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Source control SUDS delivery on a global scale and in Scotland including approach by responsible organisations and professional groups

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Background to research

The Sustainable Urban Drainage Scottish Working Party via CREW commissioned this work on the implementation of source control for SUDS in Scotland. The project is being carried out by researchers based at Abertay University Dundee involves three phases. These are presented in separate reports; this report covers phase 2 of that work. Source control sustainable urban drainage systems (SUDS) are an established technique in many parts of the world. Source control SUDS are a key component of what is termed the stormwater treatment train. Source controls manage the more frequent but smaller polluting rainfall events as close to the source as possible (where the rain falls). Site and regional control SUDS are larger downstream structures which manage the longer term rainfall events and provide additional treatment when required. One of the key advantages of managing the more frequent rainfall events at source is that downstream site and regional SUDS will have longer life spans resulting in overall cost efficiencies. Scotland is regarded as a frontrunner in the UK regarding implementation of SUDS with site and regional drainage structures now considered 'business as usual'. However the uptake of source control is less routine than would be expected.

Objectives of research

Phase one of this research looked at the background to the evolution of source control in Scotland to provide an insight into the enabling factors and obstacles for uptake of the systems since. Phase two (this report) appraises delivery of the systems in seven countries and case studies are developed to understand why source control was implemented and how it was achieved. The current delivery by responsible organisations and professional groups which encourage and influence the source control agenda in Scotland is also appraised. Using these findings, the transition pathway from traditional drainage to source control SUDS are reconstructed and mapped out to highlight the historical and current enabling (and disabling) factors to realise the transition to date. A transition framework is used to highlight the transition strengths developed by responsible organisations over the last two decades which had assisted in accelerating the transition.

Key findings and recommendations

Key outcomes of this research include:

- In Scotland the source control vision and agenda is fragmented due to different stakeholder drivers and funding mechanisms.
- There are examples of the use of incentives in Scotland (i.e. legislative, regulatory, financial, social and environmental) to drive integrated agendas. However these have not been successfully showcased to provide the evidence base for encouraging replication and up-scaling of the methodologies and techniques.
- There are limited frontier source control SUDS 'niches' to nurture innovative techniques such as raingardens – a learning by doing concept. A more focused research agenda to validate these systems as viable sustainable solutions for Scotland would assist in accelerating uptake.
- Lack of sector engagement, particularly with the public is a disabling factor for uptake.

A final observation from this phase of the study is that requests from various interested parties for CREW / SUDS Working Party to share outputs indicates the need for this research.

Key words

SUDS, Source Control niches, Frontier SUDS, Transition, Stakeholder Platforms, Sector engagement

1.0 INTRODUCTION

The Sustainable Urban Drainage Scottish Working Party via the Centre of Expertise for Waters (CREW) commissioned a project entitled 'Implementation of source control for SUDS in Scotland. The project is being carried out by researchers based at Abertay University Dundee.

The project involves three phases:

1. Rapid review of the background to Source Control including the history, various types, and options in a brief report.
2. Appraise how Source Control is being delivered, within the UK and Worldwide, and comment on the approach of the various responsible organisations and professional groups in Scotland.
3. Design, implement and write up the outputs from a workshop to be held at the next meeting of the SUDs working party on 27th February 2013. The workshop should consider how to progress this area within the remit of the SUDs working party

This report presents Phase 2 of this work.

Sustainable urban drainage systems (SUDS) have been implemented in Scotland since the mid 1990's. The approach was radical at the time as it contrasted with traditional drainage management techniques which did not offer the benefits provided by SUDS. These benefits provide a holistic approach to draining urban areas including treatment of polluted rainfall to protect receiving watercourses whilst also providing amenity areas and wildlife habitats. To deliver optimum water quantity, water treatment and amenity benefits from SUDS, the stormwater treatment train concept was developed in Scotland. Source control SUDS (i.e. swales and filter drains) are the first level of treatment which manage the more frequent but smaller polluting rainfall events as close to the source as possible (where the rain falls). Site and regional controls (i.e. ponds and basins) are the second and third level of treatment managing the longer term rainfall events and provide additional treatment when required whilst generally offering more amenity benefits (D'Arcy 1998, McKissock *et al.* 1999, Apostolaki *et al*. 2006).

The uptake or transition from traditional drainage to SUDS in Scotland has happened in a relatively short timescale with site and regional drainage structures now considered 'business as usual' (Wild *et al.* 2002, Duffy *et al.* 2013). Considering that Scotland is regarded as a frontrunner in SUDS implementation in the UK (Duffy *et al.* 2013), it is necessary to understand why uptake of source control SUDS as part of a stormwater treatment train is less routine than would be expected.

To gain an insight as to why this is the case delivery of the systems in seven countries are appraised here and case studies developed to explain why source control was implemented and how it was achieved. To understand and appraise the delivery of source control in Scotland it is necessary to examine the different roles of the responsible organisations which implement, regulate and manage the systems and the dynamics between these organisations (Aukerman *et al.* 2011). The way that these responsible organisations and professional groups advanced the source control agenda is reconstructed and mapped out using transition management theory (Geels and Kemp 200, Rip and Kemp 2008, Jefferies and Duffy, 2010). This highlights historical and current enabling (and disabling) factors in the transition from traditional drainage practices. A transition framework (Jefferies and Duffy, 2010) is used to provide a focus on the transition strengths developed by responsible organisations during the last two decades which had assisted in accelerating the transition.

The appraisal of source control delivery in a number of countries including a more detailed account for Scotland provides a snapshot of the state of play of implementing the systems on a global scale. Enabling and disabling factors identified in order to support recommendations for encouraging uptake of source control SUDS in Scotland are: the source control vision and agenda is fragmented due to different stakeholder drivers (disabling factor); showcase existing good practice for up-scaling and replicating the systems (enabling factor); develop more source control niches for emerging technologies to validate the systems and improve stakeholder confidence (enabling factor); lack of sector engagement will become a future barrier for uptake of the systems (disabling factor).

2.0 A GLOBAL SNAPSHOT OF THE DELIVERY OF SOURCE CONTROL SUDS

This section provides a snapshot of the delivery of source control SUDS out with Scotland highlighting historical actions in implementation and uptake of the techniques. SUDS were originally 'born' in the USA to manage surface water for diffuse pollution prevention of watercourses. Several European countries since transferred this knowledge (primarily Sweden followed by Germany, the UK and the Netherlands) to develop systems for their own climates. Australia was the next nation to learn from the combined USA and European experiences where they have effectively bypassed any mistakes that had been made. South Korea is included as a nation in its infancy as it provides a good example of a top down strategic approach to managing the implementation of source control. The UK is presented first to provide context for the process which has developed in Scotland.

2.1 UK

From a stormwater source control perspective, two aspects of the Control of pollution Act, 1974 (COPA) which advocated the 'polluter pays principle' (Macrory and Zaba, 1978) are particularly important for water pollution prevention in the UK:

- Provisions to allow statutory regulations to be brought into force to specify pollution prevention requirements for the storage and handling of oil and chemicals (controlling major pollution risks at source).
- Provisions to allow the river or water authority to require formal consent for discharges of surface water (potentially providing a regulatory mechanism to require the use of SUDS).

