Coastal Outfall System Upgrades in Australia: Benefits, Costs, and Improved Transparency – Final Report

Dr. Boyd D. Blackwell
PhD PGBEcon(Hons1A) BEcon BCom

AquaEquis Consulting, Armidale, New England, New South Wales, Australia

John Gemmill
MAppSci BEng ND

Clean Ocean Foundation, Wonthaggi, Bass Coast, Victoria, Australia

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Terms and Abbreviations

BCA: Benefit-cost analysis. Refer to CBA.

Coastal Outfall: Outfalls that dispose to the ocean, estuaries and rivers on the coast

CBA: Cost-benefit analysis. Also known as benefit-cost analysis. It is a method for ascertaining the net benefit (benefits less costs) of a range of options for addressing a particular policy decision or project development. It is preferred to CEA because it takes account of benefits in addition to costs of any given option, providing a ranking of options based on the NPV of each of those options. In other words, it provides an indication of the most efficient or economically preferred option. It also includes SCBA.

CM: Choice Modelling/Choice Experiment/Discrete Choice Modelling **i**s a stated preference non-market valuation method that is used to ascertain the willingness to pay for a good or service by accounting for various factors that are most likely to determine the benefit of the good or service at the margin (small changes in the quality and quantity of the good or service provided).

COF: Clean Ocean Foundation

CSO: Has two meanings depending on the context:

- **Community Service Obligation**, a government term to describe a subsidy for the price of a good or service to account for a common or public good or where it is planned that the price will increase through time to eliminate the subsidy.
- **Combined Sewage Outfall** where when the capacity of a treatment plant is exceeded by a flood event, then the water from the streets or land flows through the treatment plant and is not treated taking raw waste into the receiving waters.

CVM: Contingent Valuation Method is a stated preference non-market valuation method that asks people directly their willingness to pay for a particular good or service within varying bounds of set parameters for the good or service and other important factors. It is a similar method to the choice modelling method, but the latter has been developed, as espoused by proponents, to overcome the shortcomings of CVM.

Discount rate: The rate used to discount future costs and benefits into present day dollar terms. It usually includes the risk-free rate (or underlying rate set by the Reserve Bank) and some premium for risk or the cost of funds (equity and debt). However, some people argue for lower rather than higher discount rates, particularly where the benefits from a good or service aren't received for a long time into the future.

HPM: Hedonic Pricing Method is a revealed preference, non-market valuation method that typically uses the property market to reveal measures of the benefits of environmental goods and services. Other markets can also be used to reveal the benefits of a particular good or service.

Mixing Zone: Is the area where disposed wastewater mixes with the receiving water as part of the receiving water's assimilative capacity. However, inevitably, the greatest damage to the environment and receiving waters occurs in the mixing zone (Blackwell, 2008; Blackwell and Iacovino, 2009; Blackwell and Wilcox, 2009). In further zones, the impacts may be less visible but can also cause negative consequences for recreation and the environment.

NPV: Is a measure of the net present value of a given option for a project or policy choice. It is an economic and financial tool that is used to bring all present and future cost and benefit flows into present day dollar terms using an appropriate discount rate.

NOD: National Outfall Database founded by Clean Ocean Foundation and other entities

Non-market valuation method: A method that is used to value goods and services that are not traded in markets or have not yet been traded in markets. These methods can be broken into stated and revealed preference methods.

- **Stated preference methods** directly ask people to state their preferences for a particular good or service. These methods include CM and CVM.
- **Revealed preference methods** use associated markets with the good or service in questions and uses the relationship between that market and the good or service in question to derive preferences for that good or service. These methods include TCM and HPM.
- **Hybrid methods** use a combination of stated or revealed preference methods and include those such as contingent behavior or contingent travel cost**.**

Outfall: A pipe or similar structure that disposes of wastewater into a receiving body of water. In this report a reference to an outfall, also includes any connecting system infrastructure which is typically the treatment plant that determines the quality of water disposed through the outfall. By outfall we are also referring to the outfall system, including the WTP. By definition, wastewater outfalls were developed to dispose of low-quality wastewater at least cost by using the simulative capacity of the ocean and coastal water. Upgrading outfalls, by definition means less wastewater being disposed into the ocean because it is of a higher quality and can be re-used.

SCBA: Social CBA, where in addition to the private, project or market costs and benefits of a given option, the broader social or non-market, public costs and benefits of a given option are also included in the analysis to ensure that all costs and benefits to all stakeholders are accounted for in the analysis. Such analyses are important when projects or policy choices involve public as well as private benefits.

Sewage: Water-based effluent that comes from households, industry and other users. It also refers to wastewater.

STP: Sewage treatment plant. A plant that treats sewage.

TCM: Travel Cost Method is a revealed preference non-market valuation method that uses the travel market to derive the benefits for a particular good or service, such as an outdoor recreation site or a particular recreational activity e.g. surfing etc.

VT: Value Transfer is a method for valuing goods and services by using values attained in one particular application for another related application, taking account of suitable adjustments for differences between the two applications. The term is also known as benefit transfer when the values transferred between the applications more specifically represent benefits.

Wastewater: Water that has been used, typically with some form of pollution or contaminants added. The pollution typically is in the form of suspended and dissolved solids, e-coli, plastics (microfibers and microbeads), nitrogen, phosphorous, pharmaceuticals, flame retardants and other hydrophilic contaminants. The term also refers to sewage.

Water: H_20

WTP: The term has two meanings which depend on the context in which the abbreviations are used.

- The first meaning is an economic one referring to the **willingness to pay**, a measure of the benefit that people receive from a good or service.
- The second is **wastewater treatment plant** which has a similar meaning to a sewage treatment plant. It is a plant that treats wastewater to improve the water's quality for potential re-use or disposal with less negative impacts and enhanced positive impacts.

WAMNERPs: Water Management and Nutrient and Energy Recover Plants. A term for WTPs or STPs that better reflects the opportunities for a broader set of sustainable resource management goals.

Executive Summary

A large proportion (64%) of Australia's 176 coastal outfalls are currently contributing to poor water quality for Australia's coastal waterways and ocean environments because, wastewater is treated to only a lower level of quality, referred to as primary or secondary treatment (National Outfall Database, 2018).[1] As this report finds, by upgrading these outfalls to a tertiary level (a higher level of treatment) a greater opportunity for re-use is likely to be realised along with reduced disposal to the ocean and coastal waterways. Through upgrades therefore, policy and decision-makers can deliver a range of local to national benefits above costs.

As evidence, this report finds that the net benefit (benefits less costs) of coastal outfall upgrades in Australia are estimated to amount to between $12 billion and $28 billion in 2019 dollars, depending on the discount rate and the project period used. The costs of these upgrades were estimated to be between $7.3 billion to just over $10 billion.

By definition and history, coastal outfalls were established to reduce the cost of treatment, requiring a lower quality of wastewater treatment and disposal by using the assimilative capacity of the ocean and coastal waters. Such policy decisions were historically undertaken without reference to the benefits (Blackwell, 2008) and, in part, this represents the originality of our study. Such a cost minimisation approach inherently results in less than preferred policy decisions and outcomes for society because once benefits are included along with costs, a different level of preferred treatment is likely to result (Blackwell, 2003). Ascertaining the preferred level of treatment requires an assessment of the benefits in addition to the costs. This study does this for the 176 coastal outfalls around Australia, ranking them nationally and at the state or territory level.

The broad range of benefits from upgrades include improved water and resource management, agricultural output, human health and wellbeing (including improved recreational and social and cultural opportunities), and improved environmental and ecological consequences for receiving environments (Blackwell, 2008). Broader benefits to nearby properties and associated industries and local economies are also likely. By investing in these infrastructure upgrades, a series of local and regional employment and income benefits can also be delivered as regional economic development projects.

This is the first time that estimates of this kind have been calculated because of the relatively recent existence of a National Outfall Database (2018). The priority listings are designed to help decision and policy makers allocate constrained funds to the financing of upgrades in the best possible way that delivers the greatest net benefit. The report also briefly provides options for funding the upgrades and new ideas on improving the transparency and incentives to account for the broader benefits of upgrades for outfalls.

The report consists of five sections which are summarised in turn:

1. Introduction
2. Literature Review

[1] These outfalls predominantly receive wastewater from wastewater treatment plants, that then have the capacity to treat wastewater at different levels of treatment, with primary being the most basic, secondary providing a greater level of treatment and tertiary being the highest level of treatment. In this report a reference to wastewater outfall upgrade means a wastewater outfall system upgrade such as upgrading the treatment plant that delivers water to the outfall.

3. Methods
4. Results and
5. Improved Transparency, Funding and Recommendations.

1. Introduction

Wastewater outfall upgrades present a significant opportunity to capture both the private and public benefits that result from increased recycled water use, byproducts and the improvements in environmental conditions of receiving waters from disposal. The National Outfall Database (NOD) is an initiative of the Clean Ocean Foundation and the Marine Biodiversity Hub, supported by funding from the Australian Government. For the first time in Australia's history, the NOD provides a national inventory of Australia's 176 coastal outfalls including the volume of water and the amount of pollutants and nutrients disposed into coastal receiving waters. The existence of the NOD raises awareness at various scales – local, regional, state, national and international – of the extent of our waste in water use and provides essential information to assess the impacts on receiving waters. Most importantly the NOD also supports the estimation of likely benefits in addition to the costs of upgrades. Calibrating and estimating the benefits and costs of upgrades nationally can achieve a ranking for a planned sequential response to undertaking any upgrade implementation.

Economic and Public Policy Fundamentals

Economic theory and practice (Blackwell, 2008) demonstrates that users, society and service providers benefit from wastewater upgrades but that the benefits from doing so, are not necessarily immediately obvious to the market or to decision makers whom act on behalf of organisations and society to fund an upgrade. This fundamental economic asymmetry sets the foundation for the approach taken in this report. In the body of the report, a figure is provided that depicts the market for recycled water and encapsulates these concepts.

Upgrading outfalls delivers on a number of important public policy issues:

1. means **improved conditions for receiving waters** that are likely to result in improved outcomes for the local environment, society and economy through **increased diversification and quality of recreation and tourism**
2. means **improved conditions for the health of humans** using the water either directly for eventual consumption or indirectly through activities such as **recreation and tourism** in and near receiving waters
3. provides a much-needed additional sources of water during **drought**
4. can help better support secure supplies of water, independent of rainfall, for **agricultural production**, **other industries, and parks, gardens and sporting facilities**
5. improves **local economies** both directly through the jobs and income created through the funded upgrades, but also indirectly from the improved environmental conditions and flow-on benefits to the economy and society
6. delivers an improved economic environment for **water service providers** where additional funding is provided for upgrades and where the upgrades provide guaranteed cost savings, saleable byproducts and sources of energy

7. improves the **local economy** both directly through the jobs and income created through the funded upgrades, but also indirectly from the improved environmental conditions and flow-on benefits to the economy and society.

There are very few public policy issues which are capable of addressing such a range of benefits covering a diversity of government portfolios.

2. Literature Review

There are several important findings from the review of the literature.

Literature Review Key Finding No. 1 (LRKF1): The Gunawardena et al. (2017) review of a large number of domestic and international studies of water sensitive systems and practices identifies that the public are willing to pay significant amounts of money for wastewater treatment projects.

International Values for Treatment Upgrades

LRKF2: Logar et al. (2014) suggest that because CBA justifies investment from an economic viewpoint, it supports a Swiss national policy on a nationally supported sewage treatment plant upgrade for micropollutants. This study shows that it is standard practice to apply CBA to these types of problems.

Literature Review Key Insight[2] No. 1 (LRKI1): It is likely that treatment upgrades may generate declining returns to scale, though this should be assessed on a case by case basis for each location because it will depend on the initial quality of receiving waters and the current scale of the plant.

LRKF3: Hernández-Sancho et al. (2015) conclude that implementing wastewater programmes in developing countries is often feasible from an economic viewpoint where the environmental and health benefits are integrated into the overall economic assessment. This is similar to the findings of Blackwell (2008) in developed country settings.

LRKF4: Consideration should be given to integrating biofuel production systems with wastewater treatment given positive research findings on internal rates of returns but these are site specific and should be tested as such (Alloul et al., 2018; Xin et al., 2018).

LRKF5: Ensuring that economic analyses of wastewater treatment includes ecosystem service values or wider economic benefits reduces the tendency for serious ecological damage (Jiang et al., 2018).

LRKF6: In the longer-term, rather than considering simply retrofitting centralized treatment plants, a broader set of more viable, possibly decentralised and incentive compatible solutions to sanitation should be included as part of circular economy and lifecycle systems view.

Domestic Upgrade Values

LRKF7: Bennett et al. (2016) provide the ideal measure of the benefits to Sydney households for increased volumes of water recycling to 2030 through annual rises in rates and bills. Their study

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[2] A literature insight is different to a finding. Findings reflect those of a past study. Insights synthesise the findings of the study with other information (e.g. economic theory and practice) to draw our extended findings.

indicates that these volumetric estimates provide a measure of the broad range of benefits from recycling water that can be used in cost-benefit analyses such as those for which this report is written. The details of the Bennett et al. (2016) study are provided in the body of the report.

Household awareness of Sydney's water systems and the current use of recycled water were found to be variable (Bennett et al. 2016), with:

- 27 percent of households not aware that that desalination water was being used by Sydney homes, business and councils,
- 36 percent were not aware that recycled water was being used in Sydney
- 44 percent were not aware that recycled water Is not used for drinking and
- 39 percent of households were not aware that treated wastewater was released into Sydney's rivers and oceans.

LRKF8: Given the existence of the Clean Ocean Foundation, Surfers Against Sewage UK, Heal the Bay California, and Surfrider Northern Sydney, through people being willing to donate to support the work of these NGOs', combined with the findings of Deloitte Access Economics (2016, p. 5) that improvements in water quality at Sydney's coastal beaches through improved wastewater management account for use and nonuse values of $140m/yr, value added in tourism of $332m/yr and avoided absenteeism from illness of $140m/yr, provide clear evidence of the environmental benefits from improvements in the water quality of receiving environments.

LRKF9: While Gillespie and Bennett (1999) appears highly relevant being a study of removing sewerage discharges to the nearby ocean for the Vaucluse area in Sydney, it has its problems. These include the WTP bids not being tied to the amount of water recycled and the level of treatment specified, time periods for the payment vehicle are not specified, and CVM is used. Given these limitations we are therefore hesitant to use these estimates to value the benefits from water recycling and we believe the Bennett et al. (2016) study is superior.

LRKF10: Hardisty et al. (2013), which finds that secondary treatment in Western Australia is more optimal than tertiary treatment, should not be relied on because a number of underlying assumptions may not be valid including, no market for the sale of recycled water (Eckard, 2017), constant service provision across the scenarios (McNamara, 2018; Moore, 1978), the assumed relatively small reduction in ambient pollution (Boesch et al., 2001; Fagan et al., 1992), health impacts are not accounted for (National Research Council, 1993), amenity value should be site dependent (Blackwell and Wilcox, 2009), no spatial component is included in the value transfer (Blackwell, 2006a, 2007), and the wider benefits (externalities) (Blackwell and Iacovino, 2009; Otway, 1995; Stuart-Smith et al., 2015) from higher levels of treatment were likely to be underestimated in the analysis. However, the example given by the study's general approach of including externalities in addition to financial costs is positive and finds in favour of secondary treatment over primary.

Funding

LRKF11: Cavagnaro (2010, pp. 2, 7) indicates that 'cities and water authorities can attain (the benefits of upgrades) without investing their own capital up front' through immediate long-term guaranteed cost savings and a 'Performance Contracting Funding Model'. Operational savings are used to make payments subject to a performance contract with any underperformance being paid in cash to the upgrade recipient.

LRKF12: In a literature and case study review undertaken by the Bureau of Rural Sciences (Mooney and Stenekes, 2008) on social aspects of agricultural recycled water schemes, funding was found to predominantly come from state or Commonwealth governments to meet the necessary capital hurdle for upgrades and securing capital was a key to the success of schemes.

Transparency

LRKF13: A lifecycle approach to assessment and ranking of upgrades should be undertaken (Guven et al., 2018).

LRKF14: In the future, rather than being viewed as wastewater treatment plants these facilities may be better known as water management and nutrient and energy recovery plants (Apostolidis et al., 2011).

3. Methods

This study transfers values from the Bennett et al. (2016) study to estimate the benefits of each of Australia's 176 wastewater outfalls. Key inputs that determine these benefits include the WTP estimates from Bennett et al. (lower, mean and upper bound estimates), current plant treatment level (primary, secondary or tertiary), plant capacity and flow, relevant local populations, and net present value (NPV) analysis (using varying discount rates (3, 6 & 9 %) and time periods (15 and 30 years).

These benefits were then compared to two costs estimates, a simple one accounting for $5m fixed cost and $1m per ML per day of variable cost, and a second one that is more complex and provided by a water agency. The more complex estimates account for the non-linear (curvilinear) nature of capital expenditure (capex) and the linear relationship of operational expenditure (opex), including again NPV analysis (as undertaken for the benefits). Adding these capex and opex expenditures and then subtracting them from the benefits of upgrades provides estimates of the net benefits of any given plant upgrade. These upgrades can then be ranked based on the net benefits provided.

4. Results

The net benefit of coastal outfall upgrades in Australia is significant amounting to between $12 billion and $28 billion[3] in 2019 dollars depending on the discount rate used and the project period, with costs of between $7.3 billion to just over $10 billion. Individual projects have been ranked at an individual level by state and territory and across the nation. There is considerable variation between states and territories in the number of outfalls, the total net benefits provided and the costs of upgrades. These

[3] The estimated net benefits assume 63 percent of wastewater is recycled, an historical average calculated from Australian wastewater recycling facilities. In some cases, as much as 100 percent of wastewater may be recycled, resulting in much larger net benefits.

can be explained in part by the number of outfalls and size and geographical spread of relevant local populations that will benefit from the upgrades but also by the Individual jurisdictional asset condition and their respective histories, evolutions and success with water and wastewater reform.

All states overall have net benefits from upgrades except for the Northern Territory and Tasmania which experience net losses. Victoria's net benefits move from negative to positive when moving from a 15 to 30-year time period of assessment. NSW has the largest net benefit ($8-19 billion), followed by Western Australia ($3-5 billion), South Australia ($2-3 billion), Queensland ($90-730 m), Victoria (-$24 m to 150 m), Northern Territory ($-46 m to -54 m) and Tasmania (-$411m to -460m).

Despite most states providing positive net benefits for upgrades in total, all states and territories have a larger number of outfalls that have negative net benefits than positive. This may reflect the historically dispersed and 'local public good' nature and cost structure of wastewater treatment and disposal.[4] Having stated this, because total net benefits are positive, a number of larger investment projects in each state provide sufficient net benefits to offset those large number of projects with net losses, as is particularly the case in New South Wales, Western Australia and South Australia, in that order. This finding also holds to a lesser extent in Queensland and Victoria.

The indicative estimates presented in the tables of the body of the report provide a preliminary ranking to aid discussion on a desirable and practicable approach to wastewater upgrades around the country. More accurate estimates prepared on a case-by-case basis, taking account of specific contexts of any given case would need to be undertaken before a decision is made to undertake an upgrade at any given site. This would naturally form part of the business case preparation of any given upgrade to a specific outfall system.

5. Improved Transparency, Funding and Recommendations

This study provides an initial assessment and ranking of coastal wastewater outfalls around Australia. What this demonstrates is that improved transparency in the net benefits of upgrades will help aid decision-making and public policy preparation around upgrades. We also note from the literature review a number of innovative options for funding upgrades and because of the public benefit components of upgrades, funding from government is also appropriate. In addition to building opportunities for pooling funding, transparency[5] will help build trust between the stakeholders of wastewater upgrades leading to an improved discussion about how future work should proceed and where effort is best focused. We there have a number of recommendations in this regard:

1. To set a target for better performance and reduced waste such that all coastal outfalls around Australia be upgraded to meet the **Tertiary Class A+ standard of recycled water by 2030**.

[4] Such assumptions may of course not hold in every given situation and we have not undertaken any detailed analysis of micro-treatment and emerging technologies that may exhibit different cost structures. Future research at case specific locations could test these assumptions.
[5] More work on the issue of transparency is being prepared by COF to further elaborate these policy issues.

2. There is a need for adoption of **National Standards for Reporting of WTP data** including **transparency criteria** implemented as a prerequisite for WTP upgrade funding. An **Initial "Pilot" program** could be implemented on selected WTP upgrades.

3. To establish a **working group** to rapidly implement a set of key **publicly available National Reporting Standards** relating to the operation of WTPs and their interaction with the environment. This group would comprise of key industry, community, academic and government participants.

   This would include standards to transparently evaluate:

   I. **Plant Performance**:

      a. Process Costs

      This would ensure that the community and industry could understand a plant is reaching the upper limit of capability in terms of operational costs and its impact on the environment and recreational users etc.

      This is especially important for proactively identifying ageing infrastructure and the opportunity for capital upgrades involving options for recycling and climate change adaptation.

      Parameters would include:

      - Number of connections/Population
      - Plant performance efficiencies measures such as operating costs, failures and remedial actions taken to ensure best practice nationally.
      - Flows and composition and efficiency. Integration with real time 24/7 publicly accessible data wherever possible e.g. bypass events and out of license discharges, number, reason.

      b. Environmental and Social Costs

      Indicators of environmental monitoring e.g. last time outfall environment monitored results. This would include real-time assessments of the assimilative capacity of local receiving waters and whether these are being breached and the associated economic costs (e.g. losses in recreational, commercial and other values from lower levels of treatment).

      c. National Standards and Management of Emerging Pollutant Issues

      National standards are required for how WTPs engage and report on standards required for a framework to manage emerging pollutant issues.

4. **Evaluate Community Satisfaction with Engagement and Transparency**

   Citizen science projects that have been successfully undertaken could be used case examples for responsible agencies in better managing their outfalls and improved collaboration with communities. Examples include those from Chesapeake Bay in North America. Other international and some domestic examples are also likely to be available.

