Attachment F

Final Concept Pond Design

FINAL CONCEPT POND DESIGN

Yarralumla Brickworks, Canberra, BLOC

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Abbreviations

Alluvium	Alluvium Consulting Australia Pty Ltd
AHD	Australian Height Datum
ARI	Average Recurrence Interval
EDD	Extended Detention Depth
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NWL	Normal Water Level
SWMS	Surface/Storm Water Management Strategy
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids

1 Introduction

Alluvium Consulting Australia Pty Ltd (Alluvium) has been engaged by BLOC to prepare a proof of concept for a proposed amenity and stormwater treatment pond and wetland in support of a development tender for the Yarralumla Brickworks site in Yarralumla, Canberra. This proof of concept is phase 1 of what will ultimately form a Surface/Stormwater Management Strategy (SWMS).

The objective of a SWMS is to propose management strategies for stormwater quality and quantity. Through meeting this objective, the SWMS acts as a critical component of the development planning and urban design process and ensures stormwater is managed in accordance with requirements in the ACT. Information with respect to the pond is provided at a concept design level.

Reference material
A variety of reference material was drawn upon to determine both the existing and developed site conditions and to use the correct parameters for designing the pond and wetland. These materials included:

- The Development Masterplan
- The Canberra Brickworks Precinct Proposed Services Connection Plan (Sellicks Consultants, June 2016)
- Irrigation Area Diagram (McGregor & Coxall, December 2016)
- The Waterways Water Sensitive Urban Design General Code (ACT Planning and Land Authority)
- The ACT Practice Guidelines for WSUD (ACT Planning and Land Authority 2016)

2 Site overview

The Yarralumla Brickworks site covers an area of approximately 16 hectares and is generally bounded by Bentham Street to the north, the Royal Canberra Golf Course to the west, and connects to Dudley Street to the south. There are remnants of the former Yarralumla Brickworks Railway, and a depression currently exists at the site of the former quarry. This is where the pond has been proposed to be built.

