Externalities Associated with Urban Water Asset Management


Water for a Healthy Country Flagship Report
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The Water for a Healthy Country Flagship aims to achieve a tenfold increase in the economic, social and environmental benefits from water by 2025.

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EXECUTIVE SUMMARY

Water infrastructure delivers substantial service benefits to the residents of urban communities. However, asset and service failures can also impose welfare costs that are un-consented and uncompensated; these are referred to as ‘externality costs’ in the economic literature. The objective of this report is to inform development of a common framework for the treatment of externalities in urban water asset management. The research forms part of CSIRO’s effort to help the Australian water sector align its asset management strategies with sustainability concepts. Consideration of externalities is a necessary step in delivering sustainability-based asset management.

Taking account of externalities in asset management will affect decisions concerning the mix of assets used to deliver urban water services and the way in which existing and future assets are managed. Five externality groups were identified to aid in the process of describing and estimating these externalities:

1) Pollution or contamination;
2) Environmental impacts;
3) Public health and safety;
4) Non-compensated financial losses; and
5) Social disruption.

Externalities are difficult to identify and to accurately assess and incorporate into sustainability-based asset management frameworks because they fall beyond the immediate physical asset boundaries and impact on an undefined group of people.

Asset managers are tasked with the difficult process of incorporating externality considerations across strategic and tactical planning. Strategic considerations focus on identifying the best asset mix to provide services to the community and environment in light of existing asset stocks, including which assets should be replaced and the timing of that replacement. Implicitly or explicitly, a key consideration is the impact of externality considerations on the net benefit delivered by different asset configurations or management strategies.

Estimating the impact of externalities requires recourse to the concepts of total economic value in order to ensure that all values, use and non-use, are included. Total economic value will usually need to be considered using the concept of marginal change; i.e. the difference in values with and without a specified intervention such as a different management procedure, asset type and so on. A number of techniques are available to value the externality impacts of urban water asset management, which can be grouped into:

- Market price based approaches based on direct costs incurred in markets. Such approaches do not capture non-use and passive-use values;
- Surrogate or proxy market approaches, which estimate the impact the externality has on market behaviour. They are limited by the complexity in disentangling externality and other impacts on market behaviour and by the degree of impact on market prices;
- Survey based methods, which ask people their willingness to pay for (or to avoid) externality impacts. These are able to value externalities that have no impact on market prices but may be regarded as less reliable than market-based approaches;
- Benefit transfer from other suitable primary studies which is limited by the availability of prior research and its relevance to the particular externality impact and location under consideration.
To inform the inclusion of externalities in asset management decision-making, we synthesised previous work by Young (2000); Bowers and Young (2000) and Plant et al. (2007) into a five step framework, shown in the Table below:

<table>
<thead>
<tr>
<th>Step</th>
<th>Critical Issues</th>
</tr>
</thead>
</table>
| 1. Pragmatic scoping | Water authorities should first consider:  
  - Which impacts to include?  
  - Are these impacts really externalities?  
  - Are they likely to have a negligible impact in the context of the decision?  
  - Is there an economic/affordable option available that does not impose a specific and significant negative externality? |
| 2. Define externalities for consideration | Clarify the link between the urban water asset and people, which in turn generates indirect impacts on ecosystem functions and human wellbeing  
  - Identify who is affected in the transaction, i.e. the ‘others’  
  - Identify if positive (i.e. provide a benefit to others) or negative (i.e. create a cost to others)  
  - Identify what ‘value’ is appropriate for inclusion, i.e. financial, costs and benefits or welfare  
  - Determine specific boundary conditions that relate to; people, environment, governance, time, space, measurement unit and event. |
| 3. Quantifying impacts | Identify the physical magnitude of each externality  
  - Determine who is affected  
  - Determine what magnitude of physical impact is expected |
| 4. Value externalities | Determine the preferred & pragmatic method and data for value estimate; e.g. market price, surrogate markets, survey based and benefit transfer  
  - Undertake analysis |
| 5. Evaluation | Determine appropriateness of valuation to current decisions and context (socio-political, management and environmental); and  
  - Undertake sensitivity analysis across all relevant externalities to assess the robustness of available options, across a range of values |

This five step framework is intended to draw together the processes of identifying the likely externality impact and delivering quantitative estimates of that externality for inclusion in asset management decision-making. The five steps could be directly integrated into existing risk-based asset management tools such as PARMS-Risk. PARMS-Risk uses physical probabilistic models in conjunction with cost-benefit analysis to determine the economic timing of pipe replacement. Little or no structural change would be required to the approach used in PARMS-Risk but substantial attention would need to be given to describing the range and extent of externalities associated with different asset management strategies and intervention options.

Unfortunately, there are significant shortcomings in the extent of information available to support inclusion of externalities within asset management tools. We recommend that the research effort required to support inclusion of externalities be focused on testing the type and extent of externalities and on prioritising which assets in urban water are most susceptible to poor decision-making when externalities are not adequately included.

To deliver the necessary knowledge we recommend a strategic focus on proactive asset management. We also suggest identifying the portfolio of assets where the inclusion of externalities in decision processes may be sufficient either to shift asset management from reactive to proactive or for which investment shifts to a different class of assets (for example from end of pipe to distributed sewage treatment for example).
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1. INTRODUCTION

1.1. Background

This work is funded through the Urban Water theme of ‘Water for a Healthy Country’ Flagship, CSIRO. It sits under a broader umbrella of research focused on identifying and putting into practice tools, methods and ideas that the urban water industry can use to contribute to ‘sustainable development’ efforts. This work adds to this larger body of work by focusing on externalities, which comprise a subset of the considerations necessary to deliver sustainable outcomes in the urban water space.

1.2. Research Focus

Water infrastructure delivers substantial service benefits to the residents of urban communities. However, asset and service failures can also impose welfare costs that are unconsented and uncompensated; these are referred to as ‘externality costs’ in the economic literature. Some externality costs associated with water collection through damming and diversion activities have received a significant amount of attention, as have those associated with effluent discharge. Others associated with asset installation, maintenance, unforeseen asset failures and consequent repair activities have received less consideration. Nevertheless, such externalities impose a range of costs on residents, businesses, and in some cases, others such as downstream communities or water users.

1.3. Objective

The overarching objective of this work is to develop a suitable framework for the measurement of these externalities and the resultant research needs. Our aim is to inform development of a common framework for the treatment of externalities in urban water asset management. To achieve this aim a number of objectives are addressed:

i. Defining an externality in urban water asset management;
ii. Understanding the economic value of externalities and methods for deriving such value;
iii. Documenting known values of externalities in urban water asset management;
iv. Developing a framework for including externalities in asset management; and,
v. Incorporating externality values into asset management tools.

This research is intended to inform the work undertaken by asset managers, researchers in asset management and environmental economics and the broader urban water industry.

