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Forestry and Natural Resources

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Are Constructed Wetlands a Viable Option for Your Waste Management System?

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Introduction

Efficient and practical manure management systems are an important component of livestock operations; and typical options such as lagoons, storage pits, and recirculation or irrigation systems have been used alone or in combination to treat animal manure. But a new option that is growing in popularity is the use of constructed wetlands to assist in the treatment of animal wastewater. This publication will assist you in evaluating whether constructed wetlands can be a viable, economically feasible option as one piece of your total manure management system.

When the Federal Water Pollution Control Act Amendments were passed in 1972, most of the regulatory attention focused on pollution from industries and municipalities. Regulations and management for the past 25 years have considerably reduced pollution resulting from point sources, or a definable point (such as a pipe) at which pollutants enter a body of water. The Environmental Protection Agency (EPA) has delegated regulatory authority to the Indiana Department of Environmental Management (IDEM). Under this authority, IDEM has developed management guidelines and a permit system that applies to all producers who manage at least 300 cattle, 600 sheep, 600 swine or 30,000 poultry in confined animal feeding operations, or CAFOs (IC 13-11-2). Operations at or in excess of these numbers must comply with the Indiana Confined Feeding Law. In Indiana, producers may not discharge animal wastewater into any surface waters. All CAFOs must have a management plan approved by IDEM that allows for a minimum 180 days storage of all animal manure and runoff, a plan to apply the stored material by land application, and documentation that sufficient acreage exists for land application of waste.

In many cases, producers are seeking management options to reduce the number of acres needed for land application or reduce salt (struvite) buildup in recirculating systems. Many also desire a reduction in maintenance and handling costs of animal waste. Constructed wetlands may help solve these issues for producers.

Advantages of Constructed Wetland Systems

Substantial improvements in farm wastewater quality have been made by reducing nutrient loads in wastewater. Natural biological, chemical, and physical processes act to eliminate or transform much of the nutrient and waste load in water moving through wetlands. Landowners also may derive the additional benefits of wildlife use and aesthetic appeal.

Constructed wetland treatment of wastewater occurs for the following reasons.

1) Water moves slowly through the wetland, allowing extended contact time with microorganisms. The velocity of the water is reduced and particulate matter settles out.

2) Suitable environments for both aerobic and anaerobic microorganisms are present in the wetland and carry out the biological processes necessary to remove or transform pollutants such as nitrates, phosphates, ammonia, manganese, sulfur, and carbon carried by the water.

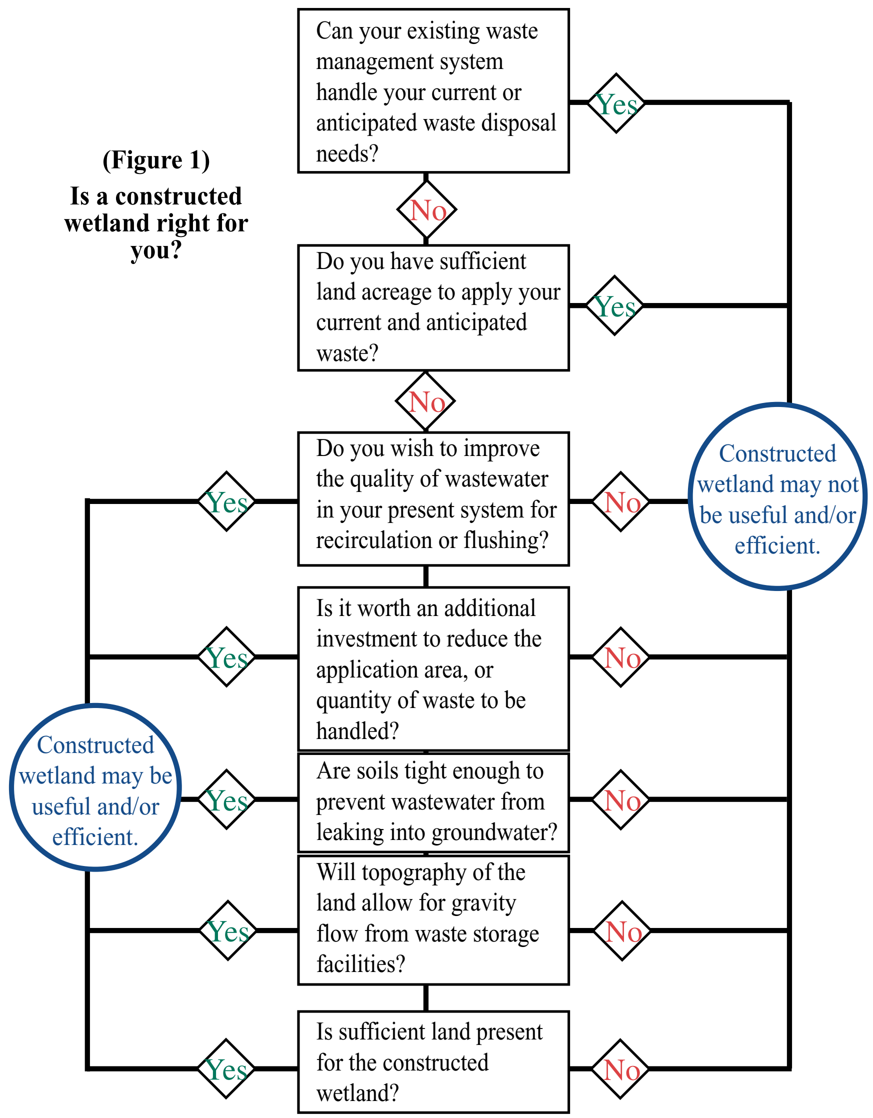
Microbes (microscopic organisms) provide most of the treatment. Plants in the wetland remove nutrients and improve aesthetics, but their primary function is to provide a surface area for the growth of microbial films. More plant stems in the water column translate into more microbes cleaning the water. System design and operation should be aimed at enhancing features that improve these characteristics of the wetland system.

