Atlantic Committee on Land and Engineering

Constructed Wetlands for the Treatment of Agricultural Wastewater in Atlantic Canada

Original Publication: 1998
Revised: 2005

What are constructed wetlands?

Constructed wetlands are shallow, manmade aquatic systems that can provide an environment for treating agricultural runoff and wastewater. They have recently become popular as a result of their low cost and potential effective treatment of agricultural effluents. Constructed wetlands may replace the need for an expensive storage or conventional wastewater treatment system.

Constructed wetlands have the added benefit of providing excellent habitat for birds and other aquatic species.

Figure 1. Wetland treating dairy wastewater on Prince Edward Island.

What types of wastewater can they be used to treat?

Constructed wetlands have been utilized as secondary and tertiary treatment systems for several types of wastewater including:

- milkhouse washwater from dairy operations;
- manure storage and feedlot runoff;
- drainage tile outflow;
- agricultural field surface runoff; and
- food processing wastewater.

Under Atlantic Canada climatic conditions, wastewater entering a constructed wetland should have:

- Biochemical Oxygen Demand (BOD5) < 1000 mg L-1
- Total solids < 1500 mg L-1
- Ammonia <80 mg L-1

How do they work?

Constructed wetlands utilize a series of physical, biological and chemical processes which facilitate the year round treatment of wastewater. More specifically:

Most aquatic vegetation placed in constructed wetlands (eg. cattails) have large and extensive root systems which help provide oxygen rich environments that support aerobic bacteria which breakdown organic material in the wastewater (Fig. 2).

Figure 2. Cattails one year after planting in the shallow zone of a constructed wetland.

Constructed wetlands provide a combination of aerobic (shallow vegetated area) zones to transform ammonia (NH_3-N) to nitrate (NO_3-N) and anaerobic deep zones to convert the NO_3-N into nitrogen gas which leaves the system.

Constructed wetlands provide an environment conducive to the settling and filtration of solids (Fig. 3).

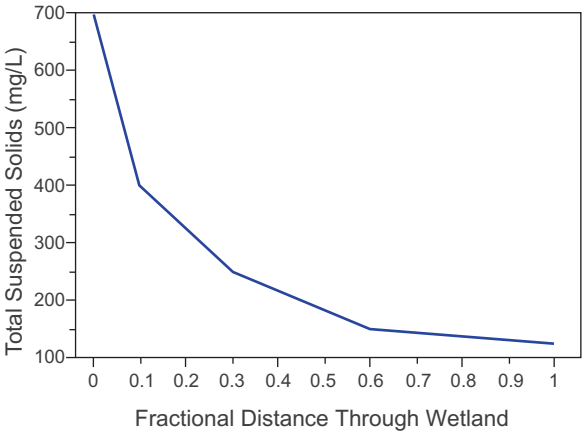

Figure 3. Removal of total suspended solids from the wastewater as it moves through a constructed wetland in Pictou County, Nova Scotia.

Phosphorus removal from the wastewater occurs through adsorption to soil and sediment surfaces as well as precipitation reactions (Fig. 4).

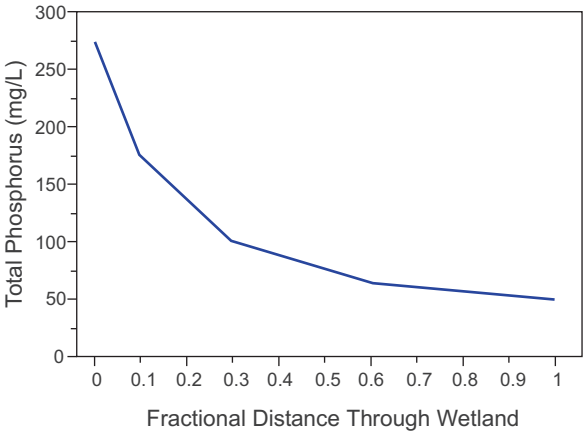

Figure 4. Removal of phosphorus from the wastewater as it moves through a constructed wetland in Pictou County, Nova Scotia.

Fecal coliform bacteria attached to suspended solids die as a result of remaining outside of their host organisms, through degradation by ultra-violet radiation, and from toxins excreted from the roots of the aquatic vegetation.

How well have they worked in Atlantic Canada?

