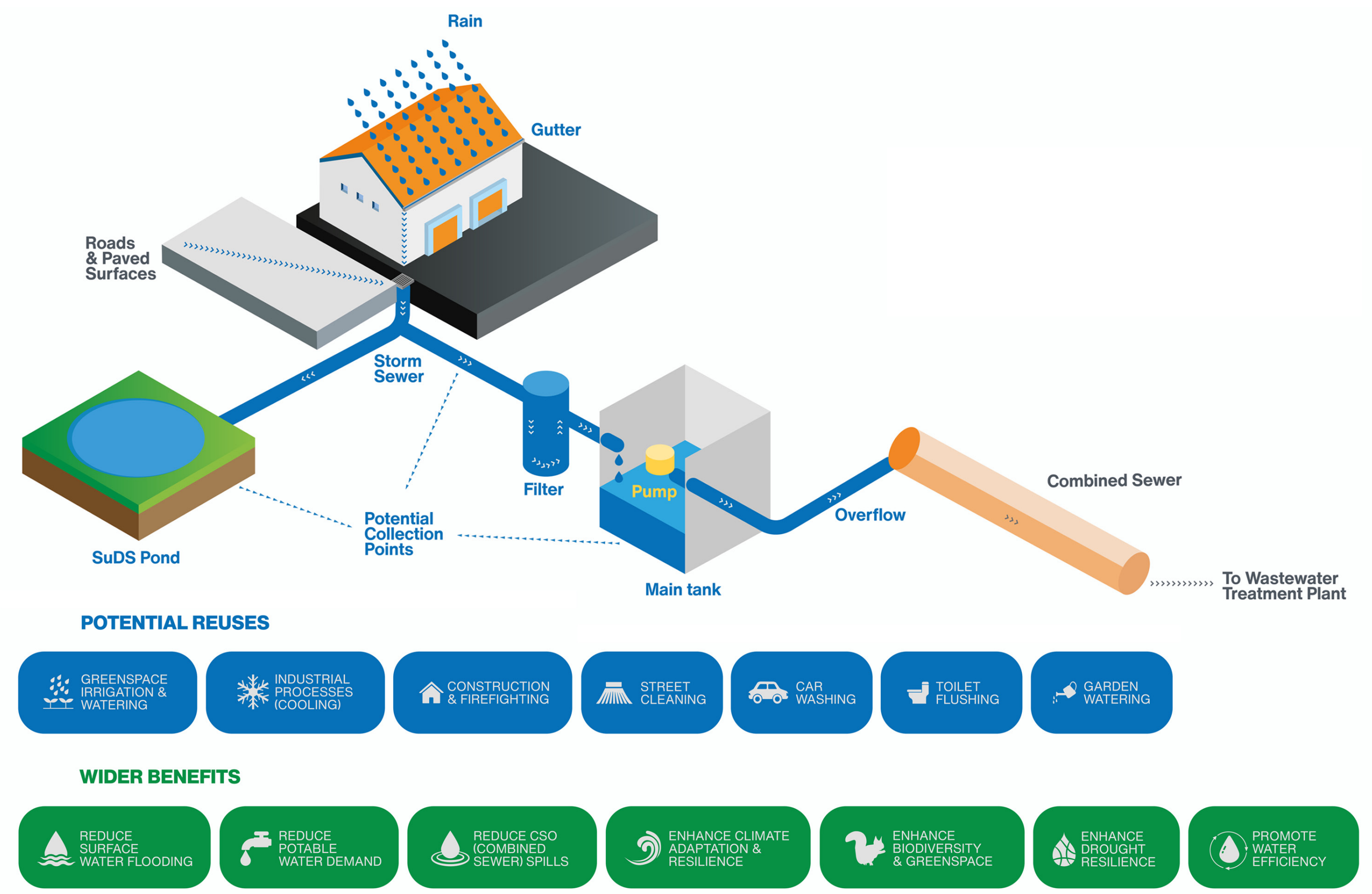
CREW CENTRE OF EXPERTISE FOR WATERS

Transitioning Surface Water Collection to Surface Water Reuse Systems

Main Report

Cuthbertson A., Wade R., Black A., Duffy A., Hendry S., Leask F., Ralph E., Sezen E., Varghese A., Ward K.



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Glossary

A variety of terminologies are used, both in literature and in legal and policy documents. This glossary is intended to show how key terms are used in this report.

In the academic literature, and across disciplines, these terms may be used interchangeably, or they may have specific meanings within disciplines or professions. This is unavoidable and is reflected in the literature review, where literature may use some of these terms differently. The glossary notes where key terms are often interchangeable in different contexts.

In specific pieces of legislation, terms may be given specific meanings only used in that jurisdiction or that piece of legislation.

Blue-Green Infrastructure (BGI)	Blue-green infrastructure uses networks of natural and semi-natural features and areas of green spaces within the built environment to manage water and reduce flooding in towns and cities. It is about making the most of urban green spaces and natural water bodies to capture rainwater where it falls and to reduce run-off and reduce water flowing into our drainage systems. It is sometimes used synonymously with *Nature-Based Solutions*. This project will use BGI to refer to a wide variety of features and techniques, including water butts, raingardens, ponds and basins, as well as trees and parks and other open green space.
Circular Economy	The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible. This project will use 'circular economy' as a policy frame to indicate closing resource loops and encouraging reuse of surface water.
Greywater	Greywater, or grey water, is often defined as wastewater generated from a washing machine, bathtub, shower or bathroom sink, collected separately from a sewage flow. It does not include wastewater from a toilet ('black water'). Some literature, or some practitioners, may use greywater to refer to *surface runoff*. This project will not use greywater as synonymous with surface water.
Nature-based solutions (NBS)	Nature-based solutions refer to interventions that are inspired and supported by nature and use, or mimic, natural processes to contribute to the improved management of water. This project will use NBS to include *blue-green infrastructure (BGI)*, and *Sustainable (Urban) Drainage Systems (SuDS)*. NBS can also include Natural Flood Management, which is often more appropriate in a rural context.
Rainwater harvesting (RWH)	The collection of rainwater, often from roofs or gutters. Often referring to water butts, and / or underground storage, but can be used for a variety of techniques and technologies, some of which overlap with SuDS (below).
Reclaimed water	Treated ('fit-for-purpose') wastewater that can be used under controlled conditions for beneficial purposes, such as irrigation. This is used inconsistently in the literature.
Recycled water	Treated ('fit-for-purpose') wastewater that can be used under controlled conditions for beneficial purposes within the same establishment or industry. This is used inconsistently in the literature.
Runoff	Refers to water running across a surface before it enters a drain or watercourse, or soaks into the soil.
Stormwater/surface runoff/ urban runoff	This project uses the terms *stormwater, surface runoff* and *urban runoff* to mean surface runoff of rainwater in the urban environment, which may be collected in storm drains, SuDS, or combined sewers, or may soak away into the soil where the ground is not hard standing. These terms are often used interchangeably.
Sustainable (Urban) Drainage Systems (SuDS, SUDS)	Sustainable Drainage Systems (SuDS) are an approach to managing drainage in and around properties and developments. They work by slowing and holding back water that runs off from a site. They help manage and control surface water. A number of different techniques may be used for SuDS. In Scotland, 'Sustainable Urban Drainage Systems' (SUDS) have a specific legal definition.
Wastewater	This project uses the term *wastewater* to describe piped effluent from buildings (i.e. households and non-domestic buildings). *Wastewater* can also be used to describe stormwater, surface runoff or urban runoff, but this project does not do so. The EU uses the term *urban wastewater* to include municipal and industrial wastewater and urban runoff.

Executive Summary

The Centre of Expertise for Waters (CREW) commissioned this capacity building project to help support Scottish Water's ambition to reduce the volumes of rainwater entering the combined sewer network by transitioning Scotland's surface water collection and treatment systems to surface water providing systems, enabling water reuse in the urban environment. This is driven partly by Scottish Water's Climate Change Adaptation Plan 2024 (Scottish Water, 2024) that describes how warmer and drier summers may increase the risk of deteriorating raw water quality, droughts and water security issues, and how more frequent, more extreme storms will disrupt Scottish Water assets and service provision. The Surface Water Policy (Scottish Water, 2017) drives a "no more in, what's in out" ambition to reduce the volume of rainwater entering the combined sewer system. One option to support this strategy is through the collection and reuse of rainwater for **non-potable** water use, such as for non-crop irrigation, green space cultivation, municipal cleaning activities, vehicle washing and industrial cooling applications. This proactive approach can help reduce sewer flooding and overflows into the water environment, while reducing overall demand for potable water supplies by reusing collected surface waters for **non-potable** purposes, particularly during periods of water stress.

This report addresses some of the knowledge gaps around the overall potential of Scotland's surface water management network to provide a viable water source for wider **non-potable** uses. In particular, it focuses on improving knowledge of current best practice in water reuse in UK and international contexts, exploring the potential for place-based solutions for reuse of untreated surface waters, understanding regulatory requirements and barriers, and the economic drivers to enable this transition, as well as consumer enthusiasm to adopt surface water reuse.

Project aim, research questions and methodology

The overall aim of this project is to explore the emerging area of interest in surface water reuse for non-potable uses before the next regulatory planning period (April 2027–March 2033). This focuses specifically on determining (i) potential surface water sources and collection points, (ii) potential non-potable uses of untreated surface water within current legislation, (iii) potential feasibility of pre-treatment to permit wider reuse of collected surface waters, and (iv) current legislative, technical, environmental and socio-economic barriers to the implementation of surface water reuse in Scotland. The key research questions addressed in this report are:

- *What can be learned from perspectives and practical examples of water reuse in surface water management networks in the wider UK and internationally?*
- *What are the potential sources (type and estimated volumes) for water reuse within Scotland's current surface water management network?*
- *What are the opportunities/limitations/challenges/practicalities of surface water reuse within Scotland's current surface water management network?*
- *What are the key recommendations for next steps in the implementation of surface water reuse in Scotland?*

The methodology adopted to address these research questions includes: (i) a comprehensive **literature review** covering UK-wide and international experience and practical case study examples on surface water reuse; (ii) a **review of current policy and legislation** around surface water reuse from Scottish, UK-wide and EU perspectives; (iii) **data collection, mapping and GIS analysis** within the specific focal area (Dundee, Scotland) to assess potential surface water reuse scenarios within different urban contexts; (iv) a **stakeholder consultative workshop** to help develop a strategic vision identifying the best approach to transition Scotland's surface water, and associated assets, from collection to reuse; (v) a **SWOT analysis** for implementation of surface water reuse within Scotland's current surface water management network; and (vi) an exploration of **future opportunities** in the transition from surface water collection to reuse.

Summary of key findings

Current knowledge and knowledge gaps

The project identifies the high degree of knowledge and understanding of different technologies and methods to collect and reuse surface water runoff, both from UK and international examples. However, clear knowledge gaps remain around the lack of well-documented case studies that provide strong evidence to support the wide implementation of non-potable surface water reuse in a Scottish context. This highlights an urgent need for pilot projects to assess the challenges and opportunities around surface water reuse in Scotland and identify the types of reuse schemes that should be prioritised.

Legislation and policy

There is also a clear lack of enabling legislation and policy around surface water reuse in Scotland, specifically within the land use planning system and building standards, while a lack of financial incentives and/or the setting of statutory targets around water consumption also disincentivise developers and the general public in adopting more water efficient practices.

Surface water reuse scenarios

Surface water reuse scenarios undertaken at eight case study sites across Dundee demonstrate the overall potential for reuse schemes to contribute positively to reducing potable water demand (for non-potable purposes) and surface runoff volumes entering the combined sewer network. These scenarios are modelled during "wet" and "dry" years, based on historic rainfall records, with the feasibility of water collection and reuse considered for a range of different sources and scales, including rainwater harvesting from roofs, surface water collection from paved areas, and direct abstraction from stormwater sewers and SuDS. These scenarios show that the availability of surface water volumes can often far exceed the requirements for the various non-potable reuse applications considered in each case study.

Stakeholder workshop

Finally, stakeholder discussions held in the consultative workshop indicated widespread enthusiasm for the adoption of surface water reuse in Scotland. Barriers to reuse, which are also key areas for action, were identified as relating to (i) individual stakeholder responsibilities, strategic leadership roles, and cross-sectoral engagement and collaboration (including co-working with the public), (ii) costs versus benefits of adapting current surface water infrastructure, including SuDS, to support water reuse, and (iii) uncertainties around surface water quality and treatment, and how needs and expectations can be met and monitored.

Recommendations

The key recommendations from the project are:

- To develop surface water reuse pilot projects that address **technical challenges and innovations** including establishing water quality and quantity protocols for a range of non-potable uses.
- To use **public engagement and education** to address misconceptions around water scarcity, promote and incentivise water efficiency, and support community-based co-creation activities in sustainable urban water management that encourage surface water reuse for non-potable uses.
- To develop guidance on the wider **social and environmental benefits** of blue-green infrastructure and in the adoption of surface water reuse to enhance **biodiversity, nature capital and public amenity value** of urban greenspaces.
- To advocate for changes to existing **policy and legislation** that enable and incentivise the transition to greater water efficiency and surface water reuse.

Responsibility for these actions lies predominantly with the Scottish Government (funding, policy & legislation), Scottish Water and local authorities (project implementation, monitoring, community engagement), while other stakeholders such as SEPA, NatureScot, businesses and the general public have crucial roles in ensuring the multiple benefits associated with surface water reuse can be achieved.

1. Introduction

Continued growth of the built environment, associated with urban expansion and increasing urban populations, is placing considerable pressure on critical water infrastructure and the urban water cycle. Key pressures include increasing potable water demand and the inability of combined sewer networks to cope with increasing volumes of surface water runoff generated from rainfall onto impervious surfaces. Globally, urban water demand is expected to increase from present levels of 15–20% up to about 30% or higher of the total water demand by 2050 (World Bank Group, 2021), placing increased stress on potable water supplies and reducing water security. This is compounded by climate change impacts (e.g. increasing rainfall intensities and droughts) and inadequate or aging infrastructure (e.g. limited surface water drainage capacity) that can increase urban flood risk and result in more frequent combined sewer overflow (CSO) discharges of untreated wastewater, with an increased risk of habitat degradation and biodiversity loss.