1.4. Report Structure

The report is structured as follows.

− Section 2 provides background information on urban water asset management, a definition of externalities and a conceptual mapping of externalities in urban water asset management.
− The range of externalities that may be generated by asset management are detailed in Section 3.
− In Section 4, a range of methods that could be applied to measuring urban water asset management externalities are described, along with a recommended framework.
− A set of recommendations completes the paper in Section 5.
2. EXTERNALITIES IN URBAN WATER

2.1. Introduction

Recent efforts in the urban water industry have been directed towards achieving ‘sustainability’ (Kenway et al. 2006). Sustainability concepts reflect broad societal goals and are often difficult to describe and define at the individual and community level. The industry has begun to address this challenging issue through incorporation of triple bottom line objectives within their strategic outlook, rather than just ‘profit maximisation’.

Specifically, urban water utilities have begun to incorporate social and environmental issues into their management decisions. This shift has been undertaken in a variety of ways including: framing urban water life cycles within long time horizons; incorporation of whole of life cycle value analyses; and use of multi-criteria analysis to strategically assess a wider range of the costs and benefits of project options. Nevertheless, interest in sustainability is still compartmentalised (see Marlow and Humphries, 2009). There is evidence of adoption at the strategic level and within long-term planning processes, but it has yet to be fully implemented within asset management frameworks (Marlow et al. 2010a).

As will be shown throughout this report, one means of addressing sustainability issues within asset management is to extend the consideration of costs and benefits to address impacts that are currently not captured by the market; the so-called ‘externalities’. An economic analysis undertaken in this context would address welfare impacts of different asset management strategies and explicitly encompass both monetary and non-monetary impacts. This is important because historical experience shows that failure to consider externalities like pollution and greenhouse gas emissions tends to skew decision-making towards short-term or inefficient investment actions or strategies, at least when viewed from a societal perspective.

While consideration of ‘externalities’ represents a subset of broader sustainability issues, it is confined within a broadly defined economic framework, which does not address ethical issues such as equity. In particular, taking into account all externalities in decision-making does not make an outcome sustainable; this still requires a decision to be made within a broader sustainability framework. Nevertheless, we assert that the consideration of externalities (including external costs and other welfare losses) is a necessary condition for sustainability.

2.2. Background to Economic Theory on Externalities

From the economics perspective, there are a variety of definitions of externalities as they relate to water, including:

i. An externality is any impact caused by an activity that can be traced back to a human activity, such as water consumption, whose costs (or benefits) are not factored into the decisions of the economic agents involved in the transactions (van Bueren & Hatton MacDonald, 2004).

ii. A legitimate action by one economic unit that impacts on the welfare of another economic unit that does not take place through markets (Bowers, 1997)

iii. A cost or benefit that arises from an economic transaction that falls on people who do not participate in the transaction (McTaggart et al. 1999)

There is, however, necessarily a commonality between all such definitions, and any economic consideration will generally reflect the fact that externalities:

i. Have direct impacts on the physical characteristics or attributes of the environment and people, which in turn generate indirect impacts on ecosystem functions and human wellbeing (van Bueren and Hatton MacDonald, 2004);

ii. Occur when those impacted are not involved in a transaction;
iii. Can be positive (i.e. provide a benefit to others) or negative (i.e. create a cost to others);

iv. Are measured as a change in welfare or social wellbeing; sometimes termed social cost and social benefit (from Bowers and Young, 2000); and,

v. Have specific boundary conditions that relate to: people, environment, governance, time, space, measurement unit and event (e.g. pollution spills are case-specific, with different impacts according to their context).

Two examples of externalities are; should a sewage treatment plant, who legally disposes of treated effluent into a stream, be concerned with the negative affect this has on stream ecological health or the activities of a private marina downstream? Or, should a water utility be concerned when it has a leaking pipe resulting in increased flow of water to trees in urban areas and hence improved amenity and increased bird numbers generating an indirect benefit to the local neighbourhood?

2.2.1. Treatment of externalities

As externalities are so broad and to some degree will vary with any transaction, the important element is to identify which ones are significant and which are trivial. With this challenge in mind, we are concerned with designing a framework that facilitates robust and coherent treatment of externalities arising from urban water infrastructure. The inclusion of externalities in the planning and management process is called ‘internalising externalities’.

Internalising externalities generally means that the costs (or benefits) of the externality are taken into account in production decisions. Technically, internalisation is the result of producers including externality costs in decision processes, which can include:

i. Being informed of the externality being provided;

ii. Providing payment to those affected or to remediate the environment; or

iii. Changing production outputs or processes, which is the option of most interest to urban water asset management.

Any response is dependant on the nature and extent of the externality, who holds the initial property rights and what a socially efficient solution would be. Internalising externalities will result in strategic and operational changes in utility management. Strategic changes would result in modifications to the way in which utilities consider future investments. Tactical and operational changes are more specific and are the result of actual changes to decision processes and structures.

A review of existing literature yielded a typology of strategic assessment frameworks and ‘units’ for measuring value. For the purposes of this discussion, we consider that there are four frameworks and three units, as illustrated in Figure 2-1. Importantly, each dimension in Figure 2-1 can be considered nested: i.e. welfare measures necessarily include financial cost and benefits; sustainable development necessarily includes understanding life cycle costing and capital cost assessments.

Traditionally, planning and justification of infrastructure investment was focused on capital costs alone (‘business as usual’ in Figure 2-1). Over the last decade or so, the industry has, however, started to extend standard practices (implied by the green dotted arrows in Figure 2-1) to incorporate more sophisticated approaches that analyse asset life cycle costs. Various approaches are available that differ in the time scales considered and scope of the costs/impacts analysed (Boussabaine and Kirkham, 2004). For example, the boundaries of cost analysis can be expanded to consider any externalities that could significantly influence the decisions being made (Burn et al., 2001); this approach is taken in whole of life costing (WLC). A complimentary approach is life cycle analysis (LCA), which is a technique for evaluating all processes involved with an asset, ‘from cradle to the grave’, that is, from resources, through transport, to use and disposal of the asset (Todd, 1996). LCA can also incorporate factors such as social issues (e.g. community values and social acceptance),
which allows this technique to incorporate wider sustainability principles (Maheepala et al. 2003).

<table>
<thead>
<tr>
<th>Assessment framework</th>
<th>Financial costs</th>
<th>Financial cost and benefits</th>
<th>Welfare measures</th>
</tr>
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<tbody>
<tr>
<td>Capital costs</td>
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<tr>
<td>Whole life costing</td>
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<tr>
<td>Whole of life value</td>
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<td></td>
<td></td>
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<tr>
<td>Sustainable Development</td>
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</tbody>
</table>

**Figure 2-1: Strategic assessment frameworks and extent of economic values included**

The concept of whole life value (WLV) builds on these life cycle techniques. WLV represents the optimum balance of stakeholders’ aspirations, needs and requirements, and costs over the life of an asset (Mootanah, 2005). WLV includes the consideration of the perceived costs and benefits of some or all of the stakeholders’ relevant value drivers. As detailed in Bourke et al. (2005), the assessment of WLV is not a single methodology as such, but is instead achieved through application of a range of methodologies including WLC, LCA, value management, and risk management. WLV is an important concept, since it reflects the limitations of any one methodology in being able to constrain the relative merits of one possible intervention over another, and requires value to be considered from the perspective of a range of stakeholders.

