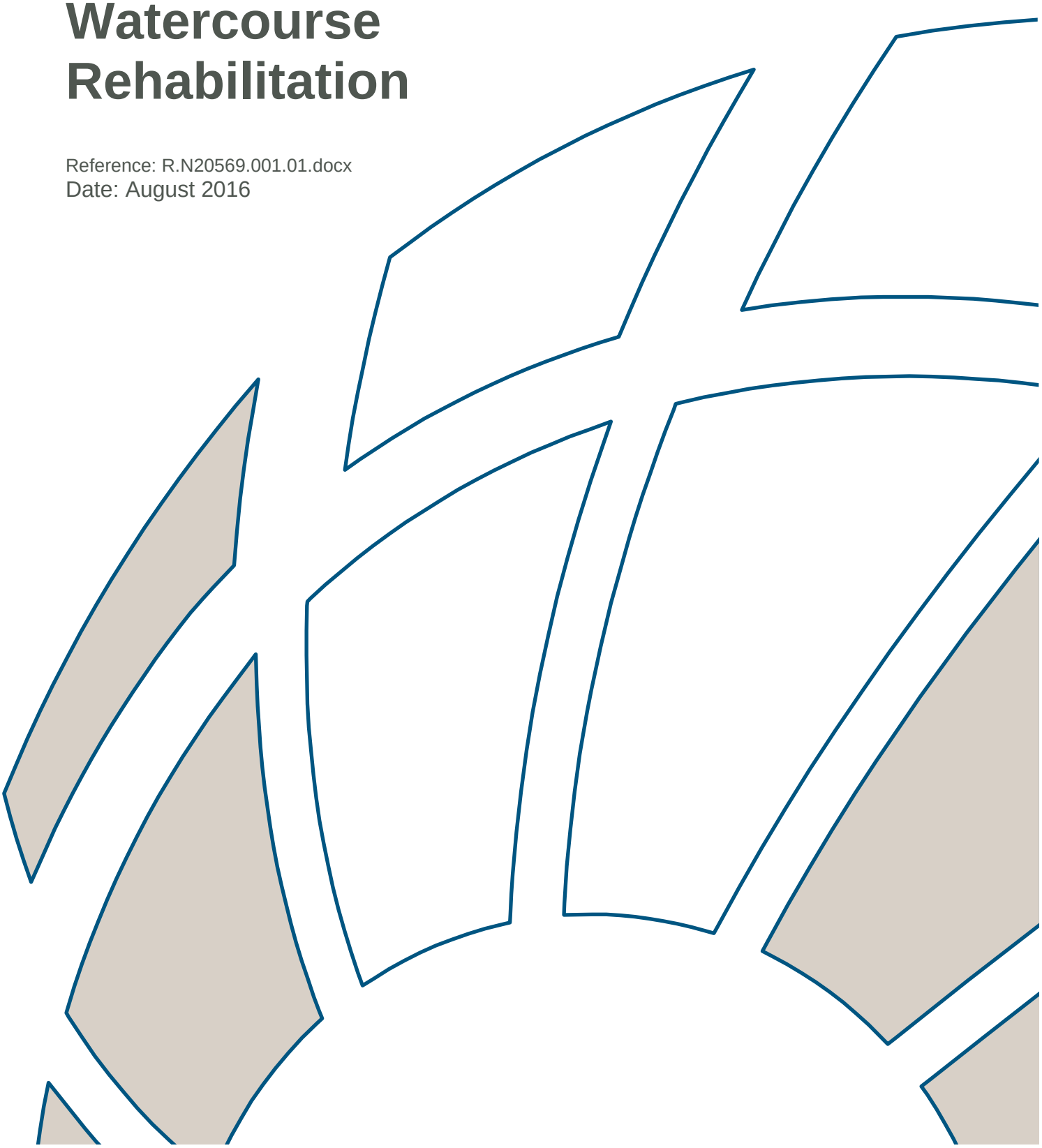
BMT WBM

Town Creek Flooding and Watercourse Rehabilitation

Reference: R.N20569.001.01.docx
Date: August 2016



Town Creek Flooding and Watercourse Rehabilitation

Prepared for:	Great Lakes Council
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies)

Offices

Brisbane
Denver
London
Mackay
Melbourne
Newcastle
Perth
Sydney
Vancouver

Document Control Sheet

BMT WBM Pty Ltd
126 Belford Street
Broadmeadow NSW 2292
Australia
PO Box 266
Broadmeadow NSW 2292

Tel: +61 2 4940 8882
Fax: +61 2 4940 8887

ABN 54 010 830 421

www.bmtwbm.com.au

Document:	R.N20569.001.01.docx
Title:	Town Creek Flooding and Watercourse Rehabilitation
Project Manager:	Luke Kidd
Author:	Luke Kidd
Client:	Great Lakes Council
Client Contact:	Geoff Love
Client Reference:	

Synopsis: **This document provides a summary of the preliminary flooding, geomorphology and ecology investigations completed to progress development of a concept rehabilitation plan for Town Creek, Nabiac.**

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
0 1	10 Aug 2016 24 Aug 2016	L. Kidd		L. Kidd	

DISTRIBUTION

Destination	Revision										
	0	1	2	3	4	5	6	7	8	9	10
Great Lakes Council BMT WBM File BMT WBM Library	1 1	1 1									

Contents

List of Figures

List of Tables

1 Introduction

1.1 Site Locality

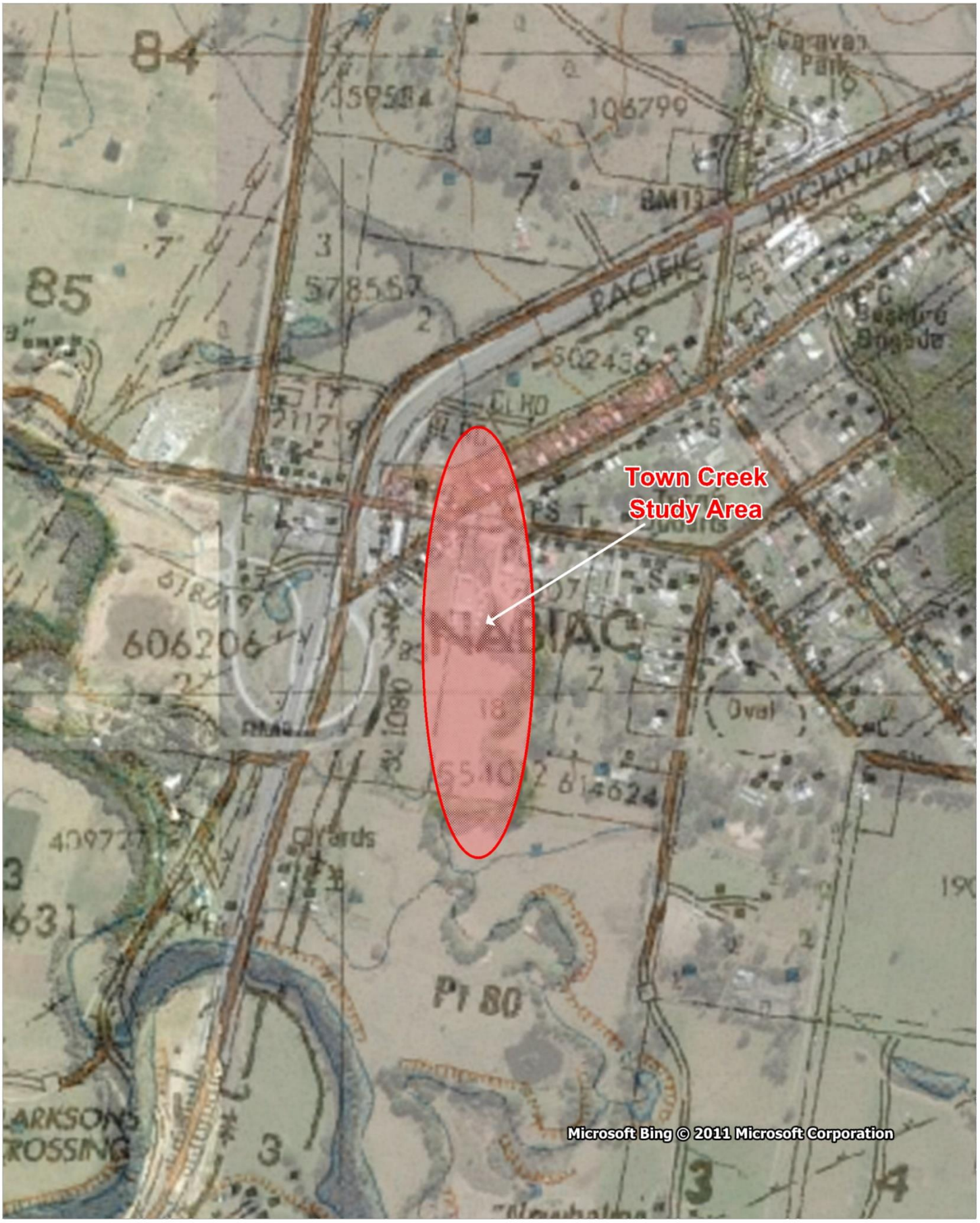
Nabiac is located within the central part of the Mid Coast Council LGA, on the Pacific Highway some 320 km north of Sydney. A key urban watercourse draining through Nabiac business area is Town Creek. Town Creek has been identified in the Nabiac Floodplain Risk Management Study (WMAwater, 2015) for rehabilitation to improve flood conveyance, remove weeds and restore riparian vegetation. A locality map showing the general location of Town Creek and the surrounding landscape is shown in Figure 1-1.

Town Creek drains a relatively small catchment with varied land use in the surrounding areas. Multiple roads cross above the creek, with water being diverted through culverts. The most significant road crossing the creek is the Pacific Highway. Nabiac Street and Clarkson Street cross the creek in the town whilst Candormakh Creek Road crosses the creek upstream. Upstream, the land is either cleared vegetation or agricultural land with residential land use occurring further downstream in the town of Nabiac. Downstream from Nabiac, the creek runs through more agricultural or cleared land before reaching a small dam. The creek then continues through cleared land before flowing into the Wallamba River (ECA, 2016).

1.2 Site Conditions

An overview of site conditions as they relate to the proposed creek rehabilitation is provided by ECA (2016). The catchment is largely cleared and contains rural residential and agricultural land uses with some remnant bushland located within the riparian zone and adjacent floodplain areas. The flow regime of the creek is likely to be significantly altered due to increased stormwater runoff as a result of increased impervious surfaces in the area surrounding the creek. The conversion of vegetated areas into roads, residential areas and cleared areas for agriculture would all contribute to a reduction in the infiltration ability of stormwater, causing increased flows in the creek. Increased stream flow has the added disadvantage of facilitating the transport of increased nutrients and sediment from agricultural and residential land and other impurities such as oils and heavy metals from roads and residential areas.

These factors generally result in an overall reduction in water quality, placing pressure on aquatic and terrestrial habitats. The combination of cleared riparian vegetation from the heavy agriculture of past decades, increased nutrients and altered flow regimes appear to be impacting the available habitat of the creek. These factors would be a contributor to the high proportion of invasive plant species in the riparian zone in terrestrial areas whilst algal blooms and associated eutrophication would be promoted in the aquatic areas. All of these conditions area factors for biodiversity decline and may promote aesthetically unsightly areas.



Title:
Site Locality Map

Figure: **1-1**

Rev: **B**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 125 250m
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20569_Town_Creek_Rehabilitation\MI\WS

1.3 About this Report

This document outlines a summary of the preliminary flooding, geomorphology and ecology investigations completed to progress development of a rehabilitation plan for Town Creek, Nabiac. Initial consultation was carried out with Nabiac community representatives during a site meeting to document their desired outcomes for the project.

Section 1 introduces the study site.

Section 2 provides a summary of flood modelling undertaken to inform development of the concept plan.

Section 3 outlines geomorphic design concepts, design objectives and criteria, and the existing geomorphic behaviour of Town Creek.

Section 4 provides a summary of key elements of the ecology investigation including vegetation management and planting recommendations.

Section 5 presents the objectives of the rehabilitation concept plan and constraints and opportunities identified for the study site.

Section 6 contains a list of references used during the study.

This document should be read in conjunction with the ecology report prepared by Ecology Consultants Australia (ECA) (2016) which provides further advice and recommendations in relation to rehabilitation of Town Creek (see Appendix A).

2 Flooding and Stormwater

2.1 Local Flooding

2.1.1 Candoormakh Creek

A preliminary review of existing data indicated the potential for interaction between flows within Candoormakh Creek and the Town Creek floodplain upstream of the Pacific Highway. Review of aerial imagery and LiDAR data suggests that there is a 'pinch point' in Candoormakh Creek immediately downstream of the confluence of Candoormakh Creek and Nabiac Creek. At this location, LiDAR data indicates that above bankfull flow events would spill over the eastern bank.

An example cross section through Candoormakh Creek is shown in Figure 2-1. This typical section was derived from LiDAR data and is viewed looking upstream with the Town Creek floodplain shown on the right hand side of the figure. The section indicates that Candoormakh Creek is perched above the adjacent floodplain, and that flows exceeding the bank full capacity of the creek would spill into the Town Creek floodplain and flow towards Nabiac.

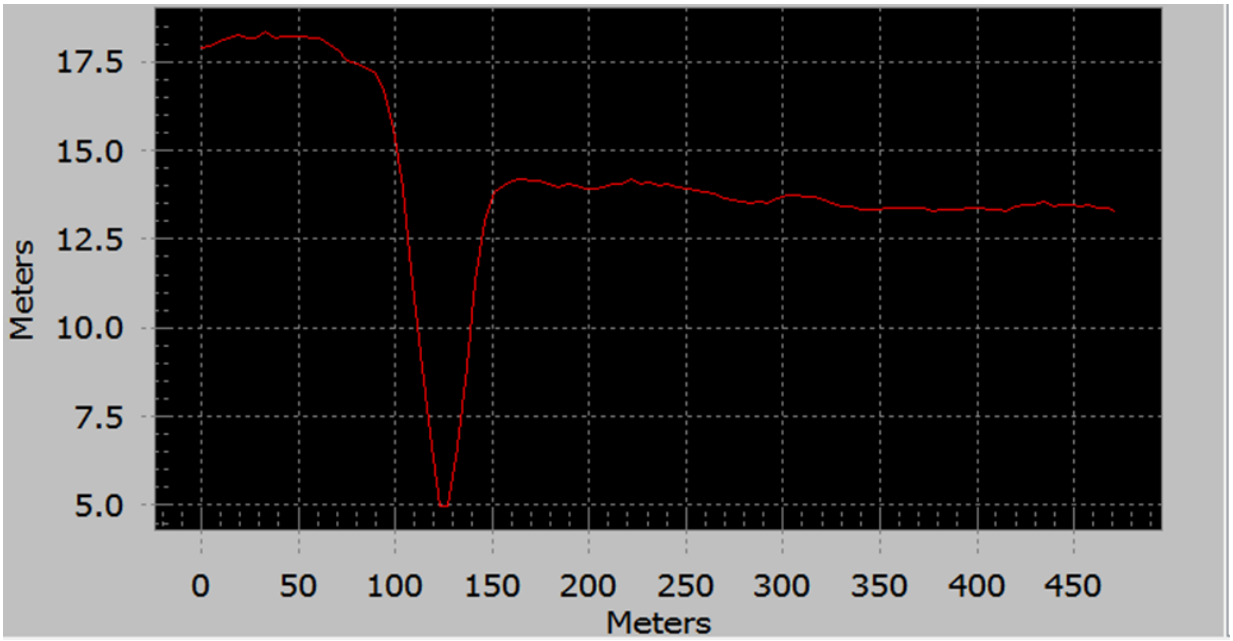


Figure 2-1 Typical Section of Candoormakh Creek

BMT WBM completed preliminary hydraulic modelling of Candoormakh Creek upstream of the Pacific Highway based on available LiDAR data using the 1-dimension hydraulic model HEC-RAS. Model runs were completed for a range of event magnitudes (1% AEP, 0.5% AEP, 0.2% AEP and PMF). Although further investigation is considered to be warranted, the preliminary results indicate that the existing Candoormakh Creek channel downstream of the confluence would have sufficient capacity for the 1% AEP.

The preliminary modelling also indicated that the eastern channel bank of Candoormakh Creek would be breached for an event somewhere between the 1% and PMF, with flow then directed into

the Town Creek floodplain and through to Nabiac. We understand that interaction between the Candoormakh Creek catchment and Town Creek catchment during these higher magnitude storm events may not have been considered previously. It is recommended that further consideration of this flooding behaviour be investigated as a component of a broader floodplain risk management study. This is considered important as the PMF flow contribution from Candoormakh Creek into the Town Creek catchment and through Nabiac may potentially significantly dwarf the local Town Creek catchment contribution and be the dominant flooding mechanism for consideration of defining flooding hazard in Nabiac.

This suggests that any option to divert part of the local catchment back to Candoormakh Creek near the recent highway overpass construction works should also consider the potential for much higher overbank flows from the main Candoormakh Creek and Nabiac Creek tributaries to mitigate flood hazards in the Nabiac Town Centre during the PMF and other large flooding events.

2.1.2 Town Creek

2.1.2.1 Hydrology

Peak discharges were estimated for the Town Creek catchment for the 3-month, 1-year, 2-year and 100-year Average Recurrence Interval (ARI) events for input to the concept design for Town Creek.

Flooding hydrology for Town Creek was previously modelled as a component of the Nabiac Flood Study (Cardno Lawson and Treloar (CLT), 2010). The Town Creek local catchment modelled by CLT included two sub-catchments, TOWN 1 and TOWN 2. The TOWN 1 sub-catchment includes land on the upstream side of the Pacific Highway. CLT estimated that the existing TOWN 1 catchment area is 130.4 ha. It was identified by CLT that construction works associated with formation of the off-ramp from the Pacific Highway have resulted in the local catchment area to Town Creek increasing due to re-direction of some of the catchment. Floodplain management measures are currently being planned to divert part of the TOWN 1 catchment away from Nabiac town centre back to Candoormakh Creek.

Council has confirmed that the reduced TOWN 1 catchment should be considered for the purpose of preparing concept designs for the rehabilitation of Town Creek through Nabiac (pers. comm., Geoff Love). After partial diversion of the TOWN 1 sub-catchment, the area of this catchment would be reduced from 130.4 ha to 51.2 ha (approximately 60% reduction). In addition to the TOWN 1 sub-catchment, an additional TOWN 2 sub-catchment would contribute to flow in Town Creek. The TOWN 2 sub-catchment is located downstream of the Pacific Highway and includes some of the urban areas in Nabiac. The TOWN 2 sub-catchment has an estimated area of 30.6 ha. Therefore, the total catchment draining to the Clarkson Street culvert on Town Creek is estimated to be approximately 81.8 ha.

BMT WBM prepared an RAFTS-XP model of the two study catchments to estimate 3-month, 1-year, 2-year and 100-year ARI peak flows. The model was prepared adopting similar model parameters at CLT, 2010. BMT WBM estimated that the 100-year ARI discharge along Town Creek would be approximately 11.1m^3/s. This is approximately 15% higher than the equivalent peak discharge of 9.6 m^3/s estimated by CLT (2010) as shown in Table 2-1. The ratio of the BMT WBM modelled 3-month ARI, 1-year ARI and 2-year ARI flow estimates to the BMT WBM modelled 100-

year ARI estimate was applied to scale the CLT (2010) Town Creek 100-year ARI flow to estimate discharges for the 2 year, 1 year and 3 month ARI events. The scaled CLT (2010) flows were utilised as inputs to the preliminary hydraulic model of Town Creek.

Table 2-1 Town Creek – Design Flow Estimates (m^3/s)

ARI (years)	BMT WBM (2016)	CLT (2010)
100	11.1	9.6
2	3.5	2.9
1	2.0	1.7
0.25	1.0	0.9

2.1.3 Hydraulics

The focus of the study is to improve conveyance along Town Creek in the study area with a goal to reduce flood levels/extents for the 100-year ARI flood event whilst providing opportunities to enhance the ecological function of the existing creek. Preliminary hydraulic modelling was completed to estimate potential reductions in flood levels that could be achieved along Town Creek through implementation of a range of management options. The options investigated are summarised below in Table 2-2.

Table 2-2 Model Scenarios

Model Scenario	Description
Option 0	Existing situation.
Option 1	Clearing of invasive plants, aquatic weeds/typha and accumulated sediment. Replace with species that would lower the hydraulic roughness along the full extents of the study area.
Option 2	Option 1 including increasing the Town Creek channel conveyance in the vicinity of the Nabiac Road footbridge. This would include steepening and rock lining the channel banks, and regrading the channel bed immediately upstream and downstream of the bridge. Note: separate investigations are being completed by Council to evaluate the structural integrity of the existing bridge.
Option 3	Option 2 including regrading and widening of the Town Creek channel from downstream of the Pacific Highway culvert to upstream of the Clarkson Street culvert.
Option 4	Option 3 including widening the Town Creek channel to form benches downstream of the footbridge. This option is unlikely to improve flooding conditions significantly due to the downstream Ferris Place culvert being the main hydraulic control for flooding in this section of the creek. The benches would potentially improve access to the creek, improve habitat and provide good views from the rear of the Village Café.

2.1.3.1 Model configuration

Flooding behaviour was modelled using the HEC-RAS one-dimensional hydraulic model. A model representing the existing creek condition was established and used in steady state mode to estimate backwater profiles corresponding to peak flows estimated for design rainfall events for the study catchment. A 500 metre reach of Town Creek downstream of the Pacific Highway was defined. Model creek cross sections were developed from survey data provided by Council. A schematic plan of the HEC-RAS model layout is shown in Figure 2-2.

Figure 2-2 Schematic Plan of HEC-RAS Model

Channel and floodplain roughness values were selected based on site observations and professional experience in similar creek systems. The hydraulic model was configured using constant Manning's *n* roughness values ranging between of 0.060 and 0.160. Manning's *n* values were adjusted to reflect existing (and proposed) creek vegetation roughness within the major segments of Town Creek as summarised below in Table 2-3.

Table 2-3 Adopted Manning's *n* Roughness Values

Creek Segment	River Station	Option 0	Option 1 to 4
D	22	0.060	0.060
	21	0.060	0.060
	20.5	0.060	0.060
	20	0.060	0.060
	19.5 – Culvert		
C	19	0.045	0.080
	18.5	0.045	0.080
	18	0.045	0.080
	17.5 – Bridge		
B	17	0.155	0.080
	16	0.155	0.080
	15.9	0.155	0.080
	15.8	0.155	0.080
	15.5	0.155	0.080
	15	0.155	0.080
	14.5 – Culvert		
A	14.4	0.155	0.155
	14	0.155	0.155
	13	0.155	0.155
	12	0.155	0.155
	11	0.155	0.155
	10	0.155	0.155

Modelled culvert dimensions, inverts and weir levels were adopted from survey data supplied by Council. The Nabiac Road footbridge was modelled based on dimensions and data provided by Council. Default expansion and contraction coefficient values of 0.3 and 0.5 were adopted for cross sections immediately upstream and downstream of these structures. Details of structures modelled are summarised below in Table 2-4.

Table 2-4 Structure Details

Type	Location	Shape	Dimensions	Manning's *n*
Culvert	RS 19.5 Clarkson Street	Box	No. cells = 2 Length = 12 m Span = 2.4 m Rise = 2.1 m	0.012
Culvert	RS 14.5 Ferris Place	Box	No. cells = 2 Length = 6 m Span = 2.4 m Rise = 2.4 m	0.012
Pier	Nabiac Footbridge	Not applicable	Width = 0.1 m	Not applicable

A 100-year ARI upstream flow boundary condition of 9.6 m^3/s, and a downstream fixed water level boundary condition of RL 6.26 m AHD was adopted from the Nabiac Flood Study (CLT, 2010).

2.1.3.2 Model results

Peak Water Level

Estimated 100-year ARI peak water levels are summarised in Table 2-5 (shaded values represent sections where notable reductions in peak water levels are observed). The results indicate that implementation of Options 1 and 2 would have the most significant impact on lowering 100-year ARI peak water levels when compared to the existing scenario.

Table 2-5 Estimated 100 Year ARI Peak Water Levels

Cross Section	Location	Estimated 100 Year ARI Peak Water Levels (m AHD)				
		Option 0	Option 1	Option 2	Option 3	Option 4
XS 22	Upstream	6.99	6.84	6.75	6.75	6.75
XS 21	Upstream Clarkson St	6.97	6.82	6.73	6.72	6.72
XS 20	Clarkson St culvert inlet	6.93	6.78	6.67	6.67	6.67
XS 19	Clarkson St culvert outlet	6.89	6.73	6.63	6.63	6.63
XS 18	Footbridge upstream	6.88	6.67	6.60	6.60	6.60
XS 17	Footbridge downstream	6.69	6.53	6.53	6.53	6.53
XS 16	Downstream footbridge	6.65	6.52	6.52	6.52	6.52
XS 15.9	Council Profile 8	6.56	6.49	6.49	6.49	6.49
XS 15.8	Council Profile 9	6.51	6.48	6.48	6.48	6.48
XS 15	Ferris Pl culvert inlet	6.45	6.45	6.45	6.45	6.45
XS 14.4	Ferris Pl culvert outlet	6.41	6.41	6.41	6.41	6.41
XS 13	Downstream Ferris Pl	6.39	6.39	6.39	6.39	6.39
XS 12	Downstream Ferris Pl	6.33	6.33	6.33	6.33	6.33
XS 11	Downstream Ferris Pl	6.29	6.29	6.29	6.29	6.29
XS 10	Downstream section	6.26	6.26	6.26	6.26	6.26

Peak backwater profiles modelled for Option 0 and Option 4 are shown in Figure 2-3. The results show a reduction in peak water levels for the 100-year ARI of approximately 0.25 metres upstream of the Nabiac footbridge and Clarkson Street culvert for Option 4 when compared to the existing situation (Option 0). The reduction to peak flood levels between the Ferris Place culvert and Nabiac footbridge are notably less (typically less than 0.07 metres). Downstream of Ferris Place flood levels are predicted not to change due to the influence of mainstream flooding (tailwater conditions) along Wallamba River.

Peak Velocity

Estimated 100-year ARI peak average channel velocity are summarised in Table 2-6. The results indicate that the average channel velocity ranges between 0.1 m/s (at the downstream section) and 0.8 m/s (near Clarkson Street culvert). The average channel velocity along the upper, middle and lower reaches of Town Creek is approximately 0.6 m/s, 0.5 m/s and 0.4 m/s respectively.

