the flood floodplain and surrounding areas. The model used LiDAR data captured in 2009 which is consistent with this study. The Bendigo model had calibrated hydrology (using RORB) and hydraulic modelling verified via multiple means. This model is considered to be an excellent starting point for the flood mapping work required for this project.

Results from the Bendigo Urban Flood study have been presented in this document. Supporting information from this study is available via the web link below:

https://www.bendigo.vic.gov.au/About/Document-Library/bendigo-urban-flood-study-2013

Epsom Ascot Huntly Floodplain Management Study

Epsom, Ascot and Huntly Floodplain Management Study was completed in January 2019 by BMT and Molino Stewart. This Floodplain Management Study aimed to investigate and assess all options to manage flooding in the area in order to determine methods that deliver the best result for the entire community (Molino Stewart 2019).

In this study a new hydraulic model (TUFLOW) (the 2019 model) was built to represent the floodplain between Epsom, Ascot and Huntly. The flood model was used to assess flood impacts of the eight favoured mitigation options. Details on the model development were not available at the time of writing this report.

A simple comparison between the model extents was conducted in this investigation to glean whether this updated modelling:

- Agrees with the 2013 model results.
- Agrees with the current project model results.

An example output from the Epsom Ascot Huntly Floodplain Management Study is shown in Figure 5-1, more information of the flood study is available via the link below:

https://www.bendigo.vic.gov.au/sites/default/files/2020-07/R.M20754.006.05.DetailMit_Summary-compressed.pdf