As noted previously, the water sector has recently began to shift its attention to formal consideration of sustainability issues, which can be considered a holistic framework within which to consider the impact of business operations (Marlow and Humphries, 2009). Sustainable development remains a vague concept, and can perhaps best be conceptualised simply as an aspiration, defining the direction towards some preferred state, even if the state itself is not well defined (Marlow et al., 2010b). Importantly, these aspirations take the concepts underpinning WLV and extend them in terms of the impacts and stakeholders considered, including to consideration of future generations.

As shown in Figure 2-1, different measurement units of value can be mapped onto these assessment frameworks. Hence, decisions relating to strategic planning where initially considered in terms of financial costs alone, with cost judged only from the perspective of the utility. Recently, more sophisticated approaches have been applied that consider broader economic cost and benefits, again from a financial perspective. Ultimately, the aim is to reflect economic principles through a framework of sustainable development that measures value from a welfare perspective. Welfare may be measured either cardinally in terms of “utils” (a measure of relative satisfaction) or through any numeraire such as dollars. Welfare change can be positive or negative and refers to the overall welfare or wellbeing of society, which is assumed to be the summation of the welfare of all the individuals in the society.

The challenge for the sector is to continue this trend by pushing frontiers to consider financial benefits and non-financial elements (shown by green dotted lines and arrows in Figure 2-1) within the context of a holistic assessment framework. It should be recognised, however, that analysis undertaken will still not encompass all costs and benefits for a variety of reasons, which include practicality of estimation and decision-making remit of utilities.

**2.2.2. Relevance to asset management**

There are a number of differences in the extent and measurement of externalities between urban water managers and economic theory. These are caused by a combination of practicality in implementing economic definitions and because of the scope of impacts that can be effectively considered by utility managers.
From an asset management perspective, there are two ways of considering externalities: from the community perspective and from the asset management perspective:

1. **From the community perspective**, externalities are associated with welfare changes (loss or benefit) imposed on communities, where this loss is contrary to community expectations, and is associated with the actions of a water utility. The value placed on the externality is a true economic consideration; it is concerned with the degree of net welfare loss (or benefit) experienced by society. This perspective assumes that there is a ‘social license to operate’ which establishes community expectations and requirements within the urban water industry. The social license is framed within expectations that may or may not be explicitly set out within customer service level agreements. Deviation from these expectations (resulting in a change to welfare) is then considered to be an externality. The change to welfare can be estimated through a variety of methods (see Section 4 for further detail).

2. **From the asset managers’ perspective**, externalities (including external costs and other welfare changes) are associated with consequences that arise due to asset failures but are un-costed. These asset failures impose impacts on the community, are not financially compensated and are potentially within the ‘legislated’ agreements established for the utility to operate. In general, these will be local considerations and the value placed on avoiding these consequences will reflect the willingness of the water utility to avoid negative publicity or relationship with customers, community, regulators, etc.

In both cases, there is a need to prioritise externalities by their magnitude, likelihood and consequences to determine what is a significant impact and to assess if this can be managed through an alternative intervention. However, in the later case, the process is internal, it is a consideration of what the business is prepared to pay out of its existing budgets to avoid. In the former case, it is more about the willingness of the community to pay to avoid (or to be compensated).

Taking into account all of the impacts associated with a management option that are valued by society, irrespective of whether they are captured by the market, interventions are judged from the perspective of the welfare change imposed on society.\(^1\) may change:

i. The type of management strategy adopted (e.g. level of maintenance provided)

ii. The type of intervention selected (e.g. trenchless technology versus trenched replacement)

iii. The type of incentive to stimulate a response (e.g. billing structures that encourage low water use).

Clearly, for this to be the case, the relative magnitude of the externality imposed needs to be sufficient to influence decisions.

### 2.3. Externalities Addressed in this Project

The five point description of externalities provided in Section 2.2 is applied to urban water asset management externalities presented in Table 2-1. This project involved a desk based analysis and there is likely to be some variation across the data with respect to this definition.

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\(^1\) We note that technically externalities are uncompensated impacts implying rights. Where there are no rights but opportunities for potential Pareto improvements (i.e. compensation leaves both better parties better off) then the total cost is important. If there is no potential Pareto improvements, then total cost is not relevant and focus should be around rights.
### Table 2-1: Definition of externalities applied in this project

<table>
<thead>
<tr>
<th>Externality definition</th>
<th>Project definition of externality</th>
</tr>
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<tbody>
<tr>
<td>Direct impacts on the physical characteristics or attributes of the environment and people, which in turn generate indirect impacts on ecosystem functions and human wellbeing.</td>
<td>Direct impact of urban water assets/infrastructure construction and failure on community and environment.</td>
</tr>
<tr>
<td>Occur when those impacted are not involved in a transaction.</td>
<td>‘Others’ are defined as community. Transaction relates to the provision of water services to individuals.</td>
</tr>
<tr>
<td>Can be positive (<em>i.e.</em> provide a benefit to others) or negative (<em>i.e.</em> create a cost to others).</td>
<td>Focus on negative externalities.</td>
</tr>
<tr>
<td>Measured as a change in welfare or social wellbeing; sometimes termed social cost and social benefit.</td>
<td>Measured where possible in dollar numeraire, although this will represent a variety of values; production, compensation, welfare etc.</td>
</tr>
<tr>
<td>Have specific boundary conditions that relate to; people, environment, governance, time, space, measurement unit and event.</td>
<td>People: community Environment: direct area of impact Governance: current urban water utility legislation Time: short Space: local Measurement unit: dollars Event: asset construction and failure</td>
</tr>
</tbody>
</table>
3. THE ROLE OF EXTERNALITIES IN ASSET MANAGEMENT

3.1. Introduction

The approach adopted to manage a utility’s asset stock, along with the performance characteristics of the assets themselves, underpin the delivery of service to customers, communities and the environment. In this context, asset management is a key business capability for any water utility.

Asset Management is still an ill-defined term, and many definitions exist in the literature. Notwithstanding the value of other definitions, the following working definition is considered by the authors to encapsulate the most desirable features of this emerging discipline (Marlow et al., 2007):

A combination of management, financial, economic, engineering and other practices applied to (physical) assets, which has the objective of maximising the value derived from an asset stock over the whole life cycle, within the context of delivering appropriate levels of service to customers, communities and the environment, and at an acceptable level of risk.

