Artificial Wetlands

INTERVENTION CATEGORY: CREATED HABITATS

DESCRIPTION

Artificial (or "constructed") wetlands are created with the aim of mimicking hydrological processes of natural wetlands. They usually take the form of shallow depressions with dense and diverse vegetation and function as biological treatment systems that make use of natural processes involving wetland vegetation, soils, and their associated microbial assemblages. Typically, a wetland is created through excavation of upland soils to elevations that will support the growth of wetland species through the establishment of an appropriate hydrology. Often, construction of wetlands is accompanied by other NbS such as river restoration measures (floodplains, connectivity, etc.).[1] Activities involved in creating artificial wetlands can involve removing underground drainage tiles, installing dykes or plugging open ditches.[2]

Artificial wetlands commonly act as a supplement or a substitute to conventional treatment plants.[3] They are often used for nutrient pollution control of various wastewater streams, such as domestic wastewater, urban wastewater from sewage, industrial wastewater, and sludge. Constructed wetlands are also used to remove nutrients and sediments and mitigate surface runoff from agricultural and livestock fields.[3] In urban environments, they are applied to mitigate impacts of polluted stormwater runoff and wastewater. Constructed wetlands are increasingly proposed as a disaster risk management strategy, due to their potential to safeguard against extreme climate events.[2]

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WATER SECURITY CHALLENGES (WSCs) ADDRESSED

TYPE		IMPACT	MAGNITUTE	DEPTH OF EVIDENCE BASE
Water availability	Groundwater recharge	Increased mean annual groundwater recharge	★★☆	★★☆
	Dry season flows	Maintained dry season flows	★★☆	★★☆
Disaster risk	Flood risk	Reduced peak discharge	★★★	★★☆
Water quality	Erosion and sedimentation	Reduced on-site erosion and sediment yields	★★☆	★★☆
	Nutrients and pollutants	Reduced in-stream nutrient and pollutant concentrations	★★☆	★★★

Wetlands can store large amounts of stormwater runoff, and release it slowly, helping to regulat[e] water quantity and achieve a more even distribution of water availability in time. An acre of wetland can store 3.8 to 5.7 million liters of floodwater, thereby reducing the peak load on stormwater and wastewater systems.[4] It is estimated that constructed wetlands can reduce 5–10 % of the volume of incoming runoff through seepage (and groundwater recharge) and evaporation.[3] Still, the effectiveness of a wetland in reducing flood risks is not always significant and strongly depends on its situation in the watershed.

By attenuating peak flow velocities and volumes, wetlands also contribute to reduced soil erosion. They can reduce downstream transport of sediments by trapping suspended solids.

Vegetation and sediments provide a growth media for microbes, which filter and settle pollutants attached to sediments. One of the reasons to construct wetlands is to provide secondary and tertiary wastewater treatment and improve water quality, through their natural geochemical and biological processes. The pollutant removal rates are as high as 85 % for suspended solids, 75 % for phosphorus, 55 % for nitrogen and 45 % for organic carbon.[2, 3] An extensive review of constructed wetland projects showed that constructed wetlands have been used successfully for many types of industrial effluents, such as petrochemical, dairy, meat processing, abattoir, breweries, and pulp and paper factory effluents.[5]

OTHER BENEFITS

WHAT?	HOW?
Water temperature control	Provision of shade by vegetation
Biomass for energy production	Constructed wetlands can produce relatively large quantities of biomass, which can be regularly harvested to be used as biofuel.[6]
Habitats/biodiversity	Important habitats can be established for various bird species, fish populations and other wildlife.[3]
Carbon sequestration	Vegetated wetlands can act as carbon sinks when CO_2 is sequestered in biomass.[7]
Provisional ecosystem services	Provision of food, fiber, timber, medicinal resources, etc.[8]
Recreation and tourism	Increased aesthetic value and more pleasant environment

LINKAGES TO CLIMATE CHANGE

Mitigation: Constructed wetlands can sequester large amounts of carbon and therefore contribute to mitigation of climate change effects. However, at the same time they can emit large quantities of greenhouse gasses. The carbon–GHG budget needs to be assessed on a case-by-case basis.[7]

Adaptation: Intensification of hydrological extremes is projected in many areas worldwide as a consequence of climate change. Artificial wetlands contribute to adaptation by reducing flood risk (especially for minor flood events, due to their often limited size) and enhancing groundwater recharge and dry season flows.

