CRC for
Water Sensitive Cities

QUARTERLY PROJECT REPORT

Project Number:	IRP2	Project Title:	Comprehensive Economic Evaluation Framework
Project Leader/s:		Dr Sayed Iftekhar	
Report for Quarter ending:		Q4 FY16/17 April - June 2017	

1. Progress executive summary

Key developments & overall summary of project status (~250 words)
IRP2 has delivered three milestone reports this quarter under WP1, WP2, and WP3. WP6 has completed a Work Plan. **WP1 (Stakeholder engagement)**: The final Stakeholder Engagement Strategy has been circulated to the PSC for comments and will be submitted shortly. IRP2 researcher, Mark Siebentritt, conducted several interviews with internal staffs across the CRCWSC program and some stakeholders who are closely involved with the CRCWSC program. The result is a highly consultative strategy that will guide the communication, engagement and adoption processes to enable industry to adapt and apply new, innovative concepts and tools produced by IRP2. *Immediate task (next 4-6 weeks) for this WP is to finalize the SES based on feedback from the PSC.* **WP2 (Non-market valuation and benefit transfer tool)**: The report on existing non-market values of water sensitive systems and practices is complete and has been shared with the PSC and key case study partners for their feedback. The information collected for the review will be used to populate the database. *Immediate task (next 4-6 weeks) for this WP is to finalize the report based on feedback from the PSC and case study partners.* **WP3 (Cost-benefit analysis tool)**: IRP2 expert researcher, David Pannell, has undertaken over 10 full length interviews with industry representatives, including all the PSC members, to gain their views and perspectives on what a BCA tool would need to comprise of to become the accepted standard for water-related investments. Professionals in the industry and researchers in the field have sent through existing BCA tools currently being used in the sector, which will also inform the development of the new tool. *A report capturing this data collection has been circulated to the PSC. Immediate task (next 4-6 weeks) for this WP is to finalize the report based on feedback from the PSC.* **WP4 (Financial models and policies)**: Research around existing finance models and policies for selected cases is underway and we will be in a position to start conversations with regulators shortly. PSC are considering specific contacts of who we should target our engagement, and the ways in which we can engage them in this dialogue. **WP5 (Case studies)**: The information collected for the NMV report and BCA tools will contribute to further development of the case studies. In particular, IRP2 participated in the CRCWSC and WA Water Corp's 2-day Research Synthesis workshop in Perth on 24-25th May to identify future uses for land surrounding the Subiaco waste water treatment plant. This workshop progressed the land use scenarios, which is essential for the WP5.2 case study. Water Corp has confirmed their financial contribution to IRP2 to fund the research required for this case study. There are on-going discussions in terms of shaping up the existing case studies and develop ideas for one or two more case studies. **WP6 (Heat island mitigation)**: A revised work plan has been submitted and accepted. A two-month delay on creating modelling scenarios occurred as a result of discussions with industry partners about the most appropriate case study site. That matter has now been resolved and creation of modelling scenarios has commenced with only minor changes in time frames for deliverables. Good progress has been made in setting up the climate-modelling environment so that modelling can commence as soon as scenarios are provided. A review of the relevant economic evaluation literature has commenced.
Key findings for quarter (~150 words)

A book chapter has been produced which is currently being internally and externally reviewed.
Research translation and utilisation activities (~150 words) *(Summarise the application of research outputs by end-users in research case studies, trials, pilot studies, etc)*
Preparations for the session at the CRCWSC Conference in July in Perth have been in progress, which translates a lot of research activities from tranche 1 to a broad audience.
Key communication and stakeholder engagement activities (~100 words) *(Note that details must be reported in Section 3)*
IRP2 facilitated a stakeholder need assessment workshop at the Water Services Association of Australia (WSAA)'s Adaptive Planning & IWM Network event in Brisbane, 4 – 5th May, 2017. Representation from the key water utilities around Australia attended, and the IRP2 project was discussed at length, enabling utility stakeholders to provide context and identify the gaps and challenges that require new purpose-built tools and approaches. A number of stakeholder consultations and interviews have been carried out with key industry partners and CRC representatives as part of development of SES and BCA tools. The IRP2 Project Steering Committee meeting on 6th June this quarter via teleconference keeping them informed and consulted as we proceed. We welcomed two new members to the PSC, Karen Campisano from the WSAA and Joanne Woodbridge from EMRC. Joanne's nomination on the WA RAP was ratified at the July meeting. Bios of each PSC member have been collected for use in upcoming presentations and workshops. We put a "call-out" in the June issue of WaterSENSE encouraging CRCWSC participants to get involved in WP3. We already have received a number of responses. Communication lines have been set up with these people, and they will be contacted for their inputs, as and when needed. We are currently drafting a flier summarising the IRP2 project for use when networking with on-ground practitioners and other stakeholders who are interested in learning more about our project. It encourages the reader to open links on CRCWSC website for more information. IRP2 has spoken with representatives from SEQ Water and the Water Environment & Reuse Foundation in the US (http://www.werf.org/) about potential funding to undertake work related to IRP2.

Key Issues or Risks Anticipated	Risk Management Activities
Case Study stakeholders expectation of faster progress than the project can deliver	Create a work plan and communicate timeline, keep stakeholders updated on progress of the development of the tool to be tested.
Unrealistic expectations about the extent to which the project will incorporate industry needs and preferences	Manage expectations and undertake engagement activities where we can articulate and clarify our project's role and outcome

2. Milestones and deliverables

Milestones and deliverables description *from Project Agreement, Annual Workplan, and/or C'wealth milestone (include number)*	**PA milestone due date;** *also add Annual Workplan due date if revised*	**Status update and list any actual outputs** *Enter publications into Section 3. Provide detail and justification for issues with delivery & budget*	**Management response** *How are delivery delays or issues being managed?*	**% Complete**	**Status***
Commonwealth Milestones					
Under review					
Project Agreement Milestones					
WP1:Working paper on existing non-market values of water sensitive systems and practices	June-17	Submitted to the PSC		100%	☺
WP1:Stakeholder engagement strategy (SES)	June-17	Submitted to the PSC		100%	☺
WP1: Stakeholder needs assessment report	Sept-17	Under preparation		50%	☺
WP1:Training sessions	Sept-18 & Dec-19			0%	☺
WP2: Database on existing non-market values of water sensitive systems and practices	Dec-17 Dec-18 Dec-19	*Draft* Design underway		30%	☺
WP2: Benefit-transfer guidelines	June-18			5%	☺
WP3: Report on existing BCA tools and lessons for our tool	June-17	Submitted to the PSC		100%	☺
WP3: Benefit: Cost Analysis tool (draft version for testing)	Sept-17			20%	☺
WP3: Benefit: Cost Analysis tool (revised version)	Dec-18			0%	☺
WP3: Guidelines for Benefit: Cost Analysis tool	Dec-19			0%	☺
WP4: Review of existing finance models and policies for selected cases	Mar-19	Ready to engage with regulators		20%	☺
WP4: Finance models and policies for selected cases (tested and finalised)	Sept-19			0%	☺
WP5: Integrated economic valuation report: Final report (WP 5.1) Greening pipeline	Jun-17 Jun-18 Jun-19	Workshop completed		15%	☺

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WP5: Integrated economic valuation report: Final report (WP 5.2) Wastewater Precinct	Sept-17 Sept-18	Workshop completed		10%	☺
WP5: Integrated economic valuation report: Final report (WP 5.3) Living stream	Mar-19	Workshop completed		10%	☺
WP5: Integrated economic valuation report: Final report (WP 5.4) Arden Macaulay	Jun-18 Dec-18	Discussions taking place		5%	☺
WP5: Integrated economic valuation report: Final report (WP 5.5) Breakout Creek Wetlands	Mar-19 Sept-19			0%	☺
WP6: Revised Work plan submitted and accepted	Jun-17	Completed	N/A	100%	☺
WP6: Landscape scenarios development for Study Site 1 (Sunbury, Melbourne) and report	Jun-17 (revised date in new work plan)	Delayed because of discussions with industry partners on case study site. Review of the no intervention model (scenario 1) and current policy model (scenario 2) has commenced with 13 critical variables identified to date. Interaction with modellers to confirm, then in next month development new scenarios and models for new stormwater objectives (scenario 3) and achieving the desired temperature outcome (scenario 4).	Now on track within the new Work Plan time frame	30%	☺
WP6: UHI modelling and heat mitigation for Study Site 1 (Sunbury, Melbourne) scenarios and report	Dec-17 (revised date in new work plan)	Main progress in modelling has been setting up the modelling environment (generic configurations for Toolkit2 and SURFEX models which then can be replaced with the specific domain details of the scenarios). Forcing data being obtained from BOM; scripts being written to generate the needed forcing files for the specific scenario periods; creation of the analysis scripts to process the model results.	N/A	25%	☺
WP6: Integrated economic valuation of Study Site 1 (Sunbury, Melbourne). Report	Mar-18 (revised date in new work plan)	At this stage a preliminary scan of the published literature on UHI economics has been undertaken and will be developed further in the next two months.	N/A	10%	☺
WP6: UHI modelling and heat mitigation for Study Sites 2-4 (Sydney, Brisbane and Perth) and report (subject to funding)	Jun-18	Subject to funding	Subject to funding	N/A	N/A
			Overall Project status		☺

*

☺ - *on-track to meet milestone as per agreed timeframe and budget;*

😐 - *unlikely or not on-track to achieve milestone by agreed timeframe and budget;*

☹ - *will not achieve milestone within agreed timeframe and/or budget*

3. Communication, stakeholder engagement and adoption activities

Please attach a copy of any published articles or reports with this quarterly report

Formal publications - peer reviewed, *PUBLISHED in this quarter** **-** *includes books, book chapters, articles in refereed journals, full written conference papers (refereed proceedings)*		
Publication Type *(choose from list above)*	**Reference** *(Harvard Style)*	***Request to Publish form*** **submitted? Y/N**
None this quarter		

Publications and reports for end-users – *for this quarter*, *aimed at transferring know-how or practical information for end-users.* **-** *includes technical or milestone reports, end-user reports or guidelines, synthesis reports; newsletter articles, industry notes, fact sheets, audio-visual materials (videos, CD-ROMs, DVDs), flyers, presentation materials, booklets, computer programs, blogs, websites.*			
Publication/product type *(choose from list above)*	**Reference & other details** *(Authors, description, publisher, web address, location, etc)*	**Status** *(in draft; in press/review; published/final)*	***Request to Publish form*** **submitted?**
Agreement Milestone report	Review of nonmarket values of water sensitive systems and practices: An update. Asha Gunawardena, Fan Zhang, James Fogarty and Sayed Iftekhar	Under internal review	Not yet
Agreement Milestone report	Stakeholder engagement strategy. Mark Siebentritt and Sayed Iftekhar	Under internal review	Not yet
Agreement Milestone report	Report on existing BCA tools and lessons for our tools. David Pannell	Under internal review	Not yet
Flyer	Overview of IRP2	In draft	Not yet
Video	Pannell, D. Economics of green infrastructure in cities. Video produced by New Water Ways and uploaded 4th May 2016. https://www.newwaterways.org.au/new-water-ways-speaker-series/wscss-tube-videos/	Available Online. Comms team to put on CRCWSC website, too.	Yes

Communication and stakeholder engagement activities **-** *includes seminar / workshop; conference, meeting, research synthesis activity, training, education or capacity building, PSC, CRCWSC-AC, other*							
Date	**Location**	**Type** *(choose from list above)*	**Activity details and purpose**	**Key attendees and organisation** *(list name and organisation where possible)*		**# of attendees**	**Host** *(CRCWSC or other - specify)*
6th June	Tele-conference	PSC meeting	To discuss overall progress of the project	Grace Tjandraatmadja	MW	12	CRCWSC IRP2
				Greg Finlayson	GHD		
				Ursula Kretzer	DoW		
				Mellissa Bradley	Water Sensitive SA		
				Sayed Iftekhar	IRP2 / UWA		
				Tammie Harold	IRP2 / UWA		
				James Fogarty	IRP2 / UWA		
				Karen Campisano	WSAA		
				Joanne Woodbridge	EMRC		
				Ben Fallowfield	Northern beaches		
				Jurg Keller	CRCWSC / UQ		
				Nigel Tapper	IRP2/ Monash		
4th May	Brisbane	Stakeholder Workshop	To gain better understanding of stakeholder needs and the key challenges in the industry. To raise awareness of IRP2 project and outputs	Gayathri Jasper	WSAA (Secretariat)	15	WSAA's Adaptive Planning & IWM Network event Session hosted by CRCWSC IRP2
				Charles Agnew	Sydney Water (Convenor)		
				Emma Pryor	Sydney Water (Chair)		
				David Hughes-Owen	Water Corporation		
				Ian Johnson	South East Water		
				Shane Tyrrell	Queensland Urban Utilities		
				Nigel Corby	City West Water		
				Ashley Lorenz	Unitywater		

				Solvej Patschke	Seqwater		
				Dimity Lynas	Seqwater		
				Christine Grundy	Coliban Water		
				David Flower	Melbourne Water		
				Ian Jennison (partly)	Queensland Urban Utilities		
				David Pannell	IRP2/UWA		
				Sayed Iftekhar	IRP2/UWA		
24-25th May	Perth	Stakeholder Workshop	To develop an integrated approach to planning land use in the buffers of wastewater treatment plants, focusing on the Subiaco Strategic Water Resource Precinct IRP2 had an interest in this due to the direct relationship with the case study	Jamie Ewert	CRCWSC	~ 30+	CRCWSC and Water Corporation of Western Australia
				Ursula Kretzer	DoW		
				Sayed Iftekhar	IRP2 / UWA		
				More names available from Jamie Ewert, CRCWSC			
4th April	Perth	Engagement and capacity building	A Symposium on Green Infrastructure to recognise everyone's roles and responsibilities in the delivery of green infrastructure, and the risks, costs and need for long term planning. IRP2 had a session on "What are the key issues and how do we overcome them"	*List available from Shelley Shepard, Urbaqua*		~ 30+	New WAater Ways Presentation made by CRCWSC IRP2
		Meeting		David Pannell	IRP2/UWA	9	CRCWSC IRP2

22nd May	Tele-conference		To discuss overall progress of the case studies, and areas of work by the IRP2 project researchers	Sayed Iftekhar	IRP2/UWA		
				Tammie Harold	IRP2/UWA		
				Asha Gunawardena	IRP2/UWA		
				Mark Siebentritt	IRP2/SEED Consulting		
				Joanne Woodbridge	WP5.4 / EMRC		
				Naomi Rakela	WP5.4 / EMRC		
				Kym Whiteoak	IRP2/KMCG		
				Nigel Corby	WP5.4 / City West Water		

4. Project personnel

<u>Project personnel changes</u>

- includes new, exiting and change of details for this quarter

Title & Full name	**University or Organisation, and Department**	**Position**	**Date (Start / Exit)**	**Phone**	**Email**	**FTE (full-time equivalent)**	**Cash funded or in-kind?**
Naomi Rakela	EMRC	PSC member	Exit: May 2017	(08) 9424 2273	Naomi.Rakela@emrc.org.au	-	In-kind
Joanne Woodbridge	EMRC	PSC member	Start: May 2017	(08) 9424 2273	Joanne.Woodbridge@emrc.org.au	-	In-kind
Karen Campisano	WSAA	PSC member	Start: June 2017	(02) 8397 7296	karen.campisano@wsaa.asn.au	-	In-kind

<u>New and graduating students for this quarter (PhD, Masters, or other Postgraduate)</u>

** if graduating, please provide details of graduate employment destination (if known)*

Full name	University, Faculty / Department	Thesis topic	New – start date Graduating – end date	Contact details *(Phone & email)*	Cash funded; top-up or in-kind?	Supervisors *(including organisation)*
No changes						

5. Other project highlights and issues – IP, funding, awards

Research Case Study progress

Research Case Study name	Key outcomes/outputs to date	Issues identified & management actions
WP5.2 Economic Evaluations for Land use scenarios and funding, Subiaco	Ideas for land use scenarios is progressing	None.
WP5.4 Arden Macaulay Urban redevelopment	None.	Some aspects around this project are yet to be consolidated making the case study site unconfirmed. We are in contact with the case study leaders and lead agency of the project and will continue to monitor and offer our assistance, when and as needed.

Intellectual Property, Awards

Item	Details
New intellectual property (Centre IP)- identified	
Regulatory activities undertaken or completed	
Awards and acknowledgements	

Additional funding

New financial assistance / grants for quarter
- *excludes funds from CRCWSC participant contributions*
- *includes those awarded by Commonwealth/state/territory government sources or agencies*

Grant Title	Granting Body	Date Awarded	Total Grant Amount $	Grant Period	Amount per Financial Year

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6. In-kind contribution from industry partners*

**For SME participants (small and medium enterprises) and non-participant organisations only*

Staff time contribution *e.g. Project Steering Committee, research case study workshops, in-house meetings / presentations, preparation for CRCWSC workshops, dedicated staff*				
CRCWSC event or activity	**Organisation**	**Name**	**Position**	**Hours contributed**
IRP2 Project Steering Committee	Alluvium Consulting	Fiona Chandler	Consultant	6 hours
IRP2 Project Steering Committee	Northern Beaches Council	Ben Fallowfield	Senior Environment Officer	6 hours
IRP2 Project Steering Committee	Water Sensitive SA	Mellissa Bradley	Program Manager	6 hours
IRP2 Project Steering Committee	RMCG	Kim Whiteoak	Senior Consultant	6 hours
IRP2 Project Steering Committee	WSAA	Karen Campisano	Manager, Research and Innovation	6 hours

Non-staff contributions *such as provision of office space, meeting rooms, catering, facilities, IT, travel expenses*		
Event, activity, purpose	**Organisation**	**Estimated value**

7. Steering Committee and Project Leader endorsement

Communication with Project Steering Committee (PSC)

Report provided to PSC on 17th July, 2017.
Return feedback to Project Team by 24th July, 2017.

PSC member name	Organisation	Feedback/Comments

Project Leader's comments and endorsement

Comments from Project Leader (on overall project or in response to PSC feedback):

I confirm that the information in this report is correct and updated for the quarter.

Project Leader name: Sayed Iftekhar

Signature: **Date:**

Attachment A2.2

CRC for
Water Sensitive Cities

Stakeholder Engagement Strategy

IRP2 - Comprehensive Economic Evaluation Framework
(2017 – 2019)

Australian Government
Department of Industry, Innovation and Science

Business
Cooperative Research Centres Programme

Document title
IRP2 Stakeholder Engagement Strategy (Draft)
IRP2 Integrated economic assessment and business case development of Water Sensitive Cities
IRP2-2-2017

Authors
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1 Introduction

1.1 Background

The CRC for Water Sensitive Cities (CRC WSC) aim is to create knowledge and solutions that help communities become more water sensitive. The first four years of the CRC WSC (Tranche 1, 2012-2016) delivered 35 discrete research projects across four program areas (Society, Water Sensitive Urbanism, Future Technologies and Adoption Pathways). Over the next five years, Tranche 2 (2016-2021) projects will work with regional stakeholders to adapt and apply new, innovative concepts and tools to a whole-of-city or metropolitan scale.

Within the CRC, support is provided for Integrated Research Projects (IRP). These address priority industry needs that require ongoing research and development efforts through the integration of proposed research activities.

1.2 Integrated Research Project 2

Integrated Research Project 2 (IRP2) will be delivered under Tranche 2. The aim of IRP2 is to develop, test and apply a broadly applicable framework for conducting integrated economic assessment to support business case development for investing in water sensitive, liveable and resilient cities. The project will build on knowledge and outputs generated in Tranche 1.

In Tranche 1 there was strong emphasis on generating non-market values for different elements of water sensitive cities to understand the scope of the opportunities and problems. Selected examples from Tranche 1 include:

- Valuing environmental services associated with local stormwater management in Melbourne and Sydney
- Valuing alternative land uses adjacent to traditional wastewater treatment facilities in Western Australia
- Valuing Australia's green infrastructure using hedonic pricing analysis for various parts of Australia
- Valuing restoring urban drains to living streams in Perth
- Estimating the capitalised value of rainwater tanks in property prices in Perth
- Valuing ecosystem services of raingardens in Sydney and Melbourne
- Valuing constructed wetlands in Australia and China
- Valuing water sensitive gardening styles in Perth

IRP2 will build on the results from these studies and draw on existing information on market and non-market values from broader (published and grey) literature set, CRC end users and industry practitioners, particularly for the costs of implementing water sensitive cities elements.

Within this broader framework the project has seven objectives:

1. Build a common understanding amongst stakeholders on which elements of water sensitive cities provide the greatest benefits to the community (which includes benefits to the environment), clearly articulating market and non-market values, and contributing to transition towards liveable and resilient cities.
2. Understand the requirements of stakeholders in government and industry in the design and delivery of economic evaluation tools and frameworks.

3. Review the currently available benefit-cost analysis tools and integrate the key elements of existing tools and identify gaps and improvements needed.
4. Develop an economic evaluation framework which would allow inclusion of benefits and costs and will help users to identify who the beneficiaries are.
5. Test, refine and apply the economic evaluation framework in selected case studies in collaboration with industry partners.
6. For selected cases, review the existing finance models and policies and recommend suitable approaches for investment in water sensitive systems and practices.
7. Develop effective adoption pathways to promote and support the use of economic evaluation frameworks and tools.

The key deliverables for the project are a:

- benefit transfer tool and guideline;
- benefit-cost analysis tool and guideline; and
- financial regulation framework.

1.3 Objectives

The aim of this engagement strategy is to increase the likelihood that key stakeholders, especially end users such as local government and water utilities, will want to use the tools, frameworks, information and lessons generated from the Project. This will be achieved by designing an approach that involves end users with the *development, testing and use of different tools and the framework.*

In order to meet the project objectives, the specific objectives of this engagement strategy are to:

- identify and encourage key stakeholders, especially targeted end users in local government and water utilities, to adopt and use the tools and framework;
- raise general awareness about the existence of the tool and framework amongst possible future users to encourage adoption;
- guide internal, project team communications; and
- build on existing internal reporting mechanisms and ensure that the CRC WSC Board is aware of the project's progress and achievements.

Longer term engagement will be required to ensure ongoing use of the tool that is developed during this project. It is noted that CRC is exploring various options to support ongoing adoption of tools and products. This assessment of developing a longer term more sustainable tool is beyond the scope of this strategy.

2 Methodology

This Engagement Strategy was developed in a collaborative manner with input from the:

- Project team;
- Project Steering Committee (PSC);
- Members of the Regional Advisory Panels (RAP); and
- CRC WSC executive and staff.

The aim was to ensure that key stakeholders have had an opportunity to inform how they want to be engaged during the development of the project. Levels of engagement have been structured according to the IAP2 spectrum of public participation, described further in Section 3.

Key meetings and interviews conducted to obtain information to inform the development of the Strategy were as follows:

- Sayed Iftekhar, David Pannell, James Fogarty (IRP2 Project Team) – 20 February 2017;
- Mellissa Bradley (Water Sensitive SA, PSC member) – 17 March 2017;
- Mellissa Bradley, Sayed Iftekhar, David Pannell, James Fogarty, Tammie Harold – (Project team and subset of PSC) – 4 April 2017;
- The draft Engagement Strategy was shared with the PSC and discussed during a PSC meeting - 18 April 2017
- Chris Tanner (QLD Regional Manager, CRC WSC) – 22 June 2017;
- Jamie Ewert (CRCWSC National Engagement Manager, Chair SA RAP) – 8 June 2017;
- Barry Ball (Research Adoption Executive, CRC WSC) – 9 June 2017;
- Grace Tjandraatmadja (Melbourne Water, PSC) – 9 June 2017;
- Greg Claydon (Department of Water, Chair of the WA RAP) – 21 June 2017;
- Warren Traves (GHD Australia, Chair of the QLD RAP) – 21 June 2017;
- Briony Rogers (Project Leader Program A, Project Leader IRP1) – 23 June 2017;
- Emma Church (Eastern Regional Manager, CRC WSC) – 26 June 2017;
- Rob Skinner (Monash University, CRC WSC Board member) – 26 June 2017; and
- Antonietta Torre (WA Department of Water, representative on WA Community Engagement Subcommittee) – 26 June 2017.

3 Target audience

Stakeholders will benefit by being part of the project directly (such as through participation in the case studies or workshops) or indirectly (such as through our communication and adoption activities). The stakeholders directly engaged will gain first-hand experience from the development and testing of the economic evaluation framework. Further, participants of the case studies will benefit from the case specific economic evaluation which will help them to devise appropriate water management strategies for their particular problem / issue.

In order to meet the engagement objectives for this project, the target audience has been divided into groups of internal and external stakeholders.

The external stakeholders are a combination of water utilities and local government bodies (councils, agencies) that are actively seeking to make investment decisions in water sensitive cities technology, either now or in the future. External stakeholders also consist of key influencers in State and Local Government decision making, namely regulators and treasuries.

<u>External stakeholders</u> are primarily in four categories:

- Active End Users (ES1) – End users who commit to using the tool for actual decision making during the life of the project. Ideally, 2-3 active end users will emerge during the project.
- Case Study End Users (ES2) – End users who actively inform the development of the tool and test it during the life of the project, but do not necessarily use the tool to inform actual decision making. Case studies are identified in Table 1 and Case Study End Users in Table 2.
- Treasuries and Regulators (ES3) – External stakeholders who will have a major influence over whether the tools and framework can be used to support investment in water sensitive urban design technologies e.g. IPART in NSW, ERA in WA.
- Indirect End Users (ES4) – End users who have an interest in investing further in water sensitive cities technology or who want to provide support in developing the underlying business case but are not actively involved with the project case study development and testing. This group forms part of the broader target audience that will need to be engaged if the project is to be adopted more broadly in the longer term and includes water utilities, local government, state government and consulting firms. This group will provide an opportunity to engage with states outside of where the case studies are located.

<u>Internal stakeholders</u> are primarily in four categories:

- Senior management of the CRC (IS1) – Past project experience suggests that engagement with the Board and Executive to ensure they are aware of progress and achievements is important for the overall success of the project.
- Project Steering Committee (IS2) - The Project Steering Committee consists of representatives of a range of key stakeholder organisations, including a number involved with case studies.

- Regional Advisory Panels (IS3) – Regional Advisory Panels exist in WA, NSW, Qld, Vic and SA and their members include people who are also on the PSC. RAPs also provide a conduit to the broader water industry.
- Project team (IS4) – The project team is spread across Australia and involves the following entities: the University of Western Australia, Monash University, Seed Consulting Services (Adelaide), RMCG (Melbourne), E2DesignLab (Melbourne).
- Other CRC Projects and researchers (IS5) – The CRC has a broad range of organisations involved as participants and partners with a general level of interest in the outcomes of this project.

The general approach to Project Governance is provided in Attachment A.

Engagement of the target audience will need to be cognisant of other engagement processes occurring in other CRC WSC projects. This will occur by regular communication between the Project Leader and the CRC WSC executive.

Table 1. Classification of case studies against work packages.

Work package	**Description**
WP5.1	Greening the Pipeline in Melbourne Case Study
WP5.2	Economic evaluation of land use scenarios and funding options for Strategic Water Resource Precincts (Subiaco) Case Study
WP5.3	Converting an open drain into a living stream (Bellevue) Case Study
WP5.4	Arden Macaulay Urban Redevelopment Case Study
WP5.5	Restoration of Breakout Creek Case Study

Table 2. Case study end users listed alphabetically.

Stakeholder	**Type**	**Case study***	**Case study location**
Adelaide and Mt Lofty Ranges NRM	State Government	WP5.5	SA
City of Charles Sturt	Local Government	WP5.5	SA
City of Melbourne	Local Government	WP5.4	VIC
City of Moonee Valley	Local Government	WP5.4	VIC
City of Nedlands	Local Government	WP5.2	WA
City of Swan	Local Government	WP5.3	WA
City of West Torrens	Local Government	WP5.5	SA
City West Water	Water utility	WP5.1, WP5.4	VIC
Department of Environment, Land and Water Planning	State Government	WP5.4	VIC
Department of Parks and Wildlife (Rivers and Estuaries Division)	State Government	WP5.3	WA
Department of Water	State Government	WP5.2, WP5.3	WA
Developer – Taliska Securities Pty Ltd	Industry	WP5.3	WA
Melbourne Metro Rail Authority	State Government	WP5.4	VIC
Melbourne Water	Water utility	WP5.1, WP5.4	VIC
SA Water	Water utility	WP5.5	SA
Shire of Mundaring	Local Government	WP5.3	WA
South East Water	Water utility	WP5.4	VIC
VicRoads	State Government	WP5.1	VIC
Victorian Government (via Victorian Planning Authority)	State Government	WP5.4	VIC
WA Planning Commission/Department of Planning	State Government	WP5.2	WA
Water Corporation	Water utility	WP5.2, WP5.3	WA
WESROC group of local governments (Municipalities of Nedlands, Subiaco, Cottesloe, Peppermint Grove, Claremont, Mosman Park)	Local Government	WP5.2	WA
Wyndham City Council	Local Government	WP5.1	VIC
Yarra Valley Water	Water utility	WP5.4	VIC

* As the case studies evolve the list of end users would be updated

4 Approach

The engagement approach followed for this project is that developed by the International Association for Public Participation (IAP2) and summarised in the IAP2's Public Participation Spectrum (Figure 1). "Adoption" of the project results is not listed in this diagram because it is an outcome of the engagement process rather than a level in the Spectrum.

The spectrum is designed to assist with the selection of the level of participation (engagement) that defines a stakeholder's role in an engagement program (International Association for Public Participation, 2017). It shows that differing levels of participation are legitimate depending on the goals, time frames, resources and levels of concern in the decision to be made. The Spectrum also sets out the "promise" being made to stakeholders at each participation level.

The Spectrum has been used in this project as a framework for deciding what level of engagement is appropriate for each target audience segment, based on the notion that not all stakeholders will be engaged equally.

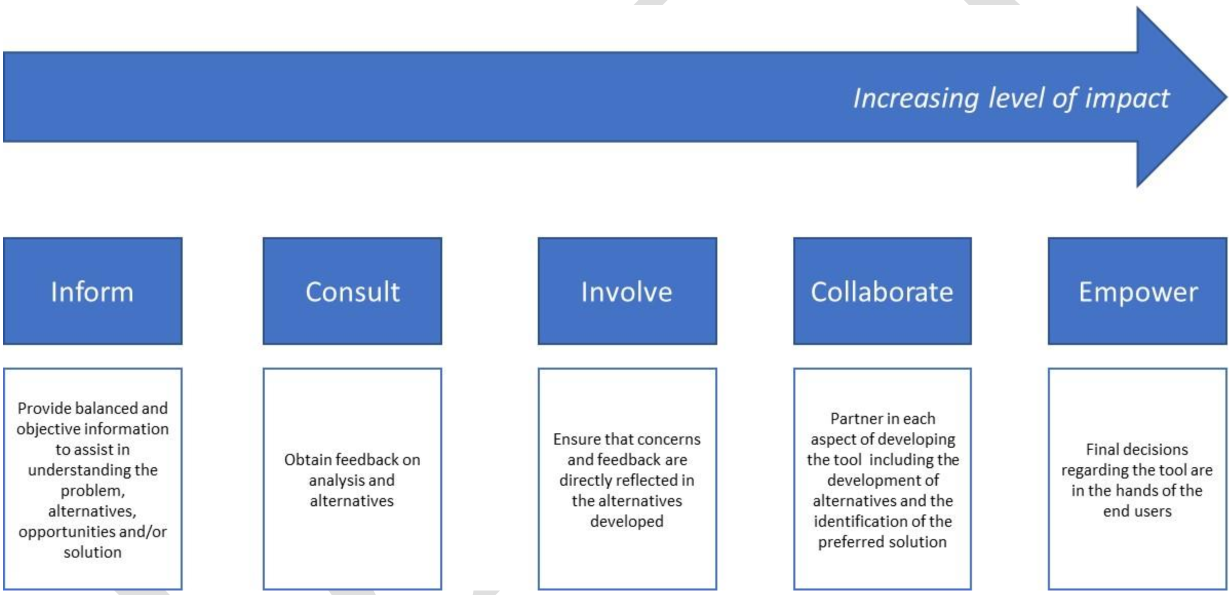

Figure 1. IAP2's Public Participation Spectrum, outlining the five levels of participation and the broad goal for each relevant to this project. Source: International Association for Public Participation - IAP2 Federation.

Our engagement approach differs across the external stakeholder group as follows:

- Active End Users (ES1) – **Collaborate**
- Case Study End Users (ES2) – **Involve**
- Treasuries and Regulators (ES3) – **Involve**
- Indirect End Users (ES4) – **Inform**

Our engagement approach across the internal stakeholder group is as follows:

- Senior management of the CRC (IS1) – **Inform**
- Project Steering Committee (IS2) – **Collaborate**
- Regional Advisory Panels (IS3) – **Involve**
- Project team (IS4) – **Collaborate**
- Other CRC Projects and researchers (IS5) – **Inform**

These levels of engagement determine the subsequent nature of all engagement activities for each segment of the target audience.

The different levels of engagement across stakeholder groups is reflected through our tiered engagement approach, with the amount of effort and resources dedicated to engagement increasing from Indirect End Users through to Active End Users (Figure 2).

We will use a range of communication approaches to provide information, seek feedback and involve stakeholder in the project, including:

- Digital
    a. WaterSENSE e-newsletter;
    b. CRC WSC webpage;
    c. webinars;
    d. e-fact sheets;
    e. email correspondence;
    f. teleconferences;
    g. synthesis and profile reports;
    h. feature articles;
    i. audio-visual materials (videos, CD-ROMs, DVDs);
    j. presentation materials;
    k. social media platforms e.g. LinkedIn;
- Face-to-face
    a. interviews;
    b. workshops;
    c. meetings;
    d. conferences;
    e. industry events.

