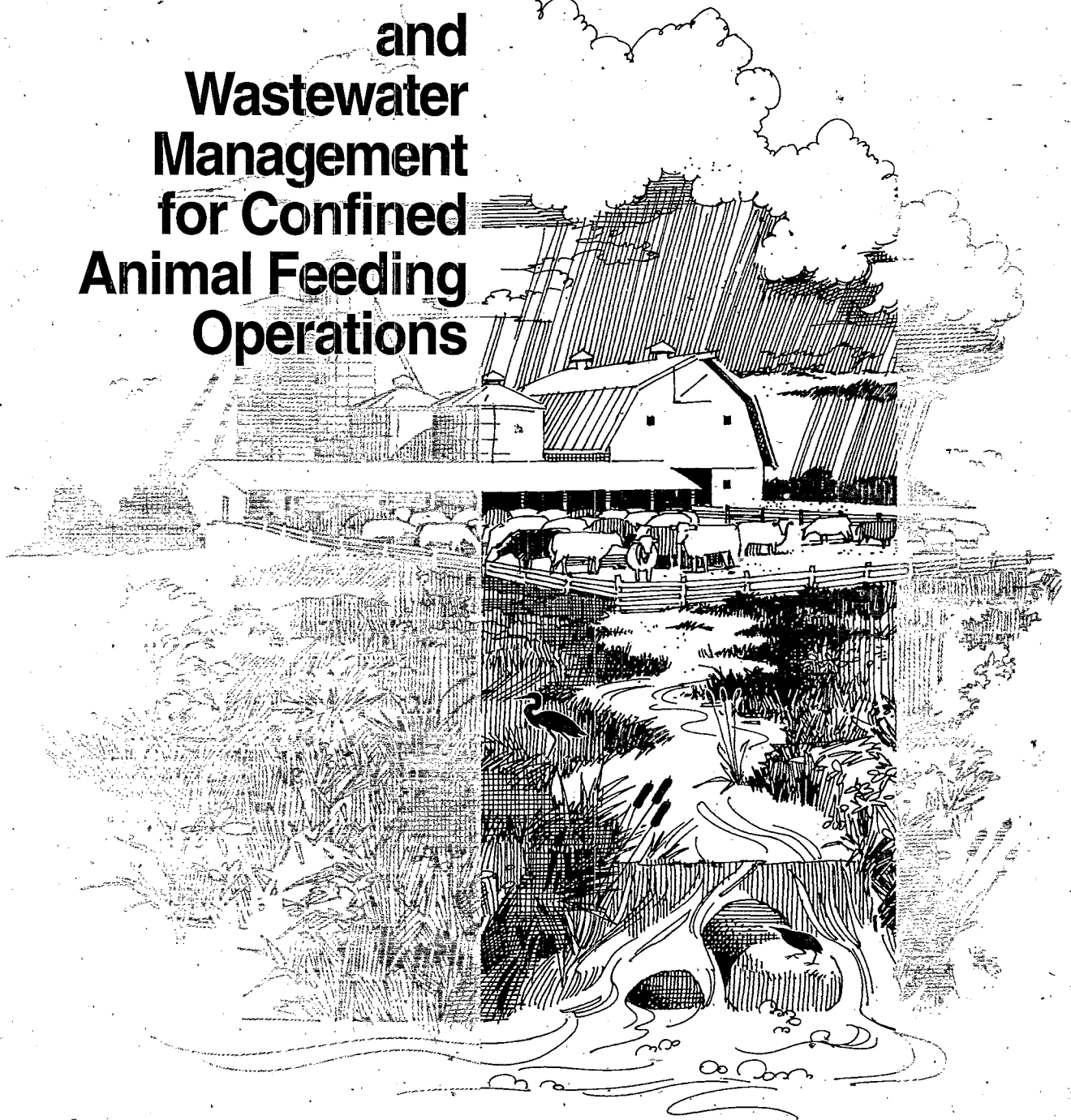


# Constructed Wetlands

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and  
Wastewater  
Management  
for Confined  
Animal Feeding  
Operations



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# **Constructed Wetlands and Animal Wastewater Management**

Dairy, cattle, swine, and poultry producers can help improve the quality of our streams, lakes, rivers, and estuaries by reducing the amount of pollutants released with wastewater. To do so, producers need practical and cost-effective ways to treat wastewater before it leaves the farm. One of those treatment options is a constructed wetland—a treatment system that uses natural processes to improve water quality. Constructed wetlands have been treating other kinds of wastewaters for many years, and, as this brochure demonstrates, they show promise for treating wastewaters from confined animal feeding operations as well. Designed to be an overview of how wetland systems can be used to manage wastewater, this brochure introduces the following topics:

- What wetland systems are and how they work
- How wetland systems have performed for existing confined animal feeding operations
- How to incorporate a wetland into a wastewater management system
- What is involved in designing and constructing a wetland system
- Where to get more information

## Relationship between Confined Animal Production and Water Quality

After 30 years of trying to reduce water pollution, it is still a major concern in North America. We have made progress with reducing the amount of pollution discharged in pipes (called point source pollution). Now we are paying more attention to reducing pollution that enters water bodies through surface runoff. This type of water pollution is called nonpoint source pollution and is typically contributed by land-intensive activities such as agriculture, forestry, and mining, and urban/commercial development.



*Applied in excess, the land or water cannot handle the nutrients and pathogens in wastewaters from aquaculture and other confined animal feeding operations. As a result, the ecological balance is disrupted, and plants and animals die.*

Agriculture has been identified as one of the major generators of nonpoint source pollution. Eroded soils, farm chemicals, and manure find their way into streams, lakes, rivers, and estuaries. As a result, agricultural producers have been and will continue to be asked to reduce the amount of pollution leaving the farm. At the same time that producers are being asked to reduce pollution, agricultural operations are becoming more concentrated, making wastewater management an even more important issue.

Farmers and ranchers have already responded to concerns about water quality by taking steps to reduce the amount of pollution they generate and release into the environment. The greatest progress has been in the control of soil erosion, which has reduced the amount of solids entering water bodies.

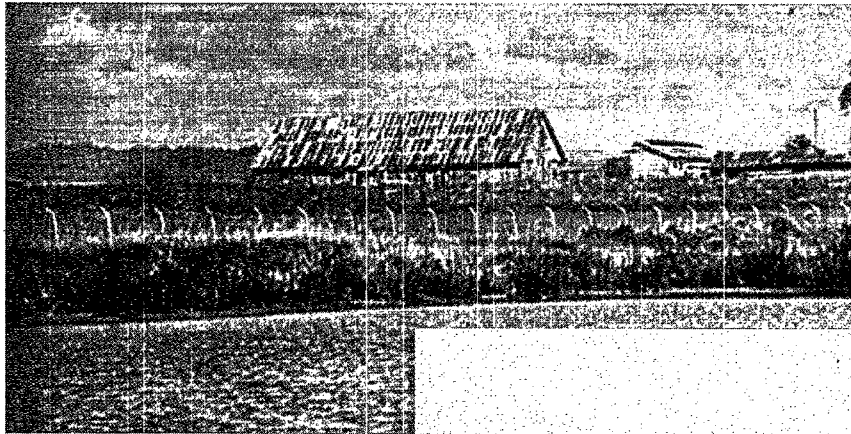
For many confined animal feeding operations, the challenge is to prevent manure from being discharged with the water. The organic matter and nutrients in the manure are important resources that need to be recycled to the land to maintain high crop productivity. However, released into natural water bodies, the organic matter and nutrients promote algal growth and deplete dissolved oxygen, leading to further problems.


