Initial Investigation into the Governance and Management Models for Rainwater Tank Systems

Magnus Moglia, Grace Tjandraatmadja and Ashok Sharma

September 2011

Urban Water Security Research Alliance
Technical Report No. 50

Queensland Government
National Research FLAGSHIPS Water for a Healthy Country
CSIRO
Griffith UNIVERSITY
The University Of Queensland AUSTRALIA

Urban Water Security Research Alliance Technical Report ISSN 1836-5566 (Online)
Urban Water Security Research Alliance Technical Report ISSN 1836-5558 (Print)

The Urban Water Security Research Alliance (UWSRA) is a $50 million partnership over five years between the Queensland Government, CSIRO's Water for a Healthy Country Flagship, Griffith University and The University of Queensland. The Alliance has been formed to address South East Queensland's emerging urban water issues with a focus on water security and recycling. The program will bring new research capacity to South East Queensland tailored to tackling existing and anticipated future issues to inform the implementation of the Water Strategy.

For more information about the:

UWSRA - visit http://www.urbanwateralliance.org.au/
Queensland Government - visit http://www.qld.gov.au/
Water for a Healthy Country Flagship - visit www.csiro.au/org/HealthyCountry.html
The University of Queensland - visit http://www.uq.edu.au/
Griffith University - visit http://www.griffith.edu.au/

Enquiries should be addressed to:

The Urban Water Security Research Alliance
PO Box 15087
CITY EAST QLD 4002

Ph: 07-3247 3005; Fax: 07-3405 3556
Email: Sharon.Wakem@qwc.qld.gov.au

Authors: CSIRO Land and Water, Highett, Victoria

Moglia, M., Tjandraatmadja, G. and Sharma, A. (2011). *Initial Investigation into the Governance and Management Models for Rainwater Tank Systems,* Urban Water Security Research Alliance Technical Report No. 50.

Copyright

Disclaimer

Cover Photograph:

Description: Rainwater tank in South East Queensland.
Photographer: Clare Diaper.

ACKNOWLEDGEMENTS

This research was undertaken as part of the South East Queensland Urban Water Security Research Alliance, a scientific collaboration between the Queensland Government, CSIRO, The University of Queensland and Griffith University.

Particular thanks go to Alan Hoban (Healthy Waterways Partnership), Belinda Hodges (Lake Macquarie City Council), Brian McIntosh (Water Centre), Melissa Cordy (Clearwater in Victoria), Kate Black (Centre for Water Sensitive Cities), Vourn Lutton (Queensland Water Commission), Ann Gardiner (DERM), Cara Beal, Jan Warken and Rodney Stewart (Griffith University), Bradley Hodginkson (Moreton Bay Council), Gary Ellis and team (Ipswich City Council), Greg Bird and Donald McKenzie (Logan Council), Mark Breen (Sunshine Coast Council), Mim Buchhorn (Hunter Councils), Gary Mays, Glen Howard (Master Plumbers Association of Australia), Water Tactics, Mark Roberts and Sanja Oldridge (Aurecon), Mirela Magyar (Melbourne Water) and Tim Hurst (Queensland Institute of Medical Research). Also thank you to employees at the Queensland Water Commission, Department of Infrastructure and Planning, Queensland Health, Office of the Water Supply Regulator (at DERM), and local councils.

Also particular thanks to Don Begbie and Sharon Biermann at the Urban Water Security Research Alliance.

Thank you also to all survey participants who generously shared their experiences and opinions.

FOREWORD

Water is fundamental to our quality of life, to economic growth and to the environment. With its booming economy and growing population, Australia's South East Queensland (SEQ) region faces increasing pressure on its water resources. These pressures are compounded by the impact of climate variability and accelerating climate change.

The Urban Water Security Research Alliance, via targeted, multidisciplinary research initiatives, has been formed to address the region's emerging urban water issues.

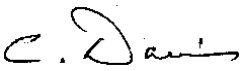
As the largest regionally focused urban water research program in Australia, the Alliance is focused on water security and recycling, but will align research where appropriate with other water research programs such as those of other SEQ water agencies, CSIRO's Water for a Healthy Country National Research Flagship, Water Quality Research Australia, eWater CRC and the Water Services Association of Australia (WSAA).

The Alliance is a partnership between the Queensland Government, CSIRO's Water for a Healthy Country National Research Flagship, The University of Queensland and Griffith University. It brings new research capacity to SEQ, tailored to tackling existing and anticipated future risks, assumptions and uncertainties facing water supply strategy. It is a $50 million partnership over five years.

Alliance research is examining fundamental issues necessary to deliver the region's water needs, including:

- Ensuring the reliability and safety of recycled water systems.
- Advising on infrastructure and technology for the recycling of wastewater and stormwater.
- Building scientific knowledge into the management of health and safety risks in the water supply system.
- Increasing community confidence in the future of water supply.

This report is part of a series summarising the output from the Urban Water Security Research Alliance. All reports and additional information about the Alliance can be found at http://www.urbanwateralliance.org.au/about.html.



Chris Davis
Chair, Urban Water Security Research Alliance

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

In Australia, rainwater tanks in urban areas are one of the tools relied upon to reduce the overall indoor water consumption of urban households, being mandated for new dwellings in Queensland, South Australia and New South Wales and also promoted across the country via rebate schemes.

Whilst in South East Queensland (SEQ) a qualified plumber is required to install a rainwater tank, private ownership of infrastructure providing a public benefit creates a management dilemma. Maintenance of rainwater tanks requires the observance of simple and uncomplicated tasks. However, almost no information is available on the condition and management status of the existing rainwater tank stock.

This report aims to explore the issues of management of rainwater tanks in SEQ urban areas by addressing the following research questions:

- What is the current institutional context of rainwater tanks in SEQ?
- What is known about the condition of rainwater tanks?
- Is there a need for a new governance mechanism for rainwater tanks in SEQ?
- What are the possible mechanisms for governance of rainwater tanks in SEQ?

To address those questions and understand the current context and state of knowledge on the issue the following research methodology was adopted:

- Review of the literature on rainwater management (state of knowledge and legislative framework);
- Interviews with key stakeholders' representatives (government, private practitioners, researchers) on their views on rainwater tank management and associated risks;
- Web-based survey of over 250 professionals associated with rainwater tanks on their perceptions on rainwater tank issues, risks, management and governance needs.
- Mont Carlo simulation of failure rates using the perceived risks and management practices to evaluate the impact of operation and maintenance (O&M) practices.

The results indicate that there is a real concern about rainwater tanks and their O&M amongst a large number of stakeholders, but no real data to support this. The perception of frequency of rainwater tanks failure is high and inspections and regular maintenance are seen as critical to ensure that tanks are in good condition and providing adequate benefit to the community. However, there is high variance in the perception of rainwater tank O&M status and perceived householder practices among various stakeholder groups. More reliable data is required in order to undertake a cost-benefit analysis of inspections.

It is also clear that the majority would like to have the main responsibility for operation and maintenance of tanks retained by householders. Thus, if the status quo is unsustainable but householders remain responsible, any governance arrangements need to find collaborative arrangements with householders. Householders then need to be encouraged and empowered to manage this private infrastructure which has public benefits. Provision of information to householders is seen as critical.

Initial suggestions of governance strategies have been explored, however, there is a real need to explore the issue and strategies in more detail. This will require the cooperation of a number of stakeholders as well as legitimisation of options by further deliberation and selection. Therefore, an important next step is to procure data on the actual condition of rainwater tanks to determine if the perception of failure is justified and to invite key stakeholders to a workshop to discuss the findings, governance issues and the preference for possible options.

1. INTRODUCTION

This project report is an output of the Decentralised Systems Project of the Urban Water Security Research Alliance. The Decentralised Systems project is focussed on addressing knowledge gaps in the strategic planning and implementation of rainwater tanks. The main aim of the project is to understand the effectiveness of achieving the 70kL/household/year water saving target by mandated rainwater tanks as specified under the South East Queensland (SEQ) Water Strategy (November 2009), through monitoring, validation and modelling of mandated tanks. This report explores the possible governance and management aspects of individual rainwater tanks investigated under this project.

In Australia, rainwater tanks in urban areas were initially aimed at reducing the use of mains water for irrigation of gardens. However, in an attempt to improve the effectiveness of this water conservation measure, emphasis has recently been placed on reducing the overall water consumption within the household for indoor uses such as toilet flushing and/or laundry use, as has now been mandated for SEQ in the Queensland Development Code Part 25 – Water saving target (now MP 4.2). The expected water conservation benefits from rainwater tanks as part of the overall water planning strategy and the ongoing operation of these tanks for their effectiveness is a critical concern for water planners and regulators.

Whilst in SEQ a qualified plumber is now required to install a rainwater tank, private ownership of infrastructure providing a public benefit creates a management dilemma. Maintenance of rainwater tanks requires the observance of simple and uncomplicated tasks and also some more complicated tasks of pump operation including switching valves connecting to mains supply in case of low water levels in rainwater tanks. The main regular maintenance tasks required are: upkeep of first flush devices; strainer and/or filter clean-up to prevent blockage of the entrance to the tank and ensuring adequate protection of tank openings to prevent entry of vectors or breeding of mosquitoes; ensuring structural integrity of tank; and ongoing operation of pump systems.

Whilst some tasks are straightforward, maintaining structural integrity of tanks and ongoing operation of pump systems could impose a financial burden on the house owner, which can be detrimental to the upkeep of these systems. There are currently no monetary or non-monetary incentives for individual households to maintain a rainwater tank. Furthermore, there are currently no checks or controls to determine if the maintenance is being carried out properly and that those systems are operational. Given the mandatory nature of rainwater tank provisions for new dwellings in SEQ (QDC MP4.2), a lax rainwater tank maintenance regime may have a detrimental impact on long-term water planning of the area. It may also cause the water quality in the tank to deteriorate, posing a public health risk (for example, breeding of dengue mosquitoes in tropical climates) and lead to mains water use (either inadvertent or deliberate) for applications where rainwater could be used.

Rainwater tanks are also linked to changes in water use behaviour. For example, tanks installed for indoor water use in SEQ often have an automatic switch to mains water that in many cases does not alert the householder to the use of mains water instead of rainwater. In such cases, a homeowner may be increasing the use of mains water, thinking that it is rainwater. To address these concerns, this project has been undertaken to investigate possible governance and management models for rainwater tanks in urban areas in close consultation with State regulatory agencies and local water agencies, as well as academia and water professionals.

The purpose of this report is to investigate ways to ensure on-going, safe operation of rainwater tanks in SEQ. This study explores some of these questions, but is by necessity exploratory, because there is very limited reliable information on the topic. The research questions of this study have been:

- What is the current institutional context of rainwater tanks in SEQ?
- Is there a need for a new governance mechanism for rainwater tanks in SEQ?
- What is known about the condition of rainwater tanks and what is not known?
- What are the possible mechanisms for governance of rainwater tanks in SEQ?

These questions are asked in acknowledgment that the widespread adoption and utilisation of rainwater tanks is partially shifting the responsibility of urban water management to householders and citizens in urban areas. This shift has come out of the necessity to utilise local water resources and reduce mains water usage, but has also meant that a large pool of infrastructure is now the responsibility of home owners. This is largely unprecedented in the urban Australian context, and therefore there is no clear system available for adequate operation and maintenance of this infrastructure. The question of how to best manage this infrastructure is hence debatable and a common understanding will be difficult. The aim of this report is to initiate the discussion on governance of rainwater tanks and highlight some possible governance options for further discussion and investigation.

2. RESEARCH ACTIVITIES: ACTIVITIES AND OUTPUT

The key research activities involved: literature review, interviews with stakeholders, survey of professionals, and simulation. These activities are described below.

2.1. Literature on Rainwater Tanks

There is some literature and publically available information on the uptake, legislation, maintenance and guidelines for rainwater tanks. That literature is described in this section.

2.1.1. Rainwater Tank Uptake

Rainwater harvesting and collection using tanks is adopted in many countries around the world (UNEP 2011). Their use is driven by necessity, either due to insufficient access to piped mains water or by the need for increased sustainability and security of water supply to households. Historically in cities around the world, when a reliable supply of mains water becomes available, rainwater tank water harvesting becomes obsolete and is superseded. However, in many developed countries such as Australia, rainwater tanks are finding renewed acceptance in urban areas as their uptake has been promoted via legislation and rebate schemes.

Rainwater tank uptake has increased markedly across the country and in particular across Queensland (Figure 1). From 2007 to 2009, the uptake of rainwater tanks in Queensland increased by 15.9 percent, with rainwater tanks installed in 38 percent of households in Queensland by 2009 (Australian Bureau of Statistics, 2007, 2009). Brisbane experienced the largest uptake; with rainwater tanks in 43 percent of suitable dwellings (Australian Bureau of Statistics, 2010), whilst in SEQ over 36 percent of detached dwellings have rainwater tanks. Rebate programs contributed to over 230,000 domestic rainwater tanks being installed between 2006 and 2008 (Queensland Government, 2005), and, since 2007, MP4.2 resulted in an additional 30,000 tanks being installed in new homes (Gardiner, 2010). Rainwater tank uptake is highest in new dwellings, with 57% of new houses less than 1 year old connected to a rainwater tank (Australian Bureau of Statistics, 2010). It is estimated that by 2026 an additional 575,000 new dwellings will be required within the state and each of them is likely to have a mandated tank (Queensland Government, 2005).

Figure 1. Uptake of rainwater tanks in capital cities across Australia (ABS 2010).

2.1.2. Legislation in Australia

2.1.2.1. Mandated Tanks

In Queensland, the installation of rainwater tanks in new dwellings is promulgated in the Queensland Development code MP4.2 (Queensland Department of Local Government and Planning, 2009). This code requires new dwellings to achieve minimum water saving targets which are most commonly fulfilled by the installation of rainwater tanks.

Similarly to Queensland, rainwater tanks (or suitable alternatives) are also mandatory for new housing in New South Wales (BASIX, 2004) and are the easiest means to achieve the mandated water demand reductions in new housing in South Australia (Planning SA, 2006).

Across other jurisdictions, uptake of rainwater tanks in dwellings has been mainly voluntary. In Victoria, in particular, the Six Star Standard for new dwellings allows the option of installing either a rainwater tank connected to a toilet, or a solar hot water system (Building Commission 2011). Up to June 2011, most capital cities also offered rebate programs for installation of an internally plumbed rainwater tank to existing dwellings (ACT Government, 2011; Queensland Government, 2011; Government of South Australia, 2011; Northern Territory Government, 2007; State Government of Victoria, 2011; NSW Government, 2011; Water Corporation, 2011; and Hobart City Council, 2011).

2.1.2.2. Approval Process

Rainwater system installation and approvals typically follow the process outlined in Figure 2. Installation requires compliance with relevant state legislation and local government regulatory requirements. Site assessment and product selection are typically conducted by a developer, builder or the home-owner (if the dwelling is self-built). Products adopted should comply with the relevant Australian standards. Installation is conducted by a developer, builder, home-owner or a contracted third party.

Upon completion of the new dwelling, a certified building inspector issues a certificate of compliance for the building, which includes a certificate of compliance for the installation of the rainwater tank. The building inspector can be either a council building inspector or a third party. A plumbing inspection is also required to ensure that the rainwater tank is internally plumbed as per the local regulations. In states with mandated tanks, certificates of installation and inspection are typically, but not always, sent to local government for record keeping. In the case of retrofitted tanks, rebates are only issued if installation is conducted by a licensed plumber. Currently, no certification process is in place for retrofitted tanks. Examples of approval requirements across the states are shown in Table 1. For new housing estates, typically all the above steps are handled by a developer or its contractors.

After installation, on-going maintenance becomes the responsibility of the home owner. Government agencies have no involvement, unless there is a complaint to council that requires investigation. In Queensland, under the Public Health Regulation 2005, councils are given the responsibility to ensure that rainwater tanks are built, installed and maintained to stop mosquito breeding (Queensland Government, 2005). A number of councils also offer rainwater quality testing services upon request. On-going maintenance relies on the level of awareness and self interest of the householder. A number of State government agencies and local councils have developed brochures on rainwater tank installation and upkeep (Department of Environment and Resource Management, 2011, Gold Coast City Council, 2011, Queensland Health, 2002, 2007). Across other States and Territories a similar reference framework is adopted, however government authorities have limited involvement on day-to-day management of rainwater tank used for non-potable applications.

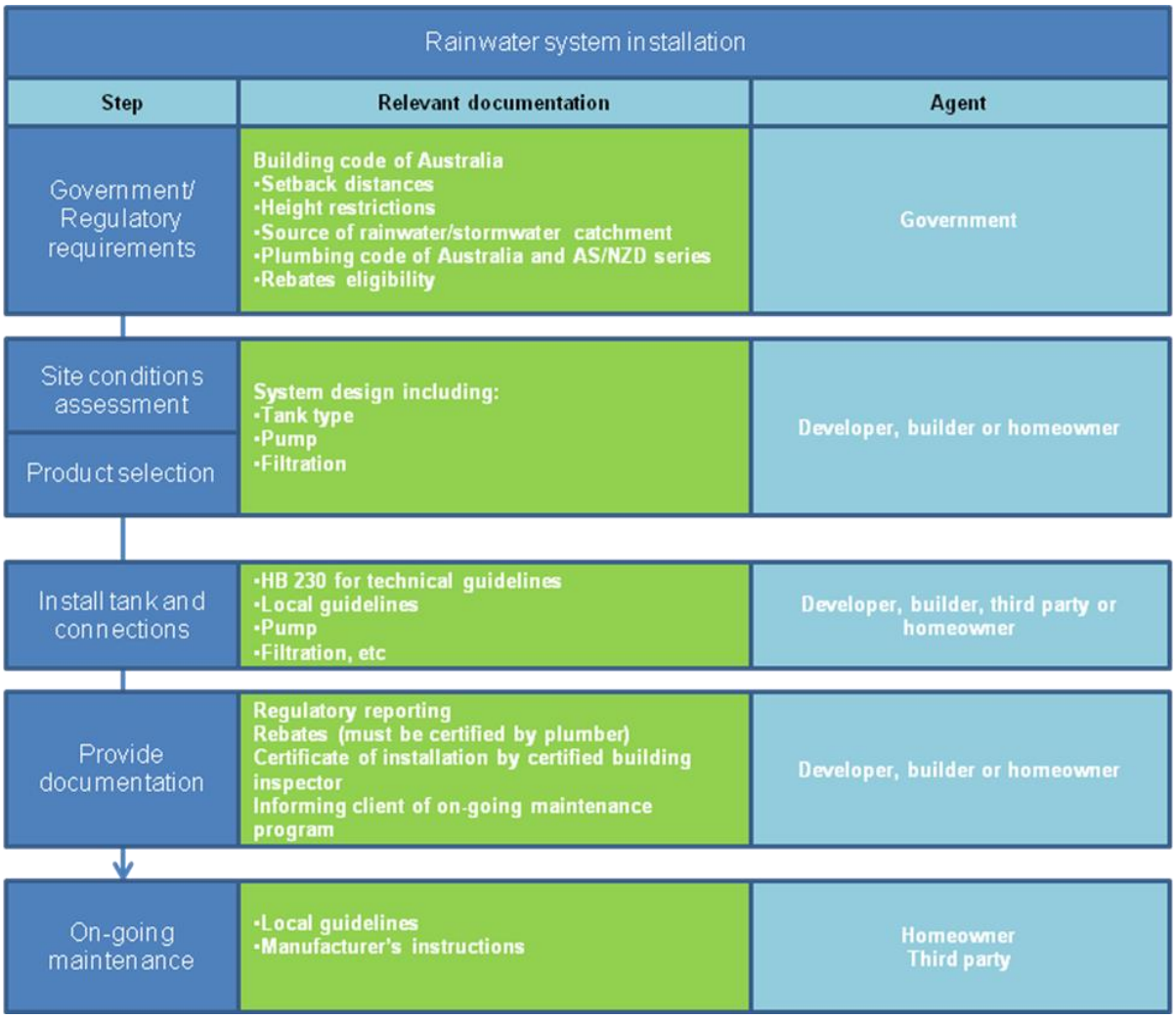


Figure 2. Process for installation of rainwater systems*.
***Note**: Adapted from HB230 (Standards Australia, 2008).

Table 1. Approval requirements for rainwater tank installation in Australia.

Jurisdiction	Installation Conditions
ACT	Subject to local council regulations. Development application and approval required if tank impacts amenity, streetscape character, restricts access to easements, is used for internal household water uses. Rainwater supply for internal use requires plumbing by a licensed plumber. For details see conditions specified in ACT (2010).
NSW	New dwellings: BASIX certification and tank inspection for all new dwellings, tanks connected to indoor uses or Sydney water supply (http://www.sydneywater.com.au/Water4Life/InYourGarden/RainwaterTanks/Plumbers.cfm) Only rainwater tanks larger than 10kL require council approval for installation. Subject to local council regulations.
NT	Building permit required if tank is 600mm or more above ground level. No permits required for tanks placed on a pad or on the ground (NT undated).
SA	Subject to local council regulations for installation to existing houses. New dwellings: A licensed plumber must: install the piping system delivering the rainwater to the water closet, water heater or cold water laundry outlets and complete a Certificate of Compliance certifying that the installation has been installed in accordance with AS/NZS 3500 and the SA Variations. The certificate of compliance must be provided to SA Water and the home owner within 7 days of completion of the work.
Tas	Subject to local council regulations.
Qld	New dwellings: certification and approval for installation at new dwellings. Subject to local council regulations for installation to existing houses.
Vic	Subject to local council regulations. Building permit may be required if thank is supported by an existing building or on a stand.
WA	Subject to local council regulations.

2.1.2.3. Legislation and Technical Guidance

A number of pieces of legislation and technical guidelines are relevant to the uptake, installation and maintenance of rainwater tanks. In addition, a number of government agencies (state and local) provide additional information on rainwater tank management and rainwater use in factsheets, brochures and/or websites.

National

Technical Guidelines

(a) HB230 (Standards Australia, 2008) Rainwater tank design and installation handbook: provides comprehensive technical advice on all aspects of rainwater tank design, installation and maintenance.

(b) Guidance on use of rainwater tanks (Australian Government, 2004): The key reference document developed by the enHealth Council and referred to by all states and territories. It adopts the framework for drinking water quality management to address rainwater end uses, health risks and their management, monitoring and maintenance and also provides information on tank design, material selection and installation. The document describes major hazards identified using systems analysis (microbial hazards, mosquitoes, dead animals, chemical hazards, atmospheric emissions, pesticides, bushfire, slow-combustion heater, roof materials (e.g. treated wood, tiles, lead flashing), tank materials, pipework, accumulated sediment). The guide provides advice on maintenance requirements and frequency. It also includes recommendations for tank inspection for householders moving into a house with an existing tank (Australian Government, 2004). The guidelines are referred to in each state as a major source of information on rainwater use and maintenance.

(c) Standards: Compliance with relevant Australian standards is stipulated for the majority of materials, pipes, rainwater tank and devices adopted in rainwater systems. However, the level of specification details varies for various system components (WSAA 2002). Pipes need to show compliance with standards and quality assurance and are typically marked to show their origin, manufacturer, pressure rating and batch, as do polymer tanks, but other rainwater tanks typically on sale have no documentation demonstrating quality compliance. A list of current rainwater tank relevant standards is provided in Table 16 in Appendix A.

