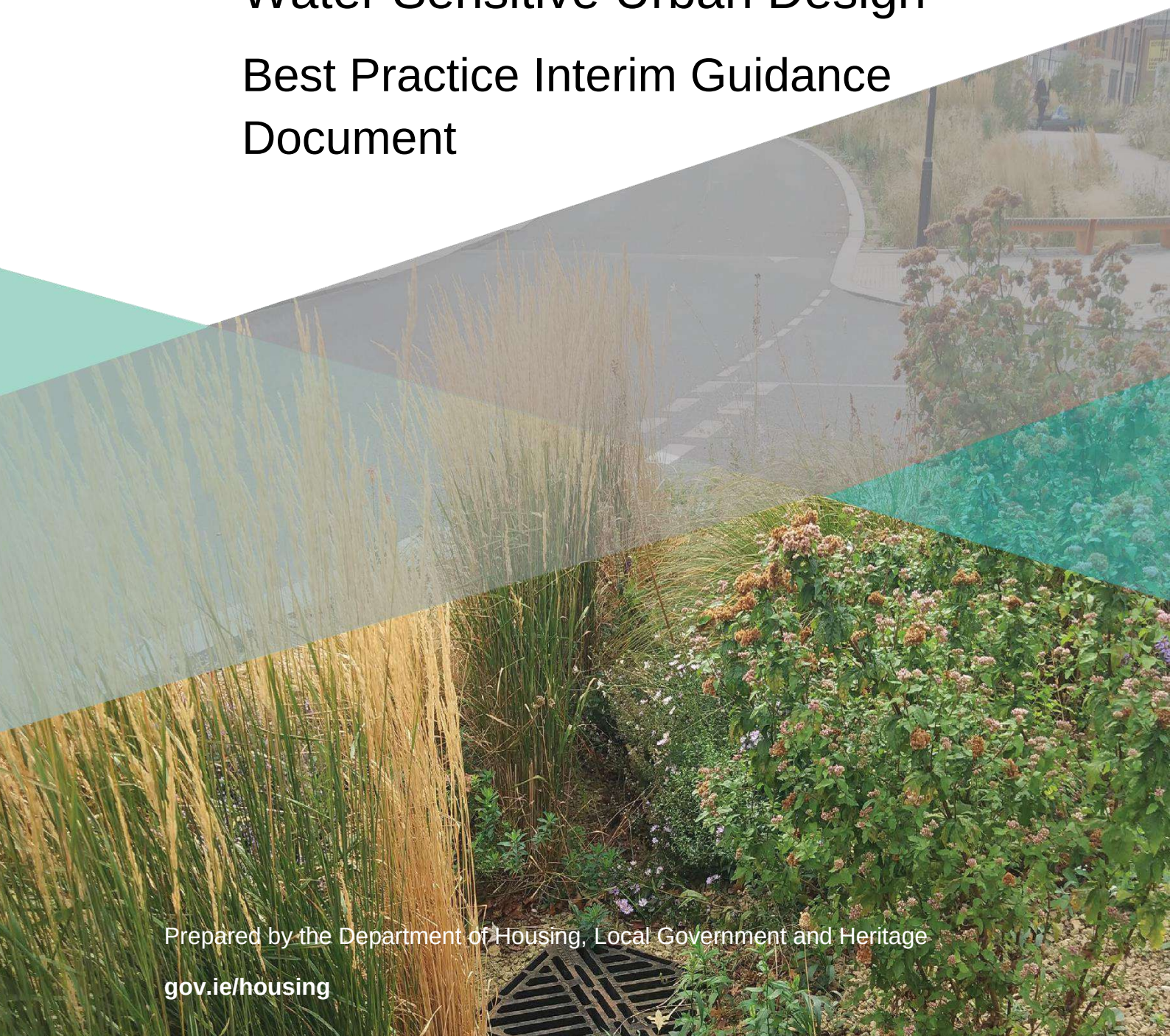
Rialtas na hÉireann
Government of Ireland

Nature-based Solutions to the Management of Rainwater and Surface Water Runoff in Urban Areas

Water Sensitive Urban Design

Best Practice Interim Guidance Document



Prepared by the Department of Housing, Local Government and Heritage

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Front cover: Existing gully incorporated into rain garden

Source: Urban Design London, Designing Rain Gardens, A Practical Guide

Executive Summary

Population increase inevitably requires the necessary expansion of urban areas. This can result in increasing pressure on our natural resources. Sustainable urban development solutions, such as water sensitive urban design, can help to mitigate the potential for environmental degradation in the form of biodiversity loss, pollution of water bodies, and increased flood risk as the demand for urban development to accommodate a growing population continues to increase.

Runoff is a natural process where rainfall, not infiltrated into the soil, finds its way naturally from the catchment areas into the streams and rivers and on to the oceans. In urban areas the natural water cycle is disrupted due to the extent of impermeable surface cover that modifies natural infiltration, surface reflectivity and evapotranspiration. In addition, temperatures in urban areas are more elevated than in rural areas creating “urban heat islands” and changes to precipitation patterns. In urban areas, where natural infiltration is reduced, rainfall runoff can be 400% greater in volume than in rural areas and prone to extreme flows in a severe rainfall event.

Furthermore, the runoff from urban areas includes a toxic cocktail of pollutants washed off the urban impermeable areas into the receiving water bodies. This polluting effect has been identified by the Environmental Protection Agency (EPA) as one of the primary sources of pollution from urban areas, alongside discharges from urban wastewater systems.

The impact of extreme rainfall events is increasing with climate change and this is significantly increasing both the level of pollution from urban runoff and the flood risk arising from the greater volume of that runoff from the largely impermeable urban area.

This Best Practice Interim Guidance Document is for urban planners and all built environment professionals involved in the planning process such as engineers, architects and landscape architects and shows how to move towards a more systematic and sustainable approach to urban planning and design that seeks to mimic the natural water balance of rural areas through “water sensitive urban design”. This is to be achieved through the replacement of impermeable surfacing with nature-based planted areas that are designed to absorb, retain, store, and treat urban runoff prior to discharge back into the environment. The successful integration of nature based solutions for the management of rainwater and surface water runoff in urban areas requires a collaborative approach from a range of built environment professionals, both from the public and private sectors, from the earliest stages in the planning process.

This will reduce pollution and reduce flood risk as well as improving biodiversity and a greener more pleasant urban environment.

While there have been policies supporting sustainable urban drainage systems (SuDS) in place for many years, there has not been much success in changing the urban landscape.

It is now proposed to move to a plan and design-led approach whereby all urban interventions or projects must incorporate water sensitive urban design and manage rainwater in a nature-based and sustainable manner.

The Interim Guidance Document sets out the various steps that can be taken to achieve this in the context of current planning policy and provides supplementary information and links in a series of Appendices.

It is anticipated that there will be a more detailed Guidance Document produced in the medium term as part of an overall national strategy for the implementation of nature based management of urban rainwater.



Ecosystem-based approaches Source: IUCN

1.0 Introduction

The EU Water Framework Directive (2000/60/EC) (WFD) requires all Member States to protect and improve water quality in all water bodies in order to achieve good ecological status by 2015 or, at the latest, by 2027.

The Directive's objectives are delivered in Ireland through the river basin planning process. Ireland is currently developing its third cycle River Basin Management Plan (RBMP).

The impact of urban surface water runoff on the quality of adjacent water bodies is recognised as is the related issue of the volumetric control of surface water in terms of flood management in urban areas. Both of these issues are also being further highlighted by the changing weather and rainfall patterns driven by climate change.

In terms of the broader issue of urban design, there is a growing recognition of the important role of blue and green spaces and biodiversity in urban areas and the need to move from a car-based design to one that is more focused on sustainable transport and increasing use of outdoor spaces.

Accordingly, the National Planning Framework 2018 (NPF) sets out clear policies that require a changed approach to urban planning and design as can be seen from the following extracts:

National Policy Objective 57

Enhance water quality and resource management by:
• Ensuring flood risk management informs place-making by avoiding inappropriate development in areas at risk of flooding in accordance with The Planning System and Flood Risk Management Guidelines for Planning Authorities.
• Ensuring that River Basin Management Plan objectives are fully considered throughout the physical planning process.
• Integrating sustainable water management solutions, such as Sustainable Urban Drainage (SuDS), porous surfacing and green roofs, to create safe places.

National Policy Objective 58

Integrated planning for Green Infrastructure and ecosystem services will be incorporated into the preparation of statutory land use plans.

It is also important to consider the interrelationships between biodiversity, natural heritage, landscape and our green spaces.

Green infrastructure planning will inform the preparation of regional and metropolitan strategies and city and county development plans by:

- Assisting in accommodating growth and expansion, while retaining the intrinsic value of natural places and natural assets;

- Providing increased certainty in planning by proactively addressing relevant environmental issues;

- Encouraging more collaborative approaches to plan-making by enabling examination of the interactions between future development requirements and the capacity of receiving areas; and

- Ensuring that sufficient and well planned green spaces, commensurate in scale to long-term development requirements, are designated in statutory plans.

2.0 Scope and Purpose of Document

This is not a technical manual but, rather, a high-level best practice interim guidance document for all those whose work impacts on the urban environment.

The need for a significant change in the way we plan, design, build and maintain our urban areas is driven by three main factors:

- Environmental – The impact of urban runoff on our water environment has long been recognised. However, in Ireland, we have not adequately addressed this issue during the first two cycles of our River Basin Management Plans that covered the period from 2009 to the current year of 2021. If we are to comply with our obligations under the WFD to achieve "good status" in all our water bodies, we must intervene in a significant way during the third RBMP 2022 to 2027;



Urban Rain Garden

- Climate Change – as we will see later, the weather and rainfall patterns in Northwest Europe, including Ireland, have already significantly changed with increased experience of high intensity localised rainfall events. There needs to be a consequent change to the way we deal with rainfall in urban areas; and

- Flood Risk – Increased Rainfall intensity and ever-increasing areas of impermeable urban surfacing combine to increase the risk of urban flooding. There is an urgent need to address this issue by the retention of rainwater as close as possible within the catchment to where it occurs, and the management of any surface water flows in the urban area.

This Best Practice Interim Guidance Document seeks to demonstrate how, through appropriate changes to the way we plan and design urban areas, we can address these three related issues.

These changes will also bring added value in terms of improved place making and urban biodiversity and in the facilitation of policies promoting sustainable transport and outdoor urban living.

Of the three factors listed, the area of climate change and the need to adapt our urban areas to a changed climate in terms of rainfall patterns is the unifying concept in terms of the scope of this document. Climate change and adaptation are also a driver for an increase in urban planting and biodiversity. If an overall plan is followed, these green areas can form part of an overall urban plan with green corridors to promote ecology and biodiversity, rather than having disconnected “green islands” within an urban landscape.

Climate Adaptation and Climate Resilience are the desired outcomes of the new approach. It is also recognised in the document that this change will take time.

Therefore, this Best Practice Interim Guidance Document seeks to promote the use of a long-term and plan-led approach that combines nature-based solutions to the management of rainwater and surface water runoff in urban areas (nature-based solutions) with spatial planning, particularly at the level of the individual urban settlement, large or small. Over time, this approach will allow iterative changes to be made to urban areas as planned urban developments proceed, both public and private.