The definition has been modified specifically to incorporate the important elements of sustainability, namely:

i. Whole of life considerations;

ii. A focus on net value (benefits net of cost) rather than just cost; and,

iii. The ‘triple bottom line’ requirement to simultaneously fulfil financial (through a customer focus), social (through a focus on the wider community) and environmental responsibilities.

Asset management undertaken in line with this definition can be termed ‘sustainability-based asset management’. Adoption of sustainability-based asset management requires externalities to be taken into consideration, both to facilitate decision-making and to improve performance with respect to financial, community and environmental indicators. To achieve these ends, externalities need to be incorporated into the way decisions are evaluated, and the way in which risk assessments are carried out (Marlow, 2009).

Asset managers use decision analysis at two levels; strategic planning and managing existing assets. With respect to planning, managers are keen to determine:

i. What scheme will provide the best solution (adding on to existing network, or something different); and,

ii. Given the scheme selected, which asset represents best value and acceptable risk, with asset defined in terms of its location and the asset itself?

Whilst with respect to existing assets, managers face a different set of questions:

i. Should I leave it or replace it?

ii. If I replace it, should I replace it with the same or something different?

iii. If something different, then what will be the impacts on my existing assets and thus service, what about service provided by the new assets? and finally

iv. If I can't afford to replace it, should I do something else such as change the way I manage the asset or the service delivery standards (i.e. pressure management)?

To incorporate externalities into these decision processes, priority needs to be given to the type of assets that are likely to have significant externalities associated with management decisions and failures, and secondly to identifying the type of externalities that may occur.
3.2. Types of Externalities in Asset Management

There are no known frameworks for identifying the types of externalities expected in urban water asset management. There are however several examples of incorporating a better understanding of socio-economic issues in urban water management such as CARES (Computer Aided Rehabilitation of Sewer networks), SLIM (Social Learning for the Integrated Management and sustainable use of water) and HarmoniCOP (Harmonizing Collaborative Planning). These sources provide a strong basis for identifying the impacts of difference asset management strategies, as well as a first pass assessment of externalities associated with the asset management water sector.

The type of externalities experienced from any event would depend upon a combination of factors:

i. Scale and type of event (i.e. magnitude of sewer collapse, depth of flood, volume and duration of effluent discharge to a river, etc.);
ii. System conditions (i.e. climate and its contingencies, built environment characteristics, type of infra-structure and management);
iii. Impact setting (i.e. business, residential, rural, etc.); and
iv. Social group (i.e. demographic and socio-economic population characteristics, risk perceptions and protective behaviours).

These factors combine to provide the contextual background for incorporation of externalities into proactive and reactive asset management decision-making (Burn et al. 2007). We divide the likely range of externalities into five groups:

i. Pollution or contamination;
ii. Environmental impacts;
iii. Public health and safety;
iv. Non-compensated financial losses; and
v. Social disruption.

It can be argued that pollution or contamination is not in itself an externality; rather it is the cause of the societal or environmental impact which is the loss. However, given the way in which the urban water sector measures performance, this scheme is to be retained for now. Importantly, many externalities are provided as “joint goods”, i.e. they are produced from a single inseparable production process that generates several externalities together. For example, social disruption could be caused when residents are negatively affected by odours from a nearby stream due to a sewerage spill. The spill has generated joint production of environment harm to river water quality and social disruption to livelihood.

Table 3-1 below is a first pass attempt to describe these externalities in more detail and to map them onto the asset stock used in urban water, using sewers as an example. Specifically effort has been made to explicitly map the lifecycle stage (i.e. construction, operation, failure, rehabilitation and disposal) of the sewer to the type of externality that may occur. Table 3-1 suggests that many of the externalities associated with sewers have potentially negligible (not applicable and minor) impacts at various stages of the lifecycle.
### Table 3-1: Externalities in the asset management cycle for gravity (critical) sewers

<table>
<thead>
<tr>
<th>Category</th>
<th>Externality</th>
<th>C</th>
<th>O</th>
<th>F</th>
<th>R</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pollution/contamination</td>
<td>Air quality impact</td>
<td>m</td>
<td>S</td>
<td>x</td>
<td>m</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Land contamination</td>
<td>x</td>
<td>m</td>
<td>m</td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td></td>
<td>Groundwater contamination</td>
<td>x</td>
<td>S</td>
<td>S</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Greenhouse gas emission</td>
<td>S</td>
<td>m</td>
<td>m</td>
<td>S</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Iconic river/stream impact</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Fishing river/stream impact</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Pristine river/stream impact</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Healthy river/stream impact</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Degraded river/stream impact</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Sediment contamination (riverine)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Sediment contamination (estuarine)</td>
<td>x</td>
<td>x</td>
<td>m</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Sediment contamination (marine)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Bathing beach impact (freshwater)</td>
<td>x</td>
<td>x</td>
<td>m</td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Bathing beach impact (marine)</td>
<td>x</td>
<td>x</td>
<td>m</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Environmental impacts</td>
<td>Habitat loss/generation</td>
<td>m</td>
<td>x</td>
<td>x</td>
<td>m</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Biodiversity impacts (terrestrial)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Biodiversity impacts (riverine)</td>
<td>x</td>
<td>x</td>
<td>m</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Biodiversity impacts (estuarine)</td>
<td>x</td>
<td>x</td>
<td>m</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Biodiversity impacts (marine)</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Disruption to heritage sites</td>
<td>m</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Loss of archaeological value</td>
<td>m</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Public Health and Safety</td>
<td>Health impacts (general)</td>
<td>x</td>
<td>x</td>
<td>m</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Health impacts (vulnerable group)</td>
<td>x</td>
<td>x</td>
<td>m</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Safety impact (general)</td>
<td>x</td>
<td>m</td>
<td>S</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Safety impacts (vulnerable group)</td>
<td>x</td>
<td>m</td>
<td>S</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Social disruption</td>
<td>Road/pavement damage</td>
<td>x</td>
<td>x</td>
<td>m</td>
<td>S</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Domestic disruption</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>S</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Noise nuisance</td>
<td>S</td>
<td>x</td>
<td>S</td>
<td>S</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Odour nuisance</td>
<td>x</td>
<td>m</td>
<td>S</td>
<td>S</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Dust nuisance</td>
<td>S</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Congestion</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>S</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Rail/tram disruption</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>S</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Aesthetic impacts</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>S</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Recreational impacts</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>S</td>
<td>x</td>
</tr>
<tr>
<td>Non compensated financial loss</td>
<td>Opportunity cost of water</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Opportunity cost of wastewater</td>
<td>S</td>
<td>S</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Opportunity cost of land (asset/landfill)</td>
<td>S</td>
<td>x</td>
<td>m</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td></td>
<td>Property damage</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td></td>
<td>Impact on property value</td>
<td>S</td>
<td>x</td>
<td>x</td>
<td>S</td>
<td>x</td>
</tr>
</tbody>
</table>

**KEY**

Asset Management Cycle: C: Construction; O: Operation; F: Failure; R: Rehabilitation; D: Disposal.

m: minor impact possible (assuming normal practice); short term, generally local spatial extent;
S: significant impact possible (assuming normal practice); and x: externality not relevant

### 3.3. Investigating Externalities

Incorporating externalities into urban water asset management is challenging. For example, consider the example in the text below. To address these issues, we propose that there are five broad steps that managers must undertake to do this:

i. Identify the contextual background factors creating opportunity for externalities;
ii. Determine the types of externalities associated with expected damages;
iii. Evaluate and estimate magnitude of externalities;
iv. Determine data required;
v. Design and deliver projects that estimate values, scale, costs and likely outcomes from different strategies to internalise externalities.