5. Economic Instruments for Improved Societal Outcomes

A review of potential economic incentives to help ensure greater incentives for transparency and the building of trust and collaboration between wastewater stakeholders could be investigated including tradable pollution permit schemes. This review would naturally include an assessment of funding options for wastewater upgrades.

6. Circular Economy, Lifecycle Approach and Plant Description

Noting **LRKF14,** rather than being called wastewater treatment plants (WTPs), these facilities should be called water management and nutrient and energy recovery plants (WAMNERPs) (Apostolidis et al., 2011).

1. Introduction

1.1. Background

This report provides first-time estimates of the likely benefits and costs of upgrading Australia's coastal outfalls[6] to provide a priority listing for decision and policy makers. Because outfalls historically receive and dispose of wastewater treated to the lowest levels of quality, that is, primary or secondary level treatments, upgrades to outfalls represent a significant opportunity for policy and decision makers to deliver benefits to local people across the country. Upgrades to tertiary levels for treatment plants improves opportunities for wastewater re-use and improves the quality of, and reduces the quantity of, wastewater disposed of into ocean and coastal waterways. These later benefits translate into the co-benefits of improved community recreational and health outcomes (Blackwell, 2008). Broader benefits beyond these direct benefits are also likely (Blackwell, 2008).

Determining a national policy on ocean outfall upgrades presents an opportunity for addressing a range of policy issues in health, water scarcity (drought) and agriculture, recreation, building regional jobs and income and adaptation to dynamic climate systems.

While this report is focused on coastal (including ocean and estuarine and river) outfalls, indeed there could be a much larger set of outfalls into receiving freshwater environments inland from the coast, presenting another opportunity to deliver lasting health, recreational, water scarcity, agricultural and economic benefits to rural, regional and remote Australia.

Upgrading Australia's estimated 176 (National Outfall Database, 2018) outfalls (see Figure 1) is not cost-less and needs to be competitive with other uses of public funds such as opportunities for public and private investment in education and other areas of health.

Therefore, there is a need to compare costs and benefits of upgrades to provide an indication of the return to public (and private) funds spent on upgrades.

Given this brief background, this study attempts to answer a series of salient research questions.

- *Research Question 1 (RQ1). Conceptually, what are the direct and indirect benefits, both market and non-market from upgrading Australia's coastal outfalls?*
- *RQ2. Which of these benefits are easily measured through methods such as value transfer, while which are more difficult and will require more time and effort and what is the relative magnitude of the less well-known values?*
- *RQ3. What are the likely costs of upgrades?*
- *RQ4. What are the net present values of the net benefits (benefits –costs) and how do outfalls rank across Australia?*
- *RQ5. What is the best approach to funding the upgrades to provide incentives for more transparent reporting while supporting upgrade completion?*

[6] While this report refers to upgrading outfalls, the meaning here is an upgrade to the wastewater treatment plant that feeds the outfall wastewater to dispose of it into coastal waters. In this sense it is an upgrade to the outfall system.

1.2. Australia's Coastal Outfalls

According to the National Outfall Database (2018), Australia has an estimated 176 coastal outfalls (see Figure 1) comprising 109 ocean outfalls and 67 estuarine or river outfalls as summarized in Table 1.

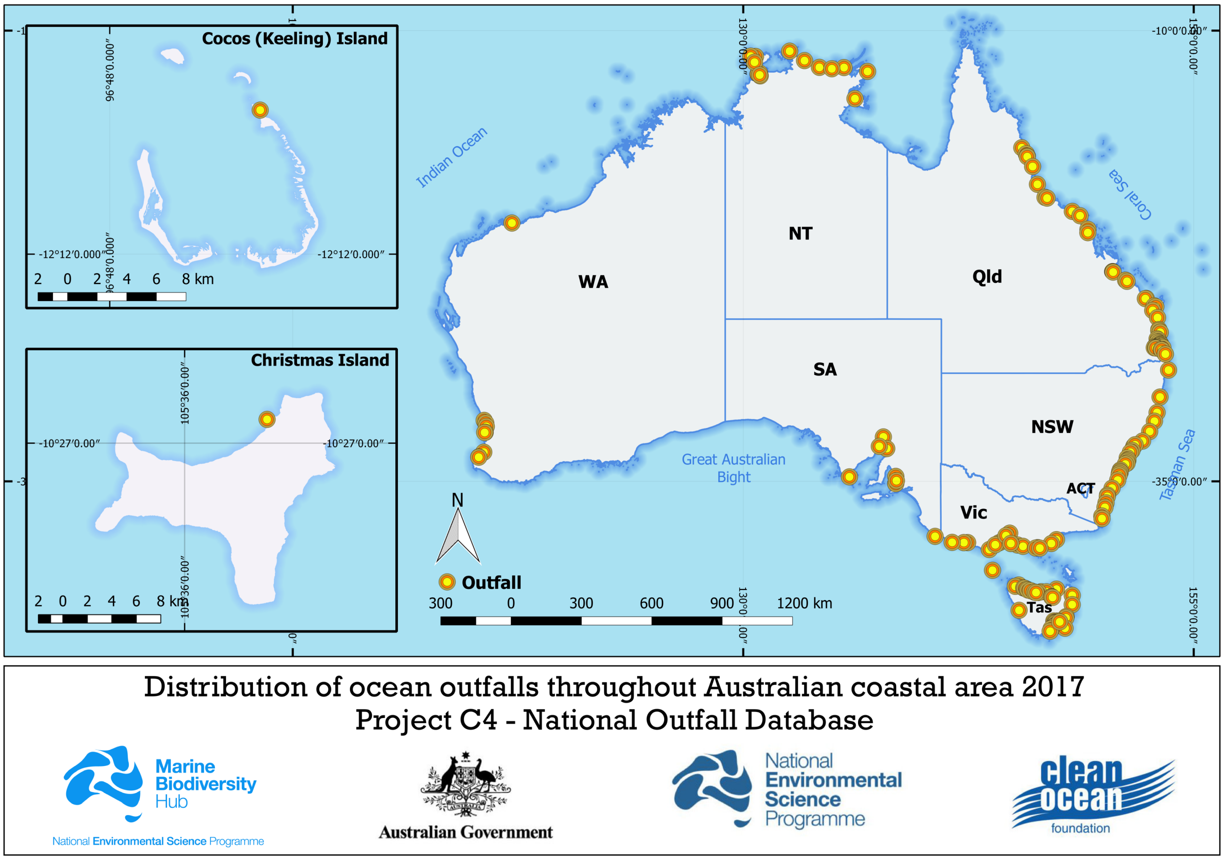


Figure 1: The 176 coastal outfalls mapped by the National Outfall Database. Source: (Clean Ocean Foundation, 2017).

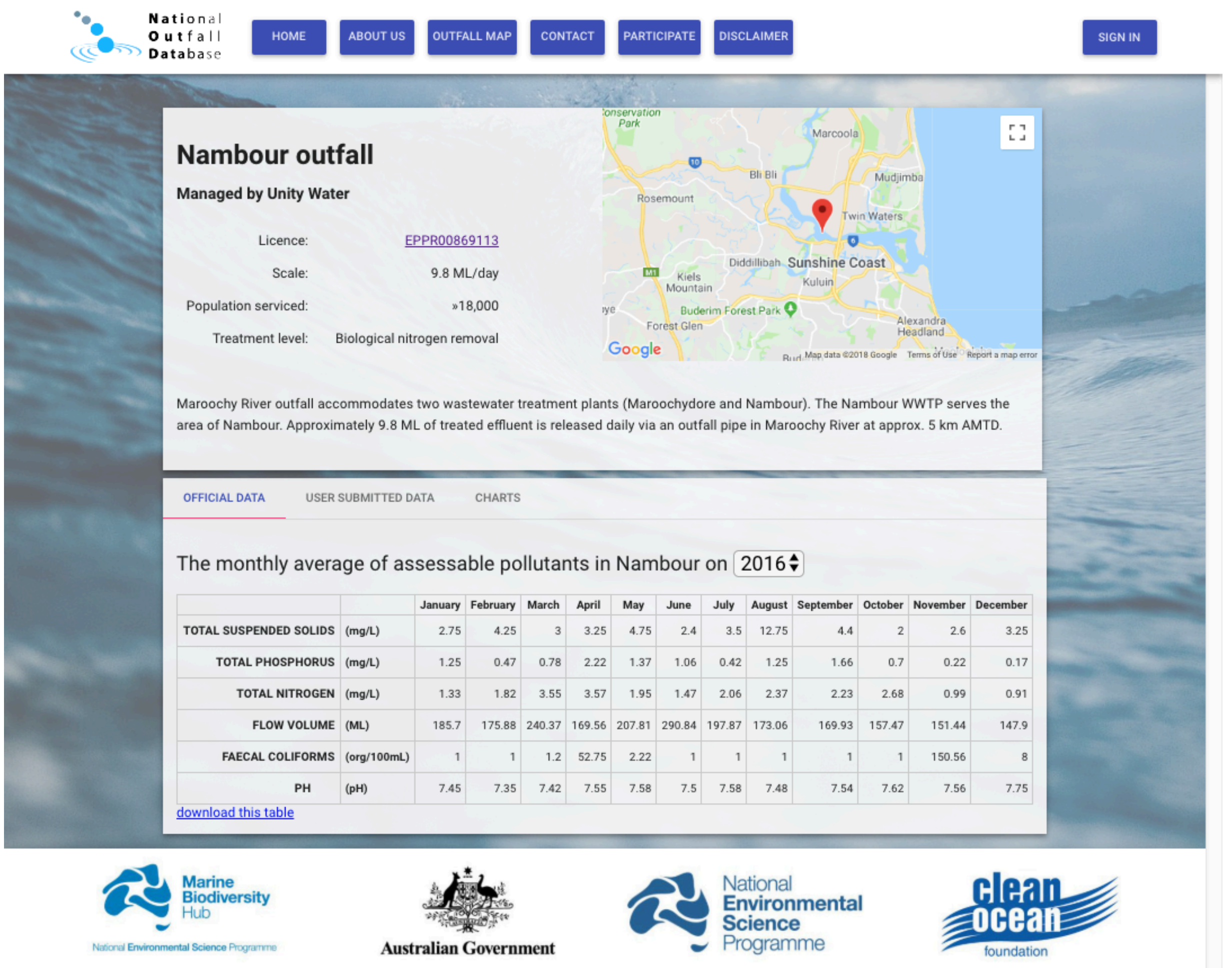
Table 1: Australia's Coastal Outfalls by State/Territory

States	Estuarine	Ocean	Total	Upgrade* %	Upgrade^ Flow (GL)	Upgrade* Flow / Total Flow
New South Wales	-	29	29	64%	1,229	94%
Victoria	-	19	19	63%	84	13%
Queensland	40	*11*	51	53%	221	40%
Western Australia	-	12	12	83%	209	84%
Tasmania	27	14	41	85%	81	89%
South Australia	-	10	10	60%	113	67%
Northern Territory	-	14	14	100%	31	100%
Total	67	109	176	64%	1,968	64%

Notes and Sources: Synthesis of various items from National Outfall Database (2018). * means outfall systems currently treating to a lower level of treatment at primary or secondary treatment levels. ^Of course, not in all cases, will all this water be re-used and we assume 63% is used. See the methods section for more details.

The information in Figure 1 and Table 1 comes from the National Outfall Database (National Outfall Database, 2018) which tracks 33 different indicators to identify the quality of outfall effluent along the coastal areas of Australia.

The National Outfall Database is a collaboration between the Clean Ocean Foundation (2018), the Australian Government and leading Australian Universities through the Marine Biodiversity Hub as part of the National Environmental Science Programme (National Outfall Database, 2018). The National Outfall Database was an initiative which began between the Clean Ocean Foundation and the Australian Maritime College (later subsumed by University of Tasmania) to identify the extent and content of water being disposed of around Australia's coastline.



		January	February	March	April	May	June	July	August	September	October	November	December
TOTAL SUSPENDED SOLIDS	(mg/L)	2.75	4.25	3	3.25	4.75	2.4	3.5	12.75	4.4	2	2.6	3.25
TOTAL PHOSPHORUS	(mg/L)	1.25	0.47	0.78	2.22	1.37	1.06	0.42	1.25	1.66	0.7	0.22	0.17
TOTAL NITROGEN	(mg/L)	1.33	1.82	3.55	3.57	1.95	1.47	2.06	2.37	2.23	2.68	0.99	0.91
FLOW VOLUME	(ML)	185.7	175.88	240.37	169.56	207.81	290.84	197.87	173.06	169.93	157.47	151.44	147.9
FAECAL COLIFORMS	(org/100mL)	1	1	1.2	52.75	2.22	1	1	1	1	1	150.56	8
PH	(pH)	7.45	7.35	7.42	7.55	7.58	7.5	7.58	7.48	7.54	7.62	7.56	7.75

Figure 2: Example of Information on a single outfall – Nambour Outfall. Source: National Outfall Database (2018).

Prior to the development of the NOD, little was publicly known about the extent of the wastewater resource being disposed into receiving coastal waters at any geographical scale. The NOD now provides detailed information at a range of spatial scales including national, state and outfall-specific scale. Figure

2 provides an example of the information presented for the Nambour Outfall at Maroochydore on the Sunshine Coast, Queensland. Such information is now accessible to anyone, raising a greater awareness and understanding for all stakeholders. As can be seen in Figure 2, the NOD tracks water quality indicators such as suspended solids, phosphorus, nitrogen, faecal coliforms, PH level and flow volume of water disposed. The existence of the database now allows for a net benefit assessment and prioritization of upgrades across Australia's 176 coastal outfalls as delivered through this report. These outfalls discharge an estimated 1350 GL of water annually, the equivalent of almost three Sydney harbours (Clean Ocean Foundation and Marine Biodiversity Hub, 2018). Leading state discharges include New South Wales, Victoria and Tasmania each disposing into coastal waters of hundreds of thousands of litres of wastewater per person per year (Clean Ocean Foundation and Marine Biodiversity Hub, 2018). Included in these disposals are relatively substantial amounts of nitrogen and phosphorous for New South Wales, Victoria, Western Australia, Queensland and South Australia (Clean Ocean Foundation and Marine Biodiversity Hub, 2018).

1.3. Some Economic and Public Policy Fundamentals

There is not a great deal written about the economic theory of coastal outfalls and wastewater in Australia. However, Blackwell (2008) provides a key piece of theory and practice that better helps conceptualise the problems and thus the opportunities associated with wastewater and outfalls in Australia and more generally across the globe. The market for wastewater fails as depicted in Figure 3.

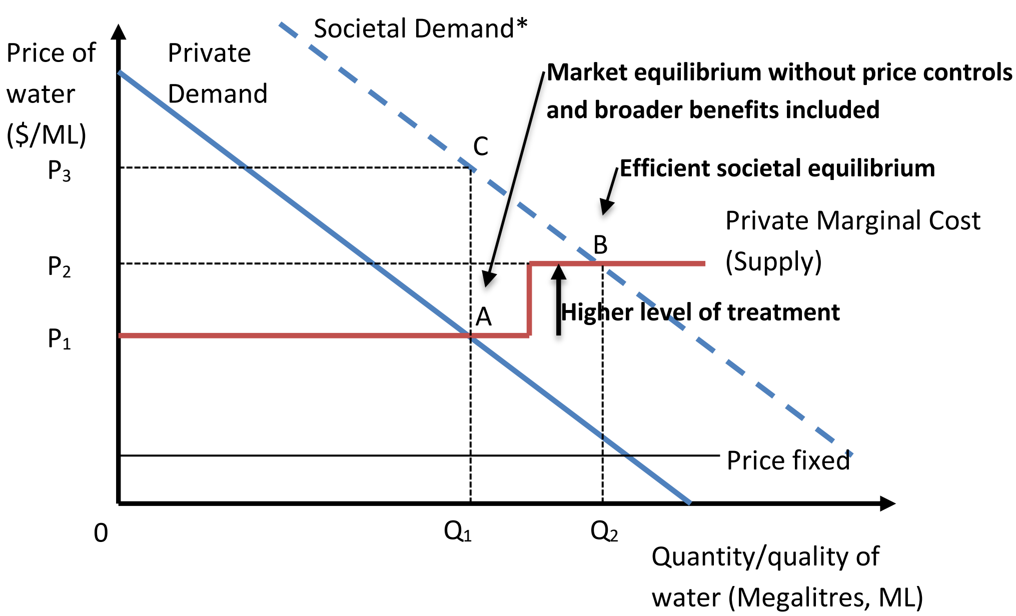


Figure 3: Demand and Supply for Recycled Water. Notes: * Social Demand includes all positive broader benefits (called 'externalities') that would result from reusing the wastewater and not disposing of it into receiving waters. Source: Adapted from Blackwell (2008, p. 4).

By considering the broader benefits and costs to society beyond simply market demand and supply, the broader opportunities of wastewater plant upgrades can be conceptualized and captured. Figure 3 depicts such a case. The vertical axis depicts the price of water, while the horizontal axis depicts the quantity or quality of water. The private demand and private marginal cost or supply of recycled water are identified in the figure. The supply curve is kinked because wastewater treatment or recycling is limited to the capacity of a given plant – additional supply beyond its capacity can only occur where the facility is upgraded and this is typically a significant upfront fixed cost for a local government authority or service provider, raising the average or marginal cost per unit of water supplied. The higher level of treatment allows a higher level of societal demand to be achieved with an efficient societal equilibrium at point B versus the current less than optimal equilibrium at point A. The amount of water recycled increases from Q1 to Q2 and the price desired by society of P2 which is higher than the current market price of P1 or a subsidized price of the 'price fixed' line. Moreover, the figure shows that the value of the recycled water is higher from society's perspective at P3 than that from the market (service provides and direct water users) at P1. Thus, at current levels the value per ML of broader benefits from recycling water are the difference between P3 and P1 at a recycled amount of Q1. The higher benefits from upgrades are twofold with an increase in the volume and quality of water recycled and in the price. In this case the benefits to society of consumers is increased from 0P1AQ1 to a much larger rectangle, 0P2BQ2.

In short, users and society benefit and service providers benefit from a wastewater upgrade but the benefits from doing so, are not necessarily immediately obvious to the market or to decision makers whom act on behalf of society to fund an upgrade. This is the reason for the National Outfall Database and for the commissioning of this report; to provide an estimate of the net benefit (benefits less costs) of upgrading each of Australia's coastal outfalls to support prioritised and strategic decision making on allocating funds for upgrades. These net benefit measures can be compared between upgrade sites and against other competing opportunities for spending government, private sector or NGO funds. In this sense, these estimates are designed to be transparent and transferable.

Upgrading outfalls deliveries on a number of important public policy issues:

1. provides a much needed additional sources of water during **drought**
2. can help better support secure supplies for **agricultural production**, **other industries, and parks, gardens and sporting facilities**
3. means **improved conditions for receiving waters** that may result in improved outcomes for the local environment, society and economy (e.g. through increased and diversification of recreation and tourism)
4. means **improved conditions for the health of humans** using the water either directly for eventual consumption or indirectly through activities such as recreation and tourism in and near receiving waters
5. delivers an improved economic environment for **water service providers** where additional funding is provided for upgrades and where the upgrades provide guaranteed cost savings, saleable byproducts and sources of energy.
6. improves the **local economy** both directly through the jobs and income created through the funded upgrades, but also indirectly from the improved environmental conditions and flow-on benefits to the economy and society (see item 3 above).

7. provides an opportunity to **protect and secure critical infrastructure from rising sea levels** associated with the dynamic climate systems.

There are very few public policy issues which are capable of addressing such a range of benefits reflected in a diversity of government portfolios.

1.4. Report Outline

The remainder of the report consists of six sections. Section 2 provides a brief literature review to place the Australian experience outfalls within the domestic and international context. Section 3 outlines our approach and methods. Section 4 presents the results. The report ends with Section 5 which makes a number of recommendations for delivering funding and improved transparency including through the use economic and other incentive mechanisms.

2. Literature Review

2.1. Introduction

The goal of this review, covering the economic valuation literature for studies that have assessed the values of wastewater upgrades, was to inform the study's approach, gather information for the transfer of values, and provide context and insights for finance options and incentive structures that provide greater transparency and incentives to deliver improved outcomes for all stakeholders.

The literature consists of five main focus areas:

- studies that relate to value of recycled and reused water from an upgrade facility – that is, the market value of the water when upgraded, whether for potable use, agricultural, sports fields or other industrial re-use;
- values for the improvement in the water quality of receiving waters which can be further broken into value for:
  - improvements in recreational and visual amenity
  - improvements in health outcomes for users of the receiving waters
  - improvements in the health of ecosystems that form part of the receiving waters
- upgrade matters in general including the grey literature of government reports relevant to upgrades of coastal outfalls
- finance options
- tools and instruments that can improve transparency and incentives in the industry to direct upgrades where they provide a net benefit to society (to all stakeholders including private as well as public benefit)
- domestic (particularly those for sites which fall within the NOD) versus international studies of the above areas

Each of these are addressed in turn and we end this section with a conclusion.

As an overview, an important review of economic valuation studies of water sensitive systems and practices was completed in 2017 by (Gunawardena et al., 2017) which summaries a large number of studies that are relevant to wastewater management. These include international and Australian studies that have used a range of methodologies including contingent valuation, choice experiments (choice modelling), and shadow price evaluations and costs-benefit studies. **Literature Review Key Finding No. 1 (LRKF1): The Gunawardena et al. (2017) review of a large number of domestic and international studies of water sensitive systems and practices identifies that the public are willing to pay significant amounts of money for wastewater treatment projects.**

2.2. International values for upgrade benefits

Table 2 outlines a selection of recent international studies that value the benefits of outfall upgrades. As can be noted from the table, typically these studies obtain willingness to pay (WTP) for improvements in sewage/wastewater treatment to improve the health of receiving waters such as rivers (Birol and Das, 2010; Ndunda and Mungatana, 2013) lakes (Zhang, 2011) and wetlands (Kaffashi et al., 2013).

