Tributary Foreshore Assessment: Bennett Brook

Conservation and Ecosystem Management Division

March 2019

GOVERNMENT OF WESTERN AUSTRALIA

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Front cover: Simla Wetland restoration site in July 2018. Photo – Melinda McAndrew

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Acknowledgments

Ngala kaaditj Noongar moort keyen kaadak nidja boodja

We acknowledge the Noongar people as the original custodians of south-western WA, and the Whadjuk people as the traditional owners of the lands and waters of Bennett Brook.

The tributary assessment project is an initiative of the Healthy Catchments Program within the Department of Biodiversity, Conservation and Attractions (DBCA) Rivers and Estuaries Branch. The field assessment of Bennett Brook was carried out by Alison McGilvray, Michelle Crow, Veronica Wilson and Melissa Bascombe from DBCA; Melinda McAndrew from the City of Swan and Friends of Bennett Brook; and Kelly Morley and Will Oversby from Department of Planning, Lands and Heritage (DPLH). Jake Chandler also assisted as a DBCA volunteer.

Patrick Maslen and Leah Botten from DBCA set up the data collection system and Pat has provided data management and GIS support.

The Friends of Bennett Brook, Whiteman Park Board and the City of Swan have provided input and feedback into this report. Penny Hussey from Helena River Catchment Group assisted with weed and native species identification.

DBCA's Species and Communities Branch supplied GIS shapefiles of threatened flora, fauna and community records adjacent to the river. DBCA's Aboriginal Heritage Unit have reviewed the cultural values section of this report.

Photos from DBCA's 2007 foreshore assessment were taken by Christie Atkinson.

Summary

Bennett Brook and its floodplain are significant cultural and spiritual grounds for Noongar people past and present. Much of Bennett Brook is located within Whiteman Park, which is managed by DPLH for recreation and conservation.

Friends of Bennett Brook has restored many parts of Bennett Brook from Marshall Road to Clarry Small Park since 1998 and works closely with Whiteman Park's environmental management team.

Bennett Brook Catchment is one of eight priority catchments in the Swan Canning river system. A Local Water Quality Improvement Plan (WQIP) for Bennett Brook Catchment was published by the Swan River Trust (now DBCA) in 2011.

The plan sets aspirational targets for partnerships between government, non-government organisations and the community to improve water and sediment quality through restoration activities in the brook and catchment. This assessment contributes to a review of the WQIP to help determine progress towards a healthy catchment.

Field surveys were conducted from November 2016 to January 2017 in a downstream direction. The stream bank was split into segments based on vegetation structure, bank type and substantial changes in land use.

Previous assessments of Bennett Brook were made in 2007 by DBCA and in 1998 by the former Water and Rivers Commission (WRC). Results enabled a comparison with stream condition in 2017.

Objectives of this assessment are to:

- determine riparian vegetation condition;
- identify management issues including erosion, weed incursion and vegetation loss;
- determine recommendations for restoration activities; and
- compare the current condition to that determined in 2007 and 1998 assessments.

The following major observations were made in 2017:

North – Headwaters to Marshall Road

The headwaters of Bennett Brook have been impacted by grazing and historic clearing, but where the brook enters Whiteman Park the vegetation is representative of its remnant form prior to European settlement. Bank stability is good for most of the North section.

Vegetation condition is good throughout Whiteman Park, although several invasive weeds become evident near Mussel Pool, and there is a corresponding decline in vegetation condition, with most segments in average condition downstream to Marshall Road. Most of the North section has minimal to moderate weed cover.

The highest Pen and Scott grade is A1 and the lowest is C2. Only one short segment scored a grading of A1. Fifteen out of the 23 segments are in the A grades (pristine to slightly disturbed). No segments within the A gradings are located south of Mussel Pool.

Key recommendations:

- review and resolve private property encroachment into the brook which is resulting in weed invasion, domestic animal access into the brook and erosion of the bank;
- stabilise bank erosion around stormwater pipe outfalls;
- establish canopy and mid storey layers within the headwaters west of Beechboro Rd;
- manage *Zantedeschia aethiopica* (arum lily) immediately upstream of Mussel Pool (this is its highest extent noted in the brook);
- manage priority invasive weeds between Mussel Pool and Marshall Road to reduce their spread downstream: *Rubus* sp. (blackberry), *Schinus terebinthifolia* (Japanese pepper) (their highest extent noted in the brook) and arum lily; and
- investigate the source of nitrogen and implement activities to improve water quality near high priority hotspots BCSN11 - Upstream from Mussel Pool and BBCSN17 - Horse Swamp.

Central – Marshall Road to Benara Road

Several drainage channels enter the brook in this section and are a weed transport vector. Throughout the section erosion is not apparent and bank stability is good.

Most of the stream bank has been revegetated and has good coverage of sedges, understorey plants and tree roots. Weed cover is mostly moderate from Bandicoot Creek downstream to Simla Park. The weed control efforts of the Friends of Bennett Brook are effective as large areas of *Cenchrus clandestinus* (kikuyu) have been controlled and replanted with native sedges and rushes. On the upper banks annual grasses have been replaced with native dryland species. However, weed cover is extensive from Marshall Road to Reid Highway, with kikuyu making up the bulk of the understorey.

No segments are graded in Pen and Scott's A grades. The highest grade is B1 and the lowest is C2. Segments are evenly spread across B and C grades.

Key recommendations:

- continue to support the efforts of the Friends of Bennett Brook in managing weeds, and restoring the brook and tributaries in this section;
- control watercress and lantana in Oriole drainage channel, and *Isolepis prolifera* immediately downstream of Bandicoot Creek (their highest extent noted in the brook);

- continue to restore and monitor for invasive weeds in compensation basins and drains to reduce erosion and nutrient and non-nutrient contaminants; and
- investigate the source of nitrogen and implement activities to improve water quality near high priority hotspot BBCSN14 - Bennett Brook along Marshall Road.

South – Benara Road to Swan River confluence

Grogan Swamp is the most significant feature of the South section. The swamp is comprised of diverse ecosystems, including braided channels, claypans, open waterbodies with emergent vegetation, samphire flats and sedgeland. Much of the area is inaccessible due to the density of vegetation and low-lying wet flats. A series of drains is also present on the western side that contain a native overstorey but many weed species in the under and midstorey.

Bank stability is in good to average condition for most of the South section, with some small areas of localised erosion. Vegetation condition ranges from average (most commonly) to poor. Most segments have extensive weed cover, although where samphires are dominant, weeds appear to be limited by salinity and weed species richness is low.

No segments are rated in Pen and Scott's A grades because weeds are prominent throughout the section, although the vegetation structure is complex. The highest grade is B1 and the lowest is D3, indicating the wide range in stream condition across the section.

Key recommendations:

- control *Isolepis prolifera and* arum lily throughout the section, and Japanese pepper and other identified weeds at high priority segments (see categorisation table);
- protect the natural diversity of Grogan Swamp by undertaking activities to prevent further degradation, including weed control. Engage with the Noongar community and relevant stakeholders to stage weed removal and revegetation with a diverse mix of native species;
- increase the width of the riparian zone south of Grogan Swamp;
- revegetate Lockridge drainage channel to reduce erosion and nutrient and non-nutrient contaminants; and
- investigate the source of nitrogen and implement activities to improve water quality near high priority hotspot BBCSN16 - Clarry Small Park.

Key recommendations across Bennett Brook:

- Seek funding to continue the rehabilitation of Bennett Brook Reserve to stabilise banks, reduce sediment loads, and improve water quality and habitat.

- Partner with WAPC, Whiteman Park, City of Swan, Town of Bassendean and Water Corporation to leverage funds, share resourcing and coordinate management activities along Bennett Brook.
- Engage with the Noongar community in restoration works and protection of cultural and natural heritage sites.
- Engage residents adjacent to the brook in Bennett Springs and Caversham in restoration and education activities.
- Remove weeds from their most upstream source and remove highly invasive weed species that are not currently prevalent in segments.
- Create connection with Bush Forever sites and threatened and priority ecological communities when considering sites for revegetation.
- Support Whiteman Park's development of an environmental management plan and revegetation program for the Park. Provide input into the planning process for improved catchment health.
- Support Whiteman Park's plans for trails and linkages between the southern reaches of Bennett Brook with Mussel Pool, and link with education and cultural programs where appropriate.

1 Introduction

1.1 Area description

Bennett Brook is located on the central part of the Swan Coastal Plain where the Pinjarra Plain and Bassendean Sands geological units meet (Pearson and Tedeschi 1999).

The headwaters of Bennett Brook flow from Cullacabardee, a rural suburb north of Perth, for approximately 13 km to the confluence with the Swan River in Bassendean, adjacent to Success Hill Reserve (*Figure 1*).

The brook is a seasonal tributary to the Swan River. Its main water source is groundwater seepage from the Gnangara Mound, and to a lesser degree surface runoff from the floodplain and flood events in the Swan River (SERCUL 2013; Arnold 1990).

The brook consists of permanent creek channels which connect several remnant swamps – Mussel Pool, Horse Swamp and Grogan Swamp - to the Swan River.

Grogan Swamp is a large permanent section of open water in the lower reaches of Bennett Brook and is about 800m across at its widest part. It has been reported to be the largest remaining and most relatively intact lagoonal system in the Swan Canning river system (Luke Penn pers comm. reported by Pearson and Tedeschi 1999).

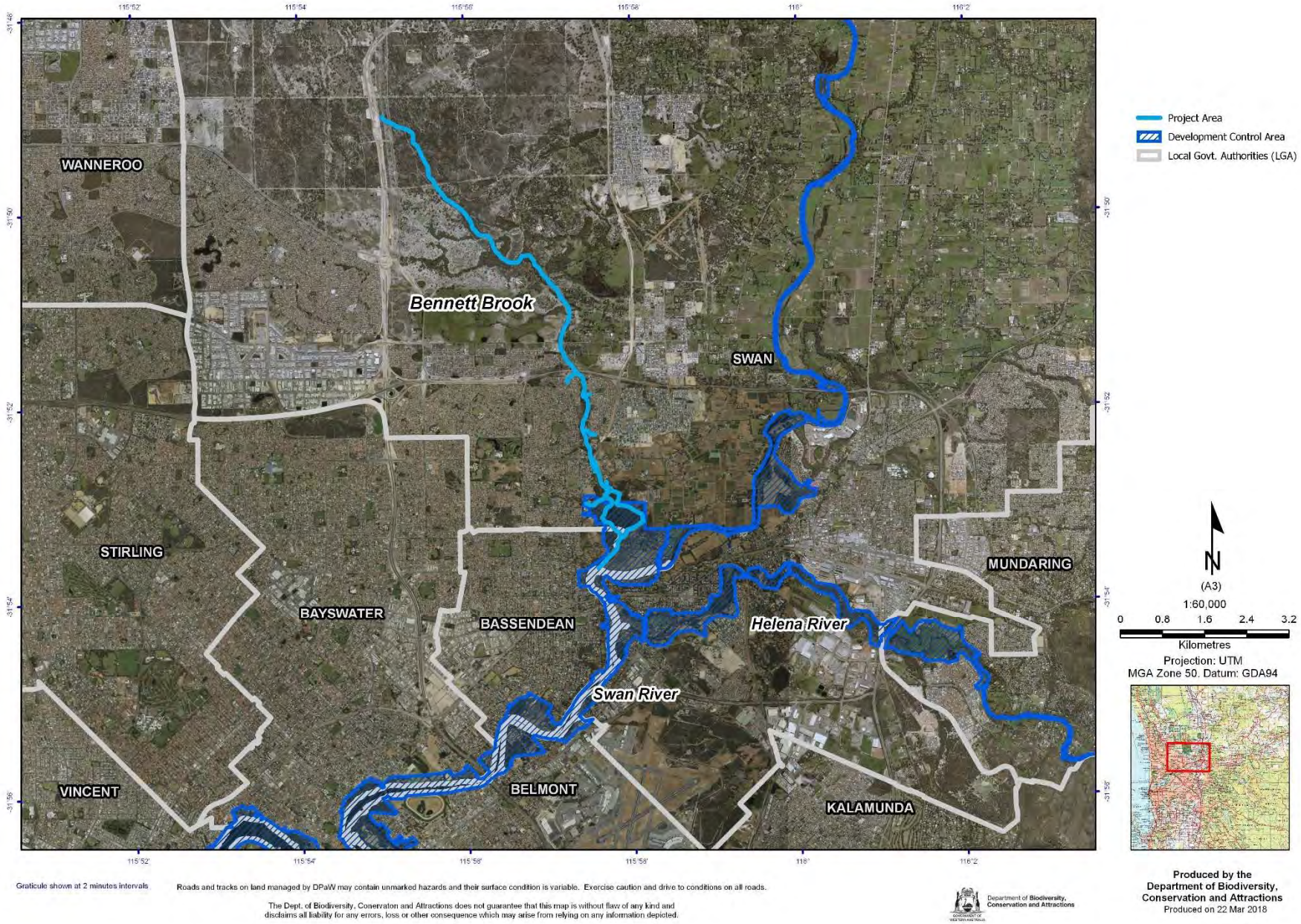


Figure 1: Extent of the Bennett Brook assessment, Perth NRM subregions, and Swan River Trust Development Control Area (DCA).

1.2 Cultural values

Bennett Brook is located on Whadjuk Noongar country. Water is central to Aboriginal tradition and the close social, spiritual and cultural tie between Aboriginal people and water carries an obligation to protect this resource for the future (Langton, 2006).

Bennett Brook is on the Dreaming Track of the Rainbow Serpent, the Waugal. The sharp bend in the Swan River where Bennett Brook meets it is known as Waugal's Bend or Devil's Elbow. This is an area where the Waugul lives (Tedeschi 1999). According to Hughes-Hallett (2010) many local Noongar people are wary of this location and practice rituals before entering the site.

Bennett Brook and its floodplain are significant cultural and spiritual grounds for Noongar people past and present. The soaks, springs and waterways of Bennett Brook are registered Aboriginal sites, as well as ancient burial grounds, certain trees, meeting areas and the home grounds of Noongar ancestors (Tedeschi 1999) (*Figure 2*).

Traditional occupation sites are located near the lower reaches of Bennett Brook. Noongar families who were displaced from their living areas at the time of European settlement resided on private land on the properties 'Pyrton' and 'Lockridge' in Eden Hill until about 100 years after settlement (SWALSC 2018; Hassell 2011).

These areas have since become Pyrton and Lockridge reserves. The Swan Valley Nyungah Community built houses and community buildings on Lockridge Reserve in 1994, and while the built structures have since been removed, members of the community still meet regularly near the site.

City of Swan has planned for an Indigenous cultural centre on Bennett Brook land and there is also a plan for an Indigenous interpretation trail along the brook (WAPC 2017).

1.3 Historical context

Early European explorers noted that Aboriginal people had most likely modified the areas around the river by fire stick farming, to regenerate vegetation for hunting purposes (Carter 1986).

Market gardens and fruit orchards were established by Chinese farmers on the lower reaches of Bennett Brook in the early 1900s. They also bred Carp near the confluence of the brook and the Swan River.

Clay deposits in the lower reaches of the brook were mined from the late 1800s. Bristile Roofing is still located on the eastern fringe of Grogan Swamp but the floodplain is no longer mined and the area is used for storage of raw materials.

Cattle were grazed along Bennett Brook in the early 1900s, and Mussel Pool was developed as a popular picnic site in the 1960s. This land was purchased in the 1970s by the Western Australian Planning Commission (WAPC), and Whiteman Park opened in 1986 as a tourist destination (WAPC 2017).

In the 1950s the Pyrton property was taken over by WA's Mental Health Services to develop a training centre for disabled children. The buildings were decommissioned in 2000 and later demolished but the site remains undeveloped. In 1994 the Swan Valley Nyungah Community was established on Lockridge Reserve, but was closed in 2003.

1.4 Natural values

Bennett Brook is recognised as having high regional and state conservation significance (Semeniuk 1987). The Western Australian Water Resource Council lists Bennett Brook as a regionally significant wetland for ecosystem maintenance and cultural purposes. It is an important fauna corridor, linking the Swan River with Whiteman Park and Ellen Brook (Cooper and Dell 1996).

Bennett Brook and the Bennett Brook Catchment are located on the Gnangara Mound, a shallow unconfined aquifer that is a major contributor to Perth's public water supply (Department of Water 2017).

Almost the entire length of Bennett Brook is federally listed Threatened Ecological Community (TEC) – *Banksia Woodlands of the Swan Coastal Plain* (*Environmental Protection and Biodiversity Conservation Act 1999*), which is also listed as Endangered under WA legislation (*Figure 4-Figure 6*). The southern part of Grogan Swamp is a different vegetation type and is not included in the TEC.

Three Bush Forever sites cover the length of Bennett Brook. The headwaters are within *Beechboro Road Bushland, Cullacabardee/Ballajura* (Site 198). *Whiteman Park, Whiteman/West Swan* (Site 304) extends downstream to Marshall Road and *Bennett Brook, Eden Hill to West Swan* (Site 305) extends downstream from Marshall Road and includes the Swan River upstream to Guildford.

More than 70% of the Whiteman Park Bush Forever site was assessed as having very good to excellent condition vegetation, with some areas of severe localised disturbance. It has a rich and diverse flora and fauna with a relatively large number of significant species, including the largest known stands of the Priority 3 sedge *Cyathochaeta teretifolia* (DEP 2000).

The Bennett Brook Bush Forever site is significant as it is unusual for four species of samphire to co-occur; *Salicornia quinqueflora*, *Tecticornia halocnemoides*, *T.lepidosperma*, and *T.pergranulata* are located on the floodplain of Grogan Swamp (DEP 2000).

Records of threatened fauna include the native water rat rakali, quenda and Carnaby's black cockatoo (DBCA 2018).

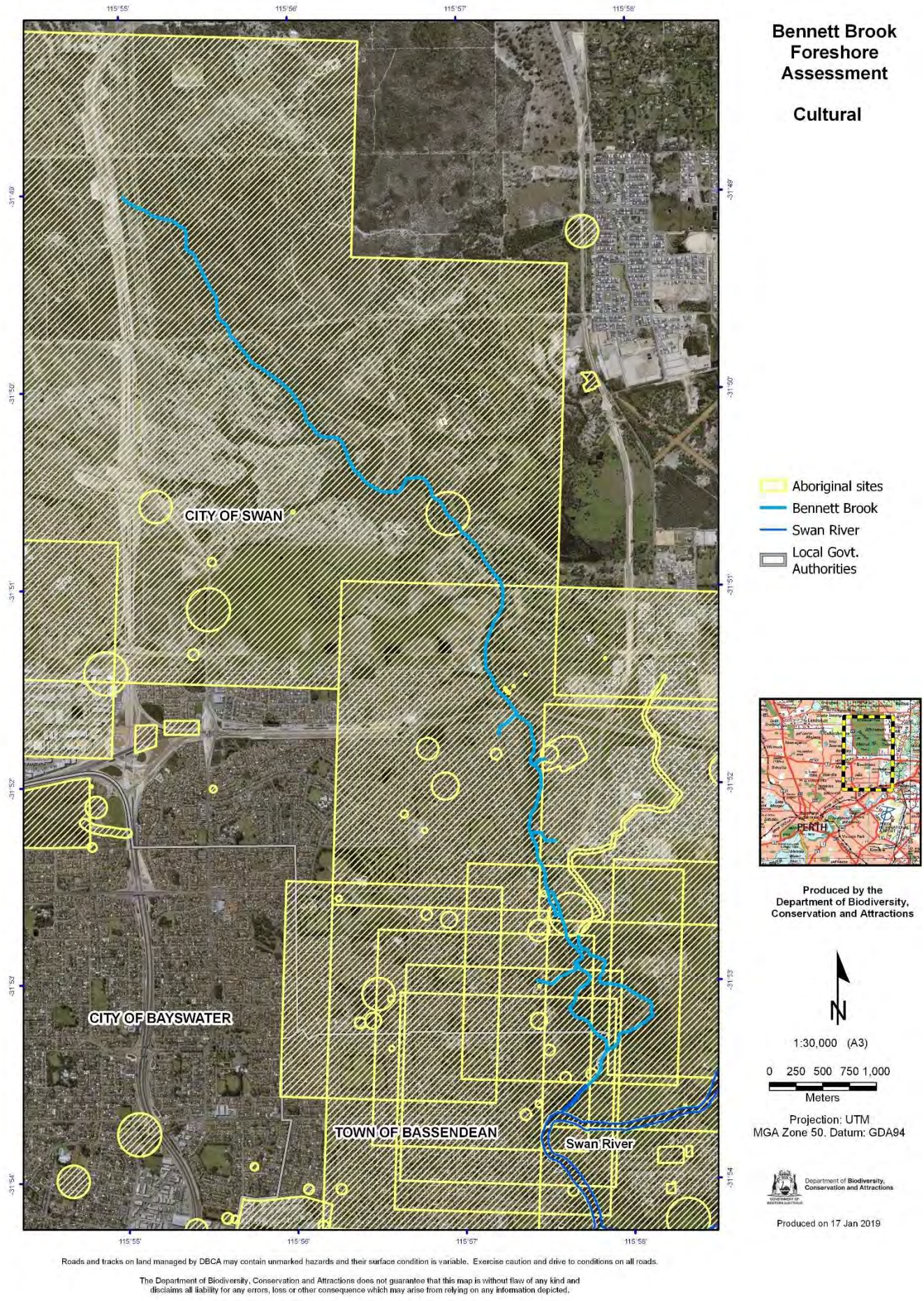


Figure 2: Recorded Aboriginal sites within a 500m buffer of Bennett Brook.

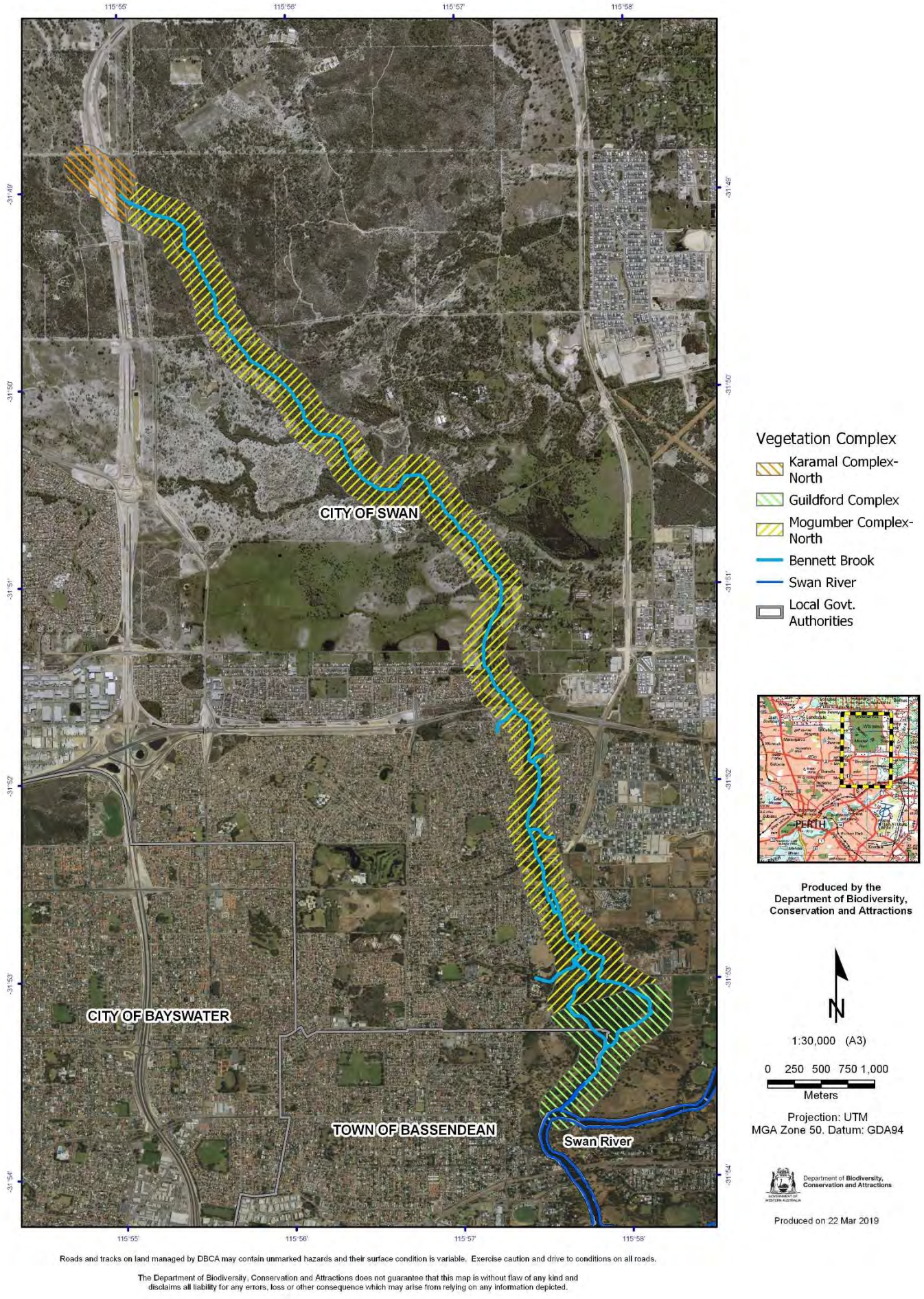


Figure 3: Vegetation complexes within a 500m buffer of Bennett Brook.

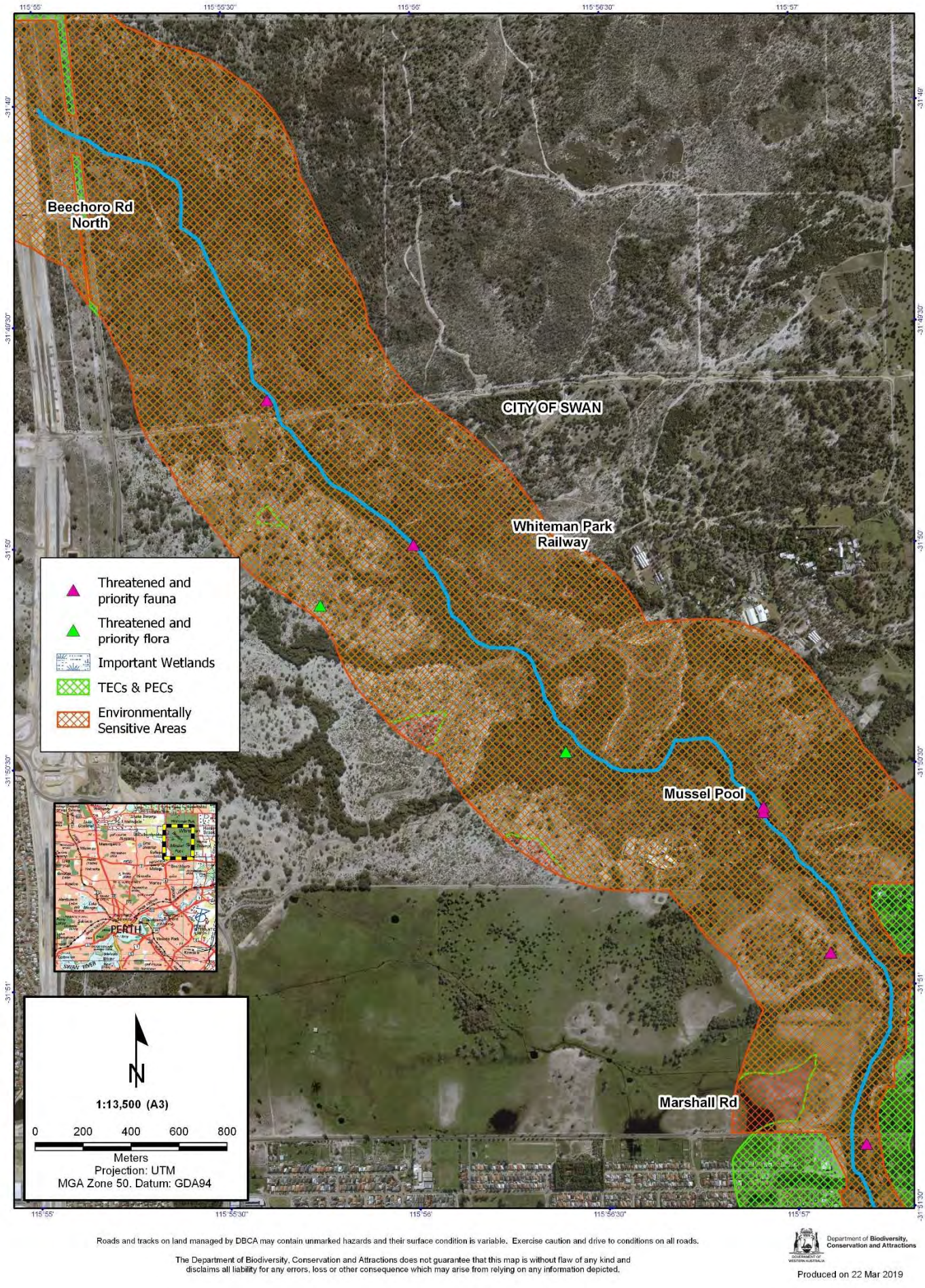


Figure 4: *Recorded natural values for Bennett Brook, North section.*

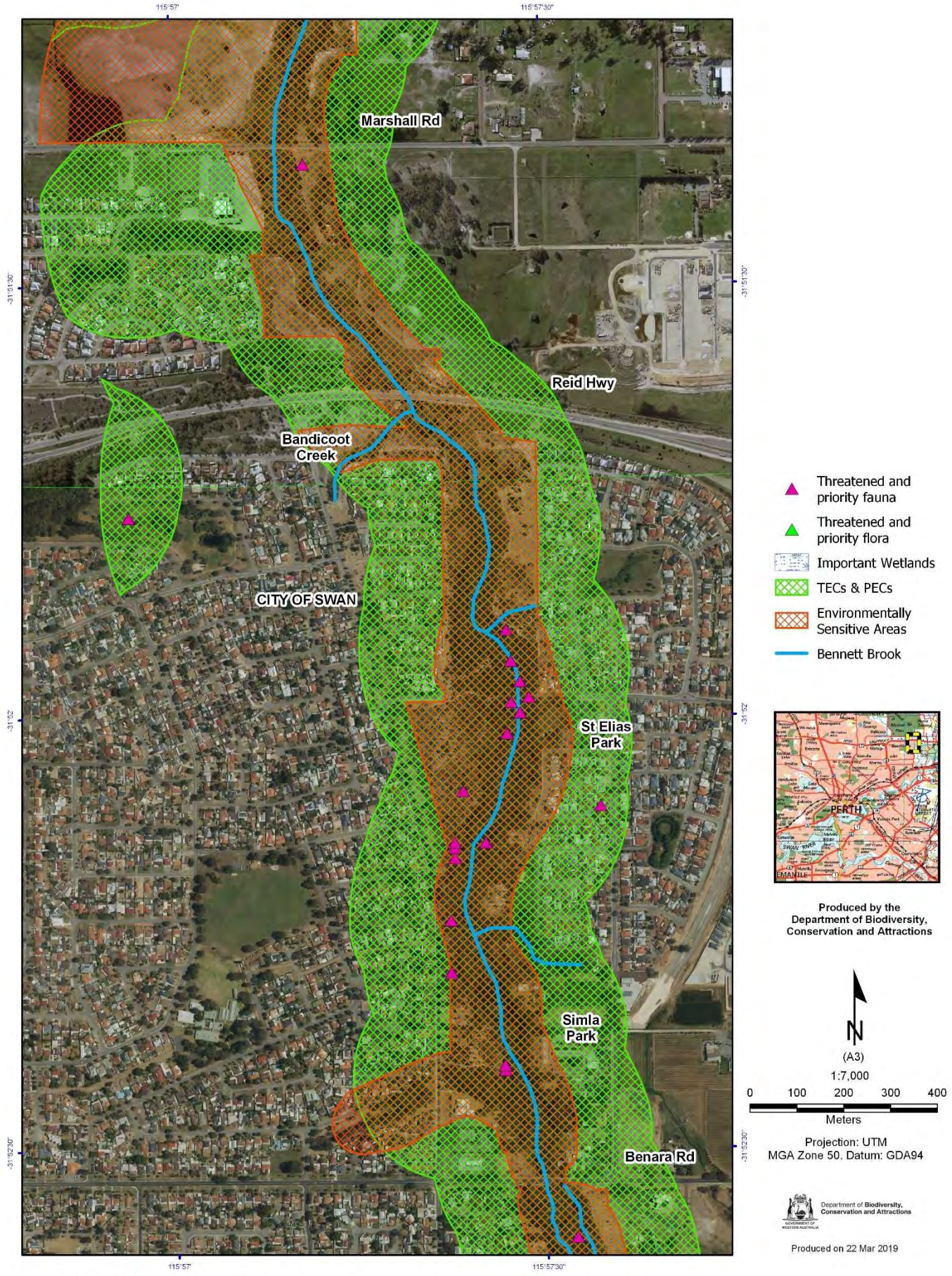


Figure 5: Recorded natural values for Bennett Brook, Central section.

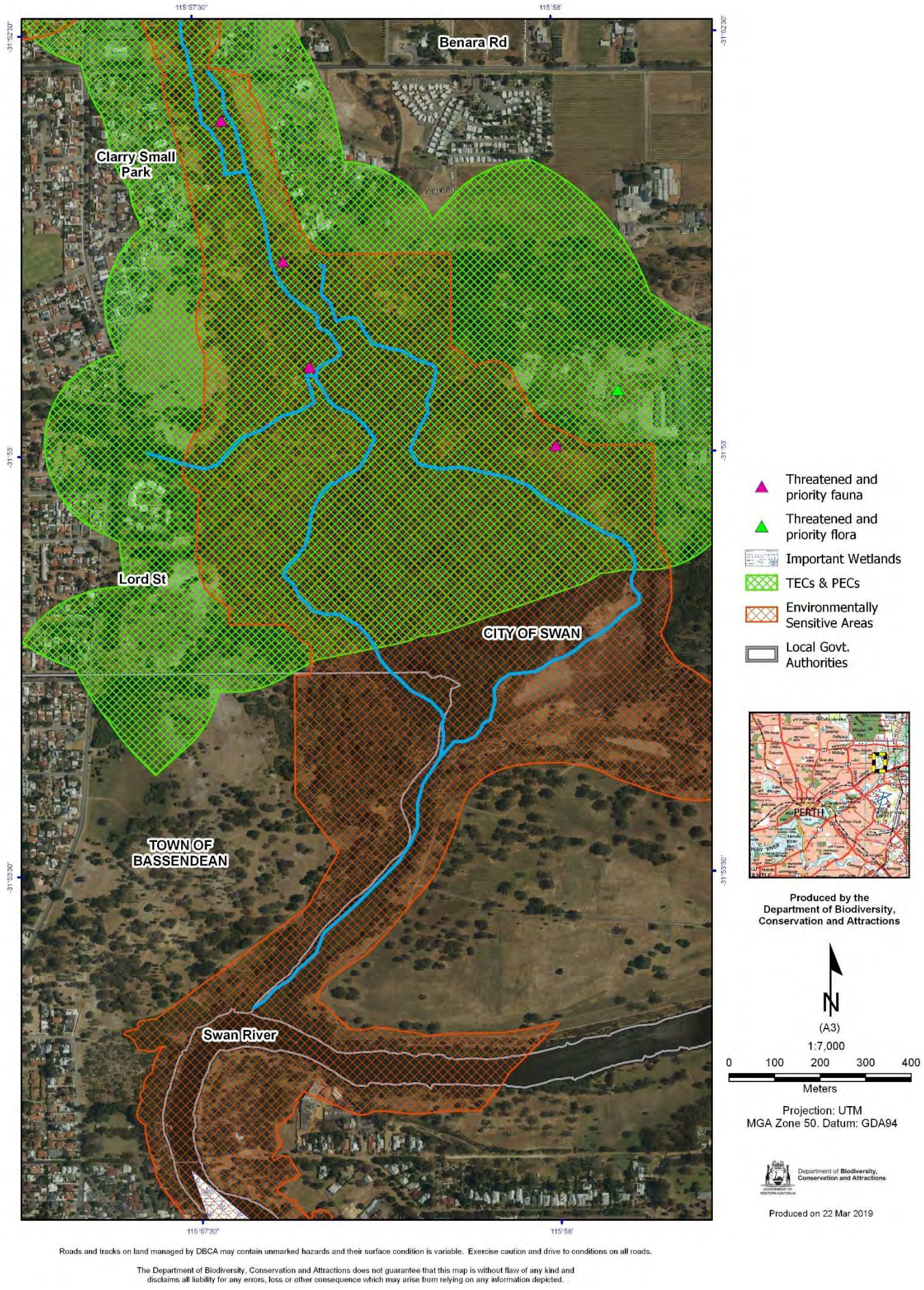


Figure 6: Recorded natural values for Bennett Brook, South section.