1.1 Project background and scope

From a Scottish perspective, the expectation of warmer and drier summers, droughts (CREW, 2020; SEPA 2025), and more frequent extreme rainfall events (Scottish Water, 2024), not only exacerbates the risks of water scarcity through reduced availability of raw source waters, leading to disruptions in local or regional potable water supplies (BBC, 2025), but also increases the risk that urban drainage systems will become increasingly overwhelmed by surface waters and grey waters entering the network. Supporting the transition of Scotland's surface water collection and treatment systems to surface water providing systems, by reducing the overall volume of rainwater entering the combined sewer network (Scottish Water, 2025a), is a key aim of this CREW project. This will enable the reuse of surface waters in the urban environment and, hence, reduce demand from other treated water sources. In this regard, surface water reuse represents an untapped opportunity to alleviate growing pressure on Scotland's combined sewer network, whilst reducing overall potable water demand and supporting national net-zero goals (Climate Change Committee, 2024), including Scottish Water's Net Zero Emissions Routemap (Scottish Water, 2025b). This is consistent with recent policy work by the Scottish Government (2023).

To ensure sustainability in the future management of surface waters, Scottish Water's Surface Water Policy (Scottish Water, 2017) is not to accept any new surface water connections to their existing combined sewer system, with an ambition to reduce the overall volume of rainwater entering the network. This requires the adoption of new surface water management strategies, including the potential reuse of rainwater that can be collected (and potentially treated) in grey water systems for non-potable purposes, thus reducing potable water demands from mains supplies that experience significant stress during sustained periods of low rainfall (BBC, 2025).

1.2 Current knowledge gaps and project objectives

At present, knowledge gaps lie around the potential for Scotland's surface water management network to provide a viable water source for widespread non-potable uses, including technical feasibility, environmental impacts, potential legislative barriers, and societal acceptance. For example, information is currently lacking around the potential for place-based solutions for reuse of untreated surface waters, the regulatory requirements needed to facilitate this, the economic drivers to enable this transition, and consumer perception and enthusiasm to adopt surface water reuse as a replacement to potable water supplies for everyday non-potable purposes. The main goal of this CREW project is therefore to address these current knowledge gaps associated with surface water reuse in Scotland, through targeting the following project objectives in:

i. identifying and exploring the main emerging areas of interest around surface water reuse in Scotland to help inform and shape future strategy and policy,

ii. assessing the viability of, potential for, and multiple benefits afforded by large-scale adoption of surface water reuse in urban settings in Scotland (in terms of both water quantity and quality assessments),

iii. identifying and assessing available technologies and systems for rainwater harvesting and grey water reuse, including the potential adoption of SuDS and/or other nature-based solutions to enhance surface water quality through provision of preliminary/partial/minor treatment to widen water reuse potential (highlighting Scottish, UK-wide and international examples of good practice), and

iv. identifying current opportunities and barriers in the development and implementation of place-based solutions for surface water reuse in Scotland for non-potable purposes (including current and future legislation around water quality, public health, environmental protection, agriculture and irrigation, climate change, net zero and circular economy), in accord with Scottish Water's Water Sector Vision (Scottish Water, 2025a).

Each of these objectives is addressed through a multi-disciplinary methodology, designed to answer the key research questions around surface water reuse, including: (1) learning from UK-wide and international experience and case studies (including the review of relevant policy and legislation); (2) identifying and quantifying potential surface water sources for reuse in Scotland's current surface water management network; (3) identifying opportunities, limitations, challenges and practicalities around widespread implementation of surface water reuse in Scotland; and (4) providing future recommendations around regional, economic and environmental benefits and priorities to take the reuse agenda forward.

In this context, it is crucial to learn from recent UK and international case studies on how decentralised and circular approaches to urban water management, including examples of surface water reuse, can help mitigate urban flood risk, diversify water sources for non-potable uses, and provide additional ecosystem services and benefits (e.g. targeting net-zero).

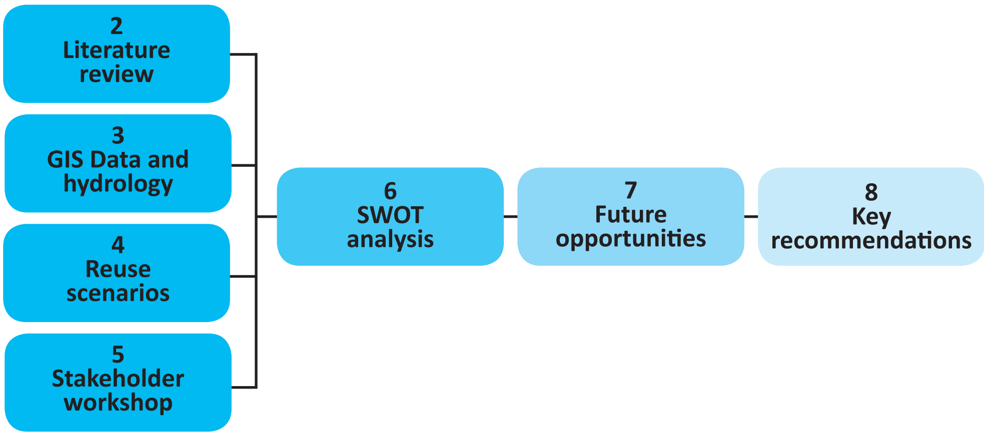

Figure 1.1: Structure of study and report layout

1.3 Outline of report structure

This introductory section is followed by a summary of the main findings from the literature review (**Section 2**) detailing important aspects associated with the potential non-potable reuse of surface waters through UK-wide and international perspectives, case study examples, and relevant policy and legislation. **Section 3** details the geospatial data availability, GIS analysis and mapping techniques, and hydrological (rainfall-runoff) modelling and analysis applied within the focal geographic area of study (Dundee, Scotland), chosen for the feasibility assessment of a range of different surface water reuse scenarios within different urban settings. **Section 4** then provides the main findings and conclusions from these surface water reuse case study scenarios. The main findings from stakeholder consultative workshop, aimed at identifying the best approach to transition Scotland's surface water and associated assets from collection to reuse, are presented in **Section 5**. These sections collectively serve to inform a SWOT analysis for widespread implementation of surface water reuse in Scotland's current surface water management network (**Section 6**) and future opportunities to support the transition from surface water collection to reuse (**Section 7**). Finally, the key conclusions and recommendations are provided in **Section 8**.

A number of report annexes are also included, as detailed in the table of contents.

2. Literature Reviews

2.1 Summary of UK-wide and international water reuse experience

This section summarises the different perspectives and practical examples in surface water reuse from Scottish, the wider UK, and international experience. The current CREW project differentiates between (1) surface water capture and reuse, which may, or may not, involve treatment, but which avoids surface water being disposed to sewers; (2) recirculation of water within an internal piped system, including the use of greywater for toilet flushing, or water recycling within an industrial context; and (3) the reuse of treated urban wastewater. While options (2) and (3) are outside of the current project scope, they are covered within the wider water reuse context set out in the literature review, which is separated into the following themes: technologies; sector applications; economics; and public awareness/perception. A number of practical examples from the UK and internationally are then highlighted to demonstrate the breadth of surface water collection and reuse options available, while a summary of findings from a policy and legislation review is provided in Section 2.2.

2.1.1 Technologies for non-potable water reuse

The literature review explores a wide range of surface water reuse and some other non-potable water technologies already adopted to diversify urban water sources (Stang *et al*., 2021). There are multiple overlapping terminologies. ‘Blue-Green Infrastructure’ (BGI) and ‘Nature-Based Solutions’ (NBS) are both used as general terms in the literature. Sustainable Drainage Systems (SuDS) and rainwater harvesting (RWH) are also used widely and may each cover a variety of specific techniques and technologies, such as water butts, green roofs, permeable pavements, raingardens, basins, wetlands, ponds, infiltration systems, and underground storage (Jones *et al.,* 2023; Scottish Government, 2023). All these techniques will reduce runoff pressure on sewer networks and have the potential to reduce the use of potable water, contribute to climate goals, enhance biodiversity and improve public amenity (Scottish Government, 2023).

When properly managed, they can support groundwater infiltration and recharge, reduce pollution, save energy, and enhance urban water resilience by providing a decentralised water supply (National Academy of Sciences, 2016). These decentralised systems provide water sources for non-potable uses, offering climate-resilient, relatively low-cost, locally deployable alternatives to potable supplies, and providing multiple ecosystem services benefits (Jose and Wade, 2023). Key challenges include installation and maintenance costs, challenges in retrofitting dense urban areas, water quality concerns, public perceptions, and regulatory frameworks.

Recent guidance in England, such as the CIRIA report: enabling development (Cecil *et al.,* 2025) and the National Standards for SuDS (DEFRA, 2025) create a preferred ‘discharge hierarchy’ for surface runoff with benefits such as reduced potable water demand, lower energy and carbon costs, and increased drought resilience. Similar water reuse priorities were already reflected in Scottish Water’s Surface Water Policy (2017), as shown in Figure. 2.1.

Non-potable water reuse technologies include both open-loop and closed-loop systems, with closed systems, including greywater reuse, offering higher efficiency as water is recirculated in the system,

Discharge Hierarchy	Scottish Water (2017) Surface Water Policy	CIRIA Report C823F (2025) Outfall Option
Must be considered first	Option 1: Rainwater is stored and reused, such as RWH and/or water butts	RWH and reuse
	Option 2: Surface water is drained into the soil through the use of a soakaway	Infiltration into ground
	Option 3: Surface water is drained to a watercourse (open or piped), canal, loch or existing /proposed SUDS	Attenuation and discharge to a waterbody, ordinary watercourse or main river
	Option 4: Surface water is drained to a surface water sewer	Attenuation and discharge to public surface water sewer
Only if all options are unavailable	Option 5: Surface water is drained to a combined sewer	Attenuation and discharge to public combined sewer

Figure 2.1: Surface water discharge hierarchy for new developments. Adapted from SW (2017) and Cecil *et al*. (2025)

reducing the need for abstraction and minimising water loss and environmental exposure (EA, 2025). Rainwater reuse is normally associated with open-loop systems, such as irrigation, but scenarios exist where rainwater supports closed-loop industrial processes, such as heating and cooling.

Commercial smart water tanks and residential smart water butts that use predictive weather controls to release water ahead of storms have demonstrated improved stormwater attenuation (compared to non-smart systems), while supporting rainwater reuse (SDS Ltd., 2019; River Severn Partnership, 2025).

Both greywater reuse and direct on-site reuse of captured surface runoff/harvested rainwater can result in improved water efficiency and economic savings, particularly for new-build, although existing infrastructure can be retrofitted. Maintenance requirements and regulatory barriers mean this approach is more viable for large-scale commercial sites (e.g. airports, stadiums) or multi-residential settings (Pitt *et al.,* 2011; NYSDEC, 2013).

Pollution from surface waters can be mitigated by SuDS treatment trains that filter contaminants through permeable surfaces, significantly reducing runoff of harmful pollutants to water bodies (Monachese *et al.,* 2025). Rainwater from roofs is comparatively cleaner than other impermeable surfaces such as car parks and roads; however, it can still contain heavy metals and particulates from roofing materials, gutters, and downpipes, and microbial bacteria. The UK has no regulatory water quality standards for non-potable rainwater reuse, although British Standard BS 8515 provides guidance for bacteriological and general monitoring (BSI, 2013). Risk assessments for surface water reuse must consider intended use, exposure pathways, environmental setting, and necessary treatment levels, with pathogens presenting potential risks even for low-exposure applications like toilet flushing (National Academy of Sciences, 2016).

2.1.2 Sector applications for water reuse

Globally, water reuse plays a key role in agriculture and industry where large water demands are driving the need for alternative supplies. In agriculture, reclaimed water aids irrigation, improves drought resilience, and reduces pressure on freshwater sources. When paired with efficient irrigation systems, it can significantly reduce water waste and fertiliser loss (WWAP, 2017). Reuse also reduces runoff of nutrient-rich pollutants (Lepcha *et al.,* 2024).

Industrial water reuse is common in cooling and boiler feed systems, and manufacturing processes (EPA, 2012), which require careful attention to water quality. Industry sectors such as brewing and distilling present multiple opportunities for non-potable water reuse (e.g. rinsing, cleaning and cooling) that often adopt closed-loop systems to reduce water consumption (Ashraf *et al.,* 2021). The infrastructure and treatment requirements of these systems are outside the scope of this project, but there may be potential for the use of captured runoff.

Data centres rely on cooling systems to dissipate heat and maintain optimal operating conditions for server hardware, including high-performance chips. These are classified as Critical National Infrastructure (Kyle, 2024), with a recent report by Kenny (2025) highlighting that their operational resilience must be sustainable, particularly in the case of water use and reuse. Recent advances in closed-loop cooling systems, liquid cooling, direct to chip and immersion cooling offer improved heat transfer capabilities, reduced water consumption and increased sustainability (McCarthy *et al.,* 2025; Heymann, 2025). There is also an important recognition that water for cooling systems 'does not need to be drinking water quality' (UK Parliament, 2025). Scotland currently has 20 data centres that utilise 0.005% of the mains water supply, and that figure has quadrupled since 2021 (BBC Scotland, 2025).

In the energy sector, there is potential scope for use of reclaimed water, for cooling and other process uses. Green hydrogen is an energy technology that can potentially reuse rainwater for hydrogen production if appropriately treated, making it viable for off-grid or decentralised systems. The Scottish Government is supporting green hydrogen (Scottish Government, 2024a), along with Scottish Water Horizons, the innovation arm of Scottish Water (Scottish Water Horizons, n.d.).

For both green hydrogen and other new industrial users such as data centres, surface runoff may be a feasible source of water for green hydrogen. However, co-location with wastewater treatment plant would seem desirable to ensure a continuous quantity and quality of supply. The Forth Ports is using wastewater from Seafield wastewater treatment plant to produce their green hydrogen (Hydrogen Scotland, 2024).