DESIGN-ENABLING CONDITIONS AND TYPICAL CONSTRAINTS

- There are three main types of constructed wetlands: surface flow wetlands, subsurface flow wetlands, and hybrid systems. A wide range of design configurations is possible, defined among others by dominating macrophytes, flow patterns, configurations of wetland cells, type of wastewater to be treated, treatment level, and type of loading (interval or continuous). Several technical guidebooks are available that discuss opportunities and limitations under different conditions.[9, 10, 11,1 2]
- Flow in subsurface-flow wetlands can be horizontally or vertically oriented. Vertical flow constructed wetlands are considered more efficient with less area required. However, they need to be interval-loaded and require more know-how while horizontal flow constructed wetlands can receive wastewater continuously and are easier to design and build.[13]
- A relatively large area of land is generally required, particularly for horizontal flow systems, causing wetland treatment to be less economical in cases where land is expensive.[10]
- Constructed wetlands need to show that they can treat water to existing and anticipated future regulatory standards.[14]
- Stakeholder involvement in wetland construction activities, from planning up to implementation stages, has proven to be very important for success.[1]
- Maintenance needs, depending on context:[12, 13]
  - Regular checking of the pretreatment process: inlet structures, outlet structures, and pumps
  - Regular checking of influent loads and distribution on the filter bed
  - Checking of wetland vegetation for diseases and insects
  - Removal of weeds and predatory plants until the wetland vegetation is fully established

RELATION TO GREY INFRASTRUCTURE

INFRASTRUCTURE?	SERVICE PROVIDED BY GREY SOLUTIONS	TYPE OF RELATION
Water treatment infrastructure	Primary water treatment	Complementary
Stormwater storage tanks	Storage of stormwater and slow release to the hydrological system	Alternative

Constructed wetlands are often intended as secondary (subsurface flow) or tertiary (surface flow) treatment systems, meaning that effluent needs to first pass through a primary treatment process which effectively removes solids. Grey infrastructure solutions for performing primary treatment can e.g. involve a septic tank or anaerobic baffled reactor.[13]

COMMON RISKS AND TRADE-OFFS

- Rapid growth of invasive species in the nutrient-rich habitats.[15]
- Particularly in tropical regions: the creation of new habitats for mosquitos and thereby vector-borne disease risks.[16]
- Wetlands have the potential to accumulate toxic substances, in effect turning wetlands into potential 'hotspots' where high levels of contamination can prove detrimental to wetland ecosystem functioning and health.[17]
- In some circumstances, wetlands can contribute to natural processes that generate hazards. For example, wetlands may attenuate flood flows at the start of the rainy season when they are relatively dry, whereas they generate runoff and potentially contribute to flood flows later in the wet season under saturated conditions.[2]
- Treatment efficiencies may vary seasonally in response to rainfall dynamics.[11]
- A certain hydrological regime is required for wetlands to stay healthy. They are not resilient to complete drying, which may be a risk in certain environments.[11]