(d) Requirements for installation of rainwater and greywater systems in Australia (MPMASS 2008): overview of knowledge, consent requirements, standards, codes and approvals for installation of greywater and rainwater systems in each State.

In Queensland, the key pieces of legislation and guidelines are:

Policy

(a) Queensland Development Code MP4.2 (Queensland Government, 2009): stipulating mandatory water savings in new class 1 residences, which may include installation of rainwater tanks with connection to toilet, washing machine and at least one outdoor tap. It covers rainwater tank sizing and installation, water quality protection measures and specifications for parts, including stands (AS/NZS 1170.1:2002), openings, overflow devices (AS/NZS 3500:2003), including screens for leaves, first flush diverters (if connected to showers, hot water, kitchens and basins), mosquito mesh (as per HB230), mandatory internal mains switch (flow rates and volume specifications), vermin proofing, backflow prevention devices and materials signage, and materials (AS/NZS4766:2006, AS1397:2001, ASTM A240/A240-05, AS3735:2001, AS/NZS 1546.1:1998). The relevant standards are outlined in Appendix A. In addition, all plumbing and stormwater requirements also need to comply with local government requirements (Standards Australia, 1998, 2001a, b, 2002, 2003, 2005, 2006a, b).

(e) Public Health Act 2005 (Queensland Government, 2005): establishes the requirement to ensure that the breeding of mosquitoes in tanks is prevented and this Act is enforced by local government. In urban areas, Queensland Health does not recommend the use of rainwater for drinking and food preparation if mains water is available. If such uses are considered,

Queensland Health recommends adoption of a risk management framework as described in: "Guidance on use of rainwater tanks" for their management (Australian Government, 2004).

(f) Guidelines to minimise mosquito and biting midge problems in new development areas (Queensland Health, 2002) and associated health legislation: Queensland has specific legislation on mosquito control (Health Act 1937, Health regulation 1996 on vector/pest control). Queensland Health is the government agency responsible for prevention and control of mosquito-borne diseases in the State. Local council town planning and health services often also provide additional documents and regulations.

Factsheets

Factsheets are the most common form of guidance provided to rainwater tank owners by local councils and other government. Examples are:

(a) Rainwater tanks: *a guide to keeping your tank safe* – a fact sheet from Queensland Health for householders on maintenance requirements for rainwater tanks and explanation of fines for failing to do so (Queensland Health, 2007); and
(b) Rainwater tanks factsheet: factsheet from with general information on rainwater tanks and considerations (Department of Environment and Resource Management, 2011).

Additional policy and legislation for other jurisdictions and guidelines vary between States and are explained in MPMSAA (2008).

Maintenance Requirements

Across Australia and around the world, the responsibility for maintenance of rainwater tanks is on the rainwater tank owner. Rainwater systems require simple and regular monitoring and upkeep of catchment surfaces, rainwater tanks and devices at intervals ranging from 3-6 months to 2 years. HB230A (Standards Australia, 2008) includes a universal and comprehensive list of inspection as well as operation and maintenance practices required for rainwater tanks (Appendix A.1). In the guidelines for Queensland, some inspections are recommended at a greater frequency than HB230A (Standards Australia, 2008). The simplified list of typical inspection requirements and maintenance procedures recommended by Queensland authorities is summarised in Table 2, this is based on the Queensland Health guidelines (Queensland Health, 2007) and is also used as a reference by some local councils (Queensland Health, 2002).

Table 2. Recommended inspection and maintenance for rainwater tanks*.

Frequency	Activity	Maintenance Required
3 months	Inspect and clean gutters.	Remove leaves and debris.
	Inspect and clean first flush devices and leaf guards on rainheads.	Clean, repair or replace if necessary.
	Check screens on tank overflow outlet.	Repair or replace if necessary.
6 months	Check roof and flashings for defects and remove overhanging branches.	Repair if necessary and remove overhanging branches.
	Checks tank for defects, screens and lids are in place and functional.	Repair if necessary.
	Check water quality.	Identify cause for quality change.
	Check rainwater taps have correct signage.	Repair or replace if necessary.
	Check pump for noise, pressure, leaks and acoustic enclosure if applicable.	Repair or replace if necessary.
Annual	Check tank support for structural integrity.	Repair or replace if necessary.
2-3 years	Check sediment level in tank.	Organise removal with a qualified contractor if sediments pose a risk to block tank outlet.

***Note**: This table has data adapted from a document from Queensland Health (2007).

In addition, a number of private rainwater tank service providers provide maintenance information via websites. Information on maintenance requirements for rainwater tanks is provided by a number of councils through factsheets and websites in Australia (Appendix A). However, the availability of information and the extent of details vary significantly between the local governments across the country. In other states, the level of guidance provided tends to be very similar in focus. Most of the information available to the public has a focus on rainwater tank selection and installation.

International Guidelines: USA

Internationally, there also exist some guidelines for rainwater tanks in the USA. However, regulation on rainwater harvesting varies between jurisdictions in the USA. Rainwater collection codes and guidelines are available in some local jurisdictions. Rainwater collection is, however, largely not addressed in associated building codes, such as the plumbing or building code.

In some jurisdictions, rainwater is classified as reclaimed water and subject to more stringent requirements than necessary. For instance, the State of Texas allows rainwater for uses subject to adequate treatment, whilst other States allow for only non-potable uses (Kloss 2008). In general, the focus of most codes and guidelines is on water quality and treatment needs, as well as design and installation. Operation and maintenance is the responsibility of the property owner. Municipal inspection occurs during installation. Inspections of backflow prevention systems are recommended on an annual basis. For the property owner, operation of a rainwater tank is considered to be similar to the operation of a private well, with requirements for periodic testing for water quality if the water is used for indoor purposes. Inspections are carried out by municipal water authorities, but the inspection specifications (type, requirements and documentation requirements) are similar to those already conducted as routine inspection by municipal departments for private potable water systems.

Most US jurisdictions differentiate between a “rain barrel” and a “rain cistern”. A “rain barrel” is a residential low volume tank equipped with mosquito barriers and overflow prevention. These types of rainwater tanks, for which no permits are required, are typically intended for outdoor uses. “Rain cisterns” are large systems that require more complex treatment and signage. Such systems require permits and inspections by the Health Department as they are typically intended for potable use.

Municipal authorities concentrate efforts on information and education of homeowners for the purpose of harvesting and maximising the effectiveness of rain barrels (Kloss 2008). The best feature of the communications that are adopted is that information for the public is provided in formats that are simple and easy to understand by homeowners; such as checklists, diagrams, simplified codes with use of common language, etc.

2.1.3. Maintenance Practices of Householders

Scientific data on the motivations and practices of householders is scarce, with only a few studies available on rainwater tank management (Gardiner, 2009, 2010, Gardiner *et al.*, 2008, Tilbrook, 2009). A number of studies are currently being conducted but detailed results have not yet been published (Tucker *et al.*, 2011). Upkeep and maintenance of rainwater tanks is closely linked to the level of engagement and knowledge of householders regarding their tanks and rainwater collection system (Gardiner, 2010). In rural and remote areas where households depend solely on rainwater for their water needs, there is a long history of rainwater use for all purposes, including drinking, and a track record of appropriate maintenance. However, in urban areas where mains water supply is also available, rainwater is connected mainly to garden tap, laundry and/or toilet cistern. In addition, rainwater tanks must be fitted with mains water back-up to ensure continuous water supply. As a result there is large variance in the understanding of rainwater risks and attitudes towards maintenance (Gardiner, 2009, 2010, Gardiner *et al.*, 2008). In the 2007 and 2008 study of urban rainwater tank owners, Gardiner (2011) identified three major attitudinal segments in the community: ‘environmentalists’, ‘uninterested’ and ‘my independent supply’ The three segments differed in their attitudes to rainwater tanks, tank use and management behaviour, including motivations as summarised in Table 3.

2.1.3.1. Mandated Tanks

Awareness of operation and maintenance (O&M) needs and tank operation is lower in dwellings with mandated tanks. Gardiner (2009, 2010) verified that, in dwellings where tanks were already installed, and in particular when these were installed close to the house and internally plumbed to appliances, householders felt little connection with the tanks and were mostly unaware of the O&M needs. Eighty percent of respondents in the "uninterested" group were new home owners in greenfield areas with 'mandated' tanks, or were purchasers of homes that already had rainwater tanks. The rainwater tank was considered as part of the overall water infrastructure and did not impact their lifestyle. They were also the group most likely to call a third-party service provider if problems with water were identified; and expressed the least awareness of the condition of their tank. Many in this group saw rainwater tanks as only a temporary measure to combat the drought (Gardiner, 2010). The risk of lack of maintenance and disconnection from their tanks in case of failure was high in this group.

2.1.3.2. Retrofitted Tanks

Gardiner (2010) found that 90% of owners of tanks that were retrofitted used them for garden and outdoor purposes alone. People in this group were comprised of 'environmentalists' and 'my independent supply' (Gardiner, 2010). The "my independent supply" group had pride in their tanks, showed interest in maintenance, but were not confident about maintenance needs (Gardiner, 2010). The majority of this group saw tanks as their own private water resource and would resent any regulation on rainwater tanks (Gardiner, 2010). Environmentalists felt the strongest connection with their rainwater tanks and were motivated to keep them as part of their lifestyle. They also tended to be more proactive about maintenance. About a third of this group used rainwater for drinking purposes (Gardiner, 2010). They were also in favour of legislation for greater control of tanks.

Table 3. Geographical segmentation of tank owners*.

	Peri-urban	Retrofit	Greenfield
Age range	45-54 (73%)	55-65+ (63%)	<44 (63%)
Tank capacity (kL)	>20	3-5	2-3
Length of experience	>6	<1	<1
Attitudinal segment	Environmentalists Uninterested	My supply Environmentalists	Uninterested
Maintenance	High (gutters, pipes and inside tanks)	High (mainly gutters and traps)	Low

***Note:** This data is adapted from a paper by Gardiner et al. (2008).

White (2009) conducted a survey of 279 SEQ households with rainwater tanks, regarding O&M practices, and concluded that maintenance of rainwater tanks was adequate, with tank owners reporting on average 6.2 h per year on gutter maintenance, with 76% performing self-maintenance, 12% relying on professional service and 12% relying on visiting friends or family. However long-term behaviour can be difficult to gauge, as the majority of tanks were less than 3 years old and 86% less than one year old at the time of that survey (White, 2009).

In addition, in another survey of 1051 people in SEQ conducted over 2007-2008, Gardiner (2010) verified that, although 95 percent of tanks owners reported confidence in managing their tanks, a significant number did not conduct proper maintenance. For instance, 50 percent of the sample of owners of mandated tanks reported never to have conducted maintenance such as cleaning of gutters or screens, or inspection of the inside of the tank; or only did so if a problem was detected (Gardiner, 2010). Lack of maintenance was also an issue verified in other studies of mandated tanks in other states, such as Tilbrook (2009) in New South Wales.

Thus, there appear to be gaps between perception and reality. In addition, despite the simple requirements for rainwater tank maintenance and the availability of technical references, the previous studies also indicate a gap in the level of awareness of tank O&M requirements, particularly among owners of mandated tanks.

2.2. Interviews with Stakeholders

Twenty representatives from major stakeholder groups involved with tank management were interviewed for clarification of their agency's roles, influence and their insights into the issues surrounding rainwater tank governance. These included: Consultants (3); Academics (4); Catchment management (1); Private enterprises – Plumbing specialising in rainwater tanks (3); Department of Environment, Resource and Mines (1); Department of Infrastructure and Planning (1); Queensland Water Commission (1); Queensland Health (1); Office of the Water Supply Regulator (1); and SEQ local government (4). These revolve around the themes: people's role in the life cycle of rainwater tanks; risks, liabilities and opportunities perceived regarding rainwater tank governance; and identification of potential issues associated with rainwater tank maintenance and their impact.

2.2.1. Perceptions on Rainwater Tanks

All respondents associated rainwater tanks with greater environmental sustainability; however the majority believed that, since the rain started again in Queensland, the public was not concerned about tanks.

2.2.2. Implementation and Role of Stakeholders

The process of implementation of mandated rainwater tanks is characterised by a number of stages. The understanding of the implementation, based on discussion with the stakeholder representatives, is outlined below under the various stages.

(a) Policy Development

Legislation and policy on rainwater tanks is developed by State government (e.g. Building Code, MP 4.2, Qld Plumbing Code and the Public Health Act 2005). Rainwater tanks fall under planning and building infrastructure in the Building Act. Current legislation covers the asset classification, roles and responsibilities regarding rainwater tank specifications and installation, including minimum roof area for rainwater collection, sizing of the rainwater tank and plumbing connections. Enforcement of MP 4.2 is the responsibility of local councils via the system of building approvals and certification.

(b) Decision

Legislative requirements set by the State government mandate water demand reduction of 70kL/yr for new dwellings in SEQ. In MP4.2, the adoption of rainwater tanks is not the only option to achieve mandated targets, but it is one of the cheapest options for achieving the water saving, and is the option most commonly adopted by developers or builders in SEQ.

(c) Design and Implementation

Rainwater system design is typically conducted by a developer, building company or by a third party hired by the building company (e.g. a consultant). More elaborate systems, such as communal rainwater tank systems, are often designed by specialised consultants. Consultants or engineers develop design and equipment specifications and ensure compliance with existing regulation. The majority of the components for rainwater systems are readily available off-the-shelf. The selection of rainwater system components used in new dwellings is typically decided by the developer. Installation is conducted by the developer or its contractors.

(d) Certification

Certification of the rainwater system occurs at completion of the rainwater tank installation and can be conducted by a building certifier from local government or by an independent building certifier. No further assessment is required during the lifetime of the tank.

(e) Operation and Maintenance (O&M)

Operation and maintenance of a rainwater system is the responsibility of the homeowner. If complaints are made to council regarding public health, contaminants or amenity (breaches of a local law or a breach of public health), councils can be called to investigate, but prosecution is limited to the extent of the local government law breach only. Plumbers are often called for investigation of rainwater tank systems by homeowners and provide advice on system maintenance, however the homeowner has the power to take on advice or delay any maintenance. Tenants in a leased property have no liability or responsibility regarding rainwater tank O&M at present.

(f) Property Transfer

Upon transfer of title of a property, no requirements or mechanisms exists in current legislation to ensure the new home owner is aware of rainwater tank condition or its O&M practices, nor are there any requirements for documentation of O&M history. Some greenfield developments establish requirements for rainwater tank placement and appearance in body corporate caveats, but there is insufficient information of O&M requirements. There is also insufficient data to determine if subsequent home owners are aware of the rainwater tank condition and needs in their property.

A number of stakeholders contribute to the uptake and operation of mandated rainwater tanks in SEQ. Their roles, responsibilities, expertise, degree of influence and liability regarding rainwater tank operation are examined here in view of rainwater tank implementation. The role of each of the stakeholder agencies regarding rainwater tank policy development, uptake, installation and upkeep is outlined in Table 4.

Table 4. Role of stakeholders in a rainwater tank lifecycle.

Stakeholder type	Policy	Decision	Design	Implementation	Certification	O&M	Property Transfer
DERM	Environment and conservation policy		Providing information, advice and research				
QWC	Has strong incentives for rainwater tanks to be utilised – as it influences water balances		Interacts with engineers and consultants			Provide information to householders	
DIP	Strongly involved in guidelines, codes and acts on rainwater tanks	Put in place legislation for mandated tanks	Sets up Plumbing and Drainage Act Building Codes Interacts with plumbing association	Interacts with plumbing association etc			None
QH	Monitoring and evaluating public health risks Upholding the Public Health Act Provides advice into Building Codes		Sets up rainwater tank requirements on basis of PHA			Interacts with local councils about upholding public health standards	
Local government	Enforce legislation	None	None	None	Enforces requirements as per legislation. Certification of installation at time of house completion can be conducted by a council certifier or by a third party.	None. Investigates complaints made regarding public health, contaminants or amenity complaints.	None
Master Plumbers and representatives	None	None	None	Plumbers can be hired for installation of rainwater tanks in building projects.	None	Provide technical advice and conducts service if requested by home owner.	None.
Consultants	Adhere to guidelines, requirements, policy and regulations in design and execution of projects.	None	Project dependent, may provide engineering design and specifications for implementation according to design guidelines, ensures compliance with standards and legislative requirements.		None	None	None
Academics	Independent scientific research and technical advice						
Homeowner	None	None	Selects rainwater tank package among home package options offered by developers	None. Unless self built.	None	Responsible for O&M of rainwater tank system.	Undefined
Builder	None	Selects the water saving options to be implemented in dwelling – typically the rainwater tank package.	Commonly selects the rainwater tank system incorporated in home package.	Implements or hires 3rd party to conduct rainwater system implementation	Organises approvals and certification via a building certifier	None	None
Tenant	None	None	None	None	None	Undefined	None

2.2.3. Risks and Liabilities Associated with Rainwater Tanks

The stakeholders that were interviewed were asked to identify risks that could arise from negligence in rainwater tanks installation and maintenance. Two of the respondents believed that there were no real issues with rainwater tanks when compared to other alternative water sources, given their simple maintenance needs. Whilst respondents agreed that O&M needs were simple, the majority thought there could be risks associated with lack of compliance in urban areas. The most common risks identified by participants are shown in Table 5. A comprehensive list is provided in the appendices. The major risks identified were:

(a) Health risks (n=6): diseases associated with mosquito breeding due to poor maintenance or removal of mosquito screens; algae and pathogen growth due to lack of cleaning or removal of covers, plumbing mistakes such as cross-connections.
(b) Undetected technical failure (n=4): due to poor design, wear and tear of system components, such as top-up systems or screens or blockage of screens. This could lead to increased use of mains water or impact water quality.
(c) Tank structural failure (n=4): due to poor manufacture, poor installation, blockage of overflows, resulting in tanks leaks or by-pass, erosion of tank footing or damage to house infrastructure for tanks placed in proximity to house walls.
(d) Aesthetics (n=2): discoloration of water associated with lack of cleaning and removal of leaves from gutters and tank openings.
(e) Environmental impacts: associated with reduced savings of mains water (n=4) or high energy use for rainwater supply (n=4), these were often seen as a consequence of (b) and (c).
(f) Social (n=3): loss of confidence in rainwater tanks due to poor performance, backlash in public opinion as a consequence of previous failings.
(g) Economic (n=2): loss of capital invested in rainwater infrastructure, unrealised water and infrastructure savings.

Ultimately, if the problems described above occur too frequently, that could diminish the appeal of, and confidence of householders in, rainwater use. Abandoned rainwater tanks would not only result in further increase in mains water use, but could also compound the risk of mosquito breeding. Mosquito breeding was the risk which was most frequently mentioned and was a concern expressed by plumbers and local government alike. Entry of mosquitoes into the tank was often attributed to breakage of screens due to overloading with debris and sediment or removal of screens by householders after tank installation.

Failure of system components, such as wear of top-up floats and blockage of screens, tank structural failure, or leaks and high energy consumption, received four mentions each. Lack of detection of system failure by householders was deemed a perverse outcome of the current tank system designs. Householders were believed to often not be aware of problems unless they observed changes in water colour in the toilet or laundry or if they happened to observe rainwater overflowing from the tank during a rain event (in case of a blockage). The problem was also believed to be compounded by the automatic mains water back-up systems; householders cannot discern if they are using rainwater or mains water, until they receive a water bill. A number of respondents also mentioned that poor water quality caused by a lack of cleaning and maintenance could ultimately lead to water discoloration and ultimately tank disconnection, if not resolved.

Structural failure risk was attributed to either poor bedding installation or erosion of bedding due to rainwater run-off associated with blockage of inlets/outlets and inadequate drainage to stormwater. Concern was also expressed by a respondent of the risk of a leaning tank due to installation in close proximity to the dwelling base. Fear of structural failure of tanks due to material aging was mentioned as a possible risk, associated particularly with polymer tank imports during the peak of the rebate period by a couple of respondents. The plumbing companies interviewed have not observed any catastrophic structural failures in the field; however two of the companies had reported leaks from the rupture of seams in slimline polymer tanks attributed to uneven wall thickness and poor manufacture.

Table 5. Problems and concerns associated with rainwater tanks.

Risk Classification	Description (mention)	Cause
Health	Mosquito breeding (6)	Access of mosquitoes into the tank due to removal or breakdown of mosquito screens.
		Removal or breakdown of screens.
	Cross-connection (3)	DIY plumbing.
	Water quality (5)	Contaminant build-up due to lack of regular O&M (gutters, first flush diverters and screen cleaning, desludging of tank). Installation of water outlet too close to tank bottom. Infiltration in underground buried tanks.
	Algae growth (can lead to blockages) (1)	Removal of screens (3) and or failure due to lack of cleaning (4).
Wear and Tear	Failure of equipment leading to use of mains water instead of rainwater (6)	Break down of top-up float for mains back-up system.
	Lack of inspection or O&M.	Poor location or buried tank.
	Pump failure (cavitation, breakdown) (3)	Undersize or cheap pump. Pump exposed to elements.
Aesthetics	Water discoloration (sediment and colour in toilet or laundry) (2), seasonal odour (1)	Lack of cleaning of gutter, screens, first flush diverters, tank.
Environmental	Energy usage for rainwater is unknown or high (4)	Unknown. Lack of data.
	Water savings overestimated (4)	Rainwater underutilised. Lack of data on mains water savings and rainwater use. Unknown how many tanks are in operation.
	Water savings decrease over time as tanks go off-line (4)	Wear and tear or disillusion by tank owner.
Structural (4)	Leaning tank	Poor bedding installation, erosion of bedding dur to overflows.
	Rainwater run-off	No connection to stormwater drain (incorrect installation).
	Leaks or splits	Observed in some of the slimline plastic tanks because of thin walls and high stress caused by blockage of overflows.
	Overflow	Screen blockage. Some tanks have difficult to access overflow that makes cleaning difficult.
Economic	Lack of real data on actual life cost of rainwater system (2)	Lack of data on performance, O&M costs and impact on water savings.
Social	Disillusion with rainwater tanks by householders (3)	Poor performance or poor water quality, costs seen as too high.

All plumbing companies interviewed reported encountering pump issues or breakdowns in their visits. These included pump breakdown associated with inferior quality or undersized pumps; and failures associated with poor maintenance such as exposure of pump to elements (absence of a pump cover) and blockage of lines with sediment leading to pump cavitation.

Incorrect installation was also reported by all plumbing companies. Cross-connections and incorrect plumbing were observed to be most common in DIY installations according to the plumbing service companies. "Incorrect installation used to be common, particularly in the height of the rebate period, but it is better now". Post-installation modifications to rainwater tank were feared as a risk by some of the respondents, and also verified to occur by plumbing service companies. However, there is not enough data to determine the extent of such practices.

Gaining access to the tank for inspection and even awareness of problems with the tanks were seen as potential issues associated with lack of maintenance. The location of tanks against walls and fences, often in tight spaces, and out of sight or underground tanks increased the difficulty of inspection and could contribute to "out-of-sight, out-of-mind" attitudes in householders. In the long-term, failure of rainwater tanks systems and dissatisfaction by tank owners could lead to abandonment of the assets, with economic, environmental and political implications.

