

A I T H E R

Valuing externalities for integrated water cycle management planning

A report prepared for the Victorian Department of Environment, Land, Water, and Planning

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Executive summary

Over the last three to four years, the Department of Environment, Land, Water and Planning (DELWP) has been investigating the potential for Integrated Water Cycle Management (IWCM) solutions to provide a range of benefits compared with more traditional water servicing approaches.

IWCM initiatives have the potential to provide a range of benefits to the community, many of which are considered externalities because they are unpriced in markets. Many IWCM actions increase the supply of water available for beneficial uses and reduce the velocity, frequency, volume and pollutant loads of stormwater run-off, and as a result contribute to reductions in flood impacts, drainage requirements, and downstream ecological impacts on waterways and the bays.

The purpose of the project is to provide DELWP with a review of the economic literature on externalities that are relevant to IWCM planning, along with some guidance on how this information could be applied in the context of IWCM assessments. The focus is primarily on information that is relevant for use within a Melbourne context.

The key objectives are as follows:

- review information from the literature on externalities that are relevant to IWCM, and extract key information and economic data that may be useful for application in IWCM assessments
- provide guidance on the use of that information in IWCM assessments, including potential misuses and pitfall such as double-counting of benefits
- identify key uncertainties and gaps in the economic literature and provide recommendations for further work.

The intent of the report is to provide a first point of reference for DELWP when undertaking IWCM assessments that involve externalities. Although guidance on the use of externality data is provided, it should be recognised that appropriate economics expertise should still be sought when applying the information presented here. As with many technical disciplines, the 'devil is in the detail' and the robustness of the economic assessment is heavily dependent on the conditions under which the information is applied.

The scope of the project includes the following:

- establish a framework to assess the studies referenced to ensure that:
 - the desired benefits/values are being addressed (i.e. to ensure the study is not focusing on benefits where DELWP already has sufficient data and knowledge)
 - the research is of high quality, is relevant, scalable and transferable
 - double-counting risks are identified and avoided
- undertake a literature review of research material from a range of sources including journals, articles, reports, theses and social research data. The focus of the review is on the following key externality categories, in order of importance for DELWP's IWCM planning needs:
 - benefits from improved ecological health of waterways and bays
 - amenity and recreational benefits provided by waterways and bays

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- other social values from increased water use and availability (e.g. urban cooling, amenity and public health benefits of increased green space and urban forests)
- benefits of reductions in flood risks
- select a sample of high quality reports detailing these benefits, articulate the economic value of the benefits, and demonstrate the relevance and transferability of the values obtained from the shortlisted studies
- identify key issues and recommendations for future work to address key knowledge gaps.

Summary of findings

The review undertaken here has considered the externalities associated with these outcomes and assessed available information for use in assessments of IWCM, particularly within a Melbourne context. Although it uncovered some useful data and methodologies for use in IWCM assessments, there is a general lack of Melbourne-centric studies, which creates a relatively high level of uncertainty in their application.

Benefits from improved waterways and bays

The review of externalities associated with waterways and bays uncovered a large body of literature both locally and internationally. However, the majority of waterway studies focus on large, rural, and often iconic waterways, which limits their application to the types of waterways that IWCM often seeks to protect and improve - namely small, urban streams and creeks. That said, protection of enough of these smaller waterways within a catchment is expected to provide improvements to larger downstream waterways and bays – these impacts are more amenable to the economic values discussed in this report.

Key to the assessment of waterway benefits is a good understanding of how IWCM actions lead to biophysical changes that the community understands, perceives, and values. The literature on the discrepancy in value between willingness to pay and willingness to accept compensation for commensurate environmental changes provides evidence that, all other things being equal, the protection of pristine waterways is more highly valued than the restoration of degraded ones. This suggests that IWCM efforts should be focussed towards protection of waterways currently in pristine ecological health.

Other social values from increased water use and availability

Increased water availability generated through IWCM solutions provides the potential for additional benefits derived from additional uses of water such as increased and enhanced green spaces and consequential amenity, urban cooling and other benefits. Some methods and data for estimating the value of green space and urban cooling have been provided, with the focus of recommendations relating to water use and applications in IWCM assessments.

The construction of the Victorian Desalination Plant (VDP) has provided a significant augmentation to the water supply network. Despite the considerable cost involved in its construction, these costs are now sunk and irrelevant to decisions regarding marginal changes in future water use. Its significant supply capacity means that additional augmentations are not likely to be required for some time, and as a consequence, the Long Run Marginal Cost (LRMC) of additional water is relatively low, despite the operational costs of running a desalination plant. Since relatively low cost

water is available, the value of providing additional water provided by alternative sources is also low, regardless of the application of the water (for urban landscapes or otherwise).

While some data and methodologies for estimating the beneficial outcomes of increased water use have been discussed and provided, the avoided LRMC of water supply provides the best current economic measure of the marginal benefit of additional water (where a reticulated supply is available) as this represents the least cost alternative, as well as being based on a robust process that is relatively simple to apply in IWCM assessments. More sophisticated portfolio or real options approaches should be considered to place a value on the risk management benefits provided by IWCM options, as an alternative to LRMC.

Reduced flood impacts

The review of flooding externalities uncovered a range of impacts. More quantifiable impacts such as damage to physical infrastructure have better representation in the literature, with sound methodologies and good data for assessment. Others such as psychological, physical health, and disruption impacts have less data available, but good approaches to assessment. Of importance in applying these data and methodologies is a clear technical understanding of the physical reductions in impacts of different sized flood events as a result of IWCM measures. The avoidance of costs that would have otherwise feasibly been incurred in managing floods, such as additional drainage infrastructure, also provides an indication of the benefit of IWCM in reducing flood risks.

Recommendations

The application of values for externalities in IWCM assessments can only be as accurate as the technical links between IWCM initiatives, their physical and biophysical outcomes, and then to attributes that are valued by the community. To this end, it is recommended that further work goes into developing these understandings – particularly in regard to the connections to ecological responses and flood impacts of IWCM options.

If the above provides evidence that clear benefits are likely to exist, it is recommended that original willingness to pay studies are undertaken to assess the value that the community places on improvements in the health of Melbourne's waterways. A better understanding of this could potentially reveal considerable benefits provided by IWC approaches that are not currently well represented in feasibility studies and cost benefit analyses.

In particular, a stated preference study that focuses on willingness to pay for improvements across a catchment (rather than focussing on small individual waterways) would be valuable for IWCM assessments, and a valuable contribution to the State's knowledge base for environmental management generally. Melbourne Water is currently managing a willingness to pay study with these sorts of objectives.

Similarly, improved flood modelling of IWCM impacts within a catchment would help assess reductions in flood risks that can be measured using established depth damage relationships and the Annual Average Damage approach.

The review revealed significant gaps in the literature regarding studies that are specific to Melbourne. Beyond the specific recommendations above, it is therefore also recommended that further studies are undertaken that are more focussed on the valuation of externalities within a Melbourne context, particularly those regarding the value that Melbournian's place on urban forests and green spaces as sources of recreational opportunity and amenity.

The findings here should be augmented as new studies become available, with a focus on studies that:

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- assess marginal benefits - absolute values are of little use in any analysis of actions except as a means to assessing marginal changes due to an intervention (ie the change in absolute values with and without some potential intervention). For example, the absolute value of a river does not help in making decisions about its management. The value of a *change* in the state of a river as a result of management is useful (which may be preventing a decline rather than an improvement), as it can then be compared against the cost of management, and against alternative options, in a meaningful way
- are focussed on values that are expected to be significant factors in decision making
- have clear linkages to IWCM outcomes, and have been developed and expressed in ways that have a clear connection with possible, and available, technical outputs of IWCM planning

1 Introduction

1.1 Background

Over the last three to four years, the Department of Environment, Land, Water and Planning (DELWP) has been investigating the potential for Integrated Water Cycle Management (IWCM) solutions to provide a range of benefits compared with more traditional water servicing approaches. Decentralised solutions such as stormwater harvesting have the potential to reduce other water servicing costs, improve water supply security, and contribute to a range of broader environmental and liveability outcomes.

Draft Investment Lifecycle Guidelines – Water Supplement (ILG-WS) were developed by DELWP. They highlight the need for IWCM options to undergo rigorous economic appraisal to ensure that these benefits can be realised and that they present optimal solutions from a societal perspective.

Initial work through a number of planning studies and case studies has highlighted that liveability outcomes are important in terms of influencing the overall outcome of most Cost Benefit Analyses (CBAs) for IWCM solutions.

The Draft ILG-WS set out the procedure for the economic component of IWCM options analysis and state that estimations for non-market values for IWCM, such as these liveability aspects, can be included in economic analysis if:

- the value estimations can be reliably transferred to the specific planning context
- the assumptions of the estimations are made clear
- a clear logic map of how the externality results from the initiative is provided.

However, many of the benefits of IWCM initiatives involve non-market values that remain difficult to capture in monetary terms. As a result, economic appraisals may not accurately reflect all of the outcomes achieved and underestimate the value provided to the community. In turn, this means there is uncertainty regarding the optimal type and level of investment in IWCM solutions.

The ILG-WS does encourage appropriate use of qualitative analysis (including multi-criteria analysis) alongside the CBA to incorporate consideration of non-market values into the option evaluation if a suitable estimation for the value of the non-market item cannot be sourced. However, in the absence of more robust estimates of non-market values, the case for investment in IWCM measures and for planning and regulatory measures to foster IWCM is weakened.

1.2 Purpose and objectives

The purpose of this project is to provide DELWP with a review of the economic literature on externalities that are relevant to IWCM planning, along with some guidance on how this information could be applied in the context of IWCM assessments. The focus is primarily on information that is relevant for use within a Melbourne context.

The key objectives are as follows:

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- review information from the literature on externalities that are relevant to IWCM, and extract key information and economic data that may be useful for application in IWCM assessments
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- identify key uncertainties and gaps in the economic literature and provide recommendations for further work.

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1.3 Scope

The scope of the project includes to:

- establish a framework to assess the studies referenced to ensure
 - the desired benefits/values are being addressed, i.e. to ensure the study is not focusing on benefits where DELWP already has sufficient data and knowledge
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 - double-counting risks are identified and avoided.
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 - benefits from improved ecological health of waterways and bays
 - amenity and recreational benefits provided by waterways and bays
 - other social values from increased water use and availability (e.g. urban cooling, amenity and public health benefits of increased green space and urban forests)
 - benefits of reductions in flood risks
- select a sample of high quality reports detailing liveability, amenity and environmental benefits related to IWCM, articulate the benefits and demonstrate the relevance and transferability of the values obtained from the shortlisted studies
- identify key issues and recommendations for future work to address key knowledge gaps.

1.4 Report structure

Beyond this introduction (Section 1) the report is structured as follows:

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- Section 2 describes the economic framework underpinning IWCM assessments, including the nature of externalities and the methods used to assess them
- Sections 3 to 6 describe the assessment of externalities in each of the categories described above in Section 1.2. For each category the assessment contains the following structure:
 - Description of externalities relevant to IWCM
 - Literature review findings (including key qualitative findings and economic data)
 - Discussion on how these findings could be used (including the connection between IWCM and externality benefits, how the data could be applied in assessing these benefits, and identification of data gaps and recommendations for further work)
- Section 7 concludes the report with a summary and recommendations.

2 Externality evaluation framework

2.1 Total economic value

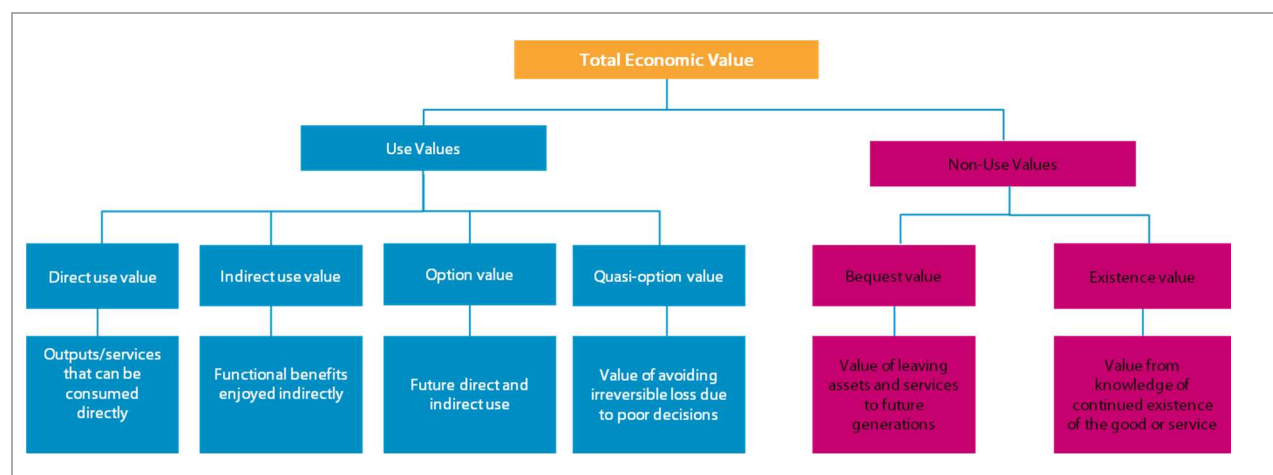
While the value of some of the beneficial outcomes of IWCM are readily assessable through reference to market prices and avoided costs, many are not. It is important that any assessments of IWCM consider all benefits derived from these initiatives, so that the Total Economic Value (TEV) is assessed.

TEV can be broadly classified into two types – ‘use’ values and ‘non-use’ values:

- *use values* correspond to the benefits obtained from actually using a natural resource, e.g. taking part in fishing, beach walking or other activities. Use value can be further sub-divided into direct and indirect use values (direct use values include those derived from consumption, e.g. fishing in a river; indirect uses include flood control and water purification services, e.g. as offered by a wetland).
- *non-use values* reflect the satisfaction that people derive from knowing that some environmental attribute or species is to be protected or preserved — even though they may never make use of the natural resource. Non-use value components include bequest value (the value of preserving some environmental attribute for future generations), option value (the value of having the option to use it in the future, e.g. land reserved for future green space enhancements) and existence value (the value of knowing that the natural resource exists).

The TEV framework is presented in Figure 1.