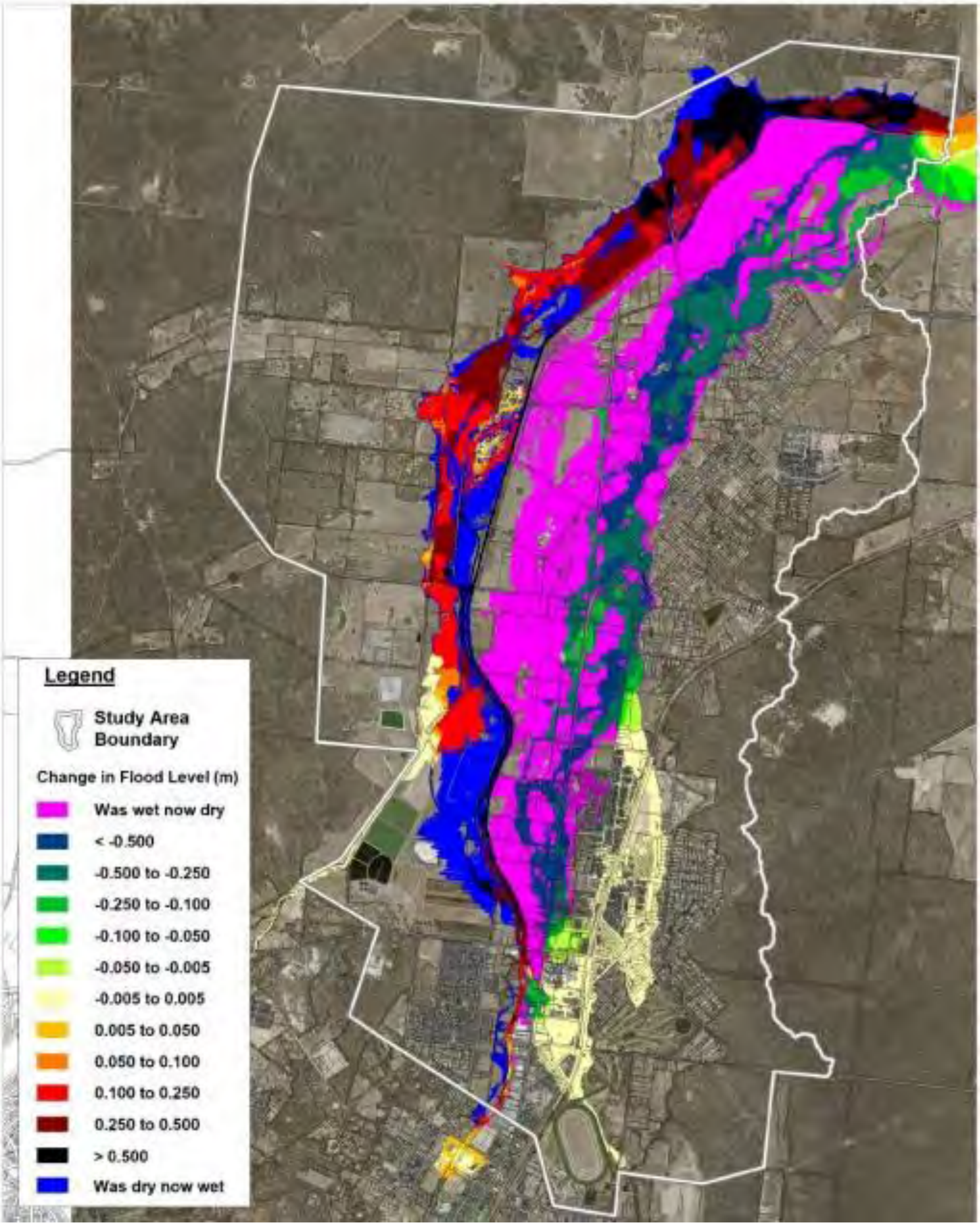

FIGURE 5-1 EXAMPLE STUDY OUTPUT - EPSOM ASCOT HUNTLY STUDY (BMT 2019)

1-3 Model Development

A TUFLOW hydraulic model was developed to assess the flood behaviour at the subject site. The model was built using the 2013 Bendigo Urban Flood Study model as a foundation. To make the model fit for purpose the following modifications were made:

- The model domain was reduced by approximately two thirds.
- New inflow boundaries were developed. The new inflow boundaries were extracted from the 2013 hydraulic model results.
- Removal of one-dimensional "spine model", instead having the two-dimensional domain calculate conveyance of the channels and the floodplain.
- Updating of one-dimensional structures to link to the two-dimensional domain (SX/CN).
- Addition of one layered flow constriction to represent Fielders Bridge (Millwood road).

Two model scenarios were analysed using the TUFLOW model. These scenarios are:

- **Existing conditions** using the 2009 LiDAR to describe the landform throughout the study area.
- **Preliminary Post Reclamation Scenario** representing the landform lowered to the pre-European sediment level as observed in the bore logs supplied by JBS&G.

Key mode input arrangements are shown in Table 5-1. The model arrangement is shown in Figure 5-2

TABLE 5-1 KEY MODELLING INFORATION

	Existing Condition	Pre European Condition
Topography	Consistent with Bendigo Urban Flood Study.	Predominately described by the 2009 LiDAR, with landform lowered inside the subject site to sediment levels as described in bore logs supplied by JBS&G
Downstream boundary	Height verse Flow (HQ) boundary set to local slope conditions and consistent with the Bendigo Urban Flood Study	
Model type	TUFLOW 1D/2D (Spine 1D model removed);	
Model build	Updated from Bendigo Urban Flood Study: 2018-03-AE-iSP-w64 – Solution scheme (GPU) (NB: Bendigo Urban Flood Study was modelled in the "classic" solution scheme)	
Inflow type	2D_SA_Inflow polygon hydrograph. *Majors Flows* (upstream of Huntly) extracted from PO lines in the 2013 TUFLOW model. *Minor Flows* (within the model domain) consistent with Bendigo Urban Flood Study	
Event(s) Modelled	1% AEP 6hr storm (ARR 1987 approach). RORB modelling shows this to be the critical storm in this segment of system.	
Roughness parameters	Consistent with Bendigo Urban Flood Study.	

	Existing Condition	Pre European Condition
Model grid size	2 x 2 m (Bendigo Urban Flood Study 5 x 5 m)	

