HEALTH BENEFITS FROM WATER CENTRIC LIVEABLE COMMUNITIES

A REPORT PREPARED FOR THE WATER SERVICES ASSOCIATION OF AUSTRALIA (WSAA)

1 MAY 2019

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The Water Services Association of Australia (WSAA) is the peak body that supports the Australian urban water industry.

Our members provide water and sewerage services to over 20 million customers in Australia and New Zealand and many of Australia's largest industrial and commercial enterprises.

WSAA facilitates collaboration, knowledge sharing, networking and cooperation within the urban water industry. The collegiate approach of its members has led to industry-wide advances to national water issues.

WSAA can demonstrate success in standardising industry performance monitoring and benchmarking, as well as many research outcomes of national significance. The Executive of the Association retains strong links with policy makers and legislative bodies and their influencers, to monitor emerging issues of importance. WSAA is regularly consulted and its advice sought by decision makers when developing strategic directions for the water industry.

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- Shaun Cox, Inxure Strategy Group. He facilitated workshops and provided strategic input on our approach.

EXECUTIVE SUMMARY

The Water Services Association of Australia (WSAA) has engaged Frontier Economics to assist in understanding and quantifying the liveability associated health benefits of water industry investments in order to better inform investment decisions.

Increased focus around water businesses' role in promoting liveability and concern around health outcomes (for example, obesity-related issues), has highlighted the need to ensure a robust approach to assessing the economic, environmental and socially optimal set of investments. The focus of this consultancy is on liveability-related health benefits potentially attributable to Integrated Water Catchment Management (IWCM) with physical connections between water, land and related resources, rather than the well-known health benefits from the provision of safe water supplies and wastewater services. There is a wide range of potential market and non-market impacts that derive their value in part from IWCM projects including environmental benefits, and potential benefits from unlocking a more compact urban form, as shown in Figure 1:

Figure 1: Categories of costs and benefits potentially related to water investments

Source: Frontier Economics

Although the value of these different benefit classes can be individually large and could impact investment choices between options, this study is focused exclusively on the potential health benefits associated with water investments which largely arise from the open space and urban cooling categories shown here. To do this, this study has developed and applied a methodology and associated tool for quantifying, in monetary terms, a range of potential liveability-related health benefits from IWCM projects.

Relationship between water investments and health benefits

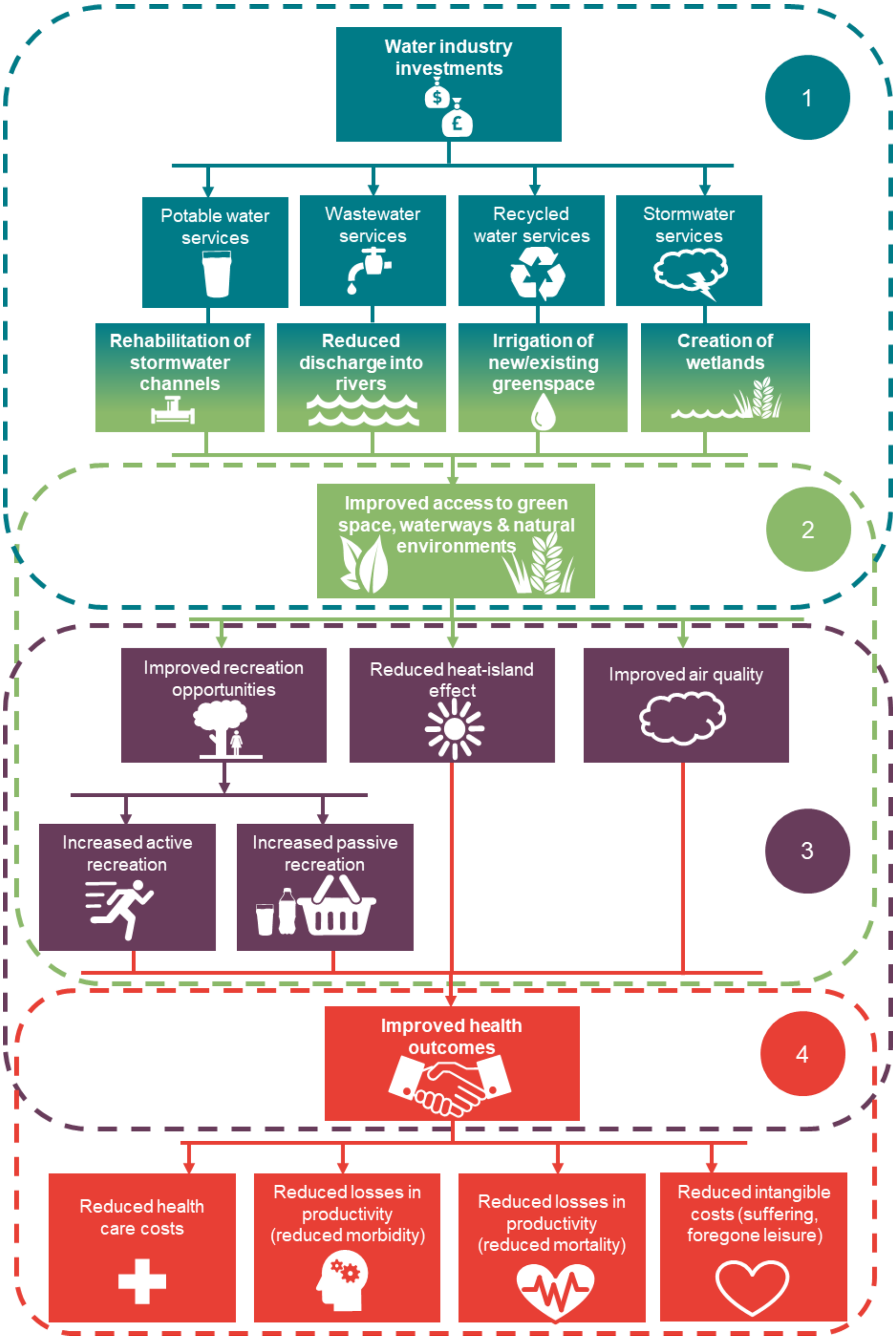
A key challenge is how to incorporate the wide potential scope of liveability-related health impacts into a framework which maps the relationship between water investments and health outcomes in a way which is sufficiently tractable to provide a practical tool for informing business cases. To ensure a credible and robust economic assessment process, it is imperative that the identified health impacts are clearly associated with the project in question.

Our approach focuses on ensuring only benefits directly attributable to the water investment are included in the assessment. As shown in **Figure 2**, this involves identifying, and quantifying (where possible) the following relationships between:

- water industry investments and more amenable and accessible greenspace and natural environments
- the presence of more amenable and accessible greenspace and natural environments and health risk factors
- health risk factors and improved health outcomes; and
- improved health outcomes and improved economic outcomes.

While the framework developed here focuses on all of the steps linking water investments and health outcomes, we would note that many of the steps are also likely to be useful in considering other potential external impacts, such as ecological values.

Figure 2: Potential relationships between water industry investment and health-related liveability benefits



Source: Frontier Economics

Figure 2 shows that IWCM investments ultimately can improve health outcomes by improving access to amenable green and bluespaces. Better access to green and bluespace has the potential to reduce pre-existing health risk factors in the population for a range of health conditions, and thereby generate improved health outcomes.

In considering how the attribution framework outlined above applies to water sector investments, we have identified four key health pathways:

- Improvements in health resulting from more active recreation
- Improvements in mental health resulting from more exposure to greenspace
- Improvements in health resulting from reduced temperatures associated with the Urban Heat Island effect
- Improvements in health resulting from lower air pollution.

Based on the research and analysis undertaken for this study, in our view these four pathways represent the most material, tangible and widespread links between water industry investment and liveability-related health outcomes.

Health Pathway 1: Improvements in health resulting from more active recreation

It is feasible to estimate monetary values of liveability-related health benefits attributable to increased physical activity due to more amenable and accessible greenspace linked to water investments. In doing so, the most well-established relationships are those links between increased activity and health outcomes, and health outcomes and economic outcomes:

- Physical inactivity is a known risk factor for various diseases, including certain cancers, coronary heart disease, dementia, diabetes and stroke. Inactivity is also linked to depressive disorders. Moreover, estimates exist of effect of exercise on physical-activity related health burdens (measured in DALYs) in given populations.
- Well-accepted methodologies also exist to translate improved health outcomes into economic outcomes.

The more problematic element is establishing how much additional activity can be attributed to more amenable and accessible greenspace, and the extent to which this improvement stems for an IWCM initiative. However, some defensible assumptions on the extent of increased participation in physical activity can be made depending on the quality and location of the greenspace. **Section 8** outlines how we have applied quantitative relationships from the literature and key assumptions to monetise the health benefits of reduced inactivity in three indicative case studies.

Health Pathway 2: Improvements in mental health resulting from more exposure to greenspace

Most of the literature supports a relationship between exposure to more amenable and accessible greenspace and improved mental health outcomes. A recent Australian study provides a defensible basis for quantifying the impact of exposure to nature and the prevalence of depression for use in business cases. We have been able to use this study to monetise these mental health benefits in our three hypothetical cases (more details provided in **Section 8**).

Health Pathway 3: Improvements in health resulting from reduced temperatures associated with the Urban Heat Island effect

Most studies support a negative relationship between greenspace/bluespace and the urban heat island (UHI) effect via direct shading which prevents solar radiation from heating the surface (albedo) and evapotranspiration which cools the air.

However, the size of the relationship varies widely with the meteorological location and urban characteristics (e.g. significant greenspace and canopy cover on a catchment scale is necessary to reduce the UHI effect). Thus, in the absence of location-specific studies such benefits will be hard to justify in business cases.

Where such site-specific studies exist, however, it is possible to draw a link between heat (especially heatwaves) and health outcomes, especially among the most vulnerable members of the population (i.e. the very young and elderly and for lower socioeconomic status (SES) groups) and make reasonable quantitative estimates of reduced UHI effect on heat-related health burdens (measured in DALYs) in given populations and healthcare costs. In our three applied cases, we have provided monetised estimates of the value of urban cooling where the case study site has sufficient scale for those benefits to be realised (see Case Study #1 in **Section 8**).

Health Pathway 4: Improvements in health resulting from lower air pollution.

While the bulk of the literature supports a relationship between the presence of urban vegetation and air quality, and between air quality and health outcomes, it is difficult to define a defensible quantitative relationship. This is primarily because the relationship between urban vegetation and air quality varies significantly with location, types of trees etc.

Nevertheless, there is prima facie evidence that the impact on health of air pollution could be significant. This suggests that in cases where there is scope to significantly affect urban design including vegetation through IWCM investments, the potential health benefits could also be substantial. However, in the absence of location-specific studies such benefits will be hard to justify in business cases. Similarly to Health Pathway 3, in our application of our framework to hypothetical case studies we have monetised the potential health benefits from improved air quality where the scale of the IWCM investment is sufficient (Case Study #1).

Implementation and application of the framework

In order to better illustrate how these relationships identified from the literature operate in practice, we have quantified and monetised benefits from the four health pathways in three illustrative, hypothetical case studies of possible IWCM investments. As shown in **Figure 3**, the relevance and/or size of the health benefits will vary across the case studies, as a result given differences in the investment, including in the availability of open space for active and passive recreation, the size and scale of the project and the location.

Figure 3: Overview of costs and benefits of the case studies

Case study	Active recreation benefits	Mental health benefits	Urban cooling health benefits	Air quality health benefits
1 Large greenfield development	✓	✓	✓	✓
2 Urban stormwater rehabilitation	✓	✓	✗	✗
3 Semi-arid regional town water supply	✓	✓	✗	✗

Source: Frontier Economics

To do this, we have created an Excel-based economic assessment model (a ‘Ready Reckoner tool’) to assist with the estimation of health benefits:

- Direct costs, in terms of:
  - Reduced healthcare costs
- Indirect costs, in terms of:
  - reduced productivity losses from absenteeism and presenteeism
  - reduced productivity losses from mortality
- Willingness to Pay[1], to avoid the cost of:
  - reduced years of ‘healthy’ life — measured in DALYs.

The summation of the direct and indirect costs is reported separately from the estimates of willingness to pay as these two measures are not comparable.

These are estimated for four potential sources of health benefits:

- Benefits from increased activity
- Increased wellbeing from exposure to greenspace
- Benefits from reduced urban temperatures
- Benefits from increased air quality

The tool allows the user to input values and change assumptions as relevant for the real-world IWCM investment at hand. To begin, the user specifies whether each of these four sources of potential benefits is relevant to the project in question. We would anticipate that in virtually all cases, the first two types of benefits (relevant to greenspace) will be relevant to the evaluation. In contrast, benefits from reduced urban temperatures and air pollution may only be material for large-scale projects.

[1] It is important to note that the community’s willingness to pay for an extra year of healthy life is not the same as their *actual capacity* to pay, however capacity to pay is not what is being measured in this report. Economic appraisal of possible water investments should measure the overall economic benefit to the community (the willingness to pay), not the actual capacity to pay.

While the case studies illustrate the application of the ready reckoner tool to some hypothetical case studies, it is able to be applied to other projects which may have different characteristics.

In doing so, however, it should be recognised that:

- Estimates of the potential health benefits from the ready reckoner will need to be integrated into the overall assessment of a potential investment and indeed requires that a robust investment evaluation framework (as discussed in **Section 2**) has already been developed for the investment in question. For example, application of the ready reckoner tool requires that the base case and the proposed investment option or options have already been clearly defined.
- In applying the ready reckoner tool to evaluate potential liveability-related health benefits from an IWCM investment, in many cases these benefits may represent a relatively small component of the overall benefits of a project.

Subject to these caveats, we have provided some guidance on the use of the ready reckoner tool to estimate liveability-related health benefits attributable to specific IWM investments.

We applied the Ready Reckoner tool to three stylised, hypothetical case studies to estimate their potential liveability-related health benefits and to demonstrate how the tool works. Our case studies involved a large scale greenfield development where water infrastructure is provided for the first time (Case Study #1), an urban stormwater channel rehabilitation project (Case Study #2), and providing for current and future water needs in a semi-arid regional town (Case Study #3). Tables 1 and 2 contain an overview of results for direct/indirect costs and willingness to pay estimates respectively.

Table 1: Case Study results comparison: Direct and indirect costs ($2017-18)

HEALTH BENEFIT (COI APPROACH)	CASE STUDY 1	CASE STUDY 2	CASE STUDY 3
Population affected	1,500,000	10,000	50,000
Health Pathway 1: Benefits from increased activity ($/pp)	28.10	16.29	12.06
Health Pathway 2: Increased wellbeing from exposure to greenspace ($/pp)	48.14	24.07	24.07
Health Pathway 3: Benefits from reduced urban temperatures ($/pp)	14.41	0.00	0.00
Health Pathway 4: Benefits from increased air quality ($/pp)	3.69	0.00	0.00
TOTAL HEALTH BENEFITS OF PROJECT ($/PP)	94.34	40.35	36.13
TOTAL BENEFIT ($)	**141,508,488**	**403,543**	**1,806,366**

Source: Frontier Economics Ready Reckoner tool

Table 2: Case Study results comparison: Willingness to pay ($2017-18)

HEALTH BENEFIT (WTP* APPROACH)	CASE STUDY 1	CASE STUDY 2	CASE STUDY 3
Population affected	1,500,000	10,000	50,000
Health Pathway 1: Benefits from increased activity ($/pp)	161.92	67.45	81.52
Health Pathway 2: Increased wellbeing from exposure to greenspace ($/pp)	189.67	94.83	94.83
Health Pathway 3: Benefits from reduced urban temperatures ($/pp)	115.74	0.00	0.00
Health Pathway 4: Benefits from increased air quality ($/pp)	14.77	0.00	0.00
TOTAL HEALTH BENEFITS OF PROJECT ($/PP)	482.10	162.28	176.35
Total benefit ($)	**723,156,743**	**1,622,814**	**8,817,699**

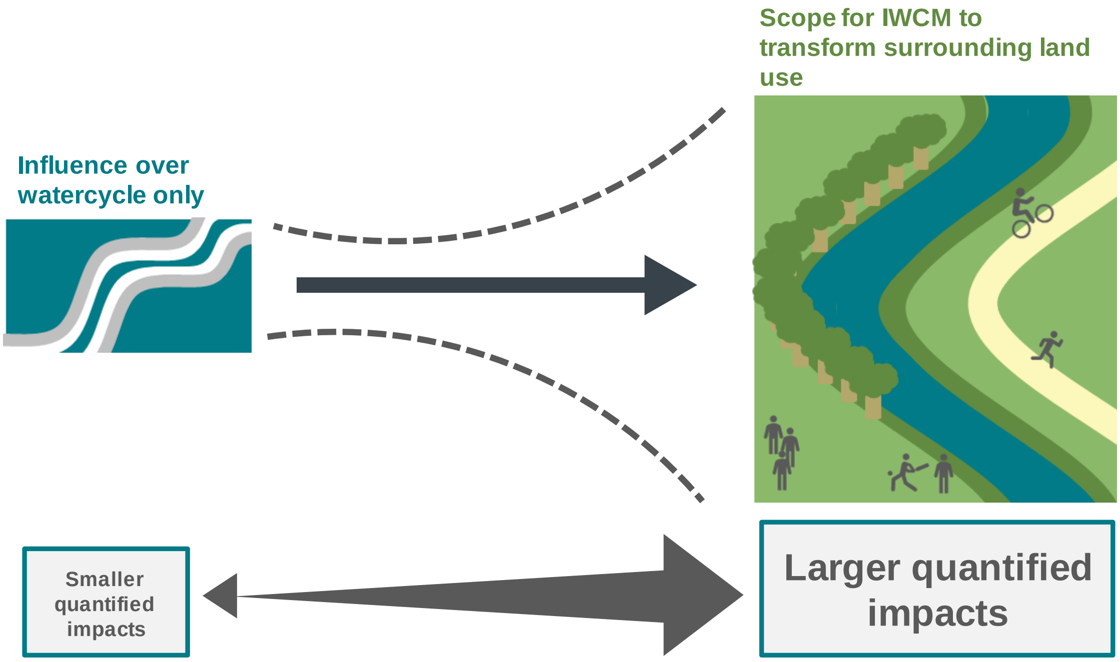
*Source: Frontier Economics. *Note: WTP: Willingness to Pay*

These results and the process of applying the quantitative relationships mapped out in these four health pathways generate a number of key learnings for monetising health benefits associated with IWCM projects, including the following:

- **The population exposed to any given benefit is a key driver of overall benefit magnitudes**. For example, mental health benefits from passive recreation in greenspace typically as much as or more in monetary terms than the health benefits from active recreation because of the limited number of people who will actually increase their physical activity due to more amenable or accessible greenspace (facilitated by IWCM).
- In many cases there is already greenspace and natural environments in the area, and thus, the health benefits that can be attributed to the water industry investment may be relatively small.

In particular, **Figure 4** shows that the degree of benefit achievable with any given water investment is positively related to the amount of surrounding land use that the water investment can possibly influence. Where change is confined narrowly to the water resource itself, benefits tend to be more limited. However, where surrounding greenspace can be generated or transformed to facilitate broader use, larger benefits can emerge.

Figure 4: Spectrum of potential liveability benefits



Source: Frontier Economics

- While some quantifiable impacts are generic and transferable, in other cases estimating the impacts will require a localised, site-specific assessment – this is because nature of relationships are complex and vary significantly across different types of physical liveable environments.
- In considering which types of health impacts to quantify, principles of investment evaluation would suggest that more effort should be expended on those health impacts which are likely to be more significant given the circumstances of each case (e.g. UHI effects in hot regions) and for which there is a sound evidence base.
- The size and nature of health-related benefits vary considerably depending on a range of factors (e.g. climate, characteristics of population such as lower socioeconomic status).
- Health impacts are likely to be larger where scale effects exist. For example, a reduction in the UHI effect is only likely in areas with significant canopy cover, which requires a large land area to plant the trees.

It should also be noted that some health benefits may be encompassed within broader methodologies which pick up a range of attributes/values (e.g. willingness to pay studies) so care is needed to avoid double-counting.

It is also apparent that quantification of health benefits attributable to investment in integrated water management is currently constrained by the availability of robust evidence on some of the relationships which link the investment to health outcomes. We have identified a few important, broad level research directions for future work in this area that would benefit real world economic appraisals with a focus on the greatest returns to industry. There would also appear to be a need for internal capacity building in economic evaluation to support high quality, industry led investment appraisal. There would also appear to be a need for internal capacity building in economic evaluation across the urban water sector to support high quality, industry led investment appraisal. We note that the Cooperative Research Centre for Water Sensitive Cities (CRCWSC) is undertaking work in this area.

Beyond quantification

Even where health-related benefits are not or cannot be quantified, the analysis in this report identifies a number of learnings about how to design IWCM projects in order to maximise health-related benefits from IWCM projects, including:

- Ensuring greenspace is accessible, safe etc for active and passive recreation
- Facilitating greenspace which provides connectivity and active transport
- Prioritising greenspace in areas currently not well served by greenspace

It is also important to recognise that quantification of liveability-related health benefits attributable to IWCM investments does not equate to funding for those investments.

Seeking funding in recognition of the health benefits attributable to IWCM projects requires first identifying the beneficiaries and then engaging with them about potential co-funding arrangements.

Given the nature of the health benefits identified in this report, a case could be made that some IWCM projects should receive funding from health budgets as they can lead to avoided costs in the healthcare system as well as better health outcomes in the community.

Claims for co-funding to support are likely to be stronger where the link from the IWCM project to the consequent health benefits relies on relationships where the evidence base is the strongest. There is also a case for focusing on IWCM projects where the funding gap is not large.

1 INTRODUCTION

1.1 Purpose of this study

The purpose of this study is to assist in understanding and quantifying the liveability associated health benefits of water industry investments, in order to better inform investment decisions.

In recent years there has been a paradigm shift towards more active consideration of role that water businesses may play in delivering value beyond their core business of water and sanitation services to contribute to the liveability of cities, waterway health and the management of the environment[2]. In doing so, it recognises that Australia has a responsibility to advance the Sustainable Development Goals (SDGs) as a signatory to the United Nations 2030 Agenda for Sustainable Development[3].

Based on a review of international and Australian literature and liveability indices, WSAA has adopted the following definition of liveability:

Liveability is all of those things that make a place somewhere people want to live, communities flourish and businesses choose to invest. To be long lasting and resilient, a liveable city or region must consider the needs of future generations and use systems thinking to understand and respond to shocks and long-term change[4].

As WSAA has observed:

The water industry brings a strong understanding of the value water and sewerage services can bring to the liveability of a community. The industry understands how water links to health, urban planning, prosperity and social connectedness. Individually and collectively, utilities want to collaborate with others who work in these spaces to achieve liveability outcomes greater than the sum of individual parts[5].

This has encouraged water businesses to consider a more holistic approach to the planning and management of the water cycle, one that recognises the range of the social, environmental and economic benefits of water infrastructure investment–including supporting liveable communities. However, as regulated monopoly providers, water businesses need to justify to their customers and regulators why they undertake certain tasks. This has highlighted the need to ensure a robust approach to assessing the economic environmental and socially optimal set of investments. **Figure 5** maps out a

[2] WSAA's recent occasional paper *Next Gen Urban Water: The role of urban water in vibrant and prosperous communities*, covers the broader value provided by utilities and includes over 20 case studies.

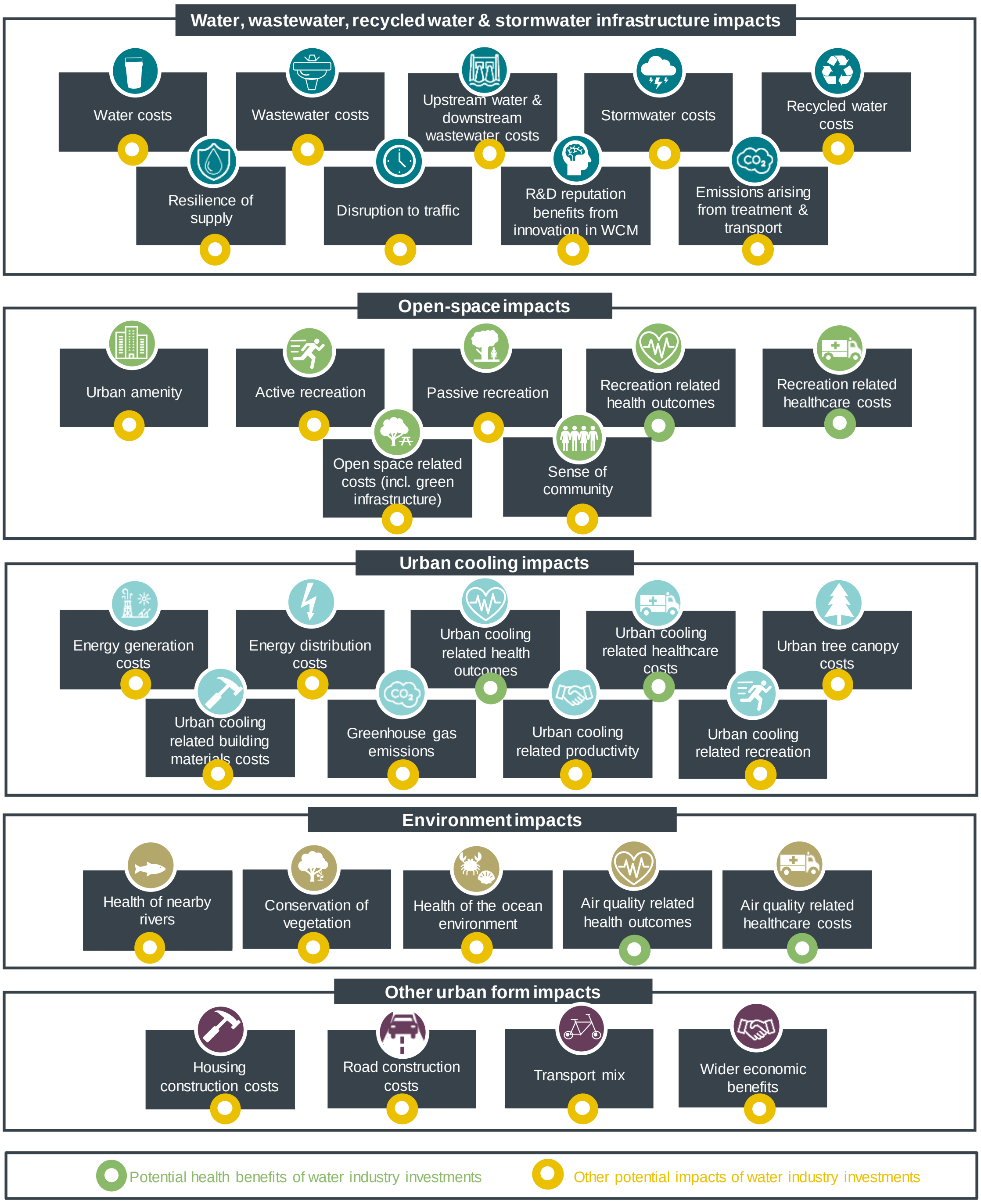
[3] SDG 11 is 'sustainable cities and communities', while SDG3 is 'good health and well-being'.

[4] WSAA, Occasional Paper No 31, Liveability Indicators A report prepared for the water industry, April 2016, p.

[5] WSAA Global Goals for Local Communities: Urban water advancing the UN Sustainable Development Goals, p. 6.

range of possible costs and benefits from water industry investments, with those impacts that have been quantified and monetised in the Ready Reckoner tool shown with a green traffic light. While this report is focussed on health-related impacts, water investments in integrated water management may have a range of other non-health related net benefits.

Figure 5: Overview of costs and benefits of water industry investments in integrated water management[6]



Source: Frontier Economics

[6] While a number of categories could apply to the range of different costs and benefits of water industry investments in integrated water management, impact categories shown in Figure 5 have been developed to assist in the organisation and clarity of results. The *Active Recreation* and *Passive Recreation* categories are marked with a yellow traffic light because although these impacts are quantified in the Ready Reckoner Tool, green traffic lights highlight **health impacts** amongst a range of other possible impacts of water investments. Hence, *Recreation related health outcomes* and *Recreation related healthcare costs* have a green traffic light as these are health-specific outcomes of active/passive recreation.

One of these potential benefits relates to promoting physical and mental health. As noted in the brief, while there is a wide body of research linking more amenable greenspace and natural environments to improved physical and mental health, there are a number of gaps in understanding and evaluating these health benefits and apportioning them to water industry investment.

The bulk of the research which has been undertaken on the link between greenspace and health relates to physical activity, with less focus on other relationships such as the effect of greenspace on heat or air pollution-related conditions.

Estimating the value of these liveability-related health benefits can often be difficult, as they do not accrue to the water business itself. Including such benefits in business cases has been problematic given the lack of a rigorous and consistent investment and benefits capture framework and methodology that is accepted by key stakeholders and investment agents.

Against this background, the Water Services Association of Australia (WSAA) has engaged Frontier Economics to assist in understanding and quantifying the liveability associated health benefits of water industry investments in order to better inform investment decisions.

This project establishes a methodology for identifying and quantifying these potential liveability-related health benefits and pilots it on a number of case studies. As part of this consultancy, we have developed an Excel-based tool to help the understanding and quantification of such benefits and assist with business cases for such projects.

1.2 Scope of the review

This study looks to further explore and apply research which “shows that water industry investments that result in more amenable and accessible greenspace and natural environments promote physical and mental health.”

This project deliberately focuses on the health benefits associated with Integrated Water Cycle Management (IWCM)[7] – broadly characterised by projects with physical connections between water, land and related resources. IWCM projects can bring multiple benefits, which are still being better understood and defined.

Another key issue is what is meant by the term ‘health benefits’. The World Health Organisation (WHO) defines health as follows:

> *Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.*

This definition highlights the need to incorporate mental and social well-being within the scope of health benefits which may be affected by IWCM projects (e.g. by recognising the mental health benefits associated with exposure to greenspace).[8]

[7] The coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in a suitable manner, without compromising the sustainability of vital ecosystems (The Global Water Partnership).

[8] As a general rule this does not provide a point of difference between any options being analysed in this report. All hypothetical case studies analysed in Section 8 apply the same definition of health.

Our definition of ‘natural environments’ extends beyond ‘greenspace’ to other aspects of the physical environment which can affect health outcomes: air quality, temperature. Another threshold issue therefore is to define what is meant by ‘greenspace’ (see Box 1).

Box 1: Defining ‘greenspace’

Recent work has observed that the ability to integrate findings on ‘greenspace’ research from studies from multiple disciplines has been compromised by a lack of understanding of what the term ‘greenspace; was describing: “whether greenspace is used as a series of land-use types, includes water or ‘bluespace’ as with coastal areas, or is considered generally as ‘greenness’, the understanding differs in the literature”.

While the review of 125 journal articles concluded that less than half had defined what ‘greenspace’ is, the report discerned two broad definitions:

- The first is that greenspace refers to bodies of water or areas of vegetation in a landscape, such as forests and wilderness areas, street trees and parks, gardens and backyards, geological formations, farmland, coastal areas and food crops. This interpretation refers to an overarching concept of nature, or natural areas in general
- The second includes urban vegetation, including parks, gardens, yards, urban forests and urban farms – usually relating to a vegetated variant of open space. This interpretation could be described as a subset of the overarching concept of greenspace that is confined to the urban environment and a subset of open space;

An example of this definition is that of the National Environmental Science Programme 2016):

“Urban greenspace is all the vegetated areas that occur in cities. Greenspaces can be found on public land (e.g. parks) and on private land (e.g. residential gardens). Urban greenspaces are commonly categorised by land use, which distinguishes areas used for public recreation, biodiversity conservation, residential dwellings, commercial or industrial activities, and transport corridors. These spaces can also be categorised by land cover, such as planted trees, shrubs or lawn, or native vegetation… Urban greenspaces are widely understood as ‘improving’ cities by increasing amenity and providing places for both passive and active recreation”.

Rather than proposing a single prescriptive definition, the authors suggest that researchers construct a definition of greenspace for the context of their research that both qualifies and quantifies what they mean by the term.

Source: Frontier Economics

Given the specified scope of this current study for WSAA (to understand and quantify the liveability associated health benefits of urban water industry investments and activities, via the potential for these investment and activities to result in “more amenable and accessible greenspace and natural environments”), we have deliberately adopted a broad definition which encompasses both vegetated urban land and ‘bluespace’ (e.g. waterways) within urban centres in Australia.

While the water industry has a long-standing role in promoting better public health through the provision of safe drinking water supplies and wastewater services to prevent water-borne diseases, this public health benefit is well-known and is accepted as a fundamental part of the functions which businesses are legally obligated to undertake. Efficient costs of activities relating to meeting these obligations are therefore accepted by economic regulators as justified and recoverable in water and wastewater charges. These health-related impacts have therefore been excluded from the scope of this study.

It is also recognised that there are a number of other discretionary activities which water businesses undertaken which could improve health outcomes (e.g. educating schoolchildren about the benefits associated with drinking water, or the health impact on hardship payment schemes). Such activities have also been excluded from the scope of the study because they do not have an IWCM focus. This does not mean that such projects are not worth pursuing, but rather, that focusing on health-related liveability impacts linked to IWCM ensures the study was manageable within the timeframe.

This study should therefore be seen as a starting point for examining the health benefits of water industry investment. Future work examining the health benefits of other liveability investments (e.g. drink tap, bill assist) could in our view be usefully undertaken.

1.3 Key deliverables

The key deliverables are:

- Matrix of physical and mental health benefits that liveability projects can materially influence
- Comprehensive literature review of evidence
- Repeatable methodology and tool to aid development of business cases
- Application of methodology to 3 case studies
- Key findings on way forward for quantifying and maximising health benefits from IWCM projects
- Final report

We have sought to develop a framework which

- Is evidence-based (giving more weight to Australian studies) but recognises uncertainties in quantitative relationships
- Is even-handed (e.g. recognises disbenefits as well as benefits)
- Is practicable
- Is consistent with approaches used to evaluate health impacts both in the water industry (e.g. for DWQ standards) and in health sector
- Is based on societal perspective (as per cost-benefit analysis (CBA)) but recognises some business cases may have narrower view.

1.4 Approach to the review

The key steps in our approach are to:

- Define the key economic evaluation framework necessary to identify the potential health-related impacts from water urban water investments.
- Articulate the cost and benefits and logical causal linkages between water investments and health benefits.
- Develop a conceptual framework and tool to assist in the quantification of these benefits (i.e. reduced health care costs and reduced mortality and morbidity), accounting for different contexts (e.g. regions served, demographic characteristics etc).

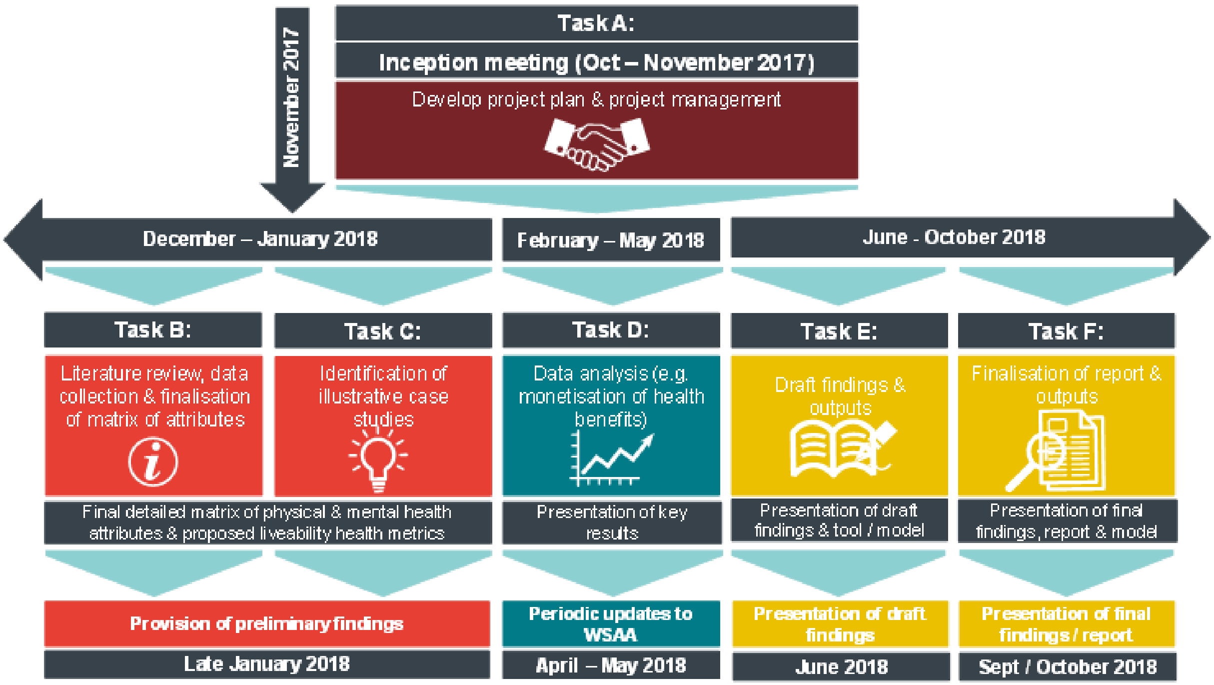
- Apply our framework and model to three illustrative case studies.

As shown in **Figure 6**, our approach to providing these deliverables focused on the following tasks:

- Task A: Provide finalised project plan, data request and the criteria to guide the identification of case studies.
- Task B: Literature review, initial data collection and finalisation of matrix of attributes and liveability metrics;
- Task C: Identification of potential case studies;
- Task D: Data analysis;
- Task E: Draft findings and provision of tool/model; and
- Task F: Finalisation of report and outputs.

This report summarises the outcomes of all these tasks.

Figure 6: Work program and timeframe of our review



Source: Frontier Economics

1.5 Structure of this report

The remainder of this report is structured as follows:

- **Section 2** provides context to the analysis by providing an overview of the role of economic assessment in water investment decision-making, including outlining principles for determining the appropriate base case and alternative options and the process for identifying and monetising relevant costs and benefits.
- **Section 3** provides an overview of our framework for linking water investment to health benefits.

- **Sections 4 to 7** distil key insights on the nature and strength of the relationship between water industry investments and health outcomes for four identified health pathways, drawing on our review of Australian and international literature.
- **Section 8** demonstrates the application of our conceptual framework through describing the Ready Reckoner health benefit valuation tool we have developed as part of this project and its application to three stylised case studies.
- **Section 9** provides further guidance on the quantification and design of IWCM projects to maximise potential health benefits.
- **Appendix A** provides a summary of our literature review.
- **Appendix B** provides detail on the selection of the case studies.
- **Appendix C** provides further details of our Ready Reckoner modelling tool.

2 THE ROLE OF ECONOMIC ASSESSMENT IN WATER INVESTMENT DECISION-MAKING

2.1 Best practice principles

Many IWCM projects generate costs and benefits that go beyond the direct financial costs and benefits associated with supplying water, wastewater and recycled water and stormwater services to customers.

It is well accepted across the investment economics literature and various state and Commonwealth investment and project evaluation guidelines that consideration of the full set of costs and benefits is a critical element of investment decision-making and the capital planning and prioritisation process.[9]

This is because, while useful, a narrow financial approach to assessing the viability of a project risks overlooking the often significant, external impacts (such as health benefits) incurred in the supply of water services. Failure to incorporate such costs and benefits increases the risk that the economic, environmental and socially optimal set of investments - such as investment in greenspace which may lead to significant health benefits but may be more expensive than a traditional supply option-may be undervalued and under-provided.

An overview of best practice principles and methodologies for economic assessment in water investment decision-making is provided in **Figure 7**.

[9] Including: Australian Government Department of the Prime Minister and Cabinet Office of Best Practice Regulation (2016), *Cost-Benefit Analysis*; Department of Treasury and Finance (2013), *Economic Evaluation of Business Cases Technical Guidelines*; NSW Government The Treasury (2017), *NSW Government Guide to Cost-Benefit Analysis.*

Figure 7: Best practice principles for the use of economics assessment

Principle	Rationale
Economic assessment should be undertaken for all major projects	**Rather than only for those projects with certain cost recovery or funding pathways.** The appropriate economic assessment technique (such as cost-benefit analysis or break-even analysis) will depend on the project.
Consideration of the full set of costs and benefits is a critical element of investment decision-making	While useful, a narrow financial approach to assessing the viability of a project risks overlooking the often significant external impacts incurred and **the economic viability of potential investments may be materially influenced by the value of this broader set of internal and external impacts**.
There should be a causal link between the identified impact and the project	Unless a causal can be identified, we cannot be sure that the impact arises as a result of the project.
The monetisation technique should be proportional to the size of the impact	There is typically **a trade-off between ensuring the most accurate estimate of an impact and its value and ensuring that resources are not wasted attempting to monetise minor impacts** or impacts that are unlikely to be influential to the overall viability of the project relative to other potential projects.
Projects should be evaluated from a consistent starting point and should extend to over the project's full lifecycle	**To enable an accurate comparison of the costs and benefits across different projects with varying timeframes, an appropriate assessment length must be determined**. However, as the lifecycle of projects increase, so too does the difficult in accurately forecasting future cash flows, and as a result of the application of discount rates, longer term estimates may have little impact on the NPV of the project.
The discount rate should reflect the riskiness (non-diversifiable risk) of the future cash flows	To the extent that the riskiness of the cash flows differ from one project to another, the appropriate discount rate may also vary.
Economic assessment should include tools for managing risk & uncertainty	Forecasting cost and benefits (and cashflows) is an uncertain process, with projects often subject to significant risk and uncertainty. **To ensure accurate comparison of costs and benefits economic assessment should include tools for managing risk and uncertainty, both in the size and timing of particular impacts.**
The incidence of costs and benefits must be identified	To identify the potential sources of co-funding and to ensure that potential equity impacts of investment proposals are fully understood, who bears the associated cost and benefits (the incidence) must be identified.

Source: Frontier Economics; Australian Government Department of the Prime Minister and Cabinet Office of Best Practice Regulation (2016), Cost-Benefit Analysis; Department of Treasury and Finance (2013), Economic Evaluation of Business Cases Technical Guidelines; NSW Government The Treasury (2017), NSW Government Guide to Cost-Benefit Analysis.

