



### Variation Agreement Project B2.2/3

THIS AGREEMENT is made on the \_\_\_\_\_ day of \_\_\_\_\_ 2017

THE CRC FOR WATER SENSITIVE CITIES, Building 74, Monash University, Clayton, Victoria, 3800 (CRCWSC)

AND the parties named in Item 1 of the Schedule (Other Parties)

**BACKGROUND:**

- A. CRCWSC and the Other Parties entered into the Document named in Item 2 of the Schedule (Document).
- B. CRCWSC and the Other Parties wish to vary the Document in accordance with this Agreement.

**IT IS AGREED AS FOLLOWS:**

- |  |  |
|--|--|
| <p><b>1. Definitions</b></p> <p><b>1.1</b> Terms which are defined in the Document and used in this Agreement have the meaning given to them in the Document, unless stated otherwise.</p> <p><b>2. Effective date of variation</b></p> <p><b>2.1</b> The effective date of this Agreement is the date set out in Item 3 of the Schedule (Effective Date).</p> <p><b>2.2</b> Clause 2.1 does not affect any right or obligation arising before the Effective Date.</p> <p><b>3. Variation</b></p> <p><b>3.1</b> The parties agree that from the Effective Date the Document will be varied in accordance with Item 4 of the Schedule.</p> <p><b>3.2</b> Save for varying the Document as specified in this Agreement, all other provisions in the Document remain unchanged.</p> | <p><b>4. General</b></p> <p><b>4.1 Costs:</b> Each party remains responsible for its own costs and expenses in entering into this Agreement.</p> <p><b>4.2 Signatories:</b> The signatories to this Agreement warrant that they have the authority to enter into this Agreement on behalf of the party they are stated to represent.</p> <p><b>4.3 Counterparts:</b> This Agreement may be executed in any number of counterparts. All counterparts taken together will constitute the one Agreement.</p> <p><b>4.4 Electronic Signatures:</b> Each party may communicate its execution of this Agreement by successfully transmitting an executed copy of this Agreement by facsimile or email to each other party.</p> |
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EXECUTED as an Agreement

SIGNED for and on behalf of [CRCWSC] by its authorised officer:

Signature: 

Name: BEN FORMAGE

Date: 25/9/17

SIGNED for and on behalf of **DEPARTMENT OF WATER** .....  
by its authorised officer:

Signature:.....

Name:.....

Date: .....



SIGNED for and on behalf of **UNIVERSITY OF WESTERN AUSTRALIA**.....  
by its authorised officer:

Signature

Name: Dr Campbell Thomson

Date: 18 August 2017

## SCHEDULE

Item	Description
1. Other Parties	<b>DEPARTMENT OF WATER</b> (ABN: 28 420 443 065), 168 St Georges Terrace, Perth WA 6872 <b>UNIVERSITY OF WESTERN AUSTRALIA</b> (37 882 817 280), Registrar's Office, The University of Western Australia, 35 Stirling Highway
2. Document	Project Agreement B2.2/3. Protection and restoration of urban freshwater ecosystems: informing management and planning. Executed 10 June 2015.
3. Effective Date	1 January 2017
4. Variations	<b>Project Agreement revised budget for FY1617 provided to:</b> <ul style="list-style-type: none"><li>Extend Project end date from Jan 2017 to June 2017 due to unavoidable staff absences.</li><li>In total carry over \$74,220 into Q4 FY1617.</li><li>Transfer \$20,000 from Department of Water residual FY1617 budget to UWA in Q4 to enable project completion.</li></ul> <b>Milestone variation:</b> <ul style="list-style-type: none"><li>Develop framework and principals to support management and restoration. To be completed end June 2017 (Delayed from Sept 2016)</li><li>Produce verified conceptual models that describe the influence of drivers on a system in a typology. To be completed end June 2017 (Delayed from July 2016)</li></ul>

SIGNED for and on behalf of **DEPARTMENT OF WATER** .....  
 by its authorised officer:

Mike Rowe  
 M Director General

Signature: .....  
 Name: Mike Rowe .....  
 Date: 18/8/17 .....

SIGNED for and on behalf of **UNIVERSITY OF WESTERN AUSTRALIA**.....  
 by its authorised officer:

Signature  
 Name:  
 Date:

**SCHEDULE**

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1. Other Parties	<p><b>DEPARTMENT OF WATER</b> (ABN: 28 420 443 065), 168 St Georges Terrace, Perth WA 6872</p> <p><b>UNIVERSITY OF WESTERN AUSTRALIA</b> (37 882 817 280), Registrar's Office, The University of Western Australia, 35 Stirling Highway</p>
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# Cooperative Research Centre for Water Sensitive Cities



## Project Agreement

Project Number: B2.2\3

Project Title: Protection and restoration of urban  
freshwater ecosystems: informing management and  
planning

