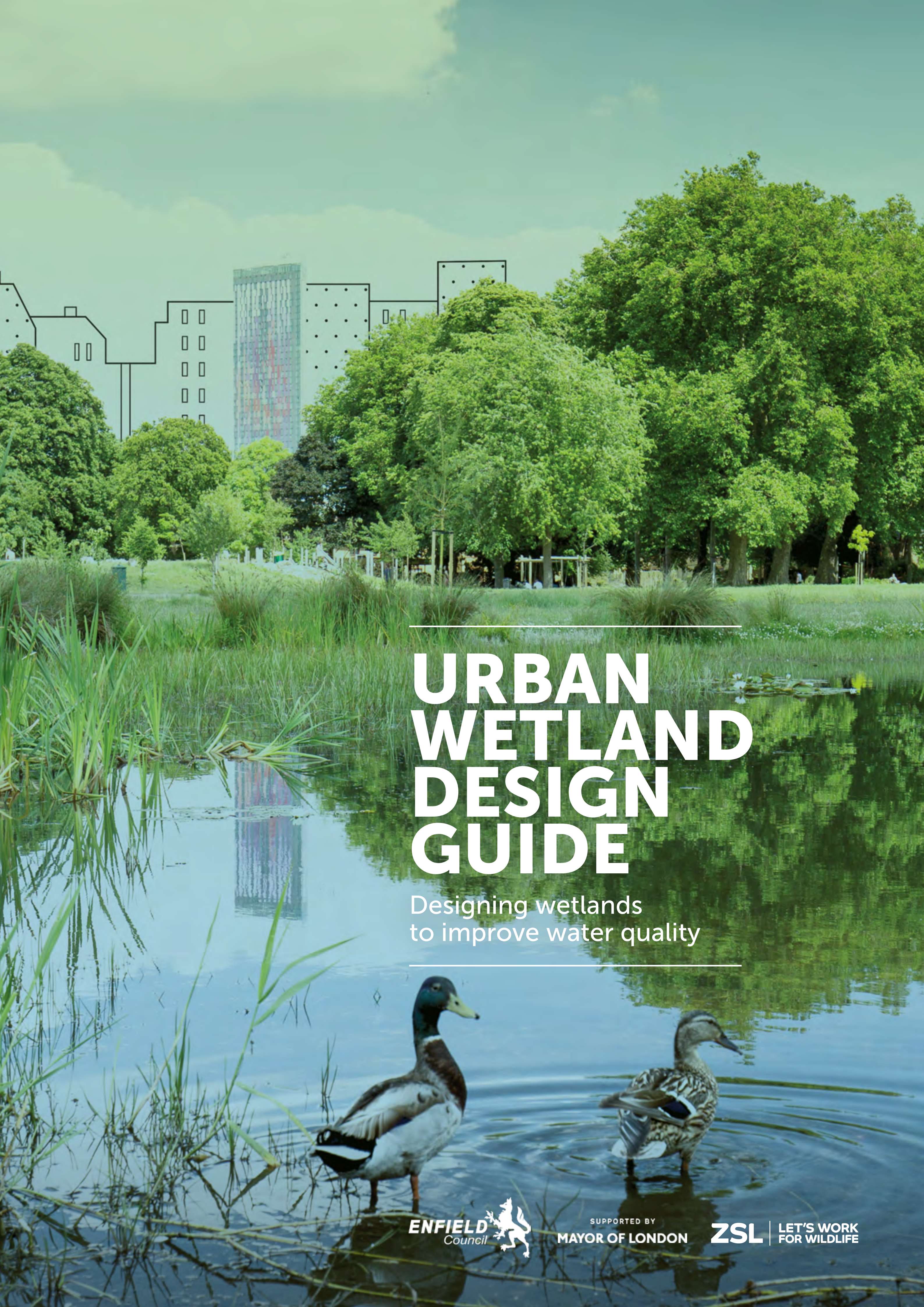

URBAN WETLAND DESIGN GUIDE

Designing wetlands to improve water quality

ENFIELD Council

SUPPORTED BY MAYOR OF LONDON

ZSL LET'S WORK FOR WILDLIFE

The principal author of this guide is Ian Russell, London Borough of Enfield, with support from Joe Pecorelli and Azra Glover of ZSL.

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The guide is an output of a wider partnership led programme of work in London to address the issue of waterborne pollutants from roads.

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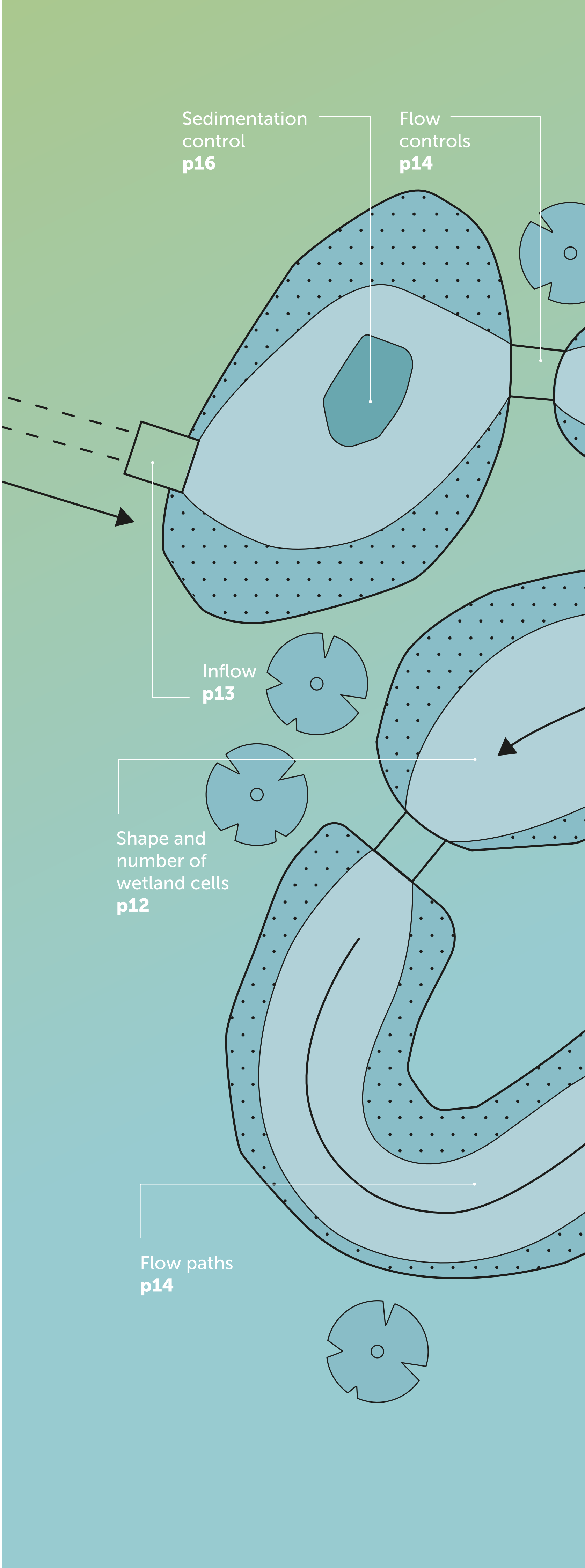

