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The influence of context and perception when designing out risks associated with non-potable urban water reuse

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Abstract

Perceptions and cognitive bias in relation to reuse water can influence the responses to risk and reward. Much has been written on community perspectives and risk perceptions with regard to recycled water for non-potable use. This paper is distinct in that it focuses on the scheme proponents and those involved in designing and delivering schemes. An analysis of five case studies in Australia across a range of diverse settings revealed that the levels of treatment for various end-uses were in excess of the Australian Guidelines for Water Recycling. The evidence shows that the water industry has a fairly narrow view when identifying risks, and has an insurance type response to mitigating the risk. The overarching drivers for this are either the mitigation of the perceived risk associated with using reuse water, or the lack of an adaptive response to changes in the circumstances.

1 Introduction

Reuse water has been generally perceived as a reliable source of rain independent water for irrigation, non-potable residential use and commercial processes for a few decades now. And in some parts of the world, such as Windhoek (Namibia), direct potable reuse water has been supplied (Hatt et al. 2006; Rodriguez et al. 2009). More recently reuse water has been used to create liveable urban landscapes which benefit local residents (Brown et al. 2009; Mukheibir et al. 2015). Utilities gain a dual benefit in that they need to source relatively less clean water for supply, and dispose of lower volumes of waste water, thereby having a lower impact on the aquatic environment, and potentially reducing their costs to operate the distribution networks and treatment facilities.

However, as this paper will demonstrate, concerns about the health and operational risks associated with the quality and distribution of reuse water have in some cases led to higher treatment regimes than those specified in the Australian Guidelines for Water Recycling (AGWR), thereby negating the benefits just described. This has resulted in an inefficient initial capital investment, ongoing additional operational and maintenance costs, and ongoing environmental costs (e.g. increased GHG emissions). Drawing attention to this over-treating practice i.e. using higher quality water for lower grade purposes, is not new, as demonstrated by the United Nations Economic and Social Council statement in 1958 "No higher quality of water, unless there is surplus of it, should be used for a purpose that can tolerate a lower grade" (UN ECOSOC 1958).

To move towards a more efficient treatment approach - one that is *fit-for-purpose*, requires an appreciation of the risk perceptions of individuals and the risk adverse organisational and sectoral cultures that underlie the current practice.

Risk, its assessment and our responses to it, is central to investment in and uptake of recycled water services. The traditional framing of risk involves identifying a hazard or potential risk, describing the exposure to that risk, and assessing the relation between the magnitude of exposure and the probability of occurrence of the health effects in question (i.e. the dose response) (Fowle & Dearfield 2000). Understanding the scale of the impact or consequences due to the hazard is important since it establishes the magnitude of the risk and associated financial implication if the hazard were to eventuate.

In the case of water quality, an *exposure assessment* estimates how much of a pollutant people might ingest during a specific hazard event, and barriers required to reduce *exposure pathways* (EPA 1991; Fowle & Dearfield 2000). This may involve an assessment of the number of people exposed to the hazard, and how the statistical risk stacks up compared to other hazards encountered by the community. In addition, *exposure pathways* to the hazard may already be blocked through existing barriers, such as existing treatment trains, signage, time of use, etc., and therefor do not require additional interventions.

When considering the risks and uncertainties associated with recycling schemes, it is useful to distinguish between technical, operational risks and broader business risks. Existing guidance resources on recycled water focus on the technical and operational risks, which are all about regulatory compliance – identifying and managing hazards and ensuring the quality of the product from a public health perspective (Foley et al. 2006). However, very few of these resources deal with what might be termed the broader 'business risks', discussed in this document. Getting the technical operational risks under control is absolutely fundamental to managing business risks, but what the research in this paper shows is that there are broader business risks that historically have received inadequate attention.