Unfortunately relevant source control provisions in COPA were not implemented for many years. Eventually the powers to control pollution from surface water drainage were used in Eastern Scotland from 1995 onwards (Watson 2013, D'Arcy 2012).

Legislative basis notwithstanding, implementation of SUDS in the UK is routinely driven forward through planning consultations as part of the development control process in each local authority. Yet even where major public body stakeholders (environmental agency, water utility and the local authority planning and other key departments) have positive policies specifically in relation to SUDS, promotion of source control techniques is not usually an identified priority.

2.1.1 England and Wales

In England and Wales there has to date, been no formalised requirement for the use of SUDS, although a number of local authorities have historically requested their use as part of the planning process. This situation is now changing, driven by the Flood and Water Management Act (2010) which places a requirement for SUDS for all new developments, similar to the Scottish WEWS Act. SUDS Approval Bodies (SABs) at Local Authority level will approve and eventually adopt SUDS.

National Standards for Sustainable Drainage are being developed to underpin the design and the detailing of SUDS for adoption. A draft of the National Standards (Defra 2011a) and a consultation on the formation of SABs (Defra 2011b) have been released to the public however neither of these documents stipulates the use of source control SUDS, rather they promote the stormwater treatment train concept.

There is at present, little incentive and no legislative requirement for the use of source control techniques however there are many examples of local authority adoption of SUDS, including innovative source control techniques (Digman et al, 2012). Two notable examples are: Raingarden retrofit in Islington implemented in partnership with Homes for Islington, Thames Water and Middlesex University (Lundy *et al* 2013); and a Home Zone redevelopment at The Dings, Bristol partly financed by the EU Visionary and Vibrant Actions through a Local Transport Initiatives programme (CIRIA 2008). Other privately owned source control SUDS have been implemented with the majority of these being public (e.g. schools) or commercial buildings.

Where water charging is in place it presents an economic driver for water re-use. The Government consultation Future Water (Defra 2008) proposes to reduce domestic potable water use to 130 litres per person per day by 2030 (from 150 litres). Whilst this target is achievable it will require some form of financial benefit (subsidies). Pratt (1999) and Geiger (1995) identified an increase in awareness of rainwater harvesting systems due to increasing water demand, which cannot be satisfied without developing new resources. They also recognised over abstraction and water distribution over large distances are issues which will need to be addressed.

The Highways Agency has recently developed a water risk assessment tool (HAWRAT) for practitioners in the field which includes the prediction of polluted runoff load concentrations to receiving waters. These are compared with ecologically-based standards to help designers decide if mitigation measures (including source control) are needed prior to construction (Dempsey, 2009). A range of tools, including HAWRAT for identifying the presence of urban diffuse pollution and solutions are reviewed in CREW project CRW2012/1 (Wade et al. 2013). There is scope for HAWRAT to be tried and tested in Scotland.

2.1.2 Northern Ireland

There is, to date, no formal requirement for the implementation of source control techniques in Northern Ireland. Current planning policy promotes the use of SUDS within PPS15 Planning and Flood Risk as does the Northern Ireland Sustainable Development Strategy (2006). The Northern Ireland Sustainable Urban Drainage Working Party was established in 2006 and a consultation Managing Stormwater ‘A Strategy for Promoting the Use of Sustainable Drainage Systems (SuDS) within Northern Ireland’ was issued in 2009. SUDS are also promoted by the Northern Ireland Environment Agency (NIEA) and Rivers Agency; and will shortly enter planning legislation following the findings of the 2009 consultation (McCloy Consulting 2013).

The Working Party was replaced by the Stormwater Management Group in 2011. This group comprises stakeholders from the Department of the Environment and Department for Regional Development. Other organisations include the Department of Agriculture and Rural Development, the Rivers Agency, Northern Ireland Authority for Utility Regulation, and Northern Ireland Water (NIEA 2012). A priority being driven by the political need for urban regeneration is to overcome development constraints in combined sewer areas by using retrofit SUDS (Close, pers. com. 2012).

2.2 United States

The use of pollution control structures known as urban BMP techniques (later accepted elsewhere as SUDS or WSUD) was first set out in USA (Schueler 1987, Schueler et al 1992). Multiple benefits were advocated such as amenity and ease of integrating with other aspects of stormwater management, such as drainage for flood risk management. Source control was a key part of the BMP approach from the outset (swales, filter strips) and early development of the MDCIA concept (Urbonas 1999) advocating source control techniques to Minimise Directly Connected Impervious Area. Later focus on combined sewers in older conurbations led to Low Impact Development (LID). These small scale measures are used for disconnection of surface drainage from sewer networks. Low Impact Development is regarded as one of the most important concepts for stormwater management as they manage the more frequent but smaller pollution rainfall events at source (where the rain falls). Low Impact Development is now an accepted concept in the USA and is applied in most new developments. In the UK, the majority of SUDS schemes use site and regional SUDS control despite the stormwater treatment train concept which promotes source-site-regional control strategies.

Several elements of LID - such as preserving natural drainage and landscape features - fit into the Green Infrastructure (GI) approach which is a growing concept in the USA (Hirschman and Kosko, 2008). Green infrastructure encompasses a range of LID techniques both new and retrofit, and many states now have a green infrastructure plan (i.e. see New York City Department of Environmental Protection, 2009).

Figure 1 LID key elements (adapted from UFC, 2004)

Low Impact Developments have proven to be very effective in managing small scale storm events, reducing the size and complexity of downstream BMPs and providing effective treatment at source (UFC, 2004). Key concepts for LID asset design include (**Figure 1**):

- Balanced approach better integrates the built environment with the natural environment.
- Small scale measures typically within the curtilage of a single property or managing a small area.
- Making efficient use of space; using roofs, road verges, driveways, areas adjacent to buildings.
- Cost effective measures involving minimal construction with focus on vegetated rather than hard engineered systems.

- Maximising developable space reducing the need for large drainage assets, and integrating the LIDs into other less intrusive or often redundant areas.

LID emergence in the USA was primarily driven by legislation; the Clean Water Act (1972) supported by other legislation such as the Water Quality Act, 1987, the Endangered Species Act, 1973 and the Safe Drinking Water Act 1974. Subsequent Acts have strengthened the requirements further. Surface water management was therefore a political issue to ensure compliance was met with the above Acts.

Water management issues such as pluvial flooding and combined sewer overflow spills in areas with high rainfall (i.e. Portland and Oregon) and winter flooding twinned with summer drought conditions (i.e Los Angeles) have driven the case for the use of green infrastructure (GI) combined with LID to mitigate these issues and relieve pressures on existing grey infrastructure (Schweitzer 2013). Subsequently, each state has published its own LID design guidance, with states such as New York and Oregon leading the way with research into new and innovative techniques. In addition to State regulations and guidance, national guidance is available from the Environmental Protection Agency (USEPA); this is intended to support decision and policy makers at state level. Many USEPA recent publications focus on GI, including guidance for green streets, GI retrofit, and GI funding options.