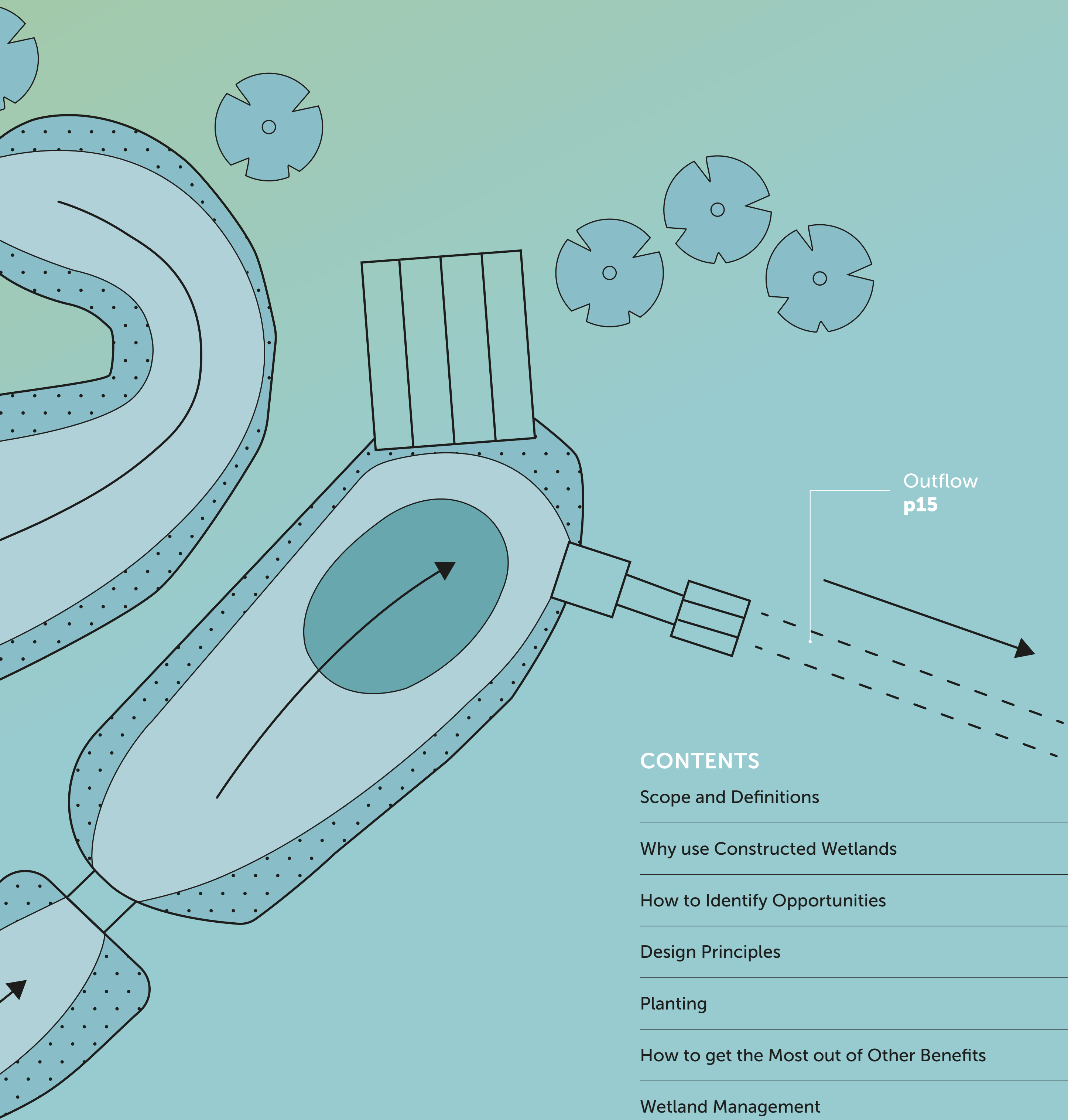

CONTENTS

Scope and Definitions	4
Why use Constructed Wetlands	6
How to Identify Opportunities	8
Design Principles	10
Planting	17
How to get the Most out of Other Benefits	20
Wetland Management	22
Consents	24
Links to Further Reading	24
Pollution Removal Efficiency Examples	25
Glossary	26

Scope and Definitions

SCOPE

The aim of this guide is to provide comprehensive and practical advice on the design and maintenance of constructed wetlands for the purpose of mitigating **urban diffuse pollution**. It is based on the London Borough of Enfield's track record of delivering urban wetlands in a variety of settings. The subject area is complex and, in some areas, still the focus of ongoing research so where appropriate we have provided pointers to further information and support.

The ability of wetlands to clean water that passes through them is proven but, as with all treatment systems, they have their limitations and there are often conflicting design considerations between optimising pollution control and biodiversity and amenity value. It is important to stress at the outset that their use should be considered part of a wider strategy for managing surface water quality that also includes **source control measures**.

There are a number of different types of constructed wetlands that can be employed for pollution control. The focus of this guide is on simple surface flow systems which are passive, driven by gravity, and require relatively little maintenance.

This guide is intended for anyone who is interested designing wetlands to improve water quality, particularly landscape designers looking for an introductory guide for designing in urban scenarios.

KEY MESSAGES

The bigger the better
The greater the area of wetland in a catchment, the greater the treatment. Creating a number of wetlands distributed around a river catchment is more effective than a single large wetland

Design for people and nature
Creating wetlands with varied shapes can create more interesting spaces for people and better habitat for wildlife

Keep an eye on pollutants
Wetlands need looking after to get the best out of them, management plans should be developed alongside the design

Think about the future
Wetlands are great at treating some types of pollution but can get overloaded. Baseline pollutants should be monitored and taken account of in the design process and pollution should always be removed at source where possible

DEFINITIONS

Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar definition). Constructed wetlands are specifically designed features installed in the landscape that use naturally occurring physical, ecological and chemical processes to treat polluted water.

Surface water drainage systems are intended to convey **rainfall** to the nearest watercourse. Along the way, this water becomes contaminated by pollutants, from sources such as roads and sewer **cross connections**, termed **urban diffuse pollution. Road run-off** is one of the most challenging sources of pollution to assess and resolve with the potential to contain over 300 different pollutants[1].

The ecological impacts of diffuse pollution are often associated with nutrient enrichment (**eutrophication**), sediment contamination and siltation. Once present within a catchment, urban diffuse pollutants mix, producing a cocktail of pollutants within which a further array of biological and physicochemical processes can take place[2]. In some cases, urban rivers subjected to high levels of pollution may become home to only a few pollution tolerant species.

Using constructed wetlands to intercept polluted rainfall runoff, prior to discharge into the natural environment, can improve the ecological health of surface water systems. Constructed wetlands can be located at any point within a surface water **catchment** area, the closer they are situated to the end of the pipe, the greater the proportion of the catchment area they will treat. For larger urban areas it is more effective to create several smaller wetlands distributed across the catchment, than to have one large feature at the end.

1 Greater London Authority (GLA) (2019) Road Runoff Water Quality Study, Executive Summary. Available at: www.london.gov.uk/sites/default/files/road_runoff_water_quality_study_exec_summary_dec_19_0.pdf

2 Lundy, L. and Wade, R. (2013) A critical review of methodologies to identify the sources and pathways of urban diffuse pollutants. Available at: crew.ac.uk/publications

Why use Constructed Wetlands

Constructed wetlands can clean polluted water, they do this through four key mechanisms:

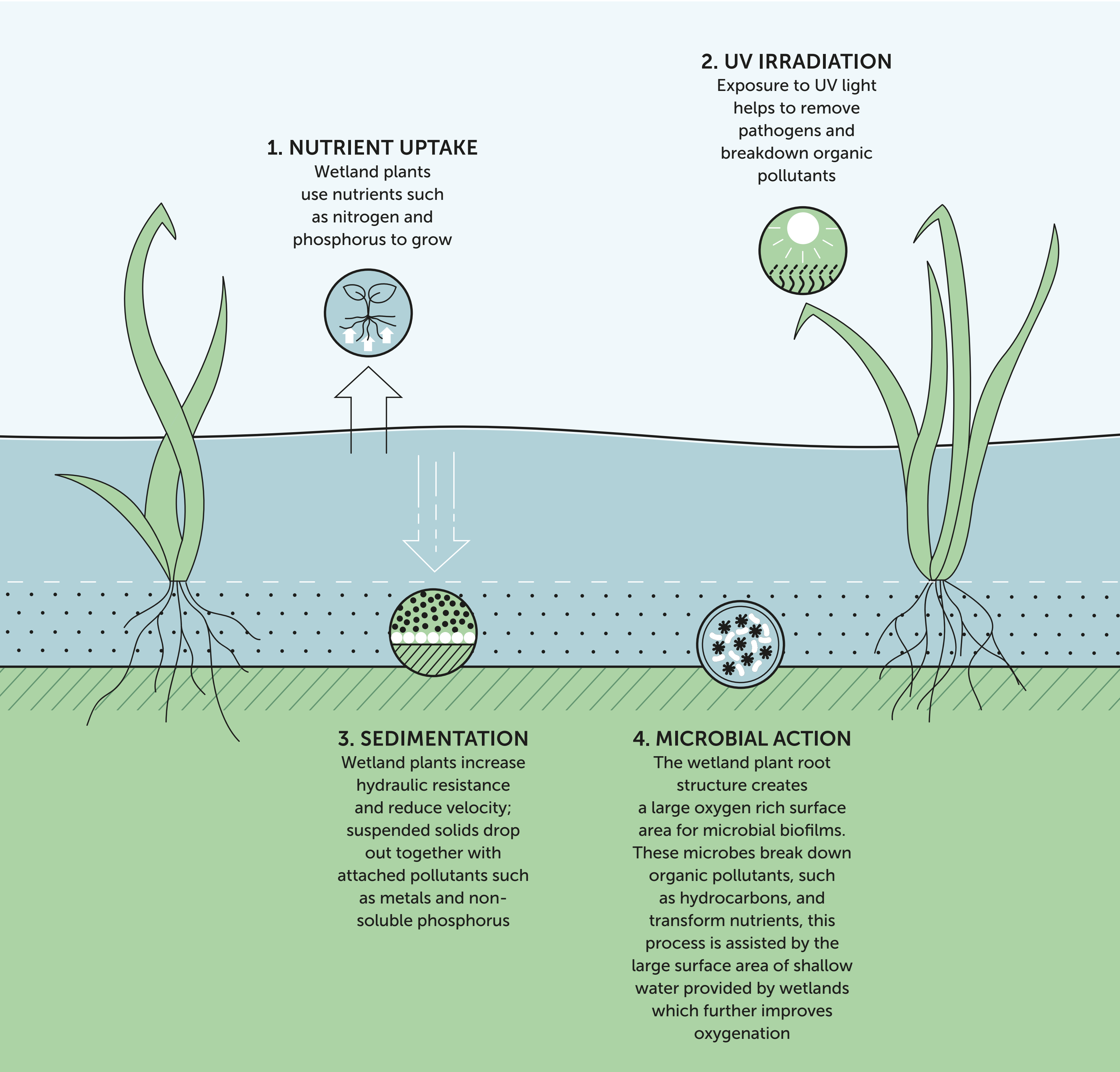

Figure 2.1 Key mechanisms

As well as improving water quality, constructed wetlands can provide additional benefits:

FLOOD RISK REDUCTION

Slowing surface water flows and providing storage for attenuation can significantly reduce the risk of flooding downstream

WILDLIFE

Wetlands provide habitat for a wide range of wildlife including birds, insects and amphibians, their importance is magnified by the relative absence of these types of features in urban areas

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AMENITY

Well-designed wetlands can also create interesting, diverse landscapes for people. There are many examples of wetlands that have been used to enhance parks and open spaces, making them more desirable places to visit and spend time, delivering wider benefits to the local community and improving public health and wellbeing

How to Identify Opportunities

Constructed wetlands require space and water – finding both of these together is rarely straightforward in a typical urban environment, but with a bit of detective work, opportunities can be found.

A good place to start is by looking at what water features existed prior to urbanisation. Overlaying modern surface water sewer maps and/or surface water flood maps (which show where overland flows will occur during extreme rainfall events) on to historical maps often show that modern drainage systems, and flood issues, are aligned with the routes of old watercourses. Once the main water routes have been confirmed, opportunities for wetlands can be identified by overlaying maps of parks and other open spaces. If multiple opportunities are identified, the best options to take forward can be prioritised by considering the health of the receiving water body, the size of the drainage catchment area that will be treated, the pollution loading and the opportunities for partnership working.

PRIORITISING WETLAND OPPORTUNITY SITES IN LONDON

The road runoff pollution risk of Greater London's strategic road network has been modelled as part of a partnership approach to tackling road runoff pollution in London. The model, developed by Thames21 and Middlesex University, has enabled the identification of the worst polluting roads. This information allows road owners and local authorities to prioritise and target key stretches of the most polluting roads to design and deliver water quality improvement interventions. Roadside interventions that trap pollutants at source are needed as a priority, with downstream wetlands installed in suitable greenspaces as a secondary treatment system. Greenspaces were ranked in order of priority for the treatment of road runoff by calculating the accumulated pollution risk of the roads entering the surface water drain network upstream of the greenspace (see links on page 24).

These open spaces will often be subject to constraints which need to be considered as part of the overall feasibility assessment, the main ones include:

- Existing uses (such as sports pitches)
- Existing wildlife and habitats including sites protected for nature conservation
- Heritage designations and archaeology
- Contaminated land
- Buried services (utilities such as gas, electricity and water)
- Existing watercourses (especially main rivers)

CONSTRUCTION ISSUES

The safest way to avoid actions that could have an adverse impact on receiving water bodies, such as disturbing sediments and allowing them to flow downstream, is to carry out construction works offline and only connect the new wetlands to the drainage system upon completion. This can be done several months later, allowing wetland plants to fully establish and thereby significantly reducing the risk of erosion leading to mobilisation of sediments. Advice relating to working on or near water is published by the Environment Agency. It should be noted that most construction activities within 8 metres of a main river require environmental permits from the Environment Agency. Ordinary watercourse consents may also be required from the Lead Local Flood Authority for activities on or near non-main rivers.

Planning consent may be required, depending on the size and location of the wetlands, local guidance should be sought

ENGAGEMENT

Engagement with local residents, park users (such as Friends groups) and other stakeholders is a critical step which should be carried out before proposals are significantly developed.

A good way to engage with the public is to present the proposals, ideally at concept design stage, at a consultation event such as a Friends group meeting. Holding a dedicated, well-advertised event at the location itself is a good way to engage with park users who would not ordinarily attend formal public meetings.

Other stakeholders that will need to be consulted include:

- The local water company
- Environment Agency
- Landowners or tenants
- Local Authority (including different departments where relevant)
- The relevant Catchment Partnership
- Conservation/wildlife charities

A range of surveys and tests will be required to inform the feasibility and design of your wetlands

- Topographical survey
- Tree survey
- Preliminary ecological appraisal (this will identify whether more detailed ecological assessments are required)
- Ground investigation (to understand local geology and confirm depth to water table as well as investigate potential contaminated land issues and groundwater pollution risks)
- Buried services searches (including gas, sewers, water, electricity, telephone and cable)
- Water quality testing (and water flow estimates – for high and low events)

Design Principles
(with water quality as a key design criterion)

The key design principles outlined below are focussed on maximising water quality benefits but wider benefits for wildlife and people, such as improved habitat and reduced flood risk, should also be considered throughout the design process (see pages 20-21 for further information on other benefits).

LOCATION

This design guide is focussed on the construction of **online** wetlands on the piped surface water sewer network, the aim is to treat water before it reaches an open watercourse. Constructed wetlands can be located at any point within a surface water **catchment** area, but the closer they are situated to the end of the pipe, the greater the proportion of the catchment area they will treat. The optimal location for a wetland may be the one that offers the best opportunity to treat runoff from the largest possible area within the local drainage catchment; however, other considerations need to be made including the pollution loading, the size of the catchment and the space available for wetlands. In many cases it will be preferable, and more feasible, to create a series of small wetlands spread across the catchment.

SEPARATE SEWER SYSTEMS VERSUS COMBINED

Early sewer systems combined rainfall runoff and sewage water together whereas modern sewer systems have separate pipes for surface water and foul water – Central London has a combined sewer system whereas outer London is mostly served by separate systems. One of the main advantages of separate sewer systems is that surface water runoff can be released into rivers without treatment. This can also be a disadvantage however as it can lead to widespread pollution of rivers.

The available space should ideally meet the following criteria:

- **Proximity** – it must be close enough to the surface water drainage network to enable water to be diverted into the wetland (and back again after its been treated), the maximum distance from the surface water drainage network depends on local topography
- **Depth** – the wetland excavation will need to be as deep as the surface water sewer that's being diverted, as a general rule this should be limited to a maximum of **3 metres** as landscaping becomes increasingly challenging beyond this depth (in some cases, depths can be reduced by diverting pipes higher up the network and running them to the wetlands at a shallower gradient but this is likely to be an expensive option)
- **Space** – there is no such thing as a typical constructed wetland but the average size of a feature such as this in an urban area is likely to be around 1,000-3,000m^2. Depending on depth requirements, the space required to construct a feature of this scale will probably be 2-3 times larger than this (this allows for slopes around the wetlands and bunds between individual wetland cells)
- **Catchment area** – the urban area draining into the wetland should normally be at least **8 hectares**, this is to ensure effective operation and to counter the risk of drying-out and vegetation wilting effects caused by prolonged dry periods (this requirement can be ignored if the wetland is targeting a specific known pollution source, or delivers significant wider benefits such as biodiversity or flood alleviation)
- **Pollution sources** – where possible, wetlands should be located to treat runoff from pollution sources such as heavily trafficked roads, combining wetlands with source control measures can significantly enhance the treatment benefit they provide to the receiving water body

