THE ESTABLISHMENT OF A CONSTRUCTED WETLAND TO TREAT WASTEWATER FROM A CONFINED ANIMAL OPERATION

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Introduction

Since 1935, the Soil Conservation Service (SCS) has been involved in water quality. In 1935 the 74th Congress passed Public Law 46 creating SCS and mandating that SCS develop and carry out conservation programs to enhance and protect the nation's soil and water resources. More recently, water quality has been elevated to the number two priority resource goal as defined in the updated United States Department of Agriculture National Program for Soil and Water Conservation. Because water is an inseparable component of the resource base and because pollution control assistance is needed by livestock producers, SCS has taken an active role in solving agriculturally related water quality problems. SCS is also taking an active leadership role in technology development and transfer. This is exemplified by the revision of Chapter 13 of the Engineering Field Manual which will be used at the field office level for wetland restoration, enhancement, and creation and also the issuance of a draft national standard for constructed wetlands.

There are as many definitions of wetlands as there are types of wetlands. Niering (1985) describes wetlands as areas where water is the primary factor contributing to the environment and the associated plant and animal life. Natural wetlands such as marshes, swamps, and bogs are characterized by hydric soils and a predominance of hydrophytic vegetation. The United States Environmental Protection Agency (EPA) (1988) defines wetlands as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to maintain saturated conditions.

Regardless of how wetlands are defined or described, their value as natural resource systems is becoming better understood as our knowledge of ecological processes increases. Scientists have discovered that wetlands are, in fact, natural assets that provide important benefits to people and their environment (USEPA 1988). One of the most important values of wetlands is their ability to help maintain and improve the water quality of lakes, rivers, and streams (USEPA 1988).

Mississippi has an estimated 58,000 milk cows in approximately 720 dairy operations. It is estimated that only 50 percent of these have waste treatment facilities. The state of Mississippi allows continuous discharge and excess flow from animal waste lagoons which have the potential to degrade the water quality of receiving waters. Constructed wetlands may be an economical and viable component of animal waste treatment systems. A cooperative project between the Newton County, Mississippi, Soil and Water Conservation District; Mississippi State University; and the SCS to establish and evaluate a constructed wetland as part of an animal waste treatment system was initiated in 1989.

Nature and Scope

The state of Mississippi allows continuous discharge of effluent from animal waste treatment lagoons. During excess flows, extremely high organic pollutant loadings can reach receiving streams, lakes, and rivers and degrade water quality or cause water use impairments. The possibility also exists for ground water contamination. A fairly new technology of treating wastewater with natural or constructed wetlands is being explored.

Research has demonstrated that natural wetlands have the ability to assimilate, degrade, and remove pollutants. Environmental engineers have understood these removal processes as being similar to unit operations and processes used in the mechanical treatment of municipal wastewater. The ability of wetlands to influence water quality is the reason for current interest in research and evaluation on their use for wastewater management (Metcalf and Eddy 1979). Novotny and Chesters (1981) also have stated that the use of wetlands for storage and treatment is becoming a promising means of controlling water pollution. Pollutant removal takes place primarily at the root zone level by bacterial processes. It is generally understood that the aquatic plants themselves provide very little treatment but utilize metabolites and byproducts generated from bacterial metabolism. According to the EPA (1988), the roots and stems of aquatic plants in the water column function as surfaces for bacterial growth and serve as a media for filtration and adsorption of solids. The stems and/or leaves at or about the water surface attenuate sunlight and thus prevent the growth of algae, reduce wind effects on gas transfer, and are important in the transfer of oxygen to and from the submerged parts of the plants.

Steiner, Watson, and Hammer (1987) defined constructed wetlands as an engineered and constructed complex of saturated substrate, emergent and submergent vegetation, animal life, and open water that simulates natural wetlands for mans' desired uses and benefits. Constructed wetlands properly designed and installed can maximize the pollutant assimilative and removal capacities and process natural wetland systems. The term "natural system" is intended to describe the processes that depend primarily on natural components to achieve the intended purpose (Reed et al. 1988).

Over the past two decades, constructed wetlands and natural systems have been used to treat wastewater from various sources. These sources have been mainly from municipal systems. Wolverton (1988) stated that a very promising simplified method of wastewater treatment, using natural biological processes, has been developed by the National Aeronautics and Space Administration. This process used aquatic plant systems and their associated microorganisms. Wolverton went on to say that the aquatic plant systems are far more diverse than present-day mechanical treatment systems.