Table 2: International studies of sewage/wastewater treatment facility upgrades

Authors, year date	Title	Journal	Benefits captured	Method	Payment Vehicle	Attributes	Population, sample size	Values
Birol and Das (2010)	Estimating the value of improved wastewater treatment: The case of River Ganga, India	JEM	Improvements in capacity (all primary) & technology (for secondary treatment) of STP on banks of River Ganga, India	Choice experiment, conditional logit model with interactions, face-to-face	Higher monthly municipal tax	Treated wastewater quality and quantity, regeneration of a park	Chandernagore municipality resident households, n=150	INR/mnth 5.82 (USD0.08) for secondary treatment & INR 3.54 (USD0.05) for high quantity of water; = INR 100.32/yr/h =3.3m/yr/municipality
Kaffashi et al. (2013)	We are willing to pay to support wetland conservation: local users' perspective	IJSDWE	Value of Shadegan wetland non-market services, Iran, 537,700 ha	Choice experiment and dichotomous choice contingent valuation of wetland users	Once-off donation to wetland conservation	Natural scenery, water quality (un,moderately, & acceptable) biodiversity, ecological functions	Shadegan town & related villages, n=400	High level conservation of wetland: CVM USD 3.03/h; CE USD 8.28/donation; acceptable water quality USD 4.23/h. 136308 households=$0.5m
Kontogianni et al. (2003)	Social preferences for improving water quality: An economic analysis of benefits from wastewater treatment	WRM	Full operation of WTP for improvements in Thermaikos Bay water quality, Thessalonki, Greece	Contingent valuation, maximum WTP open ended	Incremental increase in water rates for 5 yrs	Socio-economics, actual and intended behaviour	Thessalonki 794330 residents, n=466	Euro 15.23/4mths/h
Logar et al. (2014)	Cost-benefit analysis of the Swiss national policy on reducing micropollutants in Treated Wastewater	EST	Benefits of upgrading STPs to reduce environmental & health risks of MPs, Switzerland	Choice experiment, mixed multinomial logit model, online	Increase in annual household water bill (current level $US374)	Potential environmental risk reduction, impact spatial scale reduction, new knowledge availability of impacts on human health	Swiss national public, n=1,000	USD73/yr/h to reduce potential environmental risk to a 'low level'; USD113m across all STP catchment households –v- USD97m cost to upgrade 123 STPs
Ndunda and Mungata	Evaluating the welfare effects of improved	JEM	Improved wastewater treatment	Discrete choice experiment,	Municipality tax per household per month	Quality and quantity of treated wastewater	Urban & peri-urban irrigation farmer	KES/mnth/h 51 (USD0.51) for low to high quality, 17.39

na (2013)	wastewater treatment using discrete choice experiment		programs to mitigate impacts of water pollution to Motine-Ngong River in Nairobi, Kenya	random parameter logit model		for irrigation, riverine ecosystem restoration	households, n=241	(USD0.17) for high quantity, 22.18 (USD0.22) riverine ecosystem restoration (dummy); KES 90.57 (USD 0.90) in total = 163m (USD 1.61m) annually across 150,000 farmer households
Zhang (2011)	Measuring the value of water quality improvements in Lake Tai, China	JZU-SA	Improvements in water quality (Grade V) in Lake Tai, 2338 km^2	Contingent Valuation	Environmental fee	People more dissatisfied with water quality were WTP more	5 lakeside cities, n=	141 CNY/yr/h; all 5 lakeside cities amounts to CNY 3.8 billion over next 10 years undiscounted

Notes and Sources: EST=Environmental Science & Technology. IJSDWE=International Journal of Sustainable Development and World Ecology. JEM=Journal of Environmental Management. JZU-SA=Journal of Zhejiang University- Science A. WRM=Water Resources Management. H=household. MP=micropollutant. STP = sewage treatment plant. USD= US dollars. KES=Kenyan Shillings. INR=Indian Rupiahs. Conversions done using https://www.xe.com/currencyconverter/ as at 26 September 2018.

Most importantly amongst these studies, a Swiss study (Logar et al., 2014) undertook a cost-benefit study of 123 sewage treatment plants (STPs) using a choice experiment through a national online public survey to assess the potential to reduce the environmental risks of micropollutants (MPs) to a low level. Households were WTP USD $73 per annum to reduce the potential environmental risk to a 'low level'. Across all households within the STPs' catchments, the environmental risk reduction benefits were estimated at $113m versus the costs of the upgrades at $97m with a net benefit to the Swiss catchment constituents of $16m annually (Logar et al., 2014, p. 12500). **LRKF2: Logar et al. (2014) suggest that because CBA justifies investment from an economic viewpoint, it supports a Swiss national policy on a nationally supported sewage treatment plant upgrade for micropollutants. This study shows that it is standard practice to apply CBA to these types of problems.**

Concurrently with the above study, Eggen et al. (2014) outline the benefits of upgrading wastewater treatment plants including the reduction in discharge of micropollutants in the Aquatic Environment. The authors indicate that because of full scale studies of ozonation or carbon treatment through upgrades to WTPs that reduce MP discharges and concomitant reduced toxicities, social and political acceptance, and technical and cost-effectiveness feasibility, the Swiss authorities implemented additional wastewater treatment steps to improve water quality. The authors suggest that considerations by the Swiss authorities will be of interest to other countries as well. Upgrading WTPs is not the only solution to reduce MP discharge but should be part of a broader multipronged mitigation strategy.

In Portugal a bio-economic model was used to estimate the relationship between ecological and chemical status of freshwater wetland systems using value transfer for cultural ecosystem services from surface water status (Roebeling et al., 2016). This provided a relationship between surface water status and cultural ecosystem values. Improving the status of surface waters to good provided a marginal benefit of 0.48m Euros per year (2.02-1.54m for the wetland before and after the change respectively) (Roebeling et al., 2016, p. 219). The authors found that this marginal benefit, though remaining positive, declined as surface waters are further improved. **Literature Review Key Insight[7] 1 (LRKI1): It is likely that treatment upgrades may generate declining returns to scale, though this should be assessed on a case by case basis for each location because it will depend on the initial quality of receiving waters and the current scale of the plant.**

Hernández-Sancho et al. (2015) undertook a study of the economic valuation of wastewater considering the cost of action and the cost of no action. They state that undertaking a financial analysis of wastewater treatment is typically undertaken by the service provider while an economic analysis is required to inform public decision making and take into account the broader costs of inaction, notably:

- adverse human health effects associated with reduced quality of drinking and bathing/recreational water
- negative environmental effects due to the degradation of water bodies and ecosystems where untreated or inadequately treated wastewater is discharged
- potential effects on those economic activities that use polluted water for crop production, fisheries, aquaculture or tourism.

These costs of inaction naturally become the benefits of taking action to treat wastewater. **LRKF3: Hernández-Sancho et al. (2015) conclude that implementing wastewater programmes in developing countries is often feasible from an economic viewpoint where the environmental and health benefits are integrated into the overall economic assessment. This is similar to the findings of Blackwell (2008) in developed country settings.**

Birol and Das (2010) undertook a choice experiment to ascertain mean WTP by households for water quality and quantity improvement for a municipality, Chandernagore in India to clean up the Ganga River. They found that households' benefits were INR 5.82/month (USD 0.08) in higher municipal taxes for secondary treatment (high quality) disposal to the Ganga River and INR 3.54/month (USD 0.05) for a high quantity of water (capacity of treatment expanded such that all is primary treatment). These estimates amount to INR 100.32 per household per year or INR 3.3m across the municipality. At the time only 24 percent of wastewater with a running cost of INR 2.5m per year expanding to INR 10.4m for 100 percent treatment. Given this 'back-of-the-envelope' CBA (Birol and Das, 2010, p. 2170), costs exceed benefits and the rise in taxes would not be sufficient to meet the costs of the upgrade. The authors conclude that their study results are only preliminary and a more thorough set of beneficiaries needs to be included (farmers, industry, local, national and international public), including an extended choice experiment, more accurate cost estimates of upgrades and maintenance, and long-run discounting (i.e. NPV analysis) are required to make an informed decision.

[7] A literature insight is different to a finding. Findings reflect those of a past study. Insights synthesise the findings of the study with other information (e.g. economic theory and practice) to draw out and extend the findings.

In contrast, Ndunda and Mungatana (2013) undertook a study of the WTP by urban and peri-urban farmers for upgrades in wastewater treatment in Nairobi, Kenya to improve the quality of wastewater for use on farms and disposed to the Motoine to Ngong Rivers. Farmer households were WTP KES 51 per month for improvements in water quality from low to high, KES 17.39 for low to high quantity of water, KES 22.18 for riverine ecosystem restoration (dummy) amounting to KES 90.57 in total. Annually across 150,000 farmer households this represents KES 163m (USD 1.61m). The authors conclude that these estimates could be used in a CBA of upgrades once costs and the broader benefits are assessed. These would include benefits to other stakeholders from pollution abatement in the river and the maintenance costs and the costs to reconstruct wetlands. Similar to (Birol and Das, 2010), the authors also point to including a long-run discount rate in the CBA to capture welfare effects on future generations.

While the two studies from India and Kenya present after conversion very low values these should be considered within the context of the purchasing power of their domestic currencies. What is important is the relativity of benefits to costs or benefit cost ratios or positive net benefits.

Xin et al. (2018) found that integrating biofuel production with wastewater treatment was cost-effective way for better waste remediation and reduced environmental impact for biofuel production. A techno-economic analysis was undertaken using biofuel production, wastewater treatment improvement, tax credits, carbon credits and co-products utilization within the integrated system (e.g. glycerol used as organic carbon. The internal rates of return of the integrated system were superior in comparison to non-integrated systems. **LRKF4: Consideration should be given to integrating biofuel production systems with wastewater treatment given recent research findings.** These findings are similar to a study undertaken in Europe (Alloul et al., 2018) where sewage has a strong potential for biorefinery feedstock subject to future research.

In a Chinese study (Jiang et al., 2018) that modeled the trade-off between pollution control cost and ecosystem damage cost found that wastewater treatment cost functions show economies of scale in plant capacity (i.e. as capacity increase, the per unit cost declines). The study also found that with a low value attached to ecosystem services serious ecological damage resulted and the receiving waters assimilative capacity increased by prohibiting over extraction of water. **LRKF5: Ensuring that economic analyses of wastewater treatment includes ecosystem service values or wider economic benefits reduces the tendency for serious ecological damage (Jiang et al., 2018)**.

2.2.1 Constructed Wetlands, the Circular Economy and Sanitation Alternatives

Often in the valuation of environmental goods and services, the cost of creating human built systems to manage waste or address environmental degradation are used to proxy the value or shadow price of such services. In contrast, the reverse logic could also be used, where the value of treating, recycling and reusing wastewater could be assessed through the cost of creating natural system imitations of infrastructure alternatives such as WTPs and STPs. One area of growing interest in recent decades is the use of constructed wetlands to help process waste and recycle water. For example Masi et al. (2018) consider the role played by constructed wetlands (CWs) as an alternative to conventional sanitation in a new circular economy within an ecosystem services paradigm.

A companion field of research to constructed wetlands and the circular economy is micro-scale and decentralized wastewater treatment (e.g. see Makropoulos et al., 2018). Again, this could no doubt be part of a future vision of wastewater treatment but for the majority of wastewater treatment Australians use centralized large-scale treatment facilities. However, new greenfield residential and industrial developments present an opportunity and success for decentralized treatment (Horne, 2016) and some success in retrofitting brownfield development is emerging (e.g. see Makropoulos et al., 2018).

Ormerod (2016, p. 537) argues that 'the trend towards potable water recycling disrupts the normally hidden process of urban water delivery, treatment, and disposal' and by doing so, brings into question the assumption that waterborne sanitation is the only method and instead refocuses our attention to alternatives including composting toilets and dry sanitation.

LRKF6: In the longer-term, rather than considering simply retrofitting centralized treatment plants, a broader set of more viable, possibly decentralised and incentive compatible solutions to sanitation should be included as part of circular economy and lifecycle systems view.

2.2.2 Ecoservice Values of Wetlands and Swamps

Values for wetlands in treating water run-off from the land are part of the work on global assessment of ecosystem services. A key study in the environmental economic valuation of global ecosystems is that of Costanza and colleagues (1997), which provided one of the first valuations of the world's total marine and terrestrial ecosystems and resulted in a large body of supporting and critical literature (see examples from Ayres, 1998; Daly, 1998; Herendeen, 1998; Hueting et al., 1998; Serafy, 1998). One outgrowth from this work was the development of the Millennium Ecosystem Assessment (MEA 2005), whose Current States and Trends reports including chapters provides an overview of the techniques for linking the assessment of ecosystems to human well-being (DeFries et al., 2005) and summarizes the health of the world's marine fisheries (Pauly et al., 2005). Such assessments clearly demonstrated the importance of marine ecosystems to human wellbeing around the globe, as well as some of the threats to these marine ecoservices.

Since then, there has been a burgeoning scientific and conservation literature discussing how to best operationalize the definition, measurement, policy and economic uses of ecosystem services (e.g., new *Journal of Ecosystem Services* created in 2012; Special Issue, *Ecological Economics*: The Dynamics and Value of Ecosystem Services: Integrating Economic and Ecological Perspectives 2002 volume 41). In turn, others have questioned both the technical limits and wisdom of our ability to monetize various ecoservices (e.g., see Farley, 2012; Parks and Gowdy, 2013). Nonetheless, the framework of ecosystem services continues to expand and become increasingly influential at both national and international levels of the government, business, and conservation sectors. For example, a national-level macro-assessment of coastal ecoservices for Australia, conducted by Blackwell (2006a, b, 2007), is summarized in Table 3, noting that total values for beaches were missing from the global assessment, upon which the Australian assessment was based.

Table 3: Macro-level assessment of Australia's coastal ecoservices, including values associated with both marine and aquatic habitats

Category	Ecosystem	Sub-ecosystem	Area of selected ecosystems (km^2) A	Value /km^2 ($AUS 2005) B	Total annual value ($AUS billion 2005) C=A×B
Marine			12,438,119	103,704	1,359.3
	Open ocean		10,256,150	45,314	464.7
	Coastal		2,181,969	728,645	894.5
		Estuaries	16,592	4,105,563	68.1
		Open beaches [a]	14,686	-	-
		Seagrass/algae beds	51,217	3,417,227	175.1
		Coral reefs	48,960	1,092,383	53.5
		Shelf	2,065,200	289,504	597.9
Peri-terrestrial			-	124,604	-
	Wetlands		-	2,658,582	-
		Tidal marsh/mangroves	21,790	1,796,364	39.1
		Swamps/floodplains	-	3,520,801	-
	Lakes/rivers		-	1,528,078	-

More recently, there has been progress in expanding treatments of ecoservices to cultural values (Chan et al., 2012; Daniel et al., 2012). There has also been a shift in focus within marine ecosystem valuation to analyses that can help with adaptation, resilience, and transitioning, given ongoing and projected impacts from a changing climate for marine ecosystems (e.g., Cooley and Doney, 2009; NCCARF 2013). Some researchers are now calling these "adaptation values" (Butler, 2013) for which (Rolfe et al., Forthcoming) have responded in part with adaptation values for coastal crown lands in Australia.

Table 3 shows that wetlands through tidal marsh and mangroves provides a value of $1.8m AUD per square kilometer in 2005 and swamps and floodplains provide values of 3.5m AUD per square kilometer. The latter is one of the highest value biomes along with estuaries to where wastewater is typically disposed. However, at the time of the study it was known that open beaches were highly valued ecosystems for their recreational values, though these values had not been included in the global assessment upon which the national assessment was based. Logically, high value beaches and estuaries will be degraded where higher volumes and lower quality disposal of wastewater occurs. Inversely, where disposed wastewater quality is improved and the volume reduced, then the health of high value beaches and estuaries will improve. The key question here however is by how much? One value that is included in the ecosystem services provided by wetlands is for their wastewater-recycling capacity. In effect, ascertaining the costs of upgrades provide an opportunity-cost value for filtration services provided by wetlands.

2.3. Domestic Values for Upgrades

The Australian domestic values for upgrades are summarized in Table 4. Bennett et al. (2016) is the key domestic study which ascertained the WTP for:

- recycled water volume in Sydney by 2030
- recycled water reuse by (i) local councils, (ii) homes, (iii) business and industry or (iv) flush out rivers and creeks in western Sydney, and
- disposal of remaining wastewater into Sydney rivers or the ocean.

Table 4: Domestic studies of sewage/wastewater treatment facility upgrades, AUD

Authors, year date	Title	Journal	Benefits captured	Method	Payment Vehicle	Attributes	Population, sample size	Values
Alam, Rolfe & Donagy (2006)	Economic and social impact assessment of water quality improvement	AJRS	Full range of economic and social benefits of improving water quality in rivers, coastal waterways and estuaries of Queensland	Referencing values from various activities associated with use and non-use of waterways	NA	NA	Queensland, NA	Indicative rather than precise
Gillespie and Bennett (1999)	Using Contingent Valuation to Estimate Environmental Improvements Associated with Wastewater Treatment	AJEM	Untreated Sewerage treatment and disposal options for Vaucluse, area in Sydney, but level of treatment not specified	Contingent Valuation Method, Dichotomous Choice	Bid values: $5, $20, $50, $100 per household. No time frame provided so appears to be a once-off payment	Options: (a) diversion channel to Bondi STP (b) new STP at Vaucluse Christison Park & discharge through 3 existing outfalls	(a) 200 Vaucluse households; 50 Randwick households (b) 50 Vaucluse households	Median WTP, Vaucluse Tunnel $137 Randwick Tunnel $71 Vaucluse STP $76
Hardisty et al. (2013)	Determining a sustainable and economically optimal wastewater treatment and discharge strategy	JEM	Wider environmental and social benefits of adv. secondary treatment including: water, greenhouse gases, ecological impacts and community amenity, Western Australia (WA)	Value transfer included in CBA including financial costs (capital & operations) for a single site in WA over 30 yrs	NA	Financial costs (CAPEX & OPEX) and externalities	8600 households, a single site assessment	VT: See Table 5.
Bennett et al. (2016)	Community preferences for recycled water in Sydney	AJEM	Increased volume and alternative end uses (industrial, open space irrigation, domestic, enviro-flows) of recycled water for urban expansion in Sydney	Choice modelling, online	Higher rates and bills/yr	Volume of extra wastewater recycled in Sydney 2030, use alternatives: councils, business & industry, rivers & creeks, homes; disposal rivers or ocean	Sydney residents, n=824	Mean for recycled H2O: WTP/GL/yr=8.69 (6.19-11.15) 95%CI; Use: Business/Industry 19.67 (11.06-28.85) Disposal: rivers (tertiary) rather than ocean (primary)=5.69 (0.46-11.11)

Notes and Sources: CBA=cost benefit analysis. AJEM=Australasian Journal of Environmental Management. JEM=Journal of Environmental Management. AJRS=Australasian Journal of Regional Studies. H=household. MP=micropollutant. STP = sewage treatment plant. VT=value transfer.

The payment vehicle used was extra annual household council rates or bills within a choice modelling context, much like being offered a range of varying quality and quantity of goods at a supermarket with equally varying prices (payment vehicle costs). For this reason, the choice modelling approach and the context for these values are realistic.

A final dataset from the Sydney population provide a usable sample of 824 respondents, starting from a base of 18,888 email invitations with 1673 respondents accepting and 1255 completing a questionnaire.

Household awareness of Sydney's water systems and the current use of recycled water were found to be variable, with

- 27 percent of households not aware that that desalination water was being used by Sydney homes, business and councils,
- 36 percent were not aware that recycled water was being used in Sydney
- 44 percent were not aware that recycled water Is not used for drinking and
- 39 percent of households were not aware that treated wastewater was released into Sydney's rivers and oceans.

Those households more likely to be aware of recycled water use in Sydney typically lived closer to where it was used or is planned to be used by households, for example, Western Sydney, whereas households in Sydney's inner city and eastern regions were found to be less aware.

On average respondents were found to prefer an increase in recycled water for Sydney with a WTP of between $6.19 and $11.15 per year for each extra GL of recycled water to 2030 (Bennett et al. 2016, p. 63).

In addition, respondents were willing to pay between $11.06 and $28.85 each year for recycled water to be used to displace potable water use by business and industry, rather than to displace water use in homes (Bennett et al. 2016, p. 63). However, respondents were unlikely to pay (indifferent) for recycled water to be used by Western Sydney Councils or for environmental flows in Sydney rivers rather than in homes.

Importantly for this outfall upgrade study, respondents were also found to be WTP between $0.46 and $11.1 each year to have extra wastewater disposed into Sydney rivers rather than the ocean (Bennett et al. 2016, p. 63). The preference for the rivers was interpreted by Bennett et al. (2016) as reflecting a respondent understanding that wastewater disposed in rivers was required to be treated to a higher level (tertiary) than that disposed in the ocean (primary).

Bennett et al. (2016, p. 63-64, words in brackets added) go on in their study to emphasise the use of care in the interpretation of these estimates for 'cost-benefit analysis of water recycling infrastructure projects':

> We would recommend that benefit-cost analyses of specific recycling projects focus on the volumetric WTP estimates in this study (i.e. first set of estimates outlined above) and treat those estimates as a measure of all the benefits that accrue to households. The estimate of WTP to see recycled water used by business and industry as distinct from other uses should not be used as an estimate of the benefits from specific recycling projects, since respondents are not WTP this amount for each and every recycling project that contributes to the total volume of water recycled by 2030. (Bennett et al. 2016, p. 64, words in brackets added)

LRKF7: Bennett et al. (2016) provide the ideal measure of the benefits to Sydney households for increased volumes of water recycling to 2030 through annual rises in rates and bills. Their study indicates that these volumetric estimates provide a measure of the broad range of benefits from recycling water that can be used in cost-benefit analyses such as those for which this report is written.

The work of Bennett et al. (2016) is directly related to the work undertaken by Marsden Jacob Associates (2014a) and their overarching conceptual pricing and framing report for Sydney water recycling (Marsden Jacob Associates, 2013). We also note the practical guidance from Marsden Jacob Associates (2014b) for assessing the environmental and social values associated with non-potable recycled water but we note that Marsden Jacob Associates (2013, p. 32) state that:

> Finally, we note that despite a widely held intuition that water recycling will provide other environmental benefits, the effective environmental regulations in Australia mean that water extraction and wastewater discharge impacts are minimised. Therefore the most significant benefits of recycled water schemes are often reflected in the avoided costs of meeting the minimum regulatory requirements (such as lower wastewater treatment costs, nutrient abatement costs or carbon prices) rather than in direct environmental benefits.