2.2 Investment evaluation methodologies

In order to ensure a credible and robust assessment process, it is important to undertake economic assessment for all major investments projects. While cost-benefit analysis is generally the most suitable method of economic assessment, in some cases a less quantitative approach (such as break-even analysis) may be more appropriate.

Table 3: Common evaluation methods

EVALUATION METHOD		ADVANTAGES	DISADVANTAGES
Cost-Benefit Analysis	Assesses the net impact on society from a project or investment, including consideration of the costs and benefits of those external to a transaction.	Allows the comparison of benefits and costs across projects. Does not require that all costs and benefits be monetised	Can be quite resource intensive.
Break-Even Analysis	Break-even analysis considers the amount of money required to change the assessment of the option from positive to negative (or vice versa), or to change the relative ranking of options.	Can be used where it difficult to monetise the main benefits but it's possible to monetise the main costs associated with the project.	Does not quantify the benefits
Cost-Effectiveness Analysis	Cost effective analysis (CEA) assesses the cost of achieving a specific outcome or target, expressed in terms of physical units (e.g. health and safety outcomes). It is often used when effects can be quantified but not monetised.	Can be used when effects can be quantified but not monetised.	Does not analyse whether the benefits of a project outweigh its costs. Requires that the physical outputs being measured have the same value across projects, and that there are no other benefits that vary across projects.

Source: Frontier Economics; NSW Government The Treasury (2017), NSW Government Guide to Cost-Benefit Analysis.

Regardless of the precise technique adopted, to ensure a credible and robust economic assessment process, it is imperative to ensure that identified impacts are clearly associated with the project in question.

In particular, to identify a robust and defensible set of impacts associated with each servicing option, it is imperative to establish a credible causal link between the water investment and the identified impact even in cases where it is not appropriate to monetise the impact. Then following section establishes a robust framework for linking IWCM projects to health benefits.

2.3 Valuing non-monetary impacts

Non-monetary impacts (such as health impacts) are more difficult to incorporate – both because it may be difficult to measure or quantify the impact of the investment as well as subsequently value or monetise the impact. Both of these quantification and valuation elements can require a significant investment of time and money and there is typically a trade-off between ensuring the most accurate estimate of an impact and its value and ensuring that resources are not wasted attempting to monetise minor impacts or impacts that are unlikely to be influential to the overall viability of the project, relative to other potential investments.

It should be noted that economic assessment does not require the monetisation of all relevant impacts (although impacts must be quantified to ensure a causal link between the project and the impact), but rather, in cases where the cost of assigning a monetary value to an impact in a robust manner outweighs benefits of doing so, then an assessment with a lower degree of quantification and monetisation (which although less accurate, is also less time consuming) may be more appropriate.

In cases where it is appropriate to monetise the impact, as shown **Figure 8** there are broadly three techniques for incorporating non-monetary impacts:

- **Benefit transfer** – adopts a value based on existing analysis of similar impacts in other locations.
- **Market-based and revealed-preference valuation** – infers a value by examining consumer behaviour in similar/related markets; and
- **Stated preference** – infers a value through undertaking a survey to determine a customer's willingness to pay.

Figure 8: Approaches for incorporating non-monetary impacts

Complexity of assessment	Low	⟷	High
Technique	**Benefit transfer**	**Market-based and revealed-preference valuation**	**Stated preference**
Summary	Adopts a value based on existing analysis.	Infer a value by examining consumer behavior in a similar/related market.	Undertake an original survey to determine customer's willingness to pay.
Data required	Estimations from other, relevant surveys.	Values from a similar/related market.	Survey responses around a customer's willingness to pay to achieve an outcome.
In practice	Using an estimation of the value of reduced productivity arising from a respiratory related illness.	Using the costs of visiting a gym to estimate willingness to pay for certain forms of exercise	Develop a survey that asks how much they would pay to reduce a respiratory related illness.

Source: Frontier Economics

While the appropriate method of monetisation is likely to vary depending on the impact of interest, available data and the information required, the benefit transfer technique is often adopted for projects with limited resources that require less complex or intermediate assessments or for impacts with a large body of associated research from which to draw relevant values.

Box 2: Applying benefit transfer in practice

The benefit transfer technique adopts a value from an existing body of research as a proxy for the monetary value of the impact of interest. As the benefit transfer technique borrows values (rather than undertaking original in-depth research), it is much quicker, easier and less expensive than other quantitative approaches such as surveys. This makes it more appropriate for projects with limited resources that require less complex or intermediate assessments. However, it should be noted that although benefit transfer does not require the estimation of the monetary value of the impact in question, the impact's size must still be quantified.

There are several conditions that must be satisfied in order for benefit transfer to be a reliable and appropriate method of monetisation:

- The source study must be based on adequate data, sound economic methodology and correct empirical techniques;
- The magnitude of the change in the relevant variables measured and valued in the source study must be similar to the magnitude of the change at the target site.
- The policy context and characteristics of the source and target site should be similar;

The market or households of the source and target site must have similar socioeconomic characteristics.

Source: Frontier Economics

A key issue for this study is establishing which health impacts can be robustly valued using a benefit transfer approach (and which may be capable of incorporation into a Ready Reckoner tool), and which require a bespoke valuation.

3 FRAMEWORK FOR LINKING WATER INVESTMENTS TO HEALTH BENEFITS

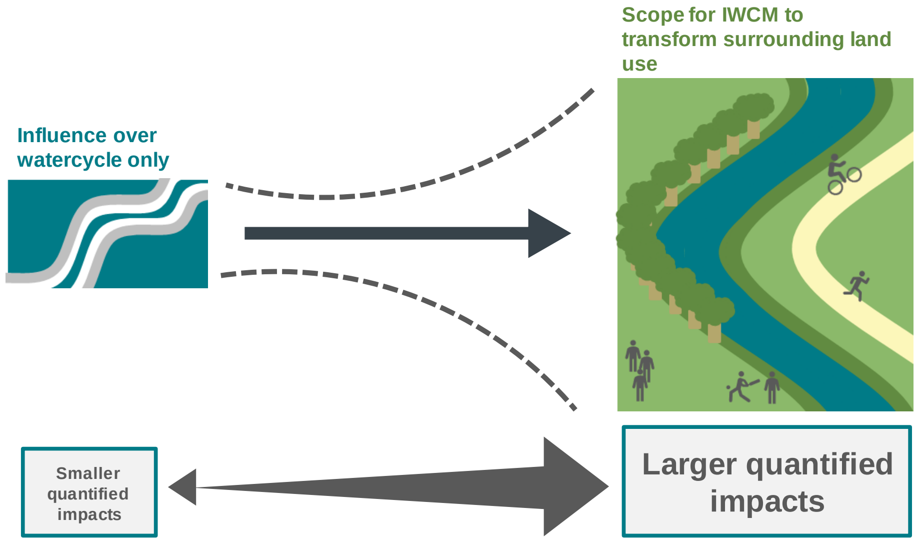
A key challenge is how to incorporate the wide potential scope of liveability-related health impacts into a framework which maps the relationship between water investments and health outcomes in a way which is sufficiently tractable to provide a practical tool for informing business cases. To ensure a credible and robust economic assessment process, it is imperative to ensure that the identified health impacts are clearly associated with the project in question.

Our approach focuses on ensuring only benefits directly attributable to the water investment are included in the assessment (see **Figure 10**). This involves identifying, and where possible quantifying the following relationships:

- between water industry investments and more amenable and accessible greenspace and natural environments;
- between the presence of more amenable and accessible greenspace and natural environments and health risk factors;
- between health risk factors and improved health outcomes; and
- between improved health outcomes and improved economic outcomes.

It should be noted that, the degree of benefits achievable with any water investment will depend heavily on the degree of change of the surrounding land-use and urban form. In particular, where change is restricted to changes in water itself, benefits tend to be more limited. However, where surrounding open space (for example) can be transformed to facilitate broader use, larger benefits can emerge (See **Figure 9**).

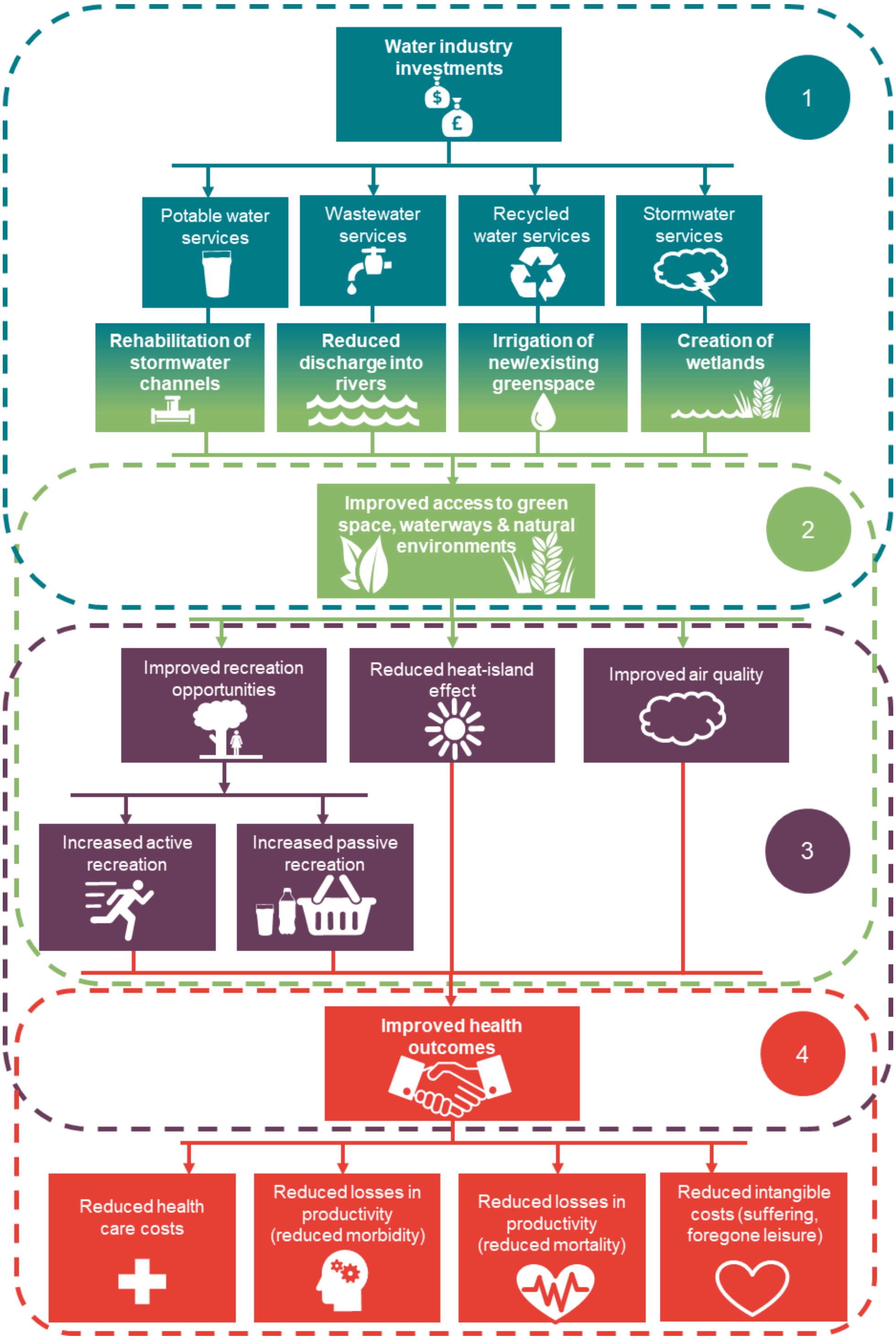
Figure 9: Spectrum of potential liveability benefits



Source: Frontier Economics

While the framework developed here focuses on all of steps linking water investments and health outcomes, we would note that many of the steps are also likely to be useful in considering other potential external impacts. For example, understanding the link between water investments and air pollution is relevant not just to assessing potential health impacts but also environmental and other impacts associated with air pollution.

Figure 10: Potential relationships between water industry investment and health-related liveability benefits



Source: Frontier Economics

As Figure 10 illustrates, IWCM investments can ultimately lead to better health outcomes because those investments improve access to amenable green or bluespace, and this has the potential to reduce pre-existing health risk factors in the population. Reduced health risk factors generate improved health outcomes.

The following sections briefly describes each of these posited relationships. Subsequent sections examine the evidence on these relationships, drawing on an extensive literature review. Further detail is available in Appendix A (including a summary of our literature review methodology).

3.1 Relationship between water investment and improved natural environments

The first step in investigating the relationship between water investments and liveability health benefits is to establish the link between water investment and improved access to more amenable and accessible greenspace, waterways and natural environments.

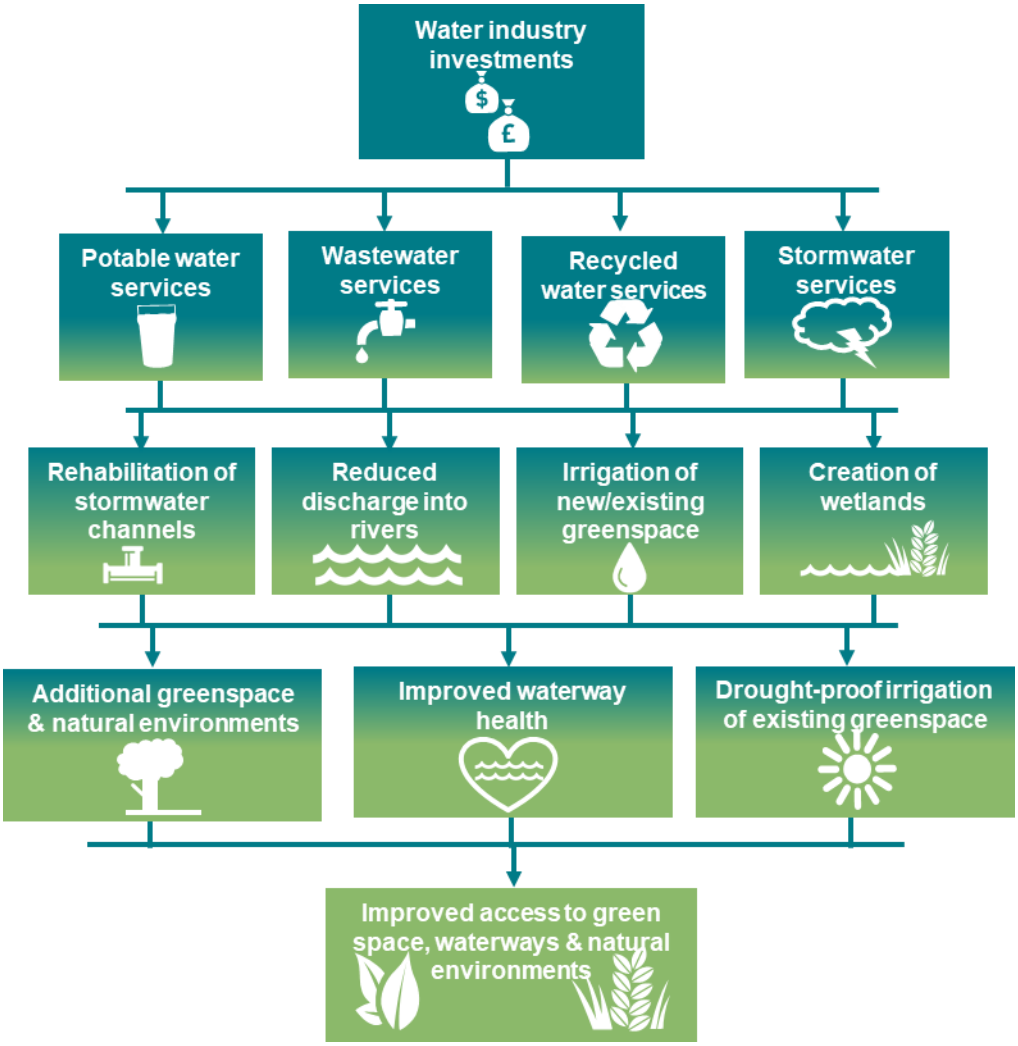
Establishing this causal link is fundamental to appropriately attributing the liveability associated health benefits of water industry investments or activities in a manner consistent with accepted investment evaluation principles.

For example, a project that involves recycling stormwater or wastewater may allow the creation of additional greenspace if it provides the opportunity to irrigate with recycled water (where using potable water is not a viable option due to cost or availability at times of water scarcity). However, care must be taken to ensure that the presence of the greenspace is directly attributable to the water industry investment (i.e. that the greenspace would **not** be available in the absence of the water project).

This will involve clearly establishing a causal link between the water investment and more amenable and accessible greenspace, waterways and natural environments. As shown in **Figure 11**, there are three broad methods that water investment can lead to more amenable and accessible greenspace, waterways and natural environments:

- **A project may create additional greenspace,** through the rehabilitation of an existing, concrete stormwater channel to include ovals and cycle paths, or through the use of natural stormwater retention lakes. For example, the 'Greening the Pipeline' project transformed the Melbourne Outfall Sewer into a linear parkland, connecting disparate communities in the city.
- **A project may lead to drought-proof irrigation of greenspace**, allowing for greenspace throughout the year (compared to a counterfactual involving potable water irrigation of the greenspace, which would be subject to water restrictions). In this case, the relationship between the water investment and greenspace is that the greenspace is green throughout the year, rather than the investment creating additional greenspace.
- **A project may create additional greenspace through improved swimming opportunities in downstream rivers.** For example, a recycled water project may result in reduced wastewater discharge in a nearby river, improving the swimming opportunities.

Figure 11: The relationship between water industry investments and improved access to greenspace, waterways and natural environments



Source: Frontier Economics

This discussion suggests that establishing the counterfactual or 'base case' becomes critical in determining the appropriate 'attribution factor' (potentially ranging from 0% to 100 %) of the availability of the greenspace to the water sector investment or activity. Further guidance on the establishment of an appropriate 'attribution factor' based on comparing the impact of the water investment relative to a base case is provided in **Section 8.8**.

3.2 Relationship between improved natural environments and health risk factors

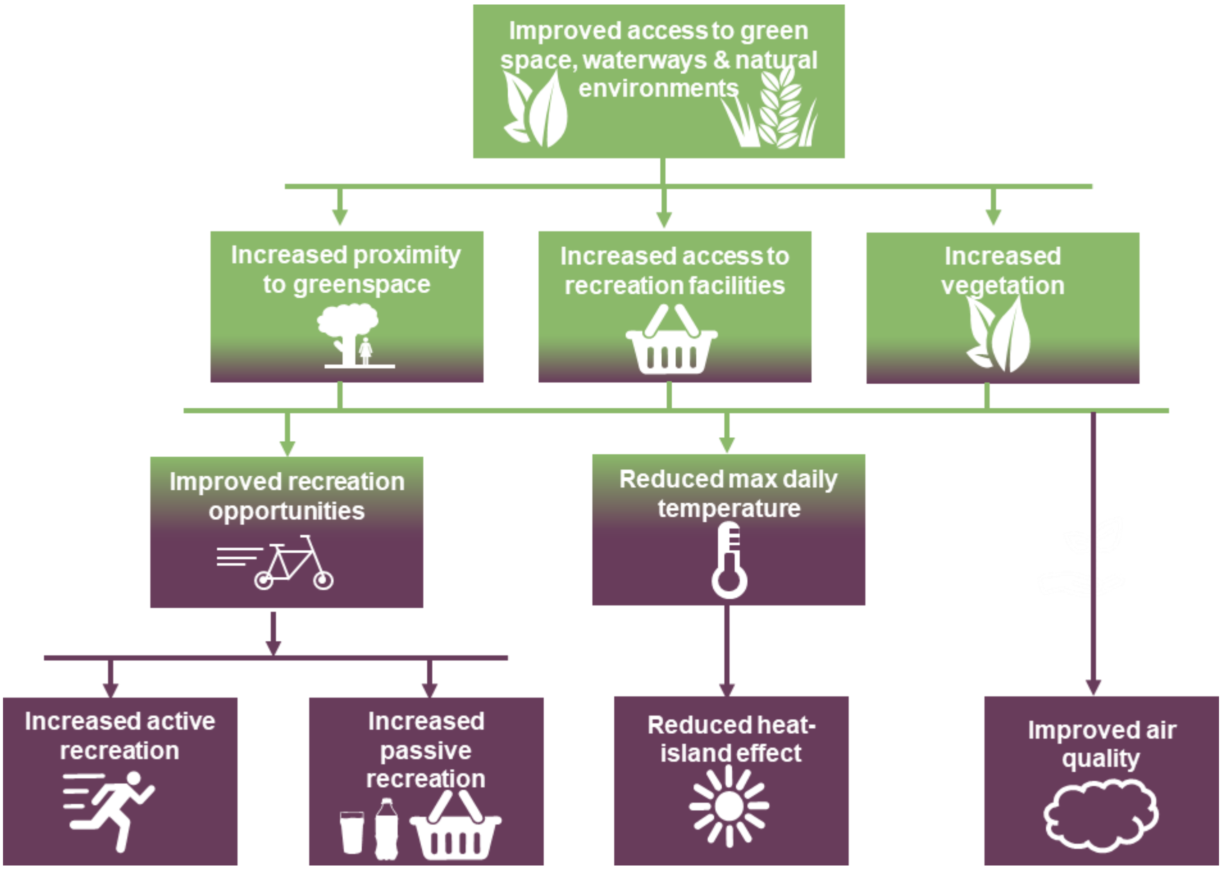
To generate liveability benefits, a link must then be made between the presence of more amenable and accessible greenspace, waterways and natural environments and improved recreation opportunities or other drivers of improved health outcomes (e.g. reduced heat island effect). In particular, as shown in **Figure 12**, this involves identifying the relationship between:

- more amenable and accessible greenspace and active recreation;

- more amenable and accessible greenspace and passive recreation;
- greenspace and the urban heat island (UHI) effect[10]; and
- greenspace and improved air quality.

Each of these relationships is discussed in more detail below.

Figure 12: The relationship between improved access to greenspace, waterways and natural environments and health risk factors



Source: Frontier Economics

3.3 Relationship between health risk factors and improved health outcomes

In order to quantify the impact of water investment it is important to clearly identify the relationship between reductions in health risk factors catalysed by the water investment, and improved health outcomes for the affected population. A risk factor is any factor that causes or increase the likelihood of a health disorder or other unwanted condition or event.

This involves:

- Understanding the epidemiological relationships between health risk factor and health outcomes

[10] The UHI effect is defined by the differences in observed ambient temperatures between urban areas & the surrounding non-urban areas, caused by increase in heat-retaining impervious surfaces arising from increased urbanisation.

- Developing a metric for the improved health outcomes.

3.3.1 Epidemiological relationships between health risk factor and health outcomes

In general, reduced health risk factors (in the form of increased recreation, reduced heat island effect and improved air quality) can be expected to have flow-on effects through reduced morbidity and mortality associated with linked diseases or conditions.

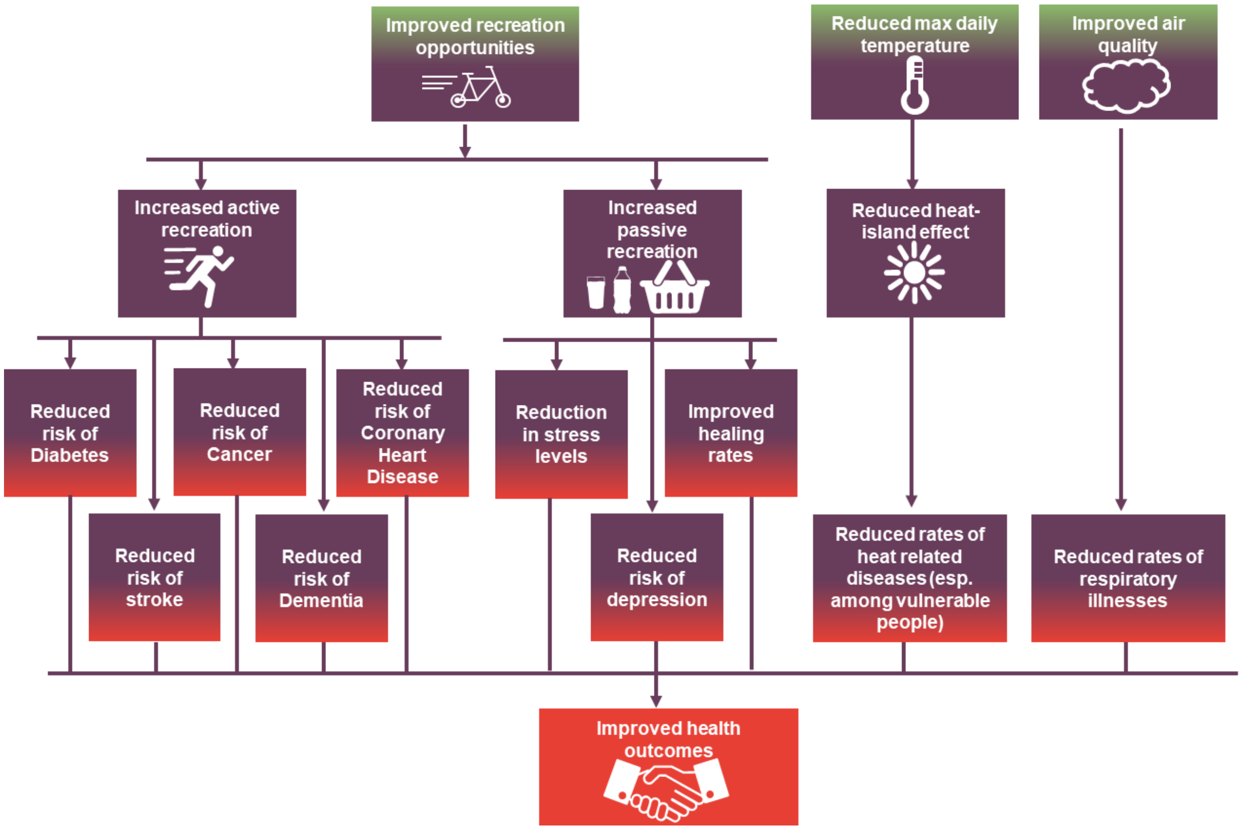
Relative risks are used to quantify the increased risk for an individual exposed to the identified risk factor. While the health risk factors discussed above are rarely listed as the cause of death, various studies have found that reduced physical recreation, poor air quality and increased heat leads to increased risk of death or disease. For example, obesity (of which lack of physical recreation is a key indicator) is associated with many serious illnesses, such as coronary heart disease, and as such, an increase in physical activity and a subsequent reduction in the rates of obesity may be associated with a range of health outcomes.

As such, step three is to identify the relationship between relevant health risk factors and improved health outcomes. As shown in **Figure 13**, this involves identifying the relationships between:

- increased active recreation and physical health outcomes;
- increased passive recreation and mental health outcomes;
- reduced UHI and improved health outcomes; and
- improved air quality and improved health outcomes.

Evidence on each of these relationships – identifying the relevant linked diseases and how they are affected by the risk factors - is discussed in more detail in **Sections 4 to 7**.

Figure 13: The relationship between health risk factors and health outcomes



Source: Frontier Economics

3.3.2 Metrics for improved health outcomes

As noted in the brief, a key element in developing a framework for understanding liveability-related health benefits is to establish accepted metrics for quantifying these benefits.

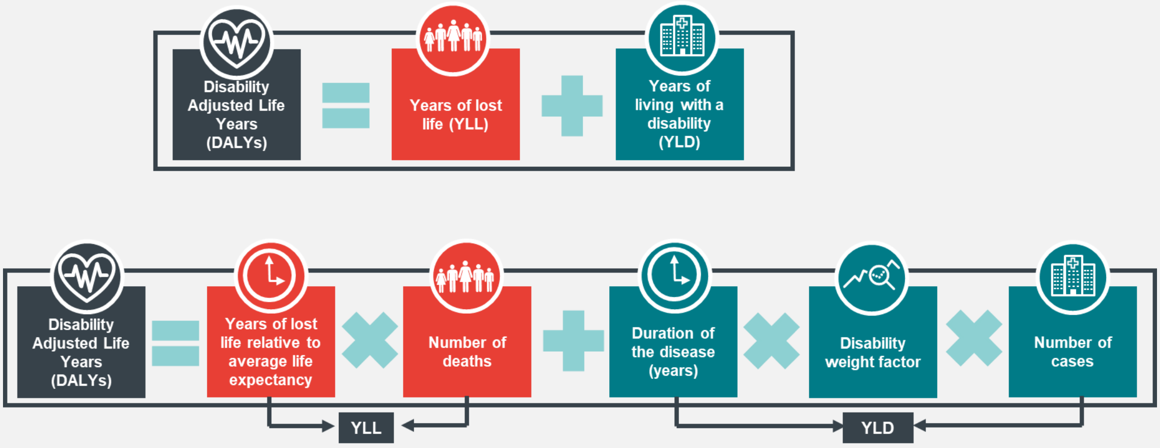
We have adopted disability-adjusted life years (DALYs) lost as the key measure of the change in health outcomes related to water industry investments.

DALYs is widely accepted as a measure for comparing health outcomes across different diseases and causes. One DALY can be thought as a measurement of the gap between current health status and an ideal situation where everyone lives into old age, free of disease and disability (so one DALY is equivalent to the loss of one year of full health). When applied to a population the number of DALYs can be regarded as a measure of the attributable burden of disease (BOD) or the total disability incurred due to a specific disease.

We also note that DALYs are already used in water industry for determining desired health outcomes when managing drinking water quality. Adopting DALYS (rather than Quality-Adjusted Life Years (QALYs)[11]) therefore ensures the liveability-related health benefits attributable to IWCM projects can be readily compared to the more well-known health benefits the water industry generates through the supply of safe drinking water and sanitation services.

[11] A Quality Adjusted Life Year (QALY) is an alternative measure of health outcome or health benefit that is commonly used in some other jurisdictions like the United Kingdom. A QALY is calculated by taking each year of life expectancy and applying a weighting factor between 0 (death) and 1 (full health free of disability or disease) to reflect the quality of life in that year. Methodologies for calculating the weighting factors vary.

Box 3: DALYs



A DALY is defined as the sum of years of life lost (YLL) and years lived with a disability (YLD).

- YLL measures the number of years of life lost due to premature mortality (also referred to as 'fatal burden').
- YLD measures the impact of living with ill-health, that is, the non-fatal component of the burden of disease. The disability weights are within a scale of 0 to 1, where 1 = death & 0 = perfect health. The Australian Institute of Health and Welfare (AIHW) have published a set of disability weights for a range of conditions.

Source: Frontier Economics

Quantifying the relationship between a change in a health risk factor attributable to a water investment requires estimating the change in disease burden (as measured by DALYs) based on the population attributable fraction (PAF). This is a measure, for a particular risk factor and causally linked disease or injury, of the percentage reduction in burden that would occur for a population if exposure to the risk factor were avoided or reduced to its theoretical minimum. In this case, we are seeking to estimate the impact of a reduction in the risk factor (rather than its elimination) due to the water industry investment.

3.4 Relationship between health impacts and economic impacts

The final part of the attribution framework is to identify the relationship between health outcomes and economic outcomes. This is about the value to society of improved health outcomes leading to lower morbidity and mortality. This entails:

- Identifying the nature of these economic cost or benefits
- Applying a methodology for estimating the value of these economic costs/benefits[12].

3.4.1 Identifying the nature of these economic cost or benefits

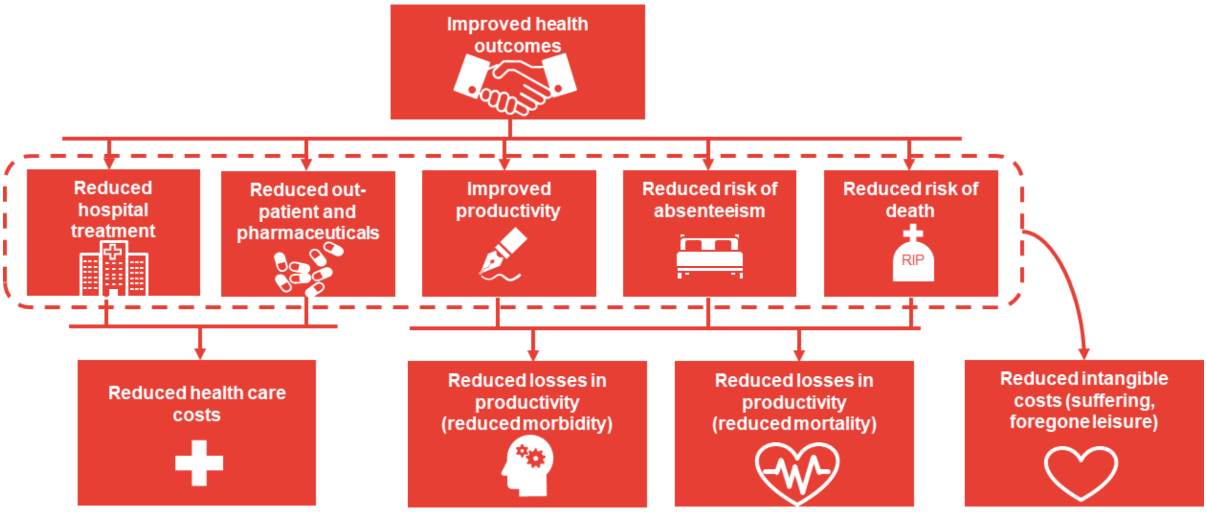
There are several types of economic impacts associated with changes in health outcomes. These can be broadly categorised as:

- Direct costs associated with the healthcare system.

[12] An accessible overview of the key types of costs and methodologies for estimating them may be found in Jo, C. (2014). "Cost-of-illness studies: concepts, scopes, and methods." Clinical and molecular hepatology **20**(4): 327-337.

- Indirect costs and in particular the impact on productivity associated with mortality and morbidity.
- The 'intangible' costs experienced by individuals including pain and suffering and loss of leisure opportunities.

Figure 14: The relationship between improved health outcomes and improved economic outcomes



Source: Frontier Economics

Direct (healthcare) costs

Improved health outcomes translate into reduced utilisation of healthcare services, which can generate significant financial savings for the healthcare system. This monetary cost must be accounted for when estimating the value of liveability associated health benefits. Healthcare costs are typically disaggregated into:

- patient hospital services
- out-of-hospital medical services
- prescription pharmaceuticals.

The direct cost estimates associated with chronic disease are typically higher than those of acute or communicable diseases.

Other direct costs which have been incorporated into some cost of illness studies include non-healthcare costs incurred by patients or their families such as transportation, household expenditure, relocation costs and informal care.

Indirect (productivity) costs

High rates of death or disease leads to a direct and indirect loss in the labour force of the economy, in the form of reduced labour force participation and reduced productivity. These lost productivity costs can be seen as comprising:

- Mortality-related productivity: permanent loss of people from the workforce.
- Morbidity-related productivity: absenteeism (absence from work) and presenteeism (lower productivity while at work).

Productivity loses from disease can be significant. For example, recent work by the Victorian Department of Health highlighted that:

People with chronic disease were less likely to participate in the labour force and be employed full time, than those without chronic disease … and also had more time off work due to their own illness. The estimated cost of absenteeism to the Australian economy was $7 billion per year, while the cost of presenteeism (not fully functioning at work because of medical conditions) was nearly four times more, estimated at almost $26 billion in 2005-06. In addition to financial costs, the cost of disability, lost wellbeing and premature death due to chronic disease is high in Victoria.[13]

Reduced likelihood of premature death from diseases (including diabetes, obesity and respiratory conditions) results in an increase in the available workforce and thus a direct benefit to the economy. Estimating the benefits in reduced productivity losses attributable to water industry investments requires estimates of the number of deaths and impacts on absenteeism and presenteeism of the linked diseases.

Intangible costs

In addition to the economic and financial costs associated with the healthcare system expenditure and lost productivity, morbidity and mortality also imposes a loss of wellbeing experienced by individuals suffering from the diseases (e.g. pain and suffering and foregone leisure opportunities). These intangible impacts are not reflected in the financial and economic measures outlined above.

3.4.2 Methodology for estimating the economic value of these health benefits

There are two common approaches in the literature to valuing changes to morbidity and mortality:

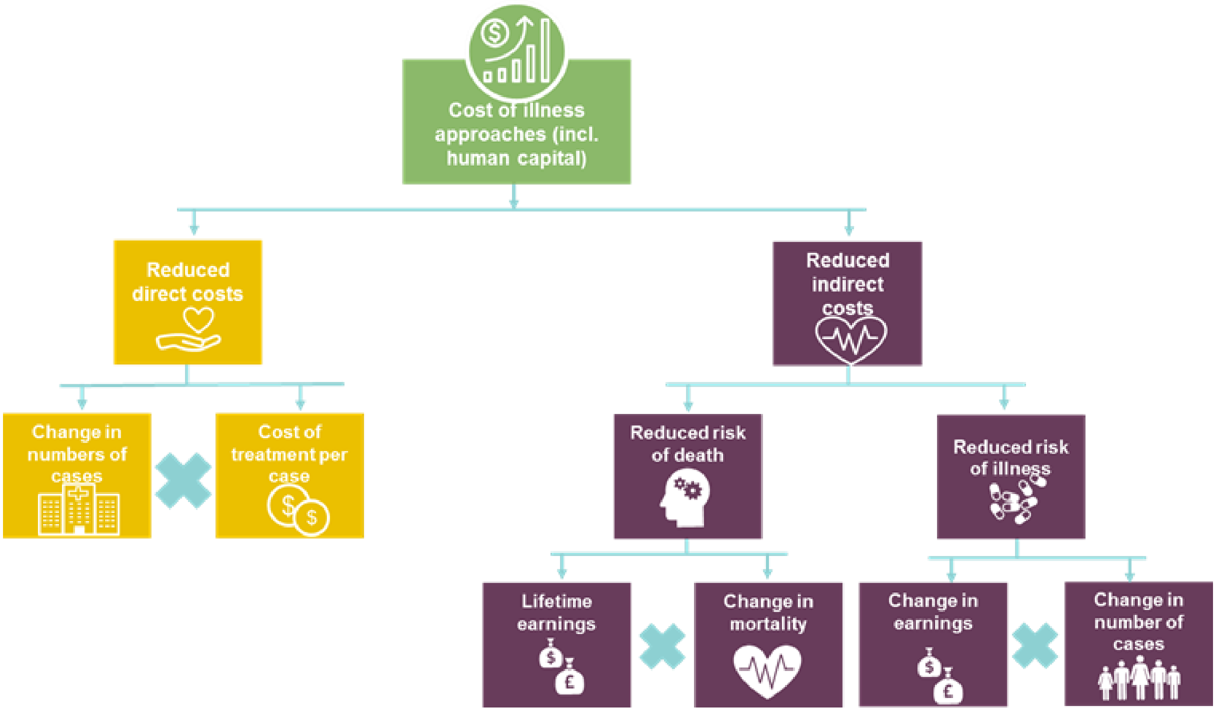
- The ‘cost of illness’ approach.
- The ‘willingness to pay’ approach.

‘Cost of illness’ approach

Under this approach the benefits of actions which improve health benefits are valued on the basis of the direct and indirect costs (**Figure 15**) which are avoided as a result of the intervention (in this case, the water industry investment).

[13] State of Victoria (2015), *Health and Wellbeing Status of Victoria: Victorian public health and wellbeing plan 2015-2019 companion document*, p.18.

Figure 15: 'Cost of illness' approach



Source: Frontier Economics

Direct costs – healthcare system costs

There are two broad approaches for estimating direct healthcare costs in cost of illness studies:

- **Prevalence**: Economic burden of a condition over a defined period (usually one year). Prevalence based studies estimate the number of cases of death and hospitalisations attributable to a given disease in a given year and then estimate the cost which flow from those deaths or hospitalisations.
- **Incidence**: Lifetime costs of a condition from its onset until its disappearance usually by cure or death, with reference to the number of new cases arising in a predefined time period.

We have valued healthcare costs based on the prevalence approach. Most studies use this method because of data challenges in knowing the course of illness and duration under an incidence approach.

Estimating how healthcare costs are likely to be affected by reduced prevalence of linked diseases requires some assumptions about how aggregate costs of treating these disease/conditions (where such estimate area available) are likely to change[14]. A common default assumption used is that there will be a reduction in healthcare costs proportionate to the estimated reduction in DALYs.

Indirect costs – lost productivity

There are two main approaches to measuring lost productivity attributable to mortality:

- The '**human capital'** approach: this measures lost productivity as the amount of time by which working life is reduced due to illness. This work time lost is then valued at the market wage; which economists assume, in a competitive market, reflects the value of that work to society.

[14] The Australian Institute of Health and Welfare (AIHW) has published data on aggregate healthcare costs by disease, including most but not all of the linked diseases of interest here.

- The ‘**friction cost’** approach: this approach proposes that society only incurs losses during the period it takes to replace a worker (the so-called ‘friction period’) due to illness, with internal labour reserves taking up the slack of a missing employee in the short term. For longer term or permanent workplace departures, the friction cost approach assumes that there is a pool of unemployed workers who can take over the role either directly or at the end of a chain of job movements. Under this method, losses are again valued using the market wage[15].

We have adopted the ‘human capital’ approach in the attribution framework for this study. The friction cost method is used less often because it requires extensive data to estimate the losses only during the friction period.

A number of approaches have been adopted to estimating lost productivity related to morbidity (i.e. absenteeism and presenteeism). Essentially, this entail estimating how may days an employee with a particular disease or condition is likely to be absent from work as well as how much their productivity while at work is likely to be reduced.

A recent development in the literature is to measure the impact of disease on workplace productivity through a ‘productivity-adjusted life-year (PALY). A PALY is similar in concept to a disability adjusted life year (DALY), except that each year of life lived is multiplied by a productivity index reflecting reduced work productivity[16] rather than an index reflecting reduced quality of life. For example, for diabetes a productivity index of 0.921 was calculated based on estimates by the American Diabetes Association of the impacts of diabetes on absenteeism and presenteeism.

