Leaky Loos Phase II

Water Industry Collaborative Fund Project

Report for Affinity Water

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aqualogic water conservation

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Executive summary

This final report describes the findings from a physical investigation into leakage (or wastage) from domestic water closets (WCs) in the UK. The work builds on a previous desk based study (Leaky Loos Phase I) which identified that leakage from WCs could represent a significant proportion of average per capita consumption (PCC).

The key objective of this study was to refine our understanding of the scale (quantity of water wastage and number of WC's leaking) of the issue and to identify if any particular groups of households are more likely to have leaking WCs. Further to this the project aims to identify in more detail the technical reasons for leaks occurring in WCs so that a strategic approach, to reduce the amount of leakage and to prevent further leakage in the future, could be developed.

Physical investigation of leaking WCs

To ensure a statistically robust approach the physical investigation of WC leakage was undertaken in two phases. A random sample of toilets was investigated in the first phase to identify the potential scale of the problem, and to test and refine the hypothesis that '10% of all WCs leak' as outlined in the Leaky Loos Phase I study. While in the second phase a more targeted approach was adopted to investigate the range of leaks detected and the causes behind these. By developing the approach through each phase a greater understanding of the most efficient methods of detecting and locating leaking WCs and how to improve the speed and rate of repair was gained.

The findings show that WC leakage **is not as significant** an issue in terms of scale and water wasted as previously recognised:

- On average approximately **4.1% of WCs** were found to be leaking.
- Average leakage rates of **215 litres/toilet/day** (based on the sample mean) and **72 litres/toilet/day** (based on the sample median) were derived from the study.
- **Total wastage** from WC leakage is estimated to be **397 Ml / day** (based on the sample mean) and **133 Ml / day** (based on the sample median)
- The **overall contribution** of WC leakage to the average PCC is between **1.65%** and **4.63%**.

While the evidence does not indicate any significant relationships between whether a property is metered, smart metered, or owner-occupied and whether a toilet leaks the findings support the perception that there is a higher proportion of leakage in modern WCs. In particular, the data showed properties built between 2000 and 2010 are more likely to have leaking toilets (than houses built in other time periods), and properties built between 1970 and 2000 are less likely to have leaking toilets (than houses built in other time periods). This suggests that WC leakage is not primarily caused by wear and tear of aging flushing parts as if this was the case then much higher leakage rates would be expected in older properties.

Statistically significant differences in the specifications of leaking toilets versus non-leaking toilets were identified. In particular 81% of leaking WCs had a flush valve mechanism, whereas only 58% of WCs that were not leaking had flush valves. This confirms that the higher leakage rates witnessed in newer properties have been driven by the changes to the Water Supply (Water Fittings) Regulations which were introduced in 1999. It also supports the observation that WCs in houses built before 1970 are more likely to have been replaced or upgraded with new WCs which are more likely to leak. For those properties built between 1970 and 2000 the evidence suggests that a decreasing number of old siphon operated WCs have been retained and these mechanisms are less likely to leak. This is probably due to long term home owners who have not yet replaced their bathroom or WC suite.

It is possible that the change in Regulations brought about a 'perfect storm' whereby the introduction of flush valve mechanisms combined with the fact that non-compliant products can be legally purchased and the fact installers do not require any form of certification or accreditation, means that non-compliant products (of potentially poorer quality) are freely available on the market and could be installed by plumbers or householders that are unaware of the Regulations. A further concern is that there is no requirement for flushing mechanisms and components to be labelled. Thus it is difficult to establish

whether a leaking device in situ is compliant with the Regulations or for an installer to verify product compliance at installation. Due to a lack of product labelling no evidence was found during this study to support the hypothesis that non-compliant products are a major cause of WC leakage.

The findings did suggest that there are two different scales of WC leakage – smaller hidden leaks, which may go unnoticed by the customer, and large higher consumption leaks. Of the 138 leaking WCs investigated the majority (80%) had a leakage rate of less than 300 litres / toilet / day with 36% less than 25 litres / toilet / day, and just 12% above 500 litres / toilet / day. In comparison to previous studies (including Leaky Loos Phase I), which reported higher average values for leakage, there is an indication that a leak needs to develop to around 300 litres / day before the customer starts to recognise there is an issue either as it is audible, it becomes more visible, or through higher bills. This provides a sense of the point of escalation for a normal unaware customer however, a better understanding of how small leaks develop to this point and over what timeframe is required.

While the scale of the issue is less significant than originally anticipated, data on WC leakage by property age suggests that the issue may become worse in the future as the remaining siphon mechanisms are replaced with flush valves and more WCs are installed to meet demand. This will primarily be driven by the development of new homes to meet the needs of an increasing population and demographic changes but coupled with greater property ownership, and a move towards second bathrooms and cloakrooms, it means that the number of WCs in the UK housing stock is set to continue to rise. As such in future there will be greater potential for WC leakage and it will remain an issue that affects all water companies.

Causes of WC leakage

For each of the leaking WCs investigated the cause of the leak was established and recorded.

- The most **common single cause** of WC leakage is **flush valve seal degradation.**
- **Two-thirds** of all leakage is **caused by three factors**:
    - flush valve seal degradation;
    - faulty fill valves; and
    - faulty dual flush valves,
- Over **43% of leakage** is associated with **the fill valve mechanism**.
- The **highest rates of leakage** were generally associated with **faulty fill valves** and **faulty dual flush mechanisms.**

In terms of WC leakage repairs like all other working parts a key issue for WC flush mechanisms is the need for regular maintenance. However, the flush mechanism is becoming less accessible to the enthusiastic DIYer or the handyman. While many new design features allow for the removal of flush valves without the need to disrupt the connection between the cistern and the pan this is not the case for the majority of the older stock. On some exposed models the flush actuation mechanism has further been simplified to allow easier removal of the lid without disrupting the cable or rod mechanisms. However, there is no standard approach to the flushing mechanisms contained within the cistern.

The development of concealed cistern systems is adding further complications to maintenance. Whilst the flush devices have access made available via front hatches through larger plate button housings, they are not always practical and may be more accessible to plumbers rather than home owners. Consideration should also be made towards design that allows for easier serviceability. The study highlighted that some customers were aware they had a leaking WC but felt unable or unwilling to investigate it further and used this project as an opportunity to have it repaired. Of the leaks repaired around 70% of them were fixed by the plumber on the first visit. The balance required specialist components or structural alterations.

Stakeholder consultation and strategy development

A number of industry stakeholders were consulted during the study and the initial results from the physical investigation phase presented at a stakeholder workshop. In general stakeholders were not surprised by the findings however, there was a great deal of appetite to understand more about the causes of leakage and whether the products and mechanisms were compliant with the regulations and whether they had been installed correctly either through retrofitting or as new. The high percentage of

flush valves that were shown to be leaking was of concern and with an estimated lifespan of 15 years it was acknowledged that, without action, the problem could get a great deal worse as the remaining siphon mechanisms are replaced with flush valves and more WCs are installed to meet increasing demand.

There was a general consensus that the current legislative situation whereby non-compliant products can be purchased but not installed is unsatisfactory and insufficiently policed. However, it was appreciated that any change to the regulations would require a change in primary legislation which was deemed unlikely. While there was some recognition that the issue needs to be tackled by the whole supply chain awareness across the sector of the impact of WC leakage and product compliance, was viewed to be low. A number of other potential intervention options were identified for each of the stakeholder groups. These included:

- Government:
  - *Increased enforcement of the current regulations.*
  - *Raise awareness of the need for compliance amongst retailers and suppliers, plumbers and the customer.*
- Water industry:
  - *Increased awareness to customers e.g. information in bills, leak strips, home visits.*
  - *Continue targeting high consumption customers and scale up current retrofit programmes.*
  - *Improved targeting of WC leakage e.g. property age*.
- Product Manufacturers:
  - *Raise awareness of compliant products e.g. to suppliers, retailers and housebuilders.*
  - *Increased product and part labelling.*
  - *Investment in product design e.g. push button siphon mechanism.*
  - *Technical information to customers to enable DIY repair.*
- Plumbers:
  - *Installation of only compliant products.*
- Housebuilders:
  - *Specification of WRAS approved products.*
  - *Better / improved access to concealed cisterns.*
- Householders:
  - *Use of accredited plumbers only.*
  - *Increased awareness of the issue and what to do.*

Despite this list of potential interventions there was a feeling among stakeholders that many of the options and recommendations raised were merely '*tinkering around the edges*' and that without regulatory reform the issue may be '*too hard to tackle'*. But as the stakeholder workshop established regulatory reform is unlikely thus WC leakage will probably remain largely an issue for the water companies and their customers. But its overall significance in comparison to supply leakage remains small thus a balance needs to be struck in terms of where they invest. Customer metering will help this and large scale installation programmes are in progress across many water company regions.

The findings of this study are of real significance to the water industry and its stakeholders as they suggest that previous studies had overestimated the scale and rate of WC leakage and thus the overall level of wastage. However, WC leakage is a complex issue. Overall there needs to be greater awareness of the situation across the supply chain from regulatory compliance and what that means, to the impacts on customers and what they should do. In addressing the issue the most feasible option is to continue with the approaches that are already being adopted by the water industry around retrofitting and high consumption queries and where possible 'piggy back' on existing initiatives. However, as the cost benefit analysis shows these may not be cost effective particularly if the scale of WC leakage is not as significant as initially anticipated.

Recommendations:

- The most cost effective way of approaching WC leakage is for the water companies to continue targeting high consumption customers and repairing those leaks identified.
- Undertake full cost benefit analysis on the other WC leakage and prevention measures identified in the study.
- Improved targeting of WC leakage based on property age – this could be incorporated into home visit initiatives.
- Raise awareness of the need for compliant products among retailers and suppliers, plumbers and the customers. Further customer and stakeholder education is also required regarding compliance. This could be achieved through the provision of advice and information.
- Establish a better understanding of how a small leak develops and over what timeframe.
- Increase customer awareness of the issue of WC leakage through information in bills, leak strips and home visits.
- Improvements to the design of leak strips to minimise the potential for incorrect installation.
- The water industry should consider promoting a preference for low or dual flush siphon toilets and improved labelling for dual flush systems.
- Design WCs with a focus on serviceability and repair to allow customers to attempt a repair where possible. This should include improving access to concealed cisterns.
- Improved parts and component labelling with the provision of technical information to customers to enable simple repairs.
- Improved access to concealed cisterns. Design for serviceability.
- Explore the potential to re-instate the requirement for external overflows (particularly where cisterns are concealed) so that WC leakage becomes more apparent to the householder and can be addressed more quickly.

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1 Introduction

This final report describes the findings from a physical investigation into leakage (or wastage) from domestic water closets (WCs) in the UK. The work builds on a previous desk based study (Leaky Loos Phase I)[1] which identified that leakage from WCs could represent a significant proportion of average per capita consumption (PCC).

The project was commissioned as part of the water industry collaborative research fund set up in 2012 in response to water companies' duty to promote water efficiency as part of the Water Industry Act 1991. The key objective of the study was to refine our understanding of the scale (quantity of water wastage and number of WC's leaking) of the issue and to identify if any particular groups of households are more likely to have leaking WCs. Further to this the project aims to identify in more detail the technical reasons for leaks occurring in WCs so that a strategic approach, to reduce the amount of leakage and to prevent further leakage in the future, can be developed.

The physical investigation stage of the study was phased such that in Phase 1 a random sample of households were targeted to test the hypothesis that 10% of all domestic WCs leak. In Phase 2 households with known WC leaks were identified from a range of sources (primarily through ongoing water company initiatives) such that the rates and causes of leakage could be established. Repairs were then instigated at these properties.

This final report presents the results from a robust assessment of WC leakage and provides an overview of the strategic options and recommendations to reduce the current levels of leakage and for preventing future leakage from domestic WCs.

1.1 Aims and objectives

The key aims and objectives for the project are to:

- Improve and refine the evidence base. Refine understanding of the scale (quantity of water wastage and number of WC's leaking) of the issue and identify if any particular groups of households are more likely to have leaking WCs. Identify in more detail the technical reasons for leaks occurring in toilets.
- Develop efficient methods of detecting wastage. Research the most efficient methods of detecting and locating leaking WCs and improve the speed and rate of repair.
- Identify efficient ways to reduce existing wastage. Identify and recommend ways of reducing the levels of wastage from malfunctioning WCs within the existing stock; And in doing so quantify the costs and benefits.
- Identify ways to prevent future wastage. Provide an improved understanding of identifying and clarifying the reasons for malfunctions, and propose methods to prevent malfunction in the first place.
- A physical investigative study, of at least 300 leaking toilets in partnership with water companies, to be analysed for leak causes and wastage data.

1.2 Report structure

This report presents the findings of the project which was undertaken between May 2014 and July 2015 and is structured as follows:

- Section 2 provides an overview of the background and the findings from a review of the literature;
- Section 3 provides an updated analysis of previous water company data in this area;
- Section 4 presents the findings from the physical investigation phase of the project including analysis of WCs leakage, the types of leaks, cause of leaks and recommendations;
- Section 5 provides an overview of the strategic options available to tackle the issue; and,
- Sections 6 and 7 provide a discussion on the results and a summary of the conclusions and recommendations.

[1] Artesia Consulting, Final Report on Leaky Toilets Project (2012) for consortium of eight water companies

2 Background

Leakage (or wastage) from WCs is estimated to represent a significant proportion of average per capita consumption (PCC). Research from the 2012 Leaky Loos Phase I study[1] identified that approximately 10% of toilets were found to be leaking and estimated total losses at 400 litres / toilet / day. From this an estimate of 1.8 billion litres of treated water potentially being lost through wastage from toilets was derived for the UK - this equates to around 9% of the average PCC. However, evidence on the actual cause of leakage was limited to anecdotal responses on failing flush valves, inlet valves, seals, and improper cistern set-up leading to over-filling and over flushing.

By taking a strategic / proactive approach to the identification, repair and prevention of leaking toilets this wastage component of PCC could be significantly reduced. However, further physical investigation is required to confirm the proportion of leaking toilets as well as the causes behind these to support strategy development.

2.1 Literature review

To gain an understanding of the background to the issue of leakage from domestic WCs a concise literature review was undertaken. The findings from the review were also used to support the investigation and analysis tasks but more specifically the strategy development task. This includes a more detailed assessment of current and future market trends, consideration within standards and labelling schemes and the range of policy approaches considered internationally that can apply to strategy development in the UK.

2.1.1 Regulatory Framework

The Water Supply (Water Fittings) Regulations 1999 are national requirements for the design, materials, installation and maintenance of plumbing systems, water fittings and appliances. Their purpose is to prevent waste, misuse, undue consumption and the contamination of water supplies. The Regulations were introduced on 1st July 1999 and superseded the Water Bylaws in England and Wales.

An overview of the differences between the former Water Byelaws and the Water Regulations was provided in the Phase I report[1] and is not discussed in detail here. However, with respect to WCs it is important to note that the Regulations extended the range of acceptable flushing apparatus beyond siphons with the addition of dual flush mechanisms, drop valves and flap valves. The primary driver for the introduction of flush valves into the Water Regulations was the need to conserve water and the fact that flush valve mechanisms would allow for reduced flush volumes (e.g. through dual flush). Further to this the Regulations were also extended to allow internal overflow pipes (in addition to external overflow pipes) as a warning mechanism for WC leakage. However, there is some anecdotal evidence that flush valves are associated with WC leakage and the inclusion of internal overflow pipes has meant that leaks are less apparent than if they were discharging from an external overflow.

The water supply companies are responsible to the Government for the enforcement of the Regulations which aim to ensure that all newly installed WC systems are compliant. All new components should comply with the performance requirements set out in the Regulators Specification for WC Suites[2]. These form the basis for testing to demonstrate the compliance of products with the Regulations and include product endurance and leakage tests. As part of the physical endurance test, WC Inlet valves and flushing devices must be leak-free after 200,000 flushes. Mechanical tests include checking the porosity of the fitting's body, the leak tight closure of valves, corrosion resistance, connection dimensions, identification marks and backflow performance. However, it is not an offence in the UK to sell a non-compliant product only to install it. As such it is possible for non-compliant products to be purchased and installed.

To demonstrate compliance with the Regulations the Water Regulations Advisory Scheme (WRAS) was set up as a voluntary scheme that product manufacturers can use to demonstrate third party certification of compliance with the Regulator's Specification. However, manufacturers are not required by law to have their products tested or approved by WRAS and this is reflected in the 2012 research[1] which estimated that around only 30% of the devices on the market had undergone WRAS approval testing. While there are other methods to demonstrate product compliance (e.g. third party testing, self-

[2] http://webarchive.nationalarchives.gov.uk/20130123162956/http:/archive.defra.gov.uk/environment/quality/water/industry/wsregs99/

certification) it is possible that a high proportion of the WC flushing components and devices currently on the market are in fact non-compliant and could fail causing wastage. However, there is currently no data or information in the literature to support this hypothesis and generally products are not clearly labelled thus it is difficult to establish whether a leaking device in situ is compliant with the Regulations or for an installer to verify product compliance at installation.

2.1.2 WC types and flushing mechanisms

According to European Standard BS EN 997:2012[3], a WC suite is a "*WC pan combined with either a flushing cistern with integral warning pipe connection – or a device deemed to be a no less effective device – and inlet/outlet devices, or a pressure flush valve, with WC and flushing device installed as a functioning unit*".

There are a range of different WC types currently available in the UK market and these are typically defined by the cistern volume and flushing mechanism. Single-flush and dual-flush toilets are currently available that are more water efficient than the minimum required by the Water Supply (Water Fittings) Regulations (Table 1). WC suites are defined further by the arrangement of the pan and cistern, for example:

- Close coupled where the cistern sits on the back of the toilet pan and flushes directly through the connecting point. Typically all modern toilets are close coupled.
- Low and high level where the cistern is wall hung and sits above the pan and uses gravity to create a strong flush.

More recently there has also been a trend in modern bathrooms towards concealed cisterns where the cistern is built into the wall behind the toilet pan.

Table 1 Types of toilets and regulation in the UK

WC type by nominal flush volume	Factors affecting actual volume	Regulation/Approval**
Single flush mechanisms		
>9 litres	Range of cistern sizes	Illegal to install
7.5 litres	Cistern size Partial re-flush	Illegal to install
6 litres	Cistern size	Maximum full flush permitted under the Water Supply (Water Fittings) Regulations
4.5 litres	Cistern size Double flushing	WRASˆ has approved a 4.5 and 4 litre WCs. The 1.5 litre flush Propelair has also been approved. Vacuum WCs are not currently approved by WRAS.
<4.5 litres	Designed rinse volume	
Dual flush mechanisms		
6/4, litre dual flush	Flush ratio Leaking valves Double flushing	Maximum dual flush permitted under the Water Supply (Water Fittings) Regulations
6/3.7, 6/3.6, 6/3.5, 6/3, 5.8/3.55, 4.5/3, 4/2.6, 4/2.5 and 4/4.2 litre dual flush		WRAS* approval granted.

**** European Standard EN 997:2003 all WCs sold in the UK must adhere to class 2 which is equivalent to UK standards**
ˆ Other approval systems are available

2.1.2.1 WC flushing mechanisms and components

WC flushing mechanisms can be divided into those with valves and those that are valve-less, with the former sub-divided into single-flush and dual-flush or (for domestic installations) into drop-valves and flap-valves. In the UK the only valve-less flush mechanism currently available is the siphon, which was

[3] BS EN 997:2012 replaced BS EN 997:2003 in March 2012.

a legal requirement under the Water Byelaws (superseded by the Water Supply (Water Fittings) Regulations 1999). Currently, most dual-flush WCs use drop-valve mechanisms which allow the use of double buttons or a sensor system to activate the full and part flushes.

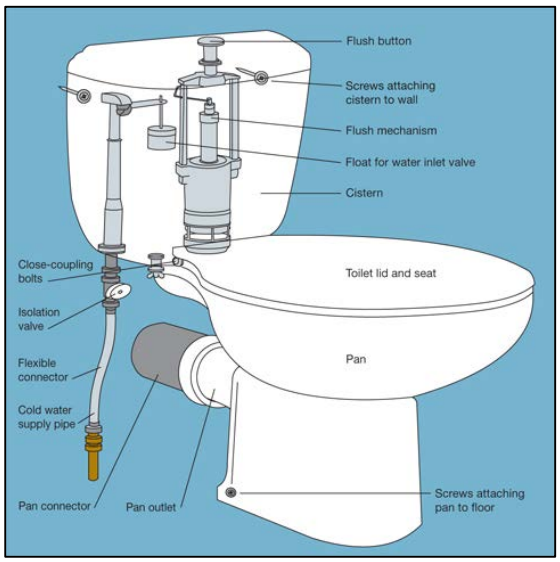
In addition there are also a number of retrofit WC flushing devices that are fitted to existing cisterns or WC suites to enable a reduction in the volume of water per flush. This is usually obtained through the provision of either a reduced single or dual flush mechanism or the delivery of the required volume of water through an interruptible flush mechanism.

Flush (flapper / drop) valves

In toilets using a flush valve the outlet at the bottom of the cistern is covered by a buoyant (plastic or rubber) cover (flapper), this is held in place by the pressure of the water in the cistern. When the toilet is flushed, the valve is opened and the water in the cistern flows rapidly into the pan. As the water level drops, the floating flush valve lowers back to the bottom of the cistern and covers the outlet pipe again.

The majority of low flush WCs available on the UK market are dual flush valves. Figure 1 illustrates the flush valve mechanism in a close coupled WC and a dual flush valve.

Figure 1 Close coupled WC cistern and pan with flush valve mechanism[4] and flush valve[5]



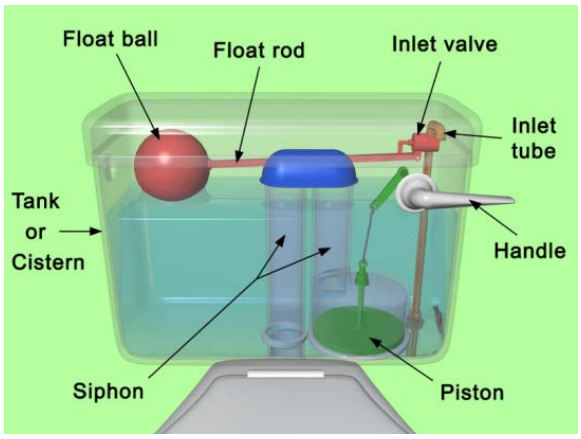
While one of the primary reasons for introduction of valve flushing mechanisms into the Water Regulations was the need to conserve water, concern has been expressed over the potential for valve operated toilets to leak and it remains to be established whether or not there is a significant difference between the nominal flush volume of a WC and the installed flushing volume due to leakage[6,7]. Problems with the flushing mechanism could be caused by the build-up of limescale in hard water areas, degradation of the valve seals, incorrect installation or mechanical failure[5].