We disagree with this statement because there is evidence that often WTPs are unable to fully process wastewater, particularly during wet and heavy weather events, such that typical standards and guidelines are breached in receiving waters, despite authorities simultaneously meeting their regulatory requirements under their licenses (see for e.g. Perraton, 2015; Perraton et al., 2015). We would therefore argue, as further evidenced through the existence of Clean Ocean Foundation and proliferation of similar NGOs (people are willing to contribute monies to these foundations to help cleanup receiving waters) and the findings of Deloitte Access Economics (2016, p. 5) for Sydney Water on the benefits of improved water quality at Sydney's coastal beaches through improved wastewater management (e.g. use and non-use values of $140m/yr, $332m/yr in value added tourism, and $140m in avoided absenteeism from illness attributable to beach water quality), that there are significance environmental (and social and economic) benefits from improvements in the quality of water being discharged into receiving waters and environments. There may be similar arguments for extraction of water resources also but we do not address those here.

LRKF8: Given the existence of the Clean Ocean Foundation, Surfers Against Sewage UK, Heal the Bay California, and Surfrider Northern Sydney, through people being willing to donate to support the work of these NGOs', combined with the findings of Deloitte Access Economics (2016, p. 5) that improvements in water quality at Sydney's coastal beaches through improved wastewater management account for use and nonuse values of $140m/yr, value added in tourism of $332m/yr

and avoided absenteeism from illness of $140m/yr, provide clear evidence of the environmental benefits from improvements in the water quality of receiving environments.

Gillespie and Bennett (1999) appears to be a highly relevant Australian study being based on valuing two options (a. pipe tunnel to existing Bondi STP or b. new STP at Vaucluse to dispose through three existing coastal outfalls) for managing untreated wastewater disposal in the Vaucluse area of Sydney. The values obtained were $137 for Vaucluse households and $71 for Randwick households for the tunnel option (a), and $76 for Vaucluse households for the new STP in Vaucluse. While the study refers to 5.1 ML/day of untreated sewage being discharged via three coastline outfalls, unfortunately the level of treatment (primary, second or tertiary) is not specified for any of the options though the first option would suggest little or no disposal in the Vaucluse area. Regardless, for Vaucluse residents, the benefit of removing discharge to the Vaucluse area coastline is a median of $26.86 per household per ML/day of discharge.

For an example of a simple cost-benefit analysis, these benefits equates to $26,860 per household per GL. The payment bid time periods are unspecified suggesting they are once-off payments. Given there are 11,840 people in Vaucluse, Watsons Bay and Rose Bay area (SA2), with an average of 2.7 people per household, there are 4,385 households in the area. With this number of households, the benefit to the Vaucluse area from removing discharges on the Vaucluse coastline is $0.6m. The Randwick residents (140,660 people, 2.5/household) WTP adjusting for the $76 in value, amounts to $4.3m. Together with the values from Vaucluse households, the total benefit from the discharge removal amount to almost $5m in benefits. Escalating this value to present day dollars using a discount rates three, six and nine percent results in a values of $9.3m, $17m and $31m.

The costs, assuming an upgrade to tertiary treatment (though this is not specified in the article) using the data we have in the method section (provided by South East Water) amounts to almost $14m. The net benefits range from -$4.7m to $17m for the range of discount rates considered. These calculations demonstrate the capacity to quickly calculate the net benefits from this given option and the sensitivity of the net benefits to the discount rate.

LRKF9: While Gillespie and Bennett (1999) appears highly relevant being a study of removing sewerage discharges to the nearby ocean for the Vaucluse area in Sydney, it has its problems. These include the WTP bids not being tied to the amount of water recycled and the level of treatment specified, time periods for the payment vehicle are not specified, and CVM is used. Given these limitations we are therefore hesitant to use these estimates to value the benefits from water recycling and we believe the Bennett et al. (2016) study is superior.

In another Australian study, similar to the above Swiss study, though at a state level in Western Australia (WA) based on a single site, Hardisty et al. (2013) undertook an economic analysis of upgrades in WA to establish the optimal level of treatment given a number of treatment options:

1. Facultative Pond Treatment, Stream Disposal – status quo, is protective of human health but is the lowest level of treatment of alternatives considered.

2. Advanced Secondary Treatment, Stream Disposal – involves intermittently decanted extended aeration plant and sand filtration and UV disinfection. Has higher capital cost and higher level of treatment than option 1 but higher quality of effluent is disposed to receiving waters.
3. Facultative Pond Treatment, Evaporation Pond Disposal – All treated wastewater is contained within the pond and except for extreme events there is no continuous discharge to the environment
4. Facultative Pond Treatment, Storage Dam Disposal, Sale of Water – Storage in the dam prevents continuous discharge to receiving waters and water can be sold to local users where demanded.
5. Tertiary Treatment, Stream Disposal – Reverse Osmosis (RO) is added to the secondary treatment option. It raises water quality to drinking level (potable). Typically exhibits high-energy requirements and cost.
6. Tertiary Treatment, Dam Storage Disposal, Sale of Water – provides the highest level of treatment and highest level of protection to the environment along with sale of the water where demand permits.

The financial costs of each of the above six options were assessed taking account of the experience of costs of the Water Corporation in Western Australia (WA) and are outlined in Table 5. Capital costs (CAPEX) include all materials, equipment and labour required to upgrade the facility. Operating costs (OPEX), including energy and non-energy costs are again based on the Corporation's empirical data from similarly sized facilities across the state. As the level of treatment increases with reduced disposal to receiving waters and increased option for sale of the water, the costs increase, both OPEX and CAPEX, though advanced secondary treatment (option 2) has higher energy operating costs than options 1, 3 & 4 which involve facultative pond treatment. Tertiary treatment (options 5 & 6) have the highest energy costs of all.

Table 5: Financial Costs of Upgrade Options, Single Plant, Western Australia, $AUD m 2008.

Option	Description	CAPEX	OPEX (/yr) – non energy	OPEX (/yr) – energy, 2009	OPEX (/yr) – energy, 2038
1	(STATUS QUO) Facultative pond treatment + stream discharge	0	0.28	0.13	0.97
2	Advanced secondary treatment, stream discharge	8	1.93	0.17	1.26
3	Facultative pond treatment, evaporation pond discharge	13	3.44	0.13	0.97
4	Facultative pond treatment, dam discharge, water sale	20	5.51	0.13	0.97
5	Tertiary treatment, RO, stream discharge	24	3.72	0.82	5.97
6	Tertiary treatment, RO, dam discharge, water sale	44	8.95	0.82	5.97

Source and notes: Hardisty et al. (2013). RO=reverse osmosis

Table 6 outlines the values transferred in the study and their literature sources. The service provision value comes from a Greek study and is not Australian.

Table 6: Benefit measures, Single Plant, Western Australia, $AUD 2008

Category	Units	Low	Base case	High	Source
Greenhouse Gasses	$/t CO_2e	0	25	85*	*Stern (2006)
Water total economic value	$/m³	0	0.35**	1.65*	**WADP&I (2007); *Wade (2001)
Biodiversity	$/hh/y	5.9	11.79*	23.58	*Loomis and White (1996)
Ecosystem support of streams	$/hh/y	25	30*	60	*Le Goffe (1995)
Community amenity of streams	$/hh/y	120*	171**	560*	**Sutherland and Walsh (1985); *Greenley et al. (1982)
Service provision	$/hh/y	-100%	17	+100%	Kontongianni et al. (2001)

Source and notes: Hardisty et al. (2013).

'Water total economic value' in Table 6 includes direct use-value, ecological support value and the option value. 'Biodiversity' related to the loss of endemic or high value species. 'Amenity value' used a study that included recreational and bequest, option and existence values. Service provision reflects a value to society from the wastewater treatment.

There are a number of assumptions in the analysis which are questionable or do not hold in the case of coastal treatment plants and outfalls; specifically:

- Assuming the outfall only contributes 10 percent of ambient pollution (In the case of Sydney's outfalls this appears much higher according to (Fagan et al., 1992) and similarly for the United States (Boesch et al., 2001)) .
- Disposing of freshwater into saltwater has negative effects on the surrounding ecosystems and environment (Blackwell and Iacovino, 2009).
- A reduction in indirect health costs is not included in the analysis (National Research Council, 1993)
- Amenity values would vary by site, for example, there is no spatial treatment in the transfer of values (Blackwell, 2006a, b, 2007).
- Under tertiary treatment, no value is attributed to reduced loss of biodiversity across all the scenarios (Otway, 1995; Stuart-Smith et al., 2015).
- There is limited value across the scenarios attributed to stream ecosystem support value (Otway, 1995; Stuart-Smith et al., 2015) or amenity value (Blackwell and Wilcox, 2009)
- Service provision remains constant across the scenarios (McNamara, 2018; Moore, 1978)
- The on-sell of water appears not to occur in scenario 4 (i.e. the authors believe there is no market) (Eckard, 2017).

Given these limitations, the authors expect that the benefits of tertiary treatment are underestimated and therefore the conclusions drawn about secondary treatment being the most optimal (while appears sound from a conceptual/theoretical economic perspective – i.e. zero or 100% treatment is not likely to be optimal – rather some level or middle quality of treatment is optimal) may not be valid once these externalities are better accounted for.

LRKF10: Hardisty et al. (2013), which finds that secondary treatment in Western Australia is more optimal than tertiary treatment, should not be relied on because a number of underlying assumptions may not be valid including, no market for the sale of recycled water (Eckard, 2017), constant service provision across the scenarios (McNamara, 2018; Moore, 1978), the assumed relatively small reduction in ambient pollution (Boesch et al., 2001; Fagan et al., 1992), health impacts are not accounted for (National Research Council, 1993), amenity value should be site dependent (Blackwell and Wilcox, 2009), no spatial component is included in the value transfer (Blackwell, 2006a, 2007), and the wider benefits (externalities) (Blackwell and Iacovino, 2009; Otway, 1995; Stuart-Smith et al., 2015) from higher levels of treatment were likely to be underestimated in the analysis. However, the example given by the study's general approach of including externalities in addition to financial costs is positive and finds in favour of secondary treatment over primary.

2.3.1. Managed Aquifer Recharge

A recent study reviewed the success of managed aquifer recharge where wastewater is used to recharge aquifers replying on a natural treatment process of filtration, sorption, degradation and infiltration through the unsaturated zone to 'polish' a given source of water to a desired quality prior to reuse (Bekele et al., 2018). Cases are referred to Perth, Western Australia, Monterey, California and Changwon, South Korea. This type of reuse is related to the ideas of constructed wetlands and has shown to provide opportunities for setting compliance targets for mitigating risks to human health while maintaining high performance MAR schemes (Bekele et al., 2018).

2.4. Improvement in Receiving Waters' Quality

2.4.1. Valuation of Marine Ecosystems

The economic literature that estimates values for components of marine ecosystems is vast but dominated by extractive and other commercial market uses, such as fisheries, aquaculture, oil and gas, and transportation. For this project, however, we focused on studies that estimate values of the marine environment for its conservation and recreational use.

2.5. Grey Literature

There is an extensive grey literature that documents the 'benefits of wastewater treatment plant upgrades'. Just in a single Google search using this term resulted in over 37 million results. Institutions from local to global scales are espousing the benefits of upgrading wastewater treatment plants, from environmental benefits (Hydroflux, 2018) of improving water quality in receiving rivers, improved river protection status, environmentally sensitive design and latest treatment and monitoring benefits, improvements in plant building heating from greater methane gas creation, and lifecycle costing reductions (City of Cornwall, 2014).

In a Canadian case study, the costs of the wastewater treatment plant upgrade was shared between the Government of Canada, Province of Ontario and City of Cornwall, each contributing $18.5m for a $55.5m Canadian dollar upgrade of the Cornwall Wastewater Treatment Plant to include secondary treatment (City of Cornwall, 2014). This will help meet Provincial and Federal policies and regulations and increase the plant's overall capacity, supporting future growth and development of the city and allowing it to better manage potential Combined Sewer Overflows.

Through the Climate Action Programme, Cavagnaro (2010) indicates that upgrades present an opportunity to:

- improve operating efficiency of a plant by automating processes and enabling limited staff to accomplish more
- help the local environment through
  - reductions in greenhouse gas and other air emissions, displacing fossil-fuel energy with renewables, such as digester gas, wind and solar power
  - enhancing water quality and wildlife habitats
- provide economic benefits such as
  - boosting the economy by creating construction, operations and maintenance jobs
  - improving the quality of biosolids provided to farmers, landscapers and residents
- improve the reliability of and consistency in permit compliance
- enhance the community's quality of life through enhanced aesthetics and recreation from improved water quality and wildlife habitats and curtailment of odors to improve community relations

A selection of examples from the world wide web include positive reports on upgrades in Cronulla, Dugog, Queanbeyan, Morpeth, North Head (NSW); Calliope (Gladstone), Mareeba, Point Lookout (Qld); Blackmans Bay (TAS); Geraldton (WA); Drouin (VIC) along with company and government website listings.

In an industry online based article, Grant (2018) presents the value of on-site wastewater treatment as including improvements in public image, compliance, cost savings, flexibility and resource recovery. Energy supplies can be neutral through anaerobic digestion systems, water can be re-used by being strategically treated to a level that is required by the organization, and by-products such as nutrient rich fertilizer can be produced high in nitrogen and phosphorus. Two case examples are provided: one where a snack manufacturer eliminates sewer charges (cost savings) through an upgrade and a second where a local authority required a confectionary manufacturer to pretreat wastewater (compliance).

2.6. Funding Options

LRKF11: Cavagnaro (2010, p. 2, 7) indicates that 'cities and water authorities can attain (the benefits of upgrades) without investing their own capital up front' through immediate long-term guaranteed cost savings and a 'Performance Contracting Funding Model'. Finance is usually structured such that monthly savings are greater than the monthly payment on the improvements (Cavagnaro, 2010, pp. 2-3). With a 'Performance Contracting Funding Model' the energy and cost savings gained through the more efficient operation of plant are defined under a performance contact over 10 to 15 years with an energy service company (ESCO). The improvements are offset from the savings that result – annual results are guaranteed by the performance contract. Where savings in a given year fall short of the contract amount, the ESCO pays the water or local government authority the difference, ensuring that set upgrade repayments are met.

In a local case study presented by the Queensland Government's Department of State Development (n.d.), the 2017 Mareeba Wastewater Treatment Plant Upgrade had a total project cost of $15m, with State Government Building our Regions funding of $1.5m, Local Government funding of $7.5m and Commonwealth funding of $6m. The Department refers to:

- 45 jobs that were created during construction,
- improved wastewater capacity to allow town population to expand to 12,500 people with future expansion to 16,500
- reduced operating and maintenance costs of the plant of $200,000 per year over the 20-year life of the plant – totaling $4m.
- improved water quality for effluent released into Two Mile Creek and operating within state government environmental standards
- biosolids used as fertilizer by local farmers on sugar cane, avocados, bananas, mangoes, lychees and cropping pastures

This information provides a sense of the $4m operating and maintenance cost savings relative to the local governments contribution to the capital costs of $7.5m which helps in covering any cost of capital.

In another example, the Cronulla Wastewater Treatment Plant in Sydney was upgraded from primary to tertiary treatment in 1999 by SUEZ (2017) to a project cost of $90m serving 210,000 people at 52.7 ML per day (dry weather). Three ML per day of recycled water is available for reuse. SUEZ operated the plant for a three year period following construction then returned it to Sydney Water with 100 percent compliance with all contractual obligations including process performance, operating cost verification and training of the future operations team. This upgrade has improved water quality at Cronulla local beaches and Bate Bay while meeting the sewage treatment needs of a growing population.

The Australian Government's Bureau of Rural Sciences (Mooney and Stenekes, 2008) undertook in 2008 a literature review and analysis of the social aspects of establishing agricultural recycled water schemes. Key drivers for schemes were the need for pollution control because of impacts of nutrients on local waterways and increasingly stringent pollution control regulations. One finding from the study was that the success of schemes depended on the creation of new water markets, where recycled water was emerging as a substitute for freshwater supplies when the later was scarce. Success of schemes depended on institutional champions including farmers and early community and stakeholder engagement as a key part of the planning process. Importantly for our study, they study also found that environmental, social and economic values were explicitly incorporated into standard assessment procedures used for recycled water options. **LRKF12: Funding was found to predominantly come from state or Commonwealth governments to meet the necessary capital hurdle for upgrades and institutional; that is, securing capital was a key to the success of schemes**. Legal arrangements were needed to overcome the competing objectives of finding alternative mechanisms to dispose of treated wastewater and the risk of securing long-term water markets for recycled water. Legal arrangements were required to cover risk of recycled water users from service providers to farmers.

2.7. Transparency

Guven et al. (2018) found that a full lifecycle approach to assessment should be undertaken to evaluate the performance of wastewater treatment plants and to compare different upgrading options, particularly in regards to evaluation of environmental impacts such as climate change, terrestrial acidification, ecotoxicity and fossil depletion. Adding food waste to wastewater can help in regards to climate change for the case at hand involving a WTP in Istanbul, Turkey. **LRKF13: A lifecycle approach to assessment and ranking of upgrades should be undertaken in order to capture the broader benefits and costs of upgrades across time.**

Apostolidis et al. (2011) state that given the recent decadal dry period combined with aggressive targets for the volume of water recycled, Australia provides an array of case studies of the developments in recycling from policy, regulatory and technological perspectives. During this time, recycled water became a legitimate source of water for non-drinking purposes in 'a diversified portfolio of water sources to mitigate climate risk' (Apostolidis et al., 2011, p. 869). The authors identify the challenge of indirect potable reuse schemes which have lacked community and political support to date. In the future, recycled water demand will increase with a growing population, urbanization and as climate change impacts are realized. Also, the evolution to date suggest that schemes will become more energy efficient reducing their GHG contribution, be integrated with urban planning, greater substitution of sources, and greater efficiency on premises of businesses allowing for multiple uses of the water before it is released to the environment. Furthermore there will be greater recovery of valuable by-products such as phosphorus, nitrogen, potassium and other commodity chemicals. **LRKF14: In the future, rather than being viewed as wastewater treatment plants these facilities may be better known as water management and nutrient and energy recovery plants.**

2.8. Conclusion

This literature review has outlined the range of values associated with wastewater treatment and water recycling. The literature on international values is vast and demonstrates a range of issues that need to be considered within the context of a domestic study on the benefits of WWTP upgrades at a national level. Of particular note is the Swiss study which assess the significant net benefits of undertaking upgrades for WWTPs across the nation to remove micro-plastics. Our reform process in Australia is yet to consider this. Such as study also demonstrates a shift in the science and public opinions on wastewater and how it could best be recycled and disposed of. In Australia, Bennett et al. (2016) provides the most recent and accurate measure of people's WTP for wastewater treatment and recycling in Australia. It uses the state of the art method, choice modelling, to estimate Sydney households WTP for each extra GL of water to 2030 from annual rates and bills. They also provide direction for the use of their estimates in undertaking a cost benefit analysis such as is undertaken in this study. For these reasons we use this estimate as described in the next section.

Other issues of importance to this study found in the literature include:

- the use of constructed wetlands, appreciation of the circular economy and dry-sanitation alternatives provide a broader understanding of alternatives and the future for wastewater management
- managed aquifer recharge has shown to provide benefits for wastewater treatment in Western Australia and poses as an alternative to traditional wastewater treatment plants
- Swamps and wetlands provide an alternative to human constructed wastewater treatment plants, but the natural habitats have limits in terms of their capacity to manage pollution and deliver such ecosystem goods and services (ecoservices)
- innovative funding solutions through immediate long-term guaranteed cost savings and performance contracting funding models, balanced by an appreciation of the public private benefits provided by upgrades and the need for Australian government to support upgrades to deliver the broader public and social benefits
- improved transparency by undertaking a lifecycle approach to the assessment and ranking of upgrades to capture the broadest possible assessment of costs and benefits over time along with an evolutionary view of seeing wastewater treatment plants as water management and nutrient and energy recovery plants.

3. Approach and Methods

3.1. Introduction and Overview

This initial study of the benefits and costs of upgrades for coastal outfalls around Australia used a relatively simply approach to capture the benefits. There is a broad range of benefits from improving wastewater upgrades as depicted in Figure 4. We used the value or benefit transfer method to assess the benefits of upgrades and relied on two approaches to the cost of upgrades; a simple one and a more complex industry approach. Because this is an initial study, there are a number of benefits which are not explicitly captured in our approach, but we make note that the Bennett et al. (2016) estimates used, without explicitly being stated represent the total WTP for the benefits received from recycling water.