No print material (e.g. hard copy fact sheets) is proposed for communication activities.

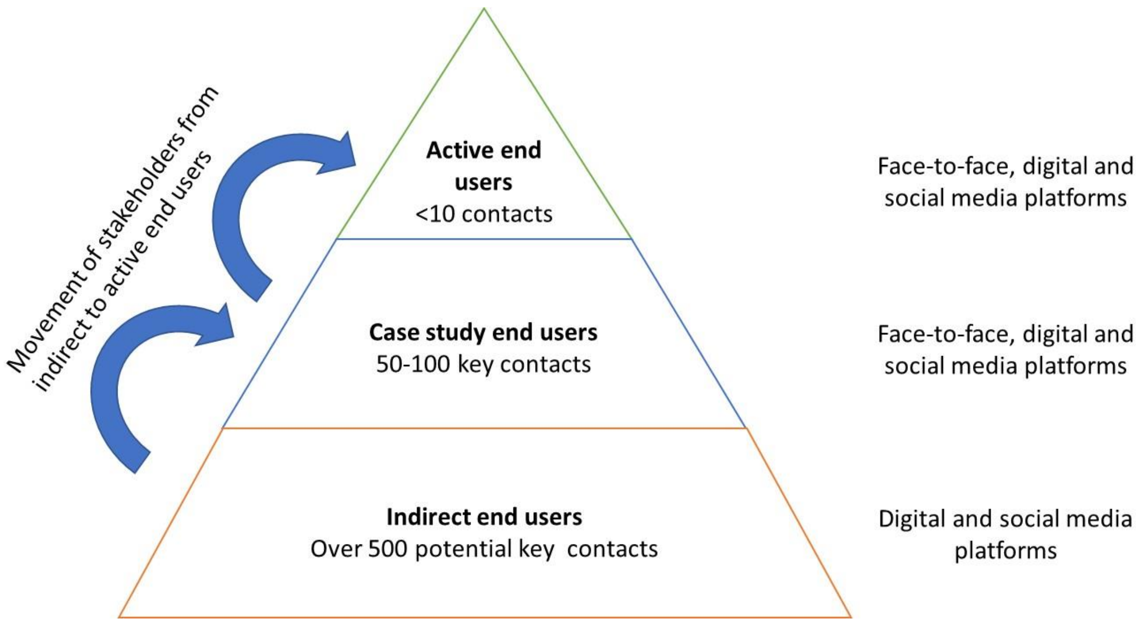

Figure 2. Tiered approach to engagement of the three external stakeholder groups.

5 Engagement process

A summary of engagement activities for each external stakeholder group is provided at Attachment B. Further detail is provided in the following sections. Only those work packages deemed relevant to a stakeholder group are described.

The specific engagement activities described aim to:

- review and validate existing identified benefits – rather than starting from zero base;
- clarify the nature and scale of projects for which industry would be seeking either benefit valuations (for their own tool) or an entire cost-benefit tool;
- use the above to prioritise benefits for valuation;
- concentrate efforts on what data local government, state government, utilities and the consulting industry can bring to the project; and
- stream line the collation of data.

5.1 External stakeholders

5.1.1 Active Case Study End Users (ES1) – Collaborate

Active End Users will be identified later in the project and engagement will initially follow the same approach as for Case Study End Users. In general, there will be a stronger emphasis on collaboration with active end users.

5.1.2 Case Study End Users (ES2) – Involve

Engagement activities will be conducted with Case Study End Users with the aim of achieving an ***Involve*** *level of engagement to ensure that that concerns and feedback are directly reflected in the alternatives developed.*

Case study end users will be involved through a combination of digital, social media platforms and face-to-face engagement. There will be at least two face to face sessions per state over the life of the project.

WP1: Stakeholder Engagement

Notification about project commencement – A formal letter will be sent from the Project Leader to the nominated contact to notify them that the project has commenced, outlining how engagement with them will occur and what we expect them to contribute.

Activities – Distribute letter and conduct follow up phone calls

WP1.1 Inform the stakeholders about the current knowledge on economics of water sensitive urban designs – Inform the stakeholders about the current knowledge on economics of water sensitive urban designs. We will expand and update the collection and update the review, adding new published studies (from CRC and others), grey literature and existing relevant economic tools.

Activities - Distribute e-document to end-users; Webinar provided to all external stakeholders

WP1.3 - Stakeholder consultations for needs assessment - A thorough stakeholder needs assessment will be carried out to determine needs and agreed types of values/benefits and costs that need to be incorporated into the tools. To understand industry needs or gaps, there will be a selected number of issue-based or thematic workshops. The workshops will be held in several states to capture variation in local contexts in different parts of Australia. Where possible, some of these workshops will be organized in collaboration with IRP1 (and other CRC researchers) to incorporate a wider community view point. At the completion of this activity, a summary of the needs assessment will be prepared and be made available for distribution.

Activities – Thematic workshops; Interviews; Distribute needs assessment to end-users

WP1.4 - Training and capacity building - Building on the outputs (such as manuals, tools and learnings) produced by other parts of the project, we will develop a training module and deliver training in the application of economic tools and framework. To deliver the training, the team will work closely with industry partners.

Activities – Training module; Deliver training in the application of economic tools and framework; Promote training through digital platforms

WP2: Updated Collation of Existing Non-Market Valuation Information and Development of a Benefit Transfer Tool

WP2.2 - Development of benefit-transfer guidelines – We will develop accessible guidelines for end users on how to conduct benefit transfer for water sensitive practices, including choosing appropriate methods for the particular context. The guidelines will be tested with the stakeholders and adapted accordingly.

Activities: Stakeholder testing of benefit-transfer guidelines

WP3: Development of a User-Friendly Benefit-Cost Analysis (BCA) Tool Tailored to Water Sensitive Cities Investments

WP3.1 - Review of existing benefit-cost analysis tools relevant to water-sensitive cities – Existing literature and relevant stakeholders will be consulted to understand what tools are already being used (and by whom) and the extent of their use in decision making processes. Existing tools for benefit-cost analysis will be reviewed to determine their suitability for assessing water sensitive systems and practices at different scales and for users of varying capacity.

Suitability of tools will be determined with respect to quantifying benefits for a range of possible factors e.g. ecosystem health, human health/well-being, economic prosperity, and climate change adaptation/mitigation, ease of use and data availability.

Activities: Stakeholder interviews / meetings

WP3.3 - Develop a BCA tool – Based on the review and existing tools and approaches - We will decide about whether to adapt an existing tool or develop a new tool to meet the specific needs of Australian end users.

Activities: Advise stakeholders of the decision as to which tool will be developed through the use of a range of digital platforms.

WP3.4 - Guidelines for benefit-cost analysis tool - Develop a guideline document to support the application of the BCA tool. This will provide guidance on critical concepts and approaches that underpin the tool, step-by-step guidance on how to apply it, and information about its assumptions and limitations. It will also provide several examples based on the case studies under WP5 on how to apply the framework in practice. This would include a discussion on alternatives for assisting decision-making when some elements (such as monetized benefits) are not available.

Activities: Stakeholder interviews / meetings used to inform development of the tool.

WP4: Finance Models and Policies to Foster Investment in Water Sensitive Cities

WP4.1 - Review existing finance models and policies - Work with end users to identify existing finance model, policies and mechanisms (such as financial incentives) used to foster public and private investment in water sensitive cities.

Activities: Stakeholder interviews / meetings

WP4.2 - Engage with regulators and agencies to design new approaches - Building on findings from WP4.1 and WP1.2, design a small number of alternative approaches to investment financing and policy that appear likely to be effective in the context of water sensitive cities. We will workshop these approaches with CRC end users, policy makers and experts in financing projects to evaluate their likely success.

If we are able to identify approaches that are judged to be likely to succeed, then we can work with policy agencies to explore the legal, practical, political and financial feasibility of implementing the approach.

Activities: Stakeholder workshops / meetings

WP5: Testing the Integrated Economic Evaluation Framework in Selected Case Studies

WP5.1-5.5 - Case studies - Engage with end users to understand the feasibility of implementing various options and generate a set of recommendations for the implementing organisations. The case studies will be conducted in such a way that the intermediate results are continually disseminated to allow for transferability and quick uptake.

Activities: Case study development and testing; Use of digital platforms and face to face communication

WP6: Economic Value of Urban Climate Improvement: Urban Heat Island (UHI) Mitigation

This work package will explore the UHI mitigation produced from different scales of investment in urban greening, and quantify in dollar terms the value of this benefit, for example by reduced mortality/morbidity, reduced energy demand and increased productivity.

Activities: Use of digital platforms to promote the results of the economic analysis.

5.1.3 Treasuries and Regulators (ES3) – Involve

*Engagement activities will be conducted with Treasuries and Regulators with the aim of achieving an **Involve** level of engagement to ensure that that concerns and feedback are directly reflected in the alternatives developed.*

WP1: Stakeholder Engagement

WP1.1 - Inform the stakeholders about the current knowledge on economics of water sensitive urban designs - Inform stakeholders about the current knowledge on economics of water sensitive urban designs. We will expand and update the collection and update the review, adding new published studies (from CRC and others), grey literature and existing relevant economic tools.

Activities: Digital platforms; Presentations at industry events and conferences

WP1.3 - Stakeholder consultations for needs assessment – The needs assessment will include interviews with Treasury and Regulator representatives to determine needs and agreed types of values/benefits and costs that need to be incorporated into the tools.

Activities: Interviews / meetings / workshops

WP3: Development of a User-Friendly Benefit-Cost Analysis (BCA) Tool Tailored to Water Sensitive Cities Investments

WP3.1: Review of existing benefit-cost analysis tools relevant to water-sensitive cities – Existing literature and relevant stakeholders will be consulted to understand what tools are already being used (and by whom) and the extent of their use in decision making processes.

Activities: Interviews / meetings

WP3.4: Guidelines for benefit-cost analysis tool - Develop a guideline document to support the application of the BCA tool. This will provide guidance on critical concepts and approaches that underpin the tool, step-by-step guidance on how to apply it, and information about its assumptions and limitations.

Activities: Promote the BCA tool using digital platforms

WP4: Finance Models and Policies to Foster Investment in Water Sensitive Cities

WP4.1 - Review existing finance models and policies - Work with Treasury and Regulator contacts to identify existing finance model, policies and mechanisms used to foster public and private investment in water sensitive cities.

Activities: Interviews, meetings

WP4.2 - Engage with regulators and agencies to design new approaches - Building on findings from WP4.1 and WP1.2, a small number of alternative approaches to investment financing and policy will be designed. These approaches could include beneficiary identification methods, risk sharing, cost-sharing principles as well as payment mechanisms such as value capture.

Activities: Workshops, meetings

WP5: Testing the Integrated Economic Evaluation Framework in Selected Case Studies

Case studies will be developed with Case Study End Users and the results communicated to Treasury and Regulator contacts via digital platforms.

Activity: Communication via digital platforms.

5.1.4 Indirect end users (ES4) – Inform

*Engagement activities are conducted with Indirect End Users with the aim of achieving an **Inform** level of engagement to provide balanced and objective information to assist in understanding the problem, alternatives, opportunities and/or solution.*

WP1: Engagement Initiation

WP1.1 - Inform the stakeholders about the current knowledge on economics of water sensitive urban designs – Inform stakeholders about the current knowledge on economics of water sensitive urban designs. We will expand and update the collection and update the review, adding new published studies (from CRC and others), grey literature and existing relevant economic tools.

Activities - Distribute e-document to end-users; Webinar provided to all external stakeholders; Social media posts.

WP1.4 - Training and capacity building - Building on the outputs (such as manuals, tools and learnings) produced by other parts of the project, we will develop a training module and deliver training in the application of economic tools and framework. In addition to train for case study end users, we will also provide limited training for indirect end users, targeting practitioners from a range of sectors such as utilities, local councils, agencies, state governments, and peak bodies (such as WSAA). To deliver the training, the team will work closely with industry partners, of which many will be key members on our Steering Committee across Australia.

Activities – Training module; Deliver training in the application of economic tools and framework

WP2: Updated collation of existing non-market valuation information and development of a benefit transfer tool

General information sharing on collation of non-market valuation information and development of a benefit transfer tool.

Activities - Distribute e-document to end-users; Webinar provided to all external stakeholders; Social media posts

WP3: Development of a user-friendly Benefit-Cost Analysis (BCA) tool tailored to water sensitive cities investments

WP3.4 - Guidelines for benefit-cost analysis tool - Develop a guideline document to support the application of the BCA tool. This will provide guidance on critical concepts and approaches that underpin the tool, step-by-step guidance on how to apply it, and information about its assumptions and limitations. It will also provide several examples based on the case studies under WP5 on how to apply the framework in practice. This would include a discussion on alternatives for assisting decision-making when some elements (such as monetized benefits) are not available.

Activities: Webinar to inform external stakeholders on how to use and access the tool; social media posts

WP4: Finance models and policies to foster investment in water sensitive cities

General information sharing on collation of non-market valuation information and development of a benefit transfer tool.

Activities - Distribute e-document to end-users; Webinar provided to all external stakeholders; social media posts

WP5: Testing the integrated economic evaluation framework in selected case studies

Case studies – Following completion of the case studies, content will be developed to upload to the CRC website promoting the case study findings. This will be complemented by webinars and social media postings.

Activities: Webinar provided to all external stakeholders; Social media posts

WP6: Economic Value of Urban Climate Improvement: Urban Heat Island (UHI) Mitigation

This work package will explore the UHI mitigation produced from different scales of investment in urban greening, and quantify in dollar terms the value of this benefit, for example by reduced mortality/morbidity, reduced energy demand and increased productivity.

Activities: Use of digital platforms to promote the results of the economic analysis.

5.2 Internal stakeholders

5.2.1 Senior management of the CRC (IS1) – Inform

Senior management of the CRC will be regularly contacted to ensure project progress is communicated, especially following delivery of major work packages. This will be the responsibility of the Project Leader to coordinate. Senior management could also be invited to support social media posts (e.g. through likes and comments) and contribute to webinars by introducing speakers and content.

Activities: Focus on digital platforms, with periodic meetings to update senior management on progress.

5.2.2 Project Steering Committee (IS2) - Collaborate

The Project Steering Committee will be regularly updated on project progress via teleconferences and meetings. They will also receive general digital communications distributed to all other stakeholder groups.

Activities: Teleconferences, meetings, e-newsletters, email correspondence

5.2.3 Regional Advisory Panels (IS3) - Involve

The RAPs will be updated on project progress via a bi-monthly project update report. PSC members who sit on the RAPs are expected to provide a thorough update of the Project to the PSC. The IRP2 Project Leader will endeavour to a deliver face to face workshop/meeting with the RAPs. This may be as part of a workshop/meeting with other stakeholders as well.

Activities: Bi-monthly report, PSC member updates, face-to-face workshop/meeting

5.2.4 Project team (IS4) - Collaborate

The project team is spread across four organisations in WA, SA and Victoria. Ensuring consistent delivery of key messages to project team members, and then onto key stakeholders will be essential for project success.

Following completion of the draft engagement strategy, a presentation will be given to all team members on its structure and the proposed implementation approach. This will provide an opportunity to confirm the approach and key messages.

Following this initial briefing, the Project Leader will provide quarterly project progress reports to the project team.

In addition to delivering workshops and conducting interviews, team members will be expected to provide content for engagement activities such as social media posts and webinars.

Activities: Teleconferences, meetings, e-newsletters, email correspondence

5.2.5 Other CRC Projects and researchers (IS4) – Inform

Other CRC Project participants and researchers will receive the same level of engagement as Indirect End Users, with a focus on digital platforms and presentations at conferences and industry events. There will be a focus on ensuring that other IRP Project Leaders are aware of the progress with project and can act as an advocate for it (and vice versa). This can be facilitated by regular meetings/teleconference calls between project leaders.

Activities - Distribute e-documents; Webinars; Social media posts; project leader meetings

6 Engagement schedule

Table 3 provides a description of the proposed engagement activities, the intended target audience, and when delivery is required. In a number of instances a single engagement activity will be designed for multiple stakeholder groups.

Implementation of this engagement schedule should be monitored on a monthly basis and amended based on feedback from the stakeholder groups. This may result in changes to type of engagement activity and/or its timing.

Table 3. Schedule of engagement activities from July 2017 to December 2019.

	Target audience									2017/18												2018/19												2019/20					
	ES1	ES2	ES3	ES4	PS1	PS2	PS3	PS4	PS5	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
TASK																																							
WP1: Stakeholder Engagement																																							
Notification about project commencement																																							
- Distribute letter and conduct follow up phone calls	x	x								x	x																												
WP1.1 Inform stakeholders about economics of WSUD																																							
- Distribute pdf report to end-users	x	x	x	x	x	x	x	x	x			x																											
- Webinar provided to all external stakeholders	x	x	x	x									x																										
- Presentations at industry events or conferences	x	x	x	x	x	x	x	x	x					x			x																						
- Social media post regarding release of report				x								x																											
WP1.3 - Stakeholder consultations for needs assessment																																							
- Thematic workshops										x	x																												
- Interviews	x	x	x							x	x																												
- Distribute needs assessment report to end-users												x																											
WP1.4 - Training and capacity building																																							
- Promote training through digital platforms	x	x	x	x																		x	x													x	x		
- Deliver training in the application of economic tools and framework	x	x	x	x																				x														x	
WP2: Non-Market Valuation and Benefit Transfer Tool																																							
WP2.2 - Development of benefit-transfer guidelines																																							
- Stakeholder testing of benefit-transfer guidelines	x	x															x	x	x																				
- Social media post regarding release of report				x																	x	x																	
- Distribute pdf report to end-users	x	x	x	x																	x																		
WP3: Benefit-Cost Analysis (BCA) Tool																																							
WP3.1 - Review existing benefit-cost analysis tools																																							
- Stakeholder interviews	x	x	x							x	x																												
WP3.3 - Develop a BCA tool																																							
- Advise stakeholders about which tool will be developed	x	x	x								x	x																											
- Development of tool	x	x	x									x	x	x	x	x	x	x	x	x																			
- Testing of revised tool	x	x	x																					x	x	x													
WP3.4 - Guidelines for benefit-cost analysis tool																																							
- Stakeholder interviews	x	x	x																												x	x						
- Promote the BCA tool using digital platforms	x	x	x	x	x	x	x	x	x																											x	x		
- Social media post regarding release of report				x																																x	x		
- Webinar	x	x	x	x	x	x	x	x	x																											x	x		
WP4: Finance Models/Policies to Foster Investment																																							
WP4.1 - Review existing finance models and policies																																							
- Stakeholder interviews	x	x	x																						x	x	x												
WP4.2 - Engage with regulators and agencies to design new approaches																																							
- Stakeholder workshops / meetings	x	x	x																												x	x	x						

	Target audience									2017/18												2018/19												2019/20					
	ES1	ES2	ES3	ES4	PS1	PS2	PS3	PS4	PS5	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
TASK																																							
WP5: Testing the Economic Evaluation Framework in Case Studies																																							
WP5.1 - Greening pipeline																																							
- Collect and review relevant information – workshop / meeting	x	x								x	x																												
- Assess potential of b-t tool to use existing data – interviews / meeting	x															x	x																						
- Workshop economic analysis methods and data requirement – workshop / meeting	x	x																					x	x															
- Understand feasibility of implementing options – interview / meeting	x	x																									x	x											
- Social media post	x	x	x	x	x	x	x	x	x																								x	x					
- Webinar	x	x	x	x	x	x	x	x	x																								x	x					
WP5.2 - Subiaco wastewater preccinct																																							
- Collect and review relevant information – workshop / meeting	x	x										x	x																										
- Assess potential of b-t tool to use existing data – interviews / meeting	x	x														x	x																						
- Workshop economic analysis methods and data requirement – workshop / meeting	x	x																x	x																				
- Understand feasibility of implementing options – interview / meeting	x	x																		x	x																		
- Social media post	x	x	x	x	x	x	x	x	x															x	x														
- Webinar	x	x	x	x	x	x	x	x	x															x	x														
WP5.3 - Living stream																																							
- Collect and review relevant information – workshop / meeting	x	x											x	x																									
- Assess potential of b-t tool to use existing data – interviews / meeting	x	x															x	x																					
- Workshop economic analysis methods and data requirement – workshop / meeting	x	x																				x	x																
- Understand feasibility of implementing options – interview / meeting	x	x																								x	x												
- Social media post	x	x	x	x	x	x	x	x	x																					x	x								
- Webinar	x	x	x	x	x	x	x	x	x																					x	x								
WP5.4 - Arden Macaulay																																							
- Collect and review relevant information – workshop / meeting	x	x																			x	x																	
- Assess potential of b-t tool to use existing data – interviews / meeting	x	x																				x	x																
- Workshop economic analysis methods and data requirement – workshop / meeting	x	x																					x	x															
- Understand feasibility of implementing options – interview / meeting	x	x																						x	x														
- Social media post	x	x	x	x	x	x	x	x	x																		x	x											
- Webinar	x	x	x	x	x	x	x	x	x																		x	x											
WP5.5 - Break-out Creek																																							
- Collect and review relevant information – workshop / meeting	x	x																												x	x								
- Assess potential of b-t tool to use existing data – interviews / meeting	x	x																													x	x							
- Workshop economic analysis methods and data requirement – workshop / meeting	x	x																														x	x						
- Understand feasibility of implementing options – interview / meeting	x	x																															x	x					
- Social media post	x	x	x	x	x	x	x	x	x																											x	x		
- Webinar	x	x	x	x	x	x	x	x	x																											x	x		

	Target audience									2017/18												2018/19												2019/20					
	ES1	ES2	ES3	ES4	PS1	PS2	PS3	PS4	PS5	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Sep-19	Oct-19	Nov-19	Dec-19
TASK																																							
WP6: Economic Value of Urban Climate Improvement																																							
- Workshop / meeting to identify key benefits										x	x																												
- Develop landscape scenarios (interviews/meetings)														x	x																								
- Social media post	x	x	x	x	x	x	x	x	x									x	x																				
- Webinar	x	x	x	x	x	x	x	x	x									x	x																				
Project communication																																							
- Project update report (one-pager) (bi-monthly)					x		x				x		x		x		x		x		x		x		x		x		x		x		x		x		x		x
- Material for website (bi-monthly)	x	x	x	x	x	x	x		x		x		x		x		x		x		x		x		x		x		x		x		x		x		x		x
- PSC teleconference						x						x		x		x		x		x				x		x		x		x		x				x		x	
- Enewsletter article - Contribution to WaterSense (bi-monthly)	x	x	x	x	x	x	x	x	x		x		x		x		x		x		x		x		x		x		x		x		x		x		x		x
- Annual F2F PSC meeting (in conjunction with CRC Conference)							x			x												x												x					
- Project team teleconferences (quarterly)								x		x			x			x			x			x			x			x			x			x			x		
- Project leader meetings (bi-monthly)									x		x		x		x		x		x		x		x		x		x		x		x		x		x		x		x

7 Risk management

A risk rating matrix is provided in Table 4, which is used to generate risk scores in Table 5.

Table 4. Risk rating matrix.

	Likelihood				
Consequence	**1**	**2**	**3**	**4**	**5**
	Rare	**Unlikely**	**Possible**	**Likely**	**Almost certain**
5 Catastrophic	5	10	15	20	25
4 Major	4	8	12	16	20
3 Moderate	3	6	9	12	15
2 Minor	2	4	6	8	10
1 Negligible	1	2	3	4	5

Table 5. Stakeholder engagement risk assessment matrix. L – Likelihood, C – Consequence, R - Rating.

Potential risk	**Potential impact**	**Risk assessment**			**Action required to mitigate risk**	**Residual risk**		
		L	**C**	**R**		**L**	**C**	**R**
Project outputs seen as being largely academic	May prevent the adoption of the tool in the short and longer term Would require additional post-project engagement	3	3	9	Ensure communication activities emphasise the practical nature of project outputs	2	3	6
Project team members become advocates for technologies that are not viable for some end users	Lead to disengaged end users who believe the business case for selected technologies is not relevant to their organisation	4	2	8	Project team management ensures that individual team members communicate agreed key messages	2	2	4
Unrealistic expectations about how the project will address existing stakeholder needs	Project outputs do not meet user needs and adoption rates of tool during and following the completion of the project are low.	2	3	6	Use the engagement strategy to understand and manage stakeholder expectations. Re-enforce the types of project outputs at regular intervals	1	3	3
Project is seen as a series of independent case studies rather than a single tool	Following completion of the project adoption of the tool as an industry indirect is limited	3	2	6	Project Steering Committee to emphasise integration of project outputs	2	2	4

Potential risk	Potential impact	Risk assessment			Action required to mitigate risk	Residual risk		
		L	**C**	**R**		**L**	**C**	**R**
Inconsistent key messages from across the team	Stakeholders become confused about how outputs will address their needs. This will result in low adoption rates.	4	4	16	Project team management ensures that individual team members communicate agreed key messages	2	4	8
Changing priorities/staff within stakeholder organisations	Initial needs identification becomes irrelevant and tool no longer addresses user needs	4	4	16	Key project staff maintain regular communication with key contacts	3	3	9

Attachment A – Project governance

The Project Leader responsible for overall coordination and reporting. The Project Steering Committee provide overall guidance to the Project, whose members are as follows:

- Ben Fallowfield
- David Pannell
- Fiona Chandler
- Grace Tjandraatma
- Greg Finlayson
- Joanne Woodbridge
- Karen Campisano
- Kym Whiteoak
- Mellissa Bradley
- Nick Morgan
- Nigel Tapper
- Sadeq Zaman
- Sayed Iftekhar
- Ursula Kretzer

The main purpose of the Project Steering Committee (PSC) is to provide a joint leadership forum between industry and research partners with direct interests in the project outputs and subsequent outcomes. The PSC is therefore a resource that is a critical part of the overall project delivery team, and it should provide valuable, constructive and active input into the project to help maximise the value and benefits of the project work and the adoption of project outputs.

Although the PSC is not formally contracted to provide the project deliveries, it should still take an overall guiding role and joint ownership in all phases of the project lifetime. Hence, the PSC should provide direct input into the development of the project proposal, actively contribute to the ongoing progress and delivery of the planned outputs, and provide support for the uptake/adoption of the project outputs and deliverables.

In particular, the PSC (with support from local/regional steering groups, if existing) should help to ensure that:

- the project scope, activities and outputs are both technically/scientifically achievable and practically relevant;
- the ongoing directions and progress of the project remains on track to generate the expected outputs;
- the project activities and deliverables are regularly reviewed and revised if necessary;
- any proposed, or additional, inputs and/or resources are available to enable or improve the project outputs;
- the Research Case Studies within the project are effective and suitable to help deliver industry-ready project outputs; and
- the outputs from the project are actively being tested, implemented, promoted and, if necessary, modified or expanded during the lifetime of the project.

Attachment B – Summary of engagement activities

Codes relate to work packages (WP) and external stakeholder (ES) groups: ES1 – Active Case Study End Users, ES2 – Case Study End Users, ES3 – Treasuries and Regulators, ES4 – Indirect End Users.

	Digital								Face-to-face					
	WaterSENSE e-newsletter	Webinars	Webpage	e-fact sheets	Email correspondence	Teleconferences	Synthesis and profile reports	Social media platforms	Interviews	Workshops	Meetings	Conferences	Industry events	Training
WP1.1		ES1, E2, ES3, ES4		ES1, E2, ES3, ES4										
WP1.3									ES1, ES2	ES1, ES2				
WP1.4	ES1, E2, ES3, ES4				ES1, E2, ES3, ES4			ES1, E2, ES3, ES4						ES1, E2, ES3, ES4
WP2.2									ES1, ES2	ES1, ES2	ES1, ES2			
WP3.1									ES1, ES2					
WP3.3	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4						
WP3.4									ES1, ES2					

	Digital								Face-to-face					
	WaterSENSE e-newsletter	**Webinars**	**Webpage**	**e-fact sheets**	**Email correspondence**	**Teleconferences**	**Synthesis and profile reports**	**Social media platforms**	**Interviews**	**Workshops**	**Meetings**	**Conferences**	**Industry events**	**Training**
WP4.1									ES1, ES2					
WP4.2									ES1, ES2, ES3					
WP5.1	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4
WP5.2	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4
WP5.3	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4
WP5.4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4
WP5.5	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4
WP6.1	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4	ES1, E2, ES3, ES4			ES1, E2, ES3, ES4							

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Attachment A2.3

CRC for
Water Sensitive Cities

Review of nonmarket values of water sensitive systems and practices: An update

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Australian Government
Department of Industry, Innovation and Science
Business Cooperative Research Centres Programme

Review of nonmarket values of water sensitive systems and practices: An update
IRP2 Integrated economic assessment and business case development of Water Sensitive Cities
IRP2-1-2017

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Executive summary

Water sensitive systems and practices provide multiple indirect benefits such as environmental and ecological services. Many of these services are not considered during investment decision making due to lack of information on monetized value of these services. Compilation and synthesis of non-market valuation estimates of water sensitive systems and practices could facilitate better integration of their multi-functional benefits in traditional economic evaluation to make investment decisions. They are also helpful in conducting comprehensive post-hoc analysis of investment in water management projects.

In this report, we have carried out an extensive review of existing studies on key benefits or services of water sensitive systems and practices. We have summarized the information in terms of major services: values associated with green infrastructure, ecological and environmental values of water, benefits of climate change mitigation, non-point source pollution reduction, flood hazard reduction, improved groundwater, securing reliable water supply and wastewater management. We have mainly focused on non-market benefits, however, in some cases we have presented estimates of market benefits (or tangible benefits captured through existing markets) and cost information. A summary of our findings on key services are presented below.

Our review reveals that for green infrastructure, most of the non-market values are available for the amenity benefits. Both stated and revealed preference methods have been used to calculate these benefits. However, these estimates are sensitive to various factors such as location, types of green infrastructure, distance and estimation methods. More importantly, economic valuation studies are rare for many types of services such as mental and physical improvement, overall improvement of well-being and improvement in liveability. This indicates potential gap in economic assessment of total benefits of green infrastructures.

There are some estimates of climate change mitigation benefits (such as urban heat island mitigation, carbon sequestration and reduced carbon emission) using direct measurements (such as value of carbon or capacity of trees to store carbons). Sometimes they use indirect measurements such as loss in productivity due to extreme heat. More importantly, even though there is lack of non-market valuation studies on people's preferences of different climate change mitigation options estimates obtained for other services, such as, benefits of green infrastructure could be directly relevant for climate change mitigation options evaluation.

There have been plenty of non-market valuation studies carried out on water quality improvement. However, most of them are concentrated in the US. Generally evaluations were focused on one or two of the key elements that affect the value of water quality, water quantity, and its time and location distributions. To date research has been more focused on water quality issues than water quantity issues. Overall it also remains the case that the ecological and environmental values of water are difficult to evaluate, with the ecosystem benefits provided to human still not well understood.

Non-market valuation estimates on water quality improvement could be directly linked to the benefits of non-point source pollution reduction. However, so far, inclusion of non-market benefits in formal analysis of various pollution control approach have been scant. Often abatement cost (based on life cycle cost analysis) of removing pollution from waterbodies / storm water are estimated and used for decision making rather than looking at the total value (or benefits) of various options.

Economic assessment of flood damage and different control options have been relatively standardized due to the localized and concentrated nature of floods. Most of the impact are also direct, which makes them easier to measure. Often heuristics like stage-damage relationships are used to estimate the benefits of different flood management options. Our review indicates that there are some estimates of broader non-market benefits of different flood management options through stormwater. There is potential to use these non-market benefits to evaluate different flood management options.

A substantial portion of the Australian economy depend on groundwater and there are partial estimates of direct use values of different groundwater systems. Available estimates of direct uses reveal high contribution of groundwater to the well-being of community and people. However, information on non-market values is relatively scarce for groundwater management. Generation of such information would help in understanding the total value of groundwater systems.

Studies on water supply and pricing provide a comprehensive coverage of people's willingness to pay to ensure a reliable good quality water supply. There are standard economic analysis of elasticities of water supply, which we did not cover. The non-market estimates reveal that people's willingness to pay depend on not only the supply options but also the baseline water supply and their socio-economic conditions.

Finally, we have looked at the studies focusing on wastewater management options. We found that people are willing to use recycled wastewater, but, mostly for outdoor and non-contact uses. Wastewater recycling projects could provide other external benefits, such as, production of electricity and biogas, production of fertilizers, reduction of pollution load in the downstream waterbodies and reduction of pressure on exiting infrastructures. These benefits could be considered during formal cost-benefit analysis.

Glossary of selected terms

Choice Experiment (CE): A non-market valuation technique where willingness to pay is elicited by surveys in which people can choose between different bundles of goods with varying characteristics. The goods could be market or nonmarket goods (Meyer et al., 2014).

Contingent Valuation (CV) method: A non-market valuation technique where people are asked in surveys about their willingness to pay to avoid (or gain) a given decrement (increment) of a particular non-market good, or about their willingness to accept its deterioration by receiving a certain amount of compensation (Meyer et al., 2014).

Control or prevention costs, averting behaviour: This method relies on the assumption that it is possible to quantify the economic value of externalities in terms of the avoidance costs of implementing actions that prevent the damage produced (Holguín-Veras et al., 2016).

Cost of Illness approach: This approach uses costs of health impacts (such as medical costs and lost wages due to illness) to estimate the value of a good or project (Meyer et al., 2014).

Damage (restoration) costs approach: This approach relies on quantifying the value of the impacts as the cost required to repair the damage, and restore things to their original condition (Holguín-Veras et al., 2016).

Hedonic pricing approach: This technique uses existing market price information to estimate the impact of a project or services. For example, by comparing the prices of similar houses in different areas of a city it is possible to estimate the capitalized amenity values of green infrastructures.

