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Natural Water Retention Measures

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Individual NWRM

Rain gardens

Office International de l'Eau

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I. NWRM Description

Rain gardens are small-scale vegetated gardens used for storage and infiltration. The term 'rain garden' is often used interchangeably with 'bioretention area' (although the latter could also be applied more loosely to other measures such as filter strips or swales).

Rain gardens are typically applied at a property level and close to buildings, for example to capture and infiltrate roof drainage. They use a range of components, typically incorporated into the garden landscape design as appropriate. These components may include:

- Grass filter strips to reduce incoming runoff flow velocities and to filter particulates. For example, these may be used at the base of roof drainage downspouts to slow and filter roof runoff as it enters the rain garden.
- Ponding areas for temporary storage of surface water prior to evaporation, infiltration or plant uptake. These areas will also promote additional settling of particulates.
- Organic/mulch areas for filtration and to create an environment conducive to the growth of micro-organisms that degrade hydrocarbons and organic matter. These may be particularly effective where rain gardens are used to treat excess highway runoff.
- Planting soil, for filtration and as a planting medium. The clay component of the soil can provide good adsorption for hydrocarbons, heavy metals and nutrients.
- Woody and herbaceous plants to intercept rainfall and encourage evaporation. Planting will also protect the mulch layer from erosion and provide vegetative uptake of pollutants.
- Sand beds to provide good drainage and aerobic conditions for the planting soil. Infiltration through the sand bed also provides a final treatment to runoff.

The filtered runoff is then either collected and returned to the conveyance system (using an underdrain) or, if site conditions allow, infiltrated into the surrounding ground. They aim to capture and treat stormwater runoff from frequent rainfall events, while excess runoff from extreme events is passed on to other drainage features as part of a SuDS 'train'. Rain gardens should be planted up with native vegetation that is happy with occasional inundations.

Rain gardens are applicable to most types of development, and can be used in both residential and non-residential areas. They can have a flexible layout and should be planned as landscaping features, enhancing the amenity value.

II. Illustration

Example of rain garden (photo courtesy of Andras Kis)

III. Geographic Applicability

Land Use	Applicability	Evidence
Artificial Surfaces	Yes	Rain gardens are primarily applicable to urban areas, where they are incorporated in to developments to reduce surface runoff. They are applied in locations that may otherwise be an artificial surface (e.g. conversion of a car park to incorporate rain garden features) and/or to take the runoff from artificial surfaces. In terms of CORINE land uses, they are most likely to apply to: Urban Fabric; Industrial/Commercial/Transport Units; Artificial non-Agricultural Vegetated Areas
Agricultural Areas	No	
Forests and Semi-Natural Areas	No	
Wetlands	No	

Region	Applicability	Evidence
Western Europe	Yes	Rain gardens can be designed to be useful in any part of Europe, as long as the vegetation is adapted to be suited to the local conditions.
Mediterranean	Yes	

Baltic Sea	Yes	
Eastern Europe and Danube	Yes	

IV. Scale

	0-0.1km²	0.1-1.0km²	1-10km²	10-100km²	100-1000km²	>1000km²
Upstream Drainage Area/Catchment Area	✓					
Evidence	Individual components of rain gardens are designed only to capture runoff from a small surface area, for example a roof or car park. In combination, a suite of rain gardens may capture total runoff from a larger area.					

V. Biophysical Impacts

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	Medium	Rain gardens are effective at capturing runoff from small and medium sized rainfall events, providing limited storage and encouraging infiltration. Some rain gardens are designed to more specific criteria than others. For example, the 'Rain Garden Guide' in the UK and 'Rain gardens: a how-to manual for homeowners' in the US both provide guidance for informal incorporation of rain gardens that does not require detailed design, instead being more focussed on encouraging property owners to make low-cost contributions to reducing runoff, recognising that permeable surfaces and vegetation will almost always improve the situation compared to hardstanding and rapid runoff through a traditional drainage system. In these cases, the ability to store and slow runoff is rarely quantified, although simplified sizing calculations are included. Some more formal case studies do exist and are providing limited data to quantify local impacts on runoff (for example case study UK-04, Day Brook, where data is being collected in 2014). A further example in Lambeth, London in the UK anticipates reduction in peak runoff rate of 70-96% for a 1 in 2 year event, 8-39% for a 1 in 30 year storm, and 4-16% for a 1 in 100 year event (URS, 2013).
	Slow Runoff	Medium	