Figure 1. Total Economic Value Framework



Source: Adapted from IUCN (2003)

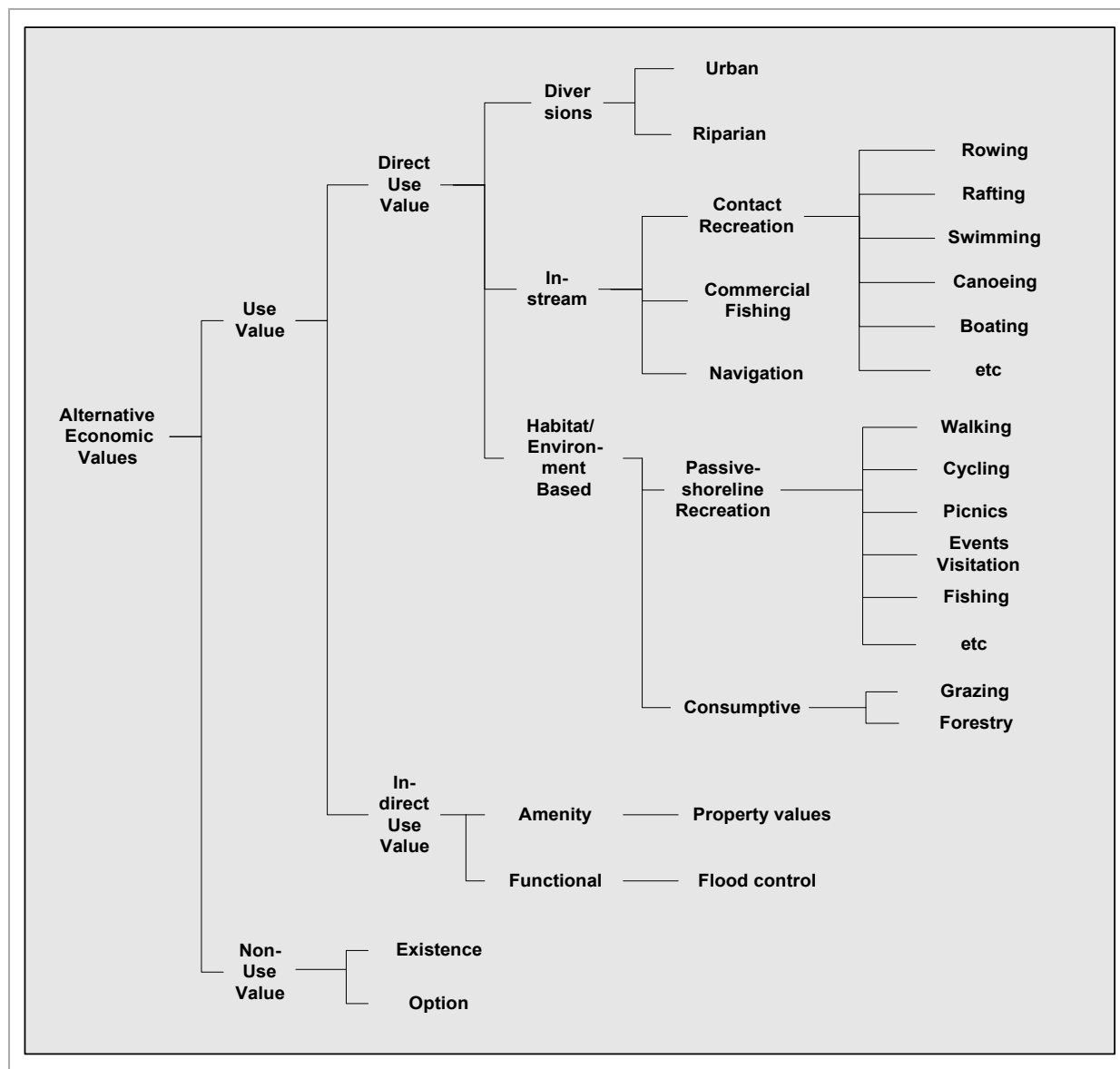
2.2 Non-market values

Costs and benefits for goods you can buy or sell (**market goods and services**) will be reflected in market prices. These are relatively straightforward to determine and generally reliable (e.g. construction costs and production benefits).

Environmental and social effects are not usually bought and sold and therefore do not have a known market value – these are known as **non-market effects** and typically include all aspects of public goods (e.g. clean air, open space).

A range of market and non-market values associated with waterways is provided in Figure 2. Note that the descriptions provided on the right side of this figure are examples of values rather a complete list. For example, the value of amenity may be evident within property values but are not in any way confined to them.

Figure 2. Values associated with waterways



Source: OECD (1995)

2.2.1 Externalities

In the broadest terms an **externality** is a cost or benefit that is incurred by a third party who did not choose to incur that cost or benefit. However, many economists narrow this definition to a cost or

benefit arising from an economic transaction that falls on people that do participate in that transaction (McTaggart, 1999). Non-market values are therefore externalities since the benefits and costs associated with them are not directly captured within a market transaction, and therefore remain unpriced.

Externalities can be either positive or negative. A positive externality raises the economic welfare of a party that is external to the action. For example, when a property owner installs a rainwater tank the benefits to improving the downstream waterways are accrued by anyone who values the health of these waterways. The value of this improvement does not form part of the transactions associated with the installation of the rainwater tank, and are therefore external to it.

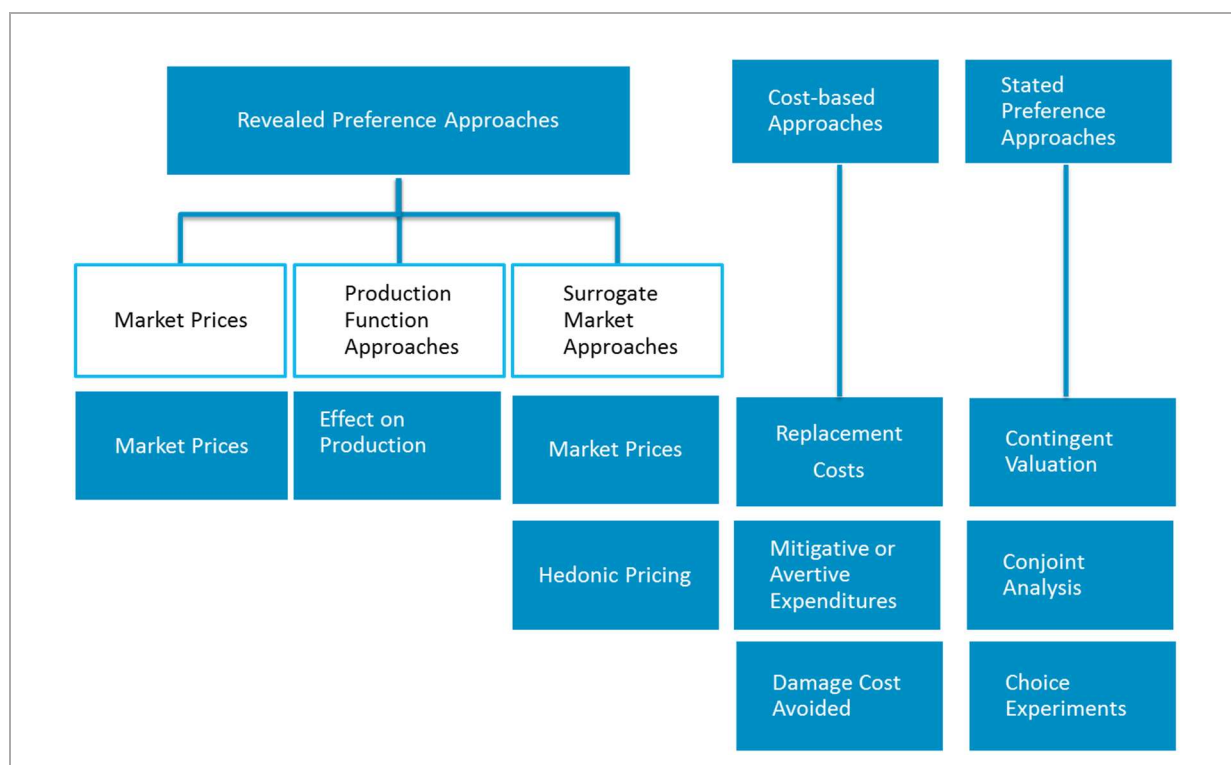
A negative externality lowers the welfare of a party that is not directly involved in the action or transaction. For example, a property owners' decision to cover a significant portion of their land with impervious surfaces contributes to negative impacts on the downstream ecology in the form of pollutant loads and altered hydrology of waterways. Those within the community who value the waterway experience this impact but have no part in the landholder's decision nor the costs involved in the action.

Since the impact of the action is not captured directly in market transactions, prices do not reflect the value of these benefits and costs. Other valuation methodologies are therefore required to price these externalities.

2.3 Valuation methodologies

A variety of techniques are available for estimating market and non-market values (externalities), including revealed and stated preference approaches plus cost based methods (see Figure 3). Note that regardless of whether they are derived from market activity or otherwise, all techniques in some way seek to assess Willingness To Pay for some incremental improvement in well-being or Willingness To Accept payment (or compensation) for some incremental loss of well-being.

Figure 3. The different approaches to economic valuation



Source: Based on *Value* by the IUCN (2003)

Revealed preference (RP) techniques rely on observations of peoples’ actions in buying and selling goods and services that are in some specific way related to the non-marketed impact under consideration. For instance, the hedonic price method is one RP technique that uses peoples’ preferences for housing – as reflected by the prices paid for property – to infer the values they hold for environmental and social factors that affect house prices but which themselves are not marketed directly. The travel cost method is another RP technique and uses expenditure on travel as a way to infer the value of different site characteristics for recreation, based on how much people are willing to pay to visit the area. RP techniques are best suited to valuing use values.

Stated preference (SP) techniques involve people being asked questions in the format of a survey regarding the strength of their preferences for specified environmental or social changes. The questions are designed to focus on the trade-offs people are willing to make between environmental and social improvements and their personal wealth and well-being. People express their preferences through their Willingness to Pay (WTP) or Willingness to Accept Payment (WTA) for achieving gains or accepting losses. This is made possible by creating a hypothetical market such as a voluntary payment or a levy to ensure government action to achieve a gain in environmental quality. SP techniques include ‘choice-modelling’ and the ‘contingent valuation method’ and they are the only techniques capable of capturing use and non-use values.

Cost based methods generally rely on reference to the market values of costs that would have otherwise been incurred to achieve an equivalent benefit. For example, the value of water saved by IWCM interventions is often assessed with reference to the avoided costs of providing water through conventional centralised processes. Cost based methods make reference to market prices and are often supported by better data than stated or revealed preference approaches. They are a lower-bound measure of benefit and should only be used as a measure of value where there is confidence

that a cost would have otherwise been incurred that would have resulted in a net benefit (i.e. benefits exceed costs).

Each method has pros and cons which depend on the specific application, and no method is perfect. However, it is important to be clear about what attribute is being valued, the beneficiaries, and the method being used.

2.4 Benefit transfer

Values for non-market goods and services can sometimes be inferred from the results of existing valuations for similar resources in other locations. This process is commonly referred to as 'Benefit Transfer'.

The use of Benefit Transfer in economic assessments has been explored by a number of economists, most notable being Smith (1992) and Desvovges, Naughton and Parsons (1992).

The latter authors suggest four criteria that must be satisfied before values are transferred from an original study to the appraisal of interest:

- the original study must be based on adequate data
- the original and new locations must offer similar experiences or opportunities to a similar spectrum of households (the socio-economic context is similar)
- the benefits to be valued at the new site must be similar to those valued at the original site; and
- the original study must contain regression analysis of value (measured by willingness to pay) as a function of socio-economic and environmental variables.

The essence of these criteria is that the studies should be sound, that the sites satisfy the common-sense requirement that they be 'comparable' and that there be sufficient information to allow systematic adjustment for differences between sites (Read Sturgess and Associates 2000).

Provided these criteria are met there are a number ways that Benefit Transfer can be applied (see Table 1).

Table 1. Types of Benefit Transfer

Types of Benefit Transfer Method	Description	Example
Single point value transfer	A single value is transferred without adjustment from source study to target site	A wetland protection value of \$50/person is transferred from case study site A to site B
Marginal point value transfer	A single value that allows for site differences is transferred	A wetland protection value of \$2/hectare/person is transferred from case study site A to site B. The values are adjusted for the size of the area protected.
Benefit function transfer	A valuation function is transferred, allowing for variety of site differences	A wetland valuation function, that involves the relationship between several attributes and the overall wetland value, is transferred from case study site A to site B
Meta-value analysis	Results of several studies are combined to generate a pooled model	Results from studies A, X, Y and Z are pooled to estimate a value for Site B

Source: Rolfe (2006)

2.5 Approach to reviewing literature

The literature review firstly involved casting a fairly wide net to gather as many relevant studies as possible, within subject matter relevant to IWCM. These studies were collected from the following sources:

- Aither’s internal economic literature database
- Melbourne Water’s non-market valuation database
- A list of study references provided by DELWP
- Internet search.

A two-step approach has been taken to reviewing the literature:

1. An initial screening to ensure literature is relevant and economic in nature
2. Detailed review to critique literature and extract relevant findings and economic data.

2.5.1 Key components of the literature review

For each study that passed the initial screening, a more detailed review was undertaken to:

- assess the purpose, type and findings of the study
- extract relevant data and information
- outline the conditions under which it may be applied

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- outline key uncertainties associated with the outputs
- discuss potential for double-counting in reference to IWCM applications.

This framework is presented in Table 2.

Table 2: Framework for assessing literature review

Component	What is involved?
Study Name	Title of study
Category of benefit	Use, non-use, etc.
Summary of study purpose	Brief snapshot of the purpose of the study
Type of study/assessment technique employed	Eg Contingent valuation, choice modelling, travel cost etc
Findings	Brief discussion of the key findings and outcomes of the study
Useful economic data and other qualitative results	Quantified economic data and qualitative information pertinent to IWCM assessments
Benefits Transfer conditions	Requirements for transferring values derived from study to other applications. For example, characteristics of waterways from study area.
Key uncertainties	Discussion of robustness of results and limitations of study
Potential for double-counting	Brief discussion of potential for double counting with other likely IWCM values

The key outcomes of the literature review, including recommendations for applying non-market values, are discussed in the following sections of this report.

3 Benefits from improved ecological health of waterways and bays

3.1 Description of benefits relevant to IWCM

Victoria is home to a myriad of waterways that vary in size, quality, and economic, environmental and social value. South of the Great Dividing Range, Melbourne's waterways feed into, and impact, Port Phillip and Westernport Bays, which are also host to a wide range of economic, social and environmental values.

For the purposes of this review, the definition of waterways is aligned with that described in Melbourne Water's Healthy Waterways Strategy in which the term waterway refers "collectively to rivers, estuaries, and wetlands". We also consider the health of both bays within the region.

Urban development in Greenfield areas and increased densification of existing urban areas puts pressure on existing waterways. This is largely a result of the increase in impervious area that accompanies development, which results in increasingly more rapid conversion of rainfall to runoff entering waterways. The unnatural rate of runoff impacts directly on waterways (e.g. erosion and altered flow regime) and carries increased nutrient and pollutant loads.

By undertaking actions that aim to slow, retain, and infiltrate runoff, IWCM provides opportunities to reduce the impacts described above and improve the quality, volume, and rate of inflows to waterways and bays. IWCM interventions also provide opportunities to reduce potable water consumption by making better use of stormwater and wastewater resources. These interventions therefore have the potential to improve the ecological health of waterways, along with the social and economic values that are derived from them.

The focus of this section is the value to the community of improving the ecological health of the waterways and bays in the Melbourne region. The following description taken from Flint et al (2012) provides a relevant definition of ecological health for waterways:

Simply, a healthy river (or healthy aquatic ecosystem) is a river in good condition (Karr, 1999). Describing the characteristics of a healthy aquatic ecosystem is more difficult (Norris and Thoms, 1999), however fundamentally a healthy aquatic ecosystem can be characterised by the presence of integrity, resilience and vigor in different components of the freshwater ecosystem (Rapport *et al.*, 1998, Karr, 1999). Essentially, after disturbance a healthy ecosystem is able to bounce back to a similar condition to what it was before disturbance.

The value of recreational opportunities within these water bodies is to a degree dependent on their health, however these are explored in the discussion of recreation and amenity benefits in Section 4. It is recognised that many of the benefits associated with improvements in the health of waterways exist as a 'bundle' composed of use and non-use values that are difficult to break down into components.

An overview is provided in each subsection of whether any Melbourne based and Australian studies have been identified. Findings of the most relevant studies are then outlined recommendations in relation to the use of these studies is provided.