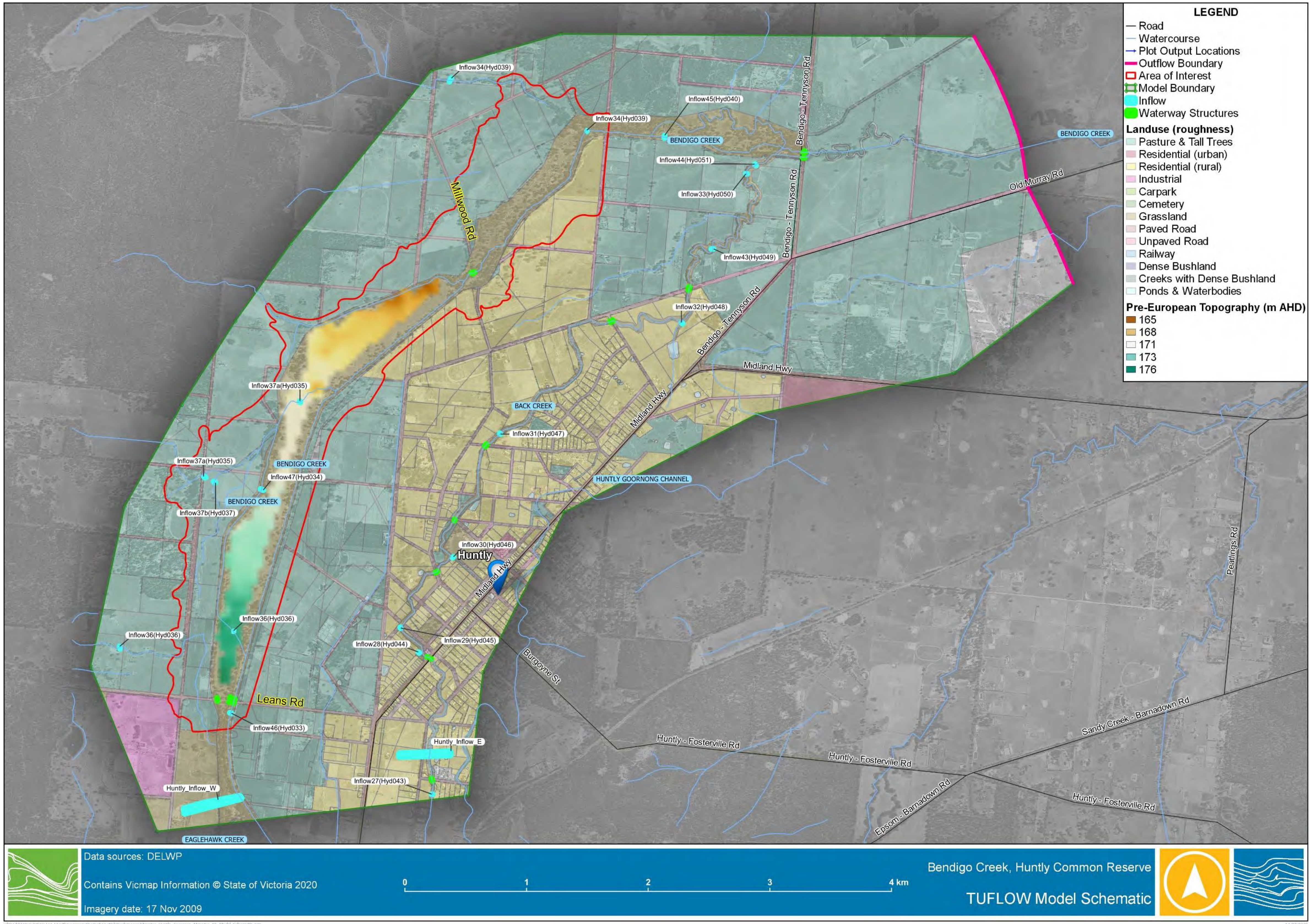

FIGURE 5-2 TUFLOW MODEL ARRANGMENT

1-4 Model validation

Bendigo Urban Flood Study

Model results from the current study were compared to those from the Bendigo Urban Flood Study. Checks included.

- Flood extent comparisons (see Figure 5-3).
- Flood level checks.

The initial results from the current model showed that flood extents were less within the subject site compared to the Bendigo Urban Flood Study. In an attempt to induce breakouts and increase the area of inundation at the subject site, the major inflow into Bendigo Creek was increased from ~200m³/s to 250m³/s. This resulted in an increase in water levels on the floodplain to levels higher than identified in the Bendigo Urban Flood Study; however, it did not induce breakouts and significantly increase the flood extent. It is possible that the higher grid resolution (2x2m rather than 5x5m) is better representing the levees and resulting in higher levees in the new model compared to the Bendigo Flood Study model. A review of levee elevation and hydraulic performance of the Leans road crossing is recommended if further modelling is pursued.