In summary, respondents agreed that properly maintained tanks are unlikely to represent a risk to the community. However, all perceived that issues could arise from lack of proper installation and lack of O&M to ensure the integrity of the system. The major repercussion is the risk of mosquito borne

diseases if mosquitoes gained entry into tanks, and the lack of water mains use reduction. On the other hand, a number of impacts mentioned, such as energy consumption, water savings and overall life cycle cost, were deemed as unknown as they had not yet been quantified. Examples of poor design and procurement were also observed and could lead to early replacement costs incurred for tanks and parts by householders. The design and location of rainwater systems, often out of sight and equipped with mains back-up systems, may contribute to preventing the detection of some types of system failure. Hence, if regular inspection is not conducted, the risk of undetected failure and the compounding of O&M consequences would be likely to increase.

2.2.4. The Main Cause for Concern

All respondents perceived that the lack of maintenance of rainwater systems by tank owners was the root cause to the majority of the risks and problems associated with rainwater tanks. Respondents also perceived that the level of awareness of the maintenance needs and O&M practices varied among tank owners, and owners of mandated tanks were perceived to have very little knowledge of O&M requirements. A common sentiment can be gleaned from the following quote (quotes in this section are from transcripts of interviews):

> "*Householders in semi-rural properties and in households that deliberately choose to install a rainwater tank are more conscious of tank maintenance and quality of water. Whilst many people who claimed rebates (paid little) for their tanks or who are in areas where tanks are mandated were shocked to learn that on-going maintenance is required.*"

It was also perceived that the level of awareness is also low among tenants and non-primary home-owners. This was assumed to stem mostly from lack of information and education, and it could also be compounded by the expectation of urban dwellers to always have mains water available without the need of any maintenance by their part. Whilst a number of technical resources and guidelines are available and were deemed adequate, the ignorance regarding O&M was perceived to come from: (a) ignorance about the system and its operation; and (b) if aware of maintenance needs, not knowing how and where to access relevant information. According to respondents, the majority of public campaigns and advertisement to date have focused on the harvesting of rainwater, whilst information on practical maintenance has been scarce. According to the plumbing service providers:

> "[The] *majority of tank owners are likely to resort to newspaper ads, which may refer to a website for further info*".

It was also noted that there is often very little emphasis placed on maintenance:

> "*People need to know that rainwater tanks are low maintenance, not no maintenance*".

The same sentiment was echoed by academics, consultants and local government. In addition, plumbing service providers have noted that, when their customers were eager to find more information, they often did not know where to search. Practical information was not easily found by the general public and generally was comprised of high level information. For example, the information on rainwater tanks varies across local government websites, whilst the majority of SEQ councils have information on the certification process, not all have information on O&M practices and the level of detail varies (Appendix A.1). The low emphasis on post-installation maintenance is further reinforced by the absence of follow-up after installation – according to local government.

2.2.5. The Extent of the Problem

The majority of respondents (government, academics, local government, consultants) highlighted that there is a lack of data to assess the long-term impact of rainwater tanks on actual potable water demand reduction and the condition of residential tanks. Without the actual data it is difficult to establish if rainwater tank failure is an issue or not. Uncertainty also surrounds what the current number, status, condition and savings from rainwater tanks are.

Local government believes that potential risks could arise from inadequate rainwater tank maintenance and suspects that most tank owners have limited awareness of actual O&M needs and practices. However, given the lack of data to establish the extent of the condition of rainwater tanks and their impact within their jurisdictions (i.e. whether they might pose a problem or not), responses suggest that councils do not feel able to determine if tanks are an issue or not. For instance there is no data on actual water savings, water quality, condition of tanks or on the number of tanks in use. Whilst most councils have records of new dwellings with mandated rainwater tanks post 2007, and records of rebates claimed for rainwater tanks, there are no records for retrofitted tanks if rebates were not claimed. Local government also does not have finances and staffing resources to investigate the issue further.

Plumbing service providers interviewed have expressed significant concern about the condition of rainwater tank stock and the greatest sense of urgency among the groups interviewed. They expressed concern based on their observations during service calls regarding the rate of failure, poor workmanship, inadequate modifications and lack of O&M observed in rainwater tank installations. More significantly they also reported a number of anecdotes where people were surprised that maintenance was required at all. They are, however, a valuable source of information, having also closely observed the evolution of component and part design and performance in the field. However, it has to be considered that they are called upon to inspect tanks that have problems and the extent of the problem in the overall tank population cannot be fully characterised.

Poor installation observed by plumbing service providers has been typically associated with "do it yourself installations". But removal or breakage of mosquito screens has also been observed and is of concern. Plumbing providers considered the risk of mosquito and, particularly, the lack of O&M during the period when it rains frequently, may increase risk factors for the current tank stock.

Without evidence to quantify the extent of the problem, neither councils nor government are able to assess if further action is required, or the urgency of the issues. One of the plumbing service providers described rainwater tanks in their current state as a "*ticking bomb*".

2.2.6. Roles and Responsibilities

Whilst the majority of stakeholders recognise that there are adequate technical guidelines on rainwater tank design, installation and maintenance, the majority of stakeholders also believe that the level of awareness among owners of mandated rainwater tanks is low. This might be further compounded by the lack of clarity in the legislative framework. Current legislative and building requirements have focused on the implementation of rainwater tanks, with less emphasis on the post implementation follow-up, as noted by one respondent (quotes in this section are from transcripts of interviews):

> "*There are no formal mechanisms for such follow-up.*"

Councils have expressed concerns regarding the current certification and documentation process for existing tanks, regarding both mandated and voluntary uptake. Certification of rainwater tanks in new dwellings has two components: (1) rainwater tanks are deemed as part of the planning and building infrastructure under the building act and fall under the jurisdiction of building certifiers; and (2) the connections between the tank and internal plumbing are verified by a licensed plumber.

Councils expressed concern regarding level of training of independent building and plumbing certifiers and the rigour in assessment of rainwater tank installations. Both councils and plumbers have reported that they have often come across examples where connection to stormwater infrastructure was not inspected during certification. Instead the emphasis in plumbing inspection is perceived to be typically on the connection to internal plumbing, as noted by one plumber:

> *"There is lack of well trained and interested plumbing inspectors."*

In addition, one of the councils also reported that the standard of certification reports varies, it does not always receive a full assessment report from building certifiers, and in a number of cases drainage to stormwater has not been reported. As compliance certificates are generally issued to the developer, often householders are not aware that installations need to fulfil compliance requirements, as noted by one plumber:

> *"Even when pamphlet packs are provided during property handover, home owners do not necessarily read them."*

Roles and responsibilities for rainwater tanks are clearly defined in the legislation up to the implementation stage. However, there is a general perception of lack of clarity in post-implementation roles compounded by limited follow-up. Local government believed there was need for clarification to specify if rainwater tanks were a building or a plumbing issue, and to help define which department should take responsibility for them. Local government has jurisdiction over components that fall under *the Plumbing Act*, but under *the Building Act* tanks are considered part of the Planning and Building Infrastructure.

The onus of rainwater O&M maintenance is on home owners. Whilst this is not an issue if tank owners are able to look after their tanks, government, academics, local council, consultants and plumbers perceive that, whilst the O&M requirements for mandated rainwater tanks are simple, there is a wide variation in the degree of knowledge and practice of urban householders about rainwater tank operation and maintenance needs. Current post-implementation follow-up covers public health (mosquitoes), which is under the responsibility of Queensland Health and is enforced by councils. A number of respondents from academia, local government and plumbing service providers advocated the need to clarify the liability and responsibility of parties' post-tank installation, particularly regarding tenants and non-primary home owners. In addition, no mechanisms are in place to verify that modifications to rainwater tank installations after the initial compliance certification is within existing regulations or guidelines. Whilst there are penalties for lack of compliance, academics, councils and plumbing service providers also felt that there was a gap in mechanisms for enforcement and prosecution of non-compliant and/or default on warranties or poor workmanship of rainwater systems.

Other stakeholders who may become involved in the post-implementation stages include plumbers, if called upon by home owners as service providers, and councils if called upon to investigate complaints regarding mosquito breeding risk or nuisance. However, neither of the last two groups has any specific mandate regarding the enforcement of other rainwater tank O&M practices. Respondents were also asked who would be the most appropriate stakeholder to look after O&M of private rainwater tanks. All interviewees believed that that the responsibility for O&M should remain with the home owner; however, they also believed that investing in education of this group was required. Under the current conditions, councils are not resourced to extend their role beyond the present certification process, public health follow-up and prosecution process, due to lack of limited staffing and financial resources. They are satisfied to retain their current functions. They also believed that the industry should be allowed to self-regulate, provided better enforcement and more stringent performance standards were developed. In addition, academics, plumbers and local government perceive that householders are averse to over-regulation by government and antagonistic to any increase in regulation that could lead to future increase in rates or taxation on their tanks.

2.2.7. Governance and Management Options Issues

All the stakeholders who were interviewed believed that registration and governance of rainwater tanks is a delicate issue and that needs to be handled cautiously in order to avoid the ire and outrage of the public and disillusion and abandonment of rainwater tanks. The perception of stakeholders interviewed and, in particular, academics, local government and plumbing service providers, was that the public was likely to resist increased regulation on rainwater tanks. However, early segmentation studies of tank owners (Gardiner, 2010) indicate that attitudes towards governance may vary. A number of respondents also highlighted the need to avoid penalising tank owners who looked after

their rain water tanks properly. Overall, stakeholders commented that they were uncertain on how to address the issue, but were able to offer suggestions on various aspects related to rainwater tank implementation and long-term operation. Thus, any considerations on management strategies would require a detailed assessment of existing rainwater tank stock, rainwater end uses, volume, equity, householder awareness level, cost distribution and social implications, etc. Respondents did, however, agree that the greatest need at present was:

(a) To develop an understanding of the risk of rainwater tank failure;
(b) But more than anything, to increase the awareness of householders of rainwater tank operation and O&M practices and needs by making information available; and
(c) After those factors were fulfilled, to then reassess governance issues.

2.2.8. Recommendations for Improving Maintenance Practices

Respondents provided a number of suggestions for improving the understanding of rainwater tank condition, roles and responsibilities. The list below includes all suggestions provided by respondents.

(a) Knowledge Gaps and Needs

- Lack of data on existing rainwater tank stock. Existing tank records have limited reliability, as not all tanks are included.
- Gather data to establish uptake of tanks and their effectiveness. Follow this by an assessment of risks.
- Lack of minimum standards for evaluation of design of system components and their effectiveness, e.g. mosquito meshes, pump energy efficiency, etc.
- Lack of data on trees that should not be planted near rainwater tanks.
- Lack of data on effectiveness of trickle top-up and automatic water switching devices on water savings.
- Lack of data on life cycle costs and benefits associated with rainwater tanks.

(b) Recommendations

- Establish a registry (inventory) of certified rainwater tanks.
- Consult with councils and practitioners to better understand rainwater tank issues. They have the most experience of residential tank installations.

(c) Legislation

- Legislation is not transparent and lacks clarity, particularly in aspects such as infrastructure funding. Develop regulations using cost-benefit analysis of various governance options.
- Place tanks under the Plumbing Code, this would give councils more control over them.
- Place tanks under the Plumbing and Drainage Act, but modify the Act to include stormwater drainage.
- Ensure tank purchases or installations are conducted only by, or in consultation with, a licensed plumber. Plumbers are supposed to be up-to-date with legislated requirements.
- Classify all size tanks as structures under the Building Code to allow councils to regulate their placement, or tighten the placements requirements for rainwater tanks to ensure that they are not difficult to access.
- QDC needs to be more specific about internal plumbing set-up requirements to avoid dual plumbing of potable and rainwater in laundry taps.
- Develop framework for assessment based on differences in rainwater end use (internal or external uses) and demonstrate clarity in assessment.
- Develop post-implementation strategies based on education follow-up.

(d) Standards

- Introduce a certification and labelling scheme on the body of tanks, similar to pipes (tags showing manufacturer, volume capacity, compliance with standards and manufacturer contact details).
- Certification programs are required to implement minimum efficiency requirements and performance of system components.
- Tighten accreditation/training of building certifiers.
- Introduce inspection of stormwater drainage and infrastructure into tank certification.
- Develop rainwater system performance standards or accreditation to ensure that minimum environmental outcomes, energy or water savings are achieved.

(e) Education

- Provide householders annually with information on the risks and benefits from O&M .
- Promote awareness of rainwater tanks and the risk of mosquito prevention.
- Distribute rainwater maintenance material and implement O&M workshops for instance in large hardware centres.
- Conduct government campaigns to remind householders about maintenance needs for rainwater tanks every few (2 to 4) years. State government can develop a program and material for distribution to householders and local utilities can organise the roll-out to residents.
- Include a reminder for tank maintenance checks with the rates notice.

(f) Post–implementation management models

Model 1

Dwellings with rainwater tanks are registered with councils or in a register run by the State.

Home owners send in a compliance certificate sent by the service provider every 2 to 3 years. Home owners or certifiers can access the compliance certificate via the web to verify if properties are current in their rainwater tank compliance. If evidence of maintenance is not provided, a reminder is sent to the tank owner. If no action is taken following warnings and a grace period, a contractor is organised to inspect the tank and the cost is billed to the tank owner via the water bill or council rates.

Model 2

At renewal of leases or sale of dwellings, a certificate of inspection and compliance should be issued for the rain water system. House owners would be required to pay for the certification process as they do with smoke alarms (Queensland government 2006).

Model 3

Random audit programs of sample tanks following a risk assessment based on tanks reaching a certain age and other risk factors.

Model 4

An accredited service provider carries the responsibility for installation and service of rainwater systems and is paid a fee by house owners; this could be a third party or a water utility.

2.3. Survey: Perceptions of Rainwater Tank Issues

An online survey (questions shown in Appendix A) was distributed via email to water professionals in Queensland and around Australia. The questions in the survey were developed using existing understanding and knowledge of rainwater tanks. The formulation of the survey, and its distribution

style was reviewed and accepted by the CSIRO Ethics approval committee. The majority of the participants that undertook the survey were invited because of their attendance at the previous Urban Water Security Research Alliance science forum. The results of the survey are described below according to the themes of:

- Failure causes modes: what causes tanks to fail, and how do they fail?
- Failure rates: for each of the failure modes, how often/quickly is a tank likely to fail?
- Responsibilities: who ought to take responsibility for inspection as well as operation and maintenance of tanks; and should anyone pay for it?

2.3.1. Participant Categories

To be able to identify various biases in the judgments about rainwater tanks, some key characteristics of the survey participants were collected. In particular, participants were asked about which state or territory they live in; whether they own a tank or not; and what type of stakeholder they would categorise themselves as. Some key summary data are shown in Table 6.

Table 6. Response counts per state and territory.

State/Territory	Response Count	Response Percent
Australian Capital Territory	3	1.2%
New South Wales	22	8.6%
Northern Territory	1	0.4%
Queensland	175	68.4%
South Australia	11	4.3%
Tasmania	2	0.8%
Victoria	25	9.8%
Western Australia	11	4.3%
No response	6	2.3%

The number of responses in Queensland (72%) dominates the survey which is consistent with the distribution of the survey. Two factors that are likely to impact on the participants' responses are their stakeholder perspective and whether they own a rainwater tank. The two key factors that the survey queried about were the stakeholder category (Table 7), and ownership of rainwater tank (Table 8).

Table 7. Response counts per stakeholder category.

Stakeholder Category	Response Count	Response Percent
Work for council	33	13.4%
Government	43	17.5%
Private	41	46.3%
Other*	15	6.1%
No response*	114	16.7%

***Note**: The category "Other" is self defined and participants in this category have described themselves as researchers, having an interest in sustainability, consultancy professionals or working for a water service provider. Those not indicating a stakeholder category are denoted as "No response".

Table 8. Rainwater tank ownership amongst participant.

Stakeholder category	Response count	Response percent
Participant owns rainwater tank	141	57%
Participant does not own a rainwater tank	106	43%

For the rest of this report, tables will be referring to the results from the Queensland respondents only.

2.3.2. Failure Causes and Modes

The types of problem that were considered as possible concerns were:

- Breakdown of pumps and/or their parts.
- Tank breakdown (structural integrity).
- Mosquitoes breeding in tank creating a risk for disease transmission.
- Poor water quality.

The response to the question *"What do you believe are the most likely problems and malfunctions likely to cause problems with mandated tanks?"* is shown in Figure 3, with responses to the same question by stakeholder group shown in Figure 4. Breakdown of pumps and/or parts is the first and foremost concern (30-36%), followed by water quality and mosquitoes. There is, however, considerable difference in the types of judgments made by respondents, and a large number of the "N/A" category respondents considered that there are no major problems with rainwater tanks. Government respondents are most concerned with "Other" issues. Those working for council are most concerned with "Water quality issues", and those working in private enterprise are most concerned about pumps and their parts.

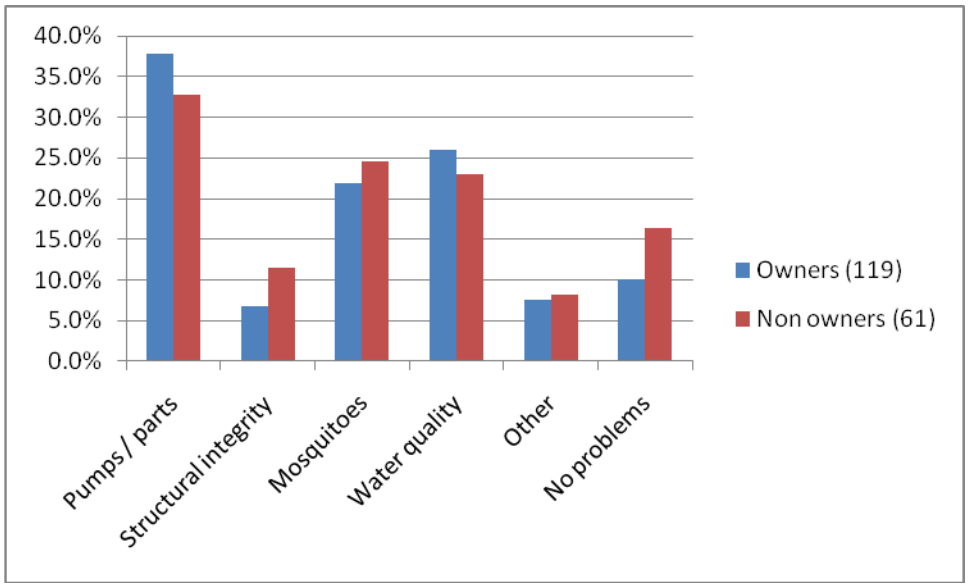


Figure 3. Failure modes in rainwater tanks (Owners vs. Non-owners).

Note: *The number of respondents is shown in brackets for each category in the above figures.*

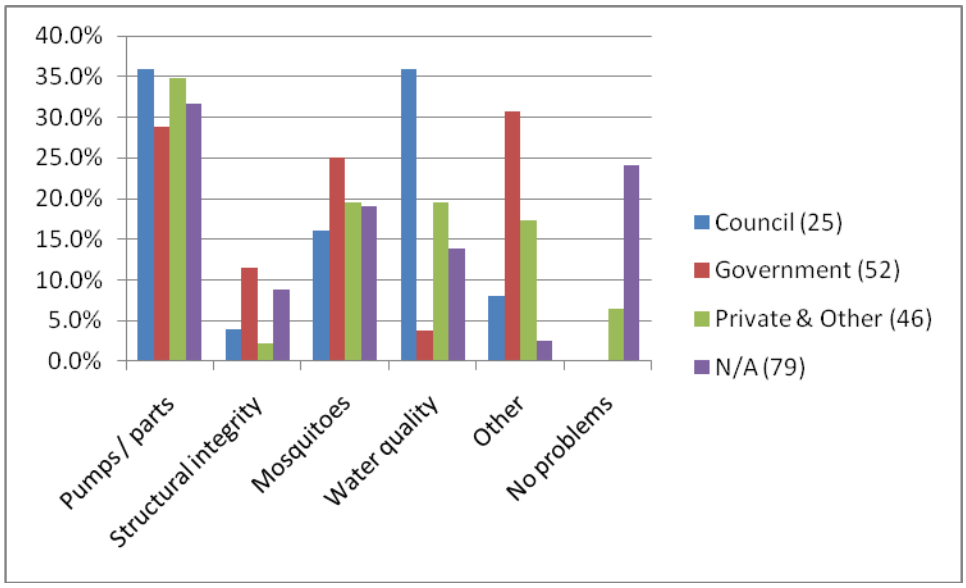


Figure 4. Failure modes in rainwater tanks (by stakeholder group).

In terms of the comprehensiveness of the list of problem categories, fewer than 10% of respondents suggested additional types of problem, although some were noted, including:

- Filters/mesh get clogged
- Sludge build-up
- Blocked inlet screens reducing tanks' ability to store water
- Failure of tank support (presumably the foundation of the tank)
- Discoloration of water
- Noise from pumps.

The response to the question on causes of rainwater tank failure is shown in Figure 5, and the breakdown per stakeholder group for this question is shown in Figure 6.

It is clear that many respondents judge that "Lack of operation and maintenance" is the major cause of problems with rainwater tanks, but that there is a combination of factors contributing to issues. In particular, many private enterprise respondents judge that poor installation is a common problem, and many council respondents judge that incorrect operation and maintenance is a significant contributor to problems. Owners also judge lack of O&M as less of a problem than do non-owners. Other causes mentioned by respondents are:

- Short life of pumps
- Buying cheap products (both pumps and tanks)
- Lack of education about rainwater tank maintenance.

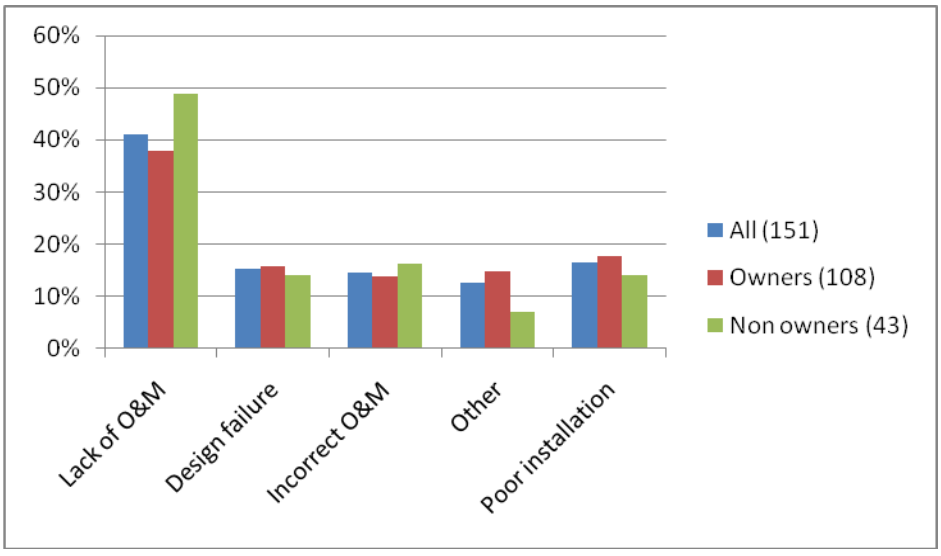


Figure 5. Common causes of failure in rainwater tanks (Owners vs. Non-owners).