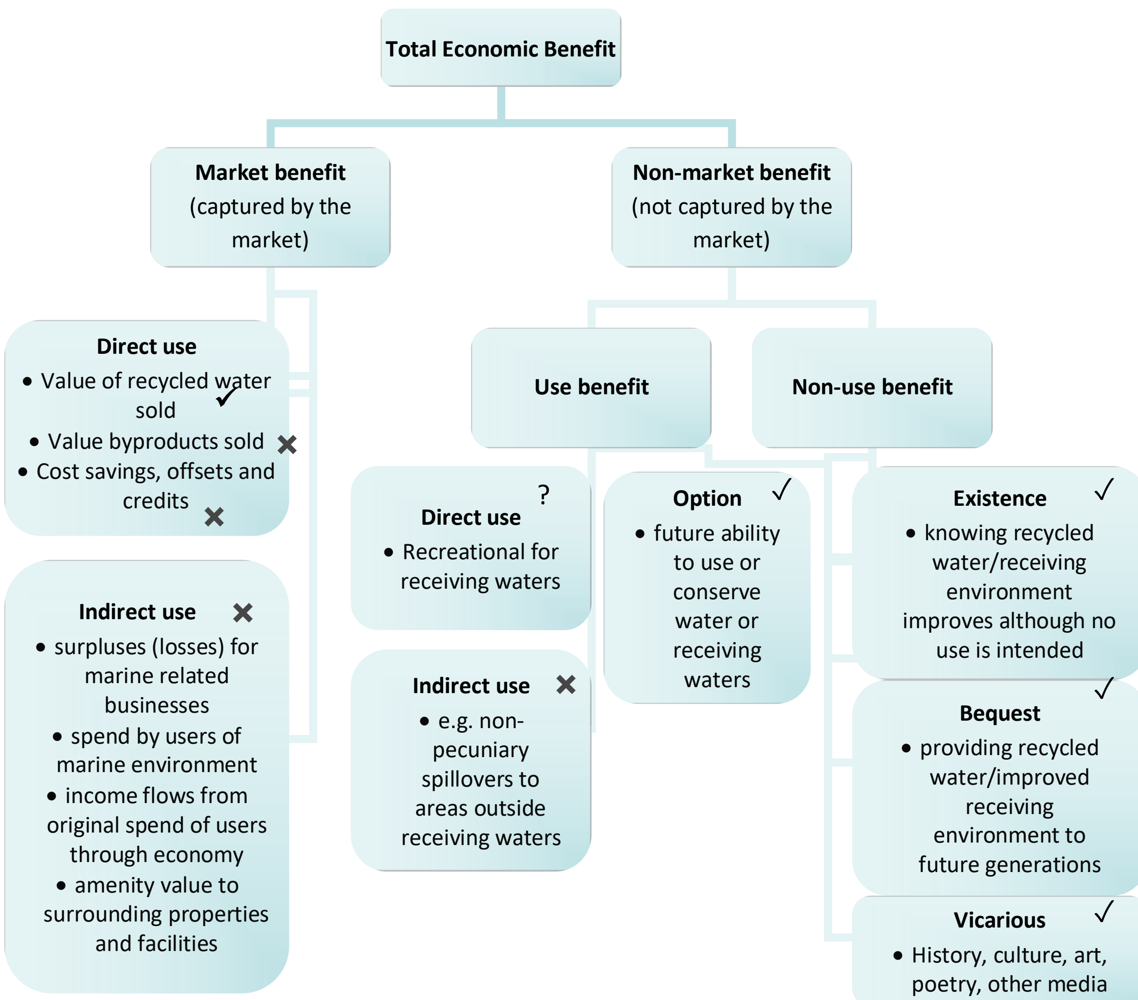


Figure 4: Market and non-market benefits of wastewater upgrades. Tick=assessed in this study; Cross=not assessed in this study and left for future research.

Therefore, to identify which components of value have been explicitly captured and which have not is difficult. A tick in Figure 4 provides those benefits that are likely to be captured through our approach, while those that are not likely to be captured in the estimates provided by Bennett et al. (2016) are indicated by a cross. Those for which wastewater recycling WTP studies typically underestimate and so whether Bennett et al. has captured these is marked by a question mark. For these reasons, we believe the estimates provided are likely to be lower bound and true benefits are likely to be larger than those presented in this report. Thus, future research could focus on those benefits not yet captured that are likely to be more significant than others. In this section we briefly outline the types of benefits and the methods used.

3.2. Types of Benefits

3.2.1 Direct and Indirect Benefits

When an upgrade to a WWTP is undertaken there are three broad groupings of benefits as a result. The first is in terms of improved quality of quantity of water recycled and available for direct use in a range of opportunities. Specifically these include for use in industry, parks and gardens and sporting facilities, and agricultural applications as well as urban water use more generally. These are particularly important when supplies are short in times of drought and recycled water has a degree of rainfall independence.

The second set of benefits that are indirectly related to the creational of additional recycled water and include improvements in plant operational efficiency resulting in cost savings such as through co-digestion and generation of methane gas to generate electricity offsetting a plants power requirements and reducing its carbon footprint (with subsequent carbon credits should there be a market for carbon).

A third set of benefits relate to the improvement in the quality and quantity of the receiving environments into which WWTP dispose the remaining wastewater. Upgrades to WWTPs, with increased water recycled, may result in less water being disposed to receiving waters, but even when there is increased water disposal (along with increased recycling – i.e. the plant capacity is expanded to meet the demands of a growing population), this is disposed at a higher quality and creates less pollution and degradation of receiving environments. With environmental improvements comes a range of economic, social and cultural, and environmental and ecological benefits.

3.2.2. Market and Non-market Benefits

Market benefits refer to those goods and services provided by upgrades that are traded in markets. Such market goods and services typically have well known prices and include the market value of recycled water that is sold, and by-products from raising the level the treatment as well as cost savings in plant operations from, for example, co-digestion and generation of methane gas to offset the plants power requirements. Where there are markets created for carbon, a reduction in the carbon footprint from such upgrades can also be considered as a market benefit. In contrast, non-market refers to those goods and services provided by the upgrade that are not traded in markets, and are therefore un-priced and not as well known. Where these are no market for carbon for example, any reduction in carbon footprint would translate to a non-market benefit. Any benefits that are captured by improved environmental, ecological or social consequences for the receiving waters location, may tend to be a non-market benefit, though these benefits may be subsequently captured by various markets in part such as marine recreation goods and service providers and tourism ventures. Together, market and non-market benefits make up the total economic benefit (TEB) of upgrades as depicted in Figure 4.

3.2.3. Use and Non-use Values

A further distinction is made in Figure 4 through application of use and non-use benefits. "Use" includes both consumptive (or extractive) and non-consumptive (non-extractive) utilization of a good or service. Recycled water used for irrigation or sporting fields are consumptive (though typically from a common pool of water resources), while recreators or tourists whom share the area of improved water quality from receiving waters enjoy non-consumptive use of the resource.

In contrast to use values, non-use or conservation values of upgrades include existence, bequest, vicarious, and option values. People in a community may value the existence of improved environmental and ecological health of an area of receiving waters (i.e. beaches, rivers, estuaries, bays and the ocean) though they may never use these locations themselves. Others may also value bequesting to other people (including their children or future generations) improved environmental and social outcomes for receiving waters. Vicarious value of improvements in water quality may also translate to improved opportunities in the arts, song, dance and cultural more generally. Furthermore, while some people may not currently use the receiving water's location for recreation or tourism, once upgraded and the water quality improves, they then have the option of doing so, even where they don't currently use the site. Option value is therefore an important to conceptualizing the opportunities for improved benefits through outfall upgrades. In this sense, there is a latent demand for recreation at a polluted receiving waters site, which is not realized until the upgrade is complete, environmental quality improves, and the demand for recreation is realized over time.

3.2.4. Ecosystem Goods and Services – "Ecoservices"

The final distinction in values is that provided through the concept of ecoservices (ecosystem goods and services). Such an approach identifies the goods and services provided by ecosystems into key types:

- provisioning services, such as food and materials;
- regulating services, such as storm and flood protection;
- cultural services, such as providing for recreation, health, spirituality, and education; and
- supporting services, such as providing refuge for species and for its reproduction

A taxonomy of ecoservice components is provided in Table 7. Note in the table that there are specific water related ecoservices provided by well-functioning receiving water environments such as the provision of freshwater (through the water cycle), water regulation and purification, serenity and amenity values, recreation and tourism, water cycling and nutrient cycling and regulation. However, healthy receiving water ecosystems, provide the full range of ecoservices outlined in Table 7. With a deterioration of the health of receiving water ecosystems (including the associated zones such as the open ocean, riparian zones, shores and beaches), the full range of ecoservices can deteriorate. By undertaking upgrades, water quality and receiving environment health can improve, with co-benefits to the full range of improvements in ecosystem services detailed in Table 7.

The ecoservices approach helps align the well-being of humans with the health of the ecosystems that they rely on. As the health of an ecosystem deteriorates, so too do the sustainable flows of ecoservices and the benefits to humans. A recent global analysis of marine and coastal ecosystem health, calculated country by country, utilizes this framework of sustainable ecosystem services and human benefits to develop an Ocean Health Index (Halpern et al., 2012). In general, marine ecosystems (including coastal ecosystems) can assimilate and process certain levels of pollutants, for example from wastewater outfalls, without having populations and communities reach tipping points that change ecosystem dynamics in non-linear and unfavorable ways. However, with increased pressure from a number of sources, including increased human populations and increased wastewater pollution, coastal waterway assimilative capacity can be breached, particularly in the mixing zone of the outfall. For this reason, WTP upgrades often have multiple goals of improved recreational outcomes in addition to broader biodiversity conservation. These multiple goals are implicitly represented in the different TEB components depicted in Figure 2.

Table 7: Types of ecoservices (Blackwell, 2006b).

Category	Ecoservice
Provisioning services	Freshwater
	Food
	Fiber (*including clothing and shelter*)
	Fuel
	Genetic resources
	Biochemicals, natural medicines and pharmaceuticals
	Ornamental resources
Regulating services	Air quality regulation
	Climate regulation
	Water regulation
	Erosion regulation
	Water purification
	Waste treatment
	Disease regulation
	Pest regulation
	Natural hazard regulation
Cultural services	Cultural diversity
	Spiritual and religious values
	Knowledge systems
	Inspiration
	Aesthetic and *serenity* values
	Social relations
	Sense of place
	Cultural heritage, historic and artistic values
	Recreation and ecotourism
Supporting services	Sand or soil formation
	Photosynthesis
	Primary production
	Nutrient cycling/regulation
	Water cycling

3.3. Methods

In order to gain net benefits we subtracted from the estimated benefits of upgrades their respective estimates costs. Upgrades occurred for secondary and primary levels of WWTP. Where a plant was tertiary, no upgrade was warranted and these are presented as no change in the priority ranking tables in the results section.[8] Upgrading all plants to the same tertiary level was required to be assumed ensure that across upgrades, the quality of water disposed into receiving waters was the same, comparing like for like in preparation of the cost and benefit estimates. In terms of nexus with wastewater, the costs of upgrade were driven by discharge limits (as undertaken by South East Water – see below) and the benefits from upgrade were driven by the amount of flow adjusted for a proportion that would not be recycled (assuming not all water will be recycled in realty all cases). The costs of upgrades are not driven by the same parameters as the benefits of upgrades – there is a natural dichotomy here and these are detailed in the following sections.

3.3.1 Benefit Estimates

The main method we have used to estimate the benefits from wastewater upgrades is to transfer relevant economic benefit estimates ('values') from previous studies.[9] The literature review in the previous section outlines the range of values available in the literature. For the reasons noted, the most relevant is the study by Bennett et al. (2016) which undertook a choice modeling study of Sydney residents on their WTP for recycled water. In their study, they note specifically the application of their values to cost-benefit studies. Bennett et al. (2016) stipulate that the estimates can be used in wastewater upgrade assessments but that their estimates for increased water recycling are the key ones to use rather than where the water is ultimately used or how the water is disposed (rivers or ocean). We therefore apply this advice in the study at hand. We do so by taking Bennett et al. estimates of WTP per household per GL of recycled water, converting them to 2019 current dollars on per ML basis, and multiplying by the flow of the relevant wastewater treatment plants collected by the NOD, over the period of the project, using Net Present Value analysis. Because not all wastewater flow in any given year will be recycled, we reduced the annual amount of water to be recycled to 63 percent which reflected the weighted average wastewater recycled, calculated from schemes surveyed across Australia using Apostolidis et al. (2011). We also used two time periods for the upgrade project, 15 and 30 yrs and a range of discount rates (r = 3, 6 or 9%) in the NPV analysis to allow for sensitivity analysis of the benefits.

In applying the value transfer method we followed the process suggested by John Rolfe (pers. comms, 7 January 2019) to consider the following steps:

1. **Assess target situation** – this is the upgrading to tertiary treatment level Australia's 176 coastal outfall systems.
2. **Identify source studies available** and select benefit transfer type where the type is dependent on source studies. While there were three main studies available, as noted above, Bennett et al. (2016) is the most recent and appropriate study that assesses the total benefits for recycled water in Sydney. Gillespie and Bennett (2009) is less preferred because

[8] There are actually different levels of tertiary treatment and future research should distinguish between those that treat to a higher level.

[9] Value transfer involves reviewing primary research undertaken to assess the economic value of similar or related sites and translating these values to the case study site. This approach can be quite complex and appropriate measures to transfer the values from the primary site(s) must be used. Such measures can include areas of habitat and numbers of users depending on the particular valuation method used in the primary research.

it involves contingent valuation, considered less rigorous to choice modelling (as undertaken by Bennett et al. (2016), and because it only assesses the benefits of removing disposal, not the total benefits of using the recycled water. Marsden Jacob (2014) is the same study as Bennett et al. (2016). The benefits from Gillespie and Bennett (1999) could be added to those from Bennett et al. (2016) but this may involve some double counting.

3. **Assess site difference**s and identify if Benefit Transfer (BT) is possible and basis for BT adjustment. While no two sites are identical, Sydney represents the majority of the Australia population, is specific to Australia and involves decisions of recycling and disposal. The key adjustment mechanism is the flow of wastewater through the outfall system. For value transfer, having an example like Bennett et al. (2016), which is so close the cases at hand, is not typical of benefit transfer applications.
4. **Assess population differences** by identifying if BT is possible and the basis for the BT adjustment. At each outfall system, the relevant local or serviced population was obtained typically from the ABS 2016 census data or from the service provider licenses. These were then converted to household numbers using an average household size making the BT adjustment possible.
5. **Assess scale of change in both cases** and identify if BT possible and basis for BT adjustment. As noted above, the scale of change, is the amount of flow treated and available for reuse. These were obtained from the NOD for all of Australia's outfalls. A limitation is that the Bennett et al. (2016) study was for GL of water recycled by 2030, where in many small scale outfall systems, the scale is in the order of ML. Regardless, conversions were made for scale to assess the benefits at the smaller scale.
6. **Assess framing issues** (scope, scale, instrument, payment vehicle and length, WTP or accept format used, use versus non-use) to test if the source study is appropriate for BT and identify any basis for BT adjustment. The study by Bennett et al. (2016) used choice modelling to assess Sydney households WTP to increased water recycling by 2030. As noted in the literature review, it did so by also considering whether disposal should be moved from rivers to the ocean but people had lower WTP for this option, most probably as the authors point out because river disposal requires higher levels of treatment. Adjustments were made for scale and scope through the flow measures. Payment vehicle and length were appropriate being household annual water rates or bills. Bennett et al. (2015) represents the total benefits from recycling the water but may have a greater reflection of use versus non-use values, though by using these measures, the benefits will be conservative.
7. **Assess statistical modelling issues** by identifying appropriateness of model in source study and identify any basis for BT transfer. There were very few statistical modelling issues in Bennett et al. (2016) – the main one being that respondents were found to not be willing to pay more for disposal of wastewater to the ocean rather than rivers, because as the authors suggested, people saw rivers as providing higher treatment levels. This sits will with the study at hand.
8. **Perform benefit transfer process** – we do this as stated above and present the results in the results section.

3.3.2 Cost Estimates

Two estimates of costs were prepared. One using a simple method based on an upfront fixed cost of $5m, regardless of the capacity of the treatment plant, combined with a variable cost of $1m per ML per day.

The second estimate was prepared by South East Water engineers and includes a component for capital expenditure and operational expenditure both of which depend on the capacity of the plant. This analysis provided tenth (lower bound), likely and ninetieth percentile (upper bound) estimates of costs. We simply add capital and operational costs for a given plant's capacity. We present the likely costs here noting that actual costs are subject to a range of site-specific variations and should be prepared separately on a case by case basis before any upgrade decision is made. For this reason, the cost estimates provided here are preliminary and with further estimates required taking account of site-specific context to increase their accuracy. Figures 5 and 6 provide illustrations of the cost estimates prepared by South East Water and used in this study.

3.3.3 Stakeholders

Key stakeholders are outlined in Table 8. Beneficiaries of upgrades include local households (and their political representatives) and visitors (both benefit from increased water supply or increased benefits from improvements in receiving waters), water service providers and non-use interest populations within and outside the local area. Stakeholders whom may help in funding upgrades include the service providers themselves, various levels of government, members of the local community from their rates or water charges, community and NGO groups such as COF (though typically their resources are relatively limited), and the private sector (including tourism industry and philanthropic groups).

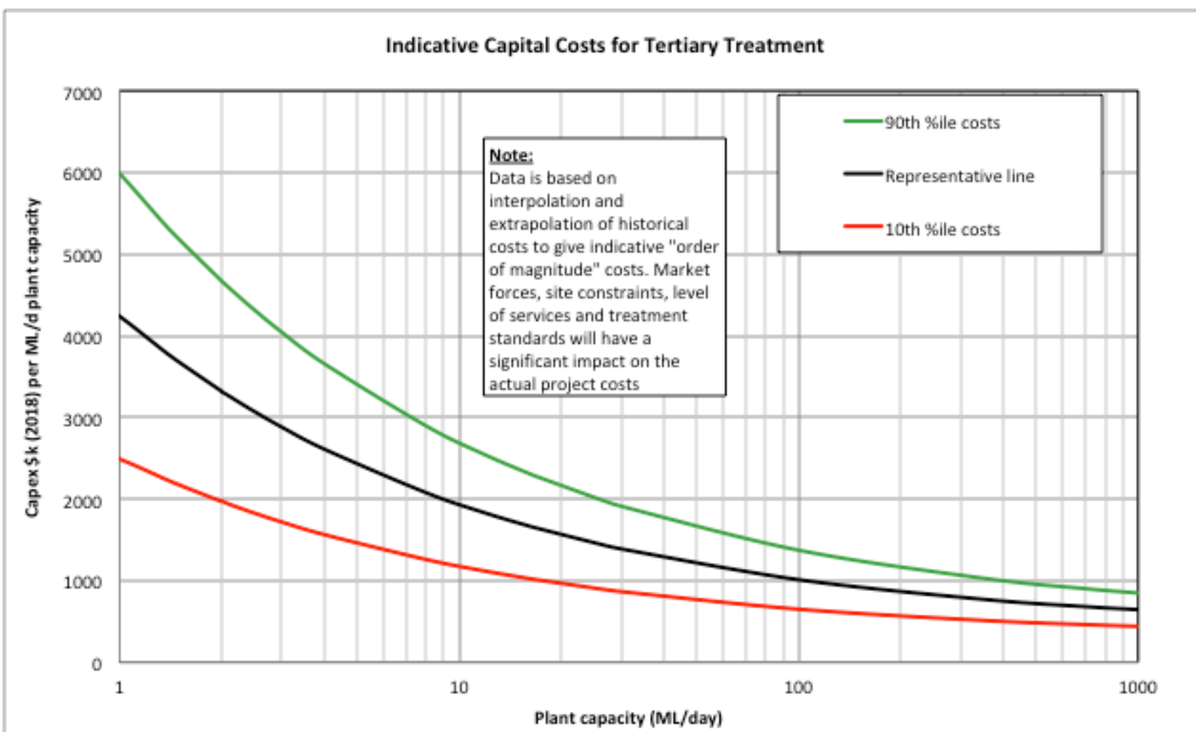


Figure 5: Indicative Capital Cost Estimates for Tertiary Treatment. (Source South East Water 2018.)

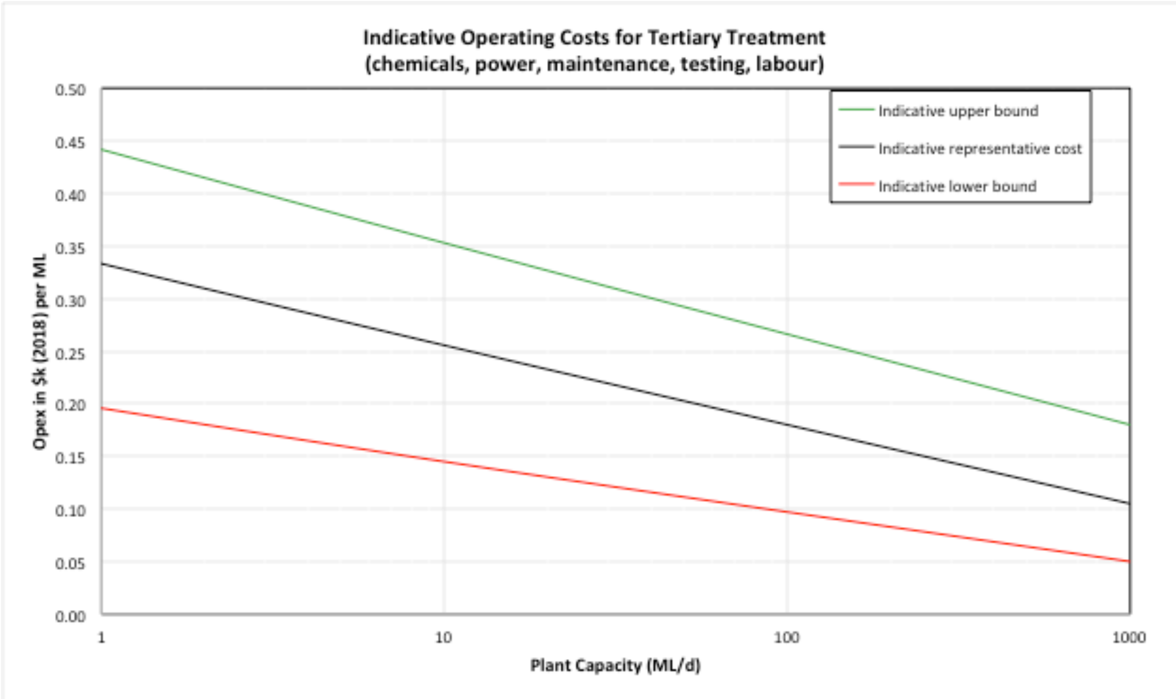


Figure 6: Indicative Operating Costs Estimates for Tertiary Treatment. (Source South East Water 2018. Accounts for chemicals, power (Assumes 500 kWhr/ML for 0.5 to 1 ML/d plant and 300 kWHr/ML for 1000 ML/d plant), testing and labour.