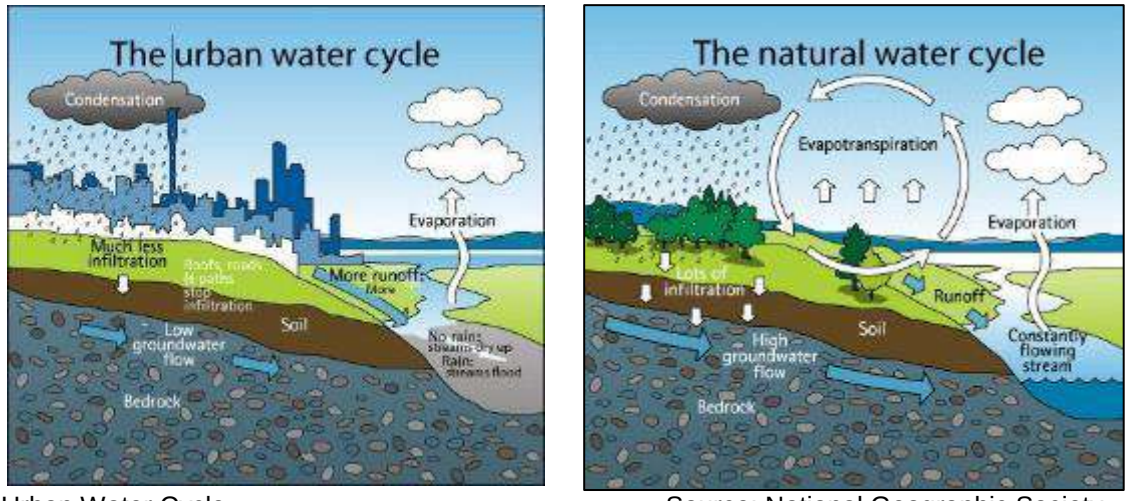
3.0 Understanding Rainfall in the Urban Environment

3.1 Rainfall in Nature and the Water Cycle

While we experience rainfall in Ireland on a regular basis, we don't always consider what happens the rain after it falls.

The water that falls as rain in a typical rural environment has a very different journey from the rain bearing cloud until it returns to the natural water environment than the rainfall that falls in an urban area. This is largely due to two factors:

- Urban areas are largely impermeable and often necessarily expanding (see Section 3.2). This leads to reduced absorption, leading to increased volumes and speed of runoff with potential additional flood risk; and
- Urban areas create a myriad of pollutants that can and do get washed into the rainwater before it returns to the natural environment.



Urban Water Cycle Source: National Geographic Society

These images focus on the hydrological impact of the urban areas. However, the environmental impact from polluted urban runoff into the receiving water bodies is also a significant impact.

3.2 Impact of Urban Development on the Water Cycle – Urban Creep – Environmental Impact and Flood Risk

The term “Urban Creep” is used to denote the increasing impermeability of an urban area, even within a fixed spatial area. This is best represented by individual property owners replacing permeable areas within their properties such as gardens with impermeable areas such as car parking bays, patios, building extensions or “low maintenance” options such as artificial grass or other options.

Other ways in which the volume of runoff from urban areas can increase is through the expansion of the urban footprint into previously rural or green areas.

Urban development can also result in the direct degradation of water bodies through culverting or channelization, thus reducing or removing the hydromorphological characteristics of the water body with a resultant loss of habitat and biodiversity.

The two main impacts of urban development on the water cycle, arising from the above factors, are discussed below.

3.2.1 Environmental Impact

The environmental impact of urban development and urban design on the water environment arise from the following factors:

- **Urban Runoff directly into the natural water body**

  The nature and range of pollutants contained within urban runoff is extremely complex and further details and links are included in Appendix 1.

  The main pollution sources are:

  - Atmospheric deposition which facilitates transfer of polluting substances and materials in the atmosphere to the urban catchment surface;
  - Urban vehicles which deposit tyre fragments as well as hydrocarbon leakages; and
  - Urban waste such as pet faeces, litter, microplastics, salt from road treatment etc.

  The resultant waste has been described as a toxic cocktail of pollutants and has been identified by the EPA as a key source of pollution to be addressed.

In the consultation document published by the DHLGH in 2019 on significant water management issues in Ireland, it is noted that “Increases of impervious surface cover due to urbanisation means that present day management of an urban river requires a holistic approach in terms of planning, flooding, surface water networks, biodiversity, hydromorphology and water quality.

With increasing urbanisation, river restoration and the use of Green Infrastructure are vital measures for improving and maintaining rivers in our towns and cities for future generations. Urban runoff delivers pollutants from roads, public areas and roofs predominately via a gully and surface water pipe to the river”.

In terms of sustainability, it is always best to deal with pollutants as close to the source as possible, rather than transferring the pollution elsewhere. Nature-based solutions allow the polluted runoff be treated close to where the rain falls. For example:

- **Overflows from combined sewers[1] which, in turn, arise from ingress of excessive volumes of rainwater into the sewer network, resulting in the discharge of sewage from overflows into the natural water body.**

  Irish Water is responsible for the preparation of Drainage Area Plans, including for urban areas where combined sewer networks exist.

  To achieve compliance with the requirements of the WFD and RBMP, Irish Water is obliged to reduce the frequency and volume of discharges from combined sewer overflows (CSOs). While heavy engineering solutions such as the tunnels recently constructed in London and Belfast are an option, the use of nature-based solutions is more climate adaptive in dealing with increasing rainfall intensity, as well as providing ancillary benefits in terms of sustainable urban design, greening, biodiversity, mitigation of urban heat island impact and the increased priority for sustainable transport modes.

  These solutions can, therefore, be delivered as part of a broader urban regeneration and be funded accordingly, rather than the single use and limited benefits of underground solutions. It is likely that there will still be a need for a new pipe network to divert excess rainwater flows but the capacity and size of these will be significantly reduced if appropriate ground level nature-based solutions are employed.

  Irish Water policy is to promote the use of nature-based solutions in urban areas in order to reduce the need for large scale and more costly underground solutions such as large pipes and tunnels.

[1] A combined sewer is one that has inflows of wastewater / sewage as well as rainwater. These are, typically, found in older town and city centres and are designed to overflow during excess rainfall or storm events.

- **Direct degradation of the water body through culverting or channelization.**

  As noted in the aforementioned 2019 DHLGH consultation document on significant water management issues, “river restoration and the use of Green Infrastructure are vital measures for improving and maintaining rivers in our towns and cities for future generations”.



Contrast between urban streams that are culverted or natural

To facilitate the restoration of rivers in urban areas, there is a need for local authorities to take a proactive approach. This should involve the consideration of any future requirements that would facilitate such restoration, in line with Water Framework Directive objectives. This is likely to include ‘making space’ for water bodies within developed areas and identifying riparian areas that need to be protected, and should be based on historic river mapping as well as on the OPW catchment flood risk modelling. This approach can be used to inform other spatial plans such as development plans and local area plans and to support the restoration of urban rivers and streams to the largest extent possible, as development takes place.

It is recognised that parts of some rivers and streams within the historic core of towns and cities may not be possible to restore.

3.2.2 Pluvial (or rainfall induced) Flood Risk

Urbanisation and associated land uses are leading to increasing risks of rainfall induced flooding.

A recent study published in the journal Nature, was led by the Vienna University of Technology and involved research institutions and academics in 24 European countries, including NUIM in Ireland.



Road flooded after heavy rainfall Source: Met Éireann

This study has shown that in north-western Europe, floods are increasing because flood generating rainfall (annual maximum seven-day rainfall totals), is increasing and soils are becoming wetter, resulting in a higher water table. Across Britain and Ireland as a whole, flood magnitudes have been increasing at a rate of about 5% per decade since the 1960s.

As a result, serious flash flood events will also occur more frequently, causing deaths and widespread damage in areas at risk. We have already seen further evidence of that in 2021 in areas of northwest European mainland.

We, therefore, urgently need to reduce the proportion of our urban areas that are impermeable and to attenuate the rate of runoff of rainwater using sustainable methods that replicate a natural catchment. This issue of climate change resilience is covered in more detail in the next chapter.

4.0 Climate Adaptation and Climate Resilient Urban Design

4.1 Climate Change and Rainfall

As was set out in Section 3.2.2, the evidence of an already changed pattern of rainfall is clear. All the available scientific evidence points to further intensification of rainfall events in the coming years. Our urban areas have drainage systems that were designed for rainfall patterns that are more representative of the earlier years of the 20th Century. Furthermore, drainage network capacities and flood risk have, traditionally, been calculated based on historic data. This is the basis of the estimated “return period” which is still widely used where a flood event is described as a “1 in 100-year event” and where flood defence measures are designed to deal with a “1 in 200 year” event.





Source: Met Éireann

To a large extent, these risk assessments are based on historic data that is no longer relevant. We need to use risk assessment methods that are based on a changed and changing climate and on new rainfall patterns. We also need to recognise that we cannot easily replace the existing urban drainage systems that are already in existence, while recognising that these systems cannot cope with the new rainfall intensities. This means that we must change our approach to plan preparation and design to deal with rainfall at ground level using nature-based solutions, insofar as is possible.

4.2 Climate Adaptive and Resilient Urban Design

To some extent the terms “climate adaptation” and “climate resilience” are interchangeable but they can be interpreted as two different aspects of climate action:

- **The term “climate adaptive” is used to look at the capacity of an urban area to adapt over time as climate and rainfall patterns continue to change.**

  It is noted that traditional engineering solutions to rainwater management using gullys and piped underground networks are not easily adapted to a changing rainfall pattern as their capacity and location are both fixed. To change either would involve extremely high cost and disruption.

  Furthermore, the underground solutions can become gradually overwhelmed by rainfall volumes without any evidence until such time as the pipes “surcharge” to ground level, resulting in sudden and potentially catastrophic flooding.

  In contrast nature-based solutions (NBS) at surface level are visible and any excess runoff that cannot be absorbed or dealt with by the NBS is clearly visible and will run overland to the next area of NBS and, ultimately, into rainwater retention areas with some further excess dealt with by residual piped networks.

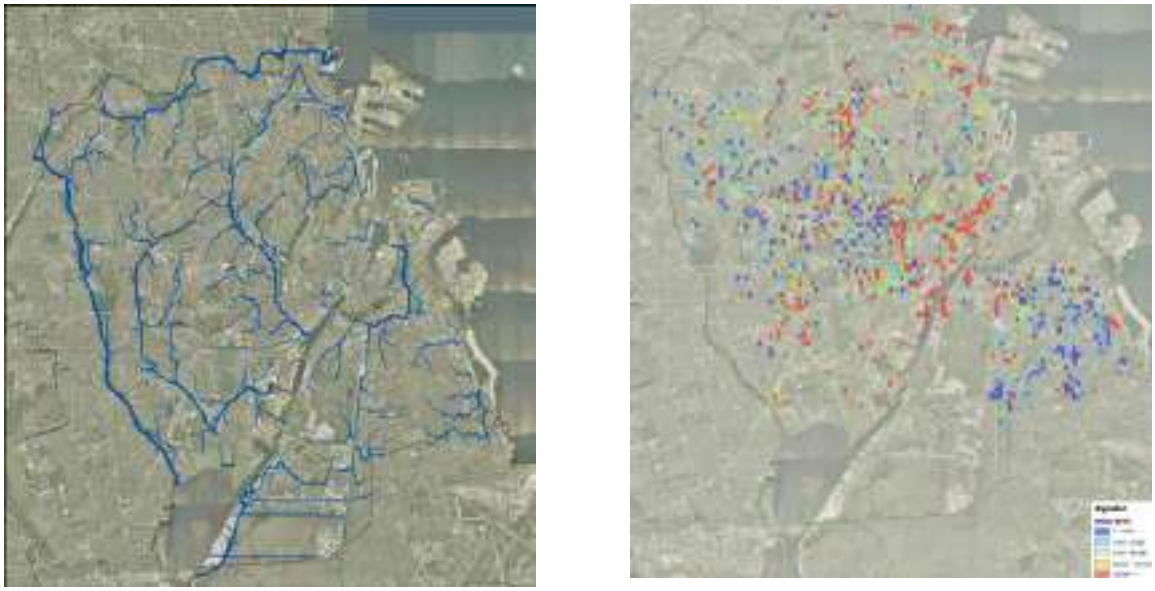
  It is relatively easy to add further planted or green areas to increase the absorption and storage capacity of the overall NBS network in an urban area. It is therefore a more readily adaptive approach to urban planning and design.