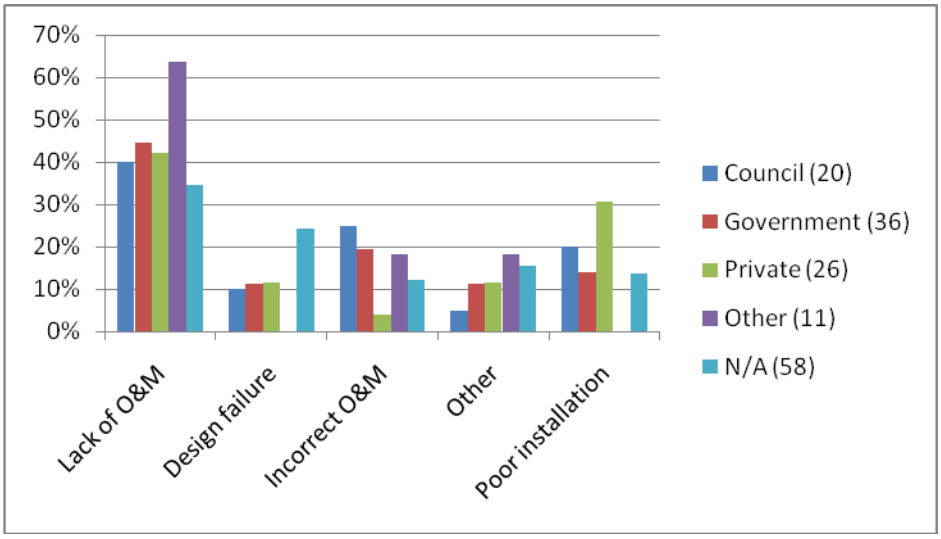


Figure 6. Common causes of failure in rainwater tanks (by stakeholder group).

Because the key cause of concern for rainwater tanks (as confirmed by the previous question) is the adequacy or inadequacy of O&M, a further question was added to the survey: *What level of maintenance do you believe is currently carried out for mandated rainwater tanks in South East Queensland?* A summary of responses to this question is presented in Figure 7 and Figure 8, showing a considerable difference in judgments between different stakeholder groups. For example 90% of government respondents believe that less than 25% of tanks are adequately maintained, in contrast, approximately half of the N/A respondents believe that 99% of all tanks are adequately maintained. It is also notable that owners are considerably more pessimistic than non-owners. To explore the difference further, consider the graph of "cumulative distribution" show in Figure 9. In simple terms, the higher up the curve, the more pessimistic a group is regarding the maintenance of rainwater tanks, and vice versa. It is clearly shown in this graph that government participants stand out as extremely pessimistic, with those that work for the council, private enterprises and other categories being somewhat pessimistic; but respondents in the N/A category are incredibly optimistic in their view of rainwater tank maintenance. Obviously the different perspectives influences the views, and in fact the differences in views on this issue show the potential for real conflict on the issue of how rainwater tanks ought to be governed. To resolve this issue, there is a need to collect reliable data on the issue.

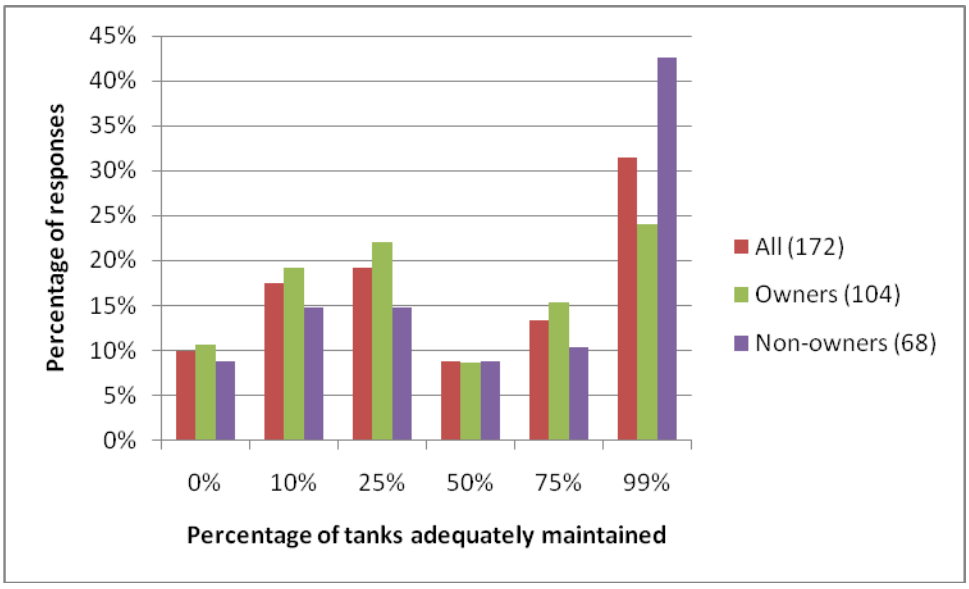


Figure 7. Level of O&M of tanks (Owners vs. Non-owners).

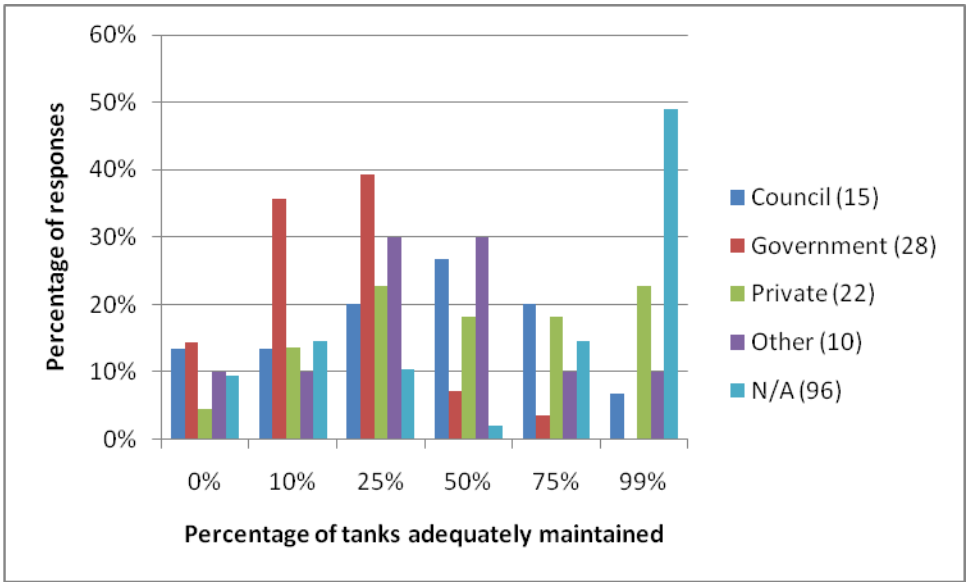


Figure 8. Level of O&M of tanks (by stakeholder group).

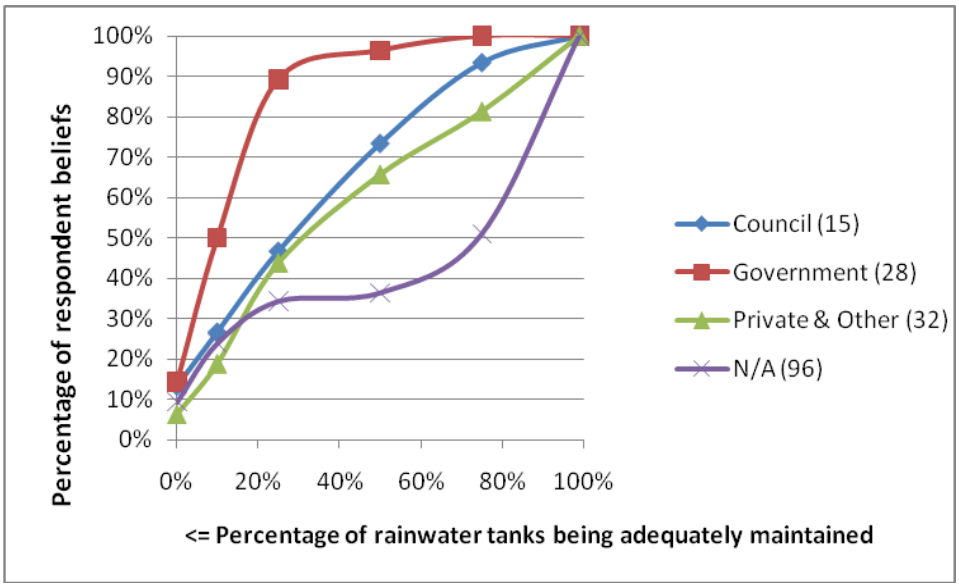


Figure 9. Cumulative distribution on judgments of levels of adequate maintenance (by stakeholder group).

2.3.3. Failure Rates

Whilst the previous section illuminates the various concerns that people have with rainwater tanks and the differences in judgments by different groups, to be able to move to real analysis of failure rates and efficiency at different types of O&M schedules, there is a need to estimate times to failure for each failure mode. Therefore, whilst it is acknowledged that cognitively this is a difficult task, participants were asked to estimate times to failure for a number of failure modes.

- Pumps
  - If a pump is not being maintained, please estimate the time before it will become non-functional?
- Gutters
  - If there are over-hanging trees and gutters that are not being cleaned, please estimate the average time before gutters will become blocked?
  - If there are no over-hanging trees, please estimate the average time before gutters will become blocked?

- Mosquito meshing
  - If the mosquito meshing is not being maintained, please estimate the time before it will break?
  - What percentage of mosquito meshing would you think have been removed by householders?
- Structural integrity
  - If the actual tank is not being maintained, please estimate the "average" time before it will break or become unusable, i.e. relating to the structural integrity?

Summaries of the responses to the above questions are shown in the figures immediately below.

Responses to the question "If a pump is not being maintained, please estimate the time before it will become non-functional?" are shown in Figure 10 and Figure 11. It can be seen that most participants believe that pumps will last for at least two years. Those participants working at the council are however slightly more pessimistic and more than 50% believe that pumps will last only two years or less.

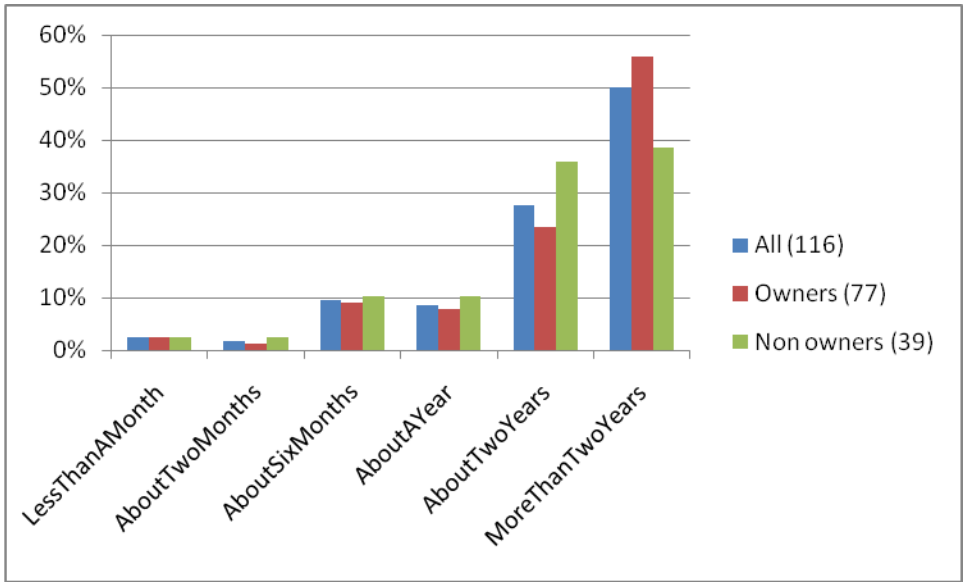


Figure 10. Time until failure of pump if no maintenance (Owners vs. Non-owners).

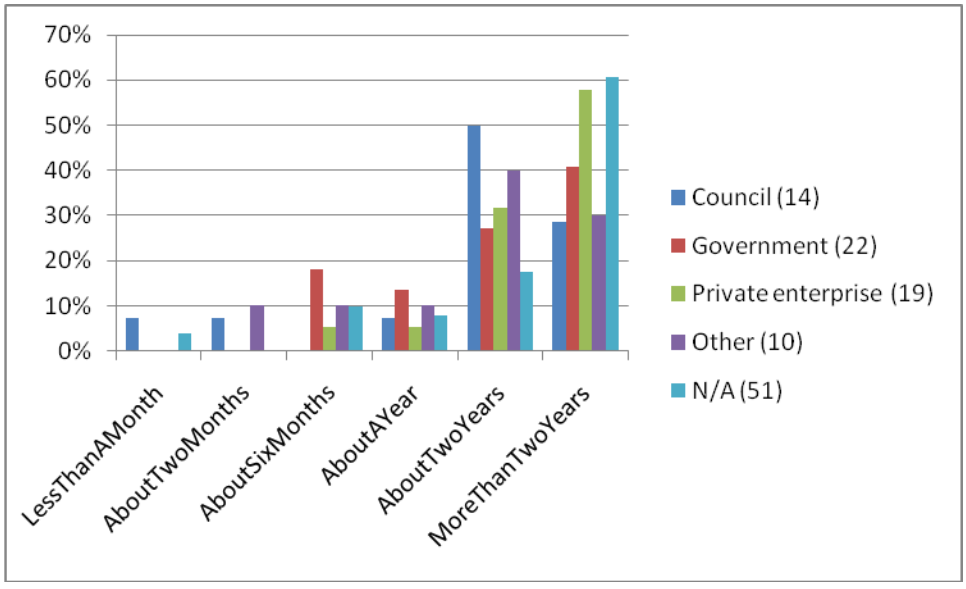


Figure 11. Time until failure of pump if no maintenance (by stakeholder group).

Responses to the question "If there are over-hanging trees and gutters that are not being cleaned, please estimate the average time before gutters will become blocked?" are shown in Figure 12 and Figure 13. It can be seen that if there are over-hanging trees, most respondents believe that gutters will block up relatively quickly, i.e. likely within two months. Again there is a difference in the beliefs between stakeholder groups. Government participants are more pessimistic and participants in the N/A category (i.e. those not providing an affiliation to a stakeholder group) tend to be more optimistic; and owners are more pessimistic and non-owners more optimistic.

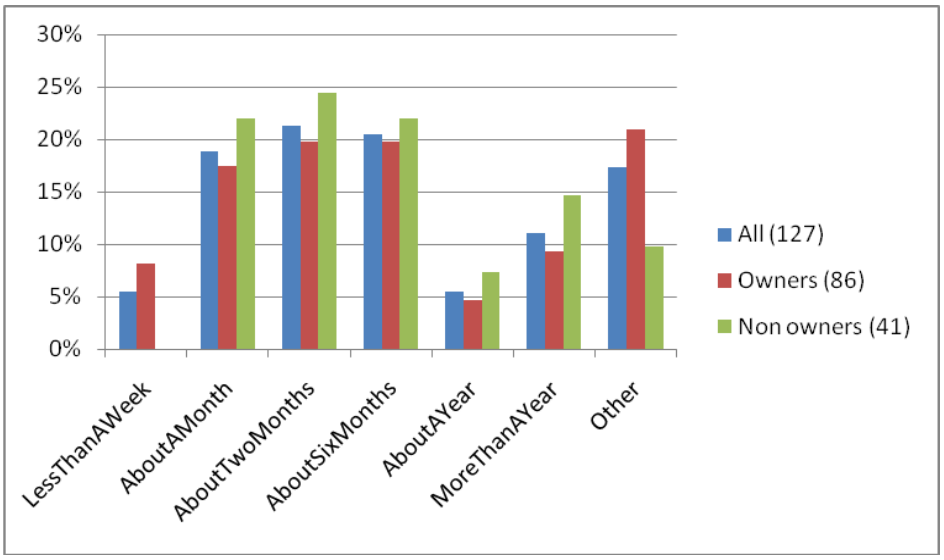


Figure 12. Time until blocked gutters if over-hanging trees (Owners vs. Non-owners).

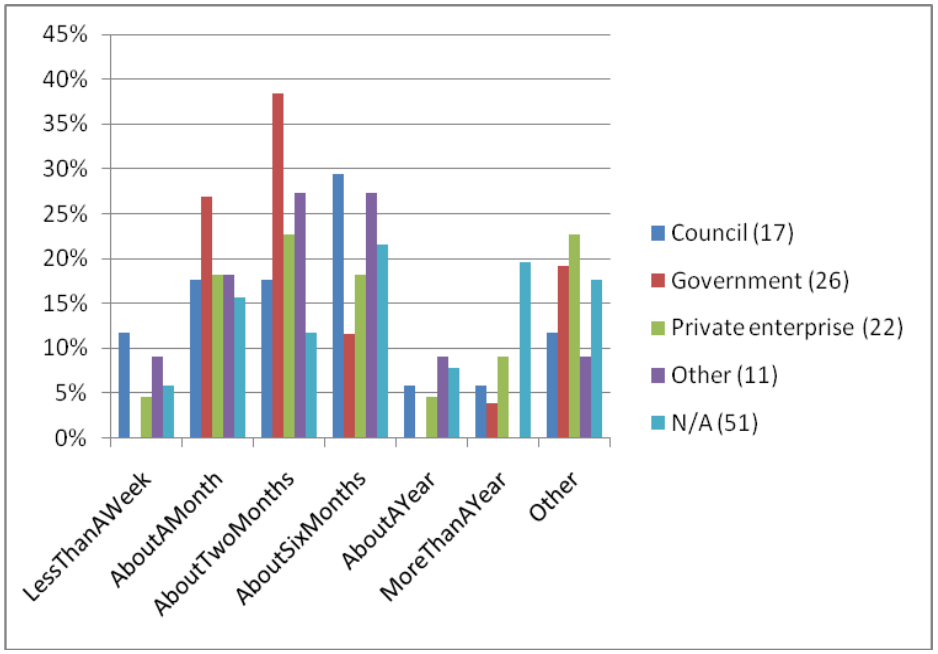


Figure 13. Time until blocked gutters if over-hanging trees (by stakeholder group).

A summary of the responses to the question "If there are no over-hanging trees, please estimate the average time before gutters will become blocked?" is shown in Figure 14 and Figure 15. We can see that respondents' assessment of how quickly gutters will block very much depends on the presence (or not) of over-hanging trees. More than 50% of all respondents believe that it will take over a year before gutters block, and very few believe that it will take less than six months. Owners and non-owners judgments are similar, but there is some variability in terms of judgments by stakeholder groups.

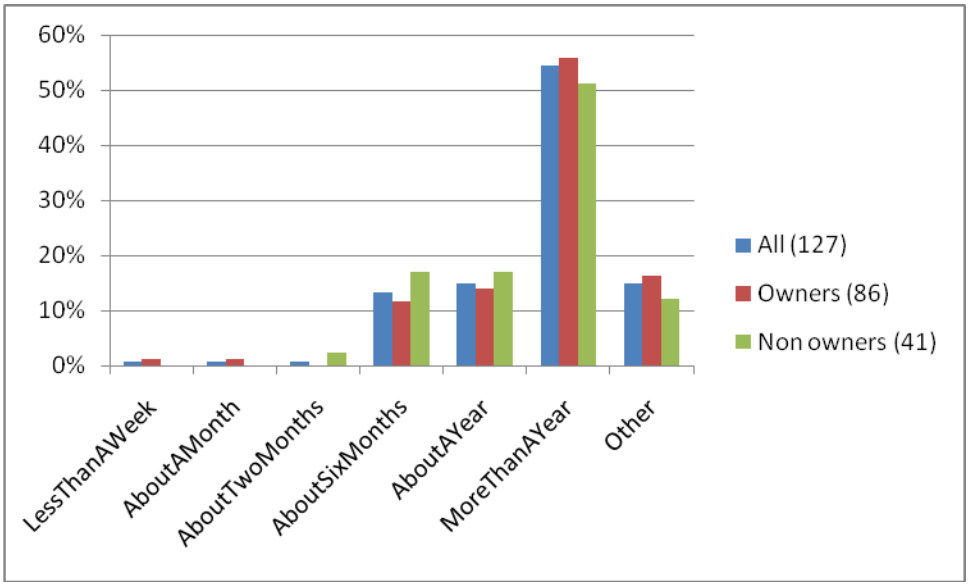


Figure 14. Time until blocked gutters if no over-hanging trees (Owners vs. Non-owners).

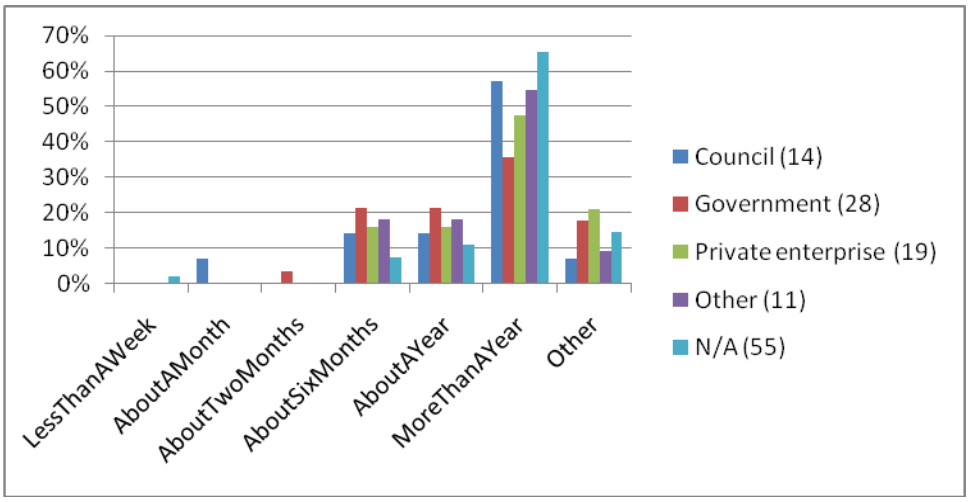


Figure 15. Time until blocked gutters if no over-hanging trees (by stakeholder group).

A summary of the responses to the question "If the actual tank is not being maintained, please estimate the "average" time before it will break or become unusable, i.e. relating to the structural integrity?" is shown in Figure 16 and Figure 17. In terms of the structural integrity of tanks, most judge that rainwater tanks will last about ten years (or possibly even more because of limited options in the survey and indeed approximately a third of respondents left this question blank). This contradicts some statements in the interviews; where it was said that cheap imported rainwater tanks may in fact fail structurally within a year or a few months due to poor design or manufacturing, or not enough UV stabilizer in the plastics.