Table 8: Stakeholder matrix

Stakeholder Grouping	Types
Beneficiaries of Upgrades	Local household population and their political representatives
	Visitors from outside the local population
	Water service providers
	Non-users within or outside the local population
Funders of Upgrades	Water Service Providers
	Local Government Authority, State and Australian Governments
	Recycled water and by-product users
	Private sector (including tourist and recreational market industry)
	Where resources available, NGO or community groups

3.4. Summary and Conclusion

This section of the report has outlined our approach and the methods used to value the benefits and costs of upgrades of WWTPs from primary or secondary to tertiary treatment levels. Once estimated, we subtract the costs from the benefits of upgrade for each of the 176 outfalls around coastal Australia to assess each outfalls net benefits. We then rank each outfall from highest to lowest net benefit in the results presented in the following section. We take account of the time value of benefits and costs by using a net present value approach (with discount rates of 3, 6 and 9%) and lifespans of plants of 15 or 30 years to allow for some sensitivity analysis.

Outfall upgrades provide a range of benefits, from increased recycle water, byproducts, cost savings and credits as market benefits through to boarder benefits from higher quality wastewater disposed to receiving environments. These broader benefits also include those related to recreation and spillovers into various industries including tourism and the value of nearby property. This in turn provides ripple effects through the local economy raising jobs and income (not just from the upgrade) and society in improving the amenity and sense of place. Given this study is a preliminary assessment, a number of these broader benefits are not assessed and should form part of future research focus. For these reasons the estimates given in this report should be seen as lower bound.

One vexed area of benefits is option values associated with upgrades, particularly those from improvements in water quality and increased demand for recreational use of the receiving water sites. Because receiving water quality is typically low for (primary and secondary treatment) outfall sites, current demand levels do not reflect the potential for increased demand given environmental improvement. Our approach does not take account of rising populations (though upgrades typically include increased capacity to treat water and increases in recycled water) of recreational receiving waters and these are likely to be latent and less obvious until the upgrades are undertaken, water quality improves and recreation demand grows at these sites. Furthermore, even where people don't hold current recreational values, they may hold significant option value to undertake recreation and other activities at the site in question. For these reasons our benefit estimates are conservative.

Two methods of estimating costs were used, one that is simple with a fixed $5m estimate plus a $1m per ML per day. The second set of estimates was provided by a water authority and account for capital expenditure and operation expenditure varying by the capacity of the given plant. For larger plants the second set of estimates tended to be less than the first, while for smaller plants the second set of cost estimates were above those of the first. These differences reflect the non-linear (curve) nature of costs accounted for in the second set of estimates, whereas the first is linear. These estimates are preliminary and actual costs and benefits of upgrades will be dependent on site-specific details and require further detailed case-by-case assessment.

There are a range of stakeholders involved in WWTP upgrades broadly broken into those that benefit and those that may help to fund upgrades. Beneficiaries include the local population and visitors (and their political representatives) (both from the increased volume of water supply and improvements in receiving water quality and adjacent areas), water service providers, and people with non-use interests (existence, bequest, vicarious). Likely funders of upgrades include all levels of government, the private sector (including tourism industry and philanthropists), NGOs and community groups (though these typically are not well resourced), service providers, the public through higher rates or water charges (or other mechanism). We discuss the options for funding in more detail in the literature review and results sections of this report along with a discussion of transparency.

4. Results

4.1. Introduction

In this section of the report, using the methods outlined in previous section, we present the results from our assessment of the net benefits of upgrades. These results can be divided into

- total state summaries and rankings
- state rankings of individual outfalls and
- national rankings of individual outfalls.

4.2. Total State Rankings

State and territory total rankings (except for ACT which is land locked) of net benefits from upgrades are summarized in Table 9 for a 30-year project period and in Table 10 for a 15-year project period. The total state rankings do not change depending on the period or discount rate (3, 6 & 9%) used. In contrast, the magnitude of net benefits changes considerably, with net benefits being larger for a longer project period. Across the nation the net benefits from upgrades sum to between $12 to 28 billion. All states and territories overall have net benefits from upgrades except for the Northern Territory and Tasmania which experience net losses. Victoria's net benefits move from negative to positive when moving from a 15 to 30-year time period of assessment. NSW has the largest net benefit ($8-19 billion), followed by Western Australia ($3-5 billion), South Australia ($2-3 billion), Queensland ($90-730 m), Victoria (-$24 m to 150 m), Northern Territory ($-46 m to -54 m) and Tasmania (-$411m to -460m).

Table 9: Net benefits (NBs) and Costs of outfalls, ranked by state totals, 2019 $m, t=30 years

State/territory	n	NB r=9%	Costs	NB r=6%	Costs	NB r=3%	Costs
New South Wales	28	11,667.3	5,246.6	14,380.0	5,887.7	18,769.8	6,959.4
Western Australia	12	3,380.3	620.2	4,118.5	675.3	5,318.3	767.3
South Australia	10	2,142.3	280.5	2,597.5	305.8	3,337.6	348.0
Queensland	51	294.7	842.4	460.0	902.7	726.5	1,003.3
Victoria	19	33.2	291.0	76.8	311.7	146.8	346.3
Northern Territory	6	-52.5	94.0	-50.0	99.7	-46.1	109.2
Tasmania	41	-413.7	499.8	-429.7	533.0	-457.4	588.5
Grand Total	**167**	**17,051.6**	**7,874.6**	**21,153.1**	**8,715.9**	**27,795.6**	**10,122.0**

Table 10: Net benefits (NBs) and Costs of outfalls, ranked by state totals, 2019 $m, t=15 years

State/territory	n	NB r=9%	Costs	NB r=6%	Costs	NB r=3%	Costs
New South Wales	28	8,430.4	4,840.2	9,157.1	5,143.5	10,118.5	5,552.2
Western Australia	12	2,553.5	585.3	2,771.1	611.4	3,060.0	646.5
South Australia	10	1,636.4	264.5	1,772.0	276.5	1,952.2	292.6
Queensland	51	88.0	804.2	128.7	832.7	182.5	871.1
Victoria	19	-23.5	277.8	-13.6	287.6	-0.5	300.8
Northern Territory	6	-57.9	90.4	-58.0	93.1	-58.3	96.8
Tasmania	41	-411.2	478.8	-421.6	494.5	-435.8	515.7
Grand Total	**167**	**12,215.7**	**7,341.4**	**13,335.7**	**7,739.3**	**14,818.6**	**8,275.6**

Costs of upgrades are also presented alongside the net benefits (NBs). Total national costs of upgrades range from $7.3 billion to just over $10 billion with a middle score of $7.9 billion for a 30-year project period at a discount rate of nine percent. The ranking of state or territory costs of upgrade do not match that for net benefits; while New South Wales has the largest and most significant state costs ($4.8-$7 billion), Queensland has the next highest total state costs ($0.8-$1 billion), followed by Western Australia ($0.6-$0.8 billion) and then Tasmania ($0.5-$0.6 billion). Northern Territory has the least costs of upgrades ($90-$110 m) closely followed by South Australia ($300-$350 m).

These cost structures are partly reflected by Queensland having the largest number of coastal outfalls at 51, followed by Tasmania with 41, and NSW at 28. The Northern Territory has the fewest number of coastal outfalls at 6, two of which have limited information.

The net loss for Tasmania reflects a recent period of difficulties in water reform with movements to regional water authorities from local government management of water and waste water services, back to a single state-based agency. This may well reflect a large number of aging assets across a relatively small population of users.

In contrast, NSW has the largest population of all states across which a larger accumulation of net benefits is likely, though one would expect the same for Victoria being the second largest populated state but it has nine fewer outfalls than NSW. Interestingly, Queensland has the largest number of outfalls and the third largest population in Australia relative to NSW and Victoria, but the benefits from upgrades are relatively smaller. This may reflect a large state area and greater dispersal of population (i.e. relatively smaller local populations for a given outfall) along the coast where outfalls are located. Victoria may suffer from smaller local populations too.

4.3. State Rankings of Individual Outfalls

Tables 11 and 12 provide state rankings for individual outfalls using a 30-year time period and discount rate of nine percent. Despite most states providing positive net benefits for upgrades in total, all states and territories have a larger number of outfalls that have negative net benefits than positive. This may reflect the historically dispersed and 'local public good' nature and cost structure of wastewater treatment and disposal.[10] Having said that, because total net benefits are positive, a number of larger investment projects in each state provide sufficient net benefits to offset those large number of projects with net losses, as is particularly the case in New South Wales, Western Australia and South Australia, in that order. This finding also holds to a lesser extent in Queensland and Victoria. Further individual state insights can be gleaned from considering the detail of Tables 11 and 12 and is left for the readers own interpretation and needs.

Further state and territory rankings at 15 years and a discount rate of nine percent are provided in Appendix A.

[10] This cost structure maybe one that is by design. We have undertaken no detailed evaluation of the analysis of micro-treatment technology and processes which may prove to have a different cost structure.

Table 11: Net benefits (NBs) and Costs of outfalls, Qld, Tas and NSW, 2019 $m, t=30 years, r=9%

Qld	NBs	Costs	Tas	NBs	Costs	NSW	NBs	Costs
Oxley	316.2	98.7	Macquarie Point	31.5	23.3	Malabar	8,178.2	1,222.6
Loganholme	199.9	110.9	Boat Harbour	0.0	0.0	North Head	3,028.7	1,408.5
Maroochydore	32.7	58.9	Cambridge	0.0	0.0	Burwood Beach	522.0	567.0
Sandgate	10.5	46.4	Rokeby	0.0	0.0	Bondi	468.5	732.5
Beenleigh	0.0	0.0	Round Hill	0.0	0.0	Belmont	81.4	532.4
Bowen	0.0	0.0	Selfs Point	0.0	0.0	Port Kembla [a]	4.0	0.0
Cannonvale	0.0	0.0	Sisters Beach	0.0	0.0	Bellambi [a]	3.3	0.0
Capalaba	0.0	0.0	Margate	-1.4	1.4	Batemans Bay	0.0	0.0
Cleveland Bay	0.0	0.0	Dover	-1.5	1.5	Camden Head	0.0	0.0
Coombabah	0.0	0.0	Richmond [b]	-1.5	1.5	Coffs Harbour	0.0	0.0
Edmonton	0.0	0.0	Bridport	-1.6	1.6	Coniston Beach	0.0	0.0
Elanora	0.0	0.0	Triabunna	-1.7	1.7	Forster	0.0	0.0
Gibson Island	0.0	0.0	Strahan	-1.8	1.8	Narooma	0.0	0.0
Innisfail	0.0	0.0	Currie	-1.9	1.9	Penguin Heads	0.0	0.0
Luggage Point	0.0	0.0	Cygnet	-2.1	2.1	Potter Point	0.0	0.0
Mackay North	0.0	0.0	Electrona	-2.1	2.1	Skennars Head	0.0	0.0
Mackay Southern	0.0	0.0	Turners Beach	-2.5	2.5	Tomakin	0.0	0.0
Marlin Coast	0.0	0.0	Bicheno	-2.7	2.7	Bermagui	-5.2	5.2
Merrimac	0.0	0.0	Orford	-2.8	2.8	Eden	-7.4	7.4
Millbank	0.0	0.0	Risdon	-3.6	3.7	Merimbula	-11.8	12.0
Mt St John	0.0	0.0	St Helens	-3.6	3.6	Crescent Head	-13.0	13.1
North Rockhampton	0.0	0.0	Port Sorell	-4.0	4.0	Wonga Point	-24.8	61.6
Port Douglas	0.0	0.0	Sorell	-4.0	4.0	Ulladulla	-36.7	39.1
South Rockhampton	0.0	0.0	Midway Point	-4.0	4.0	Norah Head	-37.7	67.0
Thorneside	0.0	0.0	Somerset	-4.5	4.6	Bombo	-71.0	73.5
Victoria Point	0.0	0.0	Riverside	-7.1	7.2	Boulder Bay	-76.4	116.9
West Rockhampton	0.0	0.0	Bridgewater	-7.3	7.4	Warriewood	-145.6	169.0
Woree	0.0	0.0	Ulverstone	-8.5	11.4	Shellharbour	-189.3	218.8
Lucinda [c]	-0.2	0.2	Cameron Bay	-10.3	12.0			
Karana Downs	-2.0	2.0	Wynyard	-10.4	10.9			
Tin Can Bay [c]	-4.5	4.5	Blackmans Bay	-11.3	12.0			
South Trees Inlet [b]	-5.2	5.2	Newnham	-11.4	11.8			
Landsborough	-5.5	6.1	Hoblers Bridge	-12.0	12.3			
Redcliffe	-6.3	25.8	Stanley	-13.5	13.5			
Fairfield	-8.0	8.7	Port Arthur	-14.1	14.1			
Bundamba	-8.4	44.2	Pardoe	-14.2	25.0			
Burpengary East	-9.0	23.3	Rosny	-14.7	16.0			
Caboolture South	-9.2	23.3	Prince of Wales Bay	-16.8	19.8			
Eli Creek	-11.0	13.1	Ti-tree Bend	-38.5	46.4			
Goodna	-11.1	39.8	George Town	-53.8	54.8			
Coolum	-11.4	15.1	Smithton	-153.8	154.2			
Carole Park	-14.1	16.0						
East Bundaberg [d]	-15.2	30.8						
Wynnum [d]	-15.7	18.9						
Gladstone [b]	-16.5	23.3						
Nambour	-16.6	22.9						
Kawana	-16.7	58.9						
Pulgul Creek	-17.9	17.9						
Murrumba Downs	-18.0	78.7						
Wacol [d]	-20.3	24.6						
Maryborough	-21.9	24.1						
Total	**294.7**	**842.4**		**(413.7)**	**499.8**		**11,667.3**	**5,246.6**

Notes: a. Net benefits for Port Kembla and Belambi represent benefits only without a cost estimate because these outfalls are mainly used for overflow during wet weather only, are part of the Conniston Beach system which is at a primary treatment level (i.e. upgrade not assessed for purposes of this report), have no discharge limit and upgrade costs are based on discharge limits. Their costs of upgrades would need to be assessed individually. b. The flow estimates of these upgrades may be subject to significant error and the resulting net benefit estimates should be interpreted with caution. Their benefits of upgrades would need to be assessed on a more nuanced case-by-case basis. c. The net benefit and cost estimates of these outfalls should be interpreted with caution and more nuanced assessments should be undertaken to gain better estimates of these upgrades. d. The cost estimates for these upgrades should be viewed with caution. Nuanced case-by-case cost assessments are required for these upgrades.

Table 12: Net benefits (NBs) & Costs of outfalls, Vic, WA, SA and NT, 2019 $m, t=30 years, r=9%

Vic	NBs	Costs	WA	NBs	Costs	SA	NBs	Costs	NT	NBs	Costs
Black Rock	170	105	Woodman Point	2,235	186	Bolivar WWTP	2,203	213	Berrimah	-6	6
Anglesea	0	0	Beenyup	1,317	180	Bolivar High Salinity	0	0	Ludmilla	-11	30
Apollo Bay	0	0	Subiaco	0	0	Glenelg	0	0	Leanyer Sanderson	-15	32
Boags Rock	0	0	Wickham	0	0	Northern outfall	0	0	Palmerston	-20	27
Boneo	0	0	Home Island	-1	1	Southern outfall	0	0	Galiwinku	Nil info.	Nil info.
Delray Beach	0	0	Christmas Island	-7	7	Port Augusta	-9	9	Maningrida	Nil Info.	Nil Info.
Lorne	0	0	South Wetlands	-15	18	Port Pirie	-11	12			
Werribee	0	0	North Wetlands	-17	18	Port Lincoln	-12	12			
Foster	-3	3	Alkimos	-20	39	Finger Point	-13	16			
Port Welshpool	-3	3	Point Peron	-27	39	Whyalla	-17	18			
Port Fairy Ind	-4	4	East Rockingham	-39	39						
Toora	-5	5	Bunbury	-46	94						
Baxters Beach	-8	10									
Port Fairy Dom	-9	9									
Cowes	-11	12									
Portland	-13	14									
Altona	-17	33									
Warrnambool	-28	34									
McGaurans	-36	60									
Total	**33**	**291**		**3,380**	**620**		**2,142**	**281**		**-53**	**94**

4.4. National Rankings

Table 13 provides a national ranking of individual outfalls from largest to smallest net benefits, regardless of state based location over 30 years at a discount rate of nine percent. Net benefits range from $8.2 billion for Malabar, $3 billion for North Head, $0.5 billion for Bondi, $0.3 billion for Oxley, $32m for Maroochydore, $11m for Sandgate, through to losses at Karana Downs of $2m and up to $190m at Shellharbour.

The national rankings change depending on the discount rate and project time period. Rankings for a period of 15 years at a discount rate of nine percent are provided in Appendix B.

Table 13: Net benefits (NBs) & Costs of outfalls, ranked by 2019 $m, 30 years, r=0.09

Outfall Name	Net Benefits $m	Costs $m
Malabar	8,178.2	1222.6
North Head	3,028.7	1408.5
Woodman Point	2,235.2	185.8
Bolivar WWTP	2,203.3	213.4
Beenyup	1,316.8	180.2
Burwood Beach	522.0	567.0
Bondi	468.5	732.5
Oxley	316.2	98.7
Loganholme	199.9	110.9
Black Rock	170.0	104.8
Belmont	81.4	532.4
Maroochydore	32.7	58.9
Macquarie Point	31.5	23.3
Sandgate	10.5	46.4
Port Kembla [a]	4.0	0.0
Bellambi [a]	3.3	0.0
Anglesea	0.0	0.0
Apollo Bay	0.0	0.0
Batemans Bay	0.0	0.0
Beenleigh	0.0	0.0
Boags Rock	0.0	0.0
Boat Harbour	0.0	0.0
Bolivar High Salinity	0.0	0.0
Boneo	0.0	0.0
Bowen	0.0	0.0
Cambridge	0.0	0.0
Camden Head	0.0	0.0
Cannonvale	0.0	0.0
Capalaba	0.0	0.0
Cleveland Bay	0.0	0.0
Coffs Harbour	0.0	0.0
Coniston Beach	0.0	0.0
Coombabah	0.0	0.0
Delray Beach	0.0	0.0
Edmonton	0.0	0.0
Elanora	0.0	0.0
Forster	0.0	0.0
Gibson Island	0.0	0.0
Glenelg	0.0	0.0
Innisfail	0.0	0.0
Lorne	0.0	0.0
Luggage Point	0.0	0.0
Mackay North	0.0	0.0
Mackay Southern	0.0	0.0
Marlin Coast	0.0	0.0
Merrimac	0.0	0.0
Millbank	0.0	0.0

Outfall Name	Net Benefits $m	Costs $m
Mt St John	0.0	0.0
Narooma	0.0	0.0
North Rockhampton	0.0	0.0
Northern outfall	0.0	0.0
Penguin Heads	0.0	0.0
Port Douglas	0.0	0.0
Potter Point	0.0	0.0
Rokeby	0.0	0.0
Round Hill	0.0	0.0
Selfs Point	0.0	0.0
Sisters Beach	0.0	0.0
Skennars Head	0.0	0.0
South Rockhampton	0.0	0.0
Southern outfall	0.0	0.0
Subiaco	0.0	0.0
Thorneside	0.0	0.0
Tomakin	0.0	0.0
Victoria Point	0.0	0.0
Werribee	0.0	0.0
West Rockhampton	0.0	0.0
Wickham	0.0	0.0
Woree	0.0	0.0
Lucinda [c]	-0.2	0.2
Margate	-1.4	1.4
Home Island	-1.4	1.4
Dover	-1.5	1.5
Richmond [b]	-1.5	1.5
Bridport	-1.6	1.6
Triabunna	-1.7	1.7
Strahan	-1.8	1.8
Currie	-1.9	1.9
Karana Downs	-2.0	2.0
Cygnet	-2.1	2.1
Electrona	-2.1	2.1
Turners Beach	-2.5	2.5
Foster	-2.5	2.5
Port Welshpool	-2.7	2.7
Bicheno	-2.7	2.7
Orford	-2.8	2.8
Risdon	-3.6	3.7
St Helens	-3.6	3.6
Port Fairy Ind	-3.7	3.7
Port Sorell	-4.0	4.0
Sorell	-4.0	4.0
Midway Point	-4.0	4.0
Tin Can Bay [c]	-4.5	4.5
Somerset	-4.5	4.6

Outfall Name	Net Benefits $m	Costs $m
Bermagui	-5.2	5.2
South Trees Inlet [b]	-5.2	5.2
Toora	-5.2	5.2
Landsborough	-5.5	6.1
Berrimah	-6.0	6.1
Redcliffe	-6.3	25.8
Christmas Island	-6.7	6.8
Riverside	-7.1	7.2
Bridgewater	-7.3	7.4
Eden	-7.4	7.4
Fairfield	-8.0	8.7
Baxters Beach	-8.3	9.8
Bundamba	-8.4	44.2
Ulverstone	-8.5	11.4
Port Augusta	-8.8	9.0
Burpengary East	-9.0	23.3
Caboolture South	-9.2	23.3
Port Fairy Dom	-9.2	9.4
Cameron Bay	-10.3	12.0
Wynyard	-10.4	10.9
Port Pirie	-10.8	12.2
Eli Creek	-11.0	13.1
Goodna	-11.1	39.8
Ludmilla	-11.3	29.9
Blackmans Bay	-11.3	12.0
Cowes	-11.3	12.0
Coolum	-11.4	15.1
Newnham	-11.4	11.8
Port Lincoln	-11.5	12.0
Merimbula	-11.8	12.0
Hoblers Bridge	-12.0	12.3
Finger Point	-12.6	16.0
Crescent Head	-13.0	13.1
Portland	-13.4	13.9
Stanley	-13.5	13.5
Carole Park	-14.1	16.0
Port Arthur	-14.1	14.1
Pardoe	-14.2	25.0
Rosny	-14.7	16.0
South Wetlands	-14.8	17.5
Leanyer Sanderson	-15.0	31.5
East Bundaberg [d]	-15.2	30.8
Wynnum [d]	-15.7	18.9
Gladstone [b]	-16.5	23.3
Altona	-16.6	33.0
Nambour	-16.6	22.9
Kawana	-16.7	58.9

Outfall Name	Net Benefits $m	Costs $m
Prince of Wales Bay	-16.8	19.8
North Wetlands	-17.1	17.5
Whyalla	-17.2	17.8
Pulgul Creek	-17.9	17.9
Murrumba Downs	-18.0	78.7
Alkimos	-20.0	39.1
Palmerston	-20.2	26.6
Wacol [d]	-20.3	24.6
Maryborough	-21.9	24.1
Wonga Point	-24.8	61.6
Point Peron	-26.6	39.1
Warrnambool	-28.1	33.6
McGaurans	-35.8	60.3
Ulladulla	-36.7	39.1
Norah Head	-37.7	67.0
Ti-tree Bend	-38.5	46.4
East Rockingham	-38.7	39.1
Bunbury	-46.4	93.8
George Town	-53.8	54.8
Bombo	-71.0	73.5
Boulder Bay	-76.4	116.9
Warriewood	-145.6	169.0
Smithton	-153.8	154.2
Shellharbour	-189.3	218.8
Galiwinku	Nil Info.	Nil Info.
Maningrida	Nil Info.	Nil Info.
National Total	**17,051.6**	**7,874.6**

Notes: a. Net Benefits for Port Kembla and Belambi represent benefits only without a cost estimate because these outfalls are mainly used for overflow during wet weather only, are part of the Conniston Beach system which is at a primary treatment level (i.e. upgrade not assessed for purposes of this report), have no discharge limit and upgrade costs are based on discharge limits. Their costs of upgrades would need to be assessed individually. b. The flow estimates of these upgrades may be subject to significant error and the resulting net benefit estimates should be interpreted with caution. Their benefits of upgrades would need to be assessed on a more nuanced case-by-case basis. c. The net benefit and cost estimates of these outfalls should be interpreted with caution and more nuanced assessments should be undertaken to gain better estimates of these upgrades. d. The cost estimates for these upgrades should be viewed with caution. Nuanced case-by-case cost assessments are required for these upgrades.