1.5 Major threats

The south-west of WA has experienced a 10-20% reduction in the dominant cool season rainfall since the 1970s and in some parts of the south-west by up 40% (CSIRO and BOM 2015; CSIRO 2012). Streamflow has experienced a similar decline (CSIRO and BOM 2016).

Increased groundwater pumping in the north of Bennett Brook Catchment for metropolitan water supply has also lowered groundwater levels and flow in the brook (Swan River Trust 2011). Impacts on Bennett Brook include loss or early drying of pools that provide fish and other in-stream fauna habitat, and increased fire risk.

In contrast, the south of Bennett Brook Catchment (from Marshall Road south) has experienced higher-than-natural flow during high rainfall events due to constructed drainage networks and increased runoff from hard surfaces such as roads and roofs (Department of Water 2016).

Many tributaries west of Bennett Brook have been modified into deeply incised drains that have heavy weed infestations and restricted habitat value.

Clearing of the catchment and floodplain for farming, grazing and market gardening in the early decades of European settlement, and now largely for residential developments, has contributed sediment, nutrients and contaminants to the brook, and reduced species diversity and habitat (Pearson and Tedeschi 1996).

Feral animals have impacted on native plants and animals through direct predation by foxes and cats, and rabbits and cattle have changed vegetation and habitat. The feral freshwater fish pearl cichlids have been found in Lanius Drain north of Benara Road, and in Bennett Brook downstream to Grogan Swamp (Beatty *et al.* 2010).

1.6 Management structure

Much of Bennett Brook is located within Whiteman Park, managed by DPLH for recreation and conservation (*Figure 7-Figure 9*). DPLH is responsible for the operational management of the Park on behalf of WAPC (WAPC 2017).

In the early 1980s the lower part of the brook was included in Whiteman Park to form a continuous link to the Swan River, and named Bennett Brook Reserve Linear Park.

Most of Grogan Swamp is vested in DPLH under Management Order to WAPC. The site of the former Pyrton training centre and Swan Valley Nyungah Community is vested in Department of Finance. The Bennett Brook Disability Justice Centre is vested in Department of Communities.

DBCA has a strong interest in the Bennett Brook Catchment as it is one of eight priority catchments in the Swan Canning river system identified to improve water and sediment quality through restoration activities in the brook and catchment.

Friends of Bennett Brook has been actively restoring Bennett Brook from Marshall Road south to Clarry Small Park since 1998. The group works closely with the environmental management team from Whiteman Park and the City of Swan.

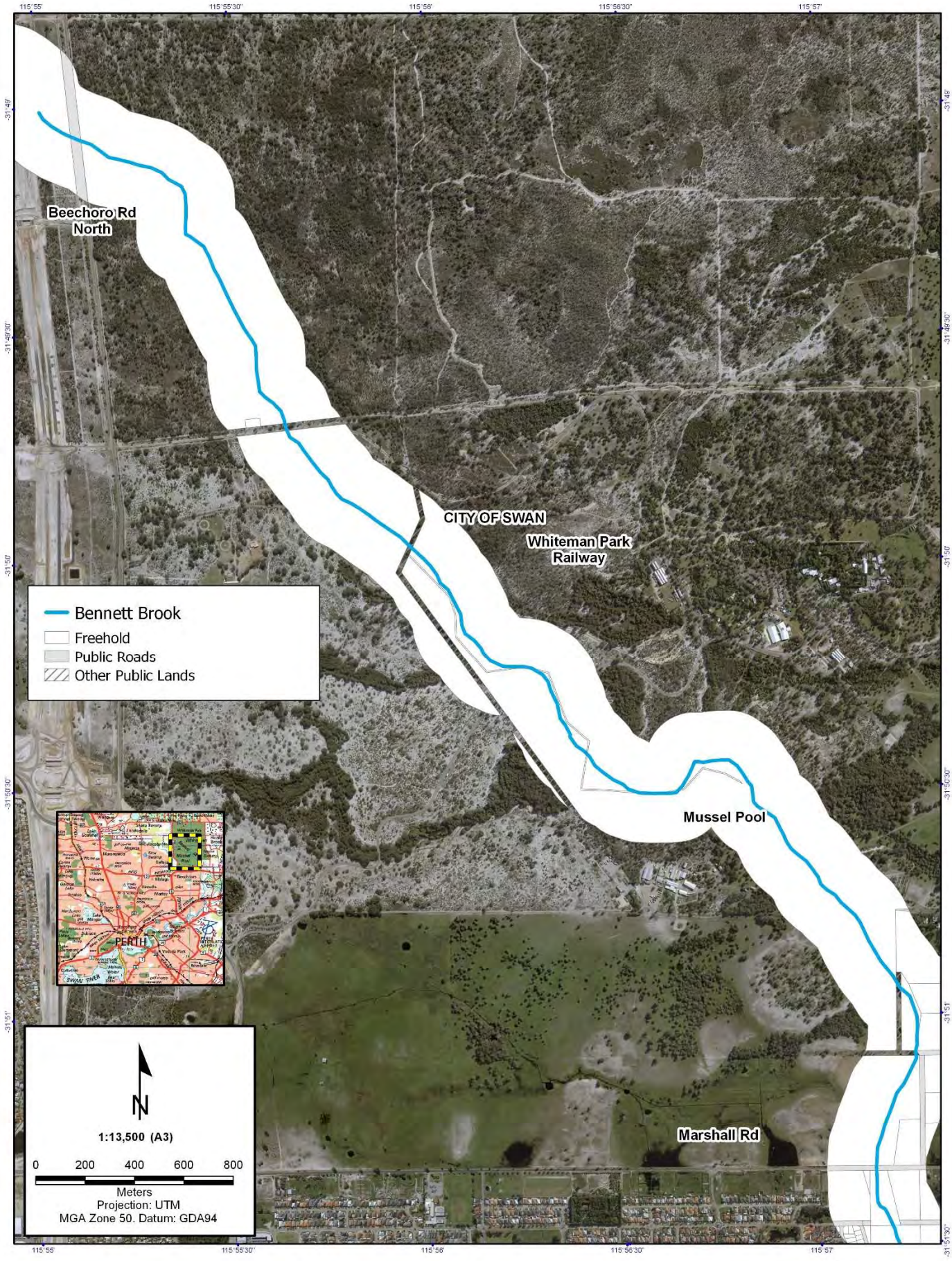


Figure 7: Land ownership within a 500m buffer of Bennett Brook, North section.

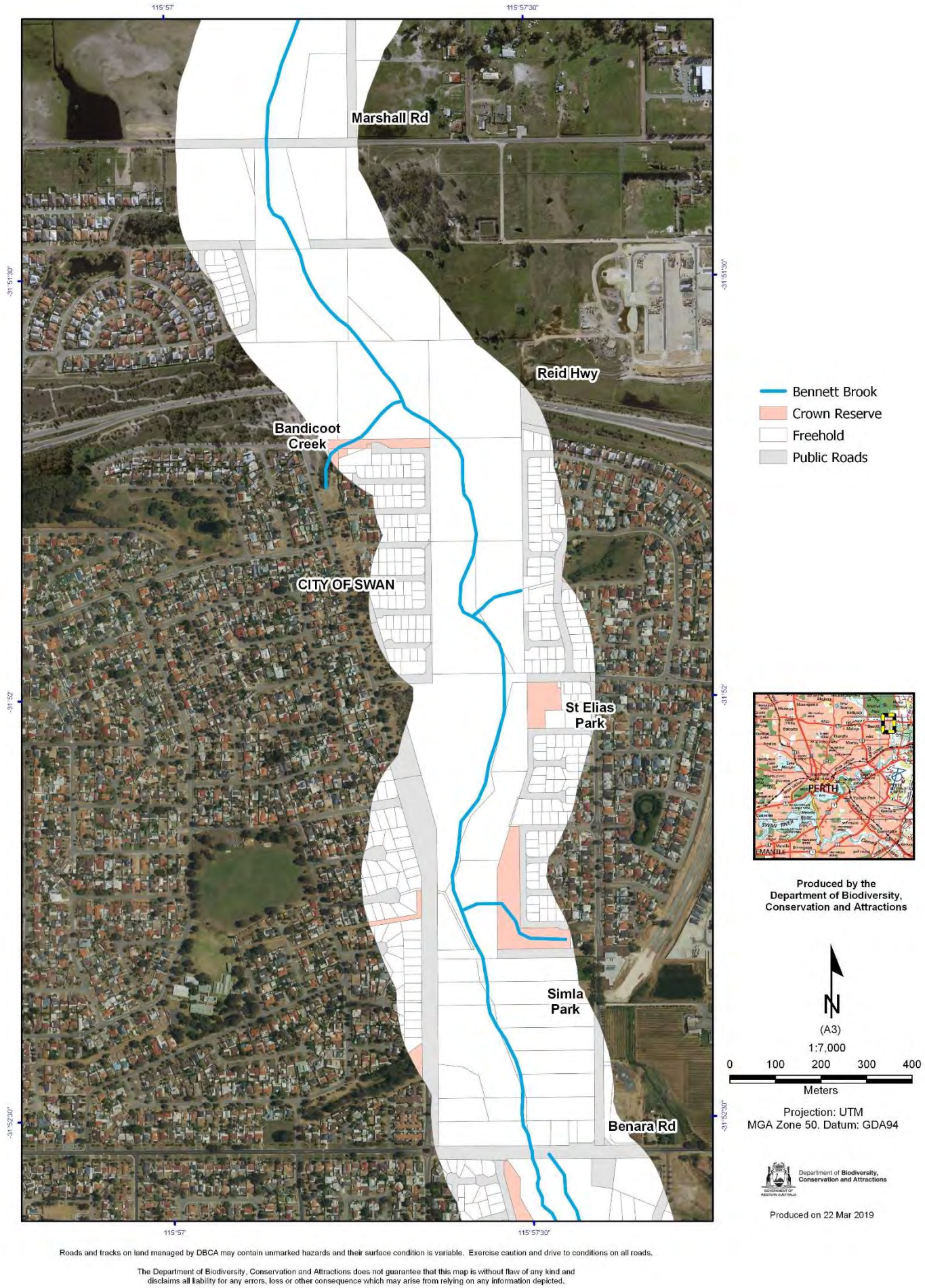


Figure 8: Land ownership within a 500m buffer of Bennett Brook, Central section.

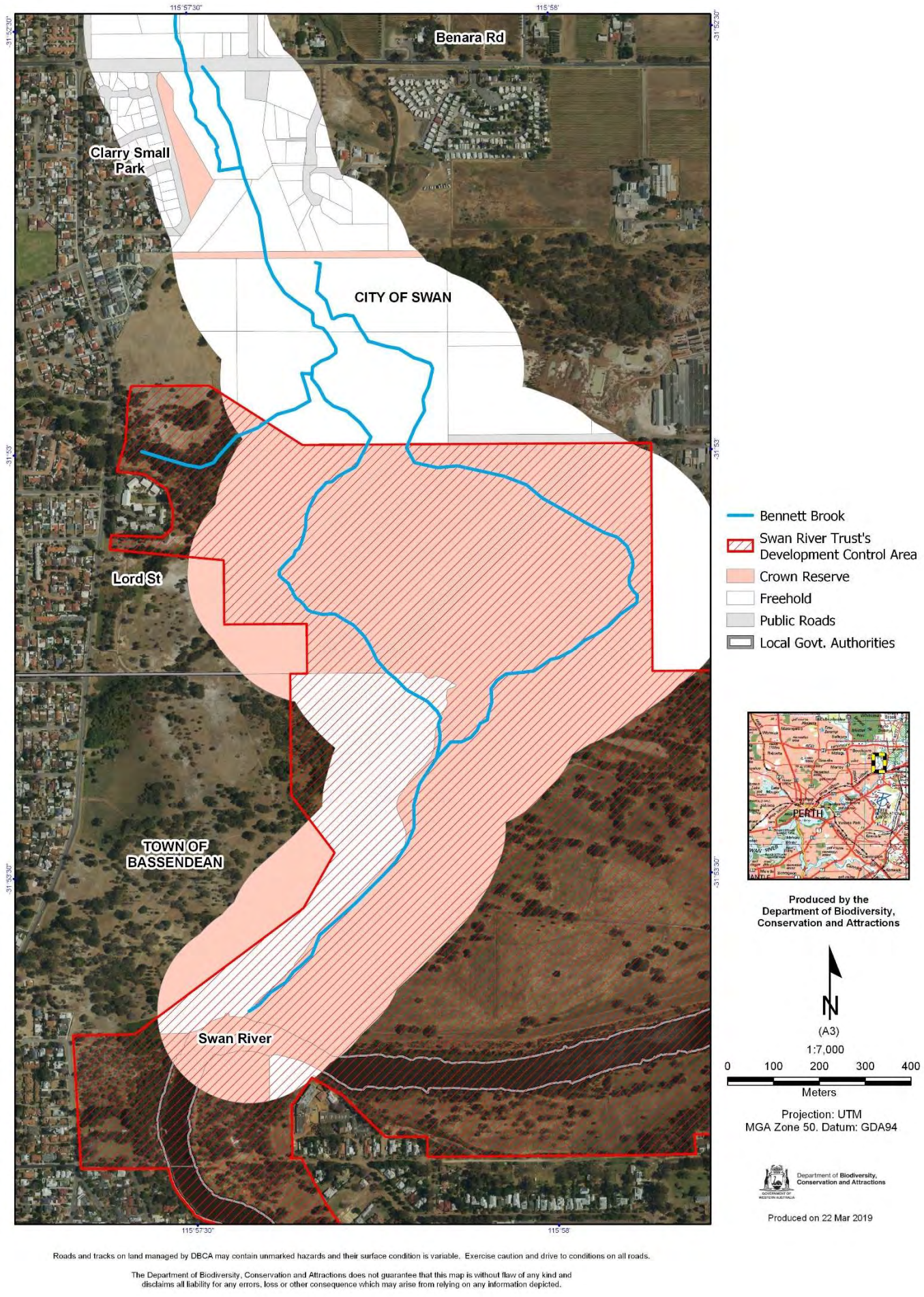


Figure 9: Land ownership within a 500m buffer of Bennett Brook, South section.

1.7 Land use changes since 2007

Perth has undergone rapid population growth in the previous decade, and significant residential expansions have occurred in Caversham and Bennett Springs. Potential impacts on Bennett Brook include increased runoff of sediment, nutrients and other contaminants, and clearing of native vegetation that once formed a wildlife corridor to the brook.

NorthLink WA is a 37km highway currently under construction between Reid Highway and Muchea to reduce pressure on Great Northern Highway. Clearing of the alignment is evident on the 2017 satellite image (*Figure 10, Figure 11*).

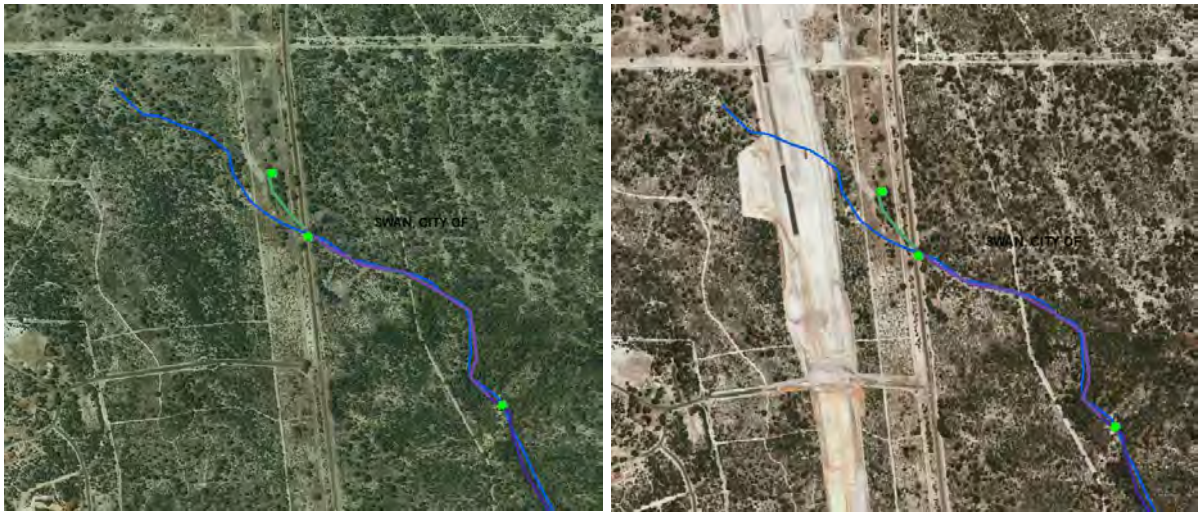


Figure 10 (left): 2006 satellite image of the headwaters of Bennett Brook prior to construction of NorthLinkWA.

Figure 11 (right): 2017 satellite image showing the cleared alignment of NorthLinkWA.

The Morley-Ellenbrook train line ('METRONET') is proposed to service Perth's north-east suburbs and its alignment is currently being planned. An option being considered is a spur line from the existing Midland line to connect communities including Bennett Springs, Whiteman and Ellenbrook.

Friends of Bennett Brook have conducted many restoration projects, carrying out weed control and revegetation over a 2.5km reach of the brook to improve its environmental and social value.

Department of Finance and WAPC (Hassell 2011) developed a draft concept plan in 2011 to develop the former Swan Valley Nyungah Community site into a cultural and environmental park, including rehabilitation and revegetation of the site. The plan states that further community consultation and endorsement by government is required.

1.8 Objectives

Objectives of this assessment of Bennett Brook are to:

- determine riparian vegetation condition;
- identify significant points of erosion;
- identify management issues including uncontrolled access, weed incursion and vegetation loss;
- determine recommendations for intermediate to longer-term management;
- identify management works that could be undertaken and achieved in the short-term; and
- compare the current condition to that determined in previous assessments.

2 Method

2.1 Previous assessments

2.1.1 Success Hill Action Group

The lower reaches of Bennett Brook were intensively studied in 1996 through a National Landcare project initiated by Success Hill Action Group, Bassendean Preservation Group and the Swan Valley Nyungah Community. Water testing, vegetation studies and fauna surveys were carried out and reported in Pearson and Tedeschi (1996), which provide a comprehensive baseline for Grogan Swamp.

2.1.2 Water and Rivers Commission

The Water and Rivers Commission (1999) adapted the Foreshore Condition Assessment Form (Pen and Scott 1995) for use in urban and semi-rural areas. Bennett Brook was assessed in mid-1998 from Benara Road upstream to Mussel Pool in Whiteman Park. An overall stream condition index was determined by using the following stream condition indicators:

- bank stability;
- foreshore vegetation;
- stream cover; and
- habitat diversity.

A colour-coded system was used to summarise the condition of each parameter based on a scale from Excellent to Very Poor, and each condition category contained a score. The condition scores were summed to give an overall stream condition index, also ranked on a scale from Excellent to Very Poor (Appendix 10).

2.1.3 DBCA

The Department of Water and Environmental Regulation (DWER), DBCA and the Ellen Brockman Integrated Catchment Group undertook foreshore assessments of 37 tributaries in the Swan Canning Catchment between 2006 and 2007 (SRT 2008b).

The Bennett Brook assessment was conducted by DBCA in 2007. It extended from the headwaters to the confluence with the Swan River.

The brook was split into ‘segments’ based on vegetation condition and bank stability (DoW n.d.). Segments were surveyed by foot or by vehicle at access points where access was limited by land tenure or terrain.

Vegetation was assessed based on Keighery’s (1994) scale of condition, including growth form, dominant species and crown cover. Data were also collected for weed percentage cover, drains, infrastructure, management pressures and management

responses, adapted from DBCA's methodology for the Foreshore Assessment and Management Strategy (2008a).

Bank stability, terrestrial and instream habitat and land use, and suggestions for management were adapted from the Foreshore Condition Assessment Form (Pen and Scott 1999). A Pen and Scott (1995) grade was given for each segment.

DBCA categorised segments based on Rutherford *et al*. (2000a and 2000b) which ranks segments based on several parameters described in Section 2.2.4. This categorisation was also applied to the current assessment to enable comparison.

2.2 Current assessment

DBCA's 2007 methodology was adopted for the current assessment for a reasonably reliable comparison over the same extent of Bennett Brook.

2.2.1 Desktop assessment

A brief desktop assessment was undertaken to note the recorded natural and cultural values adjacent to Bennett Brook. A 500m buffer to the river's alignment was applied and a search for the following data was conducted:

- Nationally Important Wetlands;
- Bush Forever sites;
- Environmentally Sensitive Areas declared under the *Environmental Protection Act 1986*;
- known populations of rare or priority flora and fauna;
- State and nationally listed threatened ecological communities (TECs); and
- registered Aboriginal sites.

Perth NRM provided a summary shapefile of restoration projects funded by the Swan Alcoa Landcare Program (SALP) and other programs from 2007 to 2017. Restoration sites on the brook were noted during the field assessment to determine whether restoration works were still evident and had improved condition.

2.2.2 Data collection

The ArcGIS *GIS Collector* application was used to collect field data on an Apple iPad. Shapefiles and a base map were created for viewing in the web version *GIS Online* and the phone/tablet application *GIS Collector*. Field data were automatically uploaded to the Cloud and were checked at the end of each field day to ensure data had been accurately captured.

The alignment of Bennett Brook was accurately digitised from aerial photography and was viewed in the field in *GIS Collector*. The start point of each segment was marked in GIS Collector. A number of attributes were recorded for each segment.

2.2.3 Field surveys

Field surveys were undertaken from November 2016 to January 2017. DBCA conducted surveys on foot where access to the riparian zone was possible, and by vehicle viewing the brook at access points where the full length of segments was not accessible due to land tenure or terrain.

The brook was assessed in a downstream direction. Left and right banks were determined when facing downstream.

The stream bank was split into segments based on vegetation structure, bank type and substantial changes in land use. Both sides of the river were assessed as one segment. Attributes were then assigned to the left and right banks. The segment extents were similar to those defined by DBCA in 2007 but were modified where land use or other attributes had changed significantly.

The following attributes were collected:

- Segment details – date, field officers
- Summary comment – and key issues of note
- Height and slope of the banks
- Land use of the banks or floodplain: agriculture, parkland, rural, residential, commercial/industrial, remnant bush/reserve and/or recreation
- Fencing of the riparian zone of the left or right banks
- Vegetation type description
- Dominant native species – from each of the prominent vegetation layers
- Condition:
    - Bank stability/erosion (good, average, poor)
    - Vegetation (good, average, poor)
    - Weed cover (minimal, moderate, extensive)
    - Level of pressure (minimal, moderate, extensive)
    - Pen and Scott's foreshore condition assessment grading (A to D grade)
- Management issues:
    - Weed species (a full list of weeds noted in the field)
    - Erosion and siltation presence, through natural means or by disturbance
    - Type of erosion present; including undermining, large silt deposits, incised scour, slumped bank, embayment retreat, exposed tree roots
    - Vegetation loss; through trampling, grazing (current and historic if known), displacement by weeds, clearing, erosion
    - Uncontrolled access; by vehicles, people (including private property owners where gardens encroached the shoreline and fences were not constructed) or stock (only included stock where sighted or signs of current presence were evident and they could access the brook)
    - Other management issues of significance
- Trajectory (stable/improving, deteriorating)
- 'Hope' for the segment if the current level of management was maintained
- Ease of rehabilitation, and factors affecting likely rehabilitation success

- Rehabilitation recommendations, such as priority weed species for control, fencing, erosion control, species for revegetation, and silt or water quality management.

See Appendix 7 for a further definition of attributes.

2.2.4 Categorisation of segments

The categorisation of segments was based on the Cooperative Research Centre (CRC) of Catchment Hydrology's framework (Rutherfurd *et al*., 2000a and 2000b). The CRC developed a 'reach priority shuffle' method (Appendix 9) to rank segments or reaches according to five parameters:

- rarity or conservation value (rare/nationally or regionally significant);
- condition (good-poor);
- trajectory (deteriorating-improving) and hope (with hope-without hope);
- proximity to good reaches, and
- ease of rehabilitation (easy-hard).

See Appendix 8 for a description of these parameters.

Each segment was assigned a category for recommended restoration strategies (*Table 1*). This prioritised segments and highlighted areas of stream bank for restoration. Once these areas were identified we considered if there was community interest and capacity and multiple benefits possible (e.g. educational, recreational).

Table 1: Criteria for assigning a category to a segment and the suggested management strategy for each category.

Category	Criteria and management strategy
0	**Condition and pressures** Pen and Scott grade = A1; Level of pressure = Minimal; and none of the following issues were recorded for the segment: o Access – vehicle, people, stock, or 'other' o Loss of vegetation – through trampling, grazing, displacement by weeds, clearing, erosion o Erosion – undermining, large deposits, incised scour, scarps/vertical shears, slumped banks, embayment retreat, exposed tree/shrub roots o Other management issues **Strategy: Only requires monitoring for the emergence of new threats in the future**

1	**Rarity or conservation value** Segments intersect with or are within 500m of one or more of the following: o Nationally Important Wetland o Bush Forever site o Environmentally Sensitive Area o Known populations of rare or priority flora and fauna o State or nationally listed threatened ecological community **Strategy: Protection or minor restoration to maintain conservation value and condition**
2	**Condition** Pen and Scott grade = A1, A2 or A3 but segment does not meet criteria for Category 1 **Strategy: Protection or minor restoration to maintain good condition**
3	**Condition and trajectory** Pen and Scott grade = B1, B2, B3, C1 or C2 and Trajectory = Deteriorating **Strategy: Restoration to prevent further deterioration**
4	**Condition, trajectory and proximity to good reaches** Pen and Scott grade = B1, B2, B3, C1 or C2; Trajectory = Stable / improving, and the segment abuts another segment that meets Pen and Scott grade A1, A2 or A3 **Strategy: Expansion of good quality segments by restoring abutting segments in poorer condition**
5	**Condition, trajectory, proximity to good reaches and ease of rehabilitation** Pen and Scott grade = B1, B2, B3, C1 or C2; Trajectory = Stable / improving; the segment does not abut another segment that meets Pen and Scott grade A1, A2 or A3, and Ease of rehabilitation = Easy **Strategy: A small investment in restoration works to stimulate natural recovery**

6	**Condition, trajectory, proximity to good reaches and ease of rehabilitation** Pen and Scott grade = B1, B2, B3, C1 or C2; Trajectory = Stable / improving; the segment does not abut another segment that meets Pen and Scott grade A1, A2 or A3, and Ease of rehabilitation = Hard **Strategy: Restoration is a lower priority as investment of resources is likely to be high, although there is a potential for recovery**
7	**Condition and hope** Pen and Scott grade = C3, D1, D2 or D3 and Hope = without hope **Strategy: Low priority for restoration as these areas are likely to be expensive and difficult to rehabilitate**
8	**Condition and hope** Pen and Scott grade = C3, D1, D2 or D3 and Hope = with hope **Strategy: Lowest priority for restoration as these areas are likely to be expensive and difficult to rehabilitate, and there is some chance of natural recovery if no action is undertaken**

3 Assessment results

Bennett Brook was divided into three sections - North, Central and South. The North section includes the headwaters and the main part of Whiteman Park. It extends south to Marshall Road, a distance of just over 6km (*Table 2; Figure 12*). Except for private property in the south east of the section land management is consistent.

The Central section extends from Marshall Road to Benara Road, approximately 3km in length (*Figure 13*). Residential developments surround the river reserve and this section is where the Friends of Bennett Brook are most active.

The South section extends from Benara Road to the confluence with the Swan River and the dominant feature is Grogan Swamp. The distance from Benara Road to the Swan River is about 2.5km, although the length of streambank assessed was over 5km as each side of the swamp was assessed separately (*Figure 14*). Residential and industrial developments are located further away from the brook than in the Central section.

Table 2: Number of segments and average segment length for each section of Bennett Brook.

Section	Length assessed (km)	Average segment length 2017 (km)	Number of segments 2017	Number of segments 2007
North – headwaters to Marshall Road	6.37	0.277	23	30
Central – Marshall Road to Benara Road	3.15	0.185	17	24
South – Benara Road to confluence with Swan River	5.36	0.185	29	47
Total	**14.88**	**0.216**	**69**	**101**

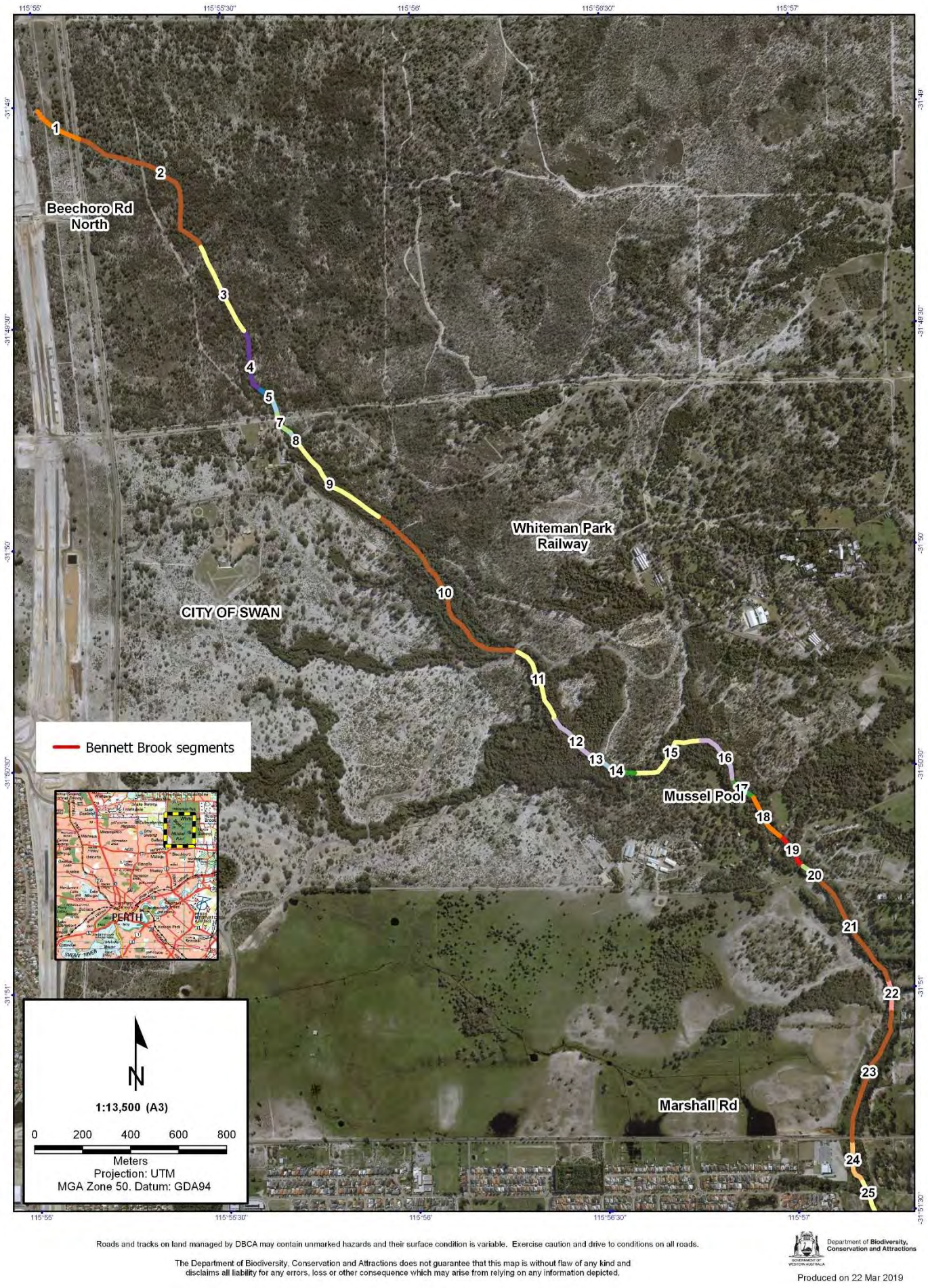


Figure 12: Bennett Brook segment numbers, North section.

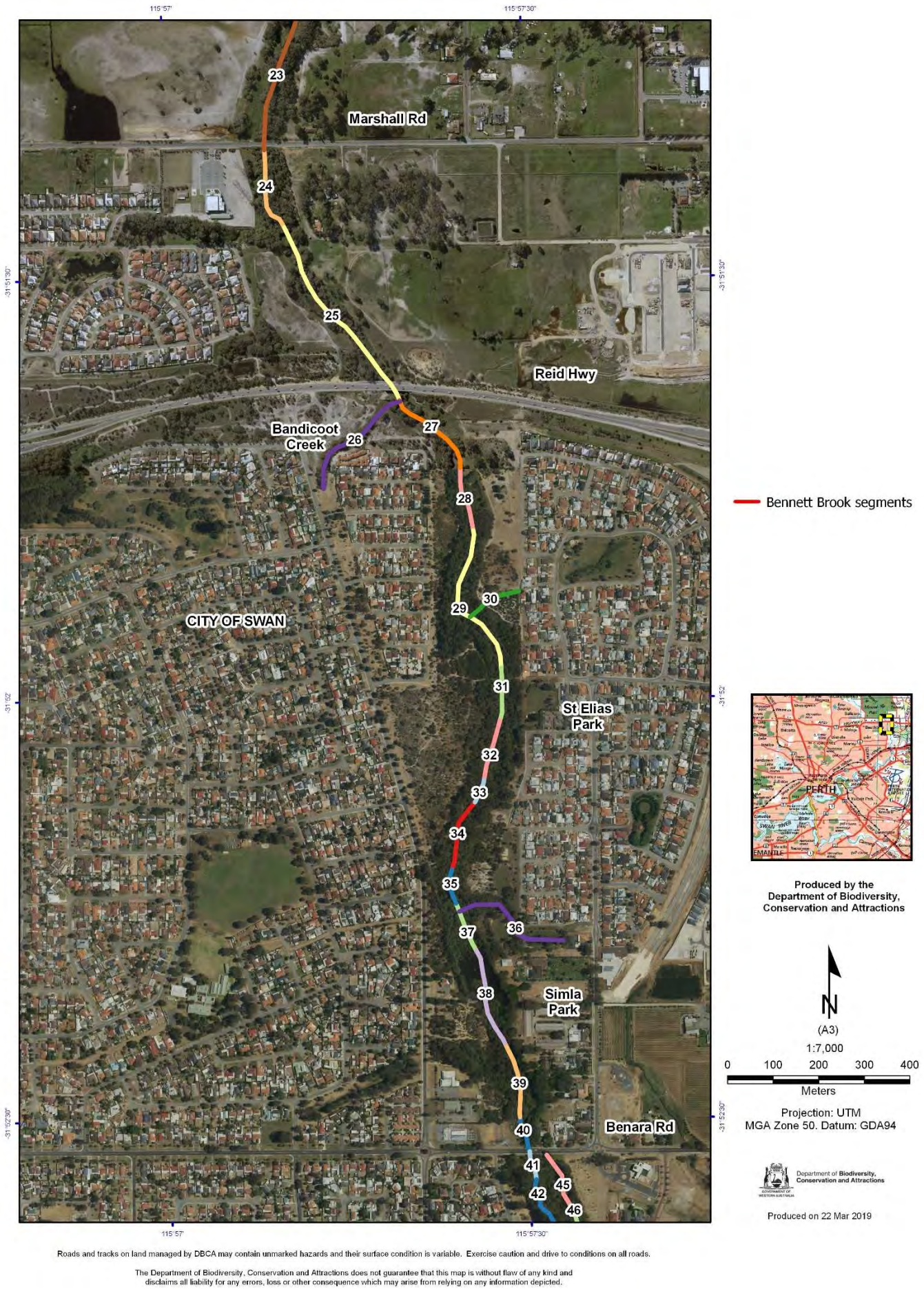


Figure 13: Bennett Brook segment numbers, Central section.