Life Satisfaction Analysis: Welfare estimations of public goods (health, environment) are estimated based on life satisfaction surveys (Meyer et al., 2014).

Production Function approach: This approach relies on estimating the contribution of an environmental good in producing a market good (Meyer et al., 2014).

Replacement Cost method: The value of an ecosystem good or service is estimated based on the costs of replacing that good or service (Meyer et al., 2014).

Stated preference (SP) techniques: Stated preference techniques use surveys to understand their preferences. Contingent Valuation and Choice Experiments are prominent examples of stated preference techniques (Holguín-Veras et al., 2016).

Travel Cost method: Recreational or environmental sites are valued by analysing observed travel time and expenditure of visitors (Meyer et al., 2014).

Willingness to accept (WTA): WTA is the amount that a decision maker is willing to accept to give up using a good or service, or to put up with a decrease in welfare (Holguín-Veras et al., 2016).

Willingness to pay (WTP): Willingness to pay is the amount of money that a decision maker is willing to part with to procure a good or service, or to achieve a higher level of welfare (Holguín-Veras et al., 2016).

Introduction

Urbanization is happening at a rapid scale in many countries of the world. Although currently urban areas cover less than five percent of the terrestrial surface, it has been predicted that by 2030 the urban area would triple (increase by 1.2 million square kilometre) from the 2000 estimates if the current trend of population growth continues (Seto et al., 2012). Globally, more than fifty percent of the population now live in urban areas, whereas, in Australia, the proportion is much higher (more than 80%) (Commonwealth of Australia, 2015).

Many Australian cities and towns, however, are facing challenges from rapidly growing population and climate change. A growing population puts increasing pressure on water supply as well as on treatment and discharge of wastewater. However, supplying additional water becomes challenging due to rapid decline of traditional water sources (such as groundwater) from over-extraction and climate change. Further, people's lifestyle choices are gradually evolving. There is an increasing demand for liveable environments with high amenity services. On the other hand, water authorities and utilities are facing increasing pressure to enhance efficiency and cost-effectiveness of their investment (Sandhu and Wratten, 2013).

Water sensitive systems and practices are planning and design philosophies which could help in addressing these critical challenges in relation to water management in an integrated and systematic manner. The concept integrates the urban water cycle — including water supply, storm water, groundwater, and wastewater management — into urban design (Brown and Farrelly, 2009). As such, adoption of water sensitive systems and practices could provide benefits or services which are easily quantifiable (such as additional water supply) and intangible benefits which are often difficult to quantify (e.g., amenity benefit from installing a rain garden). While tangible benefits are easy to incorporate into economic analysis to make an investment decision, intangible benefits are often difficult due to the absence of appropriate monetized values (Wong et al., 2013). In such situations, these benefits are often ignored in the formal analysis for investment decision making.

To estimate monetized (nonmarket) values of intangible services, economists have developed various non-market valuation techniques. There are two main types of techniques: stated and revealed preference. Revealed preference methods (such as hedonic pricing analysis) use existing market values to calculate non-market values of goods and services. On the other hand, stated preference methods (such as choice experiments) use surveys to estimate people's preferences. A summary description of different techniques have been presented in the Appendix.

Using these techniques many nonmarket valuation studies have been conducted in Australia and elsewhere and some of them have focussed on various non-market benefits generated from water sensitive systems and practices. Compilation and review of the findings from these studies would be useful to get an understanding of the current state of knowledge and to make investment decisions. In this report, we provide summary of existing available information based on a thorough review of academic and grey literature. It has been organized in terms of key services or benefits from water sensitive cities and practices –

- Non-market benefits from green infrastructure
- Ecological and environmental benefits of water
- Climate change mitigation options
- Pollution control and water quality improvement
- Groundwater management
- Water security and supply and
- Wastewater management

The report is an updated and revised version of a previously published CRC report: Zhang, F. and Fogarty, J. (2014). *Nonmarket Valuation of Water Sensitive Cities: Current Knowledge and Issues*, CRC for Water Sensitive Cities. We have added new sections on non-market benefits from green infrastructure and climate change based on recommendations from our industry user groups. Further, we have added recent findings wherever available. In many cases, we have referred to already synthesised information from other sources. In few cases, we have reported market values or aggregated estimates as we could not find any estimate of non-market values. In selected cases we have provided cost estimates as they might be useful to estimate benefits indirectly. Wherever feasible information has been synthesised in summary tables. A key feature of the summary table is that study values reviewed have been converted into a common metric: 2016 $US. The summary table allows the reader to quickly gain an overview of the literature.

Green infrastructures

In many cities and towns, open green space is rapidly shrinking causing loss of ecosystem services (Vandermeulen et al., 2011). Empirical evidence suggests that urban green space/ green infrastructure improves liveability (Badland et al., 2014) through providing: increased amenity and recreational benefits (Brander and Koetse, 2011); heat mitigation benefits (Bowler et al., 2010, Norton et al., 2015); increased physical activities (Giles-Corti et al., 2005); reduced air (Nowak et al., 2013) and noise pollution (Gidlöf-Gunnarsson and Öhrström, 2007); energy savings; lowered carbon emissions (Derkzen et al., 2017, Pandit and Laband, 2010b); better resilience to natural disasters and enhanced community social capital (Hong and Guo, 2017). In addition, urban green space provides wide range of ecosystem services including conservation of urban biodiversity (Hostetler et al., 2011, Hungate et al., 2017) and agri-ecological services such as water retention and water purification (Brander and Koetse, 2011).

In this review, we focus on valuation of public open space or green infrastructure in urban settings as public investment decisions are made mostly in this realm. Valuation studies across the globe covering different types of green infrastructures varying from urban parks, urban forests and natural areas, green spaces including sports fields, under developed lands, agricultural lands in urban fringe and urban wetlands have been reviewed. We summarize available economic valuation estimates in the following four dimensions: (1) amenity; (2) recreation; (3) health benefits; and (4) energy savings.

Amenity values

Majority of the studies on valuation of green space used hedonic pricing methods to estimate amenity values. In hedonic pricing methods it is assumed that prices of residential properties reflect how people value different attributes of properties as well as positive or negative externalities due to surrounding land use. The importance of housing and land use related attributes are inferred using a regression analysis of property values on various attributes. These methods could be used to estimate value of public open space and the externalities that different land uses impose on one another (Banzhaf, 2010).

Overall, hedonic valuation studies show that availability of green space resulted in higher real estate prices, where the net benefit depends on the (1) location; (2) quality; (3) functions; and (4) size of the green space.

Spatial location and impact of proximity to green space on property prices were evaluated by several studies. Brander and Koetse (2011) conducted a meta-analysis of 12 hedonic studies from the US and concluded that 10 m decrease in distance to the green open space may results in 1 % increase of an average house price in 2003. Another study carried out in St. Paul metropolitan area in US (based on dataset from 1997) found that halving the distance to nearest park would increase the sales price of an average house by $142 per year (Anderson and West, 2006).

Cho et al. (2008), examined property sale prices in the City of Knoxville, Tennessee in 2000, and found that moving 1km closer to the evergreen forest increased average house prices by $692. However, the same study concluded that moving 100 m closer to a deciduous forest patch decreased average house price by $589. According to Nicholls and Crompton (2005), properties located directly adjacent to a greenbelt resulted in increased prices in Texas by $44,332 and by $14,777 in Travis. In North Carolina, adjacency to a private forest block increased house price by more than $8,000 (Mansfield et al., 2005).

Votsis (2017), investigated apartment transactions in Helsinki, Finland using a dataset from 2000-2011. They found that maximum effect of distance to a forest or park is at the urban core, while that of distance to a field is in the urban fringe. On a multi-year average, the effect of a 100m increase of distance to a forest resulted a decrease of 3.7% in price / m^2 at 0 km from the CBD. The effect was zero at 6 km from the CBD. A study conducted in France based on property sales in the City of Castellón in 2001 found that every 100m further away from green area would drop house price by €1800 (Morancho, 2003). Using property data of Netherlands from 1989-1992, Luttik (2000) investigated that properties located in walking distance to a park demonstrated premium of 6 % of house price. Further, a view of a park in Leiden demonstrated 8% premium. Contrary to the main idea came out from many studies (that residents pay a premium to live closer to green spaces), study by Jun and Kim (2017) in Seoul , Korea reveals that 1km closer the nearest green belt, would reduce apartment rents by 3.83 -3,95% contributing to $34 drop in average monthly rent.

Studies that examined availability of green space suggest that green space in urban settings adds value to the property prices. For example, having a neighbourhood park would lift the house price by 14.93% in Hong Kong during 2005-2006 (Jim and Chen, 2010). Sander et al. (2010), examined property sales in Minnesota, USA in 2005 and reports that 10% increase in tree cover within 100m added $1,371 to the average property price and 10% increase in tree cover within 250m only added $836. Moreover, 1 ha increase in lawn in a home's view shed corresponded to sale price increase of $1,742. They also valued 10% increase in tree cover within 4 neighbourhoods in Minnesota and reported as $1,853, $1,030, $1,947 and $1,102 respectively (Sander and Haight, 2012).

Donovan and Butry (2010), studied value of trees in Portland, Oregon using property data in 2007 and revealed that on average street trees add $8,870 to sale price. The same authors analysed rental prices of single-family homes in Portland in 2009 and 2010. They reported that an additional tree on a house's lot increased monthly rent by $5.62, and a tree in the public right of way increased rent by $21 (Donovan and Butry, 2011).

Netusil et al. (2014), examined proximity, abundance and characteristics of the green street facilities using a larger dataset of house transactions from 2005-2007 in Portland. The study concluded that the proximity to the facility did not increase the house price. For example, an increase in distance of 1 foot away from the nearest green street facility is estimated to increase a property's sale price by $0.30. However, a 10 percentage point increase in tree canopy at the closest green street facility is estimated to increase a property's sale price by $18,707.

Using property transaction records from 2003-2004 in the city of Los Angeles, CA, Saphores and Li (2012) estimated benefit of adding one generic tree with a 16m^2 canopy cover over the impervious area of a house as an increase of property value by $204.

Using a large data set on single-family houses sold in 1997-2006 in Virginia, Poudyal et al. (2009a) found that 10% increase in square footage of the urban park in the neighbourhood increased house values by 0.03%. In addition, 100ft increase in the size of the park resulted in 0.79% of increase of price of nearby houses. Poudyal et al. (2009b), also investigated the spatial pattern and appearance of the green space and found that residents preferred open spaces in few larger plots to many smaller pieces that are scattered throughout the neighbourhood. House prices increased when diverse open green spaces were available in the neighbourhood.

Rossetti (2013), analysed a large set of property sales data from 2000 to 2010 across Australian cities combining annually aggregated postcode level enhanced vegetation index (EVI) as a proxy to green infrastructure. He found that for every house in a postcode that gains green infrastructure equivalent to 1 standard deviation change in enhanced vegetation index resulted in gain of $32,000-58,000 per property.

Further, a study conducted in 52 residential suburbs in Brisbane using data on house sales of 2010 revealed that 1% increase in foot path tree cover within 100 m represents 0.082-0.103% premium of property value (Plant et al., 2017). According to another study carried out in central part of Perth metropolitan area, it was found that 10% increase in tree canopy cover on the adjacent public space represent property price premium of about AU$ 14,500 in 2009 (Pandit et al., 2014).

Few hedonic studies looked at how much value residents place on having a scenic view of open urban space. For example, Jim and Chen (2009) investigated two major natural landscapes in Hong Kong using housing transaction data in 2005 and 2006. Having a broader view of harbour increased the value of apartment by 2.97% which is equal to $15,173. On the other hand, having a mountain view reduced the apartment price by 6.7%. Another study conducted in Hong Kong concludes that having view of a neighbourhood park would increase the property price by 1.95% (Jim and Chen, 2010). A hedonic study conducted in Guangzhou, China also valued the scenic view of green space and water bodies and found that having a scenic view of a green space increase the property value by 7.1% and having a view of water body increased a property value by 13.2% (Jim and Chen, 2006b). View of open space in a town in Netherland would demonstrate 9% higher house price (Luttik, 2000). These studies mostly shows positive impact of green infrastructure.

In some hedonic studies, on the contrary, the impact has been found to be mixed. For example, research by Cho et al. (2006) showed mixed results depending on the type and quality of the green space. They revealed that an additional patch per ha of forest in neighbourhood reduced house price by $62 based on house sales in Tennessee, US in 2000. Further, an additional meter of edge per ha of forest increased house price by $35 and an additional ha in average forest patch size decreased the property value by $1,178. A recent study conducted in China revealed that the public green space adds zero value to Shanghai property prices while each additional unit of the community green space ratio adds 8.7% to the property sale price.

The other common approach to estimate values that people place on amenity of green space are contingent valuation (CV) studies and choice experiments (CE). For example, Andrews et al. (2017), investigated the preference motives of urban parks in Norwich, UK by carrying out a survey of 386 households in 2009 and found that WTP to have a park in the city centre was £23.14 per household and WTP for a suburban park was £19.11 per household. Further, Mell et al. (2013), valued investment in green infrastructure employing contingent valuation survey of 512 respondents and reported that that residents were prepared to pay £1.88 more per month to improve their local environment with green investment while commuters and employees' WTP varied between £1.60–1.65.

A contingent valuation study conducted in Zhuhai city in south China using data from 598 respondents in 2006 estimated non-market leisure value of an ambitious new urban greening project. The study reported that the mean WTP was RMB 161.84 per household per year (Chen and Jim, 2008). del Saz Salazar and Menendez (2007), carried out a contingent valuation survey in Valencia (Spain). They analysed data from 900 randomly chosen inhabitants using both non-parametric and parametric methods to investigate the preference of people having a new urban park. Their findings suggest that individuals live closer to the site were willing to pay 11,238 - 14,497 Pesetas while the WTP for non-affected people (those who live away from the site) were ranged from 7,830 to 8,571 Pesetas. A similar study estimated the non-market benefits derived from the potential development of a new urban park in the city of Thessaloniki, Greece with the use of data from 600 inhabitants in 2013. According to their findings on average, households would be willing to pay around €4.0 to € 4.5 as a bi-monthly "green tax" to the municipal authority (Latinopoulos et al., 2016).

Tu et al. (2016), applied choice experiment to examine the value of urban green spaces, specifically peri-urban forests using data from 180 respondents in Nancy, France in 2013. The marginal WTP by home owners who did not have a private garden was € 34.84/m^2 (that was 2.7% of their current average house price). However, marginal WTP for home owners who had a private garden was € 16.42/m^2 (1.2% of their current average house price). Tenants who did not have a private garden were willing to pay € 0.12/month/m^2. On average respondents were willing to pay 9.9% more to have a scenic view of green spaces outside their window.

In addition to people preferences to establish a new park or green space, some studies evaluated value of existing green space using contingent valuation surveys. For example, Brander and Koetse (2011), conducted a meta-analysis of 20 contingent valuation studies from several countries and estimated the value of open space per hectare per year in 2003 as US$ 13,210. Another study examined the social benefits of a large park which is considered as a green backbone of the city of Valencia, Spain. They conducted 1480 face-to-face interviews in 2005 and found that on average people were willing to pay €7.60 / person for the social benefits created by the park (del Saz-Salazar and Rausell-Köster, 2008). Jim and Chen (2006c), estimated recreational value of green spaces in Guangzhou, China by conducting contingent valuation survey of 340 respondents and reported that WTP by individuals for recreational and amenity benefits was $2.1/ person/month.

Another strand of contingent valuation studies examined the values that residents place on improving or preserving existing green spaces. For example, Pepper et al. (2005) estimated mean WTP for the preservation of Hartfield Park bushland in Perth Metropolitan area, Western Australia as AUD 21.60 per person per annum.

Another study assessed the economic value of preserving of urban forest in Ghana by conducting a contingent valuation survey of 200 respondents. The overall mean WTP for preservation of urban forest was US$22.55/year (Dumenu, 2013).

Lo and Jim (2010), valued conservation of urban green spaces in the compact city of Hong Kong by surveying 495 urban residents from different neighbourhoods in 2008. The findings suggest that WTP to recover a possible loss of urban green space area by 20% as 9.90 USD per household for five years.

A similar study conducted in 15 cities in Aotearoa New Zealand with the survey of 344 households in 2003. According to the findings on average, households would be willing to pay NZD 184 annually for the avoidance of a 20% reduction in their local urban tree estate, with the commitment covering a period of 3 years (Vesely, 2007).

Further, the benefits of reclaiming urban quarries in the centre of Athens, Greece were assessed by Damigos and Kaliampakos (2003) with the survey of 200 households. They estimated mean WTP for three options:

reforestation (€29.44-30.75); backfilling and reforestation (€45.88-49.47); and partial backfilling, reforestation and new land uses (€56.44-58.20).

There are few studies that estimate implicit prices for the relationship between environment and wellbeing of people using self-reported life satisfaction or subjective wellbeing approach (Welsch, 2002, Smyth et al., 2008). Using self-reported life satisfaction data from Household Income and Labour Dynamics in Australia (HILDA) survey in 2005, Ambrey and Fleming (2014), estimated willingness to pay for urban green space by residents in Australian capital cities. According to the study, households in Australian capital cities are willing to pay $1,172 per annum for 1 percent increase of open public space (on average 143 square metres increase) in their local area.

Recreational values

A hedonic study conducted in Adelaide metropolitan area using property sales data from 2005 to 2008 revealed that being 1m closer to the Golf course, green space sport facilities and the coast increased the property price by $0.54, $1.58 and $4.99 respectively (Mahmoudi et al., 2013).

On the other hand, Pandit et al. (2013), found that 1m distance to a larger park (where bushwalking is possible) reduced the property value by $9.60 and 1m distance to a sports reserve decreased the property values by $29.59 in 23 suburbs of Perth metropolitan area.

Using contingent valuation method, Bernath and Roschewitz (2008) estimated recreational benefits of the Zurich city forests in 2004 by analysing data from 1500 residents of Zurich. The visitors' willingness to pay for an annual forest visitor permit under initial bid was $64 and $91 with respect to revised bid.

Health benefits due to reduced air pollution

Urban trees can remove air pollution by the interception of particulate matter on plant surfaces and the absorption of gaseous pollutants through the leaf stomata. A number of studies have estimated air pollution removal benefits by urban trees and shrubs in the United States. For example, Nowak et al. (2006) estimated pollution (O_3,PM_{10},NO_2,SO_2, CO) removal from urban green space in the US as 711,000 metric tons using pollution concentration data from across the coterminous US in 1994 which was worth of $3.8 billion.

Another study conducted in 10 US cities in 2010 modelled PM2.5 concentrations and human health (Nowak et al., 2013). According the study estimates the total amount of $PM_{2.5}$ removed annually by trees varied from 4.7 tonnes in Syracuse to 64.5 tonnes in Atlanta with annual values varying from $1.1 million in Syracuse to $60.1 million in New York City. The mortality reductions were estimated as person/ yr per city, but were as high as 7.6 people/ yr in New York City. The average health benefit value per hectare of tree cover was estimated about $1,600, but varied from $500 in Atlanta and Minneapolis to $3800 in New York.

Further, a study conducted in 2010 using computer simulations with local environmental data in US found that trees and forests in the conterminous United States removed 17.4 million tonnes (t) of air pollution in 2010. Using U.S. EPA's BenMAP program, the total annual pollution removal was valued as US$ 6.8 billion (Nowak et al., 2014).

Tallis et al. (2011), examined tree survey data and annual maps of PM_{10} distribution in 2006 in The Greater London Authority (GLA), UK using Urban Forest Effect Model. The annual removal of atmospheric particulate pollution was 852 – 2,121 tonnes.

A study conducted in Guangzhou ,China in 2000 using different urban land uses in the city found that annual benefits gained due to removal of air pollutants from urban green space is about RMB90.19 thousand (Jim and Chen, 2008). In addition, a field survey conducted in Beijing, China in 2002 concluded that air pollution removal by trees in the central part of Beijing in 2002 was 1261.4 tonnes and the carbon dioxide (CO2) stored in biomass form by the urban forest was about 0.2 million tonnes (Yang et al., 2005).

Yang et al. (2008), examined 170 green roofs in Chicago, US using dry decomposition model and reported that total air pollutants removed by 19.8 ha of green roofs in one year was about 1675 kg in 2002.

Improvements in physical and mental health

A growing body of literature has emerged on the health benefits of having contact with nature. Much of this literature has focused on urban green spaces as a readily available type of nearby nature with a high potential for health and well-being. Many studies across the globe confirm that natural open spaces play an important role in facilitating physical activities and helping to address sedentary behaviours (Barton et al., 2009, Bedimo-Rung et al., 2005, Coombes et al., 2010, Giles-Corti et al., 2005, Hillsdon et al., 2006, Lee et al., 2015, Lee and Maheswaran, 2011, Tzoulas et al., 2007). Most of them are qualitative studies which tried to establish the relationship or develop a conceptual framework between green space and health. For example, a study conducted in City of Bristol, England in 2005 found that respondents living closest to the type of green space classified as a formal park were more likely to achieve the physical activity recommendation and less likely to be overweight or obese (Coombes et al., 2010).

A few studies examined the link between access to neighbourhood green space and mental health. Alcock et al. (2014), analysed British Household Panel Survey with mental health data from 1992 to 2008 and found that individuals who moved to greener areas had significantly better mental health in all three post move years while individuals who moved to less green areas showed significantly worse mental health in the year preceding the move.

A study carried out in Wisconsin by Beyer et al. (2014) also found that higher levels of neighbourhood green space were associated with lower level of depression among the residents. A similar study undertaken in Perth, Western Australia from a cross sectional survey of residents in 2003 and 2005 concluded that residents in neighbourhoods with high quality public open space had higher odds of low psychosocial distress than residents of neighbourhoods with low quality public open space (Francis et al., 2012).

Zhang et al. (2015b) also reported positive relationship between attachment to local green space and better self-reported mental health in the neighbourhood in a medium sized city in Netherlands.

Lafortezza et al. (2009) investigated perceived wellbing of residents on use of green space during heat stress in Italy and the UK. They found that longer and frequent visits to green spaces could generate significant improvements of the perceived benefits and well-being of users.

Sugiyama et al. (2008) examined the link between green space and both physical and mental health in Adelaide. Their findings suggested that those who perceived their neighbourhood as highly green had 1.37 and 1.60 times higher chance of having better physical and mental health, respectively, compared with those who perceived the lowest greenness.

A study carried out in Portland, Oregon using data from resident's birth certificates and tax records found that 10% increase in tree-canopy cover within 50m of a house reduced the number of small for gestational age births by 1.42 per 1000 births (Donovan et al., 2011).

Although the relationship between green space and mental and physical health has been well established, it could be seen from the above discussion that there is a lack estimations of economic values of such benefits. There are several reasons behind this, such as complexity of establishing causal relationships, heterogeneity of community and green space (quality, quantity and spatial), cumulative exposures, lagged effects and shortage of reliable panel data. This kind of complex research needs to involve multiple disciplines with diverse methodological approaches and partnerships among economists, health researchers, communities, urban planners, and policy experts (Diez-Roux, 2007).

Energy saved

Studies have shown that having urban trees in the neighbourhood reduce electricity consumption especially during summer time due to the shading and cooling effect provided by trees. Donovan and Butry (2009), estimated the effect of shade trees on the summertime electricity savings of 460 single-family homes in Sacramento, California. Their results show that trees located in west and south sides of a house reduced summertime electricity use by 185 kWh (5.2%).

Pandit and Laband (2010a) examined the effects of trees on electricity use in Auburn, Alabama. They found that every 10% of shade coverage on average reduced electricity consumption by 1.29 kW h/day. For a house with mean shade coverage of 19.3% during the summer months, dense shade reduces daily electricity consumption by 9.3%.

A study carried out in California using tree canopy cover data from aerial photographs simulated energy savings of buildings from existing trees and new plantings. Existing trees were projected to decrease annual air conditioning energy use by 2.5% with a wholesale value of $ 485.8 million in 2010. Peak load reduction by existing trees saved utilities 10% valued at $ 778.5 million annually, or $ 4.39/tree (McPherson and Simpson, 2003).

Donovan and Butry (2009), reported that a London plane tree, planted on the west side of a house, can reduce carbon emissions from summertime electricity use by an average of 31% over 100 years.

Green urban infrastructures also provide climate change and mitigation benefits by providing thermal comfort (Yu and Hien, 2006), storing carbon (Davies et al., 2011, Escobedo et al., 2010) and balancing water flows (Demuzere et al., 2014). We provide a summary of relevant studies in the climate change section.

Ecological and environmental value of water

Rapid urbanization not only increase pressure on green infrastructure but also on local water bodies and ecosystems. For example, at Blacktown, Sydney, it has been estimated that for each million m^2 paved area 0.5 gigalitre of extra water flows to the creek causing substantial problem to the local ecology and biodiversity (Liebman et al., 2015). There have been some studies looking at people's preference for ecological and environmental services of water. The ecological and environmental value of water could be summarized in terms of water quality value, habitat conservation value and aesthetics.

Water quality value

There are numerous studies on non-market values of water quality (Gibson et al., 2016). Mostly, stated preference methods and the travel cost method are used for estimation of water quality values.

Recently, Peng and Oleson (2017) conducted a choice experiment to understand beach recreationalists' preferences and willingness to pay for water quality and associated attributes at Oahu beaches. They found that people were willing to pay US$35.71 extra per day at the beach to increase the visibility from 15 ft to 30 ft and an additional $14.80 to increase it from 30 ft to 60 ft. They also found high preference for biodiversity; $15.33 to improve coral reef cover from 10% to 25% and $4.89 to improve to 45%. The mean WTP was $7.14 for increasing the number of fish species from 9 to 18. Further, people were willing to pay $11.43 to reduce the number of days with bacteria exceedance from 11 to 5 per year and another $30.72 to reduce it from none.

In another study, MacDonald et al. (2015) based on a choice experiment survey found that the total value of a project which could achieve multiple outcomes including ensuring 25 days per year of water clarity, increasing seagrass area from 60% to 70% of the original area and protecting five reef areas was worth $AUS67.1 M to households in the Adelaide metropolitan area.

In a separate study using travel cost method, Viana et al. (2017) estimated the average consumer surplus of the Channel Islands National Marine Sanctuary located in California, USA to private recreational boaters (PRBs) at $48.62 per trip, with a total non-market value of non-consumptive private recreational boating of $86,325 annually. The value was higher locations with lower exposure to prevailing winds and greater species richness and abundance.

Alvarez et al. (2016) conducted a meta-analysis of water quality improvement in the United States. They included 19 studies (from 39 related studies) using CVM, Travel Cost and Choice Experiment methods (the original data used by them are presented in Table 1). In order to ensure consistency, they used a modified version of the Resources for the Future (RFF) water quality ladder for water quality states and numeric indicators (i.e., 0 = not safe for human use; 2 = boatable; 5 = fishable; 7 = swimmable; 9 = drinkable; 10 = pristine / unpolluted). They found that the predicted WTP is sensitive to level of urbanization and population density. People living in urban areas are willing to pay more, however, as population density increased on average people are willing to pay less (i.e., residents in small urban areas are willing to pay the most). Projecting across the 67 Florida counties they showed that the WTP for water quality improvement ranged from 4 cents and US$837 per person per year, for an improvement in water quality from level 5 (fishable) to level 7 (swimmable).

Table 1: Selected studies on water valuation used in meta-analysis by Alvarez et al. (2016)

Study	Year	State	Number of estimates	Water body type	Methodology	WTP range (2014 US dollars)
Duffield et al. (1992)	1988	MT	8	Freshwater river	CVM	93.18 – 1584.01
Cordell and Bergstrom (1993)	1989	NC	4	Freshwater reservoirs	CVM	77.24 – 139.02
Boyle et al. (1993)	1990	AZ	12	River	CVM	195.05 – 1560.38
Carson and Mitchell (1993)	1990	N/A	20	Freshwater	CVM	123.00 – 643.13
Herriges and Shogren (1996)	1993	IA	6	Lake	CVM	66.60 – 223.56
Carson (1994)	1994	SC	1	Saltwater coastal system	CVM	86.14
Berrens et al. (1996)	1995	NM	3	Stream	CVM	43.28 – 135.11
Huang et al. (1997)	1995	NC	8	Sounds	CVM	120.05 – 127.97
Whitehead et al. (2000)	1995	NC	2	Sounds	Travel Cost	79.09 – 101.40
Bhat (2003)	1996	FL	4	Florida Keys	Travel Cost	295.09 – 424.47
Farber and Griner (2000)	1996	PA	6	Freshwater stream	CE	5.5 – 161.51
Park et al. (2002)	1996	FL	1	Keys	CVM	468.45
McKean et al. (2003)	1998	ID	2	Freshwater river	Travel Cost	18.53 – 21.44
Murray et al. (2001)	1998	OH	3	Freshwater lake	Travel Cost	17.18 – 23.31
Azevedo et al. (2001)	2000	IA	2	Freshwater lake	CVM	113.34 – 566.69
Lipton (2004)	2001	MD	4	Bay	CVM	17.08 – 52.66
Shrestha et al. (2007b)	2001	FL	1	Freshwater river	Travel cost	41.89
Stumborg et al. (2001)	2001	WI	1	Freshwater lake	CVM	458.42
Eiswerth et al. (2008)	2004	WI	1	Freshwater lake	Travel Cost	55.06

In another meta-regression analysis based on 131 WTP estimates from 18 studies found that for every 10% increase in water quality index the WTP estimate would increase by 8%. Further, if the water quality improvement description included a recreational use description the mean WTP was higher by an average $14. However, the estimates were not sensitive to the baseline water quality levels (Van Houtven et al., 2007). Based on results from hedonic studies, Klemick et al. (2016) conducted a meta-regression analysis on the impact of total maximum daily load on property prices in the Chesapeake Bay and found that at an aggregate level the near-waterfront property values could increase by roughly $400–$700 million in response to water clarity improvements.

Parsons et al. (2003) measured the economic benefits to recreation from improved water quality using the choice experiments method in six north-eastern states of the USA. In the study separate choice experiment models were used for fishing, boating, swimming, and viewing. The authors found for modest improvements in water quality, almost all the benefits were associated with fishing and swimming. The annual benefit from fishing and swimming were, respectively, about $3 and $5 per person. For significant improvements in water quality, all four recreational activities were associated with benefits, and these benefits were much larger. Swimming and viewing were the activities that showed the highest gains, respectively, about $70 and $31 per person. For boating and fishing the benefit was about $8 per person per activity. Other studies, such as Parsons and Kealy (1992) and Dupont (2011) have found similar results in terms to the pattern of effects across activities with large improvements in water quality.

Another standard that can be used to measure water quality is clarity. Although water clarity and water quality are not necessarily the same thing, clarity is a term that people may find easier to understand. Marsh and Baskaran (2009) quantified people's WTP for increased water clarity in the Karapiro catchment, New Zealand, using the choice experiments approach. They found that the mean annual WTP per household for water clarity from the current clarity (around 1 meter) to: see up to 1.5, 2.0, and 4.0 meters underwater were, respectively $4.17, $21.03, and $65.82.

In another study, Ge et al. (2013) conducted a meta-regression analysis on water quality improvement based on 38 distinct studies conducted in the US. They first developed a link between water quality index used in individual studies and Secchi depth (measuring transparency of water) from the national lakes assessment (NLA) dataset and used that relationship to develop consistent water quality index across the studies. They found that for a 10-point (out of 100 points) additional change in water quality index mean WTP will increase by $45. WTP was higher for lakes and estuaries than for rivers and higher for avoiding degradation than for making improvement. They also found some variations among the estimation methods: with hedonic analysis the mean WTP was highest followed by travel cost method and contingent valuation model. Interestingly, initial condition of water quality and site size interact with each other (Table 2). For example, for a small site (only one square mile), a household living in 50,000 square mile area around the site was estimated to be willing to pay $115.14 for a 5-point increase (from 40 to 45) in the water quality index. Naturally, willingness to pay is larger for a big site than for a small one, and is also larger for a 10-point increase in water quality than for a 5 points increase (Ge et al., 2013).

Table 2: Predicted WTP for water quality improvement (Ge et al., 2013)

Site type	WQI change			
	40 to 45	40 to 50	70 to 75	70 to 80
Small site (1 sq mile) (Little Spirit, IA)	115.14	137.52	35.12	57.50
	(143.84)	(141.78)	(142.33)	(139.9)
Medium site (100 sq mile) (Lake Winnibigoshish, MN)	121.46	143.85	41.44	63.83
	(141.32)	(139.29)	(139.62)	(137.23)
Big site (10,000 sq mile) (Great Lakes)	753.89	776.27	673.87	696.25
	(210.71)	(213.64)	(197.95)	(200.84)

Note: WQI: Water Quality Index; Standard error in parentheses, in 2010 US dollars, sample region: 50,000 sq miles

Water volume also plays a significant role in recreation activities. Connelly et al. (2007) combined the contingent valuation method and the stage-damage curve approach to explain how the value of recreational boating can be assessed and linked to water levels on Lake Ontario and St. Lawrence, USA. The authors found that as the water level drops, economic losses would be expected because some boats could not get out of their slips. Approximately US$1.7 million in economic benefits would be lost if the water level was 244 feet (74.4 meters) for the entire month of August.

Sale et al. (2009) assessed the amount that recreational users are willing to pay to secure an increase in freshwater inflows into two South African estuaries, the Kowie and the Kromme using the contingent valuation method. The study relies on a sample of 150 respondents at each estuary site obtained during December 2002 to January 2003. The authors concluded that the value of freshwater inflows into the Kowie and the Kromme estuaries were around R0.072/m^3 and R0.013/m^3, respectively.