Several wetlands have been constructed on agricultural operations throughout Atlantic Canada and many have been extensively monitored. In most cases, the concentration of wastewater pollutants has been reduced by 70 - 98 %.

Additionally, a reduced volume of wastewater leaves the system compared to the inflow volume. This is primarily due to high evapotranspiration rates during the growing season.

What are the main design considerations?

Adequate system design is the most important aspect during construction of a wetland. Consider the following planning and design details prior to construction:

Before construction, a qualified engineer should be consulted to design the constructed wetland. As well, required building and environmental permits must be obtained from proper authorities.

Constructed wetlands should only be designed as secondary or tertiary wastewater treatment systems. The size of a wetland must be based on the estimated wastewater inflow volume, the concentration of pollutants in the wastewater entering the wetland and the desired level of treatment.

Site selection is very important. The constructed wetland will be more economical to build if it is located on a site close to the wastewater source and if the wastewater can flow by gravity into wetland.

Permeability tests should be performed early in the planning stage. If the wetland is constructed on a site where soils are too permeable (hydraulic conductivity greater than $1x10^{-5}$ cm sec^{-1}), it will be difficult to maintain adequate water levels through the summer months and there will be a high risk of ground water contamination. Under these conditions, a clay or synthetic liner will be necessary. If a liner is required it will add to the cost of the wetland and may be a reason to consider other options.

Many agricultural wastewater sources produce small volumes of effluent. During the summer months evaporation rates from the wetland surface are often higher than inflow volumes. To maintain water levels in the wetland additional water from an alternative source, such as roof gutters or the surrounding watershed, may have to be added to the system.

Wastewater must be retained in a settling pond prior to entering the wetland to allow for adequate separation of solids. This pond should be less than 1 m deep to ensure aerobic conditions. This will reduce the potential for odour generation.

Wetland are more efficient during the summer months. It may be desirable to design the system so that the settling pond is large enough to store the entire volume of wastewater produced during the winter months and to discharge it to the wetland only during the warmer period of the year.

The proposed site must be surveyed in order to produce an accurate topographical map. The design layout of the system will be dependant upon topography.

Constructed wetlands may contain one cell or several individual cells depending upon the topography at the site. Where the proposed construction site is on a slope it may be desirable to construct individual cells in a terrace type system (Fig. 5).

Figure 5. Aerial photo of constructed wetland in Pictou County, Nova Scotia on a 5% slope using a terrace type system.

Wastewater should be discharged to any lower cell within the terraced system via a parabolic rock lined chute underlain by a suitable geotextile. The turbulence of the flow at these locations will allow for additional oxygen to enter the wastewater stream. The topography within each wetland cell should be relatively level over the entire cell to ensure an even distribution of water over the wetland surface and prevent concentrating flow into channels.

Figure 6. Deep and shallow zones of wetland with berm constructed from subsoil.

Individual wetland cells should include both deep and shallow zones. As a rule, each cell should be at least twice as long as it is wide (Figs. 5 – 6). Shallow zones within the wetland should have operating depths ranging between 15 – 30 cm. The deep zones within the wetland help to evenly distribute water while adding to the retention time as the wastewater passes through the wetland. Deep zones should constitute approximately 25% of the surface area of the wetland and they should be at least 1 m deep to prevent the growth of aquatic plants (Fig. 7).

Wastewater is contained within constructed wetlands by earthen berms. The perimeter berms of the wetland should be approximately 1 m higher in elevation than the operating depth of the wetland. Typical side slopes of 1.5:1 are recommended. The berms should have a top width of at least 1 m (Fig 7).

Inflow and outflow structures may be considered to accurately control water levels in the wetland. In their absence, the water level in the wetland can be controlled by ensuring that the soil in the parabolic channel constructed at the outlet of any wetland cell is 15 – 30 cm higher in elevation than the upper elevation of the topsoil installed in the shallow zone in the cell above it.