Siphon flush mechanisms

A siphon flush is operated when the user presses the handle which forces some water through the siphon. This provides the suction for the remaining water in the cistern to be passed through the siphon and out into the pan. The benefit of a siphon is that it has no sealing washers like that of a flush valve which can wear out and cause leaks. Traditionally this system was common in the UK. Dual flush versions of this design are also now widely available. Figure 2 provides an illustration of a typical siphon toilet.

[4] Image source from http://www.lets-do-diy.com/Projects-and-advice/Bathroom/Replacing-a-toilet.aspx
[5] Image sourced from http://dudleyspares.co.uk/flush_valves_2.html
[6] Water Closets: Best practice since the Water Fittings Regulations 1999, GreenPro News, Autumn 2002.
[7] MTP, BNWAT20: Very low water use water closets – Innovation Briefing Note

Figure 2 Example of a siphon flush toilet[8] and siphon mechanism[9]



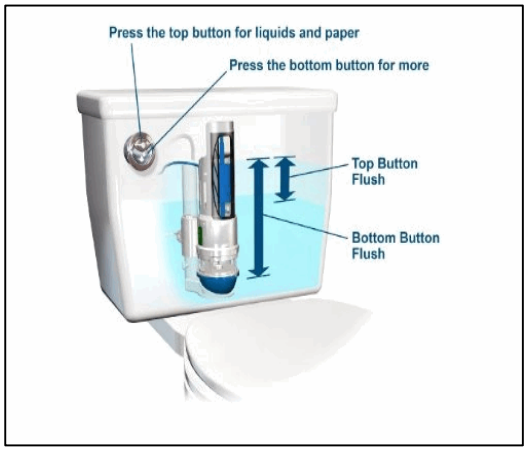
Dual flush mechanisms

The main feature of the dual flush toilet is that it has two buttons for releasing water – a small flush capacity and a large flush capacity, giving the user an option of using less water. However, a key issue with dual flush toilets is understanding how they operate and there can be confusion over which button to press which may lead to excessive amounts of water being used (Figure 3).

Both dual flush siphon and valve flushing mechanisms are currently available on the UK market but dual-flush valves differ from siphon-flush mechanisms in that they rely on gravity to remove waste from the toilet as described above. In addition to its dual flush feature, the lack of siphoning also results in requiring less water to operate.

The maximum flush volume as specified by the Water Supply (Water Fittings) Regulations is 6 litres with the reduced flush element no greater than 2/3 of the maximum flush. For siphon mechanisms, the Water Regulations require any dual-flush device to default to full flush, the reverse logic to the dual-flush siphons of the 1980s in which the default was the half-flush. The current logic is that it is better to accidentally select the full flush and clear the bowl rather than accidentally selecting the part-volume flush which may not clear the bowl, thus requiring a repeat full flush.

Figure 3 Example of a dual flush toilet[10], dual flush valve[11] and dual flush siphon mechanism[12]



WC retrofit devices

Retrofit WC flushing devices can fitted to existing cisterns or WC suites to enable a reduction in the volume of water per flush. This is usually obtained through the provision of either a reduced single or

[8] Image sourced from http://www.thefullwiki.org/Wikijunior:How_Things_Work/Flush_Toilet
[9] Image sourced from http://shop.kingswayplumbing.co.uk/thomas-dudley-turbo-s1-11-9-syphon-1638-p.asp
[10] Image from www.time-to-innovate.com
[11] Image sourced from http://geberittoiletsparesuk.com/
[12] Images sourced from http://www.thomasdudley.co.uk/bathroom/cistern-components/turbo-88-syphon.html

dual flush mechanism or the delivery of the required volume of water through an interruptible flush mechanism. Large scale retrofit projects are not uncommon in the UK water industry as they have become a cost-effective demand management option and generally well received by customers (Table 2)[13].

Table 2 Summary of customer feedback on WC retrofit devices[14]

Product	Project	Rating
Dual flush conversion devices	Essex and Suffolk Water H_2eco project Phase 1 2008	87% pleased 11% negative comments
	Essex and Suffolk Water H_2eco project Phase 2 2008	89% pleased
	Essex and Suffolk Water H_2eco project Phase 3 2009	86% pleased
	Veolia Water South East Lydd Retrofit Trial Report Jan 2012	55% recommend
	The 'Retrofitting variable flush mechanisms to existing toilets' project 2005	74% recommend
	The 'Retrofitting variable flush mechanisms to existing toilets' project 2005	85% recommend
	Sutton and East Surrey Water Preston Water Efficiency Initiative 2009	56% liked the product
Cistern Displacement Devices	Veolia Water South East Lydd Retrofit Trial Report Jan 2012	77% recommend
	Essex and Suffolk Water's Project in Witham (2003)	4.2 out of 5
	Essex and Suffolk Water Thurrock Home Survey Project	77% fitted the device
	Essex and Suffolk Water Water Saving Toolkit Project	94% installation success
	Essex and Suffolk Water H_2eco project Phase 1 2008	25% double flushed since fitted
	Essex and Suffolk Water H_2eco project Phase 2 2008	19% double flushed since fitted
	Essex and Suffolk Water H_2eco project Phase 3 2009	14% double flushed since fitted 67% installation success rate
	Veolia Water South East Lydd Retrofit Trial Report Jan 2012	Product 1 – 80% recommend Product 2 – 77% recommend
	South West Water's Water Care 2007-201	Product 1 – 76% have installed and 5% intend to install Product 2 – 70% have installed and 11% intend to install

[13] Waterwise, Evaluating water efficiency retrofit projects: an example, 2013
[14] Customer Experiences of Home Retrofit Products: An *Evidence Base* project, 2013

Cistern Displacement Devices

Flush volumes can also be reduced through the use of cistern displacement devices (CDDs) (also known as cistern volume adjusters (CVAs)) such as 'save-a-flush' bags, gel absorption bags or 'hippo' bags. As the name implies, a cistern displacement device is positioned in the toilet tank to displace the water, reducing the volume going to drain (Figure 4). CDDs typically save around 1-3 litres per flush but this may vary considerably depending on the toilet design.

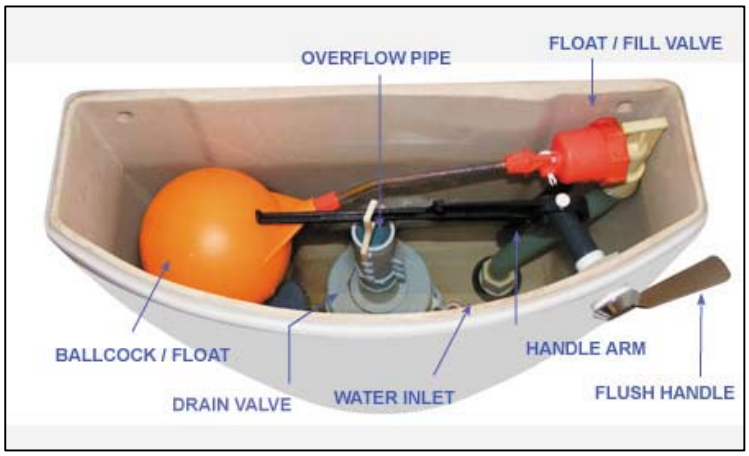
Figure 4 Cistern displacement device in situ[15]

As with retrofit flushing devices CDDs have been popular with the UK water industry and they are often provided for free to customers as a way of reducing flush volumes. However, these devices can cause problems if they are installed in modern WC cisterns which are designed for low flush volumes as the device can stop the flush mechanism from operating correctly (Table 2).

WC inlet valves

Another important component in the cistern is the WC inlet (or fill) valve which is defined on the WRAS website as the "*valve that controls and shuts off the flow of water into a cistern, usually by an arm connected to a float*[16]". During flushing the level of the float within the cistern drops allowing the inlet valve to open. As the water level increases within the cistern the float rises to the pre-set level before closing the inlet valve shutting off the water flow (Figure 5). Typically there are two types of inlet valve – bottom entry or side entry according to the point of entry of the mains supply within the cistern.

Figure 5 Inlet valve in situ[17]



[15] Image sourced from http://renergise.ie/product-category/wc-water-saving-devices/
[16] https://www.wras.co.uk/consumers/resources/glossary/wc_inlet_valve/
[17] Image sourced from http://www.home-dzine.co.za/diy/maintain-toilet-troubles.htm

Failure of the inlet valve is often associated with WC leakage in WCs with both siphon and drop valve flushing mechanisms. Typically this is caused by the valve failing to close properly due to a malfunction in the float or ballcock mechanism resulting in overfilling of the cistern.

The former Water Byelaws required a visible external overflow, which provided effective warning of inlet valve failure. However, the current Water Regulations now allow for an internal overflow whereby water will flow into the pan. While this is more 'convenient' for the customer the inclusion of internal overflow pipes has meant that leaks are less apparent than if they were discharging from an external overflow and a slow inlet valve leak could almost certainly go unnoticed.

2.1.2.2 Alternative systems

In addition to flushing WCs there is a large variety of different types of toilet systems currently on the market. The following outlines the range that are currently available[18]:

- Chemical toilets
- Squat toilets
- Urine-separation toilets
- Bidet toilets (including high-technology toilets)
- Composting toilets
- Macerator toilets
- Incinerating toilets
- Stand-alone toilet facilities
- Humid latrines
- Dry latrines

Contemporary toilets are now being design to use almost no water. For example:

- Aquatron Toilet: This is a composting system which works by separating the liquids and the solids. The toilet requires only a small amount of water (3 litres per flush) as only the liquids go to sewer and the solids go to compost. The liquid is separated from the solids due to a centrifugal force.
- Propelair® is a new type of WC system using displaced air and water which only requires 1.5 litres of water per flush.
- Bipee: Similarly to the Aquatron, this system separates solids and liquids therefore requiring less water for flushing, less than 0.5 litres per flush.

At present these systems are not widespread in the domestic WC market in the UK.

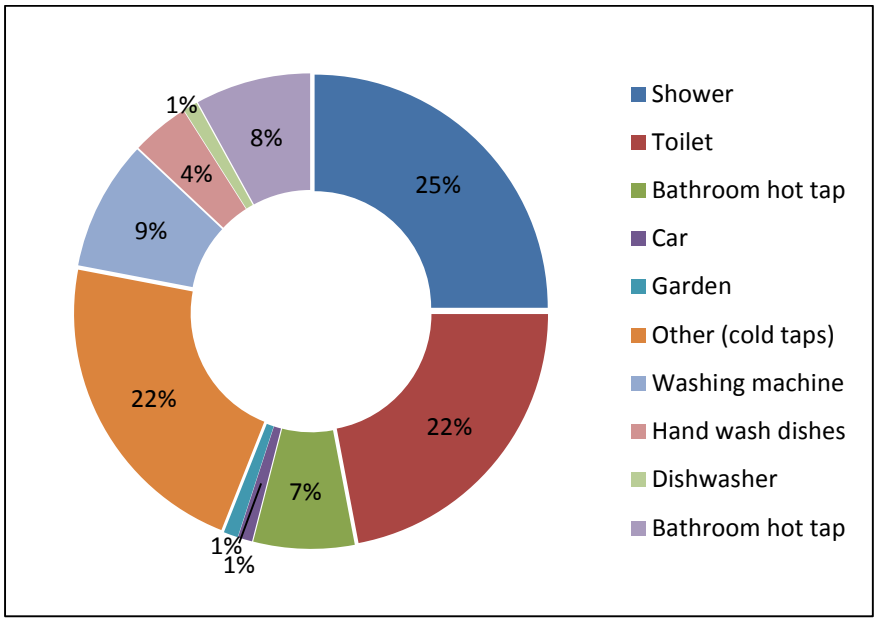
2.1.3 WC market trends

In the UK, WC cistern volumes in the existing housing stock can vary considerably. However, over the last five decades flush capacities have reduced from 20 litres (pre-1960's) through, 13 litres, 11 litres, 9.5 litres and 7.5 litres to a current maximum flush volume of 6 litres prescribed by the Water Supply (Water Fittings) Regulations, 1999. In this time dual flush WCs were also banned because of the potential for double flushing and then reintroduced in 2001.

The move towards more water efficient WC suites was highlighted in the Bathroom Manufacturer's Association's (BMA) annual *Market Trends Report*. In 2013, it identified that WC suites are being manufactured with a dual flush system using as little water as 2.6 litres[19]. However, toilet flushing still accounts for 30% of the water that's currently used in the home and makes a significant contribution to the average PCC[20]. The EST *At Home with Water* study includes self-reported data from 86,000 households. Importantly this shows toilets as the second largest water use (22%) in homes after showering (25%; Figure 6)[21] suggesting that WC consumption has reduced in recent years.

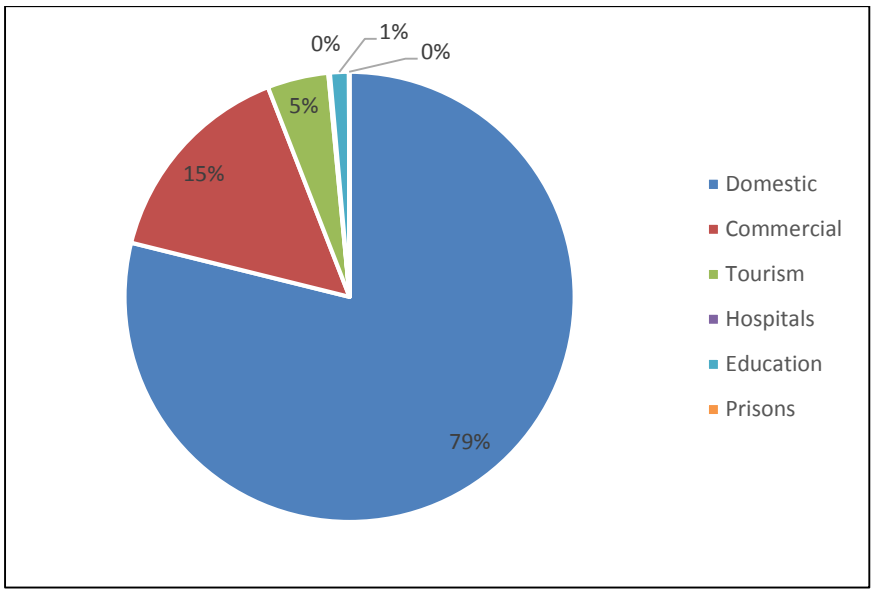
[18] Genty, *Developing an Evidence Base for EU Product Policy Instruments on Toilets*.
[19] http://www.bathroom-association.org.uk/images/editor/Brochures_and_Fact_Sheets/trendsreport13.pdf
[20] http://www.waterwise.org.uk/pages/indoors.html#2
[21] EST, At home with water, 2014

Figure 6 Breakdown of water use in the home (recreated from EST '*At home with water*', 2014)



Market and stock data for toilets across Europe was found to be relatively limited according to a study undertaken for the European Union[22]. As a result a spreadsheet model was developed to cover both domestic and non-domestic markets using EU official statistics, stakeholder responses to a questionnaire, and other relevant studies, guides and regulations. The estimate of toilet stock in 2011 across domestic, commercial, tourism, hospitals, education and prison sectors for the UK is illustrated in Figure 7. The results suggest that 79%, or around 35 million toilets, are located in the domestic sector followed by 15% in the commercial sector and 5% in the tourism sector.

Figure 7 Estimated toilet stock for the UK across industry sectors

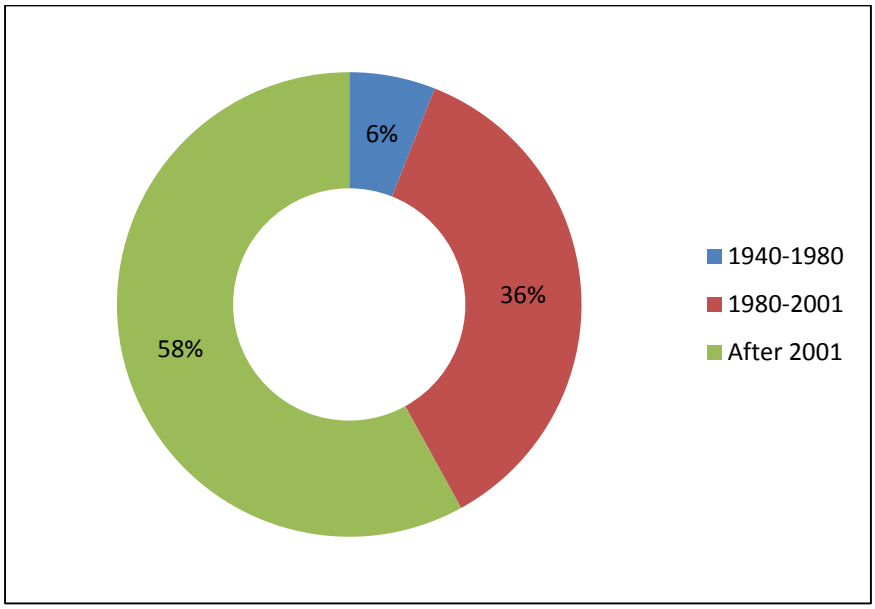


It is now estimated that there are around 45 million WCs in UK homes[20] with the majority of the existing stock with maximum flush volumes at 6 litres or below. The UK Government estimates that 7 million WC systems in households across the UK still use 13 litres of water per flush, and the UK BMA quotes

[22] AEA and IPTS, *Developing an Evidence Base on Toilets and Urinals Task 2 and Task 3*. AEA and IPTS, *Developing an Evidence Base on Toilets and Urinals Task 2 and Task 3*, accessed January 13, 2014, http://susproc.jrc.ec.europa.eu/toilets/docs/Tasks2&3_Report_Draft_oct11.pdf.

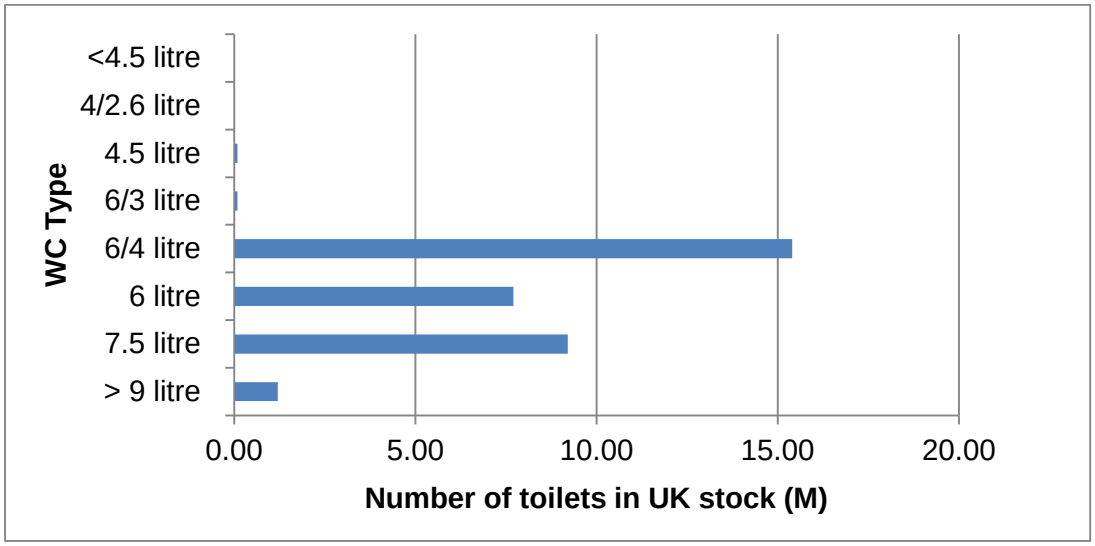
a figure of 11 million WC suites that flush over 6 litres of water[19]. However, these may underestimate the proportion of the existing housing stock with older WCs present as the EST study suggests around 42% of WCs in UK households were manufactured before 2001 (Figure 8) with around 17% having a cistern displacement device installed to reduce the flush volume[21].

Figure 8 Manufacture of existing WC stock (recreated from EST '*At home with water*', 2013)



According to modelling undertaken by the MTP in 2010 around 46% of toilets in the UK were 6/4 litre dual flush. The remainder were single flush WCs with only a small percentage of lower flush volume products installed at that time (Figure 9). By 2015, the model predicted a major shift in sales towards more efficient options. Again this is also supported by the findings of the EST study which identified around 41% of homes have a dual flush WC[21].

Figure 9 Number of WC in UK stock as modelled by MTP in 2010[23]



The typically long service life of WCs (around 15 years) means that most are likely to be replaced for reasons of style rather than failure. However, population growth and demographic changes (including a higher proportion of single occupancy households) are driving the development of new homes. At the same time the average number of WCs installed in new housing is predicted to rise from 1.4 in 2010, to 1.46 in 2030 as greater property ownership is driving a move towards second bathrooms and

[23] MTP BNWAT01 WCs: market projections and product details, 2011

cloakrooms - currently all homes in England and Wales have at least one indoor WC and 70% of new homes have two or more WCs[23].

As new homes continue to be built and people replace their bathroom fittings the size of the market for WCs in England and Wales is set to increase. In 2010 around 2.4 million WCs were sold into the UK market and it is predicted that this will rise to over 3 million per annum by 2030[23]. MTP stock models also forecast that by 2020 around 97% of the WCs in operation in domestic properties will flush 6 litres or less[23]. It is important to note that while the number of WCs is not likely to affect genuine usage - as it is people that use water not the WC - it does increase the potential for leakage which affects all water companies. WC leaks can often go unnoticed by the customer for long periods particularly as they have little impact on the customer bill. However, while WC leakage is 'technically' beyond the customer water meter it further contributes to the water companies' PCC figures.

2.1.4 Previous research on leaking toilets

2.1.4.1 UK

The objective of the 2012 Leaky Loos Phase I research was to: derive an estimate for the water efficiency targets, set by Ofwat, based on average water savings per toilet fixed (from the detection and repair of a leaking toilet); provide an assessment of the scale of the problem; and, to discuss the likely causes and solutions. This included a call for data from water companies, manufacturers and plumbing retailers, regulators, professional bodies and institutions. Based on water company data from household customer visits as a result of high consumption queries and visits by their water regulations teams an initial statistical analysis of leakage volumes was undertaken. To identify the scale of the problem questionnaires were sent within two water company areas (response rates of 18% and 21%) along with assessment of data from water regulations visits[1].