In urban and municipal settings, capture of surface runoff can contribute significantly to non-potable uses, conserving drinking water for essential needs. Examples in the literature include street/building cleaning and commercial vehicle washing (Zhang *et al.,* 2019); firefighting (Martins Vaz *et al.,* 2023; FM Global, 2010); watering green space; and use in decorative water features (National Academies of Sciences, 2016). Environmental and recreational applications of rainwater reuse include supporting wetlands, wildlife habitats, urban greenspaces, and recreational facilities such as golf courses and sports fields, many of which currently rely on main supplies or abstracted water sources (EA, 2025). In the UK, the potential for the capture and reuse of surface runoff remains under-developed, despite technological feasibility.

2.1.3 Economics of water reuse

Financial barriers remain one of the main obstacles to expanding water reuse in the UK (Anglian Water, 2025), with high initial investment and a lack of clear funding mechanisms and financial incentives hindering adoption. There is growing recognition that economic appraisal for non-potable reuse should consider scarcity (CREW, 2020), as well as wider benefits such as biodiversity net gain, nutrient neutrality, and carbon credits. Internationally, San Francisco provides an illustrative model through its Water Reuse Grant Program that offers tiered grants of up to USD $1 million for onsite rainwater and process water reuse systems, demonstrating how targeted financial incentives can accelerate adoption (SFPUC, n.d.).

Water scarcity, meanwhile, is a major barrier to new housing development, particularly in the East and Southeast of England, where current constraints could prevent the building of 61,600 homes over the next 5 years (PUBLICFIRST, n.d.), with an estimated overall cost to the UK economy of £25 billion. Implementing water smart housing with 30% higher water efficiency could recover about £20 billion of this loss, enabling construction of 49,000 of these “lost” homes, particularly in high productivity areas, such as Cambridge, St Albans and Worthing.

Fredenham *et al.* (2020) conducted a study for Waterwise, exploring the costs and benefits of rainwater harvesting and greywater recycling systems, indicating that several English water companies (Anglian, Southern and Severn Trent, Essex and Suffolk) have introduced financial incentives to encourage water efficient, new-build housing with disconnection from the public sewer system or connection via a sustainable urban drainage system (SuDS). This study recognised that uptake of these incentives by developers has been low due to lack of awareness.

2.1.4 Public perception and awareness

Barriers to water reuse may exist relating to public perceptions, for both householders and wider institutional and commercial measures. In England, there are widespread misconceptions about water scarcity, as well as fragmented water governance, coordination and common language across sectors and local authorities to address water usage (EA, 2025). For householders there is a lack of financial incentive, with a perceived lack of return on investment.

The Ofwat-funded Enabling Water Smart Communities (EWSC) project explored water scarcity impacts on housing and economic growth, including public perspectives around water use (PUBLICFIRST, n.d.). The findings indicated that 69% of the public believed they already had taken steps to conserve water, their motivation being primarily financial rather than environmental. Public support for rainwater reuse was highly accepted, especially for toilet flushing, irrigation or vehicle washing, while recycled wastewater for drinking or washing remained deeply unpopular. Greywater reuse had conditional support depending on the end uses. Cost-saving arguments were most persuasive, while environmental and “common sense” messages were also effective, although negative health messages around reuse were also highly convincing. Only 13% of the public saw water scarcity as affecting housing availability.

Research into six wide-ranging EWSC case studies (Paranage and Hargreaves, n.d) highlighted effective community engagement to be critical to creating sustainable, watersmart communities. Success was found to rely as much on community involvement as on technical innovation, with key lessons learned around recognising existing community activity, tailoring approaches to local needs, integrating community perspectives into decision making, and adopting collaborative engagement methods rather than one off consultations. Long-term relationships, co-creation, and valuing local knowledge were regarded as essential for building trust and shaping sustainable water futures.

Trust was also found to play a crucial role around contentious reuse schemes, such as purified recycled water for drinking purposes in the Southeast of England (Alexander *et al.,* 2008), with clear information from trusted expert sources deemed as vital to encouraging behavioural change around water infrastructure. Even for non-potable reuse applications, communication strategies must focus on positive messages around cost savings and practical benefits and avoid reinforcing the 'yuck' or ‘ick’ factor (Smith *et al.,* 2018; Moncrieff, 2025) or phrases that relate to ‘recycled water/wastewater’, such as ‘toilet to tap’ (Duckett *et al.,* 2024).

Strong community engagement in urban planning is key to future sustainable water management and resource allocation (EA, 2025) and serves as an engagement mechanism for promoting innovation and increasing awareness. Public perception, societal acceptance, education, and continuous stakeholder involvement are all necessary to ensure successful long term uptake of water reuse initiatives (Anglian Water, 2025).

2.1.5 Surface water reuse – Practical examples

Surface water collection and reuse should be an essential component of sustainable urban water management, especially in water-stressed regions and densely populated areas. These reuse systems can range from natural solutions to engineered technologies, with a wide range of reuse purposes. A range of practical examples of surface water reuse techniques from the UK, Europe, Asia, Australia and the US are described in detail in Annex A7. These are also summarised in Table 2.1 below with the main weblinks or references provided for further information.

2.1.6 Summary – Water reuse barriers and opportunities

The literature review and practical examples evidence considerable expertise in different types of water reuse within the commercial sector, with larger industries capable of working with their water suppliers to install closed loop systems. Large commercial developments are most likely to have greywater reuse systems for toilets etc., reducing water bills and wider environmental impacts. The majority of the reuse examples presented in Table 2.1 are relevant or transferable to Scotland in terms of the scales of intervention, rainwater collection technologies and uses. However, in most cases, some treatment would be required and this was also the view of the stakeholders at the workshop. The only clear exception would seem to be capture and reuse via water butts in domestic properties, for external use such as garden watering or car washing. Any reuse indoors, even for toilet flushing, in domestic or commercial properties, would have potential health impacts and require at least minimal disinfection, as expected by Building Standards. Such systems require approval under Scottish Water’s Byelaws. Reuse of captured water at larger scales (e.g. from SuDS or surface water sewers) would require infrastructure for storage and delivery to the end user. The cost of piped water is unlikely to make that viable.

All types of water reuse will reduce pressure on the resource and on the financial, energy and environmental costs of potable supply. Management of urban runoff can also reduce pressure on the sewer system and enhance biodiversity and urban amenity, as well as help build more resilient and adaptive communities. There is a clear policy preference to remove surface runoff from the sewer network where possible; and reuse is preferable to discharge to surface drainage and then to a freshwater body, with SuDS the most frequently used techniques. There is considerable knowledge and understanding of how to design and use these and in Scotland, this has been the expectation for three decades and in law since 2003 (and see section 2.2 below). However, there are numerous other appropriate technologies and techniques. External domestic alterations such as water butts can be relatively simple and affordable, but might need incentives, particularly where perceptions of water scarcity are low, as is the case in Scotland. Most other techniques, including the practical examples outlined in Table 2.1, will require coordinated regulations, financial support, and engagement to build public acceptance.

There is potential to use captured runoff directly, for example for watering gardens or washing cars in a domestic context, but also for firefighting, commercial vehicle washing or irrigation of public spaces. Uses which would require treatment in turn would require appropriate infrastructure. Scale is critical and impacts both the technologies and the costs. The practical examples illustrate numerous city-wide and sometimes country-wide projects at scale, led by government bodies and often in response to either significant drought or significant flood risk.

There is evidence that where there is no public health risk, public perception is positive for water reuse. It will be critical to work with communities (including domestic and commercial users) both in terms of understanding the benefits and in the design and installation of any new infrastructure, stressing the multiple wins from these approaches.

Table 2.1: Summary of rainwater reuse practical examples from UK, Europe, Asia, USA and Australia.		
Practical Example	Reuse purpose	Source
Bloomberg HQ, London	Cooling, toilet flushing	https://www.bloomberg.com/company/stories/eco-friendly-features-bloombergs-new-european-headquarters/
Community Centric Rainwater Management, London & Cirencester	Water butt planters	https://www.thameswater.co.uk/about-us/innovation/community-centric-rainwater
Community Housing Development, Edinburgh	Toilet flushing, irrigation	https://www.stormsaver.com/case-studies/residential-case-studies/ scottish-housing-development
Gooddrop Ltd, Hull	Plant irrigation, cotton production	https://www.good-drop.com/
Havenstreet, Isle of Wight	Garden watering	https://www.makewaterfamous.com/news/free-water-butts-reducing- storm-overflows
Llys Enfys Care Home, Glamorgan	Toilet flushing	Fredenham *et al* (2020)
Mickley, Tyne Valley, Northumberland	Garden watering	https://www.newtonarchitects.com/projects/mickley-square-sustainable-housing/
Nat Flatman Street, Newmarket	Storm attenuation, garden watering	https://sdsinfrastructure.com/case-studies/newmarket/
Tesco Extra, Havant	Toilet flushing, vehicle washing	Fredenham *et al* (2020).
Arkadien Asperg, Stuttgart, Germany	Irrigation, toilet flushing, washing	https://www.building.co.uk/focus/our-town/3054588.article
Benicàssim, Valencia, Spain	Water infiltration	https://link.springer.com/article/10.1007/s11269-021-02778-7
Copenhagen sponge city', Denmark.	Water infiltration and capture	https://e360.yale.edu/features/copenhagen-sponge-cities
Nuremberg – low energy development 'Prisma', Germany	Irrigation, air conditioning, fire fighting	https://sdg21.eu/en/db/prisma-nuernberg
RHW for data centre cooling, Netherlands	Data centre cooling	https://viacon.co.uk/case-studies/harvesting-rainwater-for-a-sustainable-cooling-solution/
Hawke's Brewing Co., Sydney, Australia	Indoor agriculture	https://www.csiro.au/en/work-with-us/funding-programs/SME/SME-success-stories/University-Of-Technology-Sydney
Managed Aquifer Recharge (MAR) Systems, Australia	Agriculture, urban irrigation	https://www.waterconnect.sa.gov.au/Content/Publications/DEW/Managed %20Aquifer%20Recharge%20Schemes%20in%20Adelaide_Final.pdf
Sydney Park Water Re-use Project, Australia	Green space irrigation, water features	https://www.planning.nsw.gov.au/government-architect-nsw/case-studies-public/sydney-park-water-re-use-project
Huairou, Beijing, China	Urban agriculture	Howe *et al* (2011); Jefferies and Duffy (2011).
Xuhui Runway Park, China	Raingarden, irrigation	https://www.theplan.it/eng/award-2020-Landscape/xuhui-runway-park-an-innovative-urban-revitalization-project-sasaki-
Tokyo and Fukuoka, Japan	Toilet flushing, green space irrigation	Takeuchi and Tanaka (2020).
Ryogoku Kokugikan, Japan	Toilet flushing, air conditioning	https://www.tep.uk.com/non-potable-water-reuse/
Canal Park, Washington DC, USA	Green space irrigation, fountains	https://www.epa.gov/system/files/documents/2024-12/canal-park-case-study_508.pdf
EPA Headquarters, Washington DC, USA	On-site irrigation, runoff reduction	https://www.epa.gov/npdes/smart-data-infrastructure-wet-weather-control-and-decision-support
San Francisco – online water reuse system project, USA	Toilet flushing, heating and cooling, irrigation, street cleaning	https://www.sfpuc.gov/programs/water-supply/onsite-water-reuse

2.2 Summary of policy and legislation review

2.2.1 Scotland

The practical examples in Table 2.1 and in Annex A7 show clearly that many businesses with high consumption are willing and able to take water efficiency measures with appropriate support, and in some cases, mandatory requirements. There is an important policy space here nationally and locally, in terms of matching up potential users and uses to available surface water, which in turn depends on the way that water is captured and what (if any) treatment is provided by the blue-green infrastructure. Further detail on policy and legislation, including a detailed analysis of Scotland and a comparison with England, is provided in Annex B.

In Scotland there has been extensive development of water law and policy since devolution in 1998. Ministers have a duty to develop the value of water resources and promote their sustainable use; 'value' includes 'economic, social, environmental or other benefit' (*Water Resources (Scotland) Act 2013* s 1). It is useful to recognise the widest possible conception of the value of water at a high level, but more difficult to ensure that this is reflected in assessing the costs and benefits of BGI. All water provided by Scottish Water is treated to potable standard and there is no metered charge for most household users in Scotland.

'Water Resilient Places' (Scottish Government, 2021) promotes removing surface water from sewers and expects that new developments will have BGI to manage surface water. The National Planning Framework 4 (Scottish Government, 2023) identifies blue-green infrastructure as providing multiple benefits, especially flood risk. The National Flood Resilience Strategy (Scottish Government, 2024b) refers to nature-based solutions, including SuDS, and strategic drainage networks. Local authorities must prepare Surface Water Management Plans for their areas, including mapping SUDS, under the *Flood Risk Management (Scotland) Act 2009*. There is a 'cooperation duty' under that Act and under the *Water Environment and Water services (Scotland) Act 2003* which could be extended, or enacted in revised legislation, to include management of surface runoff.

The Scottish Government consulted on water and drainage in 2023, identifying both flood risk and water scarcity as drivers for change (Scottish Government, 2023b). This identified various mechanisms to improve surface water collection on properties, such as grey water systems, water butts or raingardens. Both this consultation and the current strategic review of charges for water services for 2027–2033 (Water Industry Commission for Scotland, 2024) refer throughout to 'water, wastewater and drainage' services. The consultation proposed a 'third charge' for drainage, along with water and wastewater, to make this more visible to household customers, but this alone would not provide an incentive to change behaviour. A shift to metering might provide an incentive, but the costs of such measures would still be high relative to the charge, and there would be political impediments. There are also specific challenges in rented property and flatted dwellings, which are numerous in Scotland.

There are more mechanisms to drive change for large scale commercial, industrial and public sector developers and operators. Business customers are already specifically charged for drainage, as well as (normally) having a metered charge for water. There is a further incentive in the possibility of a reduced charge if they can reduce consumption and costs for Scottish Water (*Water Industry (Scotland) Act 2022* s 29E). The case studies in this project show how businesses and the public sector can take a lead, both to capture and store surface water and to reuse it, after appropriate treatment.

Scottish Water's Strategy (Scottish Water, 2025) references nature-based solutions including rainwater capture at household level, and raingardens and blue green spaces at community level. Their Surface Water Policy (Scottish Water, 2017) establishes a hierarchy for surface water: on-site storage and reuse; soakaway to soil; draining to a watercourse; to a surface water sewer; and where nothing else is feasible, to a combined sewer. Removing surface water from combined sewers is a key priority, and England has introduced a similar hierarchy in 2025.