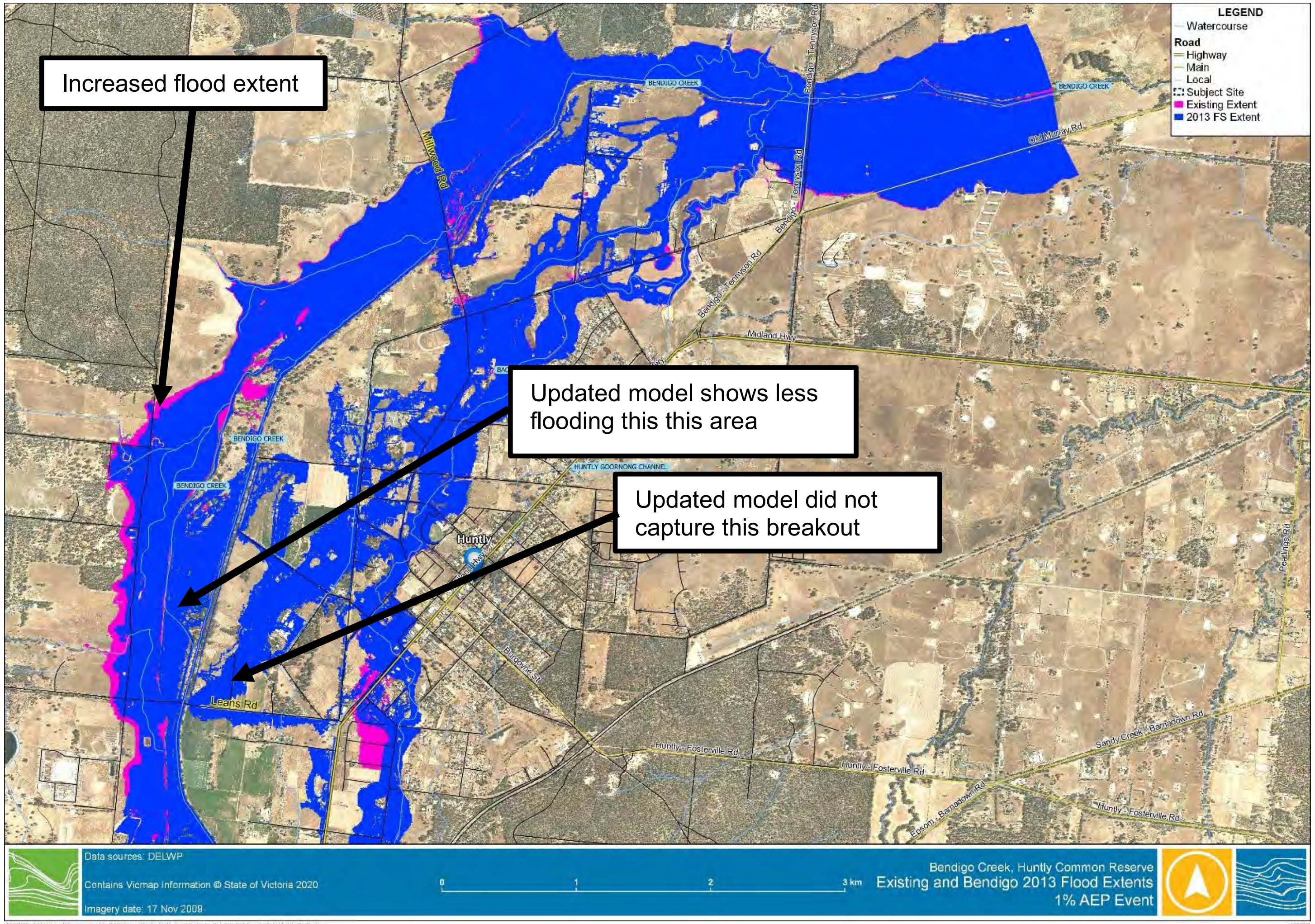

FIGURE 5-3 FLOOD EXTENT COMPARISON OF BENDIGO FLOOD STUDY (2013) AND THE CURRENT FLOOD STUDY.

Epsom Ascot Huntly Floodplain Management Study (2019)

Actual flood study results were not available at the time of this reports production. As such only high-level validation with the Epsom Ascot Huntly Floodplain Management Study model (2019 model) could be made. This model was compared to both the Bendigo Flood Study model and the current model.

Generally, the model results from the current study agreed closer with the 2019 model than they do with the 2013 modelling. This is assumed to be a function of the more recent studies (the 2019 and the current study) using finer grid resolutions. Importantly the 2019 model results have significantly less flooding within the subject site for in 1%AEP event than the 2013 model. Comparing the 2019 model and the current model results it is notable that a significant breakout upstream of Huntly (near Epsom) is not captured in the current model results; however, this has not affected the accuracy of the results within the area of interest (Figure 5-4).