The investigation concluded that wastage from leaking toilets represents a significant volume of water wastage. It recommended that 400 litres/toilet/day should be used to estimate the losses that should be claimed against the water efficiency target when a leaking toilet is detected and repaired.

Data derived from questionnaires showed that approximately 10% of toilets were found to be leaking; and that both dual and siphon types of flush mechanism are at risk of failing. This led to an estimate that in the UK every day about 1.8 billion litres of treated water could be wasted because of leakage from toilets. The study did not collate empirical evidence on the specific causes of leaking WCs; although a diverse range of problems and attributed causes were described. It identified that failing toilet flush valves, inlet valves, seals, and improper cistern set up leading to over-filling and over flushing might all be significant.

It is therefore estimated that leakage (or rather wastage) from WCs can represent a significant proportion of average per capita consumption (PCC) and if more attention to the repair and prevention of leaking toilets was made then this could form a significant part of a strategy to reduce PCC.

A second stage in the research was identified as being required to clarify the issues relating to the cause of water wastage from toilets, to improve the estimate of the volume of wastage and identify practical solutions for the existing stock of WCs.

As outlined in the Leaky Loos Phase 1 previous work also includes a 2007 investigation by AEA Technology through the Market Transformation Programme into anecdotal evidence that WC valve flushing mechanisms were leaking and therefore leading to large volumes of wasted water. All water companies in England were contacted for information and plumbers were encouraged to share their experiences of the issue with the MTP. The issue was also discussed at the National Water Conservation Group meeting held in October 2007. While this identified leakage from toilet valves as a problem there was insufficient data to estimate the scale or volume. However others have suggested a range of causes, including[5]:

- Swarf or scale on the valve seat
- Poor seating of valve due to incorrect installation
- Poor seating of valve due to distortion of plastic cisterns during installation
- Jamming of valve mechanism due to lime scale deposits
- Partial opening of the valve due to incorrect adjustment or assembly of button mechanisms
- Cracked plastic components
- Accidental damage caused by curious plumbers and DIY enthusiasts

2.1.4.2 Australia

The issue of leakage/ wastage from toilets has also been highlighted in Australian end-use or micro-component analysis studies. A review of opportunities for more efficient toilets suggested leakage from toilets makes a significant contribution to total household leaks but was not modelled as it would only affect predicted water savings if new toilet models leaked at different rates to existing toilet models[24]. The end use study for South East Queensland identified a strong correlation between leakage and toilet water consumption for all regions. In some instances this was found to account for almost 50% of total water use when investigated further through water audits and trace analysis. They identified the need for further investigation and to promote maintenance and inspection on toilet fixtures as the next step after addressing the "dual flush toilet question"[25]. Toilet leakage was partly discounted in the Melbourne end-use study, although average flushes of 5 or 6 litres compared with installed 4.5/3 litre flush toilets also suggested potential leakage[26].

A pilot study carried out by Britton et al, 2008 in Queensland looked at identifying household water leakage in residential properties located within a selected district metered area (DMA). Results of the study include a water use profile of the metered residential properties, the types of leaks encountered and the cost of leak repairs. The initial start of the program found that 2% of the meters accounted for 24% of the night time consumption. This study provides evidence that automated meter reading technology can quantify water leakage beyond the meter. The research identified seven major types of leaks, toilet leaks represented 46% of the total.

The household leaks were identified in two ways, either via an alarm which is picked up during the meter reading process or by carrying out a review of the profile read when data was exported in to their software. Out of the 47 houses that detected a leak, 21 toilets were leaking; five properties were experiencing leaks in more than one toilet. It was also reported that a 'hiss' could be heard upon entering many of the homes.

Leaks occurred in both the old single flush and the newer efficient models (Table 3). There were 8 dual flush toilets with cistern size 6/3 litres, leaking in the range of 13.3 litres per hour to 343 litres per hour. The size of the larger leak was a result of a stuck full-flush toilet button in an empty rental property. The owner was notified and turned the water off until it was repaired; this leak ran for 18 days.

There were 5 leaks identified in dual flush toilets with a cistern size of 9/4.5 litres: the range of flow rates was 13.3 litres per hour to 35.6 litres per hour. There were also 8 leaks in single flush toilets, for which the flow rates ranged from 12.2 litres per hour to 38.9 litres per hour, the cistern sizes for these ranged from 11 - 15 litres capacity. It was reported that the majority of toilet leaks were caused by failure of the 'top valve' in the cylindrical control units in the cisterns[27].

Table 3 Average leak flow rates according to toilet type

Toilet Type	Min Flow/Hour	Max Flow/Hour	Average Flow/Hour
6/3	13.3	343	16.7
9/4.5	13.3	35.6	20
Single	12.2	38.9	19.4

2.1.4.3 USA

The issue of wastage has also been identified within studies in the USA on flapper valves. The key issue of the effect of chlorine cleaning products on flapper valve seals was highlighted. The need to insist on flapper durability to protect savings from water efficient toilets was also presented, however the costs and benefits of a replacement programme required further consideration[28].

WaterSense is a U.S. Environmental Protection Agency (EPA) program launched in 2006 to encourage water efficiency in the United States through the use of a special label on consumer products. WaterSense is a voluntary program with specifications for water efficient products through a public process. If the product meets the requirements then the manufacturer can use a label making it easier for consumers to differentiate among products that use less water.

[24] Schlunke, Lewis, and Fane, *Analysis of Australian Opportunities for More Water-Efficient Toilets*.
[25] Beal, Stewart, and Huang, 'South East Queensland Residential End Use Study'.
[26] Redland, *Melbourne Residential Water End Uses Winter 2010/ Summer 2012*.
[27] 'Remote Diagnosis of Leakage in Residential Households'.
[28] Koeller & Company, *Toiley Flapper Study: Final Report*.

In 2012, EPA carried out promotional and educational events across America and virtual events across the Internet, all focused on encouraging Americans to find and fix household leaks. The 'Fix a Leak Week' 2012 also gathered significant media coverage with over 500 broadcasts, articles, blog posts and twitter.[29]

2.1.5 Government intervention and water reduction programmes

Section 81 of the Water Act 2003 introduced a duty on the Secretary of State to encourage water conservation. Since then the Government has adopted a twin-track approach to water supply and demand whereby it expects the water companies to assess the full range of options for reducing demand. Where demand measures are insufficient or unjustified in terms of cost new supply measures should also be progressed with the water company finding a cost effective balance of measures to suit its circumstances.

As a result, in 2005 the UK Environment Minister's Water Saving Group (WSG) was set up to drive water efficiency in homes in England[30]. The WSG brought together a range of water industry bodies including Ofwat, the Environment Agency, the Consumer Council for Water, Defra, Water UK, Department for Communities and Local Government, and Waterwise. The overarching aim of the Group was to reduce per capita consumption in households and members agreed to work together on a package of measures.

There was recognition that a significant amount of water efficiency activity was occurring within the water industry. However, few of the projects were sufficiently detailed to provide the evidence needed to undertake further large-scale water efficiency programmes. Therefore it was agreed that an in-depth analysis of those projects with larger sample sizes was necessary in order to establish an evidence base that could support the development of water demand management measures as resource options in their own right. For this Waterwise undertook a year-long examination of domestic water efficiency projects that had been or were being led by water companies. The final output was the Evidence Base for *Large-scale Water Efficiency in Homes* report[31], which included an analysis of several water company projects and scenarios for possible cost-effective, large-scale water efficiency programmes. While the report identified WC flushing as the single largest single water use in the home WC leakage was not considered or identified as an issue.

Since then Waterwise has continued to develop the evidence base with Phase II concluding in April 2011 and contributed further to the body of evidence built up for retrofitting in both homes and schools. Phase III has focused on defining smaller, discrete projects that are scoped and delivered on an annual basis, incorporating formal peer review.

Surprisingly there is little reference to WC leakage in the Waterwise Evidence Base[32]. However, there has been a significant amount of work undertaken by the water industry either directly or indirectly aimed at reducing household customer demand through reducing WC wastage (through reducing flush volumes and identifying potential leaks). These range from the provision of information and advice, through leaflets and online tools and materials, to free product giveaways (e.g. cistern displacement devices), and large scale communications and action programmes (e.g. home visit surveys and audits).

An overview of the data and information provided from water company initiatives such as home survey programmes, AMR and meter installation programmes and general high consumption queries, regarding WC leakage is provided in Section 3 of this report.

Other milestone initiatives that were championed by the Water Savings Group included:

- The introduction of regulations allowing water companies in areas of serious water stress to consider compulsory water metering as part of their water resource management plans;
- The development of proposals for mandatory water efficiency targets for each water company from 2010;
- Options for a product labelling scheme.

[29] http://www3.epa.gov/watersense/our_water/fix-a-leak_2012.html
[30] http://webarchive.nationalarchives.gov.uk/20130123162956/http:/www.defra.gov.uk/news/2007/071129b.htm
[31] Waterwise, Evidence base for large scale water efficiency in homes, 2008
[32] http://www.waterwise.org.uk/pages/evidence-base.html

The Water Act 2003 also placed a duty for Government to report to Parliament every three years on the steps and measures taken and those proposed for the future to further water conservation[33]. Since then two reports on the action taken by Government to encourage the conservation of water have been published covering the periods 2004 to 2008 and 2010 to 2013[34,35]. The reports specifically focus on the work undertaken across a number of key areas including household behaviour, homes and communities, products and non-household consumption and cover a range of issues.

2.1.5.1 Customer metering

In the context of WC leakage it is important to reflect on the levels of customer metering. In the UK most of the water companies offer a choice to customers regarding water metering. However, in water stressed areas such as the South and South East of England the water companies have the option to develop compulsory water metering programmes as a way of managing demand in these areas. This combined with the fact that all new properties are now metered has resulted in an increase in the average level water metering across the country from 30% in 2008[36], to 46% in 2014[37], with levels now as high as 75% in some regions[38].

While there is little specific research on the impact of metering on WC leakage there is anecdotal evidence from water company programmes that metering can be a useful tool in identifying customer side leakage particularly in identifying night- or continuous-flows. In Wessex Water's trial of alternative charging structures and smart metering they highlighted that "*Unmetered customers are far more likely to have long periods of low level continuous-use indicating problems like dripping taps and leaking toilet cisterns…*[39]*".* Further to this many water companies use customer meter data to identify instances or periods of 'high consumption' which can then be followed up directly with the customer (see Section 3). In these instances metering is useful in identifying potential WC leakage however, is important to note that even in metered properties low level or intermittent WC leaks can often go unnoticed for a good period of time.

2.1.5.2 Labelling and standards for toilets

There are a number of product standards and labels currently available for WC suites and flushing devices. An overview of these is provided below.

European Standards (BS EN 997:2012 and EN 14055: 2010)
There are two current European Standards relating to WC's and WC flushing cisterns:

- BS EN 997:20123 - WC pans and WC suites with integral trap; and,
- EN 14055:2010 - WC and urinal flushing cisterns

As a minimum products on the European market must comply with EN 997:2012. This standard has the status of a British Standard. EN997:2012 outlines the requirements for WCs from the perspective of construction and performance, emphasising functional criteria. Two classes of WC are identified within the standard:

- Class 1 covers suites for sale in mainland Europe, and a number of the tests are different from the UK requirements. A nominal flush volume of 4, 5, 6, 7 or 9 litres is specified.
- Class 2 covers WCs sold in the UK. A maximum flush volume of 6 litres for single flush WCs and a reduced flush no greater than two-thirds of this volume for dual-flush WCs is specified.

Both Class 1 and Class 2 products are subject physical endurance and leakage tests to ensure leak tightness of the cistern and flushing mechanism.

EN 14055:2010 specifies design, performance requirements and the test methods for WC and urinal flushing cisterns with flushing mechanism, inlet valve and overflow.

European Ecolabel
The EU Ecolabel helps consumers to identify products and services that have a reduced environmental impact throughout their life cycle, from the extraction of raw material through to production, use and

[33] http://www.legislation.gov.uk/ukpga/2003/37/contents
[34] Defra, Action taken by Government to encourage the conservation of water, April 2004 – March 2008, 2008
[35] Defra, Action taken by Government to encourage the conservation of water: Progress report to Parliament on the steps taken to encourage the conservation of water as required by Section 81 of the Water Act 2003, 2014
[36] Defra, Future Water, 2008
[37] http://utilityweek.co.uk/news/a-smart-move-for -water/975152#.VhOLc54tCUk
[38] Southern Water's metering programme leaflet.
[39] Towards sustainable water charging; Interim findings from Wessex Water's trail of alternative charging structures and smart metering, 2011

disposal phases. Recognised throughout Europe, EU Ecolabel is a voluntary label promoting environmental excellence which can be trusted.

From October 2013 the Eco-label was extended to cover flushing toilets and urinals, based on the amount of water that they use to flush. The primary goal of establishing EU Ecolabel and Green Public Procurement (GPP) criteria for flushing toilets and urinals is to increase their water efficiency during operation, as water consumption in the use phase has been identified to contribute most to the environmental impact caused by this product group[40]. A study overseen by the Commission's Joint Research Centre estimates that the cumulative savings for households alone across the EU would exceed £330 million with only 10% market penetration for eco-label toilets. If the eco-label had a 20% market penetration, that figure would potentially double, saving roughly £140 million in the UK alone, including non-household users[22].

WC leakage or wastage was also identified as a key issue in developing the Ecolabel Criteria. This identified the need for emphasis on exchanging worn parts and preventing leakage. Leakage was considered in developing the warranty criterion, however this was found to be covered under normal warranty terms and not included in the Ecolabel requirements[41]. The testing criteria for the Ecolabel requires products to be tested as detailed in EN 997: 2012, EN 14055: 2010 and European national law.

EU Water Label

The EU Water Label[42] is a voluntary labelling scheme which provides comparative information on the water consumption of bathroom products (including WCs, WC suites and replacement WC flushing devices) to help inform consumer purchase decisions and to encourage the purchase of more water-efficient products. As a result the scheme aims to improve the performance and water consumption of bathroom products and accessories. It sets harmonised water flow requirements conforming to legal national requirements through a system of self-declaration. The Label was developed by the UK Bathroom Manufacturers Association and has gained widespread support across Europe following its adoption in Europe in 2012.

It is a prerequisite of the Scheme that WC suites and their internal components shall satisfy all Regulatory requirements of the intended country of destination. For example, only Class 2 products will be able to be listed for the UK market as this requirement is covered by UK Water Regulations. Products (WC suites) are verified (flush volume tested) in accordance with the details in EN 997: 2012 for the relevant Class.

To ensure durability and effectiveness of the flush replacement devices must comply with the appropriate requirements of the Regulator's specification for WC suites (for UK) and any other legal National Requirements of the country of destination. This includes physical endurance and leakage testing.

Water Technology List

The Enhanced Capital Allowance (ECA) scheme offers a 100% first-year allowance for investments in certain water efficient plant and machinery. The ECA water scheme includes a variety of technologies, including water efficient toilets and retrofit flushing devices, all of which have met a water saving criteria. Eligible products are detailed on the Water Technology List (WTL).[43] Eligible products must meet the following physical and endurance and leakage requirements:

'*When tested as described in Clause 9 of the Regulators' Specification, the flushing device shall not undergo any failure or permanent distortion of any components including linkages that prevents normal operation of the mechanism. In addition, no instances of leakage are permitted. A leak is defined as being visible discharge of water amounting to more than 3 separate drops.*

Compliance may be demonstrated by WRAS approval (* or other independent test laboratory accredited to ISO 1702 5). Alternatively companies accredited to ISO 9001 may provide a declaration of self-conformity with the Regulations'*.

The Regulators Specification requires flush valves to be tested for leakage through 200,000 flush cycles. However, stakeholders remain concerned about the long-term durability of modern valve

[40] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/development-eu-ecolabel-and-gpp-criteria-flushing-toilets-and-urinals-technical-report
[41] Aurélien Genty, Malgorzata Kowalska, Oliver Wolf Development of EU Ecolabel and GPP Criteria for Flushing Toilets and Urinals - Technical Report,2013
[42] http://www.europeanwaterlabel.eu/
[43] Http://www.watertechnologylist.co.uk

flushing devices. WC testing should address this and either recognise or refute these concerns. Testing results should be shared and if appropriate could be used to influence design and manufacture.

Water Efficiency Labelling Scheme Australia

WELS is Australia's water efficiency labelling scheme that requires certain products to be registered and labelled in terms of water efficiency in accordance with the standard set under the national Water Efficiency Labelling and Standards Act 2005.

The WELS Regulator was established under the Water Efficiency Labelling and Standards Act 2005. The regulator is responsible for monitoring and enforcing the WELS Scheme and is committed to ensuring the integrity and credibility of the scheme. The WELS team is located within the Environment Quality Division in the Department of the Environment.

The minimum water efficiency standard for toilets means that you cannot supply toilets that have a higher average flush volume of 5.5 litres. Toilets are tested for their performance in discharging material at full and reduced flush, leakage and splashing, physical distortion, and the endurance of inlet and outlet cistern valves[44]. The Department of the Environment carried out analysis of Australian opportunities for more water-efficient toilets however toilet leakage was not taken into account[45].

2.1.5.3 WC rebate programmes

To encourage the move towards more water efficient practices and products rebate programmes have been successfully implemented in a number of countries. For example the City of San Diego (US) offers rebates for water butts, efficient irrigation equipment and even drought tolerant grass[46] and in Western Australia a free showerhead swap program is being offered to residents in the town of Denham[47].

In recognition of the high volume of water wasted through flushing of old inefficient WCs rebate programmes have been successfully extended to the replacement of WCs in the existing housing stock in many parts of the USA[48]. For example in Arizona a rebate of up to $75 is offered to replace a high water use toilet with a low flow toilet[49] and in California $150 is offered on a high efficiency WaterSense certified WC[50]. In Australia, Customers of Yarra Valley, South East Water, and City West Water can replace their old single flush toilet with a 4 star dual flush toilet, including installation for around $299[51].

In the UK the Government estimates that 7 million WC systems in households across the UK still use 13 litres of water per flush, and the UK Bathroom Manufacturers Association (BMA) quotes a figure of 11 million WC suites that flush over 6 litres of water[19]. This has led to a call for the introduction of a WC 'scrappage' scheme from the BMA who state that "…*if an old inefficient 13 litre pan is replaced with a modern eco-friendly product, flushing with an average 3 litres each household can potentially save an annual 50,000 litres"*[52].

While rebate schemes do not address the issue of WC leakage the replacement of the existing high flush volume WCs, containing older flushing mechanisms, with new low flush products could bring about a reduction in leakage which is caused by the failure of the older parts and mechanisms in these WCs. However, there is currently no evidence to support this hypothesis.

[44] 'Water Efficiency Labelling and Standards (WELS) Scheme'.
[45] 'Analysis of Australian Opportunities for More Water-Efficient Toilets- Water-Efficient-Toilets.pdf'.
[46] http://www.sandiego.gov/water/conservation/rebates/index.shtml
[47] http://www.watercorporation.com.au/home/faqs/saving-water/~/link.aspx?_id=0926090583B84EFBA31C9EA3B4ABE29E&_z=z
[48] http://www3.epa.gov/watersense/rebate_finder_saving_money_water.html
[49] http://waterawarenessmonth.com/rebates.html
[50] http://www.saveourwaterrebates.com/toilet-rebates.html
[51] http://www.dualflush.com.au/index.php
[52] http://www.wholebuild.co.uk/building-product/bathrooms-wash-rooms-and-toilets/news/call-for-toilet-scrappage-scheme

3 Water company data sets

Data and information from previous water company initiatives such as home survey programmes, AMR and meter installation programmes and general high consumption queries regarding WC leakage was provided as outlined in Table 4. These also included extracts of information shared for Phase I of the Leaky Loos project.

Table 4 Data provided by water companies for initial analysis

Company	Datasets received
Affinity Water	High consumption and leakage data from 2011 to 2014
United Utilities	Leaky loos with postcode – data on repairs AMR leak data and high consumption from Warrington area
South East Water	Summary data provided for Leaky Loos Phase I study Identified fixed leaks spreadsheet additional analysis from Phase I of fixed leaks identified in survey Waterlink work spreadsheet with data on leaking toilets from customer metering programmes
Sutton and East Surrey Water	Leaky Loos Survey Feedback Data from Leaky Loos Phase study
Thames Water	Green doctor project Greenwich Leaky loos (Swindon, London, Reading), survey, uptake rates, spreadsheet with results
Other water companies	No data provided to date.

Each dataset was analysed to draw out the key findings and results in relation to WC leakage. A summary of the analysis undertaken is provided in Appendix 1. Although each water company provided very different datasets some comparisons can be made. Table 5 provides a summary of comparative data for all water company datasets analysed.

Table 5 Summary of analysis of water company datasets

	Affinity Water	United Utilities	South East Water	Thames Water	Sutton and East Surrey Water
Data summary	Leakage allowance data (high consumption)	Smart metering data on leak repairs from 'Homeserve' visits.	Data from customer metering programme – QA and high consumption visits	Leaky Loos data (Swindon and Reading)	Internal WC leakage repairs and High consumption queries
Period	2011-2014	2102-2014	2013-2014	2012-2013	2010
Count	779	11	169	46	12
Average leak volume (l/p/d)	841	325	751	ND	1,018
Median leak volume (l/p/d)	589	193	510	ND	765
Confidence level (95%)	72	ND	164	ND	626
Run time (days)	ND	16 - 350	ND	ND	ND
Percentage leakage (%)	ND	ND	5%	6% Greenwich Green Doctor	7% based on high consumption queries
Location of leak	ND	WC cistern (90%) WC pan (10%)	ND	Siphon (47%) Inlet valve (33%)	ND
Cause of leak	ND	ND	ND	Mechanical (36%) Washer (25%)	ND

*ND – Not determined

The percentage of leaking toilets across these initiatives ranges from 5 to 7% with average leakage rates between 325 and 1,018 litres / toilet / day. However, the average leakage rates are impacted by a small number of large potential outliers which are linked with the wide 95% Confidence Intervals calculated for each dataset. In plotting these the datasets form a positively skewed distribution (see Appendix 1) as such the median leakage rates (193 to 765 litres / toilet / day) may be a better indication of overall leakage.