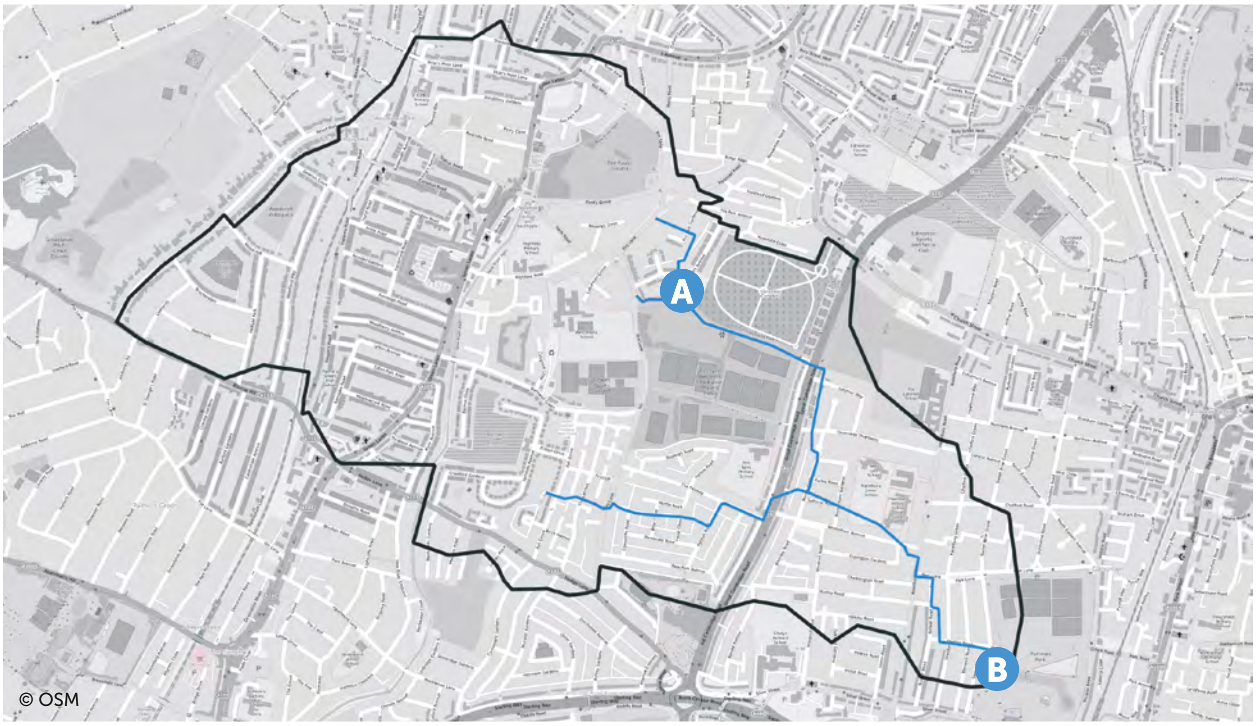


Figure 4.1 This typical urban catchment shows two potential wetland locations: the downstream location (B) has potential to treat runoff from the entire catchment but does not have enough space available for a large wetland, whereas the upstream location (A) has adequate space but can only treat runoff from a small proportion of the catchment – the optimal solution is to construct wetlands at both locations if possible

SIZE

In general, the bigger the better as the larger the wetlands the more effective it will be at removing pollutants. Nevertheless, wetlands should be sized according to the size of the catchment area they drain and the pollution loading they receive.

A good rule of thumb is that the surface area of the wetland system should be 1-5% of the catchment area[3]. Achieving even 1% can often be very challenging in an urban environment.

A further approach used successfully to size many of Enfield's constructed wetlands is based on a method derived for wastewater treatment. A simple calculation can be carried out to estimate the approximate size of wetland area required based on the Population Equivalent (PE).[4]

Area required for effective treatment (m^2) = PE x 50

The PE can be calculated based on the Biological Oxygen Demand (BOD_5) readings (at least 3 should be taken on different days and at different times, when there has not been any rainfall for at least 3 days, to obtain a reasonable average). Combining the BOD_5 readings with estimates of the Dry Weather Flow (DWF, in litres/second), and assuming that 1 PE = 54 $gBOD_5$/day, enables an estimate of PE:

PE = BOD_5 (mg/L) x DWF (L/s) x 1.6

Treatment also depends on the duration of time the water is retained in the wetlands; this depends on the overall volume of water and dry weather flow rate. Estimates for optimal retention time vary greatly, but in general the longer the better. Aiming to retain water for 12-24 hours (during dry weather conditions) is a good starting point. The retention time can be calculated using the following simple equation:

Retention time (hrs) = Volume of water in wetlands (m^3) / DWF (L/s) / 3.6

A good rule of thumb is that the surface area of the wetland system should be 1-5% of the catchment area

3 Kadlec RH and Knight RL (1996) Treatment Wetlands (Boca Raton: Lewis)

4 Integrated Constructed Wetlands Guidance Document, Department of the Environment, Heritage and Local Government, Irish Government 2010.

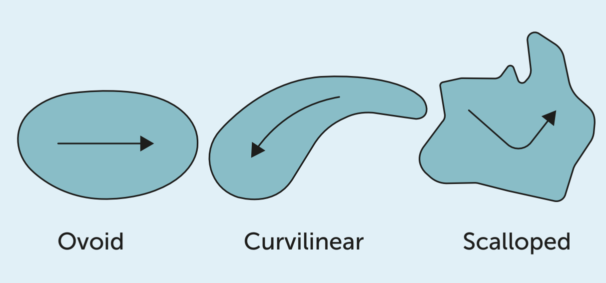


Figure 4.2 Different types of wetland cell shapes

SHAPE AND NUMBER OF WETLAND CELLS

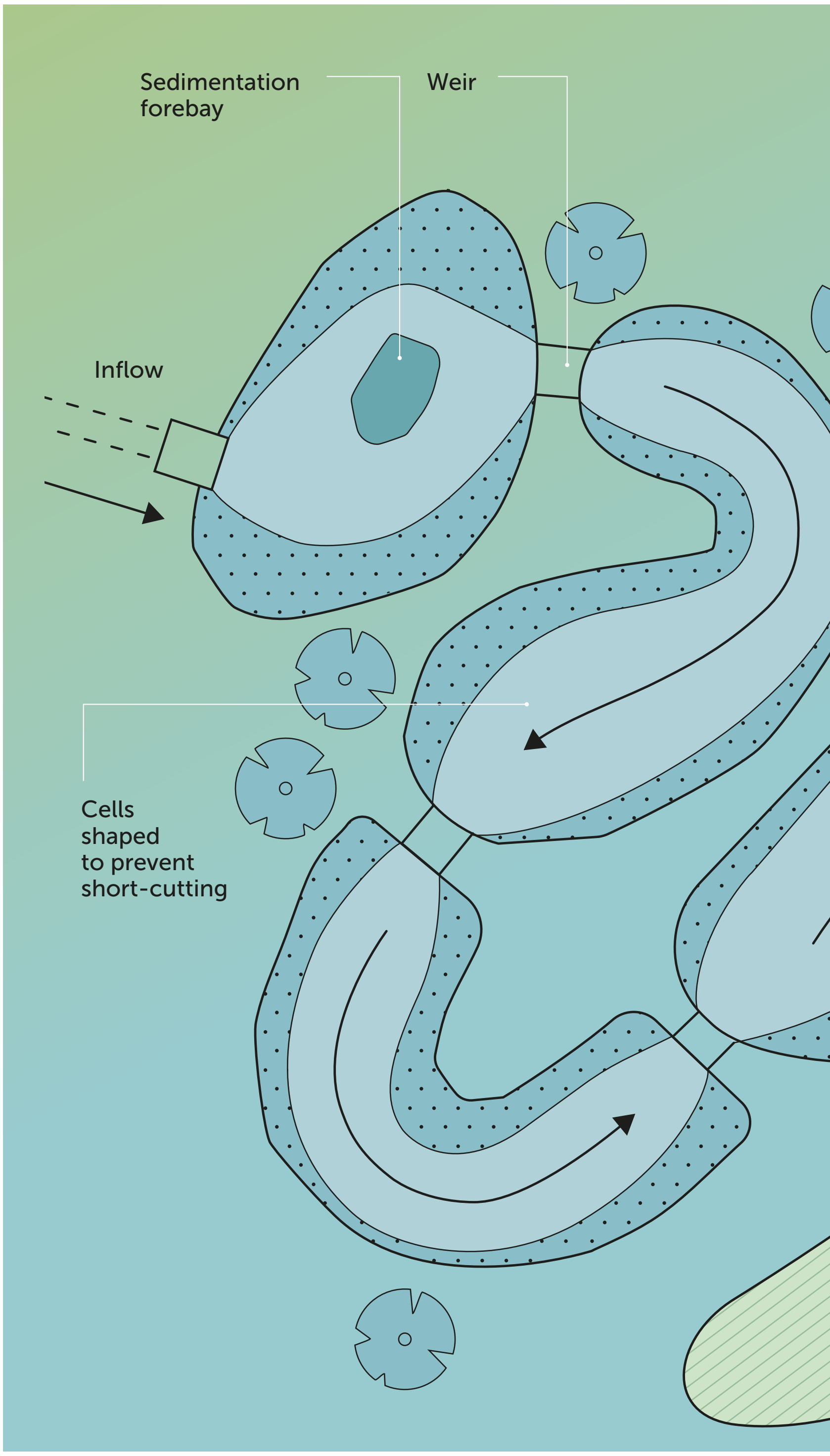
In general, an ovoid shape with an aspect ratio (length to width) of less than 4:1 is considered ideal for treatment purposes[5]. Where appropriate, curvilinear shapes that follow existing land contours should be used. Increasing the perimeter length of the wetlands by using complex shapes, such as the scalloped edges shown above, creates a richer zone of transitional habitat for wildlife but results in reduced overall wetland area with a corresponding loss in treatment value – wetlands should be designed to balance the overall habitat and treatment benefits. Long, narrow cells should be avoided as they can increase flow velocity and result in less effective phosphorus retention (long, narrow features such as swales can be used to convey flows between cells).