3.2 Literature review findings

3.2.1 Key qualitative findings

The key qualitative findings of the literature review for the ecological health of rivers and streams, wetlands, and the bays that are relevant to IWCM are presented below.

Rivers:

- In addition to recreational values, rivers provide a range of non-market benefits including visual amenity, habitat for wildlife and biodiversity, waste assimilation, drainage, nutrient cycling, flood control, fire fighting, and cultural and heritage values (URS 2006)
- There are very few studies relating to the economic value of small urban waterways – most studies focus on large iconic rivers, often in rural settings
- In a meta-analysis of 16 choice modelling studies, Rolfe and Brouwer (2008) found that WTP per km of improvements tended to be lower in larger catchments, and higher when river health is in decline
- People's willingness to accept compensation (WTA) for a loss in waterway health attributes tends to be larger than their WTP for a commensurate gain in the same attribute (URS 2003). This suggests that preserving healthy waterways from a given level of degradation provides greater benefit than restoring degraded waterways.
- It is common to witness higher WTP responses for a waterway when it is assessed individually than when it is assessed as part of a group of waterways or other environmental improvements (reflecting embedding and framing effects) (van Bueren and Bennett, 2004). This suggests that aggregating assessments of WTP for individual waterways may overstate the community's combined WTP.
- Most environmental attributes (i.e. purely related to ecological health, not amenity, which is not necessarily directly correlated with ecological health) will have only small, if any, effects on property values. Buyers and sellers would need to be aware of the environmental characteristics, and these need to be included in the price of a property. Even where prices are affected by environmental attributes, it may be difficult to distinguish values using econometric methods because other attributes, many of which are correlated, also influence property prices (NOAA Coastal Services Center 2006a).

Wetlands:

- Wetlands generate values for both their owners and the broader community. Individual wetland owners receive benefits in the form of livestock grazing use, water storage and drainage, and in some cases, hunting and tourism. The broader community receives benefits in the form of recreational use, biodiversity and habitat, and a range of other environmental and social benefits (Bennett and Whitten 2002)

- Brander et al (2006) investigated 190 valuation studies from around the world that employed a range of different techniques. They found that on average woodland wetlands tend to provide greater benefits than freshwater marshes
- Brouwer et al (1999) undertook a meta-analysis study that found that the value of riverine wetlands is twice as high as lakes, marshes and swamps
- In an economic study of people's WTP to preserve damage to Tilley Swamp and to the Coorong wetlands (in South Australia) as a whole, Bennett et al (1998) found that people's WTP varied with differences in wetland size, and exhibited decreasing returns to scale with size (ie WTP per hectare decreased as area of wetland preserved increased). Brander et al (2006) and Woodward and Wui (2001) found a similar effect.

Bays:

- Poor water quality entering a bay can lead to, amongst other things, a loss of seagrass, which occur in shallow, sheltered coastal waters. They provide a range of ecosystem services including nutrient cycling, enhanced fishery productivity, habitat, coastal protection, carbon storage and erosion control (Barbier et al 2011)

3.2.2 Key economic data

The key economic data extracted from the literature review for the ecological health of rivers and streams, wetlands, and the bays that are relevant to IWCM are presented below.

An overview is provided in each subsection of whether any Melbourne based and Australian studies have been identified. Findings of the most relevant studies are then outlined and recommendations in relation to the use of these studies are provided in Section 3.3.6.

Rivers and streams

The literature review revealed some economic data relating to ecological health of rivers and streams in Australia, but no direct studies associated with the non-market values of rivers and streams within the Melbourne region. Findings of the most relevant studies are provided as follows.

Rolfe and Broewer (2008) undertook a meta-analysis¹ of 19 Choice Modelling studies focussed on river health across five Australian states and territories (including some of the studies discussed later in this section). As stated in the study, "the accuracy of benefit transfer can be further improved by pooling data from a number of studies to allow systematic analysis". Willingness to pay for attributes across the studies were converted to a common metric of \$ per km of river in good health², expressed as a

¹ Meta-analysis is the statistical analysis of the summary findings of empirical studies

² This metric is as described in the study and may seem somewhat confusing given the attributes presented. For each attribute, "in good health" may best be interpreted in reference to the attribute rather than the overall river. For example, waterbirds "in good health" may refer to a population of waterbirds that would be found on a healthy river of similar scale. In addition, the 'River Health' attribute is a generalised category that would consist of elements of the other attributes, and should not be used in conjunction with them.

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one-off upfront payment. Key economic data derived from this analysis were as follows (all expressed as WTP per household per km of waterway in good health):

- River health: \$2.10
- Recreation: \$6.54
- Vegetation: \$3.51
- Native Fish \$4.75
- Waterbirds \$1.49

A choice modelling study of the Great Southern Region and Fitzroy Basin waterways (Van Bueren and Bennett 2004), produced the following relevant findings:

- WTP for waterway health of \$0.08 per 10km restored per household per year. Analysis suggested that this figure is appropriate if applied to a national population (allowing for 67% proportion of non-respondents), and may be up to 25 times greater per household if only applied in a regional context using Benefit Transfer of \$2.00 per 10km restored per household per year.
 - As a present value³ (to provide a comparison with the other one-off WTP payments generally shown here), this equates to \$0.11 to \$2.72 per household per km restored, depending on scaling for regionality – note that this is comparable with the Rolfe and Broewer findings discussed earlier (\$2.10 per km per household)
- WTP to prevent species extinction of \$0.67 per species per household per year. This figure may be twice as large if used in a regional context.
 - As a present value this is \$9.11 – \$18.21 (A\$ 2015) per species per household

A choice modelling study by Bennett and Morrison (2001) investigated the environmental attributes of five “representative rivers” in NSW. The average response rate for the surveys was 38%, and the authors suggest that extrapolation of these values to the broader population should therefore not be greater than 38% of households. In most cases, values were estimated for ‘in catchment’ and ‘out of catchment’ population samples. The ‘within catchment’ values are likely to involve a greater degree of use values such as recreation than out of catchment samples.

The key attribute values for each river are presented in Table 3.

³ Discounted at 6% over 20 years

Table 3. Choice modelling study of improvements to NSW rivers (expressed as one-off payments)

River	Representative Group	Value per 1% increase in length of river with healthy native veg and wetlands per HH	Value per unit increase in the number of native fish species present per HH	Value per unit increase in the number of waterbird and other fauna species per HH	Value of increasing water quality from boatable to fishable across river per HH	Value of increasing water quality from fishable to swimmable across river per HH
Bega	southern, coastal	\$2.32 (within), \$2.61 (outside)	\$7.37 (within), \$6.27 (outside)	\$0.92 (within), \$0.87 (outside)	\$53.16 (within), \$30.10 (outside)	\$50.14 (within), \$38.72 (outside)
Clarence	northern, coastal	\$2.02 (within), \$2.61 (outside)	\$2.02 (within), \$2.02 (outside)	\$1.86 (within), \$0.87 (outside)	\$47.92 (within), \$30.10 (outside)	\$24.73 (within), \$38.74 (outside)
Murrumbidgee	southern, inland	\$1.45 (within), \$2.17 (outside)	\$2.58 (within), \$3.81 (outside)	\$1.59 (within), \$1.80 (outside)	\$53.43 (within), \$30.50 (outside)	\$20.35 (within), \$60.68 (outside)
Gwydir	northern, inland	\$1.49 (within), \$2.01 (outside)	\$2.36 (within), \$3.43 (outside)	\$2.36 (within), \$0.87 (outside)	\$51.31 (within), \$29.19 (outside)	\$60.21 (within), \$30.35 (outside)
Georges	Urban	\$1.51 (within)	\$2.10 (within)	\$0.87 (within)	\$47.92 (within), \$30.10 (outside)	\$24.73 (within), \$38.724 (outside)

Source: Bennett and Morrison (2001)

Being an urban river, the Georges River is probably most relevant to the majority of IWCM assessments (where impacts on a major urban river are expected). It is 96km long, so:

- Improvements in native vegetation represent a benefit of about \$1.60 (A\$2.30, 2015) per km per household

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- Improvements in water quality from boatable to fishable represent a benefit of \$0.31 (A\$, 2015) per km per in-catchment household, and \$0.50 (A\$0.71, 2015) per km per out of catchment household
- Improvements in water quality from fishable to swimmable represent a benefit of \$0.26 (A\$0.37, 2015) per km per in-catchment household, and \$0.57 (A\$0.71, 2015) per km per out of catchment household
- Each increase in native fish species provides a benefits of \$2.10 (A\$2.96, 2015) per household
- Each increase in waterbird or other fauna species provides a benefit of \$0.87 (A\$1.23, 2015) per household.

A similar choice modelling study was undertaken in Victoria for improvements in the environmental health of the Goulburn, Moorabool, and Gellibrand Rivers (Bennett et al, 2008). It estimated the following WTP (as a one-off payment):

- \$5 per % increase in fish species and populations from a pre-settlement baseline
- \$3 per waterbird/other animal species to sustain populations
- \$3-\$6 per % increase in length of river with healthy native riparian vegetation, representing between approximately \$0.80 to \$3.00 per km per household.

Other waterways studies found the following:

- A choice modelling study of environmental improvements in waterways in Lachlan, Namoi, and Hawkesbury-Nepean catchments in NSW (Mazur and Bennett, 2009) found WTP of:
 - \$0.83 - \$1.29 per km of healthy waterway per household
 - \$4.51 - \$8.11 per native species protected per household
- A choice modelling study of improvements in the George Catchment and Bay in north east Tasmania (Kragt and Bennet 2009), found the following WTP outcomes:
 - \$7 - \$12 per household per species of rare animal or plant protected
 - \$3.5 - \$5 per km of additional riverside vegetation
- A study examined the link to 'quality' natural habitats, as opposed to man-made park-like features and property prices in Tuscon, Arizona (Bark et al., 2005). The authors found that homebuyers were willing to pay 20 percent more to live near a riparian corridor that is densely vegetated with tree species that are reliant on perennial water flows. This represented a \$47,000 price premium in 2005 dollars.

Wetlands/waterbodies

The literature review revealed some economic data relating to ecological health of wetlands, but no direct studies associated with the non-market values of wetlands within the Melbourne region. The most relevant studies identified include the following:

- Conservation of 5 NSW wetlands (Streever et al, 1998) assessed WTP through contingent valuation to conserve a wetland in respondents' local area of \$124 per household per year for 5 years

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- Valuing improvements in wetland quality – Macquarie Marshes NSW (Morrison et al, 1999): this Choice Modelling study found WTP of \$0.05 per additional km² (\$0.0005 per hectare) of wetland preserved per household, or roughly \$2,000 per hectare total (2015).
- WTP to preserve Tilley Swamp and Coorong wetlands (Bennett et al, 1998): WTP to conserve Tilley Swamp was found to be \$130 per household (\$0.8 per hectare per household across 1600 hectares, 2015) for Tilley Swamp and \$200 per household for the entire Coorong (Ramsar listed, \$0.04 per hectare per household across 4,600 hectares, 2015).
- A study of wetlands on the Murray River associated with the Barmah Forest (approx. 29,500 hectares) by Stone (1992) determined a value of approximately \$3,000 per hectare (\$A3,700 2015), which equates to roughly \$0.0015 per hectare per Victorian household (2015).
- Brander et al (2006) undertook a meta-analysis study of wetlands and estimated the average value of wetlands to be approx. \$6,000 (A\$) per hectare (\$7,400 2015). This would equate to approximately \$0.0037 per hectare per Victorian household

Bennet et al (2001) undertook a study of WTP for habitat management in the Upper South East in South Australia and found that households within Adelaide were willing to pay \$1.41 per 1000 ha of wetlands conserved (\$0.0015 per hectare per household, 2015), whereas households in the Upper South East were willing to pay \$0.45 per 1000 ha (\$0.0006 per hectare per household, 2015). This represented a range of between \$400 and \$1,000 per hectare for South Australian households.

Box 1: Cost based approach to estimating value of wetlands based on pollutant assimilation

Melbourne Water has an offset scheme in place to manage nutrient loads to waterways and the bays. Recognising that reducing nitrogen results in reduction in other pollutants loads, nitrogen removal is used as a surrogate for nutrient load reduction in general. Developers are required to manage excess pollutant loads generated by the development on-site, or purchase nitrogen offsets if onsite management is not technically or financially feasible.

The offset price is based on works that Melbourne Water would be required to undertake to remove pollutants prior to stormwater entering the waterways and bays, if no other interventions are put in place. These works involve the construction of large wetlands, which then must also be maintained at a cost on an ongoing basis (although these ongoing costs are not factored into the offset value).

The offset value was based on an analysis of five potential wetland sites that were selected for a range of community outcomes other than nutrient reduction. The capital cost (including land) per kg of annual TN treated ranged between \$323 per kg to \$6,645 per kg, with a weighted average of \$3,926 per kg across the 5 sites. The offset figure is expected to be based on the most expensive wetland (\$6,645 per kg), to provide maximum incentive for developers to manage pollutants onsite (and therefore avoid the offset cost).

Some of the implications of adopting this value as a measure of the benefits of pollutant reductions measures are discussed further in Section 3.3.5.

Bays

The literature review revealed very little economic data relating to ecological health of bays, and no direct studies associated with the non-market values of Port Phillip and Westernport Bays. The following was found to be of relevance:

- In a choice modelling study of the George Catchment and Bay in NE Tasmania (Kragt and Bennett 2009), a value of \$0.10 per ha of improvement in seagrass per household was found
- Wastewater treatment upgrade in Vaucluse, Sydney (Gillespie and Bennett, 1999) indicated a WTP of between \$70 and \$140 per local household to avoid bay impacts of an existing wastewater plant, which would include the value of lost recreation and ecological health
- Landry et al (2003) found that changes in beach condition have a negligible property price impact on properties located beyond about 500 metres away from the shoreline
- Landry & Hindsley (2011) conclude that the influence of beach quality on property prices becomes insignificant beyond 300 metres from the shoreline.

Melbourne Water's Nitrogen offset value is driven largely by capital costs required to reduce pollutants to receiving waterways, including Port Phillip Bay. The use of this value for economic valuations is discussed further in Section 3.3.5.

3.3 How can these findings be used in IWCM planning?

3.3.1 How does IWCM lead to benefits from improvements in the ecological health of waterways?

Both the rate and quality of stormwater runoff will impact on the ecology of the waterways that receive it. Typically streams in the Melbourne region would only receive direct overland runoff from areas near the stream between approximately 1 to 12 days per year in natural or near natural conditions (depending on the rainfall range). By contrast, when a catchment is urbanised adopting conventional stormwater practices, streams receive runoff 10-20 times more frequently from all parts of the catchment connected to the stormwater drainage system (Fletcher and Walsh 2007).

As discussed previously, IWCM planning can reduce the extent and impact of impervious area that would otherwise accompany development, which results in rainfall rapidly entering waterways at unnatural rates, and carrying increased nutrient and pollutant loads. Ecological health tends to be non-linear in response to changes in these run-off variables, and beyond a threshold ecological health drops off rapidly.

Although ecological health indicators such as macro-invertebrate assemblages are useful ways of assessing the current and future ecological condition of a waterway, they are not the aspects of waterway health that the public at large identify with. Focus groups used to identify community preferences with regard to waterway health consistently point to improvements in numbers and diversity of native fish, animal, and plants associated with the waterway, and water quality improvements that facilitate recreational activities.

As a result, one of the key challenges in assessing the impacts of IWCM on waterway health is being able to quantify the biophysical change attributable to IWCM with confidence and in a meaningful way (i.e. the impact on environmental outcomes that the community values).