Sustainable Urban Drainage Systems (SUDS) are a key mechanism and are defined in *the Water Environment and Water Services (Scotland) Act 2023*. SUDS were already part of land use planning following early adoption by SEPA in the late 1990s, and are expected to be used in all new developments. There are technical standards for adoption under Sewers for Scotland v4 (Scottish Water, 2018). SUDS are the usual approach for drainage from new roads (SUDSWP, 2016), and Scottish Water have agreements with roads authorities to share roads drainage infrastructure under the *Sewerage (Scotland) Act 1968*.

SuDS in general are perhaps the most developed types of blue-green infrastructure. In England statutory provision exists (*Environment Act 2021*) but is still not in force. Scotland was an early adopter, and lessons learned include the need for clarity around ownership and liability, especially for ongoing maintenance.

Scottish Water's Byelaws (2014) ensure use of approved water fittings and contractors. Under Byelaw 5, Scottish Water must give consent to grey water or rainwater harvesting systems. A building warrant would also be required, from the relevant local authority, and possibly planning permission, which makes these activities complex as well as costly for householders, combined with no financial incentive to save water through the charging regime. However, there is no national target for reducing household consumption as there is in England (*Environmental Targets (Water) England) Regulations, SI 2023/93*).

Building Standards are a key mechanism to drive change, which can be mandated in new buildings and enabled for retrofit. The Technical Handbook (Scottish Government, 2025) provides for SuDS as well as water conservation measures, rainwater harvesting, and green roofs, again with a focus on flood risk; as well as standards for reuse of water. More could be done here, perhaps in combination with mandatory targets for reductions in water use.

The land use planning system is another mechanism to drive behavioural change, especially for domestic properties. Currently, the *General Permitted Development Order SI 1992/223* (Sch 1.1, Class 3C), permits hard standings within the curtilage of dwelling houses. If between the house and the road, this must be porous, or run to a permeable or porous surface. A similar requirement could be made for any new paved areas, but that would not assist with existing driveways, patios etc. Nor would it extend to encouraging (or requiring) e.g. replacement of currently paved areas with greenspace, which might be a more desirable outcome for garden ground. Currently, as with the charging system, the incentives are operating in the wrong direction.

2.2.2 Comparative and international context

Historically, at national level, and including Scotland, urban runoff was not managed within water resources, but rather within the 'built environment', and typically through roads departments. This approach has failed to maximise the use of the resource, whilst also overloading sewer systems and contributing to urban flooding. Many countries now will have extensive policy and guidance, but not necessarily legal rules, for BGI in general and SuDS in particular. Typically, 'grey' infrastructure is much better understood, by businesses, policymakers and lenders. Internationally and nationally, there is much more provision on reuse of (treated) wastewater than on reuse of surface water (WWAP, 2017; WHO, 2006).

Internationally, there is extensive policy and guidance from organisations and institutions, and at all levels of government, around 'nature-based solutions' or 'blue-green infrastructure' (e.g. WWAP, 2018; EEA, 2021). These approaches, often used interchangeably, are recognised as meeting both climate change and biodiversity imperatives as well as sustainable development, and are addressing both water scarcity and flooding. Increasingly, policy debates are framed around water resilience and the circular economy (European Commission, 2020; 2025). It is though recognised that legal, financial, and institutional structures need to be in place before initiatives begin, or at least before they are rolled out at scale.

2.2.3 The EU

Within the EU, as well as developing policy, there is relevant law. Many EU environmental laws continue to be in force in the UK jurisdictions post-EU Exit, and the environment and water are devolved. In Scotland, there is a legal principle of continued alignment with emerging EU environmental law (*Withdrawal from the European Union (Continuity) (Scotland) Act 2021*).

The Water Framework Directive 2000/60/EC requires the management of diffuse pollution, full cost recovery for water services, and pricing policies that incentivise efficient use. The *Floods Directive 2007/60/EC* recognises urban floods as a category, and the use of floodplains for retention, as well as the role of land use planning. It promotes the reduction of flood risk and retention by sustainable land uses. The *Priority Substances Directive 2013/39/EU* sets quality standards for receiving waters for a set of listed chemicals, as well as a 'watch list' of emerging contaminants. Some of these might be present in urban runoff.

The *Water Reuse Regulation 2020/741* provides for agricultural reuse of treated wastewater, by setting minimum standards for specific classes of use, with a focus on scarcity. Some states have gone further, with technical standards for other forms of reuse beyond agriculture.

The *Urban Wastewater Treatment Directive (Recast) 2024/3019/EU* requires Integrated Urban Wastewater Management Plans for larger cities and towns. The Plans should identify where polluted runoff from separate sewers is likely to be a risk to the environment or human health; and prioritise 'green and blue infrastructure' (Art 5). Annex V makes further provision for such infrastructure, and for water retention, limiting impermeable surfaces, and rainwater harvesting, to reduce storm water overflows. The Scottish Government is considering whether to implement the UWWTD, though some aspects would require a UK-wide approach.

The EU has well-established schemes for eco-labelling, including water efficiency, and there is a Regulation (post-Brexit) on eco-design which includes water use within the product lifecycle.

2.2.4 Legislation and policy summary

Table 2.2 provides a summary of key Scottish policies and legislative provisions analysed in Annex B, as well as a small subset of the most important EU provisions.

Table 2.2: Summary of key Scottish policies and legislative provisions and most important EU provisions.

Policy or Legislative Instrument	Key Relevant Provisions	Effect/Impact in Scotland
EU provisions		
Water Resilience Strategy (2025).	Promotes 'sponge cities' and wastewater reuse.	High level policy interest.
Circular Economy Action Plan (2020).	References water and wastewater reuse.	General relevance to circular economy measures in Scotland.
Water Framework Directive 2000/60/EC.	Holistic water management; river basin planning; good ecological status; water pollution; water services.	Implemented.
Floods Directive 2007/60/EC.	Urban flooding; retention by sustainable land use.	Implemented.
Urban Wastewater Treatment Directive (Recast) 2024/3109/EU.	Recognises pollution from urban runoff; mandates drainage plans; encourages BGI and natural retention measures.	Not yet implemented; under discussion.
Water Reuse Regulation 2020/741/EU.	Sets standards for reuse of treated wastewater for agriculture.	Not yet implemented. Similar provision could be adapted for surface water reuse.
Scotland Key Policy, Guidance, etc. – Scottish Government		
Water Resilient Places (2021).	Policy Framework for Surface Water Management. Recognises pressure on drainage systems and win-wins e.g. flooding and biodiversity.	Encourages BGI, discourages drainage to combined sewers. Recognises competing priorities and issues with retrofit.
National Planning Framework 4 (2024).	National spatial strategy; part of development plans; high level policies.	BGI for multiple benefits; flood prevention and surface water management.
Water, Wastewater and Drainage Consultation (2023).	Recognises drivers around both scarcity and urban flooding. Consulted on options for payment as well as practical means to improve surface water drainage.	Proposed legislative reform – not yet taken forward.
National Flood Resilience Strategy (2024).	Flood resilient places & communities. Context of climate change and just transition.	Urban flooding and SUDS; land use planning and absorption.
Principles of Charging and Ministerial Objectives for Scottish Water.	Set the framework for the Strategic Review of Charges (by the Water Industry for Scotland) and Scottish Water's Business Plans.	Drives infrastructure improvements; WICS references urban drainage in SRC documentation for 2027-2033.

Policy or Legislative Instrument	Key Relevant Provisions	Effect/Impact in Scotland
Scotland Key Policy, Guidance, etc. – Scottish Water		
Scottish Water Byelaws (2014).	Rules on water fittings and connections. Regulatory effect.	Requires consent for rainwater harvesting and greywater reuse.
Surface Water Policy (2017).	Guidance for developers and authorities.	Drainage hierarchy; Expectation of using SUDS.
Sewers for Scotland v4 (2018).	Technical specifications.	Technical specifications for SUDS systems; mandatory if system is to be adopted by SW.
Climate Change Adaptation Plan (2024).	Managing flood and drought, infrastructure.	Remove rainwater from combined sewers; BGI.
Long-Term Strategy (2025).	Recognises key drivers – climate, population, infrastructure.	NBS for urban water.
SEPA Guidance		
Regulatory Method WAT-RM-08 (SUDS or SUD Systems).	Guidance for developers and planning authorities.	Expectation that SUDS will be used in new developments.
Scotland Key Legislation		
Water Industry Act 2002.	Established Scottish Water.	Mandates or enables all Scottish Water's activities.
Water Environment and Water Services (Scotland) Act 2003.	Implements WFD; defines 'water environment'; enables water use regulations.	Defines SUDS in Scotland.
Environmental Authorisation (Scotland) Regulations 2018/219, as amended.	Includes control regime for all water uses: permits, registrations, notifications, General Binding Rules.	Authorises discharges to surface and groundwater; General Binding Rules for some SUDS.
Flood Risk Management (Scotland) Act 2009.	Implements Floods Directive.	Requires local authorities to create Surface Water Management Plans, including mapping SUDS.
Roads (Scotland) Act 1984.	Powers and duties of roads authorities.	Duties for drainage and construction standards. Expectation of SUDS (and agreements with Scottish Water).
Building Standards (Scotland) Act 2004.	Enables technical standards for new buildings and building works.	Mandatory requirement for SUDS in new build. Rainwater harvesting; water recycling; flood prevention. Water efficient fittings; water conservation measures.
Town and Country Planning (Scotland) Act 1997 as amended.	Implements NPF4 as part of development plans.	Controls all built developments via planning authorities.
Town and Country Planning (General Permitted Development) (Scotland) Order 1992/223, as amended.	Controls developments without requiring individual consents.	Permits hard standing in curtilage of dwelling houses; requires permeable surfaces between house and roads.

2.3 Review conclusions

Overall, the review of the literature, and the policy and legislation, indicates a high degree of knowledge and understanding of different technologies and techniques for capturing and re-using surface runoff. Usually this is enabled and sometimes incentivised at policy level, with new policy frames including resilience and the circular economy.

Developed countries will have a similar matrix of complex regulation to the UK jurisdictions, including land use planning, building standards, plumbing standards, and roads management, as well as broader laws governing water resources and water services, flood management, and pollution control. It is common for building standards at national level to permit, e.g., rainwater capture, sustainable drainage, or reuse of grey water, and there may be standards for the quality of water being reused for different purposes. It is much less common for the capture or reuse of surface runoff to be mandated, even for new-build. Pay-back periods will always be long, for both major infrastructure and for small site-specific developments. Mandatory requirements for retrofit are more problematic than for new-build, for businesses as well as households. However, the policy, law, and technical standards should all be in place before changes are implemented, to ensure financing and avoid issues around liability, especially for ongoing maintenance.

In a domestic context, messaging around the environment and climate can resonate positively. However householders may see little financial incentive to change behaviour, and especially in Scotland, due to the charging mechanisms.

Local authorities have multiple relevant functions, including planning, building control, flood protection, housing, roads and transport. There is scope for initiatives led by local authorities and Scottish Water, for both households and commercial premises. Key recommendations include:

- Change can be encouraged and incentivised, and adjustments to building standards and some aspects of land use planning could mandate improvements at least for new-build.
- Development of specific reuse regulations, clarifying the treatment needs/water quality requirements for different reuses and from different sources, would be very beneficial.

Table 2.3 summarises the findings from the practical examples (Table 2.1 and Annex A.7) along with key findings from the policy and legislation review (Annex B) to show which surface water reuse techniques could be used in Scotland, and some of the regulatory and policy implications.

Table 2.3: Application of practical water reuse examples in Scotland.				
Reuse source/type	**Examples currently in UK/Scotland**	**Treatment needed**	**Regulator/regime**	**Other requirements/comments**
Domestic				
Rainwater capture for (manual) domestic external use, *e.g. garden watering, car washing.*	Y	N	N/A	Minimal technology and support; Requires householders to engage.
Rainwater capture for domestic internal use, *e.g. toilet flushing, air conditioning.*	Y	Y	Scottish Water. Building control.	Public health concerns but could be made more accessible to householders. Most appropriate for new build.
Commercial/Industrial				
Rainwater capture for external use within commercial/ industrial properties, *e.g. vehicle washing, watering green space.*	Y	Y, depending on specific use.	Scottish Water. Planning for any infrastructure.	Possible H&S concerns for employees.
Rainwater capture for internal use within the curtilage commercial/industrial properties, *e.g. toilet flushing, air conditioning.*	Y	Y	Scottish Water; Building control.	Possible public health concerns but there are many examples. Most appropriate for new build.
Capture and reuse from public SuDS systems or from surface water sewers. Potential urban uses could include *vehicle washing, watering of greenspace, water for firefighting.*	No examples of this were clearly identified.	Y; may depend on source water/specific use.	Scottish Water; SEPA. Planning and building control.	Would require infrastructure.
Cooling water, *e.g. data centres, industrial processes*	Y	Y	Scottish Water; SEPA. Planning and building control.	Most appropriate for new developments. May be more appropriate to site near WWTP.
Measures to alleviate flooding/improve drainage without capture/reuse.				
Replacement of paved surfaces with permeable surfaces, *e.g. use of greenspace as raingardens, etc.*	Y	N/A	Planning; possibly, SEPA.	For new developments this is likely to be part of planning permission; but there could be incentives to retrofit.

3. Methodology

The geographical region of focus for this study is the Hatton wastewater catchment, extending from Invergowrie to Arbroath and including the local authority areas of Dundee City, Perth and Kinross and Angus. This is a largely urban/peri-urban area which has been selected to assess potential sources, types and estimated volumes of surface waters suitable for collection and reuse in a number of different urban settings, focusing specifically on eight case study scenario sites within Dundee City itself (see Figure 3.1).

