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Individual NWRM

Infiltration basins

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Office International de l'Eau

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Environment

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I. NWRM Description

Infiltration basins are vegetated depressions designed to hold runoff from impervious surfaces, allow the settling of sediments and associated pollutants, and allow water to infiltrate into underlying soils and groundwater. Infiltration basins are dry except in periods of heavy rainfall, and may serve other functions (e.g. recreation). They provide runoff storage and flow control as part of a SuDS 'train'. Storage is provided through landscaped areas that allow temporary ponding on the land surface, with the stored water allowed to infiltrate into the soil. The measure enhances the natural ability of the soil to drain water by providing a large surface area in contact with the surrounding soil, through which water can pass.

Infiltration basins may also act as "bioretention areas" of shallow landscaped depressions, typically under-drained and relying on engineered soils, vegetation and filtration to reduce runoff and remove pollution. They provide water quality benefits through physical filtration to remove solids/trap sediment, adsorption to the surrounding soil or biochemical degradation of pollutants. Water quality is, however, a key consideration with respect to infiltration basins as the potential for the infiltration to act as a vector for poor quality water to enter groundwater may be high. Pre-treatment may be required in certain areas before infiltration techniques are appropriate for use, for example swales or detention basins to reduce sediment loading and retain heavy metals and oils.

Infiltration basins have the potential to provide ancillary amenity benefits. They are idea for use as playing fields, recreational areas or public open space. They can be planted with trees, shrubs and other plants, improving their visual appearance and providing habitats for wildlife. They increase soil moisture content and help to recharge groundwater, thereby mitigating the problems of low river flows.

II. Illustration

Example of infiltration basin, USA, Iowa

Source: http://archive.inside.iastate.edu/2008/0703/rain.shtml

III. Geographic Applicability

Land Use	Applicability	Evidence
Artificial Surfaces	Yes	Infiltration basins are potentially applicable to all artificial surfaces, subject to consideration of the suitability of underlying soils and geology to infiltrate water and consideration of the potential to mobilise contamination or act as a vector for poor quality water to enter groundwater.
Agricultural Areas	Possible	Infiltration basins are most effective when receiving runoff from impermeable or low permeability surfaces and providing retention to allow water to infiltrate. This is most effective in the context of artificial surfaces (including artificial surfaces in agricultural, forest and semi-natural areas), but can also be appropriate where runoff from low-permeability surfaces in other areas (e.g. compacted soils, farm tracks, etc), and has been effectively used to manage runoff from fields (Environment Agency, 2012).
Forests and Semi-Natural Areas	Possible	
Wetlands	No	

Region	Applicability	Evidence
Western Europe	Yes	
Mediterranean	Possible	The negative externalities caused by infiltration basins in southern Europe (water temperature increase, evaporation, mosquitoes) lead to a preference for using retention basins as a more appropriate measure.
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	In general, infiltration basins are designed to treat small drainage areas, typically covering a number of properties. They are typically used to serve drainage areas up to 20 hectares (0.02-0.2 km^2) (Young, et al 1996), and					

	MDDEFP et LAMROT (2014) discuss their use for drainage areas less than a hectare. Infiltration basins should not be used as solutions for larger drainage areas due to the increased risk of sediment loading to the basin, reducing its effectiveness as an infiltration feature and increasing the risks of pollutant loading that may be transferred to groundwater through infiltration. Even for small drainage areas, effective pre-treatment to capture sediment inflows is required to maintain the effectiveness of the basin (CIRIA, 2007).