3.3.2 Based on the findings of the literature review, how can these benefits be assessed?

There are a number of key logical steps that are required for a reasonable economic assessment of benefits to be made:

1. A connection between the actions that are being undertaken and resulting biophysical changes needs to be understood and measurable in some way (for example, change in macro-invertebrate assemblages).
2. A logical connection between these biophysical changes and attributes of the waterways that are valued by the community needs to be made, along with an assessment of the magnitude of these changes (for example, avoiding the loss of 2 species of native fish). An understanding of changes relative to a no-IWCM base-case through time is important to assess the impacts in the change in trajectory of these items.

3. A connection between the change in attributes and the community's WTP for these changes. If Benefits Transfer is to be applied, this should be done with consideration to the conditions outlined in Section 2.4.

The review undertaken here should provide a guide to which attributes of waterway health need to be assessed (step 2), and how they may be monetised (step 3).

However, the vast majority of non-market valuation studies investigating the value of waterway health focus on larger rivers, which are often iconic and situated within a rural setting. This makes them relatively inappropriate for Benefit Transfer purposes when trying to value changes to individual small urban streams. Indeed, evidence that the broader community directly values the health of these smaller streams and creeks is, for the most part, lacking.

The contribution that a catchment filled with improved streams may make to a larger receiving river, such as the Yarra, is more likely to provide environmental benefits that are assessable and quantifiable as there is a better evidence-base for benefits to the broader community of improvements in more significant waterways. IWCM measures should therefore be assessed based on their collective contribution at a larger scale rather than for individual streams and creeks if the quantification of benefits is to be robust.

3.3.3 Which of the findings are most useful for IWCM planning and how should they be used?

Rivers

Based on the findings described in the previous sections, the following information provides a reasonable basis for recommending an approach where general waterway health improvements on a significant waterway can be assessed (expressed as one-off payments in \$2015):

- Meta-analysis of 16 choice modelling studies by Rolfe and Brouwer (2008) found an average WTP of \$2.10 per km of waterway in good health per household
- Values provided by van Bueren and Bennett indicate a WTP of between \$0.11 to \$2.72 (midpoint \$1.30) per km of improvement in waterway health per household
- Based on these, a WTP of \$1.00 to \$3.00 per Victorian household per km of significant waterway returned to good health, or prevented from degrading, appears reasonable
- These values should be multiplied across a relevant number of households depending on the significance of the waterway.

Where more specific attributes can be assessed for significant waterways, such as fish species or water quality attributes, it is recommended that values for the George River and/or Moorabool River be considered, as these both exist within an urban setting in large Australian cities and are more likely to satisfy benefit transfer requirements. Note that Georges River values (see Table 3) should only be applied to 38% of households when aggregating across Victoria to account for non-respondents, and 18% of households for the Moorabool River.

Wetlands

The literature revealed a range of wetland values depending on quality, size, and location. The typical range for preservation of wetlands was found to be between \$0.0005 and \$0.005 per hectare per household.

For a Victorian application, this would equate to between approximately \$1,000 and \$10,000 per hectare of wetland conserved, highlighting the large degree of uncertainty in these estimates.

Bays

There was insufficient evidence in the literature to estimate a WTP for ecological protection/improvement of the bays. The Nitrogen offset value partially represents a defensive expenditure to prevent ecological degradation of Port Phillip Bay. This is discussed further below.

Use of Nitrogen Offset Value

As discussed in Section 3.2.2, Melbourne Water's nitrogen offset value of \$6,645 per kg of total nitrogen (TN) is based on the most costly of five potential wetland sites aimed at reducing nutrient and pollutant impacts on downstream waterways and bays (as well as providing other community benefits directly derived from the wetlands). The management of total nitrogen (TN) typically results in adequate management of other pollutants, hence the nitrogen value is used as a proxy for water quality management in general. It is unclear whether this value is representative of the least cost method of abatement, and representative of the community's WTP for abatement in general. The most costly wetland was used for the offset value to provide an incentive for developers to manage pollutants onsite. The weighted average cost of the five wetlands is \$3,936 per kg of total nitrogen (TN).

The justification for the construction of wetlands described previously is largely based on meeting targets for nutrient reductions to Port Phillip Bay, primarily nitrogen. It is not evident that these targets are based on a Cost Benefit Assessment that compares the benefits of nutrient reductions with the costs of achieving them. This would require a comparison of the impacts of nutrient loads (eg algal blooms preventing beneficial use of the bay) with target reductions being met, and without. The reduction in impacts would represent the benefits of achieving the targets, which could be assessed against the costs of achieving them (eg construction of wetlands).

If it is taken as given, however, that the benefits of meeting these targets are greater than the costs of constructing the aforementioned wetlands required to meet them, then the wetland costs could be considered a lower bound measure of the benefits. That is, on average, the benefit of reducing pollutants to the bay would be worth at least \$3,936 per kg of Nitrogen avoided. However, this is further complicated by a number of other factors.

Wetlands constructed to reduce pollutant loads also provide additional benefits to the community in the form of habitat, amenity etc. which form part of the community's WTP for the wetlands. To the extent that similar benefits are not achieved by alternative nutrient reduction solutions (such as smaller wetlands and bio-retention on-site) the use of \$3,936 per kg as a measure of WTP for pollutant reduction may be overstated.

However, it should also be noted that IWCM interventions invariably involve pollutant reductions at the source, and thus offer protection to all waterways downstream of this point (not just beyond a wetland). There may therefore be ecological values associated with these upper catchment nutrient reductions that aren't captured by this value – hence the nitrogen offset value may be understated.

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The points in the previous paragraphs are somewhat in opposition, which reflects some of the uncertainty surrounding the use of these values that should be taken into account. This apparent point of contradiction is potentially a valuable topic for further investigation, particularly since TN reduction is at the core of waterway health policy, which would be well informed by better understanding the value of TN reductions and the least cost means of abatement.

Table 4: Summary of economic values that are useful for IWCM

Benefit	Valuation approach	Value	Factors to consider when applying:
Improved waterway health, or prevention of degradation	Willingness to pay studies	\$1.00 to \$3.00 per household per km of waterway returned to good health or prevented from degradation	<ul style="list-style-type: none"> - Applies to significant waterways only - Applied as a once-off benefit (present value) per household (applicable population should be based on significance of waterway) - sensitivity of results over a large range should be tested (+/- 50%)
Wetlands	Willingness to pay studies	\$0.0005 - \$0.005 per hectare of wetland conserved per household	<ul style="list-style-type: none"> - Based on studies of conserving large, natural wetlands. It is unlikely similar ecological values are present for constructed wetlands. It is also unclear if linear scaling is appropriate for applications to smaller wetlands - Applied as a once-off benefit (present value) per household (applicable population should be based on significance of wetland) - sensitivity of results over a large range should be tested (+/- 50%)
Improved water quality	avoided cost	\$4,000 per kg TN reduced	<ul style="list-style-type: none"> - to be applied as an indicative value of water quality improvement only if the value of pollutant reduction can not be assessed by reduction in impacts resulting from pollutant reduction - cannot be used in addition to valuing waterway improvements (this would be double-counting) - sensitivity of results over a large range should be tested (+/- 50%)
Improved waterway health, or prevention of degradation	Willingness to pay studies	\$1.00 to \$3.00 per household per km of waterway returned to good health or prevented from degradation	<ul style="list-style-type: none"> - Applies to significant waterways only - Applied as a once-off benefit (present value) per household (applicable population should be based on significance of waterway) - sensitivity of results over a large range should be tested (+/- 50%)

3.3.4 Where are the uncertainties and data gaps?

Each of the key steps outlined in Section 3.3.2 involves an amount of uncertainty, and each carries through to, and compounds, the uncertainty in the following step. It is therefore crucial that the connection between biophysical changes and environmental attributes be made, and that they are made with relevant expertise.

The biggest uncertainties that relate to IWCM are the value of preserving, improving, or reducing degradation of the ecological health of small, urban waterways (streams and creeks). This may be in part because the broader community are unlikely to attach significant values to individual streams. However, the community may hold significant value in protecting a whole catchment of such waterways – evidence for the economic value of this, however, is not readily available in the literature.

The community's WTP for improvements in the ecological health of the bays is also not well represented in the literature and is an area of uncertainty for this study.

WTP studies for wetland values tend to focus on conservation of existing wetlands rather than values associated with constructed wetlands. There may be considerable lag between the construction of wetlands and the emergence of values associated with them (for example, the time taken for waterbird populations to be established), if these values are to emerge at all. It is also not clear to what extent wetland values are dependant of scale (although some discussion of literature representation of this has been provided), and therefore whether unit values such as benefits per hectare can be applied in a linear way.

3.3.5 Potential for double-counting and other pitfalls

The key risk area for double-counting is the use of the wetlands costs analysed for development of the nitrogen offset value with other ecological improvements, as this already represents a WTP for aspects of these improvements. It is important when using this value to recognise that this is an estimate of the avoided cost of building wetlands to manage pollutants – this avoided cost cannot be added to the benefits of improved water quality if the wetlands would provide this improvement. For example, if we assume that IWCM prevents 1000 kg per year of TN entering the waterways, and this avoids the need for construction of a wetland required to manage this load at the cost of \$3,936 per kg, then the benefits to improvements in the ecology of the river and bay downstream of the (now) redundant wetland cannot then be added to the avoided costs of the wetland, since the wetland would have otherwise provided this benefit.

It is also important to remember that the TN value represents an annual load, not a static mass. For example, if IWCM actions reduce 1kg per year of TN from entering the waterways and bays each year, the value of this avoided cost is \$3,936 as a present value (with the caveats and uncertainties previously outlined)– *this figure is not applied each year to each kg of nitrogen avoided, it is applied once to the annual load avoided.*

Some care will need to be made to ensure that waterway benefits transferred from other studies do not include wetland components if these are to be valued separately in the analysis. Similarly, improvements in waterway health will often encompass a range of attributes such as native vegetation, animal species and water quality, so some care will need to be taken to ensure that these benefits are not counted twice – i.e. as individually estimated attribute value plus overall waterway health benefits.

3.3.6 Recommendations for further work

Based on the literature review and our understanding of the environmental externalities associated with IWCM, Aither recommends the following:

- Greater research into the community's WTP for improvements in the ecological health of small, urban waterways. As discussed, it is our opinion that the greatest benefit from this research would be gained from a stated preference study that assessed improvements in an aggregate of small waterways across a catchment, or across Melbourne in general, rather than one that focussed on individual urban waterways. This would provide useful quantifications that could be used to assess important issues such as appropriate water quality and flow standards, and appropriate offset values for on-site mitigation
- Greater dedicated research (such as a stated preference studies) into the community's WTP for improvements in the ecological health of the bays
- Further research into the value of TN abatement based on the ecological benefits of reducing TN loads and the community's WTP for those benefits. This should also include the value of preventing adverse outcomes such as algal blooms.

4 Amenity and recreational benefits provided by waterways and bays

4.1 Description of externality benefits relevant to IWCM

Webster dictionary defines amenity as “something that makes life easier or more pleasant”. Amenity therefore includes both use values such as recreation, as well as non-use values such as aspects of environmental health (including the waterway and bay values discussed in Section 3). For the purposes of this literature review, the non-use aspects of waterway amenity are discussed in the ecological health values section (Section 3), while the use aspects will be discussed in this section.

It is well recognised that outdoor recreational activities are an important component of personal and social wellbeing. Waterways and bays are used recreationally for swimming, fishing, sailing, recreational hunting, and boating. Waterside recreational opportunities include camping, running, cycling, and walking.

IWCM provides the opportunity for improved recreational opportunities through enhanced waterway environments and the provision of assets that can be used recreationally, such as wetlands and other water bodies.

4.2 Literature review findings

4.2.1 Key qualitative findings

The key qualitative findings of the literature review for the recreational value of rivers and streams, wetlands, and the bays that are relevant to IWCM are presented below.

- There is evidence supporting the recreational and amenity value of waterways, and clear linkages to improved waterway health enhancing these values in many cases
- Recreational values for waterways tend to be lower where accessible substitutes exist

4.2.2 Key economic data

The key economic data extracted from the literature review for the recreational value of waterways that are relevant to IWCM are presented below.

An overview is provided in each subsection of whether any Melbourne based and Australian studies have been identified. Findings of the most relevant studies are then outlined and recommendations in relation to the use of these studies are provided in Section 4.3.6.

Recreational use of rivers and streams

- Sinden (1990) used the travel cost method to analyse the recreational value of 24 sites along the Ovens and King Rivers in Victoria. He found the following results for recreational use value:
 - Day visitors: \$22 per day visit (\$41 2015)
 - Campers: \$37 per camping visit (\$69 2015)

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- Fishing: \$1,000 per recreational angler per year (\$1,854 2015) with average of 15 visits per year (approximately \$123 per visit in 2015 dollars)
- Bennett et al (2008) undertook a choice modelling study that investigated improvements in water quality suitable for primary recreation (along with other attributes described in Section 3.2.2). Only values for improvements in the Goulburn River were found to be statistically significant, with the following WTP values per percentage increase in river length suitable for primary recreation:
 - In-catchment: \$2.12 per household
 - Out-of-catchment (Melbourne): \$1.64 per household
- URS (2008) estimated the value of streamside recreation, based on an analysis of a number of overseas and local studies, to be between \$10 and \$70 per recreation day (\$12 to \$83 per recreation day in 2015)
- Mattinson and Morrison (1985) used contingent valuation to estimate the WTP for improved water quality through reductions in blue-green algae in the Peel-Harvey Estuary in Western Australia. The following values were found for improvements in water quality:
 - \$27.00 per resident per annum (\$57.00 2015)
 - \$1.40 per outside visitor per annum (\$2.90 2015).

Recreational use of wetlands and lakes

- A travel cost study to assess the value of visits to Albert Park Lake and Maroondah Reservoir (Lansdell and Gangadharan, 2003) found the following visitor values:
 - Albert Park Lake \$6 per visitor (\$8 in 2015)
 - Maroondah Reservoir \$12 per visitor (\$16 in 2015)
- Rolfe and Prayaga (2006) estimated the value of recreational fishing at three inland dams in Queensland using a Travel Cost study and found:
 - the benefit to occasional fishers was between \$60 and \$900 per person per fishing day (\$75 to \$1125 in 2015 dollars)
 - the benefit to frequent fishers was between \$220 and \$440 per person per fishing day (\$275 to \$550 in 2015 dollars)
- Duck hunting is a popular recreational activity in wetlands and other waterbodies. Whitten and Bennett (2002) undertook a Travel Cost study to estimate the average value of a duck hunting day, finding it to be \$42 - \$62 per hunting day (\$58 - \$85 in 2015 dollars)

Recreational use of bays

- URS (2007) undertook a travel cost study of coastal recreation. Based on this the following value estimates were obtained:
 - \$154 per coastal trip (\$183 2015)
 - \$48 per visitor day (\$57 2015)

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- A contingent valuation study of recreational fishing in southern coastal Queensland (Campbell and Reid 2000) found the following WTP values:
 - boat fishing \$17 per fisher per day
 - shore fishing \$16 per fisher per day
- Blackwell (2007) applied the travel cost method based on a survey of 250 beach goers at five Australian beaches in Western Australia and Queensland. It found that on average, in 2011 prices, the WTP per person per beach visit to be:
 - \$23 for residents (\$25 in 2015 dollars)
 - \$141 for visitors (\$155 in 2015 dollars)
 - This above values includes the total cost of running a car plus travel time costs. The same study also provides another set of values as a lower bound measure, where only the fuel costs of running a medium-sized car is included, at \$3.13 for residents and \$15.55 for visitors
- Raybould and Lazarow (2009) used travel cost outcomes to estimate the value of visits to Gold Coast beaches in Queensland. They found WTP to be:
 - between \$15 and \$45 per visit for tourists
 - Between \$0.50 and \$2.30 per visit for locals
- A hedonic pricing study (Burgan 2003) investigated the contribution of coastal living to house prices in Adelaide. Although not directly connected to IWCM outcomes, the study provides some indication of the value that amenity and recreational use of the beach may have as a component of property prices, and changes in the quality of the bay environment from IWCM may impact on these attributes. The study found the following marginal increases in property value (from a consistent base) :
 - \$53.90 per square metre for houses having direct access to the beach
 - \$68.10 per square metre for water views
 - \$14.20 per square meter for being within walking distance of the beach.