The rationale behind selecting this region is that it has a considerable range of characteristics (e.g. housing, population density, socio-economic status, etc.) and mixed land use (i.e. residential, industrial, commercial and educational sites), lending itself to considering a range of different surface water reuse scenarios and scales. Ongoing economic development and investment in the city has resulted from key partnerships, such as Water Resilient Dundee (WRD, 2026), developed to address multiple water-related issues arising from an urban area with the highest percentage (88%) of combined sewers in Scotland, where this sewer network is often overwhelmed by stormwater runoff increasing urban flood risk. WRD is a multi-stakeholder partnership, led by Scottish Water and Dundee City Council, that is aimed at planning and sustainably managing water in the city, particularly around disconnecting stormwater from the combined sewer system. WRD includes place-based approaches to design, validation and delivery of SuDS, ecosystem service assessment, long term asset management, and outreach activities linked to public perception and adaptation for flood-resilient communities. Other multi-purpose sites in Dundee, such as Michelin Scotland Innovation Parc (MSIP), Ninewells Hospital, the University of Dundee City Campus, and Kingsway West Retail Park (KWRP), offer a wide range of different surface water reuse scenarios for investigation in this study (see Section 4).

3.1 GIS analysis: geospatial data requirements and tools

A large number of GIS datasets and layers were made available by Scottish Water via ArcGIS Online for Hatton wastewater catchment, to support analysis of potential surface water runoff and reuse case study scenarios within the Dundee City area (Figure 3.1). This included information on the distribution of combined and separate storm and foul sewer systems, CSO locations and performance, the location of existing SuDS infrastructure, gullies, and natural watercourses. Details of drainage strategy projects, land cover types (e.g. buildings, large roofs, greenspace, impermeable surfaces) and other socio-economic information (e.g. Scottish Index of Multiple Deprivation 2020, local area development plans) were also included in the datasets (tabulated and summarised in Annex C1, Table C1.1).

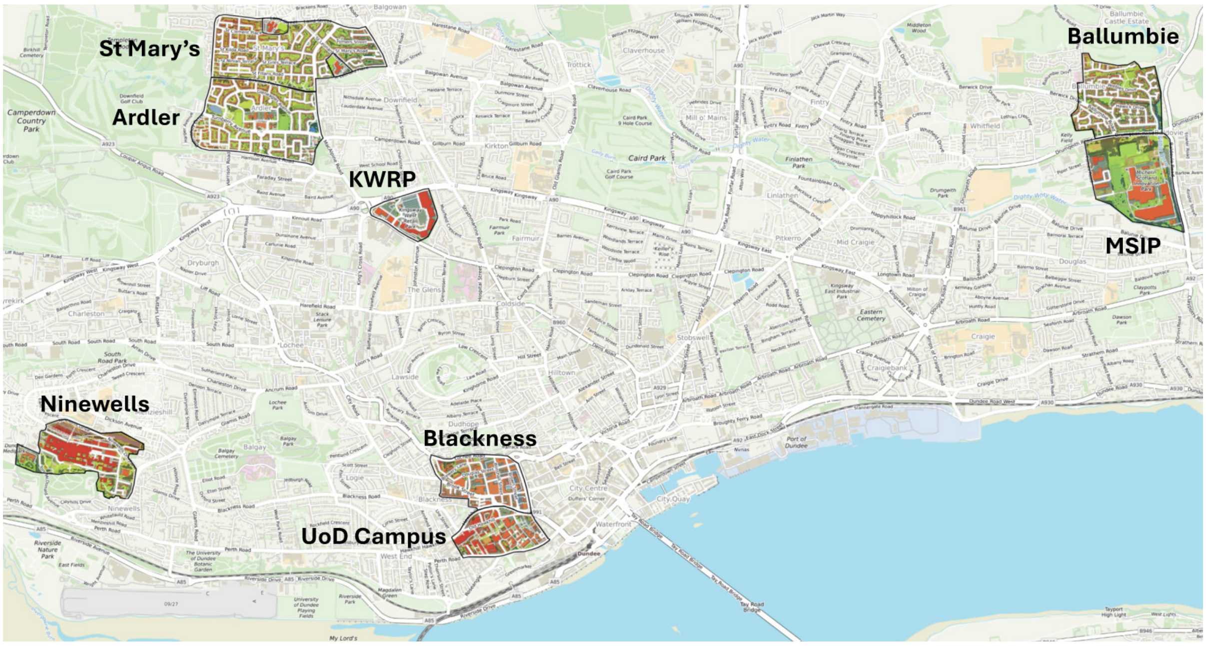

Figure 3.1: Map of Dundee City showing locations of case study sites for surface water reuse scenarios modelled (see Table E1.1 for details). Map generated using Scalgo Live. © Scalgo.

Other useful geospatial data resources and tools accessed during the project included: (i) SEPA flood maps; (ii) Scottish Water overflow maps and data; (iii) Greenspace Scotland map; (iv) Dundee City Council open data portal; (v) UK Centre for Ecology and Hydrology Flood Estimation Handbook Web Service.

The project team also utilised the Scalgo Live online platform at a number of different case study sites in Dundee to assess surface water runoff and on-site storage from a single high magnitude rainfall event (see Section 3.2). This GIS based tool calculates flash flood maps, based on terrain and land cover, providing information on expected flood areas, depths and surface runoff pathways. Scalgo Live also provides rapid assessment of different land cover types (e.g. buildings, roads, paved areas, shallow and deep vegetation, bare land) within selected workspaces and watersheds (see Annex C2).

Detailed drainage area model simulations for surface water runoff volumes from different land cover types (i.e. buildings, paved areas and permeable areas) were also conducted by Scottish Water using their InfoWorks ICM model for the Hatton wastewater catchment. These were undertaken at the case study scenario sites in Dundee for selected annual rainfall records (see Annex D). The surface water runoff volume timeseries and totals were used as the basis for the different surface water reuse scenarios considered within the study (Annex E).

3.2 Historical rainfall analysis

Analysis of the historical annual rainfall records at the Mylnfield raingauge station to the west of Dundee City was conducted to identify years that could be defined as being particularly poor and rich in terms of numbers of intense rainfall events occurring, i.e. defined as “dry” and “wet” years. Based on this analysis, 2003 and 2015 were chosen as being representative of these dry and wet years, respectively. The date/time series for the compressed 15-minute rainfall totals measured at Mylnfield for these two years are illustrated in Figure 3.2 below for visual comparison. The 2003 rainfall records indicate extended dry spells over February-April, July and August, whereas 2015 records show more consistent rainfall with only shorter, intermittent dry spells.

A more detailed analysis was undertaken to examine the seasonality of the highest rainfall intensities over a range of durations, and to consider whether any trends were visible in locally available rainfall data. Annex D1 provides the results of this detailed rainfall analysis. This shows there is a significant upward trend in event frequencies, but this is dependent on the period of data used. Linear regressions for rainfall records between 1997-2024 show the significant upward trend in event frequencies for 1 and 24 hour durations. However, starting the same analysis in 2004 shows there to be no significant trend.

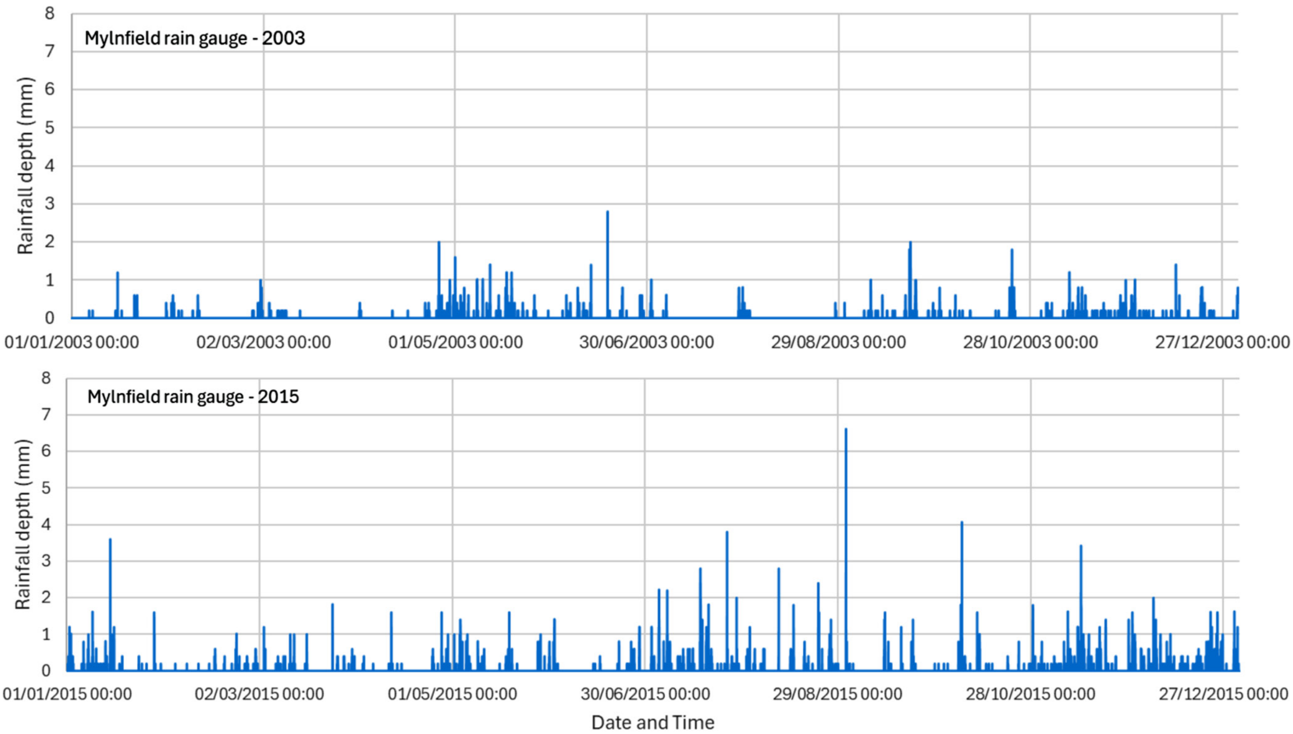

Figure 3.2: 15-minute rainfall totals at Mylnfield, Invergowrie in 2003 and 2015 (dry and wet years, respectively)

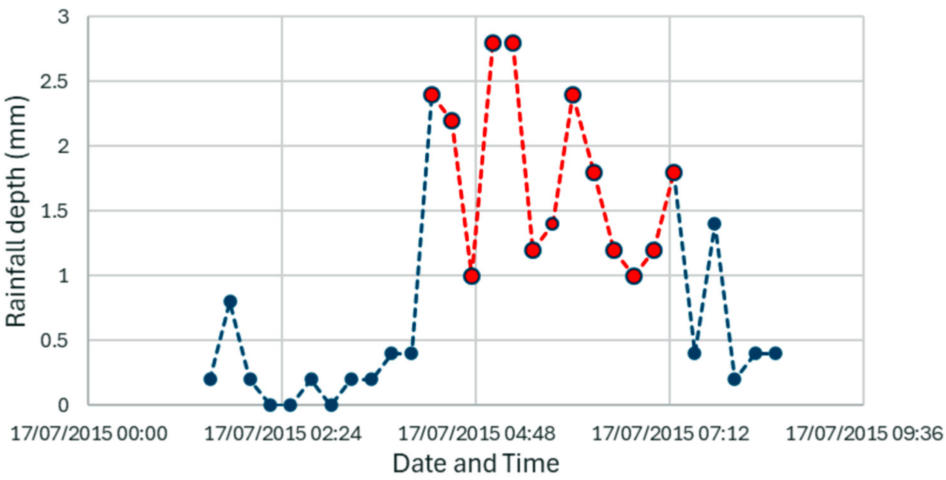

Figure 3.3: 15-minute rainfall totals at Mylnfield, Invergowrie for 01:30 – 08:30 on 17/07/2015

The two years of rainfall data shown in Figure. 3.2 were used to generate surface water runoff time series for these dry and wet years to assess surface water volumes available for potential reuse throughout these two years for the case study scenarios considered (see Section 4 and Annex E). These surface water runoff time series were generated from input of the rainfall records for 2003 and 2015 into Scottish Water's InfoWorks model of the Hatton wastewater catchment, with runoff volumes for roads and paved areas, buildings, and permeable surfaces able to be assessed separately or combined into a total runoff volume, as required in each scenario.

Assessment of flash flooding at a number of the case study sites was undertaken with Scalgo Live. This analysis was based on the assessment of surface water volumes generated during a high magnitude 25.8 mm: 4-hour rainfall event that occurred on 17 July 2015 (see Figure. 3.3) [Note: Scalgo Live flash flood analysis is based on rainfall totals over a four-hour period].

3.3 Surface water infrastructure assessment

Analysis of the surface water infrastructure began with consideration of possible access points for the collection of surface water runoff. As shown in Figure 3.4, consideration of the typical urban drainage environment identified four potential surface water collection point types: rainwater harvesting (RWH) from building roofs, collected runoff from paved surfaces (i.e. roads and other paved surfaces), abstraction from stormwater sewers and from SuDS infrastructure.

These possible surface water collection points formed a framework used to assess each of the case study areas selected for the surface water reuse scenarios. Data provided by Scottish Water on sewers, gullies and SuDS was combined with land use data in GIS to create maps for assessment. Table 3.1 provides further details that need to be considered when developing the case study scenarios further.