Some studies have considered changes in water quality and volume simultaneously. For example, Crase and Gillespie (2008) estimated the recreational values of visitors to Lake Hume under different water quality and water level scenarios using the contingent valuation method. The study concluded that the recreational benefits were increased by about $1.3 million per annum when the storage level was increased from 50 percent capacity to near full. The annual consumer surplus derived from recreational users of the lake was reduced by about $1 million in the event of an algal bloom.

Sutherland and Walsh (1985) use the contingent valuation method and show that the recreational value attributed to an asset by households can fall with household distance to the asset. This specific study was based on data from a regional household survey of WTP for water quality at the Flathead River and Lake Areas in the USA. Regression analysis was used to estimate the relationship between WTP and distance to the study area. The results showed that the WTP significantly decrease with increase in distance. This phenomenon may be partially due to the travel cost associated with increasing with distance from the asset.

Another way to estimate recreational value is the travel cost method. Fleming and Cook (2008) evaluated the recreational value of Lake McKenzie, New Zealand using the travel cost method. Based on analysis of 1,360 surveys, the authors concluded that the recreational value of the Lake ranged from $13.7 million to $31.8 million per annum or from $104.30 to $242.84 per person per visit.

There are a few studies that combine the contingent valuation method with the travel cost method to estimate recreational values, for example, Huang et al. (1997) and Azevedo et al. (2003). Rolfe and Prayaga (2007) estimated the value of recreational fishing at three major freshwater impoundments in Queensland, Australia, using both the travel cost and the contingent valuation methods. The travel cost method was used to estimate the consumer surplus of recreational anglers, and the contingent valuation method was used to estimate the marginal value of potential improvements in fishing experiences. The authors claim that different non-market valuation techniques are appropriate for different components of the valuation exercise.

Besides these methods, other methods such as dose response method (Soller, 2006) and the medical expenditure and health risk method (Zmirou et al., 2003) can also be used to evaluate the recreational value of water. These approaches are, however, not considered here.

Habitat conservation value

There are economic values in conserving natural habitats. Besides the profit gains from tourism and recreational activities, conservation of endangered animals or rare plant species provides scientific value for current and future research. Commonly seen plant species growing in an unexpected location can also be considered as “rare species” and have high values. For example, mangroves, which are commonly seen in tropical areas like North Queensland, also cover a small percentage of the Victorian coast, and in Victoria mangroves may be considered rare. The uniform low height mangroves at Millers Landing in Corner Inlet, Victoria are known as the world’s highest latitude mangroves. These mangroves also provide coastal protection and scientific value[1].

Possible approaches that can be used to estimate the value of habitats include the contingent valuation method and choice experiments. Nunes and van den Bergh (2001) summarised the methods for evaluating natural habitat and species protection and concluded that monetary valuation of changes in biodiversity can make sense. Farr et al. (2014) summarised studies on non-consumptive use and non-use values of rare or endangered species and found estimated values are particularly sensitive to the questionnaire design. This suggests study findings in this area should be treated with caution.

White (2008) assessed WTP among certified U.S. scuba divers for particular wildlife encounters while diving. The study found that the mean WTP for an increased likelihood of swimming with a sea turtle in the wild was $29.63 per year; for sharks it was $35.36 per year; and for coral it was $55.35 per year.

Ressurreição et al. (2011) estimated the public’s WTP to avoid losses in the number of marine species in the waters around the Azores Archipelago, Portugal. The author found that the mean WTP for visitors to prevent 10 percent and 25 percent loss in numbers was €71 and €83 for birds; €86 and €100 for fish; and €85 and €99 for mammals. In each case the cost was framed as a once only payment.

Johnston et al. (2011) used a choice experiment to investigate the value of species protection in Rhode Island, USA watershed. The research found that a single species increase of freshwater mussels was associated with a WTP of $1.86 per household per year, while an increase in the number of native fish species was associated with a WTP of $1.93 per household per year.

Aesthetic value

The aesthetic value and the recreational value of water are different. Although natural beauty is an attraction for people to conduct recreational activities, it is not necessarily the reason people visit a place for recreation purposes. Water has aesthetic value independent of recreation value. Beautiful water bodies are always attractive and can provide people with significant enjoyment. In fact, millions of tourists visit lakes, oceans, streams and waterfalls each year with the main purpose of just experiencing the natural beauty of the water bodies rather than undertaking recreation activities. It is also the case that people are willing to pay high prices for properties near clean and beautiful water bodies and do not want properties near dirty and smelling polluted waterways.

From the available literature, three approaches have generally been used to determine aesthetic values: the Photo-Projective Method (PPM), which asks residents to take pictures of their environment and record their descriptions of each scene on site; the opinion of experts; and the hedonic price method. Note that with the PPM information is obtained on people’s preference, but not on monetary values.

Pomeroy et al. (1983) measured the perception of an urban river scape, using unbiased differentiation of riverscape photographs. The study sample was 30 university students in Canada that came from various backgrounds and disciplines. The authors found that the cognitive response to photographic quality was completely overshadowed by the responses to the landscapes in the photographs.

Yamashita (2002) explored adults’ and children’s perception and evaluation of water in landscapes. The author found that if children are the main users of the environment, planners need to focus more on the quality of short-distance elements. Pflüger et al. (2010) assessed aesthetic preferences for river flows in eight reaches on six southeast New Zealand rivers via 449 completed online surveys. The survey results indicated that high flows and

[1] www.mangrovewatch.org.au [accessed 10 December 2013]

minimal bank exposure were preferred in small rivers; and intermediate or low flows and low turbidity were preferred in large rivers.

Water quantity is an important element of the overall aesthetic quality of water bodies. Brown and Daniel (1991) measured people's scenic beauty judgements through the use of video sequences depicting a river at different flow rates. This research found that about 10 to 25 percent of the variance in scenic beauty can be explained by flow rate. Aesthetic value can also be evaluated via expert or public opinion. Some researchers, such as Tudor and Williams (2008) and Nijnik et al. (2009) have used this approach. However, as earlier work by Hekkert and Wieringen (1996) has pointed out, aesthetic values are different for different people, with it common for there to be substantial variation between expert and public views.

Using the hedonic price approach, Blomquist (1988) found that people are willing to pay higher price for properties with a water view. Specifically, the study found that households along Lake Shore Drive, Chicago, USA, pay on average, $507 per year to obtain a water view. Further, the influence of water on the property price decreases with distance (Sander and Polasky, 2009). Finally, Fraser and Spencer (1998) found water quality was also a key factor impacting house prices.

Economic value of local storm water management

There are some studies estimating non-market benefits of stormwater management. For example, Brent et al. (2016) conducted a choice experiment in Sydney and Melbourne to understand people's willingness to pay for different types of services: avoiding water restriction, improvement in local stream health, reduction in peak urban temperature and occurrence of flash flood reduction. They found that people were willing to pay to avoid water restrictions (A$218 in Melbourne and A$118 in Sydney) and improvements in local stream health (A$278 in Melbourne and $104 in Sydney) and decreased peak urban temperatures (A$81 in Melbourne and A$47 in Sydney). However, people's willingness to pay for occurrence of flash flood reduction was close to zero.

In another study, Tapsuwan et al. (2014) compared people's willingness to pay for rainwater tanks and greywater systems in South East Queensland (SEQ) using choice experiment. They found higher WTP for greywater systems ($1,700 – $14,100) compared to rainwater tanks ($800 - $7,400). They also observed that estimated values were lower than the installation and maintenance costs of these systems. However, in a recent study using hedonic analysis techniques, Zhang et al. (2015a), that there is significant positive effect of rainwater tanks on house prices in Perth, Australia. They estimated that the presence of a rainwater tank would add AU$6,700 to $18,000 to the median price of a typical house in Perth. This benefit is large enough to cover total cost of installing and maintaining a tank.

Polyakov et al. (2016) assessed the changes in amenity benefits of an urban drainage restoration project: the Bannister Creek restoration in Perth, Western Australia over a period of time. The living stream project involved major restoration works to increase the ecological and aesthetic value of a linear drain. They observed that as expected initially the value was negative (due to disamenity from construction works) even though the amenity benefit started to become positive once the work was finished. Within eight years, the value stabilized (Figure 4). After controlling for various house specific, price inflation and general increase in house price it was found that the median home within 200 m of the restoration had increased in value by an additional $17,000 to $26,000 after eight years. They found that the total benefit across all houses within 200m of the project was more than enough to cover the cost of the project.

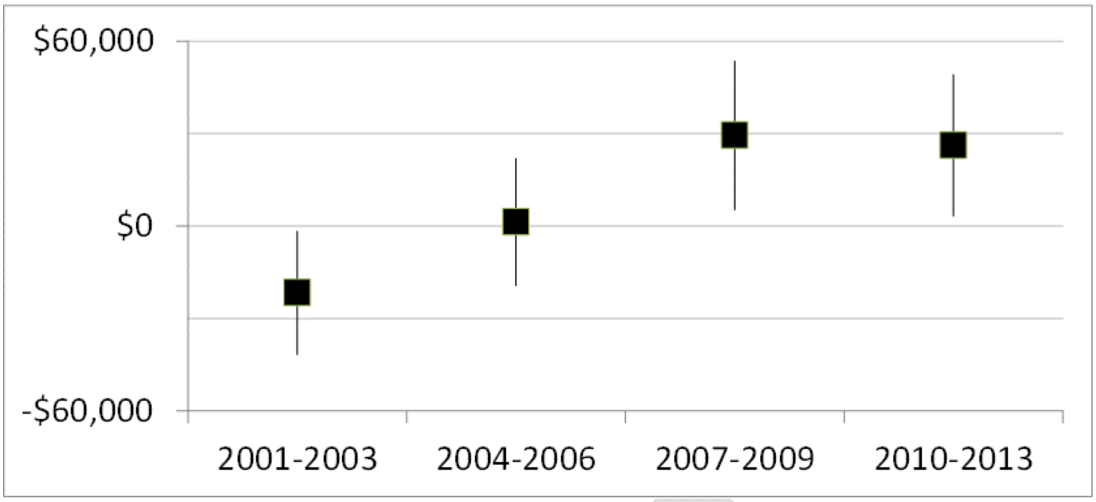


Figure 1: Changes in capitalized amenity benefits of the Bannister Creek Living stream Project (Polyakov et al., 2016)

In another case study, Mekala et al. (2015) provided potential benefits of the rehabilitation of a 1.23 km stretch of upper Stony Creek in Melbourne. Based on secondary information, they estimated the potential benefits of the project. According to their estimates, health benefit (avoided health costs) of the project was about AU$75,049 per annum. The total welfare benefit from park visitation was enough to cover 94 % of the annual maintenance costs of AU$10,000. Potential capitalized amenity benefit of the park was around AU$3.9 million.

It should be noted that it is not always possible to calculate net benefits of different storm water management options due to lack of information on non-market values of the services provided by different options. In those cases, cost-effectiveness analysis could be quite useful as it does not depend on the monetized values of benefits. However, reliable estimates of costs are quite important in such cases (Browne et al., 2013). An example set of cost estimates for different water sensitive urban design technologies are presented in Table 3.

Table 3: Water sensitive urban design life cycle costing data (Melbourne Water, 2013)

Asset	Asset parameters	Construction[1]	Maintenance Establishment (First two years)	On-going	Renewal
Wetlands[2]	< 500 m^2 500 to 10,000 m^2 > 10,000 m^2	\$150/m^2 \$100/m^2 \$75/m^2		\$10/m^2/yr \$2/m^2/yr \$0.50/m^2/yr	No data
Sediment basin[2]	< 250 m^2 250 to 1,000 m^2 > 1,000 m^2	\$250/m^2 \$200/m^2 \$150/m^2		\$20/m^2/yr \$10/m^2/yr \$5/m^2/yr	Remove and dispose of Dry waste = \$ 250/m^3 Liquid waste = \$ 1,300/m^3
On-street rain gardens[2]	< 50 m^2 50 to 250 m^2 > 250 m^2	\$2,000/m^2 \$1,000/m^2 \$500/m^2		\$30/m^2/yr \$15/m^2/yr \$10/m^2/yr	Minor reset = \$50 to \$100/m^2
Bioretention basin	< 100 m^2 100 to 500 m^2 > 500 m^2	\$1,000/m^2 \$350/m^2 \$250/m^2		\$5/m^2/yr	
Tree pits[3]	< 10 m^2 10 to 50 m^2 > 50 m^2	\$8,000/m^2 \$5,000/m^2 \$1,000/m^2	Two to five times of on-going maintenance cost	No access issues = \$150 / asset / yr Traffic issues or specialist equipment required = \$ 500 / asset / yr	
Grass swales and buffer strips[4]	Seeded – no subsoil drain Seeded – subsoil drain Turfed – no subsoil drain Native grasses established	\$15/m^2 \$25/m^2 \$20/m^2 \$35/m^2		\$3/m^2/yr	
Vegetated swales and bioretention swales[4]		\$150/m^2		\$5/m^2/yr	
In-ground GPTs	< 300 L/S 300 – 2000 L/S > 2000 L/S	\$50,000/asset \$150,000/asset \$250,000/asset		Inspection = \$100/visit Cleanout = \$1,000/visit	

Note: [1]includes planning and design; [2]Area at normal water level; [3]Area of filter media at bottom of extended detention and [4]Total vegetated area. The cost estimates should be considered as starting point only and represent best available information in 2013.

Climate change mitigation

Cities and towns are vulnerable to climate change related impacts like heatwaves, floods, droughts, and other extreme events. There are a few revealed and stated non-market valuation studies have specifically looked at the climate change impact. For example, Tran et al. (2017), investigated WTP of Atlanta households to increase urban forests to mitigate climate change. They conducted a contingent valuation survey in 2013 and found that households were willing to pay \$1.05 million to \$1.22 million per year to increase the amount of urban forests. Kim et al. (2016), investigated residents' WTP on the heat island-mitigating functions of urban forest in Korea through choice experiments. Respondents were willing to pay \$56.68–76.59 for every increase of the urban forest by $1m^2$. It has been suggested that well-designed and developed green (and blue) spaces in landscapes have the potential to minimize climate change impact (Žuvela-Aloise et al., 2016, Demuzere et al., 2014, Gunawardena et al., 2017). Many of the non-market valuations studies reported under the green infrastructure section would be relevant to climate change mitigation options as well. However, most of the studies focusing on climate change impact have reported economic estimates based on other methods, such as, averting cost.

In the following sub-sections, we provide a summary of existing information on economic costs and values of climate change mitigation options in terms of urban heat island mitigations, carbon sequestration and reduction of carbon emissions.

Urban heat island effect mitigation

Urban Heat island effect is one of the main problems that many urban cities face (Coutts et al., 2013). Heat island is a metropolitan area that experience extreme temperature especially during summer periods (Kim et al., 2016). This effect is caused by reflections from urban structures that absorb heat from the sun during daytime. Extreme heat events could lead to high rates of mortality and morbidity in cities (Roldán et al., 2015), increased energy consumption and productivity losses. Several studies have examined the ability of urban green and blue infrastructure to mitigate the heat island effect by lowering the heat intensity (Gunawardena et al., 2017, Nakayama and Hashimoto, 2011).

A study carried out in Singapore concluded that the cooling impacts of the parks are reflected through not only the lower temperatures in the parks but also the lower temperatures in the nearby built environment (Yu and Hien, 2006). Another study explored the impacts of green areas at macro-level in mitigting heat island effect in Singapore. The findings indicated a strong correlation between the decrease of temperature and the appearance of large green areas in the city (Wong and Yu, 2005). Susca et al. (2011) also confirmed the positive effect of urban vegetation in heat island mitigation in four areas of New York City. They found an average of 2 ^{o}C difference of temperatures between the most and the least vegetated areas.

Some studies evaluated different configurations of green space in terms of mitigting extreme heat events. For example, Salata et al. (2017) examined different mitigation strategies of the urban microclimate in the campus of the Sapienza University of Rome. They found that the solution combining cool roofs, urban vegetation and cool pavement leads, with respect to the current configuration of the site, to a mean and maximum decrease in the Mediterranean Outdoor Comfort Index of −2.5 and −3.5. The proposed solution had the ability to decrease of about 60% in the health risk of those who were exposed.

Žuvela-Aloise et al. (2016) also conducted a similar study in the city of Vienna, using real case simulations to explore the best combination of heat mitigation strategies. The results suggested that heat load mitigation measures may have different efficiency values depending on their locations in the city as their performance are influenced by the prevailing meteorological conditions and land use characteristics in the neighbouring environment.

Nakayama and Hashimoto (2011) examined the ability of water resources to reduce the urban heat island in the Tokyo megalopolis. The study evaluated the relationship between the effect of groundwater use in tackling the heat island and the effect of infiltration on the water cycle in the urban area. The result suggests that effective management of water resources has the ability to mitigate extreme heat.

Carbon sequestration

Studies on carbon sequestration by urban green space show the importance of green infrastructure such as urban forests to mitigate climate change. For example, the value carbon sequestration by urban forests (about 400,000 trees) in Canberra during the period 2008–2012 was estimated at US$ 300,000 (Brack, 2002). Davies et al. (2011), also estimated carbon storage of a typical British city, Leicester, by surveying vegetation across the entire urban area. They found that urban vegetation stored 231,521 tonnes of carbon (16 kg C m^{-2} of urban area).

With the use of CO_2 reduction measures from subtropical Miami-Dade and Gainesville, USA ,Escobedo et al. (2010) modelled carbon sequestration by trees to analyse policies that use urban forests to offset carbon emissions. The emission reduction due to carbon sequestration was reported as 3.6 tonnes/ha/yr in Miami-Dade and 5.8 tonnes/ha/yr in Gainesville.

Carbon storage and sequestration by urban forests in Shenyang, China was examined by Liu and Li (2012) in 2006. The C sequestration rate of the heavily industrialized city was estimated as 29,000 t/yr (RMB7.88 million, or $ 1.19 million). According to their estimates, the carbon stored by urban forests was equal to 3.02% of the annual carbon emissions from fossil fuel combustion. Carbon sequestration could offset 0.26% of the annual carbon emissions in Shenyang.

Nowak and Crane (2002), analysed field data from 10 USA cities and national urban tree cover data from 1996 and 1999 using Urban Forest Effects (UFORE) model. Urban trees in the coterminous USA, stored 700 million tonnes of carbon ($14,300 million value) with a gross carbon sequestration rate of 22.8 million t C/yr ($460 million/year). The national average density of carbon storage in the urban forest was 25.1 t C/ha.

The carbon storage by urban trees in Leipzig, Germany was estimated to be 316,000 Mg C at 11 Mg C /ha. The authors also noted that carbon storage in the city of Leipzig was in the lower range compared to cities in Europe, Asia and the USA (Strohbach and Haase, 2012).

Using plant, soil, and ecosystem carbon storage data from two grassland biodiversity experiments, Hungate et al. (2017) examined the economic value of grassland species for carbon storage. They noted that increasing species richness from 1 to 10 had twice the economic value of increasing species richness from 1 to 2.

Reduced carbon emissions

According to Akbari (2002), a tree planted in Los Angeles would avoid the combustion of 18 kg of carbon annually. It was estimated that trees can potentially save about $270 M per year in Los Angeles and can reduce peak power demand by 0.9 GW. Of the $270 M annual savings, about $58 M represent direct energy savings, $35 M indirect energy savings, and $180M savings because of the reduction in smog concentration.

A case study of the value of the Canberra urban forest with particular reference to pollution mitigation was estimated at US$20–$67 million (or $66–$223/resident) between 2008 and 2012 (Brack, 2002).

Escobedo et al. (2010), estimated the effects of urban forests on building energy use due to shading and climate regulation. Avoided carbon emissions due to energy savings as a result of shade was 0.65 tonnes per ha/year in Gainesville and 0.166 tonnes per ha/year in Miami-Dade. Avoided carbon due to climate regulation was 0.70 tonnes per ha/year for Gainesville while 0.173 tonnes per ha/year for Miami-Dade.

The value of services provided by trees in Allan Gardens, a historic public park in downtown Toronto, Canada was examined by Millward and Sabir (2011). On a per-tree basis, CO_2 removal benefits were derived from Scotch Elm was $10/tree. Silver Maple and Black Walnut reduced carbon emissions worth of $6/tree each, while Norway maple reduced emissions worth of $5/tree.

Nowak et al. (2017), estimated reduced energy cost and avoided power plant emissions by trees and forests in urban/community areas in the conterminous United States using data from 2006-2010. According to the study estimates, annual reduction of electricity use by 38.8 million MWh ($4.7 billion). Energy use for heating decreased by 246 million MMBtus ($3.1 billion). Trees avoided thousands of tonnes of emissions of several pollutants valued at $3.9 billion per year including carbon emissions.

Soares et al. (2011), evaluated benefits of urban trees in Lisbon, Portugal using thee computer tool i-Tree STRATUM. Carbon emission reductions per tree was valued at $0.33/tree. The value of energy savings were recorded as $6.20/tree. The stormwater runoff reduction was valued at $47.80/tree.

Non-point source pollution

Since at least the 1970's it has been understood that urban stormwater runoff contains pollution components (Barton, 1978). These pollutants are believed to be washed off from car parks, lawns, roads, and highways; and this type of pollution is referred to as nonpoint source pollution (Bourcier et al., 1980, Hoffman et al., 1985). With the worldwide awareness of the need to protect the environment, major point source pollution is gradually being eliminated, and in some cases nonpoint source pollution is now the dominant pollution type in urban water systems (Petrone, 2010). The main contaminants in urban water runoff include: sediment, nutrients, pathogens, and chemicals (Makepeace et al., 1995). These contaminants enter water bodies from flows carried along the stormwater drain network, or seep into the groundwater and transfer into main streams with groundwater movement.

Initial economic valuation studies on nonpoint source pollution largely focused on estimating the damage costs caused by the pollution and/ or the environmental and public health risks created by pollution (Haynes and Georgianna, 1989). As it is hard to separate the influence of point source pollution from nonpoint source pollution, initial economic evaluation studies tended to estimate the impact of different pollution sources as a whole. For example, working through an extensive economic analysis process, Farber (1992) estimated that the costs of the environmental risk caused by both point and nonpoint source pollution in the USA could be as high as 2.7 percent of GDP.

In terms of understanding the nonpoint source pollution problem, Ventura and Kim (1993) suggest that urban nonpoint source pollution can be understood as a function of land uses (such as the amount of impervious surface), land use associated contaminant sources (such as vehicles, industrial debris, leaf and animal litter, etc.) and other physical properties of the land (such as slope, soil structure, and hydrological and meteorological characteristics of an area). Therefore, for urban areas, the empirical models used to estimate pollutant load are primarily driven by land use related data.

Value of pollution removal based on abatement cost

There are some information on the value of removing pollutants from stormwater in Australia. Payne et al. (2015) reported that removal of one kilogram of nitrogen is valued at $6,645 (2014) based on past stormwater treatment works in Melbourne. On the other hand, for Sydney, the Department of Environment and Conservation (2006) provided information on removing pollutants using a hypothetical constructed wetland: Total Suspended Solids ($2.50/kg in 2012 dollars), Total Nitrogen ($625/kg) and Total Phosphorous ($2,501/kg). Liebman et al. (2015) reported treatment costs of removing major pollution using an off-site, precinct scale approach to managing stormwater as an alternative to the current on-site approach for each new development for Blacktown City Council, Sydney (Table 4).

Table 4: Cost of removing pollutants from stormwater ($/kg) using off-site treatment in Blacktown City Council, Sydney (Liebman et al., 2015)

Pollutant	Capital cost remove	Discounted maintenance cost	50 year whole of life cycle cost to remove
Total Suspended Solids (TSS)	62	20	82
Total Phosphorus (TP)	41,400	15,000	56,400
Total Nitrogen (TN)	5,900	2,400	8,300

Hall (2012) provided a comprehensive analysis of different abatement options to remove urban water pollution in Brisbane. They calculated cost-effectiveness of various options based on marginal cost estimates. Their estimates for cost-effectiveness of selected management options for removing two major pollutants (Total Nitrogen and Total Phosphorous) are presented in Table 5. It can be seen that cost-effectiveness estimates vary with the size and type of technologies. The difference is due to economies of scale and effectiveness of removing pollutants. The cost gradually increases for smaller plants. Large wastewater treatment plants with biological nutrient removal could be very cost-effective compared to some other technologies. The difference could be very large, suggesting potential large benefits from adopting cost-effective options. However, comparison of low and high estimates for individual combination of size and technology reveal that in many cases the range is quite large, which indicates high level of uncertainty associated with some these estimates.

Table 5: Abatement cost per tonne of pollutant ($AUD2010) for selected options (Hall, 2012)

Technology	Plant size (MLd) / Project	TN		TP	
		L	H	L	H
Biological nutrient removal	0-0.379	12,524	5,566	166,699	6,262
	3.79 – 37.9	3,129	1,391	4,172	1,565
	>37.9	1,056	469	1,408	528
Reuse on eucalypt sawlog plantation using effluent from wastewater treatment plants	0.5	35,142		312,370	
	1	27,558		244,961	
	2	18,745		166,623	
	5	15,807		140,511	
	10	13,429		119,372	
	20	11,206		99,611	
	50	9,943		88,381	
	100	9,385		83,424	
Tertiary filtration	5	131,507	43,836	54,795	24,353
	10	119,178	39,726	49,658	22,070
	20	104,795	34,932	43,664	19,406
	50	69,863	23,288	29,110	12,938
	100	36,986	12,329	23,117	10,274
Stormwater harvesting	5 ML/Yr	12,810,000	1,490,000	67,300,000	6,730,000
	10 ML/Yr	5,640,000	660,000	29,600,000	2,960,000
	20 ML/Yr	2,750,000	320,000	14,400,000	1,440,000
	50 ML/Yr	730,000	90,000	3,900,000	390,000
WSUD – Bioretention	Greenfield residential (sloping topography)	106,130		429,834	
	Greenfield residential (greening topography)	255,442		1,058,258	
	Townhouses	1,497,703		5,706,057	
	Urban renewal	157,477		794,356	
	Commercial development	810,707		4,724,846	
	Industrial development	568,887		2,386,216	
5-kL Rainwater tank Yield scenario	70 kL/Yr	160,000		2,490,000	
	50 kL/Yr	320,000		5,130,000	
	30 kL/Yr	710,000		11,300,000	
WSUD - Swales		454,129		21,690	

Note: Pollution abatement costs were calculated as the net present value of capital and operating costs divided by the pollution abated over the period of analysis; 3% discount rate for a 20-year period analysis. In estimating separate cost-effectiveness for removing individual pollutants two-third of the cost has been allocated to nitrogen removal and one-third to phosphorous removal.

Polyakov et al. (2017) provided one of the first systematic cost-effectiveness analysis of the management of nutrient emission in the Swan-Canning and one of the first to consider efficient abatement policy for an urban catchment. They have developed a comprehensive optimization model mimicking the decision of a single regulator who tries to minimize the cost of achieving pollution target by spreading actions across sub-catchments and time periods. The actions considered were education of households, soil amendment, removal of septic tanks and investment in constructed wetlands and banning standard fertilizers further to the restrictions introduced in 2010 on the phosphorus content of domestic fertilizers.

They compared multiple scenarios: Scenario 1) allows all abatement actions except banning standard fertilisers, and it includes the amenity value of constructed wetlands; Scenario 2) allows banning standard fertilisers and Scenario 3) is similar to Scenario 1 but it does not account for the amenity value of constructed wetlands. Simulations through different level of targets reveal that scenario 2 is relatively more effective both in terms of total cost and emission targets (Figure 2). Infill of septic tanks and constructed wetlands were policies that were applied at most levels of abatement. The cost-effectiveness of constructed wetlands was partly due to an assumption that their net-cost was reduced by a significant amenity value measured from a hedonic pricing study of the effect on house prices due to construction of the Bannister Creek living stream.

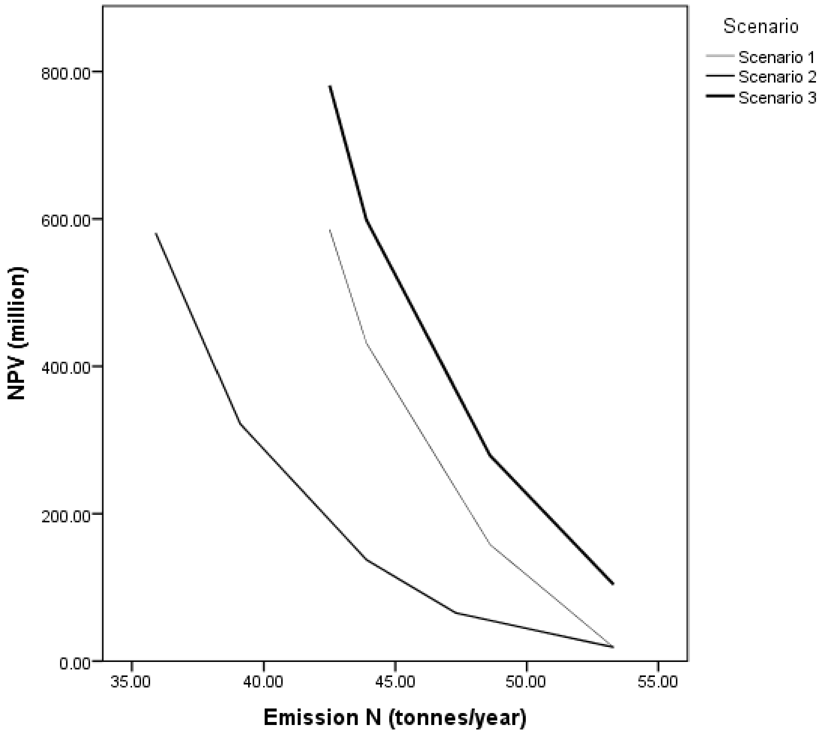


Figure 2: Abatement cost against nitrogen emissions

In urban areas, storm water runoff can cause sudden increased pollutant levels in surface waters which can lead to significant negative impacts on ecosystems and the environment (Roy et al., 2008). As reported in section 2, there is a large body of literature on the non-market values of water quality measures, which could be directly linked with pollution removal benefits from water bodies.

Flood hazard reduction

Flood is a major natural hazard faced by many urban areas in Australia. From the catchment level perspective there are two types of flood hazard: urban flooding and rural flooding. Both stormwater and mainstream flow can contribute to each type of flood. The relationship between urbanisation and stormwater flood risk is quite direct. Urbanisation involves paving parts of the watershed with asphalt, straightening and shortening water flow paths by conveying runoff through drainage systems, and the erosion of downstream channels (Parker, 2000). The stormwater collection system can then be overwhelmed, and consequently the areas serviced by the system may be subject to flooding.

According to an estimate based on a review of natural disasters in Australia occurred over 1967 to 2005 found that flood is the most the most costly natural disaster (Middelmann - Fernandes, 2010). In terms of the relative importance of stormwater and mainstream flow to flooding, SCARM (2000) report that urban flooding caused by stormwater overflow, on average, represents 11 percent of flooding costs in Australia.

The costs from flood could be grouped into five categories: direct costs, business interruption costs, indirect costs, intangible costs and risk mitigation costs (Meyer et al., 2014): Direct costs are related to the damages to the properties from direct physical impact. Business cost is related to the loss in productivity from inability to carry out as usual activities in the direct flood affected areas. Indirect costs could occur from both direct damages or from the business interruptions. These could happen outside of the direct impact area and over a long period of time. Intangible costs are related to the nonmarket impact which are not easily measurable (e.g., environmental impact or health impact). Risk mitigation cost are related to the preventive measures taken by people to reduce or minimize the flood impact. They could be again direct, indirect or intangible (Table 6).

Table 6: Cost categories of flood (Meyer et al., 2014)

Cost types		Tangible cost	Intangible (non-market) costs
Damage costs	Direct	Physical damage to assets: buildings, contents, infrastructure	Loss of life Health effects Loss of environmental goods
	Business interruption	Production interruptions because of destroyed machinery	Ecosystem services interrupted
	Indirect	Induced production losses of suppliers and customers of companies directly affected by the hazard	Inconvenience of post-flood recovery Increased vulnerability of survivors
Risk mitigation costs	Direct	Set-up infrastructure Operation and maintenance costs	Environmental damage: due to development of mitigation infrastructure or due to change in land use practices
	Indirect	Induced costs in other sectors	

Evaluate flood damage

Estimation of ex post costs can be a direct way of evaluating flood damages, and historically government authorities have counted and recorded flood damage losses after each flood event. These historical data can be used to generate estimates of the potential flood damage risks in certain areas (Thompson et al., 1997). Lovelace and Strauser (1998) reported the flood damage costs of flood events in the Mississippi river basin in 1993 by using expenditures on cleaning up and repairing the levee damages caused by flood. FEMA (2012a) estimated costs caused by flooding by adding up the direct losses of individuals, companies, and communities from the event. However, these financial losses cannot be considered as economic losses. For example, one company which is closed for several days because of a flood event may suffer lost profits, but other companies may gain extra profit due to additional sales that previously went to the closed firm. Similarly, losses from disruptions to the road network may, in the end, deliver greater profits to airline and marine transport companies.

Another method that can be used to estimate costs relies on the use of Stage-Damage Curves. This approach, according to Smith (1994), can be implemented as follows:

- Select the individual land use categories for analysis;
- Identify the main characteristics of a flood (such as depth, duration, velocity, and load);

- Within each land use category, identify significant subgroups of building types (such as one or two storey houses, houses with a basement etc.);
- Use the main characteristics (or variables) of the flood to establish relationships between the variables and damages (such as deriving a depth damage curve) for each land use subgroup;
- Use the other flood characteristics, such as velocity, to modify the base curve. For example, the stage-damage curve could have low, medium, or high velocity variants.

With the assistance of GIS methods and hydrologic modelling techniques, it is then possible to build flood damage assessment models to evaluate the damages caused by flood events. Existing models of this type include the HAZUS model from the USA (FEMA, 2012b) and the NHRC model (Leigh and Kuhnel, 2001) developed by Macquarie University in Australia. Both of these models are capable of generating stage-damage curves which can be used to estimate the damage costs by floods under various conditions.