There is a raised awareness in most states of the challenges faced for water management with evidence of community 'buy-in' to stormwater schemes. The importance of education schemes and sector engagement is highlighted in the publication 'Low Impact Development Strategies and Tools for NPDES Phase II Communities' (2013). Examples illustrate where homeowners have modified their gardens, disconnected downpipes and even (informally) maintaining LIDs near their homes.

Further uptake of local LIDs has been driven by a range of financial incentives (USEPA 2009) including:

- Stormwater Fee Discount: based on impervious surface area. If property owners reduce need for service by reducing impervious area and the volume of runoff discharged from the property, the municipality reduces the fee.
- Development Incentives: Offered to developers during the process of applying for development permits. Examples include: zoning upgrades, expedited permitting, reduced stormwater requirements and increases in floor area ratios.
- Grants: Provide direct funding to property owners and/or community groups for implementing a range of green infrastructure projects and practices.
- Rebates and Installation Financing: Provide funding, tax credits or reimbursements to property owners who install specific practices needed in certain areas or neighbourhoods.
- Awards and Recognition Programs: Provide marketing opportunities and public outreach for exemplary projects. May include monetary awards.

2.3 Sweden

The responsible organisation for delivery of stormwater drainage is the Swedish EPA. They enforce environmental policies and are responsible for the implementation of national and EU legislation and the county administrative boards (21 in total) which are also responsible for environmental issues. Municipalities within each county administrative board have a large degree of freedom within their national laws (Rudenholm 2008). Leading drainage practitioners pioneered stormwater techniques and their application in the late 1990s, e.g. the late Peter Stahre an engineer in Malmo and, Torsten Rosenqvist, a landscape architect in Halmstad. Close engagement with the USA was exemplified by the early drainage book by Urbonas and Stahre (1992), and later by a joint ASCE / Swedish /UK conference in Malmo in 1997 (Rowney et al 1999). Planning guidance sets out source control measures for within a property as well as for linear applications such as roads (Stahre 2006).

Implementation of source control in cities is driven by engagement between all parties as part of the city planning process and supported by agreed policies and practices, underpinned by SUDS guidance written for planners. The measures focus on innovative environmental improvements, including reduction in flooding and biodiversity enhancement. They are a source of considerable local pride and have received awards and accolades, hosting international visits in high profile ways (Kazmierczak and Carter 2010). There are good examples of surface channels used to convey and store stormwater in preference to drainage pipes. Surface channels keep storm water on the surface, providing a visible and less abrupt transition to flooding conditions during extreme events whilst avoiding deep drainage components (Balmforth 2011).

In many municipalities, the Water Department takes an active part in city planning becoming involved early in the process ensuring contact with the developer to facilitate land being made available for open storm water systems and provision of green areas. Design of the open stormwater systems is undertaken in collaboration with landscape architects with agreements reached on design, construction and maintenance (Rudenholm 2008). Public involvement is an important factor enabling residents to play a role in the planning and implementation which ultimately reduces opposition from local residents to novel stormwater practices (Kazmierczak and Carter 2010).

2.4 Germany

Germany has a strong federal role in the support and regulation of sustainable water management solutions. The 2010 Germany Water Resources Act (Wasserhaushaltsgesetz 2010) established directives for water resource management, including groundwater pollution, urban wastewater treatment, environmental protection, and flood risks. It also established frameworks for community action networks. Decentralised methods such as managing rainfall at source and disconnection of stormwater from existing sewer networks have officially been adopted as the preferred method for stormwater management.

The German Association for Water Management, Wastewater, and Waste has adopted water management engineering regulations to include sections on planning, building, and servicing rainwater infiltration systems. The DWA-M 153 (Handlungsempfehlungen zum Umgang mit Regenwasser 2007) and DWA-A 138 (Planung, Bau, und Betrieb von Anlagen zur Versickerung von Niederschlagswasser 2005) handbooks provide technical design specifications for water retention, infiltration, and treatment.

The Emscher Region is an excellent example of how to take advantage of opportunities arising during a major process of transition for realising a long-term and region-wide transformation to more sustainable water management practices (Salien and Anton 2011). The Emscher River was used as a wastewater canal for over a century and was ecologically stressed. Restoration was promoted as a central theme for transforming the region's image from an unattractive industrialised area to a modern eco-friendly service-oriented area with improved urban surroundings (Seiker *et al.* 2006). The Emscher Genossenschaft (regional water board) played a central role in driving the reconstruction using sustainable stormwater management practices to rehabilitate 81 km of the river (Seltmann, 2007). It initiated the 'Future Convention on Stormwater', ratified by 17 municipalities. By signing the convention, the municipalities voluntarily committed to disconnect

15% of the region's impervious area from the sewers within 15 years (by the year 2020). This convention is unique since it was the first voluntary agreement introducing sustainable stormwater management on a regional scale in Germany.

There are multiple examples in Germany of established schemes where a reduction in water / sewerage charges is given if properties disconnect roof water from the sewer network. The Emscher Genossenschaft offers financial incentives to industry, commerce and households (Salien and Anton 2011). This is aimed at reducing hydraulic loads on the sewer network and reducing stormwater treatment cost. In addition there are several indirect subsidies which provide funding options to support implementation of green roofs. The German Green Roofs Association in cooperation with Hafen City University of Hamburg recently developed a guide giving advice on which funding options can be used to enhance the implementation of green roofs (Ansel *et al*. 2011).

2.5 Netherlands

The Netherlands' continuous battle to control their rivers and seas has resulted in the country becoming expert in water management. Over the past four decades the paradigm and practice of water management has changed significantly (Van Ast 2000, Disco 2000, Van Leussen 2002, Vinke-de Kruijf 2009). In the 1970's water management in the Netherlands was technocratic and sector orientated while it is now much more interactive and integrated (Van der Brugge and Rotmans 2007). De Wit (2000) summarized this shift as "*from fighting water to accommodating water*".

In 2000, the government declared a national water policy, the 'Water policy for the 21st century', aimed at addressing climate change impacts. An important characteristic was that water management should be a guiding principle during spatial planning. The first step in the implementation process was the development of spatial adaptation plans at the river basin level. This involved inter-disciplinary stakeholder collaboration and development of regional water and development policies. Since 2003, a legally binding document (Water Toets/water assessment), connects spatial planning policies with water issues and spatial design (Schueler and Haupter 2008). Public participation is also at the heart of delivering novel surface water management measures with municipalities working to bridge the gap between the government and the public (Balmforth 2011).

It is common practice to design surface space to store surface run-off locally, which aims to separate surface water from combined sewerage systems (Schueler and Haupter 2008). There are a number of notable examples of retrofitting source control SUDS which are usually delivered as part of urban regeneration projects. These include disconnection of roof water, surface channels, infiltration basins, swales, permeable paving and water squares (Balmforth 2011).

2.6 Australia

Water Sensitive Urban Design (WSUD) is a philosophy which takes into account all areas of the water cycle (Brown et al, 2008). Source control is regarded as one of the elements of the WSUD process. In relation to stormwater management, WSUD built on the techniques of LID developed in the USA, adding rainwater harvesting and other innovations in response to a ten year drought in Melbourne. These techniques favoured source controls that allowed recharge of groundwater (Argue 1994). The chronic water shortage crisis led to a holistic water resources focus as the public as well as academics and agencies began to look at grey water use for gardens and other purposes, leading to the wider aspirations of WSUD.

