



# Constructed Treatment Wetlands

Author: Julie Hawkins, USDA-NRCS, Richmond, Virginia

## Definition:

A sediment retention and nutrient removal treatment system that uses natural chemical, physical and biological processes involving wetland vegetation, soils and their associated microbial populations to improve water quality.

## Purpose:

Excessive phosphorus is contributed by wastewater effluent, urban runoff and agricultural point and nonpoint sources. Phosphorus is most often the limiting nutrient causing eutrophication of surface waters. Treatment wetlands are an ecologically engineered system that can be used in a full-scale waste treatment system to remove phosphorus. Phosphorus retention in wetland systems occurs via sorption, precipitation and incorporation, balanced by immobilization and, most importantly, sedimentation. Research has shown that treatment wetlands can be more affordable, reliable and practical to build and operate, as well

as more sustainable, than conventional treatment technology.

Treatment wetlands are designed to use water quality improvement processes occurring in natural wetlands, including high primary productivity, low-flow conditions and oxygen transport to anaerobic sediments. Treatment wetlands also help to minimize odor problems, reduce labor costs associated with hauling and applying effluent and provide aesthetic and wildlife benefits.

## How Does This Practice Work?

There are two types of constructed treatment wetlands: surface flow systems where wastewater flows as sheet flow above the ground surface and subsurface flow systems in which water flows horizontally and vertically through porous media. Which system is used and the design of each is based on influent wastewater characteristics, pollutant removal goals, wetland sizing equations and methods, amount

and timing of wastewater flows, land area, cost and availability of plants, media cost and permeability, suitable soils, discharge standards and regulatory requirements.

Depending on the source of the wastewater (nonpoint agricultural runoff, confined animal wastewater, etc.), pre-treatment is usually necessary due to the high levels of organic carbon, nitrogen and solids in the wastewater. Otherwise, the wetland system could be overloaded with oxygen-demanding pollutants and solids that would cause the wetland plants to die. Pre-treatment facilities can include lagoons, storage ponds or solids separators.

The key to designing a wetland system to the right size is to know the constituency of the pollutants, the load concentration, the desired effluent concentration and the sources and the amounts of water being added to the wastes, yielding the total wastewater volume in the wetland system. For example, the major water sources for an ag-

ricultural system are usually flushwater to remove manure from buildings, water for cleaning milking and milk-processing facilities, rainfall runoff from roofs and open lots and direct rainfall on pretreatment facilities and the wetland.

The fate of treated water must be determined when the wetland is designed. Various options include using the water to irrigate crop areas, for recycling as flushwater, discharging to a surface water or creating additional wetland and aquatic habitat on the farm.

### **Where This Practice Applies and Its Limitations:**

Treatment wetlands have been used as a water quality improvement technique in diverse climate regimes and with varying types of wastewater. Consideration of all effluent constituents and loading rates is very important. High biological oxygen demand (BOD), a measure of organic compound load, above the accepted range of 112 kg/ha/year will likely produce microbiologi-

cal processes that are entirely anaerobic and may lead to the collapse of the entire wetland system. High ammonia can lead to ammonia toxicity, and hence kill plants in the wetland system. Plants have various ranges of ammonia levels they can tolerate; these should be considered during design. Low pollutant loading rates for any wastewater constituent may not show any removal, as wetlands systems contain background levels of nutrients, carbon and metals.

Over the long term, phosphorus storage in wetland ecosystems is ultimately limited by sedimentation. In surface flow wetlands, the amount of phosphorus sorption sites is based on the amount of calcium (Ca), iron (Fe) and/or aluminum (Al) in the soil substrate. These exchange sites may become saturated. Additions of Al and Fe may be feasible, but would need to be added upstream from the wetland, as chemical contacting is not efficient. On the other hand, subsurface flow wetlands

can use media high in Al and/or Fe or Ca to provide a high amount of sorption sites.

The land area required to meet adequate detention times and treatment goals may be limiting and unavailable. In general, these systems should be engineered and constructed in uplands, outside U.S. waters, unless the source water can be used to restore a degraded or former wetland. Federal, state, tribal and/or local regulations may be applicable.

A wetland treatment technology may not be the most cost-effective, environmentally sensitive or technically reliable process for a given wastewater or project location. It is important to consider and compare all forms of treatment for the wastewater situation.

### **Effectiveness:**

When included as a component of a farm-wide waste-management plan, treatment wetlands are effective. However, they may prove ineffective without pretreatment of the wastewater containing high pollutant loads. The feasibility of treatment wetlands varies with waste characteristics, hydraulic retention time and climate. Extremes in meteorological conditions should be considered. Treatment function still occurs at lower temperatures, although at reduced rates, and may affect the detention time. High-precipitation events or snow melts may cause unplanned temporary exceeding of water storage and treatment capacity and should be considered and planned for during design.

Average reduction in phosphorus from wetland systems at dairy, cattle, swine,



poultry and aquaculture sites was determined to be 42 percent (range of 20-90 percent). However, increasing pretreatment or wetland area would increase this percentage to equal to or above that of conventional phosphorus treatment (57 percent). In comparison to conventional spray fields, treatment wetlands are estimated to remove three to seven times more phosphorus, depending on hydraulic residence time and vegetation planted.

This is a fairly new technology and is continuously developing. There are still gaps in the understanding of these systems that restrict our ability to achieve predictable and sustained levels of water quality improvement. Specifically, soluble phosphorus may increase as water moves through the wetland system, particularly as vegetation starts to mature. If reducing soluble phosphorus is the objective of a specific project, consider reviewing other best management practices as a better solution to removing soluble phosphorus than constructed treatment wetlands.

