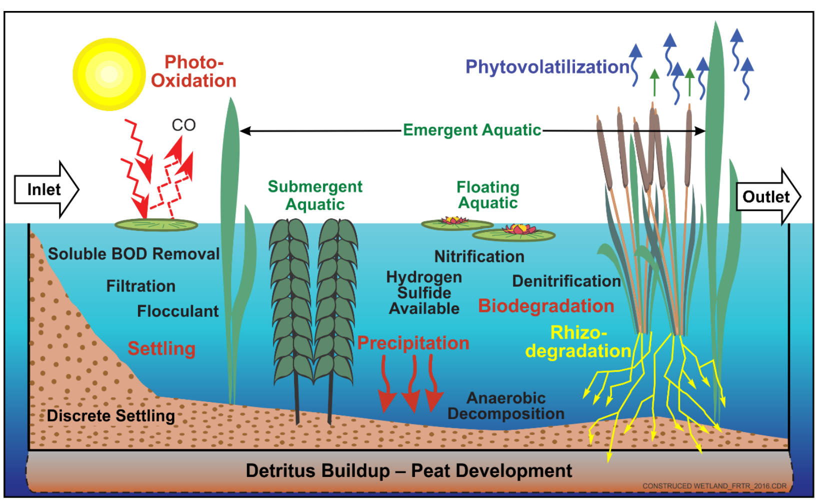
# Constructed Wetlands

On this page:

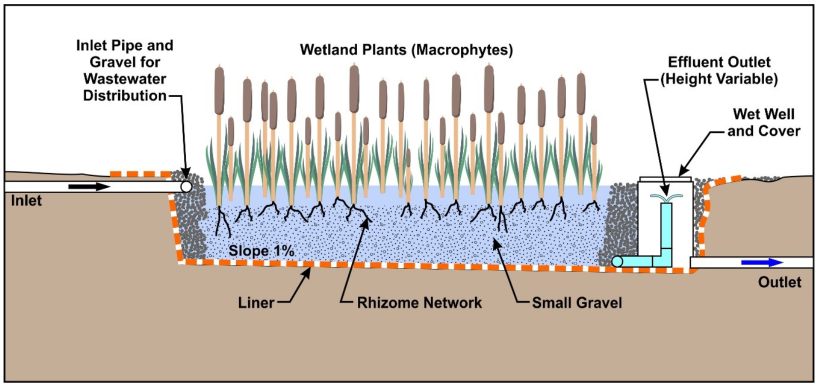


## Schematic




Schematic of Surface Flow Constructed Wetlands

*Adapted from the course "Creating and Using Wetlands for Wastewater and Stormwater Treatment and Water Quality Improvement" at University of Wisconsin, Madison*




Schematic of Subsurface Flow Constructed Wetlands

*From Tilley et al., 2014*

# Introduction

Constructed wetlands are manmade wetlands built either to treat pollutants or to offset the loss of wetlands elsewhere. This profile specifically discusses wetlands constructed to treat contaminants – typically in surface water, shallow groundwater, or waste streams such as leachate and acid mine drainage (AMD). A constructed treatment wetland is used to promote the action of natural, physical, geochemical, and biological processes to mineralize organic contaminants, immobilize inorganic contaminants, and remove suspended particulates. Constructed wetlands are considered a type of phytoremediation technology (see separate profile). Phytoremediation technologies include a broad range of processes that use vegetation and its associated microbiota, soil amendments, and agronomic techniques to remove, contain, or reduce the toxicity of environmental contaminants

# Other Technology Names

Constructed Treatment Wetlands
Artificial Wetlands
Treatment Wetlands
Constructed Subsurface Flow Treatment Wetland
Constructed Surface Flow Wetland
Reed Bed
Rock-reed Filters
Gravel Beds
Vegetated Submerged Beds
Root Method