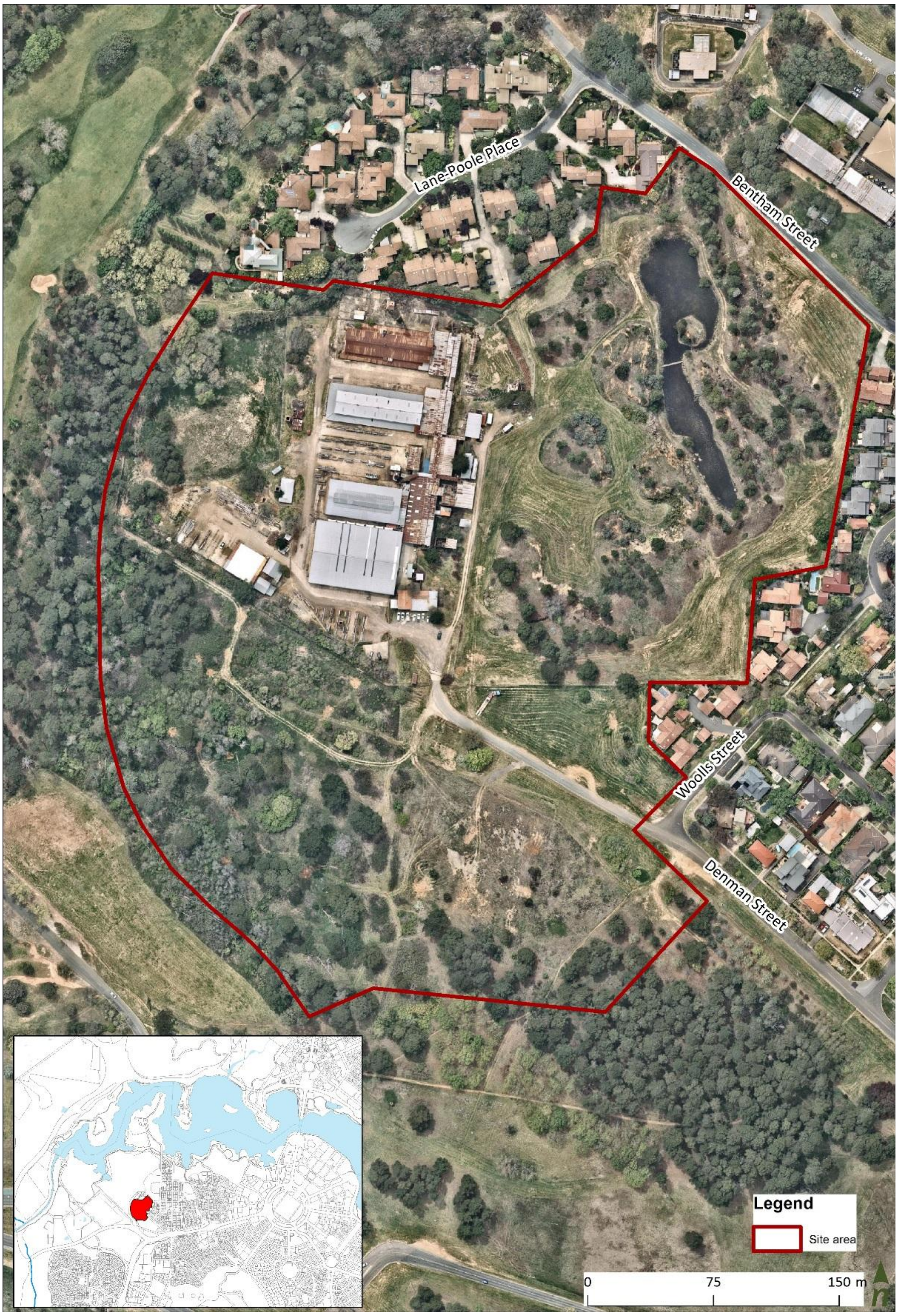

Figure 1. *Site location*

There are a number of constraints and opportunities, including:

1. There is an existing depression where the sediment pond, wetland and pond will be located (the old quarry)
2. There is an existing residential area to the west (around Lane-Poole Place) which contains a stormwater system that could be tapped into for additional water for the Water Sensitive Urban Design (WSUD) assets

The proposed site development layout can be seen at Appendix A.

2.1 Catchments

There are six subcatchments on the site according to the proposed stormwater services network (Figure 2), all connecting to a point in the north-west of the site. The existing residential catchment has also been analysed in case additional stormwater is necessary for the correct water turnover in the pond. The size and direction of these catchments are provided in Table 1.

Table 1. Study site subcatchments

Catchment	Internal/ External	Area (ha)	Flow Direction
A	Internal	1.2	South-west
B	Internal	1.5	North-west
C	Internal	2.3	North
D	Internal	1.9	North-west
E	Internal	1.5	North-west
F	Internal	1.4	West
Total	*Internal*	*9.8*	-
Existing residential catchment	External	2.6	South-west

2.2 Options

Three options for inflow to the WSUD assets have been analysed:

- **Option 1**: Inflow from catchment A only
- **Option 2**: Inflow from a pipe diversion from all catchments within the site area (pumped)
- **Option 3**: Additional inflow from the existing residential catchment into the system if necessary (for meeting reuse demand and meeting residence time)

Figure 2. *Overall Catchment Plan*

3 Site analysis

3.1 Hydrologic and hydraulic analysis

The design flows that have been used for fully developed conditions to assess pipe capacity requirements (Phase 2 of this project if required) and diversion flow for the pond have been undertaken using the rational method and are provided in Table 2 and Appendix B.

Table 2. Design flows (rational method)

Catchment	Area (ha)	Q 3 month ARI	Minor flow (5 year ARI)
A	1.2	0.024 m^3/s	0.12 m^3/s
B	1.5	0.035 m^3/s	0.08 m^3/s
C	2.3	0.047 m^3/s	0.23 m^3/s
D	1.9	0.065 m^3/s	0.32 m^3/s
E	1.5	0.037 m^3/s	0.19 m^3/s
F	1.4	0.031 m^3/s	0.16 m^3/s
Total	*9.8*	*0.205 m^3/s*	*1.02 m^3/s*
Existing residential	2.6	0.080 m^3/s	0.40 m^3/s
Total + Existing residential	2.6	0.277 m^3/s	1.38 m^3/s

3.2 Criteria for SWMS

The criteria for the proposed strategy, based on the analysis of existing conditions are as follows:

- Pollutant removal
- Proof of concept (sediment basin, wetland and pond)
- Convey major flows through the site via overland flows along road reserves (Phase 2 of project if required)
- Convey minor flows through local catchments in a piped network (Phase 2 of project if required)

4 Wetland and pond concept design

The proposed wetland and pond will be located in the old quarry within the site, where there is an existing depression. This can be seen in the landscape plan (see Appendix A). The wetland will receive inflow from the combined subcatchments within the site, with the 3 month ARI being diverted into the sediment basin, then flowing into the macrophyte zone, and finally the pond.

Key design considerations as per the ACT Practice Guidelines for WSUD (2016) include the following:

- Consideration of depth and inundation frequency to ensure the health of fringing vegetation
- Pre-treatment of the diverted stormwater to ensure minimal nutrients and sediments are entering the pond, thus reducing the risk of algal blooms
- Sufficient inflow into the pond to ensure there is a minimum residence time (turn-over of water) of less than 50 days so to avoid stagnant water and algal blooms
- 20%ile residence time between 20 and 30 days for water in the pond
- Appropriate batters to ensure public safety (minimum of 1 in 6)
- Sediment removal frequency (at least once every 5 years)
- Velocities through the pond are 0.5 m/s in the 1 year ARI
- A maximum depth of 3-4m and a minimum depth of 0.6-2m for the pond
- A maximum Extended Detention Depth (EDD) of 0.5m
- An access ramp into the sediment pond for maintenance
- A sediment dewatering area located next to the sediment pond

The pond batters have been adopted from Melbourne Water's *WSUD Engineering Procedures: Stormwater* (2004). The batter requirements, including safety benches and freeboard requirements, result in a minimum width of 24.1m needed for the pond given a 2m wide base. The pond batters are shown in Table 3 and a typical cross section of the pond is represented in Figure 3. These batters apply to the sediment basin and wetland as well.