Table 2-6 Estimated 100 Year ARI Peak Velocity

Cross Section	Location	Estimated 100 Year ARI Peak Velocity (m/s)				
		Option 0	Option 1	Option 2	Option 3	Option 4
XS 22	Upstream	0.33	0.37	0.41	0.45	0.42
XS 21	Upstream Clarkson St	0.33	0.37	0.40	0.40	0.36
XS 20	Clarkson St culvert inlet	0.73	0.78	0.81	0.81	0.81
XS 19	Clarkson St culvert outlet	0.73	0.77	0.81	0.81	0.81
XS 18	Footbridge upstream	0.59	0.92	0.75	0.75	0.75
XS 17	Footbridge downstream	0.72	0.83	0.70	0.70	0.70
XS 16	Downstream footbridge	0.34	0.39	0.39	0.39	0.34
XS 15.9	Council Profile 8	0.49	0.51	0.51	0.51	0.49
XS 15.8	Council Profile 9	0.45	0.46	0.46	0.46	0.46
XS 15	Ferris Pl culvert inlet	0.65	0.65	0.65	0.65	0.65
XS 14.4	Ferris Pl culvert outlet	0.65	0.65	0.65	0.65	0.65
XS 13	Downstream Ferris Pl	0.33	0.33	0.33	0.33	0.33
XS 12	Downstream Ferris Pl	0.29	0.29	0.29	0.29	0.25
XS 11	Downstream Ferris Pl	0.22	0.22	0.22	0.22	0.19
XS 10	Downstream section	0.13	0.13	0.13	0.13	0.12

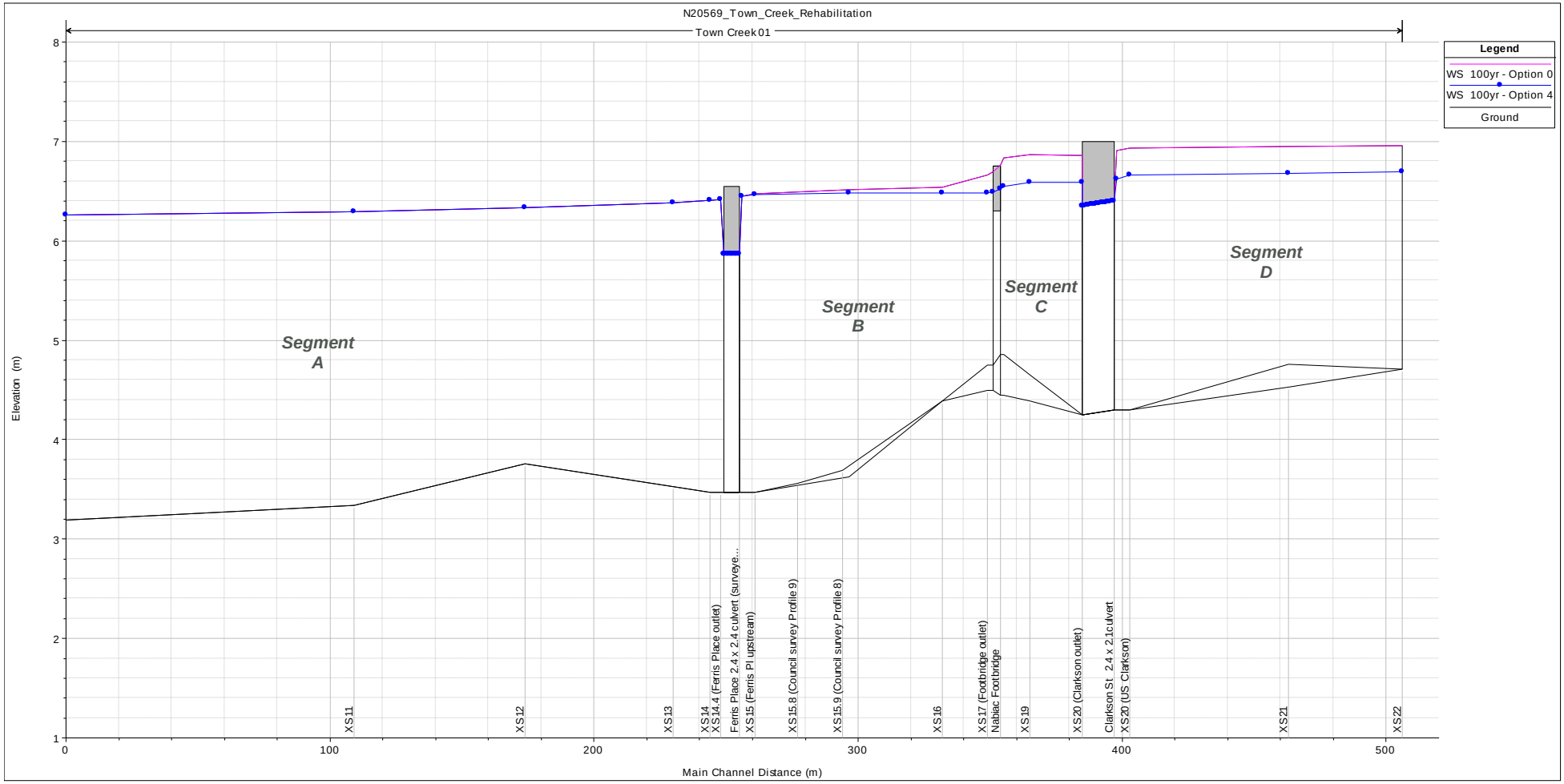


Figure 2-3 Estimated 100-Year ARI Water Level Profiles for Options 0 and 4

Bank Protection and Tractive Stress

Based on the above results, the 100-year ARI average channel velocity in the creek for Option 4 is approximately 0.8 m/s at Clarkson Street culvert and approximately 0.3 m/s downstream of the footbridge, with corresponding peak flow depths of approximately 2.4 metres and 1.3 metres respectively.

At this early stage, the concept plan has identified that creek banks would be rock lined, and based on the drawings, rock sizes of up to 0.4 metres are shown. To inform the suitability of rock sizes adopted by the concept design, an tractive stress rating for the study reach was calculated as 24 N/m^2 assuming a water depth of 2.4 metres and channel slope of 0.001 m/m. Based on ratings presented by Csaller (1984), a bank material type of dense native vegetation would be sufficient for bank stability/protection. It is noted however, that those values should only be used as a guide as other factors such as particle size, soil chemistry, soil density and vegetation can affect stress ratings.

Further consideration using rock protection and bank scour calculations was undertaken to confirm the above assumption. Based on a range of hydraulic conditions anticipated for the rehabilitated study reach (Option 4), the characteristic size of rock (d_{50}) was estimated to be less than 0.1 metres using equations provided by Escarameia and May (1992) and Pilarczyk (1990).

Based on the above, rock protection is unlikely to be required for rehabilitation of the creek from a bank stability / bank erosion perspective. However, it is noted that the design intent of rock lining creek banks would be to provide shelter habitat, introduce aesthetic value and assist with the stability of cleared banks while new vegetation is established.

2.2 Stormwater

The concept includes an end-of-pipe GPT (Net-tech device or similar) to intercept gross pollutants and a proportion of coarser sediment. The GPT would discharge into a raingarden formed off-line (for regular flooding events). The raingarden is proposed on the eastern side of Town Creek just downstream of the stormwater outlet from the Nabiac Street drainage system.

The raingarden size has been maximised to fit the available space. No stormwater quality modelling or conceptual sizing of the proposed treatment measures has been undertaken as part of the study. It is envisaged that the raingarden would perform more as a community education facility on stormwater quality than providing a significant reduction in stormwater pollutant loads discharged to the creek.

2.3 Existing Services

A Dial-Before-You-Dig enquiry was completed by BMT WBM in June, 2016. Data were provided by utilities on the approximate location of telecommunication, water supply, sewerage and electricity assets. The supplied data indicates that infrastructure in primarily confined to public roads within the study area (Clarkson St, Nabiac St and Ferris Pl). Supplied plan data indicates that some water supply infrastructure potentially crosses the creek between Clarkson Street and Nabiac Street.

The provided data suggests that the rehabilitation of Town Creek is unlikely to have significant impacts on existing services, although prior to confirming final channel extents it is recommended that the actual locations of services be confirmed in the field.

3 Geomorphology

3.1 Design Concepts

Restoration of full hydrological and geomorphological functioning (and implicitly, full ecological functioning) of the site is constrained by buildings and infrastructure in close proximity to Town Creek. This means that two natural processes that contribute to ecosystem functioning must be restricted: inundation of floodplain land, and mobility of the channel. While regular inundation of riparian land functions to allow access to those habitats, contributes sediment and nutrients to the riparian zone, and flushes carbon to the channel, in this urban situation, the project aims to reduce the risk of flooding property and damaging infrastructure.

Mobility of the channel refers to regular mobilisation of bed sediments and slow and rapid change of the alignment of the channel. The creek has changed position within the past few hundred years, evidenced by former courses visible on aerial photography and LiDAR-derived elevation data. Under the rehabilitation proposal, the channel position and dimensions (cross-section shape and slope) will be considered fixed within the design flood. This is a necessary limitation imposed by the site conditions, and is normal for an urban stream rehabilitation. Given these two key site constraints, the rehabilitation design can only partly follow guidelines in Rutherfurd et al (2000).

3.2 Objectives and Recommended Design Criteria

From the perspective of fluvial geomorphology, an appropriate design for Town Creek would be to firstly ensure that the channel dimensions, slope and roughness are adequate to convey the design flood. As the main hydraulic constraints on this creek are culverts and a narrow section near the footbridge, there is considerable flexibility in design of the morphology and roughness of the channel along the remainder of the creek's course through the rehabilitation reach. For the majority of the rehabilitation reach, aesthetic, amenity and vegetation will be important design criteria. The comments in this section focus on fluvial geomorphology aspects.

The design objectives are therefore to provide:

- Stable channel bed under design flood conditions;
- Stable channel banks under design flood conditions;
- Variable channel morphology in cross-section and longitudinally; and
- Variable bed and bank surface character (bed materials and size, bank materials, and vegetative cover).

The first two objectives will also ensure a stable channel alignment and stable channel slope under design flood conditions. Recommended geomorphic design criteria for the Town Creek rehabilitation are outlined in Table 3-1.

Table 3-1 Geomorphic Design Criteria for the Town Creek Rehabilitation

Objective	Design criteria
Stable channel bed under design flood conditions	Bed material of a size sufficient to resist shear stress at design flood. Bed material of a mixed grade to enhance stability. Smooth rounded rock shape preferable to blocky rough rock shape.
Stable channel banks under design flood conditions	Banks on outside of bend fortified with rock to top of bank. Otherwise, rock fortification of toe of bank, to level of top of bench. Bank toe at rear of top of bench also fortified with rock. Minimise rock beaching in areas of low shear stress, on inside of bends and on wider cross-sections. In areas without rock beaching, banks should be planted with a type of vegetation that binds the surface and bends under high flow conditions.
Variable channel morphology in cross-section and longitudinally	Variability in the cross-section morphology can be provided by a central low flow channel, to contain the 1 in 1 year event, and a bench at that level, alternating its position along the course of the rehabilitation reach. Benches should be positioned on the inside bend of the general creek alignment. Longitudinal variability in morphology can be provided by varying the slope of the bed, and providing shallow and deeper areas. There is a risk that pools will collect fine sediment, and these could require occasional maintenance.
Variable bed and bank surface character (bed materials and size, bank materials, and vegetative cover)	The rock material used to form the bed of the creek should be mixed in size to increase stability and to enhance heterogeneity of the bed habitat. The same principle applies to the bank material, but this is less critical from a physical habitat perspective. Diverse vegetation will enhance physical habitat heterogeneity of the banks and riparian area.

3.3 Existing Geomorphic Behaviour

The *upper reach* is unnaturally straight and uniform in morphology, and has probably been modified/simplified in the past. This reach has a low slope, which has encouraged deposition of fine sediment, and resultant invasion of macrophytes. Although variable bed morphology would enhance physical habitat, there is a risk that the bed will infill with fine sediment. This reach could require ongoing maintenance to clear sediment and macrophytes.

The *middle reach* has sufficient gradient to create variable hydraulic conditions within the low flow channel. The proposed benches are positioned in a geomorphologically-correct position. The elevation of the top of the benches is not critical and can depend to some extent on vegetation, aesthetic and amenity criteria. However, most benches in natural creeks would be at a level corresponding to somewhere between the 3-month ARI and 2-year ARI flood level.

The *lower reach* has an excavated section that does not present a hazard. There is no need to infill at this location and it could be expected to slowly infill over time through deposition of sediment from the creek. There are no particular geomorphological requirements in this reach.

In some creek rehabilitation designs, the creek bed is formed in cobbles and gravels. This might have been the natural bed material in Town Creek, but it is not likely that the creek will now sustain this bed material distribution for the following reasons. Firstly, there needs to be an ongoing source

of such material, and there is an existing upstream sediment basin that will reduce sediment supply. Also, the bed and banks are to be stabilised through the rehabilitation reach, so they will not be a sediment source. Finally, the shear stresses are high enough that gravels and cobbles would be transported under high flow conditions, and without a sediment supply to replace that material, the bed would revert to the underlying clay material.

4 Ecology

4.1 Overview

Ecology investigations in relation to rehabilitation of Town Creek were undertaken and documented in a separate report prepared by Ecology Consultants Australia (2016). The purpose of that report is to provide advice and recommendations to improve flood conveyance, remove weeds and improve the quality of riparian vegetation.

The study by ECA (2106) provides input to the following matters:

- channel design and structure components to optimise ins-stream habitat opportunities;
- the existing riparian vegetation structure, stage of rehabilitation and definition of a suitable revegetation plan;
- concept drawing suitable for preliminary costing including details of revegetation and water and soil management measures; and
- outcome of consultation with Council Nabiac Village Futures Group and Nabiac Landcare.

The ecology investigations included a review of past studies, Council vegetation mapping and data, searches of Bionet and Atlas of Living Australia, and information gained from community consultation in relation to flora and fauna in the study region. Key elements of the ecology investigation are summarised below in the following sections. Further detail is provided in the full report (see Appendix A).

4.2 Vegetation Management

A summary of the existing condition of Town Creek and recommendations for rehabilitation are provided by ECA (2016). The observations and recommendations are provided for major segments of the creek, as follows:

- **Segment A** – Downstream of Ferris Place culvert (CH0 to CH250);
- **Segment B** – Ferris Place culvert to Nabiac Footbridge (CH250 to CH350);
- **Segment C** – Nabiac Footbridge to Clarkson Street culvert (CH350 to CH380); and
- **Segment D** – Clarkson Street culvert to Highway (CH380 to CH500).

Detail for each creek segment is provided in Section 3.1 of ECA (2016). Overall recommendations for creek rehabilitation are provided in Section 3.2 which is summarised below:

- Vegetation removal should occur gradually, either in 100 m^2 increments or in subdivisions as outlined for each creek segment recommendation;
- Vegetation removal should be accompanied by the creation of temporary habitat in adjacent areas to allow migration of displaced fauna;
- Weed tree species should be cut at the stem and painted with appropriate herbicides, leaving the root system in the banks to maintain bank stability. Completely dead sections of weed tree

wood may be added back to the bank to add course woody debris for bank stability and to provide shelter habitat.

- If areas of bank soil are exposed along the flow path, a jute mat or equivalent could be placed to stabilise loose soils and prevent further erosion until riparian vegetation is re-established. If exposed soils are dispersive, a layer of non-dispersive soil could be placed prior to covering with jute mat or planting.
- Removal of over-shadowing weed canopy may stimulate the proliferation of annuals and grass weeds. Shade cloth may be employed at a height of 2 metres to the reduce weed growth and to allow for the establishment of native canopy species.

4.3 Planting

Section 3.3 of ECA (2016) presents planting schematic and a summary of recommended plantings for terrestrial (creek banks) and wetland (main channel) species. A comprehensive list of recommended plant species is provided in Appendix I of ECA (2016). Planting densities suitable for Town Creek is summarised below in Table 4-1.

Table 4-1 Recommended Planting Densities

Category	Type or Channel Position	Density
Wetland / waterplants	Wet-dry zone / edge of creek banks	4-5 plants/m
	Marsh / instream flowing or still	4-6 plants/m^2
Terrestrial	Grasses	4-6 plants/m^2
	Shrubs	8-12 plants/m^2
	Trees	1tree per 4 or 8 m^2

ECA (2016) provide draft planting plans in Figure 8A to Figure 8C. A summary of general recommendations for planting selection and design considerations for Town Creek include:

- Do not remove vegetation, particularly native, from a site, but add plants where needed;
- Remove weeds only after the establishment of replacement local native species;
- Use only local native plants for revegetation;
- Use layers of vegetation to create a structurally diverse habitat;
- Create a dense understorey of shrubs to provide essential habitat for small birds;
- Create ‘patchiness’ to provide a range of microhabitats; and
- Establish a diversity of species in each layer to increase the resilience of the plant community in the future and increase diversity of foraging opportunities for birds and their food sources.

5 Rehabilitation Concept Plan

5.1 Study Objectives

The primary objective of the Town Creek rehabilitation plan is to improve flood conveyance in the Nabiac Town Centre, and to provide a vision for rehabilitation of Town Creek that can be communicated with project stakeholders. Secondary objectives of the concept rehabilitation plan seek to introduce improved environmental, social and biodiversity features within the Town Creek corridor in line with the aspirations of local residents and the Nabiac Village Futures Group.

5.2 Constraints and Opportunities

Initial consultation with the Nabiac community, and preliminary flooding, stormwater, geomorphology and ecology investigations identified a range of constraints and opportunities for the rehabilitation of Town Creek.

These constraints and opportunities are summarised on Figure 5-1, Figure 5-2 and Figure 5-3 for the upper, middle and lower reaches of Town Creek respectively. The maps of constraints and opportunities provide the basis for development of the Town Creek Rehabilitation concept plan.

5.3 Concept Plan

The project comprises a concept plan and conceptual cross sections to illustrate some of the future planting and geomorphic features envisaged for the rehabilitated creek. The concept plan and typical sections provide a sufficient level of detail for communicating the key elements of the rehabilitation plan to the community and grant authorities in order to progress the plan.

The concept plan drawings for rehabilitation of Town Creek are presented in Appendix B.

Title:

Town Creek, Nabiac - Upper Reach Stage Site Contraints and Opportunities

Figure: 5-1

Rev: B

N

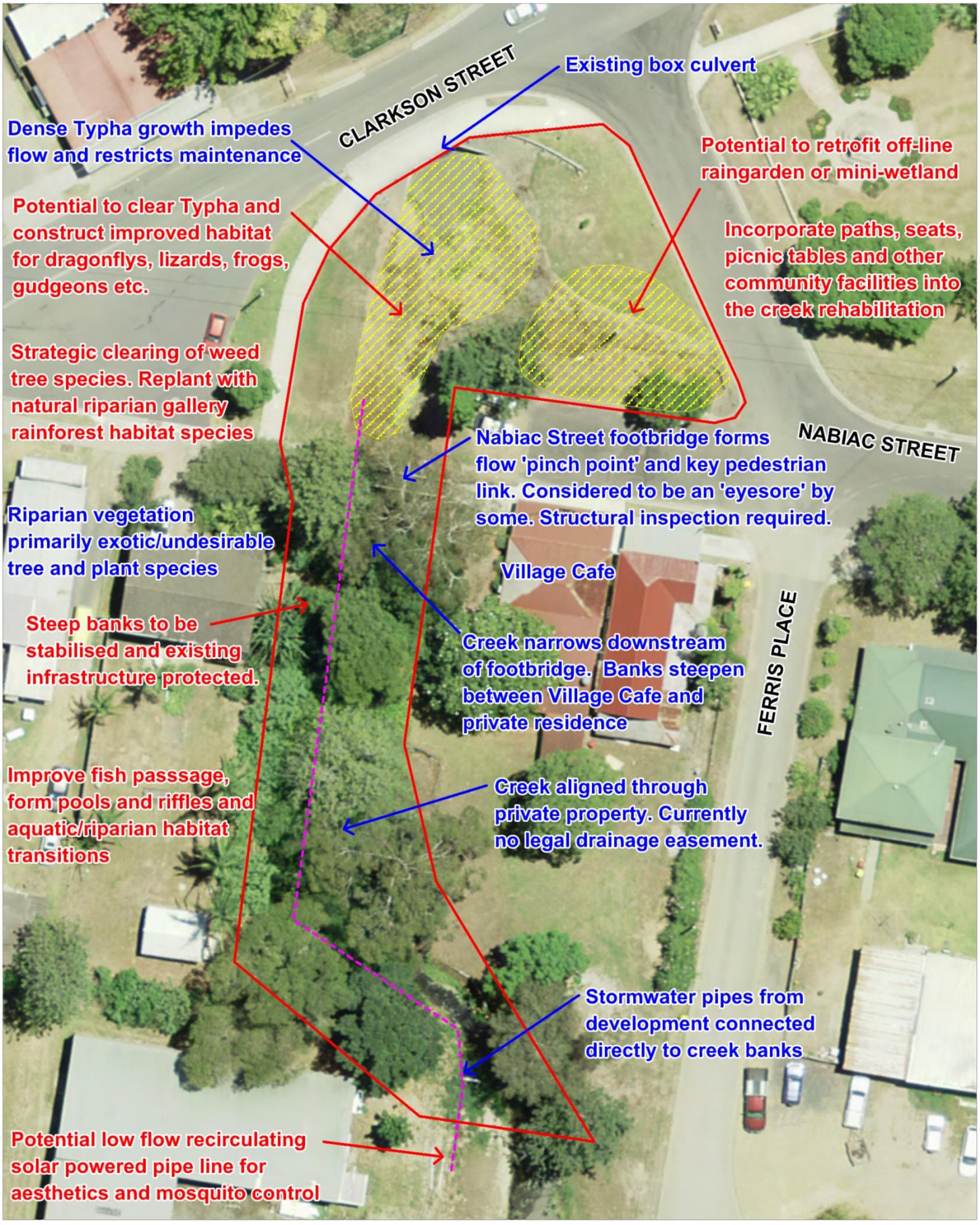
0 12.5 25m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N20569_Town_Creek_Rehabilitation\MI\WS



Title:

Town Creek, Nabiac - Middle Reach Stage
Site Contraints and Opportunities

Figure: **5-2**

Rev: **B**

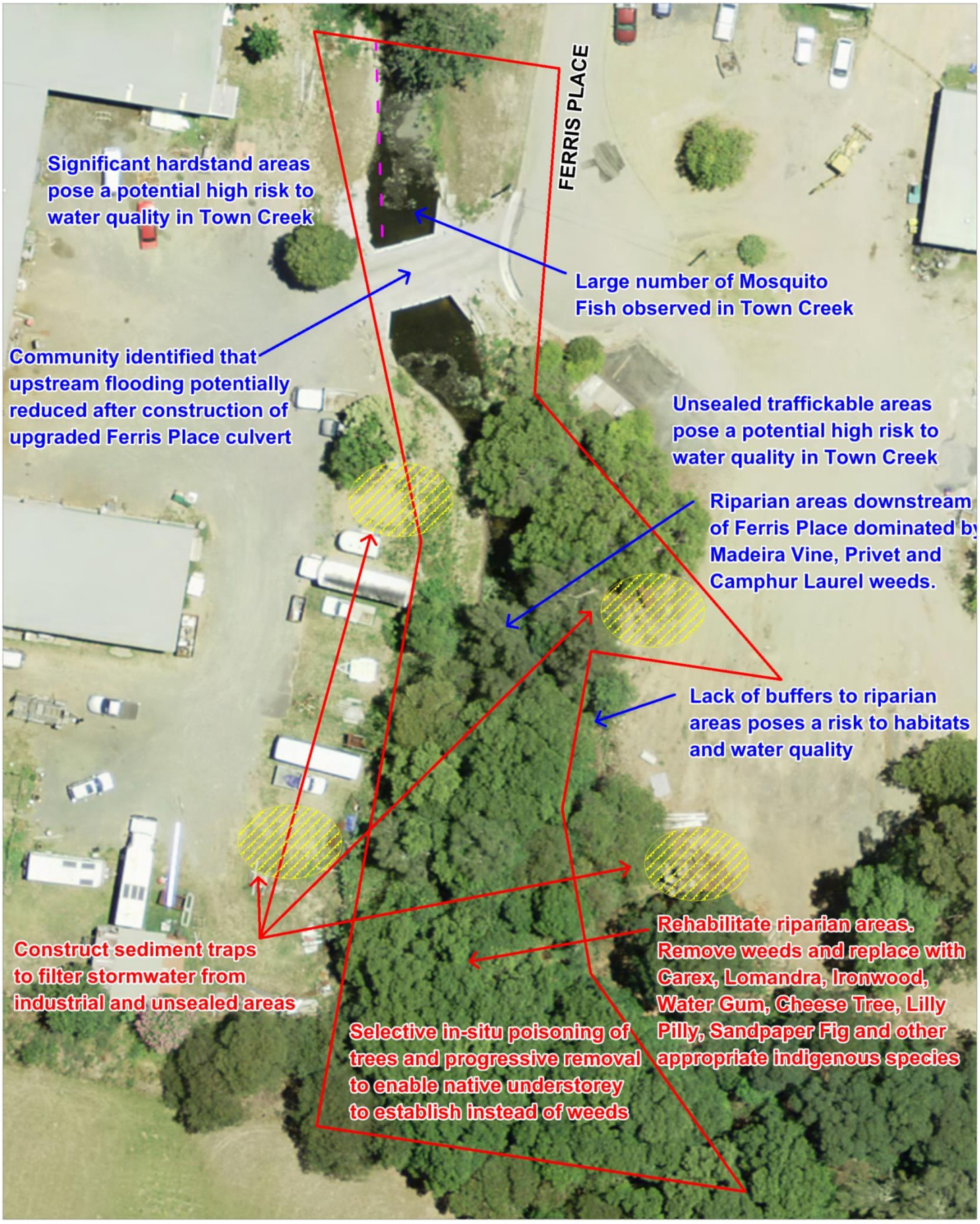
N

0 10 20m

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N20569_Town_Creek_Rehabilitation\MI\WS



Title:

Town Creek, Nabiac - Lower Reach Stage Site Contraints and Opportunities

Figure: 5-3

Rev: B

N

0 10 20m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N20569_Town_Creek_Rehabilitation\MI\WS

6 References

Cardno Lawson and Treloar (CLT), 2010. Nabiac Flood Study. Report prepared for Great Lakes Council, September 2010.

Csaller, K., 1984. Flussbau I, Genzschleppspannung und Grenzgeschwindigkeit des Wassers, Lecture Notes in River Engineering, Technical University of Munich.

Ecological Consultants Australia (ECA), 2016. Town Creek Rehabilitation Project, Nabiac, Mid North Coast, NSW. Report prepared for Great Lakes Council, August 2016.

Rutherfurd ID, Jerie K, Marsh N 2000. A Rehabilitation Manual for Australian Streams. Land and Water Resources Research and Development Corporation and Cooperative Research Centre for Catchment Hydrology: Canberra.

Appendix A Town Creek Rehabilitation Project (ECA, 2016)

Town Creek Rehabilitation Project,

Nabiac, Mid North Coast, NSW.

For: Great Lakes Council

By: Ecological Consultants Australia Pty Ltd

Date: November 2015 updated 12th April and August 2016

About this document

Copyright Statement©

Statement of Authorship

This study and report was undertaken by Ecological Consultants Australia for the Great Lakes Council. The authors of the report are Mia Dalby-Ball whose qualifications are BSc. majoring in Ecology and Botany with over 20 years' experience in this field, Lisa Jones whose qualifications are BBioCons. majoring in ecology and environmental science and Michael Davis whose qualifications are BBioCons. majoring in ecology.

Limitations Statement

Information presented in this report is based on an objective study undertaken in response to the brief provided by Council's Design and Investigation Department.

Acknowledgement

Information in this report is a combination of the authors' experience and those from many others in ecology. We give appreciation to all who have shared information. In particular, we acknowledge the Original People of this Land who continue to share their wisdom of this lands flora and fauna, seasons and cycles. We would also like to acknowledge the Great Lakes Council, Nabiac Village Futures Group and local residents working on this wonderful Town Creek.

Document Control Sheet	
Title:	Town Creek Rehabilitation Project, Nabiac, Mid North Coast, NSW
Version:	DRAFT
Author:	Mia Dalby-Ball, Lisa Jones and Michael Davis
Date:	November 2015, updated 11th April, June 6th and August 8th 2016
File location:	E:\ ECA 4 Prod\2 ECA Projects\2015-2016\Great Lakes Council
Distribution:	BMT WBM and Council's Design and Investigation Department

Signed: Mia Dalby-Ball – Director of Ecological Consultants Australia

Executive Summary

Purpose

The purpose of this report is to provide advice and recommendations in relation to rehabilitation of Town Creek channel to improve flood conveyance, remove weeds and restore riparian vegetation.

Summary

- Town Creek contains several species of weeds found adjacent along the riparian zone.

- Several stormwater overflow entry points where spotted near the foot bridge during rainfall events entering the existing drainage reserve.

Summary options to consider

- Recommended flood conveyance management aims to achieve the following:

    - Removal of sediment is recommended to increase the base width of the channel in the Stage 1 area (footbridge to Ferris Place culvert) to accommodate for 1:100 year flood events
    - Elevate the height of the existing footbridge to ensure continued stability
    - Annual maintenance works on culverts to avoid blockages from debris
    - Reinstate natural pool/riffle sequences throughout Town Creek
    - Typha subspecies located upstream from the footbridge to Clarkson Street must be conserved to maintain the structural function of the channel bed.

- Recommended weed removal management aims to achieve the following:

    - Habitat
    - Aesthetics
    - Waterway stability
    - Connectivity of vegetation along the waterway

- Recommended fish passage re-connection management aims to achieve the following:

    - Maintain low central channel
    - In-stream snags were possible (and not flood issue)

Table of Contents

1 Introduction

1.1 Scope of Work

In the past, surrounding private and commercial properties near Town Creek have been negatively influenced by the effects of flooding. See prior studies and findings of BMT WBM.

The purpose of this study is to highlight key issues affecting Nabiac's flood relief drainage reserve of Town Creek and improve its flood conveyance, remove weeds and restore riparian vegetation.

The scope of work

- Ecological input to the Design channel and structure components to optimise in-stream habitat opportunities including energy dissipation, pools and riffles
- Design of permanent revegetation recognising the rehabilitation stages and the eventual successional development of a suitable riparian vegetation structure
- A set of concept drawings suitable for preliminary costing including vegetation plans and water and soil management measures
- Engagement with Council staff, Nabiac Village Futures Group and Nabiac Landcare

1.2 Location and Background

Nabiac is within the homelands of the Worimi and Biripai First Peoples whoes knowledge of this land is intimate and extends over 1000s of year. Worimi and Biripai people continue to share knowledge and wisdom of this area.

