European Commission

Natural Water Retention Measures

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Service contract n°07.0330/2013/659147/SER/ENV.C1

Individual NWRM

Retention ponds

ACTeon environment research & consultancy

Office International de l'Eau

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Environment

This report was prepared by the NWRM project, led by Office International de l'Eau (OIEau), in consortium with Actéon Environment (France), AMEC Foster Wheeler (United Kingdom), BEF (Baltic States), ENVECO (Sweden), IACO (Cyprus/Greece), IMDEA Water (Spain), REC (Hungary/Central & Eastern Europe), REKK inc. (Hungary), SLU (Sweden) and SRUC (UK) under contract 07.0330/2013/659147/SER/ENV.C1 for the Directorate-General for Environment of the European Commission. The information and views set out in this report represent NWRM project's views on the subject matter and do not necessarily reflect the official opinion of the Commission. The Commission does not guarantee the accuracy of the data included in this report. Neither the Commission nor any person acting on the Commission's behalf may be held responsible for the use which may be made of the information contained therein.

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I. NWRM Description

Retention ponds are ponds or pools designed with additional storage capacity to attenuate surface runoff during rainfall events. They consist of a permanent pond area with landscaped banks and surroundings to provide additional storage capacity during rainfall events. They are created by using an existing natural depression, by excavating a new depression, or by constructing embankments. Existing natural water bodies should not be used due to the risk that pollution events and poorer water quality might disturb/damage the natural ecology of the system.

Retention ponds can provide both storm water attenuation and water quality treatment by providing additional storage capacity to retain runoff and release this at a controlled rate. Ponds can be designed to control runoff from all storms by storing surface drainage and releasing it slowly once the risk of flooding has passed. Runoff from each rain event is detained and treated in the pond. The retention time and still water promotes pollutant removal through sedimentation, while aquatic vegetation and biological uptake mechanisms offer additional treatment. Retention ponds have good capacity to remove urban pollutants and improve the quality of surface runoff.

Ponds should contain the following zones:

- a sediment forebay or other form of upstream pre-treatment system (i.e. as part of an upstream management train of sustainable drainage components)
- a permanent pool which will remain wet throughout the year and is the main treatment zone
- a temporary storage volume for flood attenuation, created through landscaped banks to the permanent pool
- a shallow zone or aquatic bench which is a shallow area along the edge of the permanent pool to support wetland planting, providing ecology, amenity and safety benefits.

Additional pond design features should include an emergency spillway for safe overflow when storage capacity is exceeded, maintenance access, a safety bench, and appropriate landscaping.

Well-designed and maintained ponds can offer aesthetic, amenity and ecological benefits to the urban landscape, particularly as part of public open spaces. They are designed to support emergent and submerged aquatic vegetation along their shoreline. They can be effectively incorporated into parks through good landscape design.

(Ponds installed primarily for wildlife benefit, or for other purposes besides management of runoff, may also be classified as measure N1).

II. Illustration

Example of retention pond (photo courtesy of Susdrain)

III. Geographic Applicability

Land Use	Applicability	Evidence
Artificial Surfaces	Yes	Retention ponds are applicable to all artificial surfaces, subject to land stability consideration. Lining may be required where soil contamination may influence the water quality within the pond, which may be more likely in industrial areas.
Agricultural Areas	Yes	Also applicable in agricultural areas, either to receive runoff from low permeability surfaces (e.g. tracks, farmyards, etc) or as part of the agricultural landscape (Environment Agency, 2012).
Forests and Semi-Natural Areas	Yes	Applicable as measures to store runoff in forests and semi-natural areas.
Wetlands	No	

Region	Applicability	Evidence
Western Europe	Yes	

Mediterranean	Yes	In areas of more intense rainfall, retention ponds will need to be larger to provide the same level of flood protection due to the greater critical storm depth. In warmer climates, standing water can provide a suitable ecosystem for mosquitoes, which can be related to increased transmittance of some diseases.
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	The drainage area required to support a retention pond can be as low as 0.03-0.1 km^2 (Environment Agency, 2012), or possible smaller if the retention pond has another resource of water such as a spring. There are no specific constraints on the maximum drainage area for retention ponds, although typically 3-7% of the upstream catchment area will be required for the pond (CIRIA, 2007). Larger retention ponds (>25,000 m^3 volume) require significant impoundment and may be subject to additional inspection and structural requirements (e.g. 1975 Reservoirs Act in UK).					