Spring to late fall operation is possible, and wetland systems provide improvements in water quality during these times. Significant reductions in effluent concentrations of ammonia, nitrogen, fecal coliform, phosphorus, and biochemical oxygen demand can be achieved with constructed wetlands during the growing season in Indiana as wastewater passes through them.

Limitations of Constructed Wetland Systems

Year round operation of low-flow constructed wetlands in the climate found in the upper-Midwest is impossible. As the weather cools, treatment levels decrease. However, reductions have been recorded as late as December in north-central Indiana. Wetland cells freeze during much of the winter, rendering microbial treatment of wastewater impossible. During the first half of spring, temperatures are low enough to retard treatment, and then vegetation will not become established until May in the northern parts of the state. For constructed wetland systems to be functional, livestock producers must have a method of storing wastewater during winter (180 days). A lagoon system or holding pond combined with the constructed wetland can provide the necessary storage.

(Figure 1)
Is a constructed wetland right for you?



Regulations specify that constructed wetland systems must be designated as no-discharge systems so wetland treated water cannot be discharged into either surface waters or groundwater. Therefore, the waste management plan must include provisions for reusing wetland effluent or eliminating it through non-discharge means. Effluent may be land applied where appropriate, or it may be recirculated as flush water in recirculating systems. Another option may be disposal through an infiltration strip. Producers should determine if these infiltration strips will be approved by IDEM prior to investing in wetland systems. Discharge into surface waters may be possible, but would require a NPDES (National Pollution Discharge Elimination System) permit from IDEM and regular water quality monitoring to maintain the permit. As research continues and these systems become perfected, accepted discharge from these systems may be feasible in the near future.