4.3 How can these findings be used in IWCM planning?

4.3.1 How does IWCM lead to recreational benefits of waterways and the bays?

IWCM provides the potential to improve and increase recreational opportunities and the amenity value of water related assets. By reducing the volume and rate of stormwater runoff to waterways, IWCM contributes to improvements, or reductions in degradation, of waterbodies, natural waterways, and the bays that receive them.

In addition, water-related assets that are created for IWCM purposes, such as ponds and lakes for retaining stormwater, also provide opportunities for new recreational pursuits.

The value of waterway-related recreation is dependent on the quality of the experience. This is in part a function of the environmental quality of the sites, but also of specific characteristics such as appropriate spaces to recreate, quantity of fish available for catching, access, existence of paths etc. Many of these may be unrelated to impacts of IWCM measures, for example cyclists may like to ride along waterside environments, but the existence of a path is likely to be of far more importance than the quality of the water. The availability and accessibility of substitute recreational opportunities is also an important factor, since the benefit from increasing recreation in one area as a result of IWCM initiatives is the marginal gain from the next alternative site for that recreation (rather than the full value) – i.e. people gain the full value of the new site, but give up the value of the alternative site.

4.3.2 Based on the findings of the literature review, how can these benefits be assessed?

The assessment of recreational and amenity benefits of IWCM initiatives ultimately depends on a combination of two key variables:

- Changes in the number of people using the waterways and bays for recreational or amenity purposes as a result of IWCM actions
- Changes in the value per person.

Similar to those described in Section 3.3.1, there a number of key logical steps that are required for a reasonable economic assessment of benefits to be made:

1. A connection between the IWCM actions that are being undertaken and changes to physical and biophysical outcomes. For example, regional water harvesting may provide a waterbody suitable for recreational pursuits, or reductions in runoff are expected to improve water quality in waterways by reducing pollutant loads, resulting in reductions in algal blooms and associated fish deaths in key waterways etc. The timing over which these changes are expected to occur should also be evaluated.
2. A logical connection between these biophysical changes and recreational opportunities needs to be made. For example, improvements in the waterway environment enhance riverside and instream recreational pursuits, reduce in algal blooms etc.
3. Estimate changes in the quantity of people using waterways and bays for various recreational pursuits. This may include a time component also (i.e. visitor days)

4. Assign economic values to each recreational use type, along with changes in values per visitor associated with improvements in waterway environment
5. Where increases in property values are to be counted, assign the price premium to the number of properties affected – ensuring that you do not count these residents in other assessments of benefits
6. Aggregate recreational and amenity benefits, ensuring there is no double-counting of benefits (including ecological benefits).

The review undertaken here should provide a guide to which activities need to be assessed (step 2), and how they may be monetised (steps 3 and 4). However, while this study provides an indication of the values that may be attributed to various recreational activity (step 4), it cannot provide a basis for estimating changes in the extent of recreation or use as a result of IWCM (step 3). This important step is required as part of the broader IWCM assessment.

4.3.3 Which of the findings are most useful for IWCM planning and how should they be used?

In general, the literature review encountered the same problem that existed for assessing ecological values – there are no studies that focus on Melbourne’s waterways, or small, urban waterways generally. More broadly, the literature on studies across Australia is lacking.

Almost all studies looked at the absolute value of recreational use, rather than marginal changes in value as a result of some change to the quality of the recreational environment. This limits the certainty in applying these values for IWCM assessments where improvements in the quality of the recreational experience are the outcome rather than increased recreational use.

The value of recreation and amenity is highly dependent on the specific waterway being assessed, meaning that wide bounds have been put around any general assessments of value for IWCM purposes. For IWCM planning, and based on the literature review, it is suggested that:

- Only the impacts on recreational values of significant waterways and waterbodies should be assessed when applying the values described here
- For additional recreational fishing:
 - The values of recreational fishing for waterways and wetlands range between \$60 and \$1,000 per fisher per day, with the majority at the lower end of this range. As a rough guide for IWCM planning, \$100 per fisher per day would be a reasonable starting point for a popular waterway
- For additional streamside recreation:
 - Streamside recreation is particularly difficult to estimate as it encompasses a range of activities including walking, jogging, cycling, picnicking etc. As a guide, a value of between \$10 and \$80 per visit is reasonable
 - For additional bay-related recreation:
 - Local visitors: between \$1 and \$20 per visit
 - Tourists: between \$10 and \$150 per visit

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- Marginal changes to these values need to be assessed for IWCM planning – the above values and visitor numbers should be estimated in the absence of IWCM measures, and adjusted upwards as the quality of the experience is improved by IWCM measures and the number of people using the waterways increases
- Sensitivity testing with wide upper and lower bound should be undertaken.

Table 5: Summary of economic values that are useful for IWCM

Benefit	Valuation approach	Value	Factors to consider when applying:
Recreational fishing	Willingness to pay studies, travel cost studies	\$60 - \$1,000 per visit	<ul style="list-style-type: none"> - lower end of range should be applied for most IWCM applications - value should be applied to new fishing visitors only - sensitivity of results over a large range should be tested (+/- 50%)
Streamside recreation	Willingness to pay studies, travel cost studies	\$10 - \$80 per visit	<ul style="list-style-type: none"> - based on significant waterways, unclear if applicable to smaller waterways - low end of range should be applied for these to be conservative - value should be applied to new visitors only - sensitivity of results over a large range should be tested (+/- 50%)
Bay-related recreation	Willingness to pay studies, travel cost studies	Local visitors: between \$1 and \$20 per visit Tourists: between \$10 and \$150 per visit	<ul style="list-style-type: none"> - value should be applied to new visits only - sensitivity of results over a large range should be tested (+/- 50%)

4.3.4 Where are the uncertainties and data gaps?

Many of the recreational values held by visitors to waterways and the bays are quite specific to the site, which introduces uncertainties when applying them to other sites using benefit transfer. This can partly be accounted for by expressing wide error bounds around values used, and testing the sensitivity of results from any analysis undertaken using high and low values.

The absence of Melbourne-based studies is a significant gap for the proposed uses for IWCM planning. In particular, as discussed in the ecological health section, a lack of studies relating to recreational uses of small urban waterways makes valuation difficult as benefit transfer conditions from non-Melbourne based studies (typically of larger waterways) are unlikely to hold.

There is also generally a lack of activity-specific economic data for waterway recreation, along with the relationship of the value of these activities to the quality of the environment in which they occur. Many IWCM interventions will not change the aggregate level of recreation, but rather enhance the quality of recreational and amenity experiences, primarily for local residents near IWCM assets or in waterways that benefit from them. There is very little economic evidence on the value of improved recreational quality associated with urban IWCM assets.

4.3.5 Potential for double-counting and other pitfalls

Many of the recreational values discussed here are in some way dependent on the ecological health of the waterways and waterbodies being used. There is therefore potential for double-counting ecological health benefits with recreational ones if both figures are applied.

Care should be taken when using property prices as a basis for valuation in conjunction with other recreation and amenity benefits. Property prices reflect people's willingness to pay for a range of benefits associated with the property, capitalised at a point in time. Properties near waterways and beaches provide the ability for owners to use these sites for recreation, which is often reflected in the price premium they pay for them. Including recreation and amenity benefits for these users in addition to estimates of price premiums (or property value 'uplift') would be double-counting benefits. Property prices may, however, provide a better signal as to the value of bundles of benefits provided by IWCM.

The impact of substitute environments for recreation is also a source of uncertainty. Improvements in a waterway environment may encourage visitors to shift from another site. The economic value of this change is therefore the marginal gain from this shift, rather than the full value of the visit to the new site. For example, assume that IWCM measures create improvements in downstream fishing conditions in waterways not previously used for fishing, and the value of this is estimated at \$80 per fisher per day. If the new users of this site shifted from a site that was valued at \$60 per day, the economic gain is only \$20 per fisher per day.

4.3.6 Recommendations

Based on the literature review and our understanding of the environmental externalities associated with IWCM, Aither recommends the following:

- Greater original research on the connection between IWCM outcomes and how this impacts on amenity and recreational value of specific activities
- Original research (revealed or stated preference studies) undertaken on the value of these changes in recreational quality and use of key Melbournian waterways and waterbodies, with clear linkages in the study designs to the types of changes expected from IWCM interventions.

5 Other social values from increased water use and availability

5.1 Description of externality benefits relevant to IWCM

Additional availability and security of water through IWCM has the potential to provide a number of benefits in situations where water is a limiting factor, either physically or economically.

Local capture and storage of stormwater and wastewater recycling provide the opportunity to replace current potable supplies, thus saving on costs relating to the production of water from centralised (or other) sources.

By diversifying the sources of available water, IWCM potentially provides additional water security and helps avoid the need for, and impacts of, water restrictions.

It also provides the opportunity to provide additional water for other uses, with consequential benefits. These include:

- Urban cooling, through additional shading provided by trees, and additional evapotranspiration by trees, plants and lawns. This reduces the “Urban Heat Island” effect which occurs as a result of urban areas being constructed from materials with high thermal storage capacity, such as concrete, and the removal of vegetation. A cooler urban environment provides a range of benefits including:
 - Reductions in heat-related health and psychological impacts
 - Reductions in impacts on infrastructure and services
 - Reduced energy costs
 - Reduced impacts on animals
 - General amenity benefits
- Amenity and recreational opportunities from additional and healthier green spaces. These include parks, gardens and sporting fields, along with private lawns and gardens.

These benefits are to a degree captured in property prices, resulting in improved property values when in proximity to enhanced green spaces. It is also worth noting that these benefits are available from increasing water use through centralised potable supplies also (see Section 5.3 for more on this) – IWCM actions such as passive irrigation may potentially provide a cheaper means of achieving these benefits.

5.2 Literature review findings

5.2.1 Key qualitative findings

Urban cooling

Health and social impacts of heat:

- Heat-related health problems include heat rash, heat oedema, heat syncope, heat cramps and heat exhaustion (WHO, 2008). Within the community the most vulnerable groups tend to be those with existing health or mental problems, the elderly, very young children, people with disabilities, indigenous communities, and homeless people (Brown et al, 2013)
- Prolonged periods of high temperatures can also interfere with daily activities as well as increase the potential for mistakes or injuries, reduce productivity, cause sleep deprivation, and reduce physical and mental performance (Brown et al, 2010)
- Loughnan et al (2010) found a significant correlation between hot temperatures and hospital admissions of people in Melbourne suffering Acute Myocardial Infarctions (AMI, aka heart attacks), along with the following:
 - On average, a 10.8% increase in AMI admissions on days greater than 30 degrees C
 - On average, a 37.7% increase in AMI admissions during short episodes of heat (when the 2-day average temperature is greater than 27 degrees C)
- Mentally ill patients are also particularly at risk during hot weather. Hansen et al (2008) found that hospital admissions for mental and behaviour disorders are positively correlated with ambient temperature above a threshold of 27 degrees C
- In the USA, Anderson et al (1997) found a significant correlation between violent crime and temperatures above about 32 degrees C

Heat-related impacts to infrastructure and services:

- High temperatures affect transport systems and infrastructure in a variety of ways. Trains and trams overheat, rails buckle, air-conditioning units are pushed beyond capacity, roads soften and warp, and buses and cars break down (AECOM, 2011)
- Electricity infrastructure capacity is driven by peak-load requirements, which is largely driven by energy required for cooling systems during hot days (AECOM, 2011). A cooler urban environment can therefore reduce this strain, reducing the need to augment electricity supply infrastructure.
- Increased energy demand also increases the frequency of system faults due to network overload (AECOM, 2011).

Trees and green space:

- Increased urban tree coverage may improve air quality by uptake of pollutants and airborne particles (Nowak et al, 2006)

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- Shading offered by trees in car parks in the US resulted in a local air temperature reduction of 1-2 degrees C (McPherson et al, 2002)
- A project by Manchester University found that increasing green space in cities by 10% reduced temperatures by 4 degrees C (Fisher, 2007)
- The cooling effect of urban forests is most important during very hot, dry periods, however this is when urban vegetation can be most water stressed (Norton et al 2014). The availability of irrigative water for the urban environment is therefore important to achieve urban cooling benefits
- Tree species that provide the most urban cooling and amenity benefits are often non-native and therefore may conflict with other habitat/conservation objectives
- Provision of shade can reduce overall exposure to UV radiation by 75% (City of Melbourne, 2010), resulting in reduced risks of sunburn and skin cancer
- A study of the impact of urban form on public health showed that the annual prevalence for 15 out of 24 diseases was lower for populations living in environments with nearby areas of green space. Ulrich (1984) found that post-surgical patients recovered more rapidly with a lower requirement for pain relief when views of green space were available
- Zhou and Rana (2010) investigated the benefits of green space, finding varying amounts of evidence for the following:
 - Recreational opportunities
 - Rendering aesthetic enjoyments
 - Promoting physical health
 - Improving psychological well-being
 - Enhancing social ties
 - Providing educational opportunities
- Bowler et al (2014) reported that cross-sectional studies have suggested positive relationships between green space and health however, identifying the causal pathway can be complex. In order to objectively assess whether or not there is an 'added benefit' from green space, research studies need to investigate if there is a difference in the health benefits of an activity in a natural environment (e.g. a park) compared with the same activity in a more synthetic environment (e.g. a gym)
- Lee et al (2010) undertook a literature search of academic and grey literature for studies and reviews of the health effects of green space. They found that although most studies reported beneficial health impacts, "there is weak evidence for the links between physical, mental health and well-being, and urban green space. Environmental factors such as the quality and accessibility of green space affects its use for physical activity. User determinants, such as age, gender, ethnicity and the perception of safety, are also important. However, many studies were limited by poor study design, failure to exclude confounding, bias or reverse causality and weak statistical associations"

5.2.2 Key economic data

Where IWCM results in the provision of water for green space and urban forestry outcomes that would otherwise have been infeasible or cost prohibitive, the benefits of these outcomes can, in theory, be assessed directly (ie benefits directly derived from urban green space such as recreation).

Where an alternative water source (such as from the centralised network) is available and its use for green space or urban forestry would provide net benefits, the avoided cost associated with this is the appropriate measure of benefit of water sourced from IWCM (discussed further in Section 5.3.2).

Data for use in both methods is presented here.

Urban Cooling Benefits

Health:

The following parameters provide a useful basis for estimating medical treatment associated with a change in ambient temperature.