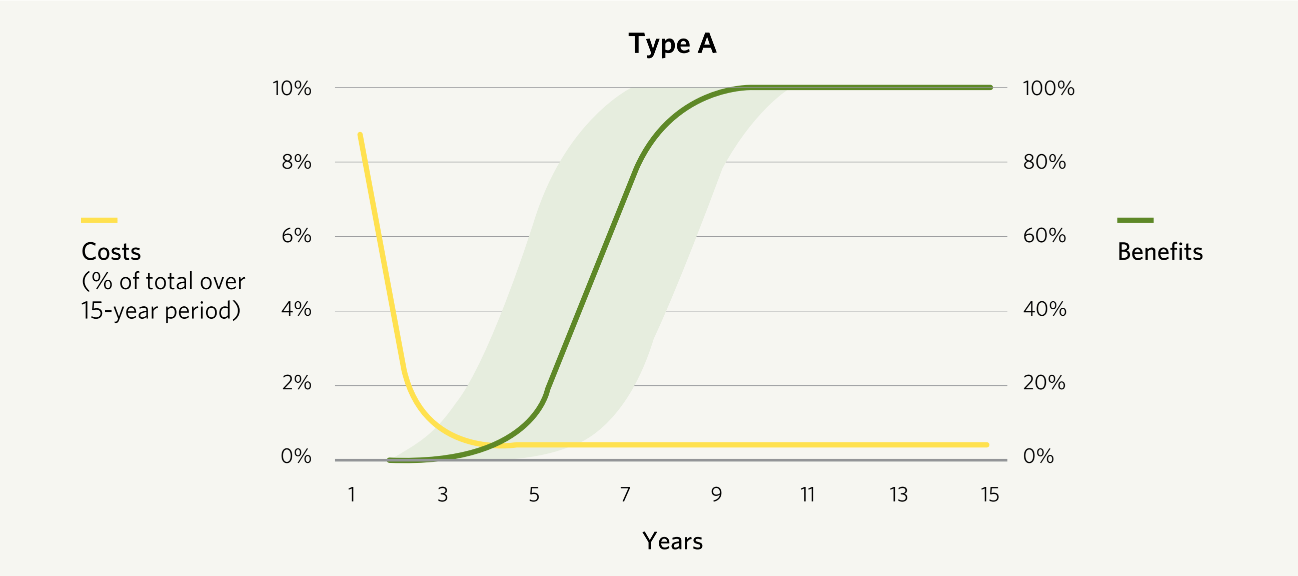
MONITORING OPPORTUNITIES

- Status of vegetated habitats can be monitored with satellite imagery, aerial photos and ground-truthing by field surveys. Different wetness indices can be computed from remote sensing imagery to monitor hydrological dynamics in wetlands.[18] (Hyper)spectral sensors can be used to monitor nutrient content in a constructed wetland.[19]
- Impacts on water quantity (dry season) can be monitored by measuring streamflow at downstream sites.
- Impacts on water quality can be monitored locally by measuring concentrations of relevant parameters (e.g., nutrients or sediments) at the inlet and outlet of the wetland.

IMPLEMENTATION COSTS AND TIMING OF BENEFITS

Costs of constructing wetlands are highly location-specific and depend on the size, land acquisition costs, structure, as well as the local costs of building materials, labor and appropriate vegetation. Typical activities generating **capital costs** include site assessment and design, excavation and layout, materials, inlet and outlet structures, pipes, pumps, vegetation, and land acquisition.[8] **Recurring costs** are relatively low and can include costs of pumping, in cases where the natural slope is insufficient, and harvesting of biomass if relevant. Other maintenance activities as described earlier include checking of pretreatment processes and structures, checking filter beds for clogging, and monitoring and maintenance of vegetation. In total, investment costs can vary from almost negligible levels to tens of thousands per hectare.[3] Small-scale cases show that constructed wetlands are often cheaper than treatment plants, but for large-scale treatment processes the increased land requirements and capital costs can become a limiting factor.[13]

Benefits of constructed wetlands will accrue relatively soon after implementation and will quickly increase with hydrological and ecological development. In addition, artificial wetlands can lead to cost savings in operation (water treatment) and help to alleviate pressures on existing water infrastructure (e.g., urban sewage systems).



Constructed wetland of 7 hectares near Hoogeveen, The Netherlands (source: ClimateScan)

EXAMPLES

Constructed wetlands are relatively widespread, with examples ranging from humid, marine climates to (semi)-arid conditions in the Middle East. Some examples are listed below:

Tolka River, Ireland[20]

Brief description: An integrated constructed wetland was created along the urban section of Tolka River (Dublin) to address problems with water quality and flooding. A fountain was installed, and barley straw bales applied to the pond to prevent algal blooms and remove further pollutants. Biodegradable anti-weed matting combined with planting was put in place to remove invasive species. Total capital costs of the project amounted to €4.1m.

Lessons learnt:

- Parks in urban areas can serve as biodiversity reserves and offer opportunities to contribute to achieving good ecological status of water bodies;
- Soft engineering techniques can be cost-effective and enhance biodiversity potential of urban catchments.

Vidrare, Bulgaria[21]

Brief description: A small-scale Vertical Flow Constructed Wetland was designed and constructed for treatment of domestic wastewater of around 100 people. Total costs incurred during construction were around €50,000.

Lessons learnt:

- Constructed wetlands can be cost-effective for small-scale applications
- Constructed wetlands require much lower running costs than grey solutions as no technical aeration is needed and less operators´ time

Texas, USA[22]

Brief description: An integrated financial and environmental assessment was performed to evaluate the construction of a wetland relative to the grey alternative (sequencing batch reactor). The wetland was constructed at capital costs of $1.5 mil and serves to meet suspended solids requirements for a wastewater treatment system. Over a 30-year period, it was estimated that net savings regarding fixed and recurring costs amount to $53 mil and $70 mil, respectively.

Lessons learnt:

- Lower energy and material inputs to the constructed wetland resulted in lower potential impacts for fossil fuel use, acidification, smog formation, and ozone depletion, and lower potential impacts for global warming;
- Land burdens for the sequencing batch reactor and the on-site acreage of the constructed wetland are similar in magnitude and importance, contrary to the assumption that green infrastructure always requires greater land area.

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