To reduce pollution while maintaining or increasing productivity, confined animal operators need practical ways to either prevent wastewater from entering surface water and groundwater or treat the water before it leaves the farm. Operators want wastewater management systems that are affordable, reliable, and practical to build and operate.

Today, various technologies are available to treat wastewater in ways that use the natural chemical, physical, and biological processes of the environment and that rely on nature's energies.

One of these technologies is a constructed wetland system. Constructed wetlands mimic the water purification properties of natural wetland systems. These constructed wetlands use the same plants, soils, and microorganisms as natural wetlands to remove contaminants, nutrients, and solids from the water. Constructed wetlands have been used for years to treat municipal wastewater, industrial wastewater, and stormwater. More recently, they have been used in confined animal feeding operations before discharge or land application of wastewater.

Results from existing constructed wetlands on farms suggest that these systems can help in several ways. Constructed wetlands can remove solids and nutrients from wastewater so that more effluent can be land applied to a given area or discharged to surface water. Constructed wetlands also help minimize odor problems, reduce labor costs associated with hauling and applying effluent, and provide aesthetic and wildlife benefits. Constructed wetlands can be integrated into the farm in a way that benefits the operator and neighbors.



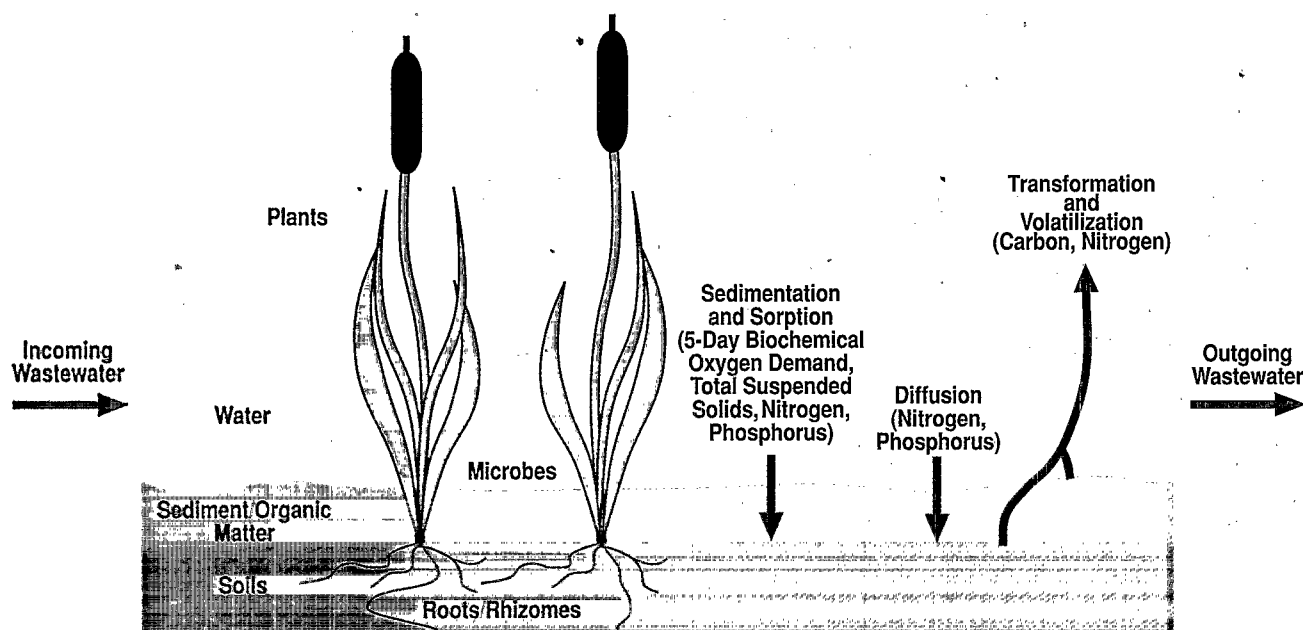
 In addition to treating wastewater, wetland systems can be attractive additions to farming operations.



# How Wetlands Work

Once considered worthless, wetlands are now recognized as one of the most diverse and productive ecosystems in the world. Wetlands clean water, produce food and fiber, provide wildlife habitat, recharge the groundwater, reduce flooding, and offer recreational opportunities.

Natural wetlands have received wastewater ever since people began to live in towns and cities. Scientists soon realized that natural wetlands were more than just a convenient disposal site—the wetlands were actually cleaning the water. As a result, researchers began to investigate using natural and constructed wetlands purposely to improve water quality. Some of the earliest investigations were in Europe, and since then treatment wetlands throughout North America have been studied, mostly for treating municipal and industrial wastewaters and stormwater. Using wetlands specifically for improving water quality has been studied for about 40 years. During the past 5 to 10 years, this technology has been researched for treating wastewater from confined animal feeding operations in particular.



*Wetland treatment systems use natural processes and energies to transform or trap pollutants.*

All treatment wetlands, constructed or natural, have the same general components of landform, water, soil, plants, microbes, plant litter (also called organic matter or detritus), and fauna. As a result of physical, biological, and chemical processes that take place in a wetland environment, many pollutants in the water flowing through the system are transformed or inactivated. The low flow rate of the water and the long time the water stays in

the wetland (called residence time) result in the settling and trapping of solids in the wastewater.

The plants provide a place for microbes to attach. These microbes take nutrients from the water to grow. The processes by which microbes transform and remove pollutants from the water are complex. With nitrogen, for example, microbes ammonify nitrogen (convert organic nitrogen to ammonia, which is used by plants as a nutrient); nitrify nitrogen (convert ammonia to nitrite and nitrate, which is used by bacteria and some plants for growth); and denitrify nitrogen (volatilize nitrogen, which is lost to the atmosphere). As a result of these processes, excess nitrogen is removed from the water.



*Constructed wetlands provide multiple benefits, including wildlife support.*

Wetland plants also absorb nutrients, and like the microbes, they convert the nutrients into a form that they use for growth. As the process of uptake, transformation, and release of nutrients in the wetland repeats itself, some of the nutrients in the system are trapped in the soils or released into the air. The result is water that is cleaner than when it entered the wetland.