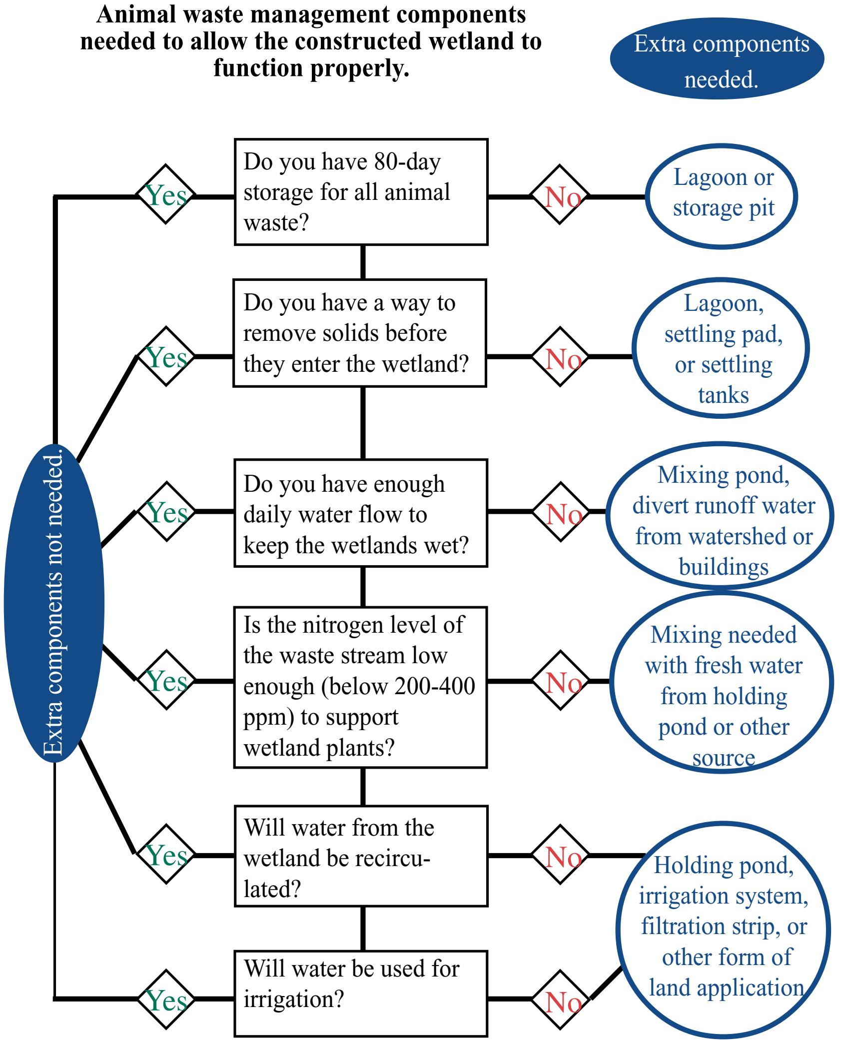
Design Considerations for Constructed Wetland Systems

Design of constructed wetland systems is important and should be tailored to best fit each individual operation. The first question to be addressed is whether a constructed wetland will be suitable (Figure 1). Constructed wetlands require sufficient acreage and suitable soils. Most constructed wetlands are 0.5 to 2.0 acres. If the soil is incapable of retaining water for an extended period of time, it is unlikely that a wetland can be developed without expensive artificial liners to retain the water and prevent groundwater contamination. This may make the cost prohibitively expensive. Research at Purdue University has found that infiltration into groundwater does not occur in wetland systems placed in unlined compacted soils with very low hydraulic conductivity. Mesic or hydric soils should be suitable for construction. The natural topography of the farm landscape should be incorporated into wetland design to reduce earthmoving expenses and to facilitate water flow.

There is no one correct way to design a constructed wetland system to fit every situation (Figure 2). General design guidelines are based on levels of contaminants in the

(Figure 2)

Animal waste management components needed to allow the constructed wetland to function properly.



wastewater and the amount of wastewater flowing through the system. There are certain aspects of design that are regulated.

Design requirements by both USDA Natural Resources Conservation Service and U.S. Environmental Protection Agency mandate that agricultural constructed wetland systems be able to handle a 25-year, 24-hour rainfall event. However, there is flexibility in how a specific system will comply with this requirement. Individual components of the constructed wetland system can be sized to accommodate this level of water flow. A system of storage structures, either lagoons or holding ponds, can be built to accommodate excess wastewater. The latter approach is preferable. System size is important in determining how well the wetland functions. A wetland should be sized to accommodate the normal expected flow, including rainfall, but should be conservative in treating contamination levels in the wastewater. For example, BOD (Biochemical Oxygen Demand) should be below 50 pounds per day per acre and nitrogen levels should be below 400 ppm (parts per million) for incoming wastewater, and preferably below 200 ppm. Samples of typical wastewater that will be treated by the constructed wetland should be analyzed to determine the expected levels of ammonia, nitrates, phosphates, and BOD. This will provide a more accurate basis for sizing the treatment system rather than relying on typical published values. Wetland cells should be sized to allow for 7 to 14 days retention time, meaning it will take 7 to 14 days for water to move from the inlet to outlet of the system. The quality of water exiting the system is dependent on the quality of water coming in and the length of time the water is retained.