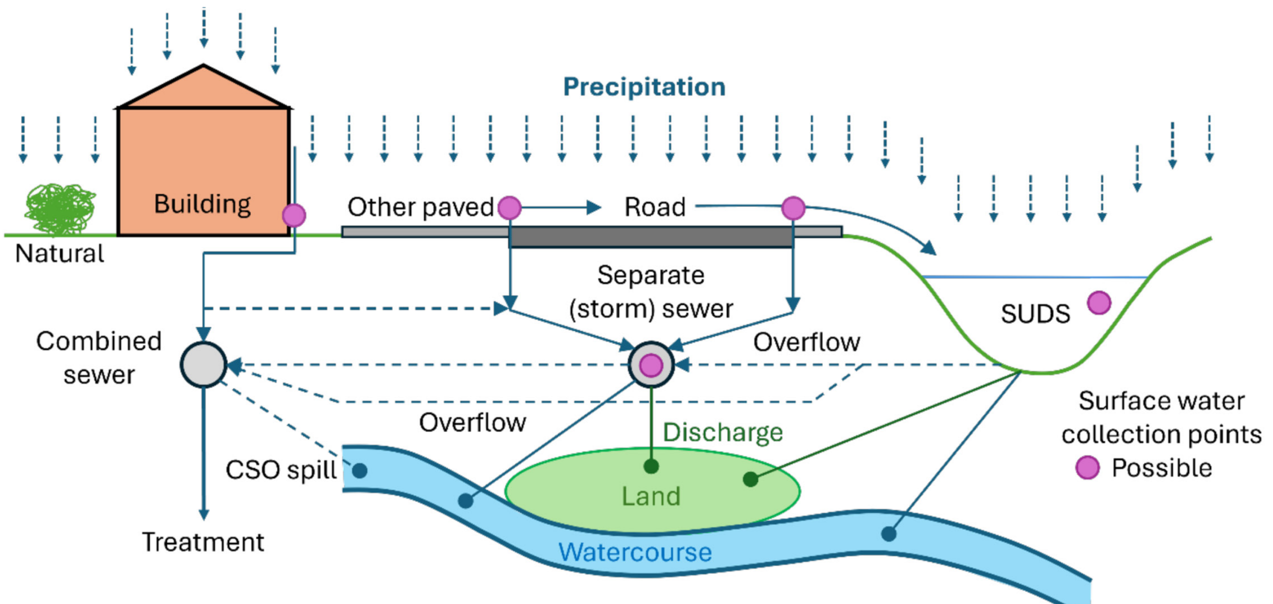

Figure 3.4: Identification of possible collection points from the urban drainage environment.

Table 3.1: Details of potential collection points for surface water reuse highlighting practicalities and potential contaminants.	
Collection point type	**Practicalities and contaminants**
Roofs: Downpipes	Often distributed around a building, consideration given on whether to collect to a single storage point or aim for distributed uses. Some contamination possible (leaves, bird droppings, general pollution).
Paved surfaces: a) non-roads b) roads	a) Surfaces could be regraded to a collection point, otherwise redirect the immediate subsurface collection to a storage/use point. Little control over contamination, may be highly varied depending on context. b) Existing drainage infrastructure can be highly distributed (e.g. gullies) which may make it onerous to pick up and divert, especially if the existing drainage connects directly to the combined sewer. If connected to storm sewer, it may be easier to extract from the sewer itself Vehicle related contamination (e.g. brake dust, tyre particulates, oil, etc.) is certain along with other debris (litter, leaves, etc.)
Stormwater sewer: a) end point extraction b) in-line extraction c) storage extraction	a) Existing end point will determine location, might not be near possible users, may need to be pumped to point of use. b) Divert into a storage tank. Suitable location for tank may limit proportion of the network that can be collected. Retrofitting tank may be difficult. c) Potential to pump to use point rather than releasing back into the system. Expected contamination from roads (see above). Potential for cross-contamination from misconnected foul sewers.
SuDS treatment train: a) overflow/end point b) abstract from a storage point	a) Similar to stormwater end point. Some SuDS systems have very little overflow except in exceptional events. Potential distance from users, requiring to be pumped. b) Pump to a storage site. Potential ecological impact on a pond. Direct use perhaps possible from attenuation storage but would need monitoring to know when water was available. Should be relatively well treated so contamination risk should be lower.

4. Surface Water Reuse Case Study Scenarios

4.1 Introduction

A number of case study scenarios have been considered at selected sites across the Dundee City area (Figure 3.1) to assess the potential for surface water reuse for a range of different land use types (i.e. residential, commercial and industrial areas; schools, universities and hospitals), surface water sources and collection points (i.e. building roofs, paved areas, roads), abstraction/storage types (i.e. rainwater harvesting, surface runoff collection/storage/abstraction), infrastructure (e.g. water butts, surface water sewers, storage tanks, SuDS), and potential water reuse options and users (i.e. domestic/property & community levels, public services, commercial & industrial purposes). These case study scenarios consider a range of different scales of surface water reuse from individual buildings and campuses to large industrial/commercial sites and residential areas. Specific details on these case studies are highlighted in Table 4.1 (see also Annex E).

Table 4.1: Summary of different case study scenarios considered for surface water reuse in Dundee City area.

Case study area/site (Annex section no.)	Land use(s)	Surface water source	Abstraction type/ infrastructure	Potential water reuse options and users
Michelin Scotland Innovation Parc (MSIP) [E3]	Industry, innovation	Roof area, roads, paved areas	Collection of runoff in on-site storage tank	Baldovie EfW facility (energy generation)
University of Dundee City Campus [E4]	University campus	University building roof area	Collection of runoff in storage tank(s)	Green space watering, road cleaning, campus maintenance.
Ninewells Hospital [E5]	Hospital	Main car parks and bus terminal	Collection of runoff in storage tank	Technology park, data centre cooling
Kingsway West Retail Park (KWRP) [E6]	Commercial/leisure	Commercial premises roof area	Collection/on-site storage in tank	Commercial car wash, industry
Ballumbie (Baldovie North) [E7]	Residential	All surface water runoff entering stormwater sewer	Direct abstraction from stormwater sewer	Baldovie EfW facility, local authority, other industry
St Mary's [E8]	Residential, Primary schools	School building roof area	RWH and on-site storage tanks	Community garden, outdoor education
Ardler [E9]	Residential	Property roofs	RWH/water-butts	Domestic/gardens
Blackness [E10]	Mixed (industry, commercial & residential)	Building roofs, roads, paved areas	Collection/storage of runoff in historic cooling ponds	Industry/commercial, local authority, fire services

4.2 Michelin Scotland Innovation Parc

Figure 4.1: Site map for the MSIP site (Map generated using Scalgo Live. © Scalgo).

Michelin Scotland Innovation Parc (MSIP) is a large industrial site to the east of Dundee with the second-largest roof area in Dundee (Figure 4.1). The surface water reuse scenario considered at this site is to utilise surface water runoff at the adjacent Baldovie Energy from Waste (EfW) facility, which currently has an annual mains water demand of approximately 66,000m^3 in generating 20MW of electricity through steam turbines. The surface water runoff volumes from MSIP (from building roofs, roads and paved areas) are calculated from Scottish Water's InfoWorks drainage model (Table 4.2), based on 2003 ("dry" year) and 2015 ("wet" year) rainfall records at Mylnfield raingauge in Dundee. These runoff volumes are routed via a storage tank with capacity 750m^3, from which water is abstracted continuously for Baldovie EfW at abstraction rates of 150, 300 or 500 litres/hr. Overall, the total surface water reuse volumes (Table 4.2) correspond to between 46-100% and 20-68% of the total runoff volumes generated from the 2003 and 2015 rainfall records, respectively, with the remainder expected to spill to the stormwater sewers beneath the site, discharging to combined sewers or waterways adjacent to the site. These reuse volumes also correspond to approximately 2-6% (up to 9% for 2015 total runoff volume) of the annual mains water demand for the Baldovie EfW plant. The Scalgo Live flash flood analysis for the MSIP site for a high intensity rainfall event on 17 July 2015 (25.8 mm over 4 hours) suggests that 79% of the surface water volume generated is stored on site (in topographic depression), while only 21% runs offsite. This indicates that a larger surface runoff volume may be available from MSIP for use in Baldovie EfW facility than estimated from the Scottish Water InfoWorks drainage model alone. As a post-industrial site, careful consideration is required as to the level of treatment needed to remove any legacy contaminants (e.g. hydrocarbons, heavy metals) from collected surface waters prior to reuse. Further details of this reuse scenario are given in Annex E3.

Table 4.2: Total run-off volume from MSIP, abstraction rates and re-use volumes, and spill into sewer system.

Year	Total runoff volume (m^3)	Abstraction rate (l/hr)*	Total re-use volume (m^3)	Re-use (%)	Total spill volume (m^3)+	Spill (%)
2003	2,726.34	150 300 500	1,263.8 2,527.7 2,726.3	46.4 92.7 100.0	1,462.5 198.69 0.0	53.6 7.3 0.0
2015	6,200.68	150 300 500	1,263.8 2,527.7 4,212.8	20.4 40.8 67.9	4,936.2 3,673.0 1987.9	79.6 59.2 32.1

* Based on constant abstraction from storage tank throughout year, maintaining water level in tank throughout.
\+ Calculated from weir equation (Eq. E3.1)

4.3 University of Dundee City Campus

The University of Dundee (UoD) City Campus (Figure 4.2) is in the west end of the city centre. University buildings, roads and paved areas, and bare land make up 78% of the total land area (0.23 km^2), with only 22% covered by vegetation. The surface water reuse scenario considered utilises run-off from university building roofs (i.e. rain-water harvesting) for campus maintenance purposes, such as watering green spaces, cleaning paved areas and roads, and washing university vehicles. Two scenarios are considered, collecting rainwater runoff from (i) the Wellcome Trust building complex and (ii) multiple buildings throughout the campus. In both cases, the surface water is routed through storage tanks (16 m^3 and 160 m^3 capacities, respectively) with estimated abstraction volumes for the non-potable water uses (see Table E4.5, Annex E4). The total roof runoff volumes based on 2003 and 2015 rainfall records are shown in Table 4.3 for both scenarios, along with estimated annual total surface water reuse volumes for each scenario (see footnotes in Table 4.3). These values indicate on-campus surface water reuse to represent only about 3–7% and 14–31% of the potential surface water volume available from the Wellcome Trust buildings and wider university buildings for their respective reuse scenarios, with equivalent reductions in the spill volumes to the combined sewer network. These reductions will be proportionally lower when compared to overall surface water runoff volumes (i.e. from buildings, paved areas, roads and bare surfaces) generated across the campus for 2003 and 2015 rainfall records. Reducing surface runoff volumes entering the combined sewer from the UoD City Campus is important given its high proportion of impermeable surfaces and sloping terrain. This is reflected in the Scalgo Live flash flood analysis for the 25.8mm: 4 hour rainfall event on 17 July 2015, which indicated 77% surface water runoff from the campus area and only 23% remaining stored within topographic depressions. This is in distinct contrast to the MSIP site (section 4.2). Collected runoff from building roofs is expected to have reduced contamination levels, compared to other reuse sources (Table 3.1), but may still contain microbiological and chemical contaminants. As such, some degree of treatment would still be required for the majority of campus reuse purposes proposed. Further details of this surface water reuse scenario are provided in Annex E4.

Figure 4.2: Site map of the University of Dundee campus (Map generated using Scalgo Live. © Scalgo).

Table 4.3: Roof runoff volume from Wellcome Trust buildings and wider campus buildings, estimated abstraction rates and re-use volumes, and residual spill volume to combined sewer system.

Year	Building(s)	Roof runoff volume (m^3)	Total re-use volume (m^3)	Re-use (%)	Total spill volume (m^3)	Spill (%)
2003	Welcome Trust	2,721	186*	6.8	2,535	93.2
	Wider campus	10,801	3,327+	30.8	7,474	69.2
2015	Welcome Trust	5,900	186*	3.2	5,714	96.8
	Wider campus	23,423	3,327+	14.2	20,096	85.8

* Total reuse scenario based on watering of University Green only (May – Aug) + road/paved areas/vehicle cleaning
+ Total reuse scenario based on watering of 1 hectare of university grounds (May – Aug) + road/paved areas/vehicle cleaning

4.4 Ninewells Hospital

Ninewells Hospital on the western outskirts of Dundee is spread over a 0.38km^2 site. The main building complex has the largest roof area in Dundee (~58,000m^2, Figure 4.3), with extended paved areas for car parks, a bus terminal and connecting roads. The surface water reuse scenario considered here was to collect runoff from these paved areas and utilise it for industrial cooling at a data centre within the adjacent technology park. It was estimated that the current mains water demand at this data centre is 1,125m^3/yr or approximately 130 litres/hr (see Annex E5). It is assumed that surface water runoff from the car parks and bus terminal can be used to replace this mains water demand. The scenario assumes this surface water is routed through a storage tank (with 72m^3 capacity), from which 130 litres/hr is abstracted for supply to the data centre. The total surface water volumes based on 2003 and 2015 rainfall records are shown in Table 4.4, along with the corresponding total reuse volumes (note: the slight reduction in reuse based on 2003 rainfall data is due to the storage tank runnning empty for a short period in early August). These surface water reuse totals correspond to approximately 6% and 13% of the total suface water volume generated by the main hospital car parks, with a corresponding reduction in the runoff entering the combined sewer system. *Scalgo Live* flash flood analysis for the 25.8mm: 4 hour rainfall event of 17 July 2015 indicates that about 60% of the rainfall volume is stored in topographic depressions on-site, with 40% surface runoff from the site. Surface waters collected from paved areas, such as car parks, are likely to contain more contaminants (e.g. hydrocarbons, heavy metals, micro-nano particulates) and would require higher levels of treatment before reuse, potentially through SuDS treatment trains. Further details of this surface water reuse scenatio are provided in Annex E5.

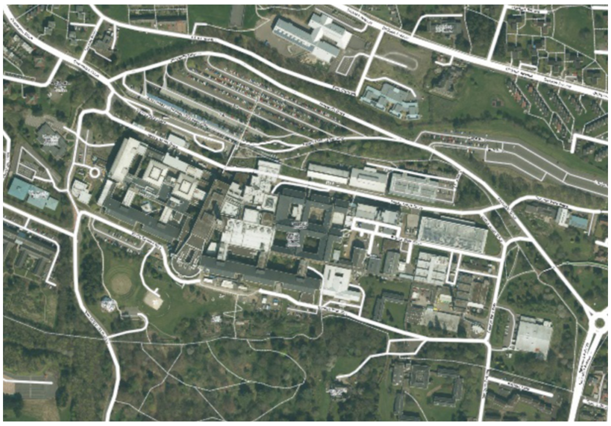

Figure 4.3: Site map of the Ninewells hospital complex (Map generated using Scalgo Live. © Scalgo).

Table 4.4: Main car park surface runoff volumes from Ninewells Hospital, abstraction rates and re-use volumes, and residual spill volume to combined sewer system.

Year	Total runoff volume (m^3)	Abstraction rate (l/hr)*	Total re-use volume (m^3)	Re-use (%)	Total spill volume (m^3)	Spill (%)
2003	8,320	130	1,088	13.1	7,228	86.9
2015	18,052	130	1,095	6.1	16,956	93.9

* Based on constant abstraction from storage tank throughout year, maintaining water level in tank throughout.