[Insert Figure 1 here]

In addition, risk and its various descriptions are highly influenced by the context within which the risk occurs, and individual and social perceptions, which can in turn affect collective and individual choices and decisions. As illustrated in Figure 1, risk perception and tolerance depends on a person's perception of their likelihood of harm, control over harm, extent of harm or hazard, willingness of exposure to possible harm, and trust in the sources of risk information (World Water Assessment Programme 2012). When water service providers are deciding on the level of risk associated with a certain service, the appetite for risk is usually influenced by the representatives on the utility board or local government council (Davison 2011), it is not surprising therefore that the individuals' perceptions of risk are brought to bear on the business risk decisions.

There is evidence that overtreatment of reuse water could be due to the prevailing perceptions of the proponents and designers (ISF 2013c) or in some cases that the overtreatment of recycled water is due to the assumptions and context changing overtime, often beyond the control of the scheme owner or operator (Turner et al. 2016). Kahneman and Lovallo (1993) suggest that the forecasts of the future are often anchored on assumptions or scenarios for success rather than on past results, and therefore the expectations of the benefits (or reward) are overly optimistic, and have led to business failures (Hammond et al. 1998).

Much has been done on understanding the psychology of risk and reward, and these lenses bring new insights to the recycled water field. The theories of perceptions of risk and reward are discussed further in the analytical framework section. Therefore, this paper firstly contextualises our framing and perceptions of risk and reward, and then sets out the types of risks associated with reuse schemes, how the industry has responded (as illustrated through the case studies), and a possible shift that is required by the water industry if reuse water is to be competitively viable. The focus of this paper is on the implicit perceptions of institutional risk (i.e. the scheme proponents) that led to decisions to overinvest in the level of water quality. Because every reuse scheme has its own context, this paper avoids prescribing solutions, but rather aims to help practitioners understand how risk could be foreseen and more efficiently managed.

2 Methodology

This paper highlights some of the key issues and questions relating to risk identification for non-potable water reuse from sewage in Australia and the responses to them.

Our intention was to explore and reveal what actually happened in practice in terms of investing in the planning, construction, and operation of these systems, and how the key stakeholders judged their success or otherwise, and what lessons might be learned for the next generation of recycled water systems. This research was undertaken at the end of a decade-long drought across the country, by which time water supplies were secure in Australia's major cities, and political attention had shifted away from the water sector.

We took a transdisciplinary approach, starting by engaging actors from the full spectrum of stakeholder types in recycled water – public and private metropolitan and regional utilities, private industry, regulators, agencies, local councils, and private developers. In line with an approach to transdisciplinary research that values professional and lay knowledge and experience alongside researcher and disciplinary expertise (Mobjörk 2010), project collaborators had central input to the research design decision to focus on a small number of in-depth case studies.

The research team and project collaborators together decided on the dimensions that should be covered by the set of case studies, namely scale, jurisdiction, end uses, and public-private arrangements. Eight case studies were conducted, using a mixed-methods approach to data collection and analysis, encompassing more than 80 semi-structured interviews with representatives from about 30 organisations, as well as document analysis. The interviewees were initially recommended by the organisations linked to the schemes, and then further interviewees were identified using the snowball sampling approach. The interviews were complimented by a review of internal business case and design documents, together with relevant policy documents (EPA Queensland 2005; EPA Victoria 2005; MWD 2012).

Semi-structured interviews were based on a number of themes we wanted to explore, including: Which organisations were involved at different stages of the project – conception, design, delivery. What was their role? What was their perception of value of the scheme? What costs were actually incurred? What risks were perceived and how were they managed e.g. levels of treatment? How did all of this change over time?

In this paper, the findings from 5 of these case studies are discussed, where higher than required water treatment was implemented (refer to Table 1 for details). Although the schemes are very different, they provide common lessons and insights about how risk (technical, operational and business) was managed, and the cognitive bias traps that may have been at play during the decision-making processes. All five schemes recycled sewage for non-potable reuse.

