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Green Infrastructure benefits of constructed wetlands

Caution: This discussion includes wetlands constructed for purposes of managing stormwater. It does not include natural wetlands. Natural wetlands should not be used for stormwater management.

Stormwater wetlands (https://stormwater.pca.state.mn.us/index.php?title=Stormwater_wetlands) are constructed stormwater management practices, not natural wetlands. Stormwater wetlands are similar in design to **stormwater ponds** (https://stormwater.pca.state.mn.us/index.php?title=Stormwater_ponds) and mainly differ by their variety of water depths and associated vegetative complex. They require slightly more surface area than stormwater ponds for the same **contributing drainage area (https://stormwater.pca.state.mn.us/index.php?title=Contributing_drainage_area_to_stormwater_BMPs)**. Like ponds, they can contain a **permanent pool** and temporary storage for water quality control and runoff quantity control.

Example of a stormwater wetland in a suburban area.

Link to Stormwater wetland articles in this manual (https://stormwater.pca.state.mn.us/index.php?title=Stormwater_wetlands).

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Green infrastructure and multiple benefits

Green infrastructure (GI) encompasses a wide array of practices, including stormwater management. **Green stormwater infrastructure** (GSI) encompasses a variety of practices primarily designed for managing stormwater runoff but that provide additional benefits such as habitat or aesthetic value.

There is no universal definition of GI or GSI (link here fore more information (https://www.interreg-central.eu/Content.Node/Definitions.html)). Consequently, the terms are often interchanged, leading to confusion and misinterpretation. GSI practices are designed to function as stormwater practices first (e.g. flood control, treatment of runoff, volume control), but they can provide additional benefits. Though designed for stormwater function, GSI practices, where appropriate, should be designed to deliver multiple benefits (often termed "multiple stacked benefits". For more information on green infrastructure, ecosystem services, and sustainability, link to Multiple benefits of green infrastructure and role of green infrastructure in sustainability and ecosystem services.

Green Infrastructure benefits of constructed wetlands

- **Water quality** (https://stormwater.pca.state.mn.us/index.php?title=Water_quality_benefits_of_Green_Stormwater_Infrastructure): Pollutants are removed from stormwater **runoff** in a wetland through uptake by wetland vegetation and biota (algae, bacterial), **vegetative filtering**, **soil adsorption**, and gravitational settling in the slow moving marsh flow. **Volatilization** and chemical activity can also occur, breaking down and assimilating a number of other stormwater contaminants such as **hydrocarbons**. Wetlands effectively remove solids and pollutants associated with solids. They are only moderately effective at removing nitrogen and phosphorus. Some designs or poorly designed and

Benefit	Effectiveness	Notes
Water quality	◕	Primary benefit is retention of sediment and associated pollutants; nutrient cycling in properly functioning wetlands; may export phosphorus if not designed and maintained properly.
Water quantity/supply	◑	Rate control, flooding benefit.
Energy savings	◔	
Climate resiliency	◑	Provides some rate control. Impacts on carbon sequestration are uncertain.
Air quality	◔	
Habitat improvement	●	Use of perennial vegetation and certain media mixes promote invertebrate communities.
Community livability	◕	Aesthetically pleasing and can be incorporated into a wide range of land use settings.
Health benefits	◑	
Economic savings	◕	Generally provide cost savings vs. conventional practices over the life of the practice.
Macroscale benefits	◑	Individual practices are typically microscale, but multiple practices, when incorporated into a landscape design, provide macroscale benefits such as wildlife corridors.
Level of benefit: ○ - none; ◔ - small; ◑ - moderate; ◕ - large; ● - very high		

maintained wetlands may export phosphorus. For information on pollutant removal for stormwater wetlands, link to Calculating credits for stormwater wetlands.

CAUTION: Using constructed wetlands for extensive water quality treatment may impair the wetland for other functions, such as habitat.