Although some natural wetlands still receive highly treated wastewater, more often constructed wetlands are being designed and built to treat higher strength wastewaters. Wetlands are constructed by excavating a shallow area, installing water control structures, and planting wetland vegetation. If the site has highly permeable soils, additional excavation may be required so that an impervious, compacted clay liner can be installed. In this case, the original soil is placed over the liner to be the growth medium for plants. The wetland vegetation is either planted manually or allowed to grow naturally from seeds. Wastewater flows across the bottom at a shallow depth, receiving treatment as it meanders through the plant stems and litter.

# Performance of Existing Wetland Systems

Although more than 68 animal wastewater treatment wetlands exist in North America, the study focused on systems with published information on the wetland's design and performance. The map below shows the number of systems found in each state or province.

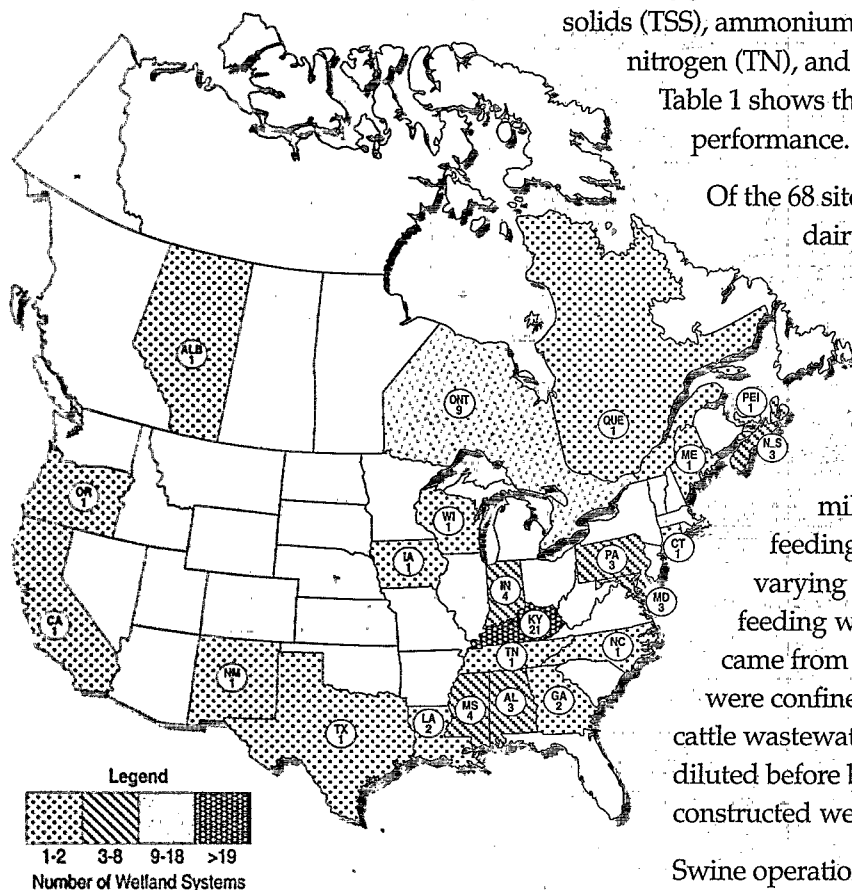
Constructed wetlands have been improving water quality at confined animal feeding operations for years. The study of published information that led to this brochure was based on accounts of farms using such systems throughout the United States and Canada. In fact, despite skepticism that wetland systems would work in cold climates, research has shown that these systems function even under ice and snow.

A literature review identified information for 68 different sites using constructed wetlands to treat wastewater from confined animal feeding operations. Overall, the wetlands reduced the concentration of wastewater constituents such as 5-day biochemical oxygen demand (BOD<sub>5</sub>), total suspended solids (TSS), ammonium nitrogen (NH<sub>4</sub>-N), total nitrogen (TN), and total phosphorus (TP).

Table 1 shows the average treatment performance.

Of the 68 sites identified, 46 were at dairy and cattle feeding operations. The herd sizes ranged from 25 to 330, with an average of 85 head. Dairy wastewater often included water from milking barns and from feeding/loafing yards with varying characteristics. Cattle feeding wastewaters typically came from areas where animals were confined. Usually, dairy and cattle wastewaters were pretreated or diluted before being discharged to constructed wetlands.

Swine operations accounted for 19 of the wetland sites in the study. Swine wastes were collected using flushwater from solid floor barns and paved lots, or they were collected directly from slatted floors in farrowing or nursery barns. In many cases, the wastewater was pretreated in lagoons and then discharged to a wetland system to further reduce concentrations to a level that could be applied to the land.





For poultry and aquaculture farms, the study found published information on constructed wetlands at one poultry site and two aquaculture sites. Although the data in this brochure do not cover all animal waste categories, they apply in general to planning new wetland systems.

**TABLE 1**  
Summary of Average Performance of Wetlands Treating  
Wastewater from Confined Animal Feeding Operations<sup>a</sup>

Wastewater Constituent	Average Concentration (mg/L) <sup>b</sup>		
	Inflow	Outflow	Average Reduction (%)
5-Day biochemical oxygen demand (BOD <sub>5</sub> )	263	93	65
Total suspended solids (TSS)	585	273	53
Ammonium nitrogen (NH <sub>4</sub> -N)	122	64	48
Total nitrogen (TN)	254	148	42
Total phosphorus (TP)	24	14	42

<sup>a</sup>Data from the Livestock Wastewater Treatment Wetland Database (LWDB), which includes wetland systems at dairy, cattle, swine, poultry, and aquaculture sites (Knight et al. 1996). <sup>b</sup>Average concentration is based on a hydraulic loading rate of 1.9 inches per day (50,000 gallons per day per acre [gpd/ac]). Averages were calculated from data for 30 to 86 systems. mg/L = milligrams per liter

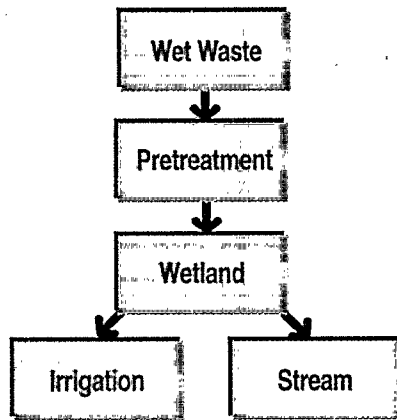
Although percent reductions of 42 to 65 percent are impressive, the average outflow concentrations in Table 1 are not low enough to allow discharge to surface water; instead, the effluent is usually collected and land applied. However, by reducing pollutant loadings to constructed wetlands by increasing pretreatment or the wetland area, effluent pollutant concentrations would approach those typical of municipal treatment wetlands summarized in Table 2. In some cases, the effluent may be suitable for discharge to surface waters.

