Contributed papers from the 4th Drainage Water Management Field Day
23 August 2011, Lamberton, Minnesota

4th Drainage Water Management Field Day

University of Minnesota
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FORWARD

Agriculture and especially crop and livestock producers are faced with many challenges. There is increasing pressure to develop technologies and strategies that contribute solutions to food and energy security and climate change and environmental quality concerns. These requirements are in addition to the usual challenges of weather, pests and uncertain markets. Simply put, we will need to grow more, in a better way, and on less land without harming the environment. Intensifying cropping systems and adapting farming practices to increase productivity, mainly through more intensive residue and nutrient management, drainage, and irrigation can result in increased production but can also result in impaired water quality and loss of biological diversity. Coupled with our growing food, feed, fiber, and fuel production demands, changes in agriculture or policy will alter farming practices and science and technology will play an increasingly important role in shaping the future of agriculture.

Drainage Water Management practices are a set of agronomic, engineering, and ecological strategies that provide opportunities for targeting specific management practices at in-field, edge-of-field, or in-stream locations with the goal of improving water quality. Some practices like controlled drainage also offer the potential for yield benefits. The goal of Drainage Water Management is to design drainage systems that provide the benefits of drainage while minimizing negative impacts on the environment. To be effective, Drainage Water Management strategies must account for the many aspects of today's farming systems. One practice alone does not constitute Drainage Water Management nor does one strategy fit all systems. With all practices, their applicability and performance depends upon the context in which they are to be implemented.

The Drainage Water Management Field Day is an event to bring producers, researchers, contractors, State and Federal agency staff, policy makers, and conservation groups together around a common issue: ***agricultural drainage for productivity and environmental benefit.*** The over arching objectives of the 4th Drainage Water Management Field Day are to (1) provide a forum for researchers to share the results of on-going research with stakeholders, (2) provide an opportunity for stakeholders to participate in educational activities, and (3) provide stakeholders an opportunity to provide input into efforts addressing soil, water, and nutrient management issues.

The 4th Drainage Water Management Field Day was designed to highlight major areas within Drainage Water Management that show promise from the standpoint of water quality protection, emphasizing the array of options available to producers. The proceedings from the Field Day include six papers which discuss research projects conducted by scientists from the University of Minnesota, the Minnesota Pollution Control Agency, and South Dakota State University.

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DISCLAIMER

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MULLENBACH TWO-STAGE DITCH CONSTRUCTION COST-BENEFIT ANALYSIS: CHANNEL STABILITY AND NITROGEN

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EXECUTIVE SUMMARY

A two-stage agricultural drainage ditch was designed, and then constructed at the site of an existing trapezoidal ditch in southern Minnesota, USA during the autumn of 2009. The two-stage ditch was dimensioned to mimic the hydraulic geometry found in natural streams and stable ditches with active floodplains. The two-stage ditch system has the potential to significantly reduce maintenance costs by creating a self sustaining ditch where net sediment deposition is negligible, seepage forces on outer banks are managed, and excessive nitrogen from adjacent land is reduced. Economic analyses were developed and curves developed to determine the economic viability of potential two-stage ditch projects. Results suggest that two-stage ditches can compete with other best management practices (BMPs) for nitrogen removal cost, and in some cases may even be economically preferable without accounting for water quality benefits. However, the nitrogen treatment benefit is intrinsically linked to water contact time with floodplain bench vegetation, soil and associated microorganisms. We have used optimal nitrogen treatment values from Tank et al. (2009) in this analysis.

INTRODUCTION

The general cost-benefit analysis for a two-stage drainage ditch requires consideration of a multitude of factors. The major costs associated with the construction of a two-stage ditch are: 1) earthwork required to enlarge the ditch channel geometry, 2) erosion control and prevention measures, 3) production land lost to widening of the ditch, 4) side-inlet and tile-outlet modifications and reinforcements. Potential economic benefits from a two-stage agricultural drainage ditch include: 1) reduced ditch maintenance and cleanout frequency, 2) water quality benefits, 3) improved habitat for both aquatic and terrestrial organisms, and 4) a more aesthetically pleasing landscape.