If wetland cells are sized to retain open lot runoff from an extreme storm event, there will be insufficient water during the dry parts of the year to maintain plants and microbial populations of the wetland. If the wetland system dries, microbes will be lost. When water is returned to the system, treatment will be greatly reduced because of the lack of microbes. A significant amount of time will pass before these organisms are reestablished. This problem can be overcome by placing a structure with water storage capacity upstream of the wetland system, an arrangement that allows gravity to do the work of moving additional water through the system as needed. If the holding pond is at the downstream end of the system, additional piping and pumps may be needed to transport water from the pond to the head of the wetland system during dry periods. Upstream storage capacity also allows for wastewater to be captured during wet times of the year, typically winter and spring in Indiana, when a wetland system will not provide a high level of treatment. Wastewater can be held and released during warmer and drier parts of the year when wetland treatment will be at its peak. Captured precipitation can also be used as dilution water, reducing the possibility of overloading the system with a sudden pulse of wastewater with a high concentration of contaminants. Upfront storage capacity of both contaminated and fresh water allows greater control of water levels in the constructed wetland system throughout the year.

Multiple Cell Operating Systems

Wetland systems using multiple cells operating in series provide the best level of treatment (Figure 3). These systems develop a gradient of water quality from the point of entry into the first cell in the series to the end of the wetland complex. Multiple cells allow for one cell to be removed for maintenance while the system continues to operate. In addition, cells can alternately be drained for a 1-week period to break the mosquito cycle if needed. Periodic short dry cycles mimic natural processes and increase oxidation of minerals and nutrients and reduce buildup of plant litter. With multiple cells, alternating unvegetated and vegetated cells is possible. This arrangement provides additional treatment benefits by allowing oxygen to reenter the system as oxygen more readily diffuses from the atmosphere into water across an unvegetated surface. Increased levels of sunlight reaching the water surface on unvegetated cells may lead to increased levels of algal production and greater precipitation of ammonia and phosphate compounds.

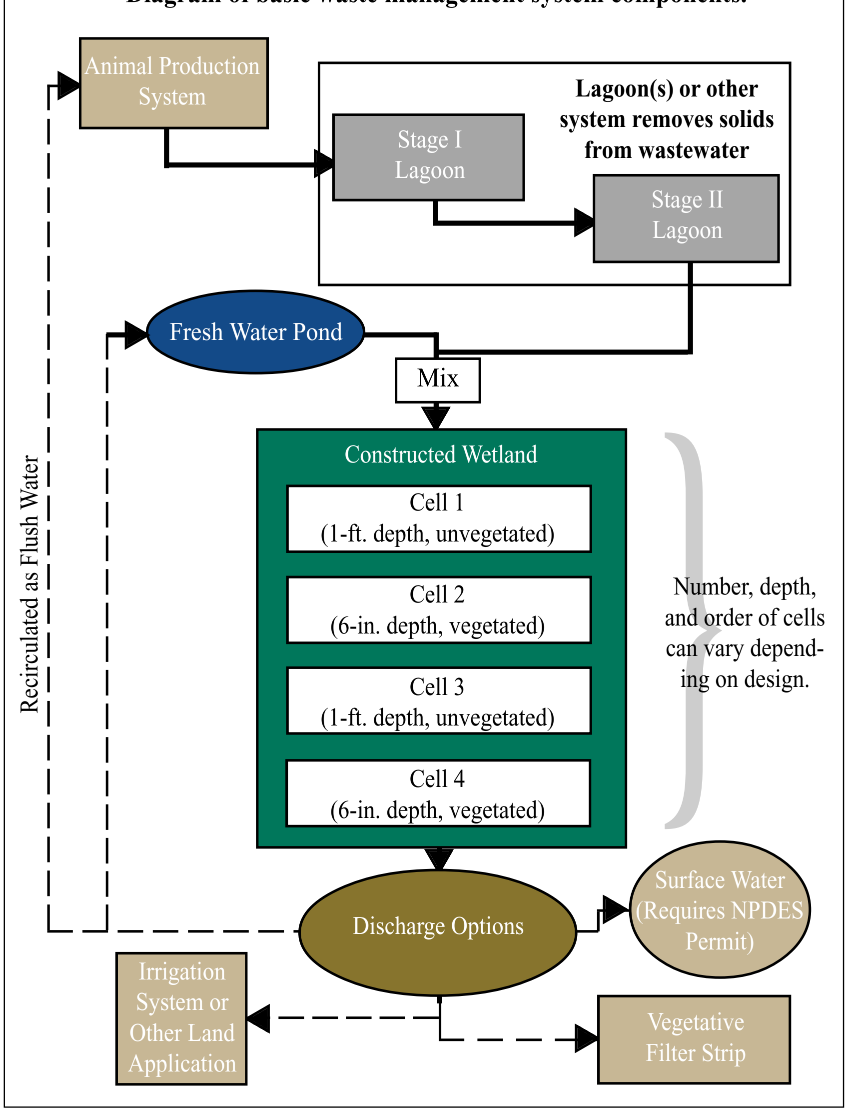
Unvegetated cells should be interspersed with vegetated cells. Shallow vegetated cells should have an effective water depth of approximately 6 inches (15 cm). Unvegetated cells should have a depth of 1 foot (30 cm) with steep sides to discourage the invasion of plants. Begin a series with an unvegetated cell to help alleviate high ammonia-nitrogen levels and act as a buffer to sudden changes in the quality of wastewater entering the system. It will act as an aerobic detention pond and provide an initial trap to further remove solids should the solids removal system prior to the wetland fail. Long-term system maintenance is facilitated by having an unvegetated zone first because it can be maintained without disturbing vegetation.