This section has provided some guidance in addressing questions one and two. The following section will provide insights into how to evaluate externalities, including data requirements (i.e. questions three and four).

**An example: structural collapse of sewer pipes**

Let us consider the case where a partial sewer collapse leads to surface soil depression: the defect “collapse” has a direct external effect, soil depression. The external impacts may be, according to the situation, damage to road structure, traffic disruption and environmental and health impacts. The intervention to address the failure also leads to a variety of externalities associated with rehabilitation works to remedy the collapse, including noise, dust, groundwater pollution, service interruption, and traffic disruption.

A critical question now is which externalities to focus on and evaluate? By using a common numeraire such as welfare we can evaluate many of the externalities by using a single approach. This ensures that even with joint production of goods (i.e. all occurring at once and inseparable) then no double counting of externalities will occur.
4. DEVELOPING THE FRAMEWORK

4.1. Introduction
In this section we focus on theory and approaches supporting an economic evaluation of an externality and hence the development of a robust framework for externality inclusion in asset management. We outline the economic perspective (theory), then move onto economic valuation tools and conclude by combining these sections into a practical framework for application.

4.2. Economic Theory
Measures of economic value are based on what people want – their preferences. Thus, the theory of economic valuation is based on individual preferences and choices (Freeman 2003). People express their preferences through the choices and tradeoffs that they make, given certain constraints, such as those on income or available time.

The economic value of a particular externality is measured by the maximum trade-off a person is prepared to make to avoid it occurring\(^2\). In a market economy, dollars (or some other currency) are a universally accepted measure of economic value. The number of dollars that a person is willing to pay for something tells how much of all other goods and services they are willing to give up to get that item (this assumes that the benefit of a dollar is the same to everyone in the community).

It is often incorrectly assumed that a good’s market price measures its economic value. However, the market price only tells us the amount that people who buy the good’s are willing to pay for it. Economic theory is based on the premise of consumer and producer surpluses. When people purchase a marketed good, they compare the amount they would be willing to pay for that good with its market price (the difference between the two being the consumer’s surplus). They will only purchase the good if their willingness to pay is equal to or greater than the price. People are generally willing to pay more than the market price for a good, and thus their values exceed the market price. In order to make resource allocation decisions based on economic values, what we really want to measure is the net economic benefit (consumer surplus) from a good or service. These surpluses are the net benefits to the individuals taking into account the cost of purchase. For individuals, this is measured by the amount that people are willing to pay, beyond what they actually pay.

The economic benefit to individuals, or consumer surplus, received from a good will change if its price or quality changes. For example, if the price of a good increases but people’s willingness to pay remains the same, the net benefit received (maximum willingness to pay minus price) will be less than before. If the quality of a good increases, but price remains the same, people’s willingness to pay may increase and thus the benefit received will also increase.

4.2.1. Total economic value
Externalities associated with urban water create a range of values to users and to the community. Changes in the structure, type, function and management of urban water assets will influence the externalities generated and hence people’s value. The concept of total economic value is applied to assess these changes.

Total economic value encompasses all potential values (both positive and negative). The components of total economic value are well established in the environmental economics literature (see for example Hanley and Spash 1993; Loomis \textit{et al.} 2000) and are illustrated in Figure 3-1. As shown, Total economic value (TEV) is comprised of two components. Use values include those that are directly used and enjoyed and which are either priced (marketed) or unpriced, as well as those that provide the underlying ecological functionality\(^2\)

\(^2\) From the perspective of this report, this assumes that the water rights are held by the water utility.
of the area. Non-use values are those that are experienced by all people, are not tied to
direct physical use of the asset, and include existence, option and bequest values.

Total Economic Value of Urban Water

Use Value

Direct use value

Marketing outputs
Eg. industry input, household water consumption for drinking, washing, gardens, etc

Unpriced benefits

Eg. recreational and aesthetics like gardening

Ecological function values

Eg. flood mitigation, habitat, waste assimilation, public health

Option values

Eg. future recreation like opportunity to build a garden

Existence values

Eg. knowledge of continued existence and liveability in the area

Bequest values

Eg. left to future generations, like garden and house designs


Figure 4-1: Elements of total economic value

The TEV of urban water relates to the flow of all values that the urban water assets provide, including when there are disruptions. There are number of conceptual approaches to estimating Total Economic Value (TEV) of externalities as follows:

1. **Production-based** approaches estimate cost of externalities via their contribution (cost) to other output (for example reduced productivity from pipe failures in industrial settings). It works best for outputs that are directly marketed.

2. **Expenditure-based** approaches can be divided into two categories. First, those that estimate actual expenditure to prevent an externality from arising. Second the expenditure to alleviate an impact, *i.e.* estimate the cost to mitigate or reverse the damage caused by a burst water pipe. These methods only value the response of people to adverse impacts, and are assumed to be a minimum value.

3. **Utility approaches** estimate the change to individual consumers' welfare due to the externality. The welfare change can be positive or negative and relates to the overall welfare of society, since societal welfare is assumed to be the summation of the welfare of all the individuals in the society. A range of surrogate or proxy market and survey based methods are used to estimate utility approaches (e.g. contingent valuation, choice modelling etc.).

4. **Benefit transfer approaches** estimate the ‘value’ of an externality based on transferring a function, amount or relationship from previous primary research (study) to the case study site. The transference can be of any type, and therefore includes all the previous three approaches. It is only appropriate for desk based or policy work where there is no time or it is considered too costly to undertake primary research, information is limited and the decision environment is sufficiently similar.

**4.2.2. Marginal changes in total economic value**

In practice, the evaluation of overall TEV is only relevant to decision-making when all or nothing decisions are proposed, such as total removal of a habitat. In general, however, a decision is between incremental or marginal change in values as a result of management decisions. This requires an understanding of the change in value (benefit or loss) associated
with different scenarios i.e. ‘with’ and ‘without’ some change. This concept is illustrated in Figure 4-2. This approach invariably means that for a particular project or scenario only a subset of values given in Figure 4-1 may be affected and hence require investigation. Importantly, the change should be in “net” terms (benefits minus costs), as a total expenditure figure or gross revenue figure does not provide the relevant marginal magnitude and direction of change necessary to understand total changes in TEV.