[Insert Table 1 here]

As mentioned in the introduction, the focus in the recycled water sector has to date been mostly on technical risks i.e. those that pertain to treatment, but there are broader business risks that matter as much or more. Therefore we consider these additional risks with a view on how they have affected the water quality treatment decisions.

3 Analytical Framework - perceptions of risk and reward

Our *analytical framework* was a synthesis of three epistemologically distinct approaches to risk. Firstly, the risk assessment and risk management frameworks embedded in international and national standards (Fowle & Dearfield 2000; EPHC et al. 2006), which take a principally *objectivist* stance in that they assume that the probability and consequence of a risk can be objectively determined and assessed. We chose this framework because it provides the fundamental structure for the governing and guidance materials in the sector nationally and globally.

We juxtapose this with the theory of risk perception first advanced by Douglas and Wildavsky (1982), and later by Steg and Sievers (2000). This theory takes a more *constructivist* stance where truth and meaning are constructed through interactions between humans and their world, and developed and transmitted within a social context. The perceptions of risk by individuals, and their corresponding responses, can be characterised into four dispositions: fatalist, hierarchist, egalitarian, and individualist (as shown in

Table 2). We chose this theoretical framework because of its power to help explain the diverse ways in which the national guidelines are implemented in practice. According to Douglas and Wildavsky (1982), risk perception should not only be viewed in the context of personality traits, preferences, or the properties of the risk objects, but also as a socially, or culturally constructed phenomenon. What is perceived as dangerous, and how much risk to accept, is a function of one's cultural adherence and social learning (Boholm 1998). One cannot account for how people perceive and understand risks without also considering the social context in which risks occur.

[Insert Table 2 here]

Thirdly, we draw on studies in behavioural psychology that explain that decision-making in the face of complexity and uncertainty, is often not a rational, impartial process, and is largely influenced by cognitive and behavioural bias (Chira et al. 2008; Barber & Odean 2001; Hammond et al. 1998). Culmsee & Awati (2011) describe *cognitive biases* as meta-risks, that is, risks that affect the process of risk analysis. Sectoral disciplines and organisational cultures play an important role in shaping the environment within which cognitive biases occur (Shore 2008). Hammond *et al* (1998) identify three cognitive bias traps that have relevance for decision-making processes under uncertainty, and that expose ourselves to far greater risks than we anticipate, or lead to missed opportunities, viz.: *overconfidence, prudence, and recallability*.

We may fall into the *overconfidence* trap when we are overly confident of our own judgements and overestimate the accuracy of our forecasts and assumptions (Kahneman & Lovallo 1993). This overconfidence trap can be driven when the certainty of our judgement is based on a myopic attention to a limited causal understanding of a past event, in other words, it is based on *hindsight bias* (Roese & Vohs 2012). In contrast, when faced with a high risk decision, we may fall into the *prudence t*rap, and be over-cautious and adjust our estimates closer to the "worst-case" scenario, despite the chances of it happening being very low. In such cases, we may hedge our bets against a technology or practice with which we are more familiar, to the discrimination of the less familiar approach. The relatively unknown or untested assumptions about reuse or decentralised schemes have often counted against such projects, whereas business as usual potable centralised schemes are more familiar to planners and decision makers and hence are scored more favourably in risk and multi-criteria assessments (Watson et al. 2012).

When our estimates are disproportionately influenced by dramatic past events, either positive or negative, which are strongly impressed in our memory, we may fall into the *recallability* trap. We are more likely to have confidence in our choice of option if it is aligns with our recent experiences with, and perceptions of, similar products and their associated risks and rewards (Chira et al. 2008), and visa versa.

We chose this framework because it provides a salutary lens for exploring and explaining the organisational failures in practice to recognise and manage the very real risks beyond technical water quality that have had significant impact on the sector in Australia. Together, these three frameworks allow us to interrogate and explain our data in rich and nuanced ways, drawing out examples and insights, and demonstrating the potential to learn from experience.