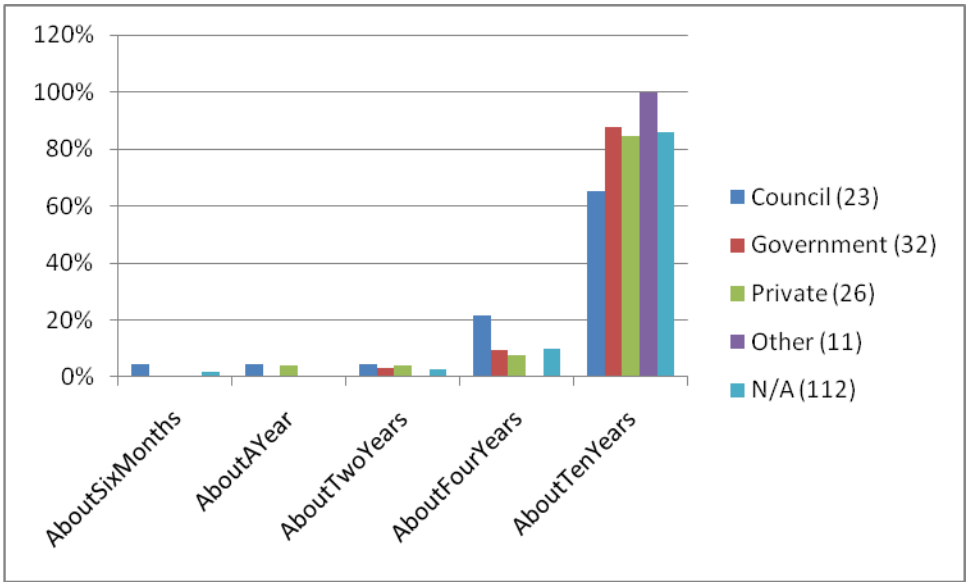


Figure 16. Time until structural failure of tank if not maintained (Owners vs. Non-owners).

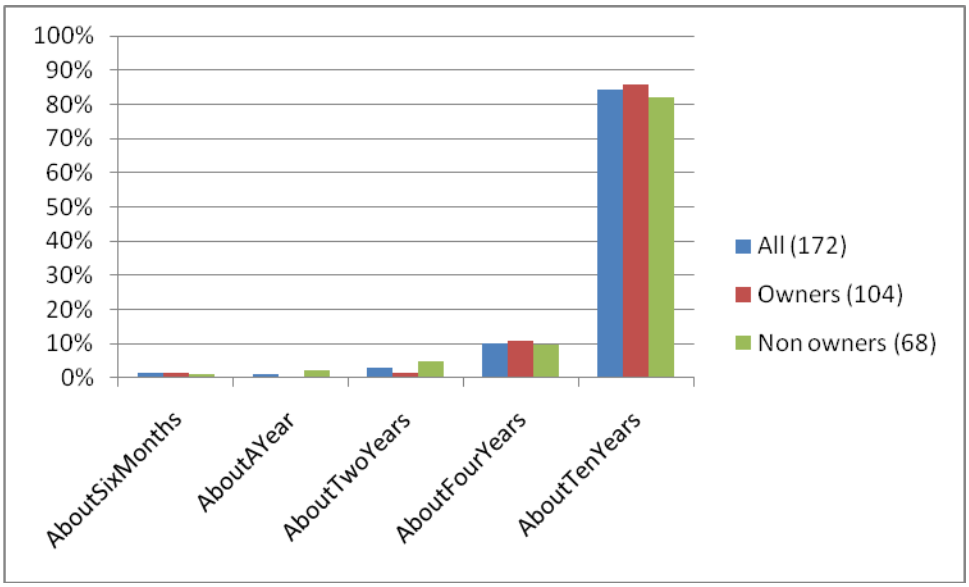


Figure 17. Time until structural failure of tank if not maintained (by stakeholder group).

A summary of the responses to the question "What percentage of mosquito meshing would you think have been removed by householders?" is shown in Figure 18 and Figure 19. Most respondents think that removal of the mosquito meshing is a rare occurrence, although almost a quarter of the council category respondents believe that half of all meshing has been removed. This is interesting from the point of view that the councils are responsible for enforcing health regulations regarding mosquito meshing, and it seems they may be taking a precautionary view. There is considerable variability in judgments by respondents, so again it will be important to get better data on this issue to evaluate the size of the problem.

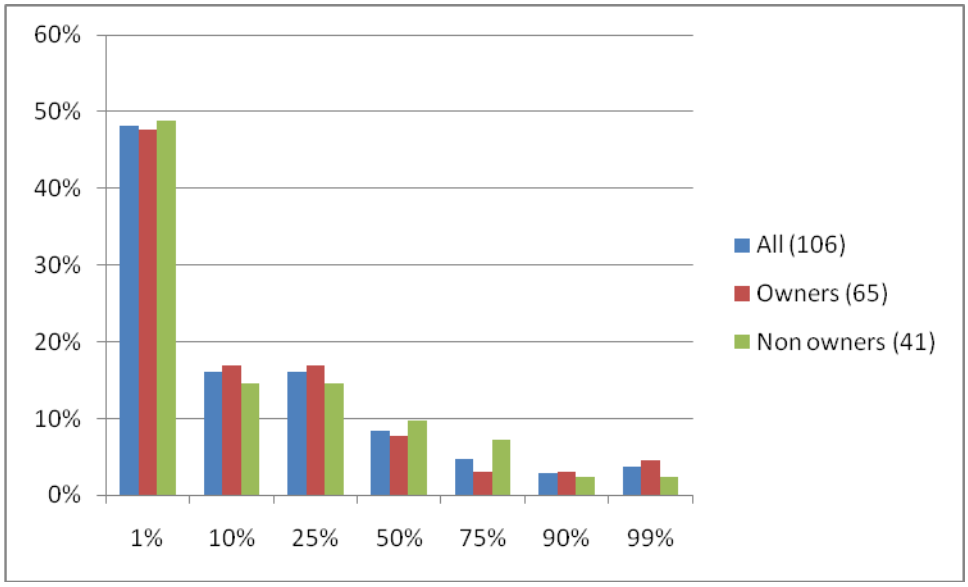


Figure 18. Percentage of removed mosquito meshing (Owners vs. Non-owners).

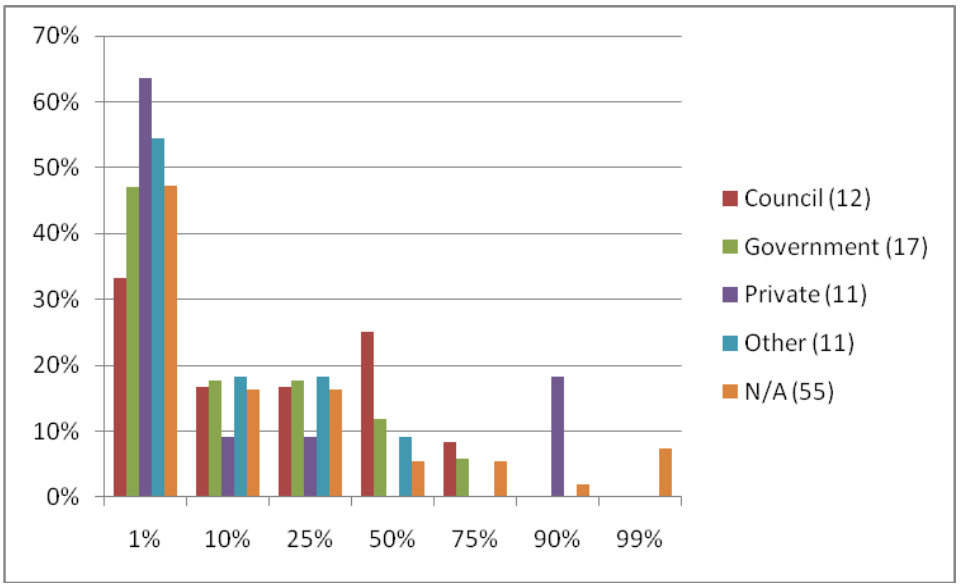


Figure 19. Percentage of removed mosquito meshing (by stakeholder group).

The question "If the mosquito meshing is not being maintained, please estimate the time before it will break?" was asked and responses are shown in Figure 20 and Figure 21. For the issue of mosquito meshing degradation, the median estimate is about two years, and about a third of respondents estimate that meshing will break in about a year, and about one eighth of respondents estimate that the meshing will break within about six months. There is relative similarity in judgments between owners and non-owners of tanks, but those employed in private enterprise or in the N/A category judge that meshing will last longer than do those in council and government.

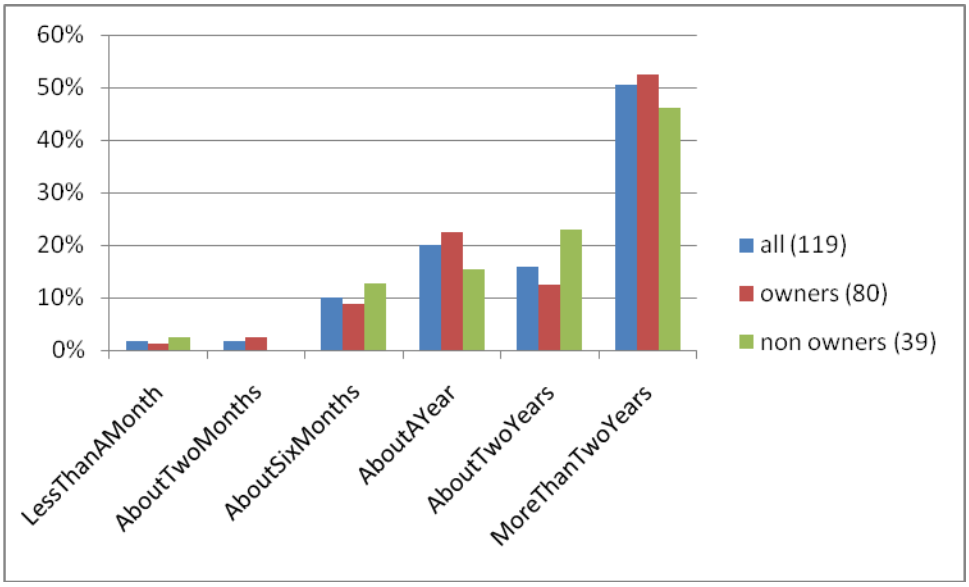


Figure 20. Time to failure of mosquito meshing if not maintained (Owners vs. Non-owners).

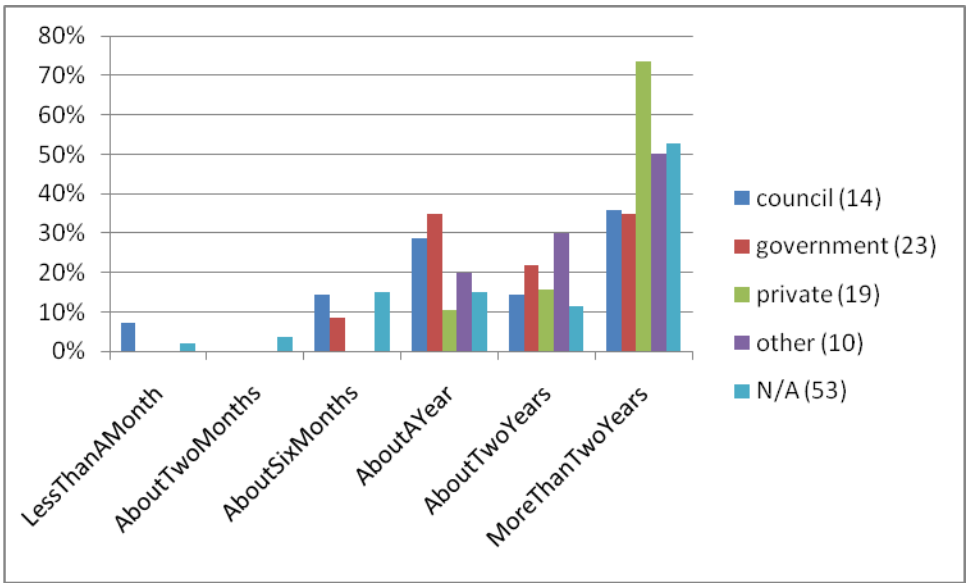


Figure 21. Time to failure of mosquito meshing if not maintained (by stakeholder group).

2.3.4. Responsibilities

So far there have been questions about concerns with rainwater tanks, how they break, what causes them to break and how quickly they break. Whilst some respondents do believe there are very few concerns with rainwater tanks, more people than not believe that there is a range of concerns with rainwater tanks and that they are not adequately maintained. If there is some problem with rainwater tank breakages, and if this leads to a reduction in their effectiveness, then the question is: who needs to do something about it? Given the relatively simple nature of rainwater tank O&M, most of the time it is about simply inspecting tanks to see whether they are functional and sound, and to deal with problems when applicable. To investigate the range of opinions, respondents were asked the following questions:

- Who do you think should be responsible for maintenance of rainwater tanks?
- Who do you think should be responsible for inspections of rainwater tanks?

- Do you think there is a greater role to be played by private enterprises in the maintenance and management of rainwater tanks?
- Do you think there is a greater role to be played by the water utility or local council in the maintenance and management of rainwater tanks?
- How much do you think a householder may be prepared to pay on an annual basis for regular upkeep of a rainwater tank?

Summaries of the responses (by those living in Queensland) to these questions are shown in the Figures in the next few pages.

2.3.4.1. Responsibility for Inspections

The question "Who should be responsible for inspections?" was asked to participants and responses are shown in Figure 22 and Figure 23.

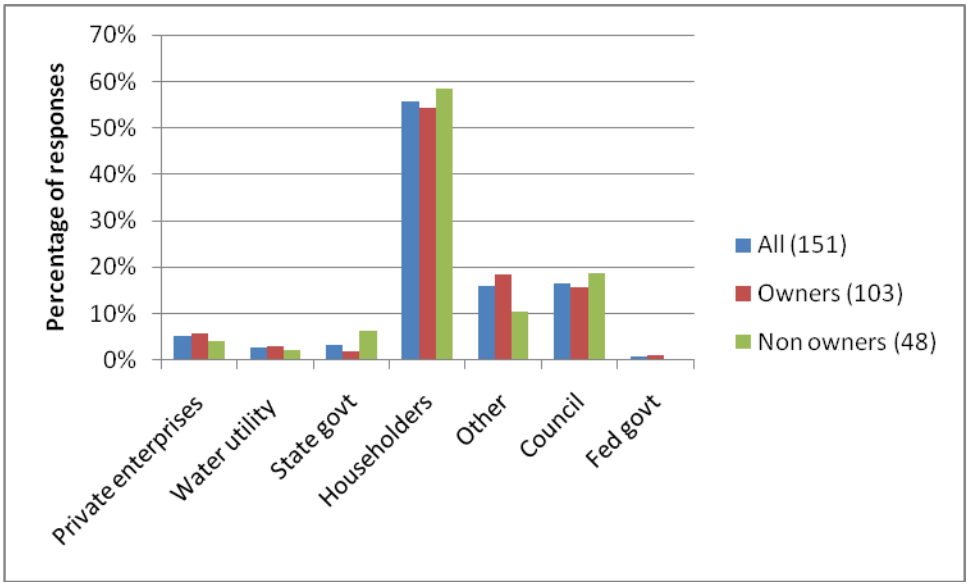


Figure 22. Opinions on responsibility for inspections (Owners vs. Non-owners).

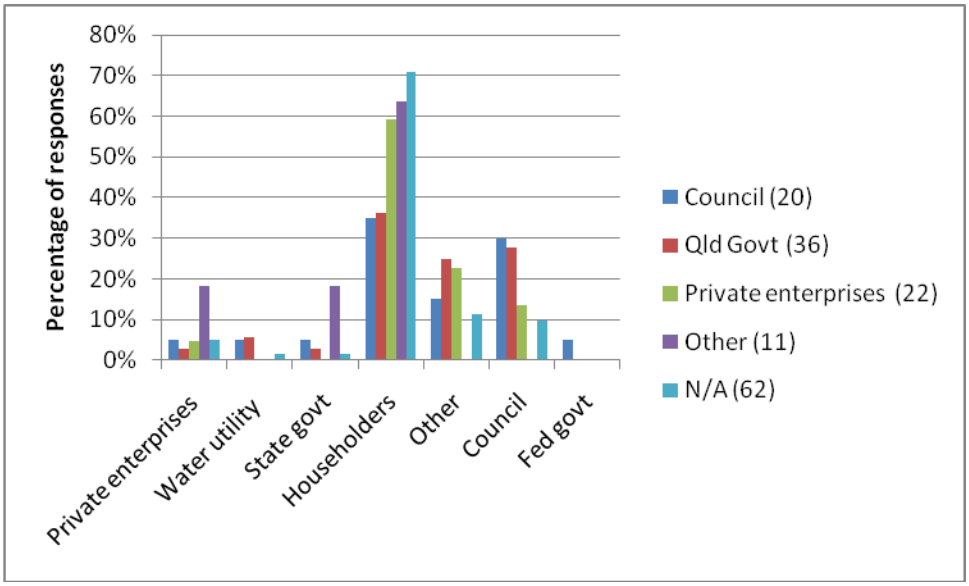


Figure 23: Opinions on responsibility for inspections (by stakeholder group).

It is noted that the majority view for most categories is that inspections should be carried out by householders. Some believe that councils may play a role in carrying out inspections. Very few believe that anyone other than householders and councils ought to be responsible. In fact, very strong opinions were raised in response to even the implicit suggestion, by asking the question, that water utility or state government may be involved. Owners and non-owners of rainwater tanks have similar views on this issue, but when responses are broken down for each stakeholder group, it is found that state government representatives and those that work for councils are much more likely to suggest that the council ought to be involved in inspections of tanks. Amongst those that have not disclosed their stakeholder groups membership (N/A), there is a very strong view (71%) that inspections ought to be the responsibility of householders.

To give a flavour of the opinions on this important issue, here is a selection of comments made in response to this question.

- *"There are too many tanks for an authority (local or State) to inspect and for the limited benefits and cost of that program including record keeping it would not warrant the expense."*
- *"Adults can be responsible for their own maintenance procedures, governments should focus on making sure we have roads and hospitals working correctly not forcing more unnecessary costs onto households."*
- *"Whoever provided money for rebates to have them installed and/or determined controls that mandated their installation"*
- *"Owned by owner; for sole use and /or benefit of owner."*
- *"To force regular paid inspections onto tank owners will just make many remove them. Given the large access charges to water in SEQ, little is saved by having tanks and actually saving water, anything that put a cost to this free water would make it even less attractive"*
- *"All tank owners (householder, commercial, government). However, more education is required from governments to raise awareness of the need for inspections and maintenance)"*
- *"Householders should be entirely responsible for compliance with requirements for rainwater tanks. State and Local Government should be responsible for setting of laws and regulations relating to water tanks. Inspections to ensure compliance with regulations and laws could be undertaken by nominees of State Government /Councils. Water Utilities would be the best choice for inspecting authorities to ensure compliance. Water Utilities could undertake this with their own staff or engage private contractors. Water Utilities are responsible for the provision of water and arguably that is the purpose of the water tank. However water tanks are more correctly intended to assist reduction of water provision from the public system. This clash of interests does not place Water Utilities in the most appropriate position to promote installation or otherwise manage the water tanks in their regions. Matters of town planning and building standards are best handled at Local Government level in terms of compliance. This clash of responsibilities between Councils and Water Utilities need not be insurmountable. A contractor, to undertake (random or directed) inspections, would need to fulfil all roles. It is a matter of jurisdiction. Provided that appropriate quality of inspections can be arranged, then a contractor that undertakes agreed inspections would be required to inspect water (tanks included) and possibly additional matters as a matter of effectiveness and efficiency. Reporting should be to Council and Water Utility. Water Utility could be responsible for arranging inspections. Council for its part should have input for water inspections if this relates to building matters or relates to promoting use of rain water tanks for community benefit."*

2.3.4.2. Responsibility for O&M

The question: "Who do you think should be responsible for maintenance of rainwater tanks?" was asked and responses are shown in Figure 24 and Figure 25. When asked about who ought to have the responsibility for maintenance of rainwater tanks, the views are even more strongly in favour of householders managing rainwater tanks themselves.

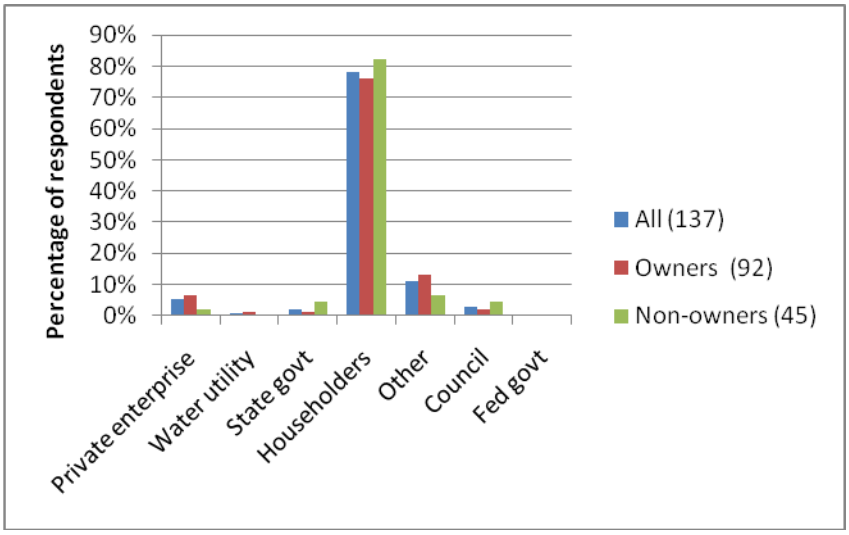


Figure 24. Opinions on responsibility for O&M (Owners vs. Non-owners).

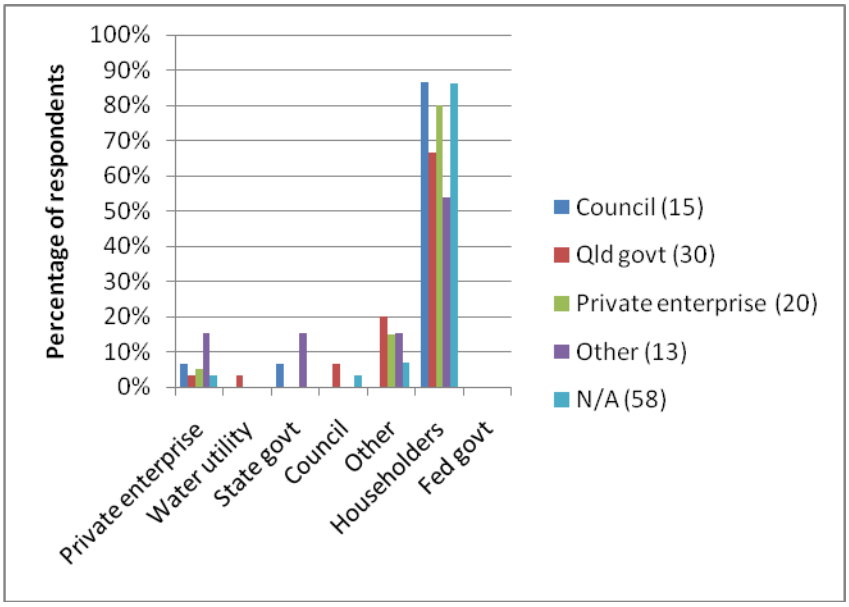


Figure 25. Opinions on responsibility for O&M (by stakeholder group).