4.5. Limitations

Naturally, given this is a first pass assessment of the costs and benefits of upgrading Australia's 176 coastal outfalls, there are a number of limitations that should be considered in interpreting the results.

Firstly, and this is related to the next section of the report on funding, inevitably all stakeholders whom enjoy the benefits of upgrades can not necessarily fairly pay for their share because mechanisms for doing so do not exist or cannot be feasibility implemented. Therefore, inevitably for effective policy implementation, some degree of cross-subsidy will occur from rate-payers to other beneficiaries. However, given the recent advancements in remote sensing and similar technologies, mechanisms for charging other beneficiaries are emerging and their costs falling. This is particularly important in improving the transparency of public perceptions on improved opportunities for recreation at closed outfall sites.

Secondly, our analysis does not consider the additional significant cost of transporting water, because in part, this will be case specific, and should be undertaken as part of a given upgrade site's business case. However, it is important to note that where water reuse is close to treatment and the surrounding conditions for reuse are favourable (e.g. favourable soils in agriculture use of treated water), then the business case is likely to be more favourable.

Thirdly, water quality is important to the sale of recycled water and some water qualities are not suitable for particular applications (e.g. water might be too saline for particular crops). Again, there is an optimal combination of the quality of water and the price at which it can be sold for any given case. Again, individual case specific analysis would be needed to know this for any given outfall system.

Fourthly, the cost structures assumed in this assessment reflect those of economies of scale. However, we have not undertaken any detailed assessment of the cost structure of micro-treatment and emerging technologies and this might be in part the reason why larger projects tend to have greater net benefits in our analysis. Further research could investigate the veracity of these assumptions in case specific locations.[11]

Finally, as noted in the report, in heavy wet weather events, WTPs are unable to treat all flows. Similarly, agricultural users of recycled water don't necessarily need, take or pay for water when it is available. These complexities again would be better dealt with in further case specific assessments.

4.6. Conclusion

The net benefit of coastal outfall upgrades in Australia is significant amounting to between $12 billion and $28 billion in 2019 dollars depending on the discount rate used and the project period, with costs of between $7.3 billion to just over $10 billion. Individual projects have been ranked at an individual level by state and territory and across the nation. There is considerable variation between states and territories in the number of outfalls, the total net benefits provided and the costs of upgrades. These can be explained in part by the number of outfalls and size and geographical spread of relevant local populations that will benefit from the upgrades but also by the individual jurisdictional asset condition and their respective histories, evolutions and success with water and wastewater reform.

These estimates are indicative and provide a preliminary ranking to aid discussion on a desirable and practicable approach to wastewater upgrades around the country. More accurate estimates prepared on a case-by-case basis, taking account of specific contexts of any given case would need to be undertaken before a decision is made to undertake an upgrade at any given site. This would naturally form part of the business case preparation of any given upgrade to a specific outfall system.

The next section of the report discusses these findings in relation to creating transparency and economic incentives for building greater collaboration between the stakeholders in the wastewater industry.

[11] While wastewater treatment and disposal are assumed to deliver economies of scale, empirical realities may suggest otherwise.

5. Transparency, Funding and Recommendations[12]

5.1. Introduction

It is vital for all stakeholders to understand the critical role transparency has in the future of water supply and waste water management. Over the past five decades there has been a revolution in the how society views the interaction between WTPs and the receiving environment for outfalls.

As local communities have demanded better water quality outcomes, facilities and water institutions have evolved. Managing plant and equipment over a plant life of sometimes in excess of 30 years requires a balancing of statutory requirements for economic viability and increasing standards of quality in minimising impacts on the environment. At the same time these water institutions deal with the reality that a general discussion of managing human waste is not a popular subject for discussion. Hence, often the only time communities discuss the realities of wastewater treatment is when things go wrong. This inherently biases the creation of an adversarial role between water authorities and communities and rewards a culture of conflict and mistrust in the wastewater sector.

Moreover, the current institutional settings fail to inform and engage the general public in taking ownership of outfall impacts on oceans and rivers relating to the disposal of their waste.

In conducting the research that forms the basis of this proposal, this study has assessed the benefits and costs for upgrades. This assessment provides an initial priority ranking for upgrades. In turn, this increased transparency provides a strong example of the advantage of further improvements in transparency[13] to raise collaboration and trust amongst stakeholders in the wastewater sector.

5.2. Why Transparency?

Decision makers require evidence to make informed decisions and community input is a significant factor in this process for success in meeting large future infrastructure requirements and improved environmental conditions.

- Infrastructure Australia (2017) emphasised the need for transparency in water reform in its report entitled *Reforming Urban Water: A National Pathway for Change*.
- An opportunity to embrace the inevitability of Industry 4.0 or the fourth industrial revolution which encompasses the use of artificial intelligence (AI), data analytics, cloud computing and the Internet of Things (IoT) are combining to disrupt how all industry sectors operate, not just water businesses (WaterSource, 2018).
- Internationally Australia also needs to meet its obligation to the sustainable goals of the United Nations (2015) both of which require an evolution in communities' relationship to WTP outfall data.

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[12] The policy in this section of the report relies on some of the literature review and the experience of COF over several decades in campaigning for wastewater outfall upgrades. Waiting for an expansive evidence base to be prepared could take several decades more. Thus, logical and intelligent policy resulting from our recommendations should not be delayed to avoid leaving society any worse-off from further delays.
[13] More work on the issue of transparency is being prepared by COF to further elaborate these policy issues.

> 14.2. By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans.
>
> 6.3. By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.

5.3. Recommendations

Given the findings of this report and previous discussion on transparency we provide a number of key recommendations:

1. To set a target for better performance and reduced waste such that all coastal outfalls around Australia be upgraded to meet the **Tertiary Class A+ standard of recycled water by 2030**.

2. There is a need for adoption of **National Standards for Reporting of WTP data** including **transparency criteria** implemented as a prerequisite for WTP upgrade funding. An **Initial "Pilot" program** could be implemented on selected WTP upgrades.

3. To establish a **working group** to rapidly implement a set of key **publicly available, National Reporting Standards** relating to the operation of WWTPs and their interaction with the environment. This group would comprise of key industry, community, academic and government participants.

   This would include standards to transparently evaluate:

   II. **Plant Performance**:

   a. Process Costs

   This would ensure that the community and industry could understand a plant is reaching the upper limit of capability in terms of operational costs and its impact on the environment and recreational users etc.

   This is especially important for proactively identifying ageing infrastructure and the opportunity for capital upgrades involving options for recycling and climate change adaptation.

   Parameters would include:

   - Number of connections/Population
   - Plant performance efficiencies measures such as operating costs, failures and remedial actions taken to ensure best practice nationally.
   - Flows and composition and efficiency. Integration with real time 24/7 publicly accessible data wherever possible e.g. bypass events and out of license discharges, number, reason.

   b. Environmental and Social Costs

Indicators of environmental monitoring e.g. last time outfall environment monitored results. This would include real-time assessments of the assimilative capacity of local receiving waters and whether these are being breached and the associated economic costs (e.g. losses in recreational, commercial and other values from lower levels of treatment).

c. National Standards and Management of Emerging Pollutant Issues

National standards are required for how WTPs engage and report on standards required for a framework to manage emerging pollutant issues.

4. Evaluate Community Satisfaction with Engagement and Transparency

Citizen science projects that have been successfully undertaken could be used case examples for responsible agencies in better managing their outfalls and improved collaboration with communities. Examples include those from Chesapeake Bay in North America. Other international and some domestic examples are also likely to be available.

5. Economic Instruments for Improved Societal Outcomes

A review of potential economic incentives to help ensure greater incentives for transparency and the building of trust and collaboration between wastewater stakeholders could be investigated including tradable pollution permit schemes. This review would naturally include an assessment of funding options for wastewater upgrades.

6. Circular Economy, Lifecycle Approach and Plant Description

Noting **LRKF11LRKF14,** rather than being called wastewater treatment plants (WTPs), these facilities should be called water management and nutrient and energy recovery plants (WANERPs) (Halpern et al., 2012).

Appendix A

Table 14: Net benefits (NBs) and Costs of outfalls, Qld, Tas and NSW, 2019 $m, t=15 years, r=9%

Qld	NBs	Costs	Tas	NBs	Costs	NSW	NBs	Costs
Oxley	232.3	93.2	Macquarie Point	20.6	22.4	Malabar	6,254.9	1,120.9
Loganholme	139.3	104.5	Boat Harbour	0.0	0.0	North Head	2,191.7	1,289.8
Maroochydore	15.8	56.0	Cambridge	0.0	0.0	Burwood Beach	330.7	523.7
Sandgate	0.3	44.3	Rokeby	0.0	0.0	Bondi	267.5	674.8
Beenleigh	0.0	0.0	Round Hill	0.0	0.0	Port Kembla[a]	3.1	0.0
Bowen	0.0	0.0	Selfs Point	0.0	0.0	Bellambi[a]	2.6	0.0
Cannonvale	0.0	0.0	Sisters Beach	0.0	0.0	Batemans Bay	0.0	0.0
Capalaba	0.0	0.0	Margate	-1.4	1.4	Camden Head	0.0	0.0
Cleveland Bay	0.0	0.0	Dover	-1.5	1.5	Coffs Harbour	0.0	0.0
Coombabah	0.0	0.0	Richmond[b]	-1.5	1.5	Coniston Beach	0.0	0.0
Edmonton	0.0	0.0	Bridport	-1.6	1.6	Forster	0.0	0.0
Elanora	0.0	0.0	Triabunna	-1.7	1.7	Narooma	0.0	0.0
Gibson Island	0.0	0.0	Strahan	-1.8	1.8	Penguin Heads	0.0	0.0
Innisfail	0.0	0.0	Currie	-1.8	1.9	Potter Point	0.0	0.0
Luggage Point	0.0	0.0	Cygnet	-2.1	2.1	Skennars Head	0.0	0.0
Mackay North	0.0	0.0	Electrona	-2.1	2.1	Tomakin	0.0	0.0
Mackay Southern	0.0	0.0	Turners Beach	-2.5	2.5	Bermagui	-5.1	5.1
Marlin Coast	0.0	0.0	Bicheno	-2.7	2.7	Eden	-7.2	7.3
Merrimac	0.0	0.0	Orford	-2.8	2.8	Belmont	-10.5	492.1
Millbank	0.0	0.0	Risdon	-3.6	3.6	Merimbula	-11.5	11.7
Mt St John	0.0	0.0	St Helens	-3.6	3.6	Crescent Head	-12.7	12.7
North Rockhampton	0.0	0.0	Port Sorell	-3.9	3.9	Wonga Point	-29.7	58.6
Port Douglas	0.0	0.0	Sorell	-3.9	3.9	Ulladulla	-35.5	37.4
South Rockhampton	0.0	0.0	Midway Point	-4.0	4.0	Norah Head	-40.6	63.6
Thorneside	0.0	0.0	Somerset	-4.5	4.6	Bombo	-67.7	69.7
Victoria Point	0.0	0.0	Riverside	-6.9	7.0	Boulder Bay	-78.3	110.1
West Rockhampton	0.0	0.0	Bridgewater	-7.2	7.3	Warriewood	-140.0	158.4
Woree	0.0	0.0	Ulverstone	-8.8	11.1	Shellharbour	-181.2	204.4
Lucinda[c]	-0.2	0.2	Wynyard	-10.3	10.6			
Karana Downs	-2.0	2.0	Cameron Bay	-10.3	11.7			
Tin Can Bay[c]	-4.4	4.4	Blackmans Bay	-11.1	11.7			
South Trees Inlet[b]	-5.1	5.1	Newnham	-11.2	11.5			
Landsborough	-5.5	6.0	Hoblers Bridge	-11.7	11.9			
Fairfield	-7.9	8.4	Stanley	-13.1	13.1			
Redcliffe	-9.5	24.8	Port Arthur	-13.7	13.7			
Eli Creek	-11.1	12.7	Rosny	-14.5	15.5			
Burpengary East	-11.2	22.4	Pardoe	-15.6	24.0			
Caboolture South	-11.3	22.4	Prince of Wales Bay	-16.8	19.1			
Coolum	-11.7	14.6	Ti-tree Bend	-38.1	44.3			
Carole Park	-14.0	15.5	George Town	-51.4	52.2			
Bundamba	-14.1	42.3	Smithton	-144.4	144.7			
Goodna	-15.5	38.1						
Wynnum[d]	-15.8	18.3						
Nambour	-17.1	22.1						
Gladstone[b]	-17.1	22.4						
Pulgul Creek	-17.3	17.3						
East Bundaberg[d]	-17.3	29.5						
Wacol[d]	-20.3	23.7						
Maryborough	-21.5	23.2						
Kawana	-22.9	56.0						
Murrumba Downs	-26.9	74.5						
Total	**88.0**	**804.2**		**-411.2**	**478.8**		**8,430.4**	**4,840.2**

Notes: a. Net Benefits for Port Kembla and Bellambi represent benefits only without a cost estimate because these outfalls are mainly used for overflow during wet weather only, are part of the Conniston Beach system which is at a primary treatment level (i.e. upgrade not assessed for purposes of this report), have no discharge limit and upgrade costs are based on discharge limits. Their costs of upgrades would need to be assessed individually. b. The flow estimates of these upgrades may be subject to significant error and the resulting net benefit estimates should be interpreted with caution. Their benefits of upgrades would need to be assessed on a more nuanced case-by-case basis. c. The net benefit and cost estimates of these outfalls should be interpreted with caution and more nuanced assessments should be undertaken to gain better estimates of these upgrades. d. The cost estimates for these upgrades should be viewed with caution. Nuanced case-by-case cost assessments are required for these upgrades.

Table 15: Net benefits (NBs) and Costs of outfalls, Vic, WA, SA and NT, 2019 $m, t=15 years, r=9%

Vic	NBs	Costs	WA	NBs	Costs	SA	NBs	Costs	NT	NBs	Costs
Black Rock	116.7	98.9	Woodman Point	1,725.6	173.9	Bolivar WWTP	1,696.7	199.4	Palmerston	-20.6	25.6
Altona	0.0	0.0	Beenyup	1,005.8	168.8	Bolivar High Salinity	0.0	0.0	Leanyer Sanderson	-17.2	30.2
Anglesea	0.0	0.0	Subiaco	0.0	0.0	Glenelg	0.0	0.0	Ludmilla	-14.1	28.7
Apollo Bay	0.0	0.0	Wickham	0.0	0.0	Northern outfall	0.0	0.0	Berrimah	-5.9	6.0
Boags Rock	0.0	0.0	Home Island	-1.4	1.4	Southern outfall	0.0	0.0	Galiwinku	Nil info.	Nil info.
Boneo	0.0	0.0	Christmas Island	-6.6	6.6	Port Augusta	-8.6	8.8	Maningrida	Nil Info.	Nil Info.
Delray Beach	0.0	0.0	South Wetlands	-14.8	16.9	Port Pirie	-10.7	11.9			
Lorne	0.0	0.0	North Wetlands	-16.6	16.9	Port Lincoln	-11.3	11.7			
Werribee	-2.5	2.5	Alkimos	-22.4	37.4	Finger Point	-12.9	15.5			
Foster	-2.6	2.6	Point Peron	-27.6	37.4	Whyalla	-16.8	17.2			
Port Welshpool	-3.6	3.6	East Rockingham	-37.1	37.4						
Port Fairy Ind	-5.1	5.1	Bunbury	-51.5	88.6						
Toora	-8.3	9.6									
Baxters Beach	-9.0	9.1									
Port Fairy Dom	-11.1	11.7									
Cowes	-13.1	13.5									
Portland	-18.8	31.7									
McGaurans	-27.9	32.3									
Warrnambool	-38.1	57.3									
Total	**-23.5**	**277.8**		**2,553.5**	**585.3**		**1,636.4**	**264.5**		**-57.9**	**90.4**

Appendix B

Table 16: Net benefits and costs of outfalls, ranked by 2019 $m, 15 years, r=0.09

Outfall Name	Net Benefits $m	Costs $m
Malabar	6,254.9	1,120.9
North Head	2,191.7	1,289.8
Woodman Point	1,725.6	173.9
Bolivar WWTP	1,696.7	199.4
Beenyup	1,005.8	168.8
Burwood Beach	330.7	523.7
Bondi	267.5	674.8
Oxley	232.3	93.2
Loganholme	139.3	104.5
Black Rock	116.7	98.9
Macquarie Point	20.6	22.4
Maroochydore	15.8	56.0
Port Kembla[a]	3.1	0.0
Bellambi[a]	2.6	0.0
Sandgate	0.3	44.3
Anglesea	0.0	0.0
Apollo Bay	0.0	0.0
Batemans Bay	0.0	0.0
Beenleigh	0.0	0.0
Boags Rock	0.0	0.0
Boat Harbour	0.0	0.0
Bolivar High Salinity	0.0	0.0
Boneo	0.0	0.0
Bowen	0.0	0.0
Cambridge	0.0	0.0
Camden Head	0.0	0.0
Cannonvale	0.0	0.0
Capalaba	0.0	0.0
Cleveland Bay	0.0	0.0
Coffs Harbour	0.0	0.0
Coniston Beach	0.0	0.0
Coombabah	0.0	0.0
Delray Beach	0.0	0.0
Edmonton	0.0	0.0
Elanora	0.0	0.0
Forster	0.0	0.0
Gibson Island	0.0	0.0
Glenelg	0.0	0.0
Innisfail	0.0	0.0
Lorne	0.0	0.0
Luggage Point	0.0	0.0
Mackay North	0.0	0.0
Mackay Southern	0.0	0.0
Marlin Coast	0.0	0.0

Merrimac	0.0	0.0
Millbank	0.0	0.0
Mt St John	0.0	0.0
Narooma	0.0	0.0
North Rockhampton	0.0	0.0
Northern outfall	0.0	0.0
Penguin Heads	0.0	0.0
Port Douglas	0.0	0.0
Potter Point	0.0	0.0
Rokeby	0.0	0.0
Round Hill	0.0	0.0
Selfs Point	0.0	0.0
Sisters Beach	0.0	0.0
Skennars Head	0.0	0.0
South Rockhampton	0.0	0.0
Southern outfall	0.0	0.0
Subiaco	0.0	0.0
Thorneside	0.0	0.0
Tomakin	0.0	0.0
Victoria Point	0.0	0.0
Werribee	0.0	0.0
West Rockhampton	0.0	0.0
Wickham	0.0	0.0
Woree	0.0	0.0
Lucinda[c]	-0.2	0.2
Home Island	-1.4	1.4
Margate	-1.4	1.4
Dover	-1.5	1.5
Richmond[b]	-1.5	1.5
Bridport	-1.6	1.6
Triabunna	-1.7	1.7
Strahan	-1.8	1.8
Currie	-1.8	1.9
Karana Downs	-2.0	2.0
Cygnet	-2.1	2.1
Electrona	-2.1	2.1
Turners Beach	-2.5	2.5
Foster	-2.5	2.5
Port Welshpool	-2.6	2.6
Bicheno	-2.7	2.7
Orford	-2.8	2.8
Risdon	-3.6	3.6
St Helens	-3.6	3.6
Port Fairy Ind	-3.6	3.6
Port Sorell	-3.9	3.9
Sorell	-3.9	3.9
Midway Point	-4.0	4.0
Tin Can Bay[c]	-4.4	4.4

Somerset	-4.5	4.6
Bermagui	-5.1	5.1
South Trees Inlet[b]	-5.1	5.1
Toora	-5.1	5.1
Landsborough	-5.5	6.0
Berrimah	-5.9	6.0
Christmas Island	-6.6	6.6
Riverside	-6.9	7.0
Bridgewater	-7.2	7.3
Eden	-7.2	7.3
Fairfield	-7.9	8.4
Baxters Beach	-8.3	9.6
Port Augusta	-8.6	8.8
Ulverstone	-8.8	11.1
Port Fairy Dom	-9.0	9.1
Redcliffe	-9.5	24.8
Wynyard	-10.3	10.6
Cameron Bay	-10.3	11.7
Belmont	-10.5	492.1
Port Pirie	-10.7	11.9
Eli Creek	-11.1	12.7
Blackmans Bay	-11.1	11.7
Cowes	-11.1	11.7
Newnham	-11.2	11.5
Burpengary East	-11.2	22.4
Port Lincoln	-11.3	11.7
Caboolture South	-11.3	22.4
Merimbula	-11.5	11.7
Coolum	-11.7	14.6
Hoblers Bridge	-11.7	11.9
Crescent Head	-12.7	12.7
Finger Point	-12.9	15.5
Stanley	-13.1	13.1
Portland	-13.1	13.5
Port Arthur	-13.7	13.7
Carole Park	-14.0	15.5
Bundamba	-14.1	42.3
Ludmilla	-14.1	28.7
Rosny	-14.5	15.5
South Wetlands	-14.8	16.9
Goodna	-15.5	38.1
Pardoe	-15.6	24.0
Wynnum[d]	-15.8	18.3
North Wetlands	-16.6	16.9
Whyalla	-16.8	17.2
Prince of Wales Bay	-16.8	19.1
Nambour	-17.1	22.1
Gladstone[b]	-17.1	22.4

Leanyer Sanderson	-17.2	30.2
Pulgul Creek	-17.3	17.3
East Bundaberg[d]	-17.3	29.5
Altona	-18.8	31.7
Wacol[d]	-20.3	23.7
Palmerston	-20.6	25.6
Maryborough	-21.5	23.2
Alkimos	-22.4	37.4
Kawana	-22.9	56.0
Murrumba Downs	-26.9	74.5
Point Peron	-27.6	37.4
Warrnambool	-27.9	32.3
Wonga Point	-29.7	58.6
Ulladulla	-35.5	37.4
East Rockingham	-37.1	37.4
Ti-tree Bend	-38.1	44.3
McGaurans	-38.1	57.3
Norah Head	-40.6	63.6
George Town	-51.4	52.2
Bunbury	-51.5	88.6
Bombo	-67.7	69.7
Boulder Bay	-78.3	110.1
Warriewood	-140.0	158.4
Smithton	-144.4	144.7
Shellharbour	-181.2	204.4
Galiwinku	Nil Info.	Nil Info.
Maningrida	Nil Info.	Nil Info.
Grand Total	**12215.7**	**7341.4**

Notes: a. Net Benefits for Port Kembla and Bellambi represent benefits only without a cost estimate because these outfalls are mainly used for overflow during wet weather only, are part of the Conniston Beach system which is at a primary treatment level (i.e. upgrade not assessed for purposes of this report), have no discharge limit and upgrade costs are based on discharge limits. Their costs of upgrades would need to be assessed individually. b. The flow estimates of these upgrades may be subject to significant error and the resulting net benefit estimates should be interpreted with caution. Their benefits of upgrades would need to be assessed on a more nuanced case-by-case basis. c. The net benefit and cost estimates of these outfalls should be interpreted with caution and more nuanced assessments should be undertaken to gain better estimates of these upgrades. d. The cost estimates for these upgrades should be viewed with caution. Nuanced case-by-case cost assessments are required for these upgrades.