4 Physical investigation

The physical investigation approach was designed to:

- Refine our understanding of the quantity of water wastage and number of WC's leaking (scale of the issue) and identify if any particular groups of households are more likely to have leaking WCs; and,
- Identify in more detail the technical reasons for leaks occurring in domestic WCs.

To ensure a statistically robust approach to addressing the question "*what percentage of toilets leak and why do they leak?"* the physical investigation was undertaken in two phases. A random sample of toilets were investigated in the first phase to identify the potential scale of the problem and to test and refine the hypothesis that '10% of all WCs leak' as outlined in the Leaky Loos Phase I study[53]. While in the second phase a more targeted approach was adopted to investigate the range of leakage problems detected and causes behind these. By developing the approach through each phase a greater understanding of the most efficient methods of detecting and locating leaking WCs and how to improve the speed and rate of repair was gained.

4.1 Phase 1: Initial assessment of scale

As customers are often unaware of leaking toilets, water company high consumption queries and water regulations visits may not identify the correct amount of leakage. To confirm the percentage of WCs that leak and the reasons why they leak, it essential to investigate enough toilets so that sufficient data is provided for statistical analysis. The aim of phase 1 was to undertake an initial assessment of 100 homes using a random sample to support identification of the scale of the problem.

4.1.1 Recruitment

There are a number of issues that are associated with WC leakage (e.g. water hardness, pressure and water quality) so to ensure the analysis outputs are robust it was important to consider (and control) these variables. As such randomly selected properties from a defined geographical area (single water company region) were chosen for the study.

A random sample of 1,000 properties was identified from a larger customer dataset provided by United Utilities for the town of Warrington. The sample was selected using the random number generating function in MS Excel and matching the outputs against property reference numbers. The sample covered a range of variables including:

- Property type and age:
  - *Multi-residential, detached, semi-detached etc.*
  - *Occupancy levels*
- Metered and unmetered
- Owner occupied / tenanted
- Socio-economic classifications
  - *i.e. based on ACORN*

Previous research by Waterwise suggests that uptake of home retrofit and visits can range from 6-60%. Letters are generally the first method of contact and should include clear messaging with factors considered important by the target, the time of year and aims of the project[54].

However, to ensure that uptake was random and would not biased in any way towards customers with known leaking WCs the key recruitment message was broadened to offer a free home water check (water audit) to customers which included checking for WC leakage, rather than focussing specifically on the issue.

Based on an assumed uptake rate of 10% co-branded (United Utilities and Leakwise[55]) letters were distributed to the selected sample. Customer responses were collated and appointments booked via

[53] Artesia Consulting, Final Report on Leaky Toilets Project (2012) for consortium of eight water companies
[54] Waterwise, *Improving Uptake in Home Visit Retrofit Programmes*, 2012, Improving uptake in home visit retrofit programmes.
[55] Leakwise is a service developed by Aqualogic. The brand was used for managing the customer facing elements of the project i.e. website (www.leakwise.uk) and Helpline.

the project team's 'Aquaint' system[56]. The Aquaint system is based on the Guaranteed Service Standards (GSS) that applies to water companies and includes measures such as guaranteeing a half-day appointment slot with customers.

Following a very poor initial response rate (1.3%) further measures to increase uptake were put in place including follow up calls (691 customers contacted) and SMS text messaging (200 customers). In addition 637 new customers who were part of the original larger customer dataset were also contacted directly by telephone (cold called). However, these actions only generated just over a half of the responses required for this phase of the analysis. As such, the recruitment exercise was extended to Affinity Water customers in Luton. A random sample of a further 2,000 properties was identified and letters distributed to each customer as outlined above.

4.1.2 Phase 1 visits

The focus of the Phase 1 visits was a home water check covering all water using fittings located in property including:

- Showers.
- Bathroom taps.
- Kitchen taps.
- WCs.

The visits were undertaken by a qualified water efficiency technician/ engineer and typically took around 30 minutes. A range of free water saving devices and information including save-a-flush bags, shower and 'toothy' timers were offered during the visit.

A range of data was captured for the following key variables:

- Property data:
  - *Age of property*
  - *Occupancy*
  - *Retrofit or new build*
  - *Number of WCs*
- Meter reading (when present) and meter check to link with any smart metering data held.
- Water utility related conditions:
  - *Water hardness*
- Shower fitting related conditions:
  - *Shower type: electric, mixer power*
- Bathroom tap fitting related conditions:
  - *Quantity*
  - *Could they be retrofitted or aerated?*
- Kitchen tap fitting related conditions:
  - *Presence of washing up bowl*
  - *Presence of plug*
  - *Presence of dishwasher*
- WC fitting related conditions:
  - *Flush type: siphon, flush valve, flapper, solenoid valve, dual, single*
  - *Flush actuation: front level, side lever, pull chain, push button, electronic actuation*
  - *Cistern: size, flush pipe, close couple, high, concealed, direct flush (victory valve), internal condition*
  - *Fitting type and manufacturer (where possible): fill valve type, flush valve type*
  - *Overflow: internal or external*
  - *Installation: when and by whom (where possible)*
  - *Was cistern supplied with pan or separately*
- WC leakage identified:
  - *Was leak known about previously?*
  - *Cause of leak*
  - *Leak flow rate*
- Estimated flow (all fittings) measured using a flow cup or ultrasonic flow and cross checked with meter data.

[56] Aquaint is a web based system developed by Aqualogic and used for the management of customer data and appointments. The web portal also provides access to project data and information to staff in the field

Where WC leakage was identified the WC was subject to a failure report encompassing all the issues surrounding the leak cause. Information on leak type, estimated quantity or actual flow where possible, age, fitting type, and water supply area were also collated. A repair was then instigated.

4.1.3 Results

The aim of this phase was to conduct a physical investigation of 100 randomly-selected properties in total and to determine the proportion of toilets found to be leaking. In Warrington, 56 properties were investigated which included 89 toilets, five of which were found to have leaks. For Luton, 38 properties were investigated which included 56 toilets, only one of which was found to have a leak.

In total, 94 properties, with 145 WCs were included in the Phase 1 investigation. While this was still short of the 100 target it was deemed sufficient for the analysis.

Confidence intervals for leakage rates

The first stage of the analysis was to calculate the percentage of leaky toilets in the sample and create confidence intervals for the leak rate.

For this analysis each individual toilet is counted as an independent unit. This assumes that all toilets in the sample are independent, even toilets that are within the same house. It is important to note that this assumption has been made because the following analysis relies on the assumption that all observations are independent. The Phase 1 sample does not suggest that if one toilet in a house leaks, another toilet in that house is any more likely to leak although there is the potential (albeit slim) for customers to think that a dribble in the pan is 'normal' and thus would be less likely to take action if a second WC in the house did the same.

Table 6 summarises the leak rates observed in each sample, and also the leak rate for the Warrington and Luton samples combined. The 95% confidence intervals for the population leak rate are also summarised for each sample.

Table 6 Summary of leak rates in each sample

Sample	Size	Number leaks	Sample leak rate	95% confidence interval
Warrington	89	5	5.6%	(0.024, 0.125)
Luton	56	1	1.8%	(0.003, 0.094)
Combined	145	6	4.1%	(0.017, 0.089)

The most common method for calculating the confidence interval for a population proportion is called the Wald method. However, studies have shown that for relatively small sample sizes (n) and small sample proportions (p), the Wald method is inaccurate. Therefore, the 95% confidence interval for the population proportion, was based on the Wilson score interval as summarised in Figure 10. This approach is robust in cases where the observed sample proportion is quite small, which is certainly the case in this study.

Figure 10 Method for calculating a confidence interval based on the Wilson score interval

$$\frac{1}{1+\frac{1}{n}z^2}\left[\hat{p}+\frac{1}{2n}z^2 \pm z\sqrt{\frac{1}{n}\hat{p}\left(1-\hat{p}\right)+\frac{1}{4n^2}z^2}\right]$$

The interpretation of the confidence intervals is as follows: based on the Warrington sample, we can be 95% confident that the leak rate for the population as a whole is between 2.4% and 12.5%. In other words, we can be 95% confident that between 2.4% and 12.5% of toilets in Warrington are leaking.

Assuming the combined samples (for Warrington and Luton) are representative of England, the 95% confidence interval shows that we can be 95% confident that between 1.7% and 8.9% of toilets in England are leaking. However, the samples do provide some indication there might be regional variations; even so, there is significant overlap between the Warrington confidence interval and the Luton confidence interval, demonstrating that the variation could be minimal.

The 95% confidence intervals for the population leak rate based on the Phase 1 investigations are broadly in line with the water company data discussed in Section 3. The percentage of leaking toilets from those datasets ranges from 5% to 7%, values which are included in all the confidence intervals above. In addition, the Warrington confidence interval (2.4%, 12.5%) does include the 10% leak rate which was the original hypothesis of this study. The Luton sample, however, shows that it could be less than 10% in some regions.

Assuming the combined (Luton and Warrington) samples are representative of England we can be 95% confident that between **1.7% and 8.9% of toilets in England are leaking.** With leakage present in on **average 4.1% of all WCs**.

Causes of leaks

The Phase 1 investigations also provided data on a number of different factors for each house and toilet inspected (as outlined above). It was anticipated that this data could be used to begin to analyse which of these factors may be more likely to cause leakages in toilets. However, with such a small number of leaks observed (6 leaks out of 145 toilets), it is not possible to draw any firm conclusions. In considering the data, there are no clear correlations between toilets that leak and other factors such as the age of the house, the flush type or the fill valve type.

Because the dependent variable in this study can only take two values – leaking or not leaking, a logistic regression was used to further analyse which factors significantly contribute to leakage rates. Logistic regression is a flexible method to test the relationships between multiple quantitative and/or categorical variables and one binary categorical outcome, as in this study.

Figure 11 summarises the output from a logistic regression with Leak/Not Leaking as the dependent variable and the following independent variables – a binary variable for age of property (2000 or newer houses = 1), a binary variable for flush type (flush valve = 1), cistern size, and a binary variable for overflow (External = 1). A number of different regressions were undertaken using different combinations of these variables but none of them showed any clearly significant relationships between a factor and whether a toilet leaks. This is not surprising given the small number of leaks observed in the sample.

Figure 11 Summary of logistic regression analysis

	coeff b	*s.e.*	*Wald*	*p-value*	*exp(b)*
Intercept	-15.9222	7.5109	4.4939	0.0340	0.0000
House built 2000 or more recently	3.7023	1.7576	4.4372	0.0352	40.5414
Flush type (Flush Valve =1)	1.0259	1.5612	0.4318	0.5111	2.7897
WC Cistern Size	1.7501	1.0430	2.8158	0.0933	5.7553
Overflow (External = 1)	0.2781	1.5585	0.0318	0.8584	1.3206

One factor that does look possibly significant is the factor for whether a house was built in 2000 or more recently. With a p-value of 0.0352 there is some evidence that newer properties are more likely to have toilets that leak. However, only one property (with 3 toilets) in the Phase 1 sample was built after 2000 so the sample is too small to draw any definite conclusions. Further analysis of this and other factors are presented in the Phase 2 investigation which focuses specifically on toilets which are known to be leaking.

4.2 Phase 2: Investigation into leakage types and causes

The objective for Phase 2 was a more targeted investigation of a larger number (300) of toilets known to be leaking such that the types of leakage and causes behind these could be identified. Furthermore once the cause of the WC leak had been established for a repair to be undertaken. While this phase of the investigation was not completely random the findings can be used to support the outcomes from Phase 1 regarding the scale of leakage.

4.2.1 Recruitment

The main recruitment strategy adopted for Phase 2 was based on 'piggy-backing' on existing water company initiatives which have identified, or aim to identify, potential customer WC leakage. These included:

- United Utilities: Home visit programme (Cumbria),
- United Utilities: Cheating Loo campaign (Oldham),
- Affinity Water: High consumption / 400 letters with leak strips (Watford),
- Thames Water: Home visit campaign (Greenwich),
- Sutton and East Surrey Water: Home visit programme (Stoneleigh, Ewell) plus high consumption queries.

The details of customers identified as having leaking WCs were passed directly into the project team to make contact and to schedule an appointment for the leak to be repaired.

It was anticipated that from these programmes alone around 300 leaking WCs would be identified for investigation. However, it soon became apparent that this initial tranche of activities were not going to generate the number of WCs required. Further to this delays were also experienced in gaining internal approvals on customer communications from some of the water companies.

In order to identify additional leaking WCs 9,000 customers across three water company regions (Affinity Water, Sutton and East Surrey Water and United Utilities) were further targeted through the provision and use of leakage detection strips. Leak strips are placed by the householder at the back of the WC toilet pan in order to detect the presence of water flow. These are preferable to dye blocks as the user does not need to remove the cistern lid and therefore reducing the potential to cause additional leaks (tampering by plumbers or DIY enthusiasts has been previously identified as a potential cause of leaks). If a leak is present then the dye from the strip will run down the back of the pan and discolour the water in the pan. An explanation of how customers use the leak strip was provided in the accompanying letter.

In addition to generate further interest Sutton and East Surrey Water promoted the programme in their customer newsletter and Affinity Water targeted its employees providing leak strips to those that believed they might have a leak.

In a similar approach to Phase 1 all communications with customers were co-branded with the local water company and customers who identified a potential leak were requested to contact the project team so that an appointment to repair the leak could be scheduled. All appointments were entered and managed via the Aquaint system.

4.2.2 Phase 2 visits

All Phase 2 visits were undertaken by a qualified water efficiency technician/ engineer. As described above each WC visited was subject to a failure report encompassing all the issues surrounding the cause of the leak. This included:

- Data capture based on the key variables outlined above (Section 4.1.2)
- Meter reading and meter check to link with any smart metering data held.
- The frequency of each leak was recorded as being either ‘constant’ or ‘intermittent’ in nature.
- Estimated leakage rate measured using a flow cup or ultrasonic flow and cross checked with meter data.
- Repair of the leaking WC

All visit data was recorded and reported through the Aquaint system to enable further interrogation and statistical analysis.

4.2.3 Repair of leaking WCs

Once the cause of the WC leak was established a repair could be instigated. While the repair required is dependent on the type of WC and the cause of the leak four categories of repair were described for this study (Table 7).

Table 7 Categories of WC leak repair

Category	Description of WC	Likely fault	Recommended solution
A	• Siphon WC with a front mounted flush handle and a removable lid and cistern not close-coupled. Will have a 1.5" flush outlet. • Most cisterns of this nature are likely to be external over flows.	Failed fill valve	Replace fill valve and / associated parts
A.1	• Similar to Category A but where the cistern is close-coupled or the flush handle is mounted on the side of the WC and is press activated. An additional fitting kit is required if cistern needs to be split to replace siphon. An additional siphon type may also be required. • Will have a 1.5" flush outlet. • These cisterns may have an internal overflow.	Failed fill valve	Replace fill valve and / associated parts
B	• Valve WC with top mounted flush button. • Has a removable lid (albeit connected by the flush button) • Typically the flush valves will be dual flush. • Typically these cisterns will be close-coupled. • The flush valve will be rod connected on the whole but can be retrofitted with a cable valve. • Typically will have a 2" flush outlet and will be close coupled. • No disconnection of the pan from the soil pipe/wall/floor is required to service the cistern.	Flush valve	Replace flush valve mechanism (in some cases the fill valve will also need replacing)
C (Concealed, specialist or unknown)	Could be pneumatically operated. Could be cistern with no lid or concealed in wall. Could be Category A or B but restricted by other fixtures, tiles etc.	Flush valve	Survey to identify the appropriate repair.

Where the repair could not be undertaken on the same day as the inspection for example, due to part availability or access (e.g. for Category C repairs) a date for a return visit was agreed with the customer.

4.2.4 Results

The aim of the Phase 2 investigation was to provide a more targeted investigation of a larger number of leaking toilets to identify the types of leakage and causes behind these. However, identifying leaking WCs was a significant challenge – in around 30% of the visits undertaken no leak could be identified as the customer had already fixed it or it was not leaking at the time of the visit.

Ultimately, the physical investigation of 172 properties took place during Phase 2 of the study, which included 322 separate toilets. The results of these investigations were combined with the investigations of Phase 1, resulting in a total of 467 toilets to include in the Phase 2 analysis. Table 8 summarises the findings for each water company. Of the 467 toilets investigated in this study, only 138 were found to be leaking. Leakage was confirmed through the visible flow of water either through the external overflow pipe (10%) or internal flow (90%) into the WC pan with just under three quarters (73%) of leaks classified as being constant in flow frequency (as opposed to intermittent).

Table 8 Summary of Phase 1 and Phase 2 data

	Water company		Property details									Is the WC leaking?	Total leakage rate (l/day)	Average leakage rate (l/day)
		Sample size	Metered	Owner occupier	Property age									
					<1900	1900-1920	1920-1940	1940-1970	1970-2000	2000-2010	New build			
Phase 1	United Utilities (Warrington)	89	62	79	0	5	10	10	61	3	0	5	130	26
			70%	89%	0%	6%	11%	11%	69%	3%	0%	6%		
	Affinity Water (Luton)	56	49	46	3	0	16	15	16	2	4	1	2	2
			88%	82%	5%	0%	29%	27%	29%	4%	2%	2%		
Phase 2	United Utilities (Cumbria)	34	16	28	2	1	2	7	6	0	16	8	270	34
			47%	82%	6%	3%	6%	21%	18%	0%	47%	24%		
	United Utilities (Oldham)	9	9	8	0	0	0	4	1	0	4	5	413	83
			100%	89%	0%	0%	0%	44%	11%	0%	44%	56%		
	United Utilities (Leak strips)	28	23	26	0	0	1	5	19	3	0	16	9,558	597
			82%	93%	0%	0%	4%	18%	68%	11%	0%	57%		
	Affinity Water (High consumption/Leak strips /Employee)	91	70	86	0	1	26	27	19	12	6	38	12,348	325
			77%	95%	0%	1%	29%	30%	21%	13%	7%	42%		
	Sutton and East Surrey Water (Leak strips / home visit/ Newsletter)	106	48	101	0	0	72	16	9	8	1	40	2,998	75
			45%	95%	0%	0%	68%	15%	8%	8%	1%	38%		
	Thames Water (Home visits)	54	43	37	0	1	5	2	13	25	8	25	3,941	158
			80%	69%	0%	2%	9%	4%	24%	46%	15%	46%		
	Total	**467**	**320**	**411**	**5**	**8**	**132**	**86**	**144**	**53**	**39**	**138**	**29,660**	**215**
			69%	**88%**	**1%**	**2%**	**28%**	**18%**	**31%**	**11%**	**8%**	**30%**		

4.2.4.1 Statistical analysis

The primary aims of the Phase 2 investigation were to identify if any particular groups of households are more likely to have leaking WCs and also to identify in more detail the technical reasons for leaks occurring in domestic WCs. A number of analyses were conducted to investigate both these issues but the categorical nature of the data limits the type of statistical analysis possible – the techniques described in the sections below are appropriate for the size of the sample and the type of data collected.

Descriptive statistics & summary tables: Where relevant, the distribution of data, the mean, median, and skewness of the data have been considered. This was particularly useful when looking at the range of leak rates found in this study. Basic summary tables have been used as they are useful for illustrating the differences in leak rates across different types of WCs.

Correlation coefficients: The relationships between all the variables were first investigated using correlation coefficients to determine whether any of the variables were significantly correlated. Correlation coefficients are a simple measure which quantify the degree of association between two variables. The correlation coefficients were a useful first step, but their use with binary data such as that collected in this study was limited.

Chi-square tests: Chi-square tests have been undertaken where the proportion of leaking toilets with a particular characteristics is noticeably different from the proportion of non-leaking toilets with that characteristic. The rationale behind the Chi-square test is that if the two variables are not related (i.e. flush valves are not related to whether or not a toilet leaks) then roughly the same proportion of leaking and non-leaking toilets that have flush valves should be observed. If the difference between the two proportions is very large, then it can be concluded that there is some association between the two variables. The Chi-square statistic is based on the difference between observed frequencies and the expected frequencies - the chi-square test compares the observed data in each cell with the expected result if the null hypothesis was true (i.e. if the proportion of leaking and non-leaking toilets with flush valves was the same). For this study the Pearson's chi-square test was used which is suitable for data in which all observations are independent and the categories are mutually exclusive and exhaustive.

4.2.4.2 Assumptions & Limitations

Given the size of the Phase 2 dataset, the type of data collected, and the way the data was collected, the following assumptions and limitations of the analysis should be noted.

- The analysis relies on the assumption that each unit (toilet) is independent from each other. Because many of the houses investigated in this study had more than one toilet, an assumption that all toilets included in this study are independent from each other has been made. This means it is assumed that the probability that the second toilet in a household is leaking does not change even if the first toilet investigated in the same house is leaking. Of the 266 households investigated in this study, only ten were found to have more than one leaking toilet. This represents less than 4% of the total sample, which is sufficiently small to conclude that the assumption has not been violated.
- A number of different methods were used for measuring the leak rates of the toilets. We have assumed that all the methods are equivalent and result in accurate estimates of the leak rates.
- Due to the nature of the study, the majority of data collected was categorical or even binary, rather than numerical data. For example, data was recorded on the different toilet characteristics, such as whether each toilet had a flush valve or a siphon. The categorical nature of the data limits the type of statistical analysis possible – the techniques described in the sections below are appropriate for the size of the sample and the type of data collected.
- The methodology used for selecting households to be investigated for this study differed depending on what made sense and was possible for each water company. Some water companies selected households based on high consumption data; some recruited participants via email; some used other methods. The different approaches to recruiting participant's means that the data for each water company summarised in Table 8 are not directly comparable.
- The data for Phase 1 was collected at random in order to test the hypothesis that 10% of toilets in the UK are leaking. In contrast, Phase 2 targeted houses expected to have a leaking toilet in order to investigate the causes and extent of the leaks. For this reason, the leak rate for Phase 2 is not surprisingly much higher than the leak rate found in Phase 1. The majority of toilets investigated in Phase 2 that were not leaking were the second or third toilets in houses which did have one leaking toilet.

- All the data collected for this study has been formatted and analysed as accurately as possible and subject to QA checks. Due to the nature of the study, a certain amount human error is still possible, especially in interpreting some of the notes made by different auditors and translating those into categorical data.
- In the analysis below, the nature of the data means that it is primarily limited to discussing which variables are correlated with each other. It is important to note that when it is stated that two variables are correlated with each other, or there is a statistically significant relationship, it is not implying causality. For example, there are statistically significant relationships between certain WC characteristics and leak rate, but that does not necessarily mean that those characteristics are causing the leaks. This was investigated at the stakeholder workshop in order to better understand (qualitatively) whether certain WC characteristics are likely to cause leaks.