Table 3. Pond batter requirements

Description	***Slope***	***Distance***
NWL to -350 mm	1 in 8	2.8
-350 mm to 1500mm	1 in 3	1.15
Above NWL	Minimum 1 in 6	Varies

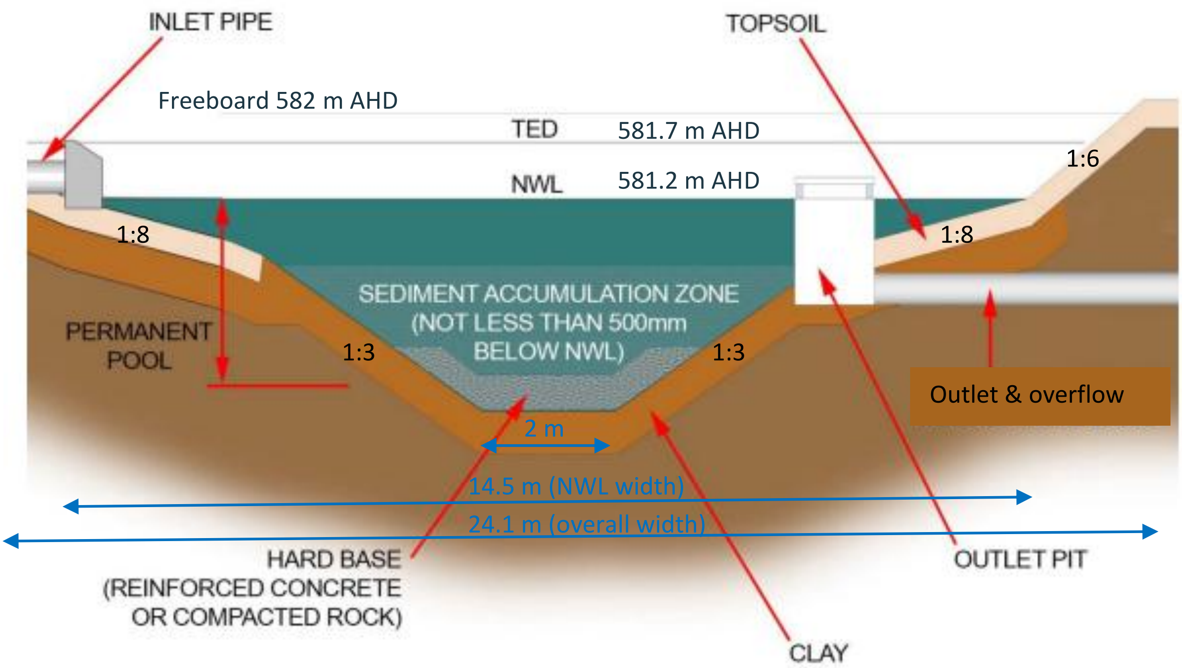

Figure 3. *Typical pond cross section (Melbourne Water Constructed Wetlands design manual) adapted to the site*

The treatment area for the wetland, sediment basin and pond have been determined by the available space and minimum batters requirements. The areas were then analysed to check they met requirements such as the residence time for the pond, and velocity and sediment capture efficiency requirements.

Table 4. Pond design parameters

Parameter	Design value
Pond area (at NWL)	1500 m^2
Pond depth	1.5 m
Normal Water Level (NWL)	581.2 m AHD
Elevation at base	579.7 m AHD
EDD	0.5 m
Freeboard	0.3 m
Volume (approximate)	1500 m^3

Table 5. Treatment asset parameters

	Wetland	*Sediment Basin*
Treatment area (NWL), m^2	880	180
Average depth, m	0.4	1.0
Volume, m^3	352	180
Extended detention, m	0.5	0.5
Freeboard, m	0.3	0.3
Extended detention time (hours)	72	12

4.1 Capture efficiency and velocity calculations

Provision for sediment dewatering has been made. These areas assume a depth of 500 mm and allow for the 5 year cleanout sediment volume to be accommodated. These calculations are based on the typical sediment loading rate of 1.6 m^3/ha/yr for a developed catchment. The possible locations of this dewatering area are provided in the concept design maps (Figure 5 and Figure 6). Full calculations for sediment pond capture efficiency and storage volume are provided in Appendix C. Provision has also been made for maintenance requirements. The design allows for a maintenance track that would typically be 3.5-4 m wide at a grade of 1:20, as well as a ramp into the pond for sediment dewatering.