Two other uses of constructed wetlands, other than municipal wastewater treatment, that are being explored are animal waste treatment and acid mine drainage. Brodie, Hammer, and Tomljanovich (1986) reported on the treatment of red water drainage by shallow impoundment planted with a variety of wetland emergent vegetation. Hammer and Watson (1988) are also evaluating a constructed wetland for the treatment of wastewater from a swine operation. Constructed wetlands are currently being used to treat wastewater from municipal sources, wood product sources, industrial sources, acid mine drainage, and animal wastes throughout the United States and Europe. However, design criteria, management techniques, economics, and removal efficiencies of certain aquatic plant species are still in the experimental stages and little data is available for animal waste systems. Hammer and Bastian (1988) stated that constructed wetlands appear to be low cost, efficient, self-maintaining wastewater treatment systems but lack precise design and operating criteria. This is especially true for animal waste treatment systems. Gutenspergen, et al. (1988) stated that few species of plants have actually been tested and evaluated for wastewater improvement studies. The USEPA (1988) published a design manual for use in designing constructed wetlands for municipal wastewater treatment. With the understanding that the basic pollutant concentrations for animal waste loads are higher than municipal waste loads, the technology in the design manual can be applied to animal waste treatment systems.

Facilities and Project Site

The constructed wetland is located at the Coastal Plains Experiment Station in Newton County, Mississippi. The station has a Grade A Dairy of 166 Holstein cows which is operated by the Mississippi Agricultural and Forestry Experiment Station of Mississippi State University. The present facilities consist of a loafing shed, milk parlor, anerobic, and aerobic lagoons. The anaerobic lagoon receives influent flow from the loafing shed, small holding area, and milk parlor. Solids from the loafing shed are currently scraped and hauled to nearby fields and do not flow into the anaerobic lagoon. Discharge is released from the aerobic lagoon through a 4-inch steel pipe with an outlet valve. Runoff is diverted around the anaerobic lagoon by a diversion. A small amount of runoff from 0.45 ha (1.1 acres) of pasture runs into the aerobic lagoon, but all other runoff is diverted.

The project site is located in the Gulf Coast Plain Physiographic Providence. The surface area is a mature, dissected upland and is situated within a topographic division of eastern Mississippi known as the North Central Hills. The topography varies from undulating broad plateau areas between major streams to dissected uplands characterized by somewhat steep side slopes and narrow ridge tops.

The area lies within the Chunky River Watershed with 86,212 ha (215,503 acres) (89 percent) in Newton County, Mississippi, (Figure 1) and 11,179 ha (27,947 acres) (11 percent) in Neshoba County, Mississippi. The watershed is in the upper reaches of the

Pascagoula River Basin. Chunky Creek originates near Union, Mississippi, and flows southeastward for about 34 km (21 miles) to its confluence with Potterchitto Creek. From this point on, it is called Chunky River and flows eastward for 8 km (5 miles) to the lower boundary of the watershed near the Chunky Community. Main tributaries of the Potterchitto Creek are Turkey, Renis, Tarlow, and Bogue Falema Creeks.

All of the streams within the watershed are classified by the Mississippi Department of Environmental Quality as fish and wildlife streams with the exception of the Chunky River lying south of Highway 80. This segment is classified as recreation.