4.2.4.3 Summary statistics

Together the Phase 1 and Phase 2 investigations resulted in a dataset for 138 leaking toilets across a total of 467 toilets. In the toilets that were found to be leaking, the leak rates ranged from very small leaks of 1 litre/day to a maximum of 3,600 litres / day. The mean leakage rate for the whole dataset is 215 litres / toilet / day (Table 9).

Table 9 Descriptive statistics for leak rates

Leakage rate (l/toilet/day)			
Mean	214.9	**Skewness**	5.0
Standard Error	42.4	**Minimum**	1.0
Median	72	**Maximum**	3,600.0
Mode	14.4	**Sum**	29,659
Standard Deviation	498.3	**Count**	138

Of the 138 leaking WCs investigated the majority (80%) had a leakage rate of less than 300 litres / toilet / day with 36% less than 25 litres / toilet / day, and just 12% above 500 litres / toilet / day illustrating the skewed nature of the data. Figure 12 shows the range of leak rates (in litres / day) observed in the study and it is clear that the data is positively skewed with a few very high leak rates increasing the average leakage figure. As such the median leakage rate (72 litres / toilet / day) may provide a better indication of the average rate of leakage. However, for the purposes of this report both the mean and median will be used in the analysis to provide a range for the average leakage rate.

Based on an average of 4.1% (as established in Phase 1) of the estimated 45 million WCs currently installed in UK homes leaking, the **total annual wastage** is in the region of:

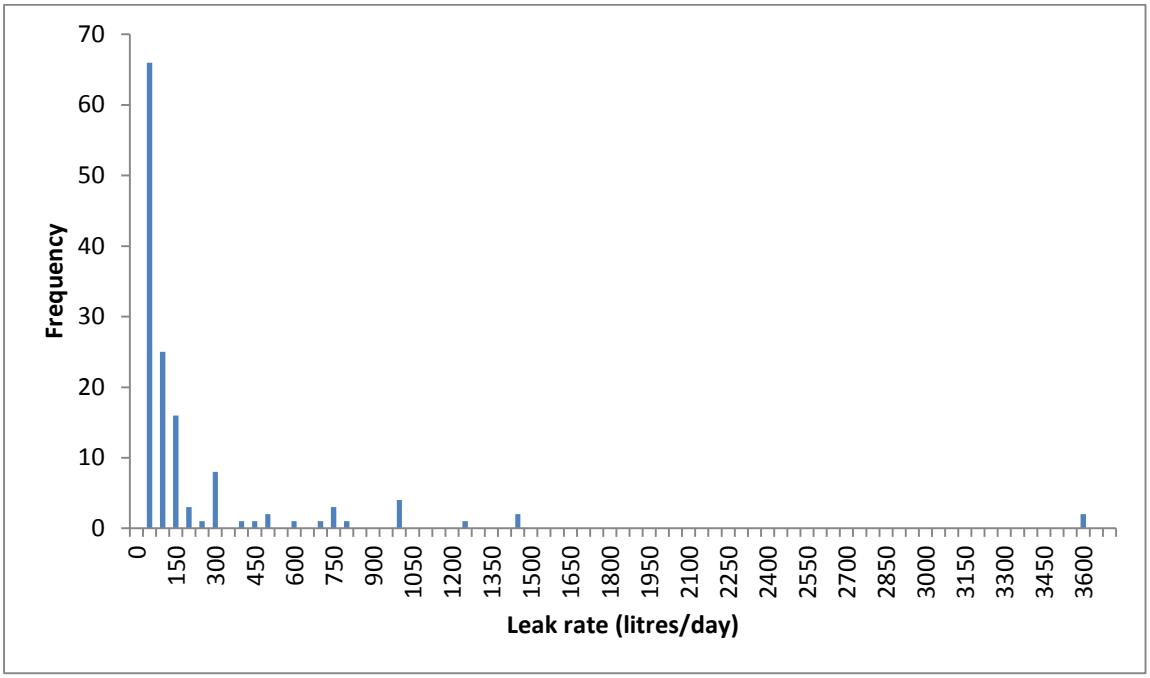
- **133 million litres per day (133 Ml / day)** based on the sample median leakage rate; and
- **397 million litres per day (397 Ml / day)** based on the sample mean leakage rate.

As shown in the histogram in Figure 12, there were two toilets (both actually in the same house) which were leaking at a rate of approximately 3,600 litres / toilet / day. These two large leaks are clearly an extreme example of the data found in the study but have been checked and confirmed to be accurate. Based on the combined sample (Warrington and Luton) in Phase 1, which suggested that on average 4.9% of the WCs in the UK could be leaking (with a 95% confidence interval of 1.7% to 8.9%), and the average leakage rates derived from the Phase 2 data the impact on PCC can be calculated. Table 10 provides an estimate of the contribution of WC leakage on PCC for both the mean and median leakage values derived from the study.

Table 10 Estimate of contribution of WC leakage to PCC

Proportion of leaking WCs	Median leakage rate (72 l/toilet/day)	Mean leakage rate (215 l/toilet/day)
Average (4.1%)	1.65%	4.13%
Lower 95% CI (1.7%)	0.57%	1.71%
Upper 95% CI (8.9%)	3%	8.96%

Figure 12 Distribution of leak rates (litres/day)



4.2.4.5 Impact of WC and property characteristics on leakage rates

Property characteristics and leakage

The data collected does not indicate any significant relationships between whether a property is metered, smart metered, or owner-occupied and whether a toilet leaks (Table 11) as there is little variance between the percentages that are leaking and not leaking.

Table 11 Property details and leakage

	Property Details									
	Metered	Smart Meter	Owner Occupier	Age of Property						
				pre-1900	1900-1920	1920-1940	1940-1970	1970-2000	2000-2010	New Build
Leaking	94	27	117	0	2	42	22	32	26	14
	68%	20%	85%	0%	1%	30%	16%	**23%**	**19%**	10%
Not leaking	226	81	294	5	5	90	64	112	27	26
	69%	25%	89%	2%	2%	27%	19%	**34%**	**8%**	8%

However, there is some indication of a possible difference in the percentage of toilets that leak across properties of different ages. In particular, the data shows variance between the percentage of leaking toilets and non-leaking toilets in newer properties (built between 2000 and 2010) than in older properties (in bold in Table 11). Furthermore the proportion of non-leaking toilets in properties built between 1970 and 2000 is much higher than in other property age ranges.

> Properties built between **1970 and 2000 are less likely** to have leaking toilets; properties built between **2000 and 2010 are more likely** to have leaking toilets**.**

The relationship between property age and leakage was investigated further. Chi-squared tests were performed on the data for properties built between 1970 and 2000, and 2000 and 2010 (Figure 13).

This shows that the percentage of toilets leaking were found to be significantly different for properties built in these two time periods.

Figure 13 Chi-square results for property age

	Leaking	Non-leaking	Total			
1970-2000	32	112	144		**Chi-square statistic:**	6.12
Other age	106	217	323		p value < 0.05	(p-value = 0.013)
Total	138	329	467		**Statistically significant**	

	Leaking	Non-leaking	Total			
2000 - 2010	26	27	53		**Chi-square statistic:**	11.22
Other age	112	302	414		p value < 0.01	
Total	138	329	467		**Statistically significant**	

These observations were explored further by considering the WC characteristics within the different aged properties. Table 12 highlights the fact that newer properties are more likely to have 6 litre cistern (92%) which is operated by a flush valve mechanism (86%) than older properties, and that newer properties are more likely to have a leaking toilet (42% in properties built post 2000). The numbers below also support the idea that WCs in houses built before 1970 are likely to have been upgraded (77% have 6 litre cisterns and 59% have flush valve mechanisms) which are more likely to leak. For those properties built between 1970 and 2000 the evidence suggests that a decreasing number of old siphon operated WCs have been retained This is probably due to long term home owners who have not yet replaced or upgraded their bathroom or WC suite.

Table 12 Property age and WC flushing mechanism

	Property age			
	Pre-1970	**1970 - 2000**	**Post-2000**	**Total**
Number of WCs	231	144	92	467
Number of leaking WCs	67	32	39	138
% of total	***29%***	***22%***	***42%***	***30%***
Cistern volume				
Number of WCs with 6 litre cistern	177 (77%)	97 (67%)	85 (92%)	359
Number of WCs with > 6 litre cistern	54 (23%)	47 (33%)	7 (8%)	108
Flushing mechanism				
Number of WCs with flush valve	137 (*59%*)	86 (*60%*)	79 (*86%*)	302
Number of WC with flush valves that leak	*57 (42%)*	*22 (26%)*	*33 (42%)*	112 (*37%*)
% of total WC leakage	**85%**	**65%**	**85%**	**81%**
Number of WCs with siphon	94 (*41%*)	58 (*40%*)	13 (14%)	159
Number of WCs with siphon that leak	10 (11%)	10 (17%)	6 (46%)	26 (16%)
% of total WC leakage	**15%**	**31%**	**15%**	**19%**

WC Characteristics and leakage

In addition to considering the relationship between property characteristics and leakage, the relationship between certain WC characteristics and leakage was also explored. For this an initial analysis of correlation between variables was undertaken (Table 13). The strongest correlation coefficients (highlighted in bold) show that certain WC characteristics are very closely related to each other. This is not unexpected as these characteristics tend to physically occur together for example, WCs with a push

button are also very likely to operate with a flush valve mechanism. However, the correlation coefficients for each of the characteristics with leakage are weak indicating that there is no evidence of a strong relationship between the WC characteristics included in Table 13, and whether a toilet leaks. This highlights the limitations of using correlation coefficients with binary data of this kind.

Table 13 Correlation coefficients for WC characteristics and Leakage

WC characteristic	Push button	Flush valve	6.0 litre cistern	Dual flush	Close coupled	Leaking toilet
Push button	1					
Flush valve	**0.9344**	1				
6.0 litre cistern	**0.6995**	**0.6889**	1			
Dual flush	**0.8472**	**0.8291**	**0.60098**	1		
Close coupled	0.2344	0.2573	0.10884	0.24791	1	
Leaking toilet	0.2008	0.2106	0.17493	0.16944	0.1091	1

Upon further investigation some noticeable differences in the specifications of leaking toilets versus non-leaking toilets can be highlighted (Table 14). For example, 81% of WCs that were found to be leaking had a flush valve mechanism, whereas only 58% of WCs that were not leaking had flush valves. Furthermore in 47% of leaking toilets had a rod flush actuation fitting as opposed to only 28% of those not leaking.

In order to determine whether these differences in the characteristics are significant, Chi-square tests were conducted as outlined in Figure 14. The results of the Chi-square tests show statistically significant results for all the variables highlighted in bold in Table 14. This indicates that toilets with certain WC specifications (such as flush valves) are more likely to leak than toilets with different specifications. As discussed previously, this does not necessarily mean that characteristics like flush valves cause leakage, just that there is a statistically significant difference in the characteristics of toilets that are leaking as opposed to those that are not leaking.

The highest proportion (42%) of leakage occurs in **properties built after 2000.**

In toilets that were identified as leaking **81% contained flush valve mechanisms.**

Table 14 Summary of WC Characteristics and Leakage

	WC Specifications											
	Push button	Flush actuation fitting			Flush Valve	6.0	Dual	Fill valve type				Close coupled
		Rod	Cable	Pneumatic				Ballcock: Bottom Fill	Ballcock: Top fill	Float: Bottom Entry	Float: Side Entry	
Leaking	110	65	30	14	112	122	98	19	7	102	8	121
	80%	**47%**	**22%**	10%	**81%**	**88%**	**71%**	14%	5%	74%	6%	**88%**
Not leaking	192	92	89	10	190	237	172	55	14	232	24	257
	58%	**28%**	**27%**	3%	**58%**	**72%**	**52%**	17%	4%	70%	7%	**78%**

Figure 14 Chi-square tests for WC characteristics

	Leaking	Non-leaking	Total			
Flush Valve	112	190	302	Chi-square statistic:		20.7
Siphon	27	138	165		p value < 0.01	
Total	139	328	467	Statistically significant		

	Leaking	Non-leaking	Total			
Single	40	157	197	Chi-square statistic:		13.4
Dual	98	172	270		p value < 0.01	
Total	138	329	467	Statistically significant		

	Leaking	Non-leaking	Total			
Rod	65	92	157	Chi-square statistic:		13.7
Cable	30	89	119		p value < 0.01	
Pneumatic	14	10	24			
Total	109	191		Statistically significant		

	Leaking	Non-leaking	Total			
6 litre	122	237	359	Chi-square statistic:		24.01
6+ litres	16	92	108		p value < 0.01	
Total	138	329	467	Statistically significant		

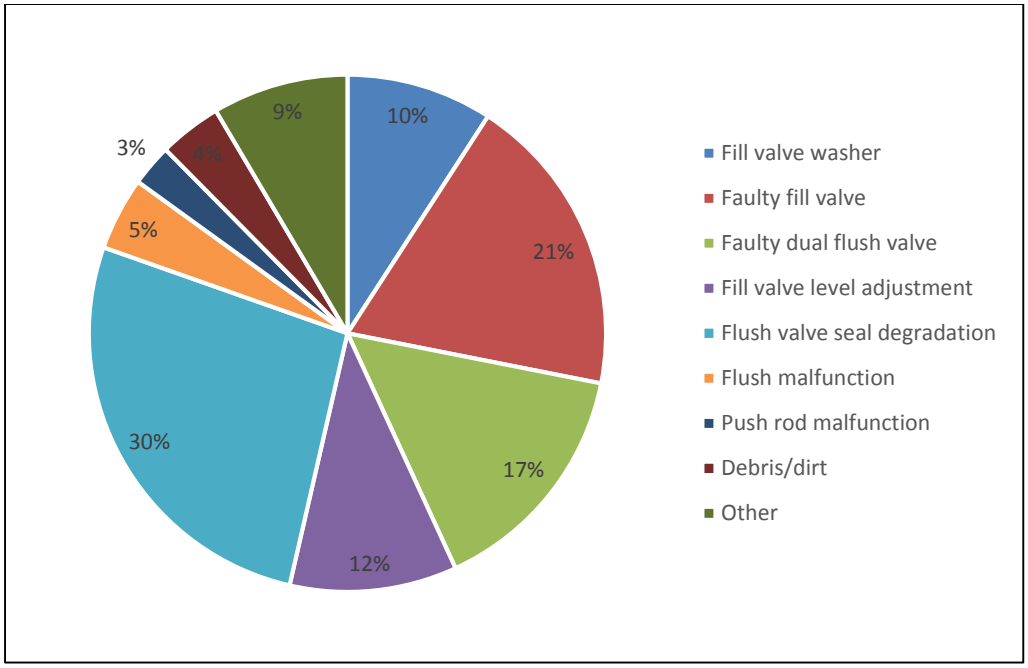
	Leaking	Non-leaking	Total			
Close coupled	121	257	378	Chi-square statistic:		5.77
Not close coupled	17	72	89		p value < 0.01	(p-value=0.016)
Total	138	329	467	Statistically significant		

	Leaking	Non-leaking	Total			
Push button	110	192	302	Chi-square statistic:		18.8
Lever	28	137	165		p value < 0.01	
Total	138	329	467	Statistically significant		

4.2.4.6 Causes of WC leakage

For each of the leaking WCs investigated the cause of the leak was established and recorded. A breakdown of the different causes identified during the study is provided in Figure 15. From this it is clear that flush valve seal degradation is the single commonest cause of WC leakage being attributed to 30% of the leaks investigated. Further to this two-thirds of all leakage is caused by three factors: flush valve seal degradation; faulty fill valves; and, faulty dual flush valves and over 43% of leakage is associated with the fill valve mechanism. A brief description of each of the causes identified is provided below.

Figure 15 Breakdown of the causes of WC leakage[57]



Faulty fill valve

In cases where the fill valve is faulty water continues to flow into the cistern and passes down the overflow. Most modern dual flush valves have internal overflows, thus water will pass into the WC pan and can go unnoticed for long periods. Tell-tale signs of this are water marks at the back of the pan or an audible hiss from the valve after filling is complete. Common faults that cause a faulty fill valve are typically debris trapped in the mechanism; and the arm or float becoming jammed possibly through the build-up of limescale. Other issues related to the fill valve that can cause leaks include failure of the fill valve washer (seal or diaphragm) and incorrect or poorly maintained float or arm level settings.

Faulty dual flush valve

The most common fault for dual flush valves (DFVs) passing water is seal failure, quite often as a direct result of seal material deterioration or debris being trapped preventing closure. Cable operated valves can pass water due to the cable becoming kinked/twisted, usually as a result of the lid being removed.

Flush malfunction

If the WC will not flush or will not flush effectively, this can have numerous possible causes.
Common faults are:

- Push button failure - Pneumatic tube no longer connected or cable failure.
- Mechanical Failure of DFV or Siphon.
- Cistern not filling to correct fill height
- Flush Siphons: Diaphragm failure, handle hook has become detached from Siphon.
- User damage to any part button/handle/valve/siphon.

[57] Some WC leaks were recorded as being caused by more than one issue hence total is greater than 100%

Push rod malfunction

Most flush actuation rods are adjustable and over time the rods can either become unscrewed (become longer) or tighten (become shorter). Some rods have lock nuts to ensure correct length is held, but if these aren't tightened correctly on installation, they can become ineffective. Typical faults include

- Push rods or button damaged by user
- Rods not aligned correctly with the corresponding internal flush pads. This can be as a result of a loose button or lid not seated correctly.
- Rods have become too short to perform flush.
- Rods are too long causing the flush valve to pass water.

Flush valve seal degradation / debris

Over time flush valve seals can become worn or degraded through the exposure to chlorine in the water in the cistern and through movement when flushed.

Other – including cistern displacement device (CDD) interference

As outlined in Section 2.1.2.1 CDD's are often placed into cisterns to reduce flush volume. These can typically save around 1-3 litres per flush however their effectiveness depends on the design of the WC. If they are installed incorrectly or within modern low flush WCs they can interfere with the inlet valve or flushing mechanism and cause leakage.

Table 15 summarises the causes of the leaks identified during the investigation in relation to different toilets specifications[58]. There are some noticeable differences in the causes of leakage in the different types of toilets however the data is generally in line with expectations for example:

- Flush valve seal degradation, the most common cause of leakage, is only found in WCs with a flush valve however it should be noted that it was only recorded in dual flush WCs.
- Debris and dirt caused more leaks in flush valve operated WCs than is siphon WCs.
- The majority of leakage found in siphon operated WCs was caused by failure of the fill valve.
- Leaks associated with failure of the fill valve were identified in all WC types.

Interestingly, it should also be noted that debris and dirt and CDD interference are not significant contributors to the causes of leakage in this study. On three occasions faulty dual flush valves were identified as the cause of leakage in single flush WCs. However this appears to be an anomaly in the data which could potentially be attributed to the cause being recorded incorrectly.

Table 16 provides a summary of the causes of leaks recorded against the rate of leakage and highlights where the leak was classed as being intermittent. The key points from the findings are as follows:

- Faulty fill valves and faulty dual flush mechanisms will generally result in a higher level of leakage.
- There are wide range of leakage rates associated with flush valve seal degradation. This is not unexpected and is likely to reflect the length of time the seal has been degrading or water hardness.
- Flush valve seal degradation is also the largest single cause of intermittent leakage.
- Fill valve level adjustment is typically associated with lower levels of leakage.
- In the majority of cases where debris was responsible for the leakage it caused an intermittent leak.
- Faults associated with the WC fill valve comprised 37% of the intermittent leaks recorded.

The most common single cause of WC leakage is **flush valve seal degradation;** however**, two-thirds of all leakage is caused by three factors**: flush valve seal degradation; faulty fill valves; and, faulty dual flush valves and over **43% of leakage is associated with the fill valve mechanism.**

There are a wide range of leakage rates associated with each cause however, **faulty fill valves and faulty dual flush mechanisms** generally result in the **highest rates of leakage.**

[58] Note that some toilets were recorded as having more than one cause of leak, thus the sum of total leaks per cause is more than 138.

Table 15 Causes of leaks vs. WC specifications

Cause of leak									
	Fill valve washer	**Faulty fill valve**	**Faulty dual flush valve**	**Fill valve level adjustment**	**Flush valve seal degradation**	**Flush malfunction**	**Push rod malfunction**	**Debris/dirt**	**Other**
Flush valves	5	24	23	4	41	7	4	5	12
Siphon	9	4	0	12	0	0	0	1	1
Dual	4	21	20	1	41	6	4	5	11
Single	10	8	3	15	0	1	0	1	2
Total leaks per cause	**14**	**29**	**23**	**16**	**41**	**7**	**4**	**6**	**13**

Table 16 Causes of leak vs. leakage rate and type

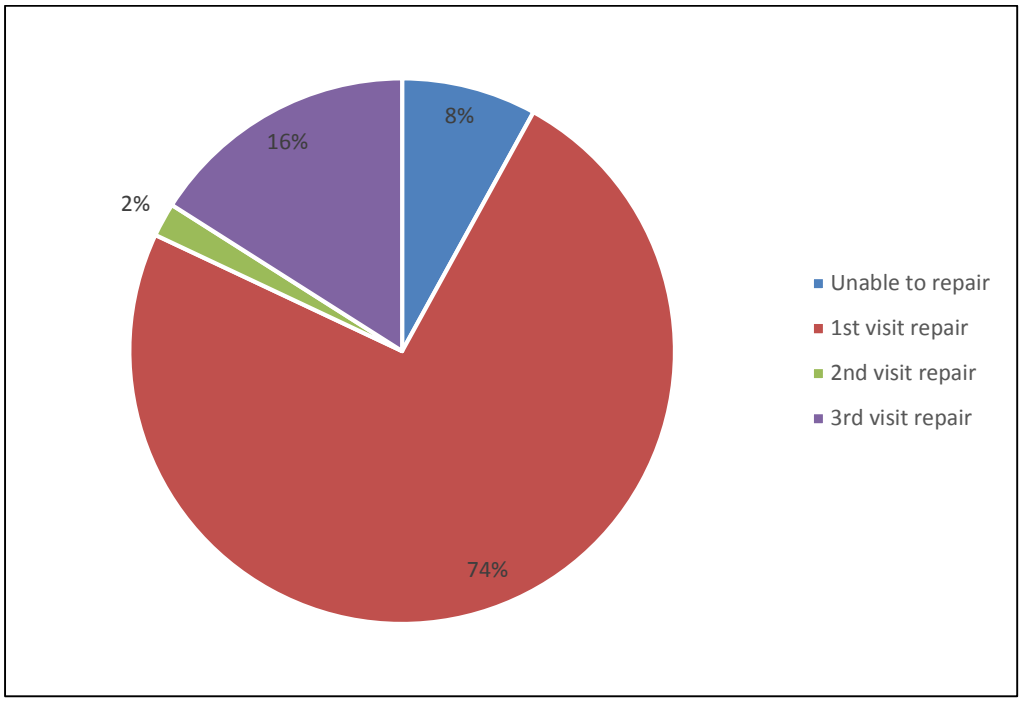
Cause of leak									
Leak type and rates	**Fill valve washer**	**Faulty fill valve**	**Faulty dual flush valve**	**Fill valve level adjustment**	**Flush valve seal degradation**	**Flush malfunction**	**Push rod malfunction**	**Debris/dirt**	**Other**
<2l/day	1	2	0	7	2	0	0	2	1
2-25 l/day	6	2	5	8	16	0	0	1	3
25–50 l/day	2	4	4	0	4	1	1	1	1
50-500 l/day	5	13	11	1	17	4	3	1	8
>500 l/day	0	8	3	0	2	2	0	1	0
Total leaks per cause	**14**	**29**	**23**	**16**	**41**	**7**	**4**	**6**	**13**
Intermittent	**1**	**6**	**6**	**7**	**11**	**1**	**1**	**4**	**3**

4.2.4.7 Leakage repair

In total 127 (92%) of the 138 leaking WCs that were identified in the study were repaired with the majority (74%) being repaired during the first plumber visit (Figure 17). However, just under 20% of the repairs required a second or third visit from the plumber. This was primarily due to the wide variety of WC fittings encountered in the properties visited and the availability of specialist, non-standard or obsolete parts.