- **The term “climate resilience” is used to describe the extent to which an urban property or area, having experienced flooding, can be restored to normal use.**

  Individual buildings can be designed or retrofitted so that the damage done to them when they flood can be significantly reduced so that the cost and time impact of the flood event is minimised.

  Buildings and their immediate curtilage can also be designed or retrofitted for the sustainable management of rainwater through the retention of rainwater on site and, where practicable, the re-use of stored rainwater to reduce the use of potable water.

  Urban layouts can also be designed to be climate resilient by planning for extreme rainfall events and by using 3D Planning and mapping to show where excess rainwater volumes will flow.



Copenhagen Flow Routes/ Areas with highest risk of significant damage as a result of high-intensity rainfall
Source: The City of Copenhagen Cloudburst Management Plan 2012

Further resilience can also be achieved through the use of overland flow mapping, the appropriate design of those roads and streets that are likely to carry the largest volumes of excess flow and the incorporation of appropriate areas of storage of excess volumes within amenity or open spaces.

3D mapping could be undertaken alongside the Strategic Flood Risk Assessment process undertaken for statutory development plans as part of a best practice approach to rainwater and surface water run-off management.

5.0 Nature Based Surface Water Management in Urban Area and Water Sensitive Urban Design

5.1 Definitions and Concepts

5.1.1 The Water Cycle

The Water Cycle refers to the natural processes set out earlier in Section 3.1.

5.1.2 Water Sensitive Urban Design (WSUD)

Water Sensitive Urban Design (WSUD) is an approach to design that delivers greater harmony between the water cycle, the environment, and communities. This is achieved by integrating water cycle management with the built environment through sustainable urban planning and urban design.



A series of rain gardens, footpaths and cycle ways
Source: Urban Design London

5.1.3 Surface Water and Rainwater

In terms of this guidance document, these terms are to be read as synonymous. The term “rainwater management” is preferred as, over time, the term “surface water” has become identified with underground piped network solutions, despite the name.

5.1.4 Overland Flow

Overland Flow refers to the characteristics of rainwater falling on an urban area where, due to the large proportion of impermeable surfacing and the limited capacity of the existing underground piped drainage network, there is likely to be a need to anticipate and design for the overland flow of excess rainwater during the increasingly common high intensity rainfall events.

5.1.5 Characteristics of Nature-based Solutions (NBS)

The particular characteristics of NBS are:

- They are on the surface at or below adjacent ground or street level, designed to accommodate rainfall runoff from the surrounding areas; and
- They consist of mixed planting into a specially designed engineered soil which is usually contained within an engineered structure. They can also include appropriately designed tree pits. Underground drainage is included to carry away rainwater runoff from the surrounding area that has percolated through the planted area.

5.1.6 Retention, Storage and Treatment

Retention, Storage and Treatment are the three critical functions required of NBS.

- Retention refers to the quantity of rainwater within the planted area itself, including the engineered soils, which delays the rainwater reaching the piped underground networks.
- Storage refers to larger volumes of excess rainfall that can be stored within swales or open spaces, prior to eventual percolation through engineered soil into an underground piped network.
- Treatment refers to the action of the filter and percolation media through which the rainwater percolates. This includes the removal of many particulates and pollutants, and the partial treatment of biological pollutants.

5.1.7 Role Of Piped Networks

The existing piped underground networks will continue to carry rainwater away from the urban areas and discharge the runoff into the receiving water body. The purpose of NBS is to act as a buffer between the rainfall running off the surface and the rainwater entering the piped network so as to reduce the level of pollution and reduce the risk of downstream flooding.

As discussed in Section 3.2.1, some urban areas are served by combined sewers that have inflows of wastewater / sewage as well as rainwater. In the case of these networks, the use of NBS is beneficial in terms of delaying the rate of rainwater runoff through providing attenuation / storage. This, in turn, reduces the frequency and volume of discharges from CSOs into the receiving water bodies and reduces the risk of sewer flooding.

5.2 A Plan and Design Led Multi-Disciplinary Approach

5.2.1 The Need for Change

Traditionally, the issue of surface water management, if considered at all, was seen as a drainage issue that was dealt with by either drainage or roads engineers after the main concepts of the project design had been finalised. These main concepts would include the spatial planning elements, scale and layouts of buildings, roads, open spaces, amenity areas, landscaping and finishes.

This approach meant that any subsequent decisions related to the management of surface water could not impact on these main concepts. This, in turn, limited the solutions largely to underground solutions such as storage tanks and pipes.

5.2.2 The Role of the Spatial Planning Team - Early Involvement

The multi-disciplinary spatial planning team (planners, architects, landscape architects, engineers, environmental/ecology etc.) involved in the planning and design of urban areas, both at a strategic level and a project level, have an important role to play in the integration of nature-based solutions to the management of rainwater and surface water runoff in urban areas. This early involvement is driven by the requirements of the statutory planning processes.

In terms of the LA planners, their role covers two statutory areas:

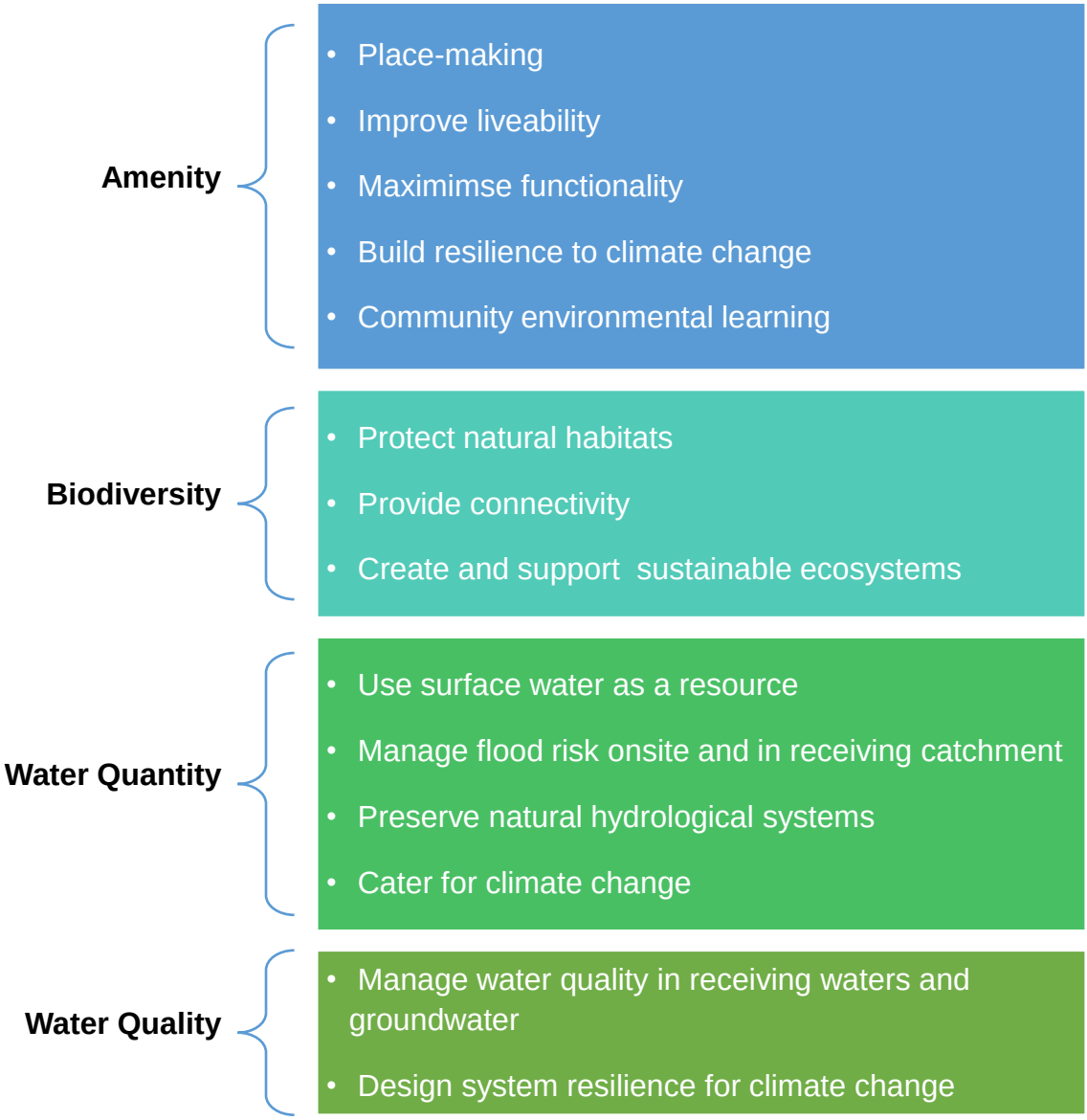
- Spatial planning strategy and forward planning such as the drafting of county development plans and local area plans; and
- Development management where the LA planner considers development proposals from private developers or by the LA itself. This role usually involves pre-planning discussions between the LA planners and the project team.

As described in more detail in Chapter 6, if nature-based solutions to the management of rainwater and surface water runoff in urban areas are to be delivered, they must be integrated into both statutory planning processes.

Also, the role and benefits of a nature-based approach as set out earlier in sections 3.2 (environmental impact and flood risk) and 4.2 (climate resilience and adaptation) must all form part of the considerations of the LA planner at spatial planning and land use stage as well as during development management decision making.

Blue-green infrastructure is becoming ever more important to deliver valuable, functional, and resilient urban environments. Planners should ensure that sustainability is at the forefront of how urban areas grow and adapt.

Professionals involved in the planning and design of urban areas should aim to maximise biodiversity and amenity benefits, manage flood risk and water quality as well as conserve or recycle water with the following design criteria:



5.2.3 Multi-disciplinary Working

- **Spatial and land use planning**

  In order to ensure that nature-based solutions and water sensitive urban design form part of spatial and land use planning, all disciplines involved in the planning process and stakeholders need to work together. While more detail is set out in Sections 5.3 to 5.6 below, the key message is to incorporate an understanding of the fact that rainfall, including extreme rainfall, will occur at various times and within various areas of the urban plan area and this needs to be planned for.