	Store River Water	None	
	Slow River Water	None	
Reducing Runoff	Increase Evapotranspiration	High	Planting within rain gardens, particularly the use of trees, will increase evapotranspiration. Rates of evapotranspiration will depend on the dimensions, residence time and type of vegetation.
	Increase Infiltration and/or groundwater recharge	High	Rain gardens may be designed to infiltrate captured storage, where appropriate with respect to underlying soils and groundwater. This is supported by using relatively high permeability soils with high organic matter content. Infiltration will increases where the residence time is higher, soil permeability is high, and/or the infiltration surface is large. Le Coustumer (2008) found that soil permeability is likely to be halved by clogging over a period of two years (depending on maximum water levels and the quantity of sediment). This can be allowed for in design. Some plants may reduce clogging (Le Coustumer, 2008; Citeau, 2006)
	Increase soil water retention	Low	Soil improvements, such as the addition of organic matter, are often included when installing a rain garden, and in any case the introduction of vegetation may over time increase the organic matter content and associated ability of the soil to retain water.
Reducing Pollution	Reduce pollutant sources	None to Low	Where infiltration can occur, the potential for pollution to groundwater needs to be considered. However CIRIA (2009) concluded that "the potential for contamination of groundwater from SuDS schemes appears to be low, except from industrial areas. The potential for serious pollution is associated with accidents rather than the continuous background pollution from these areas". This conclusion drew on recent work by SNIFFER (2008) that found "the vast majority of heavy metals, PAHs and petroleum hydrocarbons are retained in the top 10 cm of soil" based on bare-soil lysimeter tests, and noted that the addition of a vegetative layer would allow further uptake of pollutants. However it is clearly important to consider the risks of pollution to groundwater on a site-specific basis in light of the wider water management, activities occurring within the drainage area of the measure and groundwater sensitivity (depth, soil permeability). Creating green areas reduces hard surfaces and leads to reduced surface leaching of pollutant sources.

	Intercept pollution pathways	Medium	Rain gardens can be highly effective at treating urban runoff and removing pollutants. They can provide effective adsorption of hydrocarbons and heavy metals through vegetative uptake and the inclusion of clay components in planting soils. This effect is assumed based on the similarity of processes to other measures involving infiltration and uptake by vegetation, although no data specific to rain gardens have been obtained.
Soil Conservation	Reduce erosion and/or sediment delivery	Medium	Rain gardens will capture sediment in runoff, thereby reducing suspended solid concentrations downstream.
	Improve soils	None	
Creating Habitat	Create aquatic habitat	None	
	Create riparian habitat	None	
	Create terrestrial habitat	Medium to high	Through planting and landscape design, rain gardens can be effective at increasing the biodiversity of the urban environment. They should be planted with native vegetation to be most effective in enhancing biodiversity. They can be incorporated as an element in a network of green areas, thereby creating a green matrix, which is a valuable for strengthening the resilience of provision of terrestrial habitat.
Climate Alteration	Enhance precipitation	None	
	Reduce peak temperature	Low-Medium	Rain gardens could provide some contribution to lowering peak temperatures in urban areas. Depending on vegetation density and how widespread they are, they can contribute to creating cool islands in urban landscapes (as a result of evapotranspiration, water supply, shading).
	Absorb and/or retain CO_2	Low-Medium	If a rain garden is added where no vegetation would otherwise be present, this will result in a localised increase in uptake of CO_2, particularly if woody vegetation is included.