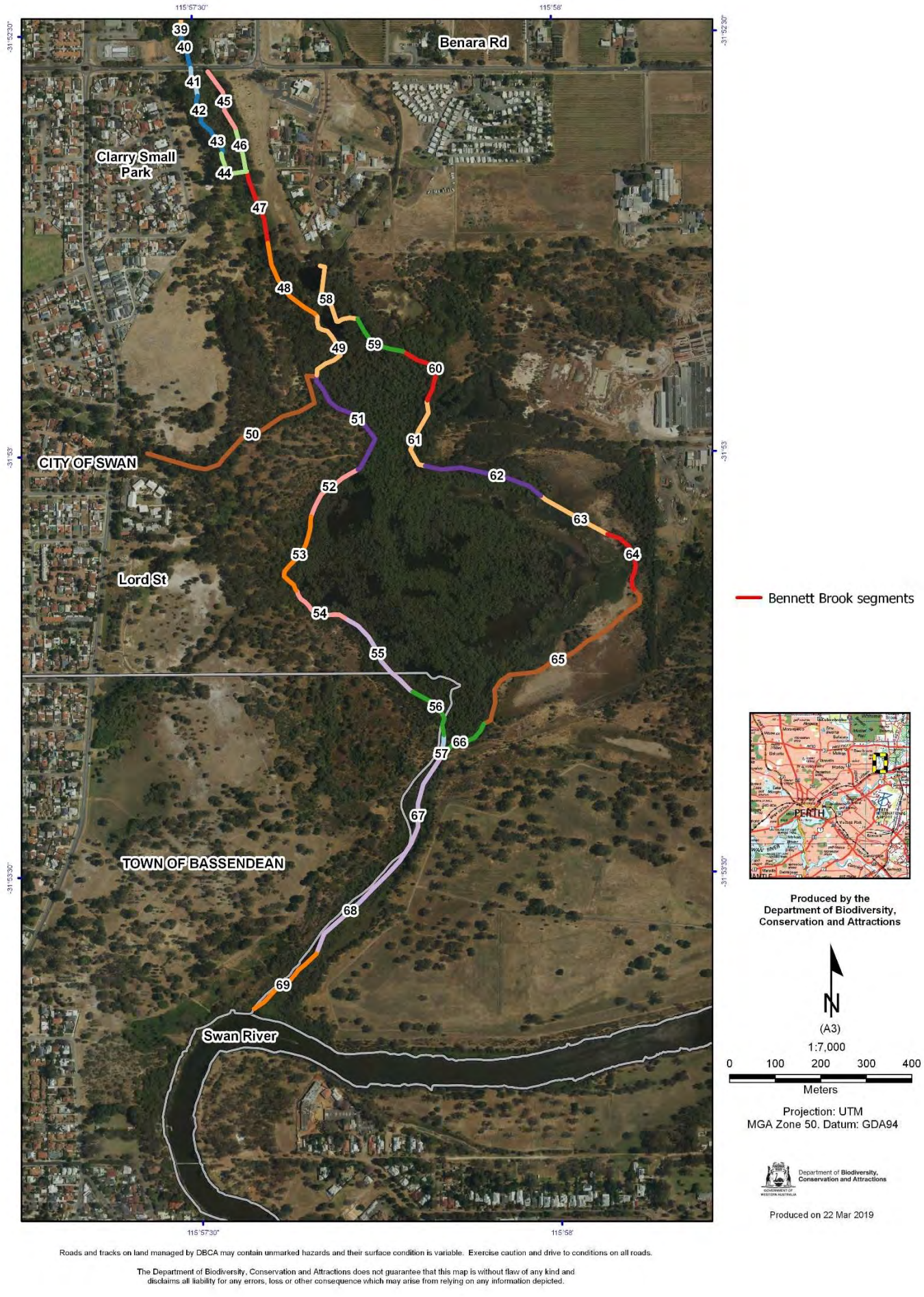


Figure 14: Bennett Brook segment numbers, South section.

3.1 Land use

The primary land use within the North section is remnant bush reserve (*Figure 15*). At the headwaters west of Beechboro Road North the brook is located in rural paddocks. In Whiteman Park the area around Mussel Pool and the dog park is primarily used for recreation. Southeast of Mussel Pool where private property abuts the brook the land use changes to rural and residential.

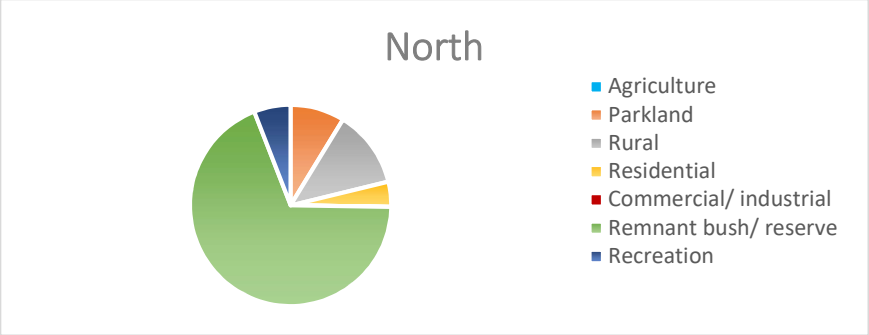


Figure 15: Land uses of river bank in the North section.

In the Central section the remnant bush reserve surrounding the brook is narrow and residential developments are within 100-200m of the brook (*Figure 16*).

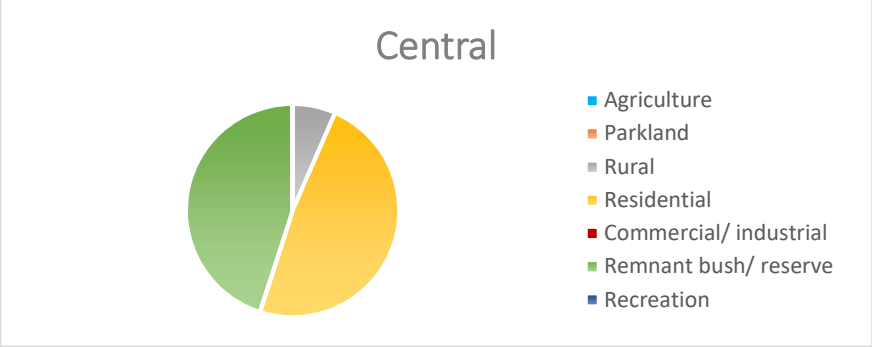


Figure 16: Land uses of river bank in the Central section.

In the South section, most of the watercourse is within remnant bush reserve (*Figure 17*). There are a few small exceptions: in Clarry Small Park where vegetation was historically cleared for agriculture, and several fenced paddocks on the eastern side of Grogan Swamp near the Bristile Roofing quarry.

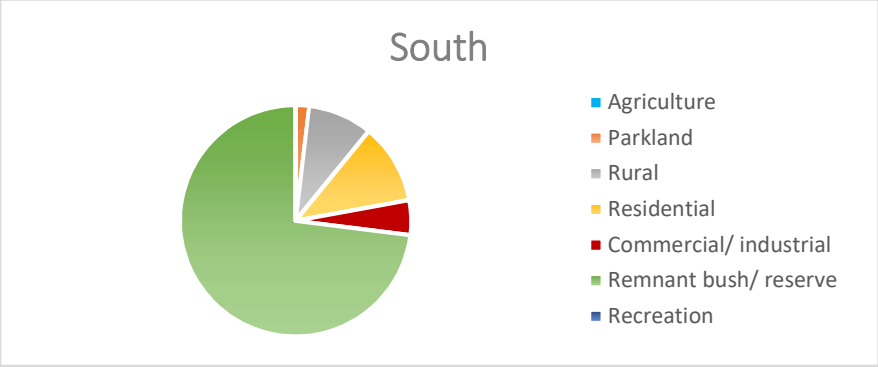


Figure 17: Land uses of river bank in the South section.

3.2 Bank height, slope and stability

North section

The headwaters of Bennett Brook are shallow and gently sloping (*Figure 18-19*). The channel is difficult to distinguish as the landscape is flat and riparian vegetation is dispersed among dryland plants.

Figure 18 (left) and Figure 19 (right): Shallow, undefined banks near the headwaters.

About 2km from the headwaters the channel becomes more marked. From this point to Marshall Road the bank height ranges from <0.5 to 1-2m. The bank slope is shallow for the rest of the section, with only two segments of medium slope.

Bank stability is good for most of the North section (*Figure 24*). In only three segments erosion or sedimentation were noted. At the headwaters localised sedimentation was associated with a culvert on the Beechboro Road North crossing. A sand-based dam is located in the brook near the northern-most rail crossing (*Figure 22*). Near another rail crossing about 700m north of Mussel Pool, the rail embankment appears to have impeded water flow and the surface water was stagnant *(Figure 20*).

Figure 20 (left): Slow-flowing to stagnant water north of Mussel Pool.
Figure 21 (right): Private property fenceline within the channel of Bennett Brook.

Figure 22 (left): Small dam on Bennett Brook in 2007 (was dry in 2017).
Figure 23 (right): The private property fenceline in 2007.

Towards Marshall Road and adjacent to private property bank stability was average where domestic sheep and pigs had access to the brook (*Figure 21, Figure 23*). This area was in a similar condition when assessed by DBCA in 2007.

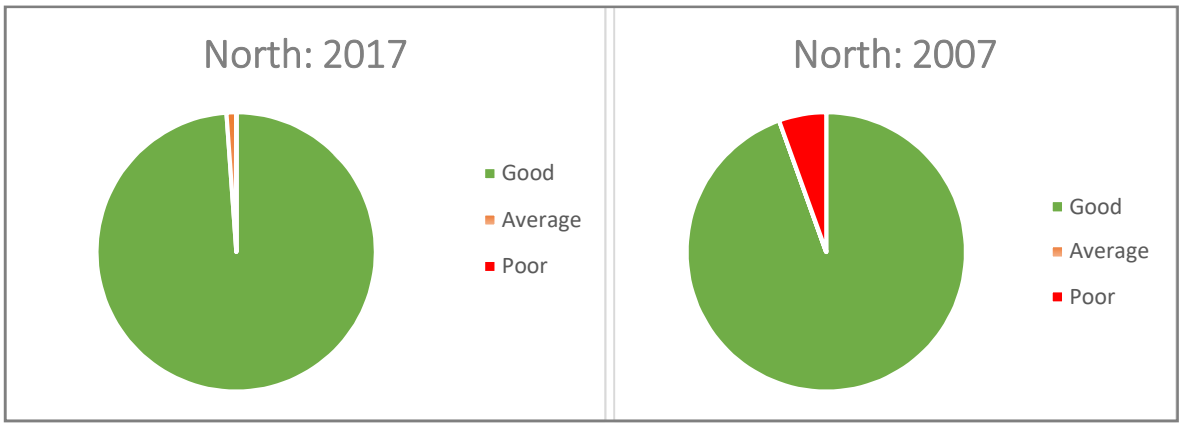


Figure 24: Bank stability ratings for the North section in 2017 (left) and 2007 (right).

WRC (1999) recorded erosion from Mussel Pool to Benara Road in low to moderate levels. This was considered largely due to a reduction in vegetation cover and the outfalls from drainage channels and pipes. Where private property abuts the brook north of Marshall Road, erosion was localised but sedimentation was significant as a result of high sediment loads and reduced water velocities within the main channel.

In winter 2018 the City of Swan redirected a drainpipe outlet to relieve flooding near houses on Marshall Road. However, the pipe was placed high on a slope, and the drop below the drainpipe onto sandy substrate together with the volume and speed of flowing water has resulted in severe gully erosion and sheeting of sand towards Bennett Brook. Some of the sand has been trapped by vegetation but a significant plume was visible at the Marshall Road crossing in September 2018 (*Figure 25*).

Figure 25: Sediment plume evident on the north side of the Marshall Road crossing.

Central section

The brook becomes deeper south of Marshall Road: in places more than 2m high, although the bank slope is shallow or medium for the whole section. Immediately above the main banks the sandy soil supports dryland plants.

Several drainage channels enter the brook in this section. Bandicoot Creek flows in immediately south of Reid Highway and is being rehabilitated with DBCA support. Coonawarra Drain is steep-sided and narrow and has been revegetated by the Friends of Bennett Brook (*Figure 26*). In 1998 this drain was noted as causing localised erosion.

At Simla Park a series of compensation basins flow into the brook from the adjacent housing estate (*Figure 27*). Erosion was evident where these basins flowed into the brook in 1998, but this was no longer noted as an issue. Lanius Drain flows into the brook north of the Buddhist temple on Benara Road. Part of this drain has also been restored by the Friends group.

Figure 26 (left): Coonawarra Drain.
Figure 27 (right): Last of a series of three compensation basins that flow into Bennett Brook.

Throughout the Central section erosion is not apparent and bank stability is good (*Figure 28*). Most of the section has been revegetated and has good coverage of sedges, understorey plants and tree roots (*Figure 29*). In the short reaches that have not yet been revegetated a dense kikuyu layer helps to provide bank stability. In 2007 bank stability was average or poor in nine of the 21 segments that had been assessed, indicating a substantial improvement in bank condition since then.

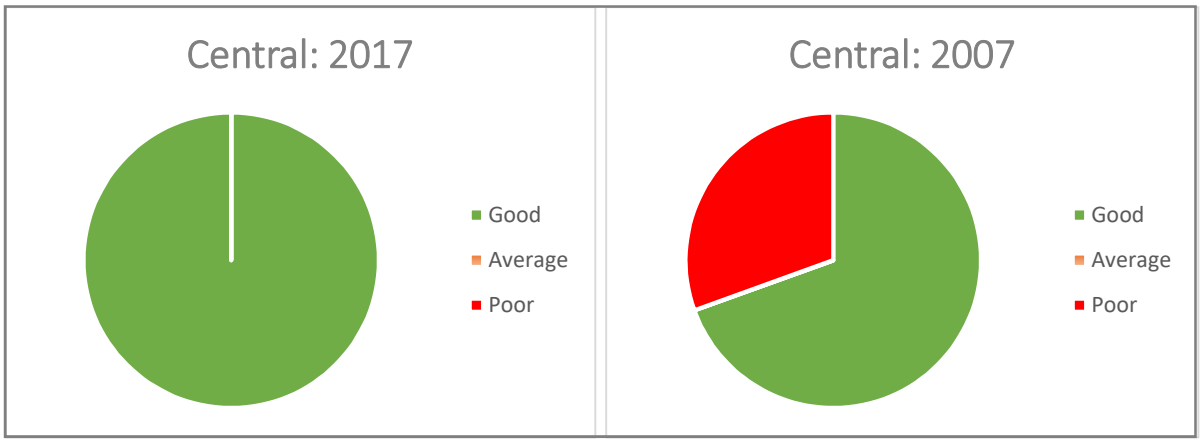


Figure 28: Bank stability ratings for the Central section in 2017 (left) and 2007 (right).

Figure 29 (left): Typical bank structure in the Central section.
Figure 30 (right): Small areas of localised sedimentation only were found.

In 1998 the area immediately south of Marshall Road was accessed by stock and large patches of bare sand, bank erosion and collapse were observed. Slumping and sedimentation were localised, but bank stability was very poor (WRC 1999). In 2007 recent revegetation and weed control was evident and bank stability was considered average due to the exposed soil. These issues were not evident in 2017, although a housing estate was being developed on the right bank.

It was noted in 1998 that winter flooding was common south of Reid Highway and sheet erosion flowed towards the main channel. Localised erosion was particularly evident below the Reid Highway bridge. Sedimentation was significant and bank stability was moderate (WRC 1999). Revegetation undertaken by the Friends of Bennett Brook has reduced these issues, although exposed sand within the Reid Highway easement is a continual sediment source (*Figure 30*).

There are several braided channels and an open waterbody in the lower reaches of the Central section (*Figure 31-Figure 34*). In 1998 the high level of weed invasion in the channels had resulted in slow stream flow and extensive retention of sediment from upstream erosion (WRC 1999). Where private property is adjacent to the left bank of the brook weed invasion is still high but where it is possible to see the bank, stability is good, and erosion and siltation issues are not evident.

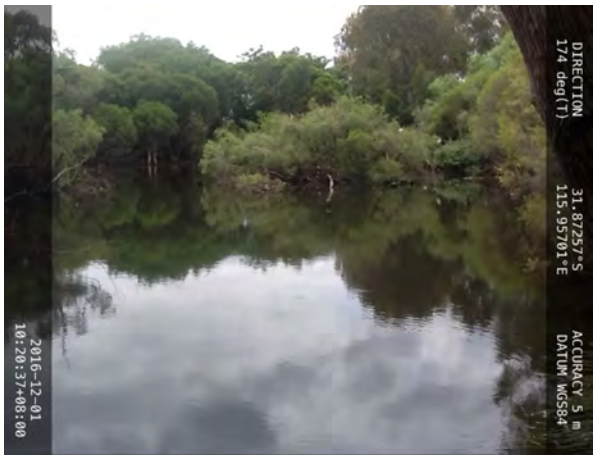


Figure 31 (left): Open waterbody on Bennett Brook 350m north of Benara Road.
Figure 32 (right): Open shallow channel near Benara Road.


Figure 33 (left): Waterbody in 2007.
Figure 34 (right): Shallow channel in 2007.

South section

South of Benara Road the brook splits into several channels. In Clarry Small Park the banks are >2m high and the slope is medium to steep. There is a cleared paddock at the south of Clarry Small Park where old farming infrastructure is present and the channel opens out, possibly modified drainage for the farm. Bank stability is average due to the exposed bank (*Figure 44*).

Close to Grogan Swamp there are multiple channels and high embankments where the drainage appears to have been modified (*Figure 35, Figure 37*). In 2007 some erosion and siltation was observed, but this was not visible in 2017 due to the dense vegetation and inaccessible banks.

Figure 35 (left): Multiple channels upstream of Grogan Swamp.
Figure 36 (right): Open water and swamp paperbark woodland in Grogan Swamp.

Figure 37: Channels north of Grogan Swamp in 2007.

The floodplain opens out around Grogan Swamp and there are several open areas of surface water within the swamp system (*Figure 36*). The banks are shallow and low. On the eastern side of the swamp several claypans and low-lying cracking clays flood during high rainfall events (*Figure 39*).

A Water Corporation drain flows into the swamp from west of Lord Street. A series of drainage channels that interconnect with the Water Corporation drain are located near the Bennett Brook Disability Justice Centre and the Swan Valley Nyungah Community site (*Figure 38*).

Figure 38 (left): Drainage channels on the western side of Grogan Swamp.
Figure 39 (right): Low-lying floodplain on the eastern side of Grogan Swamp.

Downstream of Grogan Swamp the brook becomes a single channel that flows into the Swan River (*Figure 40-Figure 43*). The banks range from 1-2m to >2m high but are gently sloped. Some erosion was noted in this area where the banks are undermining. Bank stability is average. Erosion was also recorded in 2007, where the bank was exposed and several *Casuarina obesa* (swamp sheoak) trees had fallen over. The WRC assessment did not include this section of Bennett Brook.

Figure 40 (left) and Figure 41 (right): Confluence of Bennett Brook and the Swan River.

Figure 42 (left) and Figure 43 (right): Confluence in 2007.

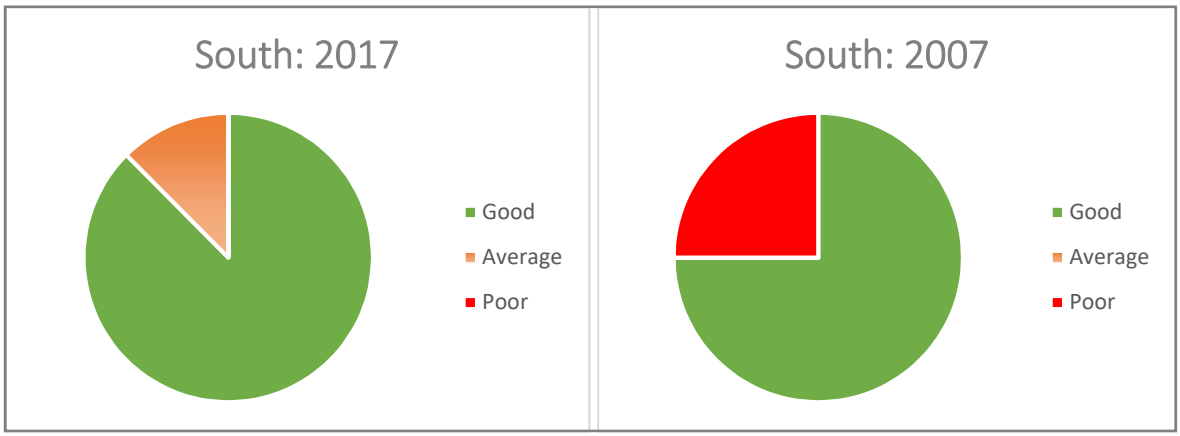


Figure 44: Bank stability ratings for the South section in 2017 (left) and 2007 (right).

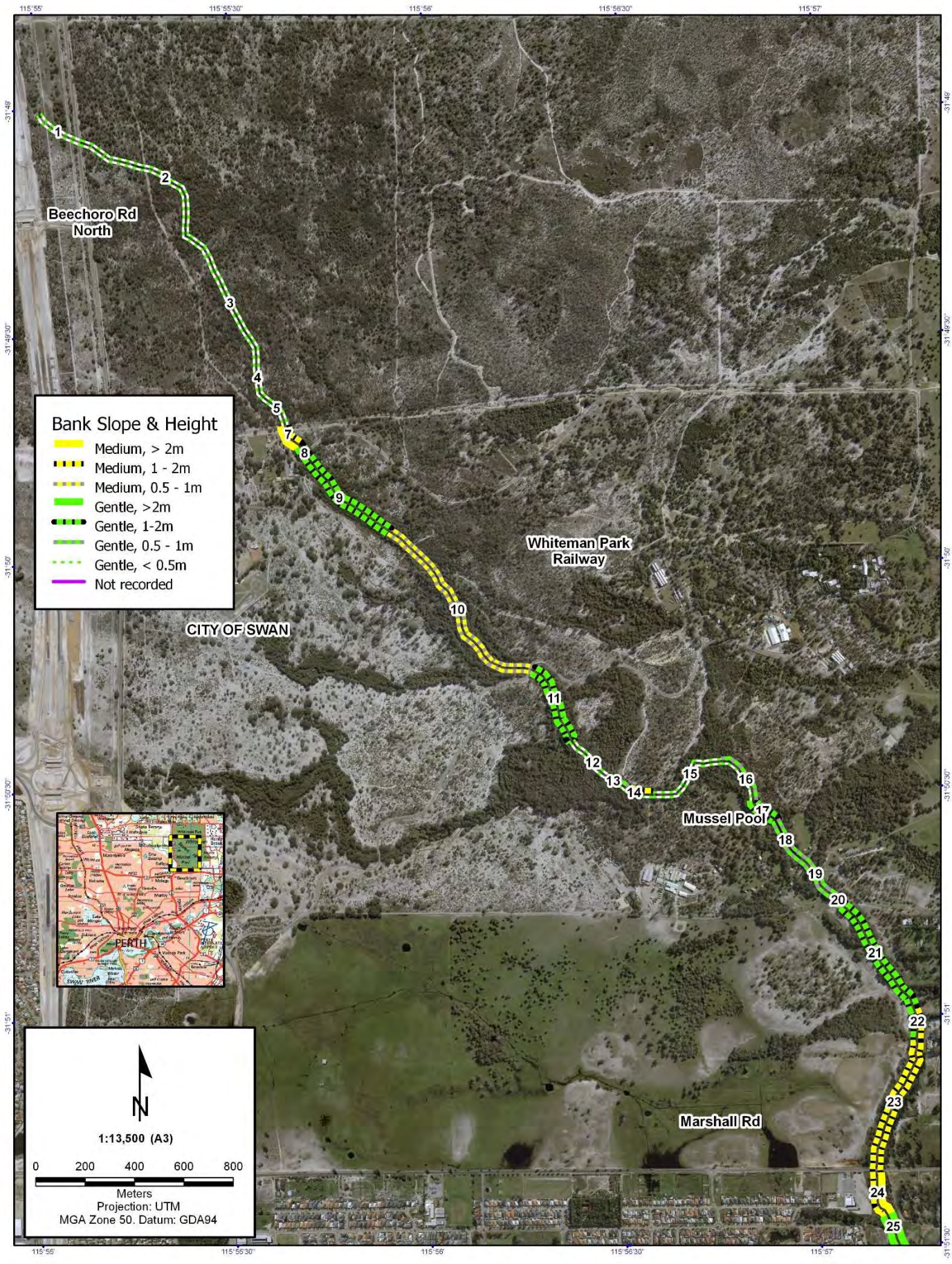


Figure 45: Slope and height of bank, North section.

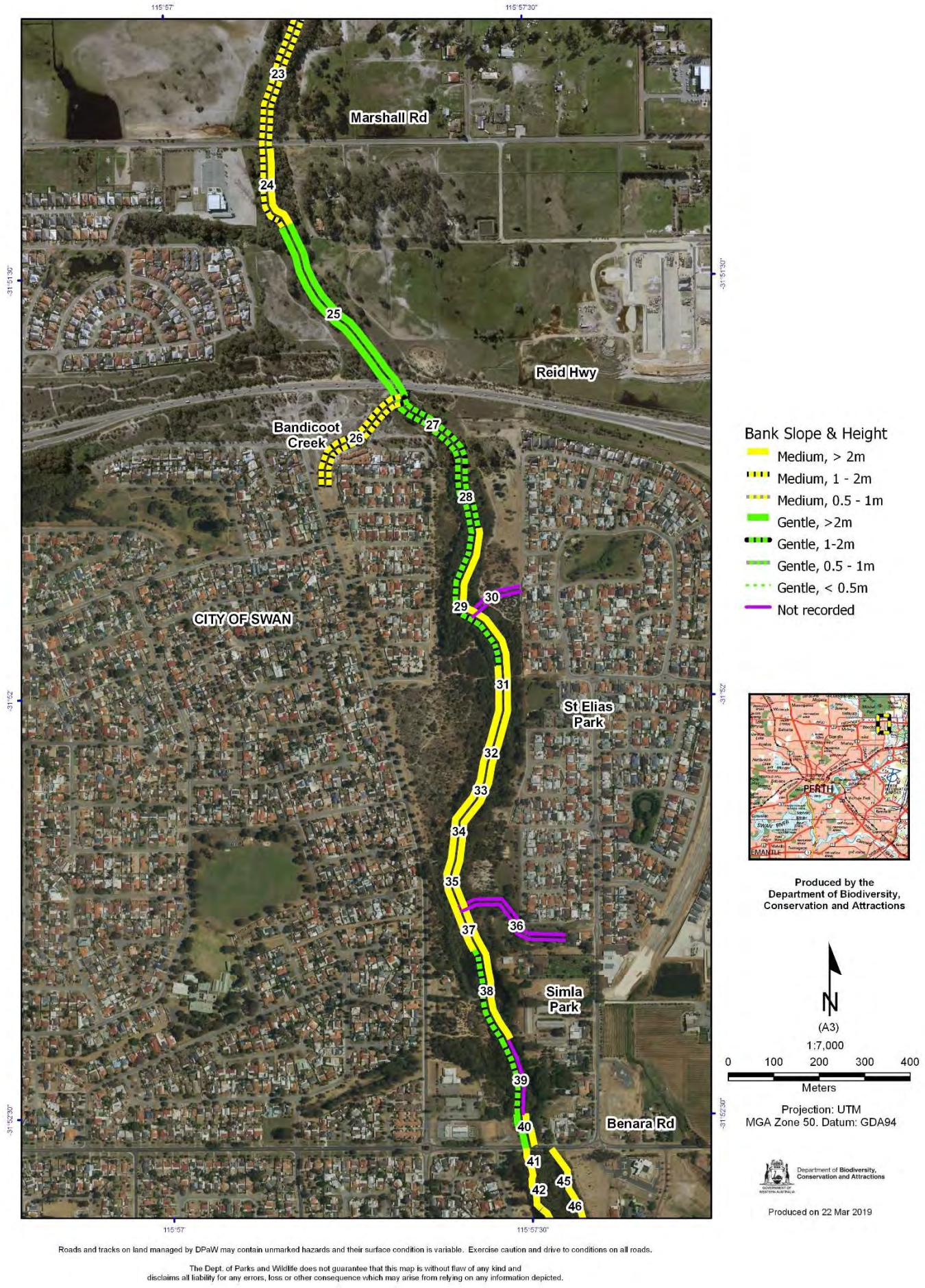


Figure 46: Slope and height of bank, Central section.

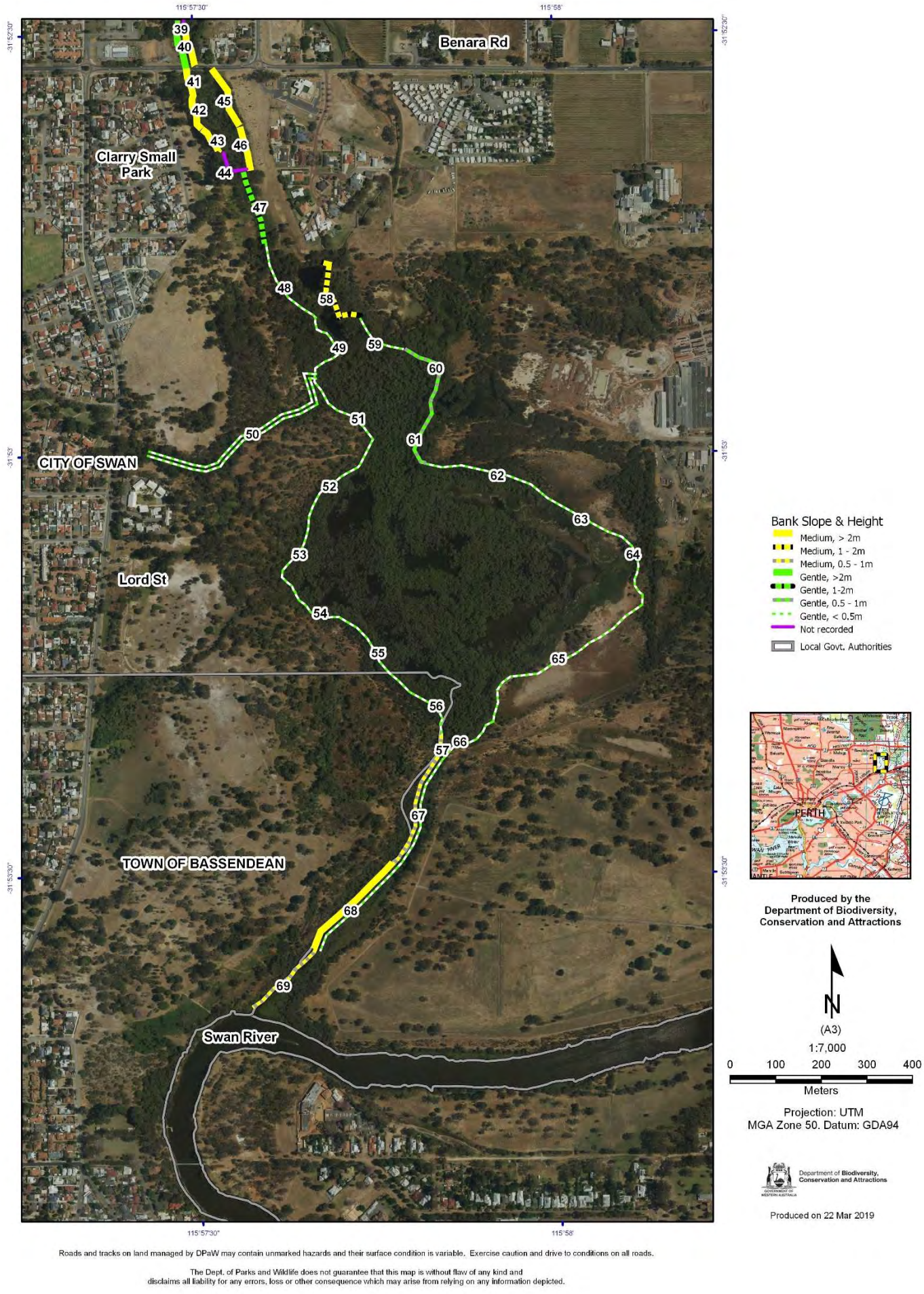


Figure 47: Slope and height of bank, South section.

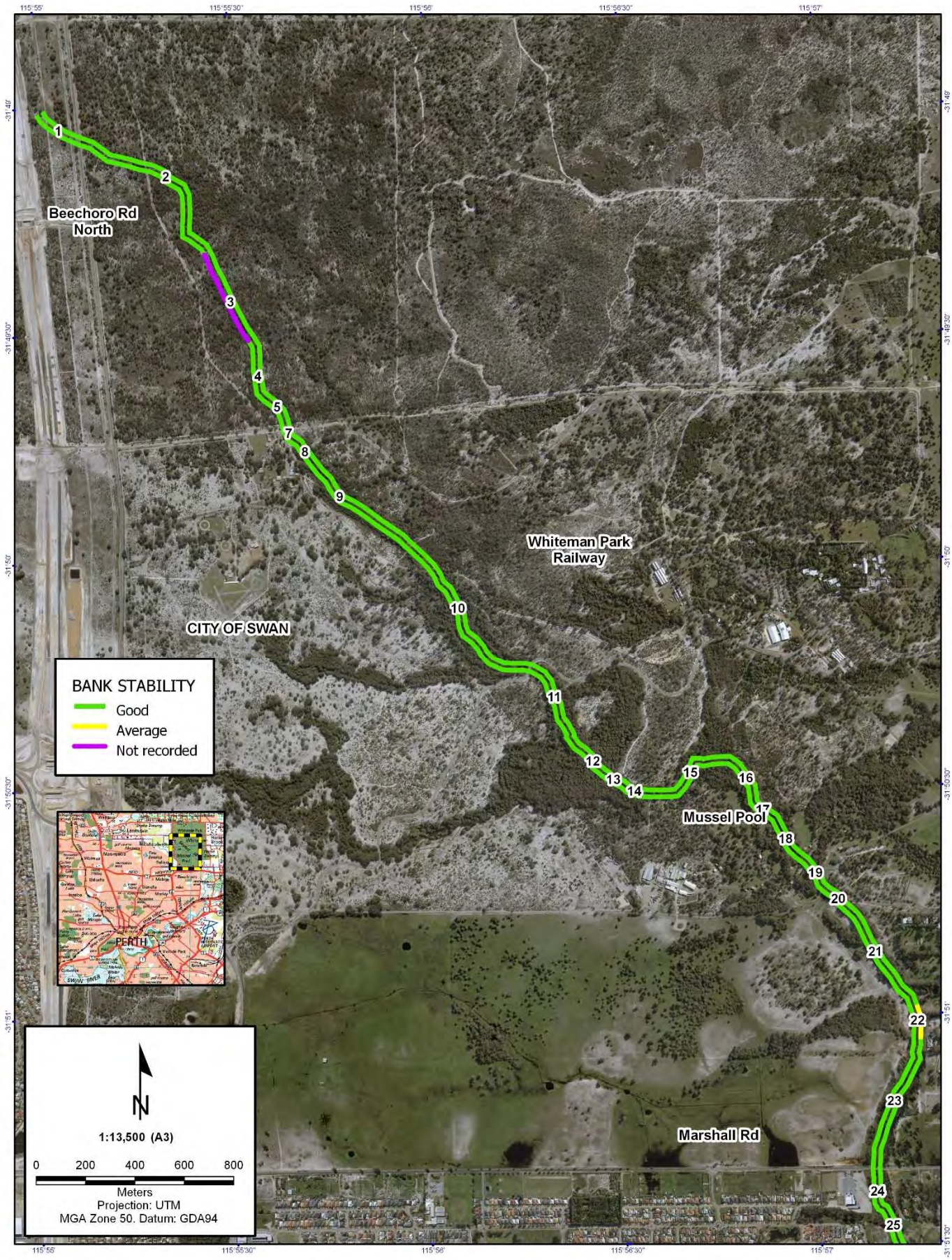


Figure 48: Bank stability, North section.

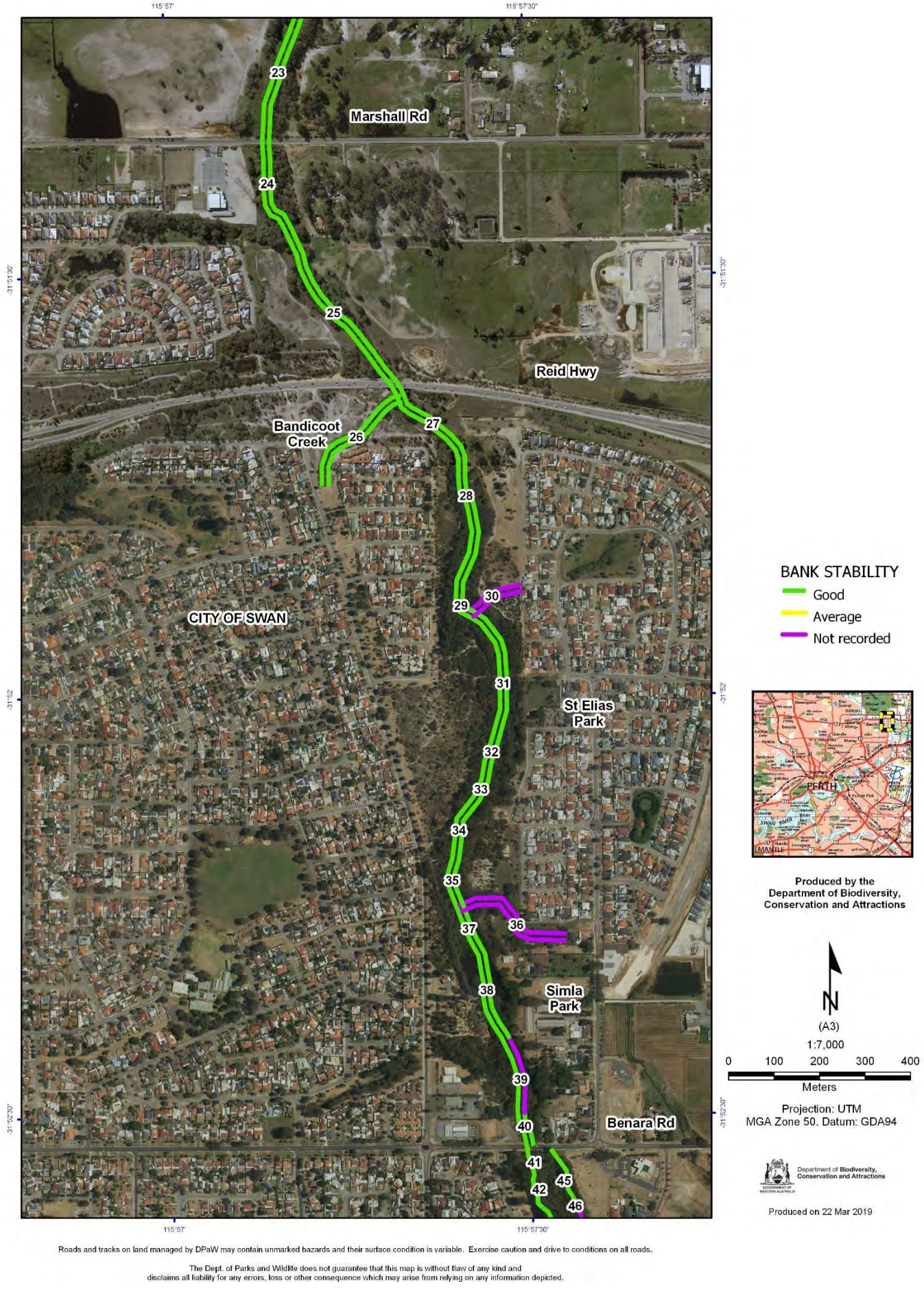


Figure 49: Bank stability, Central section.