- **Development Management**

  At the preliminary planning stages of medium to larger scale developments, local authorities may engage with cross-disciplinary teams from the developer's team. Achieving best practice results will require a range of inputs from disciplines including planners, architects, landscape architects, urban designers, engineers, and experts in ecology, biodiversity and mobility.

  The need for implementation of nature-based solutions to the management of rainwater and surface water runoff should be promoted in these discussions.

  Due to the fact that many nature-based solutions are at ground level in the urban spaces, their incorporation can and will impact on almost all areas that are currently considered at the earlier stages of development management pre-application consultation process and, therefore, must form part of the cross-disciplinary discussions within the LA departments and with any relevant external stakeholders.

  For all developments, regardless of scale, the planning authority should ask applicants for details, as part of the application, of how they propose to manage rainwater in a nature-based manner (see also Chapter 6).

5.3 Managing Rainfall through Three-Dimensional Planning and Design

5.3.1 Overview

Rainfall is unique in terms of the water cycle, flood risk and spatial planning. In the case of a river or stream, the overall catchment outside of the spatial plan area needs to be considered as has been done under the Catchment Flood Risk Assessment and Management (CFRAM) programme under the management of the Office of Public Works (OPW).

However, rainwater will fall on an urban area and the impact of that rainfall event is localised to that settlement. Therefore it is possible to plan for rainwater management at the settlement plan level, whether that be at the level of a city, a large or small town.

Rainwater has another characteristic in that the resultant surface water will flow downhill and follow the contours of the urban area. If a nature-based approach is to be taken, there is a need to manage that flow at ground level, taking account of the topography of the urban area in conjunction with the land use and spatial planning of that same area.

5.3.2 Practicalities

Land use maps are prepared by planning authorities to inform their statutory plans and identify land use zoning objectives and other objectives such as zoning for housing, commercial and industrial uses, transportation links, mobility, permeability, public realm, open spaces, community, and amenity uses. While the planning team may consider issues related to the topography of the town, particularly where there are significant level differences across the plan area, further consideration should also be given to the flow of rainfall across a plan area.

A tool that will aid in this analysis would be the use of three-dimensional mapping, which would allow the planning team to consider the overland rainwater flow patterns and where best the rainwater can be managed using nature-based solutions.

Such three-dimensional Lidar maps of urban areas are available, having been prepared by the OPW as part of the CFRAM programme.



The map shows the priority of measures in water catchment areas at three levels according to risk, implementation, and synergistic effect with urban planning and development projects.
Source: The City of Copenhagen Cloudburst Management Plan 2012

Appendix 2 provided further details on the use of three-dimensional mapping in conjunction with typical spatial urban area plans.

5.3.3 Outcome and Benefits

The natural slowing and filtration of storm water runoff from our roofs, streets and public realm can be assisted by the creation of a variety of initiatives such as green building surfaces, green roofs, raingardens, swales, permeable surfaces, bioswales, natural water collection, storage ponds. This can be complemented in the broader context of planning of our urban areas through the creation of green spaces and the extensive planting of trees within the public and private realms.

Public realm is the space that is shared communally within our towns and cities, such as pavements roads, parks, and public urban gathering spaces.

It is the three-dimensional space that exists between our buildings in urban areas, and often these public gathering spaces such as town squares, and other urban spaces that become the outdoor living rooms of our cities, towns, and villages.

Many Irish cities and towns already include significant areas of urban greening from the tree lined boulevards and squares of the Georgian and Victorian eras to the suburbs inspired by the Garden City movement at the start of the 20th Century. These examples have demonstrated that the greening of our urban spaces leads to a better quality of life for our citizens.

A greener urban area has multiple benefits that include improved air quality, noise reduction, provision of shade and a relaxed quality of spatial experience. However, greening and planting alone will not contribute to a nature-based approach to rainwater management. However, if this further benefit is appropriately planned and designed for, the same urban area can deliver additional benefits in retaining, storing and treating rainwater at ground level, thus mitigating flood risk and the environmental impact of urban runoff.

5.4 Overland Flow Routing to Identify Opportunities to Store and Treat Urban Runoff

As identified in Section 5.3, the role of topography is crucial to the effective management of rainwater in urban areas. While there are a range of possible methods of retaining, treating and storing rainwater prior to discharging it back to the water environment, it would be beneficial for the planning team to identify the optimal methods and the optimal locations and co-ordinating this, in as much as possible, with the statutory plan making processes.

Fig 5.1 is an example of overland flow mapping from the U.K. and shows how the mapping of overland flow routes, including low flow routes and higher flow or “exceedance” routes can be mapped alongside land use planning.

This will allow the incorporation of nature-based solutions to the management of rainwater within the overall urban planning and design process so that they can best deal with the rainwater flow patterns, including where to locate urban planted areas, potential swales, rain gardens, pocket parks, and larger parks. This also allows the mapping of higher flows arising from extreme events and the design of urban spaces and streets to direct such flows into areas that will result in the lowest impact in terms of economic loss or public safety risk (Appendix 2).

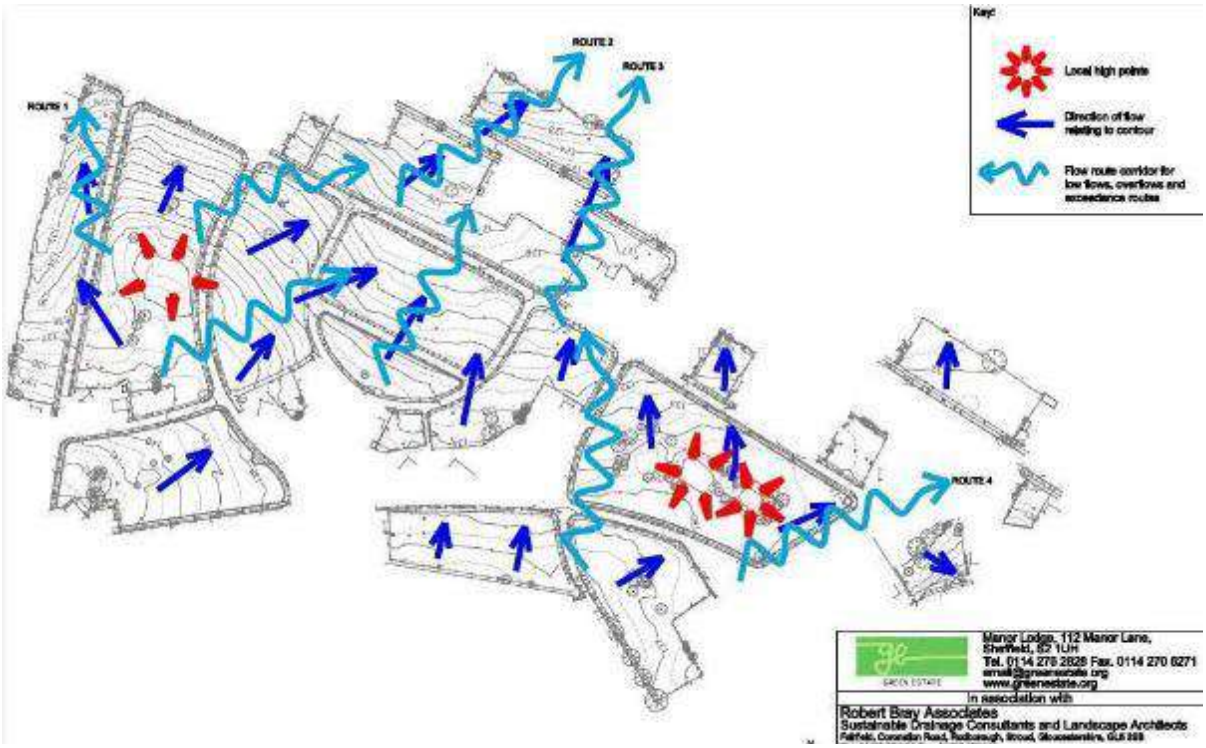


Fig. 5.1 SuDS Flow Route analysis - Falstaff Project, Sheffield (2013 Sustainable Drainage Design & Adoption)
Source: Gloucester City Council

5.5 Changes to Traditional Urban Roads and Street Designs to Facilitate WSUD

In Ireland, the design of urban roads and streets is determined by the Design Manual for Urban Roads and Streets (DMURS) which was updated in 2019. The focus of this design manual is on the promotion of urban place making in the context of the promotion of sustainable transport. The issue of rainwater management is raised in the DMURS, although not discussed in detail.

Water sensitive urban design can be incorporated into the design of urban streets, drawing on two significant elements from Chapter 4 of DMURS:

- The need to recognise that greening of the urban areas can happen even within the central areas of our cities and towns, with these green solutions designed for placemaking as well as rainwater management; and
- The need to design roads and streets so that rainwater flows from paved surfaces into the planted areas, with appropriately designed subsurface piped networks and overland flow routes, using public realm and public open spaces (see Section 5.6).

It is recommended that further advice be provided (in the form of an Advice Note) with DMURS illustrating how water sensitive urban design be incorporated into the design of urban streets.

5.6 Multiple Use of Urban Spaces, Public Realm, Open Spaces, Amenity Areas, Car Parks

One of the key elements of the successful incorporation of water sensitive urban planning and design into the existing processes is the acceptance that all urban spaces should have multiple uses.

To some extent, this is already implicit in urban design. For example, roads and streets are designed to cater for multiple users. Open spaces and parks can be used as routes for cyclists and pedestrians and to increase permeability, as well as their traditional uses. Public realm areas can be used for commercial uses such as outdoor dining.

In order to use a water sensitive urban design approach, it is important that, having looked at the urban area in three dimensions and mapped the anticipated rainfall flow patterns, that urban areas are designed to contribute, as far as practicable, to the retention, treatment and storage of rainwater, prior to its discharge back to the water environment. Using an innovative approach to urban design, it should be possible to achieve this while also enhancing place making, the use of sustainable transport and the “self-regulated streets” approach promoted by DMURS.

While there can be resistance to the use of public open spaces to store excess flows of rainwater, the appropriate sustainable design of such spaces can result in minimal interruption to their normal use as amenities.



Enghaveparken – Climate Park Source: tredjenatur.dk

This approach results in the integration of the rainwater management function into the various urban spaces, rather than the need to construct separate areas that function primarily as “SuDS areas”. This integration represents the more efficient use of limited urban space as well as better integration for the eventual care and maintenance of urban areas (see Chapter 7).

5.7 Urban Planting

It is already accepted practice to plant trees and grass verges in urban areas. The use of trees and low growing planted areas to retain and treat rainwater runoff requires a new approach.

As outlined earlier, the planted area must be designed in such a way as to allow runoff from the nearby impermeable area to infiltrate into it. Planted areas should be able to withstand wet weather and drought conditions so that there is less need for external watering during dry weather.

However, this also necessitates a new approach to the design, construction and ongoing maintenance of the planted area.

Specialised advice will be required in this area and some further details are provided in Appendix 3.

The following is a brief overview.

5.7.1 Low Growing Planted Areas, Rain Gardens and Swales

These planted areas must be designed using specialized growing media below the surface, sometimes contained within an artificial membrane and with climate and location appropriate planting.



Rain Garden



Channel



Filter Strip



Swale

Low Growing Planted Areas in the Urban Environment Source www.nwrm.eu

Ideally, these nature-based solutions should form part of an overall urban design and add value in terms of amenity, biodiversity and the promotion of sustainable transport as well as retaining and treating rainwater prior to returning it to the environment.