To clarify, consider water supply options for a new sub-division. There may be a number of different options relating to piping alignment, reliability and other factors. In this case, we are interested in the difference in the externality impacts between different options. To the extent that the externality impacts of different options are the same, we are interested in the difference in their extent and magnitude (for example the number of trees cleared under different alignments or the probability of unplanned supply interruptions). In essence, we are seeking to determine which option adds most value compared to the others.

![Figure 4-2: Marginal change in Total Economic Value](image)

4.3. Methods for Assessing Externalities

In this section, we outline four applied methods for estimating the value of externalities. These methods overlap imperfectly with the conceptual approaches described previously. **Market price methods** encompass production-based approaches and expenditure-based approaches. **Surrogate markets** are used where actual impact or expenditure data is not available but directly related expenditure is. **Survey-based** and **benefit transfer** approaches are used where market responses are not available. **It should be noted that a range of techniques may be required to estimate all externality impacts. Caution will be required to avoid double counting where multiple methods are applied to different externality impacts.**

4.3.1. Market price methods

Market price based methods place dollar values on externalities by estimating the direct costs that would be incurred to replace or repair urban water assets and the services they provide. Market price methods encompass both production-based and expenditure-based approaches. The production-based approaches include the dose-response method and the human capital method, while the expenditure-based approach includes the preventive expenditure method, mitigation cost method and the replacement cost method.

Table 4-1 presents the main methods based on market prices. The key strengths of such approaches are they use an easily understood basis for value (i.e. cost). Some weaknesses include that it is difficult to clarify the links between the environment and the direct change in welfare/wellbeing. Some parts of TEV (non-use and passive values) are also ignored. These approaches are also difficult to reconcile with economic theory of consumer and producer.
surpluses. Hence, market based approaches may not be appropriate for many externality impacts.

4.3.2. Surrogate methods

Surrogate or proxy market methods are used to estimate the value of externalities by examining the price paid for a closely associated good that is traded in the market. This approach uses observable market prices for one good to estimate the value of an externality that does not have its own price. For example, the house prices surrounding a sewage treatment plant may be lower due to odour pollution, whilst similar houses located nearby not affected by the pollution may have a higher value. Some examples of surrogate market approaches and examples are presented below in Table 4-2.

Strengths of applying surrogate market approaches are that they use market prices as a proxy and are therefore easily understood by all, data is available, they are tested in the market and are hence robust. Weaknesses include that they can not be used to investigate new goods or a change in environmental quality outside known experiences and there is a heavy reliance on the analyst’s knowledge of the causal link between the externality and the surrogate good and the actual externality under investigation.

A challenge for the application of this method is the production of joint goods or multiple goods, particularly where there may be difficulty in disentangling the value of one good from another due to both goods being produced together.

4.3.3. Survey based methods

Survey based methods are used to understand values via respondents ‘stated preferences’ about how much they are willing to pay for the utility they receive from an externality. Survey-based methods are also one of the few ways to place monetary estimates on non-use values and those use values that are difficult to estimate. The two main methods used as part of the survey based methods are described in Table 4-3.

The strengths of this method is that they elicit the full range of TEV though there remain perceived weaknesses surrounding the validity and reliability issues, i.e. strategic bias, ‘warm glow’ biases, implied value cues, misspecification of scenario, amenity or context.

4.3.4. Benefit transfer

Benefit transfer is an approach whereby results from one or more applied valuation studies are used in another valuation study, thus avoiding the need for primary research. Usually, this is undertaken by reviewing published studies to identify whether estimates can be applied to a new question in a different location. There are three general conditions under which benefit transfer is appropriate:

i. Study sites (the site where values have been estimated) and policy site (the site we want to value) must be similar

ii. The change under consideration at the policy site must be similar to the proposed change at the study site; and

iii. Socio-economic characteristics and other site details must be similar.

If these conditions are met, then benefit transfer can be carried out using a variety of methods (outlined in Table 4-4). This is a useful approach, especially in initial scoping of studies, or where only an order-of-magnitude estimate of environmental costs or benefits is required. However, it is reliant on a sufficient body of primary estimates being available for transfer. Benefit transfer can be abused if care is not taken to ensure the original study situation closely matches the situation being considered for the transfer.
<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Strengths and weaknesses</th>
<th>Case study examples</th>
</tr>
</thead>
</table>
| Dose-response (Change in productivity) | Examines changes in the dollar value of outputs resulting from a change in the quality of an environmental good; e.g. loss of production from a fishery affected by water pollution | • **Strengths**: easy to communicate results  
• **Weakness**: difficult to quantitatively make link between environmental change and productivity. | Opportunity costs of different forms of land degradation across agricultural zones in NSW (Walpole, Sinden and Yapp; 1995) |
| Human capital (Change in income)  | Examines forgone earnings and cost of illnesses to value an environmental good; e.g. the impact on health of air pollution | • **Strengths**: easy to communicate results  
• **Weakness**: difficult to quantitatively make link between environmental change and income. | Dose-response approach and quality of life analysis.  
Estimation of the health costs, to 2030, of enhanced ultraviolet radiation due to climatic change (Bryant et al., 1992). |
| Preventative expenditure (avoidance cost) | Examines expenditures made to prevent the effects of a fall in environmental quality, e.g. park management expenditure | • **Strengths**: easy to collect data  
• **Weakness**: only estimates minimum cost not net cost and difficult to quantify if the measure adopted will suffice in managing the problem in the long term. Does not reflect benefits. | Cost of planned environment protection measures, and total costs of environment protection measures currently incurred in Australia that can be attributed to algal blooms (Atech Group, 2000) |
| Mitigation cost                 | Uses estimates of the cost of repair or rehabilitation of environmental resources after environmental damage | • **Strengths**: easy to collect data and communicate results  
• **Weakness**: Does not reflect the concept of consumers or producers surplus from benefits – only costs. Theoretically weak. | Review of mitigation cost studies (Hourcade et al., 1996) |
| Replacement cost                | Uses estimates of the cost of replacing the services of damaged productive assets e.g. engineering works to prevent soil erosion after land clearing | • **Strengths**: easy to collect data  
• **Weakness**: Does not reflect the concept of consumers or producers surplus from benefits – only costs. Theoretically weak. | Calculation of maintenance dredging costs for a number of Australian locations and materials (Zvirbulis, 1993)  
Avoided appliance costs from reducing salinity in household water supply from 600mg/L to 500mg/L (Ragan et al., 2000) |
### Table 4-2: Examples of surrogated market tools based methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Strengths and weaknesses</th>
<th>Case study examples</th>
</tr>
</thead>
</table>
| Hedonic price | Uses differences in prices of market goods (property, wages) to value an environmental good | • *Strengths*: readily available data  
• *Weakness*: cumbersome data analysis and difficult to quantitatively link with environmental change | Impact of flooding on residential house prices from long-term perspective (Eves, 2002) and from critical events like hurricanes (Bin and Polasky, 2004) |
| Proxy good or averting behaviour (can use Travel cost method) | Uses value of a close market good substitute to value an environmental good. Also called ‘averting behaviour’, since this estimation technique infers a minimum value for changes in spending on ways to reduce the impact of the lower environmental quality | • *Strengths*: readily available data  
• *Weakness*: difficult to quantitatively make link between environmental change and income. Only a minimum estimate. | Averting behaviors technique used for studies include:  
• Boiling drinking water (Gilman and Skillicorn, 1985),  
• Staying indoors during times of heavy air pollution (Bresnahan et al., 1997),  
• Purchasing of air conditioners (Dickie and Gerkins, 1991), or  
• Bottled water (Abdalla et al., 1992). |