In Australia, some attempts have been made to develop stage-damage curves. For example, The State of Queensland (2002) have provided Stage-damage relationships for residential (Table 7) and commercial properties (Table 8). It can be observed that damage cost is increasingly higher with higher flood depth. It should be noted that state-damage curves only captures the direct cost. Often rule of thumb is used to calculate indirect cost. For residential properties it is assumed that indirect damage is 15% of the direct damage and whereas it is 55% for commercial properties. However, indirect damages do not consider intangible costs and risk mitigation costs. Further, these function only show potential damage as the actual damage could be lower / higher depending on the preparedness of community.

Table 7: Stage-damage relationships for residential properties (The State of Queensland, 2002)

Depth over floor level (m)	Small house: < 80m^2 and/or 1–2 bedrooms	Medium house: 80–140m^2 and/or 3 bedrooms	Large house: > 140m^2 and/or 3+ bedrooms
0	905	2,557	5,873
0.1	1,881	5,115	11,743
0.6	7,370	13,979	25,351
1.5	17,379	18,585	32,276
1.8	17,643	18,868	32,768

Table 8: Stage-damage relationships for commercial properties in Queensland (The State of Queensland, 2002)

Depth over floor level	Value class				
	1	2	3	4	5
Small commercial properties (<186m^2)					
0	0	0	0	0	0
0.25	2,202	4,405	8,809	17,618	35,237
0.75	5,506	11,011	22,023	44,046	88,092
1.25	8,258	16,518	33,034	66,069	132,137
1.75	9,176	18,352	36,705	73,410	146,819
2	9,726	19,454	38,907	77,814	155,628
Medium commercial properties (186 - 650m^2)					
0	0	0	0	0	0
0.25	6,975	13,948	27,896	55,791	111,583
0.75	16,884	33,768	67,537	135,074	270,147
1.25	25,693	51,387	102,773	205,574	411,094
1.75	28,445	56,893	113,785	227,570	455,140
2	30,281	60,564	121,126	242,252	484,504
Large commercial properties (>650m^2)					
0	0	0	0	0	0
0.25	7	15	32	61	122
0.75	39	78	154	308	619
1.25	81	162	326	649	1,297
1.75	132	267	533	1,065	2,129
2	159	318	636	1,272	2,545

Examples under individual value classes: 1: Florist, garden centres, sports pavilions, consulting rooms, vehicle sales areas, schools. Churches; 2: cafes / takeaway, service stations, pubs, second hand goods, clubs; 3: chemists, musical instrument, printing, electronic goods, clothing's; 4: bottle shops, cameras and 5: Pharmaceuticals, electronics

Evaluate flood risks and protection measures

There is some literature that estimated the value of flood risks through multiplying the estimated flood damage costs with the reduced possibility of flood risks. For example, Blong (2003) multiplied construction costs per square metre with different level of flood risks to calculate the damages to buildings from flooding in Australia. Seifert et al. (2009) used industrial and commercial asset values to estimate losses from potential flood risks in an industry zone in Germany. Estimated values from this type of approach are more closely related to the costs of flood damages rather than benefits of the flood control measures.

Hedonic price studies

The hedonic price method has been used to measure the benefits of flood risk control measures. Properties may sell for a lower price if buyers are aware of the flooding risks of that property.

Although no specific monetary values were reported, Bartosova et al. (2000) found increases in food risks could decrease the value of residential properties within the 100-year floodplain in Wisconsin, USA.

The property value changes in the USA following urban stream restoration measures, including flood protection measures, are calculated in Streiner and Loomis (1995). The authors found that flood damage reductions and stream stabilizations together can add around 3 percent to 5 percent to the value of properties. Note, however, that from the information contained in the paper it is not clear exactly how specific values were obtained.

The hedonic price method is used in Harrison et al. (2001) to estimate the housing discount for homes in the 100-year flood plain. The data for the study relate to the period 1980-97 and are for Alachua County in Florida, USA. The discount for being in the 100-year flood plain was found to be around $3,000. The authors also note that the net present value of the additional insurance premiums associated with a home on the 100-year flood plain are more than the discount in the capital price of a home on the flood plain.

Daniel et al. (2009) provided a meta-analysis of economic impact from reduced flooding risk. They used 19 studies from the US in their analysis and found that an increase in the probability of flood risk by 1% in a year could result in -0.6% reduction in prices for an otherwise similar house. As expected, with time the marginal willingness to pay for reduced risk exposure has increased and higher income areas have slightly lower willingness to pay. However, these estimates could be sensitive to the interactions of amenity benefits and risk exposure from living closure to water.

Insurance costs

In terms of using insurance costs as a measure of flood costs, Chivers (2001) argues that insurance expenses may fail to accurately predict potential flood damage risks as people under-estimate flood damages before a significant flood event, and overestimate risks after a flood event. For example, Bin and Polasky (2004) compared house price differences pre- and post-hurricane Floyd for homes on the flood plain in Carolina, USA. They found that the house price discount doubled within flood zones after hurricane Floyd. This discounted price was also significantly higher than the net present value of the additional insurance premiums. This means residents would be willing to pay a much higher value to avoid flood risks than the actual required insurance fees.

Contingent valuation studies

There are a number of potential issues with the use of the contingent valuation method to evaluate flood control measures. First, people may not really understand what kind of flood risk they are facing and how the proposed control measures could help them. Second, some residents may have difficulties in understanding technical flood terminology. For example, people that have experienced a flood twice in five years may find it difficult to reconcile their experience with a statement that they are on a one in 50-year flood plain. Thus, a reduction of flood risk from once per 50 years to once per 100 years may not make much sense to some people asked to complete a survey. Third, flood control measures such as dams are multifunctional, and it is hard to disentangle the support that is directly related to the flood control element from the overall support for the project. Despite these potential issues, there have been a small number of attempts to evaluate willingness to pay for flood protection using the contingent valuation method.

Thunberg and Shabman (1991) use the contingent valuation approach to analyse the determinants of willingness to pay for flood control projects of the residents of the City of Roanoke in Virginia, USA. The analysis was based on a relatively small sample size (74 usable responses), and focused on owners of flood-prone land. The results show that property protection aspects will influence residents' willingness to pay for flood control investment, as well as non-property considerations such as reduced psychological stress and reduced community disruptions.

The contingent valuation method is used in Bateman et al. (1995) to estimate the WTP in Broadland, UK for a multifunction project that included a flood control function. Based on 344 responses the mean WTP was estimated to be £21.75 per year per household to build flood defence works.

Zhai and Ikeda (2006) investigated the WTP of residents in Toki and Nagoya cities, Japan to avoid the inconveniences caused by flooding such as evacuations. Based on 1,259 responses the study found that the mean WTP was 1,030 yen/person/night. The authors stated that household income, individual preparedness, and flood experiences played a significant role in determining the WTP value.

Brouwer and Bateman (2005) examined residents' WTP in East Anglia, UK to conserve a wetland that had a flood control function. The study relied on 1,747 completed surveys and found a mean WTP of around £216 per year per resident. In the study the percentage contribution to total value attributed to the flood control function was not separated from the other functions of the wetland.

Estimate the value of flood reduction caused by stormwater harvesting

Conventional stormwater management focused on removing stormwater from a site as quickly as possible to reduce on-site flooding risks (Minnesota Stormwater Steering Committee, 2005). Stormwater harvesting techniques may, however, require stormwater to stay on-site for a certain period of time and then make its way into the groundwater system by some means. This process may increase the flood risk. On the other hand, stormwater harvesting techniques also involve the use of more permeable surfaces which may help reduce both the peak and total volume of stormwater. The overall impact of stormwater harvesting techniques on flood risk is therefore ambiguous.

Some design standards require flood control and stormwater harvesting to be considered separately, for example NHDES (2012) and Sunshine Coast Regional Council (2009). Yet, scientists and engineers have developed integrated systems to ensure that additional stormwater runs into the drainage system if the downward seepage rate allowed for in the stormwater harvesting design is insufficient. Household water tanks may also be a reasonably reliable technology for flood reductions (Tam et al., 2010). Overall, however, the effects of collecting stormwater to mitigate flood risks are not clear, and this remains an area where further work is required.

Other methods

Various other methods are often used to calculate monetary values of impact of flood, e.g., cost-of-illness and value of lost-production. The cost-of-illness (COI) approach is used to calculate the total cost of diseases occurred due to a natural disaster. This approach includes several categories of direct and indirect costs: personal medical care costs for diagnosis, procedures, drugs and inpatient and outpatient care, nonmedical costs, such as the costs of transportation for treatment and care, non-personal costs like those associated with information, education, communication and research, and finally income losses. The value of lost production is similar to the cost-of-illness approach which focus on on the loss of income (Lekuthai and Vongvisessomjai, 2001).

Recharge and improved groundwater quality

Groundwater refers to water stored in underground aquifers. Groundwater aquifers generally provide high quality water that requires little treatment before use. Groundwater is, therefore, an important source of fresh water. Groundwater resources support complex ecosystems and agricultural production. In some cases, they have been integrated into the potable water supply for cities. Groundwater contributes around $36 billion [2016 adjusted] per annum to the Australian economy (Chong and Sunding, 2006). If non-market values for ecosystem services were also included the contribution would be much higher.

In Australia and many other countries, however, groundwater is being extracted well beyond sustainable levels, placing them at risk (Harrington and Cook, 2014). For example, the groundwater storage in the Murray-Darling Basin, covering roughly 14% of Australia, lost around 100,000GL between 2000 to 2007 due to climate change and over-extraction (Ranjan, 2014). As aquifers are out of sight, groundwater protection is a management area that has not always been a priority. However, there are some information on the value of groundwater use in Australia and elsewhere. Relevant information on the direct and indirect use values of groundwater are presented below.

Direct use values of groundwater

Economic valuations of the use value of groundwater focus on the role of groundwater as a water supply source. There have been a number of studies which estimated the aggregated value of groundwater systems in Australia (see Table 9). The results show higher value for public water supply and industry. However, these estimates are partial as they only reflect the consumptive use. They did not capture the “non-extractive” or “option” values. An example of non-extractive use would be use of water in forestry. An example of option value when the availability of groundwater is considered during long-term planning even if the water is not used currently. For example, an irrigator may decide to plant long-lived horticulture plant knowing that groundwater is available in case surface water becomes unavailable (Deloitte Access Economics Pty Ltd, 2013).

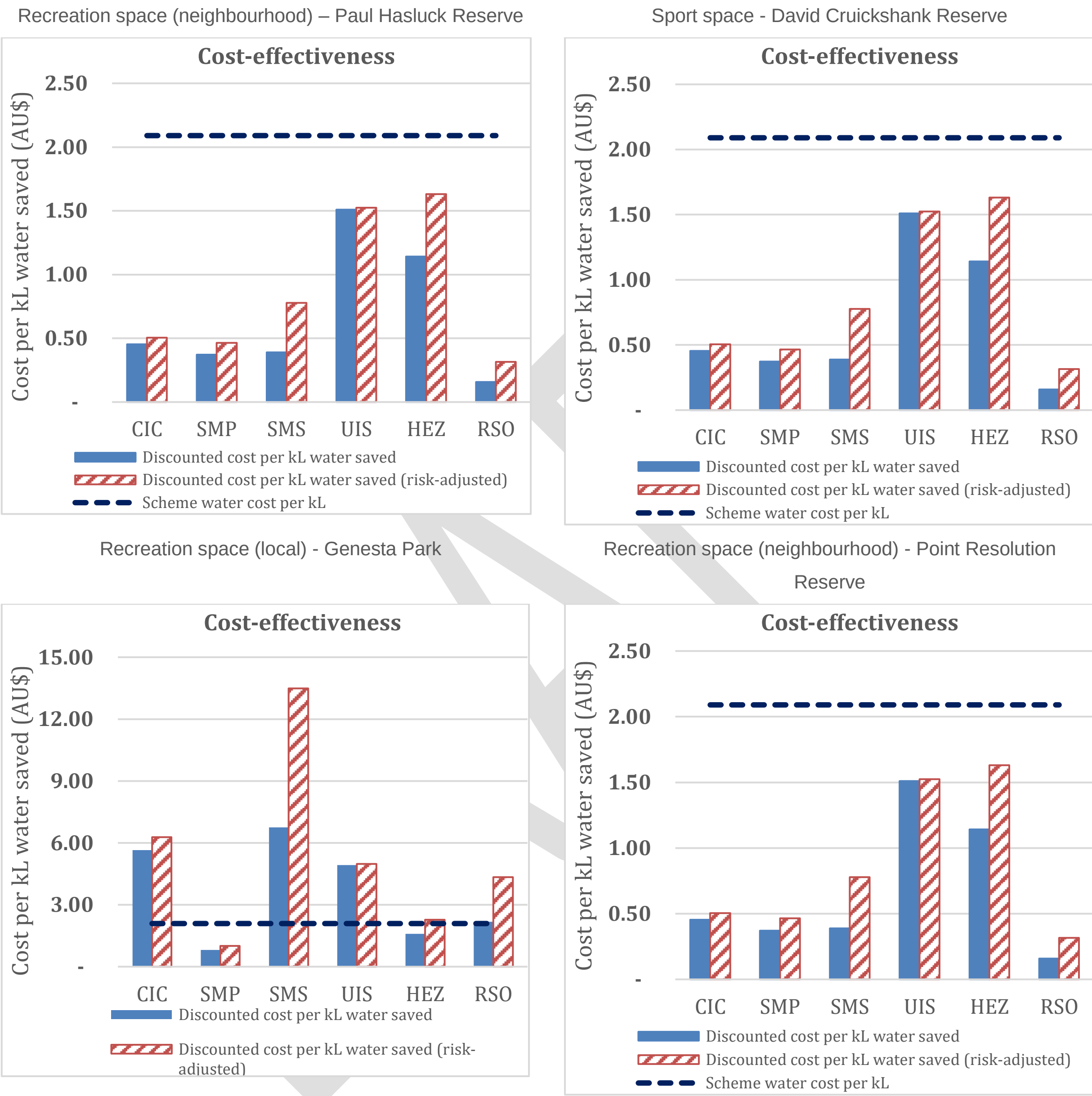
Table 9: Summary of results from selected case studies on the economic value of groundwater (Deloitte Access Economics Pty Ltd, 2013)

Study	Area and source	Scope	Result*
Marsden Jacob Associates (2012)	Gnangara, WA	Gnangara groundwater system contains the Superficial, Mirrabooka, Leederville and Yarragadee aquifers. It covers 220,000km^2 and underlies Perth's northern suburbs. Approximately 280 GL per year is extracted from the system, of which around 43% (121 GL per year) is used for Perth's public water supply, and 22% (62 GL per year) for horticulture and agriculture (Iftekhar and Fogarty, 2017).	• Public water supply: $1,800/ML • Horticulture and agriculture: $900 – $1,870/ML • Domestic bores: $100 – 1800/ML • Parks and gardens: $100-1800/ML • Industry: $1800 – $10,000/ML
	Shepparton, Vic	Shepparton irrigation region is located in the Murray Darling Basin. The region includes the Murray Valley, Shepparton, Central Goulburn and Rochester irrigation areas and some adjacent dryland areas. The region represents the largest irrigated agricultural area by volume in Victoria.	• Dairy: ceiling value of $100/ML (beyond which farmers assumed to purchase stockfeed) • Horticulture and cropping activities: • Upper traded value of $750/ML in 2007 droughts • Lower traded value of $25/ML in 2011 floods • Long run average cover 2007-2011 approximately $290/ML
	Daily river, NT	Daly river is a perennial river system and represents one of the most important ecosystems in the Northern Territory as it continues to flow throughout the dry season due to groundwater baseflows. Groundwater represents 90% of the NT's freshwater use.	• Public water supply: $2,600/ML • Agriculture: $452/ML • Industrial uses: $452/ML • Stock and domestic: $4,665/ML
	Lockeyer valley, SEQ	Circular basin covering 2800km^2 that produces 30% of the Queensland's vegetables by value. The Lockeyer Valley's main groundwater resources supply approximately 80% of irrigation water to the resident agricultural sector	• Agriculture: $600/ML
	Northern Tasmania	Focuses on agriculture in Tasmania's three most northern catchments (the Arthur Inglis-Cam region, Mersey-Forth region and Piper-Ringarooma region)	Agriculture: • Vegetables: $1000/ML • Other crops (including poppies, pyrethrum and berries): $1900/ML • Dairy: $600/ML
Tapsuwan et al. (2009)	Perth Metropolitan area, WA	Assess the economic value of groundwater from the Superficial Aquifer for irrigating lawns and gardens	Avoided costs of having to use scheme water to irrigate green space: Value to decision maker • Councils: $500/ML • Other institutions: $500/ML • Households: $329/ML Value to society: • Councils: $900/ML • Other institutions: $905/ML • Households: $629/ML
Deloitte Access Economics Pty Ltd (2013)	Australia	The estimates are based on available data from a range of sources	• Agriculture: irrigation: $30/ML - $500/ML • Mining: $500/ML - $5,000/ML • Urban water supply: $1,000/ML - $3,000/ML • Households: $1,400/ML - $6,400/ML • Manufacturing and other industries: $1,000/ML – $3,000/ML

* The values are in AUD

We also report results from two other completed studies on the value of groundwater in Perth, WA. Sonja (2017) analysed various water use efficiency improvement strategies to manage public open space. Based on empirical data, she conducted cost-effectiveness analysis of six water savings techniques for four parks of different sizes in

Perth (Figure 3). She found that even though there is substantial variation in cost-effectiveness between different techniques it is possible to maintain the same level of Public Open Space (POS) quality even in the face of water supply reduction by adopting more efficient techniques. For larger parks, it is cheaper to improve efficiency than securing water from scheme water and the most cost-effective technique is the use of ‘Rain shut off devices’. In contrast, for a small local park ‘Improving soil moisture properties’ and ‘Soil moisture sensors’. Again, except for one or two techniques it is cheaper to improve efficiency.



Note: CIC: Central irrigation control with weather station; SMP: Soil moisture properties; SMS: Soil moisture sensors; UIS: Upgrade system 85% DU; HEZ: Hydrozoning/ ecozoning and RSO: Rain shut off

Figure 3: Cost-effectiveness of six techniques for four parks from Sonja (2017)

In another study, Iftekhar and Fogarty (2017) estimated the loss in gross and net revenue for horticulturists from reduction in groundwater extraction rights or allocation in Gnangara, WA. Based on their simulation analysis, they found that the average per hectare total return and net cash return were $27,248 and $7,104, respectively and with a 25% reduction in water allocations the net allocation will fall by $1,000 per Ha, or 13.1%. However, there is large difference between different sizes of farms. For example, the expected loss in net revenue per ha for a 10-ha farm was around three times the expected loss per ha for a 1-ha farm; and the expected loss per ha for a 25-ha farm is around five times the expected loss per ha for a 1-ha farm.

Non-use values of groundwater

Non-use values include option value: the value that the groundwater resource is not currently used but may be used sometime in the future. There is also existence value, which is the value associated with preserving the groundwater resource as it currently is with no intention to use it in the future. The two other non-use values identified in the literature are altruistic value — which is the value obtained by person *i* from use by person *j*, where $i \neq j$, and the bequest value — which is the value associated with leaving the resource for future generations.

Because these values are quite hard to quantify, and because they are not linked to any tradable goods, only stated preference methods are able to estimate these values (see Table 10 for relevant literature). There has been only limited research of the non-use value of groundwater. Sun et al. (1992) used the contingent valuation method to estimate the option price of groundwater quality protection. In the study option value is used to measure the benefits of groundwater contamination abatement, and it is the individual's maximum WTP to keep the option to use this resource in the future. The study found the mean option price of groundwater protection from contamination to be $641 per year per household. Authors of early research, such as McClelland et al. (1992) took non-use values such as bequest value as total non-use values. Wright and Hudson (2013) assumed the environmental benefits as the total non-use values. However, the environmental benefits not only contain non-use values but also contain some use values. More generally, it may be hard to separate indirect use value and non-use value for groundwater. For example, reserve groundwater may contribute to plant growth and these plants may in turn provide people with a unique recreation place.

Table 10: Groundwater valuation surveys

Author	Method	Location	No. of surveys	Study	Mean WTP estimates (per household)*	Adjusted WTP value (value in $US2016)
Edwards (1988)	CV	Cape Cod coast, Massachusetts, USA	585	Estimate households' maximum WTP to prevent uncertain nitrate contamination of Cape Cod's sole source aquifer	$5 million (per 1000 households for 30 years) when the probability of supply increase by 25%; About $25 million when the probability of supply increase to 1.0	$10.45 million-$52.27 million
Torell et al. (1990)	Market value differences	High Plains aquifer, USA	N/A	Assess the market value of water in-storage on the High Plains aquifer, using price difference between irrigated and dry land farm sales	$1.09 as the value of water per acre-foot in Oklahoma to $9.5 per acre-foot in New Mexico	$2.08-$18.08
Shultz and Lindsay (1990)	CV	Dover, New Hampshire, USA	346	Estimate WTP for a hypothetical groundwater quality protection plan (protect groundwater from future pollution)	$129 per year in extra property taxes to support the plan	$256.95
Poe and Bishop (1992)	CV	Portage County, Wisconsin, USA	537	Estimate residents' WTP for groundwater protection program (prevent groundwater from agriculture contamination)	$269.3, $414.8 and $257.1 per year respectively as the WTP by ex-ante no-info group, ex-ante with-info group and ex-post group. The groups were divided by whether they received background information on nitrates in their own well water	$447.52 - $722.03
Sun et al. (1992)	CV	Southwest Georgia, USA	660	Estimate households' WTP to eliminate the potential for groundwater contamination from agricultural chemicals	$641 per year for groundwater pollution abatement	$1,115.81

Author	Method	Location	No. of surveys	Study	Mean WTP estimates (per household)*	Adjusted WTP value (value in $US2016)
Powell et al. (1994)	CV	Massachusetts, New York, and Pennsylvania, USA	Not available	Estimate the value of increased groundwater supply protection and pollution prevention	$61.55 per year for groundwater supply protection	$101.39
Stevens et al. (1997)	CV	Massachusetts, USA	537	Value groundwater protection program alternatives (aquifer protection district, town-wide water treatment facility, private pollution control device, purchase of bottled water and doing nothing)	WTP for aquifer program was the highest among other alternatives and the mean WTP was $35, $340 and $243 separately, per year per household for the binary choice model, traditional ratings model, and ratings difference model	$53-$516.09
Stenger and Willinger (1998)	CV	Alsatian aquifer, Western Europe	817	Estimate the value of groundwater quality protection	150FF to 180FF per person per year to preserve the quality of groundwater	$37.84-$48.71
White et al. (2001)	CV	Waimea Plains, Nelson, New Zealand	180	Estimate the value of the groundwater resource in terms of benefits for irrigation, commercial/industrial use and bulk water supply	The marginal value of water to irrigators is $240 to $300 per allocated cubic metre; the lower bound of WTP for household to a 20% reduction in groundwater extraction is $183 per household per year	$106.1-$174.05
Kerr et al. (2001)	CV	Christchurch, New Zealand	256	Estimate the WTP of meeting water needs by drawing and treating water from the Waimakariri River or from Ellesmere groundwater	$628-$640 to get more supply of water from the river; $527-$2,386 to get more supply of water from groundwater	$305.66-$1383.94
Hasler et al. (2005)	CV and CE	Denmark	600 for CE; 584 for CV	Estimate the value of groundwater protection	Using CE: 1,899DKK per year for naturally clean groundwater; 1,204DKK per year for water with very good conditions for plant and animal life; 912DKK per year for purified water using CE; Using CV: 711DKK and 529DKK for groundwater protection and purified water separately	$107.67-$387.41
Aulong and Rinaudo (2008)	CV	Upper Rhine Valley aquifer, France	668	Estimate WTP for groundwater protection	€42.6 per year to restore drinking water quality; €77 per year to eliminate all traces of polluting substances	$60.55-$109.45
Martínez-Paz and Perni (2011)	Production function method and CV	Gavilan Aquifer, Spain	309	Estimate the total economic value of groundwater resources	0.381 €/m^3 as the value of groundwater for agriculture; 0.010 €/m^3 as the value of groundwater for recreational activities; 0.063 €/m^3 as the value of groundwater for environmental functions	0.01$/$m^3-0.52/m^3

Note: CV refers to contingent valuation method; CE refers to choice experiments method; * unless otherwise indicated $ = $US

Water supply and pricing

One of the most important tasks for successful water management is to provide adequate and good-quality water to the public, at a reasonable price. Evaluations of the value of additional water supply have mainly focused on the benefits of avoiding government imposed water use restrictions during periods of water shortage; and improvements in water quality and service reliability. In this section, we will summarize the economic evaluation studies in terms of the main methods employed: averting behaviour studies, contingent valuation studies, choice experiment and hedonic studies.

Averting behavior studies

The averting costs associated with avoiding Giardia-contaminated water from a community water system in Pennsylvania, USA were estimated in Laughland et al. (1996). The averting costs were defined to include the opportunity costs of time to boil or haul water, and the direct costs associated with purchasing clean water, and were estimated to be $14.14-$36.33 per month per household.

For the Korean context, Um et al. (2002) estimated citizens' WTP to improve their tap water to different quality levels. The authors extended the conventional averting behaviour method into a perception averting behaviour method for valuing different pollution levels of tap water by investigating different types of drinking water and different perceived pollution level of tap water quality. Depending on household income level, the estimated minimum WTP value was found to be $4.20 -$6.10 per month per household.

Rosado et al. (2006) used both the averting behaviour method and the contingent valuation method to estimate WTP for drinking water quality in urban Brazil. The estimated WTP for treating tap water to a drinkable standard was $5.20 to $19.50 per month, per household, in addition to existing water bills. The authors argue that using a combination of different resources and datasets results in the estimation of robust WTP values. The authors also note that unless careful consideration is given to issues such as heteroscedasticity, estimates will be biased.

A case of groundwater contamination is considered in Abdalla (1990). Specifically, the study considers the averting behaviour costs of residents in a region in Central Pennsylvania, USA, where the local groundwater source was contaminated. The extent of local concern about the issue is reflected in the survey response rate. Out of a total resident household population of 1,596 the authors received 1,045 completed surveys. The study found that the cost of residents' averting behaviours, such as boiling water and buying bottled water were about $252 to $383 per household per year.

Pattanayak et al. (2005) used the averting behaviour method to estimate the averting expenditure by households in Kathmandu, Nepal, where residents only have access to an unreliable flow of poor quality water. The averting behaviour considered included pumping water from springs and deep tube wells, purchasing water, and storing and treating the poor quality water that was supplied. The results showed mean monthly household averting expenditure (including collection costs, pumping, treatment, storage and purchase costs) was around $3. Averting expenditure was, however, also shown to vary with household income, and the mean value of monthly averting expenditure for poor households was around $1.4.

A common feature of the above research is that it relies on costs (or opportunity costs) that actually occur to estimate the value of water resources. Intuitively this makes the results seem more reliable than results derived from hypothetical scenarios. There are, however, a number of issues that can lead to biases in averting behaviour studies. First, people may continue to purchase bottled water even though the tap water has improved to drinkable quality. This would lead to an over-estimate of the averting behaviour costs. Second, as averting behaviour focuses on costs rather than benefits, the values may only represent a fraction of the benefits. Third, alternative water resources may not be available. For example, it may not be convenient/ possible to buy bottled water even though the residents want to do so. A final limitation is that the method is really only useful for considering changes such as raising water quality from below drinking standard to drinkable standard.

Contingent valuation studies

In many developing countries the majority of houses do not have private connections to mains water and only public taps are available where access is shared by households. To use water from public taps there are opportunity costs in terms of the travel time required to collect water. In such scenarios contingent valuation studies can provide useful information regarding the amount communities would be willing to pay to have improved water supply services, such as an individual house connection. For households to be able to use water from private connections there are generally both charges for the connection, and for the water used.

Whittington et al. (1990) is a contingent valuation study undertaken in Southern Haiti. Based on a total of 170 completed questionnaires the study found that people would pay 1.7 percent of their monthly household income to have a public standpost near their homes, and would pay 2.1 percent of their monthly household income for private connections in their yards.

As it considers responses from the same people before and after an actual intervention, Griffin et al. (1995) is an interesting contribution to the contingent valuation literature. The surveys were conducted in the Indian State of Kerala in an area where there were salinity issues with the local water supply. The first survey was conducted in 1988 to estimate residents WTP for improved water services. The second survey was conducted in 1991 after a new water supply system became available and aimed to investigate whether residents' actual behaviour was consistent with how they said they would behave in relation to connecting to the water supply system. Although specific details were not reported, the general finding was that residents' stated behaviour did not match their actual behaviour.

In developing countries, household income, access to water connections, and the quality of water services etc. can influence people's WTP for water supply services. This in turn can make it difficult to establish a single representative WTP value from any given study. Briscoe et al. (1990) estimated the willingness to pay for water supply services in three areas in Brazil focusing on estimating the income and price elasticity of demand. Results show that the average stated maximum willingness to pay to have a connection to private yard taps was around 100 cruzados per month. At the time of the study this amount was 2.5 times higher than the actual monthly tariff.

Altaf et al. (1993) investigated the WTP of households in the Punjab region of Pakistan. The study found that households without piped water connections would like to pay Rs.56 per month (4.7 times higher than the monthly tariff at the time) for connection to a water system with standard reliability. Those who already have piped water systems would be willing to pay an additional Rs.33 per month (2.8 times higher than the monthly tariff at the time) to have adequate water supply pressure.

The WTP of households for improved water services in Kathmandu, Nepal was investigated in Whittington (2002). The study relied on 1,500 survey responses. The question of interest was how much households would be willing to pay for services from a private service operator. The private operator could provide services such as improved water quality and decreased frequency of water supply interruptions. For households already connected to water supplies provided by public operators, which only provide water for a few hours per day with low pressure, the average monthly WTP per household to be connected to water provided by private operator was US$14.3. This value was equal to 6.3 percent of average household monthly income. For households that currently have no water connections, their mean monthly WTP per household was US$11.67, and for these households this represented 5.1 percent of average monthly income.

Devoto et al. (2012) found that households in urban Morocco would be willing to pay almost double their current water bills on private water connections at home, versus $US11 per month for a public connection close to their homes with the same level of water quality. The existing costs are the fees paid to their neighbours who have water connections to access water and the time costs to collect water from public connections (they spent nearly 18 hours per month for collecting water from public connections on average). Without improved water quality and quantity, the benefits from new installed private or public water connections seem to be a function of the time saved.

In developed countries, as most houses are connected to a water supply network research has focused on water quality, water service reliability and water resource protection issues. For example, Carson and Mitchell (1993) estimated the national benefits of freshwater protection in the USA. Water quality was defined in increasing levels of quality as: fit for boating activities; fit for boating and fishing activities; and fit for boating, fishing, and swimming activities. Based on 813 survey responses the study found that the annual mean WTP per household to keep freshwater resources at a quality level suitable for: boating activity was $93; boating and fishing activity was $163; and boating, fishing and swimming activity was $241.

The WTP of Canadians to support a program to repair water distribution and sewage treatment systems to prevent a decline in current water services was investigated in Rollins et al. (1997). Based on 1,511 household surveys across Canada the study estimated that the mean WTP to support a program to repair water distribution and sewage treatment systems to prevent a decline in current water services was about CA$26 per month in addition to household current water bills. The study claimed that as the differences of WTP among Canadian regions were not significant, the results of the survey can be used to estimate the WTP of the whole nation. On this basis the national WTP was estimated as CA$1.1 billion less than the amount required to cover the estimated marginal costs of maintaining, renovating, and upgrading water infrastructure to ensure adequate water services.

In another study in Canada, Dupont (2013) reported results from a double bounded contingent valuation survey on people's willingness to pay to avoid summer water use restrictions by using reclaimed wastewater. They found that the mean WTP per household per year as between $142 and $155. The values depended on the scale of the project and expectations on neighbouring compliance with summer water use restrictions.

The WTP of residents in ten districts in California, USA to avoid water shortages was investigated in (Koss and Khawaja, 2001). Through the use of 3,769 completed survey the authors were able to establish that residents were willing to pay US$11.61 per month per household to avoid a 10 percent shortage once every ten years; and US$16.92 per month to avoid a 50 percent shortage occurring every twenty years.

Epp and Delavan (2001) investigate household WTP for a proposed groundwater nitrate pollution reduction programme in Pennsylvania, USA, and found that the WTP ranged from US$51 to US$74 per year, depending on whether an open-ended format or a dichotomous choice format was used when surveying households. More generally, the authors note that residents' WTP for water quality or reliability of water supply services are influenced by many factors in addition to the question format used, including: household income, perceived effectiveness of the programme, expenditure to avert pollution, number of children in the household, gender, and age.

Poe and Bishop (2001) is a contingent valuation study concerning protecting groundwater supplies from nitrate contamination in Wisconsin, USA. The study found that the behaviour of respondents, and their willingness to pay, was influenced by awareness of the safety risks associated with the current water supply. Those who were aware of the risks and used adverting measures such as purchasing bottled water for drinking were generally willing to pay more for water quality improvements. However, the research also found that the WTP for improvements in water quality of those in areas where contamination levels were very high may be lower than the WTP of those unaware of contamination issues. The authors' explanation of this result is that residents in areas of heavy contamination may consider a small reduction of pollution as incapable of bringing a heavily polluted water resource back to safe conditions.