Some comments are however given in acknowledgment that there may be a need for some regulation and control by state health authorities and councils in relation to mosquito breeding issues.

> "*There does need to be increased control over the breeding of mosquitoes but tanks are a small contributor to this. The mossie issue needs action by councils and state health authorities*."

When responses are broken down to stakeholder groups, it is notable that whilst many state government and council participants believe that councils should have a role in the inspections of tanks; this opinion does not extend to councils having a role in the maintenance of tanks.

2.3.4.3. Role of Private Enterprise

The question "Do you think there is a greater role to be played by private enterprises in the maintenance and management of rainwater tanks?" was asked to participant and responses are shown in Figure 26 and Figure 27. When asked about a possible greater role to be played by private enterprises, a significant proportion of respondents say that this is not appropriate, but a significant proportion of respondents also believe that it is at least appropriate sometimes.

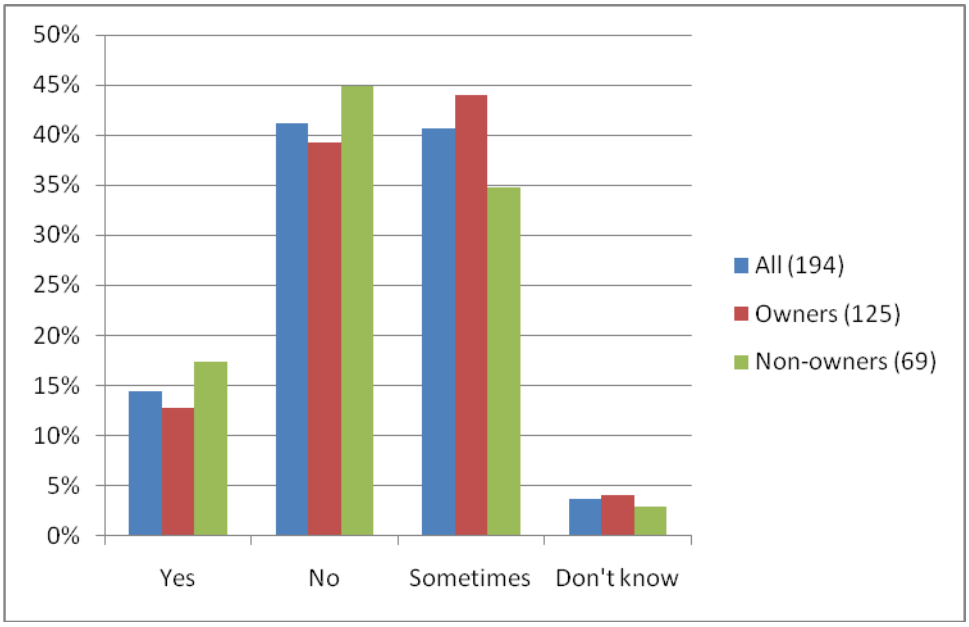


Figure 26. Opinions on role of private enterprises (Owners vs. Non-owners).

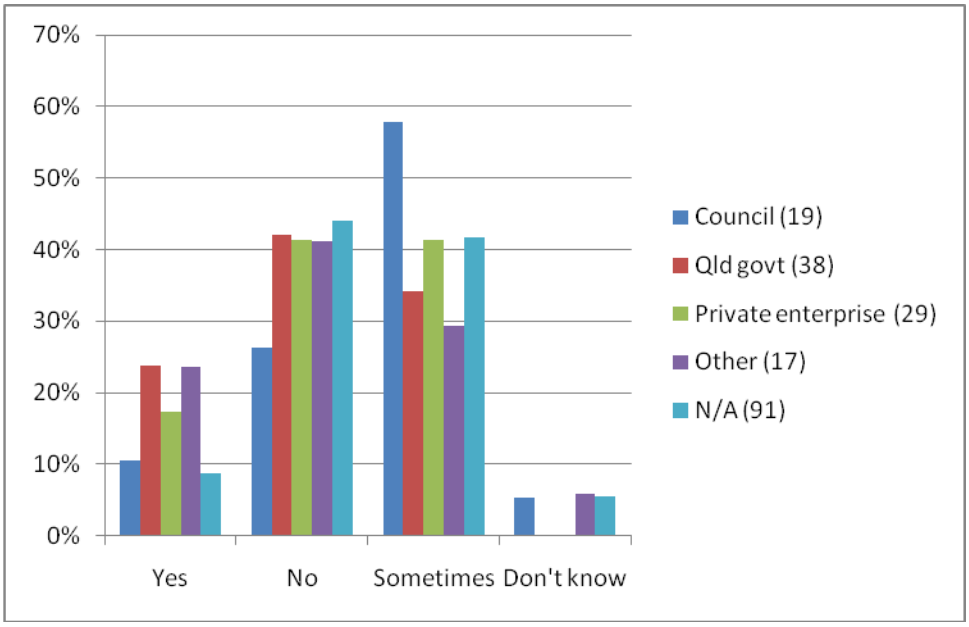


Figure 27. Opinions on role of private enterprises (by stakeholder group).

There is no clear difference in opinions between owners and non-owners. Many think that it is appropriate in some circumstances. To show the difference in views, consider the following types of comments from respondents.

- Believing that private enterprises are not capable:
  "*Household insulation! Solar panels! Need I say more? It would cost more for councils to PROPERLY supervise private enterprise, self-styled experts than it would to do it themselves.*"
- Believing it is something that home owners can use on a need basis:
  "Just like mowing services. [It is] optional and for those who are not able to do it themselves."
- Believing that private enterprises can inspect tanks:
  "There is a need for a requirement for regular inspection and service providers to offer that service. I think this is an ideal role for private enterprise."

- Thinking that PEs would charge too much:
  "Like [], they will charge too much."
- Believing PEs can help with maintenance:
  "There are many unable to do this kind of maintenance and even more that have no idea as to how to do it."
- Believing that councils should sub-contract these works:
  "Councils subcontracting tank maintenance responsibilities to approved private sector operators would provide competition and some level of pricing control."
- Believing it being a necessary thing:
  "This can't be left to householders to do as it would never get done. If council pay for this, as a rebate or similar, it is more likely to be done regularly and properly."
- Believing it could be done on some kind of scheme:
  "There may be an opportunity for private enterprise to install, maintain and manage some sort of a "scheme" somewhat akin to renting a fridge etc. Or community-based harvest and reuse scheme?"

2.3.4.4. Role of Other Actors

When asked about whether the water utility or local council ought to have a greater role, the vast majority believe that this should not be the case. Some points were made, however:

- Their involvement may be warranted in the next few years when the problems of badly maintained and neglected tanks start to become apparent.
- Many people believe that it is an imposition on people's freedom to have any involvement of these institutions.
- Some believe that it will be too expensive to have these institutions involved.
- Quite a few respondents believe that water utility and/or council should play a role in providing information and educational material to householders.
- Some believe that they are not adequately resourced to have a role to play.
- Some believe they need to monitor compliance with rules and regulations.

When asked whether any other players ought to be involved, the following were mentioned:

- EPA
- Department of Health
- Tank manufacturers
- Users of the collected water
- Health surveyors
- State government (as they are the ones who have mandated tanks and hence are thought to be responsible to ensure the funding)
- Body corporate.

2.3.4.5. Payment by Householders

When asked about how much a householder may be prepared to pay on an annual basis for regular upkeep of a rainwater tank, estimates varied considerably. As shown in Figure 28, the median estimate is $50 and the mean estimate is $100 (although 80% of participants think that it may be less than this number). A small minority believe householders could pay considerably more than that – hence the community is rather divided on the issue. The question also triggered some very strong opinions about any sort of notion that householders should pay the council or anyone else. Comments by respondents suggest that any payment ought to be voluntary and possibly to a private enterprise as this would appear to be more acceptable to the community.

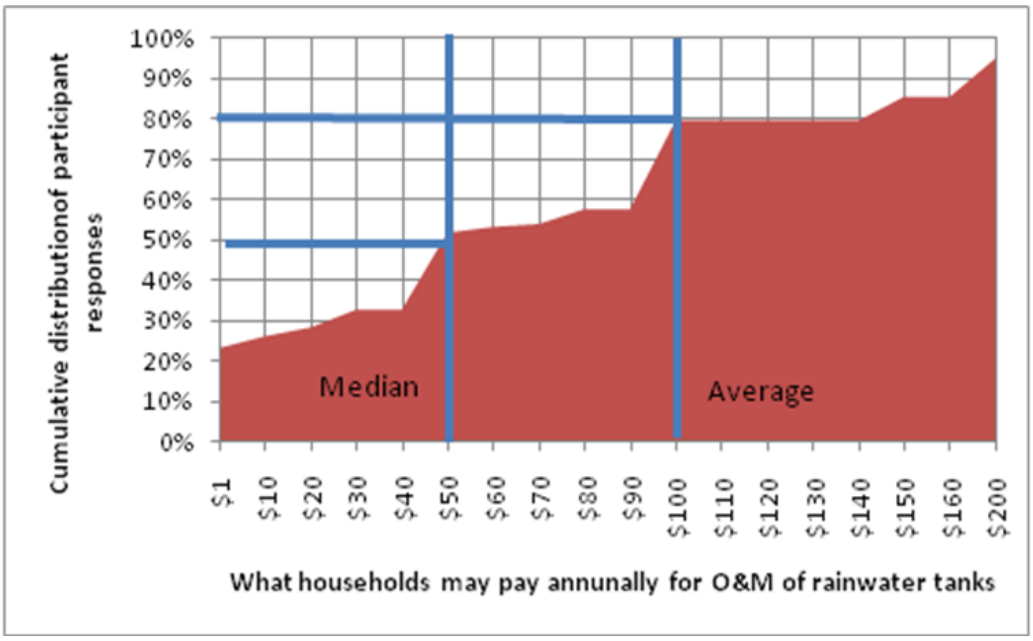


Figure 28. Cumulative distribution of estimates of how much households may be willing to pay.

2.4. Simulation

To explore the benefits of inspection and maintenance schedules in terms of reduced rates of failure and a healthier population of rainwater tanks, *Monte Carlo* simulation was undertaken (scripts available in the Appendix A.2). The simulation is essentially an experiment of what happens with a population of tanks with known probability of failure, day by day. The rates of failure have been estimated on the basis of the survey responses that are described above. This may not be the best suggestion based on limited data, but the analysis is depicted in the absence of real data.

Example of how to calculate cumulative distribution, survival function and hazard rates based on survey data: If there were 3 respondents who said that the time until failure (defined as per one of the failure mode events occurring) would be 1, 2 and 3 months respectively; then the probability distribution would be 1/3 likelihood of failure in first month, 1/3 likelihood of failure in the second month and 1/3 likelihood of failure in the third month. This would be used to calculate cumulative probability distribution, survival function and hazard function, as shown in Table 9. Definitions of these functions can be found in any standard text book on reliability theory (Crowder *et al.*, 1991):

- Probability density at time t: the probability of a failure occurring at time t.
- Cumulative probability function at time t: the probability of failure occurring at time t or before time t.
- Survival function at time t: the probability of no failure at or before time t.
- Hazard rate at time t: the probability of failure at time t in the event that no failure has previously occurred.

Table 9: Example of probability density, cumulative probability, survival functions and hazard rate.

Time [months]	Probability density, P(t) [%]	Cumulative probability function, C(t) [%]	Survival function, S(t) = 1-C(t) [%]	Hazard rate, h(t) = P(t) / S(t-1) [%]
1	33	33	67	67
2	33	67	33	50
3	33	100	0	100

These functions (probability, cumulative and hazard rate) will allow us to know the occurrence of failures, according to different failure modes in a population of rainwater tanks. The simulation has been written in the *Python* programming language that is suitable for mathematical analysis. In quasi code, the algorithm can be described as follows:

1. Within the simulation, initiate/create a number rainwater tanks that are all in good condition. Each tank has two parameters: broken or not broken represented with a zero or one (acknowledging that this is a simplification of the nature of rainwater tank problems as a problem considered a failure may not completely make the tank inoperable); and the number of days since last inspection (represented as an integer). At the start of the simulation, each tank is not broken and has zero days since last inspection.

2. Choose model parameters:

    a. N, the time duration for the simulation, i.e. the number of time steps (monthly). This number is chosen large enough so that stationary results are achieved, i.e. typically very large (10,000 or 20,000). Visual inspection, however, shows that stationary results are typically achieved within about 500 time steps so fewer may be acceptable.
    b. The integer, InspectionFrequency, is the average number of days between inspections of each rainwater tank. This is then used to calculate the probability of inspections in each time step (day). inspectionProbability = 1 / inspectionFrequency.

3. In each month (time step), $t = 1....N$:

    a. For each rainwater tank i (each tank is identified by a number i):

        i. Randomly assign inspections to tanks based on assigned frequencies;
        ii. Randomly test whether the tank has failed according to each of the failure modes (based on the stochastic times to failure); and
        iii. Increase the number of days since last inspection with 1.

    b. For every hundredth day, record the number of rainwater tanks that are broken, and compare this to the total number of rainwater tanks in the set.

4. Take an average of all the stationary results, i.e. with a starting point as what has been identified as being the start of a stationary sequence (when the curve has been allowed to converge to a stationary value and does not vary outside given limits).

Using survey data to establish failure rates (probability density), this algorithm was then repeated for different hazard rate tables (one for each failure mode) and different inspection times to arrive at the curves below (see Figure 29 to Figure 31).

On the basis of these simulations, noting that they do not consider who undertakes inspections, we can see that the frequency of faults in a rainwater tank population strongly depends on the average frequency of inspections; as shown in Table 10.

We note that, whilst gutters need to be inspected and cleaned on a regular basis (especially if there are over-hanging trees) an inspection frequency of once every 6 months appears to be acceptable. It would, however, be useful to know the likelihood of a tank being completely free of these types of faults according to this model. This can be calculated using probability theory; under the assumption that each of the events is independent of each other (this is not always true, of course). Using probability generating functions (translating a probability distribution to a polynomial); we can then calculate the probability of 0, 1, 2, 3 or 4 faults at any given time. The results of these calculations are shown in Table 10 and Table 11.

Table 10. Relationship between frequency of inspections and rates of failures in a population of tanks.

Frequency of inspections	Proportion of tanks with blocked gutters (overhanging trees)	Proportion of tanks with broken pumps	Proportion of tanks with broken meshing	Proportion of tanks that are structurally broken
1 month	17%	1%	1%	0%
3 months	39%	4%	4%	0%
6 months	54%	8%	10%	1%
1 year	67%	19%	21%	2%
2 years	75%	37%	38%	5%

Note: **The basis of this data is the computer simulations described above, with the survey data used to established probability density functions as inputs into the modelling exercise.**

Table 11. Likelihood of no faults, at different average inspection frequencies.

Frequency of Inspections	All four modes – overhanging trees	All four modes – no overhanging trees	Pumps, mosquito meshing and structural failure
1 month	81%	97%	98%
3 months	56%	88%	92%
6 months	38%	73%	82%
1 year	21%	47%	63%
2 years	9%	20%	37%

Note: The basis of this data is the computer simulations described above, with the survey data used to established probability density functions as inputs into the modelling exercise. The four modes referred to are: pump failure, meshing failure, structural failure and blocked gutters.

On the basis of Table 11, it seems that it in the case when there are over-hanging trees, gutters need to be inspected by householders on a regular basis (approximately every three months); whilst an average once-a-year inspection of other types of faults, will make sure that about 63% (as per Table 11) of the rainwater tank population is in good condition (obviously on the basis of the data that we are using).

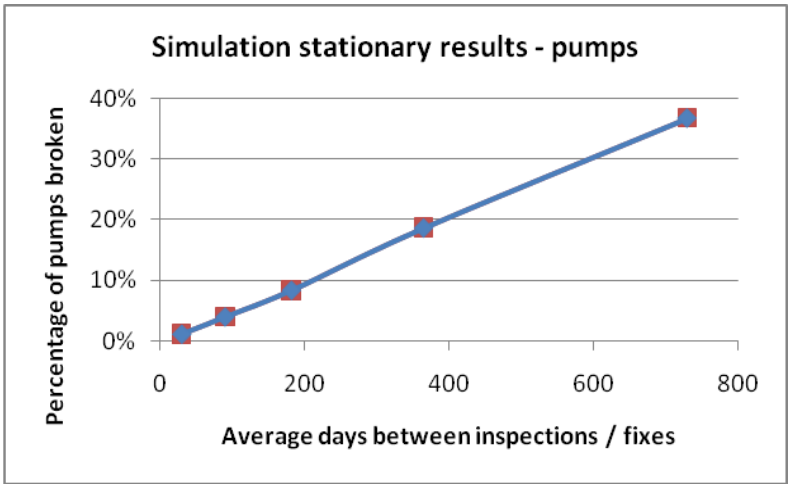


Figure 29. Simulation results showing the benefits of pump inspections.

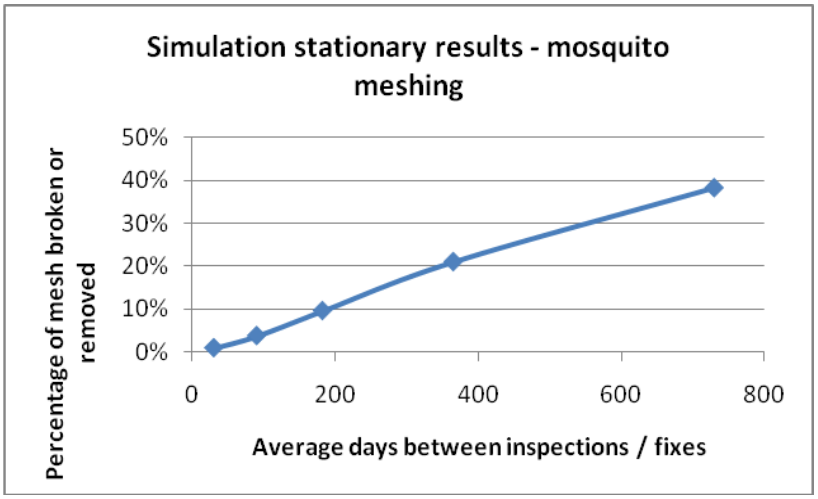


Figure 30. Simulation results showing the benefits of inspection of mosquito meshing.

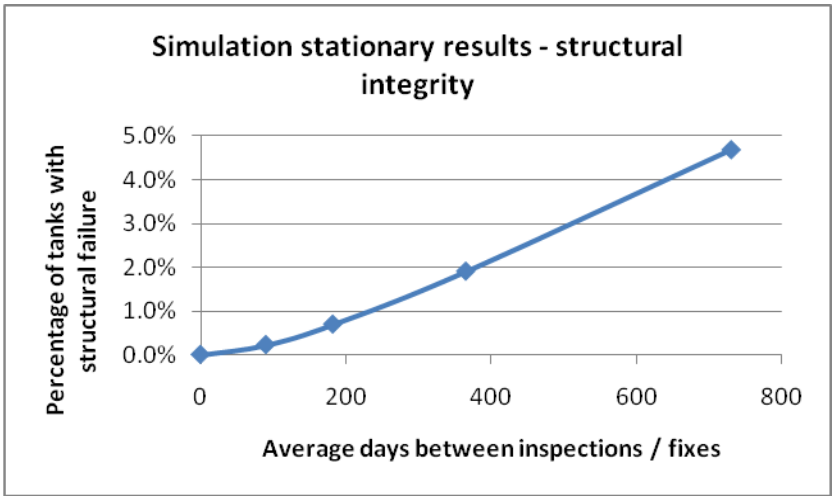


Figure 31. Simulation results showing the benefits of inspection of structural integrity.

3. SYNTHESIS AND DISCUSSION

This report has described a considerable amount of data that has been generated in this project. In some ways, there are now still more questions than answers. There are, however, some take-home messages that have been identified.

- There is inadequate information regarding the condition of the existing asset stock and its impact.
- Based on judgments of expected time for various types of tank failures to occur, tanks would need to be inspected regularly and fixed or the likelihood of failure increases rapidly (see Table 11).
- There is a considerable level of resistance and outrage in the community in response to any notion of greater government control of what is perceived as a private matter.
- Most believe that O&M as well as inspection of tanks is a matter for householders themselves.
- It is unlikely that households will want to pay much more than $50 per year for upkeep of tanks, especially if it is a mandatory charge.

These points are, however, troubling in the sense that most would agree that tanks are currently not adequately managed, but few seem to want to challenge the status quo of full householder responsibility (although councils do undertake spot checks). Householders are, perhaps on valid grounds, also not likely to want to pay for the kind of regular inspections that appear necessary based on perceptions (see Table 11, which shows failure frequencies from simulations described above which are a logical consequence of what stakeholders believe). For example, if inspections would cost $150, then the householders' contribution of $50 per year would mean only an average of one inspection every third year. If these were the only inspections, then less than a third of all tanks would be fully functional. Obviously, one will have to assume that householders do indeed take some responsibility for inspection and maintenance of tanks.

It seems clear that the key to this dilemma is in the motivation of householders to undertake the O&M of their tanks, and this is explored in a parallel project (Tucker *et al.*, 2011). It is important that policy-makers think about what motivates homeowners to maintain their tanks in a way that generates a sense of cooperation. It seems that punishing those who do not maintain their tanks is probably a mistake, given the inherent power relations of such strategies and what appears to be a low level of trust between government and citizens. The better option would seem to be to work together with the community in a respectful manner, and in a way that helps further motivate and empower householders. The difficult part, however, is that this may be a costly exercise and no-one so far seems willing to contribute the necessary funds to ensure that tanks are adequately maintained. At the end of the day, strategic water planners will need to assess the value for money of maintaining an asset stock of rainwater tanks, in comparison to other supply investment strategies. However, it is difficult to evaluate the cost benefit of inspections in the absence of hard data on failure frequencies of rainwater tanks.

If funds are found to tackle this problem, then a number of different strategies may be considered. A program of spot checks to assess the condition of tanks is an obvious component of any strategy. The extent of this program will have to be based on strict cost-benefit analysis, which will need to be based on a stocktake of tanks, and quality reliability data. Furthermore, it appears that there is a real need to provide more information to householders about O&M of tanks and the basic tasks that need to be performed. This may be distributed in many different ways, such as with the water bill, annual rate reminder, via email or in the mail. Educational programs in the media may help raise awareness and create an environment where householders are more motivated. However, there is also a considerable level of scepticism about such media campaigns and about their real value. If there was better monitoring of tank condition, it may be possible to assess the efficiency of such campaigns with the use of comparative studies.

3.1. Manufacture, Design and Installation of Tanks

There are indications that the quality of tanks, and perhaps tank installation, needs to be regulated, and there is a need to continue the program of monitoring the installation and design practices. Despite the extensive program of rainwater tank installation that currently exists, design and installation is still raised as a major cause of failure and one may ask how this program can be improved. Some of these issues are further discussed below.