# Description

A constructed wetland treatment system incorporates principal ecosystem components found in wetlands, including organic materials (substrate), vascular plants, microbial fauna, and algae. Influent waters, with organic contaminants, low pH, and/or metal contaminants (ITRC, 2003), flow through the aerobic and anaerobic zones of the wetland ecosystem. Large hydrophobic organics and metals are removed by ion exchange, adsorption, absorption, and filtration/flocculation/precipitation through geochemical and microbial oxidation and reduction. Sorption occurs as metals in the water contact humic or other organic substances in the soil medium. Oxidation and reduction reactions that occur in the aerobic and anaerobic zones transform or degrade organics and precipitate metals as hydroxides and sulfides. Precipitated and adsorbed metals settle in quiescent ponds and are subsequently filtered out as the water percolates through the soil or substrate. The majority of contaminant breakdown and precipitation is caused by microbial action. Microbial action in the root zone of plants, rhizodegradation, is the symbiotic relationship that occurs between plant root systems and microorganisms in the root zone. Plant roots excrete sugars, acids, and alcohols that contain organic carbon used by microorganisms as a food source. This provision enhances microbial activity in the root zone, resulting in a microbial contribution to soil contaminant degradation. Phytovolatilization removes contaminants from the subsurface and evaporates or volatilizes the contaminants from the leaf surface of the plant once the contaminant has traveled through the plant's system. Organic compounds in wastewater, measured as biochemical oxygen demand (BOD), are also broken down by microbial action through fermentation and aerobic/anaerobic respiration. Plant uptake and microbial denitrification can also address high nitrogen concentrations in wastewater streams.

The two major types of constructed wetlands are surface flow and subsurface flow. Surface flow wetlands consist of shallow basins in soil or any other media that will support plant roots. This type of wetland most closely mimics natural marshes. A surface flow wetland generally has a soil bottom, emergent vegetation, and a water surface exposed to the atmosphere. The water moves through the wetland above the substrate at low velocities in a quiescent manner. Areas of open water may or may not be incorporated into the design. Plants in these surface flow systems are able to withstand continuously saturated soil conditions and the corresponding anaerobic soils. Subsurface flow wetlands are generally constructed with a porous material such as soil, sand, or gravel for a substrate. They are designed so that water flows below ground surface through the substrate. Treatment in the subsurface flow system is more efficient than in the surface flow wetland because the media provides a greater number of small surfaces, pores, and crevices where treatment can occur. Contaminant-degrading bacteria can attach themselves to the various surfaces, and waste materials in the water may become trapped in the pores and crevices on the media and in the spaces between media. Sites with sandy or other highly permeable native soils may require that a liner be installed to retain water in the wetland and prevent the infiltration of the waste stream into groundwater. Some applications of treatment wetlands, such as for treatment of municipal and agricultural wastewater, require pretreatment of the water using settling ponds, aerated lagoons, or other technologies.

# Development Status and Availability

The following checklist provides a summary of the development and implementation status of constructed wetlands:

☐ At the laboratory/bench scale and shows promise

☐ In pilot studies

☒ At full scale

☒ To remediate an entire site (source and plume)

☐ To remediate a source only

☒ As part of a technology train

☒ As the final remedy at multiple sites

☐ To successfully attain cleanup goals in multiple sites

Constructed wetlands are available through the following vendors:

☒ Commercially available nationwide

☐ Commercially available through limited vendors because of licensing or specialized equipment

☐ Research organizations and academia

# Applicability

**Contaminant Class Applicability Rating for Constructed Wetlands**

**(Rating codes: ● Demonstrated Effectiveness, ◐ Limited Effectiveness, ○ No Demonstrated Effectiveness,**
**◊ Level of Effectiveness dependent upon specific contaminant and its application/design, I/D Insufficient Data)**

| Nonhalogenated VOC | Halogenated VOC | Nonhalogenated SVOC | Halogenated SVOC | Fuels | Inorganics | Radionuclides | Munitions | Emerging Contaminants |
|---|---|---|---|---|---|---|---|---|
| ◐ | ◐ | ◐ | ◊ | ◐ | ● | ○ | ● | I/D |