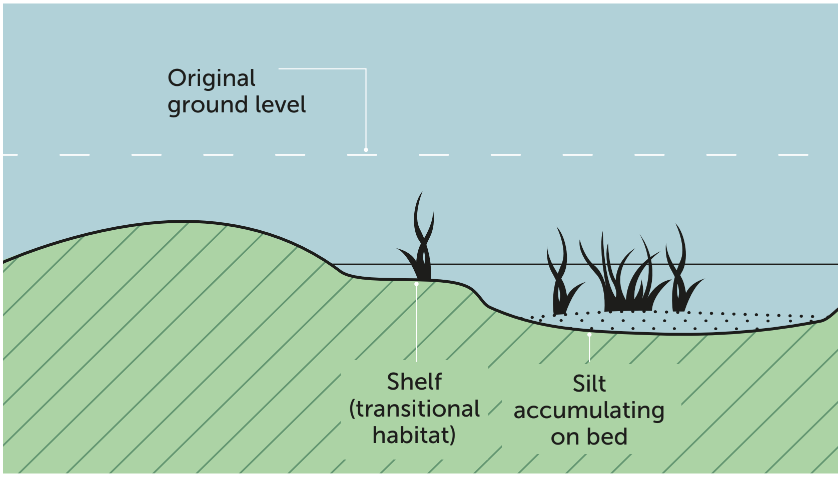
It is recommended that the design for a constructed wetland should include a minimum of 3 to 4 wetland cells of similar size – depending on topography and location this number can be extended.

The multi-cellular configuration of constructed wetlands operates as a series of individual wetland ecosystems, each with its own distinct features, influents and effluents. This arrangement increases the potential for treatment and improves the resilience of the overall system.

The gradual improvement in water quality is also an important consideration when designing constructed wetlands from an amenity perspective. If features are to be provided that encourage close engagement and enjoyment of the new natural spaces, such as seating areas or dipping platforms, these should be located at the later, cleaner wetland cells.

5 Integrated Constructed Wetlands Guidance Document, Department of the Environment, Heritage and Local Government, Irish Government 2010.





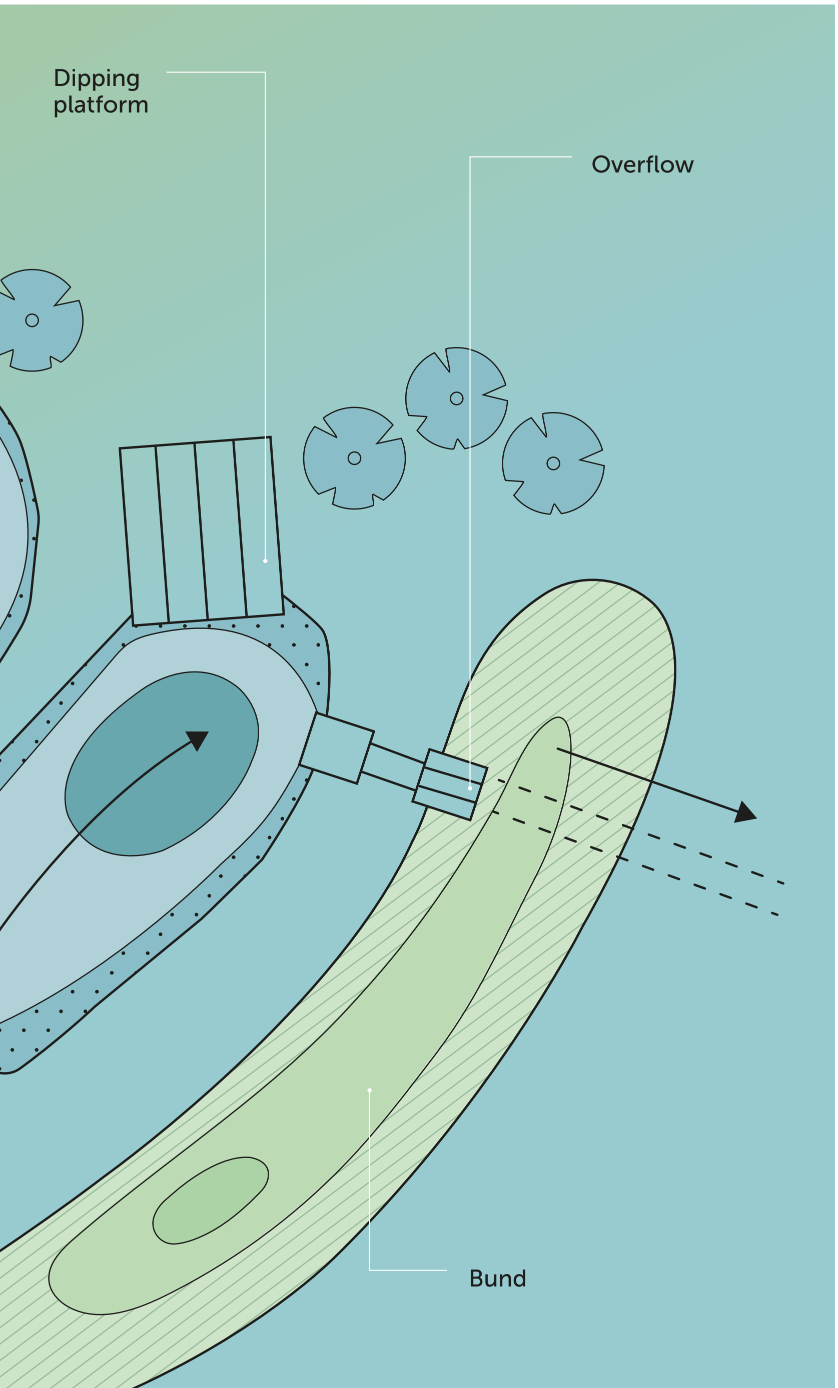


Figure 4.3 Typical constructed wetland layout with key features identified

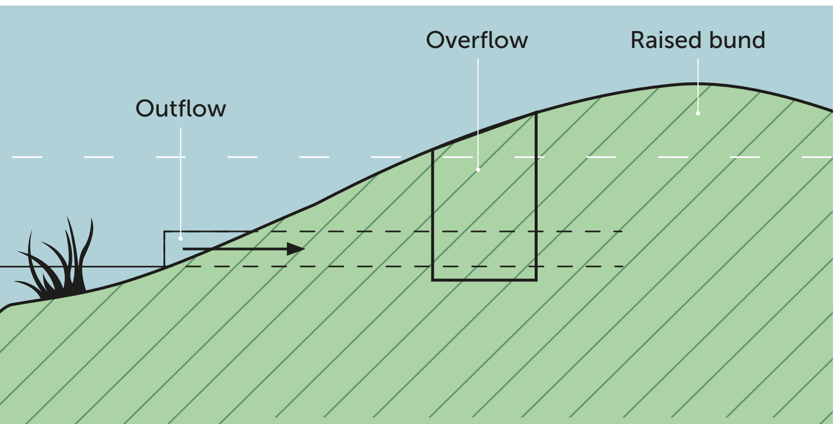


Figure 4.4 Section through wetland cell and raised bund

INFLOWS

The first consideration is how much flow to divert into the wetlands and under what circumstances. For treatment purposes it is necessary to divert all of the DWF and most, if not all, of the flow associated with the 'first flush' of rainfall – this is usually considered to be the first 5mm of rainwater. This is a fairly small amount of water (approximately 50% of all rainfall events in London are 5mm or less), but it carries the highest pollution load as it mobilises pollutants deposited since the last rain event and therefore any further rainfall following the first 5mm is likely to be relatively cleaner.