4 Research findings - where do the water quality risks lie?

Regulations for water quality in Australia are based on anticipating potential public health and environmental risks and preventing them from arising through the risk management approach provided under the National Water Quality Management Strategy in the form of the Australian Guidelines for Water Recycling (AGWR) (EPHC et al. 2006). Since 2006, the AGWR, while still providing treatment guidelines for specific sources and end-uses, has required proponents to undertake scheme-specific risk analysis, rather than comply with prescriptive standards across all schemes (as was required in the past). The AGWR guidelines necessitates greater engagement between proponents and regulators in assessing the *likelihood and consequences*. This includes identifying the required log reduction values to meet the residual risk threshold, designing the scheme (including the treatment train and onsite controls), and setting appropriate parameters for validation and verification.

The challenge has therefore become one of steering a sensible course between the extremes of failing to act when action is required and taking action when none is necessary (NHMRC 2011). A lack of action can compromise public health (NHMRC & NRMMC 2011), whereas excessive caution can have significant social, environmental and economic consequences. This move from a prescriptive approach to a risk-based approach has had a mixed response resulting in a variety of risk interpretations (LECG Limited Asia Pacific 2011). Reuse water acceptance is constrained by community and regulatory risk perceptions, which in themselves are influenced by a range of factors (Mankad & Tapsuwan 2011; Dolničar & Saunders 2006). Regardless of the scientific data, risk perceptions by developers, regulatory authorities, end-users and the community regarding the acceptability of reuse water can vary greatly.

While the AGWR risk management framework is, in theory, more flexible, it has been suggested that the uncertainty surrounding new technologies and unclear policy positions has created a climate of risk aversion (Tjandraatmadja et al. 2008; Power 2010). This has resulted in conservative recommendations in the AGWR and even more conservative risk-based treatment being implemented (ISF 2013c), causing delays and additional costs, due to a perception that best quality rather than 'fit for purpose' water is required (Tjandraatmadja et al. 2008).

As is illustrated in Table 1 and described in Table 3, many of the schemes analysed provided reuse water that exceeded, to varying degrees, the recommended treatment standards in the AGWR required for the various end-uses (ISF 2013c). The level of treatment required for reuse water depends on a combination of the scientifically assessable risks, the perceptions held by key individuals of the risks associated with the reuse water source and end-use, and the context within which the decision about the level of treatment is made. The systems reviewed in this study had been operating for widely varying length of time, and had been installed during very different political settings and to meet widely varying drivers, such as grant funding during the Millennium Drought. None the schemes were "over-serviced" because of community engagement or community acceptance concerns – in all cases it was fear of failure and the associated regulatory penalties.

[Insert Table 3 here]

From our case studies we identified three categories of drivers for over-treatment (ISF 2013c) discussed below.

4.1 Regulations to safeguard public health

Microbial pathogens in reuse water from sewage effluent are the major concern for human health, and to become infected by a pathogen you must be exposed to a sufficient number of viable pathogens. To avoid such infection, the AGWR specifies the minimum "performance levels" that should be achieved by water recycling schemes. These health and environmental risk-based targets are based on a combination of the quality of the water that people may be exposed to i.e. the *hazard* (determined by the treatment process) and preventive measures taken to prevent people from being exposed to it (*exposure pathways*). Concerns about *exposure* of the public to risk are typically focused on food irrigated with reuse water, parks and fields irrigated with reuse water, facilities supplied with reuse water through dual reticulation systems, and occupational exposure to reuse water (e.g. use of recycled water by fire-fighters). When such concerns exist, the AGWR recommends that treatment includes disinfection through chlorine dosing or UV treatment (EPHC, NRMMC, & AHMC, 2006, p. 103).