WSUD is managed on a state level with each state providing guidance on suitable measures. Each state operates different planning legislation, resulting in an unbalanced approach throughout the country (FAWB 2009). Technical guidance has been produced by well funded and effective partnerships involving universities and local government (i.e. Landcom 2009). An innovative sector and public engagement initiative has been established by Melbourne Water: the "10,000 Raingardens" campaign (Richards et al, 2012). This initiative could be replicated in Scotland, if the broad and inclusive Melbourne interpretation of a raingarden as a 'vegetated feature designed to attenuate rainfall', is adopted here.

Cost analysis by a number of organisations indicates that benefits of WSUD are likely to outweigh the costs for conventional infrastructure (Water by Design 2010). Lee and Yigitcanlar (2010) identify that in addition to economic and technical barriers other barriers include a lack of consistency of knowledge of WSUD throughout municipalities and water organisations and that 'agents of change' are necessary, particularly at governmental level.

It is both water scarcity in the warmer seasons and rainfall events in the wet seasons which have driven the use of WSUDS. Hatt *et al.* (2005) highlight the "increasing need to utilise stormwater for non-potable requirements, thus reducing the demand on potable sources", whilst Coombes *et al.* (2002) show how extensive use of source control on a regional scale can reduce peak mains water supply, extend the operational life of water supply infrastructure and delay the need to expand existing water infrastructure for growing population centres.

2.7 South Korea

The development of stormwater management techniques to control diffuse pollution in South Korea is influenced by the USA LID (Low Imapct Development) philosophy (Kim and D'Arcy, 2011). The storm event driven nature of diffuse pollution presents many challenges: for sizing treatment facilities, targeting the highest pollution load for optimum benefit and minimising costs both in construction, land-take and maintenance. South Korean research is quantifying those issues as part of an ambitious three phase national programme (see **Table 1**).

Table 1 Main goals of phased roll-out of diffuse pollution control measures (from Yung et al 2008)

Field	1st phase ('04–'05)	2nd phase ('06–'11)	3rd phase ('12–'20)
Policy system improvements	Build policy foundation (government to establish plan & leads efforts)	Charge responsibility of managing major pollution sources	Continue to strengthen management responsibilities
Related projects	Pilot projects (national)	BMP projects for the site specific conditions in four major rivers (central & local governments)	Full implementation of projects with local government in lead & central government support
Research & public support	Focus on identification of causes, and development of treatment technologies	Set technologies for monitoring & standards on treatment facilities	Facility improvements taking into consideration cost and efficiency

The first phase of the research saw the adoption by the Korean government of the TMDL (total maximum daily load) approach to setting discharge limits. The quantification of pollution challenges indicated that diffuse source pollution load associated with urban development is significant, and for example BOD (biological oxygen demand - an indicator of oxygen levels in water), will increase. This evidence led to a national suite of best management practice (BMP) projects. By 2006, the Ministry of Environment had established in excess of 40 demonstration projects with monitoring programmes in four River catchments (Maniquiz et al 2009). The main purpose the project was to set uniform removal efficiencies over a wide range of BMPs (including source control) which will be used for the

TMDL policy. From 2006 the government imposed a BMP permit system for all construction projects greater than 1 ha. This was tightened in 2010 to $450m^2$. Implementation of BMPs continues, now embracing LID techniques with development of LID guidelines which should be completed by the end of 2013.

3.0 THE DELIVERY OF SOURCE CONTROL SUDS IN SCOTLAND

Scotland is considered a frontrunner in the implementation of SUDS in the UK. To understand and appraise the delivery of source control in Scotland it is necessary to examine the different roles of the responsible organisations which implement, regulate and manage the systems and the dynamics between these organisations. The way in which these responsible organisations and professional groups advance the source control agenda is also discussed.

3.1 Responsible Organisations in Scotland

In Scotland, surface water can be the responsibility of one of four parties depending on where it lands (**Figure 2**). Surface water drainage responsibilities lie with: Transport Scotland for trunk roads or motorways; Local roads authorities for local roads; Scottish Water for domestic roofs and paved areas within the boundaries of a property; Land owner for private land. This distribution of responsibilities is a product of the historic governance of water services in Scotland.

Figure 2 Surface water drainage responsibilities in Scotland.

In the Sewerage (Scotland) Act 1968, it became the drainage authority's responsibility to drain surface water from industrial and domestic roofs and any paved ground surfaces in the property. In the Roads (Scotland) Act 1984, it became the roads authority's responsibility to drain surface water from public roads. Since both the drainage authority and the roads authority were under the same local authority, there was no clash over drainage responsibilities as this simply involved over-sizing the sewer to accommodate the additional flow from the roads (Aukerman *et al*. 2011). The Local Government (Scotland) Act, 1994, created three regional drainage authorities which became responsible for water and waste water. Local Authorities remained responsible for roads drainage and in 1997 also became responsible for flood prevention under the Flood Prevention and Land Drainage (Scotland) Act. In 2002 the regional drainage authorities were unified into a national drainage authority Scottish Water (**Figure 3**).

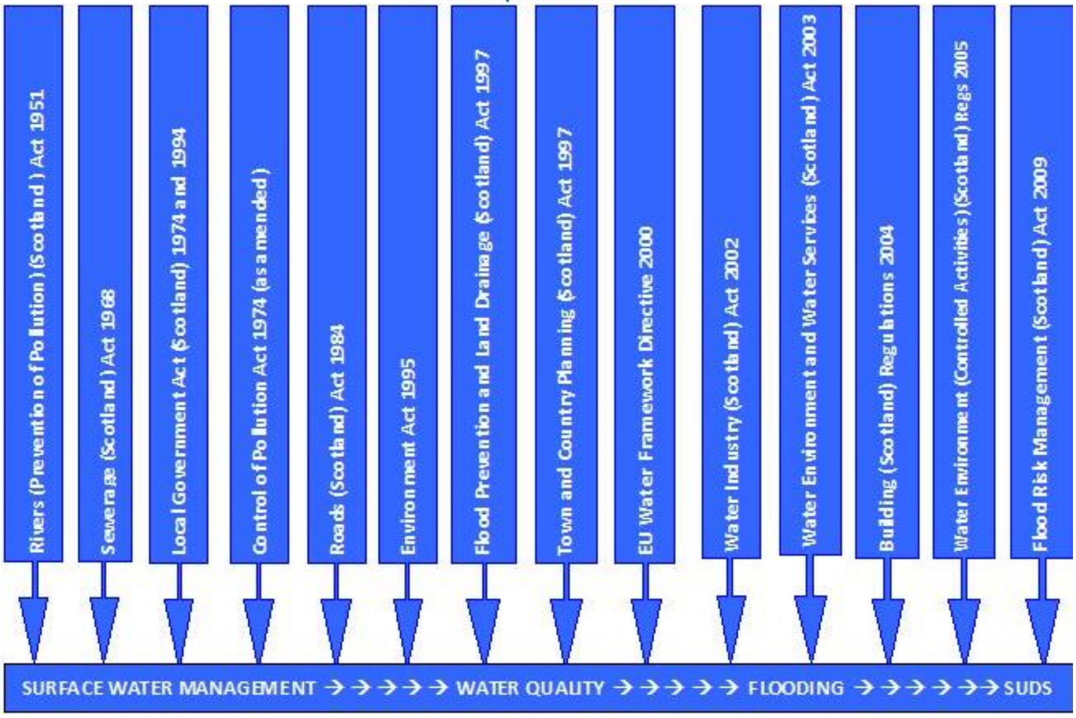

Figure 3 Scottish legislative and regulatory context for supporting implementation of Source Control