Constructed wetlands are used primarily to treat halogenated and nonhalogenated volatile organic compounds (VOCs), nonhalogenated semi-volatile organic compounds (SVOCs), and inorganics (ITRC, 2003). Constructed wetlands have most commonly been used in wastewater treatment for controlling organic matter, nutrients (such as nitrogen and phosphorous), treatment of leachate from landfills, and suspended sediments (e.g., agricultural runoff). The wetlands-based treatment process is also suitable for controlling trace metals and other toxic materials (e.g., AMD). Constructed wetlands have been used to treat AMD containing high concentrations of iron, sulfate, manganese, and other trace metals. These contaminants are passively treated by several wetland processes which may include adsorption, ion exchange, bioaccumulation, bacterial and abiotic oxidation, sedimentation, neutralization, and chemical reduction (ITRC, 2003). Constructed wetlands also have the buffering capacity to neutralize low pH AMD waters (ITRC, 2003). In the area of stormwater treatment, wetlands have shown the ability to remove fecal coliform bacteria, total petroleum hydrocarbons, and metals including lead, chromium, and zinc (ITRC, 2003). Complex chemical and biological processes can result in cycles of metal removal and release for those metals that are mobilized by reducing conditions which are often created in constructed wetlands. For example, the presence of organic matter can remove arsenic from water but also releases it from solid phases and therefore can increase arsenic concentrations in the aqueous phase (Lizama et al., 2011).

Wetland treatment has been applied with some success to wastewater in the eastern United States. The process may have to be adjusted to account for differences in geology, terrain, trace metal composition, and climate in the metal mining regions of the western United States.

Field demonstration projects have demonstrated the successful treatment of aircraft deicing fluids and munitions constituents using constructed wetlands (ITRC, 2003).

Wetland treatment is most applicable to sites having a relatively large available area, a source of year-round water, an appreciable growing season, and a relatively large volume of water requiring treatment with low to moderate contaminant concentrations. Subsurface flow systems require less land area than surface flow systems but are costlier to construct.

# Cost

Constructed wetlands are typically selected when land area and a sufficient water source are both available, water flow rates are high, but the contaminant concentrations are low to moderate. Design considerations should incorporate the surrounding landscape, geology, hydrography, and water quality. Treatability studies can be required and may involve an adaptive management approach in which a wetland is constructed that treats a portion of the targeted water, the performance is monitored, and adjustments are made. Major cost drivers include:

**Upfront Costs**

- Available land area and cost of land
- Terrain and climate
- Earthwork, engineered liner (if used), gravel, plants, hydraulic inlet and outlet structures, fencing, and piping

- Detention time required
- Treatment goals
- Media type and source location
- Need for pretreatment and type of pretreatment
- Number of cells
- Need for a liner

**Operation and Maintenance Costs**

- Wetland size and number of units
- Maintenance of any water distribution systems, including prevention of clogging
- Frequency and type of vegetation monitoring
- Need for vegetation management, odor control, and pest control
- Frequency and scope of monitoring for conventional parameters and contaminants

The list above highlights those cost dependencies specific to phytoremediation and does not consider the dependencies that are general to most in situ remediation technologies. Click here for a general discussion on costing which includes definitions and repetitive costs for remediation technologies. A project-specific cost estimate can be obtained using an integrated cost-estimating application such as RACER® or consulting with a subject matter expert.

# Duration

Wetland treatment is a long-term technology suitable for sites where time is less of an issue or wastewater management is a normal operational process. Regulators, community stakeholders, and site owners should mutually establish and understand a length of treatment time considered reasonable (ITRC, 2003). Factors that affect the duration of wetland operation and maintenance include the following:

- Cleanup goals
- Amount and concentration of contaminants
- Sediment erosion patterns
- Surrounding land use

- Wetland water balance
- Slope
- Local climate (i.e., aridity, rainfall, temperature)
- Organism type and density

# Implementability Considerations

The following are key considerations associated with implementing constructed wetlands:

- The long-term effectiveness of constructed wetland treatment is not well known. Wetland aging may contribute to a decrease in contaminant removal rates over time.
- The cost of building an artificial wetland varies considerably depending on such site conditions as topography, soil permeability, and climate.
- Contaminants removed from the system are bound in the sediment and accumulate over time.
- Constructed wetlands require more land area than many other treatment options.
- Surface flow wetlands can attract mosquitoes and other pests.
- Water distribution systems can clog.
- Improper designs may expose the odors of the waste stream.
- Wetlands are not appropriate for treating some wastewater with high concentrations of certain pollutants.
- The performance of wetlands may vary seasonally based on usage and climatic conditions.
- Complex chemical and biological processes can result in cycles of metal removal and release for those metals that are mobilized by reducing conditions which are often created in constructed wetlands.
- Biological components may be sensitive to toxins such as ammonia and pesticides.
- Treated effluent quality may not be consistent relative to water quality standards.
- Wetlands require a near continuous source of water and cannot withstand long-term droughts and complete drying.
- There may be a prolonged initial start-up period before vegetation is adequately established.

- Temperature and flow fluctuations can affect the function of the wetlands. Cold temperatures slow the rate of breakdown of organic contaminants. Also, water levels that are too high or too low can affect the survival of wetland plants and the functioning of the system.

# Resources

**American Petroleum Institute (API). The Use of Treatment Wetlands for Petroleum Industry Effluents (1998)**
This API report summarizes information about the use of treatment wetlands for managing petroleum industry wastewaters and also presents background information on the general performance, design, and operation of treatment wetlands based on experience with a variety of wastewater types.

**EPA. Constructed Wetlands Links Page**
This webpage provides links to handbooks, design manuals, case studies, and fact sheets pertaining to constructed wetlands.

**EPA. Fact Sheet Constructed Treatment Wetlands (2004)**
A fact sheet on how treatment wetlands work including design and planning considerations.

**EPA. Constructed Wetlands: Passive Systems for Wastewater Treatment (2001)**
This EPA-sponsored paper summarizes the status of constructed wetlands to remove contaminants from wastewater, and profiles several sites where constructed wetlands have been implemented for treatment applications other than municipal wastewater.

**EPA. Design Manual: Constructed Wetlands Treatment of Municipal Wastewater (2000)**
This document describes using constructed wetlands as a functional part of wastewater management.

**EPA. Guiding Principles for Constructed Treatment Wetlands (2000)**
A user's guide providing principles for planning, siting, design, construction, operation, maintenance, and monitoring of constructed treatment wetlands.

**ESTCP. Water Conservation: Tertiary Treatment and Recycling of Waste Water (2015)**
Project to demonstrate and validate an on-site wetland-based wastewater

treatment system that remediates and produces reclaimed non-potable water from graywater or blackwater by mimicking processes that occur in natural wetlands.

**ESTCP. Enhanced Biological Attenuation of Aircraft Deicing Fluid Runoff Using Constructed Wetlands (2004)**
A fact sheet for a field-scale, 0.6-acre subsurface flow wetland designed to treat runoff from the application of aircraft deicing fluid at Westover Air Reserve Base in Springfield, Massachusetts. Links to the final report and cost and performance report are included.

**ESTCP. Phytoremediation of Explosives-Contaminated Groundwater in Constructed Wetlands (1998)**
A project fact sheet for field demonstration of constructed wetlands technology to remove TNT, RDX, and other explosive compounds from groundwater at the Milan Army Ammunition Plant (MAAP), Tennessee. The site includes links to the final report and cost and performance reports for the project.

**Interstate Technical and Regulatory Council Technical (ITRC). Regulatory Guidance for Constructed Treatment Wetlands (2003)**
ITRC's Technical and Regulatory Guidance for Constructed Treatment Wetlands is designed to help regulators and others develop a consistent approach to their evaluation, regulatory approval, and deployment of specific technologies at specific sites.

**Katherin, L.A., Fletcher T.D., and G. Sun. Removal processes for arsenic in constructed wetlands. Chemosphere. 84(8):1032-43 (2011)**
This paper reviews current understanding of the removal processes for arsenic, discusses implications for treatment wetlands, and identifies critical knowledge gaps and areas worthy of future research.

**Tilley, E, Ulrich, L., Luethi, C., Reymond, P., and C. Zurbruegg. Compendium of Sanitation Systems and Technologies. 2nd Revised Edition. Duebendorf, Switzerland (2014)**
This compendium includes sections on surface flow and subsurface flow treatment wetlands.