Velocity analysis of the sediment basin and wetland was conducted to ensure the size and configuration of the assets result in velocities through the sediment basin of less than 0.5m/s, and the wetland of less than 0.05m/s. The proposed revised asset layout meets this design requirement. Velocity calculations for the assets are provided in Appendix C.

5 Stormwater quality treatment system design and residence time analysis

5.1 MUSIC model setup

The catchments and stormwater treatment performance of the pond have been modelled using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). The MUSIC model helps determine the design flow volumes following urban development, the amount of pollutants generated and ultimately the performance of treatment measures. The 'fraction impervious' values were calculated by measuring the proposed roof and road areas as a fraction of the subcatchments.

The land use types and corresponding fraction imperviousness adopted are presented in Table 6. In accordance with the ACT's Waterways Water Sensitive Urban Design General Code, Canberra Airport rainfall station was used for the period 1968 to 1977 at a 6 minute timestep. The recommended MUSIC rainfall/runoff parameters and stormwater quality parameters suggested in the General Code were also adopted. The design treatment system schematic is provided in Figure 4.

Table 6. Fraction Impervious

Catchment	*Fraction impervious adopted*
A	0.4
B	0.45
C	0.4
D	0.8
E	0.5
F	0.45
Total	0.5

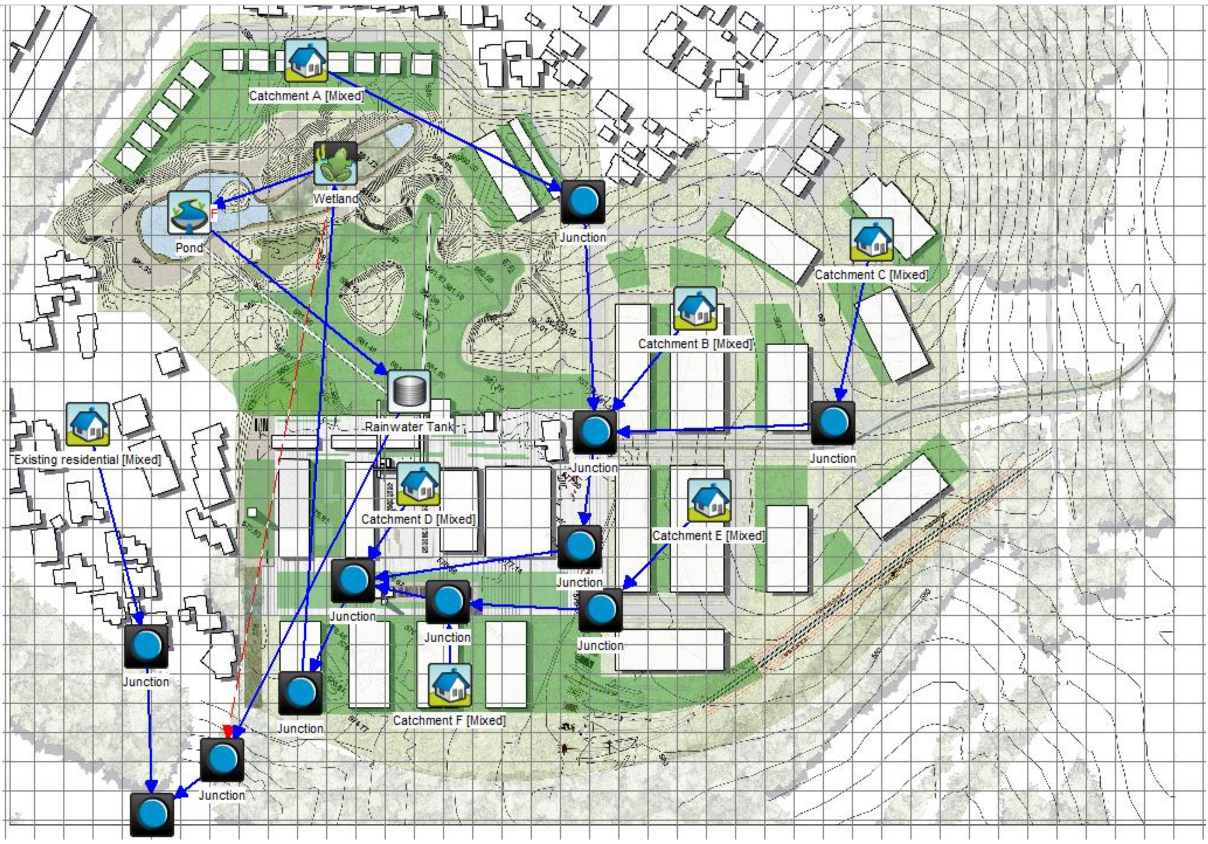

Figure 4. *MUSIC schematic of the Yarralumla Brickworks (Option 2)*

Options 1 and 2 were analysed first to check if water residence times were being met for the pond. The 3 month ARI for catchment A was all diverted into the wetland for Option 1, whilst the combined 3 month ARI for all internal catchments was diverted into the wetland for Option 2. Option 3 looks at whether it is worth tapping into the existing residential catchment, so diverting the 3 month flow from this in addition to the internal catchments.