V. Biophysical Impacts

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	High	Infiltration basins are designed to store runoff to be infiltrated. They are typically used to treat runoff from a small number of properties in residential areas and are effective at storing runoff from this scale of drainage area (less than 0.2 km^2). Infiltration basins are typically designed to infiltrate 50% of their storage volume within 24 hours of filling (CREW, 2012). Typically, infiltration basins are generally designed to capture and infiltrate runoff volumes for events up to the 1 in 30 year storm for the drainage area, but sometimes even for events up to 1 in 100 year storm. The effectiveness of the basin at providing this storage will depend on the condition of the underlying soil and the characteristics of the drainage area (CREW, 2012). Barber et al (2003) indicated that infiltration basins can be effective in reducing peak runoff by up 65-87% ("small storms"), 50-60% ("medium storms") and 40% ("large storms"). Stored runoff is infiltrated into underlying soils/groundwater.
	Slow Runoff	High	If designed correctly with an appropriate outfall, infiltration basins are also effective at slowing runoff for events that exceed the storage/infiltration capacity of the basin. Additional storage should be allowed above the outlet to allow for some slowing of runoff rates during larger events.
	Store River Water	None	
	Slow River Water	None	
Reducing Runoff	Increase Evapotranspiration	Low to medium	The rate of evapotranspiration will depend on dimensions, residence time and type of vegetation. With dense vegetation and a relatively long residence time, evapotranspiration can be substantially increased, particularly if trees are planted.

			Evapotranspiration from infiltration basins may be far more efficient than predicted by agricultural engineering. Hess (2014) carried out experiments that showed vegetation can evapotranspire more than needed if there is an excess of water, by up to 30mm per day.
	Increase Infiltration and/or groundwater recharge	High	Designed to store water to be infiltrated into underlying soils and groundwater. The infiltration performance of each basin will be unique based on specific site conditions and materials. Maintaining infiltration performance is a known challenge and deterioration in performance of infiltration basins over time is common (CIRIA, 2009), although limited quantified evidence is available for this. Lindsey at al (1992) found that 67% of infiltration devices remain operating as intended 2 years after construction, with this dropping to 49% after 6 years, although this study is old and performance is likely to have improved with learning on effective construction and maintenance approaches in the intervening years. In order to limit deterioration in performance of infiltration basins, the ratio of infiltration area: drainage area should be as high as possible, and as a minimum more than 1% (AESN et al, 2013) 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	None to low	Introduction of vegetation may increase organic matter content over time, and the associated ability of the soil to retain water.
Reducing Pollution	Reduce pollutant sources	None	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 to high	Infiltration basins can be effective at pollutant removal, particularly as a result of settling of particulate pollutants. Environment Agency (2012) carried out a literature review of evidence of pollution removal and found reductions of (based on four studies): - Between 0-99% suspended solids reduction - 0-88% reduction in total phosphorus - 0-80% reduction in nitrogen Le Coustumer (2008) found pollution reductions of between 80 and 100% for metals (copper, lead and zinc). It is likely that achieving high effectiveness at pollutant removal will be improved by good design and adequate maintenance. Pollution reduction also depends on soil permeability: very high permeability may limit effectiveness due to the low residence time.
Soil Conservation	Reduce erosion and/or sediment delivery	Medium	Infiltration basins can effectively capture sediment in urban or rural runoff (sometimes, where concentrations are high, in conjunction with a pre-treatment system), thereby reducing sediment concentrations in downstream watercourses. As shown above, a high removal rate of suspended solids is possible in a well-designed system.
	Improve soils	None	
Creating Habitat	Create aquatic habitat	None	
	Create riparian habitat	None	
	Create terrestrial habitat	Medium to High	Infiltration basins 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 corridor, which is a key issue for the provision of terrestrial habitat.
Climate Alteration	Enhance precipitation	None	
	Reduce peak temperature	Low to Medium	Infiltration basins provide green areas. Depending on vegetation density, their dimensions 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 to medium	If an infiltration basin 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	Medium	Infiltration basins are effective at storing runoff from small drainage areas and route this, via infiltration, to soil and groundwater storage. Through this impact, they enhance the potential of the landscape to store water during floods and, through preventing rapid runoff, make this water available for other purposes (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, infiltration basins may contribute to natural biomass production, particularly if the vegetation is dense (which also creates terrestrial habitat)
Regulatory and Maintenance	Biodiversity preservation	Medium	By creating green areas within the urban landscape, infiltration basins may contribute to biodiversity preservation, although this will be a limited impact. The extent to which this benefit is provided depends on the soil moisture and choice of vegetation. Even when their individual contributions are minor, their potential for contributing to networks of vegetated areas and green corridors can make them an important element in biodiversity preservation in urban landscapes.
	Climate change adaptation and mitigation	Medium	By helping to limit urban runoff and flooding, infiltration basins provide a contribution to adaptation to the higher intensity storm events expected due to climate change. Enhancing recharge to groundwater may also make a small contribution to limiting the effects of drought, although the volume of water contributed by infiltration basins will be small. In addition, if new vegetation is introduced, particularly woody vegetation, they may also increase carbon sequestration and help to regulate urban temperatures.
	Groundwater / aquifer recharge	High	Infiltration basins are designed to store water to be infiltrated to underlying soils/groundwater. They are therefore highly effective at providing enhanced recharge, although the volumes of increased recharge from each infiltration basin will be small. The use of infiltration basins as part of the widespread application of SuDS in urban areas where hardstanding would otherwise limit groundwater recharge can be effective at increasing the replenishment of aquifers.
	Flood risk reduction	High	Infiltration basins contribute to reducing the volume and rate of surface runoff, particularly from artificial surfaces (urban areas). Used in conjunction with other SuDS