Project Participants: Monash University, University of  
Western Australia and the Department of Water, WA



An Australian Government Initiative



## THIS AGREEMENT IS MADE BETWEEN

**CRC FOR WATER SENSITIVE CITIES LTD ABN 19 158 409 137** of Clayton in the state of Victoria (**Company**).

**AND**

**The Project Participants set out in Schedule 1.**

### Recitals

- A. The Company is responsible for the governance, management and co-ordination of the Centre.
- B. The Project Participants are participants in the Centre.
- C. The Centre's Activities include overseeing four Research Programs. Each Research Program has a designated Program Leader who is responsible for the coordination and conduct of the Research Programs.
- D. Within the Research Programs, the Centre determines the general nature of the research projects to be conducted and then in conjunction with the Project Participants, develops the detailed research project (**Project**). The Centre also manages the funding of the Project.
- E. The Project to which this Project Agreement relates has been approved by the Board as a Project to be carried out by the Project Participants with funding from the Company as part of the Activities of the Centre.
- F. By signing this Project Agreement, the Parties acknowledge their agreement to carry out the Project in accordance with the following terms.
- G. This Project Agreement replaces the previous Project Agreements B2.2 and B2.3.

## PROJECT DETAILS

### 1 Dictionary

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- 1.1 In this Project Agreement, unless the context otherwise requires, the following definitions apply:
- (a) **BIP Participant** means the Party that has made the relevant Project BIP available to the Project.
  - (b) **Centre** means the Cooperative Research Centre for Water Sensitive Cities.
  - (c) **Centre IP** means the Centre IP arising from the Project.
  - (d) **Contributed Personnel** means the persons identified in Schedule 1 as the personnel who will conduct or be involved in the Project.
  - (e) **Participants Agreement** means either the Essential Participants Agreement or an Other Participant Agreement, entered into by the Company and a participant in the Centre.

- (f) **Parties** means the Project Participants and the Company and **Party** means any one of them.
- (g) **Project** means the project set out in Schedule 1.
- (h) **Project BIP** means the Background Intellectual Property of the Parties described in Schedule 1 or that is subsequently made available to the Project under the Participants Agreement.
- (i) **Research Project Proposal** means the proposal for the Project attached as Annexure B.

1.2 Words and phrases used in this Project Agreement that also appear in Schedule 1 [Definitions and Interpretation] of the Participants Agreement, and that are not specifically defined in this Project Agreement, will have the meaning given to those words and phrases in Schedule 1 of the Participants Agreement.

## 2 Paramountcy

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If there is an inconsistency between this Project Agreement and a Participants Agreement, this Project Agreement will prevail to the extent of that inconsistency.

## 3 Application of Participants Agreement

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The Project Participants acknowledge and agree that:

- (a) the conduct of the Project forms part of the Centre Activities;
- (b) all the provisions of the Participants Agreement that, expressly or by implication, apply to the conduct of Projects, will with any necessary amendment, be deemed to form part of this Project Agreement; and
- (c) this Project Agreement will be read with and deemed to form part of the Participants Agreement.

## 4 Project

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In consideration of:

- (a) the payment of the Project Funds to the Project Participants by the Company; and
  - (b) the making available of the Project Contributions to the Project by the Parties,
- the Parties will conduct the Project in accordance with this Project Agreement and the Participants Agreement.

## 5 Term

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5.1 The Project will commence on the Project Commencement Date and will be completed on the Project Completion Date unless terminated earlier or otherwise agreed by the Parties.

5.2 A Project Participant may terminate this Project Agreement upon thirty days written notice to the other Parties, if another Project Participant:

- (a) abandons the Project; or
- (b) fails to achieve a Milestone or deliver a Deliverable within 60 days of the time specified in this Project Agreement,

and the Project Participant seeking to terminate has fully documented the work that it has completed and for which it has been funded before it gives notice of termination to the other Parties.

## **6 Payment and Project Contributions**

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- 6.1 Each Project Participant must make available to the Project, its Project Contributions in accordance with the Participants Agreement and Schedule 1.
- 6.2 The Company will:
- (a) pay to the Project Participants the Project Funds; and
  - (b) distribute the Project Contributions,
- in accordance with the Participants Agreement and Schedule 1.
- 6.3 In addition to its rights under the Participants Agreement, the Company may withhold some or all of the Project Funds and Project Contributions from a Project Participant that has not complied with the Project Agreement or the Participants Agreement in conducting the Project.

## **7 Performance**

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- 7.1 The Responsible Participant must ensure that the Project Leader fulfils the responsibilities and duties set out in Annexure A, in addition to any obligations set out in the Participants Agreement. The Responsible Participant must notify the Company upon becoming aware that the Project Leader is unable or is likely to become unable to fulfil the requirements in Annexure A for the duration of the Project.
- 7.2 In addition to any obligations under the Participants Agreement, each Project Participant must, and must ensure its Contributed Personnel, cooperate with the Project Leader, act in accordance with the Participants Agreement, and carry out its part of the Project to enable the Project to be conducted in accordance with this Project Agreement.