Funding for Scottish Water and the Local Authorities regulatory responsibilities comes from the Scottish Government. In the case of SUDS there are different responsibilities, so SUDS assets are split depending on where the polluted surface water originates. It has been recognised that this division makes for a surfeit of pipework. Section 7 of the Sewerage (Scotland) Act was written to provide a solution to this issue. Under Section 7, Scottish Water and the road authorities can make agreements on shared surface water drainage assets. Scottish Water has been negotiating Section 7 agreements for several years and the process is largely still underway (Aukerman et al, 2011).

SEPA acts as regulator on water quality issues and have been advocating the implementation of SUDS since the mid 1990's and actively driving the SUDS agenda for the mitigation of diffuse source pollution impacts (Wild *et al*. 2002). Environmental regulation in the form of the Water Environment (Controlled Activities) (Scotland) Regulations 2005, specifically General Binding Rule (GBR) 10 states '*If the surface water run-off is from areas constructed after 1 April 2006 or from a construction site operated after 1 April 2007, these sites must be drained by a SUDS or equivalent*'. The passing of this regulation has resulted in a dramatic increase in the numbers of SUDS implemented in Scotland. The Flood Risk Management (Scotland) Act 2009 requires a flood risk management planning process to reduce the risk of flooding. SUDS are included in the range of natural flood management techniques which reduce surface water flooding risk. SEPA has a strategic role in managing flood risk and is also the competent flood warning authority in Scotland.

3.2 A snapshot of Source Control delivery in Scotland

The Control of Pollution Act 1974 (COPA) was extremely important for the initial regulatory drive for pollution prevention measures, later named SUDS: an integrated concept for all aspects of stormwater management, biodiversity and amenity. FRPB won an appeal by a housebuilder against the requirement to treat surface water drainage, which opened up the possibility of COPA based requirements for SUDS in the mid 1990's (D'Arcy 1998, D'Arcy and Frost 2001, Ellis et al 2002).

Sustainable Urban Drainage Systems – a design manual for Scotland and Northern Ireland (CIRIA, 2000) was commissioned by SUDSWP to be a stand-alone SUDS manual, and it included source control techniques. They were identified as essential for industrial estates, and for major roads and motorways. In both cases, source control was a first 'level of treatment'. For housing developments there was insufficient evidence to make a strong case for source control at each plot, rather than an end of pipe feature such as a pond or basin (as preferred by many of the house builders for example in discussions in SUDSWP meetings). To require source control and end-of-system SUDS would have constituted two levels of treatment, as set out in CIRIA, (2000). The compromise was agreement that for housing, 'one level of treatment' was adequate; it was up to the developer whether that would be source control or a regional control. It was at this point in time that the source control agenda became fragmented. Source control tended to be advocated as swales or permeable pavements, not distinguishing plot-by-plot applications of the technology (unit plot SUDS as now known), from linear ones (e.g. roadside swales or filter drains).

SUDS for Roads (SCOTS, 2010), also commissioned by SEPA, did set out source control techniques appropriate for roads, such as swales and permeable pavements. It also included techniques not yet widely used in Scotland such as traffic calming landscape features also serving as drainage planters. Section 7 agreements between local authorities and Scottish Water should be encouraging such techniques, but very few have been made to date. An account of the development of SUDS in the UK, including comparison between Scotland and the rest of the UK, is provided in D'Arcy (2012).

3.2.1 Scottish Government

The Scottish Government has assisted the SUDS agenda via various legislative and regulatory measures. The Water Resources (Scotland) Bill (2013) further supports this by encouraging measures to ensure Scotland's water resource is managed efficiently and to the benefit of Scotland such as '*to permit the taking of steps for the sake of water quality and to protect the public sewerage network from harm*' – which can be addressed with the increased uptake of source control.

Designing Streets is the first national policy statement in Scotland for street design and marks a change in the emphasis on street design towards place-making and away from streets focused on motor vehicles (Scottish Government 2010). The policy recommends SUDS including frontier source control techniques as a primary objective when draining streets and should be read in conjunction with SUDS for Roads (SCOTS 2010) which actively promotes source control for different road categories.

3.2.2 SEPA

SEPA was instrumental in setting up the SUDS Working party in 1997 (Watson *et al* 2013) and continues to actively promote the use of source control. Responsibilities to check and approve the measures lies with the Local Authority as detailed in WAT-RM-08 (SEPA 2013). SEPA along with the Working Party have a new SUDS transition agenda which considers the evaluation of built SUDS, including source control techniques (SUDSWP, 2013). This aims to check measures are fit for purpose (constructed as per design and effectively maintained) and subsequently not posing as a risk to the aquatic environment. The stakeholder platform is also actively engaged in furthering the source control agenda to assist ministerial aspirations, initially through the commission of this study.

3.2.3 Scottish Water

The introduction of the Water Environment and Water Services (Scotland) Act 2003, and changes to existing legal definitions placed an obligation on Scottish Water to invest in SUDS. Ponds and basins were identified as appropriate SUDS to attenuate and treat the surface water from domestic roofs and hard-standing (Taylor *et. al*. 2005). Scottish Water took a significant step forward in 2007 with the publication of technical specifications for SUDS in its design guide (WRc 2007). In this guide Scottish Water promotes the use of the stormwater treatment train principle and source control as the first level of treatment. However they have no responsibility to accept surface water drainage from out with property boundaries or for road drainage irrespective if it is source, site or regional control unless a Section 7 notice is in place with the Roads Authority (Duffy *et al*. 2012).

At the recent SNIFFER Flood Risk Management Conference (February 2013), Scottish Water gave an encouraging presentation on the business' future pathway for delivering a national surface water management strategy which aims to strike a balance between traditional build drainage infrastructure and retrofit SUDS – many which will require the implementation of source control techniques: *"this will include any intervention that prevents, reduces or slows flows before reaching the sewer network".* This presents a culture change, not just for Scottish Water but other responsible stakeholders such as the Local Authorities, to ensure that mechanisms for delivering practices such as surface water disconnection is undertaken correctly (Duffy *et al* 2013).

3.2.4 Local Authorities

Local Authorities (LA) in Scotland also promote the use of SUDS and source control, as detailed in Planning Advice Notes (PANs) and the Building (Scotland) Regulations 2004. To date however, there are no legislative requirements requiring the mandatory use of source control. Many LAs have produced their own SUDS guidance. The use of source control on a plot basis is included within building regulations (Standard 3.6.4) and the use of soakaways for single plots (Standard 3.6.5). The latter has (unintentionally) restricted the use of infiltration techniques within close proximity to buildings however recent studies (Wilson 2012) have shown that this is not necessarily the case and infiltration can, with suitable investigation and where conditions allow, be used close to buildings.