V. Biophysical Impacts

Biophysical Impacts		Rating	Evidence
Slowing & Storing Runoff	Store Runoff	High	Retention ponds reduce peak runoff through storage and controlled outflow release. They must be appropriately sized to the catchment area and critical storm depth. They do not infiltrate runoff and therefore provide very little runoff volume reduction (with the exception of evaporation and evapotranspiration, which can be significant in some cases) Typically, retention ponds will be designed to attenuate runoff for events up to at least the 1 in 30 year storm for the drainage area (sometimes greater), with the excess storm volume drained within 24 to 72 hours (CIRIA, 2007).
	Slow Runoff	High	
	Store River Water	None	

	Slow River Water	None	
Reducing Runoff	Increase Evapotranspiration	Medium	The rate of evapotranspiration will depend on dimensions, residence time and type of vegetation. With dense vegetation, evapotranspiration is substantially increased, particularly if trees are planted. Evapotranspiration in retention ponds 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	None	Retention ponds provide scope for additional storage above a permanent pool. They are not designed to release water through infiltration and must be lined when located on high-infiltration soils.
	Increase soil water retention	None	
Reducing Pollution	Reduce pollutant sources	None to low	Creating green areas and open water reduces hard surfaces and leads to reduced surface leaching of pollutant sources.
	Intercept pollution pathways	High	Retention ponds can be effective at pollutant removal, particularly as a result of settling of particulate pollutants. However retention ponds, with permanent water, are likely to be less effective for removal of oils that stay on the water surface, compared to infiltration basins that dry out between events (CIRIA, 2009). Literature reviews of the effectiveness of retention ponds at pollutant removal have been carried out by Environment Agency (2012) and DTI (2006) (and probably CIRIA, 2007). Wide ranges of effectiveness were found: - Suspended solids reduction: Environment Agency (2012) 29-91%; DTI (2006) average 55% - Total phosphorus reduction: Environment Agency (2012) 0-79%; DTI average 32% - Total nitrogen reduction: Environment Agency (2012) 0-80%; DTI average 34% - Metals: DTI (2006) 26-65% The retention pond constructed at Nummela Gateway Wetland Park in Finland (case study Finland_02), for example, achieved reduction in P of 9% and suspended solids of 12%. It is likely that achieving high effectiveness at pollutant removal will be improved by good design and adequate maintenance. This is particularly evident from total ranges reported by DTI (2006), where negative values

			(i.e. reduction in water quality) could occur over time due to a lack of maintenance and build-up of sediments. The effectiveness of retention ponds at removing pollutants from runoff will also improve with increased residence time (Environment Agency, 2012). This can lead to a design trade-off between runoff attenuation and water quality improvement that must be considered in the retention pond design. According to MDDEFP (2014) it was demonstrated that retention ponds commonly are more effective at controlling water quality than detention basins.
Soil Conservation	Reduce erosion and/or sediment delivery	High	Retention ponds are highly effective at intercepting sediment loading in runoff. When designed with a sediment trap that can be easily cleared, effectiveness at sediment removal is compatible with the long-term effectiveness of the pond to attenuate runoff. Where no sediment trap is included, the gradual infilling of the pond will serve to reduce effectiveness for runoff attenuation (Environment Agency, 2012).
	Improve soils	None	
Creating Habitat	Create aquatic habitat	High	Creation of new ponds will create new aquatic habitat. Where well designed, retention ponds have the potential to provide good quality habitat and aquatic biodiversity without impact on the runoff attenuation function.
	Create riparian habitat	Medium	Well-designed and maintained ponds create opportunities for riparian habitat development.
	Create terrestrial habitat	Low	Well-designed and maintained ponds create a water source for local wildlife, which may indirectly benefit or encourage terrestrial habitat.
Climate Alteration	Enhance precipitation	None	
	Reduce peak temperature	Low to medium	Retention ponds provide green areas and open water. 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 to medium	If a retention pond is added where no vegetation would otherwise have been 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	Retention ponds are effective at storing runoff from small to medium drainage areas. 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. water to support aquatic and riparian ecology in and around the pond), although they are highly unlikely to be of sufficient size to store water for significant human use.
	Fish stocks and recruiting	None	
	Natural biomass production	Medium	Creation of retention ponds will serve to create aquatic and riparian habitat and therefore has the potential to increase natural biomass production, particularly if dense vegetation is included, and considering that terrestrial, aquatic and riparian habitat may all be created.
Regulatory and Maintenance	Biodiversity preservation	High	Retention ponds create aquatic and riparian habitat and thereby make a significant contribution to biodiversity preservation, particularly when used in urban areas. Ponds have good potential for contributing to networks and green and/or blue corridors, which 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, retention ponds provide a contribution to adaptation to the higher storm intensity storm events expected due to climate change. 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	None	In order to preserve the permanent pond, retention ponds do not act as infiltration filters and do not serve to increase recharge to groundwater.
	Flood risk reduction	High	Retention ponds contribute to reducing the rate of surface runoff, particularly from artificial surfaces (urban areas). When used in conjunction with other SuDS features, they can reduce the overall risk of surface runoff flooding and contribute to reduction in peak river flows in small catchments.
	Erosion / sediment control	Medium	Retention ponds can be effective in reducing sediment delivery in runoff (Environment Agency, 2012). Where significant sediment loading is expected, retention ponds designed with an appropriate sediment trap can offer significant sediment control and enable this to be reused.