## **8 Meetings**

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- 8.1 The Project Leader must attend the following minimum number of meetings for the duration of the Project and for a period of up to [6] months following the Completion Date, either in person or using technology available to the meeting:
- (a) two Centre workshops (industry focus) each Financial Year;
  - (b) two Centre workshops (research focus) each Financial Year; and
  - (c) all program meetings relevant to the Research Program to which the Project relates, as scheduled by the relevant Program Leader,
- provided that the Project Leader has been provided with reasonable prior notice of the meeting.
- 8.2 The Project Leader may be excused from attending a meeting personally if:
- (a) he or she has notified the CRC Executive of the reasons why they cannot attend, and suggested a nominee to attend in his or her place; and
  - (b) the CRC Executive consents to the nominee attending in the Project Leader's place.
- If consent is provided and the nominee attends the meeting, the Project Leader will be deemed to have attended the meeting for the purposes of clause 8.1.
- 8.3 The Centre may vary the number and timing of workshops specified under clause 8.1(a) or (b) by notice to the Project Leader.
- 8.4 Attendance by any one of the persons listed in Annexure B, Item 7 will be deemed to comply with Clause 8.1.

## **9 Reporting**

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- 9.1 In addition to its obligations under the Participants Agreement, the Responsible Participant must report, or ensure that the Project Leader reports:
- (a) as required by Item 10 of the Research Project Proposal;
  - (b) to the Company when requested, in the Approved Form notified by the Company from time to time;
  - (c) to the Program Leader of the Research Program for the Project, in relation to any issues adversely affecting or likely to adversely affect the Project (including any matter that the Project Leader considers will, or may, affect the ability of the Project to satisfy the Milestones or deliver the Deliverables, or to be completed within the Project Budget) as soon as practicable after that matter or issue comes to the attention of the Project Leader; and
  - (d) to the CRC Executive or Research Advisory Sub-Committee when requested.
- 9.2 The Quarterly reports required under Clause 21 of the Essential Participants Agreement must also contain a summary of the research progress made and expenditure of cash and in-kind contributions for the Project.
- 9.3 If requested by the CRC Executive or CRC Advisory Committee, the Project Participants must provide the CRC Executive or CRC Advisory Committee with any information reasonably requested in relation to the Project.

## **10 Milestones and Deliverables**

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- 10.1 Subject to this clause, the Milestones must be achieved, and the Deliverables must be delivered to the Company at the times specified in this Project Agreement.
- 10.2 A Project Participant is not required to achieve Milestones or deliver Deliverables to the extent that its failure to do so is attributable to the acts or omissions of other Project Participants or circumstances beyond its reasonable control.

## **11 Project Review**

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- 11.1 The Project will be reviewed by the CRC Executive and Research Advisory Sub-Committee in accordance with the Participants Agreement.
- 11.2 The Board may, on the recommendation of the CRC Executive or otherwise:
- (a) implement variations to the Project; or
  - (b) terminate the Project, if following a review, the Board reasonably forms the view that the Project will not achieve its objectives,
- provided the Board acts in accordance with the Participants Agreement.

## **12 Intellectual Property**

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- 12.1 Each BIP Participant makes available its Project BIP to the Project in accordance with the Participants Agreement.
- 12.2 All Centre IP will be owned by the Company. Each Project Participant will do all things reasonably necessary, including the signing of documentation, to vest the Centre IP in the Company.
- 12.3 Each Project Participant will on request from the Company provide the Company with information in relation to the Centre IP created by its personnel.

### **13 Contributed Personnel**

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- 13.1 Each Project Participant will make available its Contributed Personnel to conduct the Project in accordance with Schedule 1.
- 13.2 Subject to this clause, the Contributed Personnel of Project Participants remain subject to the terms and conditions of employment under which they are employed by Project Participants.
- 13.3 Each Project Participant will:
- (a) take all reasonably practicable steps to ensure that any working environment where:
    - (i) its Contributed Personnel work; or
    - (ii) the Project is conducted, is safe and without risk; and
  - (b) be responsible for the health and safety of:
    - (i) its Contributed Personnel at all times when they are at work; and
    - (ii) all other persons whose health or safety may be adversely affected by the conduct of the Contributed Personnel's actions.
- 13.4 Each Project Participant covenants and undertakes to procure that Centre IP created by any of its Contributed Personnel will be owned and dealt with according to this Project Agreement.

### **14 Commonwealth Obligations**

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The Parties acknowledge and agree that at any reasonable time any person designated by the Commonwealth Cooperative Research Centre Program may view the progress of the Project and that the Parties will give all assistance reasonably requested by such designated person.