VI. Ecosystem Services Benefits

Ecosystem Services		Rating	Evidence
Provisioning	Water Storage	Low	Rain gardens provide localised storage, for runoff from roofs, car parks or roads. They control the rate of runoff and promote infiltration, thereby contributing to making water available for other uses (e.g. recharge to groundwater, offering soil moisture to support terrestrial ecology).
	Fish stocks and recruiting	None	
	Natural biomass production	Low	By creating green areas, rain gardens may contribute to natural biomass production, particularly where vegetation is dense
Regulatory and Maintenance	Biodiversity preservation	Medium	By creating new areas of vegetation (normally with native planting), rain gardens contribute biodiversity to urban areas. Compared to most other types of SuDS, they can accommodate more diverse vegetation, and hence may be more effective in preserving or enhancing biodiversity. Their effectiveness will depend on soil moisture and choice of vegetation. Their potential for contributing to networks of vegetated areas and green matrices can make them an important element in biodiversity preservation in urban landscapes.
	Climate change adaptation and mitigation	Medium	Rain gardens can contribute to climate change adaptation. Predominantly this is by improving adaptation to the more intense rainfall events that are expected as a result of climate change. In addition, through the introduction of new vegetation, particularly woody vegetation, they may also increase carbon sequestration and help to regulate urban temperatures.
	Groundwater / aquifer recharge	Medium	Rain gardens are generally designed to allow infiltration to the underlying soils and groundwater (although can also be underdrained and lined where infiltration is not appropriate). Where infiltration is allowed, rain gardens will contribute locally to groundwater recharge, although the volumes of increased recharge from each rain garden will be small.
	Flood risk reduction	High	Rain gardens contribute to reducing the volume and rate of surface runoff, particularly from artificial surfaces (urban areas). In conjunction with other SuDS features, they can reduce the risk of flooding from surface runoff and contribute to the reduction in peak river flows in small catchments.
	Erosion / sediment control	Low	COWI (2014) identify urban runoff as being a relatively minor consideration for erosion and sediment control at the catchment scale. Nevertheless, sediment deposition

			is one of the key functions of rain gardens, and so does provide some contribution to this benefit.
	Filtration of pollutants	Medium	Rain gardens are effective in capturing sediments and reducing concentrations of associated pollutants. Where infiltration is allowed, there is some risk of the introduction of pollutants to groundwater, but in general, CIRIA (2009) concludes that this risk is generally low.
Cultural	Recreational opportunities	Medium	Most rain gardens are likely to be in private gardens or on residential roads where, although they will provide aesthetic improvements, the recreational benefit as such will be limited. However rain gardens can also be incorporated in to public open spaces, where the introduction of biodiversity and attractive planting and landscape, potentially combined with features such as fountains, may contribute some recreational opportunities.
	Aesthetic / cultural value	Medium	Rain gardens contribute to urban biodiversity and green spaces, and can provide a relatively wide diversity of plants, thereby providing aesthetic benefits to the urban landscape. Use of rain gardens is a good communication tool for promoting sustainable water management. Keeping water on show (rather than hiding it in traditional drainage systems) and making it aesthetically pleasing helps to raise people's awareness, knowledge and interest. This is particularly the case where the detail of the rain garden is communicated to the public, for example by installing information panels.
Abiotic	Navigation	None	
	Geological resources	None	
	Energy production	None	

VII. Policy Objectives

Policy Objective		Rating	Evidence
Water Framework Directive			
Achieve Good Surface Water Status	Improving status of biology quality elements	None	
	Improving status of physico-chemical quality elements	Low	Through contributing to reduction in diffuse pollution through filtration of pollutants and interception of surface runoff, rain gardens can make a small contribution to improving water quality in receiving waters.
	Improving status of hydromorphology quality elements	None	
	Improving chemical status and priority substances	Low	Through contributing to reduction in diffuse pollution through filtration of pollutants and interception of surface runoff, rain gardens can make a small contribution to improving water quality in receiving waters.
Achieve Good GW Status	Improved quantitative status	Medium	Rain gardens are designed to store and infiltrate runoff. As such, they enhance recharge to groundwater and thereby contribute to improving quantitative status of underlying groundwater bodies. The volume contribution from each individual rain garden is, however, small.
	Improved chemical status	None	
Prevent Deterioration	Prevent surface water status deterioration	Medium	By intercepting a potential diffuse pollution vector from the contributing catchment, rain gardens can help to protect the receiving water body from deterioration as a result of new diffuse pollution sources.
	Prevent groundwater status deterioration	Low	Rain gardens may contribute to preventing deterioration in groundwater status where they maintain the overall level of recharge to groundwater in areas where the extent of hardstanding is increasing.
Floods directive			
Take adequate and co-ordinated measures to reduce flood risks		High	Rain gardens make a significant contribution to reducing surface runoff flood risks, particularly in urban areas.
Habitats and Birds Directives			
Protection of Important Habitats		None	