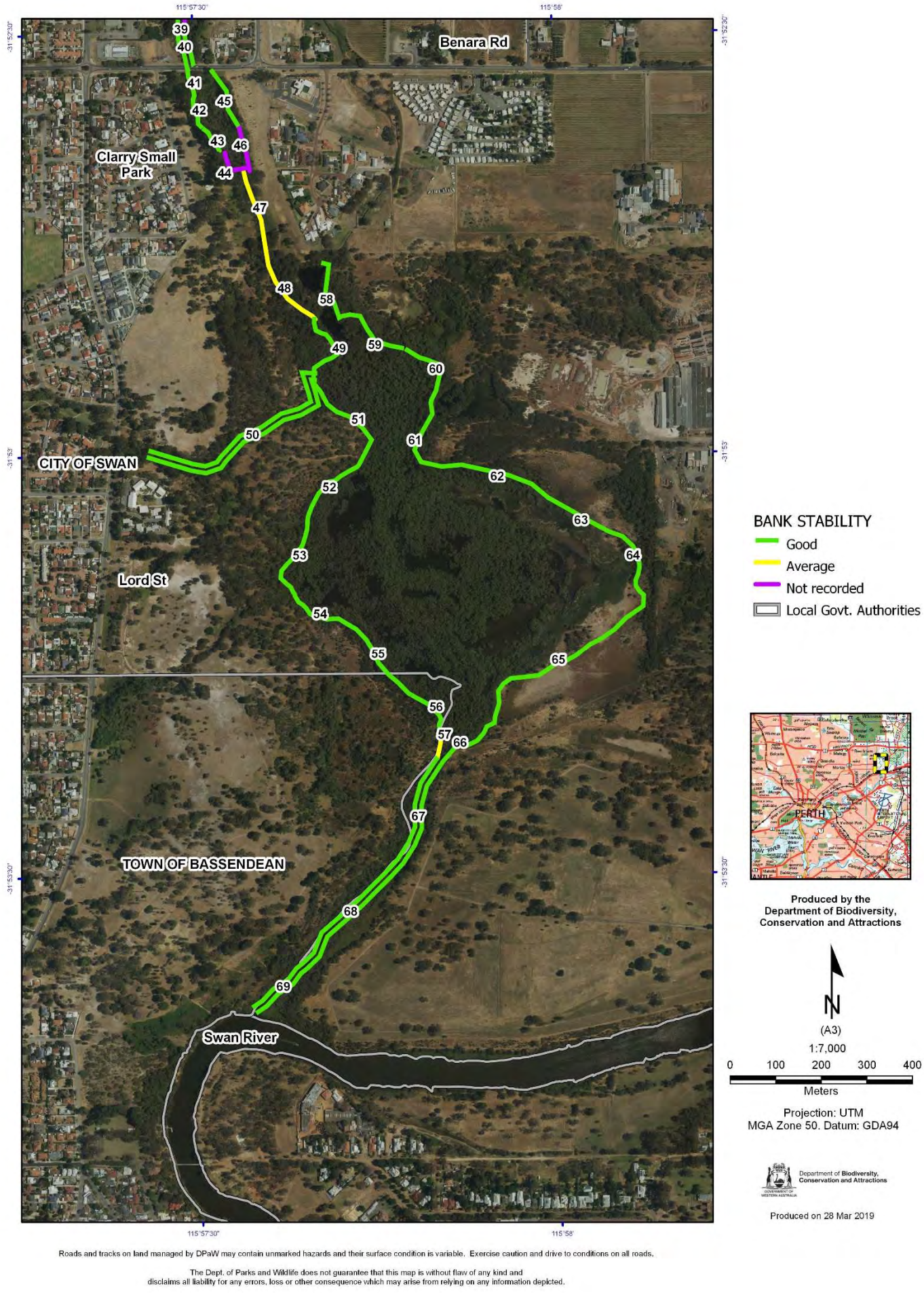


Figure 50: Bank stability, South section.

3.3 Vegetation type and condition

Overstorey vegetation is largely intact for the main channel of Bennett Brook, and it provides stream cover and permanent shade that reduces water temperature, and provides roosting and nesting sites for birds. Habitat diversity is limited for parts of the brook, however, by the lack of native vegetation in the mid and understorey.

Two species of *Typha* occur in south-western WA – *Typha domingensis* and *T. orientalis,* which until recently was considered a naturalised alien species. Evidence suggests that *T.orientalis* occurred naturally prior to European settlement (Keighery and McCabe 2015) and the species is now listed as native to WA.

The two species are known to hybridise and can be difficult to distinguish. *T.orientalis* in particular can be prolific on the shallow edges of waterways and impede water flow and outcompete other native vegetation.

T.orientalis has been removed through many restoration projects in south-west WA prior to it being listed as native. Clearing permits are now required through DWER. Where it acts as an environmental weed on public land, a clearing permit may be exempt if removal of Typha is part of an approved management plan or maintains existing cleared areas around infrastructure. On private land, however, landowners may need to apply for a clearing permit. Permit advice should be obtained from DWER.

In this assessment we have made recommendations for removal of *Typha* where it appears to be negatively impacting on native vegetation or water flow.

North section

The vegetation in the headwaters of Bennett Brook (west of Beechboro Road North) has been impacted by grazing and historic clearing, and the understorey is comprised of mixed weedy grasses and virtually no native species (*Figure 51*). Vegetation condition is poor in this segment.

Figure 51 (left): Headwaters of Bennett Brook west of Beechboro Road North.
Figure 52 (right): Undefined channel east of Beechboro Road North.


Figure 53 (left): Headwaters west of Beechboro Road North in 2007.
Figure 54 (right): Headwaters east of Beechboro Road North in 2007.

East of Beechboro Road North where the brook enters Whiteman Park the vegetation is more representative of its remnant form prior to European settlement (*Figure 52, Figure 54*). Species are diverse and dominant genera include *Banksia*, *Xanthorrhoea*, *Melaleuca* and *Corymbia*. Vegetation condition is good.

Further downstream where the channel becomes more defined riparian vegetation is dominant – flooded gums and *Gahnia* and *Baumea* sedges are present. *Melaleuca* becomes dominant in the overstorey and native *Pteridium esculentum* (bracken fern) is dominant on the upper banks (*Figure 55*). Vegetation condition is good in most segments, although several invasive weeds are evident immediately north of Mussel Pool and the condition is average.

Figure 55 (left): Bracken fern is dominant in areas of the upper bank.
Figure 56 (right): The lower bank is dominated by Melaleuca *and sedge species.*

From Mussel Pool to Marshall Road the vegetation is primarily *Eucalyptus rudis* (flooded gum) over *Melaleuca rhaphiophylla* (swamp paperbark), with sedges and mixed annual herbs and grasses in the understorey (*Figure 56*). There is a decline in vegetation condition due to the occurrence of weeds, with most segments rated average and one segment rated poor.

Figure 57 (left): Riparian vegetation around Mussel Pool.
Figure 58 (right): Weed dominated vegetation south of Mussel Pool.

Figure 59 (left): Mussel Pool in 2007.
Figure 60 (right): Understorey south of Mussel Pool dominated by weeds in 2007.

In 2007 vegetation condition for the entire section had been rated good (*Figure 61*), although weeds were prevalent from Mussel Pool downstream (*Figure 59, Figure 60*). The field assessors in 2007 may have placed greater emphasis on the apparent health of the remaining native vegetation (e.g. live canopy, no evidence of insect attack) rather than the resemblance of the overall vegetation composition to a pre-European-settlement state.

In 1998 vegetation condition was rated poor to very poor from Mussel Pool to Marshall Road as the understorey was dominated by weeds. The area where private property abuts the brook vegetation condition was considered very poor, the same area that is rated poor (the lowest category) in our assessment.

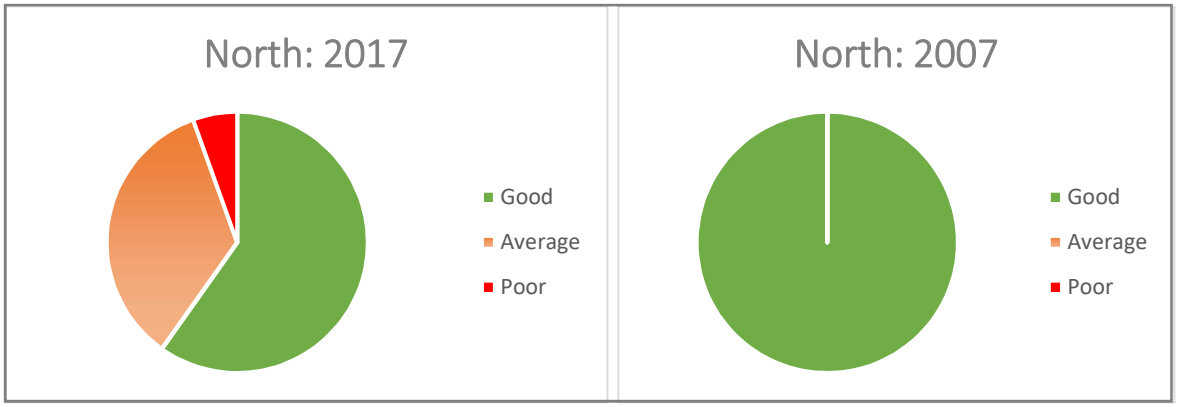


Figure 61: Vegetation ratings for the North section in 2017 (left) and 2007 (right).

Central section

Between Marshall Road and Reid Highway the vegetation is predominantly flooded gum over swamp paperbark with an understorey of native *Centella asiatica* and weedy herbs and grasses. Vegetation condition is rated average and then poor downstream of a very weed infested drain which flows through Oriole Park.

However, vegetation condition was rated good in 2007. In 1998 vegetation condition in this area was rated very poor due to the health of the overstorey and a sparse weed dominated mid and understorey. Many trees appeared to be in poor health and dying (WRC 1999). It is unlikely that the vegetation would have improved substantially between 1998 and 2007, then declined again by 2017. As mentioned above the field assessor may have put a greater weighting on the intact structure of the overstorey rather than the weedy understorey.

In Bandicoot Creek vegetation condition is average due to the presence of annual grasses on the upper banks, the poor health of mature *Acacia saligna* from infection with *Acacia* gall rust *Uromycladium*, and a partial lack of overstorey due to historic clearing (*Figure 62-Figure 65)*. Overstorey species have been planted so in time the canopy cover will increase and provide shade over the creek.

In 1998 vegetation near Reid Highway was highly degraded with a narrow strip of overstorey interspersed with completely cleared areas. The midstorey was almost absent with *Acacia saligna* occurring rarely.

Figure 62 (left): Some mature Acacia saligna *were removed from Bandicoot Creek to prevent the spread of* Acacia *gall rust.*
Figure 63 (right): Near the confluence of Bennett Brook and Bandicoot Creek.

Figure 64 (left) and Figure 65 (right): Kikuyu dominated understorey near the Bandicoot Creek confluence in 2007.

From Reid Highway to Simla Park, weed control and revegetation by the Friends of Bennett Brook is very evident. A remnant overstorey of flooded gum and swamp paperbark overhangs the channel. *Centella asiatica* and *Carex fascicularis* are extensive in the understorey (*Figure 66*). On the upper banks *Hakea*, *Corymbia* and *Jacksonia* species are dominant, with some grassy weeds amongst the understorey (*Figure 67*). Native species regeneration is evident from Reid Highway to Simla Park, where it is likely that the revegetation is amassing a seed bank and seedlings are not competing with weeds. Vegetation condition is average, due to the decreased coverage of weeds in the understorey.

In 2007, vegetation condition was considered good from Marshall Road to St Elias Park (500m upstream of Simla Park), presumably due to the intact overstorey as weed coverage ranged up to extensive. It was rated average for most of the rest of the section to Benara Road (*Figure 72*). Weed control was evident in 2007.

In 1998 native vegetation diversity was reasonable with a range of native species on the upper bank and sedges and rushes on the lower bank. Perennial weedy grasses were abundant in open cleared areas. Condition ranged from moderate to poor.

Figure 66 (left): Extensive understorey of Carex fascicularis.
Figure 67 (right): A densely revegetated upperbank of dryland species.

Near Simla Park one segment is rated poor due to extensive weed cover. Around the open waterbody south of Simla Park, vegetation condition is also poor on the left bank adjacent to private property and average on the right bank.

Immediately north of Benara Road the Friends of Bennett Brook have removed most of a dense infestation of *Typha* because of its impact of slowing water flow and sedimentation (*Figure 68-Figure 71*). There is also currently a large infestation of *Ipomoea cairica* (morning glory). In 1998 *Typha* was dominant in this area and *Watsonia* sp. was present. Vegetation condition was rated very poor.

Figure 68 (left): Typha *population north of Benara Road that Friends of Bennett Brook have removed in stages.*
Figure 69 (right): Morning glory infestation north of Benara Road.

Figure 70 (left): Typha population north of Benara Road in 2007.
Figure 71 (right): Dense kikuyu infestation north of Benara Road in 2007.

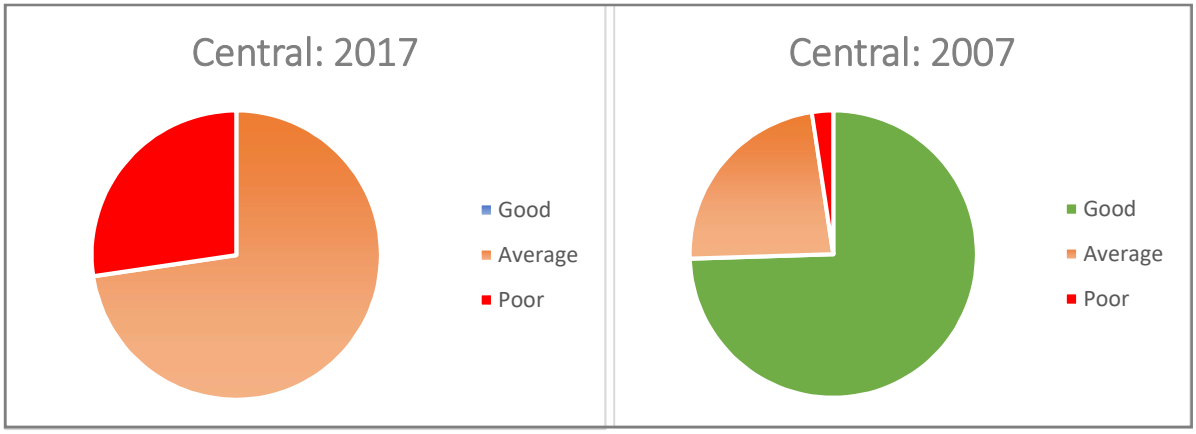


Figure 72: Vegetation ratings for the Central section in 2017 (left) and 2007 (right).*

**Note comments made above in the discrepancy of ratings between 2007 and 2017. It is unlikely that vegetation condition has declined. Photos taken during the 2007 assessment indicate that vegetation condition if evaluated by 2017 field assessors would have been rated as poor for most of this section.*

South section

At the northern end of Clarry Small Park there is a dense overstorey of flooded gum and swamp paperbark, with *Typha* common in the midstorey following on from the dense upstream infestation. Native species have been planted on the upper banks, including *Banksia*, *Astartea* and *Hakea* species *(Figure 73, Figure 75)*. Vegetation condition is average.

At the southern end of Clarry Small Park the cleared channel has no remaining native over or midstorey. The understorey is dominated by weeds, although control of arum lily is evident. Vegetation condition is poor (*Figure 74, Figure 76*).

Figure 73 (left): Dense instream vegetation at the north of Clarry Small Park.
Figure 74 (right): Cleared channel at the south of Clarry Small Park.

Figure 75 (left): Instream vegetation at the north of Clarry Small Park in 2007.
Figure 76 (right): Cleared channel in Clarry Small Park in 2007.

Grogan Swamp has significant stands of dense, mostly native vegetation comprising diverse ecosystems, including braided channels, claypans, open waterbodies, samphire flats and sedgeland. Much of the area is inaccessible by foot due to the density of vegetation and low-lying wet flats (*Figure 78-Figure 80*). A series of drains is also present on the western side that contain a native overstorey but many weed species.

Braided channels at the north of the swamp contain flooded gum over swamp paperbark and dense weedy grasses and herbs, with occasional stands of *Centella* sp. and *Juncus kraussii*, the first appearance of this salt-associated sedge in Bennett Brook. Vegetation condition ranges from average to poor (***Error! Reference source not found.***).

The claypans on the eastern floodplain are surrounded by sedges but behind this are infested with *Lolium* sp. (ryegrass) and *Avena barbata* (bearded oats) (*Figure 77*). The claypans are connected to the swamp via a vegetated floodplain and function as

an associated wetland, providing varied habitat from the wooded swamp. However, vegetation condition is poor due to the extensive coverage of weedy grasses.

Figure 77 (left): Claypan on the eastern side of Grogan Swamp.
Figure 78 (right): An open water section of Grogan Swamp.

Figure 79 (left): Open water body on the eastern side of Grogan Swamp, 2007.
Figure 80 (right): Typha population on the north east of Grogan Swamp, 2007.

Samphire flats and sedgelands border a dense *Typha* population on the south eastern side of Grogan Swamp (*Figure 81, Figure 82*). Samphire species *Tecticornia halocnemoides*, *T.lepidosperma*, *T.pergranulata* and *Salicornia*

quinqueflora occur on the floodplain, which Keighery (1996) states is significant as it is one of only a few locations where all four samphire species occur together. However, a lot of the open swamp sheoak overstorey is dead, perhaps due to changes in the water regime and salinity. Vegetation condition is average.

Figure 81 (left): Samphire flats with dead swamp sheoak in the background.
Figure 82 (right): Typha *population on the eastern side of Grogan Swamp.*

The western side of Grogan Swamp has an intact over- and midstorey, but some dense stands of Japanese pepper, *Olea europaea* (olive), blackberry and arum lily. Vegetation condition is average to poor.

Swamp sheoak is dominant at the southern end of the swamp (*Figure 83, Figure 85*). Vegetation condition is poor where tree roots have been exposed on the undermining bank, and due to historic grazing on the eastern side of the brook.

Downstream of Grogan Swamp the riparian vegetation is limited to a narrow strip as the surrounding floodplain was historically cleared. Vegetation is dominated by flooded gum, swamp sheoak, *Bolboschoenus caldwellii* and *Juncus kraussii*. Close to the confluence swamp sheoak is dense and a native understorey is almost absent. Vegetation condition is average.

Figure 83 (left) and Figure 84 (right): Dense swamp sheoak woodland on the lower reaches of Bennett Brook.

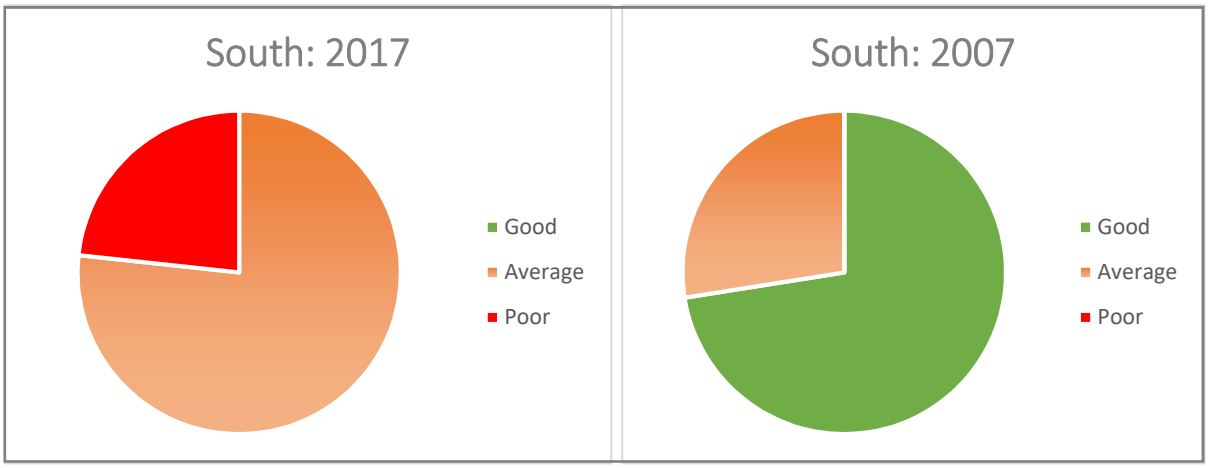


*Figure 85: Vegetation ratings for the South section in 2017 (left) and 2007 (right).**

**The apparent decline in vegetation condition from 2007 to 2017 may be because the field assessors in 2007 placed greater emphasis on the apparent health of the remaining native vegetation rather than the resemblance of the overall vegetation composition to a pre-European-settlement state.*

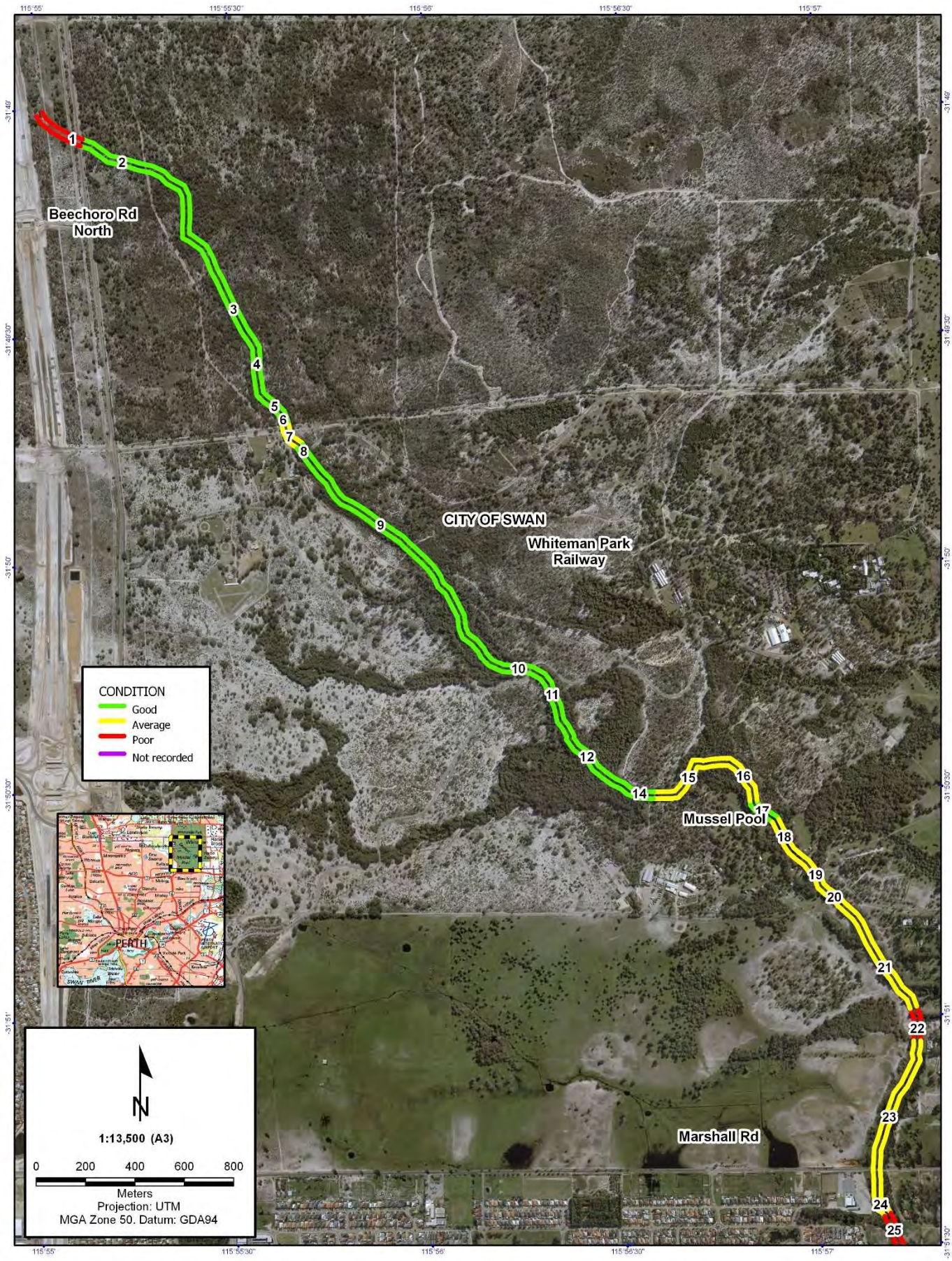


Figure 86: Vegetation condition, North section.

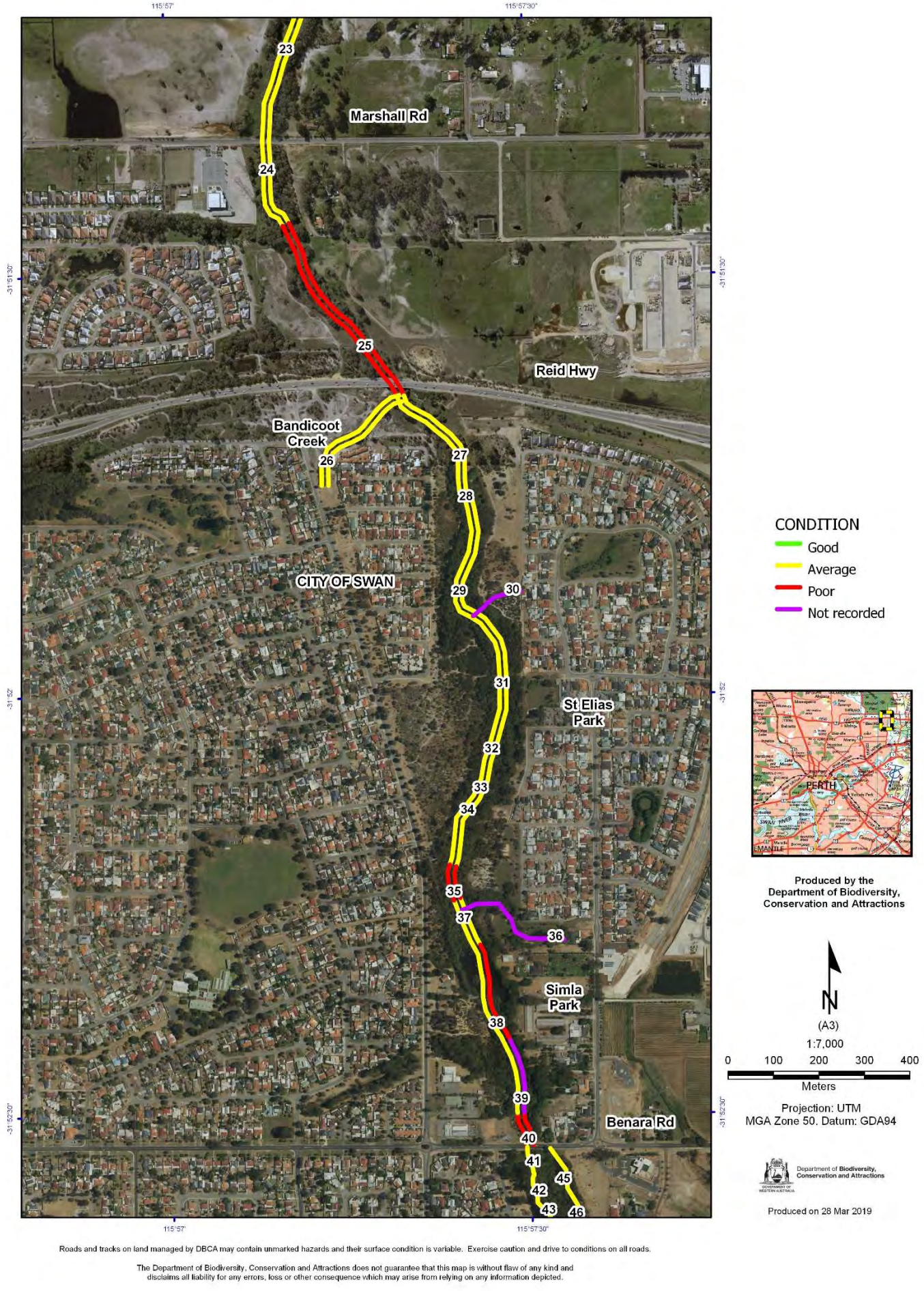


Figure 87: Vegetation condition, Central section.

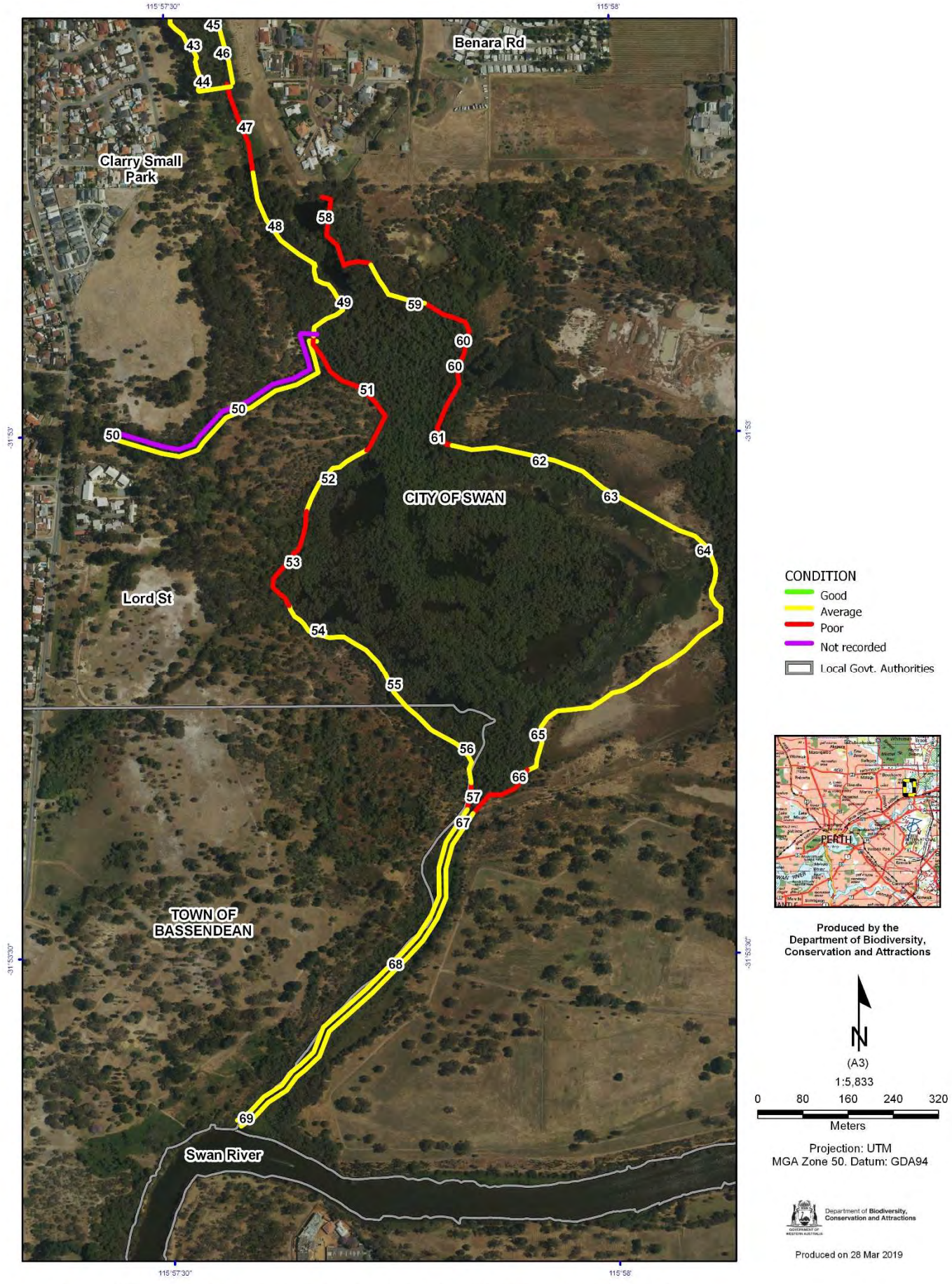


Figure 88: Vegetation condition, South section.

3.4 Weed cover and species

North section

Most of the North section has minimal to moderate weed cover. The headwaters west of Beechboro Road North, however, have extensive weed cover with the understorey entirely made up of weedy grasses and herbs, no native midstorey and a mostly cleared overstorey.

East of Beechboro Road North where Bennett Brook enters Whiteman Park, weed cover is minimal for about 3.5km. Weedy grasses including bearded oats, *Briza* sp. (blowfly grass) and *Eragrostis curvula* (African lovegrass), and herbs including *Hypochaeris* sp. (flatweed) and *Pelargonium capitatum* (rose pelargonium) are scattered on the upper banks (*Figure 89*).

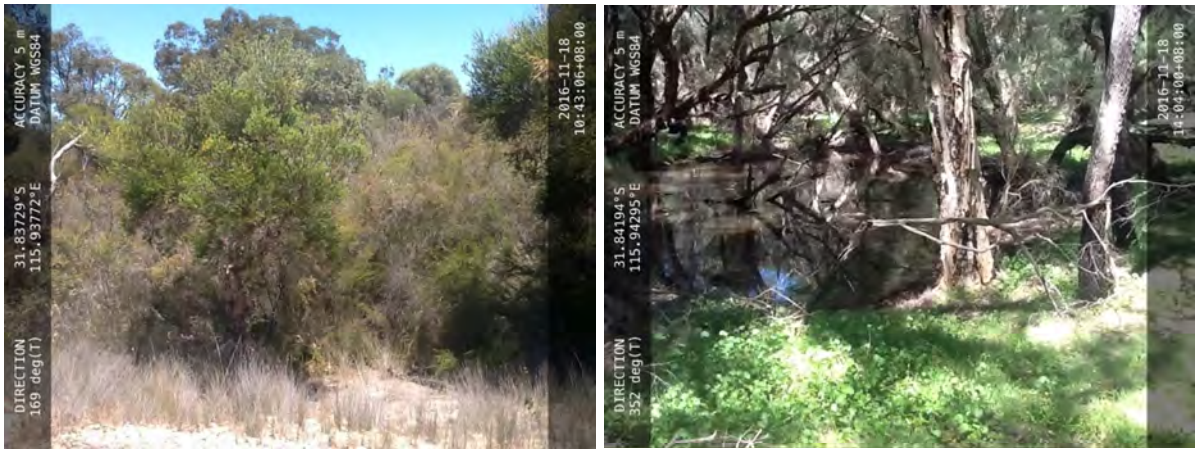


Figure 89 (left): Scattered annual grasses on the upper bank.
Figure 90 (right): Grasses and herbs are common close to Mussel Pool.

From this point downstream to Mussel Pool, weed cover is mostly moderate (*Figure 90*). Common species include *Anagallis arvensis* (pimpernel), blowfly grass and flatweed. The first sighting of arum lily in Bennett Brook is immediately upstream of Mussel Pool.

The vegetation surrounding Mussel Pool is primarily native, although arum lily, *Juncus microcephalus* and kikuyu is present on the banks.

Immediately downstream of Mussel Pool weed cover is extensive (*Figure 91-Figure 94*). Common weed species include *Ficus carica* (fig), *Juncus microcephalus*, arum lily and annual grasses. Invasive species that first appear in this area are blackberry and Japanese pepper.