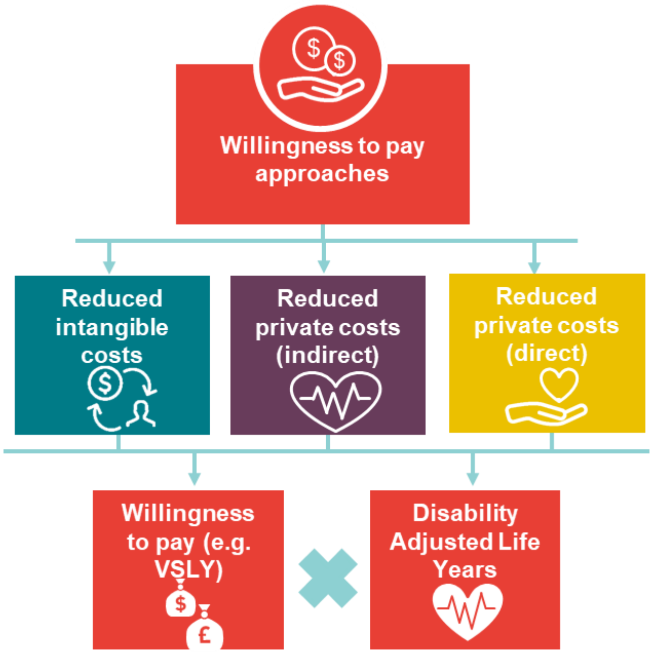
Willingness to pay (WTP) approach

The second broad approach to valuing health impacts in monetary terms is the willingness to pay (WTP) approach (**Figure 16**). This approach uses economic methods to ask people (or infer) the amount they would be willing to pay to reduce the risk a negative health event.

[15] To calculate the value of lost time there is a need to know the length of the friction period, which is based on the level of unemployment (when more people are unemployed it is easier to find a replacement worker) and the efficiency of identifying replacement workers. Because these factors vary by industry, job type and over time, the friction period is context-specific and constantly changing

[16] See Magliano, D. J., et al. (2018). "The Productivity Burden of Diabetes at a Population Level." Diabetes care: dc172138.

Figure 16: Willingness to pay (WTP) approach



Source: Frontier Economics

In principle, WTP approaches capture lost wages, as well as (privately incurred) medical expenses and intangible costs such as pain and suffering.

Under this approach, the monetary value of improved health outcomes is calculated as the DALY (or change in DALY) multiplied by the value of a statistical life year (VSLY) (see Box 4). The value of a statistical life (VSL) is an estimate of the financial value society places on reducing the average number of deaths by one. A related concept is the value of a statistical life year, which estimates the value society places on reducing the risk of premature death, expressed in terms of saving a statistical life year.

The Commonwealth Department of Premier and Cabinet have recommended the use of a specific value for VSL. The OBPR recommends the use of this value for VSL and VSLY in Regulation Impact Statements for regulatory proposals aimed at reducing the risk of physical harm. Frontier recommends this as an appropriately authoritative benchmark for use in this study (after being indexed by CPI to 2018).

Typically, WTP approaches (based on value of a statistical life) lead to higher estimates of the value of life than studies using the human capital approach as it includes capture lost wages, as well as medical expenses and intangible costs such as pain and suffering.

Box 4: Value of a statistical life

The value of a statistical life (VSL) is often used to estimate the benefits of reducing the risk of death. VSL is an estimate of the financial value society places on reducing the average number of deaths by one. A related concept is the value of a statistical life year (VSLY), which estimates the value society places on reducing the risk of premature death, expressed in terms of saving a statistical life year.

Ideally VSL would be estimated for the individual regulation taking into account the types of risks addressed and the people affected. However, as noted by the US EPA, this is likely to be too costly to be undertaken for individual regulatory proposals.

The Office of Best Practice Regulation (OBPR 2014) suggests that based on international and international research (based on various WTP studies), a credible estimate of VSL is $4.2m and the value of one VSLY) is $182 000 in 2014 dollars.

Based on this value (which is predicated on a healthy person living for another 40 years), and adopting a discount rate of 3%, VSL and VSLY can be estimated by age (reflecting years of remaining life expectancy).

The VSLY for each age group can then multiplied by the change in DALY (by age group) to generate an estimate of the dollar value of liveability-related health benefits from reduced morbidity and mortality.

Source: Frontier Economics

Some recent studies apply a ‘welfare weighting’ to WTP which leads to a dollar benefit to people in lower socioeconomic groups being valued more highly than a dollar benefit to people in higher socioeconomic groups[17]. While this approach has been endorsed in the HM Treasury Green Book, we have adopted a standard ‘unweighted’ CBA methodology which focuses on economic efficiency on the basis that inter-personal comparisons of wellbeing are inherently subjective and should be left to policymakers rather than the analyst and that such equity concerns are generally seen as being better addressed by government through direct mechanisms (e.g. the tax and social welfare system) rather than this being an appropriate function for water businesses. Merely because the government should pursue distributive goals does not mean that each and every agency should.

3.4.3 Our approach

Our framework allows for the monetisation of health benefits under both methodologies as separate concepts.

- Model 1 (Cost of Illness (CoI)): relates to the more tangible costs associated with healthcare and economic costs associated with lost productivity. These more tangible costs are arguably more closely linked to potential co-funding opportunities (e.g. health department or State economic development departments).

[17] For example, one approach adopted in some studies is to multiply the WTP by the marginal utility of income. See Fields in Trust 2018, Revaluing Parks and Greenspaces: Measuring their economic and wellbeing value to individuals Greenspaces for Good, Fields in Trust. Available at: http://www.fieldsintrust.org/Upload/file/research/Revaluing-Parks-and-Green-Spaces-Report.pdf

- Model 2 (Willingness to Pay): this can be seen as an indication of the value to society of the gain in wellbeing associated with the improved health outcomes attributable to liveability-related IWCM projects.

This dual approach avoids potential double counting issues associated with attempting to add elements of the WTP approach to the Cost of Illness approach. For example, to the extent that estimate of WTP include private healthcare costs[18] and income from wages, simply adding WTP estimates based on the VSL to estimates of direct healthcare cost and indirect productivity costs is likely to result in a significant over-estimation of health benefits due to double-counting. Reporting estimates under the Cost of Illness (CoI) and WTP approaches represents a conservative approach to avoiding such double-counting. At the same time, this dual approach allows comparison of IWCM projects (viewed as health interventions[19]) with studies of other health interventions which have adopted one or other of these methodologies.

3.5 Key health pathways

In considering how the attribution framework outlined above applies to water sector investments, we have identified four key health pathways:

- Improvements in health resulting from more active recreation
- Improvements in mental health resulting from more exposure to greenspace
- Improvements in health resulting from reduced temperatures associated with the Urban Heat Island effect
- Improvements in health resulting from lower air pollution.

Based on the research and analysis undertaken for this study, in our view these four pathways represent the most material, tangible and widespread links between water industry investment and liveability-related health outcomes.

A number of other potential pathways were also identified including:

- Impacts on water investments on vector (mosquito-borne) diseases
- Reduced injuries and fatalities from crime reflecting enhanced community cohesion from improved open public space
- Impacts on mental health from noise pollution

While a causal link between water industry investments and health outcomes for these other pathways can be hypothesised, establishing defensible quantitative relationships for these pathways appears problematic. We have therefore focused on the four pathways listed above.

The following sections summarise the available evidence on the nature and strengths of the relationships between water industry investments, health risk factors, health outcomes and economic outcomes for each of these four pathways (more detail is provided in Attachment A). We also outline our findings on the implications for quantifying and monetising the health impacts for the purposes of investment evaluation of IWCM projects.

[18] The OBPR advised that the estimate of VSL are considered to incorporate privately incurred healthcare costs (pers com Dylan Raymond, Adviser, Office of Best Practice Regulation, Economic Division Department of the Prime Minister and Cabinet 3rd August 2018).

[19] Recognising of course that health benefits are not typically the principal objective of an IWCM project, which is likely to have a range of other service and other impacts

4 HEALTH PATHWAY 1: ACTIVE RECREATION

The hypothesis underpinning Health Pathway 1 (Active Recreation) is that IWCM investment can lead to more amenable and accessible greenspace and natural environments which in turn will lead to more active recreation and to improved health outcomes.

Key Findings:

- Establishing the counterfactual or 'base case' is critical in determining the appropriate 'attribution factor' (potentially ranging from 0% to 100%) of the availability of the greenspace to the water sector investment or activity. Where the base case would entail using traditional sources of water (rather than recycled water) to irrigate greenspace, it would be inappropriate to attribute all of the consequent health benefits to the IWCM option involving recycled water.
  - Where the improvement in the greenspace and natural environment would not have materialised under a traditional approach, all or most of the consequent health benefits can be appropriately attributed to the IWCM investment.
  - The majority of recent studies support a positive relationship between parks and open spaces and the facilitation of active and passive recreation. However, the presence alone of greenspace is not sufficient to encourage recreation. Greenspace is associated with the greatest impact on recreation when it is accessible, attractive and of sufficient size to facilitate activity.
- A reasonable estimate of the proportion of the population which is likely to undertake more physical activity as a result more amenable an accessible greenspace is between 5% and 20%.
- There is a considerable literature on the relationship between increased recreation and improved health outcomes.
- Various studies have found a link between increased physical activity and reduced disease burden, but the frequency and intensity of the physical exercise was found to affect the reduction in the disease burden. Physical inactivity was found to be responsible for between 10-20% of the disease burden for cancer (breast, bowel, uterine), coronary heart disease, dementia, diabetes (type 2) and stroke.
- The greatest improvements in health outcomes may be achieved through measures which increase the levels of exercise undertaken by those members of the population at most risk (rather than additional exercise being undertaken by segments of the population who are already quite active).
- Available evidence suggests that the health disbenefits from exercise are likely to be low relative to the benefits. The majority of recent studies support a positive relationship between parks and open spaces and the facilitation of active and passive recreation.
- Improved health outcomes in the form of reduced mortality and morbidity (i.e. reduced rates of death and disease) can lead to improved economic outcomes in terms of both productivity benefits and reduced health care expenditure. The framework and data provided by the AIHW and several other studies provide a defensible basis for quantifying a link between improved health outcomes attributable to increased physical activity and economic outcomes.

4.1 Relationship between water investment and improved natural environments

Most of the available literature focuses on the benefits potentially attributable to greater access to greenspace, rather than the extent to which the greenspace itself is causally related to water sector investments. While this is not surprising, for the purposes of the current study, a key issue is to assess to what extent the existence of greenspace is directly related to the water sector investment or activity (e.g. the supply of recycled water).

For example, there may be cases where the only difference between the provision of greenspace arising from a water industry investment involving the supply of recycled water and the greenspace without the supply of recycled water is its availability during periods of drought (i.e. without water industry investment the greenspace would still exist, but would be irrigated with potable water and thus subject to water restrictions). In situations where the alternative would involve irrigation through traditional potable water supply, the existence of the additional greenspace (and thus the benefits which flow from this) cannot therefore be entirely attributed to the supply of recycled water. In such cases, the incremental difference in the availability of greenspace under each scenario is likely to be relatively minor. As noted by a study for the Australian Water Recycling Centre:

The marginal value of irrigation is to improve the aesthetic appearance and functionality of public open space. Irrigation of sports fields, for example, improves the experience of active users and potentially reduces injuries. This also improves the reliability of sporting events – the surface is more likely to be usable regardless of weather conditions.

The marginal value of irrigating public open space with recycled water is that it can be used regardless of water restrictions, which typically occur during periods of drought. This could be very valuable during a ten year drought as recently experienced in much of Australia, but less so during a period of more normal rainfall when water restrictions are relaxed. During periods of higher rainfall, all public open spaces are green and outside of drought, water restrictions may not be material.

Many urban water utilities plan for water restrictions to occur no more than a certain frequency, such as once every twenty-five years. In this context, the public health value of irrigation is the improved health outcomes achieved by avoiding restrictions for one year in twenty-five. The actual impact on overall activity rates of having green public open space for an extra year in twenty-five is open to question.

Higher values may be estimated if recycled water infrastructure was to be provided to an asset that would otherwise have no access to mains water*…. It is also argued that irrigation can leverage other investments that further increase physical activity. While conceivable, those investments would need to be assessed on their own merits.*[20]

One particular type of greenspace where there may be a relationship between a water investment and the quality and availability of the greenspace is sportsfields. As noted by Phillips and Turner (2013), sports that use large quantities of water for the maintenance of their facility's playing fields (such as turf-based sports such as Australian Rules Football, cricket soccer and clay-based tennis courts) were severely impacted by drought conditions and subsequent restrictions on water use in the period between

20 Marsden Jacobs Associates (2014), *Economic and social values associated with non-potable recycled water*, p.24.

2001 and 2010. As observed by Shilbury and Kellett (2011), sport is considered to be an important part of the social fabric of communities.

In some cases, improved natural environments including healthier waterways may be a clear distinguishing feature of approaches which entail stormwater capture and reuse compared to business as usual approaches. For example, the creation of wetlands associated with stormwater harvesting is integral to the water servicing option adopted (and thus it would be more valid to attribute 100% of the existence of this greenspace to the particular water servicing approach adopted. Such a stormwater harvesting solution may also be directly responsible for improvements in downstream waterway quality (i.e. more amenable 'bluespace'). Similarly, physical investments such as creation of a cycle path along an easement can be seen as creating greenspace which is entirely attributable to that investment.

Key Findings:

- Establishing the counterfactual or 'base case' is critical in determining the appropriate 'attribution factor' (potentially ranging from 0% to 100%) of the availability of the greenspace to the water sector investment or activity.
- Where the base case would entail using traditional sources of water (rather than recycled water) to irrigate greenspace, it would be inappropriate to attribute all of the consequent health benefits to the IWCM option involving recycled water.
- Where the improvement in the greenspace and natural environment would not have materialised under a traditional approach, all or most of the consequent health benefits can be appropriately attributed to the IWCM investment.

4.2 Relationship between more amenable and accessible greenspace and active recreation

Various studies have suggested that the presence of greenspace and natural environments can lead to improved recreation opportunities, both in the form of active recreation (i.e. physical activity) and passive recreation (e.g. the ability to sit and enjoy a park).[21] As observed a study for the Australian Water Recycling Centre:

> *Public open space is a major resource for physical activity, through organised sport, walking, running and cycling. In Australia, public open space is the third most popular venue for physical activity, after streets and home.*[22]

[21] For a summary of the relevant literature, see Appendix A.

[22] Marsden Jacobs Associates (2014), *Economic and social values associated with non-potable recycled water,* p.23.

However, the study also cautioned that:

> *Attributing a quantified health value to public open space is a significant challenge. Geographical comparison of areas linking their physical activity rates to public open space provision is frustrated by qualitative differences between parks such as design differences, infrastructure and facilities provided, and even climatic differences …Also, correlation is not causation. There may be socioeconomic or demographic differences between suburbs that account for differences in public open space use. Areas with better quality parks may also attract residents with stronger demand for those services.*[23]

In seeking to establish a quantitative relationship between more amenable and accessible greenspace and active recreation key issues to understand include:

- what proportion of the population are likely to take up the opportunities for increased recreation offered by more amenable and accessible greenspace?
- how much more physical activity these people are likely to undertake?
- are there particular segments of the population who are more or less likely to take up these opportunities?

As shown in **Appendix A**, the majority of recent studies, both internationally and domestically, support a positive relationship between parks and open spaces, and the facilitation of recreation. For example, Astell-Burt et. al. (2014) analysed 203,833 Australians in the '45 and up study' and found a 20% increase in the level of neighbourhood greenspace was linked with a 6% increase in weekly walking and an 8% increase in weekly moderate to vigorous physical activity.[24]

However, the presence alone of greenspace is not sufficient to encourage increased active recreation. As noted by various studies, greenspace is associated with the greatest impact on recreation when it is accessible, attractive and of sufficient size to facilitate activity (or connect to other areas). For example, a study by Combes et. al. in 2010 found that individuals living more than 500 metres away from greenspace were 0.64 times as likely to visit than those living less than 100 metres away, while those who lived more than 2,250 metres from formal greenspace were 0.76 times as likely to visit as those living less than 830 metres away. This suggests that in order to increase recreation levels, greenspace must be located in an accessible area near residential properties. Sports fields generally deter undedicated use, while remote greenspace is generally less valuable as a health resource, when assessed in terms of its ability to facilitate high volume and frequent physically active use.

In NSW, Ball et. al. (2001) investigated the aesthetic importance of greenspace on physical activity, concluding that individuals who perceived their environments as moderately and poorly aesthetic were 16% and 41% less likely to walk for exercise relative to individuals in high aesthetic environments, indicating the importance of irrigation.[25]

These findings mark the importance of considering not only absolute 'greenspace', but the facilities and the opportunities available for recreation stemming for the type and quality of the greenspace. In particular, a recent study 'Creating Liveable Cities in Australia' suggested that:

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[23] Marsden Jacobs Associates (2014), *Economic and social values associated with non-potable recycled water.*

[24] Astell-Burt, T., et al. (2014). "Greenspace is associated with walking and moderate-to-vigorous physical activity (MVPA) in middle-to-older-aged adults: findings from 203 883 Australians in the 45 and Up Study." British Journal of Sports Medicine **48**(5): 404-406.

[25] Ball, K., et al. (2001). "Perceived Environmental Aesthetics and Convenience and Company Are Associated with Walking for Exercise among Australian Adults." Preventive Medicine **33**(5): 434-440.

There is growing evidence of a range of health benefits associated with access to larger, proximate public open space, including encouraging recreational walking. However, to bring the greatest health benefits, it may be preferable to provide access to fewer but larger higher-quality local public open spaces within closer walking distances of dwellings.[26]

While the bulk of the literature supports a relationship between more amenable and accessible greenspace and increased physical activity, the challenge is quantifying what proportion of the population are likely to take up the opportunities for increased recreation offered by more amenable and accessible greenspace and how much more physical activity these people are likely to undertake.

Ultimately this requires adopting some reasonable and defensible assumptions reflecting the particular circumstances of the project in question.

For example, in a study valuing the benefits of creek rehabilitation in western Melbourne (in an area assessed to be relatively poorly serviced by green infrastructure), Mekala et. al. (2015) used the assumption that the number of physically active people in the project catchment increased by 10, 12 and 15% to compare the effects of more physically active recreation participants in different areas.

A Western Australian study by Giles-Corti et al. (2005) found that access to proximate and large public open space with attractive attributes such as trees, water features and bird life is associated with 24-50% higher levels of walking relative to very poor access.[27] The study also found that around 23% of people did walking sessions involving 150 minutes or more per week and also that that the chance of doing this amount of exercise increased by around 20% if the greenspace was highly accessible, rather than poor accessible). This implies incremental use across the population is about 5%.

In summary, the relationship between the provision of greenspace and increased physical activity will depend on the extent of improvement in greenspace in an area (i.e. how much of an improvement there is relative to the current state of available greenspace).

Key Findings:

- The majority of recent studies support a positive relationship between parks and open spaces and the facilitation of active and passive recreation.
- However, the presence alone of greenspace is not sufficient to encourage recreation.
- Greenspace is associated with the greatest impact on recreation when it is accessible, attractive and of sufficient size to facilitate activity.
- A reasonable estimate of the proportion of the population which is likely to undertake more physical activity as a result more amenable an accessible greenspace is between 5% and 20%.

[26] Arundel, J., et al. (2017). Creating liveable cities in Australia: mapping urban policy implementation and evidence-based national liveability indicators.

[27] Giles-Corti, B., et al. (2005). "Increasing walking: how important is distance to, attractiveness, and size of public open space?" American Journal of Preventive Medicine **28**(2): 169-176.

4.3 Relationship between increased active recreation and health outcomes

This relationship is about establishing how the increased physical activity attributable to more amenable and accessible greenspace can lead to improved health outcomes. This entails identifying the diseases or conditions which are linked to physical activity and estimating by how much health outcomes could be improved by the increased physical activity (while taking into account any negative impacts on health outcomes from increased physical activity).

Linked diseases

There is considerable literature on the relationship between increased recreation and improved health outcomes.[28]

Of particular note is a very recent study by the Australian Institute of Health and Welfare (AIWH) which examined the impact of physical inactivity as a risk factor for chronic conditions.[29, 30] The study identified seven diseases considered to have a 'convincing' or 'probable' level of evidence supporting a causal association with physical inactivity, according to criteria set by the World Cancer Research Fund:

- Cancer (breast, bowel, uterine);
- Coronary heart disease;
- Dementia;
- Diabetes (type 2); and
- Stroke.[31]

While the attributable burden varied by population characteristics such as age, sex and socioeconomic status, on average, physical inactivity was found to be responsible for between 10-20% of the disease burden for these related diseases.[32] In fact, in 2010, the WHO identified physical inactivity as the fourth leading risk factor for global mortality. Within Australia, only 43% of Australian adults meet the 'sufficiently active' threshold (150 minutes of moderate to vigorous physical activity (MVPA) a week).[33]

While AIHW identified only the seven diseases listed above as having a 'convincing' or 'probable' level of evidence supporting a causal association with physical inactivity, it noted that physical inactivity is

[28] See Appendix A for more detail.

[29] The Australian Institute of Health and Welfare (2017). Impact of Physical Inactivity as a risk factor for chronic conditions. Australian Burden of Disease Study Series no. 15. Canberra, The Australian Institute of Health and Welfare. Available at: https://www.aihw.gov.au/getmedia/df392a65-8cf3-4c09-a494-4498ede2c662/aihw-bod-16.pdf.aspx?inline=true

[30] See also: Ding, D., et al. (2016). "The economic burden of physical inactivity: a global analysis of major non-communicable diseases." The Lancet **388**(10051): 1311-1324.

[31] While physical inactivity is causally associated with a range of other conditions, we propose focusing on the seven outlined above in line with the literature on the subject. Excluding these other conditions does not mean that physical inactivity does not play a role in the development of these conditions, but rather, we have chosen to focus on the relationships with the most robust data supporting the relationship.

[32] In particular, physical inactivity was found to be responsible for 19% of the disease burden for diabetes and stroke, 16% of the disease burden for bowel and uterine cancer, 14% of the disease burden for dementia and 11% of the disease burden for breast cancer and coronary heart disease.

[33] Australian Bureau of Statistics, *Australian Health Survey: Physical Activity 2011-12*, (viewed January 2018). Available at: http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4364.0.55.004Chapter1002011-12

causally associated with a range of other conditions such as back pain, depression, heart failure, metabolic syndrome, obesity, osteoarthritis and osteoporosis[34].

A number of other studies have investigated the link between physical activity and these diseases or conditions including those omitted from the AIHW analysis.

Of particular note, a number of studies have found links between active recreation and mental health. For example, a meta-analysis by Schuch et. al. (2016) found that exercise appears to improve physical and psychological quality of life in people with depression. Golf Victoria suggest that based upon the evidence used by the Department of Health to support the current physical activity guidelines, a conservative estimate of the preventative effect of physical activity is a 25% reduction in risk of anxiety and depression.

Achievable improvement from increased physical activity

In order to estimate potential health impacts, a feasible reduction in the prevalence of physical inactivity is required.

Many studies have found a link between increased physical activity and reduced disease burden. For example, a study including 6,919 subjects from 8 European countries found that people with the greatest access to greenspace were 37% less likely to be overweight or obese than those with the least access.[35] In addition, an international study found that an increase from being inactive to achieving recommended physical activity levels (150 minutes of moderate-intensity aerobic activity per week) was associated with a reduction in the incidence of type 2 diabetes by 26%.[36] However, it should be noted that many studies were limited by poor study design, failure to exclude confounding, bias or reverse causality and weak statistical associations.[37] As such, care must be taken when interpreting the results.

Closer to home, a study investigating the association between body mass index and an objective measure of greenspace in a sample of Australian adults found that women with over 80% proximity to greenspace were less likely to be overweight than those without proximity to greenspace (relative risk ratios of 0.83-0.97). However, no similar association was found for men. [38]

The frequency and type (i.e. intensity) of physical exercise was also found to affect the reduction in disease burden. Thus, for example, activities such as jogging and cycling may be expected to have a greater impact on disease burden than less intensive exercise.

A number of studies suggest that improvement in health outcomes require people to meet minimum threshold levels of activity. In this regard, the Australian Physical Activity and Sedentary Behaviour Guidelines recommend the amount of physical activity to be undertaken each week to maintain good health. These recommendations vary by age:

- People aged 18–64 are recommended to accumulate 150 to 300 minutes of moderate intensity physical activity or 75 to 150 minutes of vigorous intensity physical activity, or an equivalent combination of both moderate and vigorous activities, each week (Department of Health 2014). The guidelines advise to be active most, preferable all, days every week and to avoid prolonged sitting.

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[34] These conditions were excluded from the AIHW's study on the basis that they were not captured as a 'disease; in ABDS 2011 or did not meet the level of confidence criteria used in the study. For some conditions, this indicates that further evidence is required to describe the causal association.

[35] Ellaway, A., et al. (2005). "Graffiti, greenery, and obesity in adults: secondary analysis of European cross sectional survey." BMJ **331**(7517): 611.

[36] Wahid, A., et al. "Quantifying the Association Between Physical Activity and Cardiovascular Disease and Diabetes: A Systematic Review and Meta-Analysis." Journal of the American Heart Association **5**(9): e002495.

[37] See for more detail Lee, A. C. K. and R. Maheswaran (2011). "The health benefits of urban greenspaces: a review of the evidence." Journal of Public Health **33**(2): 212-222.

[38] Astell-Burt, T., et al. (2013). "Greener neighborhoods, slimmer people? Evidence from 246 920 Australians." International Journal Of Obesity **38**: 156.

- People aged 65 and over should accumulate at least 30 minutes of moderate intensity physical activity on most, preferably all, days (Department of Health 2014). They are recommended to do a range of physical activities that incorporate fitness, strength, balance and flexibility. People who do not meet these guidelines are considered insufficiently active, or physically inactive.

While there is a very large literature on the relationship between physical activity and health outcomes, we have placed most weight on the recent AIHW study. This study provides a robust methodology for estimating the impact of given changes in physical activity levels on health outcomes.

The AIHW define physical inactivity as undertaking fewer than a combined 8,000 Metabolic Equivalent of Task (METS) each week (see Box 5).

Box 5: Calculating physical activity levels

According to the AIHW, physical activity is defined by the WHO as "any bodily movement produced by skeletal muscles that expends energy. This exercise may occur in a number of domains such during leisure time or for transport. Physical activity measures are based on the frequency and intensity of activity. In the AIHW study, physical activity is measured using the metabolic equivalent of task (MET), which quantifies the rate of energy expenditure. One (1) MET is equivalent to the rate of energy expended at rest in 1 minute, whereas 5 METs indicates that the energy expended is 5 times that at rest. The greater the MET, the more the energy that is exerted.

This MET intensity score is multiplied by the minutes spent at each activity intensity to give the total MET score for that activity (Jette M, Sidney K & Blümchen G 1990). Moderate exercise, such as brisk walking, recreational swimming, dancing or social tennis, have a MET intensity between 3.5 and 5. Vigorous activity requires more effort and includes running, fast cycling and many organised sports. These activities have a MET intensity of around 7 and above. The MET scores in each activity domain were mostly calculated by the duration of exercise per week in minutes, and the activity intensity from the National Nutrition and Physical Activity Survey as part of the Australian Health Survey (AHS) 2011–12. The MET scores from all activities undertaken are summed and then used to group people into physical activity categories:

- Sedentary: total MET score between 1–599
- Low: total MET score between 600–3,999
- Moderate: total MET score between 4,000–7,999
- High: total MET score of 8,000 and above.

Source: AIWH 2017

The analysis in the AIHW report indicates that 2.6% of the total disease burden in Australia in 2011 was due to physical inactivity. When physical inactivity is combined with overweight and obesity, the burden increases to 9%—equal with tobacco smoking, the leading risk factor for disease burden in Australia.

The AIHW 2017 study estimated disability adjusted life years (DALYs) lost due to physical inactivity to be 116,676 DALYs, based on adjusted population attributable fractions (coronary heart disease accounted for about one-third of the total attributable physical inactivity burden).[39]

[39] The Australian Institute of Health and Welfare (2017). Impact of Physical Inactivity as a risk factor for chronic conditions. Australian Burden of Disease Study Series no. 15. Canberra, The Australian Institute of Health and Welfare, p.35. Available at https://www.aihw.gov.au/getmedia/df392a65-8cf3-4c09-a494-4498ede2c662/aihw-bod-16.pdf.aspx?inline=true>,

Importantly, the AIHW study found that notable reductions in disease burden could be achieved with small increase in physical activity in the population at risk. An extra 15 minutes of brisk walking, 5 days each week, could reduce disease burden due to physical inactivity by an estimated 13%. If this time increased to 30 minutes, the burden could be reduced by 26%. All ages would benefit, particularly people aged 65 and over. The report suggests that small sustained increases in daily exercise, particularly for those who are sedentary, could produce sizeable future health gains for the population. Leisure and transport are the main ways people are physically active, making them best placed for targeted interventions to increase physical activity in the population.

By translating the expected increase in physical activity attributable to more amenable an accessible greenspace, the AIHW study provides a means for estimating the impacts of the extra activity attributable to more amenable and accessible greenspace into improved health outcomes (expressed as averted DALYs).

Vulnerability

The AIHW study found that in an aggregate sense, the greatest improvements in health outcomes may be achieved through measures which increase the levels of exercise undertaken by those members of the population at most risk (rather than additional exercise being undertaken by segments of the population who are already quite active). The study found that the lowest socioeconomic group experienced a rate of disease burden due to physical inactivity 1.7 times that of the highest socioeconomic group. [40]

Potential disbenefits from physical activity

Some studies recognise there may be offsetting impacts on the health benefits attributable to water sector investments (e.g. due to exercise-related accidents and injuries).

One Australian study which has frequently been drawn on for analyses of health benefits from physical activity (Medibank 2008) discounted the savings in healthcare costs by 50% to account for offsetting impacts from exercise-related injuries. However, this study did not provide the basis for this estimate.

There is relatively little literature which has explicitly addressed this issue but there does not appear to be any evidence that would support such a large offset.

Some studies suggest that the likelihood and seriousness of such injuries may depend on the nature of activity being undertaken. For example, Zheng suggests that walking is a relatively low risk activity.[41]

[40] The Australian Institute of Health and Welfare (2017). Impact of Physical Inactivity as a risk factor for chronic conditions. Australian Burden of Disease Study Series no. 15. Canberra, The Australian Institute of Health and Welfare. Available at: https://www.aihw.gov.au/getmedia/df392a65-8cf3-4c09-a494-4498ede2c662/aihw-bod-16.pdf.aspx?inline=true

[41] Zheng, H., et al. (2010). "Economic evaluation of the direct healthcare cost savings resulting from the use of walking interventions to prevent coronary heart disease in Australia." International journal of health care finance and economics **10**(2): 187-201.0

Key Findings:

- There is a considerable literature on the relationship between increased recreation and improved health outcomes.
- Physical inactivity was found to be responsible for between 10-20% of the disease burden for cancer (breast, bowel, uterine), coronary heart disease, dementia, diabetes (type 2) and stroke.
- Various studies have found a link between increased physical activity and reduced disease burden, but the frequency and intensity of the physical exercise was found to affect the reduction in the disease burden.
- The greatest improvements in health outcomes may be achieved through measures which increase the levels of exercise undertaken by those members of the population at most risk (rather than additional exercise being undertaken by segments of the population who are already quite active).
- Available evidence suggests that the health disbenefits from exercise are likely to be low relative to the benefits. The majority of recent studies support a positive relationship between parks and open spaces and the facilitation of active and passive recreation.

4.4 Relationship between health outcomes and economic outcomes

The final step is to translate the improved health outcomes into economic outcomes. This entails applying a methodology to place an economic value on the direct, indirect and intangible health costs associated with the improved health outcomes.

Numerous studies have sought to estimate the economic impacts of changes in health outcomes associated with physical activity. While these have used a range of methodologies, they have typically found that the direct and indirect economic costs of physical inactivity can be significant.

A global study by Ding (2016) estimated direct health-care costs, productivity losses, and disability-adjusted life-years (DALYs) attributable to physical inactivity using standardised methods and the best data available for 142 countries, representing 93·2% of the world's population. Direct health-care costs and DALYs were estimated for coronary heart disease, stroke, type 2 diabetes, breast cancer, and colon cancer attributable to physical inactivity. Productivity losses were estimated with a friction cost approach for physical inactivity related mortality. Analyses were based on national physical inactivity prevalence from available countries, and adjusted population attributable fractions (PAFs) associated with physical inactivity for each disease outcome and all-cause mortality. This milestone study found that in addition to morbidity and premature mortality, physical inactivity is responsible for a substantial economic burden, including some $ (INT$) 53·8 billion worldwide in 2013. In addition, physical inactivity related deaths contribute to $13·7 billion in productivity losses, and physical inactivity was responsible for 13·4 million DALYs worldwide.

While there is a considerable literature in this area (see Appendix A), we have placed particular emphasis on Australian studies.

A major study by Medibank Private in 2008 estimated the cost of physical inactivity to the Australian economy to be $13.8 billion, with an estimated 16,178 Australians dying prematurely due to physical inactivity and productivity loses due to physical inactivity of 1.8 working days per worker per year.

Average labour productivity loss caused by physical inactivity was found to cost $458 per employee per year.

A number of other studies examining the economic costs of physical inactivity in Australia appear to have drawn heavily on the results of the Medibank study. For example, Analysis by Dedman (2011) estimated the average cost of physical inactivity to be $757 per physically inactive person per year.[42] These appear to be based on the Medibank study. Similarly, Mekala et. al. (2015) estimated public benefits of avoided health costs of Brimbank, Melbourne (a poorly serviced area in terms of quality of open space) of approximately $75,049 per annum, and potential private benefits of $3.9 million.[43] This highlights the benefits associated with the provision of greenspace to areas with lower health outcomes.

Some studies have also examined the economic impacts of other physical inactivity related conditions. Drawing on work by Econtech, PWC estimated that the cost of presenteeism attributable to obesity was $544 million in 2011-12. In particular, the study found labour force productivity losses of between 0.11% and 0.35% arising from diseases associated with physical inactivity.[44]

Most of the studies examine the economic costs of physical inactivity in terms of the impact if the exposure to the risk factor (inactivity) was eliminated completely In contrast, an Australian study (Cadilhac et al 2011) sought to quantify the health and economic benefits that could be achieved following a feasible reduction (as opposed to a complete elimination) of physical inactivity in the Australian adult population and hence in reduced incident cases of inactivity-related diseases such as cardiovascular disease, cancers and depression. Based on advice from health experts and the literature, a 10% reduction in physical inactivity was selected as an ideal feasible target, and a progressive target of 5% was also modelled. The key findings of the study were that this feasible reduction in the prevalence of physical inactivity could lead to total potential opportunity cost savings of $258m, 37% of these in the health sector.

Another recent Australian study by Zapata-Diomedia et al (2018) explored a method and range of values that could incorporate monetised physical activity related health benefits in assessing a broad range of built environment initiatives. They estimated the change in population level of physical activity attributable to a change in the environment due to the intervention. Then, changes in population levels of physical activity were translated into monetary values. The study found that improvements in neighbourhood environments conferred estimated annual physical activity related health benefit worth up to $70 per person. Improving neighbourhood walkability was estimated to be worth up to $30 and improvements in sidewalk availability up to $22 per adult resident. Value of physical activity health related benefits of walking and cycling were found to be $0.98 and $0.62 per kilometre respectively.

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42 Dedman R (2011), Greening the West: a public health perspective. Presentation from the Department of Health at the Think Tank for Greening the West project meeting on 18 (2011) City West Water Office. Melbourne, Australia.

43 Mekala, G. D., et al. (2015). "Valuing the benefits of creek rehabilitation: building a business case for public investments in urban green infrastructure." Environmental management **55**(6): 1354-1365.

44 Econtech (2007), Econtech (2007), Economic Modelling of the Cost of Presenteeism in Australia. Prepared for Medibank Private. Available at: http://blogs.theage.com.au/business/executivestyle/managementline/Medibank_Presenteeism_FINAL%20(2).doc; Australian Institute of Health and Welfare (2003), The burden of disease and injury in Australia 2003, Cat no. PHE 82, Canberra: AIHW. Available at: https://www.aihw.gov.au/getmedia/f81b92b3-18a2-4669-aad3-653aa3a9f0f2/bodaiia03.pdf.aspx; Price Waterhouse Coopers (2015), Weighing the cost of obesity: A case for action. Available at: https://www.pwc.com.au/pdf/weighing-the-cost-of-obesity-final.pdf

Key Findings:

- Improved health outcomes in the form of reduced mortality and morbidity (i.e. reduced rates of death and disease) can lead to improved economic outcomes in terms of both productivity benefits and reduced health care expenditure.
- The framework and data provided by the AIHW and several other studies provide a defensible basis for quantifying a link between improved health outcomes attributable to increased physical activity and economic outcomes.

4.5 Conclusion: valuation of liveability-related health benefits

It is feasible to estimate monetary values of liveability-related health benefits attributable to increased physical activity due to more amenable and accessible greenspace linked to water investments.

In doing so, the most well-established relationships are between increased activity and health outcomes, and health outcomes and economic outcomes:

- Physical inactivity is a known risk factor for various diseases, including certain cancers, coronary heart disease, dementia, diabetes and stroke. Inactivity is also linked to depressive disorders. Moreover, estimates exist of effect of exercise on physical-activity related health burdens (measured in DALYs) in given populations.
- Well-accepted methodologies also exist to translate improved health outcomes into economic outcomes.

The more problematic element is establishing how much additional activity can be attributed to more amenable and accessible greenspace, and the extent to which this improvement stems for an IWCM initiative. However, some defensible assumptions on the extent of increased participation in physical activity can be made depending on the quality and location of the greenspace.

Section 8 provides more detail on how we have applied the quantitative relationships explored in this health pathway in practice and used key assumptions to monetise the benefits of reduced inactivity within our Ready Reckoner model.

5 HEALTH PATHWAY 2: PASSIVE RECREATION

The relevant hypothesis for Health Pathway 2 (Passive Recreation) is that IWCM investment can lead to more amenable and accessible greenspace and natural environments which in turn will lead to more passive recreation and exposure to greenspace which in turn leads to improved mental health outcomes.

Key Findings:

- The extent of increased 'participation' in passive recreation is likely to be significantly higher than the extent of increased participation in 'active' recreation because 'passive' recreation involves much less effort than does 'active' recreation and can simply entail being in visible contact with greenspace.
- Studies have found a link between greenspace and mental wellbeing, including reduced stress levels, improved job satisfaction and improved productivity.
- While the links between public open spaces and mental health are becoming better understood, it can be difficult to accurately quantify the relationship, given the lack of robust data.
- However, a recent Australian study found that visits to outdoor greenspaces of 30 minutes or more during the course of a week could reduce the population prevalence of depression and high blood pressure by up to 7% and 9% respectively.
- The impact of reductions in depression attributable to more amenable and accessible greenspace on direct and indirect costs can be estimated by assuming a proportionate reduction in the prevalence of depression.

5.1 Relationship between water investment and improved natural environments

This relationship has been discussed in **Section 4.1** above.

5.2 Relationship between more amenable and accessible greenspace and passive recreation

This relationship reflects the extent to which the population participate in additional passive recreation where there is an increase in the quality or quantity of greenspace and natural environments.

A key observation here is that the extent of increased 'participation' in passive recreation is likely to be higher than the extent of increased participation in 'active' recreation as discussed in **Section 4.2** above. This is because 'passive' recreation involves much less effort than does 'active' recreation and can simply entail being in visible contact with greenspace. This suggests that any health benefits associated with passive recreation and proximity to greenspace are likely to be enjoyed by a greater proportion of the population than that which improves their health through more physical activity (as discussed in **Section 4.2** above).

Key Findings:

- The extent of increased 'participation' in passive recreation is likely to be higher than the extent of increased participation in 'active' recreation because 'passive' recreation involves much less effort than does 'active' recreation and can simply entail being in visible contact with greenspace.

5.3 Relationship between increased passive recreation and mental health outcomes

A number of studies suggest that passive recreation/exposure to greenspace can lead to a range of health benefits including:

- Reductions in stress levels and the incidence of stress-related ailments, whereby greenspace reduces exposure to urban stressors (e.g. noise) and their detrimental effects;
- Improved healing rates after surgery and illness;
- Improved job satisfaction;
- Improved mood, through restoring the finite mental resources drawn on in daily life for making decisions, and for regulating mood and behaviour;
- Increased social cohesion and (decreased) rates of violence;
- Improved concentration / productivity.[45]

Particular attention has focused on the potential impacts on mental health outcomes.

In recent years there has been increasing recognition of the extent to which mental disorders contribute to the overall disease burden. For example, the Global Burden of Disease study found that mental disorders ranked as high as cardiovascular and respiratory disease and exceed all cancers combined[46].

A number of studies have examined the effect of greenspace on mental wellbeing.[47] For example, a study by Bratman et al. found that there are health benefits from merely being in contact with greenspace, including increases in memory, attention, concentration, impulse inhibition and mood.[48] In similar terms, Marsden Jacob Associates state that:

[45] See for example, Marselle, M. R., et al. (2013). "Walking for well-being: are group walks in certain types of natural environments better for well-being than group walks in urban environments?" International Journal of Environmental Research and Public Health **10**(11): 5603-5628; Bratman, G. N., et al. (2012). "The impacts of nature experience on human cognitive function and mental health." Annals of the New York Academy of Sciences **1249**(1): 118-136.

[46] see Chisholm, D., et al. (2006). Dollars, DALYs and decisions: economic aspects of the mental health system, World Health Organization, p. 20

[47] See Appendix A for a summary.

[48] Bratman, G. N., et al. (2012). "The impacts of nature experience on human cognitive function and mental health." Annals of the New York Academy of Sciences **1249**(1): 118-136.

Natural environments assist recovery from mental fatigue; people prefer natural environments over urban ones, regardless of nationality or culture; people are more positive in attitude and have higher life satisfaction when close to nature; future health problems are likely to be dominated by stress-related illnesses, mental health problems, and cardiovascular disease; exposure to natural environments such as public open space assist recovery from all of these health conditions.[49]

Several studies suggest that greenspace improves mental health through a 'stressor reduction pathway (Hartig et al 2014) by reducing exposure to urban stressors such as noise and in boosting capacity to deal with life stressors.