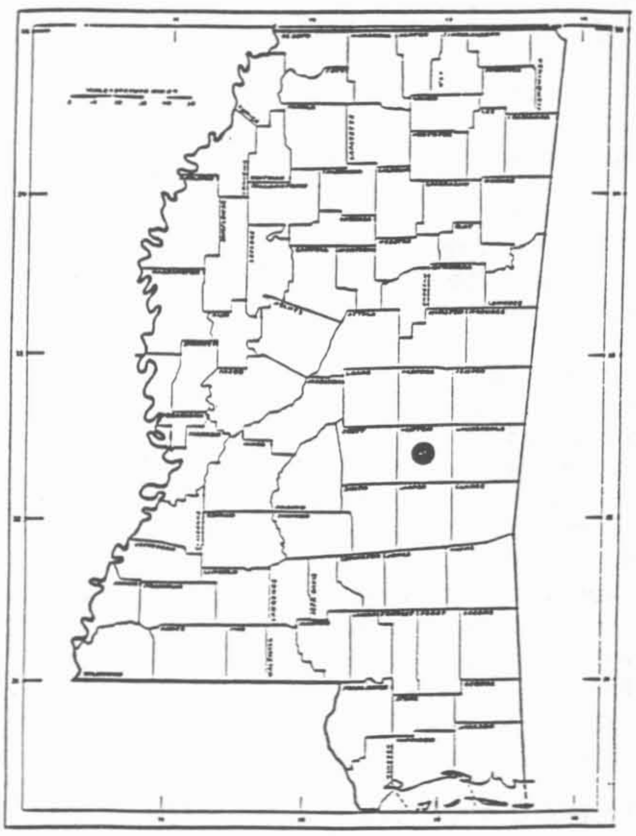

Figure 1. Location of constructed wetland, Newton, Mississippi

The average precipitation is 134.95 cm (53 inches) with about 97 cm (38 inches) occurring during the growing season of April through November. The wettest month is March with an average of 16.05 cm (6 inches), and the driest month is October with an average of 5.64 cm (2 inches). The average annual temperature is 18.2 degrees C (65 degrees F). January is the coldest month with an average temperature of 8.9 degrees C (48 degrees F), and July is the hottest month with an average of 27.5 degrees C (82 degrees F).

Objectives

The objective of the joint constructed wetland project, simply stated, was to establish a constructed wetland and evaluate its performance over a five-year period. Strong and Ulmer (1989) listed the specific objectives as follows:

1. Develop design criteria to be used for constructed wetlands to treat lagoon wastewater discharge from a dairy herd.

2. Evaluate the performance of the design criteria.

3. Evaluate the performance of different plant species.

4. Evaluate the economics of a constructed wetland as part of an animal waste treatment system.

5. Develop operation and maintenance criteria for the constructed wetland system.

Design

The constructed wetland is a surface flow system located near the downstream toe of the aerobic lagoon (Figure 2). Six 4.5-m by 30-m cells (15 feet by 98 feet) in parallel followed by six 4.5-m by 12-m cells (15 feet by 40 feet) in series were designed to treat waste loads flowing from the lagoon system. The design operating depth for all cells is 33 cm (13 inches) with a six-day detention time in the primary cells and a three-day detention time in the secondary cells. The long, narrow cell design was used to achieve plug flow conditions. Obviously, one of the most important design considerations must be hydrology. Relatiions between hydrology and the wetland ecosystem characteristics must be included in the design (Hamer 1989). Having adequate, continuous flow into the cells over the hydroperiod is extremely important to ensure the function of the system. A thorough analysis of the rainfall, runoff, evaporation, washwater, and animal waste production was made to identify seasonal volume fluctuations and provide necessary runoff and drawdown storage for continuous flow to the cells. The hydraulic loading rate to each primary cell is 8.2m^3/d (1.5 gpm).

Separate water lines from each lagoon were installed to release wastewater by gravity flow into the cells. The design is such that the cells can be loaded from