Figure 91 (left): Weeds are dominant in the understorey downstream of Mussel Pool.
Figure 92 (right): From Cranleigh St to Marshall Road trefoil, Juncus microcephalus *and paspalum are common.*

Figure 93 (left): Sedge and Centella *understorey north of Mussel Pool, 2007.*
Figure 94 (right): Similar area to Figure 80 above, in 2007.

From Cranleigh St to Marshall Road weed cover is moderate and species include *Isolepis prolifera* and *Lotus* sp. (trefoil) as well as *Conyza sp* (fleabane), arum lily and other herbs and grasses. Weed control was evident on Whiteman Park land.

In 2007, weed cover ranged from minimal to moderate from the headwaters to Mussel Pool and then was mostly rated extensive (*Figure 95*). This indicates some improvement in weed cover to 2017. Weed control was not noted in 2007.

In 1998, scattered arum lily and *Solanum nigrum* (black berry nightshade) were present. The understorey was dominated by kikuyu, *Paspalum* sp., fleabane and *Cyperus* sp. Where private property abuts the brook the understorey was an almost continuous layer of kikuyu and weedy herbs. *Juncus microcephalus* was present in low-lying depressions and *Rorippa nasturtium-aquaticum* (watercress) was frequent in the watercourse.

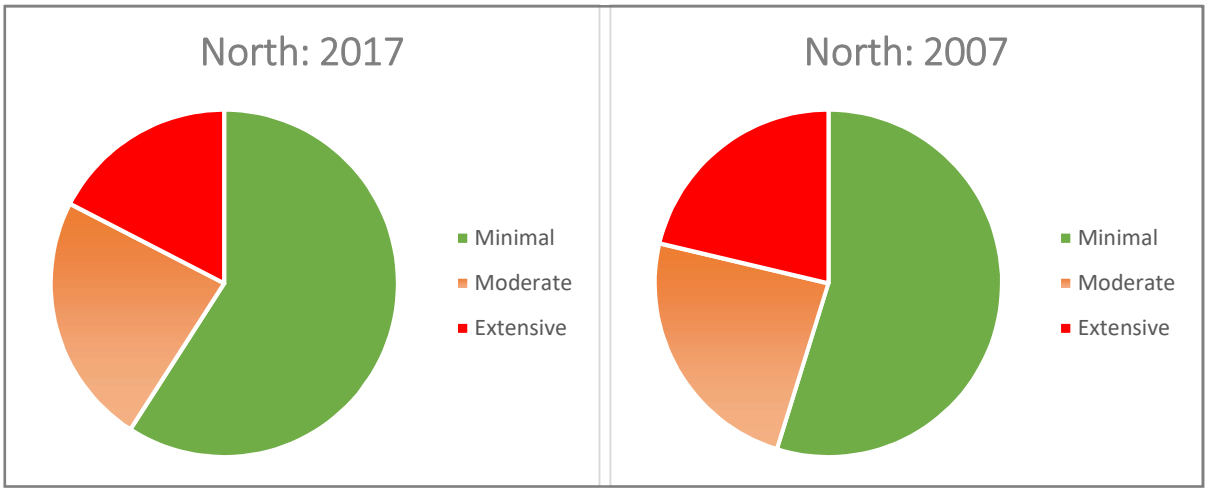


Figure 95: Weed cover ratings for the North section in 2017 (left) and 2007 (right).

Central section

Weed cover is extensive from Marshall Road to Reid Highway, with kikuyu making up the bulk of the understorey (*Figure 96, Figure 98, Figure 99*). A major weed contributor is a drainage channel from Oriole Park. Invasive species that first appear in the brook at this point include watercress and lantana.

In 2007 the segment upstream of the drain from Oriole Park had minimal weed coverage as it appeared that weed control had been recently conducted. Downstream of this drain weed cover was extensive. In 1998 the understorey was dominated by perennial weeds including kikuyu, *Fumaria capreolata* (white fumitory) and cape weed (*Arctotheca calendula*). Watercress was common.

Bandicoot Creek has extensive weed cover due to the prevalence of weedy grasses on the upper banks (*Figure 97*). These grasses have been sprayed and watercress has been manually removed from the watercourse since the assessment.

Figure 96 (left): Kikuyu is abundant in the understorey north of Reid Highway.
Figure 97 (right): Annual grasses are common on the upper banks adjacent to Bandicoot Creek.


Figure 98 (left) and Figure 99 (right): Weed dominated understorey north of Reid Highway in 2007.

Weed cover is mostly moderate from the junction of Bandicoot Creek with Bennett Brook downstream to Simla Park. The weed control efforts of the Friends of Bennett Brook are significant and effective as large areas of kikuyu have been controlled and replanted with native sedges and rushes (*Figure 100-Figure 103*). On the upper banks annual grasses have been replaced with native dryland species. The most commonly found weeds are bearded oats and *Ehrharta* sp (veldt grass).

Figure 100 (left): In many areas between Bandicoot Creek and Simla Park the native sedge Carex fascicularis *has outcompeted what had been a weedy understorey.*
Figure 101 (right): Dense kikuyu and morning glory infestation north of Benara Road.

Figure 102 (left): Blackberry infestation near Coonawarra Drain in 2007 which is no longer present.
Figure 103 (right): Arum lily and blackberry infestations near Simla Park in 2007, no longer present.

In 2007 most segments from Bandicoot Creek to Simla Park had extensive weed cover. In 1998 the understorey was dominated by kikuyu, blackberry and arum lily. Other weeds present included *Rumex* sp. (dock) and *Juncus microcephalus*. On the upper bank veldt grass and cape weed were abundant.

There is a short segment north of Simla Park where weed cover is extensive and species include *Cortaderia selloana* (pampas grass), Japanese pepper and arum lily. South of Simla Park weeds are more prevalent, and cover ranges from moderate to extensive. Adjacent to the waterbody near private property weed cover is extensive and many species are present. Common weeds are kikuyu and blackberry.

Immediately north of Benara Road there are dense populations of *Typha* and morning glory. Friends of Bennett Brook have removed a large amount of *Typha* due to its impact on reducing water flow.

While more of the vegetation had minimal weed cover in 2007 than in 2017, the area of vegetation with extensive weed cover is less in 2017 (*Figure 104*). It is difficult to make accurate comparisons in the two assessments as it appears that the vegetation condition and weed cover was rated differently to what the 2017 field assessors would have rated it.

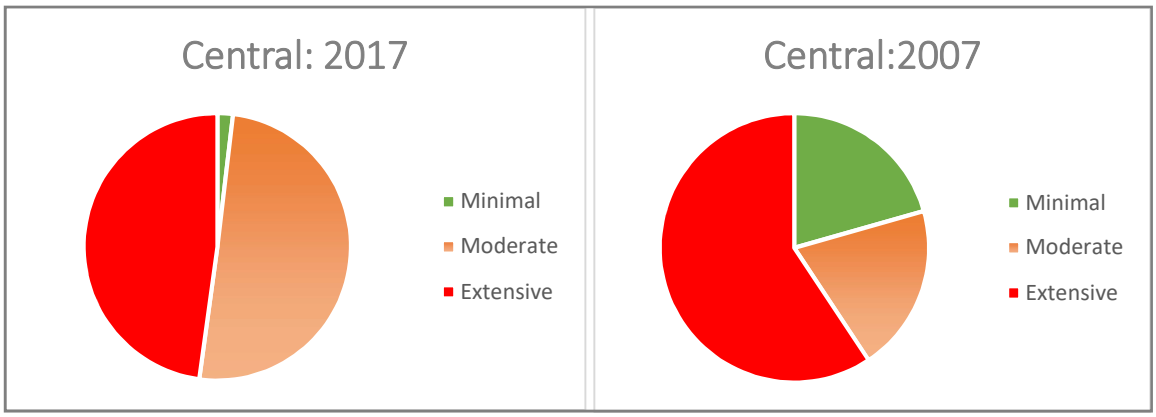


Figure 104: Weed cover ratings for the Central section in 2017 (left) and 2007 (right).

South section

Most segments have extensive weed cover, despite Grogan Swamp having an intact and diverse native vegetation structure. Several segments have moderate weed cover, such as Clarry Small Park where weed control and revegetation have taken place.

Much of the western side of Grogan Swamp contains invasive species including scattered arum lily and Japanese pepper. Veldt grass, bearded oats and *Cynodon dactylon* (couch) are dominant on the upper banks, particularly in cleared areas near Bennett Brook Disability Justice Centre and the Swan Valley Nyungah Community site.

The drainage channels near Bennett Brook Disability Justice Centre and the Swan Valley Nyungah Community site contain *Lantana camara* (lantana), arum lily and other weeds.

On the eastern side of Grogan Swamp Japanese pepper and arum lily are common. Weedy grasses, particularly *Lolium* sp. and bearded oats, are dominant away from the dense canopy of the main watercourse (*Figure 105-Figure 108*).

Figure 105 (left): Weedy grasses are common on the eastern side of Grogan Swamp.

Figure 106 (right): Scattered populations of arum lily are common in Grogan Swamp.

Figure 107 (left): Grass dominated understorey on eastern side of Grogan Swamp, 2007.

Figure 108 (right): Dense arum lily population in channels north of Grogan Swamp, not found in 2017.

Where samphires are dominant, weeds appear to be limited by salinity and species richness is low. The main weeds are coastal barbgrass (*Polypogon maritimus*) and *Cotula* sp. (*Figure 109*).

On the open waterbodies of Grogan Swamp extensive populations of *Typha* have formed monocultures, although also provide habitat and a water quality function.

Where the brook reforms as a single channel south of Grogan Swamp, veldt grass, bearded oats and *Lolium* sp. are common on the floodplain (*Figure 110*). Weeds are partially excluded from the lower banks by dense populations of native *Bolboschoenus caldwellii*.

Figure 109 (left): Coastal barbgrass is common in samphire flats of Grogan Swamp.

Figure 110 (right): Bearded oats and other grassy weeds dominate the upper banks near the confluence with the Swan River.

There appears to be little improvement in overall weed coverage of the South section from 2007 to 2017 although populations of arum lily have been controlled (*Figure 111*). There has been a reduction in weed coverage in Clarry Small Park on the right bank from extensive to moderate. Segments on the single channel below Grogan Swamp had minimal weed cover in 2007 but the assessment may have concentrated on the lower banks where weed coverage was also found to be less in 2017, rather than including the upper banks as we did in 2017. It is difficult to make accurate comparisons between weed cover from 2007 to 2017 as it appears that the field assessors gave different ratings to what we would have.

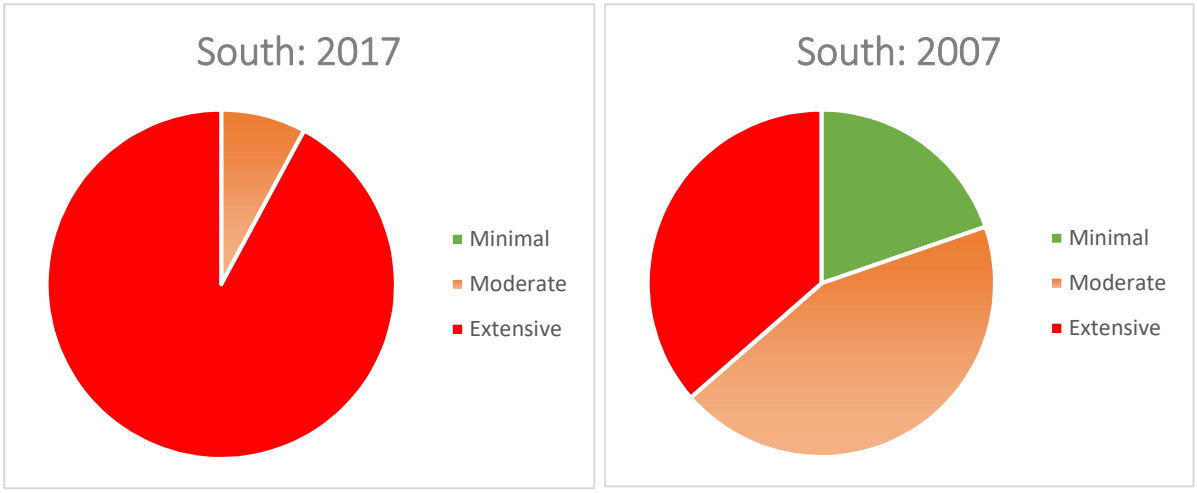


Figure 111: Weed cover ratings for the South section in 2017 (left) and 2007 (right).

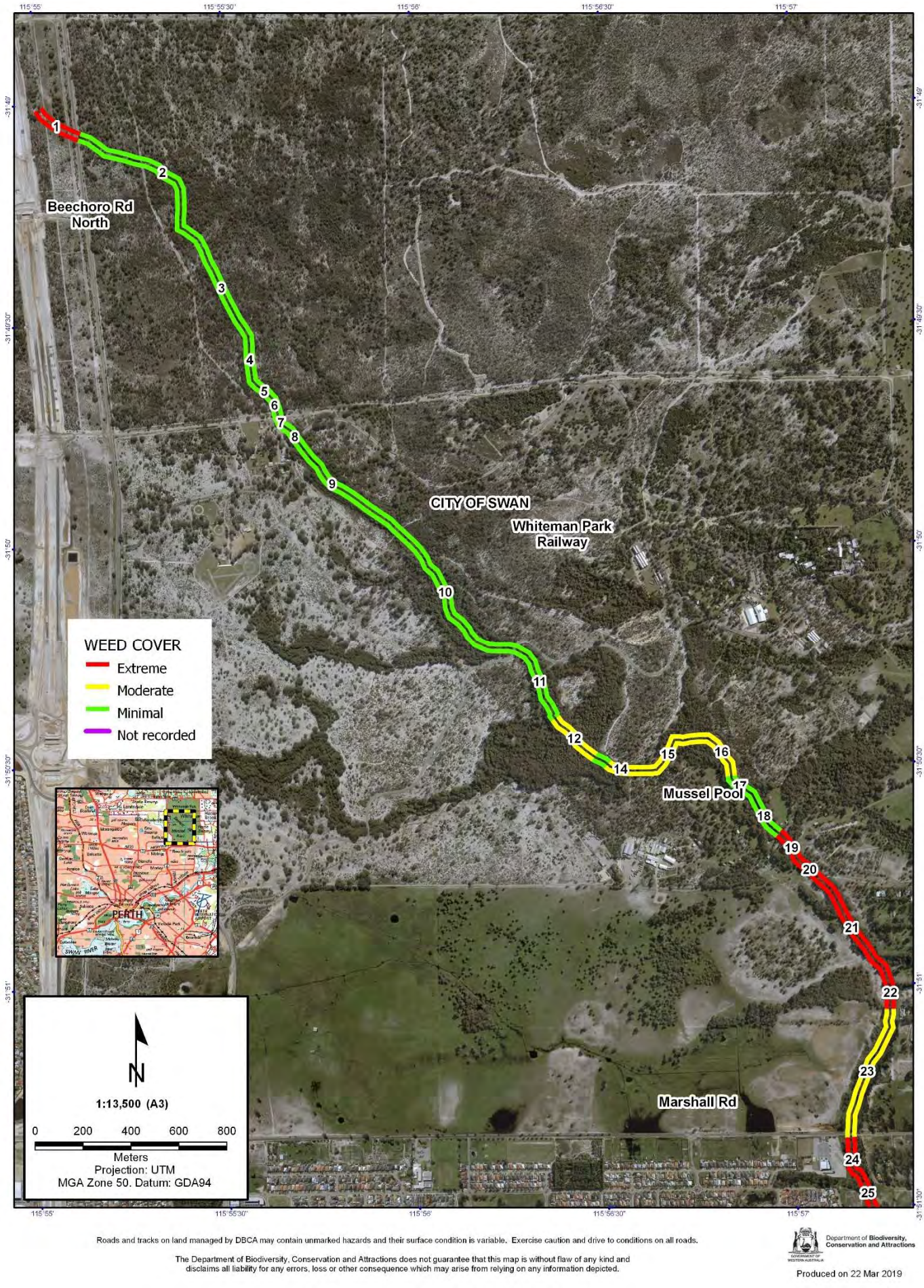


Figure 112: Weed cover, North section.

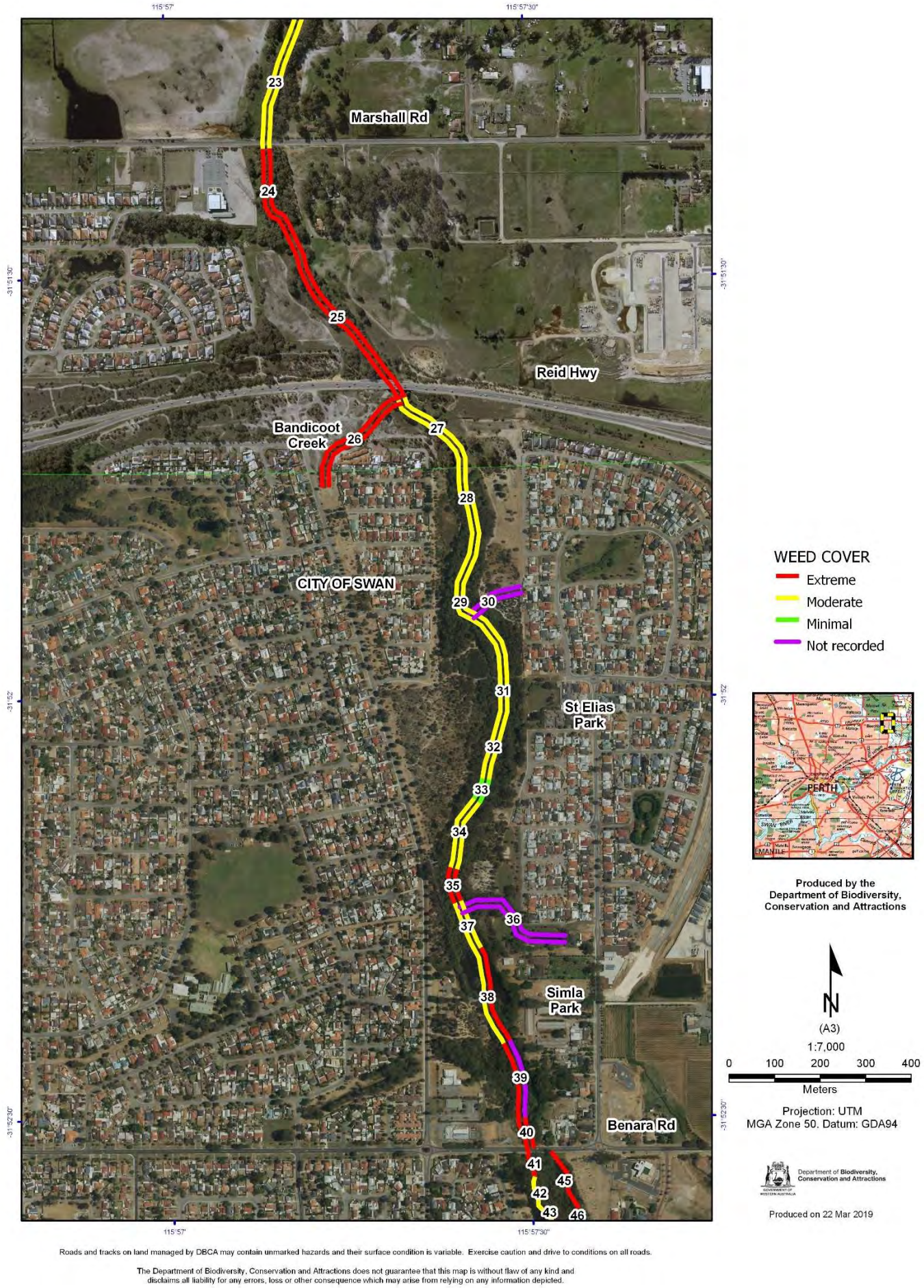


Figure 113: Weed cover, Central section.

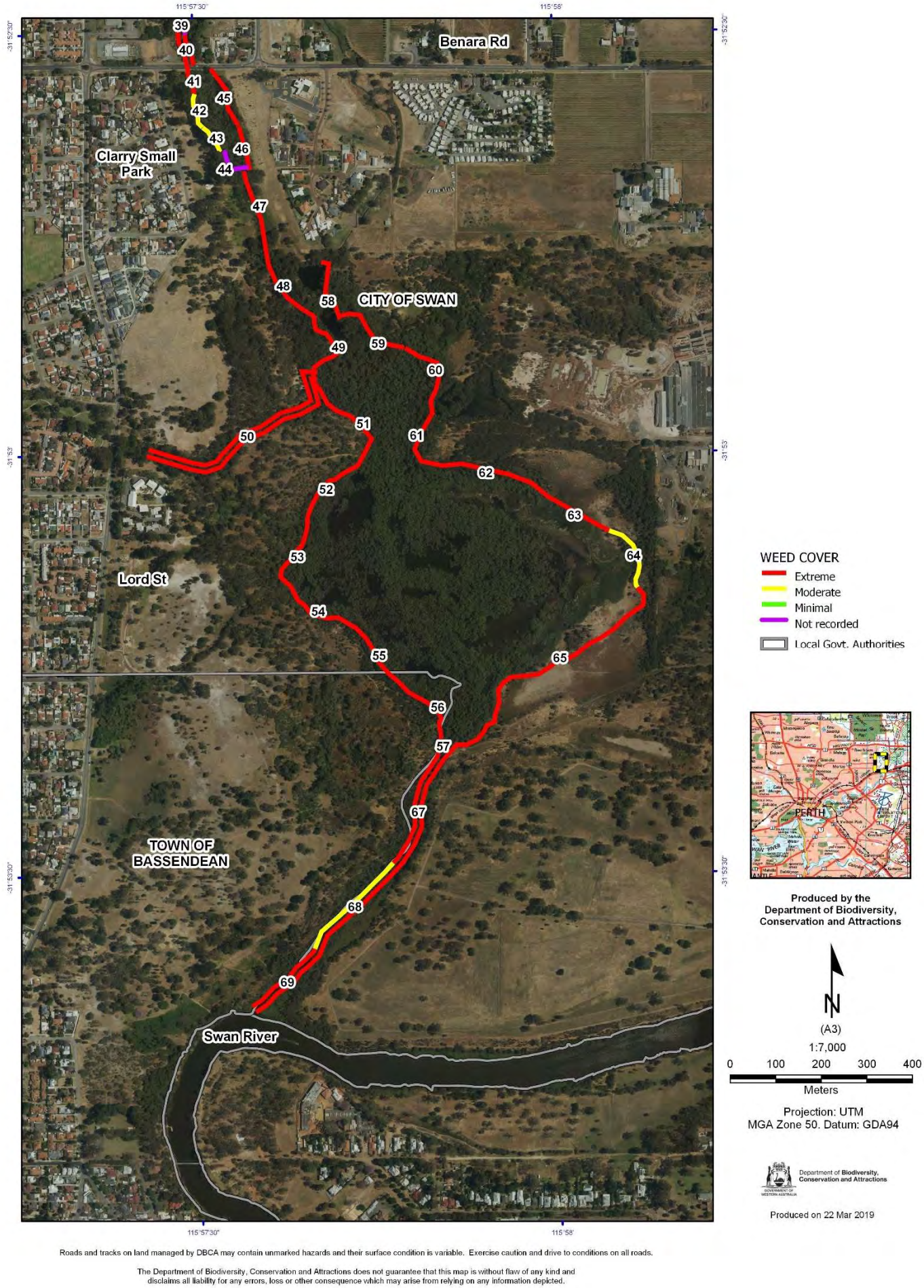


Figure 114: Weed cover, South section.

3.5 Pen and Scott grade

A description of each grade is provided in Appendix 6.

North section

The highest Pen and Scott grade is A1 and the lowest is C2 (***Error! Reference source not found.***, *Figure 118*). Only one short segment scored a grading of A1. This segment is located north of the first Whiteman Park railway crossing.

Fifteen out of the 23 segments in the North are in the A grades (pristine to slightly disturbed), with A2 (some introduced weeds in the understorey) being the most popular grade. No segments within the A gradings are located south of Mussel Pool.

Five segments are rated in the B (weed infested to weed dominated) grades – these are scattered throughout the section, with one segment at the headwaters, three near Mussel Pool and the other immediately north of Marshall Road.

There are three segments in the C (erosion prone) grade – one contains a sand-based dam in Whiteman Park and is rated C2, and the other two are near private property in Bennett Springs. One is rated C1 where there is extensive weed cover in the understorey. The other segment is rated C2 where stock access the brook and are destabilising the banks, vegetation condition is poor and weed cover is extensive.

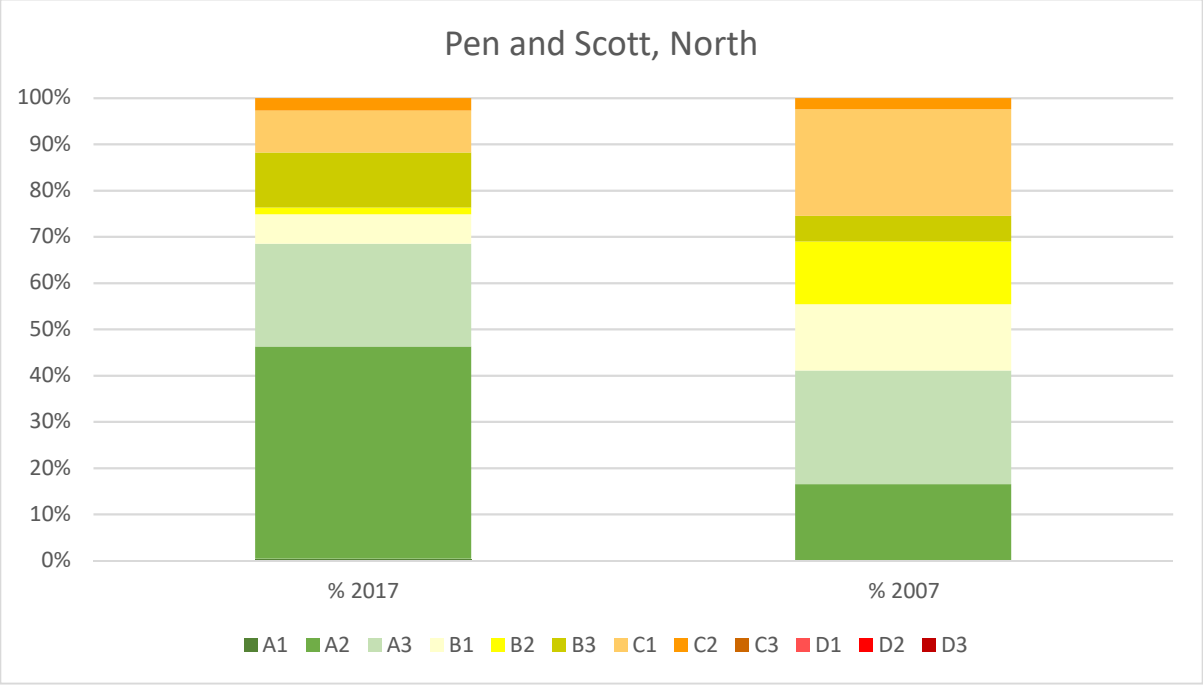


Figure 115: Comparison between Pen and Scott grades for 2017 and 2007 assessments, as a proportion of length of stream bank in the North section.

In 2007 the highest and lowest grades across the section were similar and no segments were in the D grades (*Figure 115*). Less stream bank was assigned an A grade in 2007. While this may indicate a slight improvement in condition, the subjectivity inherent in the grading system could also account for this.

Central section

No segments are graded in the A grades (*Figure 116*). The highest grade is B1 and the lowest is C2. Segments are evenly spread across B and C grades.

Three segments are rated B1 and are all located between St Elias and Simla parks where Friends of Bennett Brook are actively restoring the brook.

Bandicoot Creek is rated B2 due to the rapid growth of annual grasses on the upper banks. Weed control has been conducted since the assessment.

Only one short segment is graded C2, located immediately north of Benara Road where there are dense infestations of morning glory and kikuyu.

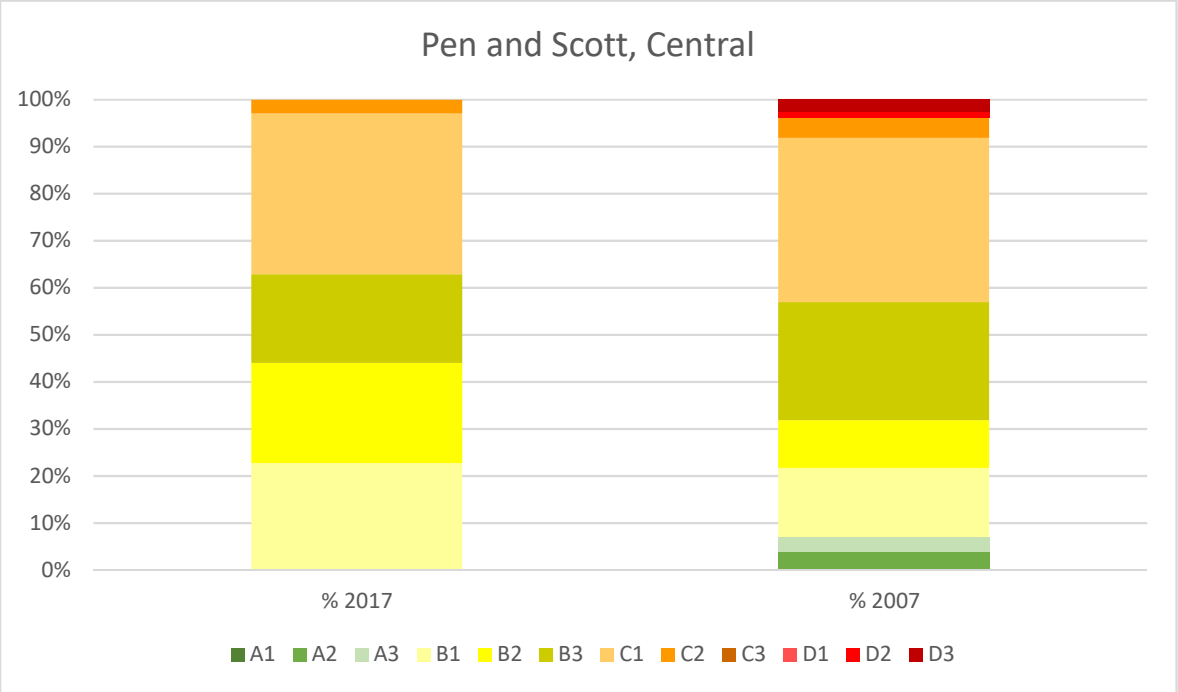


Figure 116: Comparison between Pen and Scott grades for 2017 and 2007 assessments, as a proportion of length of stream bank in the Central section.

In 2007 a small amount of stream bank had been assigned A however none was in 2017, as all segments had some level of weed incursion. More stream bank was assigned a B grade in 2017 than in 2007, and a similar amount of stream bank was assigned in a C grade. In 2007 a small amount of stream bank was graded D2 and D3; no segments were assigned D in 2017 (*Figure 116*).

South section

No segments are rated in the A grades because weeds are prominent throughout the section, although the ecosystem types are diverse and vegetation structure is complex.

The highest grade is B1 and the lowest is D3, indicating the wide range in stream condition across the section. Two segments are rated B1 – in the samphire community of Grogan Swamp where salinity appears to have restricted weed species richness; and on the north western side of the swamp, where swamp paperbark and *Juncus kraussii* are very dense.

The paddock near Clarry Small Park is rated D3 as the native vegetation structure is almost completely absent, with no overstorey providing shade or habitat. The banks are bare and erosion prone. This area was also rated D3 in 2007.

A modified drainage channel on the western side of Grogan Swamp is also rated D3 as it is almost entirely comprised of weeds and has a very open native overstorey. Twenty-six weed species are identified in the segment.

The most common grading is C1 (erosion prone), for 13 of 30 segments. In these segments the understorey is dominated by weeds and there is little evidence of native species regeneration due to competition with weeds. The banks are prone to erosion if soil is further disturbed or exposed.

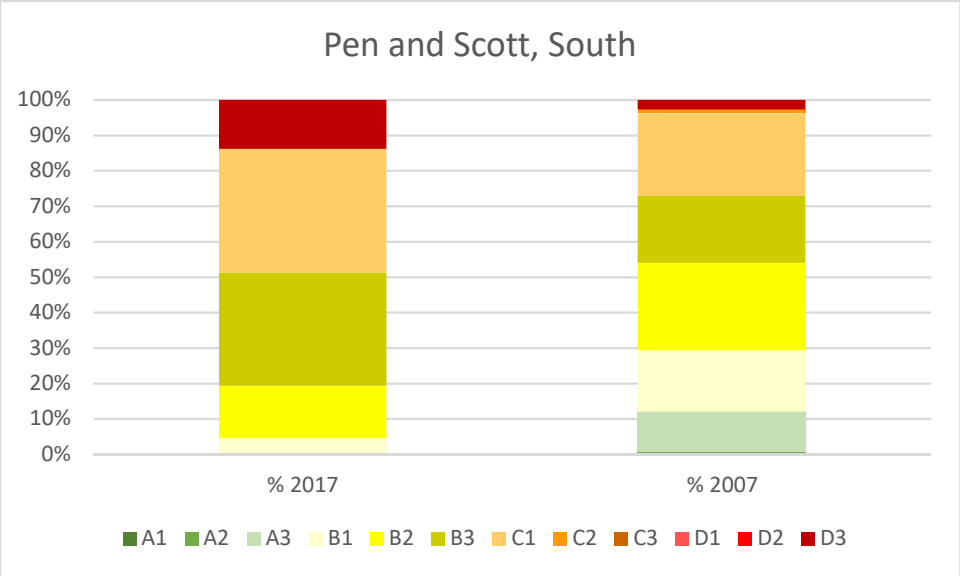


Figure 117: Comparison between Pen and Scott grades for 2017 and 2007 assessments, as a proportion of length of stream bank in the South section.

In 2007 most segments were rated in the B grades, with a small amount of stream bank in the A grades (*Figure 117*). None of the A grade segments in 2007 were rated A grade in 2017 due to the level of weed coverage. Nearly 50% of stream bank was graded C or D in 2017 while less than 30% was rated C or D in 2007. This indicates a decline in condition though should be considered in the context of subjectivity within the grading system.

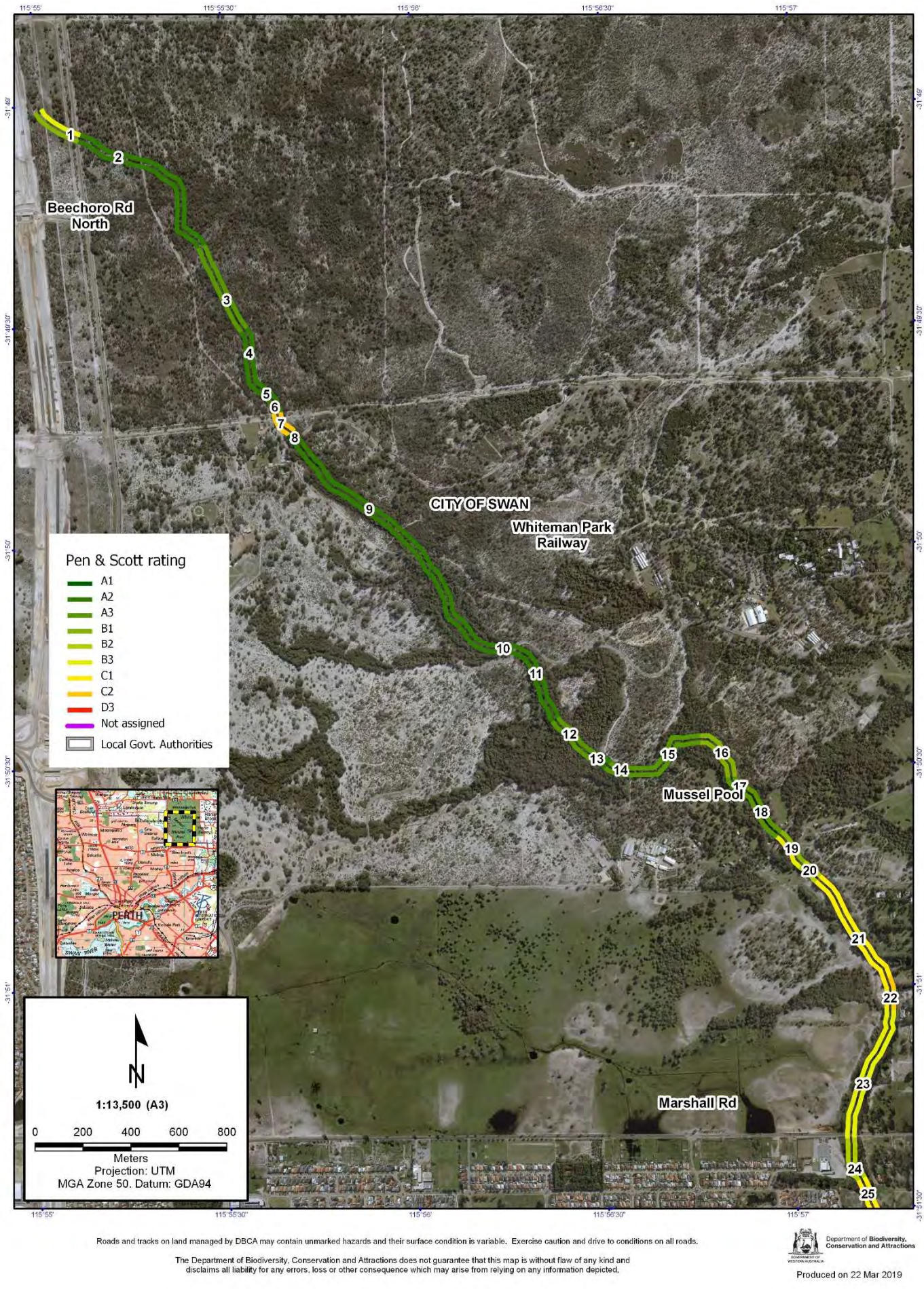


Figure 118: Pen and Scott grading, North section.