Water reuse demands were built into the pond node in MUSIC based on a 2.5ML/ha/yr demand for open space irrigation, and an approximate area of 4.2 ha of open space throughout the development (as per the irrigation area diagram provided by McGregor and Coxall). This results in a 10,400 kL annual demand. The tank size was iteratively increased so to meet demand.

5.2 Residence time analysis

The results from the MUSIC modelling were used to analyse the residence time in the pond for Option 1 and Option 2. Analysis was conducted for the time period 1968-1977. The results are shown in Table 7 below. In terms of residence time, the ACT Practice Guidelines for WSUD specify that there should be:

- Sufficient inflow to ensure there is a residence time (turn-over of water) of less than 50 days so to avoid stagnant water and algal blooms
- 20 percentile residence time between 20 and 30 days

Table 7. Residence time results for Options 1 to 3

Option	**Average Summer residence time** Target < 50 days	**20%ile residence time (annual)** Target 20-30 days
1	359 ✗	340 ✗
2	15 ✓	20.6 ✓
3	10.9 ✓	14.9 ✗

Analysis of the residence time (looking at inflows into the pond) shows that for each of the summers between 1968 and 1977 the residence time was less than 50 days for Option 2 and 3 only. Analysis of the annual inflows into the pond results in a 20th percentile of 20.6 days for Option 2 and approximately 14.9 days for Option 3, which means that only Option 2 meets the design criteria (between 20 and 30 days). This analysis shows that the pond configuration and inflows are sufficient to meet the residence time criteria for Option 2 only. This analysis also shows that the internal site catchments are sufficient to maintain a healthy pond (Option 2) without the existing residential catchment to the north being tapped into (Option 3). Option 1 is likely to result in pond water quality issues and should not be pursued.

5.3 MUSIC treatment results

The overall treatment train results for each of the scenarios modelled in MUSIC are shown in Table 8 below.

Table 8. MUSIC results for each treatment asset scenario (including harvesting)

System arrangement	***System performance (% removal)***				***System performance kg/year)***			
Option	**TSS**	**TP**	**TN**	**Gross Pollutant**	**TSS**	**TP**	**TN**	**Gross Pollutant**
1	9.5	9.4	9.4	10.1	880	0.77	11	140
2	80.1	57.3	54.4	94.8	7480	4.7	60.5	1345.6
3*	76.7	52.5	47.7	94.9	9670	5.85	71	1802.9

* Note the treatment results for Option 3 include the external catchment thus while percentages are lower kg load treated are higher.

Modelling results show that Options 2 and 3 will meet stormwater water quality treatment requirements for the proposed residential areas. Option 1 fails to meet the treatment criteria due to the low volume of water directed through the wetland and pond system.

The treatment and demand reliability results show that Options 2 and 3 provide the best reliability in terms of meeting irrigation demands. Tapping into the external residential catchment only provides a small amount of additional water for irrigation (only an additional 0.4ML/yr). Option 1 has a very low reliability of supply for irrigation given the estimated demand.

Table 9. MUSIC results for each treatment asset scenario

Option	WSUD Treatment Measure	Demand supplied (%)
1	Wetland + Pond + 300kL Water tank	4.6
2	Wetland + Pond + 300kL Water tank	71.5
3	Wetland + Pond + 300kL Water tank	75.2

6 Recommendations

Pond residence time modelling shows that the combined internal site catchments are sufficient to maintain a healthy pond (Option 2) and that the additional existing residential catchment to the north is not required to maintain this health (Option 3). The modelling also concluded that Option 1 is likely to result in pond water quality issues, due to the lack of available volume of water to turn the pond over and should not be pursued.

Water quality modelling results show that only Option 2 will meet stormwater quality treatment requirements for the proposed residential areas. However Option 1 fails to meet the treatment criteria due to the low volume of water directed through the pond.

Water reuse demands for open space irrigation show that Option 2 and Option 3 provide 71.5% and 75.2% of the irrigation needs respectively. All scenarios fail to meet the typical industry standard of 80%. However, Options 2 and 3 are close and have the potential to be fine-tuned in the detailed design.

Based on the design analysis above, Option 2 (tapping into all internal catchments within the development), provides the most suitable arrangement owing to its reduced complexity compared to Option 3 and the minimal increase in irrigation demand met by tapping into the existing stormwater main in the residential catchment to the north of the site. The proposed layout is shown in Figure 5 and Figure 6.