Genius and Tsagarakis (2006) investigated residents WTP for improvements in water quality in the Heraklion area of Greece, an area where water supply disruptions happened regularly, and where many households had refused to drink tap water because the tap water was believed to be contaminated. The authors found those who had problems with the smell or colour of the tap water, or those who had stayed in the city for a long time, were relatively less likely to drink tap water directly. Based on 294 survey responses the estimated WTP of residents for a proposed plan to improve water services such that flows were regular and the quality of tap water was drinkable was €13.8 per month in addition to their monthly bill. In subsequent work Genius et al. (2008) concluded that female respondents, households with higher incomes, households with children, and residents who normally did not use tap water for drinking, were, on average, willing to pay more. This work was based on residents in the Greek town of Rethymno, and relied on 306 completed household level survey responses.

Hurlimann (2009) conducted a survey on WTP per kilolitre (kL) of water among office workers in Bendigo bank head office, Australia in February 2007. This study draws our attention for the following reasons:

- The survey was conducted during a period of extreme water shortages in Victoria. Melbourne dam water storage was around 25 percent, and in Bendigo the situation was much worse. In 2007 with the Bendigo reservoir recorded its lowest ever storage level, which was 4 percent, and there were significant restrictions on local government water use to maintain public open green space due to water shortages;
- Because of the water shortage, water was being carted to and sold in the Bendigo region.

The study found a mean WTP of A$7.7/kL based on 305 responses. This value was around six times higher than the price of mains supplied water. The result was, however, within the retail price range for trucked water, which at the time was between A$6.3 and A$17.1/kL depending on water quality and the transportation distance. The research indicated that residents would be willing to pay prices several times higher than normal water price to avoid strict usage restrictions during drought periods. The study also demonstrates that the estimated WTP from studies can be a reasonable representation of the marginal price of water supplies.

The contingent valuation method can also be used to estimate the value of alternative water supplies. The city of Oulu, in Finland, uses groundwater as a drinking water resources, and Tervonen et al. (1994) investigated the WTP of residents for relying on treated groundwater or purifying water extracted from the Oulu River. The authors found that residents were willing to pay €54 per year per household for purified groundwater, but only €51 per household per year for purified river water. However, whether there is a statistically significant difference of residents' preferences for drinking water supply resources was not clear from this research.

Laughland et al. (1996) surveyed 226 households in Milesburg, Pennsylvania, USA. At the time of the survey the local water supply was contaminated with Giardia. The authors found that households were willing to pay $18 per month in addition to their current water bills to connect to an alternative water source that would provide drinking quality water.

The tap water in Mexico is often polluted and unsafe for drinking. With this as the background context, Vásquez et al. (2009) found that residents in Mexico would be willing to pay 92.74 Mexican pesos, which is as much as 77 percent more than their existing water bills for the provision of safe drinking water to their houses.

Recently, Holguín-Veras et al. (2016) estimated deprivation cost functions using contingent valuation technique which is able to capture the economic value of human suffering from loss of water supply.

Choice experiments examples

Blamey et al. (1999) used a multinomial logit model to investigate preferences across 294 households in Canberra, Australia. Residents were faced with choices between using recycled water for outside use, construction of new dams, and water restrictions. Use of recycled water for outdoor use was the highest ranked water supply option among the choices. The mean WTP for the provision of recycled water for outdoor use was A$47 per year. There was, however, also a clear difference in preferences between using recycled water for drinking and using recycled water for outdoor use: residents had a clear preference for avoiding drinking recycled water.

The choice experiments method was used in Hensher et al. (2005) to examine Canberra residents' attitudes towards drinking water and wastewater. Based on 211 completed surveys, the authors found that the WTP of households depended on the way the questions about reliability of drinkable water and wastewater services were set out. Annual mean WTP to reduce the frequency of water supply interruptions from twice a year to once a year was A$41.51 per household. However, if residents currently face monthly interruptions, the mean WTP to reduce the water supply interruptions to bimonthly is only A$9.58. Households' WTP to reduce wastewater flow from twice a year to once a year was estimated to be A$77.85, and for reduced wastewater flow from once per year to once every two years was estimated to be A$116.77.

Choice experiments were used in Tapsuwan et al. (2007) to assess the preferences of residents in Perth, Australia for water resource development options to avoid outdoor water restrictions. At the time of the survey residents were faced with restrictions on the outdoor use of water. Based on 414 completed surveys, the results showed that residents would be willing to pay 22 percent more on their annual water usage bills to be able to use their lawn and garden sprinklers on three days per week rather than one day per week.

Recently, Van Houtven et al. (2017) presented results from a meta-analysis on household's willingness to pay for improved water supply. They used 171 WTP estimates from 60 stated preference studies. They found that the predicted WTP values ranged from approximately $3 per month (with a ninety percent confidence interval of $1.1 to $6.1) to $33.5 per month ($17.9 to $66.0) for improvement from base case to the maximum level of improvement specified in the survey. Households with already high level of water supply were willing to pay less. They were also willing to pay less for access to public water supply.

Hedonic price studies

The extent of hedonic price studies considering water supply issues is limited. Connections to a mains water supply network are, however, still an issue in some developing countries and whether a water connection is available or not can affect the rental price of a house. Several studies have looked at this issue. In the context of Manila in the Philippines, North and Griffin (1993) examined the rental price difference for homes with and without a water connection and found that housing rent would increase by about 30 pesos per month, on average, when a water connection was available. Komives (2003) considered the issue in Panama City and found that an in-house pipe connection resulted in an increase of about $US22 per month in house rent. Finally, Alam and Pattanayak (2009) found that household, in the slums in Dhaka, Bangladesh, with piped water had rental prices that were about US$10 per month higher than houses without a piped water connection.

Where water connections are not always a standard feature of homes, having a water connection can also affect the property price. Nauges et al. (2009) studied the property market in Central American cities using the hedonic price method and found that a tap water connection added between 10 percent and 52 percent to house prices.

Wastewater management

Globally, around 90 percent of wastewater produced remains untreated, with this wastewater directly recharging rivers and oceans, and potentially causing widespread water pollution (IWMI, 2010). Treated wastewater can, however, be reused by households, industries, agriculture, and natural ecosystems (Daigger and Crawford, 2007). In Australia, although wastewater is treated, only around 10 percent of wastewater is recycled for reuse (Dimitriadis, 2005).

Historically, in Australia wastewater systems have been linear on-directional where the main objective was to collect wastewater and stormwater and discharge them as quickly as possible. The social dimension and potential multi-functional benefits from wastewater re-use was largely ignored. Perraton et al. (2015) identified six major barriers in wastewater reuse: unsupportive institutional and governance arrangement, difficulties in determining the true cost of disposal options, issues of competition (absence of effective market for urban water) and demand, inadequate water quality management, political and policy influence on decision making and perceptions of integrated water supply options (public acceptance and perception of risks).

Economic valuation studies could be useful to overcome these barriers. From the various non-market valuation methods available, the most commonly used method has been the contingent valuation method. Overall, the existing research shows that the public is willing to pay significant amounts of money for wastewater treatment projects (see Table 14 for a summary of the literature that reported WTP values).

Contingent valuation studies

Using the contingent valuation method Tziakis et al. (2009) estimated residents' WTP for a centralised wastewater treatment plant in northwest Crete. The results showed that the mean WTP for a centralised wastewater treatment plant was €21.02 in addition to their average quarterly drinking water bills.

Gillespie and Bennett (1999) estimated the environmental benefits from two sewage treatment proposals that would reduce the flow of untreated sewage from the Vaucluse area (NSW, Australia) to the ocean. One proposal involved construction of a tunnel and the other construction of a sewage treatment plant. The results showed that the mean, one-off WTP for the tunnel option was $137, and the mean, one-off WTP for the sewage treatment plant option was $76.

Genius et al. (2005) estimated the WTP for a wastewater treatment plant in three locations using the contingent valuation method. The locations were the rural and seaside tourist areas of the Municipalities of Lappaion, Georgioupolis, and Krioneridas in North-West Crete. The results showed that the mean WTP for a wastewater treatment plant was a €44 increase in household quarterly water bills. The study concluded by noting that the WTP value is higher than the investment costs of a wastewater treatment plant.

Kotchen et al. (2009) used the contingent valuation method to estimate the WTP of residents of Santa Barbara and Ventura countries, California, USA for a pharmaceutical disposal program. The program was proposed to solve a problem of pharmaceutical compounds in treated wastewater and in surface water. The results showed that the mean WTP to support the program was $1.53 per pharmaceutical prescription.

Avoiding water restrictions during drought periods is an important factor that contributes to householders' WTP for water services. Dupont (2011) used the contingent valuation method to estimate the WTP of Canadians to use recycled wastewater for toilet flushing as a way to avoid summer lawn water restrictions. The results showed that the mean WTP of households to avoid a 30 percent reduction of summer water use was about $C9.26 per month. Similar research conducted in Bendigo, Victoria, Australia found that households would be willing to pay six times the actual water price for treated grey water during a period of relatively extreme water shortages (Hurlimann, 2009).

Choice experiment studies

The number of studies that have used choice experiments to investigate households' WTP for wastewater reuse projects is limited. Gordon et al. (2001) used this method to estimate the value of recycled water for outdoor use for the residents of the Australian Capital Territory. The results showed that the mean WTP was about an increase in household water costs of about A$47. In Western Sydney, based on a survey of 800 households, (Bennett et al., 2016) found that there were community preference for increased use of recycled water, however, their first preference was to replace use of potable water for industrial uses with recycled water. Similarly, in Greece, irrigators preferred use of recycled water for perennial horticulture (such as Olive gardens) rather than for vegetables, vines or ornamental plants (Petousi et al., 2015). As indicated above the use of recycled water could improve the reliability of services and people would be willing to pay more to ensure it. For example, in Spain, farmers were willing to pay twice as much as their current irrigation water price to ensure water supply reliability through government supply guaranteed programs (Alcon et al., 2014).

Birol and Das (2010) used choice experiments to estimate residents' willingness to pay for improved capacity and technology at a sewage treatment plant in Chandenagore municipality, India. The results show that residents would be willing to pay Rs100.32 per year in addition to municipal taxes for an improved wastewater treatment plant. In another study in Hyderabad, India, Saldías et al. (2017) found farmers were willing to pay 18.8 USD/ha/year to obtain a water treatment option. Further, they were willing to pay 14.7 USD/ha/year to reduce health risk from 'tolerable health risks' to 'reduced health risks'. However, differences in socio-economic condition should be taken into consideration while evaluating their willingness to pay for different recycled water use (Woldemariam et al., 2016).

Shadow price evaluation method

By using the concept of distance function, the shadow price of environmental goods and services can be calculated. A shadow price is the maximum price that people are willing to pay for an extra unit of a given, limited resources, and this value can also be used in benefit or cost evaluations. More generally, the distance function was developed to evaluate the "difference between the outputs produced in the process under study and the outputs of the more efficient process" (Molinos-Senante et al., 2010).

Hernández-Sancho et al. (2010) estimated the avoided environmental costs from the removal of pollutants from wastewater treatment using the shadow price method. The study includes 43 wastewater treatment plants located in the Spanish region of Valencia. The results showed that the removal of nitrogen and phosphorus through the wastewater treatment process provided the majority of the environmental benefits, and was the function that had the highest shadow prices. This study also found that in terms of nutrient emissions, treating wastewater in wetland areas was far better than discharging wastewater into the sea.

Molinos-Senante et al. (2010) and Molinos-Senante et al. (2011) conducted similar research to Hernández-Sancho et al. (2010) and used the shadow price method to estimate the environmental benefits of improved wastewater treatment based on the distance function of the treatment outputs in the region of Valencia, Spain. The authors concluded that the net profits for wastewater treatment plants were positive, hence the proposed wastewater treatment plants should be considered as economically viable.

Cost-benefit studies

When the costs and benefits have both been estimated, cost-benefit analysis can be used to compare different scenarios. Ko et al. (2004) used cost-benefit analysis to compare the efficiency of using a forested wetland and conventional sand treatment for wastewater. Although both a monetary based approach and an energy based approach are used, the study did not consider the social and environmental costs and benefits.

Godfrey et al. (2009) conducted cost-benefit analysis for grey water reuse systems in residential schools in Madhya Pradesh, India. In this case study, the environmental benefits and social benefits are considered as external benefits. The external benefits were mainly analysed in terms of avoided cost and were mostly based on values from available literature. The results show that the total benefit of grey water reuse is significantly higher than the total cost.

Verlicchi et al. (2012) estimated the costs and benefits for a proposed wastewater reuse project at the Ferrara wastewater treatment plant in the Po Valley, Italy, as a case study. Only financial costs are involved in this study, but the social and environmental benefits are considered and analysed using contingent valuation method. Results show that the proposed projects are financially feasible, as indicated by various economic indicators such as cost-benefit ratio and net present value.

Conclusions

Adopting water sensitive systems and practices has the potential to provide significant benefits in terms of improving liveability, providing amenity benefits, improving water quality, tackling climate change, reducing flood risk, protecting groundwater, securing water supply and supporting the environment and ecosystems. The economic value of these benefits are often captured through various non-market valuation methods.

Our review provides an overview of the available information on monetized values of these services. The information could be used to get an understanding of the extent of benefits. However, to use them for any particular context and locations these estimates need to be properly adjusted using appropriate benefit transfer techniques. Estimation methods, uncertainty in estimated values and scope of evaluation would need to be properly considered during adjustment.

We found that attempts to evaluate the total benefits of a water-related project are rare. Most of the studies that claim to evaluate total benefits have not, in fact, considered benefits in a comprehensive fashion. Some of the studies claiming to consider total benefits ignored social, environmental, and ecological values, and considered the direct use values of water only.

Finally, even though there is widespread recognition of multi-functional benefits of water sensitive systems and practices, there is a lack of examples where non-market values have been successfully integrated in economic analysis of water sensitive projects. Therefore, proper policies and guidelines are needed to encourage regulators and utilities to make decisions that consider the full range of social and economic costs and benefits.

Table 11: Urban green space valuation studies

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Economic measures	Adjusted WTP value (value in $US2016)
Amenity and recreational values: hedonic studies						
Anderson and West (2006)	HD	St. Paul metropolitan area, US	24,862 property sales (1997)	Halving the distance to nearest special park	Increases the sales price of an average home by $142 per year	$212.34
Brander and Koetse (2011)	Meta-analysis of CV studies	Several countries including US, UK. Canada, Australia, China and Finland	38 contingent valuation studies on urban and peri-urban open space (2003)	WTP per ha of green space per year in 2003	Mean value of $1,500 per ha per year	$1,956.58
Brander and Koetse (2011)	Meta-analysis of Hedonic studies	US	12 hedonic pricing studies (in 2003)	10m decrease in distance to open space	0.1% increase in house price	
Cho et al. (2008)	HD	City of Knoxville, Tennessee, US	9571 house sales (2000)	At initial distance of 1 km, moving 100 m closer to an evergreen forest	Increases the average house price by $692 in 2000 (evaluated at the mean house price of $117,787)	$964.49
				Moving 100m closer to a deciduous forest patch	Decreases the average house price by $589 in 2000	$820.93
				An additional patch per hectare of forest in a neighbourhood	Decreases the price of a house by $62	$86.41
				An additional meter of edge per hectare of forest	Increases the housing price by $35	$48.78
				An additional ha in average forest patch size in the neighbourhood	Decreases the housing price by $1,178	$1,641.86
Donovan and Butry (2010)	HD	Portland, Oregon	2608 houses (in 2007)	On average, street trees	Add $8,870 to sales price	$10,269.47
Donovan and Butry (2011)	HD	Portland, Oregon	985 rental prices (2009-2010)	An additional tree on a house's lot	Increased monthly rent by $5.62	$6.19
				A tree in the public right of way	Increased rent by $21.00	$23.11
Jim and Chen (2006a)	HD	Guangzhou, China	652 dwelling units (2003–2004)	View of green spaces	Increased house price by 7.1%	
				Proximity to water bodies	Increased house price by 13.2%	
Jim and Chen (2009)	HD	Two major types of natural landscape in Hong Kong: harbor and mountain	1474 transactions in 2005 and 2006	A broad harbor view	Increased the value of an apartment by 2.97%, equivalent to $15,173	$18,063.62
				A confined harbor view	Increased price by 2.18% or $11,137	$13,258.72
				A broad mountain view	Decreased apartment price by 6.7%	

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Economic measures	Adjusted WTP value (value in $US2016)
Jim and Chen (2010)	HD	High-rise private residential units in Hong Kong.	1471 transactions in 2005 and 2006	Neighbourhood parks	Lift price by 16.88%, including 14.93% for availability and 1.95% for view	
Jun and Kim (2017)	HD	Seoul, Korea	3262 transactions with in 5km of the greenbelt (2010)	One unit (1km) decrease in the distance to the nearest greenbelt	Decreases the apartment rents by 3.83-3.95%: $34 drop in monthly rent	$37.42
Luttik (2000)	HD	8 Towns in Netherlands	3000 houses 1989-1992	In Apeldoorn, Walking distance to a park (400m) View of the park In Leiden Walking distance to a park (400m) View of open space Within 3-5km of attractive landscape	A premium of 6 % of the house price A premium of 8 % of the house price A premium of 9 % of the house price A premium of 7 % of the house price	
Mahmoudi et al. (2013)	HD	Adelaide metropolitan area	40923 properties (2005-2008)	1m closer to golf course 1m closer to greenspace sport facilities 1m closer to the coast	Property price increases by $0.54 Property price increases by $1.58 Property price increases by $4.99	$0.60 $1.76 $5.56
Morancho (2003)	HD	City of Castellón , France	810 houses (2001)	Every 100m further away from a green area	A drop of €1800 in housing price	$2,065.51
Mansfield et al. (2005)	HD	Research Triangle region of North Carolina	11206 observations (1996 and 1998)	Adjacency to a private forest block	Increased house price by more than $8,000	$11,779.48
Netusil et al. (2014)	HD	Portland, Oregon	29,644 transactions (2005-2007)	Each additional dam An increase in distance of 1 foot away from the nearest green street facility A 10 percentage point increase in tree canopy at the closest green street facility	Increased a property's sale price by 0.60% Increases a property's sale price by $0.30 of which $0.20 is a direct effect and $0.10 is an indirect effect Increases a property's sale price by $18,707 of which $12,590 is a direct effect and $6,117 is an indirect effect	 $0.35 - $0.23 - $0.12 $21,658.52 - $14,576.40 – $7,012.82
Nicholls and Crompton (2005)	HD	Barton Creek, Austin, Texas Travis	224 properties 236 properties (1999-2001)	Directly adjacent to the Barton greenbelt Directly adjacent to the greenbelt	$44,332 increase in property value representing 12.2% average value of adjacent homes $14,777 increase in property value representing 5.7% average value of adjacent homes in Travis	$60,079 $20,025.88
Poudyal et al. (2009a)	HD	City of Roanoke, Virginia.	11,125 houses (1997-2006)	10 % increase in square footage of the urban park in the neighbourhood	Increased the real sales price of the house by 0.03%	

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Economic measures	Adjusted WTP value (value in $US2016)
				100ft increase in the size of the park	$0.79 increase in price of nearby houses	$0.88
Poudyal et al. (2009b)	HD	City of Roanoke, Virginia.	A total of 11,125 single-family houses were sold (1997-2006)	Having a variety of open spaces in the neighbourhood	Increased house prices	
Plant et al. (2017)	HD	52 Brisbane residential suburbs	2774 houses (in 2010)	Marginal implicit price for a 1% increase in footpath tree cover within 100 m	$Us 312–393 (median house value is 530000) representing 0.082-0.103 % premium of property price	$343.41 - $432.56
Pandit et al. (2014)	HD	central part of the Perth metropolitan area in WA	5606 houses (2009)	10 per cent increase in tree canopy cover on the adjacent public space	Property price premium of about au$ 14,500	$13,188.17
Pandit et al. (2013)	HD	23 northern suburbs of the Perth metropolitan region in WA	2149 properties (2006)	A broad leaved tree on street verge (public place) in2006 1 m distance to a larger park(bushwalking) 1m distance to a sports reserve	Increases median property price of a house by au$ 16,889 (4.27 %). (median house price is 395,000) Reduces the property value by $ 9.60 (median house price is 395,000) Decreases the property value by $29.59	$15,186.21 $8.63 $26.61
Rossetti (2013)	HD	Australia	2,531,803 observations of property transactions (2000-2010)	For every house in a postcode that gains green infrastructure equivalent to 1 standard deviation change in enhanced vegetation index	$32,000 - $58,000 per property	$34,195.47 – $61,979.30
Sander et al. (2010)	HD	Ramsey and Dakota Counties, east central Minnesota, USA	9992 property sales (2005)	A 10% increase in tree cover within 100m) A 10% increase in tree cover within 250m)	Increases average home sale price by $1,371 (0.48%) Increases sale price by $836 (0.29%)	$1,684.84 $1,027.37
Sander and Haight (2012)	HD	Dakota County, Minnesota, USA	5094 single-family residential properties (2005)	Marginal implicit price of a 100m decrease in distance to a park (evaluated at the mean home sale price of $319,073) from an initial distance of 1-km A 1-ha increase in the area of lawn from the mean value (2584-m2) in a home's view shed 10-% increase in tree cover within each of these four neighbourhoods from their mean values (evaluated at the mean home sale price)	$13.16 (0.040%) Corresponded to a sale price increase of $1,742 (0.55%) Increased house price by $1,853 (0.581%), $1,030 (0.323%), $1,947 (0.610%), and $1,102 (0.345%), respectively	$16.17 $2,140.77 $2,277.18, $1,265.78, $2,392.70, $1,354.26

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Economic measures	Adjusted WTP value (value in $US2016)
Saphores and Li (2012)	HD	city of Los Angeles, CA	20,660 transactions (2003-2004)	Median benefit of adding one generic tree with a 16 m^2 canopy cover	Would increase its value by $204	$259.19
Votsis (2017)	HD	Helsinki, Finland	44.300 transactions (2000-2011)	On a multiyear average, a 100m increase of distance to a forest	Decreases 3.7% of price/m^2 at 0 km from the CBD, which gradually drops to zero at 6 km from the CBD	
Xiao et al. (2016)	HD	Shangha, China	4188 housing transactions (2007-2009)	For each additional unit of the community green space ratio One unit of additional public green space For every km nearer to a city park For every km away from public green space	Adds 8.7% to the property sale price Has zero value for home buyers. A premium of 2.6% Home buyers pay extra 4.5% of house price	
Amenity and recreational values: life satisfaction approach						
Ambrey and Fleming (2014)	LS (Life satisfacton approach)	Australian capital cities (Adelaide, Brisbane, Canberra, Darwin, Hobart, Melbourne, Perth and Sydney)	Household Income and Labour Dynamics in Australia (HILDA) survey. (2005)	Average implicit willingness to pay for a 1 per cent increase in public greenspace A one standard deviation (12.49%) increase in public green space	$1,172 per household per year Approximately $12,800 per year	$940.14 $10,267.69
Amenity and recreational values: contingent valuation(cv) and choice experiments						
Andrews et al. (2017)	CV	Norwich, UK	386 completed surveys (2009)	Willingness to pay to have a park in the City Centre Have a Suburban park	£23.14 per household £19.11 per household	$42.79 $35.34
Bernath and Roschewitz (2008)	CV	Zurich city forests	1500 residents of Zurich (2004)	Visitors' willingness to pay for an annual forest visitor permit (initial bid) visitors' willingness to pay for an annual forest visitor permit (revised bid)	$64 $91	$81.32 $115.62
Brander and Koetse (2011)	Meta analysis of CV	Several countries	20 studies with 73 observations (2003)	Mean WTP Median WTP value	$13,210 per hectare per annum $1,124	$17,230.94 $1,466.13
Chen and Jim (2008)	CV	Zhuhai city in south China	598 respondents (2006)	Mean WTP Aggregate leisure value	RMB161.84 per household per year RMB12.3 million per year	$24.02 $1.82 million
Damigos and Kaliampakos (2003)	CV	Galatsi Municipality in the center of Athens, Greece	200 households 1998 and 1999	Reforestation Backfilling and reforestation Partial backfilling, reforestation and new land uses	€30.75 (parametric mean €29.44) €49.47 (parametric mean €45.88) €58.20 (parametric mean €56.44)	$38.78 ($37.13) $62.39 ($57.86) $73.40 ($71.18)

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Economic measures	Adjusted WTP value (value in $US2016)
del Saz Salazar and Menendez (2007)	CV	Valencia (Spain)	900 randomly chosen inhabitants (2001)	Mean WTP for affected (long-term residents) Mean WTP for the less affected (short-term residents)	14,497 pesetas/person (parametric) 11,238 pesetas (non parametric) 8,571 pesetas /per person(parametric) 7,830 pesetas (non parametric)	$79.27 $77.48 $59.09 $53.98
del Saz-Salazar and Rausell-Köster (2008)	CV	City of Valencia (Spain)	1480 face-to-face interviews (2005)	Mean WTP	€7.60	$7.57
Dumenu (2013)	CV	Ghana	A total of 200 respondents	Overall mean WTP for preservation of urban forest	$22.55 per year	$23.57
Jim and Chen (2006c)	CV	Guangzhou, China	340 respondents (2003)	WTP for recreation	$2.1/ person/month	$2.74
Latinopoulos et al. (2016)	CV	Thessaloniki, Greece	600 inhabitants 2013	Mean WTP	Around €4.0 to € 4.5 as a bi-monthly “green tax” to the municipal authority	$5.35 - $6.02
Lo and Jim (2010)	CV	City of Hong Kong	A total of 495 urban residents from different neighbourhoods (2008)	WTP to recover a possible loss of urban green spaces area by 20%	Monthly average payment of HK$77.43 (approx. $9.9) per household for five years	$11.04
Mell et al. (2013)	CV	Manchester, UK	512 respondents (2011)	WTP by residents for investment in green infrastructure Commuters and employees	£1.88 more per month £1.60–1.65	$3.24 $2.75 - $2.84
Pepper et al. (2005)	CV	Perth, Western Australia	1000 questionnaires (54% responded (2001)	Mean WTP for the preservation of the bushland (Hartfield Park bushland)	AUD21.60 per person per annum	$14.79
Tu et al. (2016)	CE	Nancy	180 respondents (2013)	Home owners who do not have a private garden Homeowners who have a private garden Tenants who do not have a private garden Average respondents	MWTP was 2.7% of their current house’s price (€ 34.84/m^2) MWTP was 1.2% of their current house’s price (€ 16.42/m^2) on average WTP was 1.4% of their actual rent (€ 0.12/month/m^2) Willing to pay 9.9% more to have a scenic view of green spaces outside their window	$46.62 $21.97 $0.16
Vesely (2007)	CV and CE	15 cities in Aotearoa New Zealand	344 respondents (2003)	On average, households would be WTP for the avoidance of a 20% reduction in their local urban tree estate,	NZD 184 annually covering a period of 3 years	$138.57
Air pollution removal by green space and health benefits						
Jim and Chen (2008)	Previous study estimates	Urban trees in Guangzhou (China)	Different land uses were acquired from	An annual removal of SO_2, NO_2 and total suspended particulates Benefits gained due to removal of air pollutants	About 312.03 mg RMB90.19 thousand ($1.00 = RMB8.26)	 $1038 thousand

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Economic measures	Adjusted WTP value (value in $US2016)
			different monitoring systems (2000)			
Nowak et al. (2006)	Estimates from previous studies	United States	pollution concentration data from across the conterminous US (1994)	Totoasl annual air Pollution removal (O_3, PM_{10}, NO_2, SO_2, CO) estimated	711,000 metric tons ($3.8 billion value)	$6.15 billion
Nowak et al. (2013)	Environmental Benefits Mapping and Analysis Program (BenMAP) model	10 U.S. cities	Field data on trees were measured within randomly selected 0.04 ha plots and analyzed using the i-Tree Eco model (2010)	The total amount of $PM_{2.5}$ removed annually by trees Mortality reductions were typically around The net removal amounts per square meter of canopy cover The average health benefits value per hectare of tree cover The value per tonne of $PM_{2.5}$ averaged The health benefits value per reduction of 1µg/m^3	Varied from 4.7 tonnes in syracuse to 64.5 tonnes in atlanta, with annual values varying from $1.1 million in syracuse to $60.1 million in new york city 1 person/ yr per city, but were as High as 7.6 people/ yr in new york city Varied from 0.13 g m^2/ yr in los angeles to 0.36 g m^2/ yr in Atlanta About $1,600, but varied from $500 in Atlanta and Minneapolis to $3,800 in New York $682,000, but varied from $142,000 in atlanta to $1,610,000 in New York Aaried from $122 million in syracuse to $6.2 billion in New York, with an overall average of $1.6 billion	$1.21 million $1,761.07 ($550.33 – $4,182.53) $751 thousand ($156 – $1,772 thousand) 134 million – 6.82 billion (1.76 billion)
Nowak et al. (2014)	U.S. EPA's BenMAP program	United States	Computer simulations with local environmental data (2010)	Trees and forests in the conterminous United States Human health effects valued due to pollution reduction	Removed 17.4 million tonnes (t) of air pollution 6.8 billion U.S. Dollars	 $7.48 billion
Tallis et al. (2011)	Urban Forest Effects Model (UFORE)	The Greater London Authority (GLA), UK	Tree survey data and annual maps of PM10 distribution and observed/ predicted meteorological conditions (2006)	Annual PM_{10} removal	852 - 2121 tonnes (0.7% and 1.4% of PM_{10} from the Urban boundary layer)	
Yang et al. (2008)	Dry deposition model	Chicago US	Chicago's Department of Environment for a list of green roofs resulting in a list of	Total air pollutants removed by 19.8 ha of green roofs in one year The annual removal air pollutants per hectare of green roof	1,675 kg (O_3 accounting for 52% of the total and NO_2 (27%), 85kg	

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Economic measures	Adjusted WTP value (value in $US2016)
			170 green roofs. (2006)			
Yang et al. (2005)	Urban Forest Effect model	Beijing, China	A field survey was conducted in June 2002.	Air pollution removal by trees in the central part of Beijing The carbon dioxide (CO_2) stored in biomass form by the urban forest	1261.4 tons of pollutants in 2002 About 0.2 million tons	
Energy savings						
Pandit and Laband (2010a)	a statistical model	Auburn, Alabama	160 residences. monthly electricity usage data / household from August 2007–August 2008.	Having dense shade at the sample mean (an average during the day of 19.30% of the residential structure)	Would save a home owner $21.22/month (9.3%) in electricity costs during the summer months, as compared to a home owner with no shade falling on the residence.	$23.65
Donovan and Butry (2009)	Regression analysis	Sacramento, California	460 single-family homes	The current level of tree cover on the west and south sides of houses in our sample reduced summertime electricity use by 185 kWh (5.2%)	A london plane tree, planted on the west side of a house, can reduce carbon emissions from summertime electricity use by an average of 31% over 100 years	
McPherson and Simpson (2003)	Estimates of previous studies and computer simulation	California	Data from aerial photography were previously collect-ed for 21 California cities	Existing trees are projected to reduce annual air conditioning energy use Peak load reduction by existing trees The present wholesale value of annual cooling reductions for the 15-year period.	By 2.5% with a wholesale value of $ 485.8 million Saves utilities 10% valued at approximately $778.5 million annually, or $4.39/tree $3.6 billion ($71/tree planted)	$677 million $1085 million ($6.12/tree) $5.01 billion ($98.96/tree)
Mental and physical health benefits*						
Alcock et al. (2014)	Regression analysis with panel data	Estimation samples were limited to English residents, and BHPS respondents from Wales, Scotland, and Northern Ireland were excluded	British Household Panel Survey with mental health data (1991 to 2008)	Individuals who moved to greener areas (n = 594) had significantly better mental health in all three post move years.	Individuals who moved to less green areas (n = 470) showed significantly worse mental health in the year preceding the move (P = .031) Moving to greener urban areas was associated with sustained mental health improvements	
Beyer et al. (2014)	Multivariate survey regression	Wisconsin	data from the Survey of the Health of Wisconsin	Higher levels of neighbourhood green space were associated with significantly lower		

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Economic measures	Adjusted WTP value (value in $US2016)
	analyses e		(SHOW) database. (2008–2009, 2010 and 2011) (2,479 individuals nested in 229 Wisconsin Census Block Groups)	levels of symptomology for depression		
Coombes et al. (2010)	logistic regression	City of Bristol, England	Data from the 2005 Bristol Quality of Life in your Neighbourhood survey (6821 adults were combined with a comprehensive GIS database on green space)	The reported frequency of green space use declined with increasing distance	Respondents living closest to the type of green space classified as a formal park were more likely to achieve the physical activity recommendation and less likely to be overweight or obese	
Donovan et al. (2011)	binary logistic regression	Portland, Oregon	5696 residents (Birth certificates and tax records)	10% increase in tree-canopy cover within 50m of a house	Reduced the number of small for gestational age births by 1.42 per 1000 births (95% CI—0.11–2.72)	
Francis et al. (2012)	Logistic regression analysis	Perth, Western Australia	from a cross-sectional survey - Perth residents in 2003 and December 2005	Residents of neighbourhoods with high quality public open space	Had higher odds of low psychosocial distress than residents of neighbourhoods with low quality public open space Public open space quality within a neighbourhood appears to be More important than public open space quantity	
Sugiyama et al. (2008)	Stepwise logistic regression analyses	Adelaide, Australia:	Data from a mailed survey of adults (n = 1895) during 2003–2004	Those who perceived their neighbourhood as highly green	Had 1.37 and 1.60 times higher odds of better physical and mental health, respectively, compared with those Who perceived the lowest greenness	
Zhang et al. (2015b)	Structural Equation Modelling	A medium-sized Dutch city in the Netherlands.	Mailed surveys in two neighbourhoods (n = 223)	Greater attachment to local green space and better self-reported mental health in the neighbourhood	Green space attachment is linked to mental health	
Gidlöf-Gunnarsson and Öhrströ	MANOVA analysis	Residential areas in Stockholm and	500 residents in urban setting	Better availability to nearby green areas	Reduced long-term noise annoyances and prevalence of stress-related psychosocial symptoms	