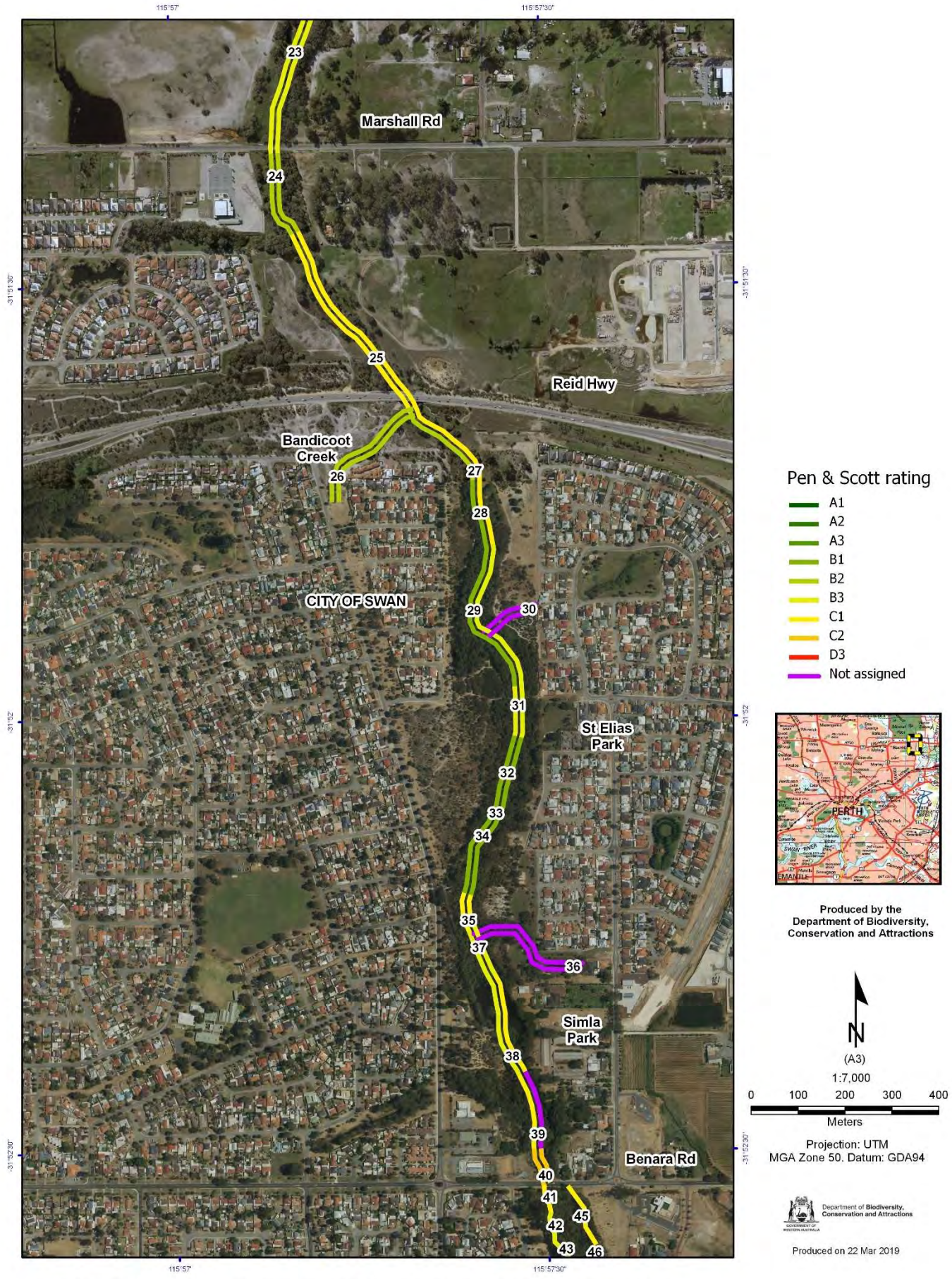


Figure 119: Pen and Scott grading, Central section.

Figure 120: Pen and Scott grading, South section.

3.6 Other management issues

3.6.1 Stock and vehicle access

Generally stock and vehicle access to the brook is well controlled. In the North section Whiteman Park is fenced on the park's boundary and internal fences are maintained so that cattle do not access the brook. However, private property encroaches on the alignment of the brook near Cranleigh Street in Bennett Springs and on one property the fenceline is located through the watercourse. Domestic animals were wallowing in the brook at the time of assessment.

Footpaths along the upper banks and footbridges provide structured walkways in the Central section (*Figure 121*), although off-road driving is evident near Bandicoot Creek and Reid Highway which limits the potential for native plant regeneration.

Most of the South section is fenced and closed to the public on Lord Street and Meadow Street. However, some trail bikes were accessing the floodplain near the Swan Valley Nyungah Community site during the assessment. A jump track has been constructed and there are several make-shift camps nearby (*Figure 122*).

Figure 121 (left): Informal pathways in the Central section.
Figure 122 (right): Bike jump track on the western side of Grogan Swamp.

3.6.2 Water quality observations

Orange-coloured stagnant water was observed in several places along the brook in 2017. From Mussel Pool downstream for about 700m the water is opaque and appeared to be iron-stained. Water quality also appeared poor at the site where private property crosses the brook near Cranleigh Street.

Poor water quality, from visual observation only, was not apparent through the Central section. It was difficult to access all of the waterway due to the soggy terrain and dense vegetation, but in the places where the brook was observed, stagnant opaque water was not seen.

In the South section, the only water quality observations made were a sulphur smell and salt scour in samphire flats on the eastern side of Grogan Swamp where there are large stands of dead swamp sheoak. Further investigation is needed into the interaction of salinity, flooding and tree death.

3.6.3 Feral animals

Foxes were evident in Grogan Swamp. A series of dens was found in clay embankments on the eastern side of the swamp. Four oblong turtle carcasses, remains of ibis and other birds were scattered in front of the den. A large healthy fox was sighted close to the dens. Fox scat, pelican feathers and turtle carcasses were also found below the Pyrton site on the western side of the swamp.

Feral animal signs were not apparent in the North and Central sections. On a positive note many quenda diggings were seen in sandy soils in the northern part of Whiteman Park.

3.7 Current management responses

3.7.1 Whiteman Park

Whiteman Park undertakes weed control each year through its environmental management program. Around Grogan Swamp there has been a focus on arum lily control in recent years.

The Park have supported Friends of Bennett Brook by funding weed control around revegetation sites between Reid Highway and Benara Road.

The Park undertake opportunistic feral cat and fox control to reduce predation pressure on native fauna.

Fire management consists of maintaining fire breaks and conducting prescribed burns on a rotational basis to reduce risk of widespread severe bushfires.

Whiteman Park are currently managing issues caused by a pipe outlet on the northern side of Marshall Road which has created sheet erosion downslope towards Bennett Brook.

3.7.2 DBCA

The Swan Alcoa Landcare Program (SALP) has provided grants to support community groups undertaking environmental improvement projects in the Swan Canning Catchment each year since 1998. The grants are funded by Alcoa of Australia and the State Government through DBCA, and administered by Perth NRM. Groups working along Bennett Brook and in its catchment have been among the recipients of these grants and many of the areas with improved vegetation

condition are due, at least in part, to SALP grants and the community groups that make use of them.

DBCA's Rivers and Estuaries Branch also provides funding to the City of Swan to employ a part-time water quality officer who has initiated and conducted many restoration activities in drainage channels and compensation basins that flow into Bennett Brook. The officer also provides support to residents and community members interested in joining or establishing Friends of groups.

Bandicoot Creek received Local WQIP funding in 2014/15 and currently receives SALP funding for weed control and revegetation. The site was selected as water quality within its catchment has regularly exceeded ANZECC trigger values for nutrient concentrations.

The Community Rivercare Program is currently funding a restoration project near Reid Highway with the Friends of Bennett Brook.

3.7.3 Friends of Bennett Brook

The Friends of Bennett Brook have focussed restoration effort on the brook between Reid Highway and Clarry Small Park, working with a number of stakeholders since 1998.

Through various funding sources the group have tackled control of blackberry, Typha, morning glory, kikuyu, and many other broadleaf weeds and grasses at 18 sites. Weed control has been undertaken by a contractor and partially by community volunteers. Weed control has been followed up with extensive planting of wetland and dryland species by volunteers.

Comprehensive revegetation site profiles from 1998 to 2016 have been compiled by the Friends group (North Metro Conservation Group and Friends of Bennett Brook 2016).

Sites have included both dryland and wetland areas and drainage channels including Bandicoot Creek, Coonawarra Gully, Wonga Way (*Figure 124, Appendix 11*). Whiteman Park, DBCA and Water Corporation have contributed funds for restoration, and the group has successfully secured support from State and Federal government funding programs.

3.7.4 WAPC

WAPC maintains parkland in the lower reaches of Bennett Brook by mowing and slashing grass regularly to reduce risk of widespread bushfire. WAPC also maintains fire breaks and fire access tracks.

3.7.5 Water and sediment quality sampling

Water and sediment quality sampling have been conducted in Bennett Brook Catchment regularly since at least 2002. Perth NRM and DBCA's Rivers and Estuaries Branch provided funding to initiate sampling and analysis plans. City of Bayswater, City of Swan and Whiteman Park currently fund the plans, laboratory analysis and annual reports. Sampling is conducted by the South East Regional Centre for Urban Landcare (SERCUL).

Sampling at four sites located on or near Bennett Brook has indicated high levels of nutrients, physical parameters, metals in water and metals in sediment, according to a report on 10 years of water and sediment quality monitoring in Bennett Brook Catchment (SERCUL 2013).

Water quality is sampled regularly about 700m upstream of Mussel Pool, where physical properties (pH, dissolved oxygen, electrical conductivity and suspended solids) and total metals in sediment have often exceeded Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines.

The dam at Horse Swamp in Whiteman Park is also sampled regularly and in 2013 it was reported that nutrients in water and metals in water frequently exceeded ANZECC guidelines over a 10 year period.

The sampling site at the Marshall Rd crossing was ranked priority 1 in 2013 (SERCUL) in the Bennett Brook Catchment to determine the source of pollutants and improve water quality. Physical properties and nutrient concentrations in water and total metals in sediment regularly exceeded ANZECC guidelines, and dissolved oxygen was low at every sampling event, indicating stress on the aquatic fauna (SERCUL 2013).

Water quality is also sampled in Clarry Small Park, near where the watercourse was extensively cleared for farming. Physical properties, nutrients in water and metals in sediment frequently exceed ANZECC guidelines.

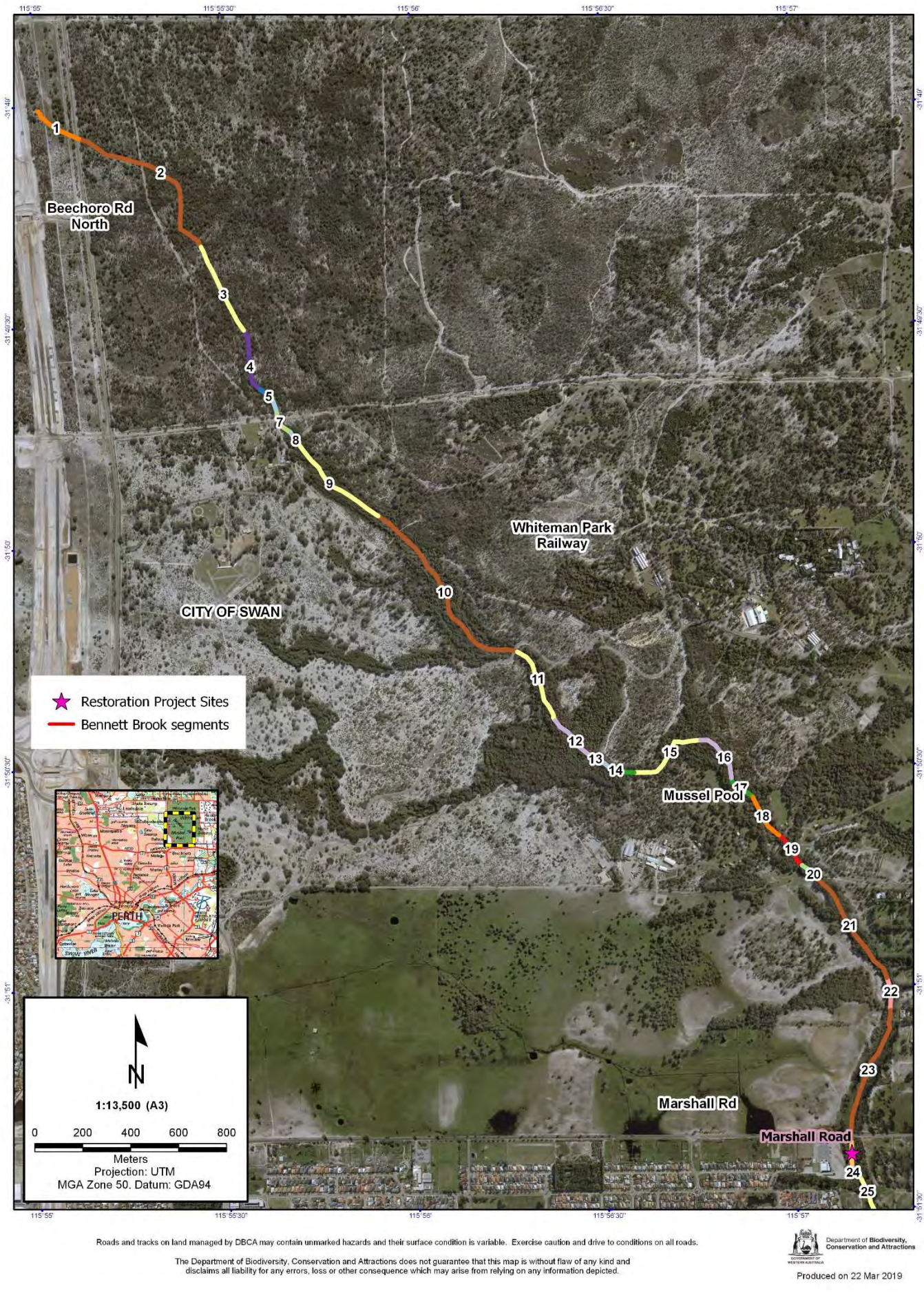


Figure 123: Known restoration project sites over current categories, North section. (Site names referenced in Appendix 11).

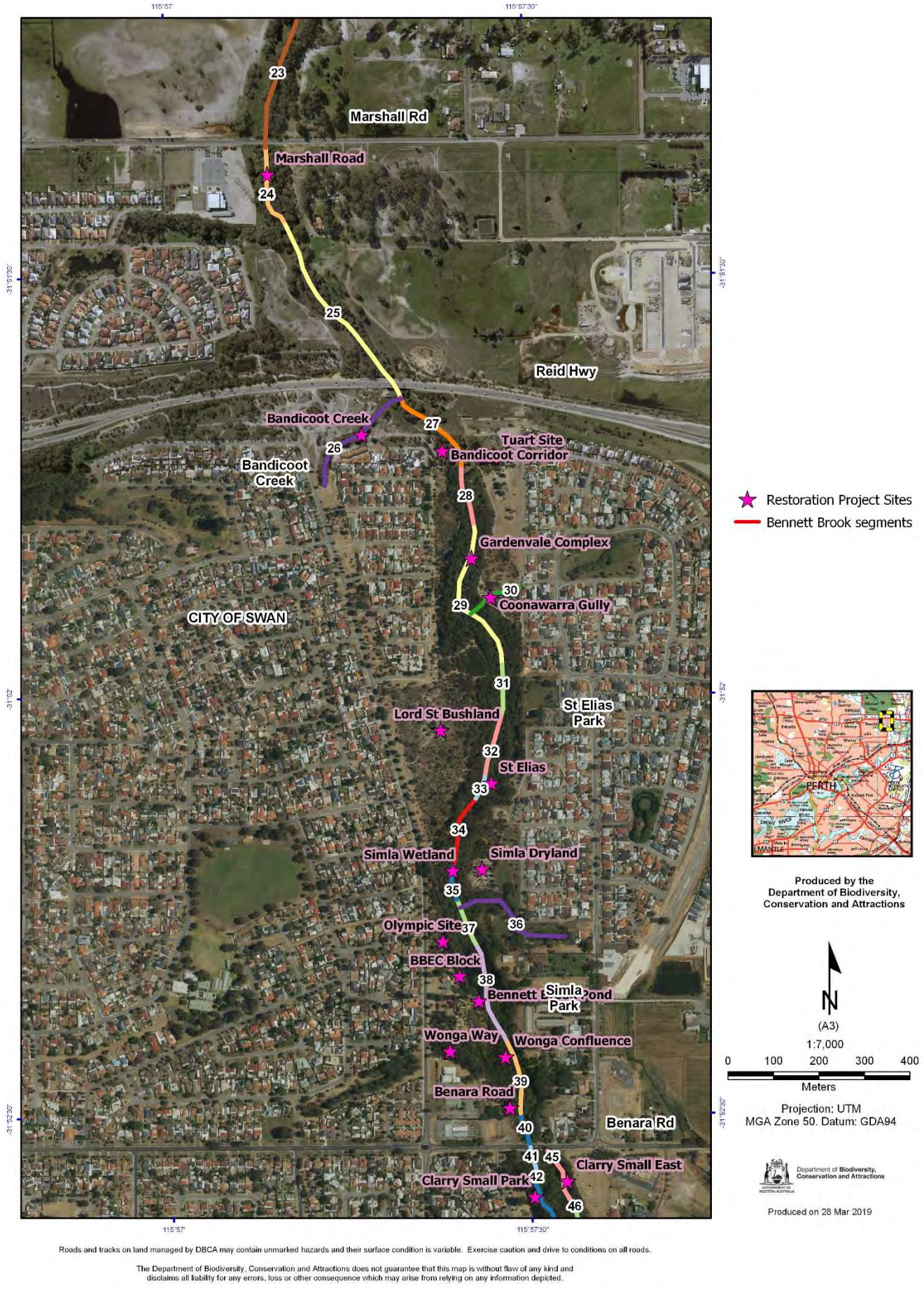


Figure 124: Known restoration project sites over current categories, Central section. (Site names referenced in Appendix 11).

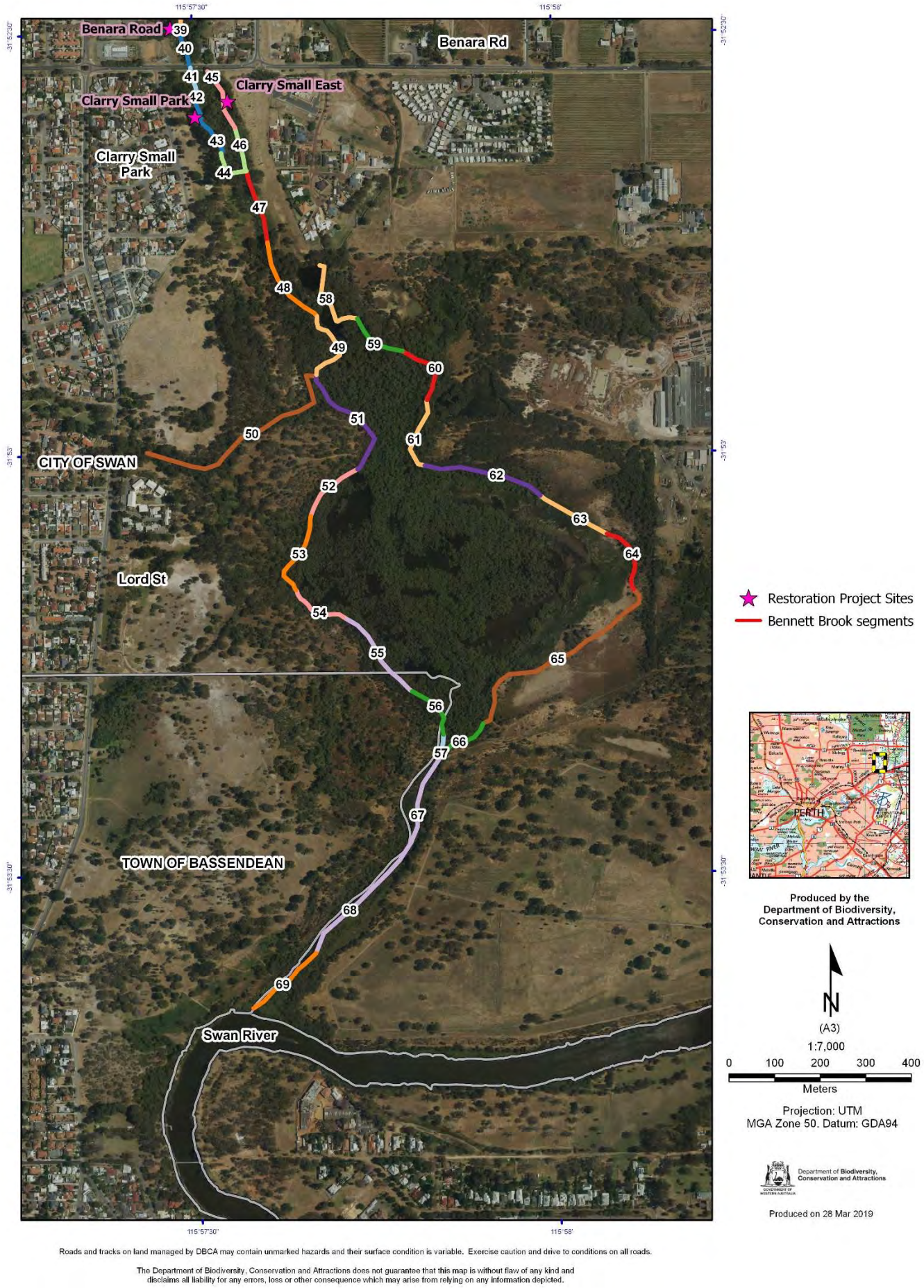


Figure 125: Known restoration project sites over current categories, South section. (Site names referenced in Appendix 11).

4 Strategy and recommendations

4.1 General recommendations

- Seek funding to continue the rehabilitation of Bennett Brook Reserve to stabilise the banks, reduce sediment loads, and improve water quality and habitat value.
- Partner with WAPC, Whiteman Park, City of Swan, Town of Bassendean and Water Corporation to leverage funds, share resourcing and coordinate management activities along Bennett Brook.
- Engage with the Noongar community in restoration works, and in the joint protection of cultural and natural heritage sites.
- Engage residents adjacent to the brook in Bennett Springs and Caversham in restoration and education activities.
- Engage with programs such as Bush Rangers WA, Millennium Kids, Duke of Edinburgh's International Award and corporate working bees for restoration activities.
- Implement activities that aim to improve water quality near high priority hotspots on Bennett Brook identified in the ten-year water and sediment quality report (SERCUL 2013): BBCSN11 Upstream from Mussel Pool; BBCSN14 Bennett Brook along Marshall Rd; BBCSN16 Clarry Small Park; and BBCSN17 Horse Swamp. Further investigation into the source of Total Nitrogen at all four sites is recommended.
- Continue to revegetate and/or monitor compensation basins and drains for emerging weeds to reduce erosion and nutrient and non-nutrient contaminants. This includes Oriole, Lanius and Lockridge drainage channels. Weed removal from these drains will also prevent spread of aquatic invasive species to Bennett Brook and support the work of Whiteman Park and Friends of Bennett Brook in the brook itself.
- Protect the natural diversity of Grogan Swamp by undertaking activities to prevent further degradation, including weed control. Engage with the Noongar community and relevant stakeholders to stage weed removal and revegetation with a diverse mix of native species;
- Increase the width of the riparian zone on the lower reaches of Bennett Brook. This needs engagement with WAPC and Department of Planning, Lands and Heritage to stage weed removal and revegetation with a diverse mix of native species. This can contribute to the planting by Trillion Trees to the south east of Grogan Swamp.

- Remove weeds from the uppermost section of the brook where they first start appearing. Remove highly invasive weed species that are not currently prevalent in segments, in particular *Isolepis prolifera.* Stage weed control works and plan actions to ensure that large amounts of sediment do not erode, and that fauna habitat is retained during or after restoration.
- Create connection with Bush Forever sites and TECs and PECs when considering sites for revegetation and promote biodiversity and habitat complexity through planting locally endemic over, middle and understorey species.
- Support Whiteman Park's development of an environmental management plan and revegetation program for the Park. Provide input into the planning process for improved catchment health.
- Support Whiteman Park's plans for trails and linkages between the southern reaches of Bennett Brook with Mussel Pool, and link with education and cultural programs being run at Whiteman Park where appropriate.

4.2 Categorisation

Each segment has been assigned a category from 0 to 8 based on its management priority. This was based on a reach priority shuffle method developed by the CRC for Catchment Hydrology (Rutherfurd *et al*., 2000a and 2000b). The categorisation allows prioritisation of segments and highlights areas of stream bank for restoration activities to be conducted.

Table 3: Length and percentage of streambank assigned to each prioritisation category (refer to Table 1 for the criteria used to assign categories).

Prioritisation category	Section of Bennett Brook							
	North		Central		South		Overall	
	Km*	%	Km*	%	Km*	%	Km*	%
0	0	0	0	0	0	0	0	0
1	8.71	68.4	0	0	0	0	8.71	34.8
2	0	0	0	0	0	0	0	0
3	3.81	29.9	3.14	58.9	4.18	60.3	11.13	44.5
4	0.22	1.7	0	0	0	0	0.22	0.9
5	0	0	1.84	34.5	2.09	30.2	3.93	15.7
6	0	0	0.35	6.6	0.14	2.0	0.49	2.0
7	0	0	0	0	0.52	7.5	0.52	2.1
8	0	0	0	0	0	0	0	0
Total	**12.74**	**100**	**5.33**	**100**	**6.93**	**100**	**25**	**100**

*Both left and right banks were assigned a Pen and Scott grade so the distances in this table reflect length of bank assessed, not overall lengths of Bennett Brook.

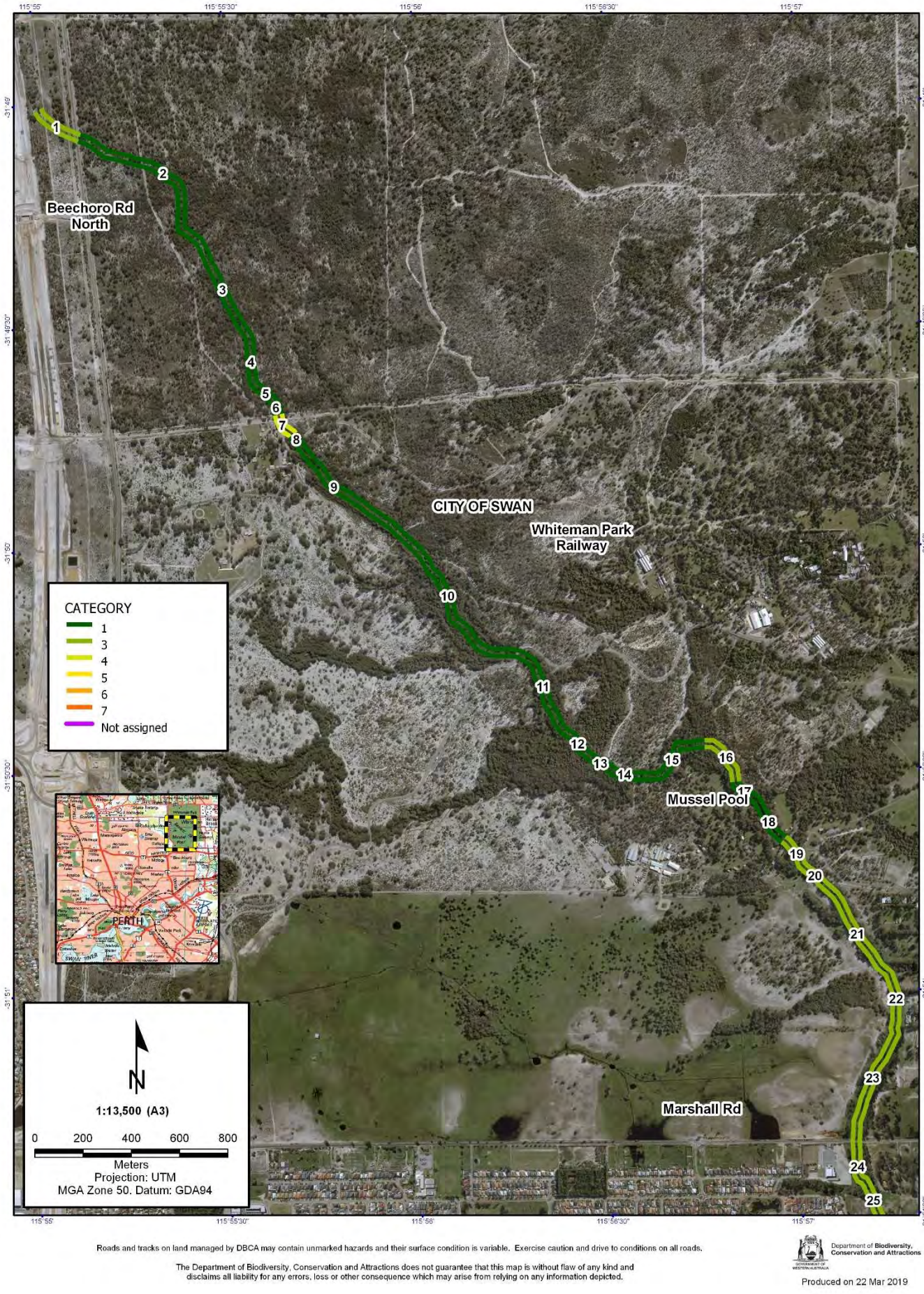


Figure 126: Management categories assigned to Bennett Brook, North section (refer to Table 1 for criteria used).

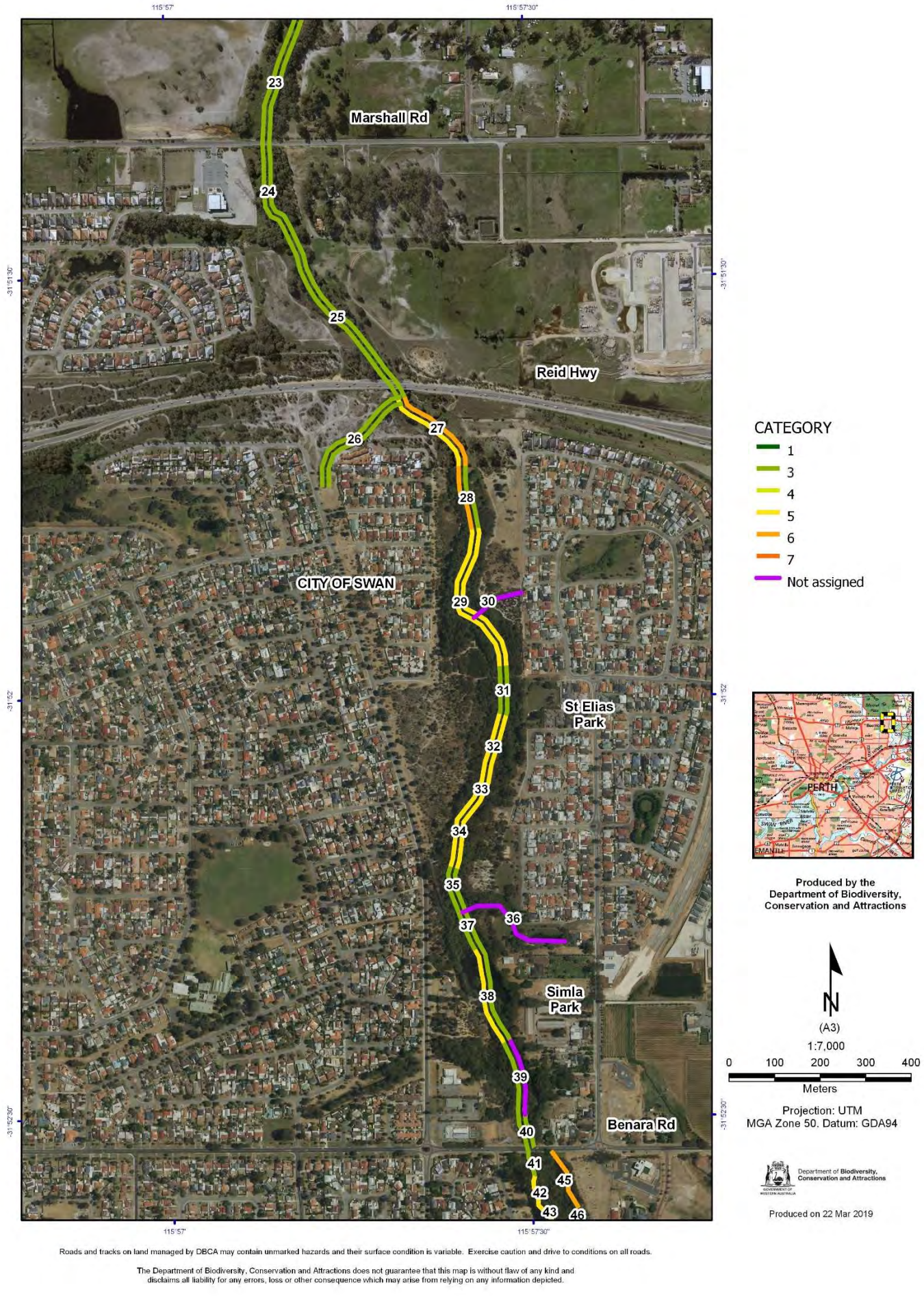


Figure 127: Management categories assigned to Bennett Brook, Central section.

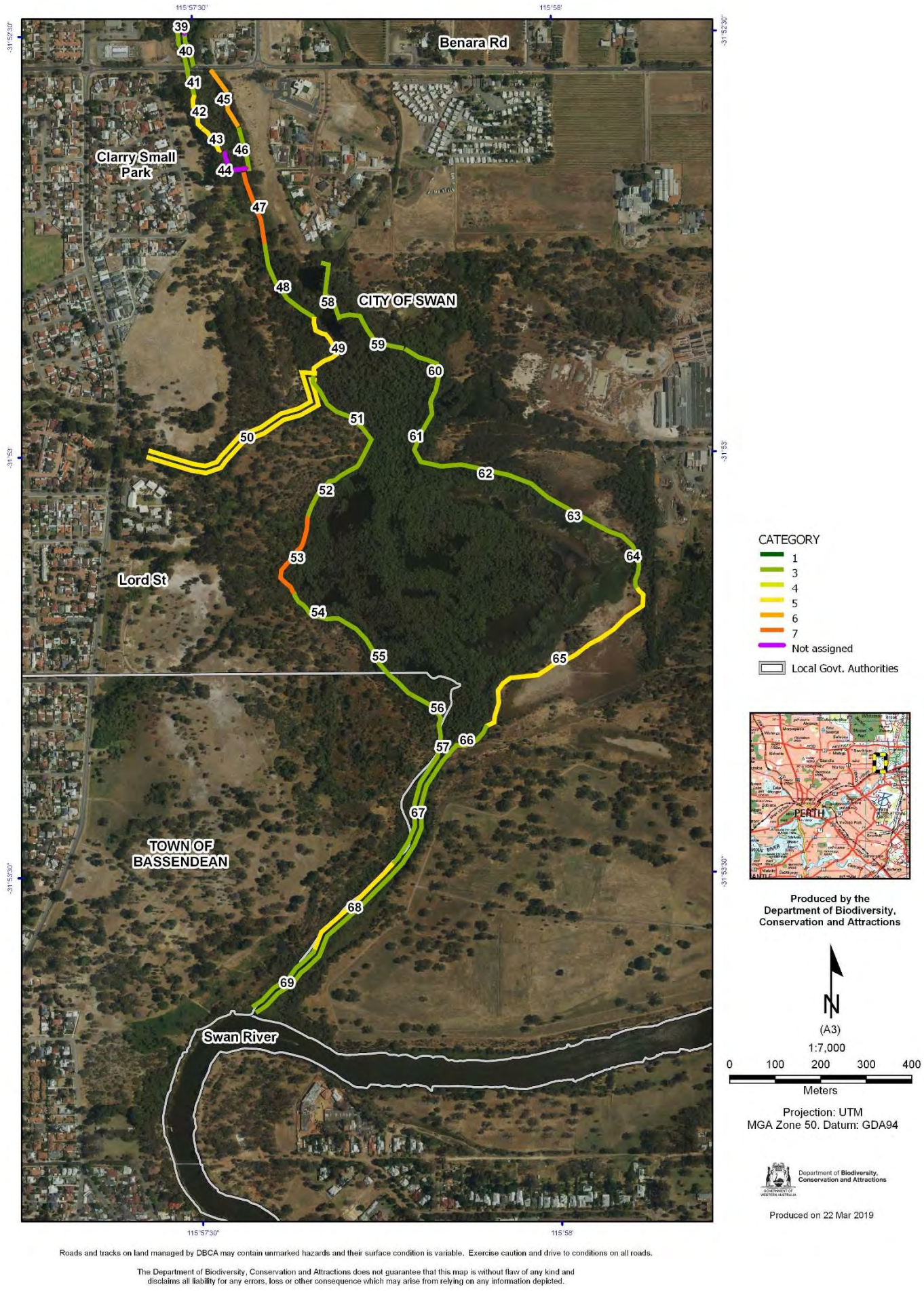


Figure 128: Management categories assigned to Bennett Brook, South section.