			Pond design should minimise the possibility of re-suspension of sediments.
	Filtration of pollutants	High	Retention ponds can be effective in reducing urban diffuse pollution (Environment Agency, 2012; DTI, 2006), although there is an overlap with sediment management to achieve this.
Cultural	Recreational opportunities	Medium	By contributing to urban green spaces and providing a water source for local wildlife, retention ponds may provide some recreational opportunity benefits.
	Aesthetic / cultural value	High	Retention ponds contribute to urban green spaces and also provide additional aquatic/riparian habitat, increasing the aesthetic/cultural value of the landscape. Ponds are 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, interest and knowledge, particularly when it is aesthetically pleasing and there are easily visible benefits to local wildlife. This is particularly the case where information about the pond 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	Although retention ponds create aquatic and riparian habitat, they are disconnected from rivers/lakes and unlikely to be of sufficient scale to make a contribution that will affect the overall status of WFD biological quality elements for a water body.
	Improving status of physico-chemical quality elements	Low	Through contributing to reduction in diffuse pollution through interception of runoff and sediment, retention ponds can make a contribution to improving water quality in receiving waters.
	Improving status of	None	

	hydromorphology quality elements		
	Improving chemical status and priority substances	Low	By contributing to reduction in diffuse pollution through filtration of pollutants and interception of surface runoff, retention ponds can make a contribution to improving water quality in receiving waters.
Achieve Good GW Status	Improved quantitative status	None	
	Improved chemical status	None	
Prevent Deterioration	Prevent surface water status deterioration	Medium	By intercepting potential diffuse pollution vector from the contributing catchment, retention ponds can help to protect the receiving water body from deterioration as a result of new diffuse pollution sources.
	Prevent groundwater status deterioration	None	
Floods Directive			
Take adequate and co-ordinated measures to reduce flood risks		High	Retention ponds 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, increased application of retention ponds will contribute to meeting this objective of the 2030 Biodiversity Strategy, particularly in urban areas.
More sustainable agriculture and forestry		Low	Where used as rural SuDS components, retention ponds can contribute to more sustainable agricultural practices.
Better management of fish stocks		None	
Prevention of biodiversity loss		High	By creating aquatic and riparian habitat, retention ponds can make a significant contribution to the prevention of biodiversity loss.

VIII. Design Guidance

Design Parameters	Evidence
Dimensions	If ponds are too small they may dry out in long periods of dry weather, ecology benefits cannot be maximised, and maintenance may be difficult. On the other hand an appropriate upstream SuDS management train should be in place to avoid the need for very large ponds which would require large land take. • The ratio of flow path length to width in the pond should be between 3:1 and 5:1. Inlets and outlets should be placed to maximise the flow path length through the pond. • Ponds should be wedge-shaped in plan so flow enters the pond and gradually spreads out, improving the sedimentation process and potential improvement in water quality. • The depth of the permanent pool should be between 1.2m and 2.0m. Deeper pools may be subject to stratification and anoxic conditions. Shallower pools may be prone to algal blooms and high biological activity during summer months. • Side slopes should not be steeper than 1:3 to ensure public safety and maintenance access. • Residence time of permanent pond should be at least 20 days to allow for biological treatment of dissolved pollutants where this is required • Additional storage volume drained in 24-72 hours after the rainfall event depending on the intensity and duration of the storm and the design specifications of the pond • Outfall design should be such that at least 50% of the maximum storage volume is discharged within 24 hours to allow for multiple events (CIRIA, 2007) Retention ponds should be designed with variable bed depths (rather than having a flat bed), and there should be shading of some parts of the pond.
Space required	Typically 3 – 7% of the upstream catchment area will be required, although this will vary depending on rainfall regime and the scale of storage required to achieve the desired level of runoff requirement.