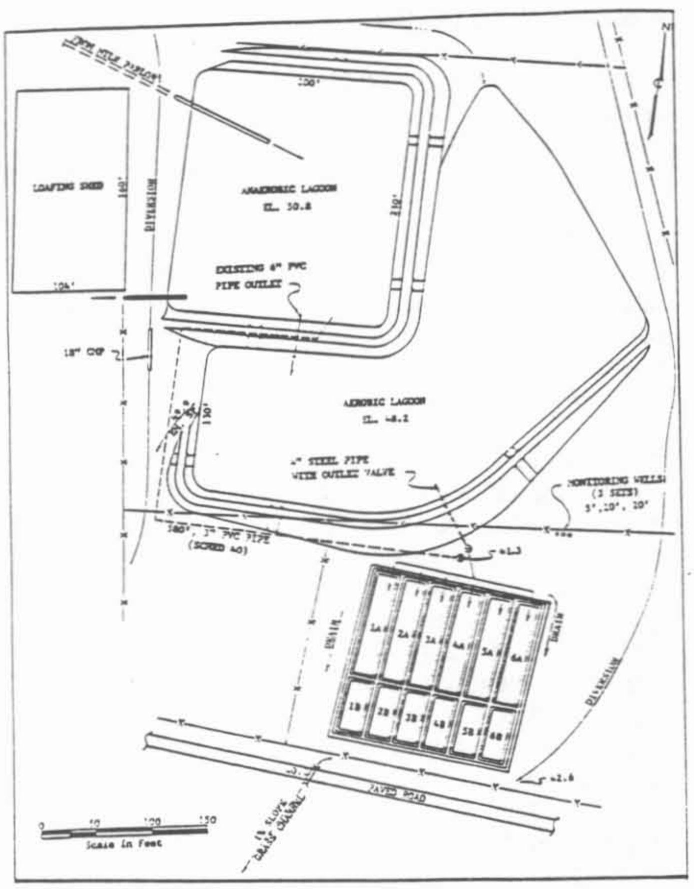

Figure 2. Constructed wetland design Coastal Plains Experiment Station, Newton, Mississippi

either the anaerobic or aerobic lagoon. Gate valves were placed on the line to allow a control for flow from either lagoon or a mixture from both. Actual inflow of wastewater into each cell was spread across the width of the cell in manifold fashion by a perforated plastic pipe. There were problems with the valves and this system of release. These will be discussed in the section on Problems Encountered. Release from each cell is taken from the width of the cell through perforated pipe. The water depth in the cells is regulated by a swivel riser that can be rotated to the side and lowered to the desired level.

Seepage from the wetland cells is a concern. Nine monitoring wells were installed in sets of three at 1.5, 3, and 6 m (5, 10, and 20 feet).

Construction

A construction contract was let on July 3, 1989, and completed on July 29, 1989, for a total cost of $16,392. During the construction phase, several observations were made that would facilitate the installation and operation of future constructed wetlands. These are listed as follows:

1. Sod removal under all levees is essential for bonding of embankment and foundation soils. Preserving the topsoil for use in the cell bottoms should promote wetland plant growth and survival.

2. Using a 3-foot-wide vibrating drum compactor in the cutoff trench provided very good compaction but can cause some caving of trench walls in sandy sections.

3. The 4-foot top width of internal levees is not wide enough to be constructed with dozers unless the levees are overbuilt and then cut back. The 4-foot top width does not allow tractor access for mowing and other maintenance operations. It is recommended that an 8-foot top width be used.

4. The 2 horizontal to 1 vertical levee side slopes are difficult to shape and traverse for construction and for moving equipment and maintenance activities. The 2.0 to 2.5-foot height does not present a long slope but will require some special effort or equipment to control undesired growth on the levee structures.

5. Cell width and length should also be compatible with dozer width to allow maneuvering and shaping operations.

6. The small hydraulic heads designed into these systems may lead to the omission compaction and pipe trench sloping requirements for seepage control along the pipe. Close attention should be given to pipe installation and backfill compaction.

7. The collection ditch (outflow of the system) should be an underground pipe system. This will remove a maintenance problem.

Vegetation

Wetland cells were planted with the following species (Figure 3):

1. Cattail (typha latifolia), 880 plants.

2. Bulrush (Scirpus vlidus), 2,205 plants.

3. Canna (Canna flaccida), 735 plants.

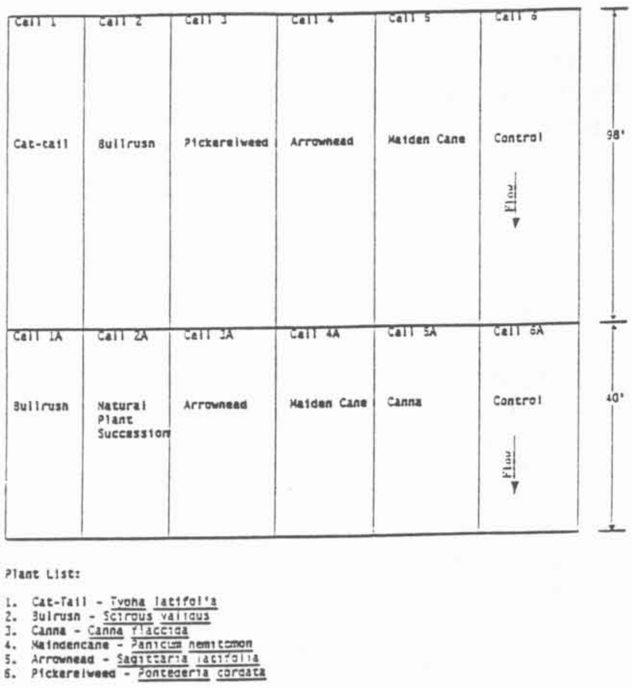

Figure 3. Constructed wetland planting scheme, Coastal Plains Experiment Station, Newton, Mississippi, July 26, 1989