As part of subsequent design phases, consideration will need to be given to pond edge effects associated with drawn down and any additional safety benches that may be required during draw down events.

Figure 5. *Concept layout overview*

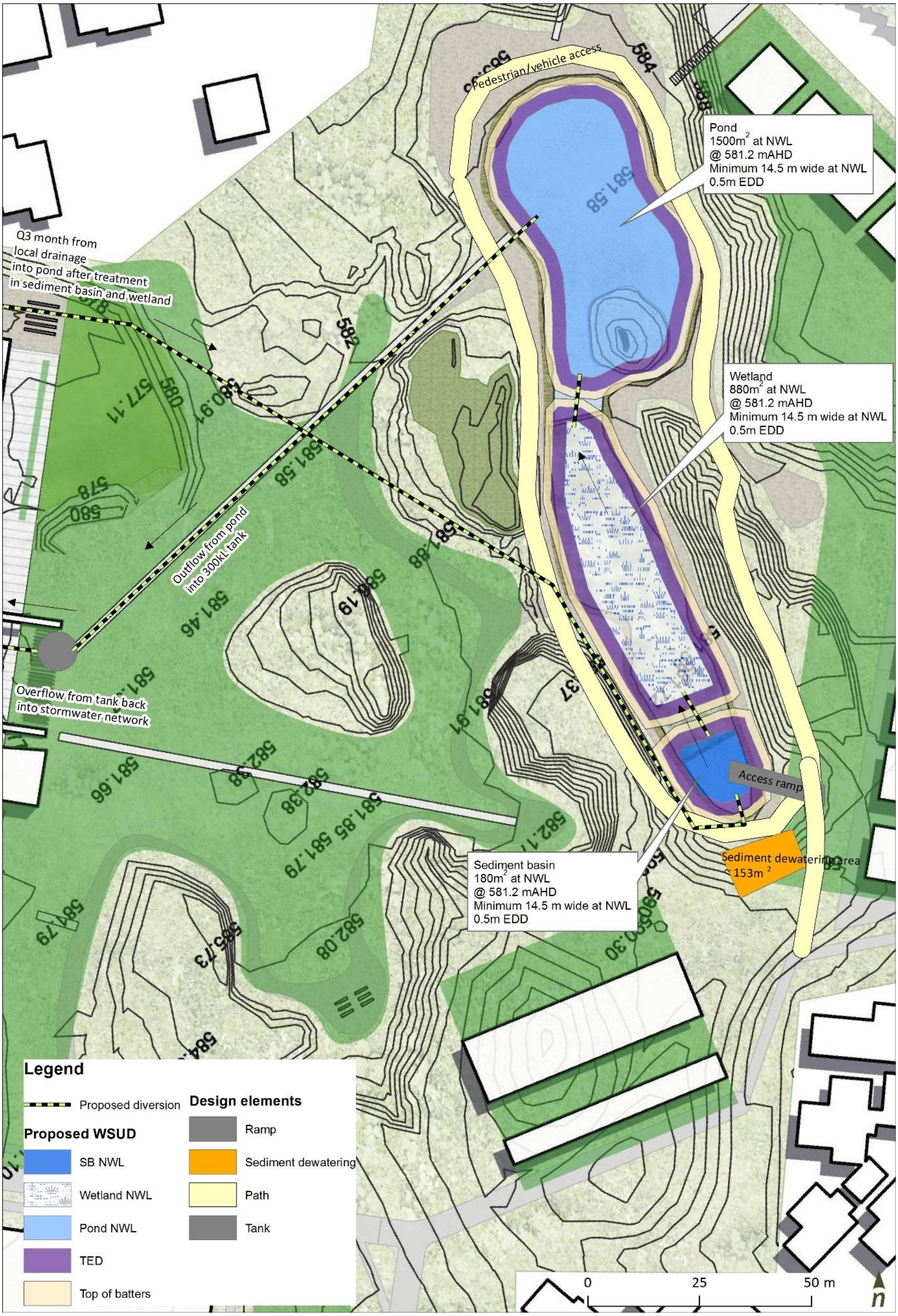

Figure 6. *Concept layout detail*

7 Costing (Option 2)

Volume and cost estimates for the recommended works are provided below in Table 10. The values provided are estimates based on the Australian Construction Handbook (2016), as well as our experience with similar projects. Note the treatment costs of the stormwater (filtration and UV) could be removed if administrative controls (watering between certain hours) are put in place.