Australia's guidelines for an appropriate level of *residual risk* demonstrate the risk averse culture of the sector internationally. The level of treatment recommended by the AGWR is based on an acceptable residual risk of less than one person in 1000 getting diarrhoea per year. This is the same as the Canadian Guidelines, but less strict than the US EPA target of an infection rate of 1:10,000 (Health Canada 2010). However, Hellard et al. (2001) demonstrated in a randomly selected Melbourne sample, where micro-organisms had been removed from the supplied potable water, that the rate of diarrhoea was still 0.8 cases per person per year. This study demonstrated that waterborne pathogens did not play a detectable role in gastroenteritis. The residual risk recommended by AGWR is more than 800 times higher than the background exposure rate. Further, the risk of diarrhoea is a function of *exposure pathways* such as consuming reuse water through cross-connections or ingesting irrigation sprays. However, the *likelihood* of ingesting a significant volume of reuse water from irrigation sprays or toilet flush water would intuitively be relatively very low.

Despite this low likelihood, the only driver for public health risk management for councils in Australia, where they are not covered by any regulation, is to protect themselves against liability. For example, Ku-ring-gai Council, responded to risk by implementing multiple disinfection for the reuse of recycled sewage on their Gordon golf course. The application of both UV and chlorine treatment provides an additional margin of safety to meet the "multiple barrier principle" of the AGWR, but results in a level of treatment that far exceeds the recommendations of the AGWR.

The likelihood of consuming significant volumes of re-use water goes up considerably with the rate of cross-connections, but here too the responses are strident. For example, the AGWR recommends putting in safeguards for supplying dual reticulation water with an annual cross-connection risk of around 1 event in 1 000 dwellings per year (EPHC et al. 2006). However, the incidence of cross-connections between recycled water and drinking water pipework in Australia is spatially and temporally rare (MWD, 2012, p. 115), with the incidence reported as being on average in the order of 1 event in 10 000 dwellings per year (Storey et al. 2007). Most of the incidents were in the early days of the sector, where for example, at the Sydney Water Corporation's Rouse Hill recycled water scheme (the first and largest scheme of its kind) 50 cross-connections were found prior to the scheme's commissioning in 2001 due to plumber error inside residences (Hambly et al. 2012). In recent years only one cross-connection incident has been reported (at a school in Melbourne), but with no related health consequences (DHHS 2015). This is a good illustration of the *recallability trap*, where one significant event influenced subsequent risk planning, and would suggest that the industry is in general over-cautious (the *prudence trap*) by over-investing in management systems that have the likelihood of one-tenth of the of the risk that the guidelines suggest is acceptable. Proponents of these types of schemes display a *hindsight bias*, since they 'know' for historical examples that recycled water systems are likely to be placed under more scrutiny and therefore overcompensate with extra treatment despite costs.

The flexibility for site specific assessments introduced by the AGWR is open to interpretation, depending on who the regulatory authority is, the scale of the scheme in question, and who the proponent is (Power 2010). This creates the potential for state regulatory authorities to have differing interpretations of the level of *residual risk* associated with various recycling sources and end uses. For example, in the state of Victoria, the level of treatment required for the use of reuse water for indoor use is higher than suggested by the AGWR (ISF 2013c). This is illustrated by the Aurora greenfield housing development in the state of Victoria, where the treatment of recycled water for non-potable indoor use is higher than the levels recommended by the AGWR (ISF 2013a)[1].

This variation in the acceptable level of *residual risk* is a result of an inconsistent assessment of the *likelihood* of the *exposure* to the public or end-user, and the need for an appreciation of the *consequences* due to that exposure. These perceptions can affect the setting of industry norms and standards. The intended approach of the AGWR is *hierarchist* (based on Douglas and Wildavsky 1982) where guidelines are provided to manage risk, but the interpretation is *egalitarian* with extra prudence, where risk is mitigated through overdesign.