It may be considered preferable to retain higher storm flows within the piped drainage system as high energy flows associated with storms can cause damage to wetland plants or erosion to soft landscaped features.

To maximise the flood benefits of wetlands by utilising them as attenuation features, it is often better to activate the storage they provide later in the storm cycle rather than filling them up immediately. With this in mind, wetlands can be designed to achieve maximum flood benefits as part-online, part-offline systems following the hierarchy below:

1. Less than 5mm of rainfall – 100% flow diverted into constructed wetlands
2. Flows following more than 5mm rainfall (but before pipe surcharges) – flow retained within piped system
3. Additional flow following pipe surcharge – allow to spill into wetlands

As a general rule, assuming a typical piped drainage system can take around 10-20mm of rainfall before surcharging (depending on the storm duration and pipe capacity), it is recommended that the first 25% of flow is diverted into the wetland via a smaller pipe. The table below suggests suitable diversion pipe sizes based on typical sewer pipe sizes.

Sewer Pipe Diameter (mm)	Suggested Diversion Pipe Diameter (mm)
300 – 450	150
450 – 600	225
> 600	300

In some cases, it may be preferable to divert the entire flow from the pipe into the wetlands (making it an entirely online system). In these situations, a baffle of some kind, such as a permeable, rocky dam or submerged berm, should be considered to take energy out of the inflowing water and reduce the risk of erosion.

FLOW CONTROLS

The wetland plants are the primary form of flow control, they act as baffles, increasing hydraulic resistance and reducing velocity, helping to spread flows across the full width of the wetland cells. This increases the detention time and ensures effective sedimentation is achieved, leading to greater efficiency of the wetland system.

Weirs can be used to control water levels within each cell, these can also be designed as crossing points for pedestrians, where appropriate, as shown in the photograph below.

On a typical, fairly flat site it will be necessary to step the weirs between cells down successively to achieve a reasonable hydraulic gradient through the system. It is recommended that each weir is at least 50mm lower than the previous one. Where possible, weirs should be designed to accommodate the movement of migratory animals such as eels and other fish species.

In situations where wider spaces are required between cells, to accommodate footpaths for example, piped connections can also be used to control flows from one part of the wetlands to another. Where pipes are used, the system should be designed to allow for overtopping in the event of a blockage, to ensure water can still spill from one cell to the next without causing flooding.

On sloping sites, weirs may need to manage greater level differences between wetland cells, in these cases erosion proof measures such as rocky slopes or steps can be used to good effect.

Pipes and weirs can also be used to slow flows as water passes through the system and maximise attenuation storage for flood risk management purposes.

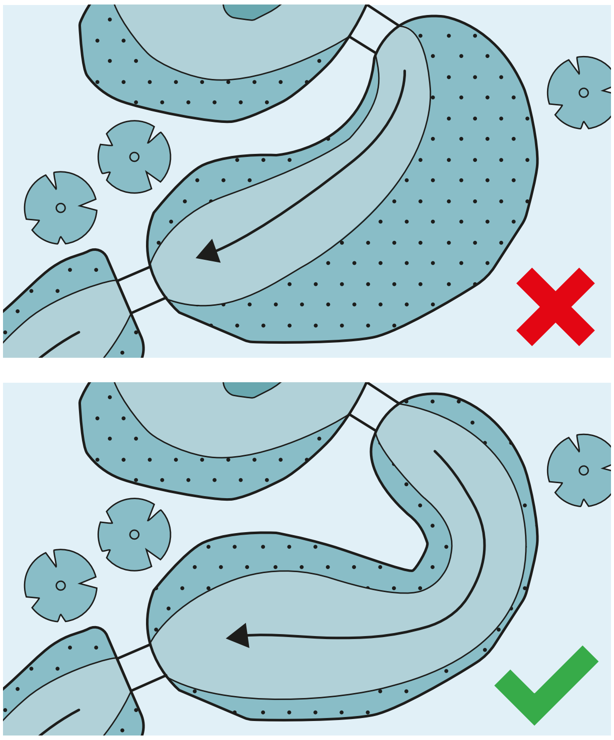


Figure 4.5 Example demonstrating how the wetland cells can be designed to minimise the risk of short-cutting

FLOW PATHS

The positioning of the weirs or pipes between cells, and shape of the cells, should be carefully considered to ensure that the maximum area of the wetlands is fully utilised – otherwise a preferential flow path may enable short-cutting, the travel time through the wetlands, and treatment potential, will be reduced.

Intermediate bunds, or submerged baffles, can also be used to maximise treatment by increasing the length of the flow path.

The positioning of the weirs or pipes between cells, and shape of the cells, should be carefully considered to ensure that the maximum area of the wetlands is fully utilised.

Example of piped crossing between two cells

OUTFLOWS

A suitable outflow will be required to ensure the open water can drain back into the piped system. There are a wide range of options for providing this, the following considerations should be made:

Vertical grille same size as outlet pipe – requires regular maintenance, for low flows only unless used in combination with an overflow

BLOCKAGES – reducing the risk of blockages is critical to avoiding failure of the overall system, particularly if the wetland outflows back into the piped drainage system; the easiest way to achieve this is to prevent debris blocking the outflow, or pipes further downstream, using a grille. In general it is advisable to size the grille to be 2-3 times as big as the outflow orifice so that it can be partially blocked without the flow capacity being severely impeded; however, in the case of constructed wetlands with dense vegetation. However as long as due consideration is given to the potential impact of a blockage failure both locally and downstream, the risk of floating debris reaching the outflow may be considered sufficiently low that reducing the grille size can justified.

Two-stage 'self-cleaning' grille several times larger than the pipe itself – designed for large flood storage areas with high flows

MAINTENANCE – the outflow must be easily accessible to operational staff so that blockage removal and other maintenance operations can be carried out.

Tall circular grille provides relatively high flow capacity with low risk of blockage

FLOW CAPACITY – the outflow should be sized according to the overall system, in general it should be at least as big as the inflow though in some cases, where flood attenuation is required for example, it may be preferred to provide a two-stage outflow consisting of a small outlet for low, day-to-day flows with a larger outlet for higher flows. A combination of pipes, weirs, slots or notches can be used to achieve various different design requirements.

Domed grille less risk of blocking than a flat grille but not suitable for high flows

EXCEEDANCE – an overflow system should be provided to ensure that excess water can be carried away as safely as possible if the maximum storage capacity of the wetland is exceeded. This emergency spillway should direct water away from properties or infrastructure where possible, and erosion protection measures should be included where appropriate.

In some cases, where the wetland is sufficiently close to the receiving watercourse, it may be appropriate simply to direct outflows towards the watercourse using an open channel such as a swale or ditch.

SEDIMENTATION CONTROL

The first cell in the constructed wetland system, sometimes referred to as the sedimentation forebay, will require special consideration as it receives the highest loading of silt and other pollution. Some wetland design guides recommend constructing this first cell as a deeper, siltation pond to capture the maximum amount of sediment. This approach is often not appropriate in an urban park setting however, as such as pond is likely to be significantly polluted, unsightly and odorous with a marked absence of any of the vegetation or wildlife that make constructed wetlands such a suitable design solution for managing diffuse urban pollution in public parks and open spaces.

Another reason to avoid the use of deep siltation ponds is that they are likely to be considered unsafe and require additional, undesirable measures such as safety fencing. Instead of a pond, it is usually the case that silt can be adequately managed by designing the first wetland cell according to the following requirements:

- Increase the depth to allow for greater siltation – up to 500mm rather than a maximum of 300mm as recommended below (plants that can tolerate this deeper water, such as *Phragmites australis*, should be used if taking this approach)
- Selecting appropriately pollution tolerant wetland plant species (see planting guide overleaf)
- Ensuring that it is easily accessible for future maintenance operations as it will be the first cell to be de-watered and de-silted (the frequency depends on the silt loading but is expected to be required after 10-20 years)

HIGH POLLUTANT LOADING

In certain situations, particularly when the runoff is from a road with more than 30,000 vehicles per day, it is important to install a sediment removal device upstream of the wetland, to capture the bulk of contaminated sediment before its enters the wetland. Suitable devices include vortex grit separators and oil/water separators and various sizes of these are widely available. These devices will need to be emptied once every 12 or 24 months but it is often more cost effective to do that than it is to remove sediment from the wetland or pond every 10 or 15 years. The sediment removal device will capture a lot of the pollution because most of the toxic metals and organic compounds in urban runoff are included in the sediment. The installation of one of these devices will add to the overall cost of the wetland, but it is worth completing a cost benefit analysis of the maintenance of the system because it can often be more cost effective to have the device included in the design.