### Table 4-3: Examples of survey based methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Strengths and weaknesses</th>
<th>Case study examples</th>
</tr>
</thead>
</table>
| Contingent valuation | Uses survey methods to directly elicit a person's willingness to pay or to accept compensation for different qualities of an environmental good. | • *Strengths*: data elicits total consumer surplus values rather than just direct use values  
• *Weakness*: cumbersome data collection and analysis for single policy outcome. Some aspects of the technique remain contested. | • WTP for 'feeling good about conserving water in Melb. City' (Plant et al., 2007).  
• WTP to improve water quality in river (Loomis, Kent et al., 2000) |
| Choice modelling | Choice modelling uses preferences for a set of bundled scenarios to determine preferences for attributes of the environmental good being examined. | • *Strengths*: data elicits total consumer surplus and can gather data for new goods not yet experienced in market  
• *Weakness*: cumbersome data collection and analysis for single policy outcome. Some aspects of the technique remain contested. | • Evaluating customers’ preferences for less water stoppages in SA (Hatton MacDonald, et al., 2005).  
• Evaluating preferences for reduced flooding and overflows in UK (Ozdemiroglu et al. 2000) |
### Table 4-4: Examples of benefit transfer based methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Considerations</th>
<th>Case study examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean unit values</td>
<td>Applying mean unit values estimated for the study site(s) to the policy site. The form of these units varies, depending upon the context. For example, valuing recreational sites typically generates a value of a ‘person day’ for each recreational activity at the site. This value is then multiplied by forecasted changes in such days for the policy site to provide the estimate.</td>
<td>This approach implicitly assumes that the consumer’s surplus or WTP experienced on average by individuals at the study site(s) is equal to that which will be experienced at the policy site.</td>
<td>Transferring values to reflect changed environmental conditions from urban water supply options (see Plant et al., 2007).</td>
</tr>
<tr>
<td>Adjusted unit values</td>
<td>Adjusted unit values are simply mean unit values that have been systematically adjusted to account for any biases or differences between the sites that might affect WTP. These include factors such as differences in user demographics, the nature of the policy change, or the availability of substitute sites or services.</td>
<td>The ability to make these adjustments depends on the availability of enough original study information to produce the correction equations and knowledge at the impact of any differences between sites.</td>
<td>• Johnston et al. 2005.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Plant et al., 2007.</td>
</tr>
<tr>
<td>Demand curve estimates</td>
<td>Application of the demand curve estimated for the study site (a prior study) to the policy site (the current study site) or in effect transferring a benefit function.</td>
<td>This is the preferred approach because it is believed to better account for differences between the source estimates and the transfer estimates.</td>
<td>Plant et al., 2007.</td>
</tr>
</tbody>
</table>

*Source: Clifford et al. (2001, pp. 190-191)*
4.4. A Framework for Including Externalities

The aim in this section is to pull together the theory of externalities from economics and associated methods to develop a framework for including externalities in asset management. The five step framework developed, shown in Table 4-5 builds on previous work by Young (2000); Bowers and Young, (2000) and Plant et al. (2007).

Table 4-5: Framework approach for evaluation of externalities

<table>
<thead>
<tr>
<th>Step</th>
<th>Critical Issues</th>
</tr>
</thead>
</table>
| 1. Pragmatic scoping | Water authorities should first consider:  
- Which impacts to include?  
- Are these impacts really externalities?  
- Are they likely to have a negligible impact in the context of the decision?  
- Is there an economic/affordable option available that does not impose a specific and significant negative externality? |
| 2. Define externalities for consideration | Clarify the link between the urban water asset and people, which in turn generates indirect impacts on ecosystem functions and human wellbeing  
- Identify who is affected in the transaction, i.e. the ‘others’  
- Identify if positive (i.e. provide a benefit to others) or negative (i.e. create a cost to others) externality  
- Identify what ‘value’ is appropriate for inclusion, i.e. financial, costs and benefits or welfare  
- Determine specific boundary conditions that relate to; people, environment, governance, time, space, measurement unit and event. |
| 3. Quantifying impacts | Identify the physical magnitude of each externality  
- Determine who is affected  
- Determine what magnitude of physical impact is expected  
- Determine what direction (positive or negative) of physical impact is expected |
| 4. Value externalities | Determine the preferred & pragmatic method and data for value estimate; e.g. market price, surrogate markets, survey based and benefit transfer  
- Undertake analysis |
| 5. Evaluation | Determine appropriateness of valuation to current decisions and context (socio-political, management and environmental); and  
- Undertake sensitivity analysis across all relevant externalities to assess the robustness of available options, across a range of values |

The framework can be implemented within a variety of evaluation contexts, e.g. full cost accounting, multi-criteria analysis, life cycle costing, whole of life costing. Each application will require the approach to be tailored to meet specific requirements for what is to be included and the types of estimates required. As all values for externalities will be estimates, it is critical that the value reflects the context specific and dynamic preferences of individuals and the community. Furthermore, it should be recognised that outcomes will merely represent a snapshot in time.

4.5. Application of Framework

Detailed application of this framework is beyond the scope of this report. However, it is informative to provide an outline of how the framework would be applied in practice. To this end, consider the case where a decision must be made over the replacement of an ageing large diameter cast iron water pipe, the failure of which could result in significant social and environmental disruption. The asset management decision under consideration is to determine the optimum (or at least appropriate) time to replace the pipe.

For such cases, analysis of risk can be undertaken using physical probabilistic modelling combined with risk-cost-benefit analysis, as detailed in Davis and Marlow (2008). The process used is summarised in Table 4-6 (left column). An interesting aspect of this approach is that the replacement decision is evaluated in terms of the net present value of an...
intervention, so it is necessary to understand not only the costs associated with failure, but also the benefits of intervention, including benefits from avoiding failures through the intervention, as shown in Figure 4-3. The inclusion of externalities in this analysis would change the timing of replacement. For example, a significant externality related to a delayed intervention would bring the time of intervention earlier in the planning horizon; the reverse would also be true.