Further to this the increasing trend to enclose (conceal) WC cisterns within the bathroom meant that around 8% of the leaks could not be resolved without structural intervention as there was limited or no access to cistern.

Figure 16 Breakdown of WC repairs



Of the leaks identified the majority (72%) required replacement parts, seals or washers to be fitted with 7% classed as Category C and potentially required additional labour (Table 17). The remaining 28% of the leaks could be repaired through simple actions such as cleaning the flush valve seals or adjustment of the fill valve level, ballcock or float.

Table 17 WC repair types

Repair category	Action	Number of repairs instigated
Cat A	Including replacement fill valve, seals, or washers	51
Cat A.1	Including replacement fill valve, seals, or washers	1
Cat B	Including replacement flush mechanism, fill valve or seals and washers.	31
Cat C	Replacement of specialist parts or difficult access. Additional labour required.	9
No category	Adjustment of fill valve level / clean seal to remove debris	35

5 Strategy development

The results from the physical investigation phase outlined in the previous section suggest that while wastage from domestic WCs may not be as significant as outlined in the Leaky Loos Phase I research it still represents a tangible (1.65% and 4.93%[59]) proportion of average per capita consumption (PCC). Developing a strategic approach to reducing existing wastage and preventing future wastage is therefore important for the water industry in reducing PCC.

5.1 Stakeholder consultation

In developing the strategic options a stakeholder workshop was held on 10th September 2015. The aim of the workshop was to present the findings from the physical investigation phase of the study and, in two breakout sessions, to explore stakeholder views on the research to inform a set of recommendations for reducing existing wastage and preventing future wastage from WCs. Attendees included representatives from the water industry, WC manufacturers, industry trade bodies and experts, policy makers and industry regulators (Appendix 2).

5.1.1 Discussion of headline findings from the study

In general stakeholders were not surprised by the findings from the physical investigation phase. However, there was a great deal of appetite to understand more about the causes of leakage and whether the products and mechanisms were Water Supply (Water Fittings) Regulations compliant and whether they had been installed correctly either through retrofitting or as new. While some product data was collected during the visits very few components within the cistern are labelled or marked (e.g. model / part number or WRAS approval) making it difficult to establish whether they are compliant with the regulations or not.

There was also a general consensus that the current legislative situation whereby non-compliant products can be purchased but not installed is unsatisfactory and insufficiently policed. However, it was appreciated that any change to the regulations would require a change in primary legislation which is unlikely. The current level of Water Regulations inspections by water companies on new build properties is between 5 to 10%, but it is understood that this varies. One water company suggested that they only accept products that have been WRAS approved. However, new build properties are only a small proportion of the existing housing stock.

Furthermore it was also suggested that the fact that products do not have to be installed by accredited plumbers can also lead to fittings being incorrectly installed or non-compliant products being used. There was some agreement that water was a poor relation to the energy / gas sectors in which fitters must be accredited (e.g. through schemes such as Corgi).

5.1.2 Strategic options for reducing and preventing leakage from WCs

The first breakout session was used to explore further with stakeholders what the results actually meant and whether they changed their perception of the issue. In addition stakeholders were asked to consider whether wastage from leaking WCs was a significant issue and whose problem it is. Finally, they were asked to identify the strategic options available to reduce leakage and to prevent leakage in the future.

Generally the findings aligned with stakeholder perceptions on the issue although it was felt that it may not be as significant an issue as initially thought. It was felt that smaller leaks, which may not be as visible and wasted less water, were less of an inconvenience for the customer and had less of an impact on bills so may go unnoticed. Customers are generally unaware of the costs associated with the wasted water but those on a meter were more likely to act (60-70% of leaking WCs were in properties that were metered). While the investigation found a few large leaks it is unclear how prevalent larger leaks are and whether customers have taken action to repair them. This is an unknown and the data set provides just a snapshot of the situation at one single point.

Stakeholders also generally agreed that it is an issue for the whole supply chain and not just the water companies. It was felt that Government are looking less towards new regulation and more could be done to enforce the current regulations. The high percentage of drop valves that were shown to be leaking was also of concern and with an estimated lifespan of 15 years the problem could get a great

[59] Based on median and mean leakage rates derived from this study

deal worse as the remaining siphon mechanisms are replaced with flush valves and more WCs are installed to meet increasing demand. But a change in the legislation was deemed unlikely.

While in the past water companies seemed to have picked up responsibility of WC leakage they need to understand the cost and benefits of targeting all leaking WCs. Generally they are trying to keep their costs down but tackling the problem could play a part in helping to meet the supply / demand balance and in reducing customer PCC. Plumbers could also make a significant difference by choosing WRAS approved products and being accredited to undertake the work. Many plumbers often stick to a certain product which has worked for them, or choose the cheapest to make money (whether compliant or not). Housebuilders should also be aware of the issues caused by the inability to access cisterns which are concealed behind tiled areas for example, for service or repair. Ultimately where cisterns cannot be accessed the leak is likely to be left un-checked.

Many product manufacturers have invested in getting their product WRAS approved and feel that non-compliances should be targeted. However, it was acknowledged that the global nature of the market where products can be readily obtained from countless sources meant that it is easier to focus on the installation rather than the product. In terms of product development a push button siphon mechanism was seen as the *'Holy Grail'* and something that manufacturers should be working towards.

Everyone agreed that it is the customer that pays for the wasted water and simple messages to this group *'to get their leaks fixed'* could also play a part. However, many may feel that it's just '*too hard to tackle'*. On this final point it was felt that the modern flush valve mechanisms were more complex (than siphons) and less DIY was being undertaken.

Ultimately awareness of the issue was seen to be low across all of the supply chain but overall the removal of non-compliant products was viewed as the largest issue. A number of strategic approaches that could be used to tackle leakage from WCs were identified (Table 18).

Table 18 Potential strategic approaches to tackle wastage from WCs identified by stakeholders in first breakout session

Intervention	Option / approach	Existing vrs. future leakage
Government	• All products WRAS approved and labelled. • Make it illegal to sell non-compliant products. • Move back to a siphon only market. • Re-introduction of the requirement for an external overflow into the Regulations. • Raise awareness of the need for compliance amongst retailers and suppliers, plumbers and the customer. • Increased enforcement of current regulations • Mandatory qualifications / accreditation for installers	Future Future Future Future Future Future
Water company	• Scale up current retrofit programmes. • Continue targeting high consumption customers. • Increased awareness to customers - information in bills, leak strips, home visits etc. • Increased water regulations inspections. • Improved targeting of WC leakage – property age etc.	Existing Existing Existing Future Existing
Product manufacturer	• Increased awareness of compliant products o Campaign on CE marking • Product design – push button siphon mechanism. • Water company / manufacturer research. • Technical information to customer to enable repair. • Product / part labelling.	 Future Future Future Future Future
Housebuilders	• Specification of WRAS approved products. • Better / improved access to concealed cisterns.	Future Future
Householder / customer	• Use of accredited plumbers only. • Increased awareness of the issue and what to do. • WC dual flush button stickers.	Existing Existing Existing

The second breakout session was then used to drill down further into the options and approaches identified in the first session and to consider the implications for each approach and who should be responsible for taking them forward. For each of the recommendations stakeholders were asked to score the key considerations such that comparisons could be made between recommendations. Table 19 provides a summary of the outputs from the session.

While there was a great deal of discussion around product compliance and the need for accredited installers the recommendation considered most feasible by the stakeholder group was the inclusion of WC leakage repairs in existing and future water company retrofitting programmes. Stakeholders scored this approach highly across four out of the five key areas considered with the issue of 'reliability' highlighted as the only concern and possibly a reflection on the challenges encountered during this study.

Table 19 Summary of outputs from second stakeholder breakout session

Recommendation	Pros / Cons	Criteria					
		Cost effective	Reliability	Scalability	Deliverability	Low carbon	Score
Add-on to retrofitting schemes.	• Signposting awareness – high consumption / owner occupier groups.	4	2	5	5	4	**20**
Increase customer awareness.	• Identification of leaks at earlier stage. • Better understanding of cost and impact. • Better purchasing decisions. • Use of accredited plumbers only.	3	3	5	4	2	**17**
Mandatory qualifications for installers.	• Less leakage due to poor installation. • Increased compliance of products.	1	4	4	3	3	**15**
Specification of WRAS compliant products by builders.	• Low cost. • Future stock only.	4	3	2	3	3	**15**
Product research.	• Proactive industry view - good networking / understanding of the issues. • R&D budget could be used. • May be seen as anti-competitive / procurement rules – must engage with BMA.	4	2	3	3	3	**15**
Make it a legal requirement for only compliant products to be sold / installed.	• Requires change in legislation. • May take significant amount of time. • Large investment by the sector. • Increased costs of products. • Counterfeiting of stamps / WRAS approval etc.	1	5	5	1	2	**14**
WRAS approval awareness and enforcement training for water companies.	• Time / cost required. • Impact may be small.	2	2	3	4	3	**14**
Practical advice to customers on easy fixes.	• Information readily available online. • Vast array of products. • Products not labelled. • Cost effective.	4	2	2	3	3	**14**
More ‘bite’ to WRAS.	• Requires better policing. • Requires increased funding. • Can’t control global sourcing. • Reputational risk to manufacturers.	3	2	3	2	3	**13**

5.1.3 Examining the costs and benefits

To better understand the costs and benefits of tackling WC leakage it is important to calculate the baseline cost of wastage that different leakage reduction options can then be compared against. Table 20 sets out the total cost of WC leakage based on the median and mean values for average leakage rates determined in Phase 1 of the investigation.

Table 20 Total cost of WC leakage

Average leakage rate (litres/toilet/day)	Total wastage (Ml)	Total cost of wastage (£M) [60]	Cost per leaking toilet (£)
Median (72l/WC/d)	133	£19.2	£8.71
Mean (215l/WC/d)	397	£57.4	£26.01

The Net Present Value (NPV) helps to determine which leakage reduction option will make the most financial sense. It takes into account the costs and benefits of different options over the lifetime of a project and takes into account the discount rate to reflect the current value of money. The NPV is calculated by assessing the present value of costs and benefits of different options using the discount factor and then the difference of these (NPV).

Based on the investment and the mix of different WC repairs undertaken during this study a cost benefit analysis for the highest scoring option identified during the stakeholder consultation (add-on to retrofitting schemes) and for a programme of WC leakage repairs (analogous to this research) is provided in Tables 21 and 22.

In both example calculations investment portfolios are considered one-off investments in year 0 with costs (charges for residual leakage) and benefits (savings accrued due to saved residual charges) accrued and discounted over a 5 year period

The analysis shows that for the baseline derived from the median leakage values both initiatives would require significant investment to undertake. However, as it is assumed that the repair programmes reduce leakage to zero for each unit for a period of 5 years, benefits are accrued resulting from the water savings that would have otherwise been wasted under the no action baseline. As a result the analysis shows that although a bespoke repair programme would still not be cost effective, a retrofit programme could result in savings of £3,630 over the 5 year period (versus the no action baseline). As such a retrofit leak repair programme added on to existing services would appear a beneficial solution due to savings made on residual costs.

In the alternate scenario where a higher average leakage rate was utilised due to the potential higher savings on residual costs both the bespoke and add-on leakage solutions could provide cost effective solutions when compared to the no action baseline with the add-on service potentially a net beneficial investment.

It is recommended that this approach is undertaken for the other leakage reduction initiatives identified by stakeholders and outlined in Table 19. However, it is clear that the analysis is highly dependent on the average leakage rate used for the calculation. Further to this a more detailed analysis of the investment requirements and costs for each of these initiatives is required.

[60] Based on the average incremental cost of 33.13p/m^3 as set out for a 'Proactive water efficiency retrofit trial' in Affinity Water's WRMP. https://www.affinitywater.co.uk/docs/WRMP-SE-Tables.pdf

Table 21 Cost benefit analysis of WC repair initiatives[61] under the median leakage scenario (72 litres per unit per day)[62]

Option	Description	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
Leak repair Programme	Investment	-£129,275						-£129,275
	Discounted Benefits		£8,258	£7,827	£7,419	£7,032	£6,666	£37,202
	NPV	-£129,275	£8,258	£7,827	£7,419	£7,032	£6,666	**-£92,073**
Add-on to existing retrofit programme	Investment	-£70,775						-£70,775
	Discounted Benefits		£8,258	£7,827	£7,419	£7,032	£6,666	£37,202
	NPV	-£70,775	£8,258	£7,827	£7,419	£7,032	£6,666	**-£33,573**
No Action Baseline	Investment							
	Residual Costs		-£8,258	-£7,827	-£7,419	-£7,032	-£6,666	-£37,203
	NPV	£0	-£8,258	-£7,827	-£7,419	-£7,032	-£6,666	**-£37,203**

Table 22: Cost Benefit analysis of WC repair initiatives under the higher leakage scenario (215 litres per unit per day)[62]

Option	Description	Yr 0	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
Leak repair Programme	Investment	-£129,275						-£129,275
	Discounted Benefits		£24,658	£23,372	£22,154	£20,999	£19,904	£111,087
	NPV	-£129,275	£24,658	£23,372	£22,154	£20,999	£19,904	**-£18,188**
Add-on to existing retrofit programme	Investment	-£70,775						-£70,775
	Discounted Benefits		£24,658	£23,372	£22,154	£20,999	£19,904	£111,087
	NPV	-£70,775	£24,658	£23,372	£22,154	£20,999	£19,904	**£40,312**
No Action Baseline	Investment							
	Residual Costs		-£24,658	-£23,372	-£22,154	-£20,999	-£19,904	-£111,087
	NPV	£0	-£24,658	-£23,372	-£22,154	-£20,999	-£19,904	**-£111,087**

[61] Based on repair of 1,000 leaking WCs over 5 years and assuming the effectiveness of each programme is 100% thus the residual cost is £0.
[62] Based on a 5.5% discounted benefit rate

6 Discussion

Since the introduction of the Water Supply (Water Fittings) Regulations in 1999 which opened up the market in the UK to flush valves and the reintroduction of dual flush mechanisms there has been concern over the potential for leakage from valve operated toilets. This potentially presents a major issue for the water industry as WC leakage has previously been estimated to represent a significant proportion of average per capita consumption (PCC). However, until now the evidence base for WC leakage has been primarily based on anecdotal information with limited robust data on the scale and causes of leakage.

Research from the 2012 Leaky Loos Phase I study identified that approximately 10% of toilets were leaking and estimated total losses at 400 litres/ toilet/ day. From this an estimate of 1.8 billion litres of treated water potentially being lost through wastage from toilets was derived for the UK - this equates to around 9% of the average PCC. However, this study was largely desk based and did not collate empirical evidence on the specific causes of leaking WCs although a diverse range of problems and attributed causes were described.

The issue of WC leakage has also been recognised in other Countries. A study of flapper valves in the USA identified that less than 6% were leaking and an end use study in South East Queensland, Australia identified a strong correlation between leakage and toilet water consumption with in some instances toilet wastage accounting for almost 50% of the total household water use. Despite these, and a handful of other studies which have identified WC leakage as a potential issue, there have been few studies on the scale and causes of leakage. By taking a strategic/ proactive approach to the identification, repair and prevention of leaking toilets this wastage component of PCC could be significantly reduced.

The key objective of this study was to, through the physical investigation of leaking WCs, refine our understanding of the scale of WC leakage and to identify if any particular groups of households are more likely to have leaking toilets. Further to this the project aimed to identify in more detail the technical reasons for leaks occurring so that a strategic approach, to reduce the amount of leakage and to prevent further leakage in the future, could be developed.

Identifying WC leakage

Historically faulty or defective fittings within a WC resulted in water visibly passing via an overflow. On the whole the overflow was externally routed, expelling water visibly, as the siphon flush mechanism was not designed within an internal overflow. But having a leaking overflow was visual and inconvenient, usually resulting in a repair to the issue being swiftly instigated by the customer. The failed fittings within these cisterns were generally ballcock washers that could be replaced by an enthusiastic DIYer or handyman. However, the current Water Regulations now allow for an internal overflow whereby water will flow into the toilet pan. While this is more ‘convenient’ for the customer the inclusion of internal overflow pipes has meant that leaks are less apparent than if they were discharging from an external overflow and small leaks could go easily unnoticed or ignored particularly as they have little impact on the customer bill.

Over the past few years WC leakage has primarily been identified through water company customer visits (regulatory visits and home water audits and health checks etc) and via high consumption queries generated from customer meter or AMR data. However, as this study has demonstrated there are a number of challenges and barriers associated with identifying and repairing WC leakage through these channels.

Phase 2 of this study aimed to identify 300 known leaks through similar on-going water company activities and from these it was anticipated that this target would be easily achieved. Of the 114 responses that were generated, 88 resulted in a completed plumber visit which identified only 68 WC leaks. The variation between the number of customer responses and the final number of completed visits was primarily due to not being able to make contact with the customer, to schedule an appointment for the visit, within water company guidelines. While a certain level of ‘drop-out’ can be expected in this case 40% is considered as high. Further to this for the 88 customers that the plumber was able to visit leaks could not be identified at 23% of the properties. In many of these cases the customer had already taken action to fix the leak or the leak could have been of an intermittent nature and not visible at the time of the visit. Either way just under one quarter of the visits were not required but had to be funded.

As a back-up customers were further targeted with letters containing leak strips. In total 9,000 leak strips were distributed across 3 water company regions which generated 93 responses resulting in 76 completed plumber visits identifying a further 52 leaks. While the 1% response rate is in line with other water company initiatives WC leaks were identified in only 68% of the plumber visits. It is believed that this was primarily due to the incorrect application of the leak strips which need to be applied to a dry surface at the back of the pan. Leak strips are a cost effective method of identifying leaking WCs but the 1% response rate suggests that many leak strips are unused and probably end up in the bin furthermore there is a significant onus on the customer to apply them correctly to avoid false positive results. This should be further tested with customers and if necessary the design of the leak strip should be improved to minimise the potential for incorrect application.

From the customers perspective the study also highlighted issues around the disruption and inconvenience caused. The need to have a plumber (can be costly) visit to repair what is perceived as small issue can be a real deterrent to repair. The waiting in, taking time off work, calling when the house is in full use, the cost, there are many unknowns for the customer that are associated with the plumber visit and these should be considered and as far as possible addressed beforehand.

Of the 467 toilets investigated during this study only 138 were found to be leaking despite Phase 2 targeting properties with known leaks. While this is less than one half the original number targeted the resources and time taken to achieve it were considerably more than initially anticipated. Based on this rate of uptake the recruitment phase of the project could have easily continued for another year before the target was met. As such it was agreed that the sample of 138 would form the basis of the analysis.

Scale of WC leakage

The Leaky Loos Phase I study reported that as many as 10% of all WCs could be leaking and WC leakage could represent a significant proportion of the average PCC. In order to address the issue it is important to better understand the scale of the WC leakage so that an appropriate level of response can be formulated. As such the primary aim of Phase 1 of this study was to test and refine the hypothesis that '10% of all WCs leak'.

In total data from 145 WCs from across two samples (Warrington and Luton) was collated and analysed. The analysis of the combined sample suggested that on average 4.1% of WCs leak and that we can be 95% confident that between 1.7% and 8.9% of toilets are leaking. While the samples did provide some indication there might be regional variations the significant overlap between the Warrington confidence interval and the Luton confidence interval demonstrate that the variation could be minimal.

While this is broadly in line with the water company data discussed in Section 3 which range from 5 to 7%, it is lower than 10% leakage rate identified in earlier research and the original hypothesis of this study indicating that WC leakage may not be as widespread an issue as originally anticipated. However, it is important to note that this is a relatively small dataset combined across two regions and that data from the Warrington sample alone suggested leakage could be higher at 5.6% (95% CI 2.4%, 12.5%).

The rates of WC leakage were determined using a flow cup or ultrasonic flow and cross checked with meter data. These methods were appropriate for the study and there was little variation in the measurements.

In line with previous studies the data forms a positively skewed distribution with a few very high leak rates. The sample showed that the majority (80%) had a leakage rate of less than 300 litres / toilet / day with 36% less than 25 litres / toilet / day. When the data is skewed in this manner the median (72 litres / toilet / day) rather than the mean (215 litres / toilet / day) flow rate may be a better indication of the overall average leak rate for the dataset. Either way both are considerably less than the 400 litres / toilet / day estimated in the previous Leaky Loos research and are less than the average flow rates described in previous water company studies (Section 3) which ranged from 325 litres / toilet / day to 1,018 litres / toilet / day.