There should be underground drainage to take the rainwater after filtration and to take any excess flows in extreme events.

If possible, there should be linkages between these planted areas to add further benefits in terms of habitat corridors and a “SuDS Train” approach.

5.7.2 Urban Tree Planting

Trees in urban areas can have multiple benefits related to aesthetics, microclimate regulation as well as forming part of nature-based solutions to the management of rainwater and surface water runoff. They are also important in terms of biodiversity and can contribute to reducing particulate air pollution. Trees also transpire, which dries the surrounding soil, thus providing greater capacity for rainwater storage.



Tree planting and tree pits should incorporated in a planted area
Source: Urban Design London

Urban areas can prove to be hostile environments for trees with roots constrained by adjacent underground structures and limited capacity to absorb water.

In order to resolve these issues, urban trees are often planted into specially designed “tree pits” that are composed of designed soils and substrates that can both support the surrounding paved areas, roads etc. and also allow for water movement, air diffusion and tree root growth. There are various proprietary designs available.

It is important that, whatever design solution is chosen, existing or new underground services can be integrated into the tree pits so that it is not necessary to sterilise the areas involved for sole use as tree pits. The design should ensure that the tree pits are in effect constructed around the underground services so that the structure of the pit prevents the services being impacted by the tree roots.

Similarly, the design should allow for the replacement of the designed soils if and when there is disturbance due to roadworks or service installation that impacts on the area.

If possible, tree planting and tree pits should be incorporated within a planted area such as a rain garden. This facilitates the percolation of rainwater from the impermeable areas and also enhances the growing environment for the tree and improves the water handling capacity of the rain garden.

5.8 Buildings and Their Curtilage

While the emphasis in this document is principally on the public realm, a significant proportion of the urban area is made up of buildings and their immediate curtilage that are the responsibility of the private owner or occupier. These buildings include houses, apartments, commercial, retail, industrial as well as public buildings such as schools, hospitals, healthcare and community facilities.

In order to manage rainwater falling on these areas in a sustainable manner, these private areas should also incorporate nature-based solutions.

The local authority should seek to use every opportunity available through funding such as capital project grant aid and grants for the retrofitting of thermal insulation to promote the reduction of rainwater runoff from private areas.

A significant proportion of the private areas is likely to be made up of impermeable surfaces and roofs. It is important, therefore, to encourage the use of permeable or green surfaces and green roofs through the planning process.

Depending on the green roof structure, a reduction in the annual rainwater runoff of between 40% and 80% can be achieved.

Pollutants Research (Johnston et al., 2004) found that 95% of heavy metals are removed from runoff by green roofs and nitrogen levels can be reduced. It can take approximately five years for a green roof to reach its maximum pollution removal capacity.

Areas around buildings should be designed to incorporate appropriate nature-based solutions to the management of rainwater and surface water runoff. Basements should be designed with sufficient vertical clearance below finished ground level that will allow sufficient soil depth for planted areas above the basements to retain and treat rainwater runoff before disposal through underground pipes into the drainage system.

This may include the use of rainwater storage to be used for the irrigation of planted areas during dry weather.

See Appendix 3a for further details on green roofs and nature-based solutions within building curtilages.

Further details and links to the concepts outlined in this chapter can be found in Appendix 5.

6.0 Implementation

With its statutory responsibilities in the area of spatial planning, urban roads and streets, flood risk management and water quality, the Local Authority has the leading role in promoting nature-based surface water management solutions.

Informed decision-making and early stakeholder engagement are essential features for the successful implementation of nature-based solutions at local level.

In practice, collaborative and multi-disciplinary urban planning and design will be required to effectively deliver nature-based solutions at a large scale and to inform local planning frameworks, policies, and adaptation plans.

Extensive collaborative research, awareness campaigns, knowledge sharing, training, educational and professional supports should be established at local government level to increase awareness and understanding of the overarching philosophy and design principles of NBS, and to encourage a wider implementation of nature-based solutions.



The municipality of Copenhagen decided to divert the traffic on Sønder Boulevard and invested DKK 18 million in the construction of a new urban park resulting in a 300% rise in property values

The extent to which nature-based solutions can be retrofitted in the urban fabric will be dependent on strong funding investment and commitments from Government to 'Finance the Transition' as per the European Green Deal.

6.1 Identifying Opportunities at an Early Stage

As previously stated, the successful integration of nature based solutions for the management of rainwater and surface water runoff in urban areas requires a collaborative approach from a range of built environment professionals, both from the public and private sectors, from the earliest stages in the planning process.

All professionals involved in the planning and design process will identify the many opportunities that arise to incorporate nature-based solutions into urban areas only if they are aware of the role of such blue-green infrastructure in protecting the environment, biodiversity, climate resilience and making urban places more liveable. Planning authorities should aim to maximise biodiversity and amenity benefits, while also managing flood risk and water quality. Given the multiple benefits that nature-based systems can offer, it is recommended that nature-based solutions to rainwater management should be identified at the early stages of the planning and design process. To effectively integrate blue-green infrastructure within the fabric of the landscape, multi-disciplinary teams should be established, and relevant stakeholders should be consulted early in the process.

To deliver targeted sustainable compact growth, urban planning must integrate green and blue spaces. Social, economic, and environmental challenges should be addressed by taking a longer-term view and a whole-system approach to maximise the co-benefits of these nature-based solutions. Green and blue spaces offer the opportunity to protect, manage and restore natural ecosystems, biodiversity, increase wildlife and address societal issues such as climate change and amenities for physical and mental wellbeing.

Urban environments are complex systems. However existing hard engineering solutions can also be “greened” through the addition of a nature-based layer. Combining grey and blue-green infrastructure present huge opportunities socially, economically, and environmentally. For example, nature-based solutions can be placed alongside traditional flood defences to provide additional adaptation and mitigation benefits connecting areas of amenity, wildlife habitat enabling species to shift their ranges as conditions change.

6.2 The Role of Planning

Planning authorities should ensure that nature-based solutions are a consideration in the preparation of spatial plans such as development plans and local area plans and in the assessment of planning applications (see Table 6.2).

Importantly, this could include the incorporation of a rainwater management plan into a statutory land use plan.

Where a rainwater management plan is prepared at the level of a settlement, subsequent spatial plans for that settlement should follow the requirements of the rainwater management plan in terms of the appropriate incorporation of nature-based solutions into the spatial plan.

The implementation of nature-based solutions at the scale of the settlement, results in a coordinated “whole of settlement” approach to the implementation of nature-based solutions, rather than seek to implement solutions at a site or development level in the absence of an overall “whole of settlement” plan.

Settlement level water sensitive urban design ensures full integration of nature-based systems at site level into the wider strategic drainage network and landscape.

Development management for nature-based solutions should be based on strategy, policies and objectives within the development plan where relevant. This sets the basis for considering planning applications in principle and decision-making.

In the case of medium to larger scale development proposals, pre-planning discussions present an opportunity to inform the developer and third-party consultants of required expectations and how best to proceed to designing appropriate nature-based systems in the locality including relevant material considerations such as community value, biodiversity, heritage, landscape, tree management, flooding and climate resilience, conservation, and preservation.

It is recommended that planning applications for larger developments include hydraulic and topographical surveys showing the proposed development within the existing natural catchment as well as a detailed rainwater management plan showing how nature-based solutions are being applied.

In relation to green roofs (Appendix 3a), it may be advisable to focus in the first instance, on larger buildings as any increased costs are mitigated due to the scale of the development.

Planning Stage	Possible Measures
Forward Planning - Development Plans, SDZ Planning Schemes, LAP's and other plans.	1. Incorporating a Rainwater Management Plan for the plan area at an appropriate level of detail. 2. Include policy to promote nature-based management of rainwater in all developments in urban areas. 3. Include a requirement that all planning applications for medium to largescale developments include integrated provisions for nature-based rainwater management (NBS) appropriate to the scale of the development.
Development Control	1. Ensure nature-based rainwater management is part of an integrated design approach and appropriate to the scale of development. 2. Discuss the integration of nature-based rainwater management at development management pre-application consultation meetings.

Table 6.2 Suggested Summary of Planning Measures

6.3 The Role of Funding Agencies and Assessment of Projects

There are multiple funding streams and funding agencies involved in projects within urban areas. The funding can be directly from the funding agency or routed through the local authority.

It is important that the positive elements of nature-based solutions as well as the statutory requirement to manage rainwater in a sustainable manner in terms of flood risk and environmental risk are adequately captured in whatever financing or assessment tool is being used by the funding agency in assessing applications.

A natural capital accounts approach should be utilised to recognise and capture the value of the benefits associated with ecosystems in corporate and strategic accounts. Natural Capital Accounting is a tool that measures changes in the stock of natural capital and integrates the value of ecosystem services into accounting and reporting systems (INCA, 2021).

Ultimately, a natural capital accounts approach enables organisations to make better informed decisions about the value of their natural assets. Indicative Case Study Assessments of Return to the Exchequer should be reported by the local authority to highlight the benefits and to encourage the wider implementation of nature-based solutions.

Costs and benefits of implementing nature-based solutions should be assessed at feasibility stage to understand the return on investment, determine the viability/affordability of the scheme and better inform decision making. Project partners, clients, funding authorities and other stakeholders should agree which assessment tool is required to meet specific objectives.

Key concepts in estimating costs and benefits include:

- Whole-life valuation;
- Discounting; and
- Uncertainty and sensitivity analysis.

Further information and examples on this are included in Appendix 4.

6.4 Project Terms of Reference / Brief

It is important that the requirement to incorporate nature-based solutions to the management of rainwater and surface water runoff in urban areas is fully reflected in the project design brief and, ultimately, in any tender documents.

Green Public Procurement has a key role supporting the EU's commitment to a resource efficient and circular economy. Green Public Procurement offers an effective means to balancing cost effectiveness and sustainable development, achieving value for money whilst ensuring minimal impact on the environment and society (refer to the Green Tenders National Action Plan for best practice). Opportunities exist for Ireland's Public Authorities to exchange experiences, improve practices and capacities with other designated Member States within the 'GPP4Growth' EU Interreg project to stimulate green growth and eco-innovation (see further details in Appendix 4a).

For private development proposals as well as public procurement, the nature-based management of rainwater should be incorporated into design briefs and tender documents as outlined in Appendices 4a and 4b.

6.5 Stakeholder and Community Engagement

An effective and integrated form of urban landscape management can be achieved through early stakeholder engagement. To address the integration of land use planning with the nature-based solutions, policymakers and all professionals involved in the planning process should recognise the value of engagement with strategic stakeholders, landowners, local communities and citizens in urban planning and management decisions at an early stage.

A ‘whole of government’ collaborative approach with government departments including active engagement with key infrastructure agencies is an essential feature of this process. At municipal district level, engagement with the Area Engineers’ Office should be considered to ensure a maintenance budget (whole-life cycle) requirements / regime is agreed and to ensure necessary resources are agreed and in place (see Chapter 7).

In terms of fragmented landownership and alignment for deliverability, it is pertinent to capture the value of engaging with local stakeholders by providing platforms to actively participate in the urban planning process.