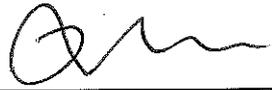
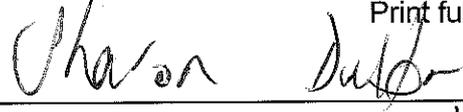








EXECUTED by DEPARTMENT  
OF WATER ABN 28 420 443  
065 by its authorised officer in  
the presence of

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 ) \_\_\_\_\_  
 ) Authorised Officer  
 ) Michael Charles Rowe  
 ) \_\_\_\_\_  
 ) Print full Name  
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 ) Witness  
 ) SHARON MACEE DUTTON  
 ) \_\_\_\_\_  
 ) Print Full Name  
 ) 19/5/2015  
 ) \_\_\_\_\_  
 ) Date

## SCHEDULE 1 PROJECT DETAILS

<b>Project Title</b>	Item 1 of the Research Project Proposal.
<b>Research Program</b> (Recital B)	Item 4 of the Research Project Proposal.
<b>Project Participants</b>	<p><b>The Company</b></p> <p><b>Name:</b> Robyn McLachlan</p> <p><b>Position:</b> Chief Operating Officer, CRC for Water Sensitive Cities Ltd</p> <p><b>Address:</b> PO Box 8000, Monash University LPO, Clayton Campus VIC 3800</p> <p><b>Telephone:</b> 613 9902 0542</p> <p><b>Mobile:</b> 61 (0)402 013 497</p> <p><b>Email:</b> <a href="mailto:robyn.mclachlan@crcwsc.org.au">robyn.mclachlan@crcwsc.org.au</a></p>
	<p><b>Monash University</b></p> <p><b>Name:</b> Prof. Pauline Nestor</p> <p><b>Position:</b> Senior Vice-Provost and Vice-Provost (Research)</p> <p><b>Address:</b> Office of DVC (Research) Building 3A, Monash University, Wellington Road, Clayton 3800</p> <p><b>Telephone:</b> +61 (0) 3 9905 2122</p> <p><b>Email:</b> <a href="mailto:pauline.nestor@monash.edu">pauline.nestor@monash.edu</a></p>
	<p><b>The University of Western Australia</b></p> <p><b>Name:</b> Dr. Campbell Thomson</p> <p><b>Position:</b> Director, Research Services</p> <p><b>Address:</b> Registrar's Office, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009</p> <p><b>Telephone:</b> +61 (0) 3 9902 9468</p> <p><b>Email:</b> <a href="mailto:campbell.thomson@uwa.edu.au">campbell.thomson@uwa.edu.au</a></p>
	<p><b>Department of Water</b></p> <p><b>Name:</b> Mike Rowe</p> <p><b>Position:</b> Acting Director General</p> <p><b>Address:</b> 168 St Georges Terrace, Perth WA 6872</p> <p><b>Telephone:</b> +61 (0) 8 6364 6804</p> <p><b>Email:</b> <a href="mailto:mike.rowe@water.wa.gov.au">mike.rowe@water.wa.gov.au</a></p>
<b>Responsible Participant</b> (clause 9)	Item 7 of the Research Project Proposal.
<b>Contributed Personnel</b> (clause 13)	Item 11 of the Research Project Proposal.
<b>Project Funds</b>	See Annexure C.

(clause 4 and 6)		
<b>Project Contributions</b> (clause 4 and 6)	See Annexure C.	
<b>Background IP</b> (clause 12)	Nil	
<b>Project Plan</b>	<i>Project Leader</i> (clauses 8 and 9)	Item 7 of the Research Project Proposal.
	<i>Project Commencement Date</i> (clause 5)	Item 2 of the Research Project Proposal.
	<i>Project Completion Date</i> (clause 5)	Item 2 of the Research Project Proposal.
	<i>Project Objectives</i>	Items 3 and 8 of the Research Project Proposal
	<i>Proposed strategy</i>	Item 9 of the Research Project Proposal.
	<i>Milestones</i> (clause 10)	Item 10 of the Research Project Proposal.
	<i>Deliverables</i> (clause 10)	Item 10 of the Research Project Proposal.
	<i>Project Budget</i>	Item 11 of the Research Project Proposal.
	<i>Third party contributions</i>	Item 11 of the Research Project Proposal.
	<i>Resources</i>	Item 11 of the Research Project Proposal.
	<i>Student requirements</i>	Item 11 of the Research Project Proposal.
	<i>New Assets or Capital Items</i>	Item 11 of the Research Project Proposal.
	<i>Analysis of Project risk</i>	Item 12 of the Research Project Proposal.
<i>Analysis of Utilisation of Project outcomes</i>	Items 13 & 14 of the Research project proposal	

## **ANNEXURE A PROJECT LEADER RESPONSIBILITIES**

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Project Leaders have responsibility for and must fulfil the following duties in relation to the Project:

- (a) Supervision of Project Activities in accordance with the Research Project Proposal.
- (b) Managing the utilisation of Contributions provided by the Company and Project Participants and any other resources made available for the Project Activities.
- (c) Ensuring the quality and timely delivery of Project Deliverables according to Milestones.
- (d) Actively fostering and facilitating the research collaboration amongst Project Participants.
- (e) Fostering integration of research outputs and insights across the Research Program and supporting the relevant Program Leader(s) in integrating research outputs across the Research Programs in the Centre.
- (f) Identifying and effectively managing and mitigating Project risk and raising any risk or performance issues concerning the Project in a timely manner with the Program Leader.
- (g) Attendance and active participation in Centre industry partner and research workshops.
- (h) Preparation of timely quarterly reports to the CRC Executive (suitable to be shown to the Board) on Project progress and Project Budget expenditures.
- (i) Identifying any Centre IP developed within the Project, maintaining proper records of the Centre IP developed and its use within the Project and notifying the Program Leader of such Centre IP and any potential future use of Centre IP within the Centre.

**ANNEXURE B RESEARCH PROJECT PROPOSAL**

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**RESEARCH PROJECT PROPOSAL****Summary Details**

**1. Title of research project proposal: B2.23** Protection and restoration of urban freshwater ecosystems: informing management and planning

**2. Proposed Project Commencement Date:** *October 2014 (Original start date July 2012)*

**Project Duration:** *4.5 years in total: remaining 2 years and 3 months*

**3. Project Abstract:**

This project has an ecological focus and will provide design and management guidance for urban waterbodies (living streams, rivers, streams, waterways, drains, wetlands, riparian zones) that fulfil recreational and aesthetic expectations, maximize biodiversity outcomes, and deliver ecosystem services while aspiring to minimize negative attributes (toxic algal blooms, fish kills).

The project recognises that freshwater functionality varies longitudinally (headwaters to lowland reaches), laterally (main channel to floodplain) and vertically (groundwater interactions), and that when ecological drivers at the landscape or local level are altered or stressed by land use change, that negative symptoms arise within urban waterbodies. The project also recognises that the severity of urban symptoms will vary, as will the range of suitable restorative or protective management actions, depending on the location of the urban footprint within the catchment, its urban design and policy attributes, and the surrounding landscape habitat quality and complexity.

Project B2.23 will review existing literature and interrogate existing data sets to investigate the extent to which landscape and local ecological drivers vary among freshwater habitats across Perth and Melbourne. Quantifying the extent to which ecosystem condition varies within and among drivers, will provide an insight into understanding the benefits that can be gained by repairing drivers. This exploration will underpin the development of conceptual typologies that describe the impact of urbanisation in different hydrogeographic settings. The conceptual typologies will be a method of communication to stakeholders and a tool to develop research hypothesis around critical knowledge gaps.

Project B2.23 will go on to develop a typology-specific urban waterway management framework that will support decisions for optimizing management and restoration effort over a range of scales. This will provide state and local planning and management agencies with the information they require to improve the health of their urban freshwaters, and assist in the transition to a water sensitive city.

Project B2.23 will also examine two fundamental questions related to the attenuation of excess nutrient loading: the role of vegetation in enhancing nitrogen removal in constructed wetlands, and the key factors stimulating and/or inhibiting denitrification in groundwater-fed systems. The findings of these studies will feed into management strategies to mitigate problems associated with eutrophication, such as toxic algal blooms.

#### 4. Number and name of CRC research program

<input type="checkbox"/> Program A – Society	<input checked="" type="checkbox"/> Program B – Water Sensitive Urbanism
<input type="checkbox"/> Program C – Future Technologies	<input type="checkbox"/> Program D – Adoption Pathways

#### 5. ANZSRC Field of Research (FoR) classification

060204 Freshwater Ecology (50%), 039901 (Environmental Chemistry (25%), 050104 Landscape Ecology (15%), 090701 Environmental Engineering Design (5%), Land Use and Environmental Planning (5%)

#### 6. Keywords: (max 6)

Urban waterways	Waterway restoration	Riparian vegetation
Ecosystem services	Biodiversity	Biogeochemistry

#### 7. Project Leader(s)

**Name:** Associate Professor Mike Grace

**Institution:** Monash University

**Department:** Water Studies Centre

**Name:** Pro Vice Chancellor Research Winthrop Professor Peter Davies

**Institution:** University of Western Australia

**Department:** Office of the Pro Vice-Chancellor (Research)

## Research Proposal

### 8. Objectives and background

#### Objectives

Project B2.23 will develop regionally-specific urban waterway management frameworks that will support decisions for optimizing management and restoration effort over a range of scales. Through an integrated experimental program it will also examine the effects of vegetation cover and groundwater influences on nitrogen removal in wetlands.