Water utilities have further reinforced this *prudent approach*, by introducing robust audit programs despite the installation of backflow prevention systems to reduce the extent of hydraulic network influence from any cross- connections that do occur (Power 2010, Storey et al 2007). This is in line with the recommendations of the AGWR for large dual reticulation schemes where all households connected to recycled water having to undergo a cross-connection inspection audit every five years, or 20 per cent of the households per year (Table

[1] The Victorian Guidelines for Class A require Virus=7 log removal and Protozoa=6 log removal, versus Virus=6.5 log removal and Protozoa=5 log removal recommended by the AGWR (EPA Victoria 2005; EPHC et al. 2006)

2.8 of the AGWR). Under current arrangements, the additional cost of this auditing regime at Aurora, for example, is around A$50/household/year (ISF 2013c) and is borne by the local water utility and then spread across the whole customer base as part of the pricing determination.

Driven by the concern of cross-connections in dual pipe systems, and to move away from manual audits, research is underway in Australia to develop in-line water quality sensors to detect contamination through cross-connections (Richards et al. 2016). Given the low *likelihood* of cross-connections explained above, this level of auditing and surveillance would appear excessive. Rather than a blanket audit of all houses, a system that audits and certifies only those houses which have had plumbing alterations would reduce this perceived risk and associated cost burden.

4.2 Reputation perception

The mitigation of risks associated with recycled water treatment is also driven by the need for owners, proponents and operators to protect their reputations and to ensure their brand and products remain untarnished and, preferably, enhanced.

The developers and operators of a high quality office space on the edge of Sydney's CBD (Darling Quarter), for example, mutually agreed to adopt a "zero risk" approach to maintain their reputation for having buildings and amenities of a high standard. This led to the identification of additional risks during the design phases of the project, such as concerns about odour from the plant potentially affecting tenant amenity. Bad publicity at the time for another high quality "green" building in the Sydney CBD (due to odour issues from their inbuilt recycling system) further fuelled this concern (*recallability bias*) (Moses 2009). This led to additional ventilation processes being installed at Darling Quarter that ensured that the likelihood of adverse odours was minimal, but had the effect of increasing the planned capital and operating costs (ISF 2013b).

The owners of a sanitary paper manufacturing plant using Class A recycled water were concerned about the potential negative public perceptions associated with the use of recycled water in the manufacture of personal hygiene paper. They therefore adopted a *prudent* approach where the recycled water was only used for industrial processes such as cooling and boilers, and potable water was used in the manufacture of the actual products (ISF 2013c).

4.3 Treatment quality chosen to respond to anticipated water quality demand

This risk category highlights higher treatment levels due to ambitious demand and water quality expectations, which then experience changing contexts over time. Changes in the anticipated demand for high quality water due to changes in the context can introduce the risk of over-treating the reuse water, and hence higher capital and operational costs. Such cases demonstrates how changing contexts require ongoing assessment of the assumptions and risks (ISF 2013d).

The main causes of forecast inaccuracies, specifically the overestimation of benefits and underestimation of costs and risks, can occur unintentionally due to optimism/over-confidence bias, or be done strategically to favour a specific political or economic agenda (Flyvbjerg & Holm 2005).

A good example of this is the Rosehill scheme where the proponents took advantage of a financial subsidy during the drought to supply high quality recycled water to a large anchor customer. Due to changes in the economic climate, the anchor client closed down their operation, with the result that the quality of the recycled water being produced is now too high for the needs of the remaining customers and their end-use purposes. It could be argued that an *over-confidence* bias resulted in them not building a flexible plant that could deliver the quality of water demand by the customers of the day.

A similar example, is the development of the Wide Bay Water WWTP at Nikenbah was built to deliver Class A quality water, with the potential to be upgraded to supply potable water (Class A+) during drought. Alignment with the then state government policy agenda driving potable reuse was influential in securing the subsidy. However, there is currently no demand for the Class A water, so it is blended with other Class B recycled water before application (mostly irrigation). Since the plant was not designed to be flexible and produce Class B water, it continues to provide water which is of a higher quality than necessary, resulting in higher operational costs. While the capital costs were provided through a government subsidy during the drought, the ongoing operational costs of producing higher than needed quality water are borne by the whole customer base.

