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A preliminary study of an alternative controlled drainage strategy in surface drainage ditches: Low-grade weirs

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ABSTRACT

This study examined hydrological characteristics of low-grade weirs, an alternative controlled drainage strategy in surface drainage ditches. Chemographs of vegetated and clear scraped (control) replicates of weir vs. non-weir treatments were compared to determine differences in time to peak (T_p) and time to base (T_b). Drainage ditches T_p and T_b were affected by both vegetation and weir presence. The order of treatment efficiency for T_p was observed to be: non-vegetated non-weir < vegetated non-weir < non-vegetated weir < vegetated weir. Furthermore, T_b for each ditch was the reverse relationship from T_p where vegetated weir > non-vegetated weir > vegetated non-weir > non-vegetated non-weir. Low-grade weirs increase chemical retention time (vegetated and clear scraped), the average time a molecule of contaminant remains in the system. Future research in water quality improvement and weir management will yield useful information for non-point source pollutant reduction.

1. Introduction

Agricultural land use requires artificial drainage for sustainability and profitable crop production. However, drainage contributes to the conveyance of non-point source pollutants such as nutrients, pesticides and sediments into surface receiving waters (Nguyen and Sukias, 2002, Zhang et al., 2004). In the Mississippi River Basin, this has profound implications downstream on aquatic ecosystem health and hypoxic zones in the Gulf of Mexico (Rabalais et al., 1996, Turner and Rabalais, 2003). Controlled drainage has been proposed as a best management practice (BMPs) primarily aimed at reducing nutrient (nitrogen and phosphorus) concentrations and loads in drainage ditches reaching receiving waters by reducing total drainage outflows (Borin et al., 2001; Evans et al., 1992; Evans et al., 1995; Gilliam and Skaggs, 1986; Gilliam et al., 1979).

Controlled drainage practices are a global phenomenon found in northeast Italy (Borin et al., 2001), southern Sweden (Wesstrom and Messing, 2007; Wesstrom et al., 2001) and North Carolina, USA (Evans et al., 1992; Evans et al., 1995). Advantages of controlled drainage include reduced outflow and outflow velocity, increased denitrification, stormwater mitigation and sedimentation, and decreased water table depths. In North Carolina, several studies have shown decreases in annual nitrogen (N), phosphorus (P) and drain outflow volumes as a result of controlled drainage (Evans et al., 1992; Evans et al., 1995). Wesstrom and Messing (2007) reported 79 and 94% reductions in drain outflows for successive years following controlled drainage implementation. These outflows corresponded to significantly reduced N, nitrate (NO_3–N) and P losses. Similarly Lalonde et al. (1996) showed drain flow and NO_3–N reductions for variable riser heights of 58–63% and 69–76%, respectively. However, as a result of decreased water table

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depths, surface runoff and the likelihood of surface N and P loss increases. Drury et al. (1996) reported consistently higher water table levels for controlled drainage as compared to tile drainage for three growing seasons from 1991 to1994. Controlled drainage also significantly decreased NO_3–N concentrations, and significantly increased surface runoff and P loss.

A commonly used practice for controlled drainage involves the use of a variable height riser in the drain or ditch outlet (Lalonde et al., 1996; Madramootoo et al., 1993; Skaggs and Gilliam, 1981). This concept relies on the ability to control drainage intensity by determining the height of the riser and thus control volume of outflow and load of solutes (Wesstrom et al., 2001). The variable height of the riser can also be used to increase groundwater levels during times of water stress and drought. For the most part, riser controlled drainage occurs seasonally when fields are fallow. Taking into consideration that certain surface drainage ditches are hundreds of meters long with variable slopes, would a temporally continuous step-wise increase of water levels improve retention and controlled drainage? An alternate controlled drainage strategy would be the use of low-grade weirs, installed in a stratified spatial arrangement within the drainage ditch. This spatial arrangement would be advantageous as it would be continuously implemented year round, while small enough to avoid large storm events flooding fields and senescing crops.