Table 6. Heat impact versus temperature relationships

Impact	Incidence rate	Unit
Ambulance Attendance - Heat related	0.09	Per 100,000 persons per 1 degree above 30.0 degrees C
Ambulance Attendance - Heat Wave	1.48	Per 100,000 persons per number of days in heat wave (i.e. 3 consecutive days above 35.0 degrees C)
ED Presentations, aged 64-74 yrs	0.52	Per 100,000 persons per 1 degree above 30.0
ED Presentations, aged 74 yrs +	3.82	Per 100,000 persons per 1 degree above 30.0
Mortality	0.08	Per 100,000 persons per 1 degree above 30.0

Source: AECOM (2012)

For example, if an urban forest reduces a given day's temperature from 33 degrees to 30 degrees for 50,000 residents, it is expected this would result on average in a reduction in ambulance attendances of $(33-30) * (50,000/100,000) * 0.09 = 0.14$ attendances for that day.

The following costs of the above impacts can then be applied to estimate the cost of medical treatment for each incremental change in ambient temperature (and hence avoided costs for reductions in temperature). For the above example, the cost saving from reduced ambulance attendances without transport would be $0.14 * \$300 = \42 for that day.

Table 7. Costs of medical treatment

Cost component	Unit Cost
Ambulance Services	\$300 (visit only, no transport) - \$1,000 (with transport)
Medical Services (non-hospital)	\$20 - \$150 per visit depending on treatment and time
Emergency Department Treatment	\$270 per patient admitted
Hospitalisation	\$3,500 - \$4,000 per treatment episode
Loss of life	\$3.5 million per statistical life, or \$151,000 per statistical life year (reduction in life expectancy in years)

Source: AECOM (2012)

Energy:

Citipower (2009) estimate that for each degree above 20 degrees C, an additional 0.228 GWh is consumed across their customer base. Based on average electricity price of \$0.26 per kWh, this is approximately \$60,000 per degree per day above 20 degrees Celsius across Citipower's service area.

For an individual IWCM project, by assessing the expected reduction in ambient temperature and estimating the number of houses affected as a proportion of Citipower's customer base, the energy saving from urban cooling could be estimated (with an assumption that Citipower's energy/temperature relationship is generally representative of Melbourne more broadly).

Other energy findings include the following (noting that these would need to be attributable to IWCM measures to be relevant):

- Moore (2012) estimated annual energy savings through reduced cooling at \$5.10 per tree (based on an urban forest of 100,000 trees saving 30 kWh per year)
- Strategic planting three shade trees per building lot can save annual heating and cooling costs by an estimated \$50 to \$90 per dwelling (City of Melbourne, 2012)

Other tree and green space benefits:

- A US based software package called i-Tree STRATUM was trialled in two Melbourne municipalities to quantify the economic benefits of street trees, which included energy, stormwater, carbon sequestration, air quality, and aesthetic/other benefits. Total benefits were found to be between \$90 and \$160 per tree, of which \$80 - \$120 belonged to the "aesthetic/other category".
- A study aimed at investigating the economic value of urban trees in Adelaide (Killicoat et al, 2002) estimated total benefits per tree to be \$171 with the following breakdown:
 - Energy savings: \$64

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- Air Quality: \$35.50
- Stormwater: \$6.50
- Aesthetics/others: \$65

Improved property prices:

- A 2011 study of property price determinants in Tucson, Arizona (Bark et al., 2011) found that after having controlled for the influence of a range of other house price determinants, the level of greenness in the suburb was positively correlated with property price. Homebuyers were willing to pay almost \$18,000 (an 8% premium) more for the greenest lot in a development, and \$12,000 (a 5.6% premium) to live near the greenest riparian corridor compared to the average.
- A recent study of Australian property prices (Rosetti, 2013) found a positive relationship between a satellite image-derived measure of greenness for a postcode, and the value of properties in that postcode. The author controlled for a wide range of other influences on property price, and modified the statistical model to control for the fact that postcodes with relatively higher property values are likely to be a 'causal factor' on relative greenness: relatively more wealthy residents are likely to maintain gardens and councils in those locations are likely to have larger operating budgets with which to maintain green open space. Having controlled for each of those influences, the study found that increasing the 'intensity' of greenness by one standard deviation would result in an increase in property prices for that suburb of between 8 and 15%.

Water supply reliability:

- In a Contingent Valuation study into households' WTP to avoid water restrictions (in addition to normal water bills), Cooper et al (2013) found the following:
 - Households with lawns were willing to pay between \$152 - \$263 per year
 - Households within water-rich cities (those that have experienced relatively lower severity or less recent water restrictions) expressed a WTP of \$158 - \$269 per year to avoid water restrictions, whereas households within water-poor cities (those with a more recent history of relatively severe water restrictions) expressed a WTP of \$137 - \$247 per year
 - Low income households generally expressed a lower WTP of \$106 - \$216 per year, compared with \$181 - \$291 per year for high income households
- Blamey and Bell (2007) undertook a choice modelling study to assess WTP for increased water supply reliability in South-East Queensland. They found a WTP of \$134-\$174 per household per year
- A contingent valuation study (Weller et al 2008) into the impact of water restrictions on use of sports grounds (which can limit their functionality and therefore the health benefits of those unable to use these assets) found the following WTP to avoid the effects of water restrictions by allowing watering at pre-drought levels:
 - Half of the respondents indicated they would be willing to pay \$10
 - A quarter of the respondents would be willing to pay \$25

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- A tenth of the respondents would be willing to pay \$100
- 15% of respondents were not willing to pay any amount.

Avoided Long Run Marginal Cost of water supply

The Long Run Marginal Cost (LRMC) of water supply is a calculation of the cost of supplying an additional volume of water, taking into consideration all future requirements in meeting this additional demand including the need to augment water supply infrastructure as well as ongoing operational costs in meeting this additional demand. Any water savings resulting from alternative supplies or efficiency gains effectively avoids the operating cost associated with producing the water from a centralised source, and pushes back the timing of augmentations to meet demand, reducing the discounted cost (present value) of these augmentations. The avoided LRMC therefore provides an estimate of the benefit of additional water provided by IWCM initiatives.

Calculations (2014) of LRMC provided by Melbourne Water based on 50 year demand projections are \$0.46 per kL for average rainfall projections, but range between \$0.20 per kL under projections of higher rainfall and \$1.20 per kL for projections of drier conditions (including scenarios predicted under climate change). These values are currently undergoing review and are expected to be updated soon. In specific cases, IWCM may also result in savings to the local transfer and distribution system (for example, deferring or avoiding pipe capacity upgrades). These avoided costs can be added to LRMC when applicable as they do not form part of its calculation.

Avoided Long Run Marginal Cost of wastewater disposal

Similar to LRMC for water supply, the LRMC for wastewater disposal is a calculation of the present value of the cost of meeting demands for wastewater disposal based on future operating costs and capital costs of augmentations. Where IWCM measures result in reduced volumes and loads being delivered to the Eastern Treatment Plant (ETP) and Western Treatment Plant (WTP), LRMC provides an estimate of the benefits (avoided cost) of this reduction.

Calculations provided by Melbourne Water (2014, currently under review) estimate the following LRMCs for the ETP and WTP over a 20 year horizon:

- Eastern Treatment Plant: \$0.67 per kL
- Western Treatment Plant LRMC: \$0.44 per kL

The above figures do not include local sewage network costs. Where individual IWCM measures are expected to avoid costs associated with these components of the sewage network, these should be added to the avoided LRMC cost.

These LRMC values are currently undergoing review and are expected to be updated soon.

5.3 How can these findings be used in IWCM planning?

5.3.1 How does IWCM lead to social values from increasing the availability and reliability of water supply?

IWCM aims to improve the management of water resources, much of which is focussed on reusing captured stormwater and recycling wastewater. This includes rainwater tanks, regional stormwater

reuse, wastewater recycling, as well as actions that reduce the need for water use such as improved efficiency of appliances and bio-infiltration to maintain soil moisture.

In addition to the downstream benefits to the environment discussed in previous sections, these actions serve to increase the supply of water available for use in residential homes and businesses, irrigating urban landscapes, and a range of other applications. In doing so they provide an alternative water source to conventional reticulated potable supplies, where these exist, which reduces the costs associated with the operation, maintenance, and future augmentation requirements of this system.

5.3.2 Which of the findings are most useful for IWCM planning and how should they be used?

Water provides the opportunity to provide a range of benefits to society. Of importance to economic cost benefit analysis of IWCM measures however, is the marginal benefit that additional water resources provide as a result of IWCM measures.

The marginal benefit of the increase in available water is always the lesser of:

- the direct benefit derived from using the water
- the cost of providing an alternative water source.

For IWCM planning, this implies the following:

1. Where a reticulated supply exists and the value of using the additional water from IWCM actions **exceeds** the LRMC of supplying it, then the avoided LRMC is the appropriate measure of marginal benefit received from the additional water supply
2. Where a reticulated supply exists and the value of using the additional water from IWCM actions **is less than** the LRMC of supplying it, then the value derived from the use of the additional water is the appropriate measure of marginal benefit
3. Where no other water supply exists that is not cost prohibitive (i.e. the combination of installation and LRMC outweigh the benefit of water provision), then the value derived from the use of the additional water is the appropriate measure of marginal benefit provided.

Note that points 1 & 2 above imply that where a reticulated source exists, the LRMC represents an **upper bound** on the marginal benefit of additional water provided by IWCM. This will be the case for the vast majority of IWCM applications.

Where the situation being addressed by IWCM initiatives is described by either point 2 or 3 above, then the value of water use should be assessed.

Quantifying this value requires that the causal linkages between increased water use and beneficial outcomes be understandable and measurable in some way. For example, for urban cooling benefits the following connections would need to be made:

- increased water availability allows additional lawns, plants and trees to be sustained
- this leads to increased evapotranspiration, resulting in reductions in urban temperatures of x degrees

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- the reduction in urban temperatures:
 - reduces various health ailments, resulting in reduced costs of treatment
 - reduces cooling requirements, resulting in reduced energy costs
 - improves the amenity of those within the area, which increases people's WTP pay for use and local real estate
 - increase productivity etc.

The findings described in Sections 5.2.2 provide some of these linkages.

The Rosetti study that correlates a suburb's 'greenness' with property prices provides a compelling case for the value of providing green space to local residents. The difficulty in applying this study as a measure of benefit lies in assessing what constitutes a "one standard deviation change in greenness" across a suburb. If the connection between increased water availability and this measure of 'greenness' can be established, the capitalised value to local residents of providing green space could be estimated with some confidence.

The studies on avoidance of water restrictions suggests that increasing water supply reliability to the point that it ensures water restrictions are avoided is valued at between approximately \$100-\$200 per affected household per year. This value should only be applied during periods where there is a high probability of water restrictions being enforced, which is a function of future expectations of rainfall and demand for water. An understanding of the likelihood of water restrictions obtained through suitable technical modelling is required to make this assessment.

Table 8: Summary of economic values that are useful for IWCM

Benefit	Valuation approach	Value	Factors to consider when applying:
Avoided reticulated supply costs	avoided cost	\$0.46 per kL of water	<ul style="list-style-type: none"> - apply where a reticulated water source could be used to produce net benefits - applies only if option provides a permanent change in water demand - cannot be summed with benefits of additional water use (benefit is the avoidance of costs associated with centralised supply) - currently under review and should be updated when better data is available
Avoided sewerage costs	avoided cost	<ul style="list-style-type: none"> - \$0.67 per kL of wastewater (Eastern Treatment Plant) - \$0.44 per kL of wastewater (Western Treatment Plant) 	<ul style="list-style-type: none"> - apply where a permanent change in wastewater volume is expected (benefit is the avoidance of costs associated with centralised treatment) - currently under review and should be updated when better data is available
Urban cooling - heat-related health impacts	avoided cost of treatment	\$1,270 per 100,000 people per degree above 30 degrees per day ⁴	<ul style="list-style-type: none"> - apply if LRMC approach not applicable - apply to each degree of urban cooling produced on each day above 30 degrees - does not include mortality impacts or additional impacts caused by heatwaves - sensitivity of results over a large range should be tested (+/- 50%)
Urban cooling - energy savings	avoided cost	\$0.24 per residence per degree above 20 degrees per day ⁵	<ul style="list-style-type: none"> - apply if LRMC approach not applicable - apply to each degree of urban cooling produced on each day above 20 degrees - sensitivity of results over a large range should be tested (+/- 50%)

⁴ Based on costs presented in Section 5.2.2

⁵ Based on Citipower costs presented in Section 5.2.2, and estimate of 250,000 residential customers connected to Citipower (Frontier Economics 2010)

5.3.3 Where are the uncertainties and data gaps?

There are very few good economic studies that seek to quantify the amenity benefits of green space, particularly to non-residents of an area. It is also difficult to separate pure amenity from some of the other benefits provided by green space described in previous sections.

While some attempt has been made to uncover the connection between temperature and community impacts such as health and energy use, better understanding of these causal links is required before good evaluations of benefits of reducing temperatures can be undertaken.

There is also some uncertainty surrounding the potential disbenefits of urban cooling in winter. More research is required to assess whether IWCM measures that encourage urban cooling adversely affect health, energy and other outcomes during the winter months.

5.3.4 Potential for double-counting and other pitfalls

The use of avoided LRMCs as a measure of the benefit of increased water supply should not be double-counted with the benefits provided by the use of that water.

As a measure of marginal benefit, LRMC should be used instead of water prices where possible (for the purposes of economic evaluation, as opposed to financial), as the latter includes non-marginal components and does not represent a true (avoided) marginal cost.

As was discussed in Section 4.3.5, care should be taken when using property prices as a measure of the benefits of additional water availability and green space, particularly if they are to be used in conjunction with other benefits. For example, a property with a connected water tank is likely to have reduced ongoing water bills. Theoretically this should increase people's WTP for the property. However, it would be double-counting to value this property value up-lift along with the benefits of reduced water use as the latter is already accounted for in the property price. The same argument applies to estimating any IWCM-related benefits to local residents at the same time as counting improved property values. In addition, since property prices reflect a bundle of benefits to the property owners, care must be taken when attributing improved property prices to IWCM actions alone.

5.3.5 Recommendations for further work

The increase in water supply provided by IWCM is often seen as an enabler for the provision of additional green space for the community, along with the recreational, amenity, and urban cooling benefits that this provides.

Although it is recognised that people hold positive values for green space in general, it is not necessarily the case that the cost of water is a significant constraint in providing these benefits. It is recommended the provision of green space should be the subject of a specific economic assessment (not necessarily as part of an IWCM assessment), recognising that water is one input to the provision of these spaces, along with land, labour, infrastructure and other items. When all benefits and costs of this are taken into account and it is shown that this is of net benefit to the community, the contribution of IWCM to this outcome (specifically to lowering the cost of water supply) should then be considered.

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To this end, a better understanding of the value of green space to the community, and specifically within a Melbourne context, gained through a dedicated WTP study would be of benefit in better understanding the magnitude of green space benefits.

More sophisticated portfolio or real options approaches might be considered to place a value on the risk management benefits provided by IWCM options, as an alternative to LRMC. Although not well developed or investigated in Melbourne, these approaches seek to understand the benefits of diversified water sources and flexibility to respond to changes in critical factors (such as rainfall, demand) as they become more certain, rather than being locked in to long-term decisions with uncertain outcomes.

6 Flood reduction benefits

6.1 Description of externality benefits relevant to IWCM

Floods are a recognised threat to the community, with a significant number of urban properties and assets at risk. Urban development results in a proliferation of impervious surfaces that substantially change the balance of the natural water cycle. Rainfall that would previously have infiltrated into the soil or evapotranspired instead generates stormwater runoff from roofs, roads, car parks and footpaths, which accumulates rapidly and in far greater volume than in an undisturbed catchment (Johnstone 2012).