Table 10. Cost estimates for the proposed works

Yarralumla Brickworks - Wetland

	Quantity	*Unit*	*Unit Rate*	*Cost*
General items				
Site establishment, sediment and erosion control	1	No	5%	$ 804,873
Subtotal				***$ 804,873***
GPT				
Supply and install < 300 L/s	1	No	$ 25,000	$ 25,000
Subtotal				***$ 25,000***
Wetland and sediment basin				
Excavation	2275.36	m^3	$ 30	$ 68,261
Dispose of excess spoil (clean)	2275.36	m^3	$ 50	$ 113,768
Supply and place clay liner	1,236	m^2	$ 30	$ 37,080
Supply and install 400 mm rock base to sed pond (400 mm thick)	86.4	m^3	$ 60	$ 5,184
Planting (6 plants/sqm)	704	m^2	$ 50	$ 35,200
Planting media (50 mm depth)	35	m^3	$ 60	$ 2,112
Supply and install inlet pipe scour pad	1	No	$ 5,000	$ 5,000
Subtotal				***$ 266,605***
Stormwater drainage works				
Supply and install stormwater diversion pipe / inlet pipe to sed pond	405	m	$ 800	$ 324,000
Supply and install low flow connection b/w sed pond and wetland	1	No	$ 400	$ 400
Supply and install wetland baffle/orifice outlet pit	1	No	$ 10,000	$ 10,000
Supply and install overflow/outlet pipe to pond	5	m	$ 800	$ 4,000
Supply and construct pipe inlet and outlet headwalls	2	No	$ 1,000	$ 2,000
Supply and install new pits	1	No	$ 3,000	$ 3,000
Subtotal				***$ 343,400***
Landscaping				
Planting (4 plants/sqm)	1,124	m^2	$ 20	$ 22,480
Supply and install signage	2	No	$ 5,000	$ 10,000
Supply and install compacted rock path (4 m wide)	1800	m^2	$ 50	$ 90,000
Supply and install seats	3	No	$ 3,000	$ 9,000
Subtotal				***$ 131,480***
Subtotal for all wetland items				**$ 766,485**
Subtotal for all items				**$ 1,571,358**
Other				
Allowance for approvals (heritage, ecology etc.)	1	No	$ 5,000	$ 5,000
Design	1	No	10.0%	$ 233,912
Site investigations (geotech, survey, service detection, potholing, contam, etc)	1	No	5.0%	$ 116,956
Maintenance and establishment period	1	No	15.0%	$ 350,867
Subtotal				***$ 706,735***
Subtotal for all items				**$ 2,278,092**

Contingency			40%	$ 911,237
Total				**$ 3,189,000**

Yarralumla Brickworks - Pond

	Quantity	***Unit***	***Unit Rate***	***Cost***
Pond				
Excavation	1,611	m^3	$ 30	$ 48,330
Dispose of excess spoil offsite (clean)	1,611	m^3	$ 50	$ 80,550
Supply and place clay liner	1,500	m^2	$ 30	$ 45,000
Supply and install 400 mm rock base to pond (400 mm thick)	600	m^3	$ 60	$ 36,000
Planting (6 plants/sqm)	702	m^2	$ 50	$ 35,100
Planting media (50 mm depth)	225	m^3	$ 60	$ 13,478
Supply and install inlet pipe scour pad	1	No	$ 5,000	$ 5,000
Subtotal				***$ 263,458***
Stormwater drainage works				
Supply and install pond baffle/orifice outlet pit	1	No	$ 10,000	$ 10,000
Supply and install overflow/outlet pipe to tank	140	m	$ 800	$ 112,000
Supply and construct pipe inlet and outlet headwalls	1	No	$ 1,000	$ 1,000
Subtotal				***$ 123,000***
Landscaping				
Planting (4 plants/sqm)	840	m^2	$ 20	$ 16,800
Subtotal				***$ 16,800***
Subtotal for all pond items				**$ 403,258**
Harvesting storage				
Supply and install tank 300KL	1	No	$ 75,000	$ 75,000
Subtotal				***$ 75,000***
Harvesting distribution/treatment				
Harvesting pond offtake headwall, pipe, wet well, senor and control panel	1	No	$ 40,000	$ 40,000
Power supply to offtake pump including conduit and cabling (assuming close proximity)	1	m	$5,000	$ 5,000
Offtake pump including guiderails and accessories	1	No	$40,000	$ 40,000
Distribution main	230	Lin m	$150	$ 34,500
PLC controls	1	No	$20,000	$ 20,000
Automatic filter and UV disinfection	1	No	$150,000	$ 150,000
Subtotal				***$ 289,500***
Subtotal for all harvesting items				**$ 364,500**
Subtotal for all items				**$ 767,758**
Contingency			40%	$ 307,103
Total				**$ 1,075,000**

Total for wetland and pond	**$**	**4,264,000**

Appendix A
Development plan layouts

Figure 7. *Irrigation Area Diagram*

Appendix B
Rational calculations

Rational calculations

For the flows provided in Table 2, the rational method has been adopted. The calculations made are presented here.