**TABLE 2**  
Summary of Average Performance of Wetlands Treating  
Municipal Wastewater<sup>a</sup>

Wastewater Constituent	Average Concentration (mg/L) <sup>b</sup>		
	Inflow	Outflow	Average Reduction (%)
BOD <sub>5</sub>	30	8	74
TSS	46	14	70
NH <sub>4</sub> -N	4.9	2.2	54
TN	9.0	4.3	53
TP	3.8	1.6	57

<sup>a</sup>Data from the North American Treatment Wetland Database (NADB) (Knight et al. 1993). <sup>b</sup>Average concentration is based on a hydraulic loading rate of 1.3 inches per day (34,000 gpd/ac).

# Incorporating a Constructed Wetland into a Wastewater Management System



*A wetland system can provide final polishing before the wastewater is applied to the land or discharged to surface waters.*

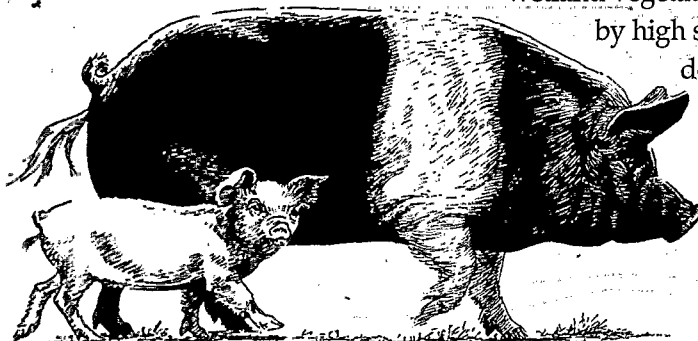
Typically, producers use a variety of methods to manage wastewater. Some of these methods are lagoons, ponds, storage structures, compost areas, filters, and sediment basins. A constructed wetland offers another option for polishing wastewater before it is recycled as flushwater, land applied, or ultimately discharged. This section discusses the following important considerations to evaluate whether a constructed wetland is right for your operation:

**System goals**—In what cases would a wetland system be beneficial? A wetland can help decrease wastewater pollutant levels, decrease odors, reduce the amount of land needed for wastewater application, meet surface water discharge regulations, and enhance the landscape.

**Pretreatment**—Does the wastewater need to be treated before it goes to the wetland system? Nearly always, wastewater from confined animal feeding operations needs to be pretreated. Otherwise, high pollutant concentrations may overload the wetland system.

**Wastewater characteristics**—What pollutants are in the wastewater? Nitrogen, phosphorus, and organic, oxygen-demanding substances (measured as BOD<sub>5</sub>) are the main pollutants of concern. Information on these pollutants is important to adequately size a constructed treatment wetland and determine effluent concentrations.

**Wastewater volume**—How much wastewater will be discharged to the wetland? The calculation of wastewater volume is critical to designing a successful treatment wetland. Dilution water is often needed to protect the wetland vegetation from being harmed by high strength wastes and from dessication when water volume is inadequate.



## Wetland System Goals

A wetland system can be helpful in the following situations:

**When the wastewater is too high in nutrients to apply to the land available.** To minimize the risk of contaminating surface and groundwater by applying too many nutrients, a producer with limited land and high-nutrient wastewater must either (1) convert to a crop that can handle higher nutrient loads or (2) find a way to reduce nutrient loads. A wetland system can reduce total nutrient loads and therefore reduce the amount of land needed at the application site. This, in turn, decreases the amount of time spent hauling or irrigating and may allow the use of smaller and more cost-effective spreading equipment.

**When you want to reduce odors at the land application site.**

Odors can be a problem when wastewaters from confined animal feeding operations are taken directly from a treatment or storage unit and applied to the land. A wetland system reduces odors, thereby minimizing the chance for nuisance complaints during land application.

**When you want to discharge wastewater to surface water, and the effluent must meet National Pollutant Discharge Elimination System (NPDES) or more stringent local requirements.** As part of an overall wastewater system with adequate pretreatment, a constructed wetland can further lower concentrations of BOD<sub>5</sub>, TSS, fecal bacteria, and nitrogen.

**When aesthetics and wildlife enhancement are important.**

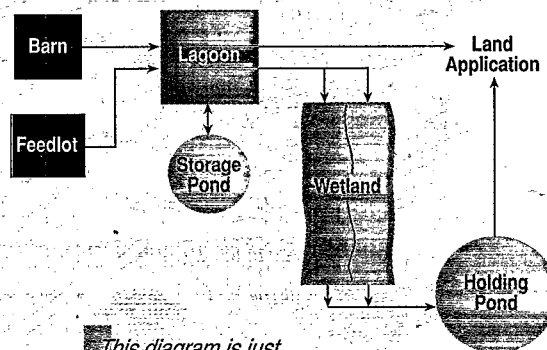
A constructed wetland can be an attractive addition to the landscape while providing excellent habitat for wildlife. These may be desirable features for the conservation-minded producer, and for the producer who wants to enhance the image of the confined animal feeding operation in the eyes of neighbors.

### Pretreatment

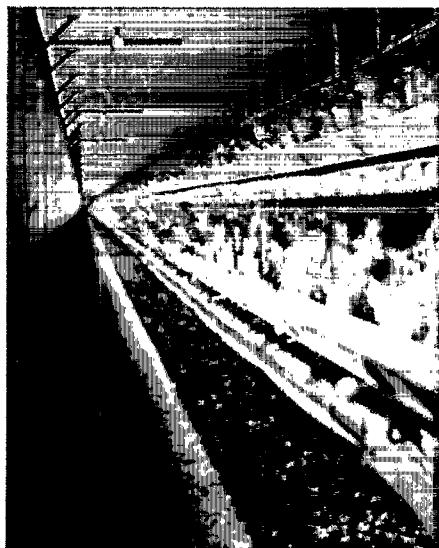
In most confined animal wastewater management systems, the wastewater must be pretreated before land application or discharge to other treatment units. The use of wetland systems does not eliminate the need for pretreatment. In fact, because of the high levels of organic carbon, nitrogen, and solids in the wastewater, pretreatment is usually necessary. Otherwise, the wetland system could be overloaded with oxygen-demanding pollutants and solids that would cause the wetland plants to die.



*Incorporating a treatment wetland into an overall wastewater management system can significantly reduce the amount of pollutants leaving the farm.*



*This diagram is just one example of how a wetland can fit into a wastewater management system.*



*As confined animal  
operations become more  
concentrated,  
wastewater management  
becomes even more  
complicated and  
important.*

The following three pretreatment practices can be used before discharging wastewater to a wetland for final polishing:

- **Lagoons** are used to settle solids and phosphorus, convert nitrogen and organic materials, temporarily store wastewater, and dilute wastewater with rainfall. This is usually the recommended pretreatment method.
- **Storage ponds** are used to collect manure and miscellaneous by-products for a specific storage period. Typically, discharge from a storage pond passes through a treatment lagoon before going to a constructed wetland.
- **Solids separators** collect solids and pass the liquid portion of the wastewater to another treatment or storage process. Solids separators remove 40 to 60 percent of solids and a significant fraction of the nutrients in wastewater. As with a storage pond, discharge from solids separators typically pass through a lagoon before going to a constructed wetland.