There is currently some good regulation regarding the design and installation of tanks. Furthermore, there is a system in place to certify installations and designs in new dwellings to make sure tanks will be functional and operable into the future. However, quite a few concerns have been raised in interviews and in the survey:

- There are tanks available for purchase on the market that are not adhering to Australian standards and which are likely to break quickly (within months), due to issues such as insufficient UV stabiliser in the plastics.
- Poor design and installation is still commonplace (as observed by interviewees who regularly inspect tanks – this is also more prevalent in DIY installations).
- The choice of incorrect or "cheap and nasty" pumps often leads to short life times.
- Incorrect pump installation occurs and leads to short pump lifetimes.

Many also argue that properly maintained tanks do not fail. Some also argue that inspections are often not done properly and that, given the importance of design and installation, this may considerably improve the overall status of the tank stock.

3.2. Ensuring the Condition of Tanks

Inspections and O&M of rainwater tanks is an important issue because attitudes vary. The mainstream view is that O&M is only rarely undertaken and in an inadequate manner. However, there is a clear conflict in perceptions between stakeholder groups, with especially council and state government representatives tending to be considerably more pessimistic in their views, whilst other groups are more optimistic. Some even state strongly that inspection and O&M of rainwater tanks is a trivial issue that should not be a concern. This may be the case, but it does not seem to be that it is incorrect O&M per se that is the concern, but more that the main concern is the lack of attention to rainwater tanks. Hence the problem is more one of motivation and reminders rather than one of education (although education may be part of the solution). This being said, most respondents still argue that it is householders themselves who have the ultimate responsibility for their tanks. This is somewhat moderated by needs to comply with regulation and legislation (in particular in relation to health and mosquito concerns). In light of this it appears that spot checks carried out by council to enforce legislation are viewed by most as a legitimate component of tank governance.

When asked about householders' willingness to spend money to make sure their tanks are in good condition, views varied widely. Many believe that $0 is what they ought to pay, but the median estimate is $50 and the mean estimate is $100 (the difference between median and mean primarily due to a small number of very large estimates up to $2,000). However, it is also clear that a mandatory fee for ensuring tank condition would generate considerable dissatisfaction and even anger in the community. Indeed, tank owners have a legitimate argument in that their tanks contribute to a public good by reducing the demand of publically provided water, and that they ought not to be financially punished for their good deeds. This argument is perhaps more valid in cases when tanks have been voluntarily purchased (usually with rebates) rather than mandated, as it can be argued that the management of a rainwater tank was negotiated between the individual and the government as part of the building approval process.

So, how often does a rainwater tank really need to be checked and put in order? On the basis of the judgments by survey respondents, it is possible to carry out some analysis (obviously only valid to the extent that the judgments are valid). It seems that gutters are a separate issue that definitely needs to be handled by householders (in particular when there are over-hanging trees), and if ignoring the issue of blocked gutters, an average inspection frequency of once every six months, would make sure that approximately 82% are in good condition (similar values for three months and one month etc can be seen in Table 11). The responsibility for this may be shared between householders and a governing organisation. Spot checks of every two years would achieve at least 37% of tanks being in good condition, but assuming that ¾ of all inspections are carried out by householders themselves, then it would mean that approximately 82% of tanks are in good condition, and if assuming that 7/8 of all inspections are done by householders, this number is brought up to approximately 92%. It seems that the most important solution to rainwater tank governance is to incentivise and make householders aware of their need to check their tanks.

Given the importance of householders' cooperation, it is imperative that the relationship between government, council and householders is based on goodwill and mutual trust and cooperation. It seems that it may be a challenge in the current climate of opinions displayed in the survey. Therefore, the governance structure needs to be based on "working with householders" and giving and taking rather than "telling them what to do". It is imperative that actions are perceived as legitimate, and this is a difficult issue in the case of rainwater as this type of infrastructure is blurring the traditional view of modern societies that is firmly based on the "social contract" of western societies (as per foundations laid down by philosophers such as Hobbes, Locke and Rousseau in the 17th and 18th centuries) and which has evolved to the current institutions that we now call democratic societies. The point is that there are fundamental philosophical challenges involved with managing public benefit assets that are owned by private citizens, and located on private property.

4. POSSIBLE WAYS FORWARD

Whilst this project should ideally have developed some clear governance models for rainwater tanks, there are still too many questions to be able to go into much detail on that issue. However, some initial ideas/concepts have nonetheless been identified that seem at least plausible, and should be brought up for discussion with stakeholders.

4.1. Increasing Householder Motivation for O&M

A key element of any strategy for rainwater tanks needs to consider improving householder motivation for inspecting and undertaking O&M on tanks. Rainwater tank governance without a strong reliance on householders would be overly expensive. Therefore, it is critical that householder motivations are explored in further detail, and therefore the study by Tucker *et al.* (2011) is critical as it explores this very issue.

4.2. Providing Educational Materials

Access to clear and simple information and educational materials was considered a potentially useful tool by many of the professional survey participants, as well as those who were interviewed, although some considered spending time and effort on information and educational materials to be a waste of money. Table 12 shows a selection of constructive responses on this topic.

In summary, educational campaigns could have the following functions:

(a) Remind householders to inspect their tanks.
(b) Instruct householders on the basics of O&M of tanks.
(c) Warn householders about the risk of mosquitoes and water quality concerns related to tanks.
(d) Instruct new and existing home owners of the tank that came with the house.

Table 12. Transcripts of participant responses on the topic of education.

Transcripts of participant responses on the topic of educational campaigns or educational materials aimed at householders with rainwater tanks
Template maintenance requirements. Organise sustainable tank workshops. Ensure developers are dealing with this as part of star rating process - one star needs to be information/education process for buyers.
Educational materials help by making the community aware of the potential hazards associated with rainwater tanks.
Educational programs advising people on HOW TO inspect, maintain and check the performance of their water tank is a great endeavour that need not be a costly exercise and should be run in the lowest rainfall months in preparation for the heavy rainfall months - to maximise the benefit gained from owning a rainwater tank
An inefficient use of money in scattergun (public advertising) approaches. An educational booklet could be supplied by the supplier to the purchaser of every water tank installed.
A simple explanation of how it works and diagrams of where the likely issues occur and how maintenance can help.
People need to be constantly reminded of the need for inspection and maintenance otherwise they will tend to get complacent.
Educational materials/campaigns could help, provided not done as a fear campaign.
The emphasis should be to include it in the Green Plumber's qualifications and to require the Water Utility to direct that only Green Plumbers may undertake installation and 'major' maintenance of rainwater tank installations supplying potable water in parallel with reticulated supplies. There maintenance to be done by householders needs to be restricted to those items with a low risk of backflow occurring to the reticulated system.
Yes, educational material would help as when we got our tank installed we were not given any advice or instructions on use/maintenance by the installer.
Yes, tell people the dangers of having poor quality water, or the dangers of mosquitoes or the costs of poor maintenance in the long term re pumps and tank failures, but also tell them how they can fix it, rather than pointing them towards further costs.
Educational campaigns are often quite inefficient unless there are dollars to gain and this message can be continually reinforced at low cost over following years. The ones who listen to the message are in most cases those who already undertake appropriate behaviour. Existing rainwater tank owners may pay some attention, however if it requires them spending more dollars or expending more personal effort for low perceived gain then few will take heed. Those who are not yet water tank owners will likely be deflected from ownership if the message is punitive.
Education is the first step to compliance. Understanding why cleaning and maintenance is important will encourage people to undertake the practice.

The types of educational materials/campaigns that may be considered are:

- Fact sheet and/or educational booklet (aiming primarily at function B, C and D).
- Reminders to inspect and maintain tank with the water bill (A).
- Television advertising (aiming primarily at function A, C and D).
- Make education and communication part of developers' star rating (B and C).
- Sustainable tank workshops (A, B, C and D).

It is also noted that educational campaigns may be costly, and someone needs to provide the funding for these. It also seems critical that all four functions A, B, C, and D are considered in any mix of educational campaigns. It is however crucial that any educational activity also helps to further motivate householders. For example, this means that the tone needs to be collegiate rather than disciplinary.

4.3. Stakeholder Suggestions of Management Models

There are many opinions on how best to manage rainwater tanks, and it would be prudent to take into account the significance of creative thinking that exists in the community to be able to deal with this issue (Table 13).

Table 13. Transcripts of participant responses on the topic of suggested management models.

Transcripts of participant responses on the topic of suggested management models.
Perhaps tank resellers or manufacturers can provide a tank checklist to be displayed in close proximity to the tank - in a similar way that CPR information must now be on display at a swimming pool. This will encourage tank owners to inspect their tank on a regular basis, and give them hints on what to look for.
Households or body corps are responsible for the upkeep of their water tanks, they are smart enough to decide whether they need to call in a plumber if there is a problem with the tank.
I think there is a Dept. of Local Government and Planning requirement for owners of household wastewater systems to get regular inspection of their systems. Something similar for tanks might be appropriate.
Central control with Councils and contractors to affect repairs/maintenance.
Set up a water tank section within the local councils, to be responsible for this area.
Education opportunities for householders with recommendations of approved private contractors. Check sheets that could be sent with rates notices for householders to complete and return to council if some sort of reporting was required. Assistance in the proper maintenance of water tanks rather than fees, charges and penalties by council. Projects similar to the Climate Smart Home Service could be offered.
Have people complete a license to own a rain water tank, so they can undertake their own maintenance. For those that don't want to be involved at this level offer adequate services it these owners in the most cost effective manner.
There are several models and include: 1. - mandatory inspection on sale of the property. 2. - 5-year licensing which is renewed upon inspection.
Owners must have a 'road worthy' certificate and must present to council once every two years. Owners can pay for maintenance and certification via private company or council could provide service.
Home owner maintenance guidebook provided to each home with RWT on yearly basis by water business. Government/water businesses do awareness campaigns. Inspections may be required when selling property or every 3-5 years. No sooner as too cost onerous and will get people off-side with tanks.
Probably easier to get water utilities to undertake inspections when read water meters... can leave a note for household to follow-up on - and household notify if done management regime should be undertaken only if significant risk (am not sure of risk).
Pool inspections and inspections of onsite treatment systems by Council are perhaps similar programs, although a rainwater tank inspection program will be more difficult. Issue of mosquito control is a significant public health issue and would justify an inspection program.
Notification on planning permits, rental contracts or home buyers' checklists that the property has a tank that needs to be maintained - if home ownership changes the new owner gets notified and information on how to maintain their tank.
Discounted water bills where a receipt can be produced for maintenance on private water tanks.
A regular check-up organised by water agencies and payed for in the water bill would be good.
Council regulatory and licensed private inspection model, with householders responsible for arranging inspection and maintenance once every 5 or so years (depending on performance risks involved). Body Corporate could provide inspection services for those living in such arrangements.
Plumbers when doing work onsite offer free assessment of tanks
I don't think that there is one best model. I think a diversity of models will be important to protect against "fads". A diversity [of models] should also generate ingenuity and new and better solutions. Local authorities do need to be given the legislative backing and frame work to ensure that overarching goals and principals are being followed. Registration and compliance will hopefully reduce specific failures and protect the community, it would also give the opportunity to measure and compare, build data and learn (what works what doesn't)

In summary, these management concepts could have the following functions:

(a) Inspections of tanks: how often tanks should be inspected by householders, and how often on average by other agencies.

(b) O&M of tanks: how it can be ensured that simple but important tasks are done.

(c) Financing of management scheme: how O&M should be financed, and the cost-benefits of schemes.

(d) Provision of incentives for management of tanks: how to motivate and work with householders to ensure tank management.

(e) Education of owners: how to ensure that owners know what to do, and how to do it.

The following ideas roughly represent the types of idea that have been elicited in Table 13.

(a) Reliance on well-trained plumbers to provide services to the community.

(b) Regular inspections of tanks by council and/or state government.

(c) Councils to manage inspections as well O&M.

(d) Get owners to complete a rainwater tank license so they can undertake maintenance.

(e) Mandatory inspections of tanks when property is being sold, or when householders move into a house with an existing tank as per Australian federal government guidelines (2004).

(f) 5-year licensing of tanks which is renewed upon inspection.

(g) Rainwater tank "use-worthy" certificate that needs to be presented to councils every 2 years.

(h) Notification on planning permits, rental contracts or home buyers' checklists about tank requirements.

(i) Water utilities undertake inspections of tanks in conjunction with reading meters.

(j) Payment for tank management via the water bill.

(k) Discounted water bills where a receipt can be produced for maintenance on water tanks.

(l) Plumbers, when doing work onsite, offer free assessment of tanks.

(m) Linking rainwater tank inspection with water meter reading by water utilities.

(n) State to promote market for rainwater tank supply and O&M for long-term lease.

(o) Incentives for plumbers interested to enter rainwater tank O&M business.

Many of the ideas are not mutually exclusive but can be implemented in combination. For example, it is possible that plumbers can offer free assessment of tanks when onsite, and that water utilities undertake inspection of tanks in conjunction with some meter readings. It is also plausible that financing of these schemes would come out of the water bill, but that tank owners get a discounted water bill on producing an inspection notice showing the tank to be in good condition. Similarly, it seems like a good opportunity to have mandatory inspections of tanks when a property is being sold; and this provides an opportunity to update new owners on the requirements of tanks.

In the end, the choice of a management strategy is likely to include a combination of these components, but the choice of a strategy portfolio should ideally be based on a cost-benefit analysis and also requires further analysis of the practicality and requirement of each strategy. In order to undertake cost-benefit analysis it is necessary to have information on the condition of tanks, something which is not currently available. It would also be prudent to be adaptive with the governance models and to implement on-going performance monitoring on the basis of results from tank inspections. This will allow for choosing the most effective portfolio of strategies for a socially complex, contentious and dynamic issue.

5. SOME POSSIBLE STRATEGY PORTFOLIOS

To give some idea about how the above elements may be put together into a package creating a consistent strategy, see Table 14. Three alternatives are proposed for consideration: 1) households manage their systems with institutional support; 2) councils manage systems; and 3) households manage their systems with some additional support in terms of educational material provided to households (almost status quo).

Table 14: Possible strategy portfolios for rainwater tank management.

Issue	Portfolio 1: Households Manage	Portfolio 2: Council Manage	Portfolio 3: Status Quo + Some Education Support
Installation	Use-worthy certification needs to be undertaken	Use-worthy certification needs to be undertaken	Use-worthy certification needs to be undertaken
O&M	Householders' responsibility	Councils undertake O&M	Householders' responsibility
Inspections	Random checks by water utility when reading meters	Councils undertake inspections	Small number of checks by councils (same as now)
Financing of scheme	All pay a small extra fee for financing random spot inspections of tanks via the water bill	All pay a small extra fee on the water bill	No additional costs
Householder support	Educational materials provided	Educational materials provided	Educational materials provided
Household incentives	Small discount on water bill when you have a well maintained tank	N/A	None
Creating an inventory of tanks	Tank owners need to register online to receive discount	N/A	Tank owners are encouraged to register their tank online
New home owners	Updated Section 94 certificates Information materials sent out with first water bill	N/A	Updated Section 94 certificates Information materials sent out with first water bill

Whether these types of strategies are acceptable or not needs to be evaluated with stakeholder groups and the community in stakeholder workshops and community forums. New models will be investigated in discussions with workshop participants and will be included in the future reports. It is suggested that strategy portfolios are assessed for the following factors:

(a) Cost to community
(b) Cost to government at various levels
(c) Effectiveness in terms of managing the tank stock
(d) Level of householder motivation for managing tanks

These general strategies have been evaluated against four criteria, based on the authors' judgments, as per Table 15. These criteria and judgments are mere suggestions, however, to be able to move towards policy decisions, key stakeholders need to populate such tables themselves. Selection of assessment criteria and elicitation of judgments may, for example, occur in a facilitated workshop setting.

Table 15: Assessment of strategy portfolios against four criteria.

Assessment Criteria	Portfolio 1: Households Manage	Portfolio 2: Council Manage	Portfolio 3: Almost Status Quo
Cost to community	2	3	1
Cost to government	2	3	1
Effectiveness in terms of managing tank stock	2	1	3
Level of householder motivation for managing tanks	1	3	2

As can be seen in the Table 15, Portfolio 2 is likely to be effective but also very expensive. Portfolio 1 is more expensive than status quo but is likely to achieve considerably higher effectiveness than Portfolio 3. However, until one knows the relative effectiveness and the cost of each program (in terms of reducing faults in the asset stock) of each strategy it is impossible to calculate the cost-benefit of each program.

6. CONCLUSIONS

It is clear on the basis of this research that there is a real concern about rainwater tanks and their O&M amongst a fairly large group of people. If the perceptions of how often rainwater tanks fail are anything to go by, then inspections and regular maintenance are critical to ensure that a decent proportion of tanks are in good condition and providing adequate benefit to the community. This has been further explored using Mont Carlo simulation by which the benefit of regular O&M can be evaluated. However, there is high variance in the perception of rainwater tank O&M status and householder practices among various stakeholder groups. More reliable data is required in order to undertake a cost-benefit analysis of inspections.

It is also clear that very few would like anyone other than householders to have the main responsibility for operation and maintenance of tanks. So, if the status quo is unsustainable but householders remain responsible, any governance arrangements need to find collaborative arrangements with householders. Householders then need to be encouraged and empowered to manage this private infrastructure which has public benefits. Provision of information to householders is seen as critical.

Some initial concepts and ideas of suggested governance arrangements have been laid out, but there is a real need to go from these rough sketches towards detailed and practical solutions. This, however, requires the cooperation of a number of stakeholders as well as legitimisation of options by further deliberation and selection. Therefore, an important next step is to invite key stakeholders to a workshop to discuss the preference of possible options.

REFERENCES

Australian Bureau of Statistics (2007). Environmental issues: people's views and practices 4602.0. Canberra, Australia.

Australian Bureau of Statistics (2009). Queensland Water Energy and Conservation October 2009, 4602.3. Canberra, Australia.

Australian Bureau of Statistics (2010). Environmental issues: Water use and Conservation March 2010, 4602.0.55.33 [Online]. Available: http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/96D8ED5A95E96BEDCA2577660017E318.

http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/4602.0.55.003Mar%202010?OpenDocument [Accessed].

ACT Government (2011). Rainwater tank rebates, http://www.thinkwater.act.gov.au/tune-ups_rebates/rainwater_tank_rebate.shtml, updated May 2011, accessed May 2011.

Australian Government (2004). Guidance on use of rainwater tanks, enHealth Council [Online]. Canberra, Australia. Available: http://www.nphp.gov.au/enhealth/council/pubs/documents/rainwater_tanks.pdf [Accessed 15/11/2010].

BASIX (2004). About BASIX website, Department of Planning, NSW government, http://www.basix.nsw.gov.au/information/about.jsp, last accessed May 2011.

Building Commission (2011). Make your home green-6 star standard introduction , Building Commission and Plumbing industry Commission of Victoria, http://www.makeyourhomegreen.vic.gov.au/www/html/1962-introduction.asp?intSiteID=3, accessed June 2011.Crowder, M.J., Kimber, A.C., Smith, R.L. & Sweeting, T.J. (1991) Statistical analysis of reliability data, London, U.K., Chapman & Hall.

Department of Environment and Resource Management (2011). Rainwater tanks [Online]. Available: http://www.derm.qld.gov.au/waterwise/gardening/pdf/rainwater_tanks.pdf [Accessed 18/06/2011].

Gardiner, A. (2009). Domestic rainwater tanks: usage and maintenance patterns in South East Queensland. Water, 36(1), 151-156.

Gardiner, A. (2010). Do rainwater tanks herald a cultural change in household water use? Australasian Journal of Environmental Management, 17(2), 100-111.

Gardiner, A., Skoien, P. and Gardner, T. (2008). Decentralised water supplies:south-east Queensland householders' experience and attitudes. Water, 36(1), 53-58.

Gold Coast City Council (2011). Fact sheet: Rainwater tanks [Online]. Available: http://www.goldcoast.qld.gov.au/attachment/goldcoastwater/PET_rainwater_tank_FS.pdf [Accessed 10/05/2011].

Government of SA (2006). Advisory Notice Technical: building code of Australia mandatory plumbed rainwater tanks for class 1 buildings, June 2006, Department of Primary Industries and Resources, Government of South Australia, http://dataserver.planning.sa.gov.au/publications/1128p.pdf, accessed May 2011.

Government of South Australia (2011). Rainwater tank and plumbing rebate, SA Water, Government of South Australia, http://www.sawater.com.au/SAWater/YourHome/SaveWaterInYourHome/rebates_rainwatertanks.htm, updated June 2011, accessed July 2011

Hobart City Council (2011). Rainwater Tanks, Hobart City Council http://www.hobartcity.com.au/Environment/Stormwater_and_Waterways/Conservation/Rainwater_Tanks, accessed July 2011.

Kloss, C (2008). Managing wet weather with green infrastructure –municipal handbook -rainwater harvesting policies, EPA-833-F08-010, Dec 2008, USA

MPMSAA (2008). Requirements for installation of rainwater and greywater systems in Australia, Waterlines Report series no.10, Master Plumber and Mechanical Services Association of Australia/National Water Commission, Canberra. http://www.nwc.gov.au/resources/documents/Final_Waterlines_full_version.pdf.

NSW Health (2007). Rainwater tanks, http://www.health.nsw.gov.au/pubs/2007/pdf/ rainwater_tanks.pdf, accessed July 2010.

NSW Government (2011). NSW rainwater tank rebate, NSW government, http://www.environment.nsw.gov.au/rebates/ccfrtw.htm, updated July 2011, accessed July 2011.

Northern Territory government (2007). Central Australia Waterwise Rebate Scheme, http://www.nt.gov.au/nreta/water/wise/rebates/index.html, accessed July 2011.

State Government Victoria (2011). Living Victoria Water Rebate Program, Department of Sustainability and Environment, Victoria, http://www.yvw.com.au/Home/Inyourhome/Savingwaterathome/Rebates/index.htm, updated July 2011, accessed July 2011

Queensland Department of Local Government and Planning (2009). Queensland Development Code MP 4.2 – Water savings targets, Available at: http://www.dlgp.qld.gov.au/building/current-parts.html, accessed May 2011

Queensland Government (2005). Public Health Act 2005, Reprint No.2B last revision: December 2010 [Online]. Brisbane, Australia. Available: http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/P/PubHealR05.pdf [Accessed 18/06/2011].

Queensland Government (2009). MP4.2 Queensland Development Code.

Queensland Government (2011). http://www.communities.qld.gov.au/housing/renting/social-housing/publications-social-housing/tenant-news/tenant-news-march-2007/rebates-available-to-tenants-who-purchase-rainwater-tanks, updated Feb 2011, accessed July 2011.

Queensland Health (2002). Guidelines to minimise mosquito and biting midge problems in new development areas [Online]. Available: http://www.health.qld.gov.au/ph/Documents/cdb/14804.pdf [Accessed 15/11/2010].

Queensland Government (2006). Fire and Rescue Service amendment Act 2006, Department of Community Safety, Queensland Government, http://www.fire.qld.gov.au/communitysafety/smokealarms/pdf/Sum_AmendAct2006.pdf, last accessed May 2011.

Queensland Health (2007). Rainwater tanks: a guide to keeping your tank safe [Online]. Brisbane, Australia. Available: http://www.health.qld.gov.au/ph/Documents/ehu/32922.pdf [Accessed 11/05/2011].

Standards Australia (1998). AS/NZS 1546.1:1998. On-site domestic wastewater treatment units - Septic tanks.