- **Water quantity and hydrology** (https://stormwater.pca.state.mn.us/index.php?title=Water_quantity_and_hydrology_benefits_of_Green_Stormwater_Infrastructure): Stormwater wetlands temporarily store water and therefore effectively control runoff rates. They are well-suited to provide channel protection and **overbank flood protection (http://stormwater.pca.state.mn.us/index.php/Overbank_flood_protection_criteria_%28Vp10%29)**. This is accomplished with **live storage** (extended detention) above the **permanent pool**. Properly designed wetlands do not directly contribute significantly to infiltration but can be used to store water as part of a stormwater reuse system (https://stormwater.pca.state.mn.us/index.php?title=Design_considerations_for_constructed_stormwater_ponds_used_for_harvest_and_irrigation_use/reuse). (References: [1] (https://eprints.mdx.ac.uk/6967/); [2] (https://www.researchgate.net/publication/232413756_Urban_wetland_planning_A_case_study_in_the_Beijing_central_region); [3] (https://www.intechopen.com/online-first/80843); [4] (https://dec.vermont.gov/watershed/wetlands/functions/storage))
- **Energy**: primary benefit is through energy saving resulting from waste treatment. Minor benefits may be provided through heat island reduction associated with evapotranspiration and vegetative sources of fuel. (Reference: [5] (https://brunswick.ces.ncsu.edu/wp-content/uploads/2013/04/Wetland-Ecosystem-Services-2011.pdf?fwd=no))
- **Climate resiliency** (https://stormwater.pca.state.mn.us/index.php?title=Climate_benefits_of_Green_Stormwater_Infrastructure): Wetlands improve ecosystem services, alleviate water shortages through water re-use, and provide flood control. Rates of carbon accumulation measured in the soils of other constructed wetlands suggest that these systems provide sequestration benefits, though constructed stormwater ponds have been shown to release carbon. Wetlands provide heat island mitigation. (References: [6] (https://www.switzernetwork.org/leadership-story/using-wetlands-mitigate-climate-change); [7] (https://www.nawm.org/pdf_lib/wetlands_and_climate_change_consideratons_for_wetland_program_managers_0715.pdf); [8] (https://ecology.wa.gov/Water-Shorelines/Wetlands/Tools-resources/Wetlands-climate-change); [9] (https://www.nature.com/articles/s43247-022-00384-y); Wong, 2006).
- **Air quality** (https://stormwater.pca.state.mn.us/index.php?title=Air_quality_benefits_of_Green_Stormwater_Infrastructure): benefits are largely indirect, such as carbon sequestration; potential concerns with improperly maintained wetlands releasing methane.
- **Habitat improvement** (https://stormwater.pca.state.mn.us/index.php?title=Wildlife_habitat_and_biodiversity_benefits_of_Green_Stormwater_Infrastructure): Constructed wetlands, because they retain a permanent water pool, provide excellent wildlife habitat. Many wildlife species are dependent on or otherwise utilize wetland habitats, including waterfowl, wading birds, shorebirds and songbirds, furbearers such as beaver, muskrat and mink, and a variety of reptiles and amphibians like turtles, snakes, frogs, salamanders, and toads. An important factor affecting the habitat value of a constructed wetland is the surrounding landscape. A complex of wetland types interspersed with upland nesting cover provides optimum habitat. Isolated wetlands provide significantly habitat value. (References: [10] (https://www.dnr.state.mn.us/excavatedponds/index.html); [11] (https://www.researchgate.net/publication/11555219_Surface_flow_SF_treatment_wetlands_as_a_habitat_for_wildlife_and_humans); [12] (https://www.sciencedirect.com/science/article/abs/pii/S0273122397000504); [13] (https://www.researchgate.net/profile/Lowell_Adams/publication/261857755_Design_Considerations_for_Wildlife_in_Urban_Stormwater_Management/links/02e7e535a65d2025c8000000.pdf); [14] (https://sora.unm.edu/sites/default/files/journals/wilson/v097n01/p0120-p0122.pdf))
- **Community livability** (https://stormwater.pca.state.mn.us/index.php?title=Social_benefits_of_Green_Stormwater_Infrastructure): Constructed ponds are an aesthetically pleasing practice. Constructed wetland urban landscapes play a role in increasing community livability by creating recreational areas. However, they require space and are difficult to incorporate in urban landscapes. A variety of vegetation can also be used, including perennial plants, shrubs, and trees. (References: [15] (https://journals.ekb.eg/article_90104_beeb063ed39d60352c7d74bd9e4bc007.pdf); [16] (https://www.epa.gov/sites/default/files/2017-05/documents/gi_parksplaybook_2017-05-01_508.pdf))