The project aims to achieve these objectives by:

1. Developing conceptual urban waterway typologies that identify the key landscape and local ecological drivers of ecosystem structure and function.
2. Comparing the relationship between urbanisation (such as catchment imperviousness, effective imperviousness or other metrics), hydrology and indicators of waterway health (e.g. macroinvertebrates, nutrients) for regions with strong groundwater interaction (e.g. swan coastal plain) and those dominated by surface water (e.g. Melbourne) using existing ecological, hydrological and catchment scale metadata.
3. Exploring the importance of refuges and landscape connectivity to urban waterway biodiversity and ecosystem function.
4. Exploring waterway health targets for urban streams.
5. Investigating the potential for remediation to improve ecosystem functionality and ecosystem service provision.
6. Constructing guidelines and a decision framework for: (i) new systems (living streams) – so that planning can incorporate features to support ecological patterns and processes; and (ii) highly urbanised existing systems – so that ecosystem services can be improved (acknowledgement that restoration may not be practicable).
7. Ensuring that urban practitioners are aware of the regional vulnerabilities/robustness of their city and adapt their rehabilitation / remediation practices accordingly.
8. Examining the role of vegetation in constructed wetlands in the effective removal of nitrate (Melbourne).
9. Undertaking an analogous study examining nitrate removal in a WA system(s).

#### Background

Freshwater habitats are an important component of urban landscapes, performing ecosystem services and delivering amenities to urban dwellers. However, the vast majority of urban freshwater systems show signs of compromised functionality - coined the 'urban stream syndrome' (Paul and Meyer 2001, Walsh et al. 2005). Symptoms include an altered hydrology, particularly increased rates of flow rise and fall, elevated concentration of nutrients and contaminants, altered thermal regimes, altered channel morphology and stability (Walsh et al. 2005). These alterations result in reduced biotic richness, with increased dominance of tolerant species (Paul and Meyer 2001, Meyer et al. 2005, Walsh et al. 2005).

The protection, rehabilitation and remediation of urban freshwaters relies on a sound understanding of the ecological processes that underpin biodiversity, ecosystem functionality, and ecosystem resilience, and how they have been altered by urbanisation. This project will synthesise current knowledge (literature review) to inform a broad understanding of the ecological effect of urbanisation on freshwaters (i.e. longitudinal, lateral, vertical and temporal perspective).

### Surface water driven vs. pronounced groundwater interactions

Most of our current understanding about the impact of urbanisation comes from studies on headwater streams (stream orders 1 to 4) in surface-water dominated systems. However, the impact of urbanisation on streams/rivers is likely to vary along the length of the river, in line with longitudinal changes in river functionality (i.e. river continuum concept, Vannote et al. 1980) and depending on the strength of groundwater interactions. For example, cities where roof runoff is delivered to a local sand-sink (e.g. Perth), rather than to the local stream via a stormwater drain, may be impacted less from altered surface hydraulics (i.e. 'flashy' flows) and more by the subsurface transport of nutrients, pollutants and organic matter. Similarly, cities that experience more uniform rainfall across the year (e.g. Melbourne) are likely to be under constant flow stress from stormwater inputs, whereas cities that experience a prolonged dry season (e.g. Perth) may switch their key stressor, from flow disturbance during winter to nutrient, pollutant, energetic or other habitat-related factors during summer.

This project will identify the key differences between two regions with very different levels of surface and groundwater dependency: south east Australia (Melbourne; clay soils, little groundwater interaction) and south west Australia (Perth; sandy soils, strong groundwater interaction). The project will investigate how these differences affect the ecological vulnerability and resilience of waterways. A major aim is to ensure that practitioners avoid a one-size-fits all approach to Water Sensitive Urban Design, and ensure that knowledge of local ecology-hydrology interactions are factored into management approaches.

The impact of urbanisation is also likely to differ between still (lentic) and flowing (lotic) habitats. Currently, there is less known about the impact of urbanisation on wetland ecology, even though wetland habitats are sometimes used to treat the impacts of urbanisation. This project will contribute to this knowledge gap by investigating the relationship between wetland biogeochemistry and ecology across the rural – urban gradient. Wetlands will also be examined in areas with strong and weak groundwater interactions.

### Remediation

This project recognises that complete rehabilitation of urban freshwaters is unachievable in highly modified catchments (Bernhardt et al. 2005). In this situation, we should aim for new targets that optimise multiple outcomes (waterway health, ecosystem services, aesthetics) given the catchment conditions (and the likely rate of change in already developed catchments) – i.e. remediation rather than rehabilitation or restoration.