WATER DEPTH

For the most part, a level base is important to ensure optimal water depth and utilisation of the maximum potential area of the wetland cells. The ideal water depth for most emergent wetland plants is from 100-300mm. As silt levels within the wetlands will inevitably build-up over time leading to a gradual reduction in depth, it is advisable to construct the wetlands at the higher end of this range initially to delay the point at which de-silting will be required.

Shallow margins, small seasonal ponds and islands within wetland cells can provide a more diverse habitat for wildlife. Opportunities should be identified to include these features within the overall design.

SUBSTRATE SELECTION

Substrate selection can be a critical design consideration for certain types of constructed wetlands, such as sub-surface flow systems. For the simple, surface flow systems described in this guide the substrate selection is not critical. Gravel is generally considered optimal and is often encountered when constructed wetlands are excavated, as they are typically located on the routes of historic watercourses, but clay, sand and silt are also acceptable. The nutrients the plants require are provided by the influent rather than the soil.

Planting

Wetland plants should be selected with water quality, and people and wildlife, in mind. Some plants thrive better than others in polluted water, some prefer cleaner water. As a very coarse guide, it often seems to be the case that the more colourful, flowering plants (such as Purple Loosestrife and Flowering-Rush) are less tolerant of pollution whereas the hardier species (such as Common Reed and Sedge) tend to be less visually diverse.

Non-native species should be avoided, with a focus placed on using suitable regionally or locally native plants.

There is a wide range of native emergent wetland species to choose from, the following species list is a good place to start but is not exhaustive (seeking expert advice on planting is highly recommended).

Lesser Pond Sedge
(*Carex acutiformis*)

Lesser Spearwort
(*Ranunculus flammula*)

Pendulous Sedge
(*Carex pendula*)

Water Forget-Me-Not
(*Myosotis scorpioides*)

Water Plantain
(*Alisma plantago-aquatica*)

Water mint
(*Mentha aquatica*)


© WWT

Purple Loosestrife
(*Lythrum salicaria*)


© WWT

FACT:
Common Reed can dominate

Common Reed
(*Phragmites australis*)


© WWT

Yellow Flag Iris
(*Iris pseudacorus*)


© WWT

Flowering-Rush
(*Butomus umbellatus*)


© LWT

Marsh-Marigold
(*Caltha palustris*)


FACT:
Submerged aquatics provide egg-laying substrate for newts, dragonflies etc

© Clearwater Photography

Particularly hardy species should be selected in the first wetland cell as it will receive the highest levels of pollution loading – suitable species include *Glyceria* (reed sweet-grass), *Phragmites, Carex* and *Scirpus*. *Typha* (Bulrush) is another pollution tolerant option however, it can become overly dominant and is therefore probably best to avoid deliberately planting it, though it has a habit of establishing itself anyway, often after a few years (for this reason it is sometimes classed as a semi-invasive native species).

Another approach to planting is to plant everything everywhere and see which species thrive best. This might seem haphazard but creating a diverse palette has the benefit of allowing each plant an opportunity to test the different environmental conditions found in different parts of the wetlands.

PLANTING PRACTICES TO AVOID

Non-native, invasive and exotic species: The introduction of invasive species, in particular species such as *Crassula helmsii* should be avoided. Non-native species have the potential to invade surrounding ecosystems and compromise the ecological value of the project. These can detract from the conservation value of constructed wetlands and act as a pathway for other invasive species to colonise local water bodies.

Deep rooted species: The planting of willow trees (Salix) near reedbeds should be avoided. The deep roots of these species can damage the composition of reedbeds and the substrate structure.

Heavily shaded reedbeds: The planting of reedbeds under cover of tree shade should be avoided where possible as patchy and poor growth can result.

6 Ellis, J. B., Shutes, R. B. E., & Revitt, D. M. (2003). Guidance manual for constructed wetlands. Environment Agency

7 Kadlec, R., Knight, R., Vymazal, J., Brix, H., Cooper, P., & Haberl, R. (2000). Constructed wetlands for pollution control: processes, performance, design and operation. IWA publishing

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Developing a 'mosaic' of plant habitats is encouraged as this helps to increase habitat structural diversity and can lead to greater pollution removal efficiencies[6,7]. This approach can increase system resiliency while also helping to support more diverse communities of local wildlife such as birds, amphibians and macroinvertebrates[8].

There are various planting options including (listed in ascending order of cost/size):

- Seeds – cheap but will take longest to establish
- Plug plants – cannot usually be planted directly into deep water
- Pot plants – suitable for marginal planting around the wetland edges
- Coir mats – semi-mature (typically 18-month-old) plants grown on coir matting, can be relatively expensive but they are very easy to install and, if planted near the start of the growing season, can establish a mature wetland within a few months

A blend of these approaches will help optimise plant survival and habitat establishment. In locations where there is an existing wildfowl population, plant protection may be required to allow young plants to establish before they are eaten – geese are often seen as the greatest threat in this area. Fencing is often used to protect plants but can be hazardous to birds and other wildlife if not installed properly, advice should be sought from experts where such measures are considered necessary. Certain plants (such as Yellow Flag Iris) are considered by some experts in the field to be less tasty to geese though there is an unfortunate lack of scientific research on this subject.

Consideration should also be given to plant selection to the areas around the wetlands. In general, it is good practice to use a mixture of grasses, trees and shrubs. In certain areas it may be desirable to keep people away from the water's edge, either for public safety reasons (if there are steep slopes for example) or to create nature areas where wildlife will not be disturbed. Using prickly shrubs such as Gorse and Hawthorn as a vegetative barrier can be a good way of managing public access in these situations. Trees such as Willow and Alder will thrive at the water's edge but require regular coppicing or they may shade out other wetland plants over time.

8 Zhang, C., Wen, L., Wang, Y., Liu, C., Zhou, Y., & Lei, G. (2020). Can Constructed Wetlands be Wildlife Refuges? A Review of Their Potential Biodiversity Conservation Value. Sustainability, 12(4), 1442

How to get the Most out of Other Benefits

WELLBEING

Wetlands in urban parks can provide important oases of calm away from hectic daily life. Examples of features you can incorporate to improve amenity value include:

Footpaths

Stepping stones

Seating areas

Outdoor classrooms

Boardwalks

Interpretation features

PUBLIC SAFETY CONSIDERATIONS

To improve public safety, steep slopes around wetlands must be avoided – otherwise safety fences will be required. As a general rule, a maximum gradient of 1 in 3 is recommended but shallower slopes are often preferable, and provide greater amenity value, if space allows. To create spaces that appear more natural a range of different gradients should be used. Other public safety measures to consider include providing dense planting around wetland edges and making sure that water depth within cells increases gradually rather than suddenly. In all cases, a public safety risk assessment should be carried out as part of the overall designer's risk assessment.

FLOOD STORAGE

The flood benefits provided by wetlands can be enhanced by increasing the volume of water stored for attenuation purposes. Excavating wetlands below the existing ground level often achieves this to a significant extent but in cases where there is known to be a risk of flooding downstream (i.e. most urban catchments), consideration should also be given to creating a flood bund on the downstream side of the wetlands to increase the storage provided – this is also a good way of re-using the spoil generated during the excavation works.

WILDLIFE

Wetlands provide important habitats for wildlife, but they have been removed from the landscape at an alarming rate in recent history. With wildlife sensitive management and access, urban wetlands can become important places for wetland species to thrive and for people to connect with nature. In London the development of wetlands can also support the habitat creation targets set out in the London Environment Strategy (Mayor of London, 2018).

Wetlands provide important habitats for wildlife, but they have been removed from the landscape at an alarming rate in recent history

Opportunities for habitat creation in areas surrounding wetlands include:

- Creating burrowing bee habitats on south facing banks, soil should be relatively bare, loose and gravelly
- Develop a series of amphibian hibernacula on banks facing wetlands by burying wood and leaving soil uncompacted, these can double as stag beetle habitats
- Construct reptile hibernacula through re-use of concrete/rock/timber materials
- Seed poor quality soil with a wildflower mix for butterflies, requires annual maintenance cut with arisings removed from wildflower area
- Debris from wildflower areas can be stored somewhere discrete, can double as a hedgehog area

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Wetland Management

Wetlands become established relatively quickly after planting, typically within 3-4 years. After this management is required to ensure that the habitat is maintained, otherwise the wetland will gradually develop into a wet woodland dominated by Willow and other water-loving trees.