2020 Biodiversity Strategy		
Better protection for ecosystems and more use of Green Infrastructure	High	As a green infrastructure component, particularly where native planting is used, increased application of rain gardens will contribute to meeting the objectives of the 2020 Biodiversity Strategy, particularly in urban areas.
More sustainable agriculture and forestry	None	
Better management of fish stocks	None	
Prevention of biodiversity loss	Medium	Providing native planting is used, rain gardens introduce biodiversity in to urban areas. The may help to improve connectivity between other green spaces/habitats, creating green corridors, contributing to the prevention of biodiversity loss.

VIII. Design Guidance

Design Parameters	Evidence
Dimensions	Rain gardens are typically small and used to treat runoff at a property level, and are therefore usually suited to drainage areas of this scale. Used in combination, rain garden components may be incorporated into larger development as parks, treating larger drainage areas. They should be appropriately sized, using guidance provided for example in CIRIA (2007) or UK or US rain garden guides. The area of a rain garden should be around 5- 10% of its drainage area (MDDEFP and MAMROT, 2008) Where an underdrain is included, an outlet pipe will be necessary to connect the rain garden to an appropriate discharge point. An overflow/bypass structure may also be advisable. Native plants should be selected for the rain garden. Vegetation should be carefully selected, to use species that can withstand occasional flooding, including prolonged inundation of the roots, but also dry soils, particularly if underdrainage is included (since strong drainage combined with infiltration may sometimes lead to a relatively dry soil). The vegetation should develop to be relatively dense, improving the sediment capture properties.
Space required	Rain gardens can be scaled to the area available to provide runoff storage and treatment. Shape is not critical for rain garden areas, but minimum widths of 3 m and length to width ratios of 2:1 will allow scattered planting of small trees and/or woody shrubs and will also facilitate operation and maintenance of the system (CIRIA, 2007). Rain gardens should be incorporated in to design for new developments, or can often be retrofitted, for example in road-side verges, driveways or patios.
Location	There are no location restrictions.

Site and slope stability	There are no specific requirements, although as designed gardens the site should be stable. A gentle slope in the garden will provide improved opportunities for retention, evapotranspiration and infiltration where possible. On slopes, a berm may be included on the downslope side to improve water retention.
Soils and groundwater	Rain gardens can be used in most ground conditions; however the base will require lining where infiltration to the ground is not appropriate.
Pre-treatment requirements	Pre-treatment is generally not required, although can be incorporated for example if hydrocarbon capture from road or car park runoff is necessary.
Maintenance requirements	Regular inspection and maintenance is important for the effective operation of rain gardens as designed. Adequate access must be provided for inspection and maintenance. Regular maintenance will include litter and debris removal, and vegetation management. Other less frequent maintenance activities will include: replacement of mulch layers, soil spiking and scarifying, managing other vegetation and removing nuisance plants; re-seeding areas or altering plant types in event of poor vegetation growth; repair of damaged areas; removal of sediment and other pollutants; inspection and clearing of associated inlets and outlets.
Synergies with Other Measures	Rain gardens may be incorporated in to a development as part of a wider SuDS scheme, in conjunction with other measures such as rainwater harvesting and permeable paving.