Currently, there is little information about the extent to which remediation techniques can deliver ecosystem gains, or the most appropriate metrics for measuring 'success'. Typically, catchment urbanisation, in particular total or effective imperviousness, is used to provide a quick coarse indicator of ecosystem health and biotic richness (Sonneman et al. 2001, Walsh et al. 2001, Danger and Walsh 2008, King et al. 2010). However, this provides little guidance in terms of remediation, because imperviousness already significantly exceeds the thresholds for impact. Without developing a response to urban waterway management in developed catchments many waterways in cities will remain in a poor condition and have sub-optimal values in terms of ecosystem services and open space values.

This project will use metadata sets and potentially other measures of ecosystem function to investigate potential ecosystem service gains in highly urbanised catchments. We aim to develop metrics (indicators) of ecosystem function and guidelines for remediation. Our conceptual understanding of which ecological processes are linked to altered imperviousness (i.e. hydrology) and which are less affected should reveal areas where remediation can be most efficacious. For example, while remediated sites may still be subject to high flow peaks, their

riparian zone can deliver biodiversity benefits and act as a green-refuge/corridor in the urban landscape. Similarly, remediated waterways and riparian zones can still assist in nutrient and carbon uptake and processing.

### Connectivity and Refugia

Remnant natural habitats that act as refugia are critical for the persistence of populations because they provide a source from which individuals can radiate out and recolonise disturbed areas (Berryman and Hawkins 2006, Lake et al. 2007). Unfortunately, urban streams often support limited local refuges because increasing sedimentation has reduced refuge spaces between substrate particles, and because geomorphic channelization and a decline in wood inputs have reduced patch and reach-scale habitat heterogeneity (Negishi et al. 2002, Pettit and Naiman 2005). This means that recolonisation is likely to be increasingly dependent on immigration from adjoining wetlands, nearby tributaries or upstream / downstream. Movement at this larger scale is dependent on the interplay of dispersal ability of the taxa (Parkyn and Smith 2011, Alp et al. 2012) and landscape connectivity (Lake et al. 2007, Pettit et al 2011, Alp et al. 2012). These relationships are likely to differ among species in accordance with the different spatial arrangement of refuges (see Vörösmarty et al. 2010), the different dispersal attributes of resident taxa and the different levels of urban stress (i.e. disturbance) among regions. This project will investigate conceptually (and potentially empirically) the role of refuges to the biodiversity of urban waterbodies.

### **Outcomes:**

This project will provide state and local planning and management agencies with information about how regional characteristics (geology, groundwater, native biota) may alter the severity of urbanisation. It will provide information about the key patterns and processes needing attention for rehabilitation, and the options for improved ecosystem services under conditions of remediation. It will also provide information about the importance of landscape connectivity / refuges to ecosystem resilience. This will assist managers to take a broad spatial approach to urban rehabilitation / remediation and improve the likelihood of ecosystem gains once hydrological stress has been reduced. It will also support management of wetlands through better understanding the effects of vegetation cover and groundwater influences on nitrogen removal.

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### Research Questions:

- 1) What are the critical ecological processes that support ecosystem functionality and biodiversity at spatial scales ranging from sites (wetland, stream, drain) to catchments, and how are these affected by urbanisation? (conceptual models)
- 2) Does reduced effective imperviousness (or other metric of urbanisation), but increased groundwater connectivity alter the relationship between urbanisation and hydrology (ecologically relevant metrics) and waterway health compared to sites dominated by surface water?
- 3) Does the amount of vegetation in constructed wetlands alter the effectiveness of nitrate removal?
- 4) Are refuges and landscape connectivity important to biodiversity and resilience, particularly for rehabilitated urban sites?

- 5) To what extent does ecosystem function / services vary among highly urbanised waterways? What metrics vary the most and could be used as metrics for remediation goals?
- 6) What management strategies will be most effective at increasing ecosystem functionality, biodiversity and ecosystem services, while reducing the negative societal impacts of urban waterways?
- 7) What is the role of vegetation in constructed wetlands in the effective removal of nitrate (Melbourne)?
- 8) What is the process for nitrate removal in Western Australian wetland system(s)?

**9. Research plan** *(methods, timelines and outputs – do not include annual workplans)*

This project proposes to undertake its activities in the following phased schedule.

Phase 1 – Develop conceptual urban stream and wetland typologies; Pilot stage nitrogen biogeochemistry (October 2014 – July 2015)

- 1) This phase will build upon the work undertaken in B2.2 and continue the development of conceptual urban waterbody typologies that describe the relative importance of interactions between the drivers of waterbody condition and ecosystem services.
- 2) Select appropriate Melbourne wetlands for investigation through consultation with Melbourne Water, and WA waterways in consultation with DoW and UWA. Complete pilot stage investigations of nitrogen biogeochemistry in the selected waterways. This will include method validation, assessment of key experimental variables, level of replication and appropriate data analysis methods.