The findings suggest that WC leakage may only comprise between 1.65% and 4.63% of PCC (within the 95% confidence intervals of 0.57% and 8.96%) which is considerably lower than the 9% estimated from previous research. The variation in these findings in comparison to previous studies may be caused by differences in the way leakage data is collected. In many of the previous studies high consumption queries are the primary source of WC leakage however, this approach will naturally identify larger leaks whereas in this study the majority of WC leaks were identified through the mailout

of leak strips (40%) and home visit programmes (40%) with high consumption queries generating around 16% of the total. As such the range of data sources used in this study may better reflect the natural levels of leakage in the overall population.

The data suggests that there are two different scales of WC leakage occurring - smaller hidden leaks, which may go unnoticed by the customer, and large higher consumption leaks. In the Leaky Loos Phase I study the data provided by the water companies consisted mainly from high consumption queries which potentially drove the higher average consumption figures. The higher average values for leakage in other water company studies may also provide an indication to the fact that a leak needs to develop to around 300 litres / day before the customer starts to recognise there is an issue either as it is audible, or it becomes more visible, or through higher bills. This is interesting as it gives a sense of the point of escalation for a normal unaware customer however, a better understanding of how small leaks develop to this point and over what timeframe is required. The installation of AMR and data loggers on meters may help to provide an early warning of WC leakage however, it is recognised that many of those currently being installed have a leak alarm value set at 8 litres / hour (192 litres / day), hence would not alarm against the lower (median) leakage value of 72 litres / day. It would however record the consumption and thus could provide some understanding of the deterioration of a WC leak over time.

These findings are of significance to the water industry as they suggest that previous studies may have overestimated the rate of WC leakage and thus the overall level of wastage. This is in line with the findings from the US flapper study which also suggested WC leakage could be over-estimated. The findings also indicate that there is a spectrum of WC leakage and that it is important to define what is included within any specific individual study.

WC leakage and property characteristics

While the data from the study does not indicate any significant relationships between whether a property is metered, smart metered, or owner-occupied and whether a toilet leaks there was some evidence of a relationship between property age and WC leakage. In particular, the data showed properties built between 1970 and 2000 are less likely to have leaking toilets than houses built in other time periods, and properties built between 2000 and 2010 are more likely to have leaking toilets than houses built in other time periods.

This is surprising and suggests that WC leakage is not primarily caused by wear and tear of aging of flushing parts as if this was the case then much higher leakage rates would be expected in older properties. The higher leakage rates in properties post 2000 could however be as a consequence of the changes to the Regulations which were introduced in 1999. This was confirmed by the leakage rates witnessed in WCs with flush valve mechanisms and supports the hypothesis that that WCs in houses built before 1970 are more likely to have been replaced or upgraded with new WCs which are more likely to leak. The evidence also suggests that WCs in properties built between 1970 and 2000 retain a decreasing number of old serviceable siphons, that have not yet been replaced for style or fashion reasons, and thus are less likely to leak.

The findings from the project also support and confirm the perceptions held by many stakeholders regarding the causes of WC leakage. However, they do not address the issue of product compliance and its association with leakage. In the UK it is not an offence to sell a non-compliant product only to install it. As such it is possible for non-compliant products to be purchased and installed. A further concern is that there is no requirement for flushing mechanisms and components to be labelled. Thus, as demonstrated in this study, it is difficult to establish whether a leaking device in situ is compliant with the Regulations or for an installer to verify product compliance at installation.

The provision of accredited installers (analogous to those in the gas and electricity industries e.g. Corgi) would potentially help to reduce the number of non-compliant products which are installed. However, the full benefit of a move towards having only accredited plumbers install or repair WCs can only be recognised if parts and components are labelled. Product labelling (to demonstrate compliance) is therefore essential in fully understanding the causes of WC leakage and in reducing potential future leakage associated with non-compliant products. The lack of labelling meant that the amount of leakage caused by non-compliant products in this study could not be established.

It is possible that the change in Regulations in 1999 brought about a ‘perfect storm’ whereby the introduction of flush valve mechanisms combined with the fact that non-compliant products can still be

legally purchased and the fact installers do not require any form of certification or accreditation, means that non-compliant products (potentially of poorer quality) are freely available on the market and could be installed by plumbers or householders that were unaware of the Regulations.

While the scale of the issue is less significant than originally anticipated data on WC leakage by property age suggests that the issue may become worse in the future as the remaining siphon mechanisms are replaced with flush valves and more WCs are installed to meet demand. This is supported by MTP stock models which forecast that, by 2020, around 97% of the WCs in all domestic properties will flush 6 litres or less[23]. This will primarily be driven by the development of new homes to meet the needs of an increasing population and demographic changes but coupled with greater property ownership, and a move towards second bathrooms and cloakrooms, it means that the number of WCs in the UK housing stock is set to continue to rise. As such in future there will be greater potential for WC leakage and it will remain an issue that affects all water companies.

Addressing the causes of WC leakage

A number of different causes of WC leakage were recorded during the study. The main cause was identified as flush valve seal degradation which is primarily caused by wear of the rubber valve over time or degradation through the exposure to chlorine in the water and through movement when flushed. Other causes were identified as faulty fill valves and faulty dual flush valves with over 43% of leakage associated with the fill valve mechanism. Interestingly debris and dirt was not recorded as a significant cause of leakage. While not a great deal can be done to standardise water conditions (hard/soft), albeit some water providers do soften their water, the development of more resilient components which last longer could reduce part failure of this nature.

Like all other working parts a key issue for WC flush mechanisms is the need for regular maintenance. However, the flush mechanism is becoming less accessible to the enthusiastic DIYer or the handyman. While many new design features allow for the removal of flush valves without the need to disrupt the connection between the cistern and the pan this is not the case for the majority of the older stock.

On some exposed models the flush actuation mechanism has further been simplified to allow easier removal of the lid without disrupting the cable or rod mechanisms. However, there is no standard approach to the flushing mechanisms contained within the cistern. The only standard sizing is at the fill valve inlet (1/2" BSP) and the flush outlet (1.5" and 2") what happens internally within the cistern only then has to comply with regulation standards for materials and durability as set out in BS or WRAS (as described in the main report).

The development of concealed cistern systems is adding further complications to maintenance. Whilst the flush devices have access made available via front hatches through larger plate button housings, they are not always practical and may be more accessible to plumbers rather than home owners.

Consideration should be made towards design that allows for easier serviceability. The study highlighted that some customers were aware they had a leaking WC but felt unable or unwilling to investigate it further and used this project as an opportunity to have it repaired. Of the leaks repaired around 70% of them were fixed by the plumber on the first visit. The balance required specialist components or structural alterations.

It was highlighted by stakeholders that more control over plumbers/standards/training would be a positive step, as would the tightening of regulations inspections. Others suggested that WRAS should be made 'easier' to operate as it '*stifles innovation and progress'*. While these are sensible ways forward and are all credible solutions the whole area still has to be policed in the non-commercial world. Based on the evidence developed during this study other solutions such as WC scrappage schemes would be largely ineffective at reducing leakage and may in fact increase overall water consumption if the reduced flush rate and the average leakage rate is taken into account.

As the stakeholder workshop established regulatory reform is unlikely thus WC leakage will probably remain largely an issue for the water companies and its customers (although smaller leaks have little impact on customer bills). But its overall significance in comparison to supply leakage remains small thus a balance needs to be struck in terms of where they invest. Customer metering will help this and large scale installation programmes are in progress across many water company regions.

However, there is a feeling that many of the options and recommendations raised were merely '*tinkering around the edges*' and that without regulatory reform the issue may be '*too hard to tackle'*.

Overall it was agreed that there needs to be greater awareness of the situation across the supply chain from regulatory compliance and what that means, to the impacts on customers and what they should do. Of all the recommendations discussed it appears that the most feasible option(s) is to continue with the approaches that are already being adopted by the water industry around retrofitting and high consumption queries and where possible piggy back on existing initiatives. However, as the cost benefit analysis shows these may not be cost effective particularly if the scale of WC leakage is not as significant as initially anticipated.

7 Conclusions and recommendations

The findings from this study have shown that leakage from WCs may not be as significant an issue in terms of scale and water wasted as previously recognised. The analysis of data from Phase 1 highlighted that on average approximately 4.1% of WCs leak, which is much lower than in previous studies. Data from Phase 2 suggests that while a large range of leak flow rates exist the mean (215 litres/toilet/day) and median (72 litres/toilet/day) values are again much lower than in previous studies. Thus the overall contribution of WC leakage to the average PCC is between 1.65% and 4.63%.

These findings are of significance as they suggest that previous studies may have overestimated the scale and rate of WC leakage and thus the overall level of wastage. As such targeting WC leakage may not be as cost effective an approach to reducing customer PCC as initially anticipated. This is in line with the findings from the US flapper study which also suggested WC leakage could have been previously over-estimated.

The evidence also supports the perception that there is a higher proportion of leakage in modern WCs with flush valve mechanisms however, failure of the fill valve is a common cause of leakage which occurs in both WCs with siphons and flush valves. Interestingly there was no evidence from this study that non-compliant products were the main cause of WC leakage. However, awareness of the requirements of the regulations appear to be low across most areas of the supply chain (with the exception of product manufacturers).

While the scale of the issue is potentially less significant than originally anticipated data on WC leakage by property age and our increasing population and demographic changes suggests that the issue may become worse in the future as more WCs are installed. The shifting trends towards the more favoured continental style of flush actuation (push button) has created a more aesthetic washroom solution, allowing for a wide variety of installation options and customer choice. The choice available within a plumbing/bathroom showroom and for flush valve cisterns is enormous, yet the choice of siphonic cisterns has dwindled to almost none. They are available but no longer mainstream despite being a better product in terms of the reduced propensity to leak.

The modern bathroom continues to evolve, flush performance of WC's is improving, with high flow rate flush valves providing fast evacuation of pans, improving flush performance and ultimately bringing flush volume down to very low levels. While there are good performing flush siphon WC's they are not offered in a wide variety of styles, restricting overall appeal and current availability.

The flush button appears to be here to stay, it's easy to operate (albeit when set up correctly), discrete and design led. The dual flush certainly has benefits with respect to water saving and compact cistern sizing. That is not to say that the siphon doesn't, but globally the flush button appears to have the market share and this was reflected in this study.

7.1 Recommendations

- The most cost effective way of approaching WC leakage is for the water companies to continue targeting high consumption customers and repairing those leaks identified.
- Undertake cost benefit analysis on other WC leakage and prevention measures identified in the study.
- Improved targeting of WC leakage based on property age – this could be incorporated into home visit initiatives.

- Raise awareness of the need for compliant products among retailers and suppliers, plumbers and the customers. Further customer and stakeholder education is also required regarding compliance this could be achieved through the provision of advice and information.
- Establish a better understanding of how a small leak develops and over what timeframe.
- Increase customer awareness of the issue of WC leakage through information in bills, leak strips and home visits.
- Improvements to the design of leak strips to minimise the potential for incorrect installation.
- The water industry should consider promoting a preference for low or dual flush siphon toilets and improved labelling for dual flush systems.
- Design WCs with a focus on serviceability and repair this would allow customers to attempt a repair where possible.
- Improved parts and component labelling with the provision of technical information to customers to enable simple repairs.
- Improved access to concealed cisterns. Design for serviceability.
- Explore the potential to re-instate the requirement for external overflows (particularly where cisterns are concealed) so that WC leakage becomes more apparent to the householder and can be addressed more quickly.

Appendices

Appendix 1: Analysis of water company data

Appendix 2: List of stakeholders

Appendix 1 – Analysis of water company data

Affinity Water

Affinity Water provided leakage allowance data (high consumption / leakage datasets) for the periods 2011/12, 2012/13 and 2013/14. The key parameters in the datasets are outlined in Table A1.1.

Table A1.1 Data parameters provided by Affinity Water

Parameter	Description
Normal daily rate	Once the customers leak is fixed the customer is asked to take two meter reads two weeks apart and use the two week data to determine their 'normal' consumption (normal daily rate is the cubic metre consumption per day).
Number of days	This relates to the number of days for the leak to be fixed, so represents the date from which a leak in the meter read data became apparent to the date on the plumber's receipt for repair. Admittedly there's a bit of a grey area around the precise start date as the following read (and increased bill) is usually the first point that the customer realises there's an issue.
Normal usage	Using the normal daily rate data multiplied by the number of days gives the total assumed consumption of water by the customer.
Amount charged	This is the total amount of water consumed over the number of days given. The amount charged (£) is the monetary equivalent.
Leakage allowance	This is the amount charged minus the normal daily rate but as a total based on the number of days that the leak ran for. It gives a total volume of water wasted and financial loss suffered by the customer.
Daily leak volume.	The total divided by the number of days to give a daily leak volume.

Results

Across the three periods a total of 779 high consumption properties were identified. Analysis of the data using descriptive statistics shows that the average leakage volume for the combined data sets was 841 litres / day (Table A1.2). However, the average leakage rates are impacted by a small number of large potential outliers which are linked with the wide 95% confidence intervals. Figures A1.1 and A1.2 show that the data sets form a positively skewed distribution. As such the median leakage rate (589 litres / day) may provide a better indication of the average flow rate for this dataset.

Table A1.2 Descriptive statistics for daily leakage rates

Daily leakage rate (l/d)	2011	2012	2013	Combined data
Mean	908.2	760.3	960.7	840.7
Standard Error	61.1	44.4	176.7	36.7
Median	654.7	516.2	463.1	588.5
Standard Deviation	1,126.1	872.6	1,298.1	1024.5
Skewness	6.71	3.69	3.25	5.49
Minimum	34.5	0	51.1	0
Maximum	14,577.4	6,847	7,469	14,577.42
Sum	308,783	294,227	51,876	654,887
Count	340	385	54	779
Confidence Level (95.0%)	120.126	87.21337	354.3252	72.0534

Figure A1.1 Histogram of daily leak rates (l/d) for Affinity Water for 2011 to 2014 data sets

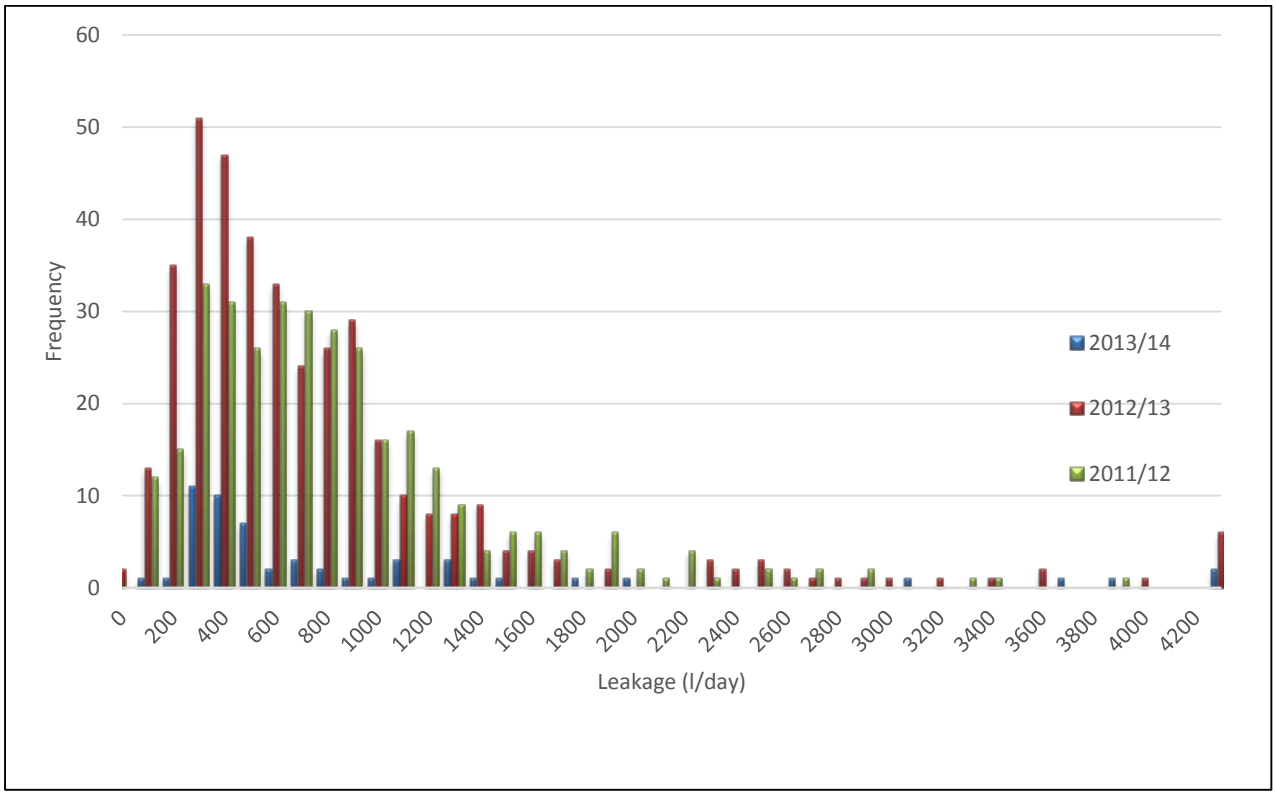
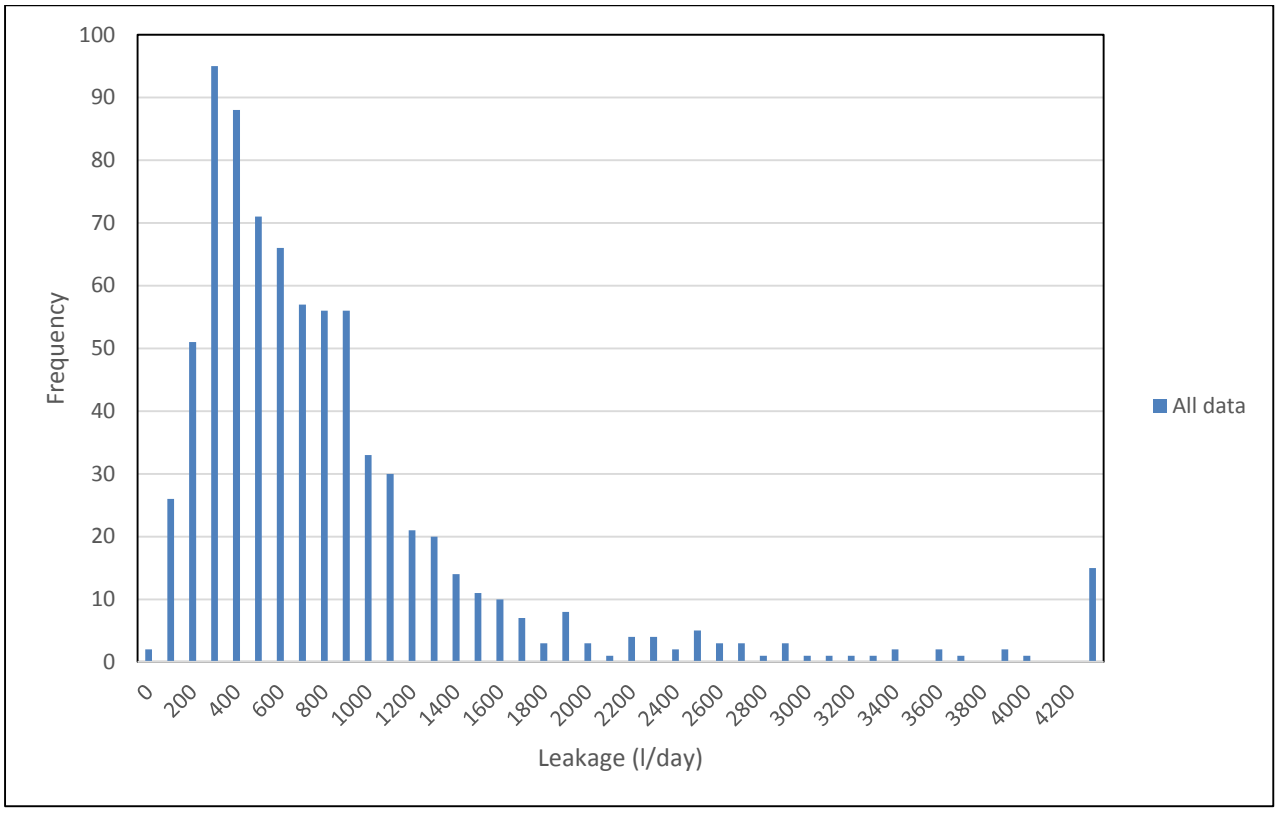


Figure A1.2 Histogram of daily leakage rates (l/d) for Affinity Water combined data set



South East Water

Data Summary

For this project South East Water shared the information provided previously for Leaky Loos Phase 1, however this wasn't analysed further as the survey results were included in the Phase 1 report and the sample size for the updated leaking toilets data was small.

Data from the South East Water Customer Metering programme was also provided and analysed. This included raw data from two types of customer visits - when a leak is identified at the meter quality check stage (i.e. QA visit) shortly after meter installation and at a high consumption read (three months after meter installation where consumption is above 70m^3 for the period).

Both data sets included average water consumption for the property for one month pre- and one month post-repair of the leak. For some properties water consumption for 2 months pre- and post – leak repair were also provided and these were included in the analysis.

Results

South East Water provided an initial summary of the results in Table A1.3. This identified 181 properties with fixed toilet leaks and that 5% of toilets were found to be leaking across both QA visits and high consumption visits.

Table A1.3 Summary of customer metering programme results

	QA visits			High consumption visits		
Period	**Number of QA visits**	**Number toilet repairs**	**% of repairs leaking toilets**	**Number of high consumption visits**	**Number of toilet repairs**	**% of repairs leaking toilets**
Apr-13	239	2	0.8%	182	13	7.1%
May-13	258	4	1.6%	205	10	4.9%
Jun-13	200	8	4.0%	119	10	8.4%
Jul-13	202	9	4.5%	142	8	5.6%
Aug-13	148	10	6.8%	103	9	8.7%
Sep-13	193	7	3.6%	74	5	6.8%
Oct-13	204	9	4.4%	51	2	3.9%
Nov-13	247	15	6.1%	77	3	3.9%
Dec-13	147	9	6.1%	77	8	10.4%
Jan-14	139	11	7.9%	179	9	5.0%
Feb-14	127	6	4.7%	118	7	5.9%
Mar-14	124	5	4.0%	73	2	2.7%
TOTAL	**2228**	**95**	**4.5%**	**1400**	**86**	**6.1%**

Analysis of the data using descriptive statistics shows that the average leakage volume for each initiative and the combined data sets (Table A1.4). Data points with no pre- or post-leak repair consumption figures were excluded from the analysis. The average leakage rate for the combined data sets is 751 litres / day. However, both data sets are impacted by a small number of large potential outliers which are linked with the wide 95% confidence intervals.