Standards Australia (2001a). AS1397:2001. Steel sheet and strip - Hot-dipped zinc-coated or aluminium/zinc-coated

Standards Australia (2001b). AS 3735-2001 Concrete structures retaining liquids.

Standards Australia (2002). AS/NZS 1170.1:2002 Structural design actions - Permanent, imposed and other actions.

Standards Australia (2003). AS/NZS 3500:2003 Plumbing & Drainage Set.

Standards Australia (2005). ASTM A240/A240M-05. Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.

Standards Australia (2006a). AS/NZS 4766:2006 Polyethylene storage tanks for water and chemicals

Standards Australia (2006b). HB230. Rainwater Tank Design and Installation Handbook. Sydney Australia.

Standards Australia (2008). HB230-2008, Rainwater tank design and installation handbook.

State of Victoria (2006). Your private drinking water supply, Department of Human Services.

Tilbrook, R. (2009). Rainwater tanks in new housing development: a survey of the issues, knowledge and uses of residents in the Northlakes Estate, a study for Lake Macquarie City Council, NSW. available from bhodges@lakemac.nsw.gov.au. Newcastle, Australia: University of Newcastle.

Tucker, D., Mankad, A. and Greenhill, M. (2011). Rainwater Tank Adoption in South East Queensland – Factors Influencing Maintenance and Management. Urban Water Security Research Alliance 3rd Science Forum. Brisbane, Australia.

Water Corporation (2011). Rainwater reward program guidelines, http://www.watercorporation.com.au/_files/Rainwater_Reward_Program_Guidelines_FINAL.pdf, accessed July 2011.

White, I.W. (2009). Decentralised Environmental Technology Adoption: The household experience with rainwater harvesting. PhD Griffith University.

WSAA (2002). WSA03-2002: Integrated rainwater tank systems -a supplement to the water supply code of Australia, Water Services Association of Australia.

APPENDIX A: STANDARDS AND GUIDELINES

Table 16: Standards relevant to rainwater tank and components.

Standard	**Major requirements**
AS/NZS 4766:2006 Polyethylene storage tanks for water and chemicals	Thermal stability: Polyethylene base resin used in compounds for tanks shall contain anti-oxidants, either singly or in combination, such that, when determined in accordance with Appendix B, the percentage melt index change shall be not more than 20% of the base resin value Carbon black for UV stability: When determined in accordance with ISO 6964, polyethylene compounds containing carbon black to provide UV stability shall contain 2.25 ±0.25% by mass of carbon black. UV resistance: When tested in accordance with ASTM D2565, the polyethylene compound for tanks, fusion-bonded fittings and welding rods shall contain UV stabilizers such that the natural (non-pigmented) compound will retain 50% tensile elongation after 8000 h of exposure in a Xenon-Arc weatherometer. Tanks certified to AS/NZS4766:2006 need to be identified with manufacturer's name, tank capacity, date of manufacture, serial number and standard number. Installation: see manufacturer's recommendations.
ATS5200.466 2004 : Technical Specification for plumbing and drainage products - Rainwater tank connection devices	Performance requirements: • Products in contact with water • Hydraulic test strength • Water tightness • Endurance test The device shall be installed and commissioned in accordance with the manufacturer's instructions. With a pressure of between 500 and 800 kPa applied to the mains supply inlet and at the manufacturer's maximum flow rate, the device shall be operated in its normal manner through rainwater/mains supply/rainwater for 50 000 cycles. During this period there shall be no leakage, visible or functional failure of any component of the operating mechanism and the operational characteristics of the device shall not evidence any change, i.e., discharge pressure mains/rainwater.
ATS 5200.467-2004 : Technical Specification for plumbing and drainage products - Rainwater tank connection valve	Performance requirements: • Products in contact with water • Pressure resistance • Endurance test (500-800kPa 2000 cycles) • Installation instructions shall be provided. Maintenance instructions: "The manufacturer shall provide maintenance instructions, which shall include the following: (a) Any regular maintenance requirements including routine service to be undertaken and frequency of service, i.e., cleaning of filters, routine operation of switching mechanism. (b) Spare parts information (c) Troubleshooting guide. (d) Contact details for after-sales service." Operating instructions Consumer instructions shall be provided in a form suitable for display at the location of installation, e.g., affixed to the rainwater tank.
AS 3735-2001 Concrete structures for retaining liquids	It does not apply to concrete tanks of less than 25kL.
HB- *230-2008* : Rainwater Tank Design and Installation Handbook	Applications: (a) Laundry washing machine connection. (b) Toilet flushing. (c) Outdoor use. (d) Pool/pond/spa top-up. (e) Garden irrigation. (f) Hot water use. (g) Fire fighting. (h) Cooling towers. (i) Drinking water uses. Pressure requirements: AS/NZS 3500.1 maximum static pressure at any outlet (other than fire service) max 500kPa, min50kPa at the minimum flow rate required at least disadvantaged outlet. Minimum pressures for appliances. Check list for ordinary maintenance over time provided. Estimates of water use per appliance.

Table 17. Inspection and maintenance practices for rainwater tanks*.

Frequency	Inspection	Maintenance activities applicable
Annual	Inspection of tree branches and overhanging roof	If safe and permitted, pruning back overhanging trees
	Inspect gutters for leaf accumulation and ponding.	Clean leaves from gutters and repair gutter to ensure water flows if necessary.
	Inspection of access covers to storage tanks is closed.	Secure open covers to prevent risk of entry.
	Inspection of integrity of screens on inlets, overflows and other openings.	Repair defective screens to keep mosquitoes out.
	Inspect tank water for presence of vectors (rats, birds, frogs, lizards, insects, etc)	Remove infestation, identify point of entry and close with vermin and insect proof mesh.
	Inspect tank water for mosquito larvae. Depending on local requirements, more frequent inspection may be required in sub-tropical and tropical northern Australia.	Identify point of entry and close with insect proof mesh (diameter $\leq$1/6mm)
	Check signage at external roof water taps.	Repair or replace missing or damages signage and fittings.
	Check for cross-connections and inappropriate tapings.	Remove any cross-connections and inappropriate tappings identified.
	Check plumbing and pump connections are watertight.	Repair any leaks if necessary.
	Check suction strainers, in-line strainers and pump location for debris.	Clear suction strainers, in-line strainers or debris.
	Check pump installation is adequate for on-going operation.	Modify and repair as required.
	Check first flush diverter, if present.	Clean and repair if necessary.
	Check condition of roof and coatings.	Investigate and resolve any apparent changes in roof condition.
Triennial	Drain, clean out and check tank walls and roof for tank deterioration	Repair any tank defects.
	Check sediment levels in tanks.	Organise removal with a qualified contractor if sediments pose a risk to block tank outlet.
	Conduct a systematic review of operational control and risks to the system.	Identify the reason for any problems during inspections and take actions to prevent future failures.
After 20 years	Monitor effectiveness of irrigation equipment to assess for any clogging due to algal growth	Clean and replace clogged equipment.
Ongoing	Inspect and follow-up on any complaints or concerns that could indicate problems with the system	Conduct repairs and/or replacements as required.

*Note: This data is sourced and/or adapted from HB230-2008, p.44-5, Standards Australia 2008.

Table 18. Queensland local government guidance and regulation for rainwater tanks.

Local government area	Information	Reference
Sunshine Coast	Regulation, Rebates, Guidelines and reference	http://www.sunshinecoast.qld.gov.au/sitePage.cfm?code=rainwater-tanks
Somerset Regional council	Regulation (no O&M data)	http://www.somerset.qld.gov.au/forms_publications?p_p_id=3&p_p_lifecycle=0&p_p_state=maximized&p_p_mode=view&p_p_col_pos=1&p_p_col_count=2&_3_struts_action=%2Fsearch%2Fsearch
Moreton Bay	Regulation Fact sheets: mosquitoes (refers to Queensland Health factsheet)	http://www.moretonbay.qld.gov.au/development.aspx?id=9911&terms=rainwater+tank http://www.moretonbay.qld.gov.au/uploadedFiles/common/policies/Installation-Rainwater-Tanks-within-Water-Supply-Area.pdf
Brisbane	Regulation Rebates Maintenance (refers to Queensland Health factsheet)	http://www.brisbane.qld.gov.au/planning-building/common-building-projects/common-improvement-projects/rainwater-tanks/index.htm http://www.brisbane.qld.gov.au/environment-waste/water/for-home/rainwater-tanks/using-your-rainwater-tank/index.htm
Redland	Policy	http://www.redland.qld.gov.au/EnvironmentWaste/GreenLiving/Pages/HarvestingRain.aspx
Logan	Policy Rebates Reference to mosquito screens in tanks.	http://www.logan.qld.gov.au/__data/assets/pdf_file/0014/8510/section7.pdf http://www.logan.qld.gov.au/environment-and-waste/pests-and-weeds/mosquitoes
Gold Coast	None	http://www.goldcoast.qld.gov.au/
Scenic rim	Reference to mosquito screens in tanks in insect pest management Domestic drinking water quality testing	http://www.scenicrim.qld.gov.au/environment/animalinsectpests.shtml http://www.scenicrim.qld.gov.au/home/-/journal_content/56/717563/F5315721D855B22EF38058EE829AE4A4
Ipswich	Rainwater tank declaration (certification forms for installation of a rainwater tank)	http://www.ipswich.qld.gov.au/index.php http://www.ipswich.qld.gov.au/documents/planning/af_b0017.pdf
Lockyer Valley	Building information Pack dwelling certification check-list	http://www.lockyervalley.qld.gov.au/images/PDF/plan_and_build/building/dwelling%20info%20pack%202010.pdf

Table 19. Issues highlighted by stakeholders

Classification	Major issues
Environmental	Carbon footprint is not regulated under QDC. Rainwater systems are installed based on lowest cost by developers, not enough concern is given to water savings, energy use or environmental outcomes. Life cycle costs and benefits of rainwater systems are not known.
O&M	Build up of contaminants in wet systems. Build-up of contaminants in tanks due to lack of desludging. Debris in gutters can cause blockage of tank screen and diverters.
Modifications after installation	Inadvertent modifications after initial rainwater tank installation by home owner: 1. Removal of leaf and mozzie guards to increase flow. 2. Householder disconnects tank from appliances due to colour in water, often related to poor gutter O&M. 3. Plumber connects laundry taps to tank and mains for cold water – leaves householder with option of using mains water for washing. 4. Householder unaware of switch between mains and rainwater. 5. Failure of float switch and householder unaware of leakage and overflow. 6. Increase in inaccuracy of automatic switch if tank runs dry. 7. Householder unaware or unconcerned about need for maintenance, etc.
Certification	Council has less control and often limited data on tanks certified by private certifiers. Not all certifiers provide council with the appropriate documentation. The standard of certification is also not guaranteed. Certifiers need to undergo a cadetship, undergraduate degree, professional certification, license via Building Association. Building Association audits building certifiers and the approval process. However the audit process is not known by council. Poorly conducted certification.
Structural integrity	Anecdotes of poor quality polymer tanks breaking down, this is attributed to lack of control on manufacture/import standards in industry. Leakage from seams of cheap polymer tanks.
Installation	Underground tanks could carry risk of inadequate sealing and risk of infiltration of groundwater, dirt or even leaking septic systems. Poor or incorrect installation, especially in retrofitted tanks. Incorrect pump selection (undersize or wrong type) Components of inferior quality (e.g. pumps) Leaning tanks from tanks placed partly on house foundation and partly on the ground. Plumbing errors (cross-connections, wrong pipe size) Tank not connected to stormwater drainage.
Disconnection	Rainwater tank by-passed after pump breakdown.
Householder awareness	Internally plumbed tank, particularly where tanks were bolted close to the house, e.g. Close to hot water heater - householders saw no differentiation between the rainwater tank and the overall water infrastructure. People believe that tank is “clean and pure water”, which might not necessarily be the case. Most tank owners had no clue on legislation, but they were aware of rebate conditions, including the fact that the rebate increased with internal plumbing. A number of people did not want to have the tank plumbed internally; instead they wanted the tank as discretionary water. Rental property tenants and real estate agents not concerned with rainwater tanks. Parts of tanks in difficult to reach places are not inspected by householders. Home owners leave rainwater tank system selection to developers.
Rebates	Are inefficient tools: they inflate price of tanks and bring opportunistic players in who are not responsible for upkeep of standards and quality. A lot of poor tank installations occurred during the rebate period.

APPENDIX B: PROFESSIONAL SURVEY

Rainwater Tank Governance Expert Survey

1.

Dear survey participant,

CSIRO, Australia's national science agency is undertaking research to help tackle national challenges. Within CSIRO, the Water for a Healthy Country Flagship is working with governments, industries and communities to develop the knowledge needed to substantially improve the way we use and manage water.

Currently, we are undertaking a survey on the topic of governance of rainwater tanks. This study is being funded by the Urban Water Security Research Alliance which has a geographical focus on South East Queensland.

We kindly ask your input into our study to help us explore this topic.

By responding to this internet survey you will contribute to the understanding of the maintenance issues involved with household rainwater tanks, as well as the understanding of how such concerns may be resolved.

The results will be directly fed back to CSIRO scientists who will analyse this information.

The responses that you provide will be anonymous and will be used in publications and reports on the topic of rainwater tank governance. Such reports may be provided to stakeholders such as government departments, water utilities or regulators to help them develop strategies for future efficient strategies will allow cities and towns in Australia to maximise the benefits from investments in rainwater tanks. For further details please contact: Magnus.moglia@csiro.au.

Regards,

Magnus Moglia, Melbourne 1st March 2011

Rainwater Tank Governance Expert Survey

2. Participation consent

Before filling in the survey please first read the following:

By filling in and returning this survey you provide consent to participate in the study.

Information gathered in this survey will not be disclosed to other parties in any way that would disclose your identity.

This study is part of a project which is fully funded by the CSIRO with support from the Urban Water Security Research Alliance (http://www.urbanwateralliance.org.au/index.html).

This survey has been reviewed and approved in accordance with CSIRO's Human Research Ethics Policy. Any concerns regarding the conduct of this survey should be directed to csshrec@csiro.au.

This survey has been reviewed and approved by a CSIRO ethics committee.

Rainwater Tank Governance Expert Survey

3.

First we would like to know a little about who you are. However rest assured that the anonymity of all responses will be maintained.

1. In which State/Territory do you currently live? Please tick the appropriate box:

- ☐ (a) ACT
- ☐ (b) NSW
- ☐ (c) NT
- ☐ (d) QLD
- ☐ (e) SA
- ☐ (f) TAS
- ☐ (g) VIC
- ☐ (h) WA

2. Please specify your major area of involvement with rainwater tanks. Please tick all that apply:

- ☐ (a) I own a rainwater tank
- ☐ (b) I do not own a rainwater tank
- ☐ (c) Work for council
- ☐ (d) Government
- ☐ (e) Private.

Other (please specify)

Rainwater Tank Governance Expert Survey

4.

In South East Queensland, rainwater tanks are mandated for new buildings. Having a rainwater tank can be a considerable resource for a householder, but it also requires some upkeep and maintenance.

3. What level of maintenance do you believe is currently carried out for mandated rainwater tanks in South East Queensland? Please tick the box below.

- [ ] (a) Adequate maintenance in almost all cases (99%)
- [ ] (b) Adequate maintenance cases in most cases (75%)
- [ ] (c) Adequate maintenance in about half of the cases (50%)
- [ ] (d) Adequate maintenance in some of the cases (25%)
- [ ] (e) Adequate maintenance in few of the cases (10%)
- [ ] (f) Adequate maintenance in almost none of the cases (0.1%)

4. What do you believe are the most likely problems and mal-functions likely to cause problems with mandated tanks?

- [ ] (a) Poor water quality
- [ ] (b) Mosquitoes
- [ ] (c) Breakdown of pumps and/or parts
- [ ] (d) Tank breakdown (Structural Integrity).
- [ ] (e) None.

Other (please specify)

5. What do you believe is the major cause for the failures you specified?

- [ ] (a) Lack of Operation & Maintenance
- [ ] (b) Incorrect Operation & Maintenance
- [ ] (c) Design failure
- [ ] (d) Poor installation.

Other (please specify)

Rainwater Tank Governance Expert Survey

6. If there are over-hanging trees and gutters that are not being cleaned, please estimate the average time before gutters will become blocked.

- [ ] (a) Less than a week
- [ ] (b) About a month
- [ ] (c) About two months
- [ ] (d) About six months
- [ ] (e) About a year
- [ ] (f) More than a year

Other (please specify)

7. Based on your knowledge and experience, if there are NO over-hanging trees and gutters are not being cleaned, please estimate the time before gutters will become blocked.

- [ ] (a) Less than a week
- [ ] (b) About a month
- [ ] (c) About two months
- [ ] (d) About six months
- [ ] (e) About a year
- [ ] (f) More than a year

Other (please specify)

8. If a pump is not being maintained, please estimate the time before it will become non-functional.

- [ ] (a) Less than a month
- [ ] (b) About two months
- [ ] (c) About six months
- [ ] (d) About a year
- [ ] (e) About two years
- [ ] (f) More than two years

Rainwater Tank Governance Expert Survey

9. If the mosquito meshing is not being maintained, please estimate the time before it will break.

- [ ] (a) Less than a month
- [ ] (b) About two months
- [ ] (c) About six months
- [ ] (d) About a year
- [ ] (e) About two years
- [ ] (f) More than two years

10. What percentage of mosquito meshing would you think have been removed by householders?

- [ ] (a) 99%
- [ ] (b) 90%
- [ ] (c) 75%
- [ ] (d) 50%
- [ ] (e) 25%
- [ ] (f) 10%
- [ ] (g) 1%

11. If the actual tank is not being maintained, please estimate the "average" time before it will break or become unusable, i.e. relating to the structural integrity.

- [ ] (a) About six months
- [ ] (b) About a year
- [ ] (c) About two years
- [ ] (d) About 4 years
- [ ] (e) About 10 years

12. If the pump is not being maintained, please estimate the "average" time before it is broken?

- [ ] (a) About six months
- [ ] (b) About a year
- [ ] (c) About two years
- [ ] (d) About 4 years
- [ ] (e) About 10 years

Rainwater Tank Governance Expert Survey

13. How often would you recommend that a tank should be de-sludged?

- [ ] (a) Once a year
- [ ] (b) Once every 2 years
- [ ] (c) Once every 3 years
- [ ] (d) Once every 5 years
- [ ] (e) Once every 10 years
- [ ] (f) Never

14. How much do you think a householder may be prepared to pay on an annual basis for regular upkeep of a rainwater tank?

Enter an approximate dollar ($) value in the following box and explain your answer:

15. How often do you think rainwater tanks need to be inspected in order to ensure their integrity?

- [ ] (a) Once a year
- [ ] (b) Once every 2 years
- [ ] (c) Once every 3 years
- [ ] (d) Once every 5 years
- [ ] (e) Once every 10 years
- [ ] (f) Never

Please explain your answer

Rainwater Tank Governance Expert Survey

5.

There is some debate on the topic of payment and responsibility for inspections and maintenance of rainwater tan

16. Who do you think should be responsible for inspections of rainwater tanks?

- [ ] (a) Households
- [ ] (b) Council
- [ ] (c) Water utility
- [ ] (d) Private enterprise
- [ ] (e) State government
- [ ] (f) Federal government

Other (please specify)

17. Who do you think should be responsible for maintenance of rainwater tanks?

- [ ] (a) Households
- [ ] (b) Council
- [ ] (c) Water utility
- [ ] (d) Private enterprise
- [ ] (e) State government
- [ ] (f) Federal government

Other (please specify)

18. Do you think there is a greater role to be played by private enterprises in the maintenance and management of rainwater tanks?

- [ ] (a) Yes, that would be great
- [ ] (b) No, that is not appropriate
- [ ] (c) Sometimes
- [ ] (d) Don't know

Please explain your answer

Rainwater Tank Governance Expert Survey

19. Do you think there is a greater role to be played by the water utility or local council in the maintenance and management of rainwater tanks? Please explain your opinion.

20. Are there any other agencies, organisations or individuals (not mentioned before) that you believe should have a role in maintenance or rainwater tanks?

☐ No

Yes (please specify)

Rainwater Tank Governance Expert Survey

6.

You have now completed the first and most important part of the survey. In the second part of the survey, we will now ask you a number of questions relating to your opinions. We would very much appreciate your responses, but understand that you may be under time pressure.

You can choose to submit responses now or continue further.

21. Do you wish to continue

☐ Yes

☐ No

Rainwater Tank Governance Expert Survey

7.

You have now completed the first and most important part of the survey. In the second part of the survey, we will now ask you a number of questions relating to your opinions. We would very much appreciate your responses, but understand that you may be under time pressure.

You can choose to submit responses now or continue further.

22. How do you think technology can help in ensuring the on-going operation of rainwater tanks? Please explain.

23. How do you think regulation and/or legislation can help to support adequate inspection and maintenance of rainwater tanks? Please explain.

24. How do you think educational campaigns can help with supporting adequate inspection and maintenance of rainwater tanks? Please explain.

Rainwater Tank Governance Expert Survey

25. Would you like to suggest some possible management models to ensure on-going operation of rainwater tanks? Please describe.

26. In your opinion, what other factors should be considered in the management of rainwater tanks? Please explain.

27. Are there any other comments or suggestions you'd like to share with us?

Rainwater Tank Governance Expert Survey

8.

Thank you for participating in this survey. You help is greatly appreciated.

For any enquiries in regards to the project please contact Magnus Moglia (email: magnus.moglia@csiro.au) or Ashok Sharma (email: ashok.sharma@csiro.au).

APPENDIX C: SIMULATION SCRIPTS WRITTEN IN PYTHON

```
import random
FailFrequencies = {}
FailFrequencies[182] = 0.014705882
FailFrequencies[365] = 0.009950249
FailFrequencies[730] = 0.030150754
FailFrequencies[1461] = 0.106060606
FailFrequencies[3653] = 1
def simInspectionsAndFailures(inspectionFrequency,failFq,N):
    tanks = {}
    results = {}
    inspectionProbability = float(1)/float(inspectionFrequency)
    for i in range(1000):
        tanks[i] = [0,0]    # (blocked,time since last clean)
    for t in range(N):
        for i in tanks.keys():
            blocked = tanks[i][0]
            timeSinceLastClean = tanks[i][1]
            RandomClean = random.uniform(0,1)
            if RandomClean < inspectionProbability:
                timeSinceLastClean = 0
                blocked = 0
                tanks[i][0] = 0
                tanks[i][1] = 0
            if blocked == 0:
                try:
                    failProb = failFq[timeSinceLastClean]
                    RandomBlock = random.uniform(0,1)
                    if RandomBlock <= failProb:
                        tanks[i][0] = 1
                except:
                    pass
            tanks[i][1] += 1
        numBlocks = 0
        for i in tanks.keys():
            numBlocks += tanks[i][0]
        if t > 5000:
            results[t] = float(numBlocks) / float(len(tanks))
    return results

InspectionFrequencies = [30,90,182,365,730]
for ifr in InspectionFrequencies:
    results = simInspectionsAndFailures(ifr,FailFrequencies,15000)
    val = float(sum(results.values()))/float(len(results))
    print ifr, val
```