Glasgow City Council has recently published 'Design Guide for New Residential Areas'. The document explains how SUDS are an integral part of road drainage design and must be discussed with the Council, Scottish Water and SEPA at an early stage in the design process to agree the appropriate levels of treatment required and the form of SUDS that will be acceptable for adoption.

Dundee City Council (DCC) is currently negotiating a Section 7 Agreement for a regeneration area where it has been agreed to share roads and residential drainage. The source control arrangement includes filter drains and in-curtilage permeable paving which discharge to a basin. Maintenance responsibilities are split with DCC managing the above ground landscaped area and Scottish Water managing below ground assets. The City have also negotiated an arrangement whereby the agreement will be a 'one size fits all' in that any future shared arrangements are covered by this Section 7 Agreement (DCC, 2013).

3.2.5 Professional Groups

There are many professional groups in Scotland and the rest of the UK also involved with encouraging and influencing the source control SUDS agenda to varying degrees. Examples include:

SUDS Working Party is composed of members who champion the SUDS cause collaboratively within the stakeholder platform and within their own organisations (**Figure 4**). Tasks undertaken by the group since inception include the development of technical guidance and troubleshooting (disputes surrounding SUDS requirements, application and adoption issues). SUDS Working Party conducted a strategic review of unfinished business of SUDS in 2010, which has led to the current focus on source control. The application of the technology at individual premises (unit plot SUDS) as well as for roads, including streets was recognised as a priority issue and opportunity.

Figure 4 Members of the Sustainable Urban Drainage Scottish Working Party (SUDSWP)

SUDS Working Party are currently working on three new agenda's: this project to facilitate further implementation of source control SUDS; development of an inspection and monitoring regime under the Harms led initiative (SEPA 2012a) to assess a range of SUDS performance to check they are fit for purpose and pose no threat to the aquatic environment; review and update the Drainage Assessment guide (SEPA 2005) in view of new legislations and changes in practice (SUDSWP 2013).

Uptake of source control within Scotland has been (predominantly) at the discretion of the **Developer / Designer** and there are a number of good examples throughout Scotland. There is however a general concern that use of source control will increase the costs of development which in the current market is unfavourable. This fact however, is not proven and a recent study (Campbell & D'Arcy 2012) has shown that using source control can maximise the number of unit plots on site, reducing the overall cost of implementation but that this process will require further research and support from planning guidance. There is generally a thought that non-mandatory use of source control could disadvantage the developer and that unless its use is mandatory (i.e. driven by legislation) then market conditions would be unbalanced (Jack 2013).

The Metropolitan Glasgow Strategic Drainage Partnership (MGSDP) is a stakeholder platform which consists of organisations involved with the operation of the sewerage and drainage network within the area (http://www.mgsdp.org). The group have developed a vision and strategic plan which focuses on: flood risk reduction; river water quality improvement; enabling economic development; habitat improvement; integrated investment planning. SUDS, including source control have been identified as important measures with land take requirements for future implementation recommended for facilitating implementation in all areas.

Glasgow and Clyde Valley Green Network Partnership aspirations are '*make the Glasgow metropolitan region one of Europe's most attractive places to live, work and play'.* This will be achieved through the creation of a large functional Green Network. It is expected that many organisations will play their part in helping to create and manage this network including, local regeneration companies, housing associations, third sector organisations, developers and volunteers. The partnership have delivered several excellent design studies for integrating green infrastructure into the urban environment which recommend and detail the use of both traditional and frontier source control SUDS (i.e. Barbar 2010).

CIRIA (Construction Industry Research and Information Association) has had a significant influence in the uptake of SUDS over the last decade with many publications to inform SUDS best practice. SUDS education and guidance for professionals is now delivered through susdrain a website which contains a range of resources for the delivery of best practice SUDS (http://www.susdrain.org/). The case study web page has a section dedicated to source control implementation though there are no exemplar sites from Scotland. CIRIA are currently updating national guidance (C697 the SUDS manual) and there may be an opportunity to offer information from this CREW study to inform these guidelines in the area of source control SUDS as this section is under review.

RSPB and **WWT** (wildfowl and wetlands trust) have recently published new SUDS guidance for LAs and Developers. They argue the case for '*more intelligent and sustainable land and water management*' schemes in the UK. The guide is not a replacement for other guidance but builds on these by providing best practice case studies including many frontier source control techniques which highlight and explain the opportunities for delivering better places for people and wildlife.

3.3 Transition Pathway for the evolution of Source Control SUDS in Scotland

Transitioning is an emerging field of science which attempts to influence the uptake of new generation socio-technical innovations such as urban water infrastructure. It is a governance methodology enabling a multi-disciplinary stakeholder platform to influence transformations from conventional practices towards more sustainable practices for the future (Geels 2005, Jefferies and Duffy, 2010). Phase one of this research looked at the background to the evolution of source control SUDS in Scotland to gain insight into the enabling factors and obstacles for uptake of the systems. We concluded that although a great deal had been achieved in a short time and with the source control toolkit expanding, the uptake of source control is less routine than was hoped at the beginning of the SUDS journey. As far as the uptake of source control SUDS are concerned, Scotland has benefitted from both top down drivers at the macro- or strategic level in the form of legislation and bottom up drivers at the operational level via research / viable case studies. Combining this information with the identification of responsible organisations and professional groups in Scotland who have played a part in the historical transition pathway is reconstructed and mapped out in **Figure 5.** A Multi-Level Perspective (MLP) (Geels and Kemp, 2000) provides an understanding of technological innovation in a social context to reconstruct the historical evolution of source control in Scotland. This concept analyses interactions between processes at different socio-technical levels which are known as the micro, meso and macro levels in transition theory (Rip and Kemp 1998, Van der Brugge and Rotmans 2007). The macro level characterises the 'landscape', a metaphor for the local situation or background of a culture which influences the pace of change during a transition i.e. trends such as climate change, environmentalism, urbanisation and wars etc. (Van der Brugge *et al.* 2005). The meso level characterises the stable, dominant 'regime' or stakeholders such as policy makers, institutions, markets and community groups which operate to rigid rules impeding attempts to influence change at the landscape level. The micro level demonstrates the 'niche' theme where innovations and alternative technologies develop without pressure from the dominant regime.