Location	Ponds would typically be sited at a low point in the catchment where it can receive drainage by gravity. Several ponds may be required at a large site, split into topographic sub catchments. The position chosen should allow safe routing of flows above the design event for the pond, and the consequence of any pond embankment failure considered. Ponds should be located outside the flood plain of any watercourse which might cause the pond to be inundated during the design event e.g. outside the floodplain of the watercourse the pond will drain to. Where possible ponds should be located in non-intensively managed landscapes where native vegetation is already established and/or will flourish.
Site and slope stability	It may be difficult to construct a pond on steeply sloping land. Ponds should be built on stable ground – soil stability and groundwater levels should be considered; ponds should not be built on waste fill, uncontrolled fill, or non-engineered fill.
Soils and groundwater	Soils below the pond should be sufficiently impermeable to stop the water drying out; a liner or impermeable material such as puddle clay can be used for permeable soils. In areas of contaminated soils or groundwater the pond should be fully sealed to prevent transfer of water between the pond and the soils/aquifer. Where groundwater levels are near the surface the design will need to ensure that the outfall from the temporary pond volume is above the maximum expected groundwater level. A liner or other impermeable material such as puddled clay will be required if the underlying soils are permeable, to stop the pond drying out, or if the soils particularly susceptible to pollution.
Pre-treatment requirements	Retention ponds should ideally be combined with upstream sustainable drainage components, such as smaller detention basins and swales, which offer primary treatment and sediment management.
Maintenance requirements	Regular inspection and maintenance is important for the effective operation of ponds as designed. Regular maintenance activities include litter and debris removal; vegetation maintenance (including cutting of bank and aquatic vegetation and removal of nuisance plants); inlet/outlet inspection and maintenance; and sediment removal from forebay (where applicable). Less frequent maintenance may include sediment removal from permanent pond; repairs; ongoing inspections and monitoring. Appropriate signage to warn of water depth must be included for public safety.
Synergies with Other Measures	Retention ponds should ideally be combined with upstream sustainable drainage components, such as smaller detention basins and swales, which offer primary treatment and sediment management.

IX. Cost

Cost Category	Cost Range	Evidence
Land Acquisition		Retention ponds 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-€10 k	Geotechnical investigations are required to confirm the land stability and underlying soil/geology conditions prior to construction.
Capital Costs	€10-€60 /m^3 storage volume	Retention pond capital costs are typically between €20 and €40 per cubic metre of volume provided for storage. CIRIA (2007) indicates a cost range of €20-€30 per m^3 detention volume, although the UK SuDS cost calculator (www.uksuds.org) provides a slightly higher cost at €40 per m3 attenuation volume, and Chocat et al (2008), identifies a larger range from €9 to €60 per cubic metre of volume provided for storage. More generally, Environment Agency (2012) indicates that “construction costs may increase if lining is required”. Requirements for pond lining, or construction on steeper slopes or less stable land may increase construction costs to ensure the integrity of the pond.
Maintenance Costs	€1-€5 per m^2 pond surface area	Annual maintenance costs vary between €1 and €5 per square metre of retention pond area. CIRIA (2007) and Wilson et al (2009) indicate a maintenance cost range of €1-€2 per m^2, although the UK SuDS cost calculator (www.uksuds.org) indicates a slightly higher maintenance cost range of €4-€5 per m^2 pond area.
Additional Costs		

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.
Management of safety concerns	Management of safety considerations with respect to areas of permanent open water in urban areas. Effective signage is required and retention ponds must be designed according to local safety requirements. Health considerations with respect to areas of open water must also be considered, particularly in warmer areas where ponds may provide a suitable ecosystem for mosquitoes which can be related to increased transmittance of some diseases.

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, ponds may constitute (all or part of) an ecological focus area, as defined under CAP Pillar I, or may be eligible for the European Agricultural Fund for Rural Development (EAFRD) in relation to improving water management and preventing soil erosion. This type of incentive is also relevant for ponds primarily for wildlife benefit rather than treatment of runoff (i.e. measure N1).
LIFE+	In some cases integrated SuDS schemes (i.e. which may include ponds along with other measures) may be eligible for LIFE+ funding. This type of incentive is also relevant for ponds primarily for wildlife benefit rather than treatment of runoff (i.e. measure N1).

XII. References

Reference	Comments
DTI (2006) Sustainable drainage systems: a mission to the USA.	
Environment Agency (2012) Rural Sustainable Drainage Systems (RSuDS)	Guidance document by the Environment Agency of England, with information on measures relevant for rural (agricultural) sustainable drainage.
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.
Wilson, S, Bray, B, Neesam, S, Bunn, S and Flanagan, E (2009) Sustainable Drainage: Cambridge Design and Adoption Guide	
Woods-Ballard, B, Kellagher, R, Martin, P, Jefferies, C, Bray, R and Shaffer, P (CIRIA) (2007) The SuDS Manual, CIRIA C697.	
MDDEFP et MAMROT (2014), Guide de gestion des eaux pluviales, Chapitre 11 – Les pratiques de gestion optimales des eaux pluviales	Manual about SuDS components in Quebec, Canada.

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	Study about SuDS components in France.