4.3 Site recommendations

Recommendations that can be achieved in the short to intermediate term have been included for each segment (Table 4). The recommendations include activities such as:

- controlling or locally eradicating weed species that are currently low in coverage and can be removed without a high investment in time or funding;
- addressing issues with uncontrolled access that are impacting on the stream bank;
- infill planting in sites where weeds have been controlled or prior revegetation has taken place; and
- planting behind single lines of trees that remain on the stream bank and are threatened by localised erosion.

In Table 15, recommendations are listed against segment numbers in order of location but can be prioritised based on management category (from 0 to 8). In some instances, there may be high community capacity or landholder ability to undertake works, or recommended works support the actions of already existing projects and their priority may be increased. See Figure 12, Figure 13 and Figure 14 for the segment number that matches to Table 4.

For each segment, recommended species for revegetation refer to the vegetation complex that the segment is located in, included in Appendix 5. Although the species along waterways passing through the Southern River Complex and the Guildford Complex are very similar, the important difference is the presence of clay and waterlogging in winter. The soil type results in slightly different species in the higher areas, many species the same along the low-lying waterways, and significantly different species in the clay winter water-logged areas.

Therefore it is important to differentiate between the soil types where the areas of winter water logging occur prior to choosing species for planting. This can be done via a field test to check if a ‘sausage’ forms when the soil is dampened or breaks up due to a high sand content.

Table 4: Recommendations that can be achieved in the short to intermediate term for each segment of Bennett Brook.

Segment number	River section	Category (Left Bank)	Category (Right Bank)	Short to intermediate term recommendation for management
1	North	3	3	Not much can be done - under road reserve and powerline. Could do some revegetation with Cullacabardee community. Remove cactus and carnation weed by culvert

Segment number	River section	Category (Left Bank)	Category (Right Bank)	Short to intermediate term recommendation for management
2	North	1	1	Maintain active management. Consider fire management to promote natural regeneration
3	North	1	1	Maintain active management. Control annual weeds in growing season
4	North	1	1	Maintain active management. Consider fire management to encourage natural regeneration. Spray or hand pull annual weeds during growing season
5	North	1	1	Maintain active management. Consider fire management to promote natural regeneration. Hand pull blowfly grass during growing season
6	North	1	1	Maintain active management. Consider fire management to promote natural regeneration. Remove annual weeds during growing season
7	North	4	4	Decide if dam is still needed or could be revegetated on right bank (RB). Hand pull annual weeds in growing season
8	North	1	1	Maintain active management
9	North	1	1	Maintain active management. Spray annual weeds near train line
10	North	1	1	Maintain active management. Hand pull grassy weeds during growing season
11	North	1	1	Spray annual weeds adjacent to bank
12	North	1	1	Maintain active management. Hand pull weeds during growing season
13	North	1	1	Hand pull blowfly grass during growing season
14	North	1	1	Spray and hand pull weeds on rail embankment. Investigate source of nitrogen in the water
15	North	1	1	Hand pull weeds in brook, spray banks & adjacent dryland where it is weedy

Segment number	River section	Category (Left Bank)	Category (Right Bank)	Short to intermediate term recommendation for management
16	North	3	3	Hand pull weeds in brook, spray weeds on adjacent dryland banks
17	North	1	1	Remove arum lily, *Juncus microcephalus* and olive. Spot spray other grasses and herbs. Remove any oak seedlings near established tree
18	North	1	1	Maintain active management. Remove arum lily, *Juncus microcephalus* and slender trefoil
19	North	3	3	Selective control of grasses amongst native species in summer. Remove arum lily and olive
20	North	3	3	Remove arum lily. Hand pull fleabane, fig and nightshade. Selective grass spray
21	North	3	3	Remove figs, blackberry, Japanese pepper and arum lily. Hand weed fleabane and nightshade. Selective control of grasses. Spot spray *Juncus microcephalus* and *Cyperus* sp.
22	North	3	3	Encourage setback of fence to restrict stock access. Remove Japanese pepper, figs and bulbous sp. Selective control of grasses. Would need dense revegetation
23	North	3	3	Some paspalum has been sprayed on RB. Remove arum lily, *Isolepis prolifera* and thistle. Spot spray weedy grasses on bank during growing season
24	Central	3	3	Continue spraying on banks during growing season. Remove arum lily. Infill plant. Investigate source of nitrogen in the water
25	Central	3	3	Remove lantana, blackberry and watercress
26	Central	3	3	Remove arum lily. Spray weedy banks during growing season. Hand pull flea bane. More infill planting

Segment number	River section	Category (Left Bank)	Category (Right Bank)	Short to intermediate term recommendation for management
27	Central	6	5	Spray grassy weeds including veldt grass on RB. Remove pigface, blackberry and kikuyu and revegetate
28	Central	3	6	Spray veldt grass on left bank (LB). Remove *Isolepis prolifera*, blackberry and nightshade
29	Central	5	5	Remove arum lily, nightshade, blackberry and *Isolepis prolifera*. Spot spray *Juncus microcephalus*. Spray grassy weeds
30	Central	NA	NA	Maintain active management
31	Central	3	3	Remove arum lily. Spot spray grass. Hand pull thistle. Plant middle bank between both channels
32	Central	5	5	Remove *Isolepis prolifera*, arum lily and nightshade. Hand pull thistle. Spot spray grass weeds
33	Central	5	5	Remove *Isolepis prolifera* and arum lily. Hand pull thistle. More infill planting
34	Central	5	5	Remove arum lily and nightshade. Spot spray grassy weeds on banks during growing season
35	Central	3	3	Stage arum removal
36	Central	Not rated	Not rated	Maintain active management
37	Central	3	3	Remove pigface and Japanese pepper. Stage arum removal. Spray veldt on banks during growing season. Infill plant
38	Central	3	5	At northern end of segment at Simla Park remove blackberry and Japanese pepper. Spray veldt grass on bank
39	Central	Not rated	3	Remove arum lily, blackberry and small amount of *Typha**. Stage kikuyu removal and infill plant
40	Central	3	3	Follow on from *Typha* removal upstream. Remove morning glory. Plant sedges instream

Segment number	River section	Category (Left Bank)	Category (Right Bank)	Short to intermediate term recommendation for management
41	South	Not rated	3	Remove arum lily and prickly lettuce. Hand pull thistle, nightshade and fumaria. Stage removal of *Typha**. Revegetate bank
42	South	Not rated	5	Remove blackberry, thistle, prickly lettuce and arum lily. Stage removal of *Typha**
43	South	Not rated	5	Remove fleabane, thistle, arum lily, nightshade, prickly lettuce and fig. Stage removal of *Typha** and paspalum
44	South	Not rated	3	Remove blackberry, thistle, arum lily and prickly lettuce. Spot spray oats, blowfly grass and veldt grass during growing season. Stage removal of paspalum and *Typha** in stream
45	South	6	Not rated	Consider a trial cool burn and follow up with chemical control. Remove Japanese pepper, fleabane and arum lily. Stage *Typha* removal
46	South	3	Not rated	Consider a trial cool burn and follow up with chemical control. Remove arum lily
47	South	7	7	Remove arum lily, Japanese pepper and juvenile *Eucalyptus*. Consider a trial cool burn and follow up with spot spray. Revegetate. Investigate the source of nitrogen in the water
48	South	3	3	Remove date palm and olive. Control arum lily and plantain. Continue to spray grasses in dryland buffer and control weeds around revegetation. Plant edges of brook to prevent further erosion
49	South	Not rated	5	Remove *Isolepis prolifera* to prevent spread and conduct follow up monitoring. Monitor for weeds that might come from upstream
50	South	5	5	Remove *Isolepis prolifera*, arum lily, olive and Japanese pepper. Spray grassy weeds on banks. Potentially a good project to link to western end of drain (Mary Crescent)

Segment number	River section	Category (Left Bank)	Category (Right Bank)	Short to intermediate term recommendation for management
51	South	Not rated	3	Remove Japanese pepper (northern end of segment), blackberry and arum lily. Follow up weed monitoring. Manage trail bike jump track
52	South	Not rated	3	Spray grass weeds when *Bolboshoenus* dies down. Replace couch with *Centella*. Remove blackberry although access is difficult
53	South	Not rated	7	Start on the river bank's edge controlling grass and planting sedges. Remove arum lily, olive, Japanese pepper and other woody weeds. Stage *Typha** control
54	South	Not rated	3	Remove arum lily. Tackle weeds on outer edge and put in grass selective spray buffer so samphires can regenerate naturally
55	South	Not rated	3	Remove watsonia on sandy bank. Spray weedy grasses. Tackle weeds on outer edge and put in grass selective spray buffer so samphires can regenerate naturally
56	South	Not rated	3	Remove *Typha**, Japanese pepper, prickly lettuce. Control grassy weeds
57	South	Not rated	3	Blanket spray grasses and weeds until native seedbank has established
58	South	3	Not rated	Consider fox control. Remove arum lily, Japanese pepper, thistle and prickly lettuce
59	South	3	Not rated	Protect clay pan from invading grasses through targeted control adjacent to native fringing vegetation and remove Japanese pepper
60	South	3	Not rated	Consider fox control. Remove Japanese pepper and watsonia
61	South	3	Not rated	Stage *Typha** removal. Remove arum lily
62	South	3	Not rated	Infill plant under swamp sheoak. Remove Japanese pepper

Segment number	River section	Category (Left Bank)	Category (Right Bank)	Short to intermediate term recommendation for management
63	South	3	Not rated	Prevent weeds encroaching on samphires. Further investigation is needed into the interaction of salinity, flooding and tree death
64	South	3	Not rated	Redirect or remove channel cut behind floodplain. Spray coastal barbgrass during growing season when ground is dry
65	South	5	Not rated	Remove derelict fence
66	South	3	Not rated	Use brush cutter on grassy weeds. Weed spray around revegetation
67	South	3	3	Remove olive, date palm and Japanese pepper. Whipper snip grasses. LB: Spray and infill plant revegetation by ripping rows more closely together. RB: Spray grassy weeds and create buffer at riparian edge
68	South	3	5	Remove date palm and olive. Leave *Melaleuca* as habitat. LB: Increase width of riparian buffer and plant flooded gum. RB: Continue reveg and weed control at Success Hill
69	South	5	3	Plant after early rains when clay is soft so plants have chance to establish. Remove Japanese pepper, bamboo (confirm ID first), thistle, fleabane. Remove moped from brook and consider removing old fence in waterway

**Typha* should only be controlled where it is threatening biodiversity or water flow and there is an approved management plan in place, or to maintain existing cleared areas around infrastructure.

5 Limitations of the assessment

The assessment method was adopted as it had been used by DBCA in 2007, enabling us to compare data and change in condition. Benefits of the method are that it is rapid, does not require specialist equipment and can be conducted by officers experienced in land management and plant identification.

Comparison with previous assessments was challenging as different methods were used for the WRC survey. The 2007 DBCA assessment was most closely aligned although different people interpreting field conditions has led to different results. Vegetation condition and weed cover ratings were often rated better in 2007 than in 2017, which is difficult to understand why but may have been due to us placing a higher emphasis on current vegetation state compared to a pre-European-settlement state.

Subjectivity is inherent in the methodology used, with the most affected fields being vegetation condition, weed cover, bank stability and level of pressure. We tried to minimise subjectivity across the 2017 assessment by using the same assessor for the whole brook.

Other subjective fields were ‘with hope/without hope’ and trajectory. Several questions were applied - for hope, we asked if the segment could recover on its own if there was no intervention. For trajectory we asked if the segment would improve or decline based on the current level of management and condition. This was important given that these fields played a significant role in assigning prioritisation categories 3 to 8.

Bank stability could have been considered good, but other factors may have been poor – the bank may have been entirely covered in weeds, providing stability, but limited habitat value. A thick understorey of weeds also made it difficult to see underlying erosion issues on the bank.

The Pen and Scott grading was originally designed for farming and rural areas so the information relating to grazing and stock access was not relevant for most of Bennett Brook. The C grades are for erosion prone banks where vegetation has been cleared by stock and not relevant to most tributaries in the Perth metropolitan area. With an absence of stock, the weedy understorey was generally intact and the bank not subject to erosion. However, the segment may have otherwise been in poor condition and subject to other pressures (such as runoff from adjacent residential development) but were not listed in this grading system.

Timing of the survey is important to consider. Season affects the species (native and weed) that are most evident and identifiable at the time of assessment. Coverage of grasses and herbs can change rapidly. This assessment was all completed in late spring/early summer, but seasonal changes need to be considered when comparing the results to the previous assessments, and to other tributaries that were assessed at a different time of year.

We were not able to access the entire stream bank for all segments due to dense vegetation and water-logged soils. It is possible that areas of erosion, weed species and other management issues were therefore not seen or recorded.

Appendices

Appendix 1 Vegetation complexes along Bennett Brook

From Heddle *et al*. (1980)

Mapping unit	Vegetation complex	Description	Other representative species
Swan Coastal Plain	Bassendean – Central and South	Ranges from woodland of jarrah-sheoak-banksia on the sand dunes to low woodland of *Melaleuca* spp. and sedgelands on the low-lying depressions and swamps. *Banksia ilicifolia*, *B. littoralis* and *M. preissiana* are common on the low-lying moister soils, where marri replaces jarrah in dominance	*Kunzea vestita*, *Hypocalymma angustifolium*, *Adenanthos obovatus* and *Verticordia* spp.
Swan Coastal Plain	Guildford	Dominated by a mixture of open forest, in sections tall open forest, of *Corymbia calophylla-Eucalyptus wandoo-Eucalyptus marginata* and woodland of *E. wandoo*, with minor components including fringing woodland of *Eucalyptus rudis-Melaleuca rhaphiophylla* along streams and the rare *E. lane-poolei*	*Banksia grandis*, *Kingia australis*, *Xanthorrhoea preissii* and *Hardenbergia* and *Hibbertia* spp.
Swan Coastal Plain	Southern River	Open woodland of *Corymbia calophylla- Eucalyptus marginata -Banksia* species on the elevated areas and fringing woodland of *Eucalyptus rudis-Melaleuca rhaphiophylla* along streams	

Appendix 2 - Natural values adjacent to Bennett Brook

Note that the Environmentally Sensitive Areas combine datasets for Bush Forever Sites, Ramsar wetlands, World Heritage property, Declared Rare Flora, Swan Coastal Plain geomorphic wetlands, Important Wetlands, TECs or are on the register of National Estate and these sites are covered in the following tables.

Nationally Important Wetlands within a 500-metre buffer of Bennett Brook

Reference code	Wetland name
WA091	Swan-Canning Estuary

Bush Forever Sites within a 500-metre buffer

Site number	Site name	Landform element
198	Beechboro Road Bushland, Cullacabardee/Ballajura	Bassendean Dunes
304	Whiteman Park, Whiteman/West Swan	Bassendean Dunes
305	Bennett Brook, Eden Hill to West Swan	Estuaries, Rivers and Creeks

Known threatened and priority flora within a 500-metre buffer

Scientific name	Common name	WA *Wildlife Conservation Act 1950* conservation status
Carex tereticaulis		Priority 3
Cyathochaeta teretifolia		Priority 3
Stylidium longitubum	Jumping jacks	Priority 4

Known threatened and priority fauna within a 500-metre

Scientific name	Common name	WA *Wildlife Conservation Act 1950* conservation status
Ardea modesta	Great egret, white egret	Migratory birds protected under International Agreement
Ardea ibis	Cattle egret	Migratory birds protected under International Agreement
Calyptorhynchus baudinii	Baudin's cockatoo	Endangered
Calyptorhynchus latirostris	Carnaby's cockatoo	Endangered
Falco peregrinus	Peregrine falcon	Other Specially Protected fauna
Hydromys chrysogaster	Water-rat, rakali	Priority 4
Isoodon obesulus fusciventer	Quenda	Priority 4
Merops ornatus	Rainbow bee-eater	Migratory birds protected under International Agreement
Westralunio carteri	Carter's freshwater mussel	Vulnerable

Threatened and Priority Ecological Communities within a 500-metre buffer

Community name	Conservation status
Banksia woodlands of the Swan Coastal Plain	EPBC: Endangered WA: Priority 3

Appendix 3 - Dominant native species

			Section of brook		
Abbreviation	**Scientific name**	**Common name**	**North**	**Central**	**South**
Aca sal	*Acacia saligna*	Orange wattle			
Ale sp	*Alexgeorgea nitens or subterranea*				
All fra	*Allocasuarina fraseriana*	Sheoak			
Alt nod	*Alternanthera nodiflora*	Common joyweed			
Atr sp	Atriplex sp.	Saltbush (possibly a weed)			
Ban att	*Banksia attenuata*	Candle banksia			
Ban gra	*Banksia grandis*	Bull banksia			
Ban lit	*Banksia littoralis*	Swamp banksia			
Ban men	*Banksia menziesii*	Firewood banksia			
Bau art	*Baumea articulata*	Jointed twigrush			
Bau jun	*Baumea juncea*	Bare twigrush			
Bau pre	*Baumea preisii*				
Bol cal	*Bolboschoenus caldwellii*	Marsh club-rush			
Cal san	*Calothamnus sanguineus*	Silky-leaved blood flower			
Cal sp.	*Callistemon* sp.	Bottlebrush			
Car app	*Carex appressa*	Tall sedge			
Car fas	*Carex fascicularis*	Tassel sedge			
Car inv	*Carex inversa*	Knob sedge			
Cas obe	*Casuarina obesa*	Swamp sheoak			
Cen asc	*Centella asciatica*	Centella			
Cor cal	*Corymbia calophylla*	Marri			
Cyc hue	*Cycnogeton huegelii*				
Das bro	*Dasypogon bromeliifolius*	Pineapple bush			
Euc mar	*Eucalyptus marginata*	Jarrah			
Euc rud	*Eucalyptus rudis*	Flooded gum			
Euc tod	*Eucalyptus todtiana*	Coastal blackbutt			
Fic nod	*Ficinia nodosa*	Knotted club rush			
Gah dec	*Gahnia decomposita*				
Gas cel	*Gastrolobium celsianum*	Swan River pea			
Hak pro	*Hakea prostrata*	Harsh hakea			
Hak sp	*Hakea* sp.				
Hak var	*Hakea varia*	Variable-leaved hakea			
Har com	*Hardenbergia compontiana*	Native wisteria			
Hyp ang	*Hypocalymma angustifolium*	White myrtle			
Jac fur	*Jacksonia furcellata*	Grey stinkwood			
Jun kra	*Juncus kraussii*	Sea Rush			

			Section of brook		
Abbreviation	**Scientific name**	**Common name**	**North**	**Central**	**South**
Jun pal	*Juncus pallidus*	Pale rush			
Jun pau	*Juncus pauciflorus*	Loose flower rush			
Lep lon	*Lepidosperma longitudinale*	Pithy sword sedge			
Lep sp.	*Lepidosperma* sp.	Sword sedge			
Mel pre	*Melaleuca preissiana*	Modong			
Mel rha	*Melaleuca rhaphiophylla*	Swamp paperbark			
Mel sys	*Melaleuca systena*	Coastal honeymyrtle			
Mel vim	*Melaleuca viminea*	Mohan			
Par lop	*Paraserianthes lophantha*	Albizia			
Pte esc	*Pteridium esculentum*	Bracken fern			
Sal bla	*Salicornia blackiana*	Samphire			
Sal qui	*Salicornia quinqueflora*	Beaded glasswort			
Sho tab	*Schoenoplectus tabernaemontani*	Lake club rush			
Tax lin	*Taxandria linearifolia*	Agonis sp			
Tec hal	*Tecticornia halocnemoides*	Shrubby samphire			
Tec lep	*Tecticornia lepidosperma*	Samphire			
Tec per	*Tecticornia pergranulata*	Samphire			
Typ dom	*Typha domingensis*	Typha			
Vim jun	*Viminaria juncea*	Swishbush			
Xan pre	*Xanthorrhoea preissii*	Balga			

Appendix 4 - Weed species sighted

			Section of brook		
Abbreviation	**Scientific name**	**Common name**	**North**	**Central**	**South**
Aga ame	*Agave americana*	Century plant			
Air sp	*Aira* sp.	Hairgrasses			
Arc cal	*Arctotheca calendula*	Cape weed			
Aru don	*Arundo donax*	Giant reed			
Atr pro?	*Atriplex prostrata,* ID uncertain				
Ave bar	*Avena barbata*	Bearded oat			
Ave fat	*Avena fatua*	Wild oat			
Bam vul?	*Bambusa vulgaris,* ID uncertain	Common bamboo			
Bou sp	*Bougainvillea* sp.	Bougainvillea			
Bra tou	*Brassica tournefortii*	Wild turnip			
Bri max	*Briza maxima*	Blowfly grass			
Bri min	*Briza minor*	Shivery grass			
Bro dia	*Bromus diandrus*	Great brome			
Bro hor	*Bromus hordeaceus*	Soft brome			
Cal sp	*Callistemon* sp.	Eastern states bottlebrush			
Car edu	*Carduus pycnocephalus*	Slender thistle			
Car sp	*Carpobrotus edulis*	Pigface			
Cen cla	*Cenchrus clandestinus*	Kikuyu			
Cen lon	*Cenhrus longisetus;* ID uncertain	Feathertop			
Che mac	*Chenopodium macrospermum*	Goosefoot			
Cit lim	*Citrus limon*	Lemon tree			
Con sp	*Conyza sp*	Fleabane			
Cor sel	*Cortaderia selloana*	Pampas grass			
Cot sp	*Cotula* sp.	Cotula			
Cyn dac	*Cynodon dactylon*	Couch			
Cyp sp	*Cyperus* sp.	Nutgrass			
Ech pla	*Echium plantagineum*	Paterson's curse			
Ehr cal	*Ehrharta calycina*	Perennial veldt grass			
Ehr sp	*Ehrharta* sp.	Veldt grass species			
Era cur	*Eragrostis curvula*	African lovegrass			
Euc sp	*Eucalyptus* sp.	Eastern state eucalypt (eg spotted gum)			
Eup hel	*Euphorbia helioscopia*	Sun spurge			
Eup ter	*Euphorbia terracina*	Geraldton carnation weed			
Fic car	*Ficus carica*	Fig			
Fum cap	*Fumaria capreolata*	Fumaria (White fumitory)			
Gla sp	*Gladiolus* sp.	Gladiolus			

			Section of brook		
Abbreviation	**Scientific name**	**Common name**	**North**	**Central**	**South**
Gom fru	*Gomphocarpus fruticosus*	Cotton bush			
Hol lan	*Holcus lanatus*	Yorkshire fog			
Hyd ran	*Hydrocotyle ranunculoides,* ID uncertain	Hydrocotyl			
Hyp sp	*Hypochaeris* sp.	Cats ear or flatweed			
Ipo car	*Ipomoea cairica*	Coast morning glory			
Iso pro	*Isolepis prolifera*	Budding club-rush			
Ixi pan	*Ixia paniculata*				
Jun mic	*Juncus microcephalus*				
Lac ser	*Lactuca serriola*	Prickly lettuce			
Lan cam	*Lantana camara*	Lantana			
Lol rig	*Lolium rigidum*	Annual ryegrass			
Lol sp	*Lolium* sp.	Ryegrass			
Lot ang	*Lotus angustissimus*	Slender birdsfoot trefoil			
Lot uli	*Lotus uliginosus*	Greater birdsfoot trefoil			
Lup cos	*Lupinus cosentinii*	Western Australian blue lupin			
Lys arv	*Lysimachia arvensis*	Scarlet or blue pimpernel			
Mel qui	*Melaleuca quinquenervia*	Broad-leaved paperbark			
Mor min	*Moraea miniata*	Two-leaf cape tulip			
Oen mol	*Oenothera mollisima*	Evening primrose			
Ole eur	*Olea europaea*	Olive			
Oro min	*Orobanche minor*	Lesser broomrape			
Oxa pur	*Oxalis purpurea*	Four o'clock			
Pas dil	*Paspalum dilatatum*	Paspalum			
Pas sp	*Paspalum* sp.	Paspalum species			
Pas urv	*Paspalum urvillei*	Vasey grass			
Pel cap	*Pelargonium capitatum*	Rose pelargonium			
Pen sp	*Pennisetum* sp.				
Per sp	*Persicaria* sp.	Knotweed			
Per sp	*Persicaria* sp.	narrow leaf persicaria impersonator			
Pha par	*Phalaris paradoxa*	Paradoxa grass			
Pha sp	*Phalaris* sp.	Canary grass			
Pho dac	*Phoenix dactylifera*	Date palm			
Pla lan	*Plantago lanceolata*	Ribwort plantain			
Pla maj	*Plantago major*	Great plantain			
Poa ann	*Poa annua*	Winter grass			
Pol mar	*Polypogon maritimus*	Coastal barbgrass			
Pru arm	*Prunus armeniaca*	Apricot tree			
Pru dul	*Prunus dulcis*	Almond tree			
Que sp	*Quercus* sp.	Oak tree			

			Section of brook		
Abbreviation	**Scientific name**	**Common name**	**North**	**Central**	**South**
Rap rap	*Raphanus raphanistrum*	Wild radish			
Ric com	*Ricinus communis*	Castor oil			
Rom ros	*Romulea rosea*	Guildford grass			
Ror aqu	*Rorippa nasturtium-aquaticum*	Watercress			
Ros DP	*Rosa Dorothy Perkins*	Dorothy Perkins rose			
Rub sp.	*Rubus* sp.	Blackberry			
Rum cri	*Rumex crispus*	Curled dock			
Rum sp	*Rumex* sp.	Dock			
Sal bab	*Salix babylonica*	Weeping willow			
Sch ter	*Schinus terebinthifolius*	Japanese pepper			
Sol nig	*Solanum nigrum*	Black berry nightshade			
Sol sol	*Soleirolia soleirolii*	Baby's tears			
Son asp	*Sonchus asper*	Prickly sowthistle			
Son ole	*Sonchus oleraceus*	Sowthistle			
Son sp	*Sonchus* sp.	Thistle			
Ste sec	*Stenotaphrum secundatum*	Buffalo			
Tri ang	*Trifolium angustifolium*	Narrowleaf clover			
Tri arv	*Trifolium arvense*	Hare's foot clover			
Typ ori	*Typha orientalis*	Bulrush			
Typ sp	*Typha* sp.*	Typha*			
Urs ant	*Ursinia anthemoides*	Ursinia			
Vic sat	*Vicia sativa*	Common vetch			
Was fil	*Washingtonia filifera*	Cotton palm			
Wat sp	*Watsonia* sp.	Watsonia			
Zan aet	*Zantedeschia aethiopica*	Arum lily			

**Typha domingensis* and *Typha orientalis* are considered native to WA, however, they may act as environmental weeds.

Appendix 5 - Suggested revegetation species

Species are based on Apace WA's (2017) Revegetation Catalogues for vegetation complexes and are available as tubestock. Other native species identified in this assessment may be used for revegetation if available and of a local provenance.

Although the species along waterways passing through the Southern River Complex and the Guildford Complex are very similar, the important difference is the presence of clay and waterlogging in winter. The soil type results in slightly different species in the higher areas, many species the same along the low-lying waterways, and significantly different species in the clay winter water-logged areas.

Therefore it is important to differentiate between the soil types where the areas of winter water logging occur prior to choosing species for planting. This can be done via a field test to check if a 'sausage' forms when the soil is dampened or breaks up due to a high sand content.

Soil type/ vegetation complex	Scientific name	Common name	Growth habit	Height	Area to plant	Season to plant
Guildford	*Acacia dentifera*		Shrub	1-3m	Upper bank or transition	Autumn
Guildford/Southern	*Acacia incurva*		Shrub	0.2-0.5m	Upper bank or transition. Winter wet. Sand and clay	Autumn
Guildford/Southern	*Acacia pulchella*	Prickly Moses	Shrub	1-2m	Upper bank or transition	Autumn
Guildford/Southern	*Acacia saligna*	Coojong	Shrub or small tree	2-6m	Upper bank or transition	Autumn
Guildford/Southern	*Anigozanthus viridis*	Green Kangaroo Paw	Herbaceous perennial	0.5m	Transition zone. Winter wet. Sand, loam & clay	Autumn
Southern	*Aotus procumbens*		Shrub	0.5m	Upper bank or transition. Winter wet areas. Sand	Autumn
Guildford/Southern	*Astartea scoparia*		Shrub	1-2m	Upper bank or transition.	Autumn

Soil type/ vegetation complex	Scientific name	Common name	Growth habit	Height	Area to plant	Season to plant
Southern	*Banksia littoralis*	Swamp Banksia	Tree	9-10m	Upper bank or transition. Winter wet. Sand.	Autumn
Southern	*Banksia telmatiaea*	Swamp Fox Banksia	Shrub	1.5-2m	Upper bank or transition. Winter wet, sand and sandy clay.	Autumn
Guildford/Southern	*Baumea juncea*	Bare Twig Sedge	Sedge	1-1.2m	Lower bank	Spring and summer or winter in seasonally wet areas
Southern	*Beaufortia elegans*	Elegant Beaufortia	Shrub	0.8-1m	Transition zone. Winter wet. Sand	Autumn
Guildford/Southern	*Bolboschoenus caldwelii*	Marsh Club-rush	Sedge	0.8-1.2m	Lower bank	Spring and summer or winter in seasonally wet areas
Guildford/Southern	*Burchardia congesta*	Milkmaids	Herbaceous perennial	0.3-0.5m	Transition zone	Autumn
Guildford/Southern	*Burchardia multiflora*	Dwarf Burchardia	Herbaceous perennial	0.1-0.3m	Transition zone	Autumn
Guildford/Southern	*Callitris pyramidalis*	Swamp Cypress	Tree	2.5-3.5m	Upper bank or transition	Autumn
Guildford/Southern	*Calothamnus hirsutus*	Hawkeswood	Shrub	0.3-1.5m	Upper bank or transition. Also winter wet. Sand and clay.	Autumn
Guildford/Southern	*Calothamnus lateralis*		Shrub	0.4-1.5m	Upper bank or transition. Winter wet. Sand and clay.	Autumn
Guildford/ Southern	*Calothamnus quadrifidus*	One-sided Bottlebrush	Shrub	1-2m	Upper bank or transition	Autumn

Soil type/ vegetation complex	Scientific name	Common name	Growth habit	Height	Area to plant	Season to plant
Guildford/Southern	*Calothamnus sanguineus*	Silky Leaved Blood Flower	Shrub	1.2-1.5m	Upper bank or transition	Autumn
Guildford/Southern	*Casuarina obesa*	Salt/Swamp Sheoak	Tree	8-10m	Upper bank or transition	Autumn
Guildford/Southern	*Centella asiatica*	Centella	Herb	0.2-0.3m	Lower bank to mid bank	Autumn
Guildford	*Chorizandra enodis*	Black Bristle-rush	Sedge	0.8-1m	Lower bank. Swamps and seeps. Clayey sand and clay	Spring and summer or winter in seasonally wet areas
Guildford/Southern	*Conostylis aculeata*	Prickly Conostylis	Grass	0.4m	Upper bank. Winter wet. Sand and clay.	Autumn
Southern	*Conostylis candicans*	Grey Cottonheads	Grass	0.3-0.4m	Upper bank or transition. Sand or sandy loam	Autumn
Guildford/Southern	*Corymbia calophylla*	Marri	Tree	10-20m	Upper bank or transition	Autumn
Guildford/Southern	*Cycnogeton huegelii*	Water Ribbons	Herb	0.3-2m	In stream	Spring and summer or winter in seasonally wet areas
Guildford/Southern	*Dampiera trigona*	Angled Stem Dampiera	Herb	0.3-0.5m	Upper bank or transition. Winter wet. Sand and clay.	Autumn
Guildford/Southern	*Dianella revoluta*	Flax Lily, Blueberry Lily	Herb	0.5m	Upper bank or transition	Autumn
Guildford/Southern	*Dielsia stenostachya*		Herb	0.3-0.6m	Transition zone. Winter wet. Sand and clay.	Autumn
Guildford/Southern	*Eleocharis acuta*	Common Spike-rush	Sedge	0.5-0.7m	Lower bank. Swamps and clay pans.	Spring and summer or winter in seasonally wet areas

Soil type/ vegetation complex	Scientific name	Common name	Growth habit	Height	Area to plant	Season to plant
Guildford/Southern	*Eucalyptus lane-poolei*	Salmon Gum	Tree	12-15m	Upper bank or transition	Autumn
Guildford/Southern	*Eucalyptus marginata*	Jarrah	Tree	10-46m	Upper bank or transition	Autumn
Guildford/Southern	*Eucalyptus rudis*	Flooded Gum	Tree	5-25m	Upper bank or transition	Autumn
Southern	*Euchilopsis linearis*	Swamp Pea	Shrub	0.1-1.2m	Upper bank or transition. Swampy places. Sand	Autumn
Guildford/Southern	*Ficinia nodosa*	Knotted Club Rush	Sedge	0.4-1m	Lower bank	Spring and summer or winter in seasonally wet areas
Southern	*Goodenia filiformis*	Slender Goodenia	Herbaceous perennial	0.4m	Upper bank or transition. Winter wet. Sandy	Autumn
Guildford/Southern	*Haemodorum spicatum*	Mardja	Herb	0.3-2m	Transition zone	Autumn
Southern	*Hakea ceratophylla*	Horned Leaf Hakea	Shrub	0.5-2m	Upper bank. Winter wet. Sand and loam	Autumn
Southern	*Hakea prostrata*	Harsh Hakea	Shrub	0.3-5m	Upper bank or transition. Sand and loam.	Autumn
Guildford/Southern	*Hakea ruscifolia*	Candle Hakea	Shrub	0.5-3m	Upper bank or transition	Autumn
Guildford/Southern	*Hakea varia*	Variable Leaved Hakea	Shrub	0.5-3m	Upper bank or transition. Winter wet. Sand and clay	Autumn
Guildford/Southern	*Hypocalymma angustifolium*	White Myrtle	Shrub	1m	Transition zone.	Autumn

Soil type/ vegetation complex	Scientific name	Common name	Growth habit	Height	Area to plant	Season to plant
Guildford/Southern	*Isolepis cernua*	Nodding Club-rush	Sedge	0.2-0.6m	Lower bank. Winter wet. Sand and clay loam.	Spring and summer or winter in seasonally wet areas
Southern	*Jacksonia furcellata*	Grey Stinkwood	Shrub	3-4m	Upper bank or transition	Autumn
Southern	*Jacksonia sternbergiana*	Green Stinkwood	Shrub	3-4m	Upper bank or transition	Autumn
Guildford/Southern	*Juncus kraussii*	Sea Rush	Herb	0.3-1.2m	Transition zone	Autumn
Guildford/Southern	*Juncus pallidus*	Giant Rush	Herb	0.5-2m	Lower bank	Spring and summer or winter in seasonally wet areas
Guildford	*Juncus subsecundus*	Finger Rush	Herb	0.3-1m	Transition zone. Clay	Autumn
Guildford/Southern	*Kunzea glabrescens*	Spear Wood	Shrub	1.5-4m	Transition zone	Autumn
Guildford/Southern	*Kunzea recurva*	Mountain Kunzea	Shrub	0.3-2m	Upper bank or transition. Winter wet. Sand and clay	Autumn
Guildford	*Leptocarpus coangustatus*	Velvet Rush	Herb	0.5-1.2m	Lower bank	Spring and summer or winter in seasonally wet areas
Guildford	*Leptocarpus scariosa*	Velvet Rush	Herb	0.6-1.5m	Lower bank	Spring and summer or winter in seasonally wet areas
Southern	*Lobelia anceps*	Angled Lobelia	Herb	0.1-0.5m	Lower bank to mid bank	Autumn
Guildford/Southern	*Melaleuca lateritia*	Robin Redbreast Bush	Shrub	0.5-2m	Upper bank or transition. Winter wet. Sandy clay and clay	Autumn
Southern	*Melaleuca preissiana*	Modong	Tree	8-10m	Transition zone. Sandy	Autumn

Soil type/ vegetation complex	Scientific name	Common name	Growth habit	Height	Area to plant	Season to plant
Southern	*Melaleuca radula*	Graceful Honeymyrtle	Shrub	0.3-2.5m	Transition zone. Sandy	Autumn
Guildford/Southern	*Melaleuca rhaphiophylla*	Swamp Paperbark	Tree	7-9m	Upper bank or transition. Sand and clay	Autumn
Guildford/Southern	*Melaleuca scabra*	Rough Honeymyrtle	Shrub	0.5-1m	Transition zone	Autumn
Guildford/Southern	*Melaleuca seriata*		Shrub	0.2-1m	Upper bank or transition. Winter wet. Sand and clay	Autumn
Southern	*Melaleuca systena*	Coastal Honeymyrtle	Shrub	0.5-2m	Transition zone	Autumn
Guildford/Southern	*Melaleuca teretifolia*	Banbar	Shrub	1.5-5m	Upper bank or transition. Winter wet. Sand and clay.	Autumn
Southern	*Melaleuca thymoides*		Shrub	0.4-2m	Upper bank or transition. Winter wet. Sand	Autumn
Guildford/Southern	*Melaleuca uncinata*	Broom Honeymyrtle	Shrub or small tree	3-5m	Upper bank or transition. Winter wet. Sand and clay.	Autumn
Guildford/Southern	*Melaleuca viminea*	Mohan	Shrub	4-5m	Upper bank or transition	Autumn
Southern	*Ornduffia albiflora*		Herb	1m	Lower bank.	Spring and summer or winter in seasonally wet areas
Guildford/Southern	*Pericalymma ellipticum*	Swamp Tea Tree	Shrub	1m	Upper bank or transition	Autumn
Guildford/Southern	*Philotheca spicata*	Salt and Pepper	Woody Perennial	0.5-0.6m	Transition zone	Autumn

Soil type/ vegetation complex	Scientific name	Common name	Growth habit	Height	Area to plant	Season to plant
Southern	*Regelia ciliata*		Shrub	1.5-2m	Upper bank or transition. Winter wet. Sand.	Autumn
Southern	*Regelia inops*		Shrub	2-2.5m	Upper bank or transition. Winter wet. Sand.	Autumn
Guildford/Southern	*Sphaerolobium medium*	Globe Pea	Shrub	0.4-0.5m	Upper bank or transition	Autumn
Guildford/Southern	*Taxandria linearifolia*	Swamp Peppermint	Shrub	2-4m	Transition zone	Autumn
Guildford/Southern	*Verticordia acerosa*		Shrub	0.4-1m	Upper bank or transition. Clay flats	Autumn
Guildford/Southern	*Verticordia plumosa*	Plumed Feather Flower	Shrub	1.5m	Upper bank or transition. Winter wet. Sand and clay.	Autumn
Guildford/Southern	*Viminaria juncea*	Swish Bush	Shrub	2-5m	Transition zone	Autumn
Southern	*Xanthorrhoea gracilis*	Graceful Grass Tree		1-2m	Upper bank or transition	Autumn
Guildford/Southern	*Xanthorrhoea preissii*	Grass Tree		0.3-3m	Upper bank or transition	Autumn

Appendix 6 – Pen and Scott foreshore condition grading

(Pen and Scott 1995, pp.4-6)

A-Grade

Foreshore has healthy native bush, similar to that which you would see in most nature reserves, state forests and national parks.