## **Wastewater Characteristics**

Before designing a wetland system, you should know the quantities of major pollutants in the wastewater. This information, called pollutant load, is key to selecting the correct wetland size so that the wetland removes pollutants at the rates you expect.

Animal wastes are often classified according to moisture content (solid, slurry, or liquid). Solid wastes consist of manure and possibly bedding material such as straw or wood chips. Solid and slurry wastes usually have very high nutrient concentrations and are good soil amendments. However, these wastes, whether fresh or stored, should not be applied directly to wetlands, or the plants will die.

Liquid wastes consist of manure, flushwater, contaminated rainfall, and other liquids and solids that come into contact with the manure. In most cases, the amount of water added to the system greatly exceeds the amount of manure. Liquid wastes are typically collected and treated in a lagoon or storage pond before being land applied.

The *Agricultural Waste Management Field Handbook* (USDA NRCS 1992), the engineering standards of the American Society of Agricultural Engineers (1985), and other technical books and publications provide information on average volumes of manure (feces and urine) and average production rates of certain pollutants produced by different types of livestock. Average quantities and concentrations of nitrogen, phosphorus, and BOD<sub>5</sub> in manure are summarized in Tables 3 through 6.

TABLE 3  
Swine: Approximate Waste Quantities

	Unit <sup>a</sup>	Growers (40 to 220 lbs)	Replacement Gilts	Sows		Boars	Nursing / Nursery Pigs (6 to 40 lbs)
				Gestation	Lactation		
Mass	lbs/d	63.4	32.8	27.2	60.0	20.5	106
Volume	ft <sup>3</sup> /d	1.0	0.53	0.44	0.96	0.33	1.70
Nitrogen	lbs/d	0.42	0.24	0.19	0.47	0.15	0.60
Phosphorus	lbs/d	0.16	0.08	0.063	0.15	0.05	0.29
BOD <sub>5</sub>	lbs/d	2.08	1.08	0.83	2.00	0.65	3.40

<sup>a</sup> Units per 1,000 lbs of animal weight. Source: USDA NRCS 1992.  
lbs = pounds      d = day      ft<sup>3</sup> = cubic feet

TABLE 4  
Dairy: Approximate Waste Quantities

	Unit <sup>a</sup>	Cow		Heifer
		Lactating	Dry	
Mass	lbs/d	80.00	82.00	85.00
Volume	ft <sup>3</sup> /d	1.30	1.30	1.30
Nitrogen	lbs/d	0.45	0.36	0.31
Phosphorus	lbs/d	0.07	0.05	0.04
BOD <sub>5</sub>	lbs/d	1.60	1.20	1.30

<sup>a</sup> Units per 1,000 lbs of animal weight. Source: USDA NRCS 1992.

## Wastewater Volume

In addition to the waste quantities being generated (also called pollutant load), you must identify the sources and amounts of water being added to the wastes. This information yields the total wastewater volume to be treated in the wetland system. The major sources typically are flushwater to remove manure from alleys and barns, water for cleaning milking and milk processing facilities, rainfall runoff from roofs and open lots, and direct rainfall on pretreatment facilities and the wetland.

Water use varies considerably from one operation to another, depending on such factors as type of buildings, method of flushing, and type of management. Flow rates for flushing and washdown can be estimated on the basis of the size of the flush tanks and the number of flushes or the flow rate of pumps and hours pumped per day. Rainfall runoff can be estimated on the basis of the area of roofs and open lots, the monthly or annual volumes of rainfall, and runoff curves.

In general, you can estimate the volume of flushwater used in swine and poultry facilities by calculating approximately 2 gallons per minute (gpm) of water per 100 pounds (lbs) of animal weight for the flushing period. For cattle and dairy facilities, use 40 to 50 gallons per cow per day to predict flushing requirements for freestall alleys (Overcash et al. 1983). Tipping buckets, siphon tanks, and drop side tanks have capacities ranging from 250 to 1,000 gallons. The frequency of daily flushing will determine the total volume of flushwater used.

TABLE 5  
Beef: Approximate Waste Quantities

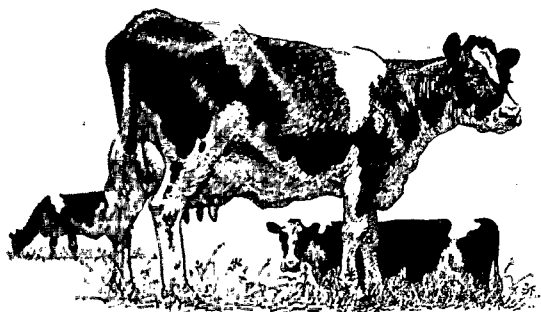
	Unit <sup>a</sup>	Feeder (750 to 1,100 lbs)			
		High Forage Diet	High Energy Diet	Yearling (450 to 750 lbs)	Cow
Mass	lbs/d	59.10	51.20	58.20	63.00
Volume	gpd	7.1	6.1	7.0	7.5
Nitrogen	lbs/d	0.31	0.30	0.30	0.33
Phosphorus	lbs/d	0.11	0.094	0.10	0.12
BOD <sub>5</sub>	lbs/d	1.36	1.36	1.30	1.20

<sup>a</sup> Units per 1,000 lbs of animal weight. Source: USDA NRCS 1992.

TABLE 6  
Poultry: Approximate Waste Quantities<sup>a</sup>

	Unit <sup>b</sup>	Layer Hen
Mass	lbs/d	60.5
Volume	ft <sup>3</sup> /d	0.93
Nitrogen	lbs/d	0.83
Phosphorus	lbs/d	0.31
BOD <sub>5</sub>	lbs/d	3.70

<sup>a</sup> Waste from most poultry facilities is handled as dry material. Waste from laying hens is often handled in liquid form; thus, waste characteristics for only the layers are shown in this table. <sup>b</sup> Units per 1,000 lbs of animal weight. Source: USDA NRCS 1992.