4.5 Kingsway West Retail Park

Kingsway West Retail Park (KWRP) is a major retail outlet in north Dundee with a number of large stores and leisure facilities, a car park for 1,200 vehicles, and connecting roads (Figure 4.4). The overall site is approximately 0.15km^2 in size with largely impermeable land cover. The surface water reuse scenario considered here is collection and storage of rainwater from the ~28,000m^2 roof area in the retail park for use in two commercial car washes. The estimated water use from these two businesses is 10,220m^3/year (based on 200 car washes per day, 140 litres per wash). The total roof runoff from KWRP based on 2003 and 2015 rainfall records is shown in Table 4.5. It is not feasible to abstract collected rainwater from an on-site storage tank continually to provide the 1,167 litres/hr water demand from the car wash businesses, especially during prolonged dry periods. With an assumed on-site storage tank of 128m^3 capacity, the maximum surface water reuse volumes that can be abstracted for the car washes correspond to about 57% and 80% of the annual water demand, with the remainder obtained from mains water supply. Rainwater harvesting from building roofs, as opposed to paved areas, is likely to reduce contaminant levels, although treatment would still be required to remove potential biological and chemical contaminants prior to reuse in commercial car washes Further details of this reuse scenario are provided in Annex E6.

Figure 4.4: Site map of Kingsway West Retail Park (Map generated using Scalgo Live. © Scalgo)

Table 4.5: Total surface run-off volume from Kingsway West Retail Park (KWRP), maximum surface water reuse volume for commercial car washes, and residual spill volume to combined sewer system.

Year	Roof runoff volume (m^3)	Maximum re-use volume (m^3)*	Reuse (%)	Residual overflow to sewer (m^3)	Spill (%)
2003	13,353	5,778	43.3	7,569	56.7
2015	31,248	8,154	26.1	23,100	75.9

*Assuming proportion of annual water demand from car washes is replaced by surface water from KWRP

4.6 Ballumbie (Baldovie North)

Ballumbie is a residential area directly north of the MSIP site (Figure 4.1) This area has a separate stormwater sewer system that collects surface water runoff before discharging to the combined sewer network or the Fithie Burn. The surface water reuse scenario considered here is direct abstraction from the stormwater sewer serving the smaller residential area to the west of Ballumbie Road (see Figure E7.2, Annex E7) to provide water supply to the adjacent Baldovie EfW facility for electricity generation. The total surface water runoff volumes from this sub-area for the 2003 and 2015 rainfall records are shown in Table 4.6. It is assumed that the upper limit of reuse volume available is equal to this total surface water runoff volume (i.e. 100% collection and reuse efficiency, see Table 4.6), which corresponds to ~9% and ~22% of the total mains water demand for Baldovie EfW plant (approximately 66,000m^3/year). In reality, more operationally feasible collection and reuse efficiencies from the storm sewer system (say 50% or 25%) are still likely to significantly reduce water demand at the Baldovie EfW plant and surface water discharges into the combined sewers or Fithie Burn. The collection of surface waters from stormwater sewers increases the risk of significant contamination levels associated with runoff from roads (e.g. hydrocarbons, oil/grease, heavy metals, micro-nano particulates, debris and sediments), and potentially from misaligned combined sewer connections. More information on this scenario is provided in Annex E7.

Figure 4.5: Site map of Ballumbie residential area (Map generated using Scalgo Live. © Scalgo)

Table 4.6: Total surface run-off volume from residential area to west of Ballumbie Road, assuming 100% abstraction from the stormwater sewer to Baldovie EfW facility.

Year	Total runoff volume (m^3)	Max. available reuse volume (m^3)*	Reuse (%)	Total volume entering combined sewer (m^3)	Spill (%)
2003	6,040.5	6,040.5	100	0	0
2015	14,466.4	14,466.4	100	0	0

*Based on continuous 100% abstraction from stormwater sewer throughout year (no spill to combined sewer)

4.7 Craigowl and St Andrews Primary Schools (St Mary's area)

St Mary's is a large residential area (0.66 km^2) to the northwest of Dundee served predominantly by combined sewers. The area has a pilot property-level water butt scheme, supported by Scottish Water and Dundee City Council, as part of the ongoing St Mary's Drainage Strategy (WRD 2026). The focus of this surface water reuse scenario, however, is two primary schools in St Mary's, Craigowl and St Andrews, that have separate storm and foul sewers (Figure 4.6). Within this scenario, rainwater from the two school buildings are collected in small storage tanks (12.5m^3 capacity). The total runoff from the school building roofs is shown in Table 4.7 for the 2003 and 2015 rainfall records (with additional paved surface water runoff volumes also available directly from the storm sewer). Surface water reuse is limited to on-site, non-potable purposes such as irrigation/watering, community rain gardens/planters, and non-food growing spaces, for which the estimated water requirement of 480 litres/day (175,200 litres/year). These reuse volumes are relatively low at 14-15% and 6-7% of the total roof runoff volumes for 2003 and 2015, respectively, indicating minimal impact on spill to adjacent combined sewers or mains water demand within the schools. Rainwater harvesting from school building roofs is again likely reduce contamination levels compared to other potential sources (see Table 3.1). However, treatment would still be required prior to reuse, especially when reuse is for outdoor educational purposes. For more details of this reuse scenario, see Annex E8.

Figure 4.6: Site map of St Mary's residential area showing two primary schools as focus of surface water reuse scenario (Craigowl to north-west and St Andrews to south-east) Map generated using Scalgo Live. © Scalgo).

Table 4.7: Total surface run-off volume from Craigowl and St Andrews Primary Schools, estimated on-site reuse volumes, and residual spill volume to combined sewer system.						
Year	**Site**	**Roof runoff volume (m^3)**	**Estimated re-use volume (m^3)***	**Reuse (%)**	**Residual overflow to sewer (m^3)+**	**Spill (%)**
2003	Craigowl St Andrews	1,176.7 1,223.3	175.2 175.2	14.9 14.3	1,001.5 1,048.1	85.1 85.7
2015	Craigowl St Andrews	2,551.2 2,652.6	175.2 175.2	6.9 6.6	2,376.0 2,477.4	93.1 93.4

*Assuming daily water "reuse" of 480 litres spread evenly throughout year

+Assuming all surface water volumes not "reused" on-site will discharge via stormwater sewer to combined sewer.

4.8 Ardler

Ardler is a northwest residential district (0.58km^2 in area) of Dundee that has been the focus for regeneration around the central Ardler Complex and community space. It is bisected (west-east) by a largely culverted watercourse, connecting two SuDS ponds. To the north, the residential area is largely served by separate storm and foul sewers, while properties to the south have a mix of separate and combined sewers. The focus of the surface water reuse scenario in this area is domestic rainwater harvesting through use of property level water butts (i.e. 100, 150 and 200 litres in size) and different water volumes usage levels (i.e. minimal and moderate summer use; moderate summer use with continual drawdown, see Annex E9 for details) based on the 2003 and 2015 rainfall records. These property level reuse scenarios, shown in Table 4.8 for the largest 200 litre water butt only, indicate that reuse of roof runoff collected in a rainwater harvesting tank reduces potable water use from mains connected hose/sprinkler systems, with the largest water savings achieved with the largest tank size and highest reuse scenario. Mains water demand is still required to cover extended periods with little or no rainfall during dry years (i.e. 2003).

Figure 4.7: Site map for the Ardler residential area (Map generated using Scalgo Live. © Scalgo).

When these calculations are upscaled from a single property to a 20% participation rate across Ardler, the overall reduction in surface water runoff from roofs to the sewer system is small, ranging from 0.17% (2015) to 0.66% (2003) and depending on the reuse scenario adopted. As this scenario is based on property level rainwater harvesting for domestic non-hose irrigation or car washing, it is assumed that no treatment would be required prior to reuse. For more details on this surface water reuse scenario at property level, see Annex E9.

Table 4.8: Summary showing impact of property level storage tank volume and reuse scenario. Figures shown are for a representative single household in north Ardler.

	2003		2015	
Storage size (litres)	Volume used from RWH (m³)	RWH contribution as % of total use	Volume used from RWH (m³)	RWH contribution as % of total use
Minimal summer use				
200	0.67	47	0.65	90
Moderate summer use				
200	1.02	56	1.20	94
Moderate summer use with continual minor drawdown				
200	1.00	55	1.19	94

4.9 Blackness

Blackness was the prime industrial area in Dundee in 19th century jute production and is now a conservation area with many historic mill buildings converted into residential, commercial, leisure and industrial premises. The main surface water reuse scenario within this area considers the hypothetical use of historic mill cooling ponds as large storage tanks for surface water runoff from impermeable surfaces (buildings, roads and paved areas) from adjacent drainage areas. Two sites with historic cooling ponds are analysed to investigate impact of water storage within these ponds, and a continual abstraction of 250 litres/hr for non-potable reuse purposes, on the residual overflow to the combined sewer system serving Blackness (see Table 4.9), based on 2003 and 2015 rainfall records. Overall, the use of historic cooling tanks for surface water storage and abstraction for reuse was found to significantly reduce surface water entering the combined sewer (by 81–100% and 38–64%, respectively, for runoff generated by the 2003 and 2015 rainfall data at both sites, see Table 4.9). This scenario is regarded as hypothetical due to the lack of information on the continued existence or condition of these historic cooling ponds (Annex E10). It is also assumed that surface waters collected from a range of different sources from within a post-industrial area would need careful monitoring of contaminant levels and appropriate treatment prior to reuse.

Figure 4.8: Site map for Blackness area in Dundee (Map generated using Scalgo Live. © Scalgo)

Table 4.9: Summary of total surface run-off volume from Site 1 (Brown Street) and Site 2 (Brook Street) in Blackness area of Dundee based on surface water volume generated from 2003 and 2015 rainfall records. Estimated abstraction volume for reuse and overflow spill volume to sewer based on storage of runoff in historic cooling ponds at both sites.

Year	Site	Total runoff volume (m³)	Estimated reuse volume (m3)*	Reuse (%)	Residual overflow to sewer (m3)+	Spill (%)
2003	(1) Brown St	5,315	2,036	38.3	1,012	19.0
	(2) Brook St	3,614	1,896	52.5	0	0
2015	(1) Brown St	11,717	2,188	18.7	7,261	62.0
	(2) Brook St	7,977	2,188	27.4	2,204	36.4

*Assuming continual abstraction and "reuse" of 250 litres/hour throughout year
+Calculated from the total runoff volume minus sum of estimated reuse volume and tank storage volume.

4.10 Summary of reuse scenarios

Each of the eight surface water reuse scenarios considered across the Dundee city area have indicated the availability of surface water volumes that often far exceed the requirements for the various non-potable reuse applications considered within each case study. It is clear, however, that even partial reuse to the surface water resource available during wet and dry rainfall years will have a positive impact on reducing discharges to local sewer networks and, in many cases, reduce the demand for mains water for these non-potable purposes. The feasibility of collection and reuse of this surface water resource from a range of different sources has also been considered over a range of scales, including rainwater harvesting (RWH) from roofs, surface water collection from paved areas, and direct abstraction from stormwater sewers or SuDS. While each individual case study scenario has identified the potential contaminants present within these different surface water sources, as well as the potential need for treatment before reuse, a more detailed assessment of water quality and the level of treatment required prior to surface water reuse is beyond the scope of the current study.

5. Stakeholder Workshop

A core component of the CREW research project was the inclusion of a stakeholder workshop. This took place online on 1 December 2025 (1pm–4pm). The workshop brought together a wide range of key stakeholders relevant to the water sector, from researchers to practitioners and regulators, with participants joining from Scotland, across the UK, and internationally.

5.1 Workshop aim

A key aim and deliverable from the workshop was to identify the best approaches to transition our surface water, and associated assets, from collection to reuse.

Preparation for the workshop utilised outputs from the other project methodologies (i.e. literature and legislation review; practical reuse examples; data collection, mapping and GIS; reuse scenarios) to inform discussions and develop a strategic vision along which this transition can be realised. The workshop outputs identified the public sector, industry and private business opportunities, as well as the legislation currently acting as a barrier to this transition.

5.2 Methods

5.2.1 Selection of participants

Working with the CREW project steering group, the project team identified relevant stakeholders based on recommendations and from their existing networks. A wide group of stakeholders representing diverse and appropriate sectors were invited to join the workshop. An invitation letter provided an explanation of the project and the purpose of the workshop (see Annex F1). Ethical approval for the workshop was gained via Abertay University research ethics committee.

At the start of the workshop, the project team were introduced, and the participants were shown slides informing them about the project, the initial findings, and the workshop aims (Annex F2).

5.2.2 Data collection and analysis

Methods chosen for workshop delivery, data collection, and subsequent analysis were a combination of the following methods:

1. Quick-fire Q&A (using Mentimeter – an online polling tool)
2. Small group discussion (breakout rooms – mix of recordings and note-taking)
3. Large group discussion (plenary – recording and note-taking)

Once collected the data was analysed using descriptive statistics directly from Mentimeter outputs (method 1) and thematic analysis of spoken contributions and notes (methods 2 and 3).

5.3 Summary of outcomes

Sixty-two participants joined the workshop from diverse locations: with the majority from Scotland (48 participants) but with expertise from England (9 participants); Europe (4 participants: France & Netherlands) and the USA (1 participant). Diverse sector representation was also achieved from: research and academia (17 participants), local authorities/councils (8 participants), water utilities (6 participants), consultancy (5 participants), NGOs (3 participants), regulators (3 participants) and Government (2 participants), with 6 participants selecting 'other'.

Quick-fire questions related to the stakeholders' perceptions of non-potable water uses that *would* and *would not* require treatment. Responses were collated with the highest number of responses. For *'uses that would not require treatment'*, responses included: watering greenspaces/gardens/non-food; toilet flushing; agriculture/irrigation; car washing; street cleaning/washing outdoor spaces; industry (inc. cooling & construction). Responses to *'uses which would require treatment'* included: food growing; industry (inc. cooling & heating); toilet flushing; car washing; hydrogen production. Some participants shared the opinion that all uses would need some form of treatment.

When the theme around benefits and barriers to transitioning to stormwater re-use was explored, the following stakeholder feedback was provided (Table 5.1 and 5.2).