A1. Pristine	The river embankments and floodway are entirely vegetated with native species and there is no evidence of human presence or livestock damage.
A2. Near pristine	Native vegetation dominates. Some introduced weeds may be present in the understorey but not to the extent that they displace native species. Otherwise there is no evidence of human impact.
A3. Slightly disturbed	Native vegetation dominates, but there are some areas of human disturbance where soil may be exposed and weeds are relatively dense (such as along tracks). The native vegetation would quickly recolonise if human disturbance declined.

B-Grade

The bush along the stream has been invaded by weeds, mainly grasses, and looks like typical roadside bush.

B1. Degraded – weed infested	Weeds have become a significant component of the understorey vegetation. Although native species are dominant, a few have been replaced by weeds.
B2. Degraded - heavily weed infested	In the understorey, weeds are about as abundant as native species. The regeneration of some tree and large shrub species may have declined or disappeared altogether.
B3. Degraded – weed dominated	Weeds dominate the understorey, but many native species remain. Some trees and large shrub species may have declined or disappeared altogether.

C-Grade

The foreshore supports only trees over weeds or pasture, or just plain pasture, and bank erosion and subsidence may be occurring but only in a few spots.

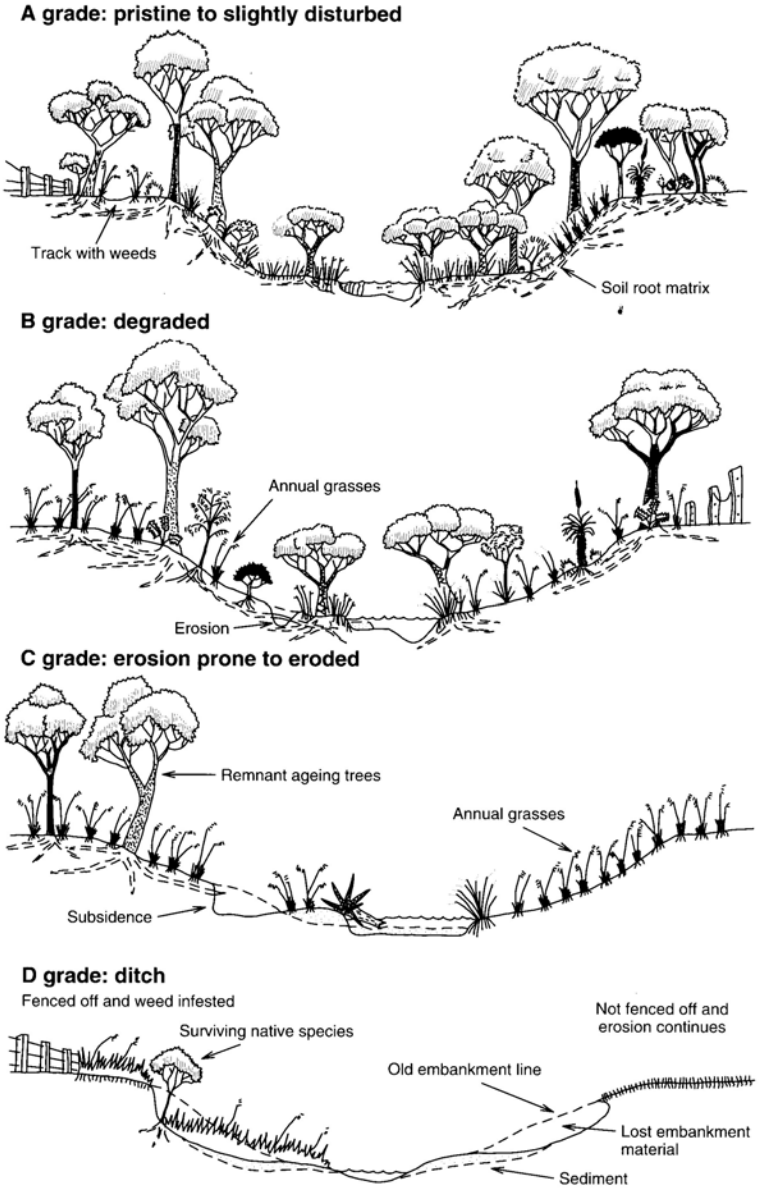
C1. Erosion prone	Trees remain, and possibly some large shrubs or grasses, but the understorey consists entirely of weeds, mainly annual grasses. The trees are generally resilient or long-lived species but there is little or no evidence of regeneration. The shallow-rooted weedy understorey provides no support to the soil, and only a small increase in physical disturbance will expose the soil and make the river embankments and floodway vulnerable to erosion.
C2. Soil exposed	Older trees remain, but the ground is virtually bare. Annual grasses and other weeds have been removed by livestock trampling or grazing, or through over use by humans. Low-level soil erosion has begun, by the action of either wind or water.

C3. Eroded	Soil is washed away from between tree roots, trees are being undermined and unsupported embankments are subsiding into the river valley.

D-Grade

The stream is little more than an eroding ditch or a weed infested drain.

D1. Ditch - eroding	There is not enough fringing vegetation to control erosion. Some trees and shrubs remain and act to retard erosion in certain spots, but are doomed to be undermined eventually.
D2. Ditch – freely eroding	No significant fringing vegetation remains and erosion is completely out of control. Undermined and subsided embankments are common, and large sediment plumes are visible along the river channel.
D3. Drain – weed dominated	The highly eroded river valley has been fenced off, preventing control of weeds by stock. Perennial weeds have become established. The river has become a simple drain, similar or identical to a typical major urban drain.



Appendix 7 - Data dictionary for field attributes in shapefile Bennett_Brook_Segments

Attribute	Description
OBJECTID *	Automatically generated unique identifier (within shapefile)
Shape *	Automatically generated geometric coordinates (within shapefile)
Date	Date the segment was assessed
Field Officer	Initials of the field officers who assessed the segment
River	Name of tributary being assessed
Summary comment	Additional observations related to the segment not included elsewhere
MANAGEMENT ISSUES: Dominant weed species	Weed species; a complete list of all weeds sighted on the segment
Dominant Native Species	Dominant native species; a list of the dominant native species from any stratum noted in the segment
MANAGEMENT ISSUES: Erosion and Siltation (L)	Erosion and siltation, Left Bank; whether erosion and siltation pose a management issue
MANAGEMENT ISSUES: Erosion and Siltation (R)	Erosion and siltation, Right Bank; whether erosion and siltation pose a management issue
MANAGEMENT ISSUES - EROSION: Undermining	Erosion, Undermining; whether undermining is present
MANAGEMENT ISSUES - EROSION: Large deposits	Erosion, Large deposits; whether large deposits are present
MANAGEMENT ISSUES - EROSION: Incised scour	Erosion, Incised scour; whether incised scours are present
MANAGEMENT ISSUES - EROSION: Slumped bank	Erosion, Slumped bank; whether slumped banks are present
MANAGEMENT ISSUES - EROSION: Embayment retreat	Erosion, Embayment retreat; whether embayment retreat is present
MANAGEMENT ISSUES - EROSION: Exposed tree roots	Erosion, Exposed tree roots; whether exposed tree/shrub roots are present
MANAGEMENT ISSUES - VEG LOSS: Trampling	Vegetation loss, Trampling; whether there is loss of native riparian vegetation through trampling by humans or livestock
MANAGEMENT ISSUES - VEG LOSS: Grazing	Vegetation loss, Grazing; whether there is loss of native riparian vegetation through grazing, including evident historic grazing (note in Mgt Issues Comment that it is historic)
MANAGEMENT ISSUES - VEG LOSS: Displacement by weeds	Vegetation loss, Displacement by weeds; whether there is loss of native vegetation through displacement by weeds
MANAGEMENT ISSUES - VEG LOSS: Clearing	Vegetation loss, Clearing; whether there is loss of native vegetation through clearing, including evident historic clearing (note in Mgt Issues Comment that it is historic)
MANAGEMENT ISSUES - VEG LOSS: Erosion	Vegetation loss, Erosion; whether there is loss of native vegetation through erosion, including evident historic erosion (note in Mgt Issues Comment that it is historic)

MANAGEMENT ISSUES - ACCESS: Vehicles	Access, Vehicles; indicates access by vehicles
MANAGEMENT ISSUES - ACCESS: People	Access, People; indicates access by people off marked trails
MANAGEMENT ISSUES - ACCESS: Stock	Access, Stock; indicates access by stock
MANAGEMENT ISSUES - ACCESS: Other (L)	Access, Other, Left Bank; indicates access by something else to the left bank
MANAGEMENT ISSUES - ACCESS: Other (R)	Access, Other, Right Bank; indicates access by something else to the right bank
MANAGEMENT ISSUES: Comment	Management Issues Comment; any additional information to record on any of the above
Slope of bank (L)	Slope of bank, Left Bank; the average bank slope in three categories: gentle, medium or steep
Slope of bank (R)	Slope of bank, Right Bank; the average bank slope in three categories: gentle, medium or steep
Height of bank (L)	Height of bank, Left Bank; The average height of the bank in metres, from water level to the top of the immediate bank
Height of bank (R)	Height of bank, Right Bank; The average height of the bank in metres, from water level to the top of the immediate bank
Fencing	Fencing; whether fencing is present along the riparian zone preventing access by humans or livestock
LAND USE: Agriculture	Agriculture; whether the land surrounding the segment is used for agriculture
LAND USE: Parkland	Parkland; whether the land surrounding the segment is used for parkland
LAND USE: Rural	Rural; whether the land surrounding the segment is used for rural purposes
LAND USE: Residential	Residential; whether the land surrounding the segment is used for residential purposes
LAND USE: Commercial / industrial	Commercial/ industrial; whether the land surrounding the segment is used for commercial/ industrial purposes
LAND USE: Rem Bush / Reserve	Remnant bushland/ reserve; whether the land surrounding the segment is used for remnant bushland/ reserve
LAND USE: Recreation	Recreation; whether the land surrounding the segment is used for recreation, ie walking/running trails or exercise infrastructure is in place
CONDITION: Vegetation (L)	Vegetation, Left Bank; Vegetation condition (ie % cover of natives compared to weeds, native regeneration, crown death etc)
CONDITION: Vegetation (R)	Vegetation, Right Bank; Vegetation condition (ie % cover of natives compared to weeds, native regeneration, crown death etc)
CONDITION: Weed cover (L)	Weed cover, Left Bank; weed cover (ie no or low weed % cover=Minimal to weed dominated=Extensive)
CONDITION: Weed cover (R)	Weed cover, Right Bank; weed cover (ie no or low weed % cover=Minimal to weed dominated=Extensive)

CONDITION: Bank stability / erosion (L)	Bank stability, erosion, Left Bank; the stability of the bank (this may not be visible if veg cover is very high & in many cases stability will then be good)
CONDITION: Bank stability / erosion (R)	Bank stability, erosion, Right Bank; the stability of the bank (this may not be visible if veg cover is very high & in many cases stability will then be good)
CONDITION: Pressures (L)	Pressures, Left Bank; Level of pressure (such as pressure from adjacent land uses, dams, weed infestations, uncontrolled stock or human access etc) on a segment
CONDITION: Pressures (R)	Pressures, Right Bank; Level of pressure (such as pressure from adjacent land uses, dams, weed infestations, uncontrolled stock or human access etc) on a segment
Trajectory (L)	Trajectory, Left Bank; whether a segment is stable/ improving or deteriorating in condition based on the current level of management
Trajectory (R)	Trajectory, Right Bank; whether a segment is stable/ improving or deteriorating in condition based on the current level of management
+VE TRAJECTORY: Weed management	Positive trajectory: Weed management; whether weed management is evident and contributing to an improvement in condition
+VE TRAJECTORY: Revegetation	Positive trajectory: Revegetation; whether revegetation is evident and contributing to an improvement in condition
+VE TRAJECTORY: Native species regeneration	Positive trajectory: Native species regeneration; whether regeneration is evident and contributing to an improvement in condition
+VE TRAJECTORY: Controlled access	Positive trajectory: Controlled access; whether access by vehicles, people or stock is controlled and contributing to an improvement in condition
+VE TRAJECTORY: Riffles	Positive trajectory: Riffles; whether riffles have been installed or are naturally occuring and contributing to an improvement in condition
-VE TRAJECTORY: Exotic species regeneration	Negative trajectory: Exotic species regeneration; whether regeneration is evident and and contributing to a decline in condition
-VE TRAJECTORY: Active erosion	Negative trajectory: Active erosion; whether erosion is evident and and contributing to a decline in condition
-VE TRAJECTORY: Loss of native vegetation	Negative trajectory: Loss of native vegetation; whether loss of vegetation is evident and and contributing to a decline in condition
Hope (L)	Hope, Left Bank; whether a segment can improve on its own or if it needs human intervention
Hope (R)	Hope, Right Bank; whether a segment can improve on its own or if it needs human intervention
Ease of Rehab (L)	Rehab, Left Bank; whether a segment would be easy (little work required, low cost) or difficult

	(large amount of ongoing work required, high cost) to rehabilitate
Ease of Rehab (R)	Rehab, Right Bank; whether a segment would be easy (little work required, low cost) or difficult (large amount of ongoing work required, high cost) to rehabilitate
REHAB EASE FACTOR: Access	Access; an attribute which tells us if we think the segment would be easy to rehabilitate, based on accessibility of the segment (eg vegetation density, steepness of slope, private land etc) (value in attribute table=easy; no value=hard)
REHAB EASE FACTOR: Condition of native vegetation	Condition of native vegetation; an attribute which tells us if we think the segment would be easy to rehabilitate, based on condition of native vegetation (eg healthy with potentially high regeneration or sickly with poor potential for native regeneration) (value in attribute table=easy; no value=hard)
REHAB EASE FACTOR: Weed prevalence	Weed prevalence; an attribute which tells us if we think the segment would be easy to rehabilitate, based on weed prevalence (eg few weeds would make rehabilitation easier and many weeds would make it difficult to rehabilitate) (value in attribute table=easy; no value=hard)
REHAB - FENCING: Construct a fence	Fencing, Construct a fence; whether a fence needs to be constructed
REHAB - FENCING: Repair an existing fence	Fencing, Repair an existing fence; whether an existing fence needs repair
REHAB - FENCING: Replace an existing fence	Fencing, Replace an existing fence; whether an existing fence needs to be replaced
REHAB - WEEDS: Identify species	Weeds, Identify species; whether weeds need to be identified
REHAB - WEEDS: Chemical Treatment?	Weeds, Chemical treatment; whether weeds require treatment (herbicide application)
REHAB - WEEDS: Mechanical Removal?	Weeds, Mechanical removal; whether weeds require mechanical removal (plant taken away)
REHAB: Species for replanting (L)	Species for replanting, Left Bank; whether planting is required and a list of suggested species
REHAB: Species for replanting (R)	Species for replanting, Right Bank; whether planting is required and a list of suggested species
REHAB: Erosion control	Erosion control; whether erosion control treatments need to be installed
REHAB - STORMWATER: Silt management required	Stormwater; Silt management required; whether silt management is required. This was only filled out if high levels of sedimentation were evident
REHAB - STORMWATER: Water quality management required	Stormwater; Water quality management required; whether water quality management is required. This was only filled out if water quality was poor by a visual assessment, eg it was a strange colour, smelt badly, high levels of algae were present
REHAB: Comment	Rehab Comment; if any other rehabilitation techniques are required, record what they are in this comment field

Survey Method	Survey method; whether the complete length of the segment could be accessed and assessed, or if viewing from access points only was possible
Survey Quality	Survey quality; whether the segment could be assessed with adequate viewing, or if some or much extrapolation was needed and some features of the segment may not have been sighted and recorded
Pen & Scott Rating (L)	Pen & Scott grading, LB; condition grading using the Pen & Scott method from A1 (pristine) to D3 (ditch)
Pen & Scott Rating (R)	Pen & Scott grading, RB; condition grading using the Pen & Scott method from A1 (pristine) to D3 (ditch)
Category (L)	Category, LB; the Rutherfurd matrix priority categories, ranging from protecting and conserving the good areas to improving the average to poor condition areas
Category (R)	Category, RB; the Rutherfurd matrix priority categories, ranging from protecting and conserving the good areas to improving the average to poor condition areas
GlobalID *	Automatically generated unique identifier (within Collector for ArcGIS)
LAT_START	Latitude of segment startpoint
LONG_START	Longitude of segment startpoint
LAT_END	Latitude of segment endpoint
LONG_END	Longitude of segment endpoint
SEGMENT	Sequential numbering of the segments from Mundaring Weir downstream to the Swan River
VegDescription	Vegetation description; structural description and including dominant species in the over, mid and understorey
RiverSection	The brook has been divided into three sections for ease of reporting: headwaters to Marshall Road (North); Marshall Road to Benara Road (Central), and Benara Road to the confluence with the Swan River (South)
Shape *	Automatically generated geometric coordinates (within shapefile)
LOCALISED_PRESSURES	Determined in the office, in the same way that the Pressures field had been completed in the 2007 assessment, considering erosion and siltation, vegetation loss and access issues that were recorded for the segment
COMPARATIVE_BANK_STABILITY	Determined in the office, in the same way that the Bank Stability field had been completed in the 2007 assessment, considering Vegetation Condition and Vegetation Loss through Trampling
COMPARATIVE_TRAJECTORY	Determined in the office, in the same way that the Trajectory field had been completed in the 2007 assessment, considering Comparative Bank Stability; Vegetation Condition and Localised Pressures

COMPARATIVE_HOPE	Determined in the office, in the same way that the Hope field had been completed in the 2007 assessment, considering Vegetation Condition, Comparative Bank Stability and Localised Pressures
COMPARATIVE_EASE	Determined in the office, in the same way that the Ease of Rehab field had been completed in the 2007 assessment, considering Vegetation Condition, Comparative Bank Stability and Localised Pressures
COMPARATIVE_CATEGORY	The Rutherfurd matrix priority categories, determined in the same way that it had been in the 2007 assessment
Shape_Length	Length of the segment in metres

Appendix 8 - Parameters used for the categorisation of river segments

Rarity or conservation value

Conservation value was determined from the desktop assessment and the proximity of segments to recognised natural and cultural assets.

Condition

The Pen and Scott grades were summarised into an overall good, average or poor condition rating for each segment for the purpose of categorisation.

- Good – A1, A2, A3
- Average – B1, B2, B3, C1 or C2
- Poor – C3, D1, D2 or D3

Trajectory and Hope

The trajectory of each segment was determined in the field.

- A segment was considered stable/improving if it was actively managed or there were few signs of pressures and threats, and vegetation was in a relatively undisturbed state.
- A segment was determined to be deteriorating if active erosion was present, no active management was occurring, or active management was not successful, vegetation condition was average to poor and exotic species regeneration was characteristic of the segment.

Deteriorating segments were prioritised above those which were stable/improving as it is considered more efficient to stabilise deteriorating segments, rather than remediating them later (Rutherfurd et al. 2000b).

Segments in poor condition were divided into those **without hope**, segments which would not recover without intervention; and those **with hope**, improving reaches which may eventually recover naturally (Rutherfurd et al. 2000b). Segments without hope are given slightly higher priority than those with hope, as the latter have a smaller chance of recovering independently over time.

Proximity to good segments

Rutherfurd et al. (2000b) explain it is more effective to expand an area which is already in good condition or being rehabilitated, rather than work on an isolated stretch adjacent to segments in poor condition. This increases the length of the stream community and provides a source of flora and fauna to colonise the newly rehabilitated reach.

In order of priority, Rutherfurd et al. (2000b) recommend working on:

1. Segments with a mix of high-quality assets and some degraded assets;
2. Poor quality segments that link two segments in good condition;

3. Poor quality segments connected by one end to a segment in good condition, then
4. Poor quality segments that are distant from good quality segments.

After the overall condition rating was applied, location of segments in relation to condition were identified using GIS, then ranked based on their proximity to good condition segments.

Ease of rehabilitation

Ease of rehabilitation was determined in the field.

- Segments that were deemed ‘easy’ to rehabilitate were those that were in good condition, with a good vegetation structure and complexity remaining, where weeds were not dominant, and where all that may be needed is short-term weed control and infill planting.
- Segments that were deemed ‘hard’ to rehabilitate were those where native vegetation structure and complexity was largely lost, and which had extensive weed cover, or where erosion was occurring at multiple points along the reach. Rehabilitation required would be wide scale and need to occur over many years to make a long-lasting impact.

Segments were assigned a category value from 0 to 8. Several modifications were made to the process that had been carried out by the Swan River Trust in 2008:

- the buffer width for conservation value was increased from 20m to 500m;
- national parks were not included in the criteria for conservation value, as it is not relevant to Bennett Brook and to be consistent with the 2017 categorisation of the Helena River;
- Environmentally Sensitive Areas were added to the criteria for conservation value;
- the level of pressure was determined in the field and included landscape disturbances such as adjacent intensive land uses, dams and modifications to the river alignment, not only the erosion, grazing and trampling issues noted in the segment;
- bank stability was considered independently of weed coverage (e.g. if no or little erosion was sighted and the banks appeared stable, despite the understorey being weedy, stability was considered ‘good’), rather than using the vegetation condition score and presence or absence of vegetation trampling; and
- trajectory, hope and ease of rehabilitation were determined in the field rather than a combination of bank stability, vegetation condition and pressure scores.

Appendix 9 - Matrix for the categorisation of river segments

Adapted from Cooperative Research Centre (CRC) for Catchment Hydrology (Rutherfurd et al. 2000)

ID segments with high conservation value assets	Pen & Scott = A1 Pressures = Minimal No threats or ideas for management	Intersection with known values Pen & Scott = A1, A2,or A3	Pen & Scott = A1, A2,or A3									
Sort according to condition	Good (Pen & Scott = A1, A2 or A3)			Average (Pen & Scott = B1, B2, B3, C1 or C2)						Poor (Pen & Scott = C3, D1, D2 or D3)			
Sort according to trajectory				(Trajectory = Deteriorating)		(Trajectory = Stable – Improving)				(Hope = Without hope)		(Hope = With hope)	
Sort according to proximity to good segments				(Close) Adjacent segment P&S =A1,A2,A3	(Distant) Adjacent segment P&S ≠A1,A2,A3	(Close) Adjacent segment P&S =A1,A2,A3		(Distant) Adjacent segment P&S ≠A1,A2,A3		(Close) Adjacent segment P&S =A1,A2,A3	(Distant) Adjacent segment P&S ≠A1,A2,A3	(Close) Adjacent segment P&S =A1,A2,A3	(Distant) Adjacent segment P&S ≠A1,A2,A3
Sort according to ease				(Easy)	(Hard)	(Easy)	(Hard)	(Easy)	(Hard)	(Easy)	(Hard)	(Easy)	(Hard)
Priority category	**0**	**1**	**2**	**3**		**4**	**5**	**6**		**7**		**8**	
	Segments in good condition throughout, that are already protected	Protect regional conservation value segments	Protect local conservation value segments	Protect and improve deteriorating segments		Expand good segments	Improve impeded recovery segments (easily fixed segments)	Improve moderately damaged segments (more difficult to fix)		Improve poor segments		Improve poor segments with hope	

Appendix 10 - Ratings for individual parameters of foreshore condition used by Water and Rivers Commission (1999)

	Blue – Excellent 8 points	Green – Good 6 points	Yellow – Moderate 4 points	Red – Poor 2 points	Black - Very poor 0 points
Bank stability	No erosion, slumping or sediment deposits; dense native vegetation cover on banks and verge; no evidence of disturbance or areas of exposed soil.	No significant erosion, slumping or sediment deposits in floodway or on lower banks; good native vegetation cover; only isolated areas of exposed soil or thinning vegetation.	Some localised erosion, slumping and sediment deposits; native vegetation cover on verges may be patchy and interspersed with patches of exposed soil.	Extensive active erosion, slumping and sediment deposition particularly during peak flows; bare banks and verges common.	Almost continuous erosion; over 50% of banks slumping; sediment heaps line or fill much of the floodway; little or no vegetation cover.
Foreshore vegetation	Healthy, undisturbed native vegetation with structure intact and verges more than 20m wide; no weed or signs of disturbance evident.	Vegetation structure dominated by native plants that comprise 80–100% of the total number of species; only scattered weeds or rarely evident in small clusters; nil or minor signs of disturbance (i.e. tracks, rubbish dumping).	Some changes in vegetation structure, native plants comprising 50-80% of the total species composition; little regeneration of trees and shrubs; weeds occurring occasionally; moderate levels of disturbance.	Modified vegetation structure with native plants comprising only 20-50% of the total species composition. Trees remain with only scattered shrubs and an understorey dominated by weeds; high prevalence of disturbance.	Insufficient vegetation to control erosion; natural vegetation structure absent with occasional native trees and shrubs comprising less than 20% of the total species composition; weeds abundant; very high prevalence of disturbance and extensive areas of exposed soil.
Stream cover	Abundant stream cover from dense overhanging vegetation providing	Abundant shade from overhanging vegetation; occasional instream cover from	Scattered fringing vegetation with occasional patches of shade; infrequent	Stream channel mainly clear; fringing vegetation almost absent providing very	Zero or minimal stream cover with no permanently shaded

	almost continuous shade; frequent instream cover from aquatic vegetation and/or leaf litter; rocks or logs.	patches of aquatic vegetation and isolated heaps of leaf litter or rocks and logs.	instream cover with little aquatic vegetation, very infrequent rocks and logs.	little permanent shade; instream cover almost absent with generally no instream vegetation and very infrequent rocks and logs.	areas and no instream cover.
Habitat diversity	Excellent water quality with permanent water (i.e. pools and creeks); three or more aquatic and terrestrial habitats including diverse vegetation types, edge waters, instream cascades, riffles, pools and woody debris.	Good water quality and some permanent water; at least three aquatic habitat types; at least one habitat type for terrestrial invertebrates; at least one habitat type for each terrestrial vertebrate category (frogs, reptiles and birds).	No apparent problems with water quality (i.e. muddy or cloudy in winter); at least two aquatic habitat types; at least one habitat type for terrestrial invertebrates; at least one habitat type for any two of the terrestrial vertebrate categories.	Possible seasonal problems with water quality and no permanent water; at least one aquatic habitat type; at least one habitat type for terrestrial invertebrates; at least one habitat type for one of the terrestrial vertebrates.	Poor water quality; almost no healthy habitats available for aquatic and terrestrial organisms.

Sum of individual parameter ratings to give an overall stream condition index (Water and Rivers Commission 1999)

Colour code	Parameter rating	Description
Blue (32 points)	Excellent	All parameters blue
Green (22-30 points)	Good	Three to four parameters rated green or better with only one parameter rated yellow; no red or black ratings
Yellow (14-20 points)	Moderate	Three parameters rated yellow or better with no more than one red; no black
Red (6-12 points)	Poor	Two or three parameters rated red with no more than one black
Black (0-4 points)	Very poor	Two or more parameters rated black

Appendix 11 - Known project sites along Bennett Brook

Projects are listed in order from the headwaters downstream to the confluence with the Swan River*.

Site name	Funding source and year funded	Brief project description
North section		
Central section		
Marshall Rd	**SALP:** 2014, 2012, 2008-2000 **Whiteman Park:** 2014, 2013 **Caring for our Country:** 2016-2014 **Volunteer contributions:** 2010, 2008	Control of *Juncus microcephala*, arum lily, *Typha*, blackberry, Japanese peppers, fumaria, Geraldton carnation weed and other weeds Planting dryland and wetland seedlings Direct seeding Translocation of sedges and rushes from an area of Whiteman Park proposed for clearing
Bandicoot Creek	**SALP:** 2018, 2017, 2014, 2013 **DBCA:** 2016 **Caring for our Country:** 2015, 2014	Control of blackberry, *Typha*, watercress, arum lily, Geraldton carnation weed, Japanese peppers and other weeds Installing a dryland buffer and planting wetland seedlings
Bandicoot Corridor	**SALP:** 2018, 2017, 2013-2010, 2008 **Whiteman Park:** 2015, 2014 **Caring for our Country:** 2016-2014 **Landcare Australia:** 2007, 2006 **Volunteer contributions:** 2009	Control of weedy grasses, blackberry, arum lily, figs and other broadleaf weeds Planting dryland and wetland seedlings
Bandicoot East	**Community Rivercare Program**: 2018/19-2020/21	Restoring riparian vegetation along a 300m length of Bennett Brook
Tuart Site	**SALP:** 2016, 2014, 2012 **Whiteman Park:** 2015-2013	Control of veldt grass, broadleaf weeds and other grass weeds Planting dryland seedlings

Site name	Funding source and year funded	Brief project description
	Caring for our Country: 2015 **Spicer's Paper:** 2013, 2011 **State NRM:** 2011 **Synergy:** 2008, 2007 **Volunteer contributions:** 2009	
Gardenvale Complex	**SALP:** 2018, 2017, 2014-1999 **Whiteman Park:** 2015-2013 **Caring for our Country:** 2016, 2015 **Volunteer contributions:** 2009, 2008 **Fishcare Grant:** 2003, 2002	Control of blackberry, arum lily, *Juncus microcephala,* fumaria, watercress, figs, Japanese pepper and other broadleaf and weedy grasses Planting dryland and wetland seedlings
Coonawarra Gully	**SALP:** 2018, 2017, 2013 **Caring for our Country:** 2016-2014	Control of grasses and other weeds Planting dryland and wetland seedlings
Lord St Bushland	**SALP:** 2012, 2008-2002 **Whiteman Park:** 2016-2012 **Swan River Trust:** 2011, 2010 **State NRM:** 2011, 2010 **State Revegetation Scheme:** 2001	Control of veldt grass, love grass, fumaria and other broadleaf weeds Planting dryland and wetland seedlings Direct seeding
St Elias	**SALP:** 2018-2016, 2014 **Caring for our Country:** 2015, 2014 **Spicer's Paper:** 2013 **Weeds of National Significance:** 2012, 2011	Control of blackberry, arum lily, *Typha*, figs, fumaria and other woody weeds and grasses Planting dryland and wetland seedlings Planting rescued wetland plants (Friends of Bennett Brook Reserve)
Simla Wetland	**SALP:** 2018-2013 **Caring for our Country:** 2015, 2014 **Spicer's Paper:** 2013 **Weeds of National Significance:** 2012, 2011	Control of blackberry, *Melaleuca quinquinerva*, arum lily, *Typha*, figs, Japanese peppers, fumaria and other woody and grass weeds

Site name	Funding source and year funded	Brief project description
		Planting dryland and wetland seedlings
Simla Dryland	**SALP:** 2018-2016 **Whiteman Park:** 2016 **Landcare Australia:** 2006 **Swann Insurance:** 2005, 2004	Control of veldt grass Planting dryland seedlings
Olympic Site	**SALP:** 2008-2005, 2003, 2002 **Whiteman Park:** 2016-2012	Control of blackberry, arum lily, black flag, Japanese pepper, tagasaste, *Melaleuca quinquinerva* and other weeds Creation of a mowing strip Planting dryland and wetland seedlings
BBEC Block	**SALP:** 2005-1999	Control of arum lily, veldt grass and other broadleaf weeds Planting dryland and wetland seedlings Direct seeding
Bennett Brook Pond and Peripheral Vegetation	**SALP:** 2011, 2008-2004 **Whiteman Park:** 2016-2012 **Volunteer contributions:** 2008	Control of arum lily, *Typha*, willows, black flag, blackberry, fumaria and other weeds Planting dryland and wetland seedlings Maintaining a firebreak through veldt grass control
Wonga Confluence	**SALP:** 2017, 2013-2011, 2008-2001 **Caring for our Country:** 2016-2014 **Water Corporation and Western Power:** 2000	Removal of silt blocking the brook at Malaga drain (Water Corp and Western Power) Control of willows, arum lily, *Typha*, blackberry, Japanese peppers, fumaria and other weeds Planting dryland and wetland seedlings
Wonga Way	**SALP:** 2017, 2014-2011, 2007-2005 **Whiteman Park:** 2015-2013	Control of arum lily, *Typha*, *Isolepis prolifera*, blackberry, *Acacia longifolia*, *Melaleuca quinquinerva*, black flag and other weeds

Site name	Funding source and year funded	Brief project description
	Caring for our Country: 2016-2014 **Volunteer contributions:** 2009, 2008 **Water Corporation:** 2004	Consolidated rock riffle to encourage oxygenation of the water and reduce erosion of the Altone Park drain
Benara Road	**SALP:** 2018-2012, 2010, 2008-2005 **Whiteman Park:** 2015, 2013, 2012 **Caring for our Country:** 2015, 2014 **NHT Envirofund:** 2004 **Volunteer contributions:** 2008	Control of arum lily, bamboo, Chilean willows, willows, Japanese pepper, *Typha*, blackberry, morning glory, figs, black flag and other weeds Planting dryland and wetland seedlings Extending the site towards adjacent sites
South section		
Clarry Small Park	**SALP:** 2016, 2014-2011, 2008-1999 **City of Swan:** 2005 **Volunteer contributions:** 2010, 2008 **Ministry for Planning:** 1998	Control of *Watsonia*, castor oil, Chilean willows, arum lily, *Juncus microcephala*, *Typha*, willows, Japanese pepper, blackberry, Planting dryland and wetland seedlings Recreation of a watercourse leading from a seep, and erosion control works Installation of kerbing to separate turfed area from reveg site
Clarry Small East Dryland	**SALP:** 2016 **Whiteman Park:** 2016	Control of veldt grass and black flag Planting dryland seedlings

*SALP funding grants are current to 31 December 2018; grants from other funding sources are current to 30 June 2016.

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