Active engagement with local communities and elected members as part of the statutory planning process should include an overview of the integrated role of all urban spaces in the sustainable management of rainwater with an explanation of the resultant benefits in terms of biodiversity, place making, amenity, sustainability, climate adaptation and resilience. The long-term maintenance of these areas as well as any concerns around public health and safety need to be addressed (see Chapter 7).

6.6 Project Design, Management and Delivery

The overall design of the urban spaces should be carried out by an experienced multi-disciplinary team incorporating urban designers, transport planners, landscape architects, engineers and experts in ecology and biodiversity.

At individual project level, it is important that the design of any planted areas is carried out in accordance with best practice (see Appendices 3 and 3a).

Experience has shown the importance of the design and construction of these planted areas in delivering the desired result of performance in terms of rainwater management and placemaking, long life and low maintenance.

All of the usual project management tools must incorporate the requirements for nature based solutions, including project risk assessment, project scope, programming and budgeting.

Appendix 5 provides further information and links to the overall approach to water sensitive urban design, nature-based solutions and related matters.

7.0 Care and Maintenance

7.1 Designing For Long Term Care and Maintenance

As described in earlier sections, the aim is to have nature-based solutions to the management of rainwater and surface water runoff in urban areas as an integral part of the overall urban design, rather than as stand-alone features or “SuDS features”.

While the function of these planted areas in terms of rainwater management may not be obvious, these areas must be designed with a level of expertise in terms of choice of materials and planting to facilitate their long-term care and maintenance.

This will require specialist expertise at plan making and early design stages. The aim should be to design the planted areas to be low maintenance, using appropriate materials and native or resilient planting schemes.

Long-term maintenance must be in the mind of the designer from the outset to ensure that a low maintenance design is produced.

Maintenance of planted areas that also have a rainwater management function must take account of both the planting as well as any subsurface features and specialist soils that support the rainwater management function.

The design needs to take account of the type of maintenance that will be required, such as access for maintenance equipment, gradients within the planted areas and the need for continuing access to and use of the surrounding urban areas.

In accordance with the requirements of the Safety, Health and Welfare legislation, the Project Supervisor Design Stage must produce a Client Safety File which, in turn, includes an Operation and Maintenance (O&M) Manual for the designed feature. This document will highlight the inspections and intervention that will be required to maintain the system at its optimal level.

Maintenance will also have to deal with issues such as invasive species, and ongoing plant maintenance and replacement, as appropriate.

More routine issues such as the removal of litter or waste as well as dealing with the impact of unplanned trafficking into the planted area, as well as periods of heavy rainfall, drought or winter weather must be catered for in the O&M Manual.

With surface infrastructure there is an advantage, in terms of maintenance, when compared with traditional underground infrastructure. Problems are visible and can be dealt with. Traditional systems are out of sight and often only manifest a problem at the time of a storm.

7.2 Use of Contracted Maintenance Period

Longer maintenance periods will be required for nature-based solutions than would normally be the case for hard landscaping.

It takes time for plants to establish themselves over several growing seasons. Plants that fail or are damaged need to be removed and replaced.

It is, therefore, likely that a “design build and maintain” contract approach will be required, incorporating a long-term maintenance period, ideally of at least five years. This will encourage site appropriate plant selection and material design.

If nature-based planted areas within the urban landscape are to become the norm and be accepted by those using the urban areas, it is important that these are well maintained so that they add to the amenity of the area, as well as providing a rainwater management solution.



A well-established and well-maintained detention basin adds amenity (The Way, Citywest Avenue, Citywest, Dublin 24

Source: R Toft, South Dublin CoCo

7.3 Responsibility For and Funding Of Ongoing Care and Maintenance

7.3.1 Public Realm

One of the key decisions that needs to be made in local authorities is the ownership and responsibility for the maintenance of these nature-based water management assets.

The departmental arrangements and responsibilities can vary between local authorities, both urban and rural.

Generally, in the urban authorities, anything concerning surface water management is dealt with by the Drainage Section, the roads are dealt with by the Road Section and open space is dealt with by the Parks or Public Realm Section.

Generally, in rural authorities, surface water is a Roads function in the absence of a dedicated Parks or Public Realm Section.

When a swale or other nature-based solution is taking water from the road, who has responsibility for its management and maintenance. Is it Roads or Drainage or Parks?



Swale Source: C Galvin, South Dublin CoCo



Grasscrete Source: D Joyce, Cork City CoCo

Due to the cross-sectoral nature of rainwater management, there can be difficulty within existing local authority structures in relation to the responsibility for the care and maintenance of these multifunctional planted areas. This has led to delays in the “taking in charge” process.

For the successful implementation of nature-based solutions, an integrated approach by the local authority to the long-term care and maintenance of all urban areas is required. This should be supported by appropriate changes to budgeting and resources where possible, to ensure this integrated approach.

Recommendations:

It is recommended that in order to assist in this process , technical design, construction, operation and maintenance standards be adopted nationally. Such standards are available from the U.K. and a number of local authorities in Ireland have drafted and adopted standards for their own administrative areas (see Appendix 3).

Training for local authority staff will be required in the design, construction, and maintenance of nature-based rainwater management infrastructure. Training courses in this area should be added to the existing training modules delivered through the Local Authority Training Group centres.

Existing maintenance equipment should also be reviewed and if necessary, specialised equipment purchased to assist in the care and maintenance of the nature-based solutions within the urban landscape.

7.3.2 Private Realm

It is recognised that some urban areas do not come under the ownership or control of the local authority and may come under the control of a private management company. As part of the planning process, the planning authority should ensure that nature-based features in private areas are designed and constructed to the highest standards. The planning authority can assess the issue of future maintenance and help to ensure that designs are conducive to long-term maintenance.

7.4 Community Involvement in Care and Maintenance of Green or Planted Areas

It is important to involve the local community and their elected members from the earliest stages in planning for and designing the nature-based management of rainwater, as an integral part of an overall urban design.

This early involvement can assess the requirements of the local community in terms of the urban space as a whole.

The multiple benefits can be demonstrated of the integration of nature-based solutions to the management of rainwater and surface water runoff in urban areas in the context of urban design.

These include increased biodiversity, climate adaptation, promotion of sustainable transport modes as opposed to car parking and car priorities, mitigation of noise and air pollution as well as dealing with the environmental and flood risks from rainwater runoff.

Successful integration, management and maintenance of open spaces and SuDS features does occur, however logistical issues can arise around taking in charge.

Experience in the U.K. and elsewhere is that local communities are prepared to get involved in the care and maintenance of nature-based areas that manage rainwater, if the requisite support and training is made available.

Resident Associations and Tidy Town committees around the country already maintain open spaces in their town and villages.

7.5 Public Health and Safety

The early engagement with the local community in the planning and design of urban spaces as highlighted in the previous section will also serve to mitigate any concerns that may arise from the presence of open water areas within the public open spaces. In some cases, the area may have open water present only after an extreme rainfall event. In other cases, the open water may be designed into the public open space for reasons of biodiversity and amenity as well as forming part of a nature-based rainwater management system.

Good design and construction, with appropriate ongoing maintenance will greatly reduce any risk arising from such water features. Water should be recognised as a resource and as a valued habitat at a time of habitat and biodiversity loss and climate crisis.

Ideally, the local community, including local schools, will take ownership of these areas and see the advantages they bring to the urban landscape.

Appendices

Appendix 1 Pollution arising from Urban Rainwater Runoff

Significant Water Management Issues in Ireland Public Consultation Document (DHLGH 2019)

Issue No. 12 – Urban Pressures:

> Urban pressures are estimated to be a significant pressure in 327 river, 17 lake, 24 transitional and four coastal water bodies nationally. Research has shown that human activities, climate change and population growth in urban areas over the years have a ubiquitous effect on surface water quality, habitat alteration and reduction in biodiversity due to the significant load of pollutants from point and diffuse sources. The combined pressures from Urban Wastewater, Industry and Urban Runoff was identified as the 2nd highest ranking risk to our rivers and transitional waterbodies not achieving good status in the second RBMP cycle. Increases of impervious surface cover due to urbanisation means that present day management of an urban river requires a holistic approach in terms of planning, flooding, surface water networks, biodiversity, hydromorphology and water quality. With increasing urbanisation, river restoration and the use of Green Infrastructure are vital measures for improving and maintaining rivers in our towns and cities for future generations. Urban runoff delivers pollutants from roads, public areas and roofs predominately via a gully and surface water pipe to the river. Developing green infrastructure policies for new developments and the retrofitting of existing areas will provide both a water quality and flood prevention benefit to our urban environments
>
> https://www.gov.ie/en/consultation/7bcef7-public-consultation-on-the-significant-water-management-issues-for-t/

Overview of Urban Runoff

After storm events in urban areas, water runs off from a range of impermeable surfaces. In areas served by combined sewer networks, this runoff is directed into these combined sewers and onwards to a wastewater plant (see Combined Sewers below).

However, most stormwater runoff is conveyed directly into aquatic environments via a separate stormwater or surface water piped network.

> This runoff may contain many chemicals deposited on road surfaces by vehicles, including metals and polycyclic aromatic hydrocarbons (PAHs) such as petroleum products, tire dust, exhaust, and brake pad dust. Stormwater runoff represents a large input of non-point source pollution to local watersheds.
>
> Pollutant concentrations vary widely between storm events and within a storm, with water from the earliest part of the storm (first flush) often containing the highest levels of many potential toxicants. First flush water is therefore associated with the majority of the toxicity.
>
> In addition, Polyaromatic Hydrocarbon (PAH) mixtures are themselves complex and highly variable, making stormwater chemistry exceedingly complicated.
>
> Pollutants in stormwater runoff can negatively impact the development of aquatic life. Multiple studies demonstrate that stormwater can be fatal to larval fish. Outside of acutely lethal effects, exposure to aquatic pollutants can cause sub-lethal effects that have long-term repercussions on organismal fitness. Early life exposure to PAHs can have long-lasting results, including negative impacts on cardiac structure and function in adulthood. PAH exposure also alters neurodevelopment, and changes in locomotion were reported in adult fish, suggesting delayed effects of embryonic PAH exposure on nervous system or muscle development.
>
> Young, Kochenkov et al., 12th. Feb 2018, www.nature.com/scientificreports

Combined Sewers

In certain older parts of cities and larger towns, there is only a single piped network that carries wastewater and sewage as well as runoff of rainwater from the surrounding urban areas.

Such a piped network is referred to as a “combined sewer”. While it would appear that the direction of the polluting urban runoff into a sewer that is designed to bring flows to a wastewater treatment plant may appear to resolve many of the issues, there are particular issues arising in terms of pollution of water bodies.

Due to the varying and unpredictable volumes of rainwater that have to be disposed of, all combined sewer networks are designed with overflows into nearby water bodies throughout the networks. This is to avoid the sewer being overwhelmed in terms of capacity, resulting in the flooding of properties and public areas.

These overflows have traditionally been referred to as Combined Sewer Overflows (or CSOs) but more recently the term Surface Water Overflows (or SWOs) is also used.

The flows spilling from the combined sewers into the various water bodies through CSOs is, obviously, contaminated with sewage as well as from the pollutants within the urban runoff.

The frequency of overflows and the volume overflowing is largely determined by the amount of rainwater that is directed into the combined sewer system. This volume has been growing due to an increased percentage of impermeable surfacing in the urban area as well as due to increased rainfall intensity arising from a changed climate.