The Great Lakes Council local government area (LGA) is situated on the Mid North Coast of New South Wales. The township of Nabiac is located on the western boundary of the LGA, on the Pacific Highway about 320 km north of Sydney. Town Creek is a small tributary within a large catchment area (of some 121 ha) and flows northwest into Wallamba River (see Figure 1). Town Creek flows through the central commercial area of Nabiac Estate.

Figure 1. Town Creek rehabilitation general location showing nearby urban areas including the over 121ha catchment. (Source: Google Earth)

1.3 Site Overview

1.3.1 Site surroundings

Town Creek is a small creek running through the small town of Nabiac with varied land use in the surrounding areas. Multiple roads cross above the creek, with water being diverted through culverts. The most significant road crossing the creek is the Pacific Highway. Nabiac Street and Clarkson Street cross the creek in the town whilst Candormakh Creek Road crosses the creek upstream. Upstream, the land is either cleared vegetation or agricultural land with residential land use occurring further downstream in the town of Nabiac. Downstream from Nabiac, the creek runs through more agricultural or cleared land before reaching a small dam. The creek then continues through cleared land before flowing into the Wallamba River.

Figure 2. Project area for rehabilitation and restoration works.

1.3.2 Site conditions

Following is a quick summary on site conditions as they relate to the project.

The flow regime of the creek is likely to be significantly altered due to increased storm water runoff as a result of increased impervious surfaces in the area surrounding the creek. The conversion of vegetated areas into roads, residential areas and cleared areas for agriculture would all contribute to a reduction in the infiltration ability of storm water, causing increased flows in the creek. Increased water flow has the added disadvantage of facilitating the transport of increased nutrients and sediment from agricultural and residential land and other impurities such as oils and heavy metals from roads and residential areas.

These factors generally result in an overall reduction in water quality, placing pressure on aquatic and terrestrial habitats. The combination of cleared riparian vegetation from the heavy agriculture of past decades, increased nutrients and altered flow regimes appear to be impacting the available habitat of the creek. These factors would be a contributor to the high proportion of invasive plant species in the riparian zone in terrestrial areas whilst algal blooms and associated eutrophication would be promoted in the aquatic areas. All of these conditions area factors for biodiversity decline and may promote aesthetically unsightly areas.

1.3.3 Site Images

Images below include those after rain events (low visible algal) and during drier periods.

All images are from within the period Nov to Feb 2016.

Upstream the water-way is dominated by dense weed species, both shrubs (Lantana) and grasses. Canopy is absent along this section. Striped Marsh Frogs and Blue Wrens were present along here during the site survey. The channel could be widened and a preferential low-flow channel could be snaked down the centre.

Canopy trees are growing near the upstream culvert. Here all are exotic with the exception of some Wattles. Works here can include the widening of the creek, removing of exotic trees and planting the batters with native trees.

A mural on the culvert with native aquatic species would improve the aesthetics. This section of waterway could be widened to provide tiered habitats and specific areas for frogs, lizards, small birds and butterflies.

Canopy trees could be planted ~20m back from the creek edge allow this section to continue to receive full sunlight for at least part of each day as well as opportunities for people to interact with the waterway and see the fauna.

Densely vegetated marsh zone – great for native fauna (frogs, wrens, invertebrates). Batters in this area could be pulled back and tiers made that suit different species including a place for a Lizard lounge. Also potential for off-line wetland to be created in the turf area to provide some water quality improvements as well as habitat (off-line = no mosquito fish = frog breeding).

Higher marsh zone – in rainfall. Water through here moves swiftly. A preferential path for low flows could be created with a slope towards it such that pooling water in dense vegetation (mosquito habitat is minimised). A central low-flow path could be rock lined.

Bridge near the CAFÉ. Vegetation here is dominated by weeds and there are no particular habitat features. Fauna will live on the bridge itself. If the bridge was higher it could be suitable for nesting Swallows.

During flows the water is bypassing official structures and running overland into Town Creek just upstream of the bridge. Location of flow inputs will influence the habitat suitability for fauna.

Immediately downstream of the bridge the riparian zone is dominated by weeds. The existing trees however, including Camphor Laurel, are providing bank cover and have habitat vales. It's recommended large trees are retained in the first stage of works. Removal is possible if that is a requirement of engineering works.

Flows, during rain, show this pinch point is likely to experience medium to high velocity flows during rain events and habitat here will be designed to accommodate those animals which occur in this habitat including some Dragonflys.

Under the 2nd culvert the water pools. Here is submerged exotic and native and aquatic plants. At the crossing the riparian zone is absent (to ~5m each side) then thickly vegetated with exotic species.

Riparian Zone – weed dominated. Providing habitat for wrens, willy wag-tails and larger carnivorous birds (currawongs)

Elephant Ears – exotic plants. Removal of weed species in this area is not difficult and the area can be converted to a native dominated riparian zone with all vegetation strata present and enhanced areas for native fish.

Canopy dominated by exotic plants and weeds particularly Small Leaf-privet. It would also provide a greater diversity of habitat for fauna and bring back some of the tree species that were once common here but now rare including the Cedars.

1.3.4 Catchment

Geology and soils are describes elsewhere and this section provides a quick overview of vegetation in the catchment.

Current condition in the catchment is largely cleared, agricultural land with tree and bushland remnants along waterways and isolated trees in paddocks.

2 Methods

2.1 Desktop Study Review

2.1.1 Vegetation

Review of past studies, council vegetation mapping and data, searches on Bionet and Altas of Living Australia. Further information could be gain from listening to First Nations people who have connections with this area.

2.1.2 Fauna

Review of past studies, council vegetation mapping and data, searches on Bionet and Altas of Living Australia.

2.2 On-Site Evaluation

Site visit, with Council, BMT WBM, LLS and Community, of project location in dry and wet-weather.

Walked the length of the project area taking note of existing ecological aspects. Drove to the upper catchment and took notes of existing riparian zones with intact vegetation.

3 Results

3.1 Town Creek Current Condition and Recommendations

Following is a brief summary of the project site separated into four main sections. The next stage of this plan is to recommend specific habitat features for each section in-line with engineering requirements.

3.1.1 Section A – Hwy to 1st culvert

Existing Vegetation

Section A upstream has a mix of native and exotic plants including good canopy cover. The middle section (most of this area) has few canopy trees and is dominated by weeds particularly grass weeds and Lantana. Canopy trees are present again near the culvert – again most are exotic species. A few native wattles are growing in the mid-story. Surface waters flow off the Hwy and overland towards water-course.

Figure 3a. Section A of Town Creek and typical images, Nabiac, NSW.

Figure 3b. Aerial of Section A. Source: RPAS Feb 2016

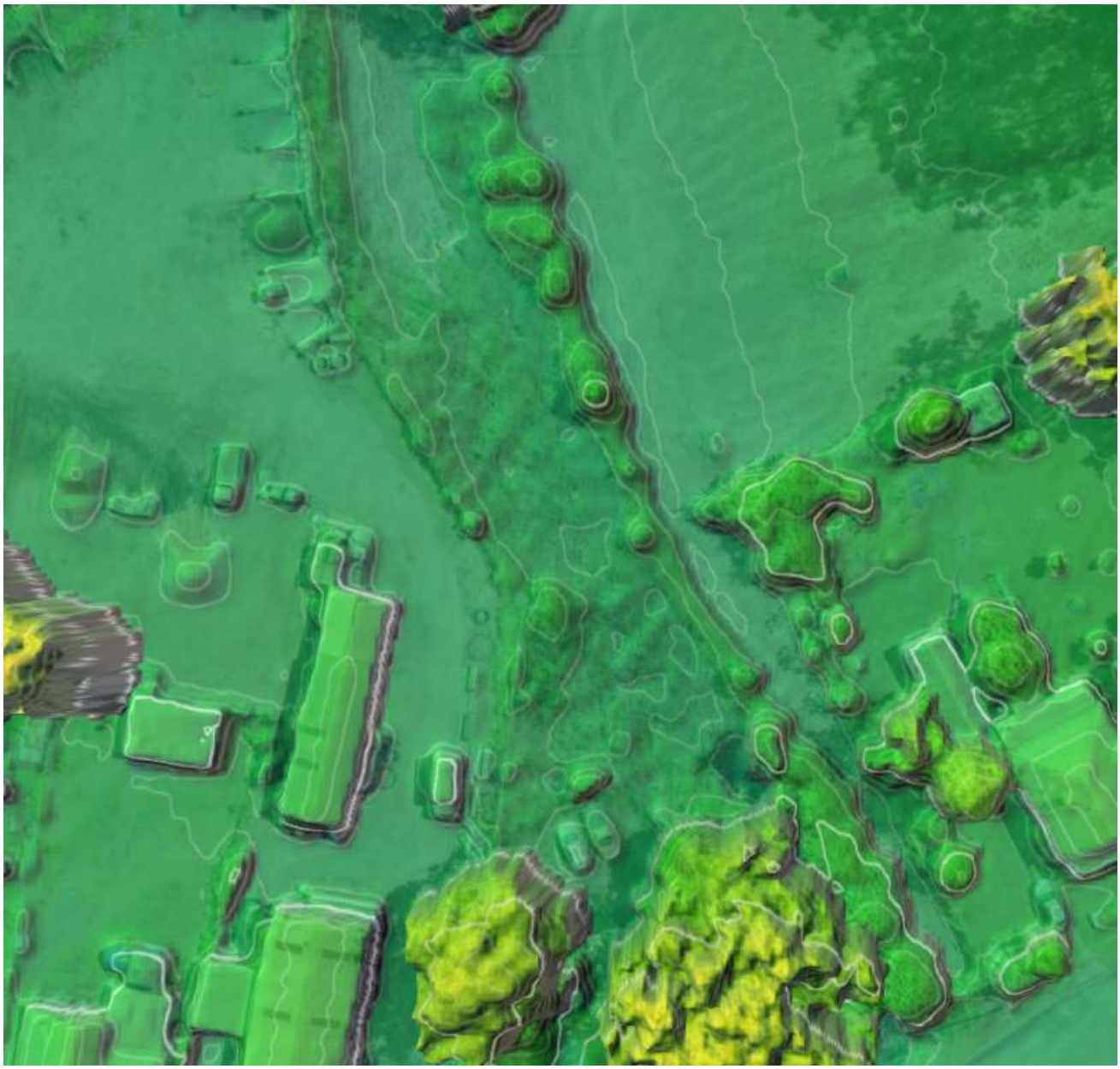


Figure 3c. Orthophoto of Section A. Source: RPAS Feb 2016

3.1.1.1 Section A Weed Removal Mangement Recommendations

All invasive vegetation in section A can be removed. Weed grasses dominate the channel. Seed will have to be managed post removal of adult plants. Burning is recommended. Burning could be does with a thermal weeder. Thermal weeding can occur during rain to reduce the likelihood of unplanned fire.

Ideally vegetation could be split into three sections along section A to facilitate sequential removal of vegetation and to retain habitat for existing small birds including wrens. If there is not sufficient habitat adjacent to areas of vegetation being removed, woody debris and sticks obtained from removed vegetation could be kept on site and placed on council owned land and adjacent private owned land if possible. This could be in the form of ~40 small patches of cut vegetation arranged into 2m by 2m mounds and retained until new vegetation is established to provide temporary habitat. Fewer larger piles would also work.

No native vegetation of high priority is growing in this section of the water-way

3.1.2 Recommendations Section A

Trees on upper banks, banks with grasses and shrubs and rock piles for lizard. Low-flow central channel rock-line with habitat for dragonflies and other aquatic macro-inverts. For plant species see Appendix I. See full drawings submitted with this project and cross-section below.

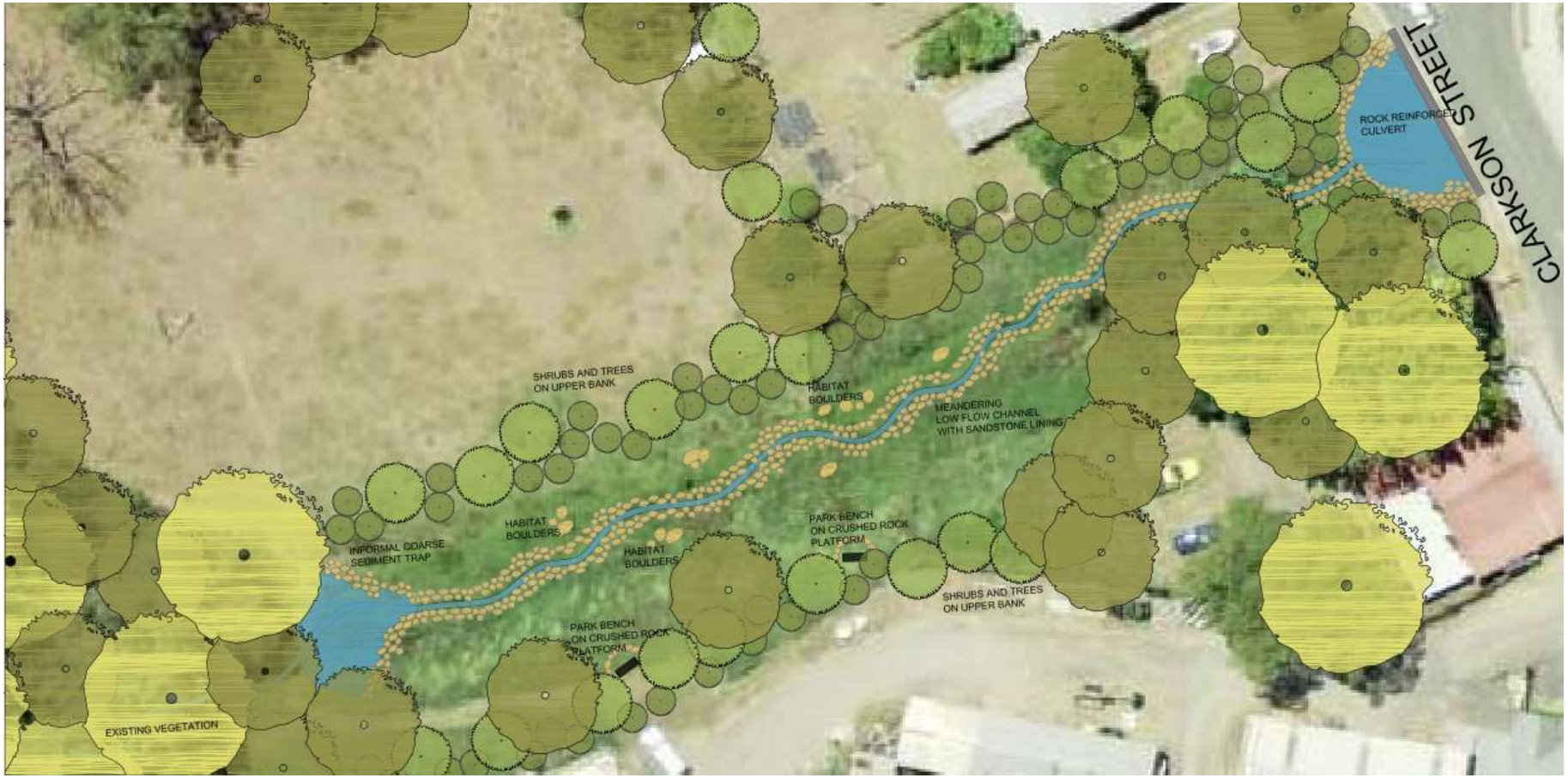


Figure 3d concept plan for detail see high resolution supplied with this report

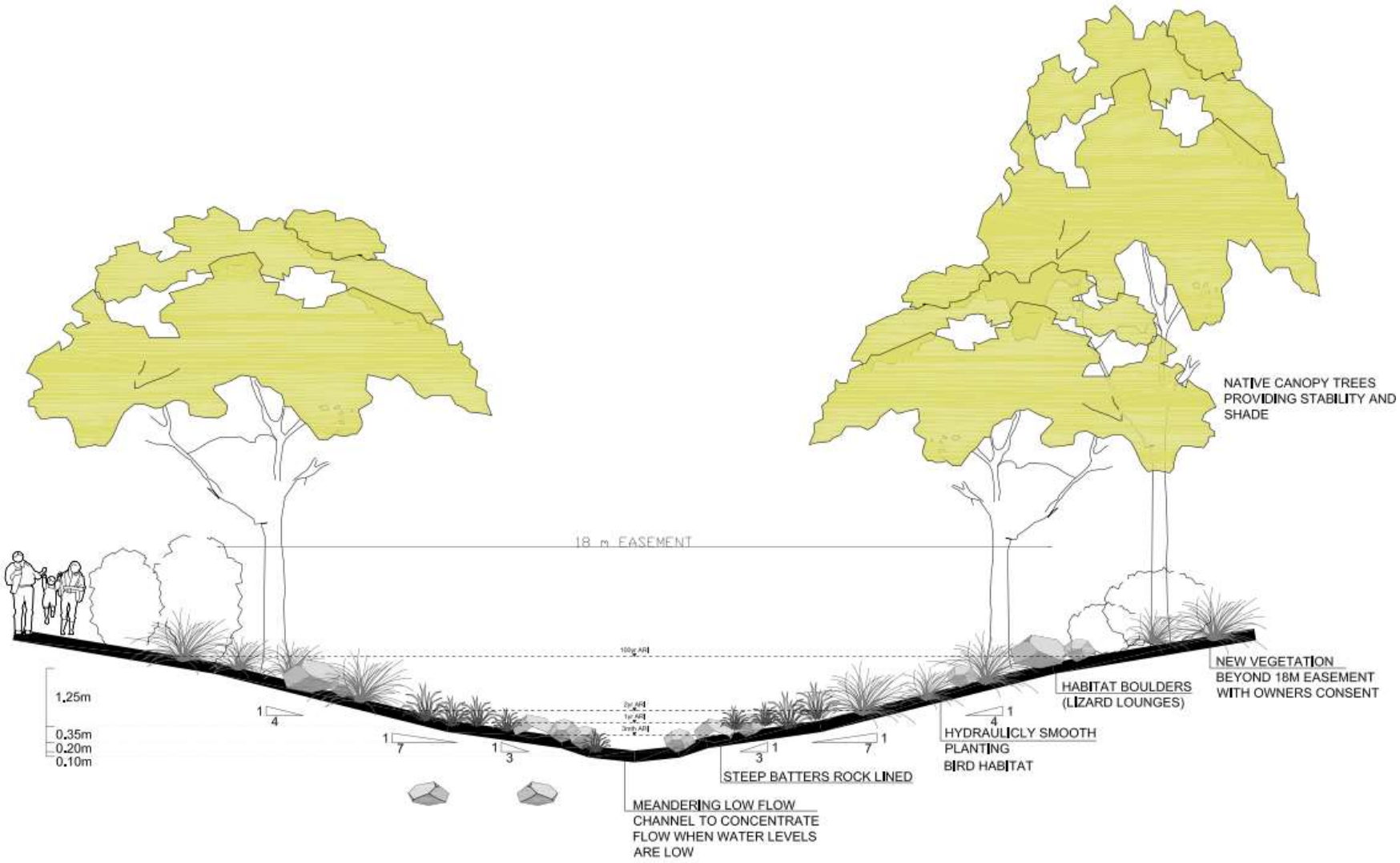


Figure 3e recommendations: for detail see high resolution supplied with this report

Plate 1. Upper bank planting (I(V):4(H) slopes) similar to this image E9

Description: trees with understory vegetation along batters. This area is key for invertebrate, frog, lizard and small bird habitat.

Management Considerations: Weeds and maintenance edges.
Management Recommendations: Clear edges between turf and planted areas. Use a hard edge including garden edging that can be dug in to slow the spread of turf into planted areas.
Ideally have crushed sandstone pathways (or equivalent) as the boundary between turf and planted areas. Set pathways back and have ground covers between shrubs and pathways.

Plate 2. Example sparce vegetation on lower banks. Image E6

Description: Low-flow centre line for carriage of low-flows and wide rock-lined channel for carriage of high-flows. Aquatic plants with low resistance (bend easily in flows) can be planted in the high flow channel rather than turf (shown here).
Management Considerations: Mosquitos and Weeds
Management Recommendations: Low-flow channel defined and re-circulation available.
Weeds will grow in the rock areas where there is damp soil. The standard maintenance is to use herbicide in these areas – this is not recommended. To avoid the need for herbicide there are 2 options, allow weeds to grow and whipper snip the tops off or plant dense low sprawling climbers or similar to reduce the area available for weeds to establish.

Plate 3. Example sparce vegetation on lower banks image E7

Description: NB: this image doesn't have any bank vegetation. Proposed works is for bank vegetation. The image does however show a rock base that has been suggested in high flow / possible scour areas.

Management Considerations: Weeds and maintenance edges.
Management Recommendations: Clear edges between turf and planted areas. Use a hard edge including garden edging that can be dug in to slow the spread of turf into planted areas.

Plate 4. Example vegetation on lower banks image E12

Description: Lomandra on lower banks. This photo shows dense plant growth along the banks. The design for Nabiac is more open with a greater diversity of bank vegetation. This image shows how there can be a low-flow channel and bank vegetation. NB this low flow channel has a potential design fault resulting in opportunities for there to be stagnant/still water for over 5 days (Mossie habitat).

Management Considerations: Weeds and maintenance edges.
Management Recommendations: ensure the low-flow change and bed can be cleared out with machinery and isolated still pools cannot form.

3.1.3 Section B - Middle section culvert to bridge

Section B has no canopy in the upper section, and marsh zone dominated by native species to about 5m from the bridge. From the bridge downstream the vegetation is all strata and exotic. Great opportunities for increase ecological values in this section through the main wetland and some of the existing turf areas.

Potentially good habitat for dragonflies, skinks, turtles and small birds.

Figure 4a. Section B of Town Creek and typical images, Nabiac, NSW.

Figure 4b. Aerial of Section B. Source: RPAS Feb 2016.

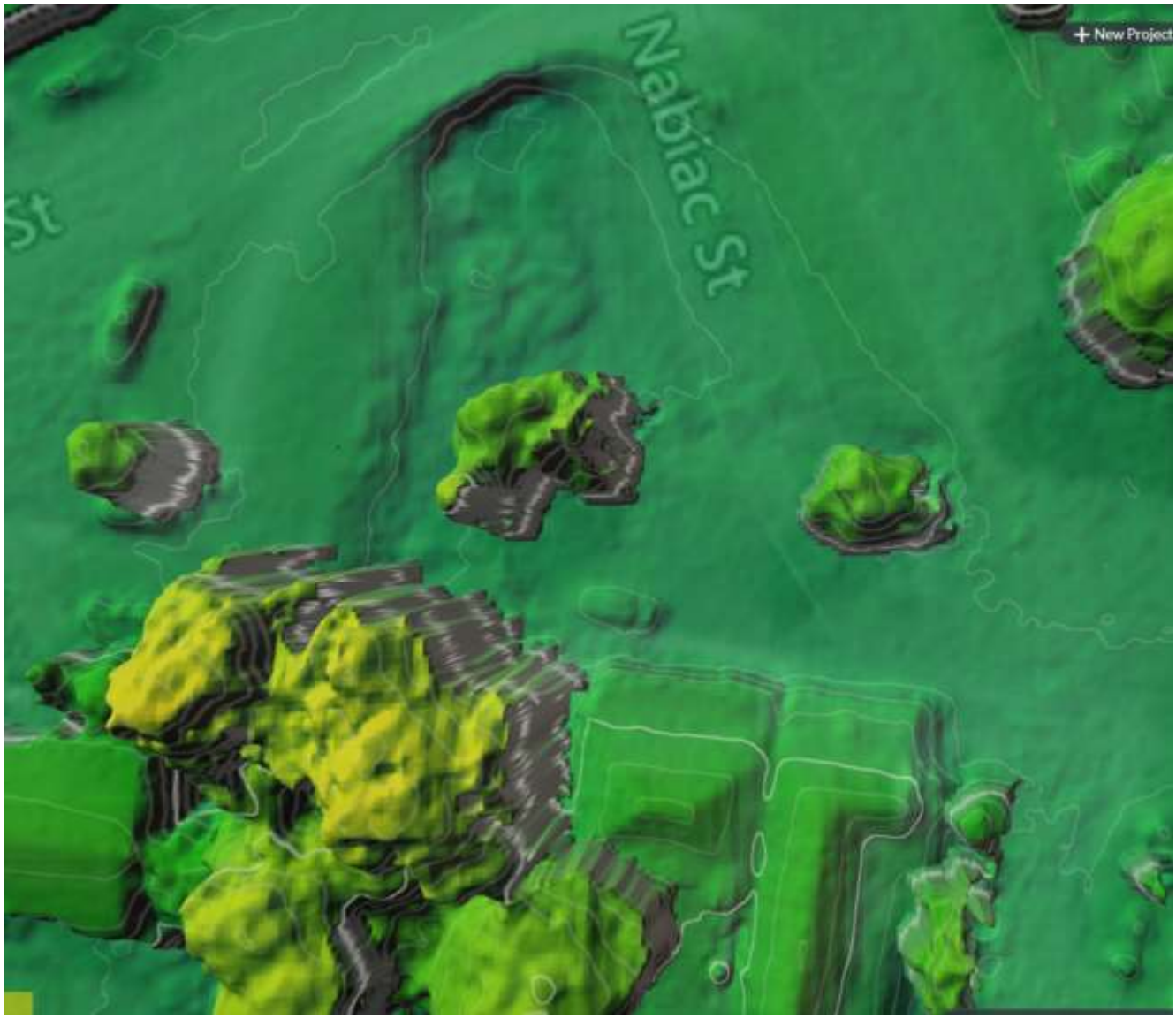


Figure 4c. Orthophoto of Section B. Source: RPAS Feb 2016.

3.1.3.1 Section B Vegetation Mangement Recommendations

Section B contains native wetland plant species extending approximately 5m from the bridge and along the channel. Desirable plants could have seed collected from them for growing up and or plants could be transplanted into the raingarden when it is built.

A temporary wetland (depression with tarp and water) could be constructed adjacent to the area marked for works to provide temporary plant storage during revegetation works.

Once work is completed, retained native species could be reintroduced to the primary waterway.