REGULAR TASKS

- Aim to remove 25% of wetland plants annually, ideally in 1m strips perpendicular to flow direction with 3m in between each row
- Cut plants down to water level in September/ October (before die-back), this can be undertaken by volunteers with appropriate training, tools and support
- Remove all plant material (within 1m) at the inlets/ outlets so flow is not impeded
- Remove invasive plants such as Bulrushes

Dead reeds form a mulch that helps stabilise sediment so when carrying out any plant maintenance care is needed to minimise disturbance of the sediments. Disturbance can cause resuspension and remobilisation of pollutants.

TO HARVEST OR NOT TO HARVEST?

It was previously thought that the regular harvesting of wetland plants was an important way of removing the nutrients and metals that bioaccumulate in the leaves. However, there is growing evidence that these pollutants are transferred to the rhizomes (roots) in the autumn, so the die-back of leaves that occurs in the winter does not result in these pollutants being released back into the water.

Furthermore, leaving areas of last year's reed is also beneficial for wildlife, it can provide nesting habitat for returning migrant birds such as reed and sedge warbler, also waterfowl. Decaying piles of organic matter are also great habitat for grass snakes and other creatures.

SILT MANAGEMENT

De-silting of the wetlands will be required on a relatively infrequent basis – potentially 10-15 years depending on silt load and the size of the wetlands. The most appropriate method of disposal will depend on the waste classification of the silt, specialist advice should be sought, and testing carried out where required. The cheapest and most sustainable way to manage silt is to mechanically remove it, dry it out on site and re-use it in the local landscape but this may not always be suitable. See further information on consents in relation to waste management in the following section. Measures will need to be taken to prevent resuspended silt being washed into the wider environment during maintenance.

COMMUNITY SUPPORT

Encouraging the involvement of community groups or local NGOs to become stewards of a wetland can be a very helpful way of ensuring it is cared for and maintained. Through citizen science, community groups can also help monitor the impact of the wetland on the chemical quality of the water that passes through it. Systemic surveys using established methods can also help gather information on the wildlife living in the wetland. Reach out to conservation organisations for support with monitoring.

Citizen science

Maintenance

Consents

Permits and consents may be required for the development of a wetland, for example planning permission, flood risk consent and waste removal from the site (where required). Local Environment Agency officers should be consulted during the early stages of project development to find out what might need to be considered.

Planning – anything larger than a small pond may require planning consent.

GUIDANCE CAN BE FOUND HERE

Flood Risk Activity Permits Guidance – flood risk modelling may be required for a wetland project. Guidance can be found here: www.gov.uk/guidance/flood-risk-activities-environmental-permits

Waste – guidance can be found here: www.gov.uk/guidance/waste-environmental-permits

Seek guidance from Natural England if a wetland is to be in, adjacent to, or within the buffer zone of a Site of Special Scientific Interest (SSSI).

Government Advice on invasive, non-native plants is here.

Planning – anything larger than a small pond may require planning consent

Links and Further Reading

The Construction Industry Research and Information Association (CIRIA) have developed guidance on the design of Sustainable drainage systems (SuDS) including constructed wetlands. Their SuDS manual is available on www.ciria.org

Their Susdrain manual provides plenty of evidence around cost-benefits and some helpful case studies www.susdrain.org

Department of the Environment, Heritage and Local Government (2010) Integrated Constructed Wetlands, Guidance Document for Farmyard Soiled Water and Domestic Wastewater Applications www.housing.old.gov.ie/sites/default/files/migrated-files/en/Publications/Environment/Water/FileDownLoad,24931,en.pdf

Malaviya, P., & Singh, A. (2012). Constructed wetlands for management of urban stormwater runoff. *Critical Reviews in Environmental Science and Technology*, 42(20), 2153-2214.

Mayor of London information on water quality, including the road runoff pollution risk map can be found here.

The London Environment Strategy (Mayor of London, 2018) is available here.

Examples of Wetland Pollution Removal Efficiency

This section shows a snapshot of the large amount of research on the processing of three groups of pollutants in constructed wetlands: nutrients (nitrogen and phosphate), metals and hydrocarbons. Research is still ongoing particularly concerning the processing of metals and hydrocarbons.

PROCESSING NUTRIENT POLLUTION IN FIRS FARM WETLANDS [9]

Water samples collected once monthly for 8 months from the inflow and outflow at Firs Farm indicated significant improvements in water quality after passage through the wetland. Phosphate reduced by 78%, Ammonia, which is particularly harmful to aquatic life, decreased by 92% . Slowing water down and allowing natural breakdown processes to occur allows the conversion of ammonia to nitrate, its less harmful form, before the water enters the river. Both ammonia and nitrate are components of total nitrogen, which decreases by 58%.

BOD5 (biological oxygen demand incubated over 5 days) is a good proxy for the amount of organic pollution, such as sewage, in the water – evaluated from the oxygen consumption of microorganisms involved in its natural breakdown. BOD5 decreased by 30%.

9 Firs Farm Wetlands Water Quality Report, Gilbert. N, Thames 21 (2016), available from Thames21.org

LONG TERM HEAVY METAL REMOVAL BY A CONSTRUCTED WETLAND TREATING RAINFALL RUNOFF FROM A UK MOTORWAY [10]

Based on the measured accumulation and projected runoff loads over a nine year study period, the apparent removal efficiencies were 60% of copper, 31% lead, 86% zinc and 5% of cadmium,

Other observations in this research were,

- Chromium, copper, lead and zinc accumulated towards the front of the wetland in the sediment.
- More metal accumulated in the sediment than vegetation.
- Zinc was found in the highest concentrations.

10 Gill, L. W., Ring, P., Casey, B., Higgins, N. M., & Johnston, P. M. (2017). Long term heavy metal removal by a constructed wetland treating rainfall runoff from a motorway. Science of the Total Environment, 601, 32-44.

ORGANIC COMPOUND EXPECTED PROCESSES IN CONSTRUCTED WETLANDS [11,12]

Polycyclic aromatic hydrocarbons	Fuels: kerosene C9–16, diesel	Gasoline C4–122,7
(3–6 rings) Sorption, microbial degradation, plant uptake and metabolism	C10–19, heavy fuel oil C20–702 Microbial degradation, sorption and sedimentation, volatilisation	Microbial degradation, volatilisation

The table above from Imfeld et al. outlines how fuel related organic compounds may be processed in wetlands. Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds that are generated by the incomplete combustion of oils and fuels. They are listed as priority contaminants because of their toxic properties. Some PAHs are biodegradable and processed by wetlands some however are not and can accumulate. These non-biodegradable PAHs are a concerning threat to freshwater environments, see for example Berhanu Desta et al. There is an urgent need for highways authorities to take responsibility for these pollutants and develop appropriate management strategies that prevent their release into the wider environment.

11 Imfeld G, Braeckevelt M, Kuschk P, Richnow HH. Monitoring and assessing processes of organic chemicals removal in constructed wetlands. Chemosphere. 2009 Jan;74(3):349-62.

12 Berhanu Desta M, Bruen M, Higgins N, Johnston P. Highway runoff quality in Ireland. J Environ Monit. 2007 Apr;9(4):366-71.

Glossary

Catchment The area contributing surface water flow to a point on a drainage or river system

Constructed wetlands Specifically designed features installed in the landscape that use naturally occurring physical, ecological and chemical processes to treat polluted water

Cross connections Any situation where foul water can get into the surface water system, these include dual manholes, where the two systems share a manhole chamber, and piped connections, which were sometimes installed to reduce the risk of sewer flooding, as well as **misconnections**

Diffuse urban pollution (as opposed to point-source pollution) Pollution arising from urban land use activities that are dispersed across a catchment

Eutrophication Water pollution caused by high nutrient levels which stimulate algal growth, excessive algal growth (or 'blooms') use up oxygen, resulting in reduced water quality

Foul water Polluted water and sewage that is discharged from houses and other buildings

Misconnections An incorrect connection, commonly when household appliances such toilets, sinks and washing machines are incorrectly plumbed into the surface water system instead of the foul system for treatment

Offline Part of the drainage system that does not receive flow during frequent events

Online Part of the drainage system that receives flow for all events

Rainfall runoff Water that flows over the land surface over impermeable (e.g. concrete yards) or permeable (e.g. fields, gardens) surfaces

Road run-off pollution Pollution generated by vehicle use that is deposited on roads and washed into water systems during rainfall events[9]

Source control The control of rainfall runoff at or near its source, it either does not enter the drainage system, or is delayed and/or treated before it enters the drainage system

Surface water Water bodies or flows that result from rainfall

Wastewater Water that is discharged following some form of processing, this includes water from sinks, WCs, baths and showers as well as water used in industrial, commercial and agricultural processes

Wetland A relatively shallow pond that has a high proportion of emergent vegetation in relation to open water

Wetland Notes