			features, they can reduce the risk of surface runoff flooding and contribute to the reduction in peak river flows in small catchments.
	Erosion / sediment control	Low	In themselves, infiltration basins are not effective measures of erosion or sediment control. Correct design of infiltration basins should include suitable pre-treatment to remove suspended solids and silt, thereby contributing to this benefit.
	Filtration of pollutants	Medium to high	Infiltration basins can be effective in reducing urban diffuse pollution (Environment Agency, 2012), although there is an overlap with sediment management to deliver this. Although care should be taken to avoid mobilisation of soil contaminants or the creation of a pollution vector to groundwater, CIRIA (2009) concluded that the potential for groundwater contamination from SuDS is minimal.
Cultural	Recreational opportunities	Medium	Infiltration basins provide green areas and may be used, depending on the way they are designed, for recreational activities, for example as a playing field.
	Aesthetic / cultural value	Medium	Creation of green areas contributes to improving urban landscapes. Using infiltration basins is a good communication tool for promoting sustainable water management. Keeping water on show (rather than hiding it in traditional drainage systems) helps to raise people's awareness and knowledge. This is particularly the case where the detail and value of SuDS 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, infiltration basins 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, infiltration basins may contribute to improving water quality in receiving waters.
Achieve Good GW Status	Improved quantitative status	Medium	Infiltration basins 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 infiltration basin 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, infiltration basins can help to protect the receiving water body from deterioration as a result of new diffuse pollution sources.
	Prevent groundwater status deterioration	Low	Infiltration basins 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	Infiltration basins 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	Medium to high	As a green infrastructure component, increased application of infiltration basins will contribute to meeting the objectives of the 2020 Biodiversity Strategy, particularly in urban areas. The extent of contribution will be more or less effective depending on the type of vegetation used and how widespread they are.
More sustainable agriculture and forestry	Low	Where used to intercept and infiltrate runoff from low permeability surfaces in agricultural areas (i.e. as rural SuDS components) infiltration basins can contribute to more sustainable agricultural practices.
Better management of fish stocks	None	
Prevention of biodiversity loss	Medium	By providing green space in urban areas, infiltration basins can make a significant contribution to the prevention of biodiversity loss. The extent of contribution will be more or less effective depending on the type of vegetation used and how widespread they are.