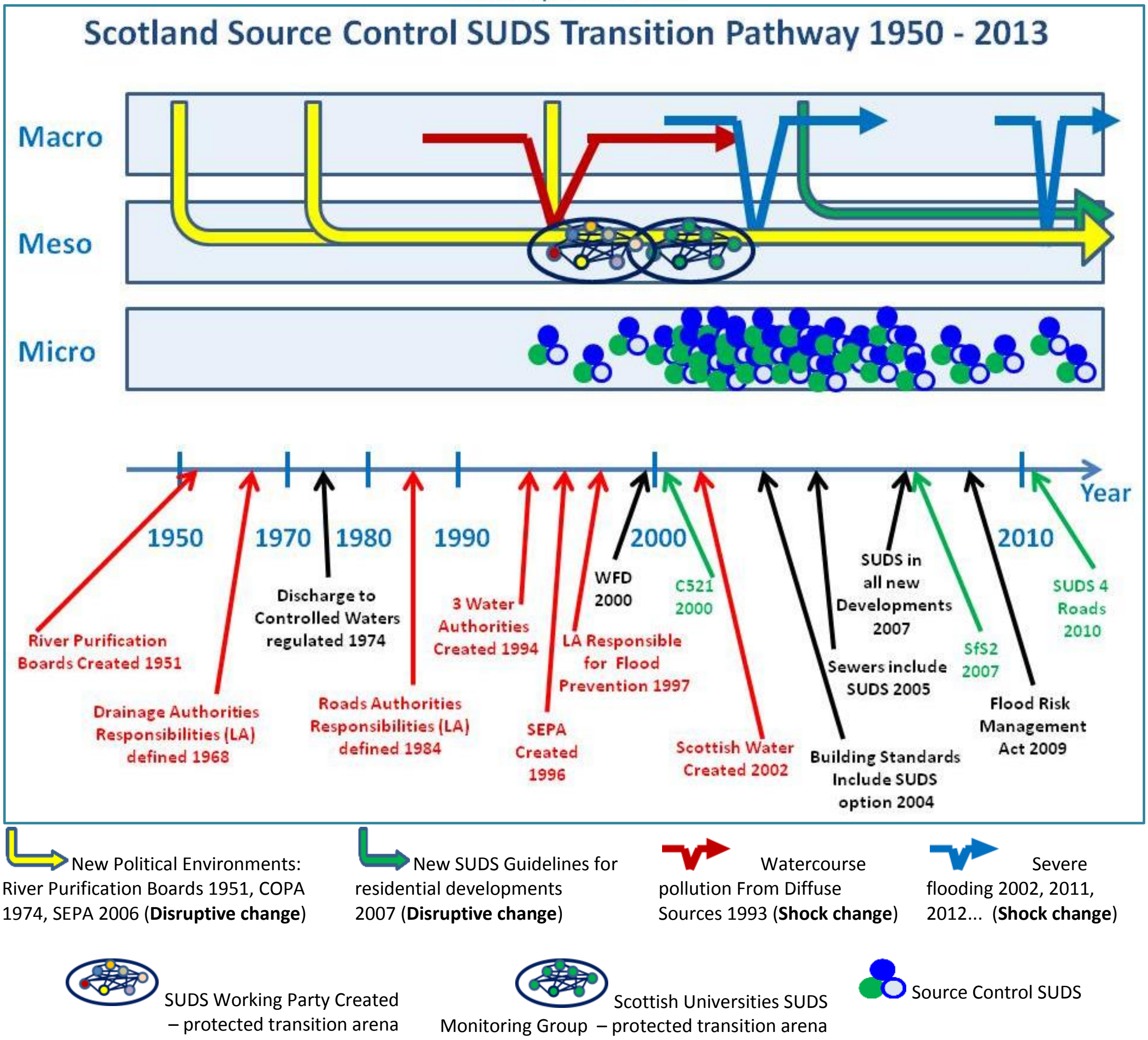

Figure 5 Scotland Historical Transition Pathway 1950-2013 (adapted from Jefferies and Duffy 2010)

The MLP concept recognises that the macro level (the broad cultural, political, natural environment view of a city) plays a significant role in accelerating or slowing down a transition either through for example, inertia at the political level or uptake at the cultural level of new philosophies such as source control (Grin and Schot 2010). As previously mentioned the implementation of source control SUDS in Scotland, for most of the last decade, benefitted from an accelerated transition pathway due to environmental and political legislative reforms. The MLP considers the dynamics of a transition over time as a series of phases. Here culture, markets, networks, institutions, technologies innovations, policies, behaviours and 'trends' evolve together from one relatively stable state to another (de Graaf 2005). In this case from traditional water management practices to sustainable drainage practices including source control SUDS – i.e. where new innovations become widely accepted or 'business as usual'.

There were four periods of what is termed disruptive and shock changes at the macro or political (environmental) level which either encouraged or discouraged the uptake of novel SUDS techniques:

- The early 1950's saw the establishment of the River Purification Boards (RPBs). Main statutory responsibilities consisting of promoting the cleanliness of rivers, inland and tidal waters, and the conservation of water resources. Statutory duties included: monitoring pollution in controlled waters, ensuring that specified water quality objectives were achieved, consenting to discharges of trade and sewage effluent, and maintaining registers of consents for public inspection (Macleod, 1997). This period (1950 – mid 1970's) resulted in a growing awareness of the significant problems needed to be addressed regarding poor water quality in Scotland's water bodies.

- The Control of Pollution Act 1974 armed the RPBs with powers to take water samples or effluent, undertake surveys and keep records of flow or volume of waterbodies and rainfall, obtain information necessary to carry out their duties, control abstractions for irrigation purposes, and operate flood warning schemes (Macleod, 1997). It was under the Forth River Purification Board regime that urban drainage as a diffuse source of pollution began to be recognised as a primary polluter of water courses (Ellis 1985, Ellis et al 1987, Hamilton and Harrison 1991, FRB 1994).
- With the creation of a single Scottish Environment Protection Agency (SEPA) via the Environment Act (1995), to replace the River Purification Boards, theses duties were passed on. The drive for implementation of SUDS including source control to address water quality issues, specifically diffuse sources of pollution began in earnest.
- The publication of national SUDS standards by Scottish Water in 2007 where ponds and basins only were identified as adoptable assets has resulted in developers implementing these systems only for new developments (and brownfield sites) which have ultimately impacted on the implementation of source control SUDS.

At the macro level, there have been several periods of change since the mid-1990's which were again enabling factors for promoting the uptake of SUDS including source control SUDS. These were:

- The study by FRPB in 1993 provided the evidence that urban drainage was one of the diffuse source of pollutants responsible for the cause of unsatisfactory river water qualities in the Forth catchment and the growing recognition that 'foul-into-surface water' was an important issue needing to be addressed (SEPA 1996, Watson *et al* 2013).
- Although there was evidence of Scotland experiencing more frequent, sudden and heavy downpours of the kind which cause flooding towards the end of the 20th century, the severe urban flooding experienced in Glasgow, winter 2002 was a wake-up call to further consider SUDS initiatives to address flood risk management issues (Tingle 2006, Cashman 2007).

At the meso level, Scotland benefitted from two protected transition arena's (or stakeholder platforms) towards the end of the 1990s which guided the transition process by creating and encouraging SUDS niche's thereby nurturing the innovative techniques (the new generation urban water systems). These were:

- The Scottish SUDS Working Party formed in 1997 in response to the formation of SEPA in 1996. The group were committed to developing and promoting SUDS implementation.
- The Scottish Universities SUDS Centre of Excellence, funded by interested stakeholders, undertook research on novel techniques to validate their application for the local climate.