Table 5.1: Stakeholder answers to the question “What benefits could come from stormwater reuse?”	
Benefits	**No. of responses**
Reduced sewer flooding/CSO spills/reduced pressure on sewers and treatment plants	27
Reduced flooding	13
Reduced potable water demand	12
Improved biodiversity and greenspace	12
Climate resilience, adaptation & mitigation	12
System and cost efficiencies	7
Energy saving	6
Drought resilience	5
Pollution reduction and improved environmental water quality	4
Circular economy benefits	4
Carbon reduction	3
Less treatment/chemical use	3
Behaviour change	2

Table 5.2: Stakeholder answers to the question “What barriers do you see for transitioning to stormwater reuse?”	
Barriers	**No, of responses**
Infrastructure/retrofitting/technology	24
Public perception/acceptance	22
Cost/Funding	20
Regulation/Policy/Legislation	10
Lack of incentives/drivers/urgency	8
Management and maintenance	7
Silo working/piecemeal approach	5
Water quality concerns	5
Treatment	4
Reliability of supply/seasonality	4
Space	3
Lack of education/understanding	2
Conflict with wildlife	2

In small group discussions (breakout rooms), participants explored cross-sectoral perspectives on what a more water resilient future, including surface water reuse, might look like and how to get there. They also collectively considered a “vision” for 2030 and “roadmap” to widespread implementation by 2050. The ‘rooms’ were themed based on outputs from the literature and policy reviews. A brief overview of some of topics shared in the sessions are given below:

Technical (Room 1):

- High level: Need for highly flexible and adaptive infrastructure. Multi-use spaces. Resource hubs for reclaimed water distribution. Development of new local networks or pipes. Systems capable of handling increased weather variability and extremes.
- Areas of discussion: treatment and reuse, storage and smart networks, challenges, risks, monitoring, governance, responsibilities, innovation & collaboration.

Behaviour (Room 2):

- The ‘Yuk’ factor (public perception). Would need care to avoid potential unintended pollution or health impacts. Importance of public messaging around behaviour change (and making it accessible and affordable). Infrastructure challenges (de-dualling).

Environmental (Room 3):

- Link to climate adaptation and urban cooling.
- Areas of discussion included: direct and indirect reuse. Multiple benefits (balancing areas of need). Feasibility and urgency. Standards and treatment needs. Balancing demand (water and energy) with ecological gains/trade-offs.

Policy and legislation (Room 4):

- To transition to water resilient cities by 2050 we will need to make the best use of every available water resource and the things we use it for, we will need to use less water to achieve the same outcome/experience. Need to think holistically. Critical systems planning. Metering. Education.

In the large group discussion (plenary), many examples and case studies, web and resource links, and contacts were shared. Collectively, the stakeholders tacked pertinent topics such as:

- Who should lead on the water reuse transition?
- The importance of planning and standards
- The need for cross-sector working and collaboration
- The value of water
- Partnering with the public
- Stick and Carrot – statutory requirements versus incentives
- Learning lessons from other transitions (e.g. to solid waste recycling)

The event contributed to delivery of direct and in-direct capacity building, in-keeping with the aims of the project. Participants reported that they came to the workshop with a desire to understand more about the topic, to realise opportunities and gain momentum for positive change. They were keen to move forward collaboratively with partners across sectors and organisations, and with the public.

Many of the insights gained from the workshop participants support the initial findings from the outputs from the other project methodologies (i.e. literature and legislation review; practical examples; data collection, mapping and GIS). Each component of the project has informed discussions and will contribute to development of a strategic vision. A full account of the stakeholder workshop can be found in Annex F.

6. SWOT Analysis

Based on the evidence collected on surface water reuse from the literature review (Section 2), catchment-based data collection and GIS mapping exercise (Section 3), surface water reuse scenarios (Section 4), and outcomes from the stakeholder workshop (Section 5), a SWOT (Strengths/Weaknesses/Opportunities/Threats) exercise is undertaken here to reflect on the potential for widespread implementation of surface water reuse in Scotland's current surface water management network. This analysis considers **Strengths** such as the potential for reduced treated water demand [and associated reductions in energy and chemical usage within water treatment plants, in line with net-zero ambitions (Climate Change Committee 2024; Scottish Water 2025b)] and reductions in urban flood risk and/or CSO spills (due to lower surface water volumes entering combined sewer systems, particularly during high intensity rainfall events). **Weaknesses** include uncertainties surrounding contamination types and levels within different surface water sources, associated high costs for new infrastructure and increased surface water quality monitoring and treatment for non-potable reuse to minimise potential environmental impacts or risks to public health. **Opportunities** include the potential to rebalance supply and demand by adopting a circular economy model in water through reuse, and the possibility of adopting nature-based solutions (e.g. blue-green infrastructure) to act as both sources and receptors of surface waters, improving amenity and ecology. **Threats** could potentially include current legislation and regulatory policy that may preclude the widespread reuse of untreated surface waters and/or the feasibility and practicality of adopting widespread surface water reuse (including water capture, storage and potentially treatment), as well as public perceptions (both in the need for reuse and its perceived suitability as a water source).

These, and other aspects associated with the potential widespread reuse of surface waters for non-potable purposes are summarised within the SWOT matrix (Table 6.1).

Table 6.1: SWOT matrix for widespread implementation of surface water reuse in Scotland's current surface water management network

Strengths	Weaknesses
• Reduced drinking water demand and reduced stress on raw water sources • Reduced water and wastewater treatment costs (i.e. energy & chemicals) • Reduced urban flood risk from sewers • Reduction in combined sewer overflow events • Enhanced urban water resilience through diversification of urban water sources • Alignment with Scottish Government's net-zero agenda and contribution to climate goals • Decentralised water reuse systems can provide multiple ecosystem services and benefits • Rainwater harvesting technologies can support both open and closed loop reuse systems	• Economic costs around decentralised surface water reuse infrastructure installation and maintenance • Majority of combined sewer systems mean collection and reuse of surface water runoff is more complex • Inadequate statutory regulation around surface water reuse in Scotland • Uncertainties around surface water quality and/or required treatment levels • Increased complexity and costs around decentralised water quality monitoring • Lack of Scottish case studies on reuse • Scale of surface water reuse in urban areas may be significantly different from available rainfall resource • Difficulties in retrofitting water collection and reuse schemes in dense urban areas
Opportunities	**Threats**
• Potential to rebalance water supply and demand through circular water model • Potential implementation of smart water reuse technologies to reduce urban flood risk and/or reduce mains water consumption in industrial processes • Potential adoption of nature-based solutions in urban areas both as sources and receptors of surface waters • Improvement of urban green spaces for enhanced amenity and ecological value • Potential to adopt new building practices that promote construction of water-efficient new-build housing • Potential for demonstrative case studies that showcase effectiveness of surface water reuse in a Scottish context • Potential for multiple sectors and local authorities to work collaboratively on water reuse initiatives • Effective community engagement and co-creation to promote development of sustainable, water-smart communities • Potential for widespread adoption of "drainage hierarchy" • Public are already largely onboard with water conservation and rainwater reuse	• Potential for legislative and policy road-blocks to hinder the wider adoption of non-potable surface water reuse • Public misconceptions on water scarcity and negative perceptions around surface water reuse for non-potable purposes • Lack of collaborative working and common language between different sectors involved in promoting water reuse • Fragmented water governance and responsibilities around water reuse • Potential shifts in government policy and priorities • Lack of economic incentives for adoption by householders, perceived lack of return on investment • Lack of clear funding mechanism for surface water reuse schemes • Lack of awareness amongst developers around available incentives for adopting water efficiency measures within new developments • No regulatory water quality standards currently exist for non-potable surface water reuse • Rapid acceleration in water demand (e.g. data centres) outstrips pace of adoption of surface water reuse

7. Future Opportunities

A significant knowledge gap that currently exists in the potential transition of Scotland's surface water collection and treatment systems to surface water reuse systems is the lack of well-documented case study sites. Addressing this is essential to building a strong evidence base to support the wider implementation of non-potable surface water reuse in predominantly urban settings. Scottish Water currently have a few pilot projects supporting rainwater harvesting initiatives within residential areas known to be at risk from flooding (e.g. Prestwick, Ayrshire and Craigleith, Edinburgh) and are collaborating with local authorities on wider urban drainage strategies that reduce flood risk through improved stormwater management, including implementation of blue-green infrastructure (e.g. Water Resilient Dundee).

However, there remains an urgent need for the development of specific pilot project case studies focused on identifying opportunities and addressing challenges around surface water reuse from different collection point types (e.g. building roofs, paved surfaces, stormwater sewers and SuDS), at different scales and for different end-use purposes. These pilot studies would need to prioritise specific geographical areas and land use types for which surface water reuse could feasibly replace mains water demand for specific non-potable purposes. This would require accurate quantitative assessments of:

- volumetric water demands from different non-potable uses, considering seasonal variability and other factors affecting demand,
- the proportion of this demand that could feasibly be replaced by surface water reuse, and
- associated whole-life benefit-cost analysis and carbon savings for surface water reuse schemes.

Pilot surface water reuse projects would also need to carefully monitor:

- their impact on runoff discharges to combined sewer systems (e.g. through smart sensor devices) to assess potential reductions in urban flood risk and combined sewer overflows (CSO spills),
- surface water quality to assess likely contaminants and contamination levels, seasonal variability, and required water treatment strategies prior to reuse.

As highlighted within the literature review and SWOT analysis, strong and effective community engagement, and their active involvement in decision-making and co-creation activities, is key to developing more sustainable, watersmart communities. The establishment of community trust, in particular, is crucial in the move to more sustainable water management practices that may increasingly include widespread reuse of collected surface water for non-potable purposes. Public perception, societal acceptance, awareness and education, and continuous stakeholder involvement are therefore all necessary to ensure the successful long-term uptake of water reuse. In this context, Water Resilient Dundee (WRD, 2026), a joint initiative between Scottish Water and Dundee City Council, provides an excellent case study of how community engagement and education around sustainable water futures can lead to more flood resilient communities, whilst providing multiple benefits through enhanced natural capital, ecosystem services, and amenity value within urban environments.

8. Summary of Recommendations

The key recommendations are based on the findings from this study around the implementation of surface water reuse in urban environments with respect to (i) technical challenges and innovations, (ii) public perception and behavioural shift, (iii) environment and natural capital, and (iv) policy and legislation. These are listed overleaf under the appropriate subheadings, with suggested key stakeholders, actions and responsibilities provided (in brackets).

8.1 Technical challenges and innovations

- **Co-design of surface water reuse pilot projects** to provide a sound knowledge base to support wider implementation of non-potable water reuse in urban environments. *(Action: Scottish Water, local authorities – funding; communities, industry, academia – co-design with funders)*.
- **Establish water quality and treatment protocols** for specific non-potable uses of surface water (e.g. greenspace watering/irrigation, industrial processes, municipal cleaning, vehicle washing, firefighting) collected from different abstraction points. *(Action: Scottish Water, SEPA, academia – working together on targeted project(s), e.g. via CREW)*.
- **Clarify the typical surface water reuse volumes** associated with these non-potable uses, including seasonality and other factors affecting temporal variability in water demand *(Action: As for co-design of pilot reuse projects)*.
- **Explore the wider opportunities to utilise existing SuDS and blue-green infrastructure** as decentralized water sources for non-potable supplies, fully utilising their water treatment capabilities to reduce harmful contaminants in surface waters prior to reuse. *(Action: Scottish Water, SEPA, academia – surface water monitoring (quality/quantity) in SuDS)*.
- **Explore the use of smart sensor technologies and AI** to monitor surface water quality and quantity needed within different open and closed-loop surface water reuse systems. *(Action: Scottish Water, business, industry – partnerships to implement water reuse)*.

8.2 Public perception and behavioural shift

- **Increase public awareness campaigns and educational programmes** to address common misconceptions around water scarcity in Scotland (and the UK) and enhance public perspectives around efficient water use and wider benefits. *(Action: Scottish Water, local authorities, communities, academia – e.g. Water Resilient Dundee)*.
- **Provide more focus on financial incentivisation** (i.e. cost-savings) for efficient water use, utilising public support for both water conservation measures and rainwater reuse to promote surface water reuse for non-potable purposes. *(Action: Scottish Government – funding provision; Scottish Water, local authorities – scheme implementation)*.
- **Promote strong community engagement** with multiple-sectors involved in urban planning decisions as key to developing the trust required for widespread adoption of sustainable surface water management that incorporates reuse initiatives. *(Action: Scottish Water, local authorities, communities, academia – e.g. Water Resilient Dundee)*.

8.3 Environment and natural capital

- **Develop guidance on the wider social and environmental benefits of blue-green infrastructure** and support their costings as viable alternatives to grey infrastructure. *(Action: Scottish Government – funding provision; Scottish Water, SEPA, NatureScot, academia, NGOs – evidence collation, production of guidance)*.
- **Explore where and how decentralised surface water reuse can be adopted to enhance biodiversity, ecosystem services, and public amenity value** of urban greenspaces. *(Action: as for co-design of pilot surface water reuse projects; SEPA, NatureScot, communities – input into wider environmental and societal benefits)*.

8.4 Policy and legislation

- **Adjust the incentives under the planning system** to incentivise (or mandate) permeable structures within the curtilage of dwellings (i.e. to reduce direct runoff to sewers). *(Action: Scottish Government – consultation on planning system and building standards; Scottish Water, local authorities, developers – implementation of changes)*.
- **Adjust building standards to mandate greywater recovery** at least for new-build housing and at least for developments above a certain scale. *(Action: As above for planning incentivisation).*
- **Streamline the requirements for householders to install greywater systems**. *(Action: Scottish Government, Scottish Water).*
- **Consider setting statutory targets for Scottish Water** for household water consumption and assess how these could be identified, implemented, and incentivised. *(Action: Scottish Government – consultation, funding; Scottish Water – implementation).*
- **Develop and implement strategic drainage plans** for all urban areas, aligned with the Recast UWWTD. *(Action: Scottish Government, Scottish Water, SEPA, local authorities, communities)*.
- **Consider developing Water Reuse Regulations** specifying water quality requirements for specific forms of reuse and from specific sources. *(Action: Scottish Government)*.

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