Wetland functional life expectancy can be incorporated into the design. Even with efficient solids removal systems, there will be an accumulation of solids and dead plant material in wetland cells. It would not be unreasonable to have buildup of ≥ 1 inch (2.5 cm) per year. Wetland cell berm height should allow for this. A berm height of three to four feet (90 to 120 cm) should result in a 20- to 30-year functional life. After this, the system may be rejuvenated by dredging and revegetating cells.

It is imperative that constructed wetland systems be combined with efficient solids removal systems, because constructed wetlands will not degrade large quantities of solids. If solids are not removed, the system will become overloaded and water treatment efficiency will be greatly impaired. This accumulation of solids also shortens the functional life of the wetland. By keeping solids out, water treatment is enhanced and functional system life can be extended. Solids must be removed before wastewater reaches the wetland. Lagoon systems eliminate solids. However, farms without lagoon systems can still utilize constructed wetlands as a part of a fully integrated waste management plan. Properly maintained manure pits or settling basins can effectively reduce solids from open lot runoff to a level that can be handled by the wetland.

Vegetation for constructed wetland cells can be obtained from a variety of sources. If commercial stock is desirable, nursery transplants should be used. Establishment of

(Figure 3)
Diagram of basic waste management system components.



wetland vegetation from seed is unpredictable and management intensive. Spoil from maintenance of wet roadside ditches can be used as a source for wetland plants since it contains good soil, plant stocks, and an assemblage of natural wetland microbes. You may be able to obtain ditch spoil from county highway departments during periods of the year when routine roadside maintenance is underway.

Operation and Management of Constructed Wetland Systems

Part of the appeal of these systems is that operation is neither costly nor labor intensive. However, this is not to say that constructed wetland systems will run themselves with no input from the operator. Farm management has a great impact on the performance of constructed wetland systems. Do not allow livestock access to constructed wetlands. Livestock can create problems when allowed access to a wetland system; overgrazing can eliminate vegetation and trampling can damage vegetation. Trampling may result in damage to the wetland berms, which could lead to water leaking from the system. Livestock deposit manure directly into the wetland, and increase solid levels. Check berms often to make sure burrowing animals don't cause a leak in the wetland.

Water level management will be necessary throughout the year. This can be accomplished by installing conventional water control structures at the inlet and outlet of each cell. In Indiana, an early-winter drawdown will provide additional storage volume for winter and spring rains. This can be followed with a mid-spring drawdown to facilitate plant establishment. Plant establishment, both at system start-up and each spring, will necessitate careful water level management by the operator. Always keep the level of the water in wetland cells below the height of the plants. Plants that are overtopped for any extended period during early growth will die. Young plants are more susceptible to stress from high concentrations of contaminants like ammonia and phosphate. A readily accessible source of dilution water during these periods increases plant vigor and decreases the time necessary to reach full system operation. Loading with full-strength effluent should not start until plants are 2.5 ft tall (75 cm). Plants that volunteer in wetland cells should not be discouraged unless they pose a weed risk to the remainder of the farm. Plants provide a surface area for microbial growth and enhance the treatment ability of the wetland. It may be necessary to periodically replant vegetation. Plants could be lost due to either a severe winter or a sudden contaminant shock during the growing season.