References

Alloul, A., Ganigué, R., Spiller, M., Meerburg, F., Cagnetta, C., Rabaey, K., Vlaeminck, S.E., 2018. Capture–Ferment–Upgrade: A Three-Step Approach for the Valorization of Sewage Organics as Commodities. Environmental Science & Technology 52, 6729-6742. 10.1021/acs.est.7b05712.

Apostolidis, N., Hertle, C., Young, R., 2011. Water recycling in Australia. Water 3, 869-881. 10.3390/w3030869.

Ayres, R.U., 1998. The price-value paradox. Ecological Economics 25, 17-19. 10.1016/S0921-8009(98)00022-6.

Bekele, E., Page, D., Vanderzalm, J., Kaksonen, A., Gonzalez, D., 2018. Water Recycling via Aquifers for Sustainable Urban Water Quality Management: Current Status, Challenges and Opportunities. Water 10, 457. http://www.mdpi.com/2073-4441/10/4/457

Bennett, J., McNair, B., Cheesman, J., 2016. Community preferences for recycled water in Sydney. Australasian Journal of Environmental Management 23, 51-66. 10.1080/14486563.2015.1129364.

Birol, E., Das, S., 2010. Estimating the value of improved wastewater treatment: The case of River Ganga, India. Journal of Environmental Management 91, 2163-2171. https://doi.org/10.1016/j.jenvman.2010.05.008.

Blackwell, B.D., 2003. The Economics of Coastal Foreshore and Beach Management: Use, Safe Bathing Facilities, Erosion and Conservation, PhD Thesis, School of Economics. The University of Queensland, St Lucia, Brisbane.

Blackwell, B.D., 2006a. The economic value of Australia's natural coastal assets: Some preliminary findings, ANZSEE Conference 2005. Australia New Zealand Society for Ecological Economics, Massey University, Palmerston North, New Zealand, pp. 143-151.

Blackwell, B.D., 2006b. The economic value of some of Australia's natural coastal assets: The value of their ecosystem goods and services – draft final report, Brisbane, Australia.

Blackwell, B.D., 2007. The ecoservice values for some of Australia's natural coastal assets: How much are our coasts worth and what's missing from the mosaic?, ANZSEE Conference 2007. The Australia New Zealand Society for Ecological Economics, Noosaville, Queensland, Australia.

Blackwell, B.D., 2008. The Economics of Ocean Outfalls and Wastewater in Australia: Some Empirical Evidence on a Dog's Breakfast, in: Economic Society of Australia (Queensland) (Ed.), 37th Australian Conference of Economists, 30 September to 4th October 2008. Economic Society of Australia (Queensland), Gold Coast.

Blackwell, B.D., Iacovino, C., 2009. Oceans outfalls in Australia: economics, ecology, recreation and education, The 2009 ANZSEE Conference Proceedings. ANZSEE, Darwin, pp. 1-19.

Blackwell, B.D., Wilcox, J.R., 2009. Valuing Ex Ante Changes in Water Quality for the Marine Environment: A Hybrid Method Applied to Bass Straight (sic., Victoria, Australia, The 2009 ANZSEE Conference Proceedings. ANZSEE, Darwin, Northern Territory, pp. 1-13.

Boesch, D.F., Burroughs, R.H., Baker, J.E., Mason, R.P., Rowe, C.L., Siefert, R.L., 2001. Marine Pollution in the United States. Pew Oceans Commission, Arlington, Virginia. 19 January 2019, http://ian.umces.edu/pdfs/ian_report_60.pdf.

Butler, J., 2013. Personal communication. Commonwealth of Australia Science and Industry Research Organisation, Adaptation Science Flagship.

Cavagnaro, P., 2010. Investing in Wastewater Treatment Upgrades: Boosting the Triple Bottom Line. Johnson Controls Inc., Milwaukee. 21 Sep 2018, http://www.climateactionprogramme.org/images/uploads/documents/Investing_in_Wastewater.pdf.

Chan, K.M.A., Satterfield, T., Goldstein, J., 2012. Rethinking ecosystem services to better address and navigate cultural values. Ecological Economics 74, 8-18. 10.1016/j.ecolecon.2011.11.011.

City of Cornwall, 2014. Wastewater Treatment Plant Upgrade, City of Cornwall,, Cornwall, Canada. 21 September 2018, http://www.cornwall.ca/en/municipalworks/wwtpupgrades.asp.

Clean Ocean Foundation, 2017. Distribution of ocean outfalls throughout Australian coastal area 2017. Clean Ocean Foundation, Wonthaggi.

Clean Ocean Foundation, 2018. Clean Ocean Foundation: Our Future Depends on a Clean Ocean, Clean Ocean Foundation, Wonthaggi, Bass Coast. 26 September 2018, https://www.cleanocean.org/.

Clean Ocean Foundation and Marine Biodiversity Hub, 2018. The National Outfall Database: Community Report, August 2018. Marine Biodiversity Hub, Hobart.

Cooley, S.R., Doney, S.C., 2009. Anticipating ocean acidification's economic consequences for commercial fisheries. Environmental Research Letters 4. 10.1088/1748-9326/4/2/024007.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253-260. http://www.nature.com/nature/journal/v387/n6630/abs/387253a0.html

Daly, H.E., 1998. The return of Lauderdale’s paradox. Ecological Economics 25, 21-23. 10.1016/S0921-8009(98)00008-1.

Daniel, T.C., Muhar, A., Arnberger, A., Aznar, O., Boyd, J.W., Chan, K.M.A., Costanza, R., Elmqvist, T., Flint, C.G., Gobster, P.H., Grêt-Regamey, A., Lave, R., Muhar, S., Penker, M., Ribe, R.G., Schauppenlehner, T., Sikor, T., Soloviy, I., Spierenburg, M., Taczanowska, K., Tam, J., von der Dunk, A., 2012. Contributions of cultural services to the ecosystem services agenda. Proceedings of the National Academy of Sciences 109, 8812-8819. 10.1073/pnas.1114773109.

DeFries, R., Pagiola, S., Adamowicz, W.L., Akçakaya, H.R., Arcenas, A., Babu, S., Balk, D., Confalonieri, U., Cramer, W., Falconí, F., Fritz, S., Green, R., Gutiérrez-Espeleta, E., Hamilton, K., Kane, R., Latham, J., Matthews, E., Ricketts, T., Yue, T.X., Ash, N., Thönell, J., Ceballos, G., Lavorel, S., Orians, G., Pacala, S., Supriatna, J., Young, M., 2005. Analytical Approaches for Assessing Ecosystem Condition and Human Well-being, in: Hassan, R., Scholes, R. (Eds.), Millennium Ecosystem Assessment: Current State & Trends Assessment. Island Press, Washington, DC, pp. 37-71.

Deloitte Access Economics, 2016. Economic and Social Value of Improved Water Quality at Sydney's Coastal Beaches, Sydney. 31 October 2018, https://www2.deloitte.com/au/en/pages/economics/articles/economic-social-value-improved-water-quality-sydneys-coastal-beaches.html.

Department of State Development, n.d. Mareeba Wastewater Treatment Plant Upgrade. Department of State Development, Brisbane. 21 September 2018, https://www.statedevelopment.qld.gov.au/resources/case-studies/bor/cs-mareeba-wastewater-treatment-plant-upgrade.pdf.

Eckard, R., 2017. Global Markets and Technologies for Water Recycling and Reuse. bccResearch, Wellesley, MA. 19 January 2019, https://www.bccresearch.com/market-research/membrane-and-separation-technology/water-recycling-resuse-markets-mst051c.html.

Eggen, R.I.L., Hollender, J., Joss, A., Schärer, M., Stamm, C., 2014. Reducing the Discharge of Micropollutants in the Aquatic Environment: The Benefits of Upgrading Wastewater Treatment Plants. Environmental Science & Technology 48, 7683-7689. 10.1021/es500907n.

Fagan, P., Miskiewicz, A.G., Tate, P.M., 1992. An approach to monitoring sewage outfalls: A case study on the Sydney deepwater sewage outfalls. Marine Pollution Bulletin 25, 172-180. https://doi.org/10.1016/0025-326X(92)90221-Q.

Farley, J., 2012. Ecosystem services: The economics debate. Ecosystem Services 1, 40-49. 10.1016/j.ecoser.2012.07.002.

Gillespie, R., Bennett, J., 1999. Using Contingent Valuation to Estimate Environmental Improvements Associated with Wastewater Treatment. Australian Journal of Environmental Management 6, 14-20. https://doi.org/10.1080/14486563.1999.10648446.

Grant, S., 2018. The Vlaue of On-site Wastewater Treatment, Industrial Water World. 26 September 2018, https://www.waterworld.com/articles/iww/print/volume-16/issue-4/features/the-value-of-on-site-wastewater-treatment.html.

Gunawardena, A., Zhang, F., Fogarty, J., Iftekhar, S., 2017. Review of non-market values of water sensitive systems and practices: An update. Cooperative Research Centre for Water Sensitive Cities, Melbourne. 18 January 2019, https://watersensitivecities.org.au/content/review-of-non-market-values-of-water-sensitive-systems-and-practices-an-update/.

Guven, H., Eriksson, O., Wang, Z., Ozturk, I., 2018. Life cycle assessment of upgrading options of a preliminary wastewater treatment plant including food waste addition. Water Research 145, 518-530. https://doi.org/10.1016/j.watres.2018.08.061.

Halpern, B.S., Longo, C., Hardy, D., McLeod, K.L., Samhouri, J.F., Katona, S.K., Kleisner, K., Lester, S.E., O'Leary, J., Ranelletti, M., Rosenberg, A.A., Scarborough, C., Selig, E.R., Best, B.D., Brumbaugh, D.R., Chapin, F.S., Crowder, L.B., Daly, K.L., Doney, S.C., Elfes, C., Fogarty, M.J., Gaines, S.D., Jacobsen, K.I., Karrer, L.B., Leslie, H.M., Neeley, E., Pauly, D., Polasky, S., Ris, B., St Martin, K., Stone, G.S., Sumaila, U.R., Zeller, D., 2012. An index to assess the health and benefits of the global ocean. Nature 488, 615-620. 10.1038/nature11397.

Hardisty, P.E., Sivapalan, M., Humphries, R., 2013. Determining a sustainable and economically optimal wastewater treatment and discharge strategy. Journal of Environmental Management 114, 285-292. https://doi.org/10.1016/j.jenvman.2012.10.019.

Herendeen, R.A., 1998. Monetary-costing environmental services: Nothing is lost, something is gained. Ecological Economics 25, 29-30. 10.1016/S0921-8009(98)00010-X.

Hernández-Sancho, F., Lamizana-Diallo, B., Mateo-Sagasta, J., Qadir, M., 2015. Economic Valuation of Wastewater - The Cost of Action and the Cost of Inaction. United Nations Environment Programme, Nairobi. 20 January 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/7465/-Economic_Valuation_of_Wastewater_The_Cost_of_Action_and_the_Cost_of_No_Action-2015Wastewater_Evaluation_Report_Mail.pdf.pdf?sequence=3&isAllowed=y.

Horne, J., 2016. Policy issues confronting Australian urban water reuse. International Journal of Water Resources Development 32, 573-589. 10.1080/07900627.2015.1090901.

Hueting, R., Reijnders, L., de Boer, B., Lambooy, J., Jansen, H., 1998. The concept of environmental function and its valuation. Ecological Economics 25, 31-35. 10.1016/S0921-8009(98)00011-1.

Hydroflux, 2018. Environmental Benefits to Upgrade of Wastewater Treatment Plant, Hydroflux, Sydney. 21 September 2018, https://www.hydroflux.com.au/environmental-benefits-to-upgrade-of-wastewater-treatment-plant/.

Infrastructure Australia, 2017. Reforming Urban Water: A National Pathway for Change. Infrastructure Australia, Sydney. 18 November 2018, file:///Users/boydnadine/Documents/Consult/2018/COF%20NOD/Lit%20review/Reforming_Urban_Water_Web_version.pdf.

Jiang, Y., Dinar, A., Hellegers, P., 2018. Economics of social trade-off: Balancing wastewater treatment cost and ecosystem damage. Journal of Environmental Management 211, 42-52. https://doi.org/10.1016/j.jenvman.2018.01.047.

Kaffashi, S., Shamsudin, M.N., Radam, A., Rahim, K.A., Yacob, M.R., 2013. We are willing to pay to support wetland conservation: local users' perspective. International Journal of Sustainable Development & World Ecology 20, 325-335. 10.1080/13504509.2013.800612.

Kontogianni, A., Langford, I.H., Papandreou, A., Skourtos, M.S., 2003. Social Preferences for Improving Water Quality: An Economic Analysis of Benefits from Wastewater Treatment. Water Resources Management 17, 317-336. 10.1023/A:1025866818391.

Logar, I., Brouwer, R., Maurer, M., Ort, C., 2014. Cost-Benefit Analysis of the Swiss National Policy on Reducing Micropollutants in Treated Wastewater. Environmental Science & Technology 48, 12500-12508. 10.1021/es502338j.

Makropoulos, C., Rozos, E., Tsoukalas, I., Plevri, A., Karakatsanis, G., Karagiannidis, L., Makri, E., Lioumis, C., Noutsopoulos, C., Mamais, D., Rippis, C., Lytras, E., 2018. Sewer-mining: A water reuse option supporting circular economy, public service provision and entrepreneurship. Journal of Environmental Management 216, 285-298. https://doi.org/10.1016/j.jenvman.2017.07.026.

Marsden Jacob Associates, 2013. Project Report, Economic Viability of Recycled Water Schemes. Australian Water Recycling Centre for Excellence, Brisbane.

Marsden Jacob Associates, 2014a. Community Values for Recycled Water in Sydney, Economic Viability of Recycled Water Schemes - Technical Report 2. Australian Water Recycling Centre for Excellence, Brisbane.

Marsden Jacob Associates, 2014b. Environmental and social values associated with non-potable recycled water - Economic viability of recycled water schemes, Technical Report 3. Australian Water Recycling Centre of Excellence, Melbourne. 20 January 2019, http://awrce.kingfishercreative.com.au/research-publications.html.

Masi, F., Rizzo, A., Regelsberger, M., 2018. The role of constructed wetlands in a new circular economy, resource oriented, and ecosystem services paradigm. Journal of Environmental Management 216, 275-284. https://doi.org/10.1016/j.jenvman.2017.11.086.

McNamara, G., 2018. Economic and Environmental Cost Assessment of Wastewater Treatment Systems, PhD Thesis. Dublin City University, Dublin.

Millennium Ecosystem Assessment (MEA), 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Mooney, C., Stenekes, N., 2008. An Analysis of the Social Aspects of Establishing Agricultural Recycled Water Schemes. Sciences, B.o.R., Canberra. 26 September 2018, https://www.researchgate.net/publication/228867056_An_analysis_of_the_social_aspects_of_establishing_agricultural_recycled_water_schemes.

Moore, D., 1978. Analysis of Operations and Maintenance Costs of Municipal Wastewater Treatmetn Systems. US EPA, Washington D.C. 19 January 2019, https://nepis.epa.gov/Exe/ZyNET.exe/9101CRB5.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1976+Thru+1980&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex Data%5C76thru80%5CTxt%5C00000028%5C9101CRB5.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back.

National Climate Change Adaptation Research Facility (NCCARF), 2013. National Climate Change Adaptation Research Facility, Brisbane, Australia.

National Outfall Database, 2018. Welcome to the National Outfall Database, Clean Ocean Foundation, Wonthaggi, Bass Coast. 26 September 2018, https://www.outfalls.info/.

National Research Council, 1993. Managing Wastewater in Coastal Urban Areas. National Academy of Sciences,, Washington D.C.

Ndunda, E.N., Mungatana, E.D., 2013. Evaluating the welfare effects of improved wastewater treatment using a discrete choice experiment. Journal of Environmental Management 123, 49-57. https://doi.org/10.1016/j.jenvman.2013.02.053.

Ormerod, K.J., 2016. Illuminating elimination: public perception and the production of potable water reuse. WIREs Water 3, 537-547. 10.1002/wat2.1149.

Otway, N.M., 1995. Assessing impacts of deepwater sewage disposal: A case study from New South Wales, Australia. Marine Pollution Bulletin 31, 347-354. https://doi.org/10.1016/0025-326X(95)00135-A.

Parks, S., Gowdy, J., 2013. What have economists learned about valuing nature? A review essay. Ecosystem Services 3, e1-e10. 10.1016/j.ecoser.2012.12.002.

Pauly, D., Alder, J., Bakun, A., Heileman, S., Kock, K.-H., Mace, P., Perrin, W., Stergiou, K., Sumaila, U.R., Vierros, M., Freire, K., Sadovy, Y., Christensen, V., Kaschner, K., Palomares, M.-L., Tyedmers, P., Wabnitz, C., Watson, R., Worm, B., Baker, J., Casasola, P.M., Lugo, A., Rodríguez, A.S., Dan, L., Tang, L., 2005. Marine Fisheries Systems, in: Hassan, R., Scholes, R. (Eds.), Millennium Ecosystem Assessment: Current State & Trends Assessment, Washington, DC, pp. 477-511.

Perraton, S.C., 2015. Cross Jurisdictional Barriers to Effective Wastewater Reuse: Management of Wastewater Disposal, Water Quality Impacts, and Reform Opportunities for Australia, Institute for Marine and Antarctic Studies. University of Tasmania, Launceston.

Perraton, S.C., Blackwell, B.D., Fischer, A., Gaston, T.F., Meyers, G.D., 2015. Systemic barriers to wastewater reuse in Australia: some jurisdictional examples. Australasian Journal of Environmental Management 22, 355-372. 10.1080/14486563.2014.955889.

Roebeling, P., Abrantes, N., Ribeiro, S., Almeida, P., 2016. Estimating cultural benefits from surface water status improvements in freshwater wetland ecosystems. Science of The Total Environment 545-546, 219-226. https://doi.org/10.1016/j.scitotenv.2015.12.063.

Rolfe, J., Scarborough, H., Blackwell, B.D., Blackley, S., Walker, C., Forthcoming. Estimating recreation values for beach and foreshore assets and protection against future climate change impacts.

Serafy, S.E., 1998. Pricing the invaluable: The value of the world's ecosystem services and natural capital. Ecological Economics 25, 25-27. 10.1016/S0921-8009(98)00009-3.

Stuart-Smith, R.D., Edgar, G.J., Stuart-Smith, J.F., Barrett, N.S., Fowles, A.E., Hill, N.A., Cooper, A.T., Myers, A.P., Oh, E.S., Pocklington, J.B., Thomson, R.J., 2015. Loss of native rocky reef biodiversity in Australian metropolitan embayments. Marine Pollution Bulletin 95, 324-332. https://doi.org/10.1016/j.marpolbul.2015.03.023.

SUEZ, 2017. Cronulla Wastewater Treatment Plant, SUEZ, Rhodes, NSW. 21 September 2018, http://www.degremont.com.au/projects/cronulla-wastewater-treatment-plant/.

United Nations, 2015. Sustainable Development Goals.

WaterSource, 2018. Is the water sector ready for the next industrial revolution?

Xin, C., Addy, M.M., Zhao, J., Cheng, Y., Ma, Y., Liu, S., Mu, D., Liu, Y., Chen, P., Ruan, R., 2018. Waste-to-biofuel integrated system and its comprehensive techno-economic assessment in wastewater treatment plants. Bioresource Technology 250, 523-531. https://doi.org/10.1016/j.biortech.2017.11.040.

Zhang, W.-w., 2011. Measuring the value of water quality improvements in Lake Tai, China. Journal of Zhejiang University-Science A 12, 710-719. 10.1631/jzus.A11b01.