Table A1.4 Descriptive statistics for QA and high consumption data

Leakage rate (l/day)	QA visits	High Consumption	Combined data
Mean	704.2	796.9	750.9
Standard Error	77.6	146.8	83.1
Median	532	490	510
Mode	330	610	610
Standard Deviation	711	1,354	1,081
Skewness	2.83	5.93	6.23
Minimum	30	10	10
Maximum	4,400	11,130	11,130
Sum	59,155	67,740	126,895
Count	84	85	169
Confidence Level (95.0%)	154.3	292.0	164.1

Figures A1.3 and A1.4 show that the data sets form a positively skewed distribution. As such the median leakage rate (510 litres / day) may provide a better indication of the average flow rate for this dataset.

Figure A1.3 Histogram of QA and high consumption leakage rates

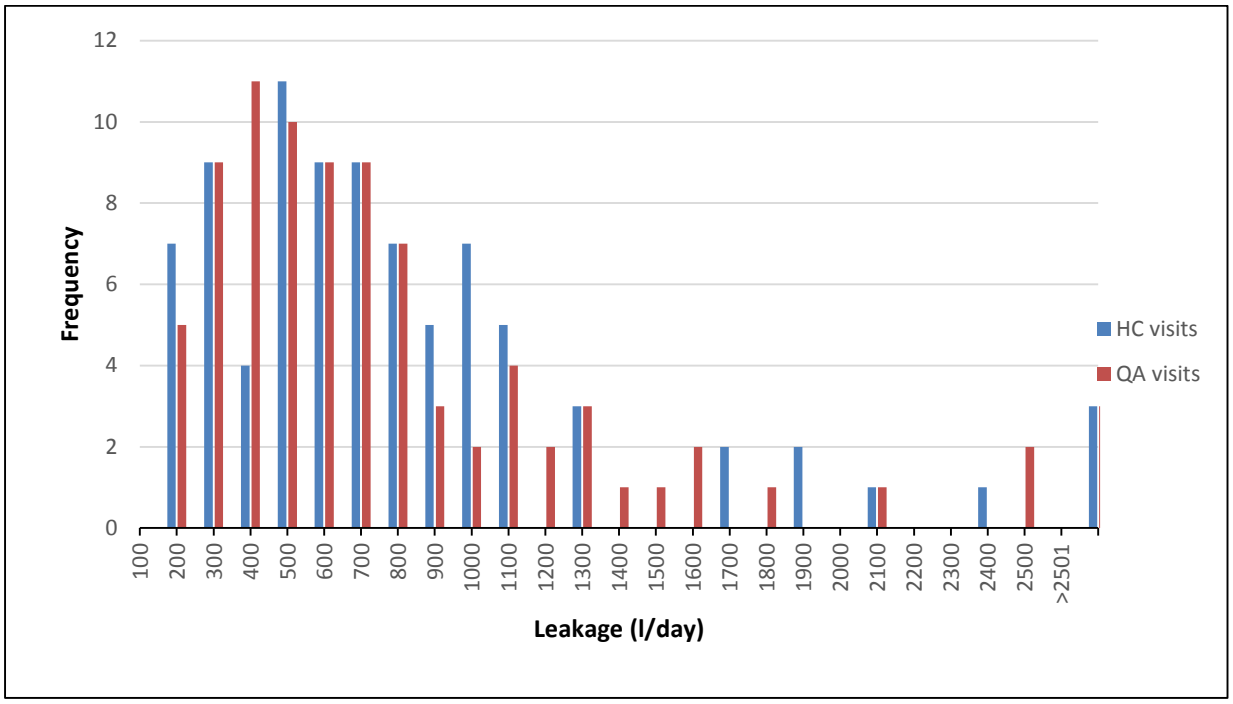
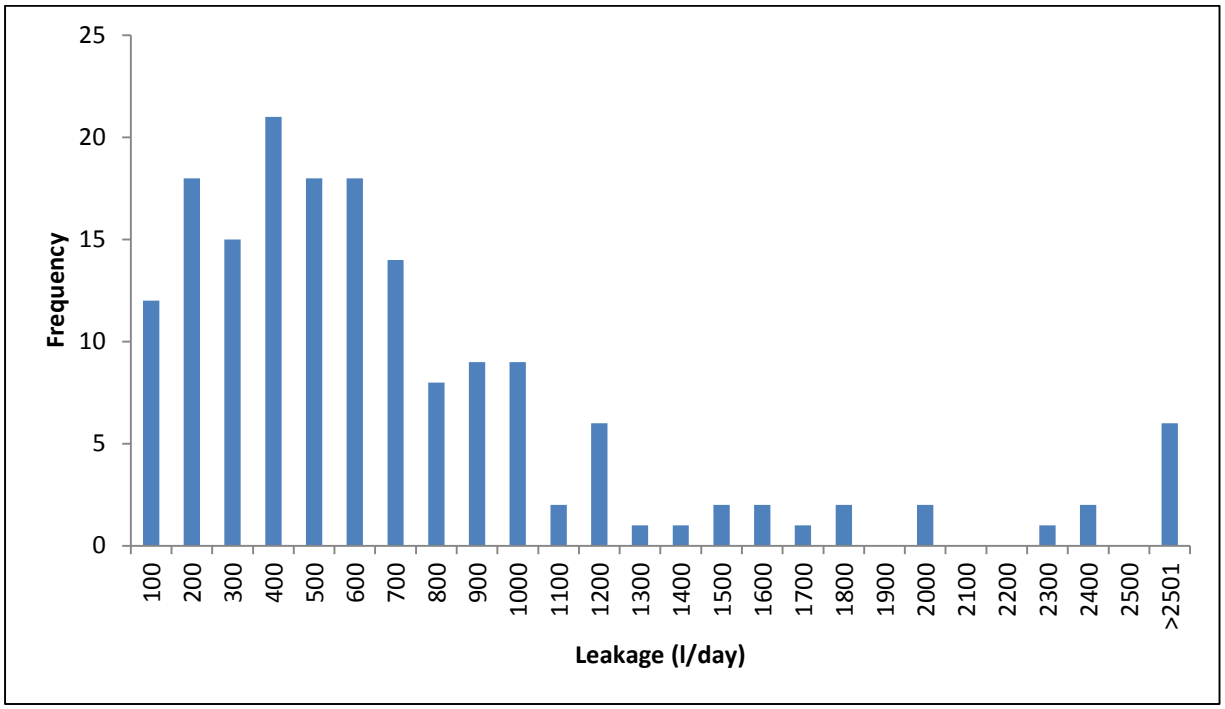


Figure A1.4 Histogram of combined data



Sutton and East Surrey Water

Data summary

Two datasets were provided by Sutton and East Surrey Water covering the findings from high consumption visits in 2010 and internal leakage repair data used for the Leaky Loos Phase1 report.

Results

The data relating to high consumption visits provided qualitative information on each property. This was analysed for references to 'toilet', 'wc' or 'w/c' which were given as causes of high consumption. The data suggested that 56 (7%) out of the 853 properties assessed had leaking toilets. No further information on potential leakage volumes were provided.

The internal leak repair dataset contained a small sample of 12 toilets which had been repaired. Analysis of the data using descriptive statistics shows that the average leakage volume was 1,018 (Table A1.5). However, the small sample size and the large range in leakage values is reflected in the 95% confidence level for the data.

Table A1.5 Descriptive statistics for internal toilet leakage data set

Leakage (l/day)	
Mean	1,018
Standard Error	284.46
Median	765
Standard Deviation	985.4
Skewness	1.50
Minimum	60
Maximum	3,330
Sum	12,210
Count	12
Confidence Level (95.0%)	626.1

The information provided also contained a summary of the repairs that were instigated at each property with 50% of the repairs associated with the inlet valve and 25% requiring new drop valves to be fitted.

Thames Water

Data summary

Thames Water provided data from their 'Leaky Loo' repairs project which was part of a wider water efficiency campaign targeting customers in areas covered by their advanced metering infrastructure (AMI) technology installed as part of their fixed network trial (FNT). This covered over 5,000 properties with smart meters installed across the Thames region. While no volumetric data was supplied, as this was analysed internally by Thames Water as part of the project, a summary of the findings was provided.

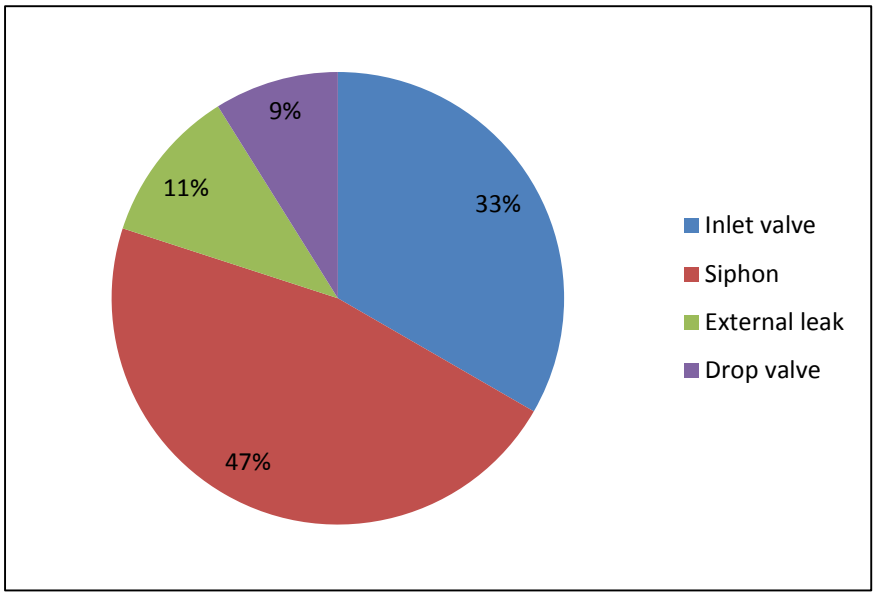
In response to customer communications a total of 45 properties were reported by the visiting plumber as having leaky toilets of these, 44 were stated as being repaired. As well customer details, information describing the issue including leaking part, overflow location, cause, cistern type, toilet system and fix details were collated. Of the 44 repaired leaks, 5 could not be matched to FNT properties and are thought to be outside of the smart metered areas. Another 10 share their supplies with other properties, leaving 29 data sets for analysis. However, the sample size was reduced further as meter data[63] was only available for a total of 19 properties.

Results

The Thames Water dataset provides a very useful analysis of leak types and causes as recorded by their plumbers. The results showed that the majority of toilets were leaking from the syphon followed by the inlet valve (Figure A1.5).

This is surprising since the siphon mechanism has no sealing washers like that of a flush valve which can wear out and cause leaks. Further analysis of the raw data highlights that around 48% of those leaks attributed to the siphon were described as 'valve systems' suggesting that there is some confusion in the terms associated with WC leakage in this data set.

Figure A1.5 Recorded data on location of WC leak

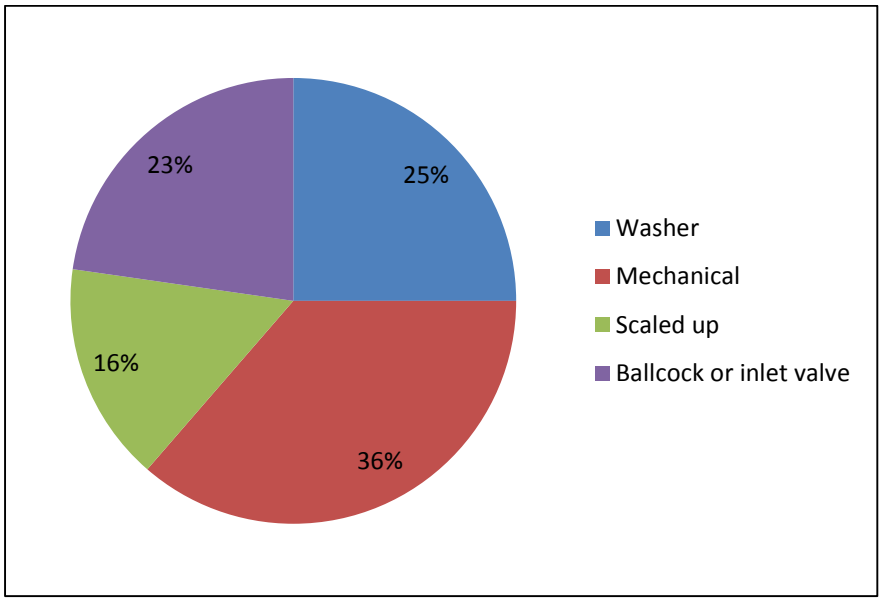


The causes of the leakage were primarily recorded as 'mechanical' followed by the 'washer' and 'ballcock/ inlet valve' (Figure A1.6).

For each property Thames Water undertook a comparison of consumption both before and after the repair was instigated (Figure A1.7). This highlights the distribution of flows recorded by the meter in 15 minute intervals with the distribution over the 4 weeks prior to the leak being repaired (red) and for the 4 weeks after the leak is repaired (blue). This example is considered to show the presence of an intermittent leak or a low rate continuous WC leak (red).

[63] Meter data was filtered for readings up to 28 days before or after a repair was carried out. Three comparisons were then made: one week before repair versus one week after, two weeks before repair versus two weeks after, and four weeks before versus four weeks after.

Figure A1.6 Recorded data on cause of toilet leak



Examples of how this method was used to illustrate the change in consumption is provided in Figure A1.8 with the report concluding that this method may have more applications in the future for detecting intermittent wastage or continuous flow.

Interestingly the data also highlighted the fact that plumbers were able to successfully repair all of the major WC leaks identified. However, on a number of occasions, where less severe leaks were identified, consumption was shown to increase following the plumber repair.

Data for consumption rates was not provided hence no correlation or statistical analysis could be undertaken on leak volumes against leak location and cause.

Figure A1.7 Example of analysis of consumption for individual property.

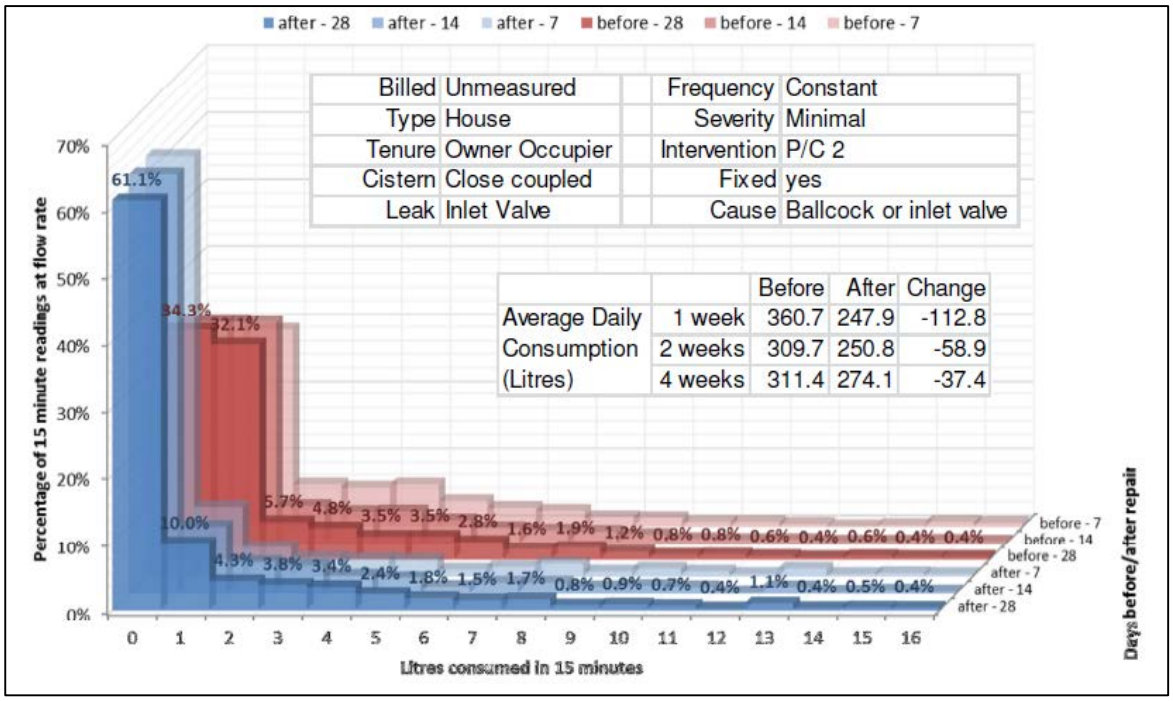
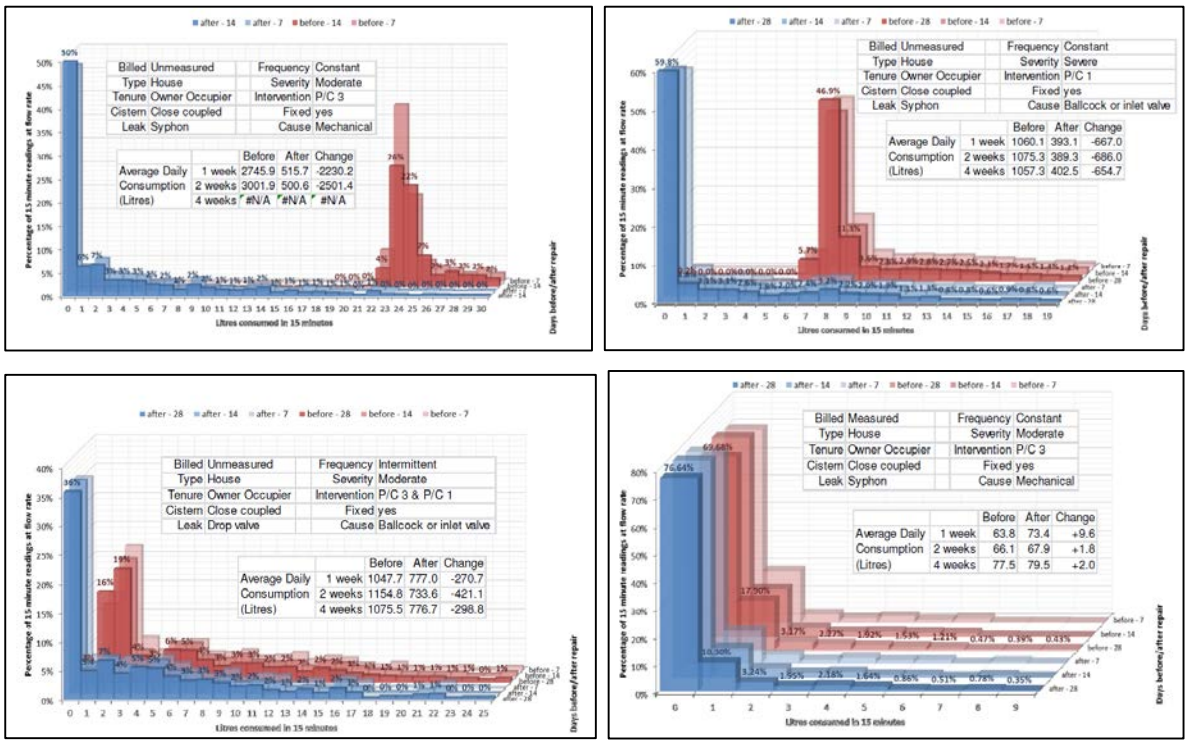


Figure A1.8 Examples of data from properties with different leakage rates[64]



[64] Top left described as significant (2,500l/day); Top right described as 'less severe (650 l/day); Bottom left described as moderate (300l/day); Bottom right described as 'minor' (2l/day)

United Utilities

Data Summary

United Utilities provided smart metering data related to WC leak repairs in 15 properties. From this the average consumption pre-leak, average consumption during the leak and average consumption post-the leak being fixed were calculated. The leak identifier provided was to the level of toilet and cistern, therefore no further analysis on location or cause of leak could be undertaken.

Information from the United Utilities Homeserve insurance programme collected from plumbers was also analysed. This dataset covered a period from 2012 to 2014 and identified if it was the pan or the cistern leaking.

Results

A summary of the results for all 15 properties is included in Table A1.6. The average leak volume calculated was 325 litres per day. The average leak run time was 106.2 days though this varied from 16 days to 350 days. Based on the small dataset no further investigation was undertaken. From the analysis of insurance data a count of the leak type showed 1,493 (90%) to be leaking cisterns and 158 or 10% to be leaking pans.

Table A1.6 Leakage data from smart metering of a sample of United Utilities customers

SP ID	Duration of leak (days)	Average consumption pre-leak (l/d)	Average consumption of leak (l/d)	Average consumption post-leak (l/d)	Average leak volume (l/d)
W106350838	42.0	203.9	572.6	168.5	404.1
W106861526	x	94.1	321.1	x	x
W106347494	x	264.1	503.5	x	x
W106438133	350.0	335.0	305.7	136.1	169.6
W107705916	210.0	149.5	62.6	87.4	24.9*
W106816874	x	x	894.0	x	x
W103380086	28.0	284.7	358.0	257.9	100.1
W107898502	190.0	277.1	539.7	134.1	405.7
W107559990	112.0	168.2	1032.8	166.8	866.0
W103987764	35.0	297.2	740.7	251.3	489.4
W107702877	36.0	342.6	427.1	233.9	193.1
W107622236	105.0	552.9	779.7	645.8	134.0
W104325324	x	x	1186.5	x	x
W105736500	44.0	419.5	1081.5	665.6	415.8
W103649976	16.0	x	543.7	471.6	72.1
Average	**106.2**	**282.4**	**623.3**	**292.6**	**325.0**

*Possible outlier

Appendix 2 – List of stakeholders

Name	Organisation
Nic Gilbert	Affinity Water
Steve Mason	Aqualogic
Lorraine Hughes	Aqualogic
Simon Gordon Walker	Artesia
Victoria Ashton	Artesia
Christian Taylor-Hamlin	Bathroom Manufacturers Association
Alison Maydom	Defra
Dene Russell	Environment Agency
Clair Cooper	Northumbrian Water
Stuart Ballinger	Ricardo E&E
Nadine Minty	Ricardo E&E
Jack Stevens	Ricardo E&E
Doug Clarke	Severn Trent Water
Ben Earl	Southern Water
Alison Murphy	Sutton and East Surrey Water
Sally Bremner	Thames Water
John Creswell	Thomas Dudley
Simon Mason	Thomas Dudley
Maxine Stiller	United Utilities

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