5 Discussion and conclusion

The analysis revealed that the water industry in Australia currently has a relatively narrow view of risk. Risks associated with reuse water are broader than only the technology risk associated with water quality, and should also include changes to the initial planning assumptions related to supply and demand volumes, financing arrangements, and stakeholder objectives. Flyvbjerg (2008) and others (Hammond et al. 1998) suggest that the inaccurate projections of costs, demand, and other impacts of planned schemes are mainly due to optimism bias and strategic misrepresentation.

It has also been shown that perceptions play a large role in framing our response to the risks. For the case studies presented in this paper, it would appear that the perception is often that "best quality" and not "fit-for-purpose" water is required to mitigate risk. The main consequence of "over-treatment" is an initial inefficient capital investment and higher ongoing operational and maintenance costs, with associated environmental costs (e.g., increased GHG emissions), that could be reduced if the water was treated for fit-for-purpose and associated risks. In addition, for small schemes and councils there is a concern that the risk management approach and processes advocated by the AGWR are costly and may be impeding investment (Watson et al. 2017).

In any population, there is a wide range of perceptions about how dangerous a risk is, about how risk is balanced with its associated rewards, and about what actions are believed to be worth taking to mitigate the risk. Institutional responses to risk are fundamental to what constitutes a plausible future for water recycling. Risks, perceptions of risks, acceptability of risks, imposition of risks, etc. are central to the discussion about reuse water in general.

Another key finding is that decisions made around reuse water risks are contextual and that in some cases these higher levels of treatment were due to an over estimation of the assumptions about the future. These case studies of demand uncertainties illustrate that deviations can happen in any reuse context, and therefore careful consideration of uncertainties in demand forecast assumptions is worthwhile when planning a reuse scheme.

Mitigating the risks for when the context changes, has also been one dimensional where the response has been a generally more expensive "insurance" approach than one which adopts a more adaptive management and flexible response, i.e. building in more redundancy to cope with change versus adopting a modular design or flexibility in the operations. An incremental modular approach to recycled water supply and quality treatment may be more prudent when the demand is uncertain. In such cases, treatment could be up-scaled to meet water quality demand when needed.

With these issues in mind, a conscious effort to guard against the biases that result in higher levels of treatment documented in this paper that in hindsight might have been avoided. While the development of a more nuanced understanding of risks of reuse water is in its infancy, it will be essential for achieving the longer term goal of a more equitable distribution of costs, benefits and risks across the stakeholders in reuse water service provision.

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A series of resources developed during the project are publicly available and can be found at the dedicated website (http://waterrecyclinginvestment.com).

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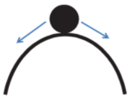
Table 1: Brief description of the case studies examined