A number of researchers have investigated potential well-being effects of greenspace for particular groups. In a literature review of the greenspace benefits to children, McCormick (2017) concludes that access to greenspace was associated with improved mental well-being, cognitive development, attention restoration, stress moderation, as well as many other benefits.[50] McEachan et al. (2015) finds strong evidence for well-being benefits of greenspace in pregnant women, where those living in the greenest quintiles (3-5) were 18-23% less likely to report depressive symptoms relative to the least green areas.[51]

However, as noted by various studies,[52] while the links between public open spaces and mental health are becoming better understood, it can be difficult to accurately quantify the relationship, given lack of robust data. For example, Gascon et al. (2015) note that although there is strong consensus in the literature regarding mental health benefits of greenspace, there is some criticism that the causal evidence is limited and inadequate due to largely cross-sectional studies, whereby random variation is more difficult to justify.[53] Interestingly, two separate studies drawing upon the same pooled dataset from Spain, UK, Netherlands and Lithuania differed in their conclusions: one found no statistically significant associations between mental health and residential natural outdoor environment, while the other found that time spent visiting greenspace improved mental health.[54] Some studies therefore suggest that in order to ensure a robust analysis, the inclusion of mental health benefits should be qualitative and peripheral to the main analysis.[55]

That said, some recent studies have sought to quantify the links between exposure to greenspace and improvement in mental health. Of particular interest is a recent Australian study (Shanahan 2016) which used a nature dose framework to examine the associations between the duration, frequency and

49 Marsden Jacobs Associates (2014), *Economic and social values associated with non-potable recycled water,* p.23.

50 McCormick, R. (2017). "Does Access to Greenspace Impact the Mental Well-being of Children: A Systematic Review." Journal of pediatric nursing **37**: 3-7.

51 McEachan, R. R. C., et al. (2016). "The association between greenspace and depressive symptoms in pregnant women: moderating roles of socioeconomic status and physical activity." Journal of Epidemiology and Community Health **70**(3): 253..

52 See for example Marsden Jacobs Associates (2014), *Economic and social values associated with non-potable recycled water,* p.25; CJC Consulting (2005), CJC Consulting, Willis. K, & Osman. L 2005, Economic Benefits of Accessible Greenspaces for Physical and Mental Health: Scoping study, Forestry Commission. Available at: https://www.forestry.gov.uk/pdf/FChealth10-2final.pdf/$FILE/FChealth10-2final.pdf

53 Gascon, M., et al. (2015). "Mental health benefits of long-term exposure to residential green and bluespaces: a systematic review." International Journal of Environmental Research and Public Health **12**(4): 4354-4379.

54 See Triguero-Mas, M., et al. (2017). "Living Close to Natural Outdoor Environments in Four European Cities: Adults' Contact with the Environments and Physical Activity." International Journal of Environmental Research and Public Health **14**(10); Van den Berg, M., et al. (2016). "Visiting greenspace is associated with mental health and vitality: A cross-sectional study in four European cities." Health & Place **38**: 8-15.

55 Jaguar Consulting Pty Ltd (2010), *Costs and benefits of stormwater harvesting, Paper prepared for the Victorian Department of Health*.

intensity of exposure to nature and health in an urban population. The study found that visits to outdoor greenspaces of 30 minutes or more during the course of a week could reduce the population prevalence of depression and high blood pressure by up to 7% and 9% respectively. Applying this 7% figure to the burden of disease estimate for depression published by the AIHW (measured in DALYs) enables an estimate of the impact of more amenable an accessible greenspace on mental health outcomes.

Key Findings:

- Studies have found a link between greenspace and mental wellbeing, including reduced stress levels, improved job satisfaction and improved productivity.
- While the links between public open spaces and mental health are becoming better understood, it can be difficult to accurately quantify the relationship, given the lack of robust data.
- However, a recent Australian study found that visits to outdoor greenspaces of 30 minutes or more during the course of a week could reduce the population prevalence of depression and high blood pressure by up to 7% and 9% respectively.

5.4 Relationship between health outcomes and economic outcomes

The final step is to translate the improved mental health outcomes into economic outcomes. As per the other pathways, this entails applying a methodology to place an economic value on the direct, indirect and intangible health costs associated with the improved health outcomes.

A number of studies have found that depression and related mental health conditions impose significant economic costs. For example, a 2006 WHO study observed that:

> *Psychiatric disorders impose a range of cost on individuals, households, employers and society as a whole…. Where a comprehensive estimate of overall economic burden for depression has been attempted, for example, total estimate costs (1990 price levels) amount to 3.4 billion pounds in the UK, and between $30-$40 billion in the US. A common feature of these studies is that the lost productivity costs exceed the direct costs of care and treatment, sometimes by as much as six or seven times*[56]*.*

Given that the AIWH has published healthcare costs for depression, the impact of reductions in depression attributable to more amenable and accessible greenspace on healthcare costs can be estimated by assuming a proportionate reduction in the prevalence of depression (i.e. 7%).

A number of studies have assessed the impact of depression on productivity. This provides a basis for estimating the reduction in lost productivity for a given (i.e. 7%) reduction in the prevalence of depression.

[56] Chisholm, D., et al. (2006). Dollars, DALYs and decisions: economic aspects of the mental health system, World Health Organization. p.21

Key Findings:

- The impact of reductions in depression attributable to more amenable and accessible greenspace on direct and indirect costs can be estimated by assuming a proportionate reduction in the prevalence of depression.

5.5 Conclusion: valuation of liveability-related health benefits

Most of the literature supports a relationship between exposure to more amenable and accessible greenspace and improved mental health outcomes. A recent Australian study provides a defensible basis for quantifying the impact of exposure to nature and the prevalence of depression for use in business cases. In our application of the findings within this health pathway to three illustrative case studies, we have used this study to monetise mental health benefits associated greenspace within the Ready Reckoner model (see **Section 8**).

6 HEALTH PATHWAY 3: URBAN COOLING

The hypothesis that applies in the case of Health Pathway 3 (Urban Cooling) is that water investments can lead to improved urban vegetation which in turn can reduce the urban heat island (UHI) effect and thus the prevalence of health conditions associated with heatwave events.

Key Findings:

- While some studies support a relationship between the presence of greenspace and the UHI, the size of the relationship varies significantly with meteorological, location and urban characteristics.
- Defensible quantification of these impacts will require drawing on location-specific studies/modelling, rather than simply applying values from studies in other locations.
- Various studies have found a link between reduced heat and improved health outcomes, especially among the most vulnerable members of the population (e.g. the very young and elderly).
- However, the exact relationship between heat and disease varies significantly by location, driven by differences in climate and demographics.
- It is feasible to estimate economic impact associated with heat-related illnesses.

6.1 Relationship between water investment and improved natural environments

The first link to establish is between the IWCM investment and a change in the natural environment (such as urban vegetation and/or water in the landscape). Again, there is little literature on this relationship as most is focused on the relationship between urban vegetation and the UHI effect (see discussion below), rather than the drivers of urban vegetation itself. Rather, a case-by-case assessment will be required of the extent to which the water investment (e.g. supply of recycled water for irrigation) impacts on the pattern of urban vegetation and/or water in the landscape relative to a base case of a traditional servicing approach. This will establish the ‘attribution factor’ or the urban vegetation to the IWCM investment.

6.2 Relationship between improved natural environments and the UHI effect

The urban heat island (UHI) effect is defined by the differences in observed ambient temperatures between urban areas and surrounding non-urban areas, caused by the increase in heat-retaining impervious surfaces arising from increased urbanisation. As noted by Gunawardena et al (2017), the urban heat island (UHI) effect results largely from modification of surface properties leading to greater absorption of solar radiation, reduced convective cooling and lower water evaporation rates. Cities typically contain less vegetation and bodies of water than rural areas, and existing green and bluespace is often under threat from increasing population densities.

As noted in a recent UNSW study undertaken in conjunction with Sydney Water and the Low Carbon Living CRC, the difference in air temperatures between urban areas and surrounding rural areas is often 3-4ºC but higher peak differences can reach 10ºC. This study also suggests that several factors affect the UHI intensity: while maximum intensity occurs during summer (except in cites with humid climates where the maximum occurs during the dry season), the peak local rise above ambient temperatures varies in time of day (some cities near midday and others during late afternoon). UHI impacts may also compound by partly carrying over into the next day[57].

There are several ways in which changes in the natural environment linked to IWCM investments could mitigate the UHI[58]:

- Trees and other urban vegetation can provide shading which prevents solar radiation from heating the surface and evapotranspiration which cools the air
- Retaining water in urban environments in open water and wetlands systems can reduce temperatures through evaporation.

There is a considerable literature on the potential impact of trees and other vegetation on urban temperatures. For example, the CSIRO and NGIA used climate modelling to estimate the cooling effects of vegetation in the CBD and found that suburbs were 0.5-0.7ºC cooler and that average summer daily maximum temperatures would be reduced by 0.3ºC if CBD vegetation was doubled to 33% of the area.[59] In addition, research by the CRCWSC found that trees can lower the Urban Thermal Climate Index by up to 10°C reducing heat stress from 'very strong' to 'strong',[60] while Kabisch, van den Bosch and Lafortezza (2017) found that urban trees and other vegetation provides cooling through shade and evapotranspiration, which reduce the impact of the UHI on hot summer days[61]. Fam et al (2008) suggest that the cooling benefits of urban vegetation (achieved through the processes of increased solar reflection and evapotranspiration) can result in air temperature reduction of between 2 and 8 degrees Celsius.

However, as noted by S.E Gill et. al. the magnitude of the UHI effect varies in time and space as a result of meteorological, locational and urban characteristics:

[57] Sydney Water Corporation (2017), Cooling Western Sydney A strategic study on the role of water in mitigating urban heat in Western Sydney

[58] There are various other measures which seek to mitigate the UHI including use of building materials in roofs, pavements and other horizontal surfaces which diffuse solar reflectivity.

[59] NGIA (2012). Mitigating Extreme Summer Temperatures with Vegetation, Nursery Papers 5, Nursery and Garden Industry Australia. Available at: https://www.ngia.com.au/Attachment?Action=Download&Attachment_id=1451

[60] CRCWSC (2016), Impacts of Water Sensitive Urban Design Solutions on Human Thermal Comfort. Available at: https://watersensitivecities.org.au/wp-content/uploads/2016/07/TMR_B3-1_WSUD_thermal_comfort_no2.pdf

[61] Kabisch, N., et al. (2017). "The health benefits of nature-based solutions to urbanization challenges for children and the elderly–A systematic review." Environmental Research **159**: 362-373.

The biophysical features of greenspace in urban areas, through the provision of cooler microclimates and reduction of surface water runoff, therefore offer potential to help adapt cities for climate change. However, little is known about the quantity and quality of greenspace required.[62]

More specifically, as noted by Adams and Smith:

The effect of increasing vegetative cover on a UHI varies between cities depending on a range of factors relating to local climate, topography and other local environmental factors. General factors include aspect, elevation, shape and size of the urban area and weather conditions including wind speed, cloud cover, relative humidity. [63]

In addition, greenspace also has the potential to increase humidity and limit any potential cooling effects. For example, Smith and Roebber (2011) investigate the ability of urban green roof space to mitigate UHI, using scenario analysis to demonstrate that evapotranspiration and increased moisture availability can reduce the cooling effect of green roofs from 2-3^{O}C to 1^{O}C, relative to their base case.[64] Humidity increases must be taken into account to properly evaluate the relationship between greenspace and UHI.

There are somewhat fewer studies on the urban cooling benefits provided by bluespace (i.e. water bodies in urban areas). However, as noted by Englart (2015), research on UHI shows that retaining water in urban environments in open water and wetlands systems reduces temperatures through evaporation. Retaining water is also essential in fostering soil moisture levels and urban forestry which also contribute to decreasing temperatures through evapotranspiration (Coutts 2012).

Given that the exact impact of greenspace and bluespace on the UHI can vary significantly with analysis-specific characteristics, such as location, care must be taken to in attributing reduced heat island effect directly to water industry investment.

This suggests that defensible quantification of these impacts will require drawing on location-specific studies/modelling, rather than simply applying values from studies in other locations. In this regard, two studies of the UHI effect in Sydney are of particular interest:

- A collaborative study by UNSW, Sydney Water and the Low Carbon Living CRC[65] examined the role of water in mitigating urban heat in Western Sydney. It found that coordinated use of water-based technologies and building materials can reduce the peak ambient temperature in Sydney's west by 2.5 degrees — by using a multi-faceted approach that includes using water technology and high solar reflectance, or albedo, on roofs, building facades and pavements. The study found that such

62 Gill, S. E., et al. (2007). "Adapting cities for climate change: the role of the green infrastructure." Built environment **33**(1): 115-133.

63 Adams, M. P. and P. L. Smith (2014). "A systematic approach to model the influence of the type and density of vegetation cover on urban heat using remote sensing." Landscape and Urban Planning **132**: 47-54.

64 Smith, K. R. and P. J. Roebber (2011). "Green roof mitigation potential for a proxy future climate scenario in Chicago, Illinois." Journal of applied meteorology and climatology **50**(3): 507-522.

65 UNSW, Sydney Water & Low Carbon Living CRC (2017). Cooling Western Sydney. A strategic study on the role of water in mitigating urban heat in Western Sydney, November.

investment could lead to a reduction in the cumulative heat-related deaths from 14 to 7.5 per 100,000 people.

- A modelling study by Adams and Smith found that for the Greater Sydney metropolitan region average land surface temperature (LSTs) are influenced by the density of vegetation cover, the presence of urban structures and coastal distance. In general, increasing green cover has a greater influence on LST than non-tree or herbaceous green areas. For the Sydney region, an increase of 10% in foliage protective cover (FPC) was found to lead to a reduction in LST of 1.13°C.

Ideally such modelling would examine the impacts of greenspace and bluespace not just on average temperatures but on the extent and duration of peak summer temperatures, given that heatwaves are strongly linked to health impacts (see discussion below).

Key Findings:

- While some studies support a relationship between the presence of greenspace and the UHI, the size of the relationship varies significantly with meteorological, location and urban characteristics.
- Defensible quantification of these impacts will require drawing on location-specific studies/modelling, rather than simply applying values from studies in other locations.

6.3 Relationship between reduced UHI and health outcomes

6.3.1 Overview

Numerous studies have linked high ambient temperatures with adverse health outcomes. Extreme heat can impact health in two broad ways:

- By triggering the onset of acute conditions as dehydration, heat stroke and heat exhaustion
- By exacerbating a range of underlying conditions such as cardiovascular disease, diabetes, and kidney disease.

According to the US Environmental Protection Agency, “the urban heat island (UHI) effect compromises human health and comfort by causing respiratory difficulties, exhaustion, heat stroke and heat-related mortality”.[66] As noted by Adams and Smith (2014):

[66] Center for Disease Control and Prevention (2006), Heat Island Impacts. Viewed January 2018. Available at: https://www.epa.gov/heat-islands/heat-island-impacts#3>(viewed January 2018), https://www.epa.gov/heat-islands/heat-island-impacts

Heat stress and related mortality form a major public health issue across broad regions of the globe as high or extreme temperature is known to have serious implications for human health. … The World Health Organisation estimates that on average an additional 141,000 people died each year from elevated temperatures during the last 30 years of the 20th century. This number is expected to increase dramatically in the future as heatwaves are expected to be more intense, more frequent and longer lasting. Additionally, mortality rates will be exacerbated by the increasing urbanisation of the world population. McMichael and Bertollini (2009) estimate that annual heatwave mortality rates will double in some cities.[67]

The Center for Disease Control and Prevention estimates that from 1979–2003, excessive heat exposure contributed to more than 8,000 premature deaths in the United States[68]. This figure exceeds the number of mortalities resulting from hurricanes, lightning, tornadoes, floods, and earthquakes combined. In addition, a study in Barcelona, Spain found that reducing heat by 4 degrees could prevent 376 deaths and increase life expectancy by 34 days. [69]

A key finding from the literature is that many studies have found a temperature-mortality relationship with a threshold temperature above which heat-related mortality and morbidity increase above baseline levels. For example, Englart (2015) reports that during the heatwaves in Melbourne in January 2014, there was a 700% rise in Ambulance Service call-outs for cardiac arrests when temperatures spiked at almost 44ºC during the heatwave.

Some studies also suggest other links between ambient temperatures and health outcomes, such as through a higher rate of suicides and increases in foodborne disease such as salmonella. However, quantifying these effects is problematic.

6.3.2 Vulnerability

In general, studies suggest that very young children and the elderly are the most vulnerable to heat-related diseases and thus most likely to suffer as a result of UHI. For example, a study by Xu et. al. (2012) that reviewed the literature regarding the relationship between ambient temperature and children's health found that children under one year of age are particularly vulnerable to heat-related diseases, including gastrointestinal diseases and respiratory diseases. In particular, the study notes that, during heat waves, the incidence of renal disease and fever among children increase significantly.[70] Similarly, Huang et. al. (2011) found that those particularly vulnerable in heatwaves include older people, young children, people with chronic disease and those living in built-up areas in cities. Loughnan et. al (2010) also found that those suffering heart conditions are also more susceptible to heat stress.

Nicholls et. al. (2008) examined the relationship between heat and mortality in Melbourne for those aged over 65 from 1979 to 2001 and found that when daily minimum temperatures exceeded 30^{0} C average daily mortality increased by 15 to 17 per cent. Loughnan et. al. (2010) found that hospital admissions

[67] Adams, M. P. and P. L. Smith (2014). "A systematic approach to model the influence of the type and density of vegetation cover on urban heat using remote sensing." Landscape and Urban Planning **132**: 47-54.

[68] Center for Disease Control and Prevention (2006), Heat Island Impacts. Viewed January 2018. Available at: https://www.epa.gov/heat-islands/heat-island-impacts#3

[69] Mueller, N., et al. (2017). "Urban and Transport Planning Related Exposures and Mortality: A Health Impact Assessment for Cities." Environmental Health Perspectives **125**(1): 89-96.

[70] Xu, Z., et al. (2012). "Impact of ambient temperature on children's health: a systematic review." Environmental Research **117**: 120-131.

for Acute Myocardial Infarction (AMI) increased by 37.3% for three-day average temperatures greater than or equal to 27ºC and by 10% for a 24-hour average temperature greater than or equal to 30ºC. Both age and socioeconomic status contributed to the spatial distribution of AMI admissions during consecutive days of hot weather: twice as many males were admitted as females with peak occurrence in the 60-64 age group.

6.3.3 Locational variations

Associate Professor Peng Bi of the University of Adelaide[71] found that identifying threshold temperatures is important to project population health, especially vulnerable groups, and that different regions may have different threshold temperatures due to various climatic characteristics. He reported results of a number of studies across Australia.

[71] Bi (Undated). Heatwaves and population health in Australia. National Climate Change Adaptation Research Facilty. Available at: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/Peng_Bi.pdf

Table 4: Australian studies of impacts of extreme heat on health outcomes

CITY	KEY FINDING
Sydney	Mortality increases between 0.45% and 1.21% were associated with a 1°C increase in daily maximum temperature (Vaneckova et. al., 2008). A 0.9% increase in total daily mortality was associated with a 1oC daily maximum temperature increase, increasing to 7.8% when maximum temperature reached 32oC (Hu et. al., 2008). In a four-day heatwave in Sydney during January 1994, with daily maximum temperatures exceeding 32ºC, there were 110 excess deaths, with a short-term mortality displacement of 59% for this event (Gosling et al, 2007). The hot and dry Synoptic Category (SC)7 and warm and humid SC3 were associated with higher all cause, circulatory and cerebro-vascular mortality, especially for the 65 and older age group and women (Vaneckova et. al., 2008).
Melbourne	An increase of 15-17% in average daily mortality of people aged 65 years or more was observed when the mean daily temperature (mean of today's maximum and tonight's minimum temperature) exceeded a threshold of 30oC. A similar increase in excess deaths was observed when minimum temperature exceeded 24oC (Nicholls et al, 2007). In 2009 heatwaves, there was a 62% increase in total all-cause mortality; a 46% increase in deaths in the 65-74, and a 55% increase in the 5-64 years age groups; Emergency Department presentations showed a 12% overall increase and a 37% increase in those 75 years or older; ambulance emergency cases increased by 46% (Victorian Chief Health Officer, 2009).
Brisbane	A 1oC increase in monthly mean minimum temperature in summer was associated with a 7% increase in all-cause mortality in the 65 years and older population (Bi et. al. 2008). The association of temperature and particulate matter with cardiorespiratory mortality and morbidity has been also investigated for Brisbane, with evidence of interactions between daily temperatures and PM10 concentrations (Ren et al, 2006).
Adelaide	For Adelaide heatwaves during the period 1993 and 2006, defined as 3 or more days of 35oC or above, a 4% increase in ambulance transports was observed compared to non-heatwave periods (Nitschke and Bi, 2007); 2.6 callouts per 1ºC rise in the max above 34.6 ºC (Hansen and Bi, 2009). There were significant increases in all age renal and mental hospital admissions (7% and 13% respectively) and an 8% increase in IHD admissions in the 65-74 years group (Hansen and Bi, 2007; 2008). All age mortality was not increased during heatwave periods (Nitschke and Bi, 2007; Hansen and Bi, 2007; 2008).

Source: Frontier Economics

A more recent study by Loughnan et al (2013) established threshold temperatures above which mortality and morbidity increase in each Australian capital city based on a heat vulnerability index. Tong et al (2014) concluded that heatwaves appeared to affect mortality more in Brisbane and Melbourne than Sydney.

In conclusion the exact relationship between heat and disease varies significantly by location, driven by differences in climate and demographics. For example, Kabisch, van den Bosch and Laforteza (2017) note that while the association between greenspaces and health is positive, the results remain inconclusive; impacted by socioeconomic confounders.[72] As such, care should be taken in interpreting the results.

Key Findings:

- Various studies have found a link between reduced heat and improved health outcomes, especially among the most vulnerable members of the population (e.g. the very young and elderly).
- However, the exact relationship between heat and disease varies significantly by location, driven by differences in climate and demographics.

6.4 Relationship between health outcomes and economic outcomes

The final step is to translate the improved health outcomes into economic outcomes.

As per the other pathways, this entails applying a methodology to place an economic value on the direct, indirect and intangible health costs associated with the improved health outcomes.

Given the nature of the health impacts associated with extreme temperatures, studies which have sought to estimate the economic impacts of such events have typically focussed on ambulance attendances and presentations to emergency departments associated with AMI (see for example AECOM (2012)). In similar terms, the UNSW study found that by creating a cooler, more liveable western Sydney, the effects of extreme heat may be dramatically reduced, in turn taking pressure off essential medical services.

Heat-related illness will also impact on mortality and morbidity related productivity[73].

Mortality-related productivity costs can be estimated using the human capital approach outlined in **Section 3.4.2**, taking into account the age profile of heat-related deaths.

Estimating morbidity-related productivity costs (or avoided costs) from heat-related illness is more problematic. One reason for this is that heat-related health conditions tend to be acute rather than chronic in nature. In addition, extreme heat may also affect absenteeism and presenteeism more directly by reducing cognitive and physical performance (e.g. direct heat exposure reduces a worker's ability to carry out heavy physical work). Some of the literature on heat stress suggests the impacts on productivity could be substantial[74]. While these direct impacts are not related to heat-related illness per se and are thus outside the scope of this study, they are clearly impacts which should be incorporated into an economic evaluation of any IWCM project which is expected to have a material impact on urban temperatures. Indeed, as these productivity-related impacts are likely to be more significant than morbidity-related productivity impacts from heat-related illnesses, it would seem appropriate to focus efforts on estimating these more direct heat-related productivity impacts.

[72] Kabisch, N., et al. (2017). "The health benefits of nature-based solutions to urbanization challenges for children and the elderly–A systematic review." Environmental Research **159**: 362-373.

[73] It is also recognised that extreme heat may also affect productivity directly through absenteeism and presenteeism (e.g. direct heat exposure reduces a worker's ability to carry out heavy physical work). While these are relevant impacts to take into account, they are outside the scope of this study.

[74] See for example, Zander, K. K., et al. (2015). "Heat stress causes substantial labour productivity loss in Australia." Nature climate change **5**(7): 647.

Key Findings:

- It is feasible to estimate economic impact associated with heat-related illnesses.

6.5 Conclusion: valuation of liveability-related health benefits

Most studies support a negative relationship between greenspace/bluespace and the UHI effect via direct shading which prevents solar radiation from heating the surface (albedo) and evapotranspiration which cools the air.

However, the size of the relationship varies widely with the meteorological location and urban characteristics (e.g. significant greenspace and canopy cover on a catchment scale is necessary to reduce the UHI effect). Thus, in the absence of location-specific studies such benefits will be hard to justify in business cases.

Where such studies exist, however, it is possible to draw a link between heat (especially heatwaves) and health outcomes, especially among the most vulnerable members of the population (i.e. the very young and elderly and for lower SES groups) and make reasonable quantitative estimates of reduced UHI effect on heat-related health burdens (measured in DALYs) in given populations and healthcare costs. **Section 8** provides more detail on how we have practically applied the context-specific nature of urban cooling benefits to three case studies. Within our Ready Reckoner model, we monetise urban cooling benefits where the project at hand can achieve the scale required for cooling benefits to materialise. The Ready Reckoner model also uses site specific information on the extent to which the UHI effect is reduced by the case study investment for the case study where such information was available.

In addition, there are some key learnings from the literature which have implications for how an IWCM project may be designed to maximise the benefits from reduced UHI effects associated with changes to urban vegetation, even if these cannot be quantified.

7 HEALTH PATHWAY 4: IMPROVED AIR QUALITY

The final health pathway we consider provides justifiable and material benefits is through improvements to air quality. The hypothesis of Health Pathway 4 (Improved Air Quality) is that water investments can lead to improved urban vegetation which in turn can reduce air pollution and thus the prevalence of health conditions associated with air pollution.

Key Findings:

- It is feasible to estimate economic impact associated with air pollution.
- While there is a considerable literature on the linkages between air pollution and health, there is less evidence on the quantitative nature of this relationship which could be used to model the potential changes in health outcomes from lower air pollution attributable to changes in urban vegetation, particularly in an Australian context.
- Nevertheless, even making some broadbrush assumptions on these relationships can be instructive, given that the health impacts of air pollution may be larger than previously assumed.

7.1 Relationship between water investment and improved natural environments

The first link to establish is between the IWCM investment and a change in urban vegetation (e.g. the number and distribution of trees). Again, there is little literature on this relationship as most is focused on the relationship between urban vegetation and air pollution (see discussion below), rather than the drivers of urban vegetation itself. A case-by-case assessment will be required of the extent to which the water investment (e.g. supply of recycled water for irrigation) impacts on the pattern of urban vegetation relative to a base case of a traditional servicing approach. This will establish the 'attribution factor' of the urban vegetation to the IWCM investment.

7.2 Relationship between more amenable and accessible greenspace and air quality

The second step in order to quantify health benefits from investments in integrated water management via this pathway is to establish the link between urban vegetation and air quality.

Urban air pollution comprises a mix of gases, compounds and particles including particulates, ozone, and nitrogen dioxide[75]. Sources of urban air pollution include emissions from industrial processes, vehicles and tobacco smoke.

[75] Common air pollutants include carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), sulphur dioxide (SO2), and particulate matter less than 2.5µm (PM 2.5) and 10 µm (PM 10) in aerodynamic diameter.

In recent years there has been considerable interest in the potential for urban vegetation to provide ecosystem service in the form of removal of air pollutants. Urban vegetation can affect air quality through:

- pollutant deposition: airborne particles and gas molecules can be deposited on plant surfaces such as trunks, branches and leaves
- pollutant dispersion: refers to air flows which transport and dilute air pollutants at different scales (e.g. trees near a road can cap pollutants under their canopies or reduce wind speeds and therefore limit dispersion).

Several international studies have investigated and validated the relationship between the provision of greenspace and surrounding air quality.

A number of studies have found that trees and shrubs remove air contaminants more effectively than green roofs or walls.

In the US, Nowak et al. estimated that trees and shrubs removed 711,300 tonnes of air pollution p.a. across 55 cities, [76] while Landry et al. estimated that 1163 tonnes of pollution was eliminated in the City of Tampa by 8.67million trees.[77]

A study of Florence found that the estimated contribution of urban forest in abating ozone and PM air pollution is substantial in absolute terms but relatively modest compared to overall pollution levels in the city, which has a very densely built centre with few green areas and high levels of pollution from car traffic and heating systems[78].

A study by Janhall found that careful design of urban vegetation barriers was required in order to relate it to the kind or air pollution targeted:

- Dilution of emission with clean air from aloft is crucial so vegetation should be low and/or close to surfaces;
- Proximity to the pollution sources increase concentrations of air pollutants and this deposition, so vegetation should be close to the source;
- Air passing above, and not through, vegetation is not filtered, so barriers should be high enough and porous enough to let the air through, but solid enough to allow the air to pass close to the surface[79].

Relatively little research has been done specifically linking urban vegetation with air quality in Australia. However, one recent study in Melbourne found that trees have the strongest ability to capture and filter air pollutants, specifically ground-level ozone, sulphur dioxide, nitrogen oxides and particulate matter.[80]

[76] Nowak, D. J., et al. (2006). "Air pollution removal by urban trees and shrubs in the United States." Urban Forestry & Urban Greening **4**(3-4): 115-123.

[77] Landry, S., Northrop, R., Andreu, M., Rhodes, C. (2013) City of Tampa 2011: Urban Forest Analysis The Structure, Composition, Function and Economic Benefits of Trees and the Urban Forest. Available at: http://waterinstitute.usf.edu/upload/projects/TampaUEA/Tampa_2011_UrbanForestAnalysis.pdf

[78] Bottalicoa, F et al "Air pollution removal by green infrastructures and urban forests in the city of Florence." Agriculture and Agricultural Science Procedia 8 (2016) 243 – 251.

[79] Janhall, S., "Review on urban vegetation and particle air pollution – Deposition and dispersion." Atmospheric Environment 106 (2015) 130-137.

[80] Kendal, D., et al. (2016). "Benefits of urban greenspace in the Australian context: A synthesis review for the Clean Air and Urban Landscapes Hub.". Available at: https://minerva-access.unimelb.edu.au/bitstream/handle/11343/122914/2016-CAUL-Benefits%20of%20Urban%20Green%20Space.pdf?sequence=1

Another Australian study found that more ozone is formed from the exhaust emissions of motor vehicles during summer periods of increasing heat in combination with strong sunlight.[81]

One key finding from the literature is that the precise relationship between urban vegetation and air quality is highly locational dependent, influenced by the type of trees (density, canopy coverage etc.) and surrounding human activity. As observed by Baro (2014), “while positive effects of air purification delivered by vegetation have been estimated at the city scale in many urban areas, pollution concentration can be increased at the site scale (e.g. street canyons[82]) depending upon vegetation configuration, pollutant emissions, or meteorology, showing apparently divergent results on the effectiveness of using urban vegetation for reducing local air pollution hotspots.”[83]. Further, as Baro states, “the ability of urban vegetation to remove air pollutants significantly depends on many factors, such as tree health, soil moisture availability, leaf-period[84], LAI[85], meteorology, and pollution concentrations”.[86] In effect, the type and qualities of the vegetation and other microclimatic variables are important for the relationship between urban vegetation and air quality.

Understanding of the relationship therefore requires the development and application of an urban forest simulation model for a city[87].

In the absence of location-specific air quality modelling, it will be difficult to establish a defensible quantitative relationship between urban vegetation and defined improvements in air quality. However, where such modelling is available, then it will be possible to progress to the next step and examine the link between improved air quality and health outcomes. As modelling techniques advance and more studies are conducted, it may become increasingly feasible to examine the link between greenspace and urban pollution reduction in the future

Key Findings:

- It is feasible to estimate economic impact associated with air pollution in those cases where there is site-specific modelling or information available on the relationship between greenspaces and pollution reduction.

7.3 Relationship between improved air quality and health outcomes

There is an extensive literature on the health effects of the major air pollutants, including numerous epidemiological and toxicological studies.

[81] Kjellstrom, T. and H. J. Weaver (2009). "Climate change and health: impacts, vulnerability, adaptation and mitigation." New South Wales public health bulletin **20**(2): 5-9.

[82] A street canyon refers to the type of urban space created by two buildings separated by a road. See Baik, J.-J., et al. (2012). "Effects of building roof greening on air quality in street canyons." Atmospheric Environment **61**: 48-55 for an analysis of the impact of roof greening on the air quality of these kinds of spaces.

[83] Baró, F., et al. (2014), pp 473-474

[84] Leaf-period refers to the seasonal variation in the amount of leaf cover as some plant species may drop leaves at certain times of year or in certain conditions.

[85] Leaf Area Index. This is a measure of the amount of canopy coverage relative to the ground area.

[86] Baró, F., et al. (2014), p 474

[87] Such models have been developed and applied for cities including Florence, Gothenburg, Barcelona amongst others

Urban air pollution has been linked to a range of diseases including ischemic heart disease, chronic obstructive pulmonary disease, lung cancer and acute lower infections in children.[88]

While it is very difficult to isolate the health effects of individual pollutants, particulate matter (PM) is often taken as a lead indicator of overall air pollution. Particulate matter – small liquid droplets and small particles, including acids, organic chemicals and soil or dust particles – can be especially damaging to health as smaller particles can go deeper into the respiratory tract. The very young, the elderly and those with pre-existing health conditions are particularly susceptible.

Research on the link between air quality in urban areas and respiratory health has produced varying results. For example, while a study in Switzerland found that greenspace was associated with reduced risks of respiratory diseases,[89] a review by the Clean Air and Urban Landscapes Hub noted that there have been mixed findings from research investigating the links between respiratory health and vegetation/canopy cover in urban areas.[90] As such, further evidence on links between the presence of trees and other green elements with respect to respiratory health is needed to establish net benefits.

A recent study (Shen and Lung 2017) explored the potential mediation pathways and effects of green structure characteristics on respiratory mortality through temperature and air pollution found that mortality of pneumonia and chronic lower respiratory diseases could be reduced by minimising fragmentation and increasing the patch percentage[91] of green structure, and that most of the mediation effects are mostly through reducing air pollutants rather than temperature[92].

While there is a considerable literature on the linkages between air pollution and health, there is less evidence on the quantitative nature of this relationship which could be used to model the potential changes in health outcomes from lower air pollution attributable to changes in urban vegetation, particularly in an Australian context. However, a 2005 NSW Government study of air pollution in Sydney estimated a range of exposure-responses for given changes in particulates for defined health endpoints including mortality, respiratory hospital admissions, cardiovascular hospital admissions, asthma attacks, acute bronchitis and chronic bronchitis. Another recent study suggests a 1 unit increase in air pollution increased CVD mortality by 0.366 (Shen and Lung 2016).

Nevertheless, even making some broadbrush assumptions on these relationships can be instructive, given a recent international study (WHO 2015) which suggests that relative to many other known environmental risk factors, the health impacts of air pollution are larger than previously assumed[93].

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[88] See for example, Donovan, G. H., et al. (2013). "The relationship between trees and human health: evidence from the spread of the emerald ash borer." American Journal of Preventive Medicine **44**(2): 139-145, which found that the percentage of the county covered by ash tree canopy reduced respiratory related deaths by 0.00522% and cardio related deaths by 0.0018%.

[89] Vienneau, D., et al. (2017). "More than clean air and tranquillity: residential green is independently associated with decreasing mortality." Environment international **108**: 176-184.

[90] Kendal, D., et al. (2016). "Benefits of urban greenspace in the Australian context: A synthesis review for the Clean Air and Urban Landscapes Hub.". p. 6 Available at: https://minerva-access.unimelb.edu.au/bitstream/handle/11343/122914/2016-CAUL-Benefits%20of%20Urban%20Green%20Space.pdf?sequence=1

[91] LPI equals the area (m2) of the largest patch of the corresponding patch type divided by total landscape area (m2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percentage of the landscape comprised by the largest patch.

[92] Interestingly, the study also found that a high proportion of but fragmented greenspaces would increase secondary air pollutants and increase health risks, demonstrating the deficiency of traditional greening policy with primary focus on coverage ratios.

[93] WHO Regional Office for Europe, OECD (2015). Economic cost of the health impact of air pollution in Europe: Clean air, health and wealth. Copenhagen: WHO Regional Office for Europe. Available at: http://www.euro.who.int/__data/assets/pdf_file/0004/276772/Economic-cost-health-impact-air-pollution-en.pdf

Key Findings:

- While there is a considerable literature on the linkages between air pollution and health, there is less evidence on the quantitative nature of this relationship which could be used to model the potential changes in health outcomes from lower air pollution attributable to changes in urban vegetation, particularly in an Australian context.
- Nevertheless, even making some broad brush assumptions on these relationships can be instructive, given that the health impacts of air pollution may be larger than previously assumed.

7.4 Relationship between health outcomes and economic outcomes

The final step is to translate the improved health outcomes into economic outcomes.

As per the other pathways, this entails applying a methodology to place an economic value on the direct, indirect and intangible health costs associated with the improved health outcomes.

The 2005 NSW Government study cited above examined the health costs of air pollution in the Greater Sydney Metropolitan Region. Based on a range of exposure-responses for given changes in particulates, it estimated the health cost of ambient air pollution is between $1,01b and $8.40b per annum.

7.5 Conclusion: valuation of liveability-related health benefits

While the bulk of the literature supports a relationship between the presence of urban vegetation and air quality, and between air quality and health outcomes, it is difficult to define a defensible quantitative relationship. This is primarily because the relationship between urban vegetation and air quality varies significantly with location, types of trees etc.

Nevertheless, there is prima facie evidence that the impact on health of air pollution could be significant. This suggests that in cases where there is scope to significantly affect urban design including vegetation through IWCM investments, the potential health benefits could also be substantial. However, in the absence of location-specific studies such benefits will be hard to justify in business cases. Nevertheless, in our Ready Reckoner model we have been able to monetise air quality improvement benefits where the case study is considered sufficiently large scale for those benefits to apply. **Section 8** provides more detail on how the findings on air quality in this section have been practically applied to illustrative case studies.

In addition, there are some key learnings from the literature which have implications for how an IWCM project may be designed to maximise the benefits from reduced air pollution associated with changes to urban vegetation, even if these cannot be quantified.

8 IMPLEMENTATION AND APPLICATION OF THE FRAMEWORK

This study has developed and applied a methodology and associated excel-based tool for quantifying a range of potential liveability-related health benefits from IWCM investments explored in **Sections 4 to 7**. In order to ensure that this study provides "lessons" that can be applied when assessing other future investment decisions, we have applied our methodology and excel-based tool to a range of illustrative case studies.

This section discusses our case studies and the results in more detail.

Key Findings:

- Overall size of benefits can be large for large projects. However, health benefits from reduced urban heat and air pollution are only relevant to large-scale greenfield projects.
- Mental health benefits from passive recreation in greenspace typically as much as or more in monetary terms than the health benefits from active recreation. This reflects the much higher 'participation' in exposure to greenspace compared to the limited number of people who will actually increase their physical activity due to more amenable or accessible greenspace.
- Most of the mental health-related benefits are in the form of reduced losses in productivity rather than reduced direct healthcare costs, as typically depression doesn't involve hospitalisation but is a widespread draw on workplace productivity.
- Health benefits from active recreation are more evenly weighted across reduced healthcare costs, and reduced morbidity and mortality related productivity costs, reflecting the nature of key linked diseases (e.g. cancers).
- Willingness to Pay (WTP) values are generally significantly higher than cost of illness numbers — this is due to the broader base of benefits that it represents.
- Results are sensitive to key assumptions such as participation in active and passive recreation, affected population and socioeconomic disadvantage. This suggests that it is worthwhile to focus on arriving at robust assumptions for these values rather than refining/finessing detail of other costs, for example healthcare costs.

8.1 Investment evaluation to include health benefits

Implementation and application of the health benefit framework could be used to supplement traditional investment evaluation to ensure that the assessment is comprehensive — i.e. inclusive of health benefits related to IWCM investments, where such benefits are significant.

Importantly, these health benefits are generally in addition to the other benefits (including network, environmental, etc) and costs (including capex, opex, etc.) that drive IWCM investment evaluation. The assumptions around the estimates of health benefits should be consistent with the assumptions made for other elements of the IWCM investment evaluation — including base case, time-frame of evaluation, and the discount rate used.

The following section outlines the ‘Ready Reckoner tool’ that has been prepared as part of this project to assist with the estimation of health benefits.

8.2 Ready Reckoner tool

The relationships identified from the literature in the previous sections have been implemented in a ‘Ready Reckoner tool’ to assist with the estimation of health benefits (see 0). This tool is an excel based economic assessment model (in line with Treasury Guidelines and best practice investment decision-making) that applies the findings of our literature review.

Box 6: The Ready Reckoner Tool

The Ready Reckoner tool estimates:

- Direct costs, in terms of:
  - reduced healthcare costs
- Indirect costs, in terms of:
  - reduced productivity losses from absenteeism and presenteeism
  - reduced productivity losses from mortality

Willingness to Pay,[94] to avoid the cost of:

  - reduced years of ‘healthy’ life — measured in DALYs.

Benefits are estimated and monetised for four potential sources of health benefits as laid out in our four health pathways:

- Benefits from increased activity
- Increased wellbeing from exposure to greenspace
- Benefits from reduced urban temperatures
- Benefits from increased air quality

The user must specify whether each of these sources of potential benefits is relevant to the project in question. We would anticipate that in virtually all cases, the first two types of benefits (relevant to greenspace) will be relevant to the evaluation. In contrast, benefits from reduced urban temperatures and air pollution may only be material for large-scale projects.

The user may also change assumptions relating to the demographic composition of the region (by selecting a relevant ABS community profile), the level of socioeconomic disadvantage of the

94 Willingness to pay results are reported separately to the direct and indirect costs **as these are not directly comparable**.

community, and the estimated incremental participation rate for utilising the greenspace (for both active and passive recreation).