4. Maidencane (Panicum hemitomon), 2,205 plants.

5. Arrowhead (Sagittaria latifolia), 2,205 plants.

6. Pickerelweed (Pontederia cordata), 1,470 plants.

Cells were planted on 0.3048 m (1-foot) intervals. One cell was not planted to serve as a control. The plants were purchased from a commercial grower at a cost of $5,423. The plants had 10-46 cm (4-18 inches) of new growth and were planted in dry cells July 26 and 27, 1989. Planting was accomplished using spades and tree planting "dibble bars."

Immediately after a cell was planted, water was added from the aerobic lagoon. The cells were kept wet with 2.5 cm to 7.6 cm (1 inch - 3 inches). Survival was approximately 98 percent and the plants were well established by the end of the 1989 growing season. Water levels were raised to the design operating level of 33 cm (13 inches) for cattail and bulrush and 15 cm (6 inches) for other cells to protect the plants from freeze damage. Extremely cold temperatures of -17.8 degrees C (0 degrees F) were experienced for a 3-4 day period during the last week of December 1989. Plant damage was minimal and vigorous growth resumed in the spring of 1990.

Problems Encountered

The most significant problem encountered in the establishment of the constructed wetland was that of maintaining a consistent flow rate to the cells. It was found that the gate valves used in the project are not well adapted to regulating the low flow rates of 8.2 m^3/d (1.5 gpm). It has been suggested that "butterfly" or "ball" valves may be better adapted. A consistent rate of flow into the wetland cells was further complicated by bacteria slime buildup at the valve opening causing clogging, which completely stopped the flow to the cells.

To overcome the variable flow rate problem, PVC pipe "DWV adapter" and threaded "end plug" were inserted into the 3-inch PVC line at the inlet to each cell and a 13/64 inch orifice was drilled in the end plug. The 13/64 inch orifice was designed for the 8.2 m^3/d (1.5 gpm) and was based on a 5-foot average pressure head between the aerobic lagoon water surface and the orifice elevation. Velocity through the orifice is approximately 3.4 m/s (11 ft/s). This velocity was found to be sufficient to shear off the bacterial build-up and thus keep a clear opening. The end plugs can be easily removed for flushing and cleaning and replacements are cheap (<$2.00) if another orifice size is needed.

Another major problem encountered was extreme summertime decline of the water level in the aerobic lagoon. The decline was due to spring drawdown followed by drought conditions in late spring and continuing through the summer. This caused flow to the cells to cease completely. As a result, water in the wetland cells had to be maintained by water hoses using an alternate water supply. The problem was solved by extending the inflow pipe with a turndown well out into the aerobic lagoon. This system reestablished flow into the 3 inch PVC pipe system and thus flow into the wetland cells.

Preliminary Results and Discussion

Difficulties encountered with valve clogging and inconsistent flow rates coupled with extremely low volume in the aerobic lagoon rendered problems with sampling during this start-up phase. With the flow rate problems being solved in late June 1990, only BOD data is available from July to August. Generally, the BOD_5 removal rates were good, ranging from a low of 43 percent for maidencane to a high of 97 percent for the same species (Table 1). Although we do not consider the BOD data to be as reliable as it could have been because of the flow rate problems, the removal efficiencies are in line with those reported from other sources (Hammer 1989).

Table 1. Percent BOD Removal Over a Four-Week Sampling Period, 1990.

Species	July 9	July 20	July 27	August 3
Cattail	57	81	86	73
Bulrush	77	96	87	78
Pickerelweed	80	93	96	93
Arrowhead	80	94	93	83
Maidencane	43	93	97	93

This project will run for an additional four years. Nutrient samples are currently being taken, and results will be reported in the future. The wastewater parameters that will be analyzed to delineate the performance of the cells are nitrates, organic nitrogen, ammonia nitrogen, TKN, ortho-P, and total suspended solids.

Acknowledgements

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