Phase 2 – Explore the potential of urban waterbodies for restoration. (January 2015 – July 2015)

- 1) This phase will expand the literature review of project B2.2 and seek to conceptualise the capacity of a degraded system to improve its waterbody condition and ecosystem service capability. The range of a typologies, ecosystem services and aspirations will be explored throughout this phase.
- 2) The wetland nitrogen cycling component will continue to be explored throughout this phase.

Phase 3 – Verify typologies; full scale seasonal study of nitrogen removal dynamics in the selected water bodies. (July 2015 – July 2016)

- 1) This phase will compare the relationship between urbanisation (such as catchment imperviousness, effective imperviousness, habitat spatial fabric, or other metric), hydrology and indicators of waterway health (e.g. macroinvertebrates, nutrients) for regions with strong groundwater interaction (e.g. swan coastal plain) and those dominated by surface water using existing ecological, hydrological and catchment scale metadata.
- 2) Using the waterbodies, selected for the pilot studies in Melbourne and in Perth and the optimised methods for these waterways, a comprehensive experimental program will be undertaken with the goals of identifying the drivers of nitrogen removal, and the dependence of these removal rates on local and seasonal factors.

Phase 4 – Develop decision support framework (March 2016 – September 2016)

- 1) This phase will develop a decision support framework with typology specific protection and restoration principles and/or indicators that protect the drivers of waterbody condition and ecosystem services from physical and social threats at different scales.

2) The nitrogen cycling component will continue until September 2016.

Phase 5 – Knowledge synthesis (July 2016 – December 2016)

1) This phase will focus on synthesising the knowledge acquired from all components of the project into methods for broader application and guidance to ensure that urban practitioners are aware of the regional vulnerabilities/robustness of their city and adapt their rehabilitation / remediation practices accordingly.

**10. Project Deliverables and Milestones** (*list quarterly, half-year or annual milestones as appropriate*)

Project Deliverables	Milestone dates
Commencement of PhD project on wetland biogeochemistry and ecology (Monash)	delivered
Commencement of Post-doctoral Fellow on wetland biogeochemistry and ecology (Monash).	delivered
Produce conceptual urban waterbody typologies that describe drivers of a system. Identification of biogeochemistry study sites in Melbourne and Perth, optimised study design, results of pilot study.	July 2015
Identify, consolidate and undertake gap analysis of datasets.	October 2015
Produce verified conceptual models that describe the influence of drivers on a system in a typology.	July 2016
Develop framework and principals to support management and restoration. Preliminary results from full biogeochemical study on nitrogen removal in Melbourne and Perth.	September 2016
Develop methods for broader application. Completion of biogeochemistry (nutrient) study including incorporation of key findings into management recommendations.	December 2016

**11. Risk and Risk Management** (*identify risks to the successful completion of the project and risk management measures adopted*)

Risk	Management Measures
Access to suitable datasets	It is proposed to use partner datasets which should minimise risk with regard to access.
Spatial support capacity	Included budget in resourcing to outsource
Appointment of an appropriate post doc	A postdoctoral candidate has already been identified and started at Monash in August 2014.
Delay of approval to commence new project	Request preliminary approval from CEO in October. Still awaiting confirmation.

## Adoption Pathways

### **12. Linkages to other Projects** (*linkages to other research activities within the Program and across other Programs within the CRC*)

#### Linkages within Sub-Program B2

Links to B2.1: This project has a natural linkage to B2.1's outputs (C. Walsh's project). B2.1 has found strong scientific evidence linking urbanisation to the degradation of stream ecosystems; however, the research has been contained within a particular physiographic setting. B2.23 is the natural progression of this research as it examines the applicability of B2.1's findings to different regions across southern Australia.

Links to B2.4: This project has a strong link with B2.1 (C. Oldham's project). Much of the rationale for project B2.23 arose from an industry awareness that findings from B2.1 are not appropriate for sandy soils with strong groundwater inputs. B2.23 will use the knowledge gained from B2.4 about nutrient fluxes in groundwater to improve our understanding of the role of groundwater in how urban waterways respond to urbanisation.

The Monash-based nitrogen biogeochemistry has direct links to both B2.1 and 2.4 and will provide points of insightful comparison regarding effects of systemic differences and drivers.

#### Other Linkages

Both the management perspective and findings on the roles of vegetation and groundwater on nitrogen removal from B2.23 provide a strong linkage with B1.2, which looks at catchment-scale planning, especially B1.2's aim to ensure that ecological and hydrological ecosystems services are incorporated into planning.

### **13. Linkages to Adoption Pathways activities** (*outline possible adoption pathways activities to disseminate and encourage industry adoption of project outputs.*)

The inclusion of an industry project facilitator from the Department of Water provides this project with a strong and clear linkage to industry. This role will facilitate dialogue with stakeholder needs at a variety of levels from state management (e.g. WA Department of Water & Melbourne Water) to on-ground management (SERCUL & MW).

**Annexure C    Project Resources**

The information displayed here is private and confidential.