Frequently Asked Questions

How big do constructed wetlands have to be?

The minimum size of a constructed wetland is dependent on the following:

1. The volume of water and animal waste entering the system.
2. The level of key pollutants (ammonia, BOD, and phosphorus) in the waste stream entering the wetland.
3. The amount of treatment (pollution reduction) required. Generally for most farm operations in Indiana, the system would require 0.5 to 2 acres.

How much do constructed wetlands cost?

The cost is highly variable and depends on the following:

1. Size of wetland needs.
2. Potential requirement of a liner. Plastic liners or sealing wetland with bentonite clay can add $10,000 to $20,000 to the cost of construction.
3. Topography of site. How much excavation and grade modification is required? The greatest cost of a constructed wetland is the excavation, piping, and water control structures. Generally, a constructed wetland system that does not require a liner would cost $10,000 to $20,000 per acre if built by a contractor.

Will constructed wetlands solve all of my waste management problems?

A constructed wetland should be viewed as one component of a total waste management system. Under present regulations, water cannot be discharged from wetlands into surface water without a NPDES permit. Therefore, the ultimate fate of wastewater will be the same with or without a constructed wetland. The advantages a wetland can offer are:

1. Reduce the amount of acreage required for land application.
2. Provide additional treatment to water that will be recirculated and used as flush water.
3. Reduce salt buildup in recirculating systems.

If this technology develops to the point that discharge regulations change, constructed wetlands would have an additional advantage of allowing for discharge after sufficient treatment was achieved.

How much paperwork is involved?

The proper local, state, and federal permits must be obtained prior to construction. If there are at least 300 cattle, 600 swine or sheep, or 30,000 poultry, an approval must also be obtained from IDEM; and, the condition of the soil, hydrology, and vegetation must be documented prior to construction. The design of the wetland must be shown to be in compliance with the permit requirements. The NRCS can help with getting the permits, documentation, and engineering of the wetland.

Are constructed wetlands considered as jurisdictional (regulated) wetlands?

No. As long as constructed wetlands are maintained as waste treatment systems, they are regarded as created wetlands and are not treated as natural wetlands subject to state and federal regulations. This also means they cannot be used as mitigation credits for natural wetlands destroyed elsewhere.

Where to Go for Help

If you think constructed wetlands may be an appropriate part of your total waste management system, contact your local USDA Natural Resources Conservation Service office for assistance. They have expertise in evaluating your operational needs and in animal waste management system design.

Other Sources of Information

In April 1994, Purdue University hosted the first national meeting dealing exclusively with the use of constructed wetlands for the treatment of animal wastes. A publication (Constructed Wetlands for Animal Waste Management: Proceedings of Workshop, edited by P.J. DuBowy and R.P. Reaves) resulted from that meeting. This publication details agency positions and experimental work, and also includes examples of systems in operation. It can be purchased for $10.00 from Purdue University Agricultural Media Distribution Center, 231 South University Street, West Lafayette, IN 47907-2064, 1-888-EXT-INFO.

USDA-NRCS has published design guidelines for agricultural constructed wetland systems. This, and other technical references are available at www.in.nrcs.usda.gov/PlanningandTechnology/fotg/Section4/section4.htm, or by calling the Indiana NRCS state office at (317) 290-3200.

U.S. EPA developed a five-volume handbook on constructed wetlands. This work contains a volume dealing with general aspects of constructed wetlands and another volume dealing with agricultural applications. More information can found by writing to:

National Service Center for Environmental Publications
P.O. Box 42419
Cincinnati, OH 45242-2419

You may also call 1-800-490-9198, or visit www.epa.gov.

The Indiana Department of Environmental Management (IDEM) has a Web site on guidelines and regulations for confined feeding operations.
Visit www.in.gov/idem/land/cfo/ or www.in.gov/idem/guides/permit/waste/confinedfeeding.html for more information, or call (317) 232-8732.