The summary page of the Ready Reckoner tool provides an intuitive interface for the choice of key assumptions so that calculations can be adapted to the nature of the IWCM investment at hand. The Ready Reckoner summary page also automatically reports results in tabular and graphical form.

We have applied the Ready Reckoner to three illustrative, hypothetical case studies of different IWCM investments.

Details of the data underpinning the Ready Reckoner tool is provided at **Appendix C**.

Source: Frontier Economics

8.3 Case studies for analysis

Water businesses were asked to provide information around their proposed illustrative candidate case studies to be assessed against defined criteria (see **Appendix E**). As shown in **Figure 17**, drawing on these case studies, we identified three illustrative case studies:

- **Case study one: Large-scale greenfield development in an outer-suburban area –** assesses options aimed at providing water and wastewater services to a large-scale greenfield development in an outer-suburban/regional, temperature area at a regional scale. It compares:
  - **Base case:** Traditional water and wastewater servicing solution; and
  - **Alternative option:** an IWCM servicing solution aimed at providing water, wastewater, recycled water and stormwater services.
- **Case study two: Rehabilitation of a stormwater channel –** assesses options aimed at replacing an ageing urban concrete stormwater channel in need of renewal, in an inner-urban, sub-tropical climate zone. Compares:
  - **Base case:** BAU concrete stormwater channel replacement; and
  - **Alternative option:** river naturalisation and associated greenspace.
- **Case study three: Regional water supply option –** assesses options aimed at providing water and wastewater services to meet current and future needs in a regional town, in a semi-arid zone. Compares:
  - **Base case:** traditional water and wastewater servicing solution; and
  - **Alternative option:** An IWCM servicing solution aimed at providing water, wastewater, recycled water and stormwater services to the town.

Figure 17: Overview of our illustrative case studies

Case study & services provided	Identifying the appropriate base case & alternative options	The relationship between water industry investment and liveable environment	The relationship between liveable environment and health outcomes
1 Outer suburban Greenfield development	• Servicing solutions aimed at providing water and wastewater services to a large-scale catchment-wide greenfield development in outer suburban area. • Potential for an integrated water cycled management (IWCM) project involving the integration of water, wastewater, recycled water & stormwater services across the catchment.	• Leads to more amenable and accessible greenspaces and retains water in the landscape (through the use of catchment wide recycled water) • Leads to reductions in urban heat island and in air quality	• Could promote increased active and passive recreation, improved air quality and reduced urban heat island effect, leading to better health outcomes.
2 Rehabilitation of a stormwater channel	• An existing stormwater channel is in need of replacement in an inner suburban, sub-tropical area. • There is the potential for replacing the existing concrete stormwater channel with a naturalized stormwater channel with an improved liveable environment.	• Improved stormwater channels leads to increased availability of greenspace and recreation opportunities (e.g. cycle path)	• Could promote increased active and passive recreation (incl. opportunities for use of community cool zones) and reduced mosquito-borne disease.
3 Regional water supply options	• Servicing solutions aimed at providing water and wastewater services to a small regional town in a semi-arid area. • Potential for an integrated water cycle management (IWCM) project involving the integration of water, wastewater, recycled water & stormwater services.	• Leads to more amenable and accessible greenspaces and retains water in the landscape (through the use of localised wide recycled water). • Leads to drought-proof greenspace (through the use of recycled water)	• Could promote increased active and passive recreation (incl. all year round sporting activities).

Source: Frontier Economics

Each of these case studies is discussed below.

8.4 Case study #1: Large-scale greenfield development in outer suburban area

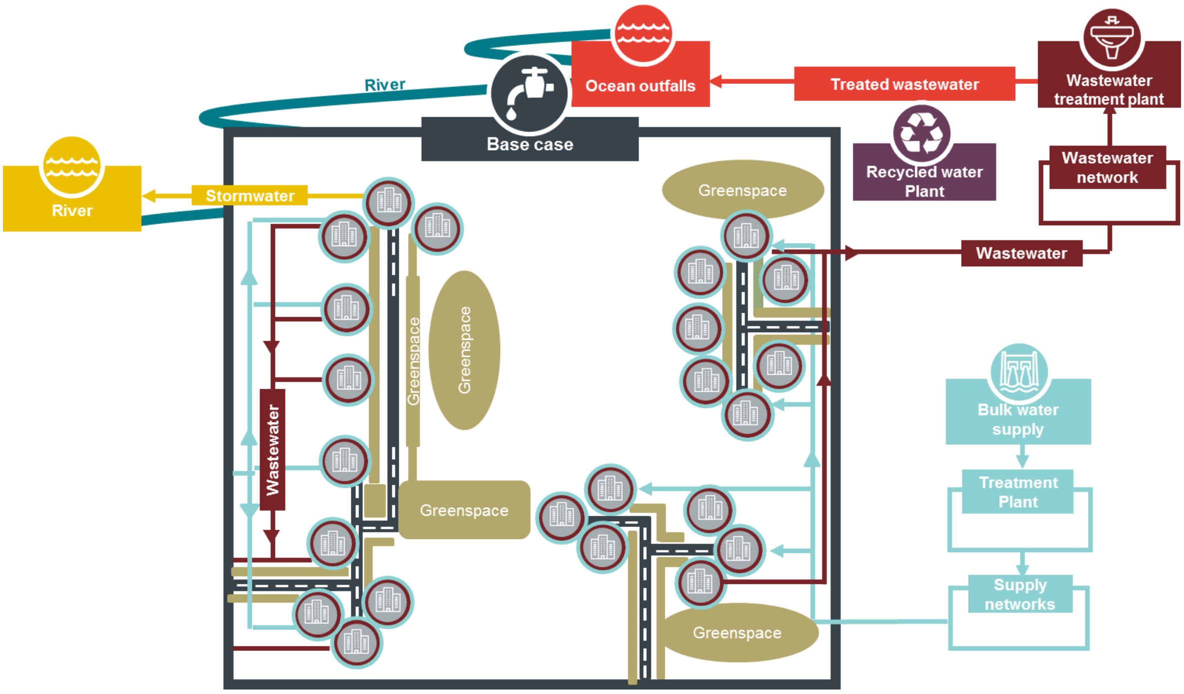
The first case study concerns provision of water and wastewater services to a large-scale greenfield development in an outer-suburban/regional, temperate area characterised by hot dry summers and cool winters. It is assumed to be an area of low to average socioeconomic status (Quintile 3 on the ABS Index of Relative Social Disadvantage).

8.4.1 Base case

Figure 18 sets out the *base case* servicing approach, which involves a 'Business as Usual' (BAU) approach to the provision of water and wastewater services. In particular it involves:

- **Potable water:** Bulk water sourced from upstream supply network, treated and reticulated to homes and businesses throughout the development (i.e. traditional potable water supply)
- **Wastewater**: reticulation network servicing the development, with wastewater treated and discharged into the ocean (i.e. traditional wastewater water collection, treatment and disposal).
- **Recycled Water:** No recycled water under the base case.
- **Stormwater:** Traditional stormwater flood management by the Council.

Figure 18: Case study #1: Large-scale greenfield development in outer suburban area – BAU (Base Case)



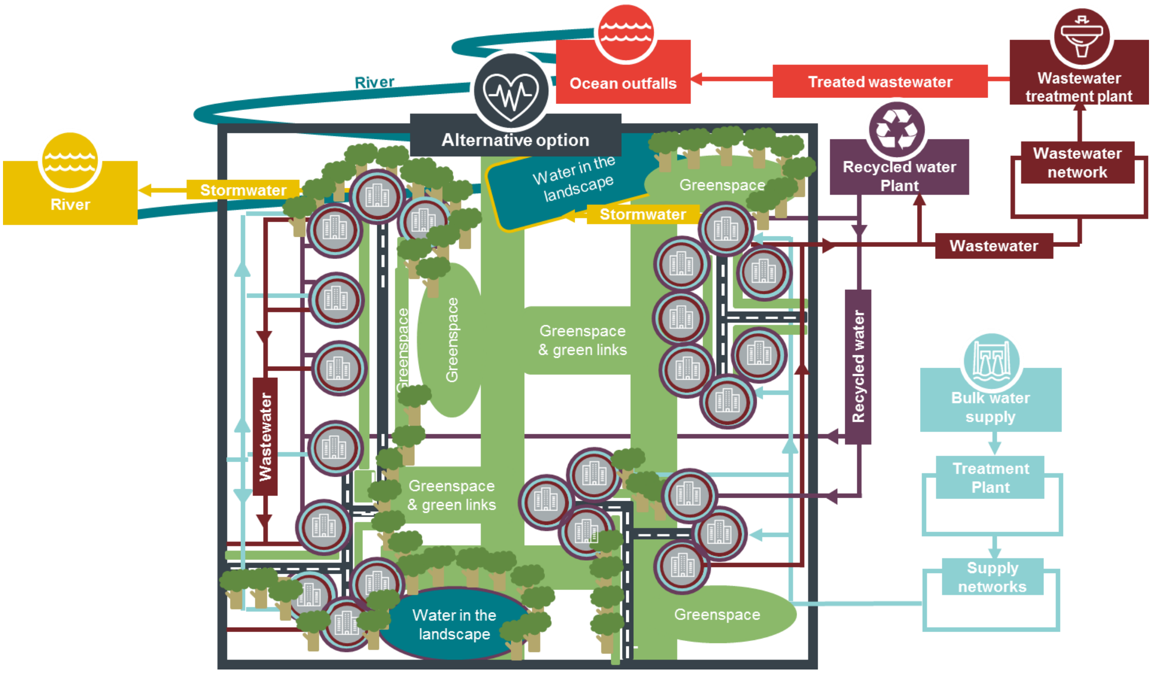
Source: Frontier Economics

8.4.2 Alternative servicing approach

Figure 19 sets out the *alternative servicing approach*, which incorporates water sensitive urban design (WSUD) and IWCM to provide water, wastewater, recycled water and stormwater services. Its key feature is that wastewater and stormwater are being treated and the produced recycled water is being transferred to the development for non-potable uses. In particular it involves:

- **Potable water:** All potable water supplied from upstream supply network, treated and reticulated to homes and businesses through the development (as per the base case). Non-potable use within the development (e.g. irrigation of greenspace) met via a combination of recycled water from a new recycled water plant and stormwater reuse.
- **Wastewater**: As per the base case, except some wastewater is recycled at an existing recycled water plant for non-potable use (e.g. irrigation), rather than simply directed to the relevant wastewater network.
- **Recycled Water:** Recycled water is piped from an existing recycled water plant for non-potable use by homes and businesses throughout the development (via a third pipe and reticulation network) and irrigation of the greenspace throughout the development.
- **Stormwater:** Some stormwater harvesting and reuse to irrigate parklands and greenspace.

Figure 19: Case study #1: Large-scale greenfield development in outer suburban area – BAU (Base Case)



Source: Frontier Economics

Figure 19 shows that compared with the base case, there is increased greenspace, vegetation and water in the landscape fed by stormwater, some of which also irrigates the greenspace. Recycled water meets the remaining irrigation needs of the extra greenspaces along with non-potable demand from homes and businesses.

8.4.3 Overview of potential liveability-related health impacts

The provision of high quality public open space that is accessible to the community can provide a range of health benefits through enhancing opportunities for active and passive recreation (including opportunities for sport and social activities), reduced urban temperature and improved air quality. Due to the large scale and scope of the IWCM project, we have assumed that the change in water cycle management can significantly improve the access to quality greenspace for the surrounding population (assumed to be 1.5 million from the central (Q3) quintile of socioeconomic advantage) (

Table 5). In particular, as result of different approaches to water cycle management, compared to the *base case,* the *alternative servicing approach* provides:

- **Increased opportunity for active and passive recreation** given increased availability of connected, irrigated amenable and accessible greenspace and improved swimming opportunities in local rivers (due to reduced wastewater and/or stormwater discharge to waterways);
- **Reduced urban temperature** as a result of increased irrigated, urban tree canopy and open space and increased presence of water in the landscape on a large scale; and
- **Improved air quality** as a result of increased irrigated tree canopy.

Table 5: Case study 1: Parameters

PARAMETER	VALUES AND COMMENTS
Regional characteristics	Population affected: 1,500,000 Socioeconomic: Q3
Active recreation	Based on incremental participation: 10% (Achieving equivalent of 15min/weekday)
Passive recreation	Based on incremental participation: 20%
UHI effect	Will reduce ambient temperature in broader region (reducing number of hot days and heat-related deaths)
Air quality	Will improve air quality with PM10 concentrations reducing by 0.1µg/m3

Source: Frontier Economics

As shown in **Figure 20**, the *alternative servicing approach* in this case study is likely to be associated with:

- **Health benefits arising from more active recreation** (including cycling, walking, running etc) from more amenable and accessible greenspaces.
- **Mental health benefits from greater opportunities** for passive recreation and community connection in safe open public greenspace.
- **Health benefits attributable to reduction in the UHI effect** (e.g. lower heat stress) and improvements in air quality attributable to increased vegetation and canopy cover.
- **Health benefits attributable to improved swimmability in local rivers**.

Figure 20: Summary of relevant health benefits of case study #1

Source: Frontier Economics

8.4.4 Estimation of health benefits using of case study #1

Table 6 sets out the estimated value of the health benefits under case study #1. Compared to the *Base Case* (i.e. BAU approach to water cycle management), the *alternative approach* is associated with:

- $42.15 million or $242.9 million in benefits from increased activity;
- $72.20 million or $284.5 million in benefits from increased wellbeing from exposure to greenspace;
- $21.61 million or $173.6 million in benefits from reduced urban temperatures;

- $5.54 million or $22.16 million in benefits of increased air quality.

This highlights that, relative to the *base case* BAU approach to water cycle management, an *alternative approach* delivers health benefits of between $142 million and $723 million (depending on the monetisation approach adopted) This is primarily driven by the size of the significant increase in availability of open-space, tree canopy and water in the landscape, arising from the large scale and scope of the IWCM project.

Table 6: Case Study 1: Estimated health benefits ($2017-18 million)

ESTIMATED HEALTH BENEFITS	COST	WTP*
BENEFITS FROM INCREASED ACTIVITY		
Reduced healthcare costs from disease associated with inactivity	15.26	
Reduced productivity losses from disease associated with inactivity (Abs&Pres)	13.52	
Reduced productivity losses from disease associated with inactivity (Mortality)	13.80	
Disbenefits from injuries associated with increased activity	-0.43	
subtotal	*42.15*	
Reduced DALYs from inactivity		242.88
INCREASED WELLBEING FROM EXPOSURE TO GREENSPACE		
Reduced healthcare costs from depression	21.97	
Reduced productivity losses from depression (Abs&Pres)	50.24	
Reduced productivity losses from depression (Mortality)	$ -	
subtotal	*72.20*	
Reduced DALYs from depression		284.50
BENEFITS FROM REDUCED URBAN TEMPERATURES		
Reduced healthcare costs from UHI	20.06	
Reduced productivity losses from UHI (Abs&Pres)	$ -	
Reduced productivity losses from UHI (Mortality)	1.56	
subtotal	*21.61*	
Reduced mortalities from UHI		173.62
BENEFITS FROM INCREASED AIR QUALITY		
Reduced health costs associated with poor air quality	2.22	
Reduced productivity losses from poor air quality (Abs&Pres)	1.66	
Reduced productivity losses from poor air quality (Mortality)	1.66	
subtotal	*5.54*	

ESTIMATED HEALTH BENEFITS	COST	WTP*
Reduced DALYs from poor air quality		22.16
TOTAL HEALTH BENEFITS OF PROJECT	**141.51**	**723.16**

*Source: Frontier Economics, Health Benefits Ready Reckoner tool. *Note: WTP: Willingness to Pay*

It should be noted that the large range of potential health benefits is driven by differences between the cost of illness and willingness to pay approaches (i.e. in general, willingness to pay estimates tend to be substantially larger than estimates derived from a cost of illness approach). This is because a person's willingness to pay covers both their willingness to avoid pain and suffering, in addition to the total private cost of illness faced by that person including cost of treatment and their wage (and is likely to be highly context sensitive and would vary considerably across projects).

8.4.5 Sensitivity of analysis to key assumptions

Table 7 shows the direct and indirect cost results from Case Study #1 when the assumption around the level of socioeconomic disadvantage in the local community is varied (although the median income is held constant). As the risk of inactivity-related disease is greatest for highly disadvantaged communities (Q1), if those communities are able to shift into more active recreation pattern because more greenspace is easily accessible, then they stand to gain the greatest benefit.

The analysis therefore demonstrates that consideration of the surrounding community characteristics can be relevant during assessment of investment options. For large scale, longer term projects however, it should be noted that these community characteristics do shift over time.

Table 7: Sensitivity to level of socioeconomic disadvantage: Case Study 1 using COI

LEVEL OF SOCIOECONOMIC DISADVANTAGE	ACTIVE RECREATION ($M)	TOTAL BENEFITS ($M)
Q1	46.59	145.94
Q2	44.06	143.42
Q3	42.15	141.51
Q4	40.24	139.60
Q5	38.94	138.30

*Note: * with Q1 being most disadvantaged and Q5 being least disadvantaged*

Source: Frontier Economics Ready Reckoner tool

The level of socioeconomic disadvantage impacts health-related benefits through two channels. Firstly, communities with higher levels of socioeconomic disadvantage bear a higher burden of disease related to physical inactivity. This means that if these groups can shift into more active recreation patterns due to increased access to greenspace, which itself is due to a water investment, then there is more burden of disease that is relieved due to the water investment — as measured in DALYs that are valued at the value of a statistical life year (discussed in **Section 3.4.2**). Importantly, the value of a statistical life year, or society's willingness to pay for an extra year of healthy life, ***does not*** vary by socioeconomic group. Rather, this value is applied to a greater total number of DALYs because communities with higher levels of socioeconomic disadvantage on average bear a higher burden of disease related to physical inactivity.

Secondly, where health benefits are calculated with the Cost of Illness (CoI) approach (see **Section 3.4.2**), the level of socioeconomic disadvantage plays a role in determining estimated health benefits via the wage level at which productivity is measured. As explained in **Section 3.4.2**, the CoI approach takes into account the indirect costs of lost productivity, and productivity is assumed to be captured by wages. This means that those indirect costs of illness, as measured by lost productivity, are generally lower for communities with higher levels of socioeconomic disadvantage as these communities generally have lower incomes.

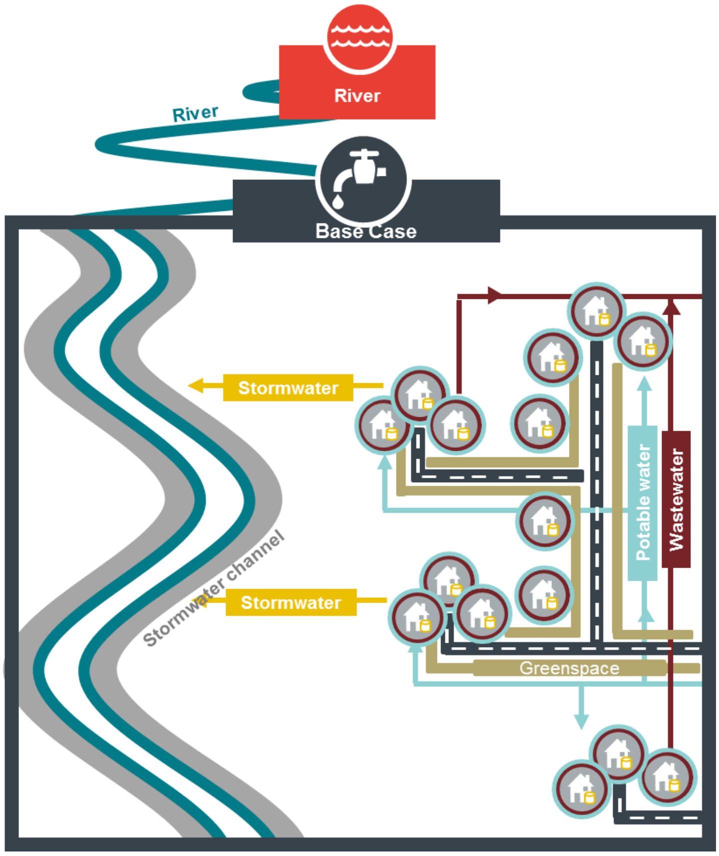
8.5 Case study #2: Rehabilitation of Stormwater Channel

The second case study concerns replacing an aging, concrete stormwater channel in need of renewal in an inner suburban, sub-tropical area. It is loosely based on real-world projects such as the Cooks River, Upper Stony Creek and Small Creek naturalisation projects. We have assumed that the area is in a higher socioeconomic group (Quintile 4 on the ABS Index of Relative Social Disadvantage).

8.5.1 Base case

Figure 15 sets out the Base Case servicing approach, which involves a BAU approach to the renewal of the stormwater channel. Stormwater flows from a development to a larger concrete stormwater channel which eventually flows through to a river. In particular, it involves traditional stormwater flood management, involving relining the stormwater channel with concrete to reduce flooding. This will maintain the drainage and flood management function but will not provide for passive or recreation recreations experiences as access and movement will be limited to following the line of the concrete channel which provides little shade or opportunities for interactivity.

Figure 21: Case study #2: Rehabilitation of stormwater channel – BAU (Base Case)

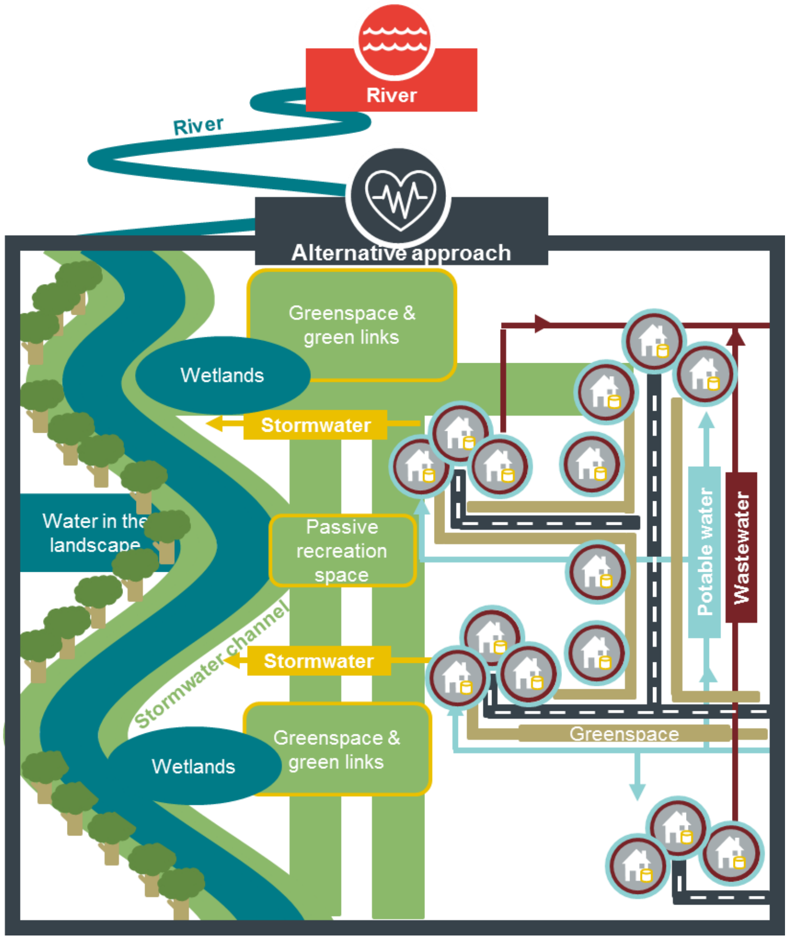


Source: Frontier Economics

8.5.2 Alternative servicing approach

Figure 22 sets out the alternative servicing approach which utilises IWCM to provide a naturalised stormwater channel. Stormwater flows from a development to a larger naturalised development which uses trees, open spaces and wetlands to improve flood and erosion management and improved aesthetics and amenity. The channel is lined with sandstone and has cycle paths and greenspace surrounding the area. In particular, it involves collaboration between the water business and local councils to replace the failing concrete riverbanks with sandstone sloped banks, surrounded by native plants and open space including informal paths, seating, viewing areas and interpretive signing. The greenspace would include shaded areas and a wetland. It also involves a cycleway along the corridor to facilitate active transport connections for residents. Stormwater is used to irrigate new, nearby greenspaces. Naturalising the waterway also leads to fewer stagnant ponds.

Figure 22: Case study #2: Rehabilitation of Stormwater Channel – Naturalised Stormwater Channel



Source: Frontier Economics

8.5.3 Potential liveability-related health impacts

Collaboration between water businesses and local councils to provide a naturalised stormwater channel can provide a range of health benefits through enhancing opportunities for active and passive recreation (including opportunities for sport and social activities). In particular, we have assumed that this case study affected 10,000 people and these people are assumed to be from an area of higher socioeconomic advantage (Q4 quintile).

However, as shown in **Table 8**, although there is increased tree canopy and shady spaces around the creek, it is unlikely to reduce ambient temperatures or air quality concerns due to insufficient scale (i.e. improvements in urban heat and air quality require large-scale projects). In particular, compared to the *base case,* the *alternative servicing approach* provides:

- **Increased opportunity for active and passive recreation** given increased availability of connected, irrigated amenable and accessible greenspace (although the increase in participation is assumed to be smaller than case study #1 given the smaller increase in availability of greenspace);
- **No change to urban heat island effect** given insufficient scale of the project, although there is likely to be reduced urban temperature in the area of direct proximity to the stormwater channel;
- **No change to air quality** as a result of increased irrigated tree canopy.

Table 8: Case study 2: Parameters

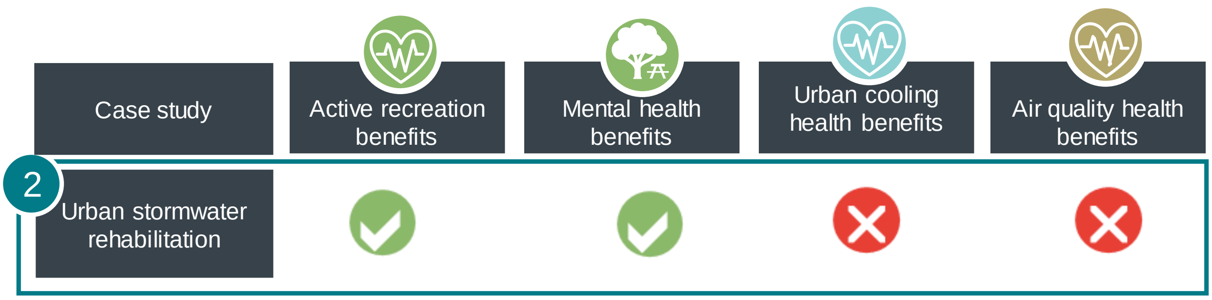
PARAMETER	VALUES AND COMMENTS
Regional characteristics	Population affected: 10,000 Socioeconomic: Q4
Active recreation	Based on incremental participation: 5%. Achieving equivalent of 15min/weekday
Passive recreation	Based on incremental participation: 10%
UHI effect	Will have shady spaces around creek but unlikely to reduce ambient temperature in broader region
Air quality	Will have increased foliage but unlikely to reduce air quality concerns

Source: Frontier Economics

As shown in **Figure 23**, in this case study there will be a number of potential health-related impacts to examine:

- **Health benefits arising from active recreation** (including cycling, walking, running etc) along the creek and in surrounding greenspaces irrigated by stormwater harvesting;
- **Mental health benefits** from greater opportunities for passive recreation and community connection;
- **Health benefits attributable to the provision of community cool zones** people can retreat to on hot days and reduced urban landscape heat;
- **Reductions in mosquito-borne disease from fewer stagnant ponds from erosion of the channel**.

Figure 23: Summary of relevant health benefits of case study #2



Source: Frontier Economics

8.5.4 Estimation of health benefits of case study #2

Table 9 sets out the estimated value of the health benefits under case study #2. Compared to the *base case* (i.e. BAU approach to stormwater channel replacement), the *alternative approach* is associated with:

- $0.16 million or $0.67 million in benefits from increased activity; and
- $0.24 million or $0.95 million in benefits from increased wellbeing from exposure to greenspace.

This highlights that, relative to the *Base Case* BAU approach to stormwater channel replacement, an *alternative approach* delivers health benefits of between $0.4 million and $1.6 million (depending on the monetisation approach adopted). The benefits from reduced urban temperature and improved air quality are zero as a result of the relatively small scale of the investment.

Table 9: Case study 2: Estimated health benefits ($2017-18 million)

ESTIMATED HEALTH BENEFITS	COST	WTP*
BENEFITS FROM INCREASED ACTIVITY		
Reduced healthcare costs from disease associated with inactivity	0.04	
Reduced productivity losses from disease associated with inactivity (Abs&Pres)	0.06	
Reduced productivity losses from disease associated with inactivity (Mortality)	0.06	
Disbenefits from injuries associated with increased activity	0.00	
subtotal	*0.16*	
Reduced DALYs from inactivity		0.67
INCREASED WELLBEING FROM EXPOSURE TO GREENSPACE		
Reduced healthcare costs from depression	0.07	
Reduced productivity losses from depression (Abs&Pres)	0.17	
Reduced productivity losses from depression (Mortality)	$-	
subtotal	*0.24*	
Reduced DALYs from depression		0.95
BENEFITS FROM REDUCED URBAN TEMPERATURES	N/A	N/A
subtotal	N/A	N/A
Reduced mortalities from UHI	N/A	N/A
BENEFITS FROM INCREASED AIR QUALITY	N/A	N/A
subtotal	N/A	N/A
Reduced DALYs from poor air quality	N/A	N/A
TOTAL HEALTH BENEFITS OF PROJECT	**0.40**	**1.62**

*Source: Frontier Economics. *Note: WTP: Willingness to Pay*

These health benefits are smaller than the health benefits under case study #1 given case study #2 is associated with a reduced affected population and is of insufficient scale to generate significant changes to urban temperature and air quality.

8.6 Case study #3: Regional water supply options

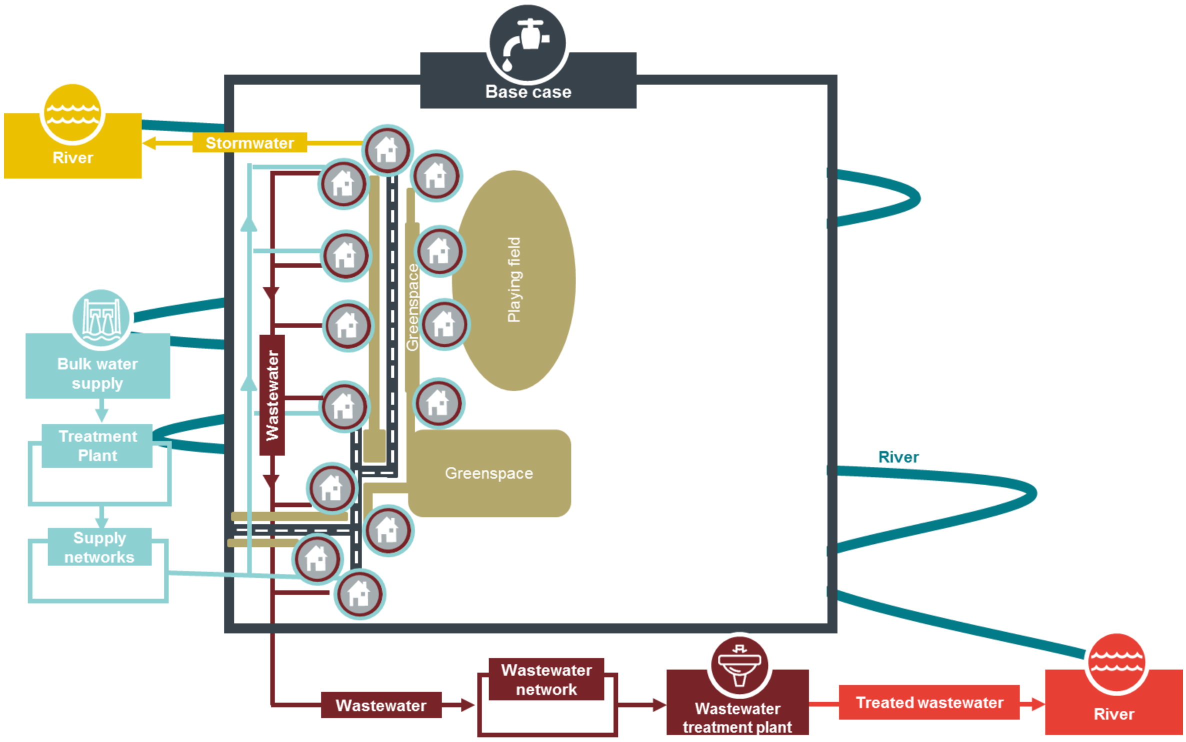
The final case study involves providing water and wastewater services to meet current and future needs in a regional town in a semi-arid zone. Compares a base case of a traditional water and wastewater servicing solution and an IWCM servicing solution aimed at providing water, wastewater, recycled water and stormwater services to the town. It is assumed to be an area of relatively low socioeconomic status (Quintile 2 on the ABS Index of Relative Social Disadvantage).

8.6.1 Base case

Figure 24 sets out the *base case* servicing approach, which involves a BAU approach to the provision of water and wastewater services. In particular, it involves:

- **Potable water:** Bulk water sourced from upstream supply network, treated and reticulated to homes and businesses throughout the development (i.e. traditional potable water supply).
- **Wastewater**: reticulation network servicing the development, with wastewater treated and discharged in a nearby river (i.e. traditional wastewater water collection, treatment and disposal).
- **Recycled Water:** No recycled water under the base case.
- **Stormwater:** Traditional stormwater flood management by the Council.

Figure 24: Case Study #3: Regional water supply options - BAU (base case)



Source: Frontier Economics

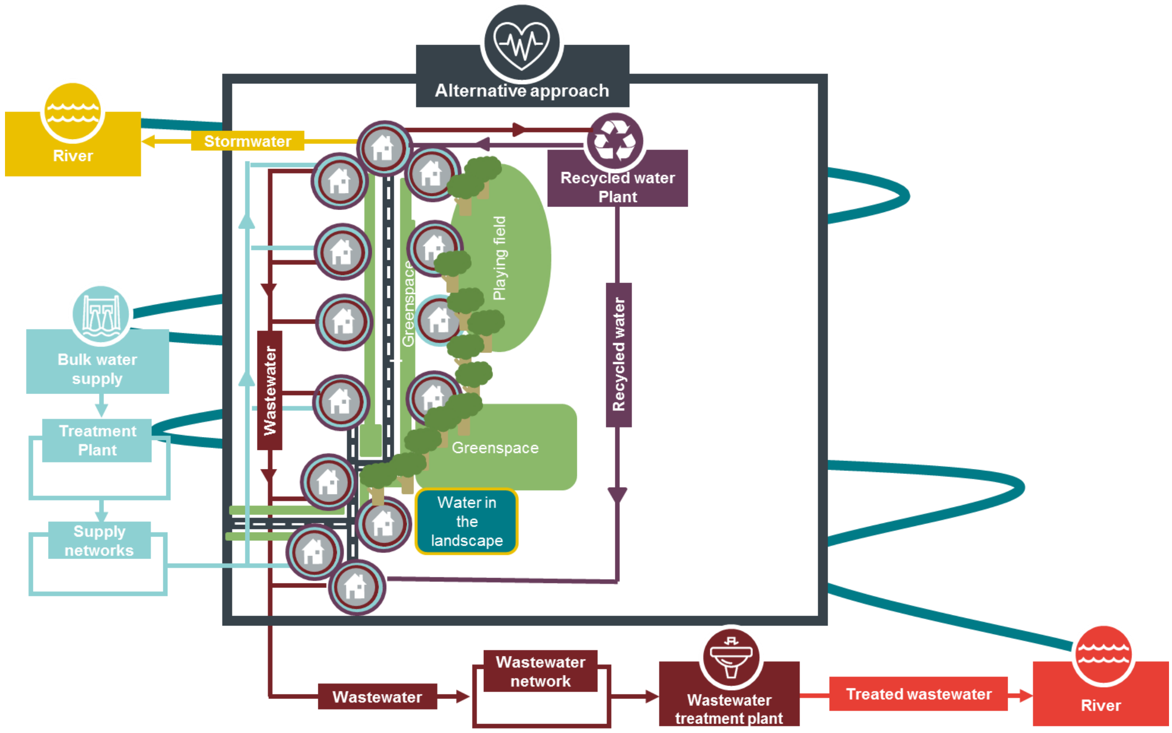
8.6.2 Alternative servicing approach

Figure 25 sets out the alternative servicing approach, which incorporates WSUD and IWCM to provide water, wastewater, recycled water and stormwater services. Its key feature is that wastewater and stormwater are being treated at an onsite recycled water plant, and the produced recycled water is being supplied for non-potable use (including irrigation). In particular it involves:

- **Potable water:** All potable water supplied from upstream supply network, treated and reticulated to homes and businesses through the town (as per the base case). Non-potable use (e.g. irrigation of greenspace) met via a combination of recycled water from a new recycled water plant and stormwater reuse.

- **Wastewater**: As per the base case, except some wastewater is recycled at a new, onsite recycled water plant for non-potable use (e.g. irrigation), rather than simply directed to the relevant wastewater network.
- **Recycled Water:** Recycled water is piped from an existing recycled water plant for non-potable use by homes and businesses throughout the town (via a third pipe and reticulation network) and irrigation of the greenspace throughout the development.
- **Stormwater:** Some stormwater harvesting and reuse to irrigate parklands and greenspace.

Figure 25: Case Study #3: Regional water supply options – IWCM approach



Source: Frontier Economics

8.6.3 Overview of potential liveability-related health impacts

The provision of high quality public open space that is accessible to the community can provide a range of health benefits through enhancing opportunities for active and passive recreation (including opportunities for sport and social activities). Due to the likely availability of open space in this case study, we have assumed that the change in water cycle management can improve access to quality greenspace for the surrounding population (assumed to be 50,000 from an area of lower socioeconomic advantage (Q2 quintile)) (

Table 5). However, due to the smaller scale and scope of the IWCM investment, it is assumed to not change urban heat or air quality outcomes in the area.

In particular, as result of different approaches to water cycle management, compared to the *base case*, the *alternative servicing approach* provides:

- **Increased opportunity for active and passive recreation** given increased availability of irrigated amenable and accessible greenspace;
- **No change to urban heat island effect.** Urban heat island effect is unlikely to be a significant issue in regional areas and given the small scale of the project;
- **No change to air quality** as a result of increased irrigated tree canopy.

Table 10: Case study 3: Parameters

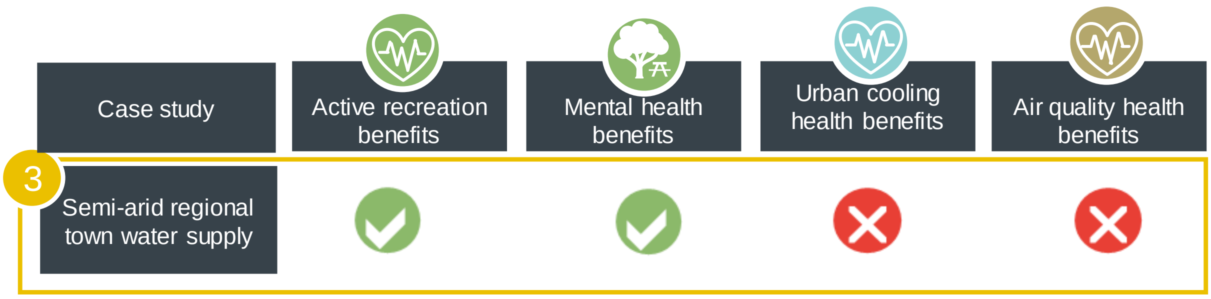
PARAMETER	VALUES AND COMMENTS
Regional characteristics	Population affected: 50,000 Socioeconomic: Q2
Active recreation	Based on incremental participation: 5% (achieving equivalent of 15min/weekday)
Passive recreation	Based on incremental participation: 10%
UHI effect	Will have shady spaces but unlikely to reduce ambient temperature in broader region
Air quality	Will have increased foliage but unlikely to reduce air quality concerns

Source: Frontier Economics

As shown in **Figure 26** , the *alternative servicing approach* in this case study is likely to be associated with:

- **Health benefits arising from more active recreation** (including cycling, walking, running etc) from more amenable and accessible greenspaces and healthier waterways.
- **Mental health benefits from greater opportunities for passive recreation and community connection** in safe open public greenspace.
- **Physical and mental health benefits from being able to have sporting fields** (e.g. football ovals) available for safe use even during times of water shortage (e.g. restrictions).
- **Health benefits attributable to improved swimmability** in local rivers due to reduced wastewater and/or stormwater discharges to waterways.

Figure 26: Summary of relevant health benefits of case study #3



Source: Frontier Economics

8.6.4 Estimation of health benefits of case study #3

Table 11 sets out the estimated value of the health benefits under case study #3. Compared to the *base case* (i.e. BAU approach to stormwater channel replacement), the *alternative approach* is associated with:

- $0.60 million or $4.1 million in benefits from increased activity; and
- $1.20 million or $4.7 million in benefits from increased wellbeing from exposure to greenspace.

This highlights that, relative to the *base case* BAU approach to water cycle management, an *alternative approach* delivers health benefits of between $1.8 million and $8.8 million (depending on the monetisation approach adopted). The benefits from reduced urban temperature and improved air quality are zero as a result of the relatively small scale of the investment.

These health benefits are smaller than the health benefits under case study #1 given case study #3 is associated with a reduced affected population and is of insufficient scale to generate significant changes to urban temperature and air quality.