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# Wetland Design and Construction Considerations

## Choosing a Site

In addition to meeting technical requirements, the wetland must be conveniently located and fit into the overall operation. To pick a suitable location, keep the following items in mind:

- **Jurisdictional wetlands**—A treatment wetland cannot be located in any part of a natural wetland as defined by applicable regulations (called a jurisdictional wetland). A professional opinion from the U.S. Army Corps of Engineers, NRCS, or other professional certified in wetland delineation is essential.
- **Floodplains**—The site should not be in an area that floods more frequently than once in 100 years. State regulations may be more stringent.
- **Soils**—The soils at the site should contain a relatively high fraction of clay to prevent wastewater from seeping into groundwater. Soils classified as clay, sandy loam, and sandy clay are preferred. Sandy soils should be avoided unless a compacted clay layer can be added or adequate pretreatment is provided. The soils evaluation also should determine the depth to bedrock. Shallow soils can cause problems during construction and seepage during operation.
- **Topography**—The lay of the land is important, with level or nearly level slopes desired. All wetland cells should be level from side-to-side. If the land has considerable slope in the lengthwise direction, it may be necessary to install several terraced cells in series, which will add to the cost of construction, the overall size, and the maintenance and management requirements.
- **Land area**—The wetland surface area will be based on treatment goals and should be as large as is practical. Additional land area will be needed for the embankments.
- **Surface and groundwater**—The proximity of the system to nearby streams and to shallow groundwater should be evaluated for possible impacts.

*Your NRCS office and other information sources listed at the end of this brochure provide detailed information on the design and construction of wetland systems. In the meantime, this section introduces the following topics:*

- **Choosing a site**
- **Sizing a wetland**
- **Engineering a wetland**
- **Selecting wetland plants**
- **Providing wildlife habitat**
- **Managing water**

*This densely planted wetland treats wastewater before it is land applied.*



## Sizing a Wetland

You're probably wondering, "How big will a wetland have to be to get the results I need?" Information on designing wetlands for animal wastewater is still being developed, and as a result no clear consensus exists on sizing systems. The simplest method for estimating the size of a constructed wetland is based on the following:

- An estimate of the amounts of pollutants produced by the animals
- An estimate of pollutant reduction in pretreatment
- A prescribed areal mass loading in pounds of pollutant per acre of wetland per day

To help estimate how many acres you might need for a wetland, a rule-of-thumb method and two examples are provided below.

Method	Example 1 - Spray Irrigate	Example 2 - Surface Discharge
<b>Step 1: Set goals for the wetland system according to requirements for final disposal of the wastewater.</b>	Assume you can dispose of 1,000 lbs of nitrogen per year (2.7 lbs/d) on 5 acres of irrigated pasture.	Assume you can discharge to surface water if the wastewater has less than 30 parts per million (ppm) of BOD <sub>5</sub> at least 80 percent of the time.
<b>Step 2: Determine the pollutant load and wastewater volume. Use Tables 3 through 6 to estimate the pollutant load in pounds per day on the basis of your herd or flock size. Estimate the wastewater volume in gallons per day (gpd).</b>	<p>Assume you have 100 confined dairy cows and they weigh about 1,200 lbs each. Calculate the estimated mass of nitrogen (pollutant load) excreted by these cattle.</p> <p>nitrogen load =  <math display="block">\frac{0.45 \text{ lbs/d}}{1,000 \text{ lbs}} \times 100 \text{ cows} \times 1,200 \text{ lbs/cow}</math> <math display="block">= 54 \text{ lbs/d}</math> <p>Assume 40 gpd per head is used for washing alleys.</p> <p>wastewater volume =  <math display="block">40 \text{ gpd} \times 100 \text{ cows} = 4,000 \text{ gpd}</math></p> </p>	<p>Assume you have 500 finishing hogs and they weigh about 180 lbs each. Calculate the estimated mass of BOD<sub>5</sub> (pollutant load) excreted by these swine.</p> <p>BOD<sub>5</sub> load =  <math display="block">\frac{2.08 \text{ lbs/d}}{1,000 \text{ lbs}} \times 500 \text{ hogs} \times 180 \text{ lbs/hog}</math> <math display="block">= 187 \text{ lbs/d}</math> </p>



**Method****Example 1 - Spray Irrigate****Example 2 - Surface Discharge**

**Step 3: Estimate pollutant reductions during pretreatment.** NRCS can provide information on the efficiency of pretreatment options.

Assume that lagoon pretreatment will reduce nitrogen concentrations by 80 percent, leaving 20 percent that will need treatment and disposal.

$$\text{nitrogen load} = 54 \text{ lbs/d} \times 0.20 \\ = 10.8 \text{ lbs/d}$$

Assume that lagoon pretreatment will reduce BOD<sub>5</sub> concentrations by 90 percent, leaving 10 percent that will need treatment and disposal.

$$\text{BOD}_5 \text{ load} = 187 \text{ lbs/d} \times 0.10 \\ = 18.7 \text{ lbs/d}$$

**Step 4: Estimate the pollutant loading rate.**

Calculate the concentration of nitrogen at the wetland outlet that is appropriate for irrigation.

$$\text{nitrogen concentration at outlet} \\ = \frac{2.7 \text{ lbs/d}}{4,000 \text{ gpd}} \times 119,841 \text{ ppm/lbs/gallon} \\ = 81 \text{ ppm}$$

From Table 7, this concentration can be achieved at a nitrogen loading rate of about 26 lbs/ac/d.

Assume a BOD<sub>5</sub> concentration of 30 ppm at the wetland outlet. From Table 7, this concentration can be achieved at a BOD<sub>5</sub> wetland loading rate of about 9 lbs/ac/d.

**Step 5: Estimate the wetland area necessary to achieve the target pollutant loads required by the disposal method.**

Calculate the wetland area needed to treat a load of 10.8 lbs/d of nitrogen at a loading rate of 26 lbs/ac/d.

$$\text{wetland area} \\ = \frac{10.8 \text{ lbs/d}}{26 \text{ lbs/ac/d}} \\ = 0.42 \text{ ac or } 18,100 \text{ square feet (ft}^2\text{)}$$

Calculate the wetland area needed to treat a load of 18.7 lbs/d of BOD<sub>5</sub> at a loading rate of 9 lbs/ac/d.

$$\text{wetland area} \\ = \frac{18.7 \text{ lbs/d}}{9 \text{ lbs/ac/d}} \\ = 2.1 \text{ ac or } 90,600 \text{ ft}^2$$

**TABLE 7**

Estimated Pollutant Loadings to Achieve Desired Wetland Outflow Concentrations<sup>a</sup>

Pollutant	Desired Wetland Outflow Concentration (ppm)						
	20	30	50	100	200	500	1,000
	Estimated Pollutant Loading (lbs/ac/d)						
BOD <sub>5</sub>	5.5	9.0	18	39	80	210	350
TSS	6.0	11.0	27	71	180	480	890
TN	3.0	6.0	10	26	53	130	185
TP	2.5	5.5	9	18	—	—	—

<sup>a</sup>Based on meeting or exceeding the stated concentration about 80 percent of the time. Estimated from information in the LWDB (Knight et al. 1996).  
ppm = parts per million = 8.34 lbs/million gallons