Flood events are typically described with reference to expected frequency, or average recurrence interval (ARI). Intense and long duration floods tend to be less frequent but cause more disruption and damage than smaller, more frequent floods. Where these smaller events impact on human activities, they are commonly referred to as 'nuisance flooding'.

The benefits of reducing flood impacts through IWCM interventions can include reductions in:

- costs involved in building/upgrading drainage infrastructure
- physical damage to buildings, cars, and other assets
- disruption to services
- health impacts (physical and psychological)
- transport disruptions (road and rail) and other impediments to access (eg foot paths)
- consequential impacts to businesses and the economy.

A number of IWCM initiatives may contribute to mitigating flood risk, including stormwater harvesting, rainwater tanks, tree planting, rain gardens and vegetated open space and wetlands.

6.2 Literature review findings

6.2.1 Key qualitative findings

Damage to physical assets (direct damage):

- The most challenging component of the assessment of residential building damages is the relationship between flood depth and the value of the resultant damages. A number of variables influence the vulnerability of residential buildings to floods (e.g. depth, velocity, duration of inundation). However, the depth of flooding is the most commonly used indicator of flood damage (Aither 2013).
- Non-residential building losses are less about structural damage, and more about damage to contents. Floors are typically concrete slabs on the ground level and walls are often steel sheet, concrete, brick or concrete block that incur minimal damage relative to residential buildings (Blong and Gissing 2004).

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- The intrusion of water under pavements has long been recognised as affecting pavement life and durability. Excessive moisture in road pavements leads to deterioration in the durability of roads, and causes effects similar to a large increase in heavy vehicle traffic. In the severest cases, pavement life may be reduced by three-quarters (Bugden 1997).

Emergency Response and Repair:

- Typically, costs due to emergency response and repair are quantified as a percentage of direct tangible damage to residential, commercial and industrial buildings only. Given that many of the components of these costs pertain to emergency food and accommodation, or community support in the post-flood period, it is likely that rates will be higher for residential buildings compared with commercial and industrial buildings (Aither 2013).

Physical health impacts:

- Physical health impacts are both direct and indirect and depend on the type of flood. The impacts can include disease, injury and loss of life. Disease is the main health concern in slow rising and long duration floods due to poor sanitation and disease vectors. In flash floods and other situations where the impact is more immediate, most deaths are due to drowning while injury is usually a result of moving debris and high winds (Legome et al 1995).
- While there is always the possibility of lives being lost due to flooding the probabilities of this occurring in any one flood are small. For this reason loss of life is rarely assessed in flood damage assessments (Few et al 2004).

Psychological Health Impacts

- The impacts of flooding on psychological health are both immediate and long lasting, and include loss of sleep, anxiety, a reduced immune system response and increased susceptibility to certain illness. Flooding can also exacerbate existing chronic mental health impacts. Studies show these impacts are greatest in the elderly and low-income groups (Few 2004).
- A social survey in Scotland (Werritty et al 2007) found that intangible impacts (relating to non-material and/or emotional losses) were more important than tangible impacts (relating to material losses), and that immediate impacts were generally higher than lasting impacts. Interestingly, respondents ranked intangible lasting impacts still higher than the tangible impacts.
- These findings are supported by the UK Ministry of Agriculture, Fisheries and Food (1999) who state that:
 - "...impacts of flooding such as increased stress, health damage and loss of memorabilia can be far more important than the direct material damages to their homes and their contents..." Although this is acknowledged, it is also stated that "...there is currently no agreed method for evaluation of these indirect impacts..."

6.2.2 Key economic data

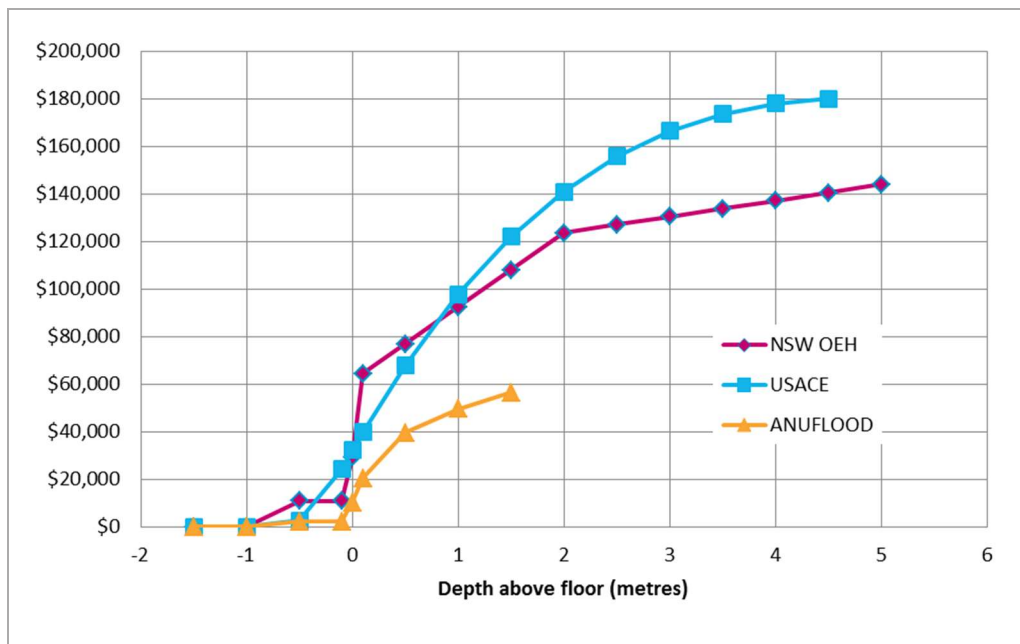
Damage to physical assets

Damage is commonly estimated based on developed depth-to -damage relationships, or alternatively as weighted unit damage per structure. Where the depth of flooding is available, either absolute or relative depth damage models can be used to assess damages. Three examples of depth damage curves that are used to estimate damage to residential buildings are presented below. These are:

- ANUFLOOD (absolute damages)
- NSW Office of Environment and Heritage (OEH) Residential damage calculation spreadsheet (absolute damages)
- FEMA/USACE depth damage functions (relative damages – expressed as percentage of building value).

A comparison of three depth damage curves suggests that ANUFLOOD estimates damages at roughly half of the other two approaches for most depths above floor (see Figure 4).

Figure 4. Comparison of residential depth damage curves (Aither, 2013)



Psychological impacts of flooding

Few studies have monetised the psychological impacts of flooding. However, a recent study in the United Kingdom determined the amount residents were willing to pay to avoid the impacts of flooding on mental health (Defra/EA 2005). The study, which used a stated preference technique, estimated that households would be willing to pay £200 (in 2002 GBP) to avoid the health impacts of flooding.

The assessment of intangible damage associated with psychological health is not common in economic appraisal. However, where the population at risk is high for relatively frequent events (e.g. 0.1% or 0.2% AEP events) physiological health impacts are likely to be substantial.

The economic value of physiological health impacts can be quantified by:

- estimating exposure – e.g. the population at risk for each flood event
- determining the vulnerability of receptors at risk– that is, economic impacts per person (vulnerability)
- Multiplying the population at risk by economic impacts per person for each flood event.

The exposure of the population can be estimated by multiplying average household statistics by the number of residential buildings inundated. The Annual Average Population Affected (AAPA) can be calculated in a similar fashion to Annual Average Damage (AAD) by integrating the population at risk probability curve (see below).

Calculating unit values for vulnerability is more difficult, and there is very little in the literature to provide estimates on this.

The use of non-monetary methods is more common. These methods include the development of indices and other approaches to provide a relative measure of impact. They are designed to support the assessment of damages as a separate measure of intangible impacts. They should not be combined with other monetary damages that have been assessed.

The Flood Rapid Appraisal Method (RAM) (DNRE 2000) recommends the use of a proxy measure for intangible health impacts based on the population at risk using the AAPA metric. It provides a measure of the expected average number of persons affected each year. This is calculated in the same way as AAD and is the area below the curve of a plot of population at risk and the probability of the flood event. Where vulnerable residents are at risk, such as the resident population in retirement villages and nursing homes likely to be affected, the Flood RAM recommends that these are listed separately.

A proxy method used in the UK is to undertake a vulnerability analysis and calculate the Social Flood Vulnerability Index (FHRC 2010). Vulnerability is the degree to which some people, or classes of people, are more susceptible to, or suffer a greater degree of harm from, some hazards. It differs from deprivation, which is a measure of the degree to which some people lack entitlements to access to resources, including income, but which also may include access to education, health and other social resources.

The intention of the index is to use common-sense methods to identify “hot spots”: combinations of people and events that will result in unusually severe impacts. A vulnerability index seeks to provide a way of predicting where those hot spots will occur.

Physical health impacts

There is presently a weak evidence-base to assess the health impacts of flooding. Relatively few rigorous epidemiological studies have been undertaken, and it is extremely difficult to assess the duration of symptoms and disease, and to attribute the cause to flooding without longitudinal data (Few et al 2004).

Jonkman (2007) has developed a generalised approach for calculating loss of life due to flooding. The work has been undertaken in the Netherlands and is suited to flooding situations associated with levee breach, rapidly rising water and no warning time. The method includes the following steps: 1) the assessment of physical effects associated with the event; 2) determination of the number of exposed persons (including effects of warning and evacuation); 3) determination of

mortality amongst the exposed population. He proposed three zones for assessing fatalities, the breach zone, the zone with rapidly rising water and the remaining zone. The model does not monetise loss of life, but rather provides an estimate of mortality as a proportion of the exposed population (or population at risk).

The United States Federal Emergency Management Agency (FEMA) do monetise injuries and fatalities in their benefit cost models to evaluate hazard mitigation projects for earthquakes, hurricanes, tornados and wildfire. However, injuries and fatalities are not assessed for assessments of flood damages.

Inconvenience and disruption

This category of impacts has market prices and can readily be quantified, but is rarely distinguished and assessed in the flood risk assessments performed in Australia. Rather, analysts group this category of loss with other indirect impacts, and calculate any impacts as an additional percentage of direct impacts. For example, the ANUFLOOD model specifies indirect costs for urban flooding as 15 per cent of direct damages for residential building and 55 per cent for non-residential buildings (Smith and Greenaway 1999). The Flood RAM (DNRE 2000) recommended 30%, but that rates between 20% or 45% may be more appropriate depending on the flood characteristics and location (Read Sturgess and Associates 2000).

In the US, FEMA quantifies indirect impacts associated with:

- Displacement from flood affected properties
- Disruption including increased travel times due to closed roads
- Loss of service due to flooded public buildings (incl. police, fire and hospitals)
- Loss of service due to flooded utilities (sewerage, electricity, water)

Displacement is estimated based on building size and market prices to rent an equivalent space. The time that a property is vacated is determined based on estimated structural damage. Depending on damages, affected people may be displaced for anywhere between a few days to six months or longer. These additional impacts should be assessed alongside the material impacts to the building and contents.

Lost time can be incurred by individuals who must take pre-disaster preventive measures, evacuate their homes or business, clean up or repair damage, manage insurance claims, experience increased travel time due to bridge or road closures, and deal with other disaster-related matters. Currently FEMA uses \$28.11 (2007 USD) per hour which is the average employer cost for employee compensation per hour for 2007⁶. They also use \$38.15 per vehicle hour (in 2007 USD) to quantify impacts from road and bridge closures.

Increased travel times are estimated from road travel counts, estimates of increased travel distances, and estimates of driving speed. Increased car expenses are included; however these are small in relation to the value of lost time. Wherever roads are inundated, these additional impacts due to increased travel time should be included alongside material damage to the road itself. AustRoads provide the standard value of travel time as part of their guidelines for transport appraisals. The value of travel time is estimated to be:

⁶ U.S. Department of Labor. 2007.

- \$14.35 per hour for private travel
- \$45.90 per hour for business travel

Various methodologies are used to value the loss of public services. Apart from police, fire and hospitals, value is measured based on the operating budget of the building affected. The assumption behind this conservative approach is that the value of the service is at least as high as what it costs to provide.

FEMA has also developed methodologies to assess the value of lost service due to flooded utilities. The values (2007 USD) used in these methodology are:

- Electricity - \$126 /person/day
- Water - \$93 /person/day
- Sewerage - \$41 /person/day

Where public services or utilities are likely to be inundated, it may be important to assess any damages as part of the flood risk assessment.

6.3 How can these findings be used in IWCM planning?

6.3.1 How does IWCM lead to flood reduction benefits?

Floods occur when runoff pools more rapidly in areas than it can drain. The problem can therefore be alleviated by either increasing the rate at which water is removed from the problem area, or by decreasing the rate and volume of water that enters it. Traditional approaches have targeted the former through improvements in drainage.

IWCM initiatives target the latter by retaining, slowing, and infiltrating runoff before it can accumulate in problem areas. Rainwater tanks and larger scale stormwater retention basins provide the greatest potential for reducing flood impacts, however bio-infiltration solutions such as raingardens are also expected to provide some contribution to reducing flood impacts.

A critical issue associated with rainwater tanks is the likelihood that they are already full, or quickly become full, during high rainfall events. Anecdotal evidence suggests that rainwater tanks and other small on-lot solutions are more effective in dealing with small floods or nuisance flood events, and less effective in addressing larger floods that result in most damages.

IWCM actions may also reduce the need for additional or upgraded drainage infrastructure, resulting in a cost saving. Preliminary investigations by Melbourne Water⁷, in conjunction with DELWP, have shown that installing rainwater tanks can achieve these benefits, and are undertaking further studies to provide greater certainty around this and better understand the situations where they are most beneficial.

⁷ See paper by Sestokas et al, entitled "Stormwater- untapping the potential" for further information.

6.3.2 Which of the findings are most useful for IWCM planning and how should they be used?

The variable nature of rainfall and flooding means that the probability of flood damage needs to be accounted for if it is to be a useful metric in assessing IWCM benefits.

The contemporary, and generally most practical, approach is to calculate the AAD caused by floods, noting that damage in this context includes any negative impact that can be quantified in monetary terms.

The NSW OEH relationship between depth of flooding and impacts to residential buildings presented in Section 6.2.2 represents the most up-to-date data and is recommended for flood damage assessments.

Other non-market values relating to flood impact can and should be included in the AAD calculation where they can be assessed and quantified. The methods for assessing impacts of individual flood events outlined in Section 6.2.2 provide a guide to doing this.