Table 11: Case study 3: Estimated health benefits ($2017-18 million)

ESTIMATED HEALTH BENEFITS	COST	WTP*
BENEFITS FROM INCREASED ACTIVITY		
Reduced healthcare costs from disease associated with inactivity	0.26	
Reduced productivity losses from disease associated with inactivity (Abs&Pres)	0.17	
Reduced productivity losses from disease associated with inactivity (Mortality)	0.17	
Disbenefits from injuries associated with increased activity	-0.01	
subtotal	*0.60*	
Reduced DALYs from inactivity		4.08
INCREASED WELLBEING FROM EXPOSURE TO GREENSPACE		
Reduced healthcare costs from depression	0.37	
Reduced productivity losses from depression (Abs&Pres)	0.84	
Reduced productivity losses from depression (Mortality)	$-	
subtotal	1.20	
Reduced DALYs from depression		4.74
BENEFITS FROM REDUCED URBAN TEMPERATURES	N/A	N/A
subtotal	N/A	N/A
Reduced mortalities from UHI	N/A	N/A
BENEFITS FROM INCREASED AIR QUALITY	N/A	N/A
subtotal	N/A	N/A
Reduced DALYs from poor air quality	N/A	N/A
TOTAL HEALTH BENEFITS OF PROJECT	**1.20**	**8.82**

*Source: Frontier Economics, Health Benefits Ready Reckoner tool. *Note: WTP: Willingness to Pay*

8.7 Case study results: key learnings

A comparative summary of the results is shown below (**Table 12**). This comparison has been undertaken on a per capita basis, given that a primary driver of difference between the case study results is the number of people that they affect.

Table 12: Comparison of Case Study results: direct and indirect costs ($2017-18)[95]

HEALTH BENEFIT (COI APPROACH)	CASE STUDY 1	CASE STUDY 2	CASE STUDY 3
Benefits from increased activity ($/pp)	28.10	16.29	12.06
Increased wellbeing from exposure to greenspace ($/pp)	48.14	24.07	24.07
Benefits from reduced urban temperatures ($/pp)	14.41	$0.00	$0.00
Benefits from increased air quality ($/pp)	3.69	$0.00	$0.00
Total health benefits of project ($/pp)	94.34	40.35	36.13
Population affected	1,500,000	10,000	50,000
Total benefit ($)	**141,508,488**	**403,543**	**1,806,366**

Source: Frontier Economics Ready Reckoner tool

A similar comparison can be made using the willingness to pay (WTP) estimates:

[95] Table shows net present value of the investment over the whole of its life, assumed to be 20 years.

Table 13: Comparison of Case Study results: Willingness to pay ($2017-18)

HEALTH BENEFIT (WTP* APPROACH)	CASE STUDY 1	CASE STUDY 2	CASE STUDY 3
Benefits from increased activity ($/pp)	161.92	67.45	81.52
Increased wellbeing from exposure to greenspace ($/pp)	189.67	94.83	94.83
Benefits from reduced urban temperatures ($/pp)	115.74	0.00	0.00
Benefits from increased air quality ($/pp)	14.77	0.00	0.00
Total health benefits of project ($/pp)	482.10	162.28	176.35
Population affected	1,500,000	10,000	50,000
Total benefit ($)	**723,156,743**	**1,622,814**	**8,817,699**

*Source: Frontier Economics Ready Reckoner tool. *Note: WTP: Willingness to Pay*

The key learnings from the case studies include:

- Overall size of benefits can be large for large projects.
- Health benefits from reduced urban heat and air pollution are only relevant to large-scale greenfield projects.
- Mental health benefits from passive recreation in greenspace typically as much as or more in monetary terms than the health benefits from active recreation. This reflects the much higher ‘participation’ in exposure to greenspace compared to the limited number of people who will actually increase their physical activity due to more amenable or accessible greenspace.
- Most of the mental health-related benefits are in the form of reduced losses in productivity rather than reduced direct healthcare costs, as typically depression doesn’t involve hospitalisation but is a widespread draw on workplace productivity.
- Health benefits from active recreation are more evenly weighted across reduced healthcare costs, and reduced morbidity and mortality related productivity costs, reflecting the nature of key linked diseases (e.g. cancers).
- Willingness to pay (WTP) values are generally significantly higher than cost of illness numbers — this is due to the broader base of benefits that it represents.
- Results are sensitive to key assumptions such as participation in active and passive recreation. This suggests that it is worthwhile to focus on arriving at robust assumptions for these values rather than refining/finessing detail of other costs, for example healthcare costs.
- Dollar benefits are higher when a larger population is involved. The primary driver of difference between the case study results is the number of people that they affect.
- The benefits of access to greenspace from active recreation are sensitive to the level of socioeconomic disadvantage in the community. Regions of higher disadvantage are estimated to benefit more from greenspace access due to the increase health issues associated with physical inactivity.

8.8 Guidance on application of ready reckoner tool to IWCM investments

While the case studies illustrate the application of the ready reckoner tool to three hypothetical case studies, it is able to be applied to other projects which may have different characteristics.

In doing so, however, it should be recognised that:

- Estimates of the potential health benefits from the ready reckoner will need to be integrated into the overall assessment of a potential investment and indeed requires that a robust investment evaluation framework (as discussed in **Sections 2 and 8.1**) has already been developed for the investment in question. For example, application of the ready reckoner tool requires that the base case and the proposed investment option or options have already been clearly defined.
- In applying the ready reckoner tool to evaluate potential liveability-related health benefits from an IWCM investment, in many cases these benefits may represent a relatively small component of the overall benefits of a project.

Subject to these caveats, the following provides some guidance on the use of the ready reckoner tool to estimate liveability-related health benefits attributable to specific IWM investments.

8.8.1 Establishing the relevant health pathways for the investment

The ready reckoner tool is based on the framework outlined in this report and potentially is able to estimate liveability-related health benefits for each of the four health pathways identified in this report, namely:

- Improvements in health resulting from more active recreation
- Improvements in mental health resulting from more exposure to greenspace
- Improvements in health resulting from reduced temperatures associated with the urban heath island effect
- Improvements in health resulting from lower air pollution.

However, not all of these pathways are likely to be relevant (or material) for all IWM projects. Reflecting this, the user of the model is required to enter 'Yes' or 'No' for each of these pathways. The following provides guidance on determining this for a given investment.

8.8.2 Does the investment lead to health benefits via active and passive recreation?

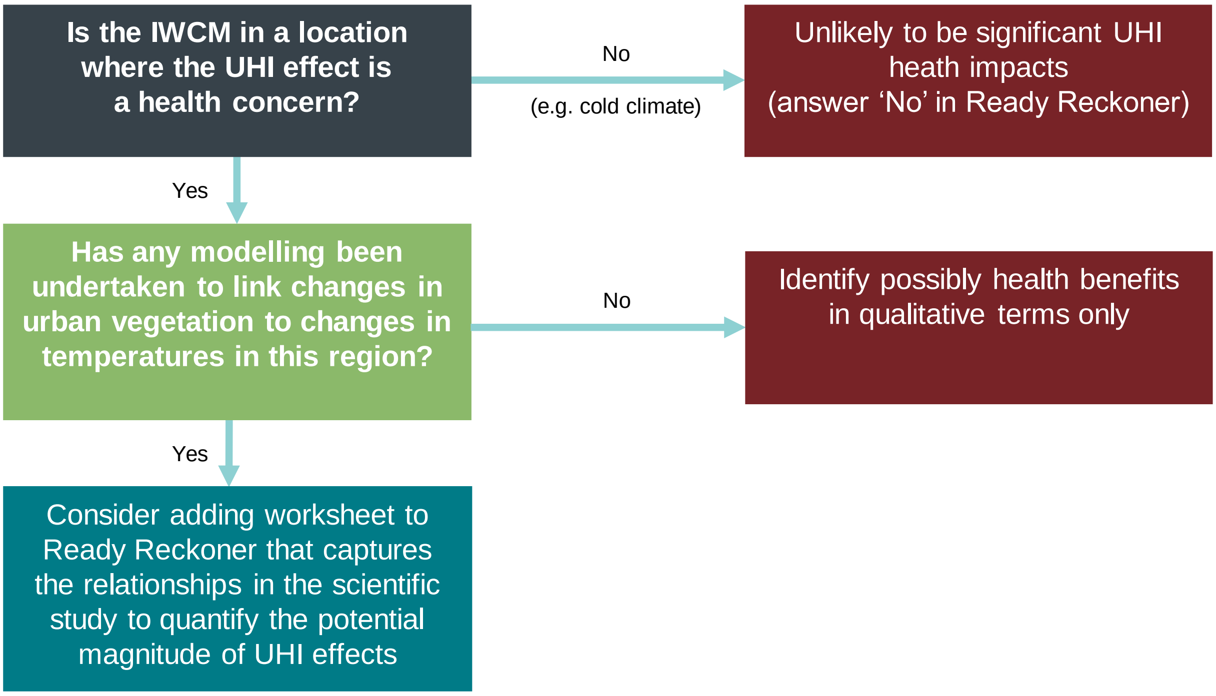
We envisage that for the vast majority of IWM investments, pathways 1 and 2 – liveability related health benefits attributable to more opportunities for active and passive recreation from improved greenspace – will be relevant. A response of "No" would be equivalent to saying that the proposed investment will make no difference to the quantity or quality of greenspace which would occur under the base case. Under these circumstance, the incremental health benefits attributable to the investment are nil. In all other cases, where the is at least some incremental improvement in the quantity and/or quality of greenspace, the ready reckoner tool will produce an estimate of the economic value of these benefits.

8.8.3 Does the investment lead to health benefits via urban cooling?

The tool also seeks the user to indicate whether pathway 3 (urban cooling) is relevant for the investment in question. While this is less likely to be relevant for many IWM investments, it may nevertheless be relevant in some cases.

The decision tree in **Figure 27** below provides guidance in determining whether this pathway is relevant.

Figure 27: Relationship between improved environment and health risk factors: UHI effect



Source: Frontier Economics

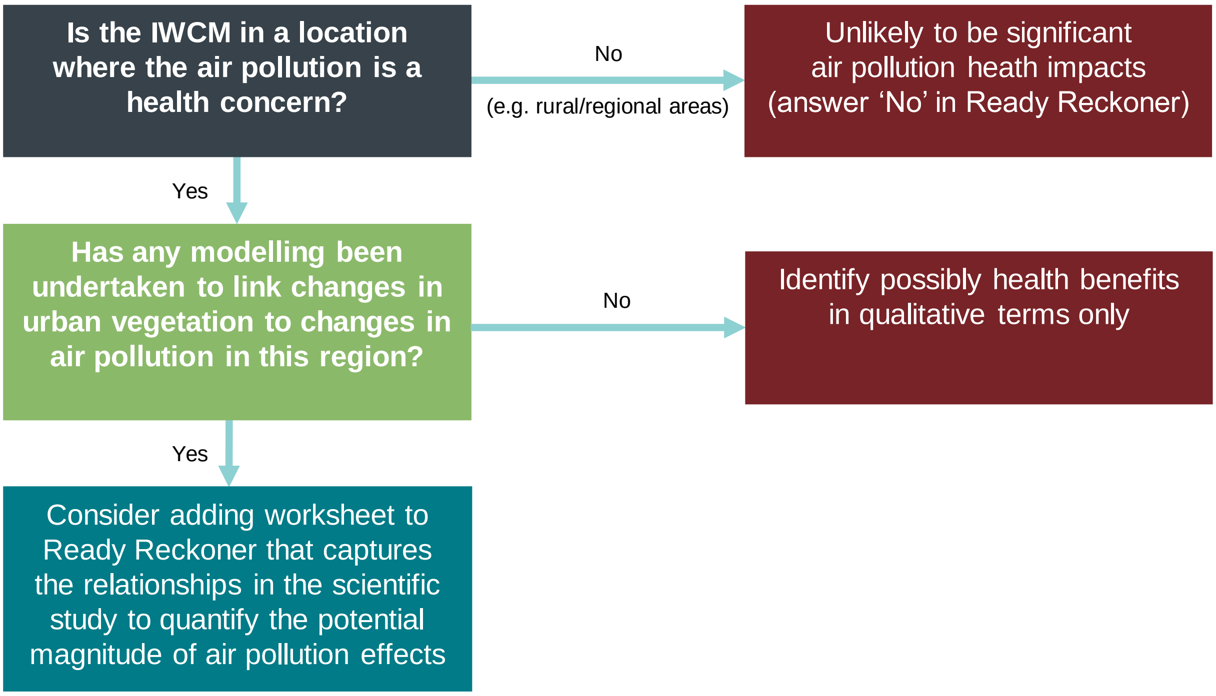
As indicated in the above schematic, where it is considered that the investment is likely to have a material impact on urban cooling, the tool requires incorporation of region-specific information on the nature of the relationship between increased vegetation and the urban heat island effect. Because this relationship is region-specific the tool does not apply a standardised assumption but rather requires this to be provided by the user (see below).

8.8.4 Does the investment lead to health benefits via reduced air pollution?

The tool seeks the user to indicate whether pathway 4 (air pollution) is relevant for the investment in question. Again, while this is less likely to be relevant for many IWM investments, it may nevertheless be relevant in some cases.

The decision tree in **Figure 28** below provides guidance in determining whether this pathway is relevant.

Figure 28: Relationship between improved environment and health risk factors: Air pollution



Source: Frontier Economics

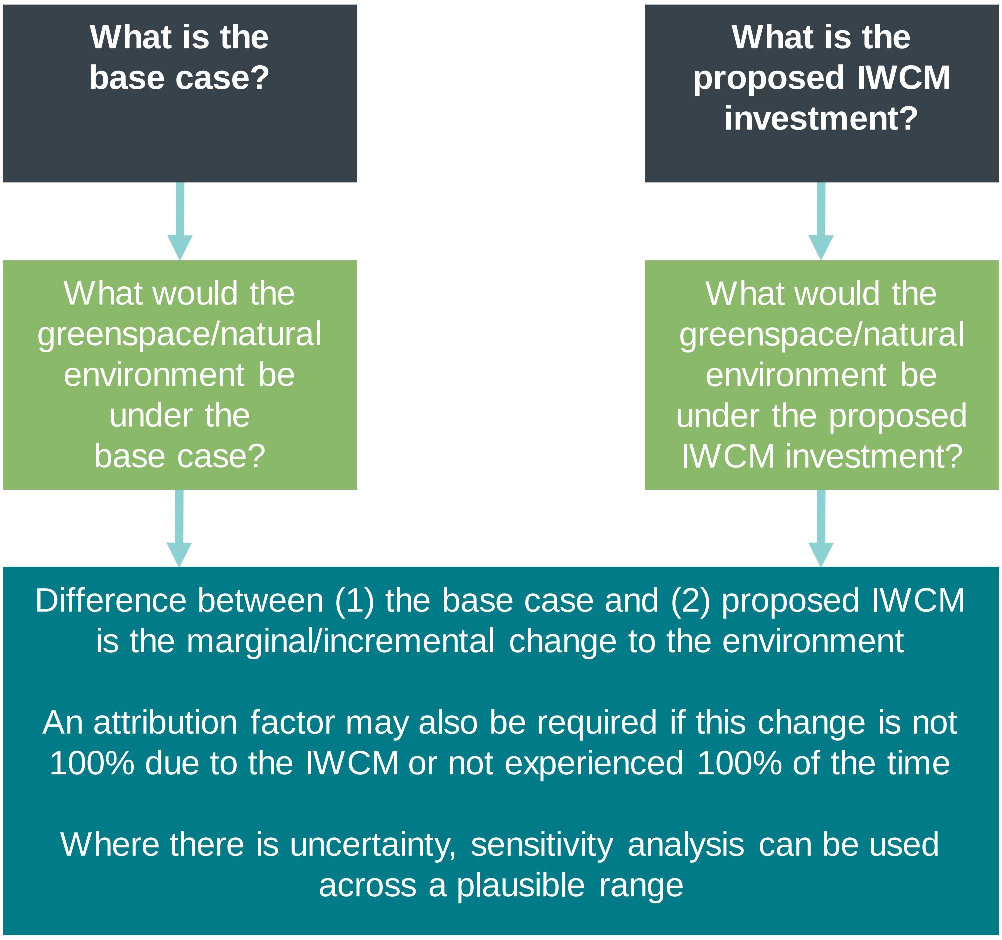
As indicated in the above schematic, where it is considered that the investment is likely to have a material impact on urban cooling, the tool requires incorporation of region-specific information on the nature of the relationship between increased vegetation and urban air pollution. Because this relationship is region-specific the tool does not apply a standardised assumption but rather requires this to be provided by the user (see below).

8.8.5 Determining the attribution factor

For each of the health pathways which are relevant to a given investment, an attribution factor must be assigned which reflects the extent of causality between the IWM investment and the improved physical environment.

As discussed in **Section 3.1**, the relationship between the IWCM investment and the improved physical environment requires comparing the environment under the investment relative to what it would be under the defined base case (see **Figure 29** below).

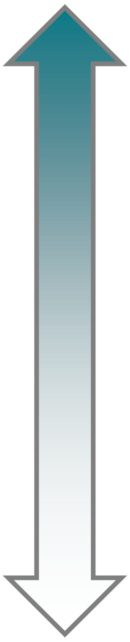
Figure 29: Relationship between IWCM investment and improved environment



Source: Frontier Economics

Figure 30 provides further guidance on the establishment of an appropriate ‘attribution factor’ based on comparing the impact of the water investment relative to a base case. Where the improved environment would not occur under the base case, an attribution factor of 100% can be attributed to the investment. At the other end of the spectrum, where the improved environment (e.g. quantity and quality and greenspace) would be no different under the base case, the appropriate attribution factor is zero.

Figure 30: Determining the attribution factor



Attribution factor	Example
100% — Improved environment entirely due to IWCM investment	IWCM projects creates greenspace or bluespace that would otherwise not exist
50% — Improvement in environment occur jointly from IWCM investment and other actions	IWCM and building code reform jointly reduce peak temperatures and hence impact of UHI
5% — Small improvement in environment under IWCM project compared to base case	IWCM project uses recycled water to irrigate greenspace during drought when this area would have otherwise left to brown off (approximately 1 year in 20)
0% — No difference between environment under base case and under IWCM investment	IWCM project involves recycled water to irrigate greenspace that would otherwise be irrigated with alternative source (e.g. groundwater)

Source: Frontier Economics

8.8.6 Population assumptions

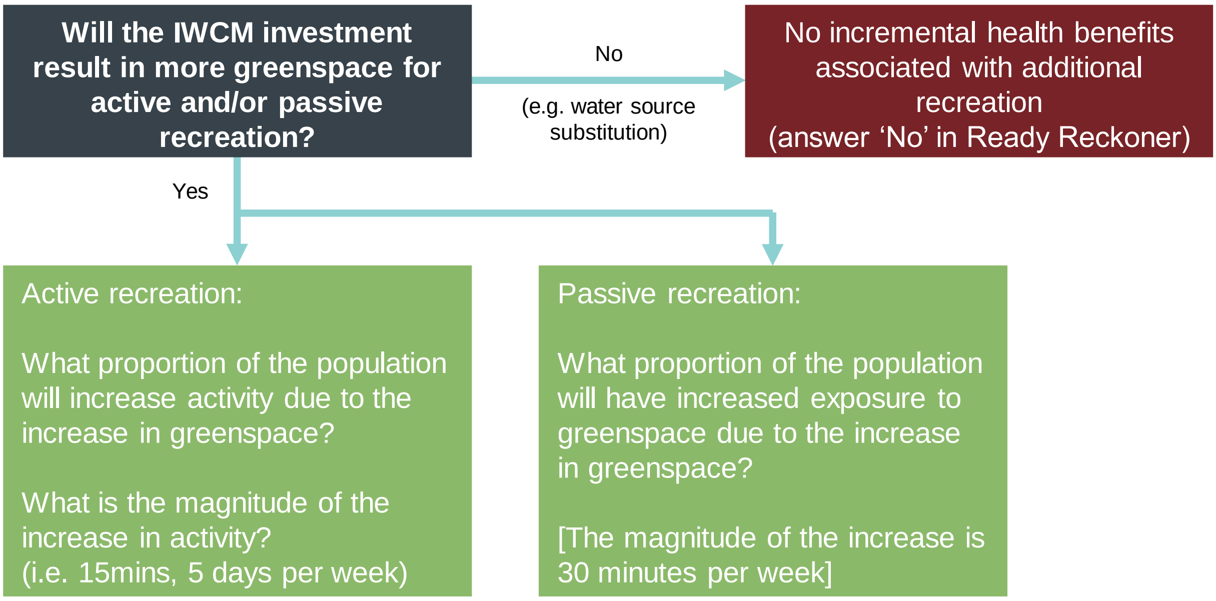
Because the quantum of health benefits depends on the underlying characteristics of the population, the tool requires the user to input key data on the relevant population. Notably, the relationship between increase activity and increased health (decreased disease burden associated with physical inactivity) was markedly different for males and females.

This information is readily available from the relevant ABS Community Profile for the IWCM study region, or the Australian average from the most recent census can be used (49.34% males; 50.66% females).

8.8.7 Open space assumptions

For investments where health pathways 1 and 2 are relevant (likely to be the majority of IWM investments), the tool requires input of a number of key variables which affect the relationship between improved natural environments and health risk factors.

Figure 31: Relationship between improved environment and health risk factors: recreation



Source: Frontier Economics

Proportion of the affected population that increases activity due to the greenspace

This variable indicates the proportion of the affected population which will undertake more physical activity due to the incremental change in the greenspace attributable to the IWM investment.

The default assumption in the tool is that 5% of the affected population will undertake more physical activity as a result of improved accessibility to greenspace. This reflects the literature as outlined in **Section 4.2**.

However, in circumstances where the nature of the investment is such that the increased uptake of physical activity could be expected to be particularly high (e.g. where the investment changes the environment from one where there is very little accessible and amenable greenspace to one where there is abundant such greenspace), the tool allows for a higher uptake factor to be input. Guidance on this assumption is provided in **Figure 32**.

Figure 32: Active recreation participation

Level of incremental participation		Comments
10% —	Higher level of incremental participation (than suggested default value) if context is base case of very limited greenspace access	IWCM projects creates greenspace(s) in large area that would otherwise have very limited access to greenspace
5% —	Suggested default value based on literature	IWCM project creates greenspace to improve community access to greenspace
<5% —	Lower level of incremental participation (than suggested default value) if context is base case of readily accessible greenspace	IWCM project creates greenspace in area that already has many accessible greenspaces

Source: Frontier Economics

Duration of the increase in activity (minutes)

This variable indicates how much more activity, on average, people will undertake due to the incremental change in the greenspace attributable to the IWM investment.

The default assumption in the tool is that people who participate will undertake, on average, 15 minutes more physical activity for five days per week at a moderate activity level. This reflects the literature as outlined in **Section 4.2**.

However, the tool allows for a higher increased amount of activity to be input. The literature supporting the relationship between increase activity and increased health (decreased disease burden associated with physical inactivity) considered time lengths of 15, 30 and 60 minutes.

Injuries associated with the increased activity

As noted in **Section 4.3**, there is little empirical evidence on the likely increase in injuries associated with increased physical activity. The tool adopts a default assumption of a low rate of increase in the rate of injuries (1%) to recognise that there will be at least some offsetting impact on health associated with injuries. However, there is scope for the user to increase this number if it is felt that the rate of injuries for the particular activities which might be expected under a given investment are likely to be higher (e.g. if more vigorous or potentially more dangerous activities such as cycling are involved rather than low impact activities such as walking).

Proportion of the affected population exposed to greenspace

This variable indicates the proportion of the affected population which will undertake more passive activity (i.e. exposure to greenspace) due to the incremental change in the greenspace attributable to the IWM investment.

It is reasonable to assume that the proportion of the population which undertaken passive recreation/exposure to greenspace is likely to be considerably higher than the proportion of the population which undertakes active physical activity, simply because of the lower threshold of effort required.

The default assumption in the tool is 10%. However, in circumstances where the nature of the investment is such that the increased uptake of passive exposure to greenspace (or other improved physical liveable environments) could be expected to be particularly high (e.g. where the investment changes the environment from one where there is very little accessible and amenable greenspace to one where there is abundant such greenspace), the tool allows for a higher uptake factor to be input.

Reduction in depression due to increased exercise

This variable indicates the relationship between physical activity and reduction in depression.

The default assumption in the tool is that physical activity leads to a 25% reduction in depression. This is based on the literature as discussed in **Section 4.3**.

8.8.8 Urban cooling assumptions

The tool allows key assumptions on the relationship between the IWCM investment and the UHI. The tool uses relationships based on a study of western Sydney that identified that the IWCM and related policy changes would result in a change in temperature (with peak ambient temperature in Sydney's west reduced by 2.5 degrees) and change in deaths (reducing the cumulative heat-related deaths from 14 to 7.5 per 100,000 people). Similarly, the change in UHI might alternatively be gauged by the modelled change to the number of hot days (defined as the frequency of days with a maximum temperature exceeding a specific threshold) or the change in cooling degree days (defined as the number of degrees that a day's average temperature is above a specified temperature — above which buildings need to be cooled).

To be able to translate this into a quantitative estimate of health benefits requires the availability of region-specific modelling and the addition of a bespoke worksheet to the ready reckoner tool. The current tool incorporates such a worksheet in respect of western Sydney (used for the purposes of illustrative case study 1).

8.8.9 Air quality assumptions

The tool allows key assumptions on the relationship between the IWCM investment and the health impacts of air quality changes — namely level of pollution after the project (µg/m^3). The tool uses relationships based on a study of Sydney that links changes in air pollutant concentrations to health impacts. In order to link this to the hypothetical IWCM investment, a representative change in air pollution due to the change in greenspace was assumed.

However, to be able to translate this into a quantitative estimate of health benefits requires the availability of region-specific modelling and the addition of a bespoke worksheet to the ready reckoner tool.

8.8.10 Sensitivity analysis

The tool has an in-built capability to undertake sensitivity analysis by running the tool with one set of input assumptions and then re-running the tool with an alternative assumption. Comparison of the results allows the user to identify the impact of the changed assumption.

9 LESSONS FOR BUSINESS CASE EVALUATION

9.1 Current practice

A variety of approaches have been adopted to valuing health benefits from water investments.

Some business cases appear to risk double-counting of benefits (e.g. add health-related benefits to property value uplift which may to some extent already reflect private health benefits) – although this has been acknowledged and avoided in some studies (e.g. analysis of Stony Creek in western Melbourne by Mekala et. al. (2015)).

A number of studies have used the per capita dollar value based on the Medicare 2008 study which estimated total costs of $13.8 billion (comprising $0.7bn net healthcare costs, $9.3bn economy-wide productivity cost in form of absenteeism and presenteeism, and $3.8 bn in mortality costs (measured in terms of foregone future wages).

While this methodology appears appropriate as general indicator of the economic costs of physical inactivity, it is based on averaged (Australia-wide) data rather than taking account of the socioeconomic profile of the affected population or climate characteristics relevant to a particular project/location.

We would also note that a number of evaluation and studies have adopted methodologies consistent with those proposed in this report. For example, a recent cost-benefit study undertaken by Griffith University for Seqwater on upgrading of water treatment plants applied approach we are proposing by estimating the impact on DALYs of upgrades of the plants to improve drinking water quality and multiplying these by the (indexed) VSLY value recommended by the Office of Best Practice Regulation (OBPR).

This highlights that the proposed methodology as outlined in this report can be used to integrate into a broader analysis of the contribution of the water industry to public health outcomes.

9.2 Possible future approaches to quantification of health benefits

It is clear from the analysis and case studies undertaken for this study that while some quantifiable health impacts are generic and transferable (i.e. benefit transfer may be appropriate), in other cases estimating the impacts will require a more localised assessment. This is because the nature of the relationships are complex and not uniform across types of physical liveable environments.

In considering which types of health impacts to quantify, principles of investment evaluation would suggest that more effort should be expended on those health impacts which are likely to be more significant given the circumstances of each case (e.g. UHI effects in hot regions) and for which there is a sound evidence base.

It should also be noted that some health benefits may be encompassed within broader methodologies which pick up a range of attributes/values (e.g. willingness to pay studies) so care is needed to avoid double-counting.

It is also apparent that quantification of health benefits attributable to investment in integrated water management is currently constrained by the availability of robust evidence on some of the relationships which link the investment to health outcomes. We have identified a few important, broad level research directions for future work in this area that would benefit real world economic appraisals with a focus on the greatest returns to industry. These include further primary research to develop the knowledge base for specific locations, for example, modelling to support health pathway 4 and the link between city-level urban vegetation and greenspace and pollution levels. This reflects the growing recognition that the health benefits from reduced air pollution are likely to be significant, but the current lack of defensible estimates of the potential contribution of investments in integrated water management to reducing air pollution. Similar considerations apply to the UHI effect (pathway 3). However, given the broad nature of such research and its potential benefits, it may be more appropriate for the water industry to support and stay abreast of such research, rather than be the primary initiator.

In relation to health benefits stemming from more active and passive recreation (health pathways 1 and 2), arguably the weakest links in the chain relate to how much incremental active and passive recreation can be attributed to specific types of improved liveable environments (whereas the links between increased active and passive recreation and improved health outcomes are relatively well documented). This suggests the industry could support further research in this area. It could also be useful to undertake surveys of users of past investments in integrated water management which have led to improved greenspace and to share the results of ex post project assessments across the industry.

There would also appear to be a need for internal capacity building in economic evaluation across the urban water sector to support high quality, industry led investment appraisal. We note that the Cooperative Research Centre for Water Sensitive Cities (CRCWSC) is undertaking work in this area.

9.3 Beyond quantification

Even where health-related benefits are not or cannot be quantified, the analysis in this report identifies a number of learnings about how to design IWCM projects in order to maximise health-related benefits from IWCM projects, including:

- Ensuring greenspace is accessible, safe, etc. for active and passive recreation
- Facilitating greenspace which provides connectivity and active transport
- Prioritising greenspace in areas currently not well served by greenspace

It is also important to recognise that quantification of liveability-related health benefits attributable to IWCM investments does not equate to funding for those investments.

In some cases, IWCM projects will be viable regardless of the extent of any liveability-related health benefits (e.g. where there are significant avoidable costs to the business resulting from the investment).

While these benefits may present opportunities to generate additional funding to offset that required from the water business (and ultimately its customers), such projects will not be dependent on securing such funding. Nevertheless, quantifying the health benefits may be useful in shoring up the business case.

Seeking funding in recognition of the health benefits attributable to IWCM projects requires first identifying the beneficiaries and then engaging with them about potential co-funding arrangements.

Given the nature of the health benefits identified in this report, a case could be made that some IWCM projects should receive funding from health budgets as they can lead to avoided costs in the healthcare system as well as better health outcomes in the community.

As IWCM projects would then effectively be competing with other health interventions, they need to be presented using similar benchmarks. In this regard, VSLY saved would be very much an upper bound.

Claims for co-funding to support are likely to be stronger where the link from the IWCM project to the consequent health benefits relies on relationships where the evidence base is the strongest. There is also a case for focusing on IWCM projects where the funding gap is not large.

GLOSSARY

Attributable burden - The disease burden attributed to a particular risk factor. It is the reduction in burden that would have occurred if exposure to the risk factor had been avoided or had it been reduced to its theoretical minimum risk exposure distribution.

Base case - This can be either the ‘do-nothing’ option or the provision of services using the ‘traditional’ method.

Cost-Benefit Analysis - Assesses the net impact on society from a project by accounting for the costs and benefits (both internal and external) of providing the service.

Disability-adjusted life years (DALY) - A year of healthy life lost, either through premature death or equivalently through living with disability due to illness or injury.

Integrated Water Cycled Management (IWCM) - A process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.'

Population attributable fraction (PAF) - For a particular risk factor and causally linked disease or injury, the percentage reduction in burden that would occur for a population if exposure to the risk factor were avoided or reduced to its theoretical minimum.

Productivity Adjusted Life Year (PALY) – The result of multiplying a productivity index to a year of life to reflect lost productivity due to disease.

Relative Risk (RR) - The risk of an event relative to exposure, calculated as the ratio of the probability of the event’s occurring in the exposed group to the probability of its occurring in the non-exposed group. A relative risk of 1 implies no difference in risk; RR<1 implies the event is less likely to occur in the exposed group; and RR>1 implies the event is more likely to occur in the exposed group.

Risk factor - Any factor that causes or increases the likelihood of a health disorder or other unwanted condition or event.

Socioeconomic Status (SES) – A composite indicator of people’s level of access to material and social resources, or their social and economic position within society.

Urban heat island (UHI) - The differences in observed ambient temperatures between urban areas and surrounding non-urban areas, caused by the increase in heat-retaining impervious surfaces arising from increased urbanisation.

Value of statistical life (VSL) - The value of a statistical life is an estimate of the financial value society places on reducing the average number of deaths by one. A related concept is the value of a statistical life year, which estimates the value society places on reducing the risk of premature death, expressed in terms of saving a statistical life year.

Willingness to Pay (WTP) – Usually applied to non-market, intangible goods; a measure of the amount consumers would be willing to pay for a good, service, or intangible value (for example an extra year of healthy life)

Years of life lost (YLL) - A measure of years of life lost due to premature mortality.

A SUMMARY OF LITERATURE REVIEW

This appendix summarises the findings of our literature review across the key relationships:

- Identifying the relationship between more amenable and accessible greenspace, waterways and natural environments and health risk factors;
- Identifying the relationship between health risk factors and improved health outcomes; and
- Identifying the relationship between improved health outcomes and improved economic outcomes.

Literature review methodology

In developing our literature review we have relied on services such as the PUBMED search engine, which accesses MEDLINE databases of life sciences and biomedical topics, focusing on the key relationships discussed above, including:

- *Broad epidemiological studies* (relationship between risk factors and health outcomes) and also the epidemiological data within the full health economics studies of disease burden.
- *Improvement in health risk factors* have flow-on effects through *reducing* mortality and morbidity associated with a range of diseases (health outcome measures include DALY, YLL, YLD etc.
  - Relationship between *greenspaces* and improved *final* health outcomes, given risk mitigation.
  - Relationship between *greenspace*, risk factors and *final* health outcomes: Where *multiple risk factors are assessed in the one study.*
- *Reduced* disease burden and associated costs and utilisation arising from active and passive *recreation* (physical exercise and mental health conditions); *reduced* heat island effect and i*mproved* air quality.
  - A key focus is *reduced* disease burden and costs associated with the changes to the risk factors attributable to *greenspaces* (the key aspect of water investments).
- *General* disease burden information for each area (useful data for modelling in the project- costs utilisation, epidemiology).

This search was supplemented by an analysis of the grey literature.

Table 14: Summary of literature review

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Improved natural environments and active recreation	Investigated the influence of proximity, attractive and size of public open space on walking in Perth.	. Found that access to proximate and large public open space with attractive attributes such as trees, water features and bird life is associated with higher levels of walking. Individuals with 'very good access' to public open space were 2.05 times as likely to use than those with very poor access. Those who used POS were 2.66x as likely to achieve recommended levels of physical activity (30min for 5 days). While accessibility was not significantly associated with achieving overall sufficient levels of activity, those with very good access to attractive and large public open space were 1.24-1.5 times more likely to achieve high levels of walking.	Australia, WA, Perth	Giles-Corti, B., et al. (2005). "Increasing walking: how important is distance to, attractiveness, and size of public open space?" American Journal of Preventive Medicine **28**(2): 169-176.
Physical activity	Improved natural environments and physical activity	Study that mapped urban policy implementation to evidence-based national liveability indicators.	To bring the greatest health benefits, it may be preferable to provide access to fewer but larger higher-quality local public open spaces within closer walking distances of dwellings. To inform policy standards, more research is required on optimal size and distance to public open space, particularly for different population groups (children through to older adults).	Australia	Arundel, J., et al. (2017). "Creating liveable cities in Australia: mapping urban policy implementation and evidence-based national liveability indicators."
Physical activity	Improved natural environments and physical activity	Examined the extent to which neighbourhood greenspace was associated with either walking, or what they call "moderate-to-vigorous-physical-activity (MVPA)" for Australians of ages 45 and up.	There is a marked increase in walking and MVPA amongst middle-to-older-aged adults, for those neighbourhoods with a larger area of greenspace. This again gives credence to the idea that areas with more greenspace are likely to encourage people to exercise more. 6% increase in the odds of weekly walking and 8% increase in the odds of weekly MVPA for 20% increase in the level of neighbourhood greenspace.	Australia	Astell-Burt, T., et al. (2014). "Greenspace is associated with walking and moderate-to-vigorous physical activity (MVPA) in middle-to-older-aged adults: findings from 203 883 Australians in the 45 and Up Study." British Journal of Sports Medicine **48**(5): 404-406.
Physical activity	Improved natural environments and physical activity	Examined prospective relationships of greenspace attributes with adults initiating or maintaining recreational walking.	Found that neighbourhood greenspaces may not assist adults to initiate walking, but their presence and proximity may facilitate them to maintain recreational walking over time. For both perceived and objectively measured attributes, those who had more greenspace in their neighbourhoods were 1.67-1.84 times more likely to maintain their recreational walking over four years, independent of psychosocial attributes.	Australia, SA, Adelaide	Sugiyama, T., et al. (2013). "Initiating and maintaining recreational walking: a longitudinal study on the influence of neighborhood greenspace." Journal of Preventive medicine **57**(3): 178-182.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Improved natural environments and physical activity	Using two different measures of park area, at three buffer distances, the study sought to investigate the ways in which park area and proximity to parks, are related to the frequency of walking (for all purposes) in Australian adults.	No statistically significant associations were found between walking frequency and park area (total and large parks) within 400 m of respondent's homes. For total park area within 800 m, the odds of walking at least weekly were lower for those in the mid (OR 0.65, 95% CI 0.46-0.91) and highest (OR 0.65, 95% CI 0.44-0.95) quartile of park area compared to those living in areas with the least amount of park area. Similar results were observed for total park area in the 1200 m buffers.	Australia, VIC, Melbourne	King, T. L., et al. (2012). "Does parkland influence walking? The relationship between area of parkland and walking trips in Melbourne, Australia." International Journal of Behavioral Nutrition **9**(1): 115.
Physical activity	Improved natural environments and physical activity	This study aimed to investigate relationships between environmental aesthetics, convenience, and walking companions and walking for exercise or recreation and to investigate differences in these relationships by sex and by reported physical and mental health.	Those reporting a moderately aesthetic environment were 16% less likely, and those reporting a low aesthetic environment were 41% less likely to walk for exercise relative to high aesthetic. Similarly – for moderately convenient 16% less likely and low convenience were 36% less likely to walk for exercise.	Australia, NSW	Ball, K., et al. (2001). "Perceived environmental aesthetics and convenience and company are associated with walking for exercise among Australian adults." Preventive Medicine **33**(5): 434-440.
Physical activity	Improved natural environments and physical activity	This report reviews and summarises the general results that can be gleaned from the existing international literature on greenspace relevant to human health and well-being. This report describes a pilot study that examined the influence of park irrigation on park-based physical activity and benefit attainment in urban South Australia.	The largest percentage of high intensity physical activity (about 60%) is associated with linear parks while the largest percentage of low intensity physical activity is associated with community parks (about 40%) and neighbourhood parks (about 23%). There was a statistically significant association between the type of physical activity (cycling vs sport) and the irrigation of urban parks rather than intensity and irrigation. Irrigated parks have the strongest association with social benefits such as spending time with friends (64%), connecting with family (54%), and being around good people (70%). Non-irrigated parks have a strong association with environmental benefits such as enjoying nature (73%).	Australia, SA, Adelaide	Schebella, M., et al. (2012). "The importance of irrigated urban greenspace: health and recreational benefits perspectives." Goyder Institute for Water Research, Technical Report Series(14/2).
Physical activity	Improved natural environments and physical activity	This study sought to examine individual, social environmental, and physical environmental correlates of walking. A cross-sectional survey was conducted among healthy workers and homemakers residing in metropolitan Perth, Western Australia.	Relative to respondents in the bottom quartile of access to public open space, the odds of walking at recommended levels were 47% higher among those in the top quartile.	Australia, WA, Perth	Giles-Corti, B. and R. J. Donovan (2003). "Relative influences of individual, social environmental, and physical environmental correlates of walking." American Journal of Public Healh **93**(9): 1583-1589.
Physical activity	Improved natural environments and physical activity	Review of literature around the relationship between greenspace and physical activity, including the impact of demographics.	Finds that majority of research supports the relationship between parks and open spaces and the facilitation of physical activity. Adults who reside in the highest quartile urban greenspace are more likely to participate in leisure-time physical activity than those living in areas with the lowest quartile of urban greenspace.	Global	Kendal, D., et al. (2016). "Benefits of urban greenspace in the Australian context: A synthesis review for the Clean Air and Urban Landscapes Hub.". Available at: <https://minerva-access.unimelb.edu.au/bitstream/handle/11343/122914/2016-CAUL-Benefits%20of%20Urban%20Green%20Space.pdf?sequence=1>