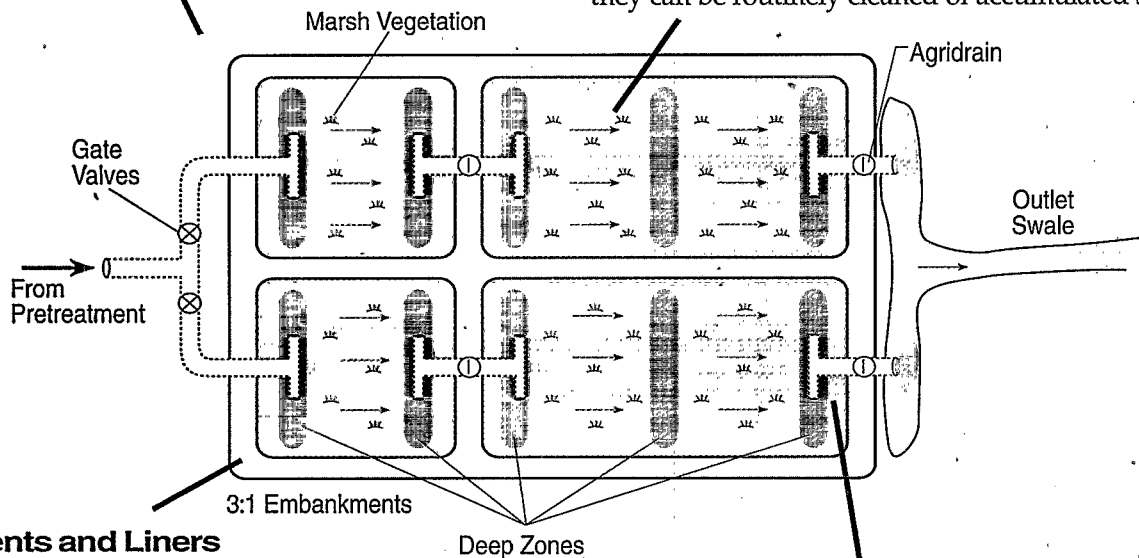
# Engineering a Wetland

## Length-to-Width

Cells can be nearly any shape that fits site requirements. Treatment performance is best when flow is evenly distributed from one end of the cell to the other. Length-to-width ratios for individual wetland cells range from 1:1 to 10:1.

## Number of Cells

Multiple wetland cells make operation and maintenance easier because cells can be shut down, cleaned out, or replanted as necessary without disrupting the entire system. Multiple cells should be parallel to each other. For larger wetland systems, cells can be arranged in parallel sets of cells in series. Preliminary cells should be smaller and more accessible so that they can be routinely cleaned of accumulated solids.



## Embankments and Liners

Embankments must be constructed using appropriate design and compaction techniques. Embankments should be 1.5 to 2 feet above the highest expected water depth to contain severe rainfall and to accommodate sediment accumulation in the wetland over time. Dikes should have side slopes that can be maintained by tractor-mounted mowers. Bottoms of wetland cells should consist of a compacted clay layer or liner covered by about 12 inches of native topsoil to serve as a rooting bed for plants.

## Water Depth

In most constructed wetlands, the water is about 1 foot deep or less. Water control structures should be designed with stop logs, gates, or moveable weirs so that the water level can be adjusted between 0.1 to 1.5 feet.

## Deep Zones

Deeper zones (3 to 6 feet below grade) can be added to the wetland to collect solids, to better mix the water, and to provide wildlife habitat. Deep zones should be perpendicular to the flow direction so that the water flow will not short-circuit the intended pathway. Relatively narrow inlet and outlet deep zones can help maintain even flow distribution.

## Selecting Wetland Plants

Treatment wetlands need densely growing plants. With nutrients and shallow water, plants grow well in wetlands and provide a carbon source and attachment area for the microbes that help treat the water. Plants do not need to be harvested as long as embankments are high enough, but plants do need to be nurtured when first established and then observed for stress.

Cattails are common in many natural and constructed wetlands throughout North America. These plants have long (up to 12 feet high), tape-like leaves that grow from a thick clump at the sediment level. Cattails grow from a fleshy rhizome and spread vegetatively by rhizome or from seed germinated in muddy ground. Cattails freeze back after the first hard frost, but they usually maintain upright, dead leaves and stems during the winter. Cattail marshes have been able to significantly reduce pollutants even under ice in northern climates.

Several species of bulrushes are also commonly used in constructed wetlands. Softstem and hardstem bulrush are tall plants with hundreds of cylindrical, pointed leaves per square yard. Masses of brown seeds dangle from the tip of each leaf, providing good food for a variety of wildlife. Like cattails, bulrushes spread vegetatively by rhizomes or from seed. During winter, bulrushes may or may not brown, and they remain standing throughout the season.

Many other plant species can be established in constructed treatment wetlands. Each species has slightly different preferences for water depth and water quality, and each species has specific benefits for wildlife. However, for water treatment performance, the species of plant is not very important. For that reason, a wetland owner should focus attention on establishing a dense population of cattail or bulrush throughout most of the wetland, and then add as many other plant species as possible. Other common species are arrowhead (*Sagittaria* spp.) and softrush (*Juncus* spp.), shrubs such as alder (*Alnus* spp.), and trees such as willow (*Salix* spp.), cottonwood (*Populus* spp.), and cypress (*Taxodium* spp.).



Cattails, bulrush, and flowering plants such as marsh mallow thrive in constructed treatment wetlands.

## Providing Wildlife Habitat

Constructed wetlands attract a variety of wildlife. Animals include amphibians (frogs), reptiles (turtles and snakes), mammals (wild rodents, muskrats, and nutria), and birds (herons, egrets, rails, sparrows, ducks, shorebirds, coots, blackbirds, and hawks). Fish may also find a home in constructed wetlands that are not overly enriched by nutrients in animal wastes. You can encourage wildlife use in constructed wetlands by following several general principles:



*Constructed wetlands can be designed to enhance the landscape for both humans and wildlife.*

**Create a wetland with habitat diversity by providing both deep and shallow areas and by planting a variety of plants in distinct zones.** The deep water areas (deeper than 4 feet) should occupy 30 to 50 percent of the wetland, and shallow areas (less than 1.5 feet deep) should occupy the remaining 50 to 70 percent. Include deep water areas within the shallow vegetated marsh zones but not adjacent to the outlet deep zone. Increase the length of edges between marsh and open water areas and include islands in deep water areas to provide safe areas for wildlife to rest and nest.

**Pretreat the wastewater as much as practical and reduce pollutant loadings to the wetland.** To enhance wildlife use, pollutant loadings at the wetland inlet should be less than 10 to 20 lbs/ac/d for BOD<sub>5</sub> and TSS and less than 3 to 5 lbs/ac/d for TN.