It is therefore, important to reduce the volume of runoff and consequently, the frequency and volume of spills through CSOs, through the use of nature-based solutions to the management of rainwater and surface water runoff in the urban catchment.

The reduction of urban runoff into combined sewers has the additional benefit of reducing the volume of flows that must be pumped towards and treated at the wastewater treatment plant. Apart from the savings in energy and other costs, the reduced flows also result in fewer overflows from those pumping stations and treatment plants into receiving waters.

Appendix 2 Three-Dimensional Planning & Devising a Rainwater Management Plan

Introduction

The choice of location of and type of nature-based solution for rainwater management should fit into an overall settlement wide rainwater management plan if each element is to be appropriate and work as part of an overall nature-based approach.

Rather than trying to devise solutions at the level of each individual project or development, the planning authority should devise a settlement rainwater management plan that considers the entire urban area, its current land use, and proposed land use.

This should be overlain on a simple 3D terrain map using Lidar or similar as rainwater will follow the contours of the urban area.

While there are various levels of sophistication and technical detail that can be used, a high-level approach applied with in house planning and GIS capability should be able to provide a better overview of where best to locate nature-based solutions or how to best utilise existing green infrastructure in the management of urban runoff.

Planning authorities should be aware that Lidar mapping of urban areas is available on the Open Topographic Data Viewer managed by Geological Survey Ireland (GSI).

https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=b7c4b0e763964070ad69bf8c1572c9f5

Technical Guidance

It has not been possible to produce detailed technical guidance or worked examples of the use of 3D planning in devising a rainwater management plan in Ireland for this Best Practice Interim Guidance. More detailed guidance specific to Ireland will be provided in due course.

However, surface water and rainwater management plans have been prepared in many cities and, for smaller urban areas the principals are the same, albeit scaled down. A basic rainwater management plan for an urban area, based on available data and technical resources is preferable to waiting for a more detailed plan.

Some references are included below:

Guide for using green infrastructure in urban environments for stormwater management

> Terrain, also referred to as topography or slope of the land surface, is an important first consideration. Where the terrain is steeply sloping in hilly or mountainous areas the runoff will move more rapidly reducing infiltration and these steep slopes will generally have shallower layers of soil. These shallow soils also reduce water storage potential. Conversely, less sloping watersheds generally achieve more infiltration due to slower run-off speeds, and also have deeper layers of soil that increase the absorption and storage potential. Installing GI systems in watersheds or sub-watersheds with significant terrain will be generally less successful than in less sloping watersheds or sub-basins. Most vegetation-based GI systems are designed to intercept sheet flow runoff. If there is a steep slope, the runoff volume and flow rate can overwhelm the system to the point of soil washout. In general, the slope for vegetation-based green infrastructure should not exceed 12%.31 If it does, site grading is required to reduce the slope. With vegetative GI, flatter slopes allow for a longer retention time which then improves the effectiveness of different pollution control strategies. (McFarland, Larsen et al.: Environ. Sci.: Water Res. Technol., 2019, 5, 643)

Finding Areas at Risk from Floods in a Downpour Using the Lidar-Based Elevation Model (Sultana Nasrin Baby, Colin Arrowsmith et al, Journal of Civil Engineering and Architecture 15 (2021) doi: 10.17265/1934-7359/2021.01.001)

Copenhagen Cloudburst Management Plan

To have an effect, the contents of the Cloudburst Management Plan needs incorporating into the Administration's general planning process: primarily the Municipal Master Plan, sectoral plans (Waste water Plan) and local master plans. Furthermore, urban renewal plans and local neighbourhood facelift schemes should incorporate the Cloudburst Management Plan into their drafting.

https://en.klimatilpasning.dk/media/665626/cph_-_cloudburst_management_plan.pdf

Appendix 3 Urban Planting

Introduction

Nature-based solutions to the management of rainwater and surface water runoff in urban areas seeks to replicate the natural water cycle whereby rainwater soaks into the open ground and from there into the groundwater. In this natural cycle, excess runoff can, if the ground is saturated and dependant on the gradient, run over the surface into the nearest open surface water channel.

In many rural areas, road drainage replicates this natural cycle whereby runoff runs directly from the paved area into a roadside verge and ditch.

However in urban areas, the level of impermeable surfacing and the traditional approach of seeking to discharge rainwater away from the impermeable surface into the underground piped network has resulted in this natural cycle being broken.

In order to restore this natural cycle to some extent, nature-based solutions seek to direct rainwater runoff into natural or planted areas which are at or below the level of the impermeable area so that the rainwater can infiltrate into the ground.

In recognition of the fact that the subsurface layers in most urban areas are not natural and have been used for a range of infrastructural services etc. the nature-based solutions applied to the management of urban runoff will usually incorporate underground drainage that encourages the dispersal of the percolated rainwater to the existing piped network.

The fact that the rainwater is directed towards these planted areas will result in slowing the speed of the runoff and also remove many of the pollutants through filtration.

Some of these planted areas may be existing planted areas such as open spaces, amenity areas etc.

The planted areas that are the subject of this Appendix are those that are designed specifically to deal with urban runoff.

> The planted areas may involve only grass or similar planting that is growing within cellular grass paving systems which should be considered for parking areas, hard standings, emergency median crossings and accesses. In-situ reinforced cellular grass paving may be advantageous where heavy goods vehicles or vehicles with high point loadings are anticipated or where poor ground may result in differential settlement between panels.
>
> https://www.tiipublications.ie/library/CC-GSW-01100-03.pdf

General Approach

The general approach should be to incorporate the planted areas into the overall urban planning and design concept so that these planted areas serve multiple purposes and are not seen as solely for the purposes of drainage or sustainable urban drainage systems (SuDS).

The planted areas should incorporate a range of local plants growing in specially designed soil media that provides filtration as well as a growth medium. The designed soils are usually contained within a proprietary artificial membrane. The predominant planting should be low growing in recognition of the fact that urban areas are generally open and there is a need to maintain movement through the urban space. Tree planting can form part of the nature-based approach in appropriate areas through the use of proprietary tree pits. Ideally tree planting should be incorporated into a larger planted area for aesthetic reasons and in order to encourage root growth and maximise the rainwater infiltration capacity of the overall planting.

Planted areas, including tree pits, should be designed to allow the incorporation of existing or planned underground services within the designed soil media, rather than seeking to have such services diverted. Trees, in particular, should be located at an appropriate distance from existing services.



Vegetated filter strip on N24, Clonmel, Tipperary also provides biodiversity and aesthetic benefits. Integrating NBS can bring multiple benefits if a multidisciplinary approach is taken.

Source: F Igoe, LAWPRO

Technical Guidance

Planted Areas

U.K. Raingarden Guide https://raingardens.info/

Designing Raingardens, a Practical Guide https://www.urbandesignlondon.com/documents/85/UDL_Rain_Gardens_for_web_0vwx1Ls.pdf

Tree Pits – Stockholm system

(PDF) Tree Pits with Structural Soils - Practice Note (Version 1.2) (researchgate.net)

Appendix 3a Planting in relation to buildings – Green Roofs, Green Walls etc.

Introduction

Within the curtilage of buildings, every effort should be made to reduce the percentage of surfacing that is impermeable.

> Starting at ground or street level, the use of cellular grass paving systems should be considered for parking areas, hard standings, emergency median crossings and accesses. In-situ reinforced cellular grass paving may be advantageous where heavy goods vehicles or vehicles with high point loadings are anticipated or where poor ground may result in differential settlement between panels.
> (https://www.tiipublications.ie/library/CC-GSW-01100-03.pdf)

Also the top finished level of underground structures such as underground basements should be designed, where possible, to provide sufficient depth of cover over the basement roof (rather than flush with ground level). This can allow ground level planting / drainage between that top level and the ground or street level within the curtilage.

Every effort should be made to ensure that rainwater runoff is minimised and directed towards a nature-based solution that allows the runoff be delayed and treated.

Green Roofs and Green walls

These may be more appropriate to large scale apartment, commercial or industrial buildings as well as buildings for institutional use such as schools or hospitals.

Planning authorities should encourage green roofs as a proportion of all roof space for all large commercial, industrial, institutional and residential buildings (apartment blocks). In that regard, it is noted that some planning authorities already have such policies in place (see below).

Ireland predominately uses concrete materials for the structural frame of buildings with steel columns and beams where necessary which has already proven to be structurally suitable to facilitate green roofs. It is estimated 30% of Irish residential buildings use timber frame construction and is expected to increase. Green Roofs are feasible on building with timber frame construction - one proprietary example can be seen in the following link: Extensive green roof on timber structure (foamglas.com)

Green roofs will bring additional costs over typical flat roof construction (see also Appendix 4).

It is accepted that public policy may result in additional cost such as the introduction of renewable technologies into the building regulations also added cost in support of public policy (Building Regulations 2021 - Technical Guidance Document L)

Costs of any newly introduced construction methodology will reduce over time as it becomes part of mainstream construction.

There are also case studies that show cost of green roofs are further neutralized considering the whole-life costing of a building as mentioned below. The greater cost would be to continue to build unsustainable buildings. Flooding and pollution arising from urban rainwater runoff result in significant cost which can be mitigated by using nature-based solutions.

It is government policy to comply with the requirements of the U.N. Sustainable Development Goals and the E.U. Water Framework Directive. Green roofs can play a key role, particularly in dense urban areas where the building footprint is close to 100% of site coverage. Benefits of green roofs can be found in Chapter 12 of the CIRIA SuDS Manual 2015.

Depending on the green roof structure, rainfall runoff can be reduced by between 40% and 80% Pollutants research by Johnston et al, (2004) found that 95% of heavy metals are removed from runoff by green roofs and nitrogen levels can be reduced.

Thirty-five years of experience with green roofs in Germany has demonstrated that a roof assembly covered with a green roof can be expected to outlast a comparable “naked” roof by a factor of at least two, and often three. Although modern green roof systems have not yet been in place much longer than 35 years, many researchers expect that these installations will last 50 years and longer before they require significant repair or replacement. For a building owner with a long-term investment in the roofing system, this benefit factor goes a long way toward paying back the initial investment in a green roof.

Living Roofs and Walls - from policy to practice - 10 years of urban greening in London and beyond (2019)
Https://Livingroofs.Org/Wp-Content/Uploads/2019/04/London-Living-Roofs-Walls-Report-2019.Pdf

Green Roofs Over Dublin, A Green Roof Policy Guidance Paper For Dublin Draft guidelines for DCC to develop planning directives for the incorporation of Green Roofs in new development (2008)
https://www.landtechsoils.ie/wp-content/uploads/2018/02/dcc-green-roof-draft-guidelines-sept-2008.pdf

Dun Laoghaire Rathdown County Council has a mandatory policy on green roofs embedded within its County Development Plan.
https://www.dlrcoco.ie/sites/default/files/atoms/files/appendix16.pdf

Appendix 4 Nature-based Solutions, Funding and Economics

Introduction

When capital investments are being considered by the public or private sector, there is usually an analysis of the costs of the investment compared to the benefits. The traditional approach to cost benefit analysis does not have the necessary tools to include the value, or benefit in monetary terms delivered to the overall project by nature-based solutions to the management of rainwater and surface water runoff and a general “greener” approach to urban design.