3.1.4 Recommendations Section B

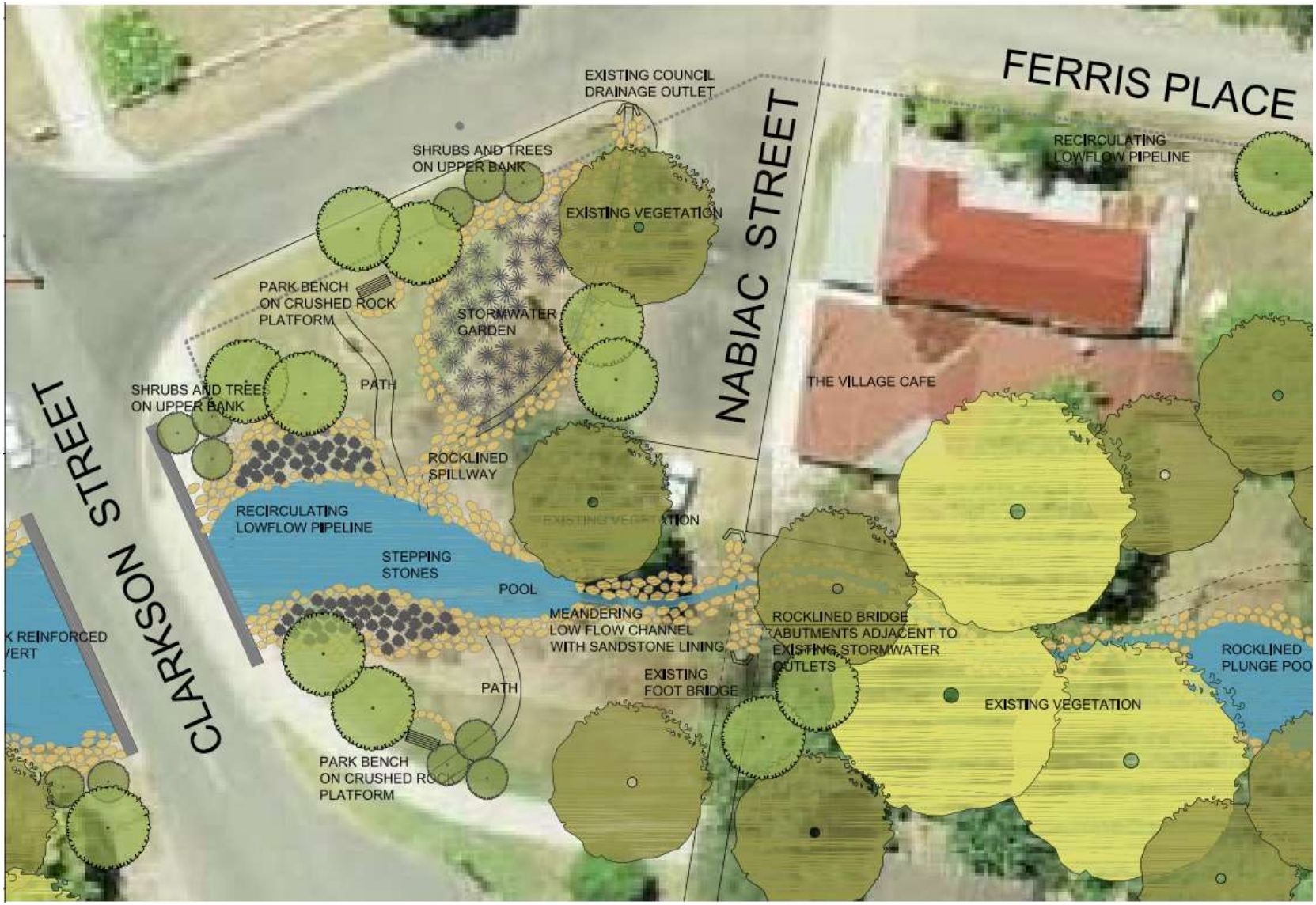


Figure 4d concept plan: for detail see high resolution supplied with this report

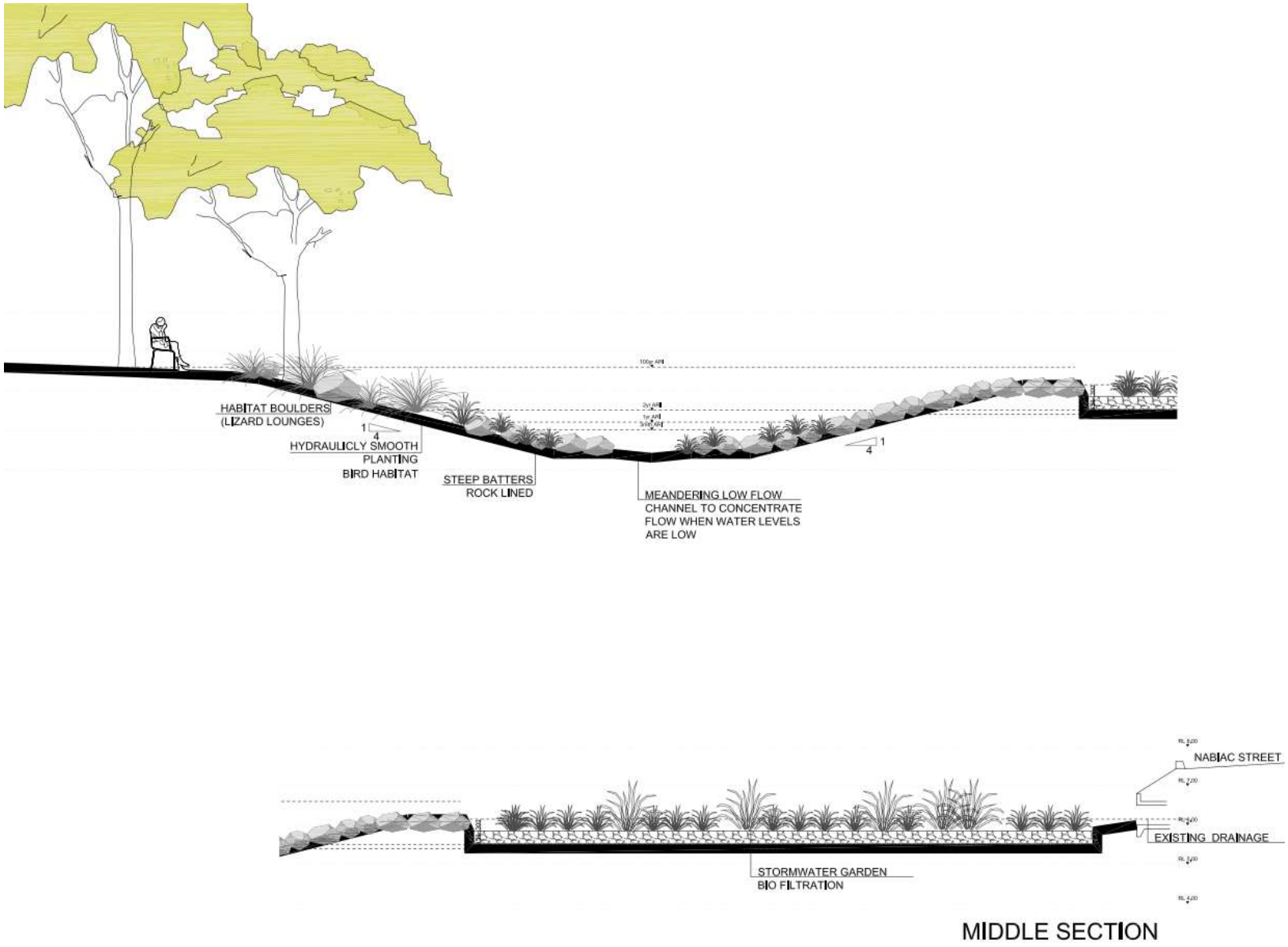


Figure 4f recommendations: for detail see high resolution supplied with this report

	
Plate 5. Example in-stream planting. Image E6	*Plate 6. Lower batter planting similar to this image E9*
Description: Low-flow centre line for carriage of low-flows and wide rock-lined channel for carriage of high-flows. Aquatic plants with low resistance (bend easily in flows) can be planted in the high flow channel rather than turf (shown here). **Management Considerations**: Access, Mosquitos and Weeds **Management Recommendations:** Low-flow channel defined and re-circulation available.	**Description:** trees with understory vegetation along batters. This area is key for invertebrate, frog, lizard and small bird habitat. **Management Considerations**: Weeds and maintenance edges. **Management Recommendations:** Clear edges between turf and planted areas. Use a hard edge including garden edging that can be dug in to slow the spread of turf into planted areas.

	**Description:** understory vegetation along upper batters. This area is key for invertebrate, frog, lizard and small bird habitat. Can include flowering plants and large trees. **Management Considerations**: Weeds and maintenance edges. **Management Recommendations:** Clear edges between turf and planted areas. Use a hard edge including garden edging that can be dug in to slow the spread of turf into planted areas.
Plate 7. Upper batter planting similar to this image E4	

3.1.5 Section C – bridge to 2nd culvert

Section C is a narrow point with building constraints both sides. Vegetation is exotic. Staged re-planting and weed removal is recommended with the aim of including habitat for small birds and butterflies.

Figure 5a. Section C of Town Creek and typical images, Nabiac, NSW.

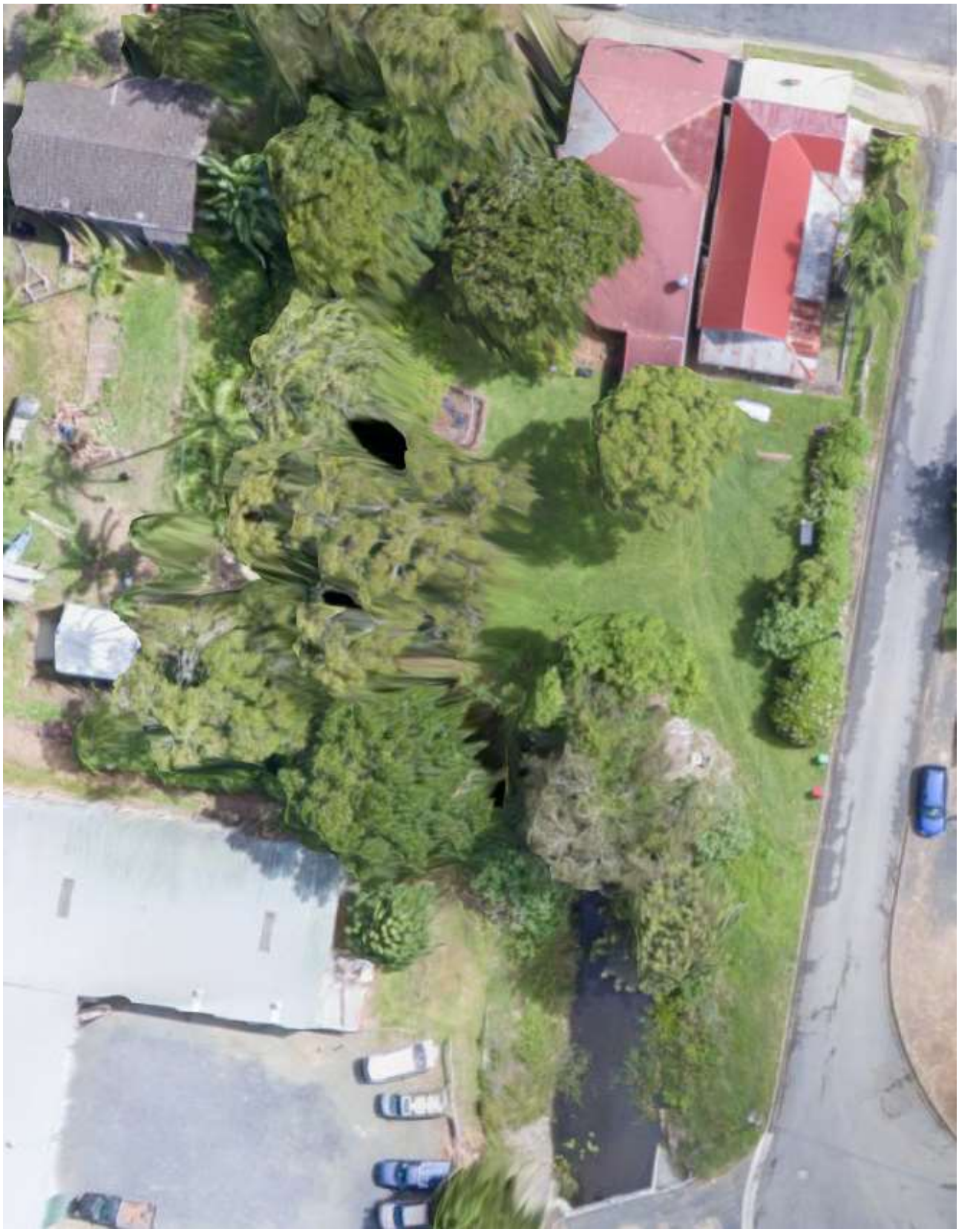


Figure 5b. Aerial Section C of Town Creek, Nabiac, NSW. Source: RPAS Feb 2016.

Figure 5c. Orthophoto Section C of Town Creek, Nabiac, NSW. Source: RPAS Feb 2016.

3.1.5.1 Sections C and D Vegetation Mangement Recommendations

Sections C and D both contain high proportions of invasive plants. Ideally invasive vegetation would be removed in alternating patches of 50m^2 leaving areas of invasive vegetation until native vegetation is established. This would retain the habitat values of the riparian zone and to maintain bank stability. Weedy tree species should be cut and stem painted with appropriate herbicide, leaving the roots in the banks to maintain bank stability. Additionally, sand-bags could be added to areas with unstable banks as a stabilizer and a medium in which certain native plants may be planted. Woody debris and sticks from weed trees could be retained onsite to maximize available habitat for lizards and small birds, however this material must be dead to reduce re-establishment of invasive plants. Reductions in midstorey vegetation will result in an increase in available light for invasive shrubs and herbs. Shade cloths could be placed at a height of 2m in the strips that have undergone vegetation removal to prevent proliferation of exotic annuals and grasses until a native midstorey and canopy is established. Shade cloths placed at 2m will allow sufficient height for subsequent work in the area and will allow native tree species to become established before shade cloth removal.A small excavator could be used for the rapid removal of aquatic weeds such as elephant ear *(Colocasia esculenta).*

3.1.6 Recommendations Section C

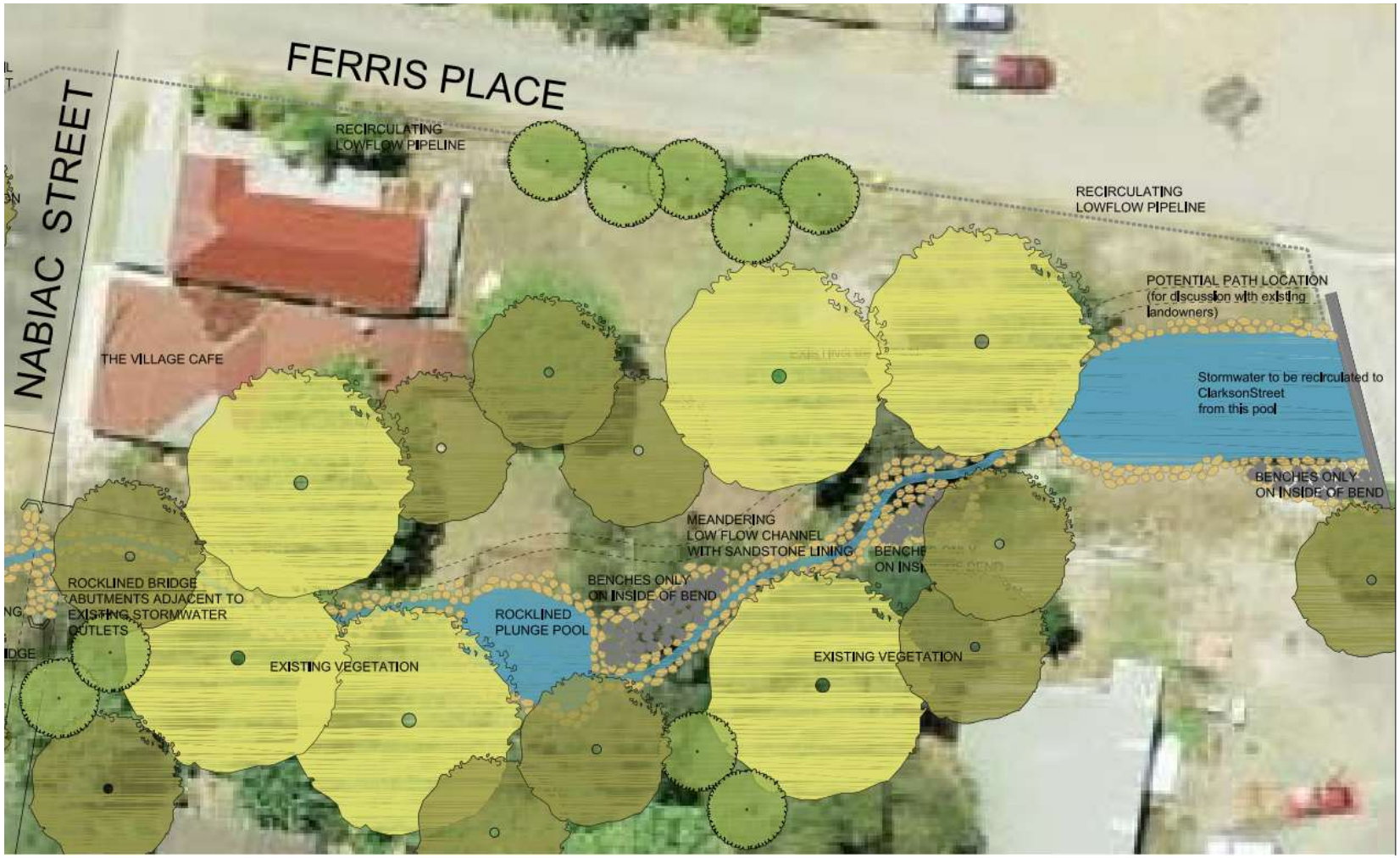


Figure 5d concept plan for detail see high resolution supplied with this report

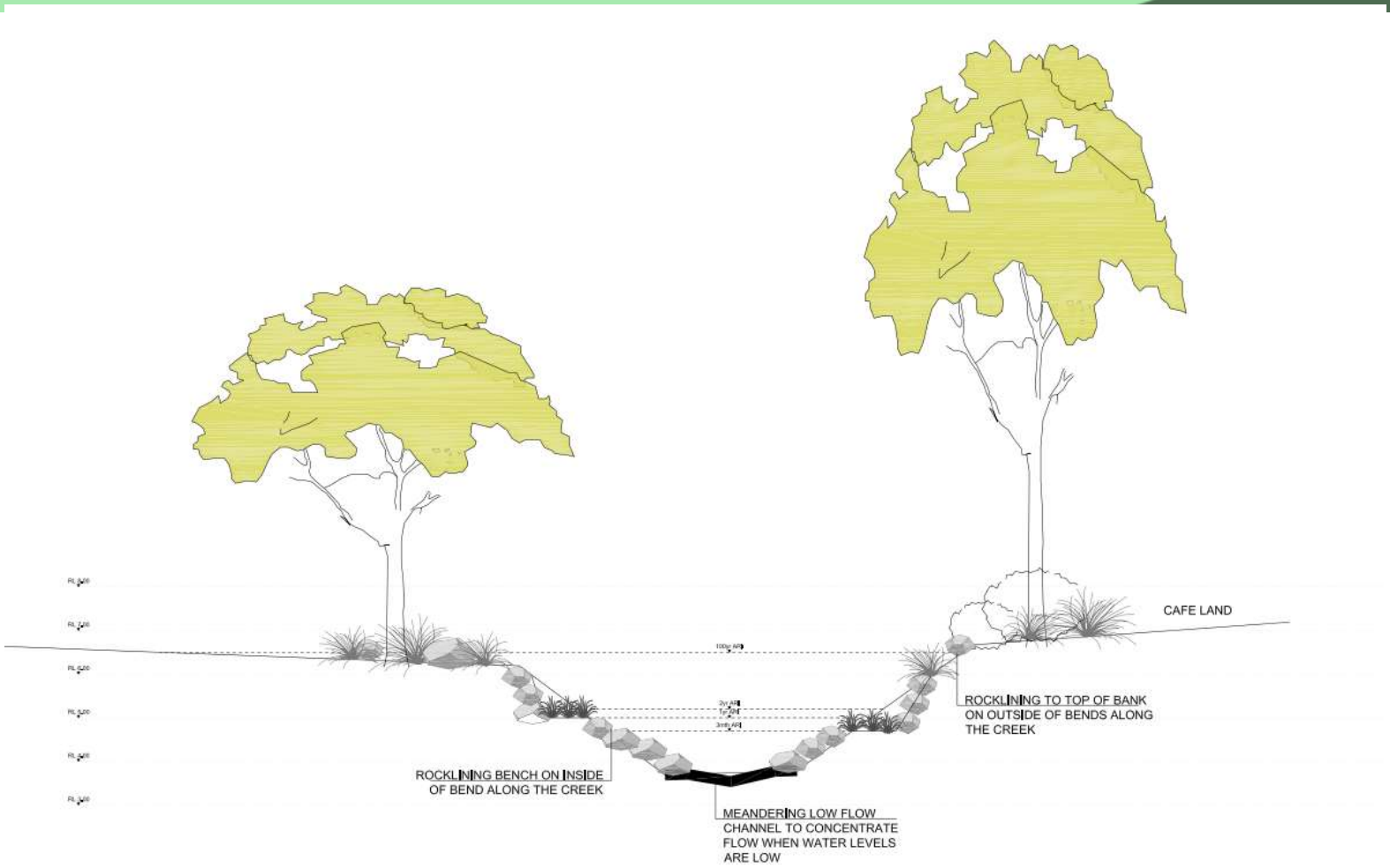


Figure 5f recommendations. For detail see high resolution supplied with this report

3.1.7 Section D - downstream from culvert

Section D has great potential as a riparian zone – and stages weed removal and replanting would see an improvement in habitat values as aesthetics. Sediment management could also occur through here with access for machinery to removed build up and the water-way could have a series of pools and runs.

Figure 6a. Section D with typical images of Town Creek, Nabiac, NSW.

Figure 6b. Aerial Section D of Town Creek, Nabiac, NSW. NSW. Source: RPAS Feb 2016.

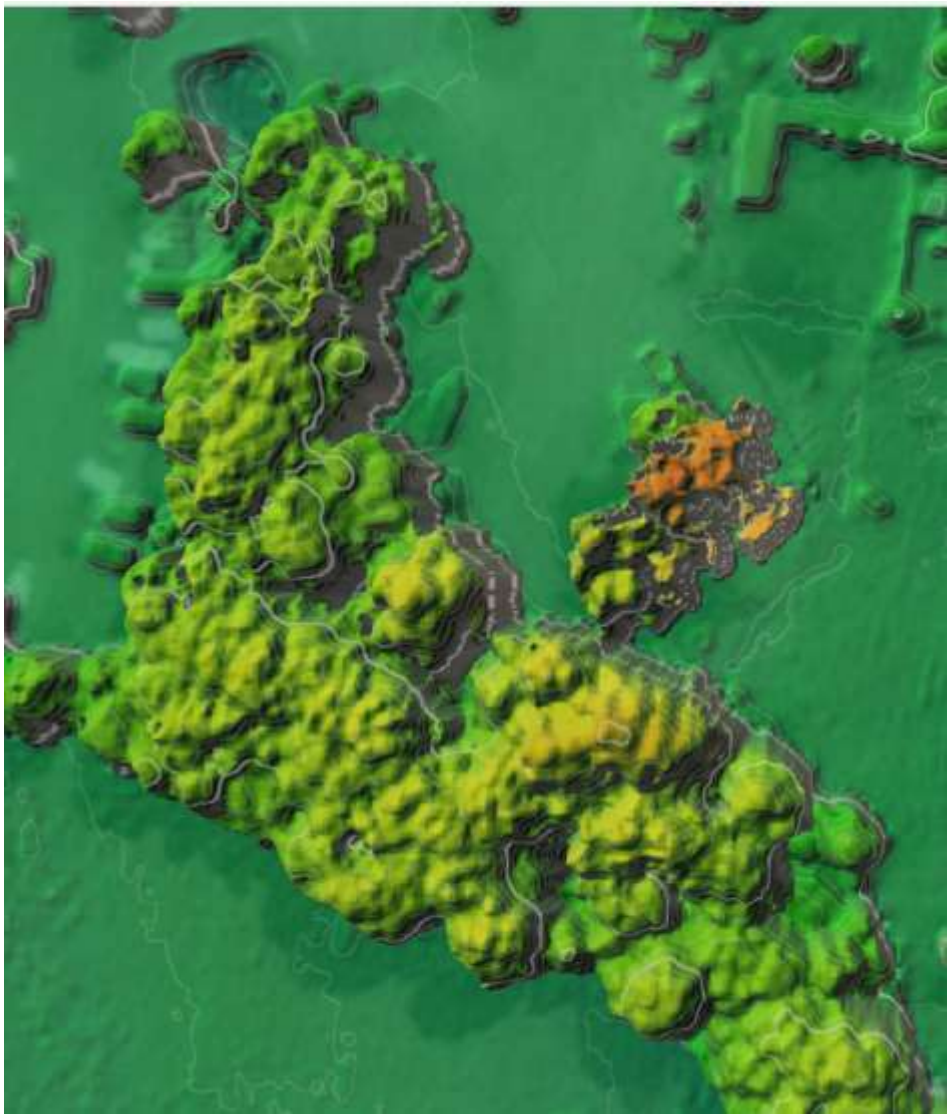


Figure 6c. Orthophoto Section D of Town Creek, Nabiac, NSW. NSW. **Source:** RPAS Feb 2016.

3.1.7.1 Sections C and D Vegetation Mangement Recommendations

See section C recommendations

3.1.8 Recommendations Section D

Figure 6d recommendations: for detail see high resolution supplied with this report

3.2 Overall Waterway Recommendations

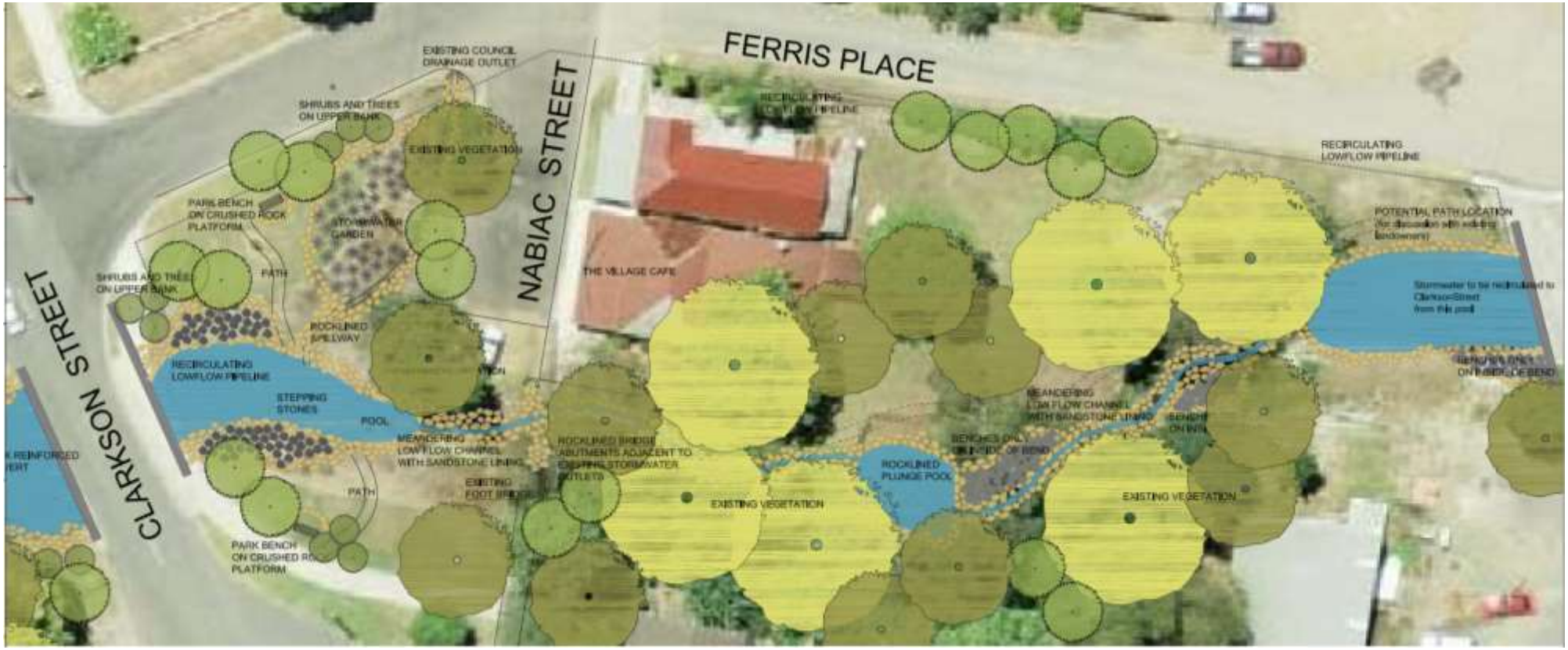


Figure 7 overview of works below Clarkson Street

3.2.1 Overall Vegetation Mangement Recommendations

Ideally vegetation removal should occur gradually, either in 100m2 increments or in subdivisions as outlined in each section's recommendations above.
Vegetation removal should be accompanied by the creation of temporary habitat in adjacent areas to allow migration of displaced fauna.
Weed tree species should be cut at the stem and painted with appropriate herbicides, leaving the root system in the banks to maintain bank stability. Completely dead sections of weed tree wood may be added back to the bank to add course woody debris for bank stability and to provide shelter habitat.

If areas of bank soil is exposed along the flow path, a jute mat or equivalent could be placed to stabilise loose soils and prevent further erosion until riparian vegetation is re-established. If exposed soils are dispersive, a layer of non-dispersive soil could be placed prior to covering with jute mat or planting. Removal of over-shadowing weed canopy may stimulate the proliferation of annuals and grass weeds. Shade cloth may be employed at a height of 2m to the reduce weed growth and to allow for the establishment of native canopy species.

3.3 Planting

Figures above show schematics for planting the creek-line and Figure 8 shows layout for planting.