**Provide other features to attract and support wildlife around the constructed wetlands.** Plant wildlife food and cover crops on dikes and surrounding upland fields; install bird houses, nesting boxes, and roosting structures such as tree snags; and fence and protect the area from disturbance by humans, livestock, and domestic pets.

## Managing Water

Although wetland systems transform and remove pollutants, they do not magically dispose of water. The evapotranspiration (water evaporation and plant transpiration) of a constructed wetland is about the same as a pond or lake of the same size. In warmer regions with low summer rainfall, the volume of water in a wetland decreases between the inlet and outlet as a result of high evapotranspiration. In areas that are cooler or have high rainfall, the volume of water stays the same or increases between the wetland inlet and outlet.

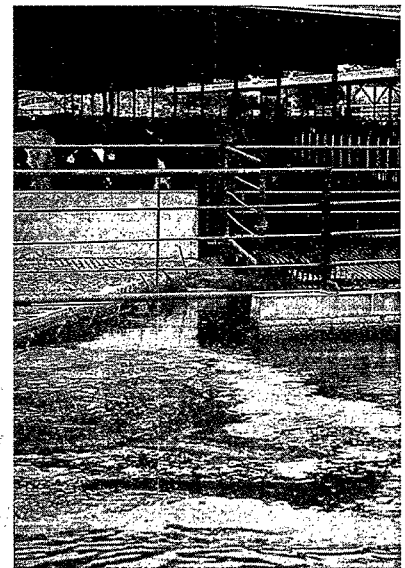
The fate of the treated water at the wetland outlet must be determined when the wetland is designed. Various options are available:

- Use the water to irrigate crop areas.
- Use the water for recycling as flushwater.
- Discharge to a surface water such as a stream, river, or lake (NPDES permit required).
- Create additional wetland and aquatic habitat on the farm.

A monthly water budget helps account for all water (wastewater and freshwater) entering and leaving the system from all sources on a monthly basis. The water budget allows the planner to determine (1) if enough water will be available for plants during dry seasons, (2) if storage will be needed to contain all sources of water during dormant or cold seasons, and (3) how water must be managed throughout all seasons.

During initial planning, determine if water will be available to the wetland during startup and all seasons thereafter. In some cases, water may need to be stored in the temporary storage unit of the pretreatment system so that enough water is available for the wetland year-round.

If wetland effluent will be collected rather than discharged, the size of the downstream storage pond must be determined. The storage pond must be sized to manage the irrigation component, and pumping requirements for irrigation and recycling as flushwater must be considered. A storage pond, pumps, and piping may be needed to transport the effluent to the appropriate irrigation system, whether center-pivot, big-gun, or flood.




■ *Once this wastewater leaves the barn, it is stored in a lagoon and then discharged to a constructed wetland. The treated wastewater is ultimately land applied.*

In low rainfall areas, the wetland can be sized so that water is disposed of through evapotranspiration. Evaporative systems require larger areas for a given wastewater flow.

Water management includes the installation of the right pipes and fittings and maintenance of water control structures so that pipes and valves remain unclogged and proper water levels are maintained. Ideally, water control structures will be designed to be self-operating most of the time.

Most states do not encourage or allow wastewater from confined animal feeding operations to be discharged to surface water. State water quality regulators will determine if the wetland effluent can be permitted for discharge under NPDES, state, or water conservation district requirements. If a permitted discharge is allowed, the owner must be fully aware of monitoring requirements and the costs of obtaining and maintaining such permits. In that case, conservative design and operation are critical to eliminate the potential for environmental harm.

Constructed wetlands are operated and maintained by controlling the water's quality, quantity, depth, and flow rate. Flexible water control structures allow the wetland owner to manage the system with minimal effort and to easily respond to changing conditions. Results from regular monitoring should guide wetland operation. This monitoring includes general observations of water control structures and plant health, as well as periodic sampling of parameters such as BOD<sub>5</sub>, TSS, nitrogen, and phosphorus.

 *Constructed wetlands are especially useful at swine facilities that use large amounts of flushwater.*



## Information Sources

Additional information concerning pollution management, the importance of wetland and aquatic habitats, and wetland design is available. Some of these sources are listed below. Be sure to ask your local NRCS or agricultural extension service representative what you can do to improve the quality of our water bodies.

American Society of Agricultural Engineers (ASAE). *ASAE Standards*. St. Joseph, MI: ASAE. 1985.

CH2M HILL and Payne Engineering. *Constructed Wetlands for Livestock Wastewater Management: Literature Review, Database, and Research Synthesis*. Stennis Space Center, MS: Gulf of Mexico Program, Nutrient Enrichment Committee. 1997.

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

DuBoway, P.J. and R.P. Reaves, eds. *Constructed Wetlands for Animal Waste Management*. Proceedings of a Workshop. West LaFayette, IN: Purdue University. 1994.

DuBoway, P.J., ed. *Proceedings of the Second National Workshop on Constructed Wetlands for Animal Waste Management*. College Station, TX: Texas A&M University. 1997.

Knight, R.L., R.W. Ruble, R.H. Kadlec, and S.C. Reed. *Wetlands for Wastewater Treatment Performance Database*. G.A. Moshiri, ed. *Constructed Wetlands for Water Quality Improvement*. Boca Raton, FL: Lewis Publishers. 1993.


Overcash, M.R., F.J. Humenik, and J.R. Miner. *Livestock Waste Management, Volume II*. Boca Raton, FL: CRC Press. 1983.

Payne Engineering and CH2M HILL. *Constructed Wetlands for Animal Waste Treatment*. Montgomery, AL: Alabama Soil and Water Conservation Committee. 1997.

U.S. Environmental Protection Agency (EPA). *Constructed Wetlands for Wastewater Treatment and Wildlife Habitat: 17 Case Studies*. EPA832-R-93-005. September 1993.

U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). *Agricultural Waste Management Field Handbook*. Washington, D.C.: NRCS. 1992.



 Publications are available that offer specific and detailed guidance on constructing a wetland.



## **Gulf of Mexico Program**

Nutrient Enrichment Issue Committee  
Building 1103, Room 202  
Stennis Space Center, MS 39529-6000  
Office (601) 688-3726

The Gulf of Mexico Program (GMP) was established in 1988 to improve the ecological and economic health of the Gulf of Mexico region. The GMP is funded by the United States Environmental Protection Agency (EPA) and public and private organizations.

The Nutrient Enrichment Issue Committee of the GMP is interested in ways to reduce the nutrient loads of the rivers and estuaries of the Gulf of Mexico region. Confined animal feeding operations directly and indirectly contribute nutrients to the area's water bodies. Realizing that farms play an important role in maintaining the area's environmental health, the Committee funded a project to review the potential of constructed wetlands to remove nutrients from wastewaters before they leave the farm. The purpose of the project was to document the ability of existing constructed treatment wetlands for removing nutrients from wastewaters in a way that was both practical and cost-effective. This brochure is one part of that project.

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