IX. Cost

Cost Category	Cost Range	Evidence
Land Acquisition	n/a	Land acquisition is unlikely to be required, as rain gardens would normally be incorporated in to existing gardens, road verges etc.
Investigations & Studies	Minor	Rain gardens aim to be relatively simple installations and in this respect, little investigation should be required. Nevertheless, particularly if a public authority is implementing the measure (as opposed to a private homeowner) it may be necessary to undertake an assessment of whether a rain garden is the most appropriate option prior to implementation. Investigations are particularly recommended where infiltration is proposed, to ensure that conditions are suitable.
Capital Costs	No cost information obtained	The construction cost of rain gardens will vary depending on the site preparation required and the type of planting selected. If the rain garden is excavated and new growing media installed, costs will be much higher. If the garden is not excavated and entails modification of an existing planted area, costs will be much lower, although the effectiveness of the garden may be compromised. (www.lowimpactdevelopment.org).

Maintenance Costs	No cost information obtained	A simple rain garden constructed in a domestic garden will have little cost over and above standard gardening time and cost for the homeowner. In contrast, rain gardens at the street level such as in the Day Brook case study (UK_04) will require maintenance by municipal authorities, although these are not expected to be onerous and can be incorporated in to normal street cleaning and drainage maintenance activities.
Additional Costs	n/a	n/a

X. Governance and Implementation

Requirement	Evidence
Stakeholder involvement	The effective planning, design, construction and operation of urban NWRM requires the involvement of a wide range of stakeholders. This may include local planning authorities, environmental regulators, sewerage undertakers, highways authorities, private landowners and land managers, and other bodies with responsibilities for drainage and water management (e.g. irrigation bodies, drainage boards, etc). Effective planning is essential to delivering urban NWRM, since they must be delivered within the constraints of the urban environment. This requires alignment between stakeholders from planning authorities through to developers and land owners.
Ensuring clear responsibility for maintenance	Although rain gardens require little additional maintenance to normal gardens, their effectiveness in delivering runoff attenuation and treatment will decline if not properly maintained. The adoption of sustainable drainage features has been a major issue in ensuring their long-term effectiveness, although there may be less uncertainty for property-level rain gardens, where maintenance responsibility is clearly that of the property owner.
Ensuring that designed rain gardens continue to serve their purpose to attenuate and treat runoff.	Ensuring that designed rain gardens continue to serve their purpose to attenuate and treat runoff. As designed gardens, there is significant potential that over time property owners will re-design and alter features of their property in a manner that does not provide the same level of attenuation or treatment.

XI. Incentives supporting the financing of the NWRM

Type	Evidence
National and local legislative and regulatory requirements	Some countries and territories encourage and/or require the use of Sustainable Drainage systems in new development. For example, in England the use of SuDS is required through planning policy for new developments over a certain size (although rain gardens and other SuDS are also promoted down to the individual household level). National and local instruments are the most widely effective for SuDS due to their wide-scale application at the household or very local level. The possibility of local incentives should always be explored (since they cannot be covered here comprehensively).

XII. References

Reference	Comments
Bannerman, R and Considine, E (2003). Rain gardens: a how-to manual for homeowners. www.clean-water.uwex.edu/pubs/raingarden	
Bray, B, Gedge, D, Grant, G and Leuthvilay, L. (date unknown). Rain Garden Guide. Downloaded from www.raingardens.info.	
CIRIA (2009) Overview of SuDS performance: information provided to Defra and the EA	
COWI (2014) Support Policy Development for Integration of Ecosystem Service Assessment into WFD and FD Implementation – Resource Document, January 2014. Draft report.	
www.lowimpactdevelopment.org	US website providing rain garden design templates and background information.
URS (2013) Lambeth Highways SuDS: Rain Garden Modelling Report. http://www.susdrain.org/files/casestudies/lambeth_rain_garden_modelling_report_draft_v2.pdf	
Woods-Ballard, B, Kellagher, R, Martin, P, Jefferies, C, Bray, R and Shaffer, P (CIRIA) (2007) The SuDS Manual, CIRIA C697.	
Ministère du Développement Durable, de l'Environnement, de la Faune et des Parcs (MDDEFP); Ministère des Affaires Municipales, des Régions et de l'Occupation du Territoire (MAMROT) du Quebec (2014), Guide de Gestion des eaux pluviales Chapitre 11 – Les pratiques de gestion optimales des eaux pluviales	Manual about SuDS components in Quebec, Canada.