- **Health benefits** (https://stormwater.pca.state.mn.us/index.php?title=Social_benefits_of_Green_Stormwater_Infrastructure): Green spaces may also improve mental and physical health for residents and reduce crime (References: [17] (https://journals.ekb.eg/article_90104_beeb063ed39d60352c7d74bd9e4bc007.pdf); Barton and Rogerson (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5663018/), 2017).
- **Economic benefits and savings** (https://stormwater.pca.state.mn.us/index.php?title=Economic_benefits_of_Green_Stormwater_Infrastructure): In addition to water quality and flood control benefits, properly designed and integrated constructed wetland practices provide life cycle cost savings. Well designed and maintained constructed wetland practices increase property values. (References, including valuation studies: [18] (https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2010WR009071), [19] (http://ec.europa.eu/environment/integration/research/newsalert/pdf/benefits_of_constructed_wetland_ecosystem_services_worth_double_the_cost_426na2_en.pdf), [20] (https://www.baylor.edu/content/services/document.php/149874.pdf), [21] (http://www.feem-web.it/ess/ess05/files/Ghermandi1.pdf))
- **Macroscale benefits**: Effects of individual ponds and wetlands are localized. However, if designed for multiple benefits, collectively ponds and wetlands can provide macroscale benefits if there are a sufficient number of them and there is some connectivity between the practices. In particular, pond and wetlands in series and combined with other vegetated practices (e.g. bioretention, swales) provide excellent habitat benefits and may provide other macroscale amenities, such as recreation areas, treatment trains, and rate control.

Design considerations

Maximizing specific green infrastructure (GI) benefits of constructed ponds requires design considerations prior to constructing the practice. While site limitations cannot always be overcome, the following recommendations maximize the GI benefit of constructed ponds.

Example of a stormwater wetland in a largely undeveloped area. Constructed wetlands in developing areas offer potential to incorporate many of the design features discussed in this section.

- Water quality (Balderas-Guzman et al., 2018 (https://lcau.mit.edu/sites/lcau.mit.edu/files/attachments/project/Design%20Guidelines_Web%20Version.pdf))
  - Distribute constructed wetlands systemically throughout a watershed to increase potential for delivering networked benefits
  - Design to maximize retention time and prevent short-circuiting
  - Create ecological diversity within the wetland to expose water to a variety of conditions where different treatment processes can take place
  - Create shallow zones were water will come into contact with plant roots and microbes and deeper zones where anaerobic processes can take place
  - Utilize a length to width ratio of 20:1
  - Construct multiple wetland cells
  - Ensure adequate **pretreatment** (https://stormwater.pca.state.mn.us/index.php?title=Pretreatment) to minimize pollutant loading that might impair other benefits, such as habitat
- Water quantity/supply
  - Distribute constructed wetlands systemically throughout a watershed to increase potential for delivering networked benefits
- Climate resiliency
  - Moore and Hunt (2012) determined that most carbon accumulated in constructed wetlands was autochthonous (derived in situ rather than imported). Thus, vegetation establishment is critical to carbon sequestration, with dense emergent communities being favored. Ensure water levels are