3.3.1 Species

A list of recommended species for planting the banks and wet areas can be found in Appendix I. Planting suggestions for the creek edges include grass species *(Aristida warburgii, Cymbopogon refractus, Dichondra repens, Echinopogon ovatus and Entolasia marginata)* and suitable shrub species (*Acacia longifolia, Acacia myrtifolia, Billardiera scandens, Breynia oblongifolia, Bursaria spinose, Eremophila maculate, Eriostemon banksia).*

Small and large trees could then be planted further from the edges of the creek along 8m intervals *(Acacia floribunda, Cupaniopsis newmanii, Melaleuca linariifolia, Casuarina glauca, Corymbia intermediam, Eucalyptus microcorys, Elattostachys microcarpa).*

Plant species from the Northern Hinterland Wet Schlerophyll Forest ecological community would provide suitable additions to the site due to the local prevalence of the community. Canopy species that could additionally be added would include *Eucalyptus pilularis, Eucalyptus propinqua, Eucalyptus siderophloia* and *Syncarpia glomulifera*. *Allocasuarina torulosa* could be added as a smaller tree species. To increase shrub diversity, the following species could be added: *Jacksonia scoparia*, *Leucopogon lanceolatus, Maytenus sylvestris, Notelaea longifolia , Ozothamnus diosmifolius, Persoonia linearis, P. media, Pittosporum revolutum*, *Podolobium ilicifolium*, *Polyscias sambucifolia and Trochocarpa laurina*.

3.3.2 Pot sizes

Wetland plant sizes
Wetland mats and larger plants are recommended for the in-line planting. This will assist plants surviving higher-flow events. **Mats of water plants** are generally grown in shallow water in strips ~1m long and 0.5m wide. The mats produce a dense mass of horizontal roots. The mats can be put in place and secured with stakes and or rock placed on-top of the root mass. Such wetland plant mats have proved successful in other locations including Wollongong University. Mats are usually multi-species with species groups being those that grow in the same habitat such as edge plants (Juncus and Carex) then shallow water (Bolboschenous and Schenoplectus).

If not mats then the larger pot sizes – **Aqua-pot** – are a great alternative with large root mass. Generally aqua-pots are 10inch pots and plants are over 700mm high when planted.

Hikos are also suitable however they may be removed by larger flows or birds (Swamp hens) prior to establishment.

Wetland plants recommendations

A range of sizes is recommended. With mats (if they can be grown locally) being 10% of aquatic plants. Aqua-pots being 20% of aquatic plant supply (most in-stream planting) and the remainder being hikos.

Terrestrial planting

Terrestrial grasses and shrubs are recommended in hikos, or equivalent, trees in Forestry Tubes or equivalent. Anything small than hikos is not recommended. Larger pot sizes may be chosen to achieve a more immediate visual effect however plants roots must be checked and no root-bound trees planted as they have an increased risk of instability. Experience has shown hiko sized plants are generally are the same size as 10L pot plants within 18months.

3.3.3 Planting density

Density will vary based on pot size chosen. The densities given here are based on hiko size for everything except trees (forestry tubes).

Wetland

Edge planting requires 1 plant every 20m so 4-5 plants per linear m.

Wetland planting 4-6/m2. Higher density is better and decreasing density is only suggested in case there is a lower than optimum budget.

Terrestrial

Grasses planting 4-6/m^2. Higher density is better and decreasing density is only suggested in case there is a lower than optimum budget. Detail layout of shrub and grass planting can be determined on-site and will follow the following guidelines:

Shrubs in groups of 8-12 plants of same species. Shrub planting at least 4m back from key pedestrian access ways or road edges.

Trees

Vegetation in this area, prior to clearing, consisted of tall forest including cedar. Historical photos show the dense forest and descriptions from early timber cutters confirm this. Oak (Casuarina) was said to be common along waterways as well. Existing vegetation along the Wallamba River is tall wet sclerophyll forest.

Ideally trees will be planted to provide continuous canopy along the water-way. Shade from trees will assist in reducing growth in the water-way. The upper water-way (Section A) has a narrow riparian zone in public ownership and effective canopy planting along here relies on the private property owners agreeing to tree planting within their boundary.

Small and large trees could be planted as a contiguous riparian zone along the water-way. It is recommended that tree planting around Section B – the more open wetland area – is set back from the wetlands to enable sun to reach the water and to provide views into the creek from the road and café.

Photograph of tree loppers (L to R) H. Croker, W. Munro, J. Lulham and Claude Wright posing in front of a tree they're in the process of falling.Courtesy of the late Les Weller's collection

Originally forested with tall forest the area can support significant trees.

The water-ways are the key remaining places with vegetation albeit weed species. Replanting with native species is strongly recommended.

"the whole being second-rate forest thickly timbered, with much oak, pleasant looking enough, but not good grass - the hills gentle and low" William Edward Parry 1830

3.4 Draft Planting Plan

The plan below is indicative and would need to be refined with any changes to the concept plan. Species mixes (A, B, C & D) have been given for each location. Densities are provided for each area in the description of planting recommended. Generally planting is 4 or 6/m^2 with trees being 1tree per 4 or 8m^2.

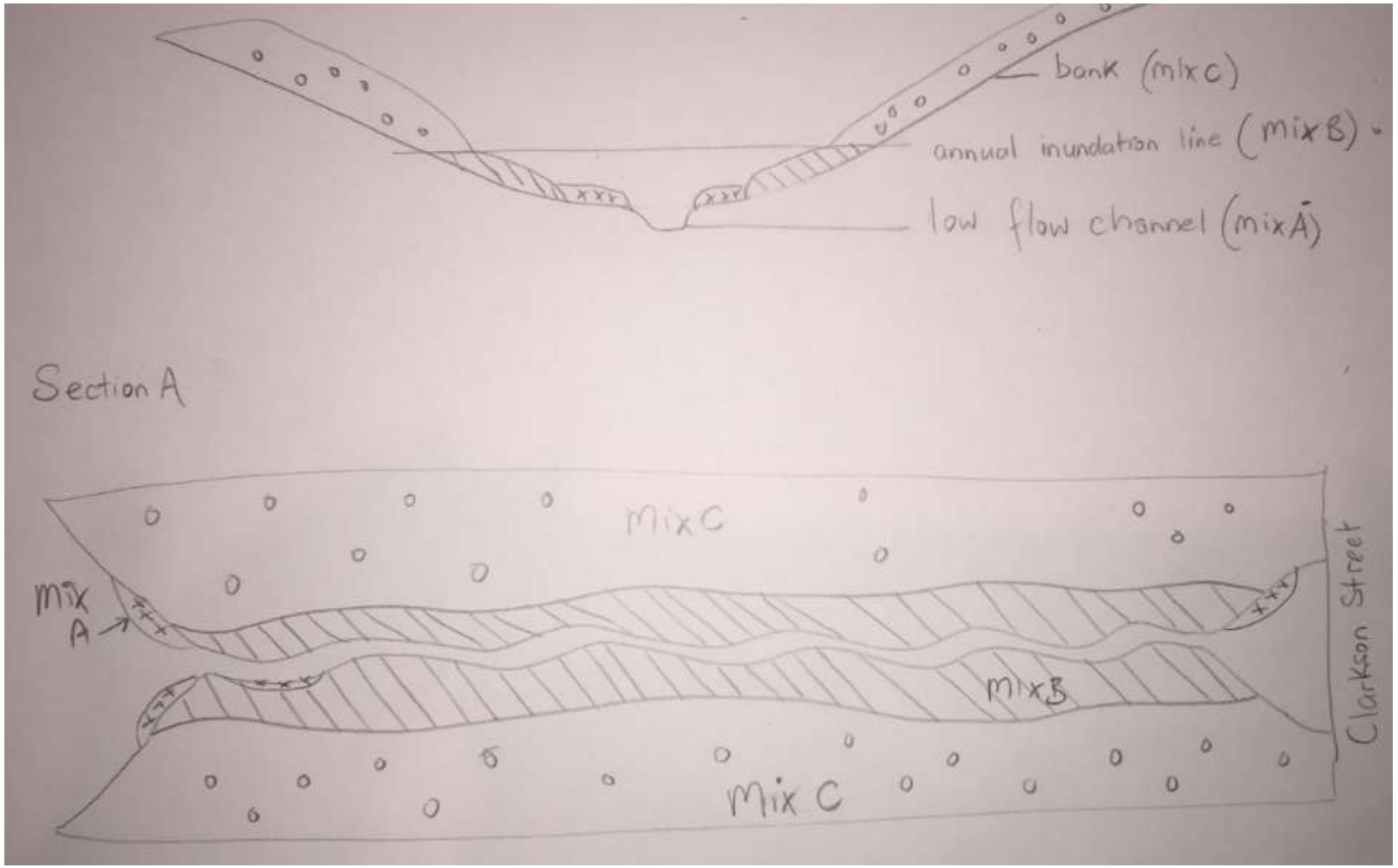


Figure 8A Planting Plan Section A

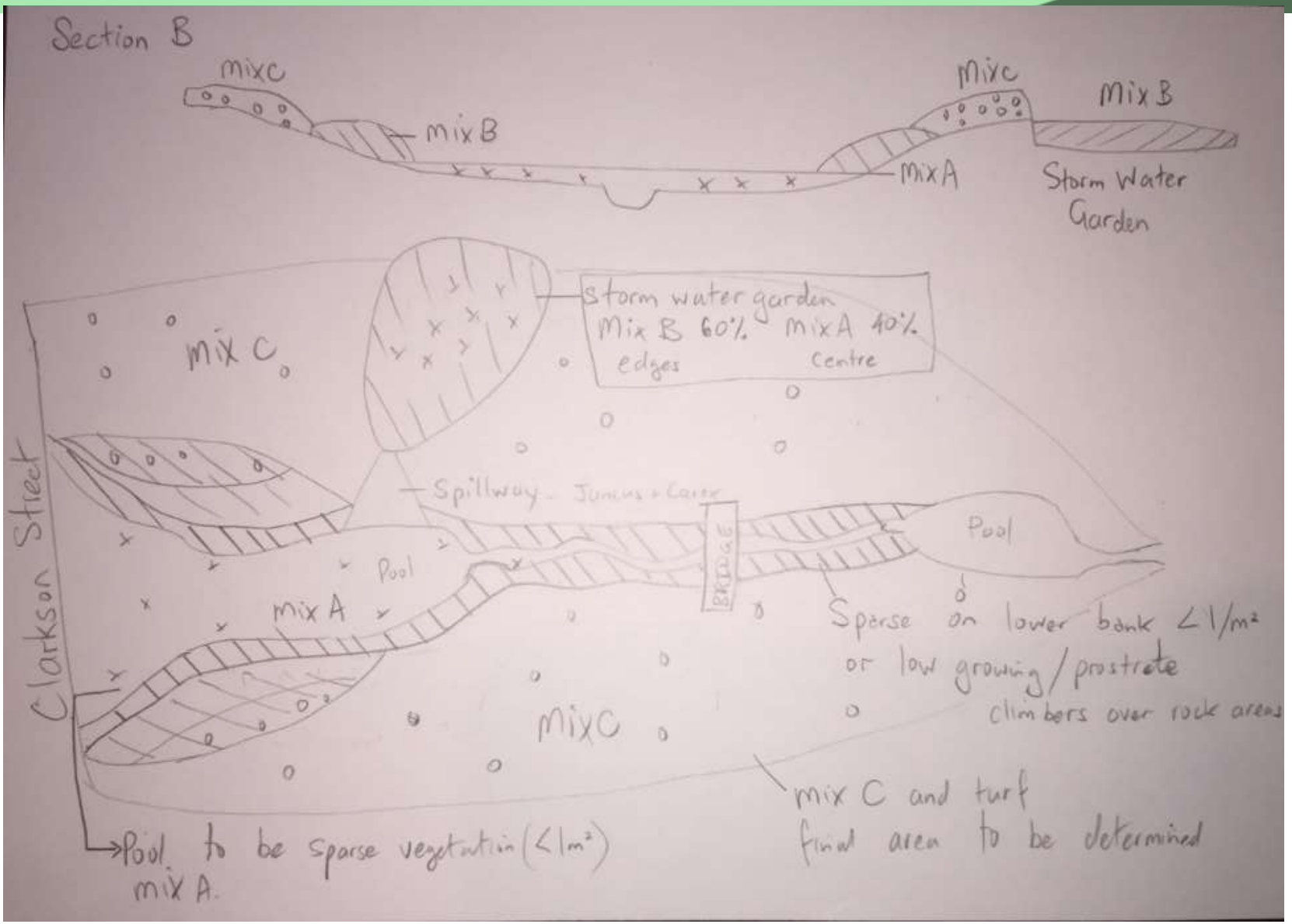


Figure 8B Planting Plan Section B

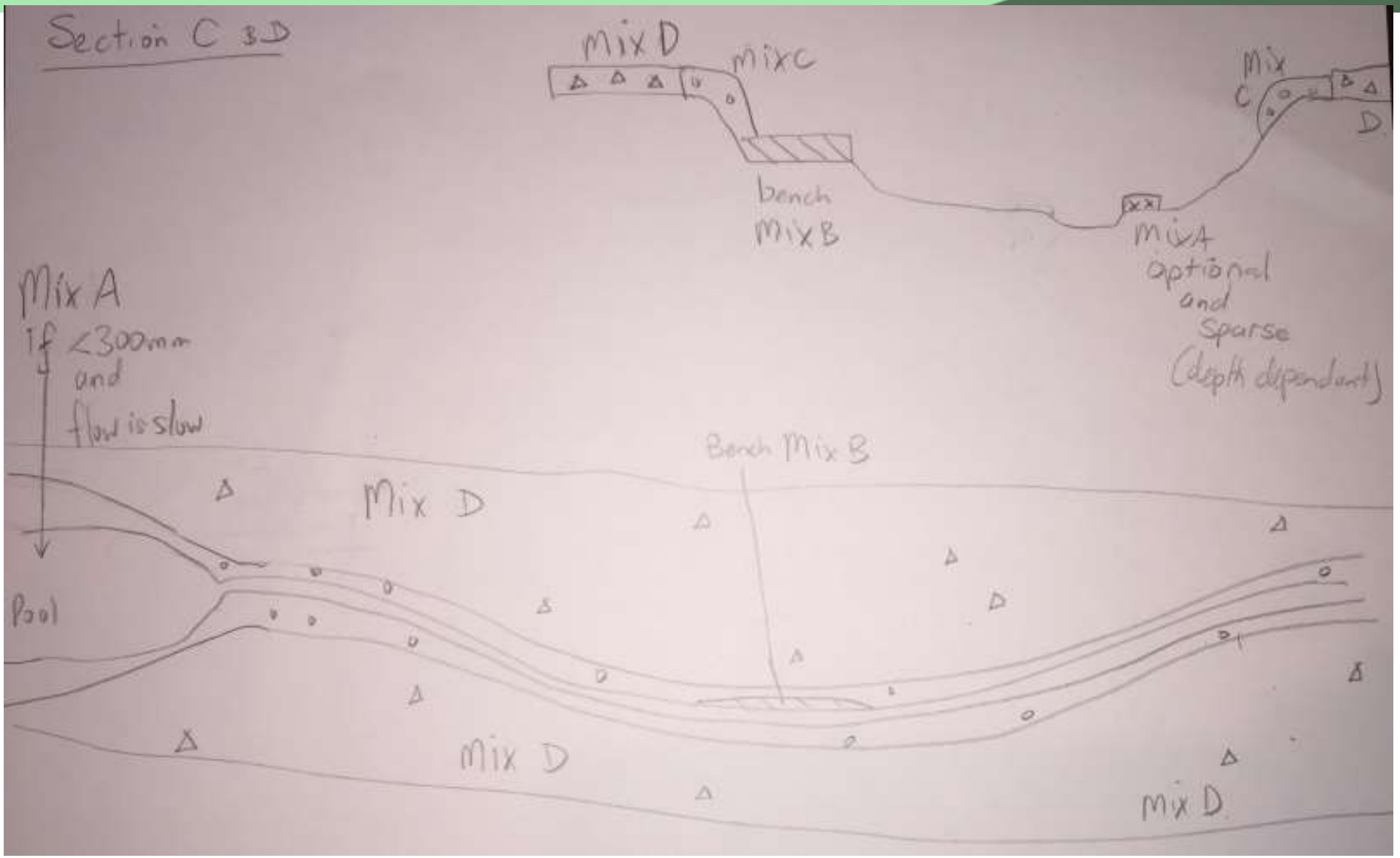


Figure 8C Planting Plan Section C and D

4 Fauna

Appendix III list Threatened and other native species that have been recorded within 10km of the site since 1980. The desk-top study showed 21 Vulnerable or Endangered species listed of those 21 species the Grey-headed Flying-fox and micro-bats could utilise the area. Others such as Bitterns, Owls and small birds could occur in the area after planting works link this and other areas of habitat.

4.1 Fauna and habitat reintroduction – general

Desirable habitat types to create as part of the works are included in the following images and have been included in the design. Following this table are design principles for each of the classes of fauna considered.

Fast running water with dense waterplants Fast running water with very thick vegetation is habitat for species of Damselflies (Common Bluetail Damselflies and Flame-head Sprite)	
	Constructed water-way which has times of fast flowing water through vegetation. This is a realignment of Ourimbah Creek, NSW. Most skimmer dragonflies like to perch on plants with roots in water. Most LIBELLULIDAE can be found in this area, such as the Blue Skimmer, Bog Skimmer and Blue Scarlet. 
Riffles with rocky drops are a specific habtiat type. A suite of macro-invertebrates live in this habitat. Here is a recently constructed riffle section. NB bank vegetation is Juncus and Carex. Above the riffle is a densly vegetated marsh.	

Boggy seepage habitat for dragonflies (Coastal Petaltail), and the damselfly, (Coastal Flatwing), Australian Tiger and Yellow Emperor.

Small areas of l boggy seepage may develop as part of the proposed works. Such as in the rain gardens.

Crevices between rocks provide habitat for skinks and invertebrates.

Running water through rocks this may at times be filled with debris

4.2 Water and wet-edge birds

Chestnut Teal – Male – open water is desirable for this and other duck species.

Buff-banded Rail. Dense edge vegetation and mudflat areas between open water and dense edge vegetation. Safe place for nesting (ground nesters).

Purple Swamp Hen may visit unlikely resident due to small area of open water

Dusky Moorhen unlikely resident due to small area of open water

Golden Headed Cisticola lives in wet vegetation around wetlands. Nest are sewn together with Spider web.

Reed Warblers requires tall reeds at least a few meters thick along open water. Wonderful song. Build nest in reeds.

'Pee Wee' mud nest over hanging open water

Pee Wee or Mud-Lark

Fish and Eels –

RECOMMENDATIONS – FISH AND EELS

- Survey and publish results of local populations of Freshwater Species.
- Conduct fish surveys to assess the effectiveness of the Wolli Creek Fish way and knowledge of the areas aquatic biodiversity
- Invite and facilitate a sharing of information from traditional knowledge holders about the aquatic animals of the river including the fish and eels and their habitats and the life cycles of these species and interactions with other species.
- Construct and or modify infrastructure to be suitable for fish.
- Reduce the impact of stormwater pollution.
- Public and business education and the treatment of stormwater prior to release.
- Protect and Manage riparian, mangrove and Saltmarsh areas.
- Design and manage public areas to include waterway health.
- Consider waterway banks and riparian vegetation in and around these areas.
- Investigate opportunities to fund and implement improvements to fish habitat.
- Research areas for the opportunity for channel reconstruction and improvement.

4.3 Frogs

The following frogs were hear during the survey or recorded for the local area

- Common Eastern Froglet *Crinea signifera*
- Striped Marsh Frog *Limnodynastes peronii*
- Peron's Tree Frog *Litoria peronii*
- Eastern Dwarf Tree Frog *Litoria fallax*
- Bleating Tree Frog *Litoria dentata*

Frog Habitat – breeding and refuge – can be created away from main water bodies and Mosquito Fish

Species such as the Eastern Dwarf Tree-frog *Litoria fallax* lays eggs on vegetation (away from Mosquito Fish).

Frog habitat should be created and protected from Mosquito Fish as far as practical. Creation of frog breeding areas (without Mosquito Fish) and refuges (small piles of logs and rocks) that can be used for over-wintering and /or safe passage between habitats.

Eastern Dwarf Tree Frog *Litoria fallax*

Eastern Dwarf Tree Frog *Litoria fallax*

Summary of Key Actions for Frogs

Create frog habitat away from mosquito fish (both breeding and refuge)

Create areas with no herbicide use along the water's edge

Connect habitat areas with long grasses

Frog habitat training for maintenance staff and other contractors.

Update the Maintenance schedules and methods to include 'frog-friendly' maintenance actions

Plate 8. Frog Habitat Rock Piles

Plate 9. Creating piles – prior to planting

4.4 Reptiles

Suitable habitats for a variety of reptiles are present along this section of Town Creek in Nabiac. The key types of reptiles include:

- Turtles
- Skinks – generalist
- Skinks and Snakes – rock/crevice dependent
- Skinks and Snakes – moisture-dependent
- Skinks–permanent water dependent

Reptiles recorded in the area that could utilise more habitat in the waterway included the following:

- Copper-tailed skink
- Barred-sided skink
- Eastern blue-tongue lizard
- Eastern snake-necked turtle
- Eastern water dragon
- Eastern water skink

Barred-sided skink

The Barred-sided skink *Eulamprus tenuis tenuis* is generally a less common species. It is smaller than many other species – only growing to 16cm. It lives mostly in wet habitats such as rainforests and wet sclerophyll forests

Eastern Blue-Tongue Lizard

The Eastern Blue-tongue Lizard *Tiliqua scincoides scincoides* could live in habitat created as part of the proposed works on Town Creek.

Eastern Water Dragons *Physignathus lesueurii*, grow to about 80 cm long. The pale brown colouring is the normal result of the lizard's old skin lifting slightly before being shed and it was later spotted with her fresh, new skin. Habitat along the creek will be suitable for Water Dragons. Edge vegetation includeing leaf-litter and areas for egg-laying (soft-soil/sand) will facilitate sustainable population of dragons. Image below: young Dragon in leaf-litter.

Rocks along water are prime areas for Water Dragons to warm up. Here a male is on a rock by a creek. If threatened they will dive into the water and swim away or stay underwater.

Eastern Water skink The Eastern Water Skink *Eulamprus quoyii* frequents streams and creeks. It grows to about 25cm long. Habitat requirements are similar to Water Dragons however Water Skinks escape predators by going into rock crevices or similar and these should be provided close to sunning rocks.

Eastern Long-necked Turtle

The Eastern long-Necked Turtle *Chelodina longicollis* a common freshwater turtle. The shell grows to 25-30 cm long. The hatchling shells are about 3cm long and usually black with orange markings. They need water to survive and are usually found in swamps and billabongs, ponds and slow-moving rivers and creeks. Egg laying habitat can be included into the creek works. See below for more on Turtles.

Most turtles living south of the Queensland border hibernate in the winter months. They dig into the mud and can extract oxygen from the water through the skin. In summer, especially after rain, the Eastern Snake-Necked Turtle may migrate overland, for distances of 2 km or more, seeking new waterholes. They can also survive droughts by becoming inactive and conserving water until it rains again. This is called aestivation.

The females are larger than the males. In the breeding season they dig holes above the waterline, about 12 cm deep and lay from 8 to 24 eggs, between late spring and early winter. The hole is covered with fresh earth and pressed down. When the young hatch, 3 to 6 months later, they have to wait for rain before they can dig themselves out. Then they head straight for the water.

Under Threat

Turtles may seem very secure in their armoured shells, but their most vulnerable time is during and straight after egg laying, until the nest site becomes undetectable. Parasites may destroy the eggs before they hatch.

The hatchlings can be easy prey until they grow larger, so they need to be on their guard from eels, snakes, birds of prey or even crows, and mammals such as dogs, cats, foxes and rats.

The future of the Snake-necked Turtles relies on successful breeding and young growing to breeding age and reproducing. While they are a fairly common species on the east coast and live a fair while, females take about 9 years to reach sexual maturity, and fox predation could be limiting new generations. Also as a carnivore and high-ranking predator, these turtles act as a useful indicator of the overall strength of stream life.

Specific Recommendations for Turtles

Awareness raising: A public display of the turtles crossing the road. Culvert to continue to include suitable turtle crossing (as it is now)

Increase Turtle Habitat and safe access in and out of the water. Create and enhance turtle egg laying areas - sandy soils that are easy to dig. Also implement fox management and / or protect egg laying sites (from foxes - they dig up eggs and from trampling by people).

Ensure any silt/sediment or other fencing placed between the waterway and the land has gaps that enable safe Turtle passage.

Summary of Key Actions for Reptiles

Re-introduce logs and other habitat for lizards in and by the water

Enhance habitat for invertebrates (reptile food)

Consider re-introductions of species – possibly from Wildlife Care organisations

Provide Schools and Community education with talks with 'live' reptiles – respectfully and teaching re: how to care for Reptiles in the wild and your gardens.

Community education regarding pet management – particularly the importance of keeping cats indoors or in other enclosed areas.

On-ground management of domestic and feral animals and foxes.

4.5 Birds

A good reference for this project is the review commissioned by Birds In Back Yards *Best Practice Guidelines for Enhancing Urban Bird Habitat Scientific Report* (by Holly Parsons). The guide include 7 general handouts http://www.birdsinbackyards.net/sites/www.birdsinbackyards.net/files/page/attachments/doc_13_guidelines_review.pdf

Key points from that along with the authors and expert community members have been included in the following section.

Birds in Nabiac generally fall into one of the following groups. Within this their habitat needs generally make them fall into 1 of three categories (urban specialist, remnant specialists, and urban generalist).

- Birds – nocturnal
- Birds – small Eucalypt-reliant
- Birds – small granivorous
- Birds – small insectivorous
- Birds – small nectarivorous and insectivorous
- Birds – migrants (winter flowering Eucalypt foragers)
- Birds – freshwater, wetland and reed-bed
- Birds – estuarine
- Birds – shorebirds (local and migratory)
- Birds – small migratory rainforest
- Birds – large migrant nest parasite

4.5.1 Urban Specialists

Urban Specialists – these are birds (usually medium to large bodied omnivores, nectarivores and fruigivores) that are now more common in urbanised environments than in their traditional habitats.

They include the:

- Pied Currawong,
- Australian Magpie,
- Noisy Miner,
- Rainbow Lorikeet,
- Australian White Ibis *Threskiornis molucca* and

- Laughing Kookaburra *Dacelo novaeguineae*.

4.5.2 Remnant Specialists

Remnant Specialists are birds that are found in large remnant areas of vegetation and are largely reliant on these for survival. They occasionally visit urbanised habitats (like suburban gardens) that are located near remnants but are unlikely to ever become residents of urban

habitats given their requirements and the current urban vegetation.

They include smaller insectivorous and nectiviorous species such as:

- Grey Fantail *Rhipidura fuliginosa*,
- Golden Whistler *Pachycephala pectoralis*,
- Eastern Yellow Robin *Eopsaltria australis*,
- Striated Pardalote *Pardalotus striatus*,
- Scarlet Honeyeater *Myzomela sanguinolenta* and
- White-throated Honeyeater *Melithreptus albogularis*

Plate 10. Pardalote Pardalotus striatus in urban garden Photographer: Callum Duffy

Plate 11. Eastern Spinebill Acanthorhynchus tenuirostris Photo: Margaret Leggoe, The Internet Bird Collection (ibc.lynxed.com)

Plate 12. Eastern Yellow Robin Eopsaltria australis, The Internet Bird Collection (ibc.lynxed.com)

Plate 13. Male Variagated Wren Photo Flicker http://www.flickr.com/photos/x

4.5.3 Urban Generalists

Urban Generalists – use both urban and remnant habitats and can survive and thrive in these areas. Urban Generalists are unpredictable in abundance in the urban matrix and, in conjunction with the remnant specialists, are thought to be in decline.

It is for these species within urban habitats (particularly gardens and parks), for which extra efforts must be made to secure their populations.

Species include small insectivorous or nectarivorous species like the:

Plate 14. Superb Fairy-wren, Malurus cyaneus Flicker http://www.flickr.com/photos/

- Superb Fairy-wren, *Malurus cyaneus*
- Male Variegated Wren
- New Holland Honeyeater *Phylidonyris novaehollandiae*, and
- Eastern Spinebill *Acanthorhynchus tenuirostris*

4.5.3.1 Birds Associated with Water

Birds associated with riparian zones such as Town Creek include the Azure Kingfishers and Herons, including Rufus Night Heron and White-necked Heron, and possibly Spoonbills, and Egrets.

Plate 15. Azure Kingfisher. Photo Callum Duffy

Plate 16. Rufus Night Heron. Photo Callum Duffy

Seasonal Birds are those that live in the area for particular months each year. Cuckoos make up a large proportion of the more common Migrants. An example is the Fan-tailed Cuckoo in Australia the species breeds from July to January. They lay one egg in the nest of other birds like fairywrens or thornbills.