Ditch cleanouts constitute the primary cost associated with maintaining many existing conventional ditches. For this reason, cleanout costs are the main determining factor in a cost effectiveness analysis of a two-stage drainage ditch. Long-term stable ditches are not necessarily good candidates for two-stage development, while those that require relatively frequent maintenance will tend to be more economically viable. Issues of channel instability and maintenance can be addressed by MADRAS (contact magne027@umn.edu). To provide a method of estimating the financial feasibility of a two-stage drainage project, an economic analysis was undertaken to develop a simple reference tool for determining the approximate cost/benefit ratio for several conditions.

A spreadsheet developed by Bill Lazarus (Lazarus, 2009) was used to determine the net present value of both conventional ditches and two-stage ditches. The spreadsheet calculates the net present value of all expected costs for each ditch system over the project life for several variables (given in Table 1); the channel design with the lowest net present value of associated costs is economically preferable. We chose a project design life of 100 years and a ditch cleanout cost of $3 per linear foot ($9.84 per linear meter) for a conventional ditch in Ohio (before conversion to a two-stage channel) as reported by Powell et al. (2007). Few other estimates are available that specify the cost of maintenance activities per cleanout event, as most literature reviewed cites annual average ditch maintenance costs for counties or states (Hansen et al., 2006 and Christner et al., 2004). Peterson et al., (2010) reported cleanout and maintenance costs of $950 - $22,000 mi^{-1} ($590 - $13670 km^{-1}). The value reported by Powell et al. (2007) will be used in this study. Two-stage ditch earthwork costs vary widely (Powell et al., 2007; USDA-NRCS, 2007). A cost of $8.55 ft^{-1} ($28 m^{-1}) is reported in this study, and the USDA-NRCS (2007) reported a range of $5 - $20 ft^{-1} ($16 - $66 m^{-1}) for the construction of two-stage ditches. The following analysis will be completed for three separated two-stage ditch prices: $5, $10, and $15 ft^{-1} ($16, $33, and $49 m^{-1}) to provide results for a range of construction costs.

For comparison purposes, the construction costs related to side inlets and tile outlets will be ignored because they are not unique to two-stage ditch construction or ditch cleanout. A further assumption will be made that the two-stage ditch will not require cleanout over the project life. The cost of agricultural land taken out of production (due to ditch widening) in the two-stage construction process is accounted for by the change in overall width between the trapezoidal ditch and the two-stage ditch. This analysis is conducted without considering ditch length, as the costs considered are all given in cost per channel.

Table 1. Summary of Inputs Used to Calculate the Economic Feasibility of Two-Stage Ditch Construction Given Existing Trapezoidal Ditch Conditions.

Variable	Value	Source
Discount rate (interest rate)	Varies (part of analysis)	N/A
Current ditch design		
Annual Cleanout Cost	$3 per linear foot	Powell et al. (2007)
Years before next cleanout	1	Assumed
Cleanout interval (years)	Varies (part of analysis)	N/A
Ditch Width (feet)	43	Mullenbach Ditch
Two-Stage Ditch		
Construction cost	$5-15 per linear foot (will be varied in analysis)	USDA-NRCS (2007), Mullenbach
Value of land taken out of production	Varies (part of analysis)	N/A
Ditch Width (feet)	63	Mullenbach Ditch