The micro level represents the protected 'niche' area where technological innovations (source control SUDS) were nurtured by the stakeholders who are actors in the transition arena (Raven *et al*, 2010). Stakeholders in both arenas comprised a diversity of actors with differing agendas (pollution prevention, flood mitigation, biodiversity enhancement etc) with a vested interest in encouraging the uptake of the systems in order for Scotland to move towards a more sustainable way of delivering drainage infrastructure.

3.4 Transition strengths for Implementation of Source Control SUDS in Scotland

The SWITCH transition framework was developed to assist with understanding how a transition process occurs and to guide a desired change process (Duffy and Jefferies, 2011). This framework was used to assess transition progress since the inception of source control SUDS in Scotland and will again be used to guide the SUDS Working Party in their efforts to further the implementation of source control SUDS (**Figure 6**). The framework has ten transition management activities or transition 'strengths'. Transition management activities are aimed at influencing, organising and coordinating processes or governance activities at three different levels; strategic (societal, long-term), tactical (institutional, medium term) and operational (projects, short term) which influence each other and operate together. The transition management cycle lies at the core of influencing change consisting of co-evolving transition clusters and activities which drive the change process. The drivers are generally a stakeholder platform with a diverse set of skills such as the SUDS Working Party. In practice, transition management activities may be carried out partially, completely, in sequence, in parallel or randomly (Grin *et al* 2010).

The transformation from traditional drainage in Scotland has occurred in a relatively short timescale in transitioning terms as they are usually long-term processes (in excess of thirty years) that occur due to the co-evolution of societal, market driven and technological processes. This can be attributed to most of the ten transition management activities occurring at one time or another during the last decade (**Figure 6**).

Transition activities over the last decade in Scotland include the creation of the SUDS Working Party and the SUDS Universities Centre of Excellence as transition arena's – both with transition agenda's driven by interested stakeholders. Transition experiments were the first source control SUDS systems implemented mainly in Eastern Scotland (the Lothians, Dundee and Fife) and the research that was undertaken to validate the systems (Dunfermline East Expansion, Ardler Regeneration, NATs car park etc. (Jefferies (Ed) 2001 and 2004)). Monitoring (and lesson learning) included evaluation of the research outputs and assessment of the systems on the ground which resulted in the national guidance manual C521 – the SUDS Manual for Scotland and Northern Ireland driven by the SUDS Working Party in collaboration with CIRIA (Watson *et al* 2013).

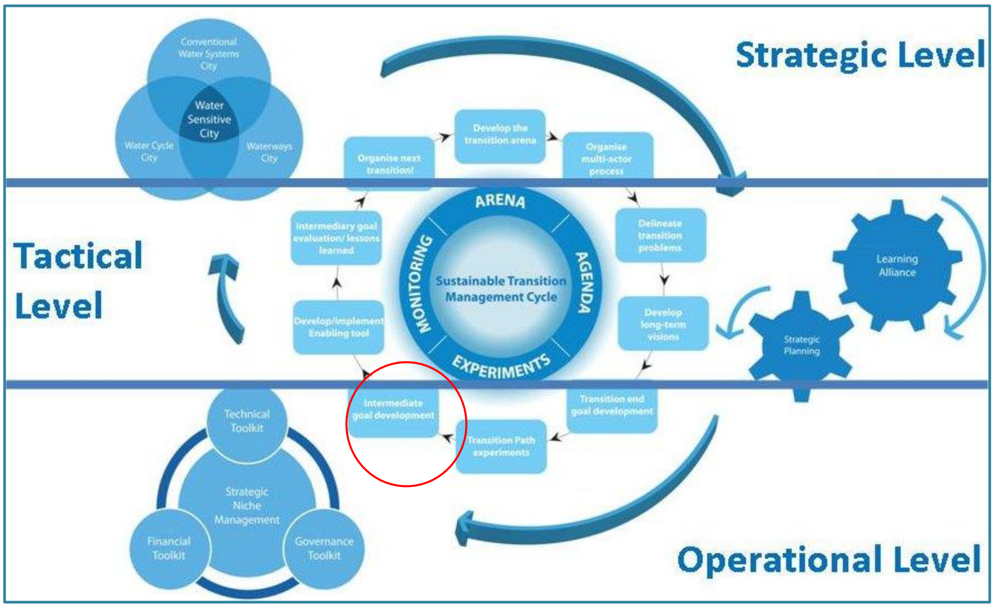

Figure 6 The SWITCH Transition Framework

The transition management activity which has not fully been exploited is the engagement of communities. However this did not appear to have impeded progress for site and regional SUDS but may prove a disabling factor in progressing the source control SUDS agenda.

4.0 SOURCE CONTROL SUDS - GLOBAL CASE STUDIES

A literature review was undertaken to examine the extent of delivery of source control, particularly frontier techniques, in the countries discussed in Section Two. Case studies are developed to explain why source control was implemented and how it was achieved. These can be found in the Appendix. Examples highlight where practices are underway in other countries which could usefully be replicated in Scotland. These will be analysed in greater detail in Phase 3 of this research to assist in providing recommendations for encouraging uptake in Scotland. Preliminary key messages are:

- There are many good examples of emerging source control techniques but few in the UK. Overall, techniques which are accepted in the UK, particularly Scotland appear to be the tried and tested practices such as swales, filter drains and permeable pavements and not the more novel source control systems such as raingardens and tree planters. There is anecdotal information which suggests that this may not be the case but the evidence base is limited.
- There are several good campaigns or sector engagement experiences such as the Melbourne 10,000 Raingardens campaign which is a significant success story regarding the uptake of source control by the general public.

5.0 CONCLUSION

This appraisal has provided a snapshot of the state of source control delivery in a number of countries including a more detailed account for Scotland. Conclusions and recommendations include:

- In all nations a clear driver (or vision) has been established and an agenda set to introduce and increase the uptake of source control SUDS. In Scotland the source control vision and agenda is fragmented due to different drivers and stakeholder responsibilities.
- Incentives (whether regulatory, legislative, financial, social or environmental) are key to the development of inter-disciplinary stakeholder platforms which were able to take advantage of cost effective multiple benefits such as multi-functional land use. There are minor examples in Scotland of integrated agendas between stakeholders providing the evidence base for replicating and up-scaling the methodologies and techniques across Scotland.
- Where frontier source control techniques are accepted, nations used opportunities such as severe events (flooding or drought) to initiate an agenda and encourage uptake.
- All nations developed source control SUDS 'niches' to nurture the innovative techniques – a learning by doing concept. From the few source control research case studies presented there is evidence that this is underway to a certain extent but a more focused research agenda would go a long way to convincing stakeholders that these systems are viable sustainable solutions and assist in speeding up the uptake of the systems.
- Most nations which implemented source control included community engagement as a key requirement of the process. This is important for empowerment, connecting people with the environment and acceptance of the systems. In Scotland this does not appear to have hindered progress for the uptake of site and regional control SUDS. This would indicate that the lack of public engagement may be a key barrier for uptake of source control.

A final observation for the conclusion of this phase of the study is that there have been several requests from various interested parties in England (and one from the Netherlands) for CREW / SUDS Working Party to share the outputs from this research, this is indicative of the need for this kind of research not just in Scotland but the rest of the UK.

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