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Improved natural environments and physical activity	Summarises and synthesizes recent reviews and provides examples of representative studies around the relationship between physical activity and food environments.	Review of related literature and provide the summary that communities that have parks and are considered walkable, are consistently associated with higher levels of physical activity in youths, adults and older adults.	USA	Sallis, J. F. and K. Glanz (2009). "Physical Activity and Food Environments: Solutions to the Obesity Epidemic." The Millbank Quarterly **87**(1): 123-154.
Physical activity	Improved natural environments and physical activity	Examined the association between objectively measured access to greenspace, frequency of greenspace use, physical activity, and the probability of being overweight or obese in the city of Bristol, England.	Living more than 500m away from greenspace meant you were 0.64 times as likely to visit the greenspace once a week relative to less than 100m away. Living more than 2250m away from formal greenspace meant you were 0.76 times as likely to visit greenspace once/week and 0.88 times likely to meet physical activity guidelines relative to less than 830m away. Visiting greenspace less frequently meant you were 0.39 times as likely to achieve physical activity guidelines.	England, Bristol	Coombes, E., et al. (2010). "The relationship of physical activity and overweight to objectively measured greenspace accessibility and use." Social Science & Medicine **70**(6): 816-822.
Physical activity	Improved natural environments and physical activity	Examines the associated of greenspace on overall physical activity levels in a large socially and environmentally heterogeneous population.	The odds of achieving the recommended amount of physical activity was 1.27 (95% CI: 1.13–1.44) for people living in the greenest quintile in England compared to those living in the least green quintile, after controlling for individual and environmental factors. However, it remains unclear whether this is due to increased physical activity typically undertaken in greenspaces or due to increases in other domains of physical activity (e.g. gardening).	England	Mytton, O. T., et al. (2012). "Greenspace and physical activity: An observational study using Health Survey for England data." Health & Place **18**(5): 1034-1041.
Physical activity	Improved natural environments and physical activity	Studied how residents in low-income, minority communities use public, urban neighbourhood parks and how parks contribute to physical activity.	People who lived within 1 mile of the park were 4 times as likely to visit once/week or more and had an average of 38% more exercise sessions/week than those living further away.	USA, Los Angeles	Cohen, D. A., et al. (2007). "Contribution of Public Parks to Physical Activity." American journal of public health **97**(3): 509-514.
Physical activity	Improved natural environments and physical activity	Studied whether park size, number of features in the park, and distance to a park from participants' homes were related to a park being used for physical activity.	While available facilities did have an impact on physical activity, park size and distance to park were found to be statistically insignificant. Parks with a paved trail were 26x more likely to be used for physical activity.	Canada, Ontario	Kaczynski, A. T. and K. A. Henderson (2007). "Environmental Correlates of Physical Activity: A Review of Evidence about Parks and Recreation." Leisure Sciences **29**(4): 315-354.
Physical activity	Improved natural environments and physical activity	Investigated associations between residential measures of greenness and physical activity within a nationally representative sample of Canadians, accounting for demographic factors.	Participants who resided in the highest quartile of greenness, based on a 500 m buffer, were more likely to participate in leisure-time physical activity (adjusted OR=1.34, 95% CI=1.25–1.44) when compared to those in the lowest quartile (based on the Normalised Differentiation Index).	Canada (national survey)	McMorris, O., et al. (2015). "Urban greenness and physical activity in a national survey of Canadians." Environmental Research **137**: 94-100.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Improved natural environments and physical activity	Using a sample of 1305 Danish adults and detailed descriptions of Urban Greenspace (UGS), the study examined the association between UGS and outdoor Physical activity (PA) in general, as well as PA in the nearest UGS.	No association between outdoor PA in general, size of, distance to, and number of features in the nearest UGS was found. The amount and number of UGS within 1 km revealed no association either. For PA in the nearest UGS positive associations with size, walking/cycling routes, wooded areas, water features, lights, pleasant views, bike rack, and parking lot were found.	Denmark	Schipperijn, J., et al. (2013). "Associations between physical activity and characteristics of urban greenspace." Urban Forestry & Urban Greening **12**(1): 109-116.
Physical activity	Improved natural environments and physical activity	This national study examines the relationship between travel time access to parks and beaches, BMI and physical activity in New Zealand neighbourhoods.	Neighbourhood access to parks was not associated with BMI, sedentary behaviour or physical activity, after controlling for individual-level socioeconomic variables, and neighbourhood-level deprivation and urban/rural status.	New Zealand	Witten, K., et al. (2008). "Neighbourhood access to open spaces and the physical activity of residents: A national study." Preventive Medicine **47**(3): 299-303..
Physical activity	Improved natural environments and physical activity	This study examined relationships between greenness exposure and free-living physical activity behaviour of children in smart growth and conventionally designed communities.	Momentary greenness exposure was positively associated with moderate to vigorous physical activity (MVPA). This association was stronger for 'smart growth' (mixed use) residents who were 1.39x more likely to do MVPA for a 10th to 90th percentile increase in exposure to greenness. Children who experienced >20 min of daily exposure to greener spaces engaged in nearly 5 times the daily rate of MVPA of children with nearly zero daily exposure.	USA, California	Almanza, E., et al. (2012). "A study of community design, greenness, and physical activity in children using satellite, GPS and accelerometer data." Health & Place **18**(1): 46-54.
Physical activity	Improved natural environments and physical activity	This study analysed data collected in the LARES study (Large Analysis and Review of European Housing and Health Status), which was done in 2002-3 in eight European countries to determine relationships between physical environments and health and well-being.	Greenery was divided into 5 different quintiles (no further info provided), and for individuals whose residential environment contained highest levels of greenery, the likelihood of being physically active was 3.32 times and being obese was 0.63 times relative to individuals whose residential environment contained the lowest levels of greenery.	Angers (France), Bonn (Germany), Bratislava (Slovakia), Budapest (Hungary), Ferreira do Alentejo (Portugal), Forlì (Italy), Geneva (Switzerland), and Vilnius (Lithuania).	Ellaway, A., et al. (2005). "Graffiti, greenery, and obesity in adults: secondary analysis of European cross sectional survey." BMJ **331**(7517): 611.
Physical activity	Improved natural environments and physical activity	This study sought to investigate whether urban greenspace was related to individual-level health outcomes, and whether levels of physical activity were likely to be a mediating factor in any relationships found.	Individuals with the highest access to greenspace (>69.77% of their census area unit) had a 0.84x lower risk of cardiovascular disease, 0.93x risk of obesity and 0.81x risk of poor mental health, and 1.44x more likely to meet physical activity recommendations.	New Zealand	Richardson, E. A., et al. (2013). "Role of physical activity in the relationship between urban greenspace and health." Public Health **127**(4): 318-324.
Physical activity	Improved natural environments and physical activity	The aim of this study was to investigate whether physical activity (in general, and more specifically, walking and cycling during leisure time and for commuting purposes, sports and gardening) is an underlying mechanism in the relationship between the amount of greenspace in people's direct living environment and self-perceived health.	No relationship was found between the amount of greenspace in the living environment and whether or not people meet the Dutch public health recommendations for physical activity, sports and walking for commuting purposes.	Netherlands	Maas, J., et al. (2008). "Physical activity as a possible mechanism behind the relationship between greenspace and health: A multilevel analysis." BMC Public Health **8**(1): 206.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Improved natural environments and physical activity	Examined whether residing in neighbourhoods with higher levels of greenness was associated with higher levels of outdoor physical activity among pre-schoolers. In addition, we also explored whether outdoor playing behaviours (e.g., active vs. quiet) were influenced by levels of neighbourhood greenness independent of demographic and parental support factors.	Higher levels of neighbourhood greenness as measured by the Normalized Difference Vegetation Index (NDVI) was associated with higher levels of outdoor playing time among preschool-aged children in our sample. Specifically, a one unit increase in neighbourhood greenness increased a child's outdoor playing time by approximately 3 minutes.	USA, Chicago, Illinois	Grigsby-Toussaint, D. S., et al. (2011). "Where they live, how they play: Neighborhood greenness and outdoor physical activity among preschoolers." International Journal of Health Geographics **10**(1): 66.
Physical activity	Improved natural environments and physical activity	This study aims to explore the role of neighbourhood greenspace in determining levels of participation in physical activity among elderly men with different levels of lower extremity physical function.	Living in a neighbourhood with more greenspace (using NDVI z-score) remained significantly associated with regular participation in physical activity (1.21x) – i.e. 21% increase in the odds of physical participation for 1SD (12%) in amount of greenspace.	Wales, UK	Gong, Y., et al. (2014). "Neighbourhood greenspace, physical function and participation in physical activities among elderly men: the Caerphilly Prospective study." International Journal of Behavioral Nutrition and Physical Activity **11**(1): 40.
Physical activity	Improved natural environments and physical activity	This study investigated whether residential availability of natural outdoor environments (NOE) was associated with contact with NOE, overall physical activity and physical activity in NOE, in four different European cities using objective measures.	Participants spent around 40 min in NOE and 80 min doing overall physical activity daily, of which 11% was in NOE. Having residential NOE availability was consistently linked with higher NOE contact during weekdays, but not to overall PA. Note whilst odds ratios were statistically significant for some buffer zones e.g. 300m, when changed to 150m/1km significance was lost.	Spain, UK, Netherlands, Lithuania	Triguero-Mas, M., et al. (2017). "Living Close to Natural Outdoor Environments in Four European Cities: Adults' Contact with the Environments and Physical Activity." International Journal of Environmental Research and Public Health **14**(10).
Physical activity	Improved natural environments and physical activity	Conducted studies to examine the correlation between urban greenspaces and physical activity.	Urban greenspaces positively associated with physical activity. Three out of three studies supported physical activities programs and change in environment to increase use of greenspace and physical activity.	Global	Hunter, R. F., et al. (2015). "The impact of interventions to promote physical activity in urban greenspace: A systematic review and recommendations for future research." Social Science & Medicine **124**: 246-256.
Physical activity	Improved natural environments and physical activity	Systematically reviewed the effectiveness of interventions to encourage physical activity.	Effective interventions included 'point of decision' prompts to encourage stair use, community wide campaigns, school-based physical education, social support in community settings, individually-adapted health behaviour change, creation of or enhanced access to places for physical activity.	United States	Kahn, E. B., et al. (2002). "The effectiveness of interventions to increase physical activity: A systematic review." American Journal of Preventive Medicine **22**(4, Supplement 1): 73-107.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Physical activity and health outcomes	Investigated the health impact of physical inactivity in Australia as a risk factor for disease.	In 2011, population sedentary rate was 31%; 49% of population undertook low levels of activity; 11% achieved high levels of activity. Physical inactivity was responsible for 2.6% of the total burden of disease and injuries in Australia (116,676 DALYs excluding obesity).	Australia	The Australian Institute of Health and Welfare (2017). Impact of Physical Inactivity as a risk factor for chronic conditions. Australian Burden of Disease Study Series no. 15. Canberra, The Australian Institute of Health and Welfare. Available at <https://www.aihw.gov.au/getmedia/df392a65-8cf3-4c09-a494-4498ede2c662/aihw-bod-16.pdf.aspx?inline=true>
Physical activity Exposure to greenspace	Physical activity and health outcomes Exposure to greenspace and mental health outcomes	Examined associations of perceived neighbourhood ‘‘greenness’’ with perceived physical and mental health and to investigate whether walking and social factors account for the relationships.	High perceived greenness meant individuals were 1.27-1.41 times as likely to have better physical health, but relationship became insignificant when walking was included.	Australia, SA, Adelaide	Sugiyama, T., et al. (2008). "Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships?" Journal of Epidemiology and Community Health **62**(5): e9.
Physical activity	Physical activity and health outcomes	Multilevel linear and multinomial logit regression models were fitted to investigate association between body mass index and an objective measure of greenspace in a sample of 246, 920 Australian adults aged 45 years and older (The 45 and Up Study).	Women with over 80% proximity to greenspace had relative risk ratios of 0.90 (95% confidence interval: 0.83, 0.97) for overweight and 0.83 (0.74, 0.94) for obese. No similarly protective association was found for men.	Australia	Astell-Burt, T., et al. (2013). "Greener neighborhoods, slimmer people? Evidence from 246 920 Australians." International Journal Of Obesity **38**: 156.
Physical activity Exposureto greenspace	Physical activity and health outcomes Exposure to greenspace and mental health outcomes	Reviewed evidence around the relationship between health and urban greenspace.	Most studies reported findings that generally supported the view that greenspace have a beneficial health effect. There is weak evidence for the links between physical, mental health and well-being, and urban greenspace. Environmental factors (e.g. quality and accessibility of greenspace) and demographics affects its use for physical activity. However, many studies were limited by poor study design, failure to exclude confounding, bias or reverse causality and weak statistical associations.	USA, UK, Netherlands, Canada, Japan, New Zealand and Australia	Lee, A. C. K. and R. Maheswaran (2011). "The health benefits of urban greenspaces: a review of the evidence." Journal of Public Health **33**(2): 212-222.
Physical activity	Physical activity and health outcomes	Empirical examination of the relationship between health and the amount of greenspace in their living environment, using number of symptoms and health indexes as measures of health.	Demonstrates consistent benefits of green and bluespace on health, even when controlling for socioeconomic variables. Presence of greenspace and bluespace reduced prevalence of symptoms by 0.015% and 0.021% respectively.	Netherlands	de Vries, S., et al. (2003). "Natural Environments—Healthy Environments? An Exploratory Analysis of the Relationship between Greenspace and Health." Environment and Planning A: Economy and Space **35**(10): 1717-1731.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Physical activity and health outcomes	This study examines the association between objectively measured access to greenspace, frequency of greenspace use, physical activity, and the probability of being overweight or obese in the city of Bristol, England.	Being located >2250m from formal greenspace increased odds of being overweight/obese by 1.27x – but was not stat sig. for any other types of greenspace. However adjusted results did not show statistically significant associations between greenspace and obesity.	England, Bristol	Coombes, E., et al. (2010). "The relationship of physical activity and overweight to objectively measured greenspace accessibility and use." Social Science & Medicine **70**(6): 816-822.
Physical activity	Physical activity and health outcomes	Meta-analysis of studies assessing the relationship between leisure time physical activity and Metabolic Syndrome (>=3/5 abdominal (central) obesity, elevated fasting plasma glucose, elevated blood pressure, high serum triglycerides, and low high-density lipoprotein (HDL) levels).	Found a negative linear associated between leisure time and incidence of metabolic syndrome. Compared to inactivity, compliance with the basic guideline-recommended level of 150 minutes of moderate physical activity per week reduced the risk by 10%. Further reductions were possible with further increased physical activity.	Global Metastudy	Zhang, D., et al. (2017). "Leisure-time physical activity and incident metabolic syndrome: a systematic review and dose-response meta-analysis of cohort studies." Metabolism **75**: 36-44.
Physical activity	Physical activity and health outcomes	Estimated the breast cancer risk associated with high versus low levels of moderate vigorous recreational activity.	Pooled relative risks for women with higher versus lower levels of moderate-vigorous recreational activity were RR=0.80 (0.74-0.87) and RR=0.79 (0.74-0.84) for premenopausal (43 studies) and postmenopausal (58 studies) breast cancer, respectively, with high heterogeneity. Inverse associations were weaker among postmenopausal cohort studies (RR=0.90 [0.85-0.95]) and studies that statistically adjusted for nonrecreational (e.g., occupational, household) activity (RR=0.91 [0.77-1.06] premenopausal, RR=0.96 [0.86-1.08] postmenopausal).	Global	Neilson, H. K., et al. (2017). "Moderate-vigorous recreational physical activity and breast cancer risk, stratified by menopause status: a systematic review and meta-analysis." Menopause **24**(3): 322-344.
Physical activity	Physical activity and health outcomes	Investigated the relationship between physical activity and risk of cardio vascular disease and type 2 diabetes by reviewing 36 studies.	An increase from being inactive to achieving recommended PA levels (150 minutes of moderate-intensity aerobic activity per week) was associated with lower risk of CVD mortality by 23%, CVD incidence by 17%, and T2DM incidence by 26%.	Europe, USA, China,	Wahid, A., et al. "Quantifying the Association Between Physical Activity and Cardiovascular Disease and Diabetes: A Systematic Review and Meta-Analysis." Journal of the American Heart Association **5**(9): e002495.
Physical activity	Physical activity and health outcomes	Investigated the relationship between physical activity and cardio vascular disease by reviewing 21 studies (and a sample size of more than 650,000 adults).	Among men, RR of overall CVD in the group with the high level of leisure time PA was 0.76 (95% CI 0.70–0.82, $p < 0.001$), compared to the reference group with low leisure time PA, with obvious dose-response relationship. A similar effect was observed among women (RR = 0.73, 95% CI 0.68–0.78, $p < 0.001$).	UK, USA, Finland, Sweden, Canada, Israel and Norway	Li, J. and J. Siegrist (2012). "Physical Activity and Risk of Cardiovascular Disease—A Meta-Analysis of Prospective Cohort Studies." International Journal of Environmental Research and Public Health **9**(2).

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Physical activity and health outcomes	Investigated the relationship between physical activity and cardio vascular disease.	Compared to those with low physical activity, moderate amounts or intensity of physical activity had 20% to 25% reduced risk of CHD and those with high amounts or intensity had 30% to 35% risk reductions.	USA, Finland, UK, Germany, Sweden, Norway, Canada and China	Shiroma, E. J. and I. M. Lee (2010). "Physical activity and cardiovascular health: lessons learned from epidemiological studies across age, gender, and race/ethnicity." Circulation **122**(7): 743-752.
Physical activity	Physical activity and health outcomes	Considers evidence regarding the association between physical activity and breast cancer risk from 73 studies conducted around the world. ,	40% of studies reviewed found statistically significant risk reduction for breast cancer when comparing highest vs lowest level of PA, 11% had borderline results. Across all studies there was a 25% average risk reduction, with a stronger effect found in the case-control studies (an average risk reduction of 30%) than in the cohort studies (a 20% risk reduction).	Global	Lynch, B. M., et al. (2011). "Physical activity and breast cancer prevention." Recent Results Cancer Res **186**: 13-42.
Physical activity	Physical activity and health outcomes	Examining the correlation between greenspaces and prevalence of diabetes in older people.	Individuals living in greenest neighbourhood quartile had 19% lower hazard of developing diabetes, irrespective of age, sex, BMI, parent's diagnosis of diabetes & socioeconomic status. Incidence of diabetes in least green neighbourhood (20% greenspace) would fall by 10.7%.	United Kingdom	Dalton, A. M., et al. (2016). "Residential neighbourhood greenspace is associated with reduced risk of incident diabetes in older people: a prospective cohort study." BMC Public Health **16**(1): 1171.
Physical activity	Physical activity and health outcomes	Evaluated the frequency of symptoms of depression and anxiety in the population of Sao Paulo, and their association with the report of practice of regular physical activity.	People who do not engage in physical activity were found to be two times more likely to exhibit symptoms of depression and anxiety compared with those who regularly practice physical activity.	Sao Paulo	De Mello, M. T., et al. (2013). "Relationship between physical activity and depression and anxiety symptoms: A population study." Journal of Affective Disorders **149**(1): 241-246.
Physical activity	Physical activity and health outcomes	Summarised the positive correlation between physical activity and the prevention and treatment of depression.	Physical activity (PA) may prevent/treat treatment-resistant depression. Benefits of PA may be explained biologically through the regulation of neurotrophic factors exert brain neuroplastic and metabolic adaptations, oxidative stress and inflammation, telomere length, brain volume and microvascular alterations and neurotransmitter and hormonal mechanisms.	Spain	Pareja-Galeano, H., et al. (2016). "Biological Rationale for Regular Physical Exercise as an Effective Intervention for the Prevention and Treatment of Depressive Disorders." Current Pharmaceutical Design **22**(24): 3764-3775.
Physical activity	Physical activity and health outcomes	Analysed the association between greenspace accessibility and mental health. Estimated global cost of mental health is £1.6 trillion annually.	Incorporating greenspaces into building architecture, healthcare facilities, social care settings, homes and communities will encourage physical activity (PA), which may lead to greater social interaction and wellbeing. Extra weekly use of the natural environment for PA reduces the risk of poor mental health by 6%.	United Kingdom	Barton, J. and M. Rogerson (2017). "The importance of greenspace for mental health." BJPsych. International **14**(4): 79-81.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Physical activity and health outcomes	Investigated the effect of intensive lifestyle intervention of reducing 7% body weight through healthy diets and brisk walking for at least 150min/week on diabetes.	58% decrease in the incidence of diabetes.	USA	Knowler, W. C., et al. (2002). "Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin." The New England journal of medicine **346**(6): 393-403.
Physical activity	Physical activity and health outcomes	Investigated whether prolonged sedentary time is associated with an increase in contracting cardiovascular disease independent of physical exercise.	Each hour increase in sedentary time is associated with a 5% (male) and 4% (female) likelihood of having cardiorespiratory fitness problems independent of physical activity.	Global	Nauman, J., et al. (2016). "Cardiorespiratory fitness, sedentary time, and cardiovascular risk factor clustering." Medicine and science in sports and exercise **48**(4): 1-36.
Physical activity	Physical activity and health outcomes	Estimated the DALYs lost due to physical inactivity in Australia.	In 2017 disability adjusted life years (DALYs) lost due to physical inactivity was estimated to be 116,676 DALYs, based on adjusted population attributable fractions (coronary heart disease accounted for about one-third of the total attributable physical inactivity burden.	Australia	The Australian Institute of Health and Welfare (2017). Impact of Physical Inactivity as a risk factor for chronic conditions. Australian Burden of Disease Study Series no. 15. Canberra, The Australian Institute of Health and Welfare. Available at <https://www.aihw.gov.au/getmedia/df392a65-8cf3-4c09-a494-4498ede2c662/aihw-bod-16.pdf.aspx?inline=true>
Physical activity	Physical activity and health outcomes	Estimates the number of premature deaths preventable via compliance with international exposure recommendations for physical activity.	Increasing physical activity from 77.7 MET minutes/week to 600 MET minutes/week for 18-64 year olds and 36.7 to 450 for >64 year olds prevents 1154 deaths and increases life expectancy by 204 days.	Barcelona	Mueller, N., et al. (2016). "Urban and transport planning related exposures and mortality: a health impact assessment for cities." Environmental Health Perspectives **125**(1): 89-96.
Physical activity	Physical activity and health outcomes	Calculated the impact of physical activity on life expectancy on people over 50 years with and without cardiovascular disease (CVD).	Moderate-high physical activity resulted in 1.3 and 3.7-year increase in life expectancy and 1.1 and 3.2 increase in years lived without CVD for men. For women, the differences were 1.5 and 3.5 years in life expectancy and 1.3 and 3.3 more years lived free to CVD respectively.	United States	Franco, O. H., et al. (2005). "Effects of physical activity on life expectancy with cardiovascular disease." Archives of internal medicine **165**(20): 2355-2360.
Physical activity	Physical activity and health outcomes	Undertook meta-data analysis of impacts that physical activity has on the quality of life of depressed persons Physical activity (PA) improved psychological domains and overall quality of life.	Inconclusive evidence regarding PA and changes to social and environmental domains. PA may treat depression, evidenced by lack of improvement in control group.	Australia, Belgium, Brazil, United Kingdom	Schuch, F. B., et al. (2016). "Exercise improves physical and psychological quality of life in people with depression: A meta-analysis including the evaluation of control group response." Psychiatry research **241**: 47-54.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Physical activity and health outcomes	Undertook statistical analysis of the synergy between greenspace and physical activity, and the impacts on well-being.	Physical activity most strongly and positively associated with mental health (statistically significant at 1% level; estimated coefficient 0.6307) & negatively associated with psychological distress (statistically significant at 10% level, estimated coefficient -0.2447).	Australia, Queensland	Ambrey, C. L. (2016). "Greenspace, physical activity and well-being in Australian capital cities: how does population size moderate the relationship?" Public Health **133**: 38-44.
Physical activity	Physical activity and health outcomes	Outlined the prevalence of sedentary behaviour and physical activity across Australia, as well as outlining barriers to active lifestyles.	Physical inactivity (PI) contributes to more than 5m deaths globally p.a. Increase physical activity lowers risks of colon cancer, diabetes type II, obesity, & CVD. Reducing prevalence of PI in adults may reduce PI-related mortality by 15% per year, DALYs lost by 14%, new cases of physical inactivity-related diseases by 13% per year.	Australia, Victoria	Victorian Health Promotion Foundation (2016). Physical activity and sedentary behaviour Evidence summary. Melbourne, VicHealth. Available at: <https://www.vichealth.vic.gov.au/-/media/ResourceCentre/PublicationsandResources/Physical-activity/2016-Physical-Activity-and-Sedentary-Behaviour.pdf<
Physical activity	Physical activity and health outcomes Health outcomes and economic outcomes	Estimated the physical inactivity risk ratios associated with a variety of diseases.	Direct health-care costs, productivity losses, and disability-adjusted life-years (DALYs) attributable to physical inactivity were estimated with standardised methods and the best data available for 142 countries, representing 93·2% of the world's population.	Global	Ding, D., et al. (2016). "The economic burden of physical inactivity: a global analysis of major non-communicable diseases." The Lancet **388**(10051): 1311-1324.
Physical activity	Health outcomes and economic outcomes	Studies that examined the economic consequences of physical inactivity in a population/population-based sample.	23 studies used a population attributable fraction (PAF) approach with estimated healthcare costs attributable to physical inactivity ranging from 0.3% to 4.6% of national healthcare expenditure; 17 studies used an econometric approach, which tended to yield higher estimates than those using a PAF approach.	Global	Ding, D., et al. (2017). "The economic burden of physical inactivity: a systematic review and critical appraisal." Br J Sports Med **51**(19): 1392-1409.
Physical activity	Health outcomes and economic outcomes	Estimated the potential health status and economic benefits to society following a feasible reduction in the prevalence of six behavioural risk factors: tobacco smoking; inadequate fruit and vegetable consumption; high risk alcohol consumption; high body mass index; physical inactivity; and intimate partner violence.	Over the lifetime of the 2008 Australian adult population, total opportunity cost savings of AUD2,334 million were found if feasible reductions in the risk factors were achieved. There would be 95,000 fewer DALYs, 161,000 less new cases of disease; 6,000 fewer deaths; a reduction of 5 million days in workforce absenteeism; and 529,000 increased days of leisure time.	Australia	Cadilhac, D. A., et al. (2011). "The societal benefits of reducing six behavioural risk factors: an economic modelling study from Australia." BMC Public Health **11**(1): 483.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Health outcomes and economic outcomes	Provided a summary of the health outcomes for the people of Victoria.	People will chronic disease were less likely to participate in the labour force and be employed full time, than those without chronic disease … and also had more time off work due to their own illness. The estimated cost of absenteeism to the Australian economy was $7 billion per year, while the cost of presenteeism (not fully functioning at work because of medical conditions) was nearly four times more, estimated at almost $26 billion in 2005-06. In addition to financial costs, the cost of disability, lost wellbeing and premature death due to chronic disease is high in Victoria.	Victoria, Australia	State of Victoria (2015), Health and Wellbeing Status of Victoria: Victorian public health and wellbeing plan 2015-2019 companion document, p.18.
Physical activity	Health outcomes and economic outcomes	Estimated the cost of obesity (in the form of direct health care costs and losses in productivity as a result of increased mortality and morbidity) in Australia and proposed potential solutions.	PWC estimated that the cost of presenteeism attributable to obesity was $544 million in 2011-12. In particular, the study found labour force productivity losses of between 0.11% and 0.35% arising from diseases associated with physical inactivity.	Australia	Econtech (2007), Economic Modelling of the Cost of Presenteeism in Australia. Prepared for Medibank Private. Available at: <http://blogs.theage.com.au/business/executivestyle/managementline/Medibank_Presenteeism_FINAL%20(2).doc >; Australian Institute of Health and Welfare (2003), The burden of disease and injury in Australia 2003, Cat no. PHE 82, Canberra: AIHW. Available at: <https://www.aihw.gov.au/getmedia/f81b92b3-18a2-4669-aad3-653aa3a9f0f2/bodaiia03.pdf.aspx> Price Waterhouse Coopers (2015), Weighing the cost of obesity: A case for action. Available at: <https://www.pwc.com.au/pdf/weighing-the-cost-of-obesity-final.pdf>
Physical activity	Health outcomes and economic outcomes	Estimated the cost (both direct health care expenditure and losses in productivity) of physical inactivity in Australia.	The cost of physical inactivity to the Australian economy was estimated to be $13.8 billion, with an estimated 16,178 Australians dying prematurely due to physical inactivity and productivity loses due to physical inactivity of 1.8 working days per worker per year. Average labour productivity loss caused by PI costs $458 per employee per year.	Australia	Medibank Private (2008), The cost of Physical Inactivity. Available at: <https://www.medibank.com.au/client/documents/pdfs/the_cost_of_physical_inactivity_08.pdf>
Physical activity	Health outcomes and economic outcomes	Estimated public benefits of avoided health costs of Brimbank,	Estimated public benefits of avoided health costs of a poorly serviced area in terms of quality of open space - $75,049 per annum and potential private benefits of $3.9 million.	Melbourne Australia	Mekala, G. D., et al. (2015). "Valuing the benefits of creek rehabilitation: building a business case for public investments in urban green infrastructure." Environmental management **55**(6): 1354-1365.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Health outcomes and economic outcomes	Estimated annual avoided costs of health care associated with physical activity.	Found that annual avoided costs of health care associated with levels of physical activity in parks across 10 U.S. cities and counties ranges from $4 million to $69.4 million per year.	United States	Cited in: Wolf, K. L. and A. S. T. Robbins (2015). "Metro nature, environmental health, and economic value." Environmental Health Perspectives **123**(5): 390-398..
Physical activity	Health outcomes and economic outcomes	Estimated annual avoided costs of health care associated with physical activity.	Estimated the average cost of physical inactivity to be $757 per physically inactive person per year .	Australia	Dedman R (2011), Greening the West: a public health perspective. Presentation from the Department of Health at the Think Tank for Greening the West project meeting on 18 (2011) City West Water Office. Melbourne, Australia.
Physical activity	Physical activity and health outcomes Health outcomes and economic outcomes	Exploring a method and range of values that could incorporate monetised physical activity related health benefits in CBAs assessing a broad range of built environment initiatives.	They estimated the change in population level of PA attributable to a change in the environment due to the intervention. Then, changes in population levels of PA were translated into monetary values. Improvements in neighbourhood environments conferred estimated annual physical activity related health benefit worth up to $70 per person. Improving neighbourhood walkability was estimated to be worth up to $30 and improvements in sidewalk availability up to $22 per adult resident. Value of physical activity health related benefits of walking and cycling is $0.98 and $0.62 per kilometre respectively.	Australia	Zapata-Diomedi, B., et al. (2018). "A method for the inclusion of physical activity-related health benefits in cost-benefit analysis of built environment initiatives." Preventive Medicine **106**: 224-230.
Physical activity	Health outcomes and economic outcomes	Outlines prevalence of obesity and associated economic costs.	In 2008, ~3.71m Australians are obese, ~290,000 of which are between 5-19 years old. By 2025, ~4.6m Australians will be obese. 197, 729 DALYs associated with obesity, up from 114,633 in 2005. Direct health costs of 3.1% over 2005-2008. Productivity losses cost per case by 12.10%. Financial cost of obesity was $8.283b (2008).	Australia	Access Economics Pty. Ltd. 2008, The growing cost of obesity in 2008: three years on Diabetes Australia, Australia <https://static.diabetesaustralia.com.au/s/fileassets/diabetes-australia/7b855650-e129-4499-a371-c7932f8cc38d.pdf>
Physical activity	Physical activity and health outcomes Health outcomes and economic outcomes	Investigated economic benefits in terms of physical and mental health of changes in the provision of accessible greenspace.	A 1%-unit reduction in the sedentary percentage would save 1,063 lives per year that would otherwise have been lost. A 1%-unit reduction in the sedentary population would reduce morbidity cases by 15,000 per year. Annual value of decreased morbidity and mortality from 1%-unit reduction in percentage of sedentary people in UK was estimated at £1.44b.	United Kingdom	CJC Consulting, Willis. K, & Osman. L 2005, Economic Benefits of Accessible Greenspaces for Physical and Mental Health: Scoping study, Forestry Commission. Available at: <https://www.forestry.gov.uk/pdf/FChealth10-2final.pdf/$FILE/FChealth10-2final.pdf>

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Physical activity	Health outcomes and economic outcomes	Analyses the costs of illness (coronary heart disease, non-insulin dependent diabetes, colon cancer) attributable to physical inactivity.	Physical inactivity (PI) is responsible for 6,4000 deaths from CHD, NIDDM and colon cancer. Annual direct health care costs of PI ~$377m annually Population attributable risks were 18% for CHD, 16% for stroke, 13% for NIDDM, 19% for colon cancer, 10% for depression symptoms.	Australia	Stephenson, J. et al. 2000, The costs of illness attributable to physical inactivity in Australia: A preliminary study, Commonwealth Department of Health and Aged Care and the Australian Sports Commission 2000. Available at: <http://www.health.gov.au/internet/main/publishing.nsf/Content/health-pubhlth-publicat-document-phys_costofillness-cnt.htm/$FILE/phys_costofillness.pdf
Physical activity Exposure to greenspace	Health outcomes and economic outcomes	Investigating the contributions of physical and mental health conditions on workplace productivity.	Health conditions impacted on both presenteeism and absenteeism; drug and alcohol problems and psychological distressed influenced absenteeism more significantly than presenteeism than other health conditions. Mental health conditions contributed more strongly to productivity loss than other investigated health conditions.	Australia	Holden, L., et al. (2011). "Which health conditions impact on productivity in working Australians?" <u>Journal of occupational and environmental medicine</u> **53**(3): 253-257.
Physical activity Exposure to greenspace	Physical activity and health outcomes Exposure to greenspace and mental health outcomes	Investigated and summarised the physical and psychological impacts associated with access to greenspace.	Having 10% more greenspace within 1km radius than average was protective of particular diseases (chronic heart disease, URT infection, asthma, chronic obstructive pulmonary disease, migraines, acute UTI and diabetes mellitus (Mass et al. (2009)).	Australia, Melbourne	Kendal, D., et al. (2016). "Benefits of urban greenspace in the Australian context: A synthesis review for the Clean Air and Urban Landscapes Hub.". Available at: <https://minerva-access.unimelb.edu.au/bitstream/handle/11343/122914/2016-CAUL-Benefits%20of%20Urban%20Green%20Space.pdf?sequence=1>
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Investigated and summarised the physical and psychological impacts associated with access to greenspace.	Greenspaces may influence mental health due to reduced exposure to 'urban stressors' (e.g. noise). Subsequent mental health impacts include increased capacity to deal with life (Hartig (2014)), concentration (Bratman (2012)), childhood developmental behaviours (Barton & Pretty (2005)) and reduced negative behaviours like aggression, poor self-esteem and mood sensitivity.	Australia, Melbourne	Kendal, D., et al. (2016). "Benefits of urban greenspace in the Australian context: A synthesis review for the Clean Air and Urban Landscapes Hub.". Available at: <https://minerva-access.unimelb.edu.au/bitstream/handle/11343/122914/2016-CAUL-Benefits%20of%20Urban%20Green%20Space.pdf?sequence=1>
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Used the nature dose framework to examine the associations between the duration, frequency and intensity of exposure to nature and health in the urban community.	Longer visits to greenspaces associated with lower depression rates and higher blood pressure. More frequent visits associated with greater social cohesion. Visits to outdoor greenspaces of 30+ minutes may reduce population prevalence of depression by 7% and high blood pressure by 9%.	Australia	Shanahan, D. F., et al. (2016). "Health benefits from nature experiences depend on dose." <u>Scientific reports</u> **6**: 28551.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Investigated the association between the presence, amount and attributes of public greenspace in new greenfield neighbourhood developments and the mental health of local residents (n = 492).	Every park within 1.6km increased mental health scores by 0.11, with varying effects for different types of parks. Every hectare within 1.6km^2 increased scores by 0.07, and greater access to park facilities for recreation/sport/nature also improved scores.	Australia, WA, Perth	Wood, L., et al. (2017). "Public greenspaces and positive mental health–investigating the relationship between access, quantity and types of parks and mental wellbeing." Health & Place **48**: 63-71.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Examined associations of perceived neighbourhood ‘‘greenness’’ with perceived physical and mental health and to investigate whether walking and social factors account for the relationships.	High perceived greenness meant individuals were 1.44-1.93 times as likely to have better mental health, still significant when accounted for by walking and social coherence.	Australia, SA, Adelaide	Sugiyama, T., et al. (2008). "Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships?" Journal of Epidemiology and Community Health **62**(5): e9..
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Investigated whether psychological benefits of physical activity are amplified in participation occurs within greener environments, focusing on adults in middle-to-older age.	In comparison to residents of the least green areas, those in the greenest neighbourhoods were at a lower risk of psychological distress (OR 0.83) and were less sedentary (OR 0.81). More greenspace did not appear to benefit mental health among the least-active (0.99: 0.85, 1.15), but there was a protective association for the more physically active (0.82: 0.67, 0.99).	NSW – Active Australia Survey	Astell-Burt, T., et al. (2013). "Mental health benefits of neighbourhood greenspace are stronger among physically active adults in middle-to-older age: evidence from 260,061 Australians." Preventive Medicine **57**(5): 601-606.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Investigated the relationship between nature and human cognitive function and mental health. .	Found there are health benefits from merely being in contact with greenspace, including increases in memory, attention, concentration, impulse inhibition and mood.	Global	Bratman, G. N., et al. (2012). "The impacts of nature experience on human cognitive function and mental health." Annals of the New York Academy of Sciences **1249**(1): 118-136.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Investigated the relationship between greenspace and mental illness.	A number of studies on mental health have found increased greenness to be associated with lower likelihood of psychological distress and other mental health outcomes and have begun identifying potential mediators such as physical activity, stress, and social cohesion, primarily in cross-sectional studies. The vast majority of studies, however, are cross-sectional, limiting the extent to which the often protective effect of greenness can be construed as causal.	USA, UK, France, Australia, Netherlands, New Zealand, Spain, Denmark, Canada, Sweden Israel, Germany	James, P., et al. (2015). "A review of the health benefits of greenness." Current epidemiology reports **2**(2): 131-142.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Exposure to greenspace	Exposure to greenspace and mental health outcomes	A cross-sectional examination of the relationship between access to urban greenspaces and counts of anxiety/mood disorder treatments amongst residents (aged 15 years and over) in Auckland City, New Zealand.	Every 1% increase in the proportion of useable or total greenspace was associated with a 4% lower anxiety/mood disorder treatment. 3% lower anxiety/mood disorder treatment for every 100 m decrease in distance to the nearest useable greenspace.	New Zealand, Auckland	Nutsford, D., et al. (2013). "An ecological study investigating the association between access to urban greenspace and mental health." Public Health **127**(11): 1005-1011.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	A cross-sectional study investigated whether group walks in specific types of natural environments were associated with greater psychological and emotional well-being compared to group walks in urban environments.	Walking participants who frequently attended in green corridor spaces (-2.81) recorded significantly lower stress scores than those who walked in urban space.	England	Marselle, M. R., et al. (2013). "Walking for well-being: are group walks in certain types of natural environments better for well-being than group walks in urban environments?" International Journal of Environmental Research and Public Health **10**(11): 5603-5628.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Reviewed the available literature on the long-term mental health benefits of residential green and bluespaces by including 28 studies that used standardized tools or objective measures of both the exposures and the outcomes of interest.	Found limited evidence for a causal relationship between surrounding greenness and mental health in adults, whereas the evidence was inadequate in children. The evidence was also inadequate for the other exposures evaluated (access to greenspaces, quality of greenspaces, and bluespaces) in both adults and children.	Spain, Lithuania, UK, Chile, Australia, USA, New Zealand, Germany	Gascon, M., et al. (2015). "Mental health benefits of long-term exposure to residential green and bluespaces: a systematic review." International Journal of Environmental Research and Public Health **12**(4): 4354-4379.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	A systematic review of the literature was done to examine the association between access to greenspace and the mental well-being of children.	Access to greenspace was associated with improved mental well-being, overall health and cognitive development of children. It promotes attention restoration, memory, competence, supportive social groups, self-discipline, moderates stress, improves behaviours and symptoms of ADHD and was even associated with higher standardized test scores.	Scotland, Spain, USA,	McCormick, R. (2017). "Does Access to Greenspace Impact the Mental Well-being of Children: A Systematic Review." Journal of pediatric nursing **37**: 3-7.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Explored the associations between time spent in greenspaces by purposeful visits and perceived mental health and vitality in four different European cities, and to what extent gender, age, level of education, attitude towards nature and childhood nature experience moderate these associations.	Every hour per month spent visiting greenspaces improved mental health by 0.03 and vitality by 0.04. (for pooled data from 4 cities).	Nested CS study – across Spain, UK, Netherlands Lithuania	Van den Berg, M., et al. (2016). "Visiting greenspace is associated with mental health and vitality: A cross-sectional study in four European cities." Health & Place **38**: 8-15.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	This study investigated the impact of nature experience on affect and cognition, by randomly assigning sixty participants to a 50-min walk in either a natural or an urban environment in and around Stanford, California	The nature walk decreased anxiety, rumination, and negative effect, and maintained positive effect.	USA, California	Bratman, G. N., et al. (2015). "The benefits of nature experience: Improved affect and cognition." Landscape and Urban Planning **138**: 41-50.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Exposure to greenspace	Exposure to greenspace and mental health outcomes	This study aimed to explore whether walking in nature may be beneficial for individuals with major depressive disorder (MDD).	Working-memory capacity and positive affect improved to a greater extent after the nature walk relative to the urban walk. Interestingly, these effects were not correlated, suggesting separable mechanisms.	USA, Michigan	Berman, M. G., et al. (2012). "Interacting with nature improves cognition and affect for individuals with depression." Journal of Affective Disorders **140**(3): 300-305.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Explored the association between greenspace and depression in a deprived, multiethnic sample of pregnant women, and examined moderating and mediating variables.	Within the 100 m green buffer zone, after adjustment, those in the greener quintiles (quintiles 3, 4 and 5) were 18–23% less likely to report depressive symptoms than those in the least green quintile areas. After adjustment, those who were within 300 m of a major greenspace were 13% less likely to report depressive symptoms.	UK, Bradford	McEachan, R. R. C., et al. (2016). "The association between greenspace and depressive symptoms in pregnant women: moderating roles of socioeconomic status and physical activity." Journal of Epidemiology and Community Health **70**(3): 253.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Investigated the relationship between greenspace and health outcomes.	While the associated between greenspaces and health is positive, the results remain inconclusive; impacted by socioeconomic confounders.	Global	Kabisch, N., et al. (2017). "The health benefits of nature-based solutions to urbanization challenges for children and the elderly–A systematic review." Environmental Research **159**: 362-373.
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Investigated the improvements in mental health associated with greater use of parks and greenspace.	Total Economic Value of greenspaces to an individual is £30.24 per year (includes personal use and non-use benefits such a as the value attributed to the preservation of greenspaces for future generations). Lower socioeconomic groups and BAME groups ascribe a higher value to parks and greenspaces than the average.	UK	Fields in Trust 2018, Revaluing Parks and Greenspaces: Measuring their economic and wellbeing value to individuals Greenspaces for Good, Fields in Trust. Available at: <http://www.fieldsintrust.org/Upload/file/research/Revaluing-Parks-and-Green-Spaces-Report.pdf>
Exposure to greenspace	Exposure to greenspace and mental health outcomes	Analysed the association between greenspaces and population health in the context of greenspace density, bird species richness and water quality.	Positive association between good health and the density of greenspace types (broadleaf woodland, arable and horticulture, improved grassland, saltwater and coastal). Bird species richness was associated with good health prevalence; poorer surface water quality associated with better population health.	United Kingdom	Wheeler, B. W., et al. (2015). "Beyond greenspace: an ecological study of population general health and indicators of natural environment type and quality." International Journal of Health Geographics **14**(1): 17.
Mental health	Heath outcomes and economic outcomes	Details the costs associated with high prevalence mental disorders such as depression, anxiety and substance use.	Total annual healthcare cost estimated to be $974m. Total annual productivity loss estimated to be $11.8b. Average annual treatment cost is A$660 (public), A$195 (individual), A$1058 (private) and A$845 (health sector).	Australia	Lee, Y.-C., et al. (2017). "Cost of high prevalence mental disorders: findings from the 2007 Australian National Survey of mental health and wellbeing." Australian & New Zealand Journal of Psychiatry **51**(12): 1198-1211.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
UHI effect	Improved natural environments and UHI effect	Overview of the urban heat island effect	The magnitude of the urban heat island effect can vary across time and space as a result of meteorological, locational and urban characteristics.	Global	Gill, S. E., et al. (2007). "Adapting cities for climate change: the role of the green infrastructure." Built environment **33**(1): 115-133.
UHI effect	Improved natural environments and UHI effect	The study modelled the potential benefit of vegetation in reducing extreme summer temperatures in Melbourne CBD under different climate scenarios.	Suburban areas are predicted to be around 0.5°C cooler than the CBD, while a relatively leafy suburban area may be around 0.7°C cooler than the CBD. A parkland (such as grassland, shrub-land and sparse forest) or rural area may be around 1.5 to 2°C cooler than the CBD. Doubling the CBD vegetation coverage may reduce 0.3°C ASDM temperature.	Australia, VIC, Melbourne	NGIA (2012). Mitigating Extreme Summer Temperatures with Vegetation, Nursery Papers 5, Nursery and Garden Industry Australia. Available at: <https://www.ngia.com.au/Attachment?Action=Download&Attachment_id=1451>
UHI effect	Improved natural environments and UHI effect	This study examines the relationship between Sydney's urban surface temperature and vegetation cover as defined by two vegetation indices; mixed vegetation cover and tree cover exclusively. The shape of this relationship and relative influence of confounding factors are explored using penalised-likelihood criteria ranked regressions.	Found that overall, increasing tree cover reduces average surface temperatures more dramatically than mixed vegetation cover. In a combined model of vegetation and other environmental factors, increase in 1 foliage projection cover (% of area covered by trees) decreases LST by 0.113OC.	Australia, NSW, Sydney	Adams, M. P. and P. L. Smith (2014). "A systematic approach to model the influence of the type and density of vegetation cover on urban heat using remote sensing." Landscape and Urban Planning **132**: 47-54.
UHI effect	Improved natural environments and UHI effect	Investigated the impact of water sensitive urban design on temperature (i.e. human thermal comfort).	Research found trees can lower the Urban Thermal Climate Index by up to 10 °C reducing heat stress from 'very strong' to 'strong'.	Australia	CRCWSC (2016), Impacts of Water Sensitive Urban Design Solutions on Human Thermal Comfort, <https://watersensitivecities.org.au/wp-content/uploads/2016/07/TMR_B3-1_WSUD_thermal_comfort_no2.pdf>
UHI effect	Improved natural environments and UHI effect	Evaluates the positive effects of vegetation with a multi-scale approach: an urban and a building scale.	The study monitored the urban heat island in four areas of New York City and found an average of 2 °C difference of temperatures between the most and the least vegetated areas, ascribable to the substitution of vegetation with man-made building materials.	United States, New York City	Susca, T., et al. (2011). "Positive effects of vegetation: Urban heat island and green roofs." Environmental pollution **159**(8-9): 2119-2126.
UHI effect	Improved natural environments and UHI effect	Meta-analysis of more than 30 studies examining the effect of greenspaces on temperature.	The average temperature reduction in the day was 0.94 ◦C between the urban temperature and the park temperature.	Spain, Italy, Mexico, Japan, Taiwan, Singapore, Sweden, Botswana, USA, Germany, Israel, Russia, Canada, UK and Greece	Bowler, D. E., et al. (2010). "Urban greening to cool towns and cities: A systematic review of the empirical evidence." Landscape and Urban Planning **97**(3): 147-155..