VIII. Design Guidance

Design Parameters	Evidence
Dimensions	Infiltration basins should be designed to treat runoff from a small drainage area (small number of properties), since use for larger drainage areas may result in increased risks of high sediment loadings that will reduce the effectiveness of the basin. Infiltration basins are appropriate for any drainage areas provided appropriate pre-treatment (via a SuDS management train) has been implemented upstream. Water quality has to be investigated first as this has a considerable influence on the design, especially of the pre-treatment part to avoid spreading of polluting substances that may afterwards be difficult or costly to treat and keep the quantity of sludge to treat as low as possible. Although designed to infiltrate stored water, an outflow control structure should also be included in the design, along with an emergency spillway where required to deal with exceedance events in a controlled manner. An appropriate freeboard should be allowed above the extreme flood level (minimum 50mm, but often greater, depending on the size of the basin, and on its location).
Space required	The size is dependent on several factors such as topography, the effective contributing area, and the relationship between the amounts of incoming and discharged water. Infiltration basins are relatively high land-take measures. Although possible to use the land for other purposes (e.g. recreational areas), careful consideration should be given to this with respect to infiltration basins to ensure that other uses would risk deterioration of the performance of the infiltration surface.

Location	Basins require a large accessible area that is relatively flat and with an appropriately-sized drainage catchment. For infiltration basins, underlying soils and geology must be highly pervious Infiltration basins should be implemented only where site and runoff conditions are suitable and geotechnical testing to confirm infiltration is an appropriate method for the location. They should not be located too close to groundwater drinking water catchments. Account should be taken of natural features that could be used to form the basin and/or provide additional storage areas in order to minimise the need for artificial landscaping.
Site and slope stability	The basin floor should be made as level as possible to maximise storage and infiltration potential and minimise the risk of erosion. This will also reduce flow velocities within the basin and maximise pollution removal potential for detention basins. Basins should not be sited on unstable ground and ground stability should be verified prior to construction. It is particularly important to avoid siting in areas where water storage and infiltration may cause slope stability or foundation problems, e.g. in areas of landslides or at the top of slopes unless a full engineering risk assessment has been carried out by a suitably qualified geotechnical engineer or engineering geologist.
Soils and groundwater	Infiltration basins should not be used on brownfield sites or other areas where there is a risk of leaching contaminants into underlying groundwater. They should also not be used to treat runoff from pollution hotspots, again to avoid pollution risk to underlying groundwater. To ensure that infiltration potential is maintained, the seasonally high groundwater table should as far as possible be more than 1m below the floor of the basin. Highly permeable soils can be a drawback. If this is the case, clay blankets may be used to compact the existing soil and make it less absorptive.
Pre-treatment requirements	Pre-treatment may be required in certain areas before infiltration techniques are appropriate for use, for example swales or detention basins to reduce sediment loading and retain heavy metals and oils.
Maintenance requirements	Regular inspection and maintenance is essential for both infiltration and detention basins to ensure effective ongoing operation. Maintenance should include: • Litter and debris removal (monthly) • Grass cutting for spillways and access routes (monthly during growing season) • Removal of sediment from inlets and outlet (annually) • Backfilling/rehabilitation of any channelling created during flush floods

Synergies with Other Measures	Large infiltration basins are susceptible to high failure rates due to sediment clogging, so pre-treatment of inflowing runoff is essential to remove as much of any suspended solids and silt from runoff before entering the basin. The most effective way of doing this is to incorporate infiltration basins into a SuDS train, with upstream filter strips, swales and sediment capture basins used to remove fine material before arriving at the infiltration basin.

IX. Cost

Cost Category	Cost Range	Evidence
Land Acquisition		Infiltration basins are high land-take measures used within the urban environment. The primary cost is therefore the cost of land acquisition or the opportunity cost of not using that land for development. This will depend on the land values at the site under considerations and cannot be generically quantified. Due to the higher costs of land, it is usually more expensive to retrofit these basins to already developed areas as compared to constructing one in an undeveloped region.
Investigations & Studies	€2 k-€10k	Geotechnical investigations are required to confirm the land stability and underlying soil/geology conditions prior to construction. These may need to be intrusive and require analysis of land contamination to determine suitability of infiltration techniques.
Capital Costs	€15-€90 / m^3 detention volume	Construction costs scale with the storage volume of the detention basin. Capital cost ranges generally fall between €15 and €40 cubic metre of detention volume. Ranges identified in the literature: • €15-€20 / m^3 detention volume (CIRIA, 2007); • €20-€40 / m^3 detention volume (www.uksuds.org); • €15-€20 / m^3 detention volume (Environment Agency, 2012) • €9 to €90 / m^3 detention volume (Chocat et al, 2008) Costs will be higher where additional retaining bunds are required and lower where greater use is made of natural or existing topographic features. Infiltration basins may incur additional costs to create an effective infiltration surface on the floor of the basin.