### **Cost of Establishing and Putting the Practice in Place:**

A variety of factors including detention time, treatment goals, depth of media, type of pretreatment, number of wetland cells, source and availability of gravel media and terrain (relatively flat topography recommended) will affect the cost of wastewater treatment wetlands. The capital costs of constructed treatment wetlands can be separated into land, excavation, liners, gravel (subsurface flow systems), plants, distribution and control structures and fencing. The single



most important factor affecting the capital cost is the cost of gravel. Second is the cost of the liner material.

The cost of a typical 50,000 ft<sup>2</sup> (4650 m<sup>2</sup>) subsurface constructed wetland is \$122,000. In general, the gravel was 43 percent of the total cost. Gravel, liner (\$32,000 – \$100,000 per ha) and excavation followed at 16, 11 and 10 percent, respectively. Plumbing and control structures and other minor items (e.g., fencing) made up the remaining percentages at 6, 6 and 8 percent, respectively. The costs are relative using a 2-foot (0.6 m) depth and typical unit prices that can be found in many places in the U.S.

In general, the median cost of surface and subsurface flow wetlands is \$20,000 per acre (\$47,000 per hectare) and \$145,000 per acre (\$378,000 per hectare), respectively. When compared to conventional treatment methods, treatment wetlands systems prove to be up to 30 percent cheaper when considering lifespan and replacement values.

To reduce earthwork costs, the designer can place smaller berms between adjacent cells and lower length-to-width ratios. When possible, the designer should use gravity flow, minimize pipeline distance and size, use open vegetated conveyance channels and radiating cells to minimize the cost and complexity of the inlet distribution system.

In general, constructed treatment wetlands are a simpler alternative and require more land and less energy to install and operate. As a return to users, lower utilities to operate these systems yield lower total costs. Although land requirements for constructed treatment wetlands are often more than conventional systems, the difference in the capital costs will be repaid by lower operation and maintenance costs in a relatively short period of time.

### **Operation and Maintenance:**

Operational costs can be divided into testing, water level adjustment, weed control, flow distribution and level

adjustment sumps. Operation and maintenance costs range from \$400 per year for surface flow systems to \$1000 to \$2000 per year for subsurface flow systems.

A long-term operations, maintenance, monitoring and funding plan that identifies the individuals responsible for maintenance and monitoring of the project, their responsibilities and funding mechanisms must be created.

Constructed treatment wetlands are operated and maintained by controlling the water's quality, quantity, depth and flow rate. Regular inspections of the constructed treatment wetland should be made that are case-specific and dependent on maintenance activities. These include checking weir settings and the inlet and outlet structures, cleaning off surfaces where solids and floatable substances have accumulated to the extent that they may block flows, removing nuisance species, maintaining the appearance and general status of the vegetation and removing sediment accumulations in forebays. Besides structures, periodic monitoring of parameters such as BOD<sub>5</sub>, TSS, nitrogen and phosphorus will guide the wetland operation.

The major concern in operating and maintaining constructed treatment wetlands is the clogging of the gravel medium. Limited data yield a range of 33 to 150 years, depending on the accumulation rate of senesced plant material and sediment. A conservatively estimated minimum of 33 years will aid in the planning process for replacing such items as gravel.

Adaptive management and manipulation are key engineering factors that must be incorporated into design and operation of treatment wetland systems. It is necessary to achieve and exceed performance objectives within a minimal space, with minimal effort and external resources and with maximum reliability.

### References:

Campbell, Craig S. and Michael H. Ogden. 1999. *Constructed Wetlands in the Sustainable Landscape*. John Wiley & Sons, Inc. New York, NY, 270 p.

CH2MHill. 2001. *Constructed Wetlands and Wastewater Management for Confined Animal Feeding Operations*. CH2MHill, Gainesville, FL, 23 p.

Clarke, Ernest and Andrew H. Baldwin. 2002. *Responses of wetland plants to ammonia and water level*. *Ecological Engineering* 18:257-264.

Cronk, Julie K. 1996. *Constructed wetlands to treat wastewater from dairy and swine operations: a review*. *Agriculture, Ecosystems and Environment* 58: 97-114.

DeBusk, Thomas A., James E. Peterson and K. Ramesh Reddy. 1995. *Use of aquatic and terrestrial plants for removing phosphorus from dairy wastewaters*. *Ecological Engineering* 5: 371-390.

Kadlec, R.H. and R.L. Knight. 1996. *Treatment Wetlands*. Boca Raton, FL, CRC Press/Lewis Publishers.

U.S. Environmental Protection Agency. 2000. *Guiding Principles for Constructed Treatment Wetlands: Providing for Water Quality and Wildlife Habitat*. Washington, DC, EPA 843-B-00-003, 41 p.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2002. *Chapter 3: Constructed Wetlands*. National Engineering Handbook, Environmental Engineering. Washington, DC, 74p.

Werker, A.G., J.M. Dougherty, J.L. McHenry and W.A. Van Loon. 2002. *Treatment variability for wetland wastewater treatment design in cold climates*. *Ecological Engineering* 19:1-11.

White, Jay S., Suzanne E. Bayley and P. Jeff Curtis. 2000. *Sediment storage of phosphorus in a northern prairie wetland receiving municipal and agro-industrial wastewater*. *Ecological Engineering* 14:127-138.

### For Further Information:

Contact your local conservation district, USDA-NRCS or Cooperative Extension Service office.