The outflow from a constructed wetland should receive final polishing by either

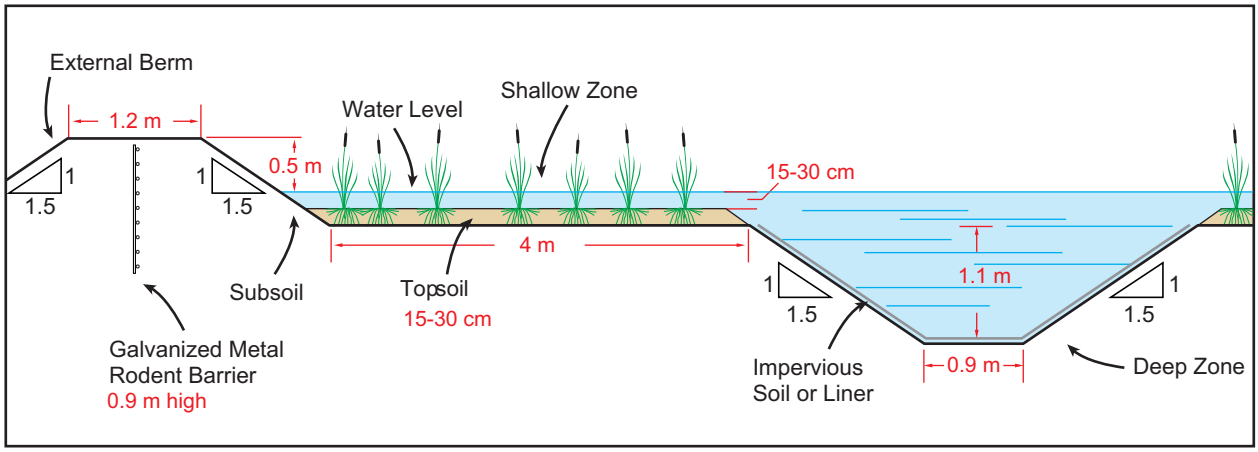

Figure 7. Cross section of concentrated wetland showing both deep and shallow zones and the external berm.

discharging it to a tertiary pond or by discharging it to a grassed waterway. The establishment of aquatic vegetation (cattails and bulrushes) is best achieved by direct transplant of plants, roots and soil from a nearby natural wetland. This material should be spread over the entire surface area of the shallow zones in the constructed wetland at a density of 1 plant m-2 (Fig. 8). A permit may be required from the Provincial Department of the Environment to remove cattails from existing wetlands.

Figure 8. Cattail transplants shortly after placement in the shallow zone of the wetland.

How is a wetland constructed?

Wetlands should be constructed in the following sequence:

- Perform permeability tests to ensure that the hydraulic conductivity of the soil is acceptable.
- Prior to construction, till the site with either a heavy set of tandem discs or a set of offset discs.
- Strip the topsoil from the entire construction site.
- Survey the site and establish required cuts and fills.
- Level the shallow areas by moving subsoil and construct the perimeter berms with subsoil from the deep zones.
- Install a clay or synthetic liner if required.
- Spread the topsoil that had been originally stripped from the site over the entire surface area of the shallow zones to provide rooting medium for the aquatic vegetation (Fig. 9).
- Plant the aquatic vegetation.

Figure 9. Cattails growing in the shallow zone of a constructed wetland in Pictou County, Nova Scotia.

What are the management requirements/considerations of constructed wetlands?

After the construction is complete, several on-going management requirements are necessary to achieve maximum performance of the wetland.

A build-up of solids may eventually occur within the pretreatment settling pond which will necessitate its removal and field application. Build-up of solids should be examined on an annual basis.

Wetlands are prone to drying up during the summer months. This may result in aquatic vegetation being killed off and possible cracking of the clay liner. To prevent this, water may have to be pumped into the system to maintain adequate water levels during prolonged dry periods.

Depending on the loading rate and the aquatic plant population in the wetland, some excavation of sediment material and plant litter may be required. If sediments become saturated with phosphorus, they may need to be removed.

Muskrats and other rodents can burrow through the wetland berms and cause water levels to drop. They also have been known to destroy aquatic vegetation. Steps should be taken to control their populations. Installation of a vertical galvanized wire mesh in thecentre of the berms may help achieve this.

Figure 10. Constructed wetland showing the deep and shallow zones in Pictou County, Nova Scotia.

Prepared by: *Nathan Boyd* *Rob Gordon* *Laurie Cochrane*
Rob Jamieson *Ron DeHaan* *Vimy Glass*

On behalf of the Atlantic Committee on Land and Engineering