Figure 4-3: Cost-Benefits associated with pipe replacement decisions

Table 4-6 (right column) also shows how the externality framework (detailed in Table 4-5) would be applied in this kind of risk assessment. As shown, the analysis of externalities will be principally included in the final steps of the risk analysis, following on from the condition assessment work. However, in a more general sense, the consideration of externalities will inform the prioritisation of assets for inspection and risk assessment.

Table 4-6: Linkage between risk assessment and evaluation of externalities

<table>
<thead>
<tr>
<th>Risk Assessment Steps</th>
<th>Evaluation of Externalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Identify asset(s) for analysis (prioritize risks)</td>
<td>1. Pragmatic scoping (this should form part of the process for identifying assets to inspect)</td>
</tr>
<tr>
<td>2. Inspect target asset: obtain raw data for condition assessment</td>
<td>2. Definition of externalities of interest</td>
</tr>
<tr>
<td>3. Convert raw condition data to corrosion rate; and estimate probability of failure using physical probabilistic models</td>
<td>3. Quantifying impacts associated with failure and intervention options</td>
</tr>
<tr>
<td>4. Determine the types of consequences associated with expected damages and intervention options</td>
<td>4. Value externalities</td>
</tr>
<tr>
<td>5. Determine data required; and design and deliver projects on estimating consequences for different interventions (values, scale, costs and likely outcomes)</td>
<td>5. Evaluation, including sensitivity analysis</td>
</tr>
<tr>
<td>6. Use failure probability and cost consequence in combination to inform future interventions</td>
<td></td>
</tr>
</tbody>
</table>

Note: see WERF (2009) for further information on risk-based asset management as it pertains to the end of asset life.

For this type of decision, there are a range of possible externalities associated with failure, inspection and replacement of the pipe using a range of options (e.g. full/partial like for like replacement; trenched and trenchless techniques). For the purposes of the current discussion, a good example is the impact on traffic and social activity.

Disruptions will occur during a failure and also during the planned replacement of the pipe. In fact, the length of time over which disruptions occur may well be longer for replacement of a pipe in comparison to those associated with a failure. Nevertheless, externalities associated with failures could still be more significant. The difference is that customers and the wider
community may be more accepting of planned events, as they can in turn plan around the known disruption, so the impact on welfare is relatively lower. In addition to this consideration, planning an intervention provides adequate opportunity for ensuring appropriate environment and health & safety controls are in place, again, indicating that the range of externalities could be lower (e.g. planning provides greater opportunity for minimising environmental impacts and public health & safety issues). Finally, it may be supposed that the imposition of impacts during a planned event are consented, assuming there has been appropriate public consultation.

In considering the impact of potential interventions, there is thus a need to consider the difference in value placed on the impacts of a planned interruption (i.e. inspection and replacement) when compared to an unplanned interruption (i.e. failure). Inclusion of externalities into analysis of unplanned failure events is thus warranted, but it may also be necessary to undertake work to confirm some of the assumptions for planned work, given the context of the particular intervention. Further details of approaches to the analysis of externalities for this kind of asset management decision can be found in Marlow & Burn (2008).

Costs of externalities can be estimated using the techniques set out above. Table 4-7 identifies a first approximation of which of these methods may be most suitable when considering the externalities associated with large pipe failure in a typical densely populated area. We note however that an alternative approach is to use benefit transfer where suitable studies are available.

Table 4-7: Potential techniques for large pipe failure externality estimation

<table>
<thead>
<tr>
<th>Externality</th>
<th>Cost estimate method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land contamination</td>
<td>Mitigation cost</td>
</tr>
<tr>
<td>Greenhouse gas pollution</td>
<td>Proxy good</td>
</tr>
<tr>
<td>Habitat loss/ generation</td>
<td>Mitigation cost</td>
</tr>
<tr>
<td>Safety of general public and vulnerable groups</td>
<td>Choice modelling</td>
</tr>
<tr>
<td>Noise and odour nuisances</td>
<td>Contingent valuation</td>
</tr>
<tr>
<td>Opportunity cost of land</td>
<td>Replacement cost</td>
</tr>
<tr>
<td>Property value</td>
<td>Hedonic price</td>
</tr>
</tbody>
</table>

(see section 3.2 for more detail)
5. CONCLUSION

This report has considered the role externalities play in an enlightened view of asset management. Part of the challenge in developing such an approach is to integrate effectively the consideration of externalities into risk analysis and decision-making. In particular, if analysis can be undertaken to represent externality issues in a consistent manner, water authorities can then select solutions that are aligned with sustainability objectives, and provide justification to stakeholders for budget levels that take into account the wider impact of their activities. Consistency in the treatment of externalities (between water authorities and individual decision makers within a given utility) can, however, only be achieved if appropriate guidelines are set and used.

The research detailed in this report has been undertaken to help address this issue, but a great deal of further work is required, including the application of the framework to a range of asset management problems at different scales, and the integration of concepts into asset management tools and processes.

Such tools and processes should be designed to facilitate asset managers to make robust decisions that are aligned, as far as is practicable, with the sustainability aspirations of their water utility. While consistency in approach is important to this aim, the costs generated in the analysis of externalities will often be non-market (or based on proxy or surrogate markets). As such, it is likely that the efficacy or otherwise of externality calculations will always be open to challenge. With this and robustness of decision-making in mind, a capacity to undertake sensitivity analysis should be considered an essential feature of any tool or process developed.

From the perspective of developing a common framework, we suggest that there are two broad areas that should receive priority treatment:

1. **Testing the type and extent of externalities** to provide a baseline for considering the extent of externality impacts in urban water management. In particular, relevance and appropriateness of five suggested categories (pollution/contamination; environmental impacts; public health and safety; social disruption; non-compensated financial loss) to all areas of asset management should be examined in detail.

2. That an immediate need is to **prioritise which assets in urban water** are likely to be most impacted by externality considerations.

We also suggest identifying the portfolio of assets where the inclusion of externalities in decision processes may be sufficient either to shift asset management from a reactive to proactive approach, or for which investment shifts to a different class of assets (for example from end of pipe to distributed sewage treatment). In other words, studies should be prioritised against those assets most likely to be impacted by externalities or for which externality impacts are most likely to change significantly the investment portfolio.

Studies should also be structured in such a way that primary research can be transferred across a range of asset management considerations. In particular, attention should be given to the information necessary to support ‘demand curve’ approaches to benefit transfer across water utility assets.
6. REFERENCES


Economic Evaluation: An introductory guide to policy-makers and practitioners, Queensland Government.