Effectiveness of controlled drainage practices is greatly influenced by their design and management. Before understanding the water quality implications of low-grade weirs, hydrological data needs to be presented to illustrate the potential of increasing water residence times within surface drainage ditches. As with subirrigation in subsurface drains, low-grade weirs aim to decrease water table depths at various spatial locations within the field and thus improve overall water and nutrient uptake for crops. The current study examined low-grade weirs as alternative water control structures in drainage ditches. The primary aim of this research was to obtain preliminary hydrological data on effectiveness of low-grade weirs in altering hydrology in vegetated and non-vegetated (control) ditch circumstances.

2. Materials and methods

2.1. Experimental setup

Chemical retention time experiments (CRT) were conducted at the University of Mississippi Field Station (UMFS) in June 2007.

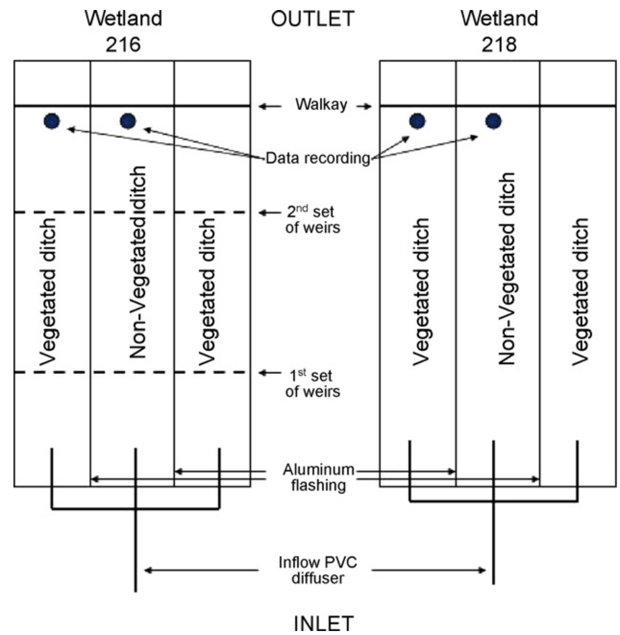

Fig. 1 – An overhead layout view illustrating the locations of experimental wetland 216 and 218, weirs, vegetated vs. non-vegetated ditches and data recording. PVC diffusers delivered a constant inflow rate for the duration of the experiment. Aluminum flashing separated individual ditches within each experimental wetland.

Experimental wetlands were specifically constructed by the US Army Corps of Engineers in conjunction with the United States Department of Agriculture-Agricultural Research Service (USDA-ARS) to aid in constructed wetland and drainage ditch research. Two experimental wetlands (216 and 218) were utilized for the CRT experiment and divided into three artificial drainage ditches respectively ($n = 6$) (Fig. 1). Within each wetland there were two vegetated ditches and a non-vegetated control ditch. Vegetation density within each vegetated ditch was around 1200 stems/m^2, comprising for the majority (>95%) obligate emergent wetland vegetation. Dominant species within each vegetated ditch were *Leersia oryzoides* (L.)Sw., *Juncus effusus* L., and *Polygonum hydropiperoides* Michx. Drainage ditches were separated and isolated by 0.5 mm thick aluminum flashing anchored to the sediment every 2.5 m with short fence posts. Bentonite clay sealant was applied to the base of either side of the flashing to isolate and avoid any water mixing between adjacent ditches. Similar

Table 1 – Physical characteristics of ditches in wetlands 216 and 218

Ditch characteristics	Weir (216) (mean ± S.E)		Non-weir (218) (mean ± S.E)	
	Vegetated	Non-vegetated	Vegetated	Non-vegetated
Ditch width (m)	4.42 ± .04	3.37 ± .04	4.56 ± .07	3.57 ± .06
Ditch length (m)	33.5	33.5	32.2	32.2
Ditch slope	0.0076	0.0084	0.0085	0.0083
Weir height (cm)	20.7 ± 3	29.15 ± 0.95	n/a	n/a
Inflow rate (L/min)	50.69	51.15	50.69	51.15
Mean weir volume (L)	10410 ± 1930	9548 ± 978	n/a	n/a
Total ditch water volume (L)	20820	19096	8966	8769