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
UHI effect	Improved natural environments and UHI effect	This study analyses the thermal performance of a small greenspace (0.24 ha) and its influence in the surrounding atmospheric environment of a densely urbanised area in Lisbon.	Park cool island (PCI) effect was a median 1.5OC difference between the surrounding atmospheric environment and the garden (ranging from 1 - 2.6OC).	Portugal, Lisbon	Oliveira, S., et al. (2011). "The cooling effect of greenspaces as a contribution to the mitigation of urban heat: A case study in Lisbon." Building and Environment **46**(11): 2186-2194.
UHI effect	Improved natural environments and UHI effect	A systematic review of 27 studies quantifying the temperature-mitigating effects of urban blue compared to other urban sites. The studies included in the review measured air temperatures at various types of urban bluespace such as ponds, lakes or rivers and compared them with reference sites at defined distances or to urban reference sites in the same city.	Concluded that the bluespaces studied could provide a cooling effect of 2.5 K on average. Wetlands showed the strongest effect (ΔT=5.2 K, min=4.8 K, max=5.6 K, n=2) and ponds the least (ΔT=1.6 K, min=0.4 K, max=4.7 K, n=6). Rivers showed a ΔT of 2.1 K (min=0.6 K, max=4 K, n=8), the unspecified urban bluespace type “water” 2.5 K (min=0.5 K, max=3.4 K, n=5).	Portugal, Japan, Germany, China, Canada	Voelker, S., et al. (2013). "Evidence for the temperature-mitigating capacity of urban bluespace—a health geographic perspective." Erdkunde: 355-371.
UHI effect	Improved natural environments and UHI effect	The effect of greenspace dynamics on land surface temperature (LST) was investigated in the Beijing metropolis.	When there was green expansion minor decreases in LST were recorded at -1.11°C to -0.67°C. Major increases in LST were recorded in areas of green loss (1.64-2.21°C).	China, Beijing	Sun, R. and L. Chen (2017). "Effects of greenspace dynamics on urban heat islands: Mitigation and diversification." Ecosystem services **23**: 38-46.
UHI effect	Improved natural environments and UHI effect	Explores the significance that green infrastructure can play in adapting urban environments for climate change.	Using the conurbation of Greater Manchester, investigation found that green infrastructure, specifically green rooftops, reduced surface temperature by 6.6 degrees between 1961-1990, making it an effective strategy to keep surface temperatures below the baseline level. Less vegetated surface areas will decrease evaporative cooling, whilst an increase in vegetative surface sealing results in increased surface runoff.	United Kingdom	Gill, S. E., et al. (2007). "Adapting cities for climate change: the role of the green infrastructure." Built environment **33**(1): 115-133.
UHI effect	Improved natural environments and UHI effect	Examines the relationship between Sydney’s urban surface temperature and vegetation cover (as defined by mixed vegetation cover and exclusive tree cover).	Increasing tree covers reduces average surface temperature significantly more than mixed vegetation cover. If an area with no vegetation was to be replaced by a typical parkland, land surface temperature would be reduced by 3.48 degrees C.	Australia , Sydney	Adams, M. P. and P. L. Smith (2014). "A systematic approach to model the influence of the type and density of vegetation cover on urban heat using remote sensing." Landscape and Urban Planning **132**: 47-54.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
UHI effect	Improved natural environments and UHI effect	Investigated and summarised the cooling and air quality implications of greenspaces.	Greenspace on air cooling in urban areas fond that parks are, on average, 0.9 degrees cooler than their surroundings during the day (Bowler et al. (2010)).	Australia, Victoria	Kendal, D., et al. (2016). "Benefits of urban greenspace in the Australian context: A synthesis review for the Clean Air and Urban Landscapes Hub.". Available at: <https://minerva-access.unimelb.edu.au/bitstream/handle/11343/122914/2016-CAUL-Benefits%20of%20Urban%20Green%20Space.pdf?sequence=1>
UHI effect	Improved natural environments and UHI effect	Reviews the effectiveness of urban green cover in reducing surface temperature.	Dark, impervious surfaces can absorb solar energy, causing the temperature of the city to rise as much as 10-20 degrees Celsius higher than surrounding air temperatures. Every 10% increase in tree cover can reduce land surface temperatures by more than 1 degree Celsius. This means that a 14% increase in tree cover would offset this thermal loading effect.	Australia, NSW	NSW Office of Environment and Heritage (2015). Urban Green Cover in NSW: Technical Guidelines, NSW Government. Available at: <https://climatechange.environment.nsw.gov.au/-/media/NARCLim/Files/Section-4-PDFs/Urban-Green-Cover-Technical-Guidelines.pdf?la=en&hash=C7FCADABE417DD2DF67461F067463054D9408E2F>
UHI effect	UHI effect and health outcomes	Reported on the effect of hot weather on persons with acute myocardial infarction (AMI).	Positive association between AMI admission to hospital and age and socioeconomic inequality. Residents from highest or lowest socioeconomic standing more likely to be admitted for AMI; younger people most likely to be admitted.	Australia, Melbourne	Loughnan, M. E., et al. (2010). "The effects of summer temperature, age and socioeconomic circumstance on acute myocardial infarction admissions in Melbourne, Australia." International Journal of Health Geographics **9**(1): 41.
UHI effect	UHI effect and health outcomes	Investigated the risk of cardiovascular hospitalisation in relation to different temperature exposures and examined the dose–response relationship of temperature-cardiovascular hospitalization by change in units of temperature, latitudes, and lag days.	The pooled results suggest that for a change in temperature condition, the risk of cardiovascular hospitalization increased 2.8% for cold exposure, 2.2% for heatwave exposure, and 0.7% for an increase in diurnal temperature. No association was observed for heat exposure. Effects did change when incorporating variation of effect sizes: 7.8% for cold exposure, 1% for heat exposure, 6.1% for heatwave exposure, and 1.5% for an increase in diurnal temperature.	Germany, South Korea, Greece, UK, Taiwan, Australia, China, Portugal, Japan, USA, Vietnam, Mozambique, Czech Republic, Denmark, Thailand, Italy, Lithuania, Slovenia, France and Russia	Phung, D., et al. (2016). "Ambient temperature and risk of cardiovascular hospitalization: An updated systematic review and meta-analysis." Science of The Total Environment **550**: 1084-1102.
UHI effect	UHI effect and health outcomes	Estimates the number of premature deaths preventable via compliance with international exposure recommendations for heat.	Reducing heat by 4 degrees prevents 376 deaths, increasing life expectancy by 34 days.	Barcelona, Spain	Mueller, N., et al. (2016). "Urban and transport planning related exposures and mortality: a health impact assessment for cities." Environmental Health Perspectives **125**(1): 89-96.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
UHI effect	UHI effect and health outcomes	Reviewed the epidemiological evidence on the relationship between ambient temperature and morbidity.	The majority of studies reported a significant relationship between ambient temperature and total or cause-specific morbidities. However, there were some inconsistencies in the direction and magnitude of nonlinear lag effects. The majority of studies reported detrimental effects of heat on the same day or up to the following 3 days.	USA, Canada, Japan, Taiwan, Australia, Greece, Spain, South Korea, UK, Switzerland and Italy	Ye, X., et al. (2011). "Ambient temperature and morbidity: a review of epidemiological evidence." Environmental Health Perspectives **120**(1): 19-28.
UHI effect	UHI effect and health outcomes	Reviewed the literature regarding the relationship between ambient temperature and children's health.	The existing literature indicates that very young children, especially children under one year of age, are particularly vulnerable to heat-related deaths. Hot and cold temperatures mainly affect cases of infectious diseases among children, including gastrointestinal diseases and respiratory diseases. Pediatric allergic diseases, like eczema, are also sensitive to temperature extremes. During heat waves, the incidences of renal disease, fever and electrolyte imbalance among children increase significantly.	Peru, Malta, Japan, Germany, UK, Bangladesh, Burkina Faso, Australia, Spain, Greece, Taiwan, USA, Cameroon and Singapore	Xu, Z., et al. (2012). "Impact of ambient temperature on children's health: a systematic review." Environmental Research **117**: 120-131.
UHI effect	UHI effect and health outcomes	Estimated impact of excessive heat exposure.	Estimates that from 1979–2003, excessive heat exposure contributed to more than 8,000 premature deaths in the United States.	United States	Center for Disease Control and Prevention (2006), Heat Island Impacts, viewed January 2018, <https://www.epa.gov/heat-islands/heat-island-impacts#3>
UHI effect	UHI effect and health outcomes	Investigated the relationship between greenspace and health outcomes.	Kabisch, van den Bosch and Lafortezza (2017) found that urban trees and other vegetation provides cooling through shade and evaportranspiration, which reduce the impact of the UHI on hot summer days.	Global	Kabisch, N., et al. (2017). "The health benefits of nature-based solutions to urbanization challenges for children and the elderly–A systematic review." Environmental Research **159**: 362-373.
UHI effect	UHI effect and health outcomes	Observation of the influence that climate change has on extreme heat exposure levels and the UHI effect.	Heat island effect contributes to greater heat exposure, which is positively associated with morbidity and mortality; mortality increases at temperatures above 28 degrees C, particularly amongst people 65+ years.	Australia, ACT	Kjellstrom, T. and H. J. Weaver (2009). "Climate change and health: impacts, vulnerability, adaptation and mitigation." New South Wales public health bulletin **20**(2): 5-9.
UHI effect	UHI effect and health outcomes	Examination of whether there were differences in heat-related deaths between 2003 and 2015 occurred in Slovenia.	People over 75 years and those with pre-existing acute circulatory diseases are most heavily impacted by heatwave. Risk factors of hypertension include being overweight and sedentary lifestyle. Older people with physiological cardiovascular impairment are more sensitive to heat waves.	Slovenia	Perčič, S., et al. (2018). "Number of heat wave deaths by diagnosis, sex, age groups, and area, in Slovenia, 2015 vs. 2003." International Journal of Environmental Research and Public Health **15**(1): 173.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
UHI effect	UHI effect and urban environments	Application of city-level forecast modelling and urban canopy modelling to investigate the cooling effect of roof vegetation/green roofs in Chicago, Illinois (USA).	Widespread adoption of vegetated roofs could reduce localised temperatures up to 3 degrees C, but the effect is similar to other technologies (e.g. white roofs). The green roof approach also has several limitations including that the reduced temperature reduces natural circulation at the warmest times. Though this could reduce pollutants in the city, it also reduces natural cooling.	USA	Smith, K. R. and P. J. Roebber (2011). "Green roof mitigation potential for a proxy future climate scenario in Chicago, Illinois." Journal of applied meteorology and climatology **50**(3): 507-522.
UHI effect	Health outcomes and economic outcomes	Estimating the extent of productivity lost caused by heat and climate change.	Estimated productivity may decrease by 11-27% in hot regions by 2080, and by 20% globally in hot months by 2050. Annual economic burden estimated to be US$6.2b for Australian workforce.	Australia	Zander, K. K., et al. (2015). "Heat stress causes substantial labour productivity loss in Australia." Nature climate change **5**(7): 647.
UHI effect	Health outcomes and economic outcomes	Observing the detrimental impact that extreme heat has on labour productivity.	Positive association between direct heat exposure and labourer's ability to carry out physical work, increased absenteeism and reduced labour productivity	Australia, ACT	Kjellstrom, T. and H. J. Weaver (2009). "Climate change and health: impacts, vulnerability, adaptation and mitigation." New South Wales public health bulletin **20**(2): 5-9.
UHI effect Air quality	Improved natural environments and UHI effect Improved natural environments and air quality	Identified 102 relevant peer-reviewed studies published between 2009 and 2014 on the effect of urban greenspace on heat and air quality.	Among the identified studies on greenspace and air pollution, 92 per cent reported pollution mitigating effects, Among studies on heat mitigation, 98 per cent reported urban cooling effects associated with greenspace.	USA, China, Japan, UK, Italy, Greece, Germany, Canada	Green Belt (2015). The impact of greenspace on heat and air pollution in urban communities: A meta-narrative systematic review. The David Suzuki Foundation. Available at: <https://davidsuzuki.org/wp-content/uploads/2017/09/impact-green-space-heat-air-pollution-urban-communities.pdf>
Air quality	Improved natural environments and air quality	City of Tampa Urban Ecological Assessment provides a detailed scientific look into the economic and ecological values of the City of Tampa's urban forest.	Found that 8.67m trees saved 398,94MWhs, avoided 8,152 tonnes of CO_2 emissions and 1163 tonnes of pollution.	Tampa, USA	Landry, S., Northrop, R., Andreu, M., Rhodes, C. (2013) City of Tampa 2011: Urban Forest Analysis The Structure, Composition, Function and Economic Benefits of Trees and the Urban Forest. Available at: <http://waterinstitute.usf.edu/upload/projects/TampaUEA/Tampa_2011_UrbanForestAnalysis.pdf>
Air quality	Improved natural environments and air quality	A modelling study using hourly meteorological and pollution concentration data from across the coterminous United States.	Demonstrates that urban trees remove large amounts of air pollution that consequently improve urban air quality. The median pollution removal value per unit canopy cover was 10.8 gm-2 a-1. Trees estimated to remove 711,300 tonnes of pollution across 55 US cities.	USA	Nowak, D. J., et al. (2006). "Air pollution removal by urban trees and shrubs in the United States." Urban Forestry & Urban Greening **4**(3-4): 115-123.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Air quality	Improved natural environments and air quality	The purpose of this study was to investigate the effect of green roofs and green walls on air pollution in urban Toronto. The research looked at the synergistic effects on air pollution mitigation of different combinations of vegetation by manipulating quantities of trees, shrubs, green roofs and green walls in the study area.	Trees and shrubs remove air contaminants more effectively than green roofs or walls, and trees are superior to shrubs.	Canada, Toronto	Currie, B. A. and B. Bass (2008). "Estimates of air pollution mitigation with green plants and green roofs using the UFORE model." Urban Ecosystems **11**(4): 409-422.
Air quality	Improved natural environments and air quality	The study investigated and summarised effect that different types of greenspace features (trees, shrubbery) conferred on air quality.	Trees have the strongest ability to capture and filter air pollutants, specifically ground-level ozone, sulphur dioxide, nitrogen oxides and particulate matter (Zupancic et al. (2015)).	Australia, Melbourne	Kendal, D., et al. (2016). "Benefits of urban greenspace in the Australian context: A synthesis review for the Clean Air and Urban Landscapes Hub.". Available at: <https://minerva-access.unimelb.edu.au/bitstream/handle/11343/122914/2016-CAUL-Benefits%20of%20Urban%20Green%20Space.pdf?sequence=1>
Air quality	Air quality and health outcomes	Observed the impacts that climate change will confer on residential air quality and the association between poor air quality and mortality.	More ozone is formed from the exhaust emissions of motor vehicles during summer periods of increasing heat in combination with strong sunlight. Reduction in car usage, to reduce emissions of GHGs and other air pollutions (particulate matter and nitrogen dioxide) can mitigate excess deaths caused by pollution.	Australia, ACT	Kjellstrom, T. and H. J. Weaver (2009). "Climate change and health: impacts, vulnerability, adaptation and mitigation." New South Wales public health bulletin **20**(2): 5-9.
Air quality	Air quality and health outcomes	A natural experiment was used to test whether a major change to the natural environment—the loss of 100 million trees to the emerald ash borer, an invasive forest pest— has influenced mortality related to cardiovascular and lower respiratory diseases.	% of country covered by ash tree canopy reduced respiratory related deaths by 0.00522% and cardio related deaths by 0.0018%.	15 US States	Donovan, G. H., et al. (2013). "The relationship between trees and human health: evidence from the spread of the emerald ash borer." American Journal of Preventive Medicine **44**(2): 139-145.
Air quality	Air quality and health outcomes	Investigated the association between residential green (greenness or greenspace) and mortality in adults using the Swiss National Cohort (SNC) by mutually considering air pollution and transportation noise exposure.	Hazard ratios for NDVI [and LU-green] per interquartile range within 500 m of residence were highly comparable: 0.94 (0.93–0.95) [0.94 (0.93–0.95)] for natural causes; 0.92 (0.91–0.94) [0.92 (0.90–0.95)] for respiratory; and 0.95 (0.94–0.96) [0.96 (0.95–0.98)] for CVD mortality.	Switzerland	Vienneau, D., et al. (2017). "More than clean air and tranquillity: residential green is independently associated with decreasing mortality." Environment international **108**: 176-184.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Air quality	Air quality and health outcomes	Applied partial least squares modelling to analyse the degree to which green structure reduces mortality of cardiovascular disease, using Taipei Metropolitan Area as an empirical case.	In addition to clarifying the complex relationships and effects of green structure, air pollution, temperature, and mortality of cardiovascular disease, this study demonstrated that green structure has a significant influence on mortality of cardiovascular disease as it reduces the effects of air pollution and heat. Increase in annual mean temperature (OC) resulted in increase in CVD mortality by 0.073, which was less than a 1 unit increase in air pollution, which increased CVD mortality by 0.366. Using various green structure characteristics, e.g. largest patch %, resulted in a 0.209 decrease in CVD mortality (total effect including both air pollution and heat effect).	Taiwan	Shen, Y.-S. and S.-C. C. Lung (2016). "Can green structure reduce the mortality of cardiovascular diseases?" Science of The Total Environment **566**: 1159-1167.
Air quality	Air quality and health outcomes	Study undertook statistical analysis of the correlation between respiratory diseases and mortality with reducing air pollution.	Mortality of pneumonia and chronic lower respiratory diseases can be reduced by minimising fragmentation and increasing the largest patch percentage of green structure. A high proportion of fragmented greenspaces would increase secondary air pollutants and enhance health risks. Respiratory mortality is associated with air pollution and temperature. Primary air pollutants have greater influence on mortality of respiratory diseases than secondary air pollutants.	Taiwan	Shen, Y.-S. and S.-C. C. Lung (2017). "Mediation pathways and effects of green structures on respiratory mortality via reducing air pollution." Scientific reports **7**: 42854.
Air quality	Air quality and health outcomes	Estimates the number of premature deaths preventable via compliance with international exposure recommendations for air pollution.	Reducing air pollution from 16.6 micrograms/cubic metre to 10 could prevent 659 deaths and increase life expectancy by 52 days.	Spain, Barcelona	Mueller, N., et al. (2016). "Urban and transport planning related exposures and mortality: a health impact assessment for cities." Environmental Health Perspectives **125**(1): 89-96.
Air quality	Air quality and health outcomes	Summarized epidemiologic evidence on the modification by temperature of the acute effects of air pollutants on non-accidental and cardiovascular mortality.	In high temperature days, a 10µg/m3 increment in PM10 concentration corresponded to pooled estimates of 0.78% and 1.28% increase in non-accidental and cardiovascular mortality. Pooled effects of O3 on non-accidental mortality on low and high temperature days were increases of 0.48% and 0.47% respectively, for 10µg/m3 increase in exposure, both significantly higher than the increase of 0.20% on medium temperature days. The effect of O3 on cardiovascular mortality was strongest on high temperature days with pooled estimate of 1.63%. No significant interactions between SO2/NO2 and temperature were detected by meta-analysis.	EU, China, India, Australia, Belgium, USA and Canada	Li, J., et al. (2017). "Modification of the effects of air pollutants on mortality by temperature: a systematic review and meta-analysis." Science of The Total Environment **575**: 1556-1570.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
Air quality	Health outcomes and economic outcomes	Estimates the health cost of ambient air pollution in Greater Sydney to assist decision making on proposals that concern air quality.	Estimated health cost of ambient air pollution is between $1,01b and $8.40b per annum.	Australia, NSW, Sydney	NSW Department of Environment and Conservation (2005). Air pollution economics: health costs of air pollution in the Greater Sydney Metropolitan Region, NSW Government. Available at: <https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Air/air-pollution-economics-health-costs-greater-sydney-metropolitan-region-050623.pdf>
All	Improved natural environments and all health risk factors All health risk factors and health outcomes	Conducted systematic review of established methodologies of finding associations between public health and natural environments.	Increase in natural greenspace accessibility strongly associated with increased physical activity, with greatest benefit being reduced CVD risk and related mortality. Inconclusive association between obesity as an outcome of physical inactivity but strong evidence of association between obesity and CVD, and obesity and mental disorders. Strong association between physical activity and reduced levels of anger and sadness. Association between excess heat and disease susceptibility due to reduced 'adaptation capacity of human thermoregulation' (may exacerbate existing chronic conditions). Moderate to strong evidence of positive association between greenspace and all-cause mortality.	Global	van den Bosch, M. and Å. O. Sang (2017). "Urban natural environments as nature-based solutions for improved public health–A systematic review of reviews." Environmental Research **158**: 373-384.
All	Health outcomes and economic outcomes	Outlining how governments can improve assessment and appraisal of infrastructure proposals when making investment decisions when monetising more economic, social and environmental impacts.	To meet infrastructure challenges over next 30 years, government has to maximise value-for-money. Utilising cost benefit analysis to capture broader economic, social and environmental impacts of health interventions, ascribing monetary values to impacts, and valuing economic, social and environmental impacts for cost benefit analysis.	Australia	Infrastructure Victoria (2016). Moving from Evaluation to Valuation: Improving Project Appraisals by monetising more economic, social and environmental impacts. Available at:<http://www.infrastructurevictoria.com.au/sites/default/files/images/Moving%20from%20evaluation%20to%20valuation.PDF>
All	Health outcomes and economic outcomes	Summarises the health and wellbeing benefits that can be implicated by the water industry.	The largest determinants to health and wellbeing are socioeconomic (40%), behavioural (30%), clinical (20%) and physical environment (10%). 100,000 deaths per year in Victoria, 60% of which can be avoided. Health inequalities cost Vic around $5b in annual productivity, $3-5b in lost taxes and increased welfare benefits (~2-3% of Victoria's GDP).	Australia, Victoria	Pamminger, F. (2017). "The Water Industry's Role in Health and Wellbeing: Insights from contemporary public health studies in Victoria." Online Journal of the Australian Water Association **2**(4).

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
All	Health outcomes and economic outcomes	Summarised the willingness to pay method to identify the value of statistical life.	WTP method is most appropriate for measuring the value of statistical life (reductions in the risk of physical harm). WTP involves identifying how much a consumer would pay for products that reduce/mitigate the risk of death or serious injury.	Global	Office of Best Practice Regulation (2014). Best Practice Regulation Guidance Note Value of Statistical Life. Australian Government Department of the Prime Minister and Cabinet. Available at: <https://www.pmc.gov.au/sites/default/files/publications/Value_of_Statistical_Life_guidance_note.pdf >
All	Health outcomes and economic outcomes	Using quantitative measures of the value of life to ascertain whether the level of expenditure on health and safety is sufficient.	VSL from studies ranged from A$3m to A$15m. Paper suggests that public agencies in Australia adopt a VSL of $3.5m for avoiding an immediate death of a healthy individual in middle age (about 50) or younger; a constant VLY of $151 000 which is independent of age; and age-specific VSLS for older persons equal to the present value of future VLYs of $151,000 discounted by 3% per annum.	Australia	Abelson, P. (2008). Establishing a Monetary Value for Lives Saved: Issues and Controversies. Office of Best Practice Regulation. Available at: <https://www.pmc.gov.au/sites/default/files/publications/Working_paper_2_Peter_Abelson.pdf>
All	Health outcomes and economic outcomes	Presented microeconomic methodology for valuing life.	While VSL is somewhat flawed as a concept to capture the value of health life, WTP approach to valuing human life have been the focus of the literature in this area since the 1960s. Revealed preference studies are generally considered superior to stated preference methods in revealing WTP as they are based on real world empirical binding market transactions. A literature review suggests a mean VSL in Australia of $5.7m and a median of $2.9m.	Global	Access Economics (2007). The Health of Nations: The Value of Statistical Life. Australian Safety and Compensation Council. Available at: <https://www.safeworkaustralia.gov.au/system/files/documents/1702/thehealthofnations_value_statisticallife_2008_pdf.pdf>
All	Health outcomes and economic outcomes	Explains the factors that contribute to an individual's WTP and subsequent VSL. France, Paris.	While in some cases, a new primary valuation study, tailored for the specific policy in question, might be needed in order to carry out an appropriate CBA, in many situations benefit transfer (where VSL values that have been estimated in one context are– with appropriate adjustments – used in policy assessments in another context) will generally be less time- and resource-consuming. Average adult VSL for OECD countries ranges between US $1.5m-4.5m, with a base value of US $3m.	Global	Organisation for Economic Cooperation & Development 2012, The valuation of mortality risk, Mortality Risk Valuation in Environment, Health and Transport Policies, OECD Publishing. Available at: <http://www.oecd.org/environment/mortalityriskvaluationinenvironmenthealthandtransportpolicies.htm>
All	Health outcomes and economic outcomes	Examines econometric issues, the role of unionisation in risk premiums, and the effects of age on value of statistical life.	Median value of VSL of prime-aged workers is $7m. Income elasticity of VSL ranges from 0.5 to 0.6.	USA	Viscusi, W. K. and J. E. Aldy (2003). "The Value of a Statistical Life: A Critical Review of Market Estimates throughout the World." National Bureau of Economic Research Working Paper Series **9487**.

HEALTH PATHWAY	RELATIONSHIP	SCOPE OF STUDY	KEY FINDINGS	LOCATION	SOURCE
All	Health outcomes and economic outcomes	Assessment of tools that measure economics costs of human morbidity and mortality, focusing on biosecurity risk assessment utility	Must consider burden of disease as when measuring consequences of illness; must consider single or multi-criteria approach, use of data, time and resources available, contribution of modelling and equity consideration when measuring economic costs. WTP method may be warranted if intangible costs are important. Review recommends use of Cost of Illness method to measure economic costs of human morbidity and mortality.	Australia	Jordan. H, Dunt et. al (Undated). Measuring the Cost of Human Morbidity and Mortality from Zoonotic Diseases. Australian Centre of Excellence for Risk Analysis. Australia. Available at: <https://cebra.unimelb.edu.au/__data/assets/pdf_file/0008/2220875/1002BOID1FR.pdf>
All	Improved natural environments and health outcomes	Organises the health benefits of increased greenspaces into three domains, and assessing the overall implication on improved health	Greenspaces have 3 functions: reducing harm (air pollution, noise reduction, heat reduction), restoring capacities (attention and focus restoration) & building capacities (encouraging physical activity & facilitating social cohesion). These functions may lead to improving physical health & wellbeing (self-perceived health, higher birth weight, lower BMI, lower risk of depression and cardiovascular disease).	Global	Markevych, I., et al. (2017). "Exploring pathways linking greenspace to health: theoretical and methodological guidance." Environmental Research **158**: 301-317.

Source: Frontier Economics

B CRITERIA FOR SELECTING CASE STUDIES

Criteria for selecting illustrative case studies

Given the limited timeframe associated with this project, and to ensure that the selected case study projects provide 'lessons' that can be applied when assessing other future investment decisions, we applied a number of criteria:

- **Table 15** sets out the criteria used for evaluating the **suitability of each candidate illustrative case study project**; and
- **Table 16** sets out the criteria applied in assessing the **appropriateness of the set of selected illustrative case studies as a whole.**

Table 15: Criteria for evaluating the suitability of each candidate case study

CRITERIA	RATIONALE
Does the project involve IWCM[96]	As noted above, focusing on IWCM approaches is likely to maximise the benefits from any "lessons" learnt and ensure that a clear causal link between the investment and associated health impacts is identifiable.
Is the project potentially associated with commonly identified health impacts?	To maximise the benefits from any "lessons" learnt, given it may provide synergies with future work for other 'similar' projects.
Is the project potentially associated with potentially significant health impacts (i.e. multiple health impacts or a large health impact)?	Greater focus on the robustness of the methodologies and processes for projects with significant health impacts may be of greater value, given the value of these health benefits (including risk and uncertainty around any estimate) may be more likely to influence the investment decision.
Are the health impacts likely to be relevant for a range of stakeholders?	To maximise the benefits from any "lessons" learnt, given it may provide synergies with future work across a variety of stakeholders.
Is the causal link between the project and the associated health impacts likely to be 'strong'?	To ensure a robust and defensible assessment framework, projects where the link between the investment and the health benefits is tenuous, should not be included.
Has the water business attempted to assess and/or monetise the associated health benefits?	Including projects where water business; have already attempted to assess and monetise the health benefits will provide the opportunity to learn from and improve on previous assessments.

Source: Frontier Economics

96 As characterised by: physical connection between water, land and related resources, the involvement of the whole of the water cycle and crosses geo-physical boundaries.

Table 16: Our approach to evaluating the appropriateness of the case studies as a whole

CRITERIA	RATIONALE
Is there diversity in terms of the services covered by the case studies?	The set of case studies should cover the range of services provided by water businesses (i.e. water, recycled water, wastewater and storm water).
Is there diversity in the range of climatic zones covered by the case studies?	The set of case studies should cover a variety of climate zones to reflect the variety in water business' service areas.
Is there diversity in the degree of urbanisation covered by the case studies (e.g. urban versus rural areas)?	The set of case studies should include a rural based case study and an urban based case study.
Is there diversity in terms of the affected parties (e.g. broader community, local government, health care sector)?	The set of case studies should include a range of affected parties to reflect the likelihood that the benefits go beyond the water utility's direct customer base.
Is there diversity in terms of the role of the water utility (e.g. project manager, facilitator and steward)?	The set of case studies should reflect the growing range of roles for water businesses.

Source: Frontier Economics

Drawing on the case studies proposed by the water businesses we identified three illustrative case studies that we feel best meets the criteria outlined above.

Table 17: Assessment of our selected case studies against the criteria for evaluating the suitability of each candidate case study

CRITERIA	CASE STUDY #1: GREENFIELD DEVELOPMENT	CASE STUDY #2: REHABILITATION OF A STORMWATER CHANNEL	CASE STUDY #3: BROWNFIELD DEVELOPMENT
Does the project involve IWCM?	✓	✓	✓
Is the project potentially associated with commonly identified health impacts?	✓	✓	✓
Is the project potentially associated with potentially significant health impacts (i.e. multiple health impacts or a large health impact)?	✓	✓	✓
Are the health impacts likely to be relevant for a range of stakeholders?	✓	✓	✓
Is the causal link between the project and the associated health impacts likely to be 'strong'?	✓	✓	✓
Has the water business attempted to assess and/or monetise the associated health benefits?	✓	✓	✓

Source: Frontier Economics

Table 18: Assessment of our proposed case studies against the criteria for evaluating the appropriateness of the case studies as a whole

CRITERIA	CASE STUDIES:
Is there diversity in terms of the services covered by the case studies?	✓
Is there diversity in the range of climatic zones covered by the case studies?	✓
Is there diversity in the degree of urbanisation covered by the case studies?	✓
Is there diversity in terms of the affected parties?	✓
Is there diversity in terms of the role of the water utility?	✓

Source: Frontier Economics

C DATA UNDERPINNING THE READY RECKONER TOOL

Regional characteristics

Population demographics are based on 2016 ABS census data. This provides information on the number of males/females and age profile, as well as the median income of individuals.

Benefits from increased activity

The quantification of the benefits from increased activity is based on data on:

- Incremental participation — Giles-Corti et al (2005)[97] Perth study found that 23% of study participants engaged in five 30 minute walking sessions per week. The study also found that the chance of doing this level of exercise was higher with very good access to greenspace — the odds ratio was 1.2 for very good access compared to 1 for very poor access (in the distance only model). Based on this, the Ready Reckoner suggests that the incremental use of greenspace for active recreation is in the order of 5% (=23% x (1.2 – 1)).
- The health benefits from increased exercise are based on the AIHW 2017 study[98] on the impact of physical inactivity as a risk factor for chronic conditions. This study linked increased activity to a reduction in the DALYs associated with physical inactivity, via reduced disease burden from Coronary heart disease, Diabetes, Bowel cancer, Dementia, Stroke, Breast cancer and Uterine cancer. This study also provides adjustments for the level of socioeconomic disadvantage.
- The value of a statistical life / life year (to monetise a change in DALYs) was from the Office of Best Practice Regulation (2014)[99] and is based on Abelson (2007)[100]. The value was inflated to 2018 dollars using the ABS All groups CPI.
- Healthcare costs are primarily drawn from AIHW (2005)[101] which is a study of health system expenditure on disease and injury in Australia. This reports total healthcare expenditure that could be converted to a measure per 1000 people and these costs use in association with the proportion of the disease's burden that was associated with physical inactivity. Cancer costs were not disaggregated and additional studies[102] were used to estimate healthcare costs for Bowel cancer, Breast cancer and Uterine cancer. Dementia healthcare costs were obtained from other AIHW

[97] Giles-Corti, B., et al. (2005). "Increasing walking: how important is distance to, attractiveness, and size of public open space?" American Journal of Preventive Medicine **28**(2): 169-176.

[98] The Australian Institute of Health and Welfare (2017). Impact of Physical Inactivity as a risk factor for chronic conditions. Australian Burden of Disease Study Series no. 15. Canberra, The Australian Institute of Health and Welfare. Available at https://www.aihw.gov.au/getmedia/df392a65-8cf3-4c09-a494-4498ede2c662/aihw-bod-16.pdf.aspx?inline=true

[99] Office of Best Practice Regulation (2014). Best Practice Regulation Guidance Note Value of Statistical Life. Australian Government Department of the Prime Minister and Cabinet. Available at: https://www.pmc.gov.au/sites/default/files/publications/Value_of_Statistical_Life_guidance_note.pdf

[100] Abelson, P. (2008). Establishing a Monetary Value for Lives Saved: Issues and Controversies. Office of Best Practice Regulation. Available at: https://www.pmc.gov.au/sites/default/files/publications/Working_paper_2_Peter_Abelson.pdf

[101] AIHW (2005).Health system expenditure on disease and injury in Australia, 2000–01. Available at: https://www.aihw.gov.au/getmedia/855126b8-cdbc-4a47-a457-9b5cbfebe5b2/hsedia00-01-2.pdf.aspx?inline=true

[102] AIHW (2013). Health system expenditure on cancer and other neoplasms in Australia 2008-09. Available at: https://www.aihw.gov.au/getmedia/296395cc-f241-4c2f-a1a2-9e0b7c6a4d79/16199.pdf.aspx?inline=true and AIHW, Cancer Australia (2012). Gynaecological cancers in Australia: an overview. Cancer series no. 70. Cat. no. CAN 66. Canberra. Available at: https://www.aihw.gov.au/getmedia/03a38ab8-3ac4-48d4-b69c-8239a97c60a5/13972.pdf.aspx?inline=true

data[103]. The change in healthcare costs was assumed to be proportional to the change in DALYs from that disease.

- Productivity cost estimates are based on studies of productivity impacts of diabetes[104]. The indicative productivity losses from diabetes were applied to other diseases, with adjustment for relative disease prevalence. These productivity losses were monetised using the median weekly income for the region.
- In order to provide net present value (NPV) estimates, annual estimates were assumed to occur in each year over a 20 year time horizon and were discounted appropriately. Doing this makes the simplifying assumption that annual estimates are not significantly changed by population growth/decline or aging.

Increased wellbeing from exposure to greenspace

In addition to above, the quantification of the benefits from increased exposure to greenspace is based on data on:

- The change in depression resulting from increased exposure to greenspace from Shanahan 2016[105]. This was implemented in combination of data on the DALYs associated with depression from AIHW 2016[106].

Benefits from reduced urban temperatures

In addition to above, the quantification of the benefits from reduced urban temperatures is based on data on:

- Research led by UNSW and Sydney Water[107] that found that that western Sydney's summer temperatures can be significantly reduced and mortality rates halved by combining water technology, cool materials and greenery.
- The healthcare cost impacts focussed on reduced numbers of heart attacks as the number of hot days reduced using data from Loughnan et al 2010[108]. The costs from ambulance call out and hospital admissions associated with the heart attacks were based on data from AECOM 2012[109].

Benefits from increased air quality

In addition to above, the quantification of the benefits from increased air quality is based on data on:

103 AIHW (2012), Dementia in Australia. Cat. no. AGE 70. Canberra. Available at: https://www.aihw.gov.au/getmedia/199796bc-34bf-4c49-a046-7e83c24968f1/13995.pdf.aspx?inline=true

104 Magliano, D. J., et al. (2018). "The Productivity Burden of Diabetes at a Population Level." Diabetes care: dc172138. And Adepoju, O. E., et al. (2014). "Can chronic disease management programs for patients with type 2 diabetes reduce productivity-related indirect costs of the disease? Evidence from a randomized controlled trial." Population health management **17**(2): 112-120.

105 Shanahan, D. F., et al. (2016). "Health benefits from nature experiences depend on dose." Scientific reports **6**: 28551.

106 AIHW (2016). Australian Burden of Disease Study: Impact and causes of illness and death in Australia 2011. Australian Burden of Disease Study series no. 3. BOD 4. Canberra: AIHW. Available at: https://www.aihw.gov.au/getmedia/d4df9251-c4b6-452f-a877-8370b6124219/19663.pdf.aspx?inline=true

107 UNSW, Sydney Water & Low Carbon Living CRC (2017). Cooling Western Sydney. A strategic study on the role of water in mitigating urban heat in Western Sydney, November.

108 Loughnan, M. E., et al. (2010). "The effects of summer temperature, age and socioeconomic circumstance on acute myocardial infarction admissions in Melbourne, Australia." International Journal of Health Geographics **9**(1): 41.

109 AECOM (2012). Economic Assessment of the Urban Heat Island Effect, Prepared for City of Melbourne, November. Available at: https://www.melbourne.vic.gov.au/SiteCollectionDocuments/eco-assessment-of-urban-heat-island-effect.pdf

- The health impacts of air quality from a NSW Government study of the Sydney area[110]. Using this methodology, the change in willingness to pay (WTP) and COI costs from a representative change in PM10 of 0.1µg/m^3 where assessed using 'low estimates' from the economic analysis.

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[110] Department of Environment and Conservation (NSW) 2005, Air Pollution Economics: Health Costs of Air Pollution in the Greater Sydney Metropolitan Region.