shallow enough to support emergent macrophytes. Adjustable outlet structures and proper construction and maintenance are tools for ensuring shallow water levels that favor emergent vegetation.
    - To avoid or minimize the potential for methane release, construct wetlands to avoid permanent inundation and properly maintain wetlands (Altor and Mitsch (https://stormwater.pca.state.mn.us/index.php?title=Green_Infrastructure_benefits_of_constructed_wetlands#References), 2006).
- Habitat
    - Include a littoral shelf that promotes emergent macrophytes (Moore and Hunt, 2012)
    - Vegetative biodiversity may be enhanced by planting littoral areas rather than relying upon natural colonization (Moore and Hunt (https://stormwater.pca.state.mn.us/index.php?title=Green_Infrastructure_benefits_of_constructed_wetlands#References), 2012)
    - Promote a diversity of predators to control mosquito populations (https://onlinelibrary.wiley.com/doi/full/10.1111/j.1936-704X.2010.00389.x Greenway], 2010)
- Community livability
    - Maximize the size of wetlands to enhance recreational opportunities (hiking, boating, fishing)(Serrano and DeLorenzo, 2008)
    - Couple wetlands with open space to enhance recreation and social activities (Schroeder and Louviere (https://stormwater.pca.state.mn.us/index.php?title=Green_Infrastructure_benefits_of_constructed_wetlands#References), 1999)
    - Include recreational infrastructure and interpretative signs (Greenway (https://stormwater.pca.state.mn.us/index.php?title=Green_Infrastructure_benefits_of_constructed_wetlands#References), 2010)
    - Ensure safety and perceived safety of wetlands and adjacent areas, which typically entails creating more open space and less wooded area (Gobster and Westphal, 2004; Schroeder and Anderson, 1984)
    - Conduct surveys prior to and after development to identify features that enhance education, recreation, and other benefits of wetlands
- Health benefits
    - See community livability above for recreation opportunities that promote health
    - Design wetlands in residential areas for safety. Options include minimizing access for children by planting shorelines to shrubs, fencing specific areas adjacent to the wetland, creating shallow shelves within the wetland to minimize the risk of drowning, properly posting the wetland (particularly in cold climates where the wetland freezes in the winter)(Constructed Wetlands: The Economic Benefits of Runoff Controls National Association of Certified Home Inspectors (https://www.nachi.org/constructedwetlands.htm))
    - Minimize mosquito exposure by maximizing open water that allows introduction and maintenance of predator species
- Economic benefits (Constructed Wetlands: The Economic Benefits of Runoff Controls National Association of Certified Home Inspectors (https://www.nachi.org/constructedwetlands.htm))
    - Maximize sight-lines to the wetland
    - Design wetland for easy access (e.g. locate close to road, create public access)
    - Integrate wetland into landscape design, including creating habitat, pathways, picnic areas, etc.
    - Create attractive side slopes using vegetation and proper erosion protection

Recommended reading

- The Role of Constructed Wetlands as Green Infrastructure for Sustainable Urban Water Management (https://www.mdpi.com/2071-1050/11/24/6981) (Stefanakis, 2019)
- Ecosystem service provision by stormwater wetlands and ponds A means for evaluation? (https://ac.els-cdn.com/S004313541100710X/1-s2.0-S004313541100710X-main.pdf?_tid=b5f73225-fa67-4de9-9e6a-1d01ec01460c&acdnat=1527777467_9b13c32b8b3b0222d1a8a4b9b1a76162). Moore and Hunt (2012). An excellent article covering carbon sequestration, biodiversity, edication, and cultural services provided by wetlands. Includes an extensive reference list.
- Constructed Wetlands: The Economic Benefits of Runoff Controls (https://www.nachi.org/constructedwetlands.htm). National Association of Certified Home Inspectors. Article discussing economic benefits of wetlands, including design considerations.

- Constructed Wetlands (https://www.epa.gov/wetlands/constructed-wetlands). U.S. EPA. EPA's main page for constructed wetlands; provides several links to useful articles on a variety of topics related to constructed wetlands.
- Constructed Wetlands: Using Human Ingenuity, Natural Processes to Treat Water, Build Habitat (https://wrrc.arizona.edu/publications/arroyo-newsletter/constructed-wetlands-using-human-ingenuity-natural-processes-treat-wa). Joe Gelt, Water Resources Research Center (1997). Nice overview on constructed wetlands.

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Stormwater wetland articles in the Minnesota Stormwater Manual

- Overview for stormwater wetlands
- Types of stormwater wetlands
- Design criteria for stormwater wetlands
- Construction specifications for stormwater wetlands
- Assessing the performance of stormwater wetlands
- Operation and maintenance of stormwater wetlands
- Cost-benefit considerations for stormwater wetlands
- Calculating credits for stormwater wetlands
- References for stormwater wetlands
- Requirements, recommendations and information for using stormwater wetland as a BMP in the MIDS calculator.