Plate 17. Black-faced Cuckoo-shrike Coracina novaehollandiae Photo: Lindsay Hansch The Internet Bird Collection (ibc.lynxed.com)

Plate 18. Channel-billed Cuckoo Scythrops novaehollandiae Photo: Tom Tarrant, The Internet Bird Collection (ibc.lynxed.com)

4.5.3.2 General Recommendations - What All Birds Need

Birds must feel safe in their environment, and while the amount and type might vary greatly, all birds need food and water, shelter and a place to nest, whether that is a dense thicket, tall tree or hollow.

The specifics of these habitat requirements are dependent upon the type of bird, but the guidelines will present generalised assessments of how to remediate urban habitats in order to create a bird-friendly environment (Holly Parsons Birds in Backyards).

4.5.3.3 Protection of remaining natural areas

The protection of remaining natural areas should always be the number one priority for providing bird habitat, but urban habitats have the capacity to support a range of bird species and become important components of the conservation network. Urban habitats also have value as an education tool, encouraging people to connect with the natural world.

Recommend aiming to provide habitat for those native birds that were once common in the urban landscape but are now in decline. Providing structural and plant diversity (preferably using local native species) is fundamental for supplying this habitat. We should be moving away from the traditional garden of tall trees and open lawn which tends to provide habitat for larger, more aggressive and abundant birds.

4.5.3.4 Remnant Vegetation

While we cannot replicate a large, continuous, nature area of vegetation, and therefore cannot encourage all birds into urban habitats, we can create habitat that can be used by a wide variety of native birds. While preserving and enhancing the remaining natural vegetation and riparian habitats in urban areas is paramount, they should be coupled with the development of a series of corridors connecting these patches throughout the urban matrix. Remediation efforts should be done slowly, and completed over a long time period in order to minimise disturbances to the birds already present and provide them with ongoing habitat. The value of exotic vegetation, including weed species, for birds should be recognised and removal only conducted after new plantings become established.

4.5.3.5 Public Parks and Gardens

The value of suburban parks, streetscapes and gardens for providing bird habitat must also not be underestimated. However, the development of suitable habitat that provides a diverse range of structures and different species needs to occur at the landscape scale rather than the individual garden scale. Still, in order to change the culture of gardening in Australia and initiate the necessary landscape scale changes, individual residents should be encouraged to make their gardens birdfriendly.

4.5.3.6 Private Gardens and Developments

The more residents that create these gardens, the better the neighbourhood will be for birds.

Best Practice Guidelines for Enhancing Urban Bird Habitat 2. The provision of bird baths and nest boxes in a garden can prove not only valuable for the birds, but a great way to educate homeowners, as long as usage by introduced species is monitored, and hygienic practices are followed.

4.5.3.7 What to Plant and where to plant it?

In order to maximise bird diversity within a habitat, regardless of whether it is remnant bushland, park or garden, selecting native vegetation (preferably local to the area) and creating habitat with a ***high degree of structural complexity (at the ground, shrub and canopy levels)*** is recommended as this is the most effective way to imitate many undisturbed habitats.

Local vegetation (native plant species that occur traditionally in the area) is usually best suited to the soil and climatic conditions at the site and therefore is likely to establish relatively easily. Creating patchiness in areas with open space as well as dense shrubby areas provides a range of different microhabitats that a variety of birds can use.

Some plants to avoid are the hybridised Grevilleas – the watery abundant nectar favours the urban specialists (and bully birds) by providing abundant food so they can establish fixed territories which they then defend and drive off all other birds – birds such as Blue Wren and other small birds will be uncommon here.

Bird Type	Food Source	Habitat Preference
Large Nectarivores (nectar feeders) Honeyeaters and some parrots e.g. Noisy Miners, Red and Little Wattlebirds, Rainbow and Scaly-breasted Lorikeets	*Banksia, Callistemon* (Bottlebrush), *Eucalyptus, Grevillea, Hakea, Melaleuca* (Paperbark)	Shrubs and trees for foraging, perching and nesting Some require hollows for nesting
Small Nectarivores Honeyeaters e.g. Eastern Spinebill, New Holland Honeyeater, Brown Honeyeater	*Banksia, Callistemon* (Bottlebrush), *Eucalyptus, Grevillea, Hakea, Melaleuca* (Paperbark), *Epacris, Correa*	Spend most time foraging and perching in shrubs but also use trees. Generally nest in dense shrubs
Granivores (Seed Eaters) Parrots, finches and pigeons e.g. Eastern Rosella, Pale-headed Rosella, Galah, Sulphur-Crested Cockatoo, Common Bronzewing, Red-Browed Finch, Double-Barred Finch, Chestnut-breasted Manikin	Trees and shrubs: *Acacia* (wattle), *Casuarina* (she-oak), *Leptospermum* (tea-tree) Grasses: *Lomandra, Themeda, Poa*	Utilise shrubs and trees for perching, nesting and foraging but also forage on mature grasses
Frugivores (fruit eaters) Pigeons and cuckoos e.g. Wonga Pigeon, Common Koel, Silvereye, Satin Bowerbird	*Ficus* (figs), *Syzygium* (Lillipillies), *Eleocarpus* (Quandong)	Shrubs and trees important habitat
Insectivores e.g. Superb Fairy-wren, Eastern Yellow Robin, Spotted and Striated Pardalotes, Willie Wagtail	Insects and other invertebrates either on the bark and foliage of shrubs and trees or on the ground	Dense shrubs important for protection and nest sites as well as some open areas for foraging
Carnivores (Meat Eaters) e.g. All species of Currawongs, Laughing Kookaburra, Grey and Pied Butcherbirds, Powerful Owl, Black-shouldered Kite, Peregrine Falcon	Other birds, reptiles, frogs, mammals, invertebrates	Tall trees for perching, roosting and nesting. Some require hollows for nesting

Source: *Best Practice Guidelines for Enhancing Urban Bird Habitat Scientific Report* (by Holly Parsons).

Planting Selection and Design Recommendations Summary for Nabiac Town Creek

General recommendations for plant selection are:

• Do not remove vegetation, particularly native, from a site, but add plants where needed

• Remove weeds only after the establishment of replacement local native Species

• Use only local native plants for revegetation

• Use layers of vegetation to create a structurally diverse habitat

• Create a dense understorey of shrubs to provide essential habitat for small birds

• Create patchiness to provide a range of microhabitats

• Establish a diversity of species in each layer to increase the resilience of the plant community in the future and increase diversity of foraging opportunities for birds and their food sources.

4.5.3.8 Cats

The impact of cats is high in suburban gardens close to remnants. It is recommend that households use cat runs or keep cats indoors, not only for the safety of wildlife but also for the cats themselves. Papers showing the impact of Cats (including domestic) on urban native birds are numerous – all showing there is a negative impact.

4.5.3.9 Feeding

Feeding birds should not be encouraged, especially of carnivores, as this can result in an over-abundance of a few more aggressive species which dominate, and may result in a loss of smaller species. Instead, emphasis should be placed on creating a bird-friendly garden through planting.

It is recognised that for many people, feeding birds is the only contact they have with wildlife and it can therefore be an important part of their wellbeing. In this case, feeding areas must be kept clean and only good quality seed or nectar mix should be provided. Some artificial foods can spread disease and are nutritionally poor.

4.5.3.10 Fragmentation: The Noisy Miner Effect

The nature of a disturbed urban habitat means that fragmentation-specialist species (both native and non-native) are very successful colonisers of this habitat. Throughout the guidelines we will refer to the impact that Noisy Miners (Manorina melanocephala) are having on bird assemblages as a result of their aggressive exclusion of other bird species.

This colonial honeyeater species is increasing in abundance, with a 15% increase in reporting rates in NSW documented by Birds Australia volunteers in 1998-2001 compared to 1977-1981, and a 10% increase nationally.

While traditionally living in eucalypt woodlands and forests, particularly along their edges where there is little understorey and an open canopy. Noisy Miners ability of this species to aggressively exclude small birds from their territories has been well documented, particularly in

rural and woodland settings. A Birds in Backyards survey conducted throughout Greater Sydney in 2000 found that gardens that had Noisy Miners were less likely to have any of seven small bird species abundant elsewhere.

Noisy Miners tend to occur in higher densities in fragmented habitats with a thin canopy, little understorey and a high proportion of eucalypt trees. There have also been suggestions that high nectar-producing Australian cultivar shrubs (especially Grevilleas) have promoted their dominance in urban areas.

Following are recommendations on how to create habitats undesirable for Noisy Miners in an attempt to minimise their impact.

- Avoid having trees with just a grassy understory (plant shrubs under trees)
- Avoid and remove hybrid grevilleas.

4.5.4 Birds of Prey

Birds of Prey in Great Lakes area are chiefly Owls and Raptors (Falcons, Kites, Eagles, and Hawks). A diversity of prey species indicates adequate food, foraging and breeding areas. Area management has to include the retention of both the physical habitat and prey food.

4.5.5 Goals for restoring bird habitat in urban areas

Plate 20. Black-shouldered Kite. Photo Gavin Gatenby

Plate 21. Brown Goshawk Photo Gavin Gatenby

Plate 22. Boo Book Owl –. Photo Sam Jones

Plate 23. Owl – "what I want to see when I grow up"

The following is a summary of the recommendations from the extensive research on urban birds in NSW (Holly parsons). The recommendations here are directly applicable to Great Lakes local government area due to both the existing habitat areas, the bird species presents, the opportunities for improving bird habitat and the already established excellent bird interest / expert groups.

The Birds in Backyards Program believes that in order to conserve urban wildlife habitat we need to promote interactions between people and wildlife and foster awareness of environmental values which will lead to behavior sympathetic to the conservation of biodiversity. Some examples of objectives/goals, for which implementation details will be provided in the next section of this report, include:

1) Improving the habitat value of areas of community land. These larger 'green' spaces have the potential to support a range of bird species, although many will require remediation in order to provide high quality habitat.

Planting with a diverse range of local native species, weeding (cautiously and slowly), allowing some grassed areas to grow (to provide seed for granivores where they are members of the bird community) and creating structural diversity, are some ways to create good bird habitat. While these areas may never be suitable for breeding, they are important to provide habitat for migratory or non-sedentary species, especially in the wake of catastrophic events, such as bushfires.

2) Building the landscape-level ecological function of a vegetation remnant. Rebuilding linkages between high-quality bushland remnants, and other patches of vegetation scattered throughout cities by:

(a) restoring riparian and other corridors.

(b) targeting private gardens along potential linkages to create extensive corridors.

(c) improving permeability of edges by planting rather than using solid fences to allow birds to better access urban areas.

Such corridor linkages may also have a critical role in response to predicted climate change.

3) Community education

Community awareness about biodiversity issues can often be enhanced by focusing on well-known species that are in decline and developing aims for conservation of locally iconic species. Creating community interest is necessary to ensure the long-term success of remediation efforts.

4.6 Bird Habitat and Town-Creek

Bird habitat is currently poor along much of the length. Small birds, including Blue Wrens are living in the weedy section west of the main road. The Key features indicating the health of a site, and therefore the amount of remediation needed include:

- The extent and quality of native vegetation available including the diversity and abundance
- The structural complexity of the vegetation. More layers available such as leaf litter, fallen logs, understorey and canopy suggest that more wildlife will be able to live within it
- The type of pollination and dispersal mechanisms required by the plants (persistence and ease of the pollination of flowers or the spread of seeds as well as the use as food sources for fauna)
- Weed types and degree of infestation
- Current and past land use as well as disturbance and fire history
- Presence of other disturbances both within the site and adjacent to it
- Habitat elements of whole of life cycle e.g. hollows for breeding.

When trees grow it is recommended to add nest-boxes to speed the process of providing suitable bird habitat.

Plate 24. Installing Nest Hollow 'Box' and photo by Gavin Gatenby

Plate 25. Nest Hollow 'Box' and photo by Gavin Gatenby

4.6.1 Overcoming Traditional Concerns Regarding Understory Planting and Maintenance

Traditional issues concerning the difficultly to maintain these areas or the aesthetics can be overcome by a variety of means including:

- Managing all weeds (including exotic grass) in the area prior to planting.
- Planting at high density (min 6 per m^2)
- Planting appropriate species (detail will be provided by ECA)
- Ensuring high success of planting (either get it done by professional 'mass-planting contractors' or have contractors drill good sized holes for volunteers.
- Ensure adequate supply of water for the establishment phase (preferable with water to each plant rather than broad spraying water). In small areas this could be via Volunteers in larger areas temporary drip irrigation is recommended. Along with planting in the appropriate seasons.
- Installing low-cost barriers between the plated areas and the turf. Such as garden edging that is dug into the ground to slow grass runners growing into the plated area.
- Changing staff culture within the parks and gardens teams via training as new placements are made so that they appreciate the reasons for having the areas of native vegetation and what is required of their work in those areas.
- Have planted areas maintained by professional bushregenerators and or volunteers supported by contractors during the plant establishment time.
- Include picture based interpretative signage showing what it was like and what is expected with photos of the birds expected to return or expand into those areas.
- Community education – this includes having positive and clear information on Council's web-site and training Council's front counter people so they can answer community concerns about long-grass, snakes, spiders, messy looking etc.
- Community education Schools – work with Schools so that they can create habitat gardens on their sites or at a near-by public park (these have been identified in the Mapping – see Category 5). Build upon the existing education resources so that it is easy for teachers to provide the theory and practical experience of appreciating and creating bird habitats at the same time as fulfilling core syllabus requirements (examples include Two Valley Trail Educational Resources http://www.wollicreek.org.au/tvt_schools/ developed by an alliance of local environmental organisations and the LLS.

4.7 Monitoring - The Value of Bird Surveys

Birds are particularly good as environmental indicators because they:

• live in almost every type of environment in Australia and occupy many different niches

• are often at the top of the food-chain and are therefore very vulnerable to accumulating chemicals

• have representatives that depend on the full range of animal and plant diets

• are easy to see and observe

• are already relatively well-known and documented, providing a good baseline against which change can easily be monitored (Parsons – Birds in Backyards)

The Atlas of Australian Birds – Specific details about the aims of the atlas can be found here: http://www.birdsaustralia.com.au/atlas/index.html.

This is usually recommended for people with some prior experience in bird watching, although pairing experienced with inexperienced birdwatchers for surveys can quickly educate participants. There are two survey methods used for Atlas data and both of these methods are commonly used in scientific studies.

The 2 ha area search involves walking a 2 ha area for 20 minutes and recording all birds seen during this time. The area search is more flexible than the 2 ha search as it involves listing all the birds seen around a central point, with the area searched being any shape. A minimum search time of 20 minutes is required and must be consistent for each of the surveys conducted at the site. Standard urban blocks could be searched using this method.

• Birds in Backyards Surveys – These are primarily designed for surveying suburban gardens but can be used to survey vegetation remnants. Because the survey method includes lists of bird species with accompanying photos and calls and are quick and easy to complete, they are more appropriate for novice bird watchers and are a good place to start. There is a range of bird surveys that can be completed and submitted online, ranging from incidental sightings of migrant visitors (such as the Common Koel, *Eudynamys scolopacea*, or Channel-billed Cuckoo*, Scythrops novaehollandiae*) through to week-long surveys of all birds visiting a garden. Details about these surveys and their methodologies can be found here: http://www.birdsinbackyards.net/surveys/index.cfm.

Results of these surveys are also available online and are regularly updated.

Professional bird surveys are also important. Councils are now engaging ecologists to conduct ongoing wildlife monitoring to measure biodiversity values over time in their local government areas.

Summary of Key Planning Actions for Birds

Linking existing patches with corridors and islands

Planting buffers to increase size and resilience of patches

Including layers of habitat – ground, mid and upper foraging areas

Maintaining existing small foraging areas

Habitat Gardens and Linkages of patches

Feral and Domestic Animals Management

Bringing Back the Blue Wren – project - this is about increasing abundance of existing populations and expanding their range.

Tree Plan needed including the keeping and /or replace seed bearing trees (Pine for She Oaks) as these are important Cockatoo Food.

Summary of Key On-ground Actions for Birds

Plant out areas between existing patches to link them

Plant buffers around existing patches

Plant gardens using bird friendly species and plants of different heights

Install educational/ interpretive signs beside bird habitat areas

Keeping and /or replace seed bearing trees (Pines for She Oaks)

4.7.1 Mammals

Mammal diversity is low however the species that could be present would be of high important including the Threatened Grey-headed Flying Fox and threatened microbats. While native ground mammals like Bandicoot and Antechinus were not observe or recently recorded suitable habitat could be re-created. The key limiting factor for these species once habitat is created is likely to be predation by foxes and feral and domestic cats.

4.7.1.1 Flying Foxes

Fruit Bats, of Flying Foxes, are Australia's only native, flying mammals. They play an important role in pollinating our forest trees.

Plate 26. Young Flying Fox in care nending rehydration 2013 heat wave. Photo Sonja Earlwood

Plate 27. Flying Fox drinking on hot day 2013 Photo Gavin Gatenby

4.7.1.2 Arboreal Mammals

Both common species of possum could utilise habitat along the riparian corridor. No evidence of them was seen during the survey however they are expected in the area. Ring-tails could make dreys (nests) in the privet and other weeds. Dreys can be constructed for Ring-tails and boxes installed for Brush-tails. This could occur after weed removal and planting. Weed trees can be killed and left in-sit-u and the truck used for installation of micro-bat, bird and possum boxes.

4.7.2 Native ground mammals for possible reintroduction

Plate 28. Brush-tail Possums

Plate 29. Ring-tail Possum

4.7.2.1 Native Bush Rats and Introduced Black Rats

Plate 30. Antechinus (from Colongra Reserve near Wyong)

Plate 31. Bush-Rat Rattus fuscipes (Bogul) Photo Lorraine Phelan

Plate 32. Swamp Rat Rattus lutreolus Photo: Max Cambell

Plate 33. Long-nosed Bandicoot Photo: C & D Frith

A good summary of the issues and recommendations associated with introduced and native ground mammals see the Catalyst article. The research suggests the native bush rat may be capable of holding its own against the invader — the European Black Rat — when in its native bush habitat.
http://www.abc.net.au/catalyst/stories/2981267.htm

A great pictorial summary poster has been put together by Rockdale Council
http://www.rockdale.nsw.gov.au/animals/Pages/pdf/Animals/a_rat_brochure.pdf

Summary of Key Planning and On-ground Actions for Mammals

Feral and Domestic Animals Management

Linking existing patches with corridors and islands and planting buffers to increase size and resilience of patches including layers of habitat – ground, mid and upper

No barbed wire

Install educational/ interpretive signs beside habitat areas

Install habitat boxes and monitor their use including for: arboreal mammals and micro-bats. Also plant and retain dense shrubs and other Ring-tail Possum 'dray' habitat.

Habitat reinstatement to support re-introduction or natural colonisation by ground mammals.

Effective management and community education about domestic and feral animals.

5 Appendix I – Recommended plant species

Following tables summaries plants species for works associated with proposed flood management at Town Creek Nabiac. Lists are aimed to be used in conjunction to plans for proposed works (see Plans June 2016). Table 6 has terrestrial plants. Table 7 has Waterplants for wet areas and edges. It is noted that addition terrestrial plants for the riparian zone will be provided and this table updated accordingly.

Table 1. Recommended terrestrial plant species for planting in **Species Mix C and D.**

Species Name	Species Mix	Type	Image	Outer banks inc private lands	U	M	L	Comments
Desmodium brachypodum	C, D	Climbing herb			-	-	Y	Good butterfly foraging habitat. Plant on outer (sunny edge) of riparian zone. Plant sparingly as this will cover other plants. Plant after 2 years establishment of other species
Desmodium rhytidophyllum	C, D	Climbing herb or trailing shrub					Y	
Cheilanthes sieberi	D	Fern		Y		Y	Y	In shaded areas and around rocks
Aristida warburgii	C, D	Grass		Y				Sunny areas

Species Name	Species Mix	Type	Image	Outer banks inc private lands	U	M	L	Comments
Cymbopogon refractus	C	Grass		Y				Sunny areas
Dichondra repens	C	Grass		Y				Sunny areas
Echinopogon ovatus	C	Grass		Y				Sunny areas
Entolasia marginata	C, D	Grass		Y				Sunny areas
Centella asiatica	C, D	Ground cover		Y	Y	Y	Y	Sunny and shared and among rocks areas
Coldenia procumbens	C	Ground cover 		Y	Y	Y		Sunny area – like around proposed seating. Butterfly food plant
Dianella caerulea Sims var. caerulea	C, D	Ground plant		Y	Y	Y	Y	Sunny and shared and among rocks areas
Cyclophyllum longipetalum	D	Orchid				Y	Y	May come when restoration works are

Species Name	Species Mix	Type	Image	Outer banks inc private lands	U	M	L	Comments
Dendrobium lichenastrum f. aurantiacopurpureum	D	Orchid						complete – could add if obtained from licenced supplier. Do when primary native trees have established.
Desmodium sp.	D	Orchid						
Acacia longifolia	C, D	Shrub		Y	Y	Y	Y	Suitable on banks and among rocks in any section. Good coloniser – expect 5-7 years. Plant with other species to provide shade while they grow (such as *Elattostachys microcarpa*). Long-term vision remove from lower and middle sections.
Acacia myrtifolia Wattle	C, D	Shrub		Y	Y	Y	Y	Suitable on banks and among rocks in any section.
Billardiera scandens	C, D	Shrub		Y	Y	Y	Y	Suitable on banks and among rocks in any section.

Species Name	Species Mix	Type	Image	Outer banks inc private lands	U	M	L	Comments
Breynia oblongifolia Breynia	C, D	Shrub		Y	Y	Y	Y	Suitable on banks and among rocks in any section.
Bursaria spinosa	C, D	Shrub		Y	Y	Y	Y	Suitable on banks and among rocks in any section.
Eremophila maculata Butterfly Bush	C, D	Shrub		Y	Y	Y	Y	Suitable on banks and among rocks in any section.
Eriostemon banksii	C, D	Shrub		Y	Y	Y	Y	Suitable on banks and among rocks in any section.
Acacia floribunda Wattle	C, D	Small Tree		Y		Y	Y	Dense foliage – suitable for grassed areas in public and private lands and banks of water-way.
Cupaniopsis newmanii	C, D	Small Tree		Y		Y	Y	Usually grows in shaded conditions. Ideal in mid-story of riparian zone.

Species Name	Species Mix	Type	Image	Outer banks inc private lands	U	M	L	Comments
Melaleuca linariifolia Tea-tree	C, D	Small Tree		Y		Y	Y	Dense foliage – suitable for grassed areas in public and private lands and banks of water-way.
Casuarina glauca Swamp Oak	C, D	Tree		Y			Y	Grows well along the water-way. Common species upstream. Suggest limited planting and plant in patches. Expect suckering.
Corymbia intermedia Pink Bloodwood	C, D	Tree		Y	Y	Y	Y	Tall tree – suitable for grassed areas in public and private lands and banks of water-way.
Eucalyptus microcorys Tallowood	C, D	Tree		Y	Y	Y	Y	Tall tree – suitable for grassed areas in public and private lands and banks of water-way.

Species Name	Species Mix	Type	Image	Outer banks inc private lands	U	M	L	Comments
Elattostachys microcarpa Scrub Tamarind	C, D	Tree 4–10 m		Y		Y	Y	Usually grows in shaded conditions. Ideal in mid-story of riparian zone.

Terrestrial Species Source: Office of Environment and Heritage, New South Wales - NABIAC Vegetation Survey: VIS flora survey module (LINK).

The NABIAC Vegetation Survey is part of the Vegetation Information System Survey Program of New South Wales which is a series of systematic vegetation surveys conducted across the state between 1970 and the present.

Table 2. Recommended aquatic plant species for planting Mixes A and B.

Species	Common Name	Form	Height (m)	Description	Density /m2 (50ml)	Comment	Mix	Priority
Edge								
Dianella caerulea	Blue Flax Lily	edge plant – above the permanently wet zone	0.5-1.0	Perennial Herb forming dense stands. Purple Flowers and Berries (edible).	4 to 6	Mass plant on upper banks along edge between mown areas and riparian zone.	Mix B	XXX
Lomandra longifolia var longifolia	Spiny Headed Matt Rush	edge plant – above the permanently wet zone	0.5-1.0	Large Tussock. Produces many seeds – seeds eaten by small birds.	4 to 6	Get local stock (not QLD)	Mix B	XXX
Ficinia nodosa (Previous name *Isolepsis nodosa*)	Knobby Club Rush	edge plant	0.5-1.5	Tall, coarse wiry & densely tufted perennial rush with creeping rhizomes. Produces seed heads that are little brown balls – one on each 'stem'.	6 to 8	Not locally native in this area. Hardy and not invasive. Only use if needed – otherwise stay with locally native species.	Mix B	X
Wet-Dry zone								
Baumea juncea	Bare Twig Rush	emergent macrophyte	0.3-1.0	Rush with creeping rhizomes	6	Not locally common but in the region. Low	Mix B	X

Species	Common Name	Form	Height (m)	Description	Density /m2 (50ml)	Comment	Mix	Priority
						water resistance. Suitable for wet/dry/damp areas in upper section. Some shade tolerance.		
Carex appressa	Tall Sedge	emergent macrophyte	0.5-1.0	Dense, robust & tough sedge. Produces abundant seed eaten by small birds.	4 to 6	Mass plant on banks wet-edge	Mix B	XXX
Carex fascicularis	Tassel Sedge	emergent macrophyte	0.5-1	Dense, robust & tough sedge. Produces abundant seed eaten by small birds.	4 to 6	Mass plant on banks wet-edge	Mix B	XX
Ghania siberiana	Red Fruited Saw Sedge	emergent macrophyte	1.5-3.0	Clumping perennial sedge. Produces abundant seed eaten by small birds. Tall black seed heads with shiny bright red, small seeds.	4	Mass plant on upper banks in clumps NB TALL	Mix B	XX
Juncus pallidus	Rush	emergent macrophyte	0.5-1.2	Rhizomatous tufted perennial rush	6 to 8	Mass plant on banks wet-edge and in shallows. Low water resistance	Mix B	X

Species	Common Name	Form	Height (m)	Description	Density /m2 (50ml)	Comment	Mix	Priority
Juncus usitatus	Rush	emergent macrophyte	0.3-1.2	Rhizomatous tufted perennial rush	6 to 8	Mass plant on banks wet-edge and in shallows. Low water resistance	Mix A, B	XXX
Persicaria decipiens	Slender Knotweed	Wet edge	prostrate - 0.6	Spreading annual herb	2 to 4	**Usually comes by itself** – good sprawling plant for low-flow conditions. Low water resistance so suitable for upper section.	Mix B	X
Marsh – still water - shallow								
Philydrum lanuginosum	Frogs Mouth	emergent macrophyte	0.3-0.6	Erect perennial	6 to 8	Low water resistance	Mix A	X
Schoenoplectus mucronatus	Club Rush	emergent macrophyte	0.3-0.6	Robust tufted rhizomatous herb	4 to 6	Low water resistance. Suitable for wet areas in upper section.	Mix A, B	XX
Triglochin procerum	Water Ribbon	emergent macrophyte	0.2-0.5	Aquatic perennial herb with erect or floating leaves	4 to 6	Low water resistance	Mix A	X

Species	Common Name	Form	Height (m)	Description	Density /m2 (50ml)	Comment	Mix	Priority
Cyperus exaltatus	Giant Sedge	emergent macrophyte	Up to 2m generally 1m	Grows in the wet-edge. Tussock-forming perennial.	4 to 6	Low water resistance	Mix A	X
Marsh – flowing or still								
Baumea articulata	Jointed Twig Rush	emergent macrophyte	1.0-2.0	Tall erect rhizomatus rush. Evergreen, robust and hardy. Bird nesting habitat. Small birds and Swamp Hens. This species should dominate the planting in terms of overall numbers of plants.	4 to 6	Moderate resistance to water flows. Too strong for upper channel	Mix A, B	XXX
Bolboschoenus caldwellii	Sea Club Rush	emergent macrophyte	0.3-0.9	Aquatic rhizomatous – **winter dormancy.** Underground bulbs favoured food of swans.	4 to 6	If saline – can use this species see also B.c Use this species if salinity is an issue	Mix A	X
*Bolboschoenus fluviatalis**	Club Rush	emergent macrophyte	1.0-2.0	Aquatic rhizomatous – **winter dormancy.** Underground bulbs favoured food of swans	4 to 6	Moderate resistance to water flows	Mix A	X

Species	Common Name	Form	Height (m)	Description	Density /m2 (50ml)	Comment	Mix	Priority
Schoenoplectus validus	River Club Rush	emergent macrophyte	0.5-2.0	Robust tufted rhizomatous perennial. Can get a rust that results in the clump dying off so plant but not in large swathes of the one species.	4	Allows high flows to push it over.	Mix A	XX
Marsh - Deep								
Lepironia articulata	Twig Rush	emergent macrophyte	0.4-2.5	Rhizomatus tufted perennial rush. Blue-grey coloured stems – stands straight even in shallow water. Habitat for small birds to nest in.	6	Very tuff and will limit water-flow. Great bank stabiliser and bird habitat	Not listed but may be used to stabalise – edges – will grow in deep water	X
Cladium procerum	Cladium	emergent macrophyte	1–2.5	Robust sedge forming strong, dense, large clumps. Bright Green. Great habitat for small birds to nest in and feed off the abundant seed.	6	Very tuff and will limit water-flow. Great bank stabiliser and bird habitat.	Not listed but may be used to stabalise – edges.	X

Species	Common Name	Form	Height (m)	Description	Density /m2 (50ml)	Comment	Mix	Priority
Eleocharis sphacelata	Tall Spike Rush	emergent macrophyte	0.5-2.0	Perennial rush with thick woody rhizome, clumps to big dense stands. Underground stem sections favoured food of swans. Above ground stems are soft and may lay over when in shallow water.	6	Only good in still to slow water. Good in deep pools – will cope with periodic high-flows.	Not listed but may be in deep slow water	X

6 Appendix II – Habitat types

The follow table has the key of Habitat types**.** The text gives specifications for each of these habitat features. It is noted that there is flexibility between what has to occur on-ground and what is specified here as the habitat features. **Habitat Features can be altered to fit the design constraints and availability of materials (such as logs).** Key elements of the habitat features must be retained for them to be function so it is advisable that changes are 'approved' by an ecologist in council prior to finalising on-ground works.