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Economic measures	Adjusted WTP value (value in $US2016)
m (2007)		Goteborg, Sweden				

* These studies used non-economic measures of benefits

Table 12: Climate change mitigation

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Non-economic measures of benefits	Economic measures of benefits	Adjusted WTP value (value in $US2016)
Akbari (2002)	Estimate from previous studies	Los Angeles Baton Rouge, Sacramento, and Salt Lake City,		A tree planted in Los Angeles Planting an average of four shade trees per house (each with a top view cross section of 50 m^2)	Avoids the combustion of 18 kg of carbon annually, even though it sequesters only 4.5–11 kg Would lead to an annual reduction in carbon emissions from power plants of 16,000, 41,000, and 9000 t, respectively (the per-tree reduction in carbon emissions is about 10–11 kg per year) Urban tree planting can account for a 25% reduction in net cooling and heating energy usage in urban landscapes		
Brack (2002)	The statistical models	Canberra urban forest	400.000 trees in Canberra (2008-2012)			The planted trees are estimated to have a combined energy reduction, pollution mitigation and carbon sequestration value of us$20–67 million during the period 2008–2012	$21 – $70 million
Davies et al. (2011)	Statistical tests	Leicester(misizedBritish city)	Vegetation survey	Total Carbon storage	231,521 tonnes (95% ci = 195,914–267,130) of carbon is stored within the above-ground vegetation across the city (equating to a mean figure of 3.16 kg C m^{-2} of urban area)		
Derkzen et al. (2017)	Multidimensional CV	Rotterdam, the Netherlands	(in 2014)	About two thirds of respondents were willing to pay for green infrastructure measures as a tax.		WTP $15 per household per year	$15.21
de Koning et al. (2017)	Agent based modelling	Greenville,NC, , US	Property market data (9793 records between 1992 and 2002) and income and housing budget data	The bias in marginal implicit price of flood risk ranges between 4.2% and 9.7%.		Clear differences in the marginal implicit price of flood risk among different behavioural risk perception models	
Escobedo et al. (2010)	Urban Forest Effects (UFORE)	Subtropical forests Miami-Dade and Gainesville,USA	Field data (2005-2008)	Emission reduction in Miami-Dade- 3.6 (tonnes/ha/yr) Gainesville 5.8 (tonnes/ha/yr)	Urban tree sequestration offsets CO_2 emissions and, relative to total city-wide emissions, is moderately effective at 3.4% and 1.8% in Gainesville and Miami-Dade, respectively		

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Non-economic measures of benefits	Economic measures of benefits	Adjusted WTP value (value in $US2016)
	model						
Hungate et al. (2017)	Experiments	North American grassland	Plant, soil, and ecosystem carbon storage data from two grassland biodiversity experiments		Increasing species richness from 1 to 10 had twice the economic value of increasing species richness from 1 to 2. The marginal value of each additional species declined as species accumulated, reflecting the nonlinear relationship between species richness and plant biomass production		
Kim et al. (2016)	CE	Summer Season in Korea	448 people from metropolitan regions of Seoul, Busan, Incheon, Kwangju, Daejeon, Ulsan, and Daegu Sept. 2010	marginal willingness to pay		$56.68–76.59 for every increase of the urban forest by 1m^2	$62.39 – $84.20
Kim et al. (2017)	HD	Woomyeon Nature Park (WNP) in Seoul, Korea which experienced a catastrophic landslide disaster in 2011	sales data of the Ministry of Land, Infrastructure, and Transport (MLIT), Korea from 2008 to 2014	Housing market premiums		Have fallen by up to 11.3% since the event due to the risk of landslide	
Lafortezza et al. (2009)	ANOVA	green spaces in Italy and the UK	800 respondents	Longer and frequent visits of green spaces	Generate significant improvements of the perceived benefits and well-being among users during the periods of heat stress		

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Non-economic measures of benefits	Economic measures of benefits	Adjusted WTP value (value in $US2016)
Liu and Li (2012)	Biomass equations, images	Shenyang, a heavily industrialized city in north-Eastern China	Field survey data and urban forests data derived from high-resolution QuickBird (2006)	Urban forests in areas within the third-ring road of Shenyang stored C sequestration rate		337,000 t c (RMB92.02 million, or $13.88 million) 29,000 t/yr (RMB7.88 million, or $ 1.19 million). The C stored by urban forests equalled to 3.02% of the annual c emissions from fossil fuel combustion and c sequestration could offset 0.26% of the annual c emissions in Shenyang	$16.52 million $1.41 million
Nowak et al. (2017)	Five types of analyses	United States	Field data on urban trees , urban/community tree and land cover maps (2006-2010)	Trees and forests in urban/community areas in the conterminous United States, Reduce energy use for heating Avoid thousands of tonnes of emissions of several pollutants Average reduction in national residential energy use due to trees The greatest avoided emissions nationally due to energy conservation came from The greatest associated savings from avoided emissions The overall value for avoided emissions nationally was		Annually reduce electricity use by 38.8 million MWH ($4.7 billion) By 246 million MMBTUS ($3.1 billion) Valued at $3.9 billion per year 7.2 percent CO_2 (43.8 million tonnes), followed by so2 (113,000 t) and Nox (39,000 t) CO_2 ($1.8 billion), followed by SO_2 ($1.0 billion) and pm2.5 ($638 million) $3.9 billion per year	$5.17 billion $ 3.41 billion 4.29 billion 1.98 billion - $1.10 billion – $702 million $4.29 billion
Nowak and Crane (2002)	Urban Forest Effects (UFORE	USA	Field data from 10 USA cities and national urban	Urban trees in the coterminous USA	The national average urban forest carbon storage density is 25.1 t c/ha, compared with 53.5 t c/ha in forest stands.	Currently store 700 million tonnes of carbon ($14,300 million value) with a gross carbon sequestration rate of 22.8 million t c/yr ($460 million / year)	$20,600 million ($921 million)

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Non-economic measures of benefits	Economic measures of benefits	Adjusted WTP value (value in $US2016)
	) model		tree cover data 1996 and 1999				
Roldán et al. (2015)	Autoregressive integrated moving average model	Zaragoza, Spain	Mortality data (Public Health Directorate of the Gov-ernment of Aragón; and, temperature data (Foundation for Climate Research and the State Meteorological Agency.) 2002–2006	Mortality showed a statistically significant increase when the daily maximum temperature exceeded 38 °C. A Relative Risk was 1.28 with a 95% confidence interval (95 %CI:1.08–1.57)		Heat-attributable deaths were estimated for the period 2002–2006, and the in-hospital estimated cost of these deaths reach € 426,087 (95 % CI €167,249–€688,907)	$652,006 ($255,927 - $1,054,179)
Susca et al. (2011)		New York City;	Survey: 2008 - 2009	Monitoring the urban heat island	Found an average of 2^{0}c,difference of temperatures between the most and the least vegetated areas, ascribable to the substitution Of vegetation with man-made building materials		
Soares et al. (2011)	The computer tool i-Tree STRATUM	Lisbon, Portugal	An inventory of all 33,232 trees was completed in 2003 under supervision of the Gardens Department of the Municipality of Lisbon	For every $1 invested in tree management, the value of		$4.48 in benefits	$5.84
				Energy savings		$6.20/tree	$8.09
				CO_2 reduction		$0.33/tree	$0.43
				Air pollutant deposition		$5.40/tree	$7.04
				Stormwater runoff reduction		$47.80/tree	$62.35
				Increased real estate value		$144.70/tree	$188.74

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Non-economic measures of benefits	Economic measures of benefits	Adjusted WTP value (value in $US2016)
Strohbach and Haase (2012)	Sampling and the allometric equations, using a bootstrap method	Leipzig, Germany	Stratified random sampling across 19 land cover classes (2009)	Canopy cover was approximately 19% of the city area Leipzig's above-ground carbon storage	316,000 mg C (at 11 mg C /ha)		
Tran et al. (2017)	Contingent valuation method (CVM)	Atlanta, Georgia, USA	Mail-based survey was developed and administered using Dillman's Tailored Design Method (2013)	Households are willing to pay		$1.05 - $1.22 million per year, or $5.24 - $6.11million over a five-year period	$1.08 – $1.25 million ($5.40 – $6.29 million)
Wong and Yu (2005)		Green areas at macro-level in Singapore	Island – wide temperature maps developed form the data derived from a mobile survey	A strong correlation between the decrease of temperature and the appearance of large green areas in the city.	The maximum difference of 4.01c was observed between well planted area and the CBD area		
Yu and Hien (2006)	Two simulation programmes using TAS and Envi-met	Natural reserve—Bukit Batok Nature Park (BBNP) (36 ha) and the other is a neighbourhood park in Singapore	Field measurements and localized weather data (11 January to 5 February 2003 and 16 June to 1 July 2003)	Maximally, 1.3 8C difference of average temperature was observed at locations around the parks. The temperature difference was caused by green areas and it may lead to savings of cooling energy and thermal comfort for residents.	The cooling impacts of the parks are reflected through not only the lower temperatures in the parks but also the lower Temperatures in the nearby built environment		
Žuvela-Aloise et al.	Real case simu	Vienna	Combined dataset of 32	With the application of several heat load mitigation	The modelling results show that equal heat load mitigation measures may have different efficiency dependent on		

Author	Method	Location	No. of records (respondents)	Definition of marginal change	Non-economic measures of benefits	Economic measures of benefits	Adjusted WTP value (value in $US2016)
(2016)	lations		different land use types and meteorological data	measures such as decrease in building density by 10%and pavement by 20 %, enlargement in green and water spaces by 20%, it is possible to achieve substantial cooling effect with heat load reduction of −10 SU or more with a relatively small change in infrastructure	location in the city due to the prevailing meteorological conditions and land use characteristics in the neighbouring environment		

Table 13: Water supply valuation surveys

Author	Method	Location	No. of completed surveys	Object	Mean WTP estimates (per household)*	Adjusted WTP value (value in $US2016)
Whittington et al. (1990)	CV	Laurent, Southern Haiti	170	Estimate the WTP for improved water services (private connection)	6.7-7.5 gourdes per household per month for private connections (accounted for 2.1% of household income)	$2.40-$2.72
Briscoe et al. (1990)	CV	Brazil	400	Estimate the WTP for water services (yard tap)	100 cruzados as the average stated maximum WTP for a yard tap (2.5 times the monthly tariff at the time of survey and accounted for 2.3% of average family income)	$2.93
Howe et al. (1994)	CV	Colorado, USA	588	Estimate the WTP for improved water service (supply reliability)	Additional $4.67-$7.97 per month per household	$7.94-$13.49
Rollins et al. (1997)	CV	Canada	1,511	Estimate the WTP for a water conservation program, which can ensure adequate water service	Additional $26.00 per month on current water service charge	$41.40
Blamey et al. (1999)	CE	Canberra, Australia	294	Estimate the WTP for possible water supply options (recycled water for outside use or drinking)	A$47 annual WTP for the provision of recycled water for outdoor use	$46.20
Koss and Khawaja (2001)	CV	California, USA	3,769	Estimate the WTP for improved water supply reliability (decreased water supply shortage)	$11.61 per month to avoid a 10% shortage once every 10 years; $16.92 per month to avoid a 50% water shortage occurring every 20 years	$18.61
Whittington (2002)	CV	Kathmandu, Nepal	1,500	Estimate households' demand for improved water services provided by a private operator (more water supply and higher water quality)	$14.31 per month for 500 litres improved water supply for households who have private connection; $11.67 per month and $3.19 per month for private and shared water connection	$4.60-$20.80
MacDonald et al. (2005)	CE	Adelaide, Australia	337	Estimate the WTP for improved continuity of water supply	A$1.10 to A$4.40 per year for decreased duration of water service interruptions; A$6.00 to A$15.40 per year for decreased frequency of interruptions in water services	$1.05-$14.84
Hensher et al. (2005)	CE	Canberra, Australia	211	Estimate the WTP for reduced interruptions of water supply and reduced number of wastewater overflows	Monthly interruptions A$9.58; two interruptions per year A$41.51; A$116 to reduce number of wastewater overflow to one time per year;	$9.20-$114.64
Nam and Son (2005)	CV and CE	Ho Chi Minh City, Vietnam	120	Estimate the WTP for improved water quality and stronger pressure	108,000 VND per month from a piped water household for the proposed improved water service; 33,000 VND per month from non-piped households for a change to a medium water quality;	$2.20-$8.57

Author	Method	Location	No. of completed surveys	Object	Mean WTP estimates (per household)*	Adjusted WTP value (value in $US2016)
					48,000 VND per month from non-piped households for strong water pressure	
Willis et al. (2005)	CE	Yorkshire, England	1,000	Estimate the benefits to water company customers of changes across various water service factors	£0.03 for each reduction in the number of water samples that failed purity tests; £0.32 for each percentage increase in the security of supply; £0.78 per year for every 1,000 fewer cases of water discoloration; £2.27 per year for every 1,000 fewer supply interruptions	$0.1-$5.23
Fujita et al. (2005)	CV	Iquitos city, Peru	1,000	Estimate the WTP for water services and improved sanitation services	24.18 sol per month for water services by household who currently do not receive water service; 8.81 sol per month for households with water service for improved water availability and water pressure	$3.35-$9.20
Casey et al. (2006)	CV	Brazil	1,479	Estimate the WTP of citizens for universal access to water services in their homes	$5.61 per month (accounted for 2% of a household's annual income)	$6.79
Genius and Tsagarakis (2006)	CV	City of Heraklion, Greece	294	Estimate the WTP of residents in urban areas to ensure a fully reliable water supply	€13.8 in addition to 3 month water bills to ensure a continuous (24 hour) water supply and stable tap water quality	$14.95
Hensher et al. (2006)	CE	Canberra, Australia	416	Estimate households' and businesses' WTP to avoid drought water restrictions	A$11.95 per year to reduce frequency of restrictions from once every 10 years to once every 20 years; A$3.98 per year to reduce water restriction from once every 20 years to once every 30 years; A$1,104 (23% of current water bill) by business respondents to avoid severe restrictions	$3.66-$10.98 for household; $1,011.90 for business
Tapsuwan et al. (2007)	CE	Perth, Australia	414	Estimate households' WTP to avoid outdoor water restrictions	22% more on households' water usage bills to be able to use sprinklers up to 3 days a week; 50% more on water bills to finance a new source of supply instead of enduring severe water restrictions	N/A
Genius et al. (2008)	CV	Rethymno, Greece	306	Estimate residents' WTP to avoid water supply shortages and improved tap water quality	€10.64 for improved water quality and quantity (accounted for 17.67% of average water bills)	$15.13
Snowball et al. (2008)	CE	Eastern Cape, South Africa	71	Estimate WTP for improvement in water services (improved drinking water quality and reduced water supply interruptions)	15.72% in addition to water bills for a decrease in bacterial quality from slight risk to no risk; 0.12% and 0.13% increase in their water bills separately for every reduction of one household experiencing water discoloration or interrupted water supply	N/A
Vásquez et al. (2009)	CV	Parral, Mexico	398	Estimate households' WTP for safe	22.68 to 229.75 Mexican peso in addition to current water bills as the median household WTP to access for safe drinking water in the house	$2.40-$2.83

Author	Method	Location	No. of completed surveys	Object	Mean WTP estimates (per household)*	Adjusted WTP value (value in $US2016)
				and reliable drinking water		
MacDonald et al. (2010)	CE	Adelaide, Australia	337	Estimate WTP for improved reliability of household water services (reduced duration of water outage)	$0.15 to reduce the duration of an interruption by one hour; $4.05 to reduce the number of annual outages by one	$0.16-$4.08
Wang et al. (2010)	CV	Chongqing, China	1,478	Estimate WTP for water service improvement (improved reliability of water supply, water quality; water draining system and sewage water service)	2.5 to 3.3 yuan per ton on average for water usage per month (accounted for 1.5 to 2% of monthly income)	$0.41-$0.54
Polyzou et al. (2011)	CV	City of Mytilene, Greece	152	Estimate citizens' monetary valuation for the improvement of tap water quality	€10.38 every 2 months for the improvement of drinking water quality (€12.69 for citizens who always drink tap water and €9.43 for those who never drink tap water)	$13.69-$18.40
Cooper et al. (2011)	CV	New South Wales and Victoria, Australia	472	Estimate consumers' WTP to avoid urban water restrictions	$6-117 per year as the median WTP	$6.79-$132.76
Akram and Olmstead (2011)	CV	Lahore, Pakistan	193	Estimate the WTP for improved piped water quality and reduced supply interruptions.	$7.5 to $9 per month for piped water supply that is clean and drinkable directly from the tap separately (about 3 to 4 times the average monthly water bill); $3 to $6 per month for improved consistency of piped water supply (eliminating supply interruptions and pressure drops)	$3.24-$9.62
Tarfasa and Brouwer (2013)	CE	Ethiopia	170	Estimate households' WTP for improved water supply services (increased water supply days and improved water quality)	$0.6 for one extra day water supply without water quality improvement; $1.3 for one extra day water supply and with water quality improvement; $0.8 and $1.5 individually for 2 extra days water supply, without and with quality improvement; $1.1 and $1.8 separately for 3 extra days water supply, without and with water quality improvement	$0.63-$1.88
Awad (2012)	CV	West Bank	525	Estimate WTP for improved reliability of water supply	NIS 31.4 per month for reliable water supplies (including both improved quality and quantity)	$8.47
Behailu et al. (2012)	CV	Shebedino District, Southern Ethiopia	635	Estimate households' WTP for safe drinking water supply	3.65 Ethiopian Birr per month for safe drinking water supply (accounted for 2.36% of average monthly income)	$0.21

Note: CV refers to contingent valuation method; CE refers to choice experiments method; * unless otherwise indicated $ = $US

Table 14: Wastewater valuation surveys

Author	Method	Location	No. of completed surveys	Study	Mean WTP estimates (per household)*	Adjusted WTP value (value in $US2016)
Gillespie and Bennett (1999)	CV	Vaucluse, Sydney, Australia	306	Estimate environmental benefits from two sewage treatment proposals (a tunnel or a sewage treatment plant)	$137 as the median WTP for Vaucluse Area tunnel option; $76 as the median WTP for the sewage treatment plant option	$71.82-$129.62
Hoehn and Krieger (2000)	CV	Cairo, Egypt	903	Estimate benefits of water and wastewater service improvements	$7.77 per month for water connection project; $7.57 per month for wastewater connection project; $3.20 per month for improved reliability of the existing water services; $2.22 per month for wastewater network maintenance	$3.45-$12.13
Kontogianni et al. (2003)	CV	Thermaikos Bay, Greece	466	Examine residents' WTP to ensure the full operation of the wastewater treatment plant to improve water quality of Thermaikos Bay	€15.23 increase in the household four monthly water rates	$18.61
Genius et al. (2005)	CV	North-West Crete, Greece	326	Estimate WTP for wastewater treatment plant	€44 increase in quarterly water bills for wastewater treatment plant	$49.65
Tziakis et al. (2009)	CV	Municipality of Kissamos, northwest Crete, Greece	450	Estimate residents' WTP for a centralized wastewater treatment plant	€21.02 in addition to average quarterly water bills for wastewater treatment plant	$29.90
Birol and Das (2010)	CE	Chandernagore municipality, India	150	Estimate residents' WTP for improved capacity and technology of a sewage treatment plant	Rs100.32 per year in addition to municipal taxes to improved wastewater treatment plant quality	$2.40

Note: CV refers to contingent valuation method; CE refers to choice experiments method; * unless otherwise indicated $ = $US

Appendix: Non-market valuation methods

Over the past decade water utilities in Australia have made substantial investments in a range of different technologies to augment water supply to urban areas. These investments have included: dam expansion projects, such as the Hinze dam expansion plant in Queensland and the Cotter dam expansion in the ACT; construction of desalination plants, such as those built in Western Australia, Victoria, and New South Wales; water recycling projects, such as the western corridor recycled water projects in Queensland and the Alkimos wastewater treatment plant in Western Australia, and various small scale stormwater harvesting projects. In total, the capital investment in water augmentation projects over the period 2005/06 to 2011/12 by Australia's largest water utilities is thought to have been around $30 billion (Productivity Commission, 2011). The scale of infrastructure investment in the water sector is therefore substantial.

It is not necessarily the case that a water-conserving project will stack up economically. For example, in net present value terms, the most robust estimates available suggest that over a 20-year period the expected welfare loss to the Victorian community from the construction of a large desalination plant, relative to alternative lower-cost options of managing water supply, is between $2.7 and $3.7 billion (Productivity Commission, 2011). Water infrastructure projects should be evaluated against economic criteria and shown to be economically viable once all the social and environmental considerations have been considered. At the moment, this is not the case. Although the appropriate framework for project evaluation is understood, there are practical difficulties regarding the estimation of the social, economic, and environmental impacts of projects required for a complete economic evaluation.

In most applications the market price for a good or service would be a basic building block in the economic evaluation process. The market price provides clear information on the extent of private benefits to purchasers of a good. The social and environmental costs and benefits would then be used to augment this initial market-derived value. However, in the case of water markets it is often the case that there are government supply subsidies, and or restrictions on where water can be sourced from. This in turn means that even the market price can be an unreliable indicator of value.

Additionally, the non-market valuation methods normally used by economists to capture the monetary value of environmental goods and services have limitations, and are not universally applicable. Although there are several different conceptual approaches, the two main groups of non-market valuation methods are revealed preference methods, which include the travel cost method and the hedonic price method; and stated preference methods, which include the contingent valuation method and choice experiments. The main difference between revealed preference methods and stated preference methods is that the former estimates the value of environmental goods and services based on observed real-world consumer behaviour, while the latter relies on information from community surveys in which respondents are asked about hypothetical scenarios.

The main limitation of the revealed preference method is that, as it is based on observed consumer behaviour, the approach can only capture information on the "use values" associated with assets. Use values are the benefits from direct or indirect utilization of natural resources. Non-use values are benefits that accrue from environmental resources without a person directly using them. Non-use benefits include option value, existence value, and bequest value; and none of these benefits are captured in revealed preference analysis. Both use and non-use values can be estimated using stated preference methods, although stated preference methods in turn have a range of limitations. These include problems with survey respondents not having enough information to understand the nature of the trade-offs they are being asked to make, and general issues regarding the validity of values inferred from hypothetical scenarios where real money transactions do not take place(Nunes and van den Bergh, 2001).

In addition to the main stated preference and revealed preference valuation methods there are a number of other methods that can be used to obtain information on non-market values. These additional approaches include: the averting behaviour method, which is based on cost analysis; and the dose response method, which is based on examining the physical process of environmental impacts and estimating the losses (or avoided losses) from environmental degradation (or environmental quality improvement). The focus on costs, or avoided costs, distinguishes these methods from the revealed preference and stated preference methods that focus on benefits.

A major issue with all non-market valuation methods is that studies almost invariably relate to a specific site at a specific point in time. Values obtained from one specific site, using one specific valuation method, are generally not transferable to another context (Boyle and Bergstrom, 1992, Morrison et al., 2002). Yet because non-market valuation studies are expensive and time consuming to complete, there is a strong temptation to apply values obtained from one case study to other contexts.

The methods used to estimate benefits in the water economics literature have been: the averting behaviour approach, contingent valuation, choice experiments, hedonic pricing, the travel cost method, the cost of illness method, the stage damage method, and the photo projective method. A brief overview of each method is presented below.

Averting behavior approach

The averting behaviour or averting cost approach estimates values through examining the costs that consumers incur if a service is not available. For example, if the quality of tap water is not at the drinking level standard, averting behaviour would include purchasing bottled water, installing purification devices in the home and office, and the regular boiling of tap water. If tap water was raised to drinking standard, the value of these activities would represent the costs averted by increasing the quality of tap water to drinking standard. Consumers may, however, have been willing to pay an amount substantially greater than this for the convenience of having drinking quality water available in the home. The averting behaviour approach can therefore be seen as finding the lower bound estimate to consumers' willingness to pay (WTP) for the improvement of environmental goods and services.

Stated preference techniques

The contingent valuation method relies on creating hypothetical market scenarios, and is a specific type of stated preference technique. The contingent valuation method seeks to uncover individual preferences for changes in the quantity or quality of a non-market good or service in the format of individual's willingness to pay. Using this method respondents' WTP for an environmental good is asked directly, and historically the contingent valuation method has been the most commonly used stated preference method in environmental economics research (Carson et al., 2001). An example of a representative question format typical of the contingent valuation approach is as follows: *Would you pay $X every year, through a tax surcharge, to support a program to improve water supply services?* An advantage of the contingent valuation method is that it can capture the public's reaction to each pricing level and establish an upper bound estimate of the value of changes in environmental conditions. This upper bound value can then be used by policy makers when considering investment decisions (Wang et al., 2010).

A common criticism of the contingent valuation method is that the method may not be able to capture the true value of an environmental good or service because people may not answer truthfully. Respondents may intentionally understate their true value or seek to 'free ride' on the responses of others, which in turn leads to invalid results (Lindsey and Knaap, 1999). It is argued that the choice experiments approach can overcome this problem because respondents are asked to choose among alternatives, and that represents a more realistic decision framework (Alberini and Kahn, 2006). For this reason, choice experiments are increasingly seen as preferable to contingent valuation for most environmental asset valuation applications. The other common criticism of the contingent valuation method is that the value derived from this method is sensitive to the level and extent of information provided by the respondents (Wang et al., 2010).

Choice experiments, as applied to nonmarket valuation scenarios, is a technique that comes from the conjoint analysis literature of marketing. In marketing applications conjoint analysis is used to determine the attributes of goods that consumers see as important. In environmental economics applications choice experiments may be thought of as a generalisation of the contingent valuation method (Snowball et al., 2008). With choice experiments, consumers are not asked directly how much they would be willing to pay to achieve some specific environmental improvement. Rather, respondents are asked to choose their preference from a series of alternatives which differ in terms of the attributes and the levels of attributes (Bateman et al., 2002). One representative choice experiments question is as follows: *Which one of the following schemes do you favour and which one would you be least likely to choose? Please keep your financial conditions in mind while answering.* Note that one of the options presented to respondents is the below example of a choice sets (as shown by Table

15). A status quo option that allows the respondents to select the option of no change in environmental conditions at no cost is a feature of all choice sets.

Table 15 Illustrative example of a choice set used in the CRC wastewater buffer zone survey

There are 4 different land use categories below to consider in each option	Option 1 (Current situation)	Option 2	Option 3
Nature conservation areas 	No change: 30%	10%	50%
Commercial / industrial areas 	No change: 30%	20%	10%
Agricultural areas 	No change: 30%	50%	30%
Sporting and recreation areas 	No change: 10%	20%	10%
There is an increase in your service provider's bill (e.g. water bill) for each option (in $ per **quarter**)	$0	$21	$39
Most preferred option	☐	☐	☐
Least preferred option	☐	☐	☐

Both the choice experiments method and the contingent valuation method rely on survey techniques and have specific strengths and weakness. An advantage common to both techniques is that they involve public opinion in the decision making process. Both methods also allow use and non-use values to be estimated which is a clear advantage of these methods (Bennett and Blamey, 2001). The main difference between these two methods is that choice experiments allow the valuation of the characteristics or attributes of the environmental good or service whereas the contingent valuation method arrives at an estimate of the environmental good or service as a whole (Bateman et al., 2002).

One criticism of the choice experiments method is that it assumes respondents view the sum of the attributes as equal to the whole value of an environmental good or service, which may be an invalid implicit assumption (Louviere et al., 2000). Using the choice experiments method, respondents are also required to understand the differences in each option where multiple attribute levels are varied. The relative complexity of the question format means that there are concerns about respondents' using decision heuristics to simplify their decision-making process. If respondents do fall back on simple decision heuristics when responding to the questions in a choice experiment survey, the results from the study are biased. A detailed discussion of this issue is presented in Bennett and Blamey (2001).

Revealed preference techniques

The basic premise of the hedonic price method is that the price of a market good is related to its characteristics, or the services it provides. This method is most commonly applied to estimate the value of local environmental attributes through modelling the variation in house prices. The central idea is that the value of a house can be decomposed into a set of main characteristics, such as size of lot, building area, number of bedrooms, or distance to the city centre; and social and environmental characteristics such as the crime rate, whether there are schools and universities nearby, proximity to environmental assets such as wetlands, etc. The hedonic regression approach treats the hedonic good as weakly separable in the consumer utility function such that consistent estimates of an implicit price for each attribute can be obtained.

There are generally accepted standards available for property valuations, such as Uniform Standards of Professional Appraisal Practice (USPAP) in the USA; Generally Accepted Valuation Principles (GAVP) in Germany; and Australian Property Institute (API) Valuation Standards in Australia. These standards help establish acceptable general equations considering different characteristics. Another advantage of the method is that the required house price data are generally available in a relatively open and transparent market. Thus, although the statistical issues involved in the estimation of a hedonic price model can be significant, the method is often the least difficult to implement.

The travel cost method is especially popular for estimating recreational values (Ward and Beal, 2000). It aims to convert the physical and social benefits produced by outdoor recreation, such as river, dam, and beach visits into monetary terms (Ward and Beal, 2000). The basic theory behind the travel cost method in valuing non-market goods, especially recreational sites and recreational activities, is that the travel cost is the implicit price visitors pay for their trip to access sites or to be able to take part in particular activities (Becker et al., 2005, Phaneuf and Smith, 2005). Through analysing the relationship between the travel costs (price) in accessing a recreational site and the number of visits per year to this site (demand), a demand curve relating the two can be found. An advantage of the travel cost method is the consistency with consumer demand theory, that is, the higher the cost, the fewer the visits. One major limitation of this method is that non-users are normally not sampled, therefore only use value can be captured (Ward and Beal, 2000).

Other methods

The other methods that have cited in this review include the cost of illness method, the stage damage method and the photo projective method. The cost of illness method has been used to evaluate the economic benefits of reduced illness from water pollution by estimating the direct medical costs associated with an illness (Van Houtven et al., 2008). The stage damage method has been used to estimate flood damage based on the understanding of physical processes of flooding (Smith, 1994). The photo projective method has been used to estimate the aesthetic value of water through asking people’s perceptions using photographs.

As can be seen from the studies reviewed, a number of different approaches have been used to investigate the value of water supply to households, and these methods are all reasonable. The limitations to the existing work do, however, need to be noted. Implied values tend to vary with approach, which is a concern. Further, within a given approach, it is also the case that there are differences in values depending on factors such as household income, gender, number of children in households, and culture. Values can also vary significantly depending on people’s awareness and understanding of current water supply service quality. It is difficult to capture all these differences in a single study and this in turn means that reported results may not capture the complete picture.

An important aspect to consider when discussing the existing literature is the transferability of the results. The estimated values may be localized and it may only reflect the value of a particular service at a particular point in time. According to Brouwer (2000), the transfer errors from unadjusted unit value transfer can be as high as 50 percent, and the transfer error can be more than 200 percent in the case of adjusted value transfers. It is therefore important to spend considerable time working through whether or not it is appropriate to transfer specific results to new locations.

A recent trend in the literature with respect to transferring values from one specific study to another location is to combine the benefit transfer method with meta-analysis information (Rosenberger and Loomis, 2000, Shrestha et al., 2007a). Meta-regression analysis in particular can be used to synthesise existing research findings when there are many varying study attributes (Glass et al., 1984). The technique can be used to develop a benefit transfer function that takes into consideration more than one study, and is able to provide more robust estimates of transfer values that in turn reflect a more detailed understanding of the differences among individual sites and resources (Shrestha et al., 2007a). Validation tests of this combined approach are, however, still required to ensure method validity.

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Attachment A2.4

CRC for
Water Sensitive Cities

Review of existing Benefit: Cost Analysis (BCA) tools relevant to water-sensitive cities

Milestone Report (Work Package 3.1)

Australian Government
Department of Industry, Innovation and Science

Business Cooperative Research Centres Programme

Review of existing Benefit: Cost Analysis (BCA) tools relevant to water-sensitive cities
Milestone Report (Work package 3.1)
Comprehensive economic evaluation framework (IRP2)
June, 2017

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CIRIA BeST (Benefits of Sustainable Drainage Systems Tool) 18

AWR CoE Recycled Water Economic Assessment Tool 20

Blackspot Funding Benefit Cost Ratio tool 21

1 Introduction

1.1 Background

Existing literature and relevant stakeholders have been consulted to understand what tools are already being used (and by whom) and the extent of their use in decision making processes. Existing tools for benefit-cost analysis have been reviewed to determine their suitability for assessing water sensitive systems and practices at different scales and for users of varying capacity (including urban green space, water sensitive urban designs, and other features identified by the Steering Committee).

1.2 Process

This process had four aims, which were to:

1. Collate information about available tools for BCA or related purposes. This was based on:
   - our existing knowledge of available tools;
   - advice from a range of stakeholders who were aware of particular tools, including advice received in one-to-one interviews;
   - responses to a call for input that was publicised throughout the CRC;
   - a web search.
2. Examine each of the relevant tools. Where possible, a copy of each tool was obtained and run on microcomputer. The main characteristics and key strengths and weaknesses were captured for each tool. Some tools identified were more relevant to the Benefit-Transfer Tool and were passed on to that sub-project.
3. Undertake one-to-one interviews with a wide range of stakeholders. See Appendix A for list of interviewees. Notes were made during each interview, but the material presented here is a synthesis across all the interviews (plus the other information sources).
4. Discuss with tool developers and economists, drawing on experience with developing and applying BCA tools and conducting general BCA studies, to derive lessons for our project. These discussions were held opportunistically in the course of other projects or meetings with people we know have been involved in conducting BCAs or developing tools for the water or environment sectors.

1.3 Tools identified and (where possible) reviewed

The following tools were identified and most were reviewed. More detailed comments on the main relevant tools are provided in Appendix B.