Table 11. Rational calculations

		Subcatchments								
	Sub catchment:	A	B	C	D	E	F	**Total**	Existing residential catchment	Total (internal + existing residential)
Parameter	Catchment area, ha	1.21	1.53	2.26	1.91	1.53	1.40	9.8	2.6	12.4
	Fraction impervious	0.4	0.45	0.4	0.8	0.5	0.45	0.51	0.7	0.55
	Length, m	335	138	295	152	129	209	770	318	770
	Drop, m	7	7	11	5	4	5	18	18	18
	Slope m/m	0.021	0.051	0.037	0.033	0.031	0.024	0.023	0.057	0.023
	Average pipe diameter, mm	600	600	600	600	600	600	600	600	600
	Velocity, m/s	3.1	4.9	4.2	3.9	3.8	3.4	3.3	5.2	3.3
	Time of concentration, min	8.8	7.5	8.2	7.6	7.6	8.0	10.9	8.0	10.9
Intensity, mm/hr	I 1 year	44.6	47.6	46.0	47.2	47.4	46.3	40.7	46.3	40.7
	I 5 year	79.5	85.2	82.1	84.5	84.8	82.7	72.3	82.8	72.3
	I 100 year	155.3	167.4	160.9	165.8	166.5	162.2	140.3	162.3	140.3
Discharge, m^3/s	Q 1 year	0.06	0.08	0.11	0.15	0.09	0.07	0.49	0.19	0.66
	Q 5 year	0.12	0.18	0.23	0.32	0.19	0.16	1.02	0.40	1.38
	Q 100 year	0.30	0.44	0.58	0.80	0.46	0.39	2.51	0.99	3.39

Appendix C
Treatment asset calculations

Pond analysis

The sediment basin has been sized to ensure a capture efficiency greater than 95% for the 3 month flow and provide adequate sediment storage. The procedure outlined in WSUD Engineering Procedures 2005 has been followed.

Table 12. Sediment basin calculations

	Parameter	Option 2	Option 3
Conditions	Contributing catchment (ha)	9.8	12.4
	Area of pond (m^2)	180	180
Capture Efficiency	Settling Velocity of Target Sediment (mm/s) [Particle size 125 µm]	11	11
	Hydraulic Efficiency (λ)	0.4	0.4
	Permanent Pool Depth, dp (m)	1.5	1.5
	Extended detention depth, de	0.5	0.5
	Number of CSTR's, n [From hydraulic efficiency]	1.7	1.7
	Depth below permanent pool that is sufficient to retain sediment, d* (m)	1	1
	Design Discharge (m3/s) [Q 3 month]	0.204	0.276
	Capture Efficiency	97.3 %	92
	Check (> 95%)	OK	Not OK
Sediment storage	Sediment Loading Rate, Lo (m^3/ha/yr)	1.6	1.6
	Desired clean-out frequency, Fr	5	5
	Storage volume required, St	76	92
	Available sediment storage volume	135	135
	Check (Available storage > required storage)	OK	OK
Sediment dewatering	Depth for dewatering area (m)	0.5	0.5
	Area required for dewatering (m^2)	153	183

Velocity Calculations

The velocities through the sediment basin and wetland are considered here. A flow depth of 0.5 m, which is the extended detention depth, has been assumed for all flows, which is a conservative approach (as a calculated smaller flow area will result in higher calculated velocities).

A manual calculation has been used to check the flow velocities through the assets for the concept design. This calculates the flow area from the flow depth (between the extended detention depth and normal water level) and the average width in that area. The average width is determined from the narrowest part of the sediment basin and wetland. Table 13 shows the calculations for the both.

Table 13. Velocity calculation – sediment basin

		Pond			
	Parameter	**Q 3 month**	**Q 1 year**	**Q 5 year**	**Q 100**
Flow conditions	Design Flow (m^3/s)	0.205	0.49	1.02	2.51
	Flow depth (m)	0.5	0.5	0.5	0.5
Sediment pond	Width at NWL (m)	14.5	14.5	14.5	14.5
	Width at EDD (m)	20.5	20.5	20.5	20.5
	Average width (m)	17.5	17.5	17.5	17.5
	Flow Area (m^2)	8.8	8.8	8.8	8.8
	Flow Velocity (m/s)	0.02	0.06	0.12	0.29
	Check	OK <0.5	OK <0.5	OK <0.5	OK <0.5

Table 14. Velocity calculations - wetland

		Pond			
	Parameter	**Q 3 month**	**Q 1 year**	**Q 5 year**	**Q 100**
Flow conditions	Design Flow (m^3/s)	0.20	0.19	1.35	
	Flow depth (m)	0.5	0.5	0.5	0.5
Wetland	Width at NWL (m)	14.5	14.5	14.5	14.5
	Width at EDD (m)	20.5	20.5	20.5	20.5
	Average width (m)	17.5	17.5	17.5	17.5
	Flow Area (m^2)	8.8	8.8	8.8	8.8
	Flow Velocity (m/s)	0.023	0.06	0.12	0.29
	Check	OK <0.05	OK <0.5	OK <0.5	OK <0.5