The impacts of different flood events should then be used to estimate AAD. AAD is calculated based on the following equation:

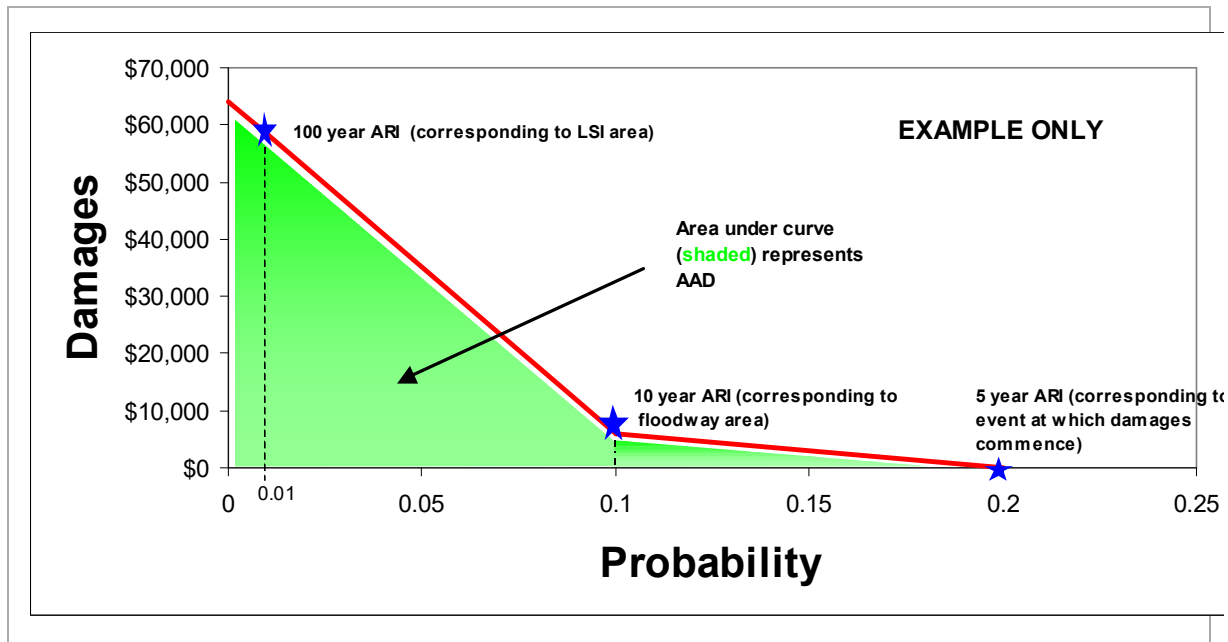
$$AAD = \int_0^1 D(p)dp$$

Where:

$D(p)$ = the expected damage for a flood event with probability p

The large damages resulting from an extreme event are multiplied by a low probability (e.g. probability of 0.01 for a 100 year ARI), and added to the relatively smaller damages from a minor flood which are multiplied by a relatively high probability (e.g. probability of 0.1 for a 10 year ARI event). In practice, this is achieved readily by integrating the area below the loss-probability curve (see Figure 5). The area under the curve represents the AAD.

Figure 5. Average Annual Damages



Source: Aither

Reductions in AAD resulting from IWCM measures can be calculated to assess the annual benefits of flood reduction.

Table 9: Summary of economic values that are useful for IWCM

Benefit	Valuation approach	Value	Factors to consider when applying:
Flood damage - residential buildings	avoided cost	Approx. \$1,000 per building cm of flood height reduced for flooding greater than 10cm below floor level	<ul style="list-style-type: none"> - apply to residential flooding only - requires technical modelling to estimate change in flood height from IWCM option - sensitivity of results over a large range should be tested (+/- 50%)
Flood impacts - car transport	willingness to pay	<ul style="list-style-type: none"> - \$14.35 per hour of disruption per vehicle occupant for private travel - \$45.90 per hour of disruption per vehicle occupant for business travel 	<ul style="list-style-type: none"> - requires an assessment of impact of lost travel time and traffic flows as a result of floods - sensitivity of results over a large range should be tested (+/- 50%)

6.3.3 Where are the uncertainties and data gaps?

There is clear evidence that household rainwater tanks can alleviate, and in many cases mitigate, flooding caused by small rainfall events if a sufficient proportion of the catchment has them installed, connected and maintains sufficient capacity within them. The effectiveness of tanks in mitigating larger events is the subject of ongoing research by Melbourne Water and DELWP. Preliminary results suggest that catchment characteristics are determinants, with tanks generally providing greater benefits in larger events for catchments that are relatively smaller and steeper. Further work will reduce this uncertainty and facilitate improved understanding of the effectiveness of rainwater tanks for flood protection.

There is still a poor evidence-base for quantifying the impacts of flooding on physical and psychological health. Quantifications of the disruption to roads and transport services are also not well represented in the literature, and are likely to be quite specific to the area being flooded.

Climate change introduces some uncertainties in assessing flood damage. This does not affect the AAD approach overall, however it will alter the likelihood and characteristics of flood events, and thus affect the shape of the AAD curve. This is really an uncertainty associated with the technical hydrological modelling of floods under altered climate patterns rather than the process of economic assessment per se.

6.3.4 Potential for double-counting and other pitfalls

The AAD approach provides the most straightforward way of addressing the uncertainties inherent in rainfall patterns into economic assessments of flood damages, and of measuring the benefits of reducing these impacts.

The prices of insurance premiums are sometimes used as a measure of the value of protection against floods. These are generally not a good reflection of the expected cost of flood impacts however, as insurance companies set prices based on pooled risks and a range of other factors. As such, it is also not necessarily the case that providing flood protection through IWCM measures would reduce insurance premiums.

In addition, care must be taken to not double-count the benefits of avoiding drainage upgrades costs along with reduced flood impacts.

6.3.5 Recommendations for further work

It is important that a good technical connection between various IWCM measures, most notably rainwater tanks, and flood impacts be established.

There are still a range of flood impacts that are not well understood. Quantification of flood impacts (and therefore benefits of flood reduction) generally requires that hydrological modelling is undertaken that provides an understanding of the depth and extent of flood impacts across different ARI events. This provides the basis for understanding economic impacts.

When estimating flood impacts, it is recommended that the AAD approach be used incorporating damage to physical assets as well as human impacts where these can be quantified. It is recommended that OEH depth damage relationships (see Section 6.2.2) are applied when assessing impacts on residential buildings.

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Where road and transport disruption is likely to be both significant and addressable through IWCM measures, it may be useful undertaking dedicated transport modelling to understand these impacts across the transport network. These networks are complex systems and the impact of disruption in one part of the network is felt across a wide area and number of people in terms of increased travel times. These impacts can therefore be significant and should be considered.

7 Conclusion

7.1 Summary

IWCM has the potential to provide a range of benefits to the community, many of which are considered externalities because they are unpriced in markets. IWCM actions increase the supply of water available for beneficial uses and reduce the velocity, frequency, volume and pollutant loads of stormwater run-off, and as a result contribute to reductions in flood impacts, drainage requirements, and downstream ecological impacts on waterways and the bays.

The review undertaken here has considered the externalities associated with these outcomes and assessed available information for use in assessments of IWCM, particularly within a Melbourne context. Although it uncovered some useful data and methodologies for use in IWCM assessments, in general there is a lack of Melbourne-centric studies, which creates a level of uncertainty in their application.

Benefits from improved waterways and bays

The review of externalities associated with waterways and bays uncovered a large body of literature both locally and internationally. The majority of waterway studies focus on large, rural, and often iconic waterways, which limits their application to the types of waterways that IWCM often seeks to protect and improve - namely small, urban streams and creeks. That said, protection of enough of these smaller waterways within a catchment is expected to provide improvements to larger downstream waterways and bays – these impacts are more amenable to the economic values discussed in this report.

Key to this is a good understanding of how IWCM actions lead to biophysical changes that the community understands, perceives, and values. The literature on the discrepancy in value between willingness to pay and willingness to accept compensation for commensurate environmental changes provides evidence that, all other things being equal, the protection of pristine waterways is more highly valued than the restoration of degraded ones. This suggests that IWCM efforts should be focussed towards protection of waterways currently in good ecological health.

Other social values from increased water use and availability

Increased water availability provides the potential for benefits derived from additional uses of water such as increased and enhanced green spaces and consequential amenity, urban cooling and other benefits. Some methods and data for estimating the value of green space and urban cooling have been provided.

The construction of the Victorian Desalination Plant has provided considerable additional supply capacity for the water supply network. Despite the considerable cost involved in its construction, these costs are now sunk and irrelevant to decisions regarding marginal changes in future water use. Its significant supply capacity means that additional augmentations are not required for some time, and as a consequence the LRMC of additional water is low. Since low cost water is available, the value of additional water provided by alternative sources is also low, regardless of the application of the water (for urban landscapes or otherwise).

While some data and methodologies for estimating the beneficial outcomes of increased water use have been discussed and provided, the avoided LRMC of water supply provides the best economic measure of the marginal benefit of additional water (where a reticulated supply is available) as this

represents the least cost alternative, as well being based on a robust and relatively simple process to apply in IWCM assessments.

Reduced flood impacts

The review of flooding externalities uncovered a range of impacts. More quantifiable impacts such as damage to physical infrastructure have better representation in the literature, with sound methodologies and good data for assessment. Others such as psychological, physical health, and disruption impacts have less data available, but good approaches to assessment. Of importance in applying these data and methodologies is a clear technical understanding of the physical reductions in impacts of different sized flood events (ARIs) as a result of IWCM measures.

7.2 Recommendations

The application of values for externalities for IWCM assessments can only be as accurate as the technical links between IWCM initiatives, the resulting physical and biophysical outcomes and to attributes that are valued by the community. To this end, it is recommended that further work goes into developing these understandings – particularly in regard to the connections to ecological responses and flood impacts.

If the above provides evidence that clear benefits are likely to exist, it is recommended that original WTP studies are undertaken to assess the value that the community places on improvements in the health of Melbourne's waterways. A better understanding of this could potentially reveal considerable benefits provided by IWC approaches that are not currently well represented in feasibility studies and cost benefit analyses.

In particular, a stated preference study that focuses on WTP for improvements across a catchment (rather than focussing on small individual waterways) would be valuable for IWCM assessments, and a valuable contribution to the State's knowledge base for environmental management generally. It is noted that work currently being led by Melbourne Water may help to fill this gap.

Similarly, improved flood modelling of IWCM impacts within a catchment would help assess reductions in flood risks that can be measured using established depth damage relationships and the Annual Average Damage approach.

The review revealed significant gaps in the literature regarding studies that are specific to Melbourne. Beyond the specific recommendations above, it is therefore also recommended that further studies are undertaken that are more focussed on the valuation of externalities within a Melbourne context, particularly those regarding the value that Melbournian's place on urban forests and green spaces as sources of recreational opportunity and amenity.

The findings here should be augmented as new studies become available, with a focus on studies that:

- assess marginal benefits - absolute values are of little use except as a means to assessing marginal changes due to an intervention (ie the change in absolute values before and after some intervention). For example, the absolute value of a river does not help in making decisions about its management. The value of a *change* in the state of a river as a result of management is useful, as it can then be compared against the cost of management, and against alternative options, in a meaningful way.

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- have clear linkages to IWCM outcomes, and have been developed and expressed in ways that have a clear connection with possible, and available, technical outputs of IWCM planning.
- are focussed on values that are expected to be significant factors in decision making.

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9 Appendix

The tables below provides a summary of externality values associated with integrated water cycle management. There are a number of limitations associated with these figures, and a number of factors that need to be considered when applying them, that are discussed in the main body of the Aither report entitled "Valuing externalities for integrated water cycle management". This report should be referred to before applying these values to ensure consistency with the recommended approach.

Waterway health externalities summary

Benefit	Valuation approach	Value	Factors to consider when applying:
Improved waterway health, or prevention of degradation	Willingness to pay studies	\$1.00 to \$3.00 per household per km of waterway returned to good health or prevented from degradation	<ul style="list-style-type: none"> - Applies to significant waterways only - Applied as a once-off benefit (present value) per household (applicable population should be based on significance of waterway) - sensitivity of results over a large range should be tested (+/- 50%)
Wetlands	Willingness to pay studies	\$0.0005 - \$0.005 per hectare of wetland conserved per household	<ul style="list-style-type: none"> - Based on studies of conserving large, natural wetlands. It is unlikely similar ecological values are present for constructed wetlands. It is also unclear if linear scaling is appropriate for applications to smaller wetlands - Applied as a once-off benefit (present value) per household (applicable population should be based on significance of wetland) - sensitivity of results over a large range should be tested (+/- 50%)
Improved water quality	avoided cost	\$4,000 per kg TN reduced	<ul style="list-style-type: none"> - to be applied as an indicative value of water quality improvement only if the value of pollutant reduction can not be assessed by reduction in impacts resulting from pollutant reduction - cannot be used in addition to valuing waterway improvements (this would be double-counting) - sensitivity of results over a large range should be tested (+/- 50%)
Improved waterway health, or prevention	Willingness to pay studies	\$1.00 to \$3.00 per household per km of waterway returned to good health or	<ul style="list-style-type: none"> - Applies to significant waterways only - Applied as a once-off benefit (present value) per household (applicable population should be based on significance of waterway)

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of degradation		prevented from degradation	- sensitivity of results over a large range should be tested (+/- 50%)
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Waterway recreation externalities summary

Benefit	Valuation approach	Value	Factors to consider when applying:
Recreational fishing	Willingness to pay studies, travel cost studies	\$60 - \$1,000 per visit	<ul style="list-style-type: none"> - lower end of range should be applied for most IWCM applications - value should be applied to new fishing visitors only - sensitivity of results over a large range should be tested (+/- 50%)
Streamside recreation	Willingness to pay studies, travel cost studies	\$10 - \$80 per visit	<ul style="list-style-type: none"> - based on significant waterways, unclear if applicable to smaller waterways - low end of range should be applied for these to be conservative - value should be applied to new visitors only - sensitivity of results over a large range should be tested (+/- 50%)
Bay-related recreation	Willingness to pay studies, travel cost studies	Local visitors: between \$1 and \$20 per visit Tourists: between \$10 and \$150 per visit	<ul style="list-style-type: none"> - value should be applied to new visits only - sensitivity of results over a large range should be tested (+/- 50%)

Other social externality values from increased water use and availability

Benefit	Valuation approach	Value	Factors to consider when applying:
Avoided reticulated supply costs	avoided cost	\$0.46 per kL of water	<ul style="list-style-type: none"> - apply where a reticulated water source could be used to produce net benefits - applies only if option provides a permanent change in water demand - cannot be summed with benefits of additional water use (benefit is the avoidance of costs associated with centralised supply)

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			- currently under review and should be updated when better data is available
Avoided sewerage costs	avoided cost	- \$0.67 per kL of wastewater (Eastern Treatment Plant) - \$0.44 per kL of wastewater (Western Treatment Plant)	- apply where a permanent change in wastewater volume is expected (benefit is the avoidance of costs associated with centralised treatment) - currently under review and should be updated when better data is available
Urban cooling - heat-related health impacts	avoided cost of treatment	\$1,270 per 100,000 people per degree above 30 degrees per day ⁸	- apply if LRMC approach not applicable - apply to each degree of urban cooling produced on each day above 30 degrees - does not include mortality impacts or additional impacts caused by heatwaves - sensitivity of results over a large range should be tested (+/- 50%)
Urban cooling - energy savings	avoided cost	\$0.24 per residence per degree above 20 degrees per day	- apply if LRMC approach not applicable - apply to each degree of urban cooling produced on each day above 20 degrees - sensitivity of results over a large range should be tested (+/- 50%)

Flood damage externalities summary

Benefit	Valuation approach	Value	Factors to consider when applying:
Flood damage - residential buildings	avoided cost	Approx. \$1,000 per building cm of flood height reduced for flooding greater than 10cm below floor level	- apply to residential flooding only - requires technical modelling to estimate change in flood height from IWCM option - sensitivity of results over a large range should be tested (+/- 50%)
Flood impacts - car transport	willingness to pay	- \$14.35 per hour of disruption per vehicle occupant for private travel - \$45.90 per hour of disruption per	- requires an assessment of impact of lost travel time and traffic flows as a result of floods - sensitivity of results over a large range should be tested (+/- 50%)

⁸ Based on costs presented in Section 5.2.2

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		vehicle occupant for business travel	
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