It is recommended the 2019 report and (if possible) the 2019 model be reviewed in detail in the next phase of the study.

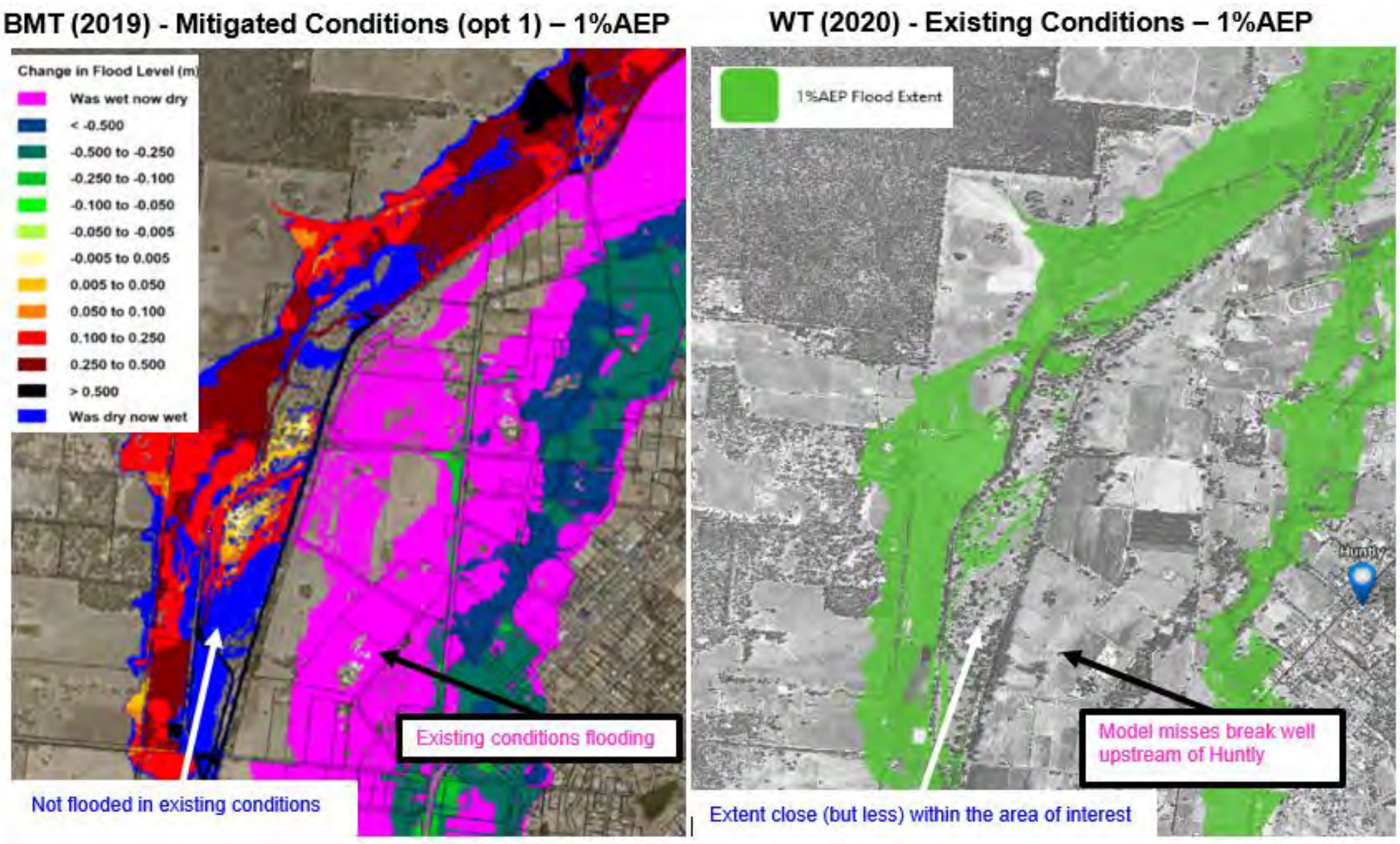

FIGURE 5-4 COMPARISON OF MODEL RESULTS: EPSOM ASCOT HUNTLY FLOODPLAIN MANAGEMENT STUDY (2019) (LEFT), CURRENT MODEL (RIGHT)

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