Scheme		Description	Treatment levels	Cognitive bias trap
1	Aurora Victoria	Residential greenfield third-pipe for 8,500 homes provided by the public utility. The concern about the risk of cross-connections due a third-pipe scheme was deeply challenging to the long-held industry values of providing low-risk services at the lowest cost.	Victoria State regulations are higher than AGWR recommendations	Prudence
2	Darling Quarter NSW	A 6-star residential & commercial precinct (Private developer Private operator and retailer). Concerns from the developers around odour from the plant potentially affecting tenant amenity, residual health risks and long term maintenance and operation, led to additional plant equipment being installed that effectively increased the planned capital and operating costs.	Reputation risks demanded higher than AGWR recommendations	Recallability
3	Wide Bay Water Queensland	Irrigation reuse of sewage by a public utility for crops and plantations, and some commercial reuse. Eli Creek, Pulgul and Nikenbah are the three main sewage treatment plants, treating sewage to B, B and A class respectively. All the reuse water is mixed together and is classified as B. Nikenbah was deliberately designed with the potential to be upgraded to supply A+ class potable water during drought as this enabled it to attract a substantial reuse subsidy. Without the subsidies from government, it is unlikely these schemes would have gone ahead, or at the very least they would have been designed to meet a specific re-use demand.	Unmet expectations resulted higher than AGWR recommendations	Over-confidence
4	Ku-ring-gai (local council) NSW	Irrigation reuse at the Gordon golf course. In 2005, the context of the drought and the fear that in future golf courses would not be allowed to irrigate with potable water, were the main drivers for the scheme. The public health risk due to the irrigation with reuse water drove the treatment to include UV and chlorination.	Risk perceptions higher than AGWR recommendations	Prudence
5	Rosehill NSW	Industrial reuse scheme (Private developer, owner and operator; Public utility retailer). The scheme emerged in the context of water security during the drought in NSW.	Changes in demand resulted higher than AGWR recommendations	Over-confidence

(AGWR - Australian Guidelines for Water Recycling)

Table 2: Perceptions of risk by individuals and their corresponding response (modified from Douglas & Wildavsky, 1982)

	Fatalist	Hierarchist	Egalitarian	Individualist
				
Risk perception	Only plan for what they know, and do not consider unknown or remote risks to society in their planning.	Believe there are acceptable risks to society which have been determined by experts	View anything we do as a potentially irreversible consequence for society	Do not view risk as a problem to them personally, even if it is a public risk.
Response	To cope with outcomes when they happen – adaptive management	Manage any irreversible outcomes by setting limits through regulations and control	Risk aversion – mitigate the risk through overdesign, or do not proceed with the activity	Public risks can be contained and are seen as opportunities for innovation for the individual

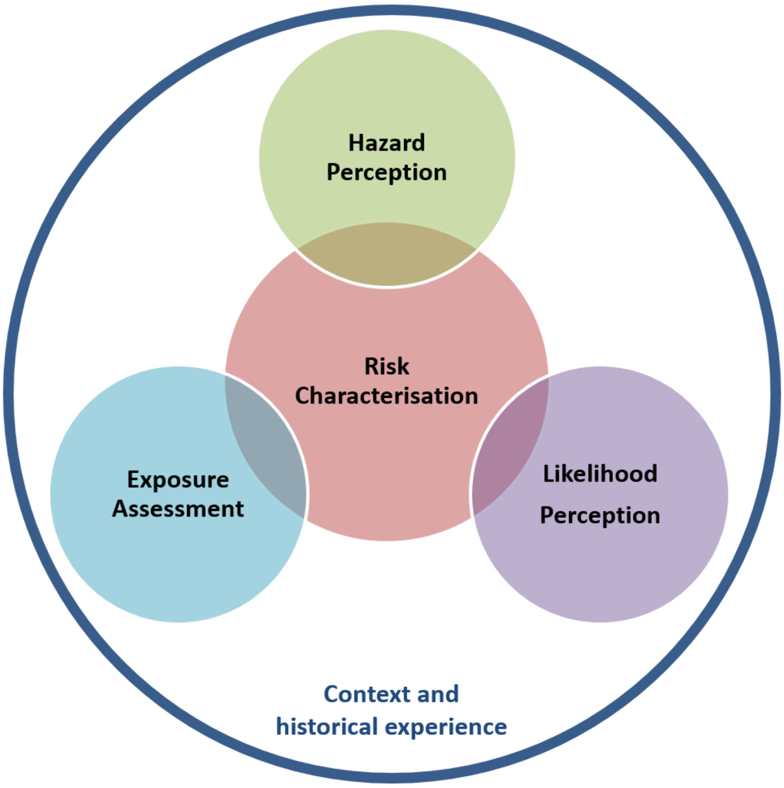


Figure 1: Risk perception (adapted from Fowle & Dearfield 2000)