In many cases these solutions are seen as bringing additional costs which are measurable whereas the benefits are not measured or taken into account. One example of this is the inclusion of green roofs where the costs are seen as relating to a non-standard roof structural design whereas the benefits in reducing rainfall runoff and improving the runoff quality are not measured.

Furthermore, when the cost of a capital project becomes an issue and the overall project is going through a “value engineering” process, it is often the nature-based elements of the design that are discarded as bringing identifiable costs but no measurable economic benefits.

Measuring the Benefits of Nature-based and Green designs

> Ecosystems contribute essential services to the economy and society. These include the provision of food, filtration of air and water, climate regulation, protection against extreme weather events such as heat waves and flooding, and many more. The ability of ecosystems to supply these services depends on their extent ('size') and condition ('health'). Despite the crucial role of ecosystems and their services for society, there is no established and regular measurement of ecosystem extent, condition and their change over time, nor of the quantity of services these ecosystems supply. Ecosystem accounting is an emerging field that aims to address this major gap and provide an internationally agreed guidance to measure and record changes in ecosystems and ecosystem services in a consistent and comparable manner.
>
> Many of the services supplied by ecosystems are public goods and are not currently priced on markets and, consequently, are often not taken into account in economic decisions. This has had disastrous consequences for the natural world, and in turn, for society. Ecosystem accounting has adopted the language and guiding principles of economic accounts (System of National Accounts) that will enable ecosystems and their services to be properly incorporated into standard accounting frameworks, and thus allow for the value of nature to be included more fully in decision making.
>
> (Accounting for ecosystems and their services in the European Union (INCA) 2021 edition, EU Commission / Eurostat p.7)

The same document includes in page 28 the following:

> Water purification is the ecosystem service with the highest aggregated value (EUR 55.6 billion in 2012). This value is determined by the supply and the use of this ecosystem service, and it would be even higher if there was more nitrogen pollution in the environment. This is a special feature of some ecosystem services that 'clean up' pollution – their quantity (and hence value) provided can be driven by the amount of pollution because the actual flow reported in accounting is not taking into account the consequences on the environment that the use of this service might cause
>
> Flood control arises when ecosystems can reduce or retain runoff water and protect downstream infrastructure and residents from flooding. It has been assessed for terrestrial ecosystems only and has been valued at EUR 16.3 billion for 2012.

Appendix 4a Green Procurement

Green Public Procurement has a key role supporting the EU's commitment to driving innovation, establishing real incentives for developing green products and services for the implementation of nature-based solutions.

In tendering for projects, Public Authorities should consider the longer-term impacts and wider goals with respect to climate change, social responsibility, economic resilience and resource efficiency. Each local authority should define its organisational requirements for the delivery of nature-bases solutions and set appropriate technical specifications (green material requirements).

Green Public Procurement offers an effective means to balancing cost-effectiveness and sustainable development, achieving value for money whilst ensuring minimal impact on the environment and society (refer to the Green Tenders National Action Plan for best practice). Opportunities exist for Ireland's Public Authorities to exchange experiences, improve practices and capacities with other designated Member States within the GPP4Growth EU Interreg project to stimulate green growth and eco-innovation.

> "EU Interreg Project GPP4Growth brings together nine partners from nine countries, to exchange experiences & practices and improve their capacities on implementing resource efficiency policies that promote eco-innovation and green growth through Green Public Procurement (GPP)
>
> GPP4Growth will support public authorities to seize new opportunities for using their purchase power to stimulate eco-innovation, resource efficiency and green growth, mostly by using new award criteria in calls and tenders that pay particular attention to environmental considerations. The updated framework that will emerge is anticipated to address the needs of the territories regarding compliance to the new EU public procurement system."
> https://www.interregeurope.eu/gpp4growth/

Ireland is one of the nine EU partners in the above project.

One action to date has been the DPER Circular 20/2019: Promoting the use of Environmental and Social Considerations in Public Procurement.

> "Public procurement professionals have expressed a clear need for accurate Green Public Procurement (GPP) guidance that they can refer to with confidence. The current GPP guidance was originally published in 2014 and required updating. The new GPP guidance is now at final draft stage and is now undergoing a period of targeted consultation before final publication in 2021. The revised guidelines will greatly assist procurers to include GPP criteria in a wide variety of procurement campaigns."
> https://www.interregeurope.eu/gpp4growth/news/news-article/10663/gpp4growth-ireland/

Appendix 4b Project Briefs / Terms of Reference

Development briefs should identify the topography, soil permeability, geological and hydrological characteristics of the site. Development briefs should identify sustainable drainage mechanisms suitable for site characteristics and should consider existing ecological impacts in terms of biodiversity and groundwater vulnerability. Run-off and site constraints should be assessed, and appropriate nature-based solutions for mitigation and compensation measures should form part of the recommendation. Depending on the scale of development, and where relevant, nature-based solutions should be integrated within the overall layout of the wider settlement masterplan rather than within individual sites (e.g. the incorporation of area wide attenuation requirements into a public open space or amenity area serving that area).

A sequential and iterative approach may be required for the design of nature-based solutions throughout the planning process. Consideration should be given to the long-term maintenance and operation of nature-based solutions within the site. Developers should engage with relevant stakeholders as early as possible in the planning process to determine the most appropriate NBS for the site. Project briefs should address the following:

- Determine soil classification for the site, soil porosity and bedrock permeability for the site;
- Determine the topography and flow routes so that the locations of future discharges can be determined and assess the status of and pressures on the receiving waters;
- Carry out a site-specific flood risk assessment in accordance with the OPW 2009 Guidance for Planners;
- The appropriateness/suitability of all available nature-based solutions and techniques, having regard to the nature of the site, the flood risk assessment, the receiving waters and the nature of the proposed development;
- Provide indicative designs and design details of proposed NBS that could be recommended for incorporation within the development;
- Establish a basis for control of the residual urban rainwater runoff having regard to the appropriate multi-component and nature-based rainwater management solutions.
- Establish and assess impacts quantitatively and qualitatively on groundwater and surface waters of post development runoff from the site based on the recommended nature-based solution.

- Attenuation of flow to greenfield run-off rates for the large-scale settlements, using surface level nature-based solutions.
- Model, examine and quantify the post-development surface water runoff design flows/volumes for the range of critical rainfall events.
- Assess options for attenuation of this flow to the maximum allowable design flow and the need to intercept hydrocarbons using surface level nature-based solutions.
- Provision should be made for nature-based rainwater runoff control and attenuation features within proposed green open spaces. These features should have adequate capacity to store surface run-off for flood events, thus mitigating the flood risk to downstream areas.

Appendix 5 Water Sensitive Urban Design and the Implementation of Nature-based Solutions to the Management of Rainwater & Surface Water Runoff in Urban Areas

Nature-based solutions should be considered from the beginning of the development planning process and should acknowledge any interdependencies between the subject site and the surrounding area. Nature-based solutions play a valuable role in reducing the rate and improving the quality of rainwater runoff from the development.

Nature-based solutions should be designed to manage rainwater close to where it discharges, manage runoff on the surface, allow rainwater soak into the ground, promote evapotranspiration, slow and store runoff to mimic natural runoff characteristics. The design envelope should address storm intensity, flood routing and climate change.

Nature-based solutions can intrinsically provide attractive features and focal points within the landscape and have added ecological value. Opportunities exist to create well-designed nature-based systems that attract wildlife and provide valuable amenities for the community. It is important that design criteria is considered at an early stage and fully integrated into the urban landscape design process.

The following are some resources that will assist in advice and guidance in relation to the matters covered in this Interim Guidance Document. It is not an exhaustive list and other resources are available.

Water Sensitive Urban Design

> Water is often central to the identity of a place. Yet the relationship between the places we live and the water resources we depend on is often not prioritised in the design and evolution of those places. Water shortages, flooding and watercourse pollution are all signs of stress where developed areas have a troubled interaction with the natural water cycle and where, conversely, water has become a risk or a nuisance rather than an asset or an opportunity.
>
> Water Sensitive Urban Design is the process of integrating water cycle management with the built environment through planning and urban design.
>
> Water Sensitive Urban Design is the process. Water sensitive places are the outcome.

Two principles are essential to its application:

1. All elements of the water cycle and their interconnections are considered concurrently to achieve an outcome that sustains a healthy natural environment while meeting human needs; and

2. Consideration of the water cycle is made from the outset, and throughout the design and planning process.

https://www.ciria.org/ItemDetail?iProductCode=C723F&Category=FREEPUBS

https://www.susdrain.org/files/resources/ciria_guidance/wsud_ideas_book.pdf

Water Sensitive Cities and Blue / Green Infrastructure

Stormwater management through Blue-Green Infrastructure (BGI) delivers multiple benefits across urban environments. However, current integrated modelling tools fail to provide a simplified way of assessing these benefits. In this study, we reflected upon the development of an interdisciplinary BGI planning-support tool, known as the Water Sensitive Cities Toolkit (the WSC Toolkit) and offer guidance for effective tool development going forward. Based on interdisciplinary research, the WSC Toolkit incorporates a suite of independent sub-modules but can be connected together to provide integrated assessment, allowing evidence-based quantification of multiple benefits associated with BGI, e.g., stormwater treatment and harvesting, stream hydrology, erosion, minor flooding, urban microclimate, etc.

https://iwaponline.com/bgs/article/2/1/383/78663/Modelling-a-business-case-for-blue-green

Rain Gothenburg Project 2021

Taking rain as our starting point we will work together to make our city even more attractive to live in, run a business in or visit. On average, it rains every third day in Gothenburg, which is not always appreciated.

When the city asked the people of Gothenburg how they want to celebrate the city's 400-year anniversary, their wishes included getting closer to the water and turning rain into a resource.

The city embraced the idea, and this led to a vision to become the best city in the world when it's raining, which also became one of the city's anniversary initiatives.

More knowledge about the climate, our lifestyle and its consequences have placed the climate issue high on the agenda in every aspect of social development.

By taking a creative approach, this initiative aims to build more robust and attractive water drainage and rainfall solutions, while also changing our perception of rain, its connection to our climate, and using it to our advantage.

The unique aspect of Rain Gothenburg is that we always highlight rain from architectural, social, cultural and climate-related perspectives when developing the city's infrastructure.

https://www.goteborg2021.com/en/jubileumsprojekt/rain-gothenburg-2/

Sustainable Drainage – a Design and Evaluation Guide – Hammersmith & Fulham 2018

There have been a number of definitions of Sustainable Drainage over the years, but the following is based on the SuDS Manual 2015, which was published by the Construction Industry Research and Information Association (CIRIA):

'Sustainable Drainage or SuDS is a way of managing rainfall that minimises the negative impacts on the quantity and quality of runoff whilst maximising the benefits of amenity and biodiversity for people and the environment'.

This guide links the design of SuDS with the evaluation requirements of planning in a sequence that mirrors the SuDS design process. This guide promotes the idea of integrating SuDS into the fabric of development using the available landscape spaces as well as the construction profile of buildings. This approach provides more interesting surroundings, cost benefits, and simplified future maintenance.

https://www.lbhf.gov.uk/sites/default/files/section_attachments/suds_design_and_evaluation_guide.pdf

SUDS Manual 2015 CIRIA

https://www.ors.ie/wp-content/uploads/CIRIA-report-C753-The-SuDS-Manual-v6.pdf

gov.ie/housing

Department of Housing, Local Government and Heritage

Rialtas na hÉireann
Government of Ireland