Table 1. Key habitat types and features.

Key	Habitat	Summary Description
H1	Logs	Logs are used for two habitat features – i) by themselves and ii) as part of Frog Habitat Piles. This section covers Logs by themselves. Materials: Logs are to be from trees other than Coral trees – preferably Native Hardwoods that have been cured (cut/died more than 6 months ago). Size: Logs can be any size greater than 1.5m in length and 400mm in diameter. The limit on size is only dictated by the space available on site and access / cost to deliver very large logs. Logs can be hollow or complete. Hollow with crevices etc is preferable. Location: Logs are to be placed in the zones that are part wet / part dry. In areas where flows are expected logs are to be keyed into bank (secured) so that they cannot wash away or move. Logs can be placed singularly or in groups. NB comments relating to where logs should be groups are given on the plans.
H2	Bird/Possum/Micro-bat/ Native Bee Homes	Materials: All boxes are to be equal to the designs in *The Nest Box Book* (see extract in Appendix). Size: Boxes can be any size providing they include a minimum of: 6 microbat boxes, 2 Large Cockatoo boxes, 2 Ring-tail Possum "Drays", 2 small bird boxes. Plus the 3+ Native Bee hives. At least 16 habitat boxes are to be installed on the site with 4 in the Location: Nest boxes are to be installed in larger trees or where no large trees present then on vertical poles. Boxes are to be a minimum of 3m off the ground and preferably over 5m above the ground.

Key	Habitat	Summary Description
H3	Exposed rock – Lizard Lounges	Materials: Lizard Lounges – these are low piles of rock with gaps and piping (e.g. terracotta pipes) they can also have logs in the pile. The materials are to be arranged in a way the maximises habitat for Lizards – that is sunning areas, crevices, spaces deep under the pile for predator protection and adjoining ground cover for protection when moving between habitat areas. Terracotta (or other) pipe should also be included in and adjoining the pile as this is excellent habitat for Blue Tongue Lizards. Size: The size of the Lizard Lounge can be varied to suite specific locations but each has to be a minimum of 5 rocks, 1 log and 3 pipes. The arrangement is to create a minimum of 2 layers of rock in each pile. Each pile is to have a minimum diameter of 1.5m and at least 20 'holes' ranging in size from 10mm to 50mm. Location: At least 1m upslope for predicted water edge. Individual rocks will be in/adjoining water for water lizards (see below). Lizard lounges should be in areas that get sun at least a few hours per day – more the better.
H4	Rock	Rock is specified for use throughout habitat areas. Rocks are used to direct water, create riffles and provide exposed surfaces (islands) within the flowing water. Material: Rocks are preferably Sydney sandstone. Size: Individual, large (300- 500mm) rocks. Location: For H4 a large rock or group of rocks is to be placed on site as habitat. This includes in the water and on the wet edge. Details of how to locate rocks to create Riffles and frog habitat are given in H7.
H5	Frog Habitat Rock Piles	Frog Habitat Rock Piles are created to provide frogs with moist areas of refuge in drier times, warm areas in winter and protection from predators. Materials: Frog Habitat Piles are made from Rock and Logs – pipe can also be used. Rocks are 100 to 500mm in size, Logs 500mm to 1.5m. Size: The size of the habitat piles can vary to suite specific locations but each has to be a minimum of 10 rocks and 1 log creating a minimum of 3 layers of rock in each pile. Each pile is to have a minimum diameter of 1.5m and at least 20 'holes' ranging in size from 10mm to 50mm. Location: Habitat Piles can be close to water or in drier areas. Locations both close to and away from water and have been selected.

Key	Habitat	Summary Description
H6	Sand	Material: Sand preferably local origin. Size: Course sand – so it doesn't wash away in higher flows. Location: on the wet/dry edge.
H7	Riffles with exposed rock	Riffles are areas of broken water within the water flow. Riffles are a specific habitat type and home for many aquatic invertebrates. Riffles with large exposed rocks spaces between rocks that are partly above water provide great habitat for some frog species. Materials: Rocks – preferably sandstone. Size: 300- 500mm diameter rocks. Locations: Locations are within the water flow path. Final locations can be chosen on-ground when the framework of the cascades is in place and water is flowing. Rocks can be brought to the location any time with final location placement occurring after structures are in place and prior to planting.
H8	Fast Water	Fast flowing water is a specific habitat type and is different to waterfalls. Materials: Rocks (or other bed material) Size: In two levels of the Cascades (3 and 4) part of the water-way bed depth is to be 50+mm deeper than surround bed. The deeper 'trough' is to be a minimum of 200mm wide and extend for as much of the length of the Cascade section as practical. In the Casuarina Grove and the linking channels between 2 and 4 the deeper trough is not required. Location: approximately central and located such that any spillway directs water into the deeper area so that when water levels are low at least this deeper area has water.
H9	Plants in Walls	H9 and H10 are created the same way. Essentially they are gaps created in any of vertical walls created as part of the Water – Reuse Project. The gaps provide habitat for native animals and for plants to be planted. As the H9 Habitat is for splash-zone wet plant species including ferns and other Sydney Sandstone species specific to the waterfall splash-zone habitat. Materials: Removal of rock/rocks from rock baskets. Size: Size is largely influenced by the space created after removing a stone. Hole size 50 - 100mm high with most being < 80mm in height. Length - any size (long and thin is like a natural ledge).

Key	Habitat	Summary Description
H10	Habitat Holes in Vertical Surfaces	See above plus notes below. Materials: Removal of rock/rocks from rock baskets. Terracotta pipe or equivalent. Size: Size is largely influenced by the space created after removing a stone. Hole size 20 - 100mm high with most being < 80mm in height. Length - any size (long and thin is like a natural ledge). Some gaps can be strengthened by inserting piping (terra- cotta or PVC etc). Pipe may be flush or extending from wall. Location: In any vertical wall. Gaps away from water will be used by Lizards and those near water by Lizards and Frogs. Some gaps under the waterfalls will be left for frogs and not planted.
H11	Dense aquatic vegetation	Dense aquatic vegetation provides specific habitat for many aquatic fauna. Dense planting is along edges and within the water flow. Materials: Plants from Species 4 Mix A and B. Size: 50ml and or 8 to 10 inch+ pots (Aqua Pots) or Mats for aquatic species Location: Areas throughout the entire site are to be planted with dense aquatic vegetation. Specifically the perimeter of the wet/dry zone in each tier (Species Mix A) with the exception of the areas to remain open including the sand area is to be planted (4-6 plants per m^2).

7 Appendix III - Fauna desktop study

Table 1. Animals within 10 km of Town Creek, Nabiac, that are **Threatened** at the State Level under the TSC Act, 1995 (BioNet).

Family	Scientific Name	Common Name	NSW status	Comm. status
Frogs Myobatrachidae	*Crinia tinnula*	Wallum Froglet	V,P	
Birds Ciconiidae	*Ephippiorhynchus asiaticus*	Black-necked Stork	E1,P	
Ardeidae	*Botaurus poiciloptilus*	Australasian Bittern	E1,P	E
Accipitridae	*^^Pandion cristatus*	Eastern Osprey	V,P,3	
Cacatuidae	*^Calyptorhynchus lathami*	Glossy Black-Cockatoo	V,P,2	
Psittacidae	*Glossopsitta pusilla*	Little Lorikeet	V,P	
Strigidae	*^^Ninox connivens*	Barking Owl	V,P,3	
Strigidae	*^^Ninox strenua*	Powerful Owl	V,P,3	
Tytonidae	*^^Tyto novaehollandiae*	Masked Owl	V,P,3	
Pomatostomidae	*Pomatostomus temporalis temporalis*	Grey-crowned Babbler (eastern subspecies)	V,P	
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella	V,P	
Mammals Dasyuridae	*Dasyurus maculatus*	Spotted-tailed Quoll	V,P	E
Dasyuridae	*Phascogale tapoatafa*	Brush-tailed Phascogale	V,P	
Phascolarctidae	*Phascolarctos cinereus*	Koala	V,P	V
Petauridae	*Petaurus norfolcensis*	Squirrel Glider	V,P	
Pteropodidae	***Pteropus poliocephalus***	**Grey-headed Flying-fox**	**V,P**	**V**
Emballonuridae	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail-bat	V,P	
Molossidae	***Mormopterus norfolkensis***	**Eastern Freetail-bat**	**V,P**	
Vespertilionidae	***Miniopterus australis***	**Little Bentwing-bat**	**V,P**	

Family	Scientific Name	Common Name	NSW status	Comm. status
Vespertilionidae	***Miniopterus schreibersii oceanensis***	**Eastern Bentwing-bat**	**V,P**	
Vespertilionidae	***Myotis macropus***	**Southern Myotis**	**V,P**	

Table 2. Plants within 10 km of Town Creek, Nabiac, that are **Threatened** at the State Level under the TSC Act, 1995 (BioNet).

Family	Scientific Name	Common Name	NSW status	Comm. status
Casuarinaceae	*Allocasuarina defungens*	Dwarf Heath Casuarina	E1,P	E
Casuarinaceae	***Allocasuarina simulans***	**Nabiac Casuarina**	**V,P**	**V**
Juncaginaceae	***Maundia triglochinoides***		**V,P**	
Rubiaceae	*Asperula asthenes*	Trailing Woodruff	V,P	V

Table 3. Native **amphibians** found within 10 km of Town Creek, Nabiac, NSW (BioNet).

Family	Scientific Name	Common Name	NSW status	Comm. status
Myobatrachidae	***Crinia signifera***	**Common Eastern Froglet**	**P**	
Myobatrachidae	*Crinia tinnula*	Wallum Froglet	V,P	
Myobatrachidae	***Limnodynastes peronii***	**Brown-striped Frog**	**P**	
Myobatrachidae	*Paracrinia haswelli*	Haswell's Froglet	P	
Myobatrachidae	*Pseudophryne bibronii*	Bibron's Toadlet	P	
Myobatrachidae	*Pseudophryne coriacea*	Red-backed Toadlet	P	

Family	Scientific Name	Common Name	NSW status	Comm. status
Myobatrachidae	*Uperoleia fusca*	Dusky Toadlet	P	
Myobatrachidae	***Uperoleia laevigata***	**Smooth Toadlet**	**P**	
Hylidae	***Litoria caerulea***	**Green Tree Frog**	**P**	
Hylidae	***Litoria chloris***	**Red-eyed Tree Frog**	**P**	
Hylidae	***Litoria dentata***	**Bleating Tree Frog**	**P**	
Hylidae	***Litoria fallax***	**Eastern Dwarf Tree Frog**	**P**	
Hylidae	***Litoria latopalmata***	**Broad-palmed Frog**	**P**	
Hylidae	***Litoria peronii***	**Peron's Tree Frog**	**P**	
Hylidae	***Litoria revelata***	**Revealed Frog**	**P**	
Hylidae	***Litoria tyleri***	**Tyler's Tree Frog**	**P**	

Table 4. Native **birds** found within 10 km of Town Creek, Nabiac, NSW (BioNet).

Family	Scientific Name	Common Name	NSW status	Comm. status
Phasianidae	***Coturnix ypsilophora***	**Brown Quail**	**P**	
Anatidae	***Anas castanea***	**Chestnut Teal**	**P**	
Anatidae	***Anas superciliosa***	**Pacific Black Duck**	**P**	
Anatidae	***Chenonetta jubata***	**Australian Wood Duck**	**P**	
Anatidae	***Cygnus atratus***	**Black Swan**	**P**	
Columbidae	***Columba leucomela***	**White-headed Pigeon**	**P**	
Columbidae	***Geopelia striata***	**Peaceful Dove**	**P**	
Columbidae	***Ocyphaps lophotes***	**Crested Pigeon**	**P**	
Podargidae	***Podargus strigoides***	**Tawny Frogmouth**	**P**	
Caprimulgidae	*Eurostopodus mystacalis*	White-throated Nightjar	P	
Aegothelidae	*Aegotheles cristatus*	Australian Owlet-nightjar	P	
Apodidae	*Hirundapus caudacutus*	White-throated Needletail	P	C,J,K
Phalacrocoracidae	*Microcarbo melanoleucos*	Little Pied Cormorant	P	

Family	Scientific Name	Common Name	NSW status	Comm. status
Phalacrocoracidae	*Phalacrocorax carbo*	Great Cormorant	P	
Phalacrocoracidae	*Phalacrocorax sulcirostris*	Little Black Cormorant	P	
Ciconiidae	*Ephippiorhynchus asiaticus*	Black-necked Stork	E1,P	
Ardeidae	*Ardea ibis*	Cattle Egret	P	C,J
Ardeidae	*Ardea intermedia*	Intermediate Egret	P	
Ardeidae	*Ardea modesta*	Eastern Great Egret	P	
Ardeidae	***Ardea pacifica***	**White-necked Heron**	**P**	
Ardeidae	*Botaurus poiciloptilus*	Australasian Bittern	E1,P	E
Ardeidae	*Egretta novaehollandiae*	White-faced Heron	P	
Threskiornithidae	***Threskiornis molucca***	**Australian White Ibis**	**P**	
Threskiornithidae	*Threskiornis spinicollis*	Straw-necked Ibis	P	
Accipitridae	*Accipiter fasciatus*	Brown Goshawk	P	
Accipitridae	*Aquila audax*	Wedge-tailed Eagle	P	
Accipitridae	*Aviceda subcristata*	Pacific Baza	P	
Accipitridae	*Elanus axillaris*	Black-shouldered Kite	P	
Accipitridae	*Haliaeetus leucogaster*	White-bellied Sea-Eagle	P	C
Accipitridae	*Haliastur sphenurus*	Whistling Kite	P	
Accipitridae	*^^Pandion cristatus*	Eastern Osprey	V,P,3	
Rallidae	***Gallinula tenebrosa***	**Dusky Moorhen**	**P**	
Rallidae	***Porphyrio porphyrio***	**Purple Swamphen**	**P**	
Charadriidae	*Vanellus miles*	Masked Lapwing	P	
Charadriidae	*Vanellus miles novaehollandiae*	[Spur-winged Plover]	P	
Turnicidae	*Turnix varius*	Painted Button-quail	P	
Cacatuidae	***Cacatua galerita***	**Sulphur-crested Cockatoo**	**P**	

Family	Scientific Name	Common Name	NSW status	Comm. status
Cacatuidae	***Calyptorhynchus funereus***	**Yellow-tailed Black-Cockatoo**	**P**	
Cacatuidae	***^Calyptorhynchus lathami***	**Glossy Black-Cockatoo**	**V,P,2**	
Cacatuidae	***Eolophus roseicapillus***	**Galah**	**P**	
Psittacidae	***Alisterus scapularis***	**Australian King-Parrot**	**P**	
Psittacidae	***Glossopsitta pusilla***	**Little Lorikeet**	**V,P**	
Psittacidae	***Platycercus elegans***	**Crimson Rosella**	**P**	
Psittacidae	***Platycercus eximius***	**Eastern Rosella**	**P**	
Psittacidae	***Trichoglossus chlorolepidotus***	**Scaly-breasted Lorikeet**	**P**	
Psittacidae	***Trichoglossus haematodus***	**Rainbow Lorikeet**	**P**	
Centropodidae	*Centropus phasianinus*	Pheasant Coucal	P	
Cuculidae	*Cacomantis flabelliformis*	Fan-tailed Cuckoo	P	
Cuculidae	*Cacomantis variolosus*	Brush Cuckoo	P	
Cuculidae	*Chalcites lucidus*	Shining Bronze-Cuckoo	P	
Cuculidae	*Eudynamys orientalis*	Eastern Koel	P	
Cuculidae	*Scythrops novaehollandiae*	Channel-billed Cuckoo	P	
Strigidae	*^^Ninox connivens*	Barking Owl	V,P,3	
Strigidae	*Ninox novaeseelandiae*	Southern Boobook	P	
Strigidae	*^^Ninox strenua*	Powerful Owl	V,P,3	
Tytonidae	*^^Tyto novaehollandiae*	Masked Owl	V,P,3	
Alcedinidae	***Dacelo novaeguineae***	**Laughing Kookaburra**	**P**	
Alcedinidae	***Todiramphus macleayii***	**Forest Kingfisher**	**P**	
Alcedinidae	***Todiramphus sanctus***	**Sacred Kingfisher**	**P**	
Coraciidae	*Eurystomus orientalis*	Dollarbird	P	

Family	Scientific Name	Common Name	NSW status	Comm. status
Menuridae	*Menura novaehollandiae*	Superb Lyrebird	P	
Climacteridae	*Cormobates leucophaea*	White-throated Treecreeper	P	
Ptilonorhynchidae	*Ptilonorhynchus violaceus*	Satin Bowerbird	P	
Maluridae	***Malurus cyaneus***	**Superb Fairy-wren**	**P**	
Maluridae	***Malurus lamberti***	**Variegated Fairy-wren**	**P**	
Maluridae	*Stipiturus malachurus*	Southern Emu-wren	P	
Acanthizidae	*Acanthiza lineata*	Striated Thornbill	P	
Acanthizidae	*Acanthiza nana*	Yellow Thornbill	P	
Acanthizidae	*Acanthiza pusilla*	Brown Thornbill	P	
Acanthizidae	*Gerygone olivacea*	White-throated Gerygone	P	
Acanthizidae	*Sericornis frontalis*	White-browed Scrubwren	P	
Acanthizidae	*Smicrornis brevirostris*	Weebill	P	
Pardalotidae	*Pardalotus punctatus*	Spotted Pardalote	P	
Meliphagidae	*Acanthorhynchus tenuirostris*	Eastern Spinebill	P	
Meliphagidae	***Anthochaera carunculata***	**Red Wattlebird**	**P**	
Meliphagidae	***Anthochaera chrysoptera***	**Little Wattlebird**	**P**	
Meliphagidae	***Caligavis chrysops***	**Yellow-faced Honeyeater**	**P**	
Meliphagidae	***Gliciphila melanops***	**Tawny-crowned Honeyeater**	**P**	
Meliphagidae	*Manorina melanocephala*	Noisy Miner	P	
Meliphagidae	*Meliphaga lewinii*	Lewin's Honeyeater	P	
Meliphagidae	*Melithreptus brevirostris*	Brown-headed Honeyeater	P	
Meliphagidae	*Melithreptus lunatus*	White-naped Honeyeater	P	
Meliphagidae	*Melithreptus lunatus lunatus*		P	

Family	Scientific Name	Common Name	NSW status	Comm. status
Meliphagidae	*Myzomela sanguinolenta*	Scarlet Honeyeater	P	
Meliphagidae	*Nesoptilotis leucotis*	White-eared Honeyeater	P	
Meliphagidae	*Philemon corniculatus*	Noisy Friarbird	P	
Meliphagidae	*Phylidonyris niger*	White-cheeked Honeyeater	P	
Meliphagidae	*Phylidonyris novaehollandiae*	New Holland Honeyeater	P	
Pomatostomidae	*Pomatostomus temporalis temporalis*	Grey-crowned Babbler (eastern subspecies)	V,P	
Psophodidae	*Psophodes olivaceus*	Eastern Whipbird	P	
Neosittidae	*Daphoenositta chrysoptera*	Varied Sittella	V,P	
Campephagidae	***Coracina novaehollandiae***	**Black-faced Cuckoo-shrike**	**P**	
Campephagidae	*Coracina novaehollandiae melanops*		P	
Pachycephalidae	*Colluricincla harmonica*	Grey Shrike-thrush	P	
Pachycephalidae	*Pachycephala pectoralis*	Golden Whistler	P	
Pachycephalidae	*Pachycephala rufiventris*	Rufous Whistler	P	
Pachycephalidae	*Pachycephala rufiventris rufiventris*		P	
Oriolidae	*Oriolus sagittatus*	Olive-backed Oriole	P	
Artamidae	*Artamus cyanopterus*	Dusky Woodswallow	P	
Artamidae	***Cracticus nigrogularis***	**Pied Butcherbird**	**P**	
Artamidae	*Cracticus nigrogularis nigrogularis*		P	
Artamidae	***Cracticus tibicen***	**Australian Magpie**	**P**	
Artamidae	*Cracticus tibicen tibicen*		P	
Artamidae	*Cracticus torquatus*	Grey Butcherbird	P	
Artamidae	***Strepera graculina***	**Pied Currawong**	**P**	
Dicruridae	*Dicrurus bracteatus*	Spangled Drongo	P	
Rhipiduridae	*Rhipidura albiscapa*	Grey Fantail	P	

Family	Scientific Name	Common Name	NSW status	Comm. status
Rhipiduridae	*Rhipidura albiscapa alisteri*		P	
Rhipiduridae	***Rhipidura leucophrys***	**Willie Wagtail**	**P**	
Rhipiduridae	*Rhipidura rufifrons*	Rufous Fantail	P	
Corvidae	***Corvus coronoides***	**Australian Raven**	**P**	
Corvidae	***Corvus orru***	**Torresian Crow**	**P**	
Monarchidae	***Grallina cyanoleuca***	**Magpie-lark**	**P**	
Monarchidae	*Myiagra rubecula*	Leaden Flycatcher	P	
Corcoracidae	*Corcorax melanorhamphos*	White-winged Chough	P	
Petroicidae	*Eopsaltria australis*	Eastern Yellow Robin	P	
Petroicidae	*Microeca fascinans*	Jacky Winter	P	
Petroicidae	*Petroica rosea*	Rose Robin	P	
Timaliidae	*Zosterops lateralis*	Silvereye	P	
Hirundinidae	***Hirundo neoxena***	**Welcome Swallow**	**P**	
Hirundinidae	***Hirundo neoxena neoxena***		**P**	
Nectariniidae	***Dicaeum hirundinaceum***	**Mistletoebird**	**P**	
Estrildidae	***Neochmia temporalis***	**Red-browed Finch**	**P**	
Estrildidae	*Neochmia temporalis temporalis*		P	
Motacillidae	*Anthus novaeseelandiae*	Australian Pipit	P	

Mia Dalby-Ball

Director of Ecological Consultants Australia. BSc (Hons I), Sydney University, 1995. Specializing in design, assessment, monitoring and rehabilitation of urban waterways, wetlands and estuaries. Twenty years direct experience in urban waterways and wetlands.

Lisa Jones

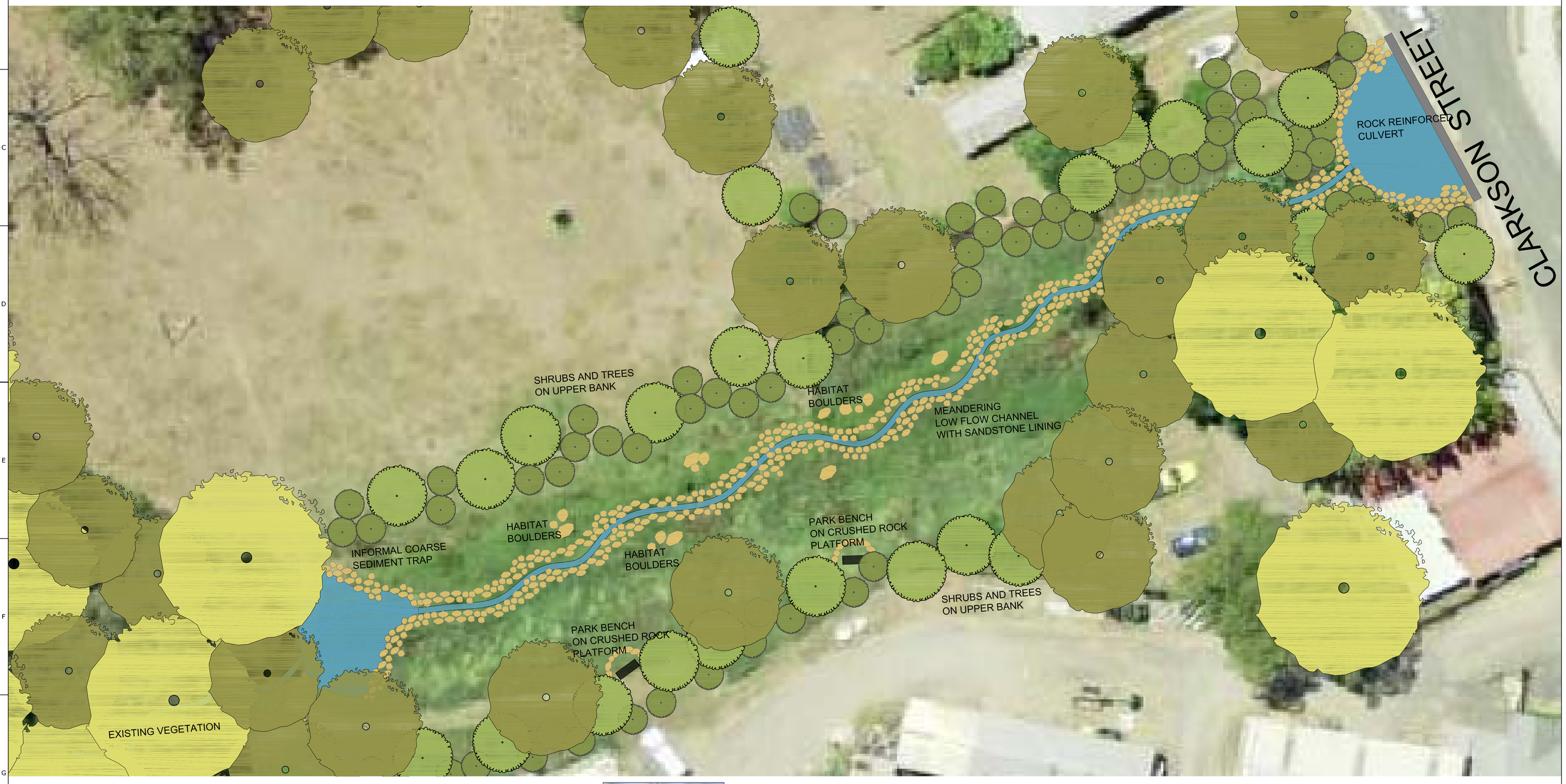
Bachelor of Biodiversity and Conservation, Macquarie University, 2015 Majoring in Zoology, Ecology and Environmental Science.

Environmental Scientist working for Ecological Consultants Australia. Has a range of experience working in the field. Volunteered at SESL Australia and conducted Primarily Site Investigation reports

Michael Davis

Ecologist at Ecological Consultants Australia. Bachelor of Biodiversity and Conservation, Macquarie University (2015), Majoring in Ecology. Michael has experience on a broad range of field and laboratory projects through his work at ECA and his volunteer research assistant role at Macquarie University.