1.3.1 BCA tools reviewed

- Catchment Management Investment Standard (detailed guidelines on investment and a tool)
- INFFER (Investment Framework for Environmental Resources)
- The i-Tree suite of tools
- AWRCoE Recycled Water Economic Assessment Tool
- Blackspot Funding Benefit Cost Ratio tool

1.3.2 Tools examined that are more relevant to the Benefit-Transfer Tool than to the BCA Tool

- CIRIA BeST (Benefits of Sustainable Drainage Systems Tool)
- Natural Capital Coalition
- Social Environmental Tool (SET)
- Ecological Accounting Protocol – A Tool to Calculate the Opportunity Cost of Drainage Infrastructure
- New Jersey developer's green infrastructure guide

1.3.3 Tools we were unable to get a copy of

- MetroNet by the Metropolitan Water Directorate, NSW, https://www.metrowater.nsw.gov.au/
- NRM North WSUD Implementation Decision Support Tool. Benefits assessment is primarily qualitative; water quality improvements are quantified. Designed for local context (Mann 2016).
- Infrastructure Sustainability Council of Australia (ISCA) Rating tool (ISCA 2016) – seems like it may not be a BCA tool in any case.

1.3.4 Not reviewed in detail due to narrow focus

- Green values national stormwater management calculator (US). Not a BCA.

1.3.5 Guidelines or protocols without tools

- VISES Green Infrastructure Economic Valuation Framework (usefully complements our BCA tool).
- PRINCE2 (https://en.wikipedia.org/wiki/PRINCE2). Too general and comprehensive for our purpose.

2 Lessons and implications for IRP2

Based on all the information collected, the interviews and discussions, and examination of existing tools, a set of high-level lessons and implications were identified for this project. Later we will look at more specific ideas identified for the tool(s).

1. Every organisation consulted recognised the important role of economic analysis, including BCA, in building business cases to convince decision makers about the merits of water-sensitive practices.
2. Some organisations make extensive use of BCAs. These are all larger organisations – water utilities, government agencies, and large councils like Brisbane City Council. There is a trend that they tend to use Multi-Criteria Analysis instead of BCA when the benefit get harder to measure (more social and environmental benefits). The intention in IRP2 is to use BCA even in these cases, using the Benefit-Transfer tool to provide values.
3. Most of the BCAs that are conducted for these organisations are commissioned from outside consultants. In a minority of organisations, some BCAs are conducted using internal expertise, but even most of these organisations also sometimes commission BCAs from external consultants.
4. Smaller organisations, particularly local governments, generally lack economics expertise, and they tend to make much less use of BCA in their existing processes (relative to the larger organisations). The need for support with economics is greatest for these organisations. Some of the larger organisations also lack

internal economics expertise. For the organisations with low internal economics expertise (both small and large), even relying on external consultants for their economics information can be problematic, as some level of economics expertise is needed to commission appropriate BCAs and interpret their results.

5. The level of expertise to successfully undertake a high-quality BCA is high. Experienced economists highlighted that there are risks in making a user-friendly BCA tool available to non-expert users. Even with the best designed and most user-friendly tool, experience shows that users need active support during the conduct of a BCA if the quality of the resulting analysis is to be assured. One tool, INFFER, includes, built into the tool itself, facilities to facilitate review of assumptions (a system for reviewers to comment on assumptions and for project developers to reply explaining their changes, and for reviewers to provide an overall stamp of approval on the process and the assumptions made).
6. There are various existing BCA tools that could be relevant to water-sensitive projects, as well as related tools, guidelines and protocols, and there are some training materials.
7. The existing BCA tools vary widely in their user-friendliness, structure, comprehensiveness and level of support. Most tend to be focused on a relatively narrow context, such as projects for catchments, urban trees, urban drainage or water recycling, each of which has a dedicated BCA tool, from somewhere in the world.
8. There is no existing BCA tool that is usable across a broad range of investment types (i.e. all of the above project types and more) and is specifically designed for projects with a focus on water-sensitive outcomes. CIRIA BeST is designed to deal with a wide-ranging set of benefits that are relevant to water-sensitive cities projects, but it does not provide a full BCA. INFFER is broadly relevant and is the most user-friendly of the tools, but it is not specifically designed for water-sensitive cities projects. There are good ideas to be obtained from the various tools.
9. There was incomplete information available about the levels of usage of the various tools, but overall it seems clear that most existing tools are used much less than hoped or expected. For example, the Catchment Management Investment Standard (and its spreadsheet tool Catchment Investment Analysis Tool, CIAT) were commissioned by the Water Services Association of Australia, but has had limited usage since.
10. A particularly interesting experience in this regard is INFFER. This tool was carefully designed with the intent that it would be used by non-expert users. Recognising the risks in that approach, it was supported by a two-day training program (which was considered to be essential before an organisation should use the tool), extensive online documentation at various levels of detail, a system for expert review of assumptions and a help-desk facility. The belief was that, with sufficient effort and support, non-expert users can conduct good quality BCAs, and a good number (dozens) have done so. Nevertheless, the way that INFFER has evolved over time is for its delivery to be increasingly done by consultants. There are still non-expert users adopting it in the originally intended way, but most recent BCAs done using INFFER have been led by consultants, and in most cases those consultants have included the team that originally developed INFFER. It seemed to the developers that this was actually a more efficient approach all round than attempting to impart sufficient expertise to non-economists for them to be fully independent users. Consistent with this, Mann (2016) concluded that, although a BCA tool is considered very useful, at least in the context of South Australia, "The tool is most likely to be used by consultants on behalf of developers and local councils, regulated water businesses, and by state government to inform policy development" (Mann 2016, p. ix).
11. Some experienced economists do not support the idea of producing a standardised BCA tool. They prefer to develop a custom BCA spreadsheet for each analysis they do. They highlight the high level of heterogeneity between cases and feel that any tool needs to be adapted to suit particular circumstances for each analysis (or else that the tool needs to be sufficiently flexible). For them, developing a custom spreadsheet for each analysis is not difficult and allows them the highest level of flexibility. They are also reticent about allowing inexpert users to conduct BCAs without sufficient support.

12. On the other hand, there was support from some economists for a tool that could become a standard for the water sector, particularly if it was seen to be endorsed by the CRC and perhaps departments of treasury. A standardised tool has the advantage of reducing the risk of error (which is always present in a custom-developed spreadsheet), of being relatively accessible to non-expert users (even if they don't end up using the tool themselves) and of supporting better standardisation of the approach used for BCA in the sector. The experience of INFFER shows that there can be value in developing a standardised tool even if it is not used by non-expert users. A comment made about the routine use of consultants was that people inside the organisation don't necessarily learn much from the arms'-length process. An additional feature of INFFER that has helped ensure its continuing use is well-designed participatory and elicitation approach that it includes.
13. Any new BCA tool produced would need to be flexible. It needs to be able to capture a wide range of benefit types.
14. Strong support emerged for a different type of BCA tool – a BCA support tool that would help an organisation in planning and preparing for a BCA. It was felt that it would be of benefit to all organisations, and that there is no existing tool of this type, whereas a traditional BCA quantitative tool would only benefit a minority of organisations and is competing with a number of existing tools or with the option of a custom-developed BCA spreadsheet. It was felt by some that this could actually be a higher priority than development of a new BCA quantitative tool per se.

3 Ideas for IRP2

3.1 Ideas for BCA quantitative tool

Based on observations of the various existing tools, and my experience using INFFER in various contexts, here are some ideas for the BCA tool, if we do decide to go ahead with developing a new quantitative BCA tool. These should be considered as ideas for discussion at this stage, rather than definite proposals.

Given the wide range of benefit types that can be generated by water-sensitive projects, and the huge range of contexts around Australia where these projects will be implemented, it seems unrealistic to expect to create a system where the quantitative estimates of all the benefits are built into the tool. This has been attempted in the CIRIA BeST tool, specifically for drainage-related projects in the UK, and even there the information requirements were enormous.

The strategy we are using in this project is to have two different tools: one related to BCA and one to assist people to estimate the more difficult-to-quantify benefits (the Benefit-Transfer Tool). This review focuses on the BCA aspect. The Benefit-Transfer Tool will need to generate values in form that are usable within the BCA tool.

For the BCA tool, it is important to be able to represent benefits that are structured in different ways. Possible benefit structures for inclusion in the tool are listed here:

- Benefit per person (on average) for a particular population (e.g., heat, health, amenity, biodiversity/ecology, recreation, tourism)
- Benefit per unit of action or area (e.g., biodiversity/ecology)
- Benefit per unit of abatement (e.g., CO_2 emissions, air pollution, water pollution)
- A total or aggregate benefit per year (e.g., development, other economic benefit, groundwater recharge, rainwater harvest, tourism, carbon storage)
- Delay or reduction in a cost (e.g., water treatment plant construction or upgrade)

- Improved condition of an environmental or community asset, expressed as a benefit for the asset as a whole (e.g. biodiversity/ecology, water quality)
- Reduced probability of a risky event that could occur with a specified probability in any year (e.g., flood, treatment plant failure)
- Custom benefits, specified year by year

We would set up the tool to capture benefits under any or all of these structures. Each of them implies a different way of calculating the benefits, and they require different parameters depending on which structure is used (e.g. the number of people affected, the number of units of pollution abatement, the number of years by which a cost is deferred).

It is important to capture that each project is likely to generate multiple benefits. The benefits may be of different structures (from the above bullet list) or there may be multiple benefits with the same structure (e.g., various benefits measured as a benefit per person).

Some of the benefits may be downstream or off-site from the location where the project actions are undertaken (e.g., effects of water pollution on a downstream water body).

Some benefits may be able to be represented by more than one of the above structures. For example, the benefits of reducing water pollution might be measured per person, or per unit of pollutant, or as the aggregate impact on a downstream water body. The user would be able to choose the structure that works best for a particular analysis. This may depend in part on the way that the information about the benefits has been estimated.

The timing of benefits is important. We would specify a year to commence transition (i.e. benefits start to grow from zero), a year when transition is complete (benefits reach their maximum), a year when the maximum benefit finishes, and a year when the benefit fades out to zero. We could allow the user to specify the same time profile for each of the benefits, or to customise the profile for each benefit.

Some projects rely on behaviour change. Without sufficient behaviour change, the benefits are not fully realised. Most tools do not include this explicitly, but I believe there is value in the INFFER approach of making assumptions about behaviour change explicit. This uses a simple but effective approach of defining a variable representing how much behaviour change the project is expected to generate, as a proportion of the level of change that would be needed to fully deliver the target level of benefits, and scaling the benefits accordingly. As with issues of timing, we could allow the user to specify the same behaviour-change parameter for each of the benefits, or to customise the parameter for each benefit.

I would also adopt the INFFER approach to capturing project risk. This defines three or four risk parameters that define the probability of the project failing to deliver its intended benefits for various reasons:

- Technical risk: the probability that the project will fail to deliver outcomes for technical reasons. Management actions are implemented but they don’t work because something breaks, or newly planted vegetation dies, or there was a miscalculation when designing the actions, or there is some sort of natural event that makes the actions ineffective.
- Social/political risk: the probability that social or political factors will prevent project success. For example, a project might rely on another government agency to enforce existing environmental regulations, but that agency is not prepared to enforce them because of the likelihood of a political controversy. Or there might be community protest, or perhaps even legal action, to stop the project.

- Financial risk: the probability that essential funding from partner organisations, or long-term funding for maintenance of benefits, will not be forthcoming. Many projects require ongoing funding for physical maintenance, or for continuing education or enforcement, without which the benefits would be lost. Sometimes the decision to provide ongoing funding is made independently of the decision to fund an initial project, so it is risky from the perspective of the funders of the initial project.
- Management risk: if different projects will be managed by different organisations, then there are likely to be differences in the risk of failure related to management. These risks might include poor governance arrangements, poor relationships with partners, poor capacity of staff in the organisation, poor specification of milestones and timelines, or poor project leadership.

In my view, the first three risks are most important, the fourth is less essential, especially if all the projects being evaluated are to be implemented by the same organisation. Some of these risks relate to all-or-nothing outcomes (e.g. there either is successful legal action against the project or there isn't), while others relate to continuous variables (e.g. maintenance funding might be deficient but not zero, resulting in some reduced level of ongoing benefits). Representing risks for continuous variables is possible, but it requires fairly detailed information. Given that we are making educated guesses when we specify these risks, going to that level of detail is probably not warranted.

What I suggest is to approximate each of the risks as the probability of a binary (all-or-nothing) variable turning out badly. I also suggest that we treat the different project risks as independent, not correlated. They are sufficiently different in nature for this to be reasonable.

The above risks all relate to the probability of a project failing to deliver its intended benefits. Another type of risk is one that creates an additional cost, unrelated to the intended benefits of the project. For example, a project to decentralise water supplies might result in a risk of adverse health impacts amongst water consumers. This could either be represented quantitatively, or if that is too difficult, captured qualitatively and reported to decision makers.

I like the way that costs are broken down in the CIAT tool (part of the Catchment Management Investment Standard). As well as the initial project costs, CIAT allows users to specify maintenance/operating costs as a % of capex, or as a fixed annual amount. It also allows for contingency costs.

I'm not sure about including a system for recording data sources for each number used. However, we could allow users to specify different stakeholder groups (whole community, industry, a particular business) and to allocate a share of costs and benefits to each. This would allow us to show a BCA from the perspective of each stakeholder group. While this would provide additional information, it would also increase the complexity of the tool.

We would provide a system for the various project options to be compared (similar in spirit to part of CIRIA BEST). The numbers assumed for each project could be compared and checked for consistency, and the overall results (in terms of Benefit: Cost Ratio or Net Present Value) could be compared.

We would require people to register to access the tool, providing email, name and organisation. Having done that, the tool would be free to access.

Need to make sure that Treasury (and other relevant regulatory agencies) are satisfied that the tool meets requirements.

If a BCA quantitative tool is developed, there are various issues that would need to be resolved.

- Where to aim on the continuum between a very simple tool and a highly detailed and sophisticated tool

- Whether the tool should be designed for non-economists or for experienced economists
- Whether the tool should be flexible and easily adapted or more rigid in its structure
- Whether it should be implemented in a spreadsheet or in an online web page (spreadsheet more flexible, online means updating is automatic and allows collection of data about usage).

3.2 Ideas for BCA support tool

The basic idea for this tool would be to help an organisation with the process of planning and preparing for the conduct of a BCA. It would be useful both to organisations that intend to conduct a BCA themselves, and also to organisations that intend to engage consultants to do a BCA. In the latter case, it would make them smarter purchasers of consulting services, and should reduce the cost of engaging the consultants (as a significant part of the work would already have been done).

Unlike the BCA quantitative tool, there are no examples to get ideas from for this tool. Based on discussions with stakeholders and experience working with various organisations, the following steps or stages could be considered for inclusion.

- Explain what a BCA can and can’t be expected to provide, and the possible uses of results.
- Screen for whether it is worth doing a BCA of the project. This could involve responding to a checklist addressing issues such as: the scale or importance of the project; whether a decision about funding of the project is likely to be influenced by a BCA; whether it is sufficiently clear what the project would involve – what specific actions or changes would occur; whether there is likely to be sufficient data and scientific understanding to underpin a worthwhile BCA; and whether the project is sufficiently likely to pass a BCA test for it to be worth conduction the BCA. If the answer is no (not worth doing a BCA), suggest what they should do instead – e.g. a qualitative BCA. This tool could help to deliver that.
- The following steps could help to formulate the problem and think clearly about it. They would also save some time (and so cost) of consultants.
- Establish the time frame for the BCA. Is it to compare benefits and costs over the next 10, 20, 50 years, or some other time frame? The tool can provide advice on pros and cons of the options.
- Establish the baseline scenario for the BCA. This is the business-as-usual scenario, describing what would happen if the project was <u>not</u> funded. It is not necessarily a continuation of the current pre-project conditions. The status of each of the relevant benefits over the relevant time frame might be expected to worsen or improve in the absence of the project.
- Identify alternative strategies or projects. Describe in detail the various options. Each strategy or project would become a BCA. Evaluating different versions of the project (e.g. different scales or intensity or location) would be encouraged.
- Identify benefit types for each project. We would develop a checklist of benefit types to be considered (e.g., amenity, biodiversity, temperature, carbon sequestration, flood mitigation, etc.). Perhaps advice about relevant experts who could advise on the likely levels of these benefits for particularly projects.
- Identify data needs for each project. This would explain the specific information needed to underpin the BCA, for each of the project options. Advise on how to deal with data gaps.
- Identify risks for each project. This could involve a qualitative assessment of the project risks for each of the INFFER categories. Or perhaps selection of risk levels from scales provided. Similarly, off-site or downstream risks could also be elicited qualitatively.

- Identify stakeholders. Elicit the nature of their stakes in the project. Elicit qualitative information about the likelihood of them supporting, cooperating with or complying with the project, or perhaps of opposing it.
- Consider behaviour change. Identify who, if anyone, would need to change their behaviour in order for the project to succeed. Identify the mechanisms in the project that would be used to encourage this behaviour change.
- Consider the risk of double counting benefits. CIRIA Best includes a simple matrix that shows which pairs of benefits are likely to overlap. This could be adapted for our tool.
- Plan the process of expert review for the BCAs. Who would be approached to be an independent expert reviewer? Which aspects of the BCAs would most need expert review?
- Maybe the process could lead to a simple qualitative BCA in cases where a full BCA is not needed or justified for whatever reason.

There are quite a few questions to resolve about the design of such a tool. Would it work best as a document, a spreadsheet, a web site, or whatever? Is it something that an individual would do, or should it be designed as a group process? What level of support should be presumed? Would we expect organisations to use the tool on their own, or with expert support? How extensive can the work required by the tool be before it gets too onerous for people? Can it be designed in a modular way, such that an organisation does as little or as much of it as they feel the need and have the ability? What training would be needed to support it, or should we aim for a tool that doesn't need training?

3.3 Ideas to encourage adoption of either tool

Based on observations of the various existing tools, and my experience using INFFER in various contexts, here Provide simple case studies showing how tools have been used to make better decisions, or decide on distribution of costs, or bring people together.

- Provide training programs for each tool. Make sure you get through a full case study during the training.
- Provide very good video training modules and very good manuals online.
- Perhaps have different training for people at different levels of expertise.
- Make sure there is high-level buy-in in organisations.
- Get endorsement from somebody in position of authority.
- Run several shorter workshops rather than one big workshop.
- Provide it for free.
- CRC provide award for best use of the tool(s) by a local government.
- Get training courses accredited.
- Create a user forum. Users can provide feedback and help each other out. Can identify gaps and suggested changes.
- For utilities: make sure that the regulators in the utility and financial decision makers are on side, not just the engineering types who putting forward proposals.
- Show that BCAs influence real decisions.

4 Key decisions for IRP2 before proceeding

The key decision required at this stage is how to balance our effort between developing a BCA quantitative tool and a BCA support tool. We would appreciate advice on this from the Project Steering Committee. To seed the discussion with the Project Steering Committee, here are a range of relevant considerations.

The approved project proposal states that we are to develop a BCA quantitative tool. The idea of developing a BCA support tool had not emerged when the proposal was developed.

Consultations revealed mixed views about whether it is worth developing a new BCA quantitative tool. Most experts felt that it was not realistic to expect organisations without strong economics expertise on their staff to conduct BCAs internally. Some external consultants may use such a tool, but others would prefer to build their own for each BCA. Also, there are various BCA tools already available that can be adapted by people with sufficient expertise. Or a customised BCA spreadsheet can be developed for each BCA.

On the other hand, various benefits of a standardised BCA tool were identified: standardisation of the approach used for BCA in the sector; reduced risk of error relative to a custom-developed spreadsheet; accessibility of the tool to non-expert users (even if they don't end up using the tool themselves); and codification of a strong participatory and elicitation approach.

There was universal support for the idea of developing a BCA support tool. The details were not clear or well developed, but everybody liked the idea. It would be useful to all stakeholders, not just those with relatively low economics expertise. It could increase the quality of BCAs conducted, and also reduce the cost of engaging consultants, by bringing relatively easy aspects of the process in-house.

As the BCA support tool was not planned, there is a trade-off between the two tool options. If we do a thorough and high quality job of one of them, if reduces what is feasible for the other. For this reason, we need to be clear about where the priority lies. Of course we would like to do both if possible, but we would like to know where to contain effort if it proves impossible to complete both to the highest standard in the available time.

References

Mann, E. (2016). Adoption of tools to assess costs and benefits of Water Sensitive Urban Design in Adelaide, Report Issued to Water Sensitive SA, University of Queensland.

Appendix A - Stakeholders consulted

One-to-one interviews occurred with a number of key stakeholders during May-June 2017:

1. Ben Fallowfield, Northern Beaches Council, NSW
2. Fiona Chandler, Alluvium
3. Jim Binney, Alluvium
4. Grace Tjandraatmadja, Melbourne Water
5. Greg Finlayson, GHD
6. Karen Campisano, Water Services Association of Australia
7. Kym Whiteoak, RMCG
8. Mellissa Bradley, Water Sensitive SA
9. Ursula Kretzer, Department of Water (WA)
10. Naomi Rakela, Eastern Metropolitan Regional Council (WA)
11. Nick Morgan, Brisbane City Council
12. Anna Roberts, Natural Decisions (co-developer of INFFER)
13. Geoff Park, Natural Decisions (co-developer of INFFER)
14. About 12 Members of the Adaptive Planning and IWM Network (of the Water Services Association of Australia). This network brings together people from water utilities around the country. Sayed Iftekhar and David Pannell met with them in Brisbane on 4 May 2017. There were extensive discussions about our project for half a day, including discussions about its design and how to maximise uptake.

Appendix B – BCA tools examined

Catchment Management Investment Standard

Inclusions

- The Standard – a 77-page document that outlines 11 key steps.
- Catchment Investment Analysis Tool (CIAT) – a spreadsheet tool that helps users prepare financial and economic analyses of source catchment investments that they are considering.
- The Source Value Transfer Database – The project developed a searchable database of more than 200 estimates of the economic and financial benefit values of source catchments as water treatment assets.

Developed by
Alluvium and Marsden Jacob Associates (consultants) in Australia

Development supported by
Water Services Association of Australia and Water Research Foundation

Intended usage and context
The developers designed the CMIS to be used by agencies and organisations who are managing source catchments, especially impaired multi-use catchments. To use the CMIS effectively you should have a good level of understanding about source catchments, their processes, and the major components of a source catchment management plan. You should also have a basic understanding of stakeholder engagement and benefit-cost analysis.

Publicly available
Yes.

Existing users
Seems to be not many.

Strengths and good ideas

- The Standard provides a good overall approach to project analysis.
- CIAT can be mined for ideas about categories of costs. Ideas to consider: including contingency costs. Including maintenance/operating costs as a % of capex, or as a fixed annual amount.
- The Source Value Transfer Database may provide studies that can be included in the Benefit Transfer Tool (Work Package 2 of IRP2).

Weaknesses or concerns

- The CIAT spreadsheet is rather generic and only designed for a limited range of benefit types.
- The Source Value Transfer Database was a start but needs further development (which we are doing in the Benefits Transfer Tool sub-project).

Web site
https://www.wsaa.asn.au/publication/source-catchments-water-quality-treatment-assets

Is it supported and being maintained and updated?
No. Take it as is.

Do we have a copy?
Yes

INFFER (Investment Framework for Environmental Resources)

Inclusions
Extensive documentation for 7-step process for designing and evaluating environmental and natural resource projects.

Frequently asked questions.

- On-line Project Assessment Form for data collection and BCA
- Spreadsheet version of the BCA
- Training materials

Developed by
David Pannell, Anna Roberts and Geoff Park (now of Natural Decisions Pty Ltd)

Development supported by
Future Farm Industries CRC

Intended usage and context

- Originally designed with/for regional catchment management bodies. Also used by government agencies and NGOs.
- Can be used to design and evaluate individual projects, or to evaluate and rank a suite of projects. Can also compare a range of variants of a particular project to help with decision making about project targets and strategy.

Publicly available
Yes.

Existing users

- Dozens of users in Australia and New Zealand, with some use also in Canada.
- Strengths and good ideas
- Was designed as a tool for non-economists to undertake BCA.
- Many ideas from INFFER, and experiences in its development could be drawn on. Key features include:
    - Highly user-friendly online interface with context-sensitive help.

  - System for expert review of assumptions.
  - Support for project design/development, including a number of test of the logical consistency of the project.
  - Training system.
  - Actively supported.
- Well-designed participatory and elicitation approach.
- Includes a number of well-considered simplifying assumptions that ease the data elicitation process to some extent.
- More comprehensive treatment of project risks than the other tools.
- The developers have recently been adapting the spreadsheet BCA to make it more relevant to water projects. The spreadsheet version, though, is not designed as a user-friendly tool for non-experts.

Weaknesses or concerns

- Was originally not specifically designed for the water context.
- Original version does not include a comprehensive range of benefit types.

Web site
www.inffer.com.au

Is it supported and being maintained and updated?
Yes. Support by Natural Decisions http://www.naturaldecisions.com.au/

Do we have a copy?
Yes

The i-Tree suite of tools

Inclusions

- A broad suite of tools, including a module on Benefit: Cost Analysis.
- It is a custom-written program, not a spreadsheet or a web page.
- Extensive documentation is available.

Developed by
USDA Forest Service.

Development supported by
USDA Forest Service.

Intended usage and context

- i-Tree is a software suite from the USDA Forest Service that provides urban and rural forestry analysis and benefits assessment tools. The i-Tree Tools quantify the structure of trees and forests, and the environmental services that trees provide.
- i-Tree is used to report on individual trees, parcels, neighborhoods, cities, and states. By understanding the local, tangible ecosystem services that trees provide, i-Tree users can link forest management activities with environmental quality and community livability. Whether your interest is a single tree or an entire forest, i-Tree provides baseline data that you can use to demonstrate value and set priorities for more effective decision-making.
- The tool includes default values for the US and the UK.

Publicly available
i-Tree Tools are in the public domain and are freely accessible.

Existing users
Since the initial release of the i-Tree Tools in August 2006, thousands of communities, non-profit organizations, consultants, volunteers and students have used i-Tree.

Strengths and good ideas

- This is an extremely detailed and sophisticated system. The investment to create this has been enormous.
- The system of registering and downloading is well designed. Users can access documentation freely without registering, but are required to register and confirm their email address before being given access to the download page.
- The focus is specifically on trees. The represented set of benefits from trees is comprehensive. It includes carbon storage/sequestration, effect on building energy use and associated CO_2 emissions, reduced stormwater runoff (although the reason for this being a benefit is not teased out), oxygen production, pollution removal (NO_2, SO_2, O_3, CO, PM2.5), UV reductions, wildlife habitat.
- It also represents emissions by trees of volatile organic compounds, which may have adverse effects, including increased ozone and increased particulate matter, depending on the species of tree.
- Data for the technical aspects (for the US and UK) are built in.

Weaknesses or concerns

- The Benefit: Cost Analysis part of the system is a very small part of the package.
- The handling of costs is limited.
- The focus is only on urban trees.

Web site
https://www.itreetools.org/

Is it supported and being maintained and updated?
Yes.

Do we have a copy?
Yes.

CIRIA BeST (Benefits of Sustainable Drainage Systems Tool)

Inclusions
Two Excel tools and two sets of guidelines:

- W045aBeST: Evaluation Tool: supporting practitioners evaluate benefits for a drainage proposal
- W045bBeST: Options Comparison Tool: Tool to compare more than one drainage proposal
- W045cBeST Technical Guidance: Provides technical information behind the tools
- W045dBeST User manual: Provides an overview of how to use the tools W045a and W045b

Developed by
Prof. Christopher Digman and Dr Bruce Horton (MWH), Prof Richard Ashley (EcoFutures) and Elliot Gill (CH2) in the UK

Development supported by
CIRIA. CIRIA is the construction industry research and information association in the UK. As a neutral, independent and not-for-profit body, CIRIA links organisations with common interests and facilitates a range of collaborative activities that help improve the industry.

Intended usage and context

- Supports practitioners estimate the impacts that drainage schemes can create.
- BeST provides a structured approach to evaluating a wide range of benefits (in the table right), often based upon the drainage system performance overall. It follows a simple structure, commencing with a screening and qualitative assessment to identify thebenefits to evaluate further. Where possible, it provides support to help quantify and monetise the benefit. For some benefits, it provides a structured approach to qualify the impact they may have. The tool creates summary tables presented under both an Ecosystem Services (ESS) and Triple Bottom Line (TBL) framework. It automatically generates a series of graphs for use in reports. An Option Comparison Tool enables data from more than one ‘simulation’ of BeST to be copied and compared with the overall net present cost, benefit and value.

Benefit category	**Monetised?**
Amenity	Yes
Biodiversity and ecology	Yes
Building temperature	Yes
Carbon reduction and sequestration	Yes
Crime	No
Economic growth	No
Education	Yes

Enabling development	Yes / No
Flexible infra./climate change adaptation	To be developed
To be developed	Yes
Flooding	Yes
Groundwater recharge	Yes
Health	Yes
Pumping wastewater	Yes
Rainwater harvesting	Yes
Recreation	Yes
Tourism	No
Traffic calming	No
Treating wastewater	Yes
Water quality	Yes

Publicly available
Yes. Free to download.

Existing users
Yes, but not clear from web site how many or who they are.

Strengths and good ideas

- It is generally well designed.
- Comprehensive documentation.
- For each type of benefit, it shows the potential stakeholders and schemes to discuss the benefits with.
- Flags risk of double counting between different types of benefits.
- Comprehensive list of benefit types.
- Outputs are a mix of monetised values and qualitative values.
- Includes sensitivity analysis.
- Builds in a set of suggested monetary values for particular impacts (a values library).
- It uses economic discounting.

Weaknesses or concerns

- It's not a full BCA. Only estimates benefits. More relevant to the Benefit Transfer tool than to the BCA.
- Discounts benefits according to "confidence". The way they have done this seems inconsistent with standard decision theory.
- It provides structure around how the benefits are specified, but in some cases this may be overly constraining.
- To keep things simple it often breaks options down into a few categories, like area being small, medium or large. It is not clear what quantitative levels (e.g. areas) would correspond to those categories.

Web site
http://www.ciria.org/News/CIRIA_news2/New-tool-assesses-the-benefits-of-SuDS.aspx

Is it supported and being maintained and updated?
It has had updates, most recently in March 2016.

Do we have a copy?
Yes

AWR CoE Recycled Water Economic Assessment Tool

Inclusions

- The Recycled Water Economic Assessment Tool is a free Excel-based system that allows users to undertake a cost benefit analysis to quantify a range of economic, social and environmental benefits, and costs for recycled water schemes.
- Also includes several supporting documents, available from http://www.australianwaterrecycling.com.au/research-publications.html.
- Marsden Jacob Associates (2014), Economic Viability of Non-Potable Recycled Water Schemes, Australian Water Recycling Centre of Excellence.
- Marsden Jacob Associates (2014), Value of recycled water infrastructure to the residents of Rouse Hill, Australian Water Recycling Centre of Excellence.
- Marsden Jacob Associates (2014), Community values for recycled water in Sydney, Australian Water Recycling Centre of Excellence.
- Marsden Jacob Associates (2014), Environmental and Social Values Associated with Non-potable Recycled Water, Australian Water Recycling Centre of Excellence.

Developed by
Marsden Jacob Associates, Project led by Phil Pickering, in Australia

Development supported by
Australian Water Recycling Centre of Excellence

Intended usage and context
It is designed as an easy-to-use system to assess alternative water recycling options, primarily for non-potable purposes. The tool uses information entered by the user on the likely costs and benefits of a particular water recycling initiative. While the tool is designed to be relatively easy to use, users should familiarise themselves with the *Economic Viability of Recycled Water Schemes* framework by the Australian Water Recycling Centre of Excellence, which is also available for download, to ensure an understanding of the context and application of the information that is to be entered.

Publicly available
Yes

Existing users
Developers advise that they have processed 168 requests for copies of the model. They do not collect feedback from users but they understand it has been used successfully multiple times.

Strengths and good ideas

- Designed specifically for water recycling projects. This allows it to represent a number of issues that are specific to this context.
- Includes a check list of logical points, such as whether the first year of properties being connected is at or after the final year of capex.
- Detailed breakdown of costs, including capital costs, operating costs, environmental/community costs (e.g. CO_2 emissions).
- Includes a range of benefits: avoided potable water cost, avoided waste water cost (e.g. disposal), wider community willingness to pay (including non-use benefits), reduced probability of water restrictions, and avoided cost of rainwater tanks.
- Represents benefits and costs for up to 100 years, but user specifies time frame.
- Generally is quite a good tool. Fairly simple and able to be comprehensive within a relatively narrow scope.

Weaknesses or concerns

- Narrow scope – recycled water projects only.
- Limited support for non-expert users. Assumes a reasonably high level of economic expertise.

Web site
http://www.marsdenjacob.com.au/recycled-water-economic-assessment-tool/

Is it supported and being maintained and updated?
Not clear. Possibly.

Do we have a copy?
Yes

Blackspot Funding Benefit Cost Ratio tool

Inclusions
A spreadsheet tool.

Developed by
Australian Government?

Development supported by
Australian Government?

Intended usage and context
Provided to local-government applicants for funding to address traffic accident black spots.

Publicly available
Yes.

Existing users
Yes. Presumably, all applicants to the Blackspot program.

Strengths and good ideas
Builds in specific benefits for particular actions. All the numbers are standardised.

Weaknesses or concerns
Strictly limited to investments in reducing traffic accidents.

Web site
http://www.dpti.sa.gov.au/towardszerotogether/safer_roads/black_spot_program_2

Is it supported and being maintained and updated?
Probably.

Do we have a copy?
Yes.

CRC for
Water Sensitive Cities

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