Maintenance Costs	€0.15-€5.5 / m^2 basin area	Ongoing maintenance is essential to maintain the effectiveness of infiltration/detention basins. Since these basins are long-lived, once in operation only minimal maintenance costs arise. Quarterly inspections of inlets and outlets as well as sediment and trash dredging might be required. Mowing around the basin margins would be possible but it may increase costs. Annual maintenance costs range considerably depending on the basin design and maintenance activities required, reflected in the range of maintenance costs presented in the literature: • €0.15-€0.40 / m^2 basin area (CIRIA, 2007) • €1.30-€2.50 / m^2 site area (Wilson et al, 2009) • €4.00-€5.50 / m^2 site area (www.uksuds.org)
Additional Costs		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 and restoration	The adoption of SuDS has historically been a major issue in ensuring their long-term effectiveness.
Ensuring that appropriate design standards and effective designs are implemented appropriately	Ensuring that appropriate design standards and effective designs are implemented appropriately at each location. The preparation of planning guidance and/or SuDS guidance documents that set out planning and design criteria, as well as local technical information (e.g. on soil types and underlying geology) can assist in this.

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. 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).
CAP funding for rural SuDS	Where applied in agricultural areas, it is possible that infiltration basins (most likely as part of a wider sustainable drainage scheme) may be eligible for the European Agricultural Fund for Rural Development (EAFRD) in relation to improving water management and managing soil erosion.
LIFE+	In some cases integrated SuDS schemes (i.e. which may include infiltration basins along with other measures) may be eligible for LIFE+ funding.

XII. References

Reference	Comments
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CIRIA (2009) Overview of SuDS performance: information provided to Defra and the EA	
CREW (2012) Natural Flood Management knowledge system: Part 1 – sustainable urban drainage systems (SUDS) and flood management in urban areas	
Environment Agency (2012) Rural Sustainable Drainage Systems (RSuDS)	
Lindsey, G., Roberts, L. and Page, W. (1992) Inspection and maintenance of infiltration facilities, Journal of Soil Water Conservation 47(6), pp 481-486	

www.uksuds.org – SuDS Construction and Maintenance Costs Calculator	This site has been developed by HR Wallingford to provide tools for site drainage design and evaluation, aimed at developers and SuDS Approval Bodies in the UK and Ireland. The site is updated with current thinking on SuDS and the requirements of UK and Ireland SuDS standards. The site includes a cost calculator to provide indicative costs of SuDS scheme components for construction and maintenance – the generic unit cost factors have been used when this website is referenced.
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Hess (2014), Monitoring of evapotranspiration and infiltration in rain garden designs, Villanova University	
AESN, LEESU, Composante Urbaine (updated in 2013), Outils de bonne gestion des eaux de ruissellement en zones urbaines, Document d'orientation pour une meilleure maîtrise des pollutions dès l'origine du ruissellement	Manual giving advice to reduce runoff and water pollution.
Le Coustumer (2008), Colmatage et rétention des éléments traces métalliques dans les systèmes d'infiltration des eaux pluviales, Institut National des Sciences Appliquées de Lyon	Study about the pollutant removal capabilities of infiltration basins, and their potential for clogging
Citeau (2006), Transfert eaux-sols-plantes de micropolluants : état des connaissances et application aux eaux de ruissellement urbaines, INRA Unité des Science du sol, AESN	Study about the reduction in diffuse pollution through filtration of pollutants and the role played by vegetation

Chocat, Abirached, Delage, Faby (2008), Etat de l'art sur la gestion urbaine des eaux pluviales et leur valorisation, Tendances d'évolution et technologies en développement, ONEMA, OIEau	Manual about SuDS components in France.