Appendix B Town Creek Rehabilitation Concept Plan (ECA, 2016)



Key Plan

WARNING

BEWARE OF UNDERGROUND SERVICES

THE LOCATION OF UNDERGROUND SERVICES SHOWN ARE APPROXIMATE ONLY AND THEIR EXACT POSITION SHOULD BE PROVEN ON SITE. NO GUARANTEE IS GIVEN THAT ALL SERVICES ARE SHOWN. THE CONTRACTOR MUST VERIFY ALL SERVICES ON SITE PRIOR TO ANY EXCAVATION WORKS.

Rev.	No.	Notes	Date	Reviewed

BUILDERS/ CONCTRACTORS ARE TO VERIFY ALL DIMENSIONS PRIOR TO COMMENCEMENT OF SITE WORK OR OFF-SITE FABRICATION. ALL SHOP DRAWINGS ARE TO BE SUBMITTED TO THE PROJECT MANAGER, AND MANUFACTURE SHALL NOT COMMENCE UNTIL RETURN OF UNAMENDED SHOP DRAWINGS. FIGURED DIMENSIONS ARE TO BE READ IN PREFERENCE TO SCALED.

Engineer

BMT WBM
PO BOX 266, 126 BELFORD STREET, BROADMEADOW, NEWCASTLE, NSW2292
TEL +61 2 4940 8882 FAX +61 2 4940 8887 www.bmtwbm.com.au

Ecologist

Ecological Consultants Australia
SYDNEY, MELBOURNE , BRISBANE
HEAD OFFICE : STUDIO 1, 30 PALMGROVE ROAD, AVALON BEACH, NSW 2107
MBL 0488 481 929 ecologicalca@outlook.com

Architects

Landscape Designers

VOLKER KLEMM LANDSCAPE DESIGN

PO BOX 760 AVALON NSW 2107 TEL/FAX 02 9973 3797 MOBILE 0403 193 337

Project

Great Lake Council
Nabiac NSW

Drawing Title

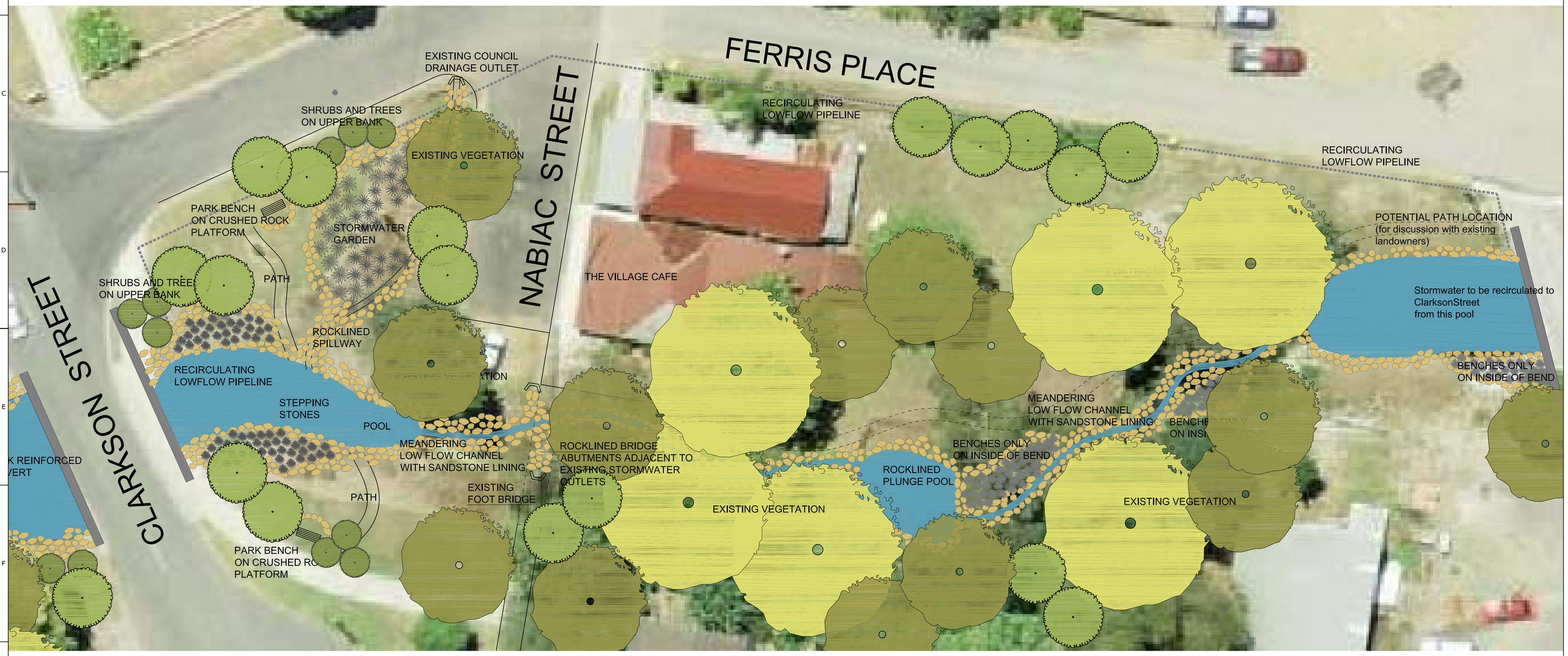
Town Creek
Rehabilitation Plan

Drawing No.	Revision No.
DA1	B
Date	**Project No.**
06/16	

Scale

1:200 @ A1

Reviewed	Approved



Key Plan

WARNING

BEWARE OF UNDERGROUND SERVICES

THE LOCATION OF UNDERGROUND SERVICES SHOWN ARE APPROXIMATE ONLY AND THEIR EXACT POSITION SHOULD BE PROVEN ON SITE. NO GUARANTEE IS GIVEN THAT ALL SERVICES ARE SHOWN. THE CONTRACTOR MUST VERIFY ALL SERVICES ON SITE PRIOR TO ANY EXCAVATION WORKS.

Rev.	No.	Notes	Date	Reviewed

BUILDERS/ CONCTRACTORS ARE TO VERIFY ALL DIMENSIONS PRIOR TO COMMENCEMENT OF SITE WORK OR OFF-SITE FABRICATION. ALL SHOP DRAWINGS ARE TO BE SUBMITTED TO THE PROJECT MANAGER, AND MANUFACTURE SHALL NOT COMMENCE UNTIL RETURN OF UNAMENDED SHOP DRAWINGS. FIGURED DIMENSIONS ARE TO BE READ IN PREFERENCE TO SCALED.

Engineer

BMT WBM

PO BOX 266, 126 BELFORD STREET, BROADMEADOW, NEWCASTLE, NSW2292
TEL +61 2 4940 8882 FAX +61 2 4940 8887 www.bmtwbm.com.au

Ecologist

Ecological Consultants Australia

SYDNEY, MELBOURNE , BRISBANE
HEAD OFFICE : STUDIO 1, 30 PALMGROVE ROAD, AVALON BEACH, NSW 2107
MBL 0488 481 929 ecologicalca@outlook.com

Architects

Landscape Designers

VOLKER KLEMM LANDSCAPE DESIGN

PO BOX 760 AVALON NSW 2107 TEL/FAX 02 9973 3797 MOBILE 0403 193 337

Project

Great Lake Council
Nabiac NSW

Drawing Title

Town Creek
Rehabilitation Plan

Drawing No.	Revision No.
DA2	C
Date	**Project No.**
06/16	

Scale

1:200 @ A1

Reviewed Approved

Key Plan

WARNING

BEWARE OF UNDERGROUND SERVICES

THE LOCATION OF UNDERGROUND SERVICES SHOWN ARE APPROXIMATE ONLY AND THEIR EXACT POSITION SHOULD BE PROVEN ON SITE. NO GUARANTEE IS GIVEN THAT ALL SERVICES ARE SHOWN. THE CONTRACTOR MUST VERIFY ALL SERVICES ON SITE PRIOR TO ANY EXCAVATION WORKS.

Rev.	No.	Notes	Date	Reviewed

BUILDERS/ CONCTRACTORS ARE TO VERIFY ALL DIMENSIONS PRIOR TO COMMENCEMENT OF SITE WORK OR OFF-SITE FABRICATION. ALL SHOP DRAWINGS ARE TO BE SUBMITTED TO THE PROJECT MANAGER, AND MANUFACTURE SHALL NOT COMMENCE UNTIL RETURN OF UNAMENDED SHOP DRAWINGS. FIGURED DIMENSIONS ARE TO BE READ IN PREFERENCE TO SCALED.

Engineer

BMT WBM
PO BOX 266, 126 BELFORD STREET, BROADMEADOW, NEWCASTLE, NSW2292
TEL +61 2 4940 8882 FAX +61 2 4940 8887 www.bmtwbm.com.au

Ecologist

Ecological Consultants Australia
SYDNEY, MELBOURNE , BRISBANE
HEAD OFFICE : STUDIO 1, 30 PALMGROVE ROAD, AVALON BEACH, NSW 2107
MBL 0488 481 929 ecologjulia@outlook.com

Architects

Landscape Designers

VOLKER KLEMM LANDSCAPE DESIGN
PO BOX 760 AVALON NSW 2107 TEL/FAX 02 9973 3797 MOBILE 0403 193 337

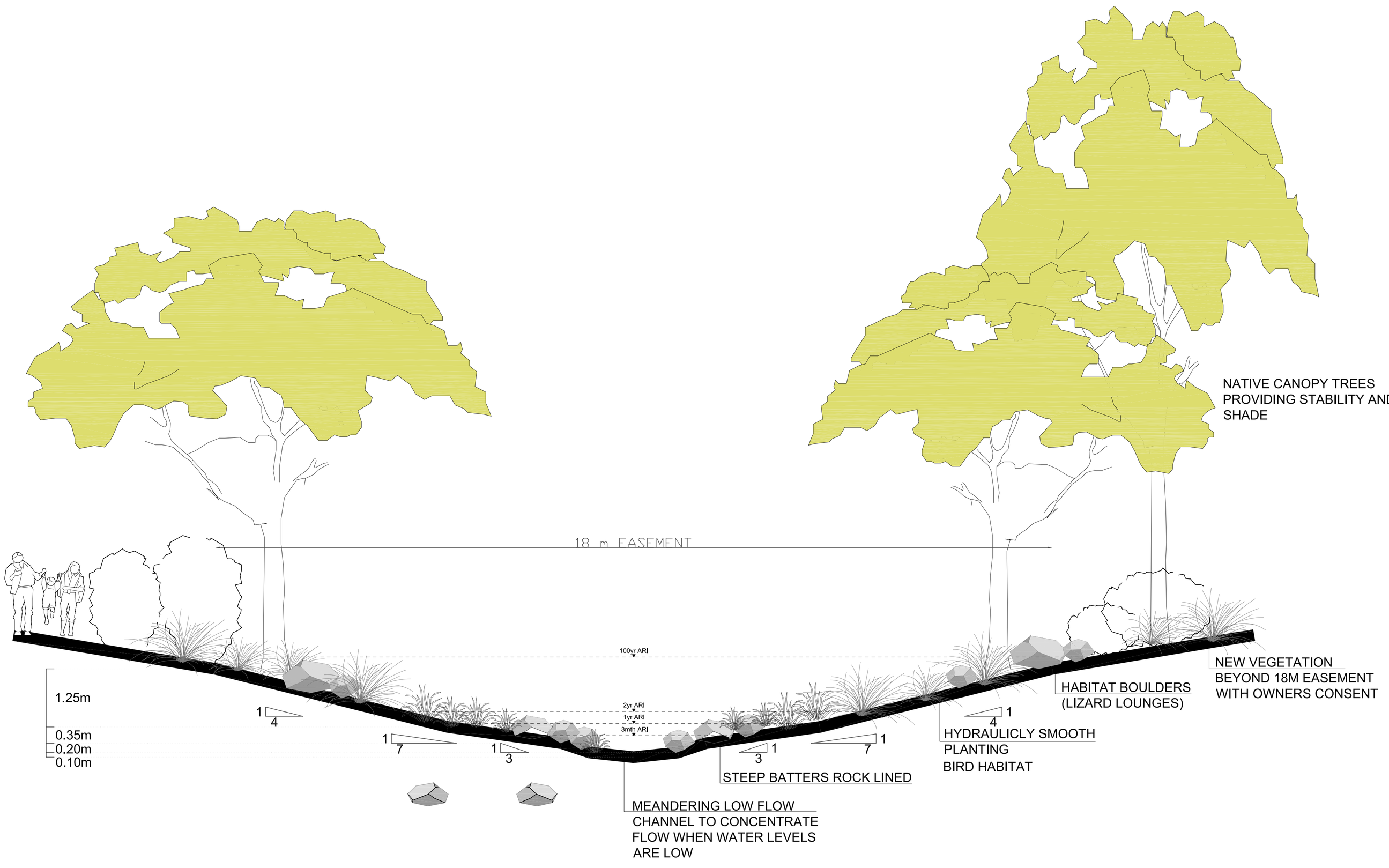
Project

Great Lake Council
Nabiac NSW

Drawing Title

Town Creek Rehabilitation Plan

Drawing No.	Revision No.
DA3	A
Date	**Project No.**
06/16	
Scale	
1:200 @ A1	
Reviewed	**Approved**



UPPER SECTION

Key Plan

WARNING

BEWARE OF UNDERGROUND SERVICES

THE LOCATION OF UNDERGROUND SERVICES SHOWN ARE APPROXIMATE ONLY AND THEIR EXACT POSITION SHOULD BE PROVEN ON SITE. NO GUARANTEE IS GIVEN THAT ALL SERVICES ARE SHOWN. THE CONTRACTOR MUST VERIFY ALL SERVICES ON SITE PRIOR TO ANY EXCAVATION WORKS.

Rev.	No.	Notes	Date	Revieved

BUILDERS/ CONCTRACTORS ARE TO VERIFY ALL DIMENSIONS PRIOR TO COMMENCEMENT OF SITE WORK OR OFF-SITE FABRICATION. ALL SHOP DRAWINGS ARE TO BE SUBMITTED TO THE PROJECT MANAGER, AND MANUFACTURE SHALL NOT COMMENCE UNTIL RETURN OF UNAMENDED SHOP DRAWINGS. FIGURED DIMENSIONS ARE TO BE READ IN PREFERENCE TO SCALED.

Engineer

BMT WBM

PO BOX 266, 126 BELFORD STREET, BROADMEADOW, NEWCASTLE, NSW2292
TEL +61 2 4940 8882 FAX +61 2 4940 8887 www.bmtwbm.com.au

Ecologist

Ecological Consultants Australia

SYDNEY, MELBOURNE , BRISBANE
HEAD OFFICE : STUDIO 1, 30 PALMGROVE ROAD, AVALON BEACH, NSW 2107
MBL 0488 481 929 ecologicalca@outlook.com

Architects

Landscape Designers

VOLKER KLEMM LANDSCAPE DESIGN

PO BOX 760 AVALON NSW 2107 TEL/FAX 02 9973 3797 MOBILE 0403 193 337

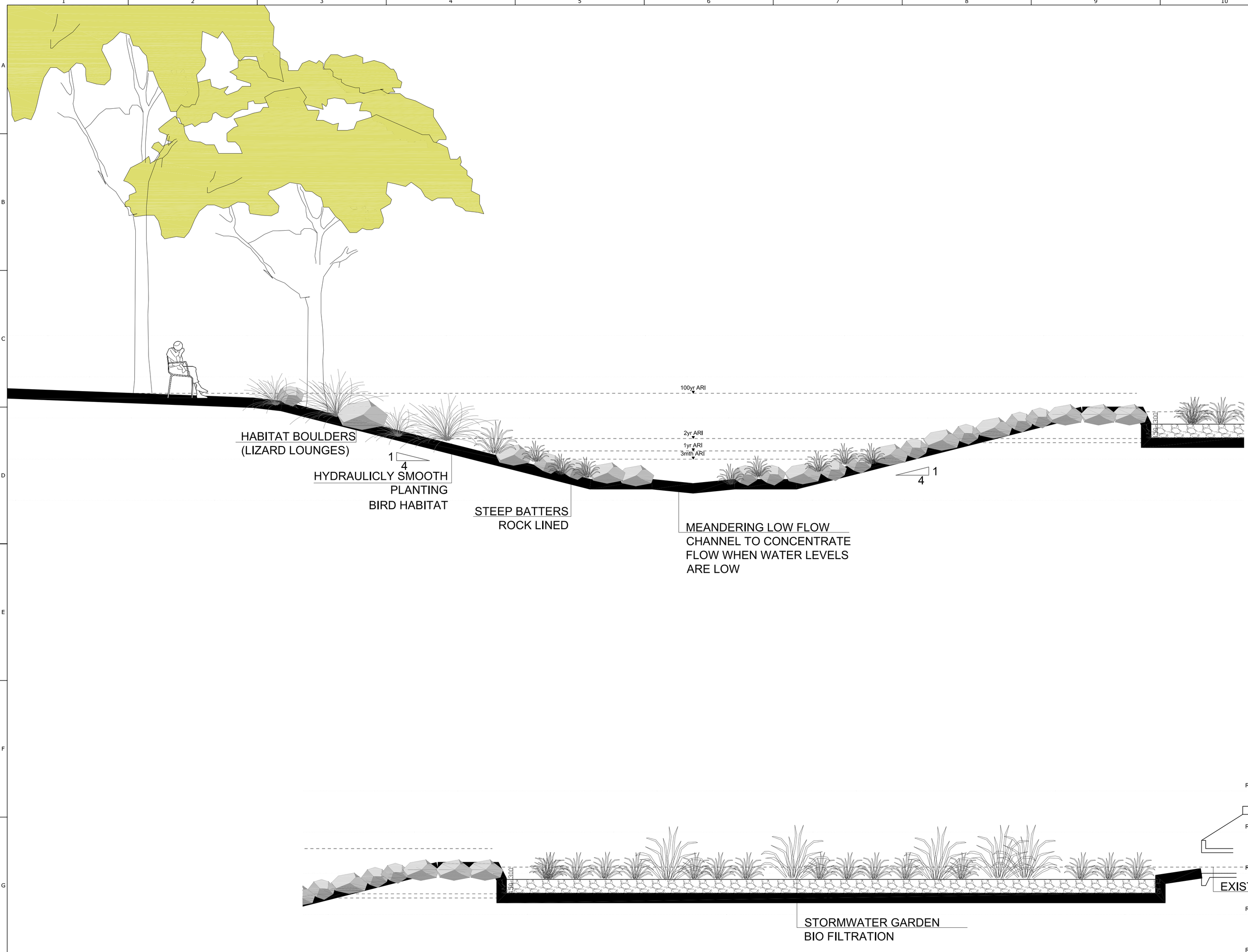
Project

Great Lake Council
Nabiac NSW

Drawing Title

Town Creek
Rehabilitation Plan- Section

Drawing No.	Revision No.
DA4	A
Date	Project No.
06/16	
Scale	
1:100 @ A1	
Reviewed	Approved



MIDDLE SECTION

Key Plan

WARNING

BEWARE OF UNDERGROUND SERVICES

THE LOCATION OF UNDERGROUND SERVICES SHOWN ARE APPROXIMATE ONLY AND THEIR EXACT POSITION SHOULD BE PROVEN ON SITE. NO GUARANTEE IS GIVEN THAT ALL SERVICES ARE SHOWN. THE CONTRACTOR MUST VERIFY ALL SERVICES ON SITE PRIOR TO ANY EXCAVATION WORKS.

Rev.	No.	Notes	Date	Reviewed

BUILDERS/ CONCTRACTORS ARE TO VERIFY ALL DIMENSIONS PRIOR TO COMMENCEMENT OF SITE WORK OR OFF-SITE FABRICATION. ALL SHOP DRAWINGS ARE TO BE SUBMITTED TO THE PROJECT MANAGER, AND MANUFACTURE SHALL NOT COMMENCE UNTIL RETURN OF UNAMENDED SHOP DRAWINGS. FIGURED DIMENSIONS ARE TO BE READ IN PREFERENCE TO SCALED.

Engineer

BMT WBM

PO BOX 266, 126 BELFORD STREET, BROADMEADOW, NEWCASTLE, NSW2292
TEL +61 2 4940 8882 FAX +61 2 4940 8887 www.bmtwbm.com.au

Ecologist

Ecological Consultants Australia

SYDNEY, MELBOURNE , BRISBANE
HEAD OFFICE : STUDIO 1, 30 PALMGROVE ROAD, AVALON BEACH, NSW 2107
MBL 0488 481 929 ecologicalca@outlook.com

Architects

Landscape Designers

VOLKER KLEMM LANDSCAPE DESIGN

PO BOX 760 AVALON NSW 2107 TEL/FAX 02 9973 3797 MOBILE 0403 193 337

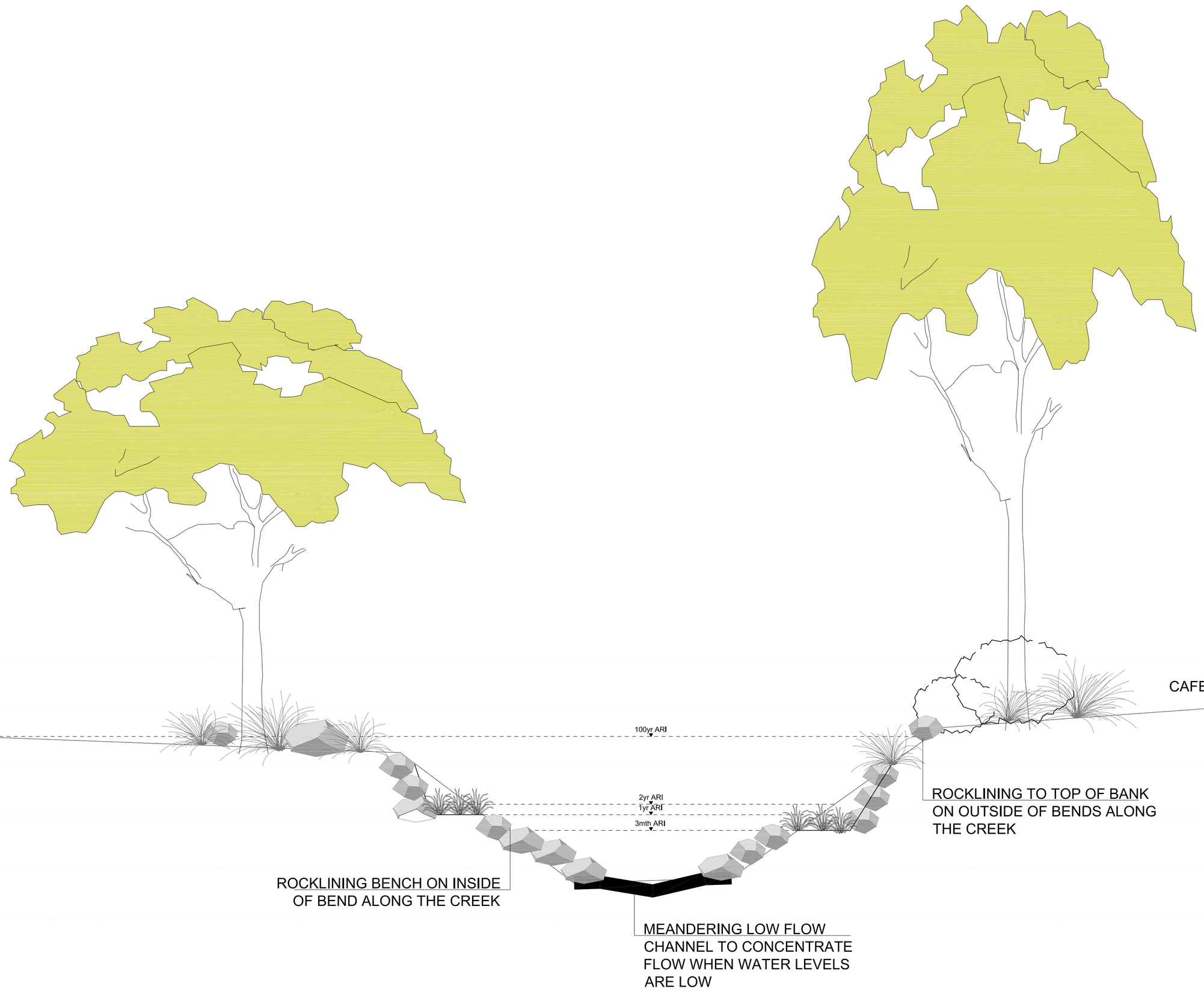
Project

Great Lake Council
Nabiac NSW

Drawing Title

Town Creek
Rehabilitation Plan- Section

Drawing No.	Revision No.
DA5	A
Date	**Project No.**
06/16	
Scale	
1:50 @ A1	
Reviewed	**Approved**



LOWER SECTION

Key Plan

WARNING

BEWARE OF UNDERGROUND SERVICES

THE LOCATION OF UNDERGROUND SERVICES SHOWN ARE APPROXIMATE ONLY AND THEIR EXACT POSITION SHOULD BE PROVEN ON SITE. NO GUARANTEE IS GIVEN THAT ALL SERVICES ARE SHOWN. THE CONTRACTOR MUST VERIFY ALL SERVICES ON SITE PRIOR TO ANY EXCAVATION WORKS.

Rev.	No.	Notes	Date	Reviewed

BUILDERS/ CONCTRACTORS ARE TO VERIFY ALL DIMENSIONS PRIOR TO COMMENCEMENT OF SITE WORK OR OFF-SITE FABRICATION. ALL SHOP DRAWINGS ARE TO BE SUBMITTED TO THE PROJECT MANAGER, AND MANUFACTURE SHALL NOT COMMENCE UNTIL RETURN OF UNAMENDED SHOP DRAWINGS. FIGURED DIMENSIONS ARE TO BE READ IN PREFERENCE TO SCALED.

Engineer

BMT WBM
PO BOX 266, 126 BELFORD STREET, BROADMEADOW, NEWCASTLE, NSW2292
TEL +61 2 4940 8882 FAX +61 2 4940 8887 www.bmtwbm.com.au

Ecologist

Ecological Consultants Australia
SYDNEY, MELBOURNE , BRISBANE
HEAD OFFICE : STUDIO 1, 30 PALMGROVE ROAD, AVALON BEACH, NSW 2107
MBL 0488 481 929 ecologicalca@outlook.com

Architects

Landscape Designers

VOLKER KLEMM LANDSCAPE DESIGN
PO BOX 760 AVALON NSW 2107 TEL/FAX 02 9973 3797 MOBILE 0403 193 337

Project

Great Lake Council
Nabiac NSW

Drawing Title

Town Creek
Rehabilitation Plan- Section

Drawing No.	Revision No.
DA6	A
Date	Project No.
06/16	
Scale	
1:50 @ A1	
Reviewed	Approved

BMT WBM Bangalow
6/20 Byron Street, Bangalow 2479
Tel +61 2 6687 0466 Fax +61 2 66870422
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Brisbane
Level 8, 200 Creek Street, Brisbane 4000
PO Box 203, Spring Hill QLD 4004
Tel +61 7 3831 6744 Fax +61 7 3832 3627
Email bmtwbm@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Denver
8200 S. Akron Street, #B120
Centennial, Denver Colorado 80112 USA
Tel +1 303 792 9814 Fax +1 303 792 9742
Email denver@bmtwbm.com
Web www.bmtwbm.com

BMT WBM London
International House, 1st Floor
St Katharine's Way, London E1W 1AY
Email london@bmtwbm.co.uk
Web www.bmtwbm.com

BMT WBM Mackay
PO Box 4447, Mackay QLD 4740
Tel +61 7 4953 5144 Fax +61 7 4953 5132
Email mackay@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Melbourne
Level 5, 99 King Street, Melbourne 3000
PO Box 604, Collins Street West VIC 8007
Tel +61 3 8620 6100 Fax +61 3 8620 6105
Email melbourne@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Newcastle
126 Belford Street, Broadmeadow 2292
PO Box 266, Broadmeadow NSW 2292
Tel +61 2 4940 8882 Fax +61 2 4940 8887
Email newcastle@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Perth
Level 3, 20 Parkland Road, Osborne, WA 6017
PO Box 1027, Innaloo WA 6918
Tel +61 8 9328 2029 Fax +61 8 9486 7588
Email perth@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Sydney
Suite G2, 13-15 Smail Street, Ultimo, Sydney 2007
Tel +61 2 8960 7755 Fax +61 2 8960 7745
Email sydney@bmtwbm.com.au
Web www.bmtwbm.com.au

BMT WBM Vancouver
Suite 401, 611 Alexander Street
Vancouver British Columbia V6A 1E1 Canada
Tel +1 604 683 5777 Fax +1 604 608 3232
Email vancouver@bmtwbm.com
Web www.bmtwbm.com