Other Related Purdue Publications

These publications can be ordered from:

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ID-206 $2.00	*Poultry Manure Management Planning*
AY-278 $.50	*Estimating Manure Spreader Capacity*
WQ-7	*Animal Agriculture's Effect on Water Quality--Pastures and Feedlots*
WQ-8	*Animal Agriculture's Effect on Water Quality--Waste Storage*

Acknowledgements

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Glossary

The following is a list of common terms encountered in dealing with water resources. Not all terms are used in this paper, but they may be encountered with other water quality issues. The list is intended as an educational guide and is not presented as a list of legal definitions. Many published texts contain material for legal definitions and also provide more detailed technical information.

Aerobic: An environment where oxygen is available or pertaining to organisms adapted to such environments.

Anaerobic: An environment where oxygen is not available or pertaining to organisms adapted to such environments.

Aquifer: A geologic formation capable of storing, receiving, and transmitting water. It is capable of supporting a well or spring.

Confined Aquifer (artesian aquifer): An aquifer separated from the atmosphere by an impermeable geologic layer.

Unconfined Aquifer: An aquifer exposed to the atmosphere and in equilibrium with atmospheric pressure.

Baseflow: The water in a stream resulting from groundwater flow.

Berm: Earthen structures placed around constructed wetland cells to create the wetland basin.

Biochemical Oxygen Demand (BOD): A measure of the level of organic contamination in water. It measures the amount of oxygen needed to decompose the material in the water. High BOD levels can lead to oxygen depletion and fish kills in surface waters.

Catchment: A surface from which runoff is collected (examples: roofs, pavement).

Channel: The bed of a natural or human-made waterway that transports a concentrated flow of water.

Concentrated Flow: Runoff that moves through well-defined channels.

Contaminated Water: Water that contains disease-causing agents or toxic substances.

Diversion: A channel placed across the land slope to intercept runoff and conduct it to an outlet.

Drainage: The removal of water from either the land surface or the soil profile.

Surface Drainage: The diversion or removal of water from the land surface through natural or constructed channels. It may be supplemented by grading land surfaces leading to these channels.

Subsurface Drainage: The removal of water from the soil profile through drain tiles, perforated pipes, or other devices.

Drainage Area (drainage basin): The land area drained by a ditch, stream, river, or subsurface system.

Effluent: Water flowing out of a system.

Grass Waterway: A natural or constructed watercourse planted with suitable vegetation for the purpose of dispersing runoff without causing erosion.

Groundwater: Subsurface water that fills the spaces in the saturated zone of geologic formations.

Hydraulic Conductivity: The rate at which water moves through a soil or rock layer. Hydraulic conductivity in the horizontal direction will not necessarily equal hydraulic conductivity in the vertical direction.

Hydric Soils: Soils which have low hydraulic conductivity and tend to be waterlogged for a portion of the year if not drained.

Hydrophytic (hydrophilic) Vegetation: Vegetation that grows well in the presence of saturated soil conditions or standing water. Plants in the USF&WS wetland plant classification that receive a ranking of obligate, facultative plus, or facultative may be considered hydrophytic.

Infiltration: The downward movement of water into the soil or subsurface.

Infiltration Strip: A confined vegetated area used for water disposal.

Influent: Water flowing into a system.

NPDES: National Pollutant Discharge Elimination System, federal program limiting pollutant discharges by point source polluters.

Polluted Water: Water containing natural or human-made impurities that exceed the acceptable standards for a particular use.

Point Source Pollution: Polluted water that is discharged through pipes or other human-made structures. Polluted water enters a body of water through a well-defined point of entry.

Non-point Source Pollution: Polluted water that enters waterways without moving through a pipe or other human-made structure. There is no well-defined point of entry.

Runoff: That portion of precipitation or irrigation water that flows across the surface and enters receiving waters.

Spoil: Waste soil containing plant stocks generated through the maintenance of roadside ditches.

Volunteer Plants: Plants that begin growing in a system without having been put there by humans.

Wastewater: Water that has been used non-consumptively for some purpose (wash water, sewage water, etc.).

Watershed: An area of land that drains into a single water outlet.

Waterway: Any natural or constructed channel through which water flows.

Wetland: An area with hydric soils where the ground is saturated at or near the surface during a portion of the growing season and which supports hydrophytic vegetation.

Created Wetland: A wetland built by humans.

Constructed Wetland: A wetland built by humans to perform a specific waste treatment function.

Restored Wetland: A wetland reestablished in an area that was previously converted from a wetland for some human use.

Wetland Cell: A single contained basin in a constructed wetland system. A system may have one or many cells. Multiple cells in a system may operate independently or in series.

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