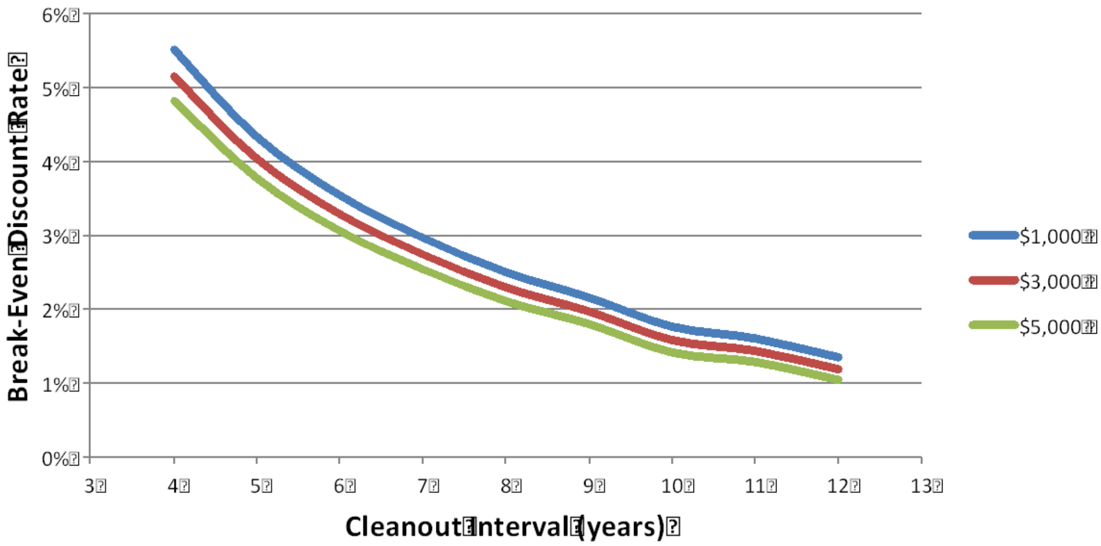

Figure 1. Break-Even Discount Rate vs. Cleanout Interval for Three Agricultural Land Prices and Two-Stage Ditch Construction Cost of \$15 ft^{-1}

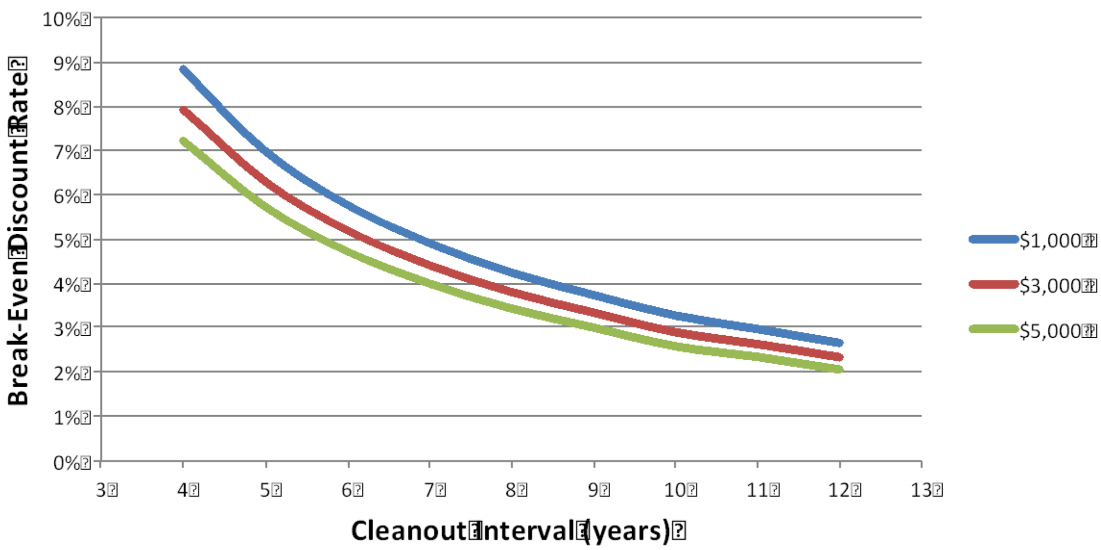

Figure 2. Break-Even Discount Rate vs. Cleanout Interval for Three Agricultural Land Prices and Two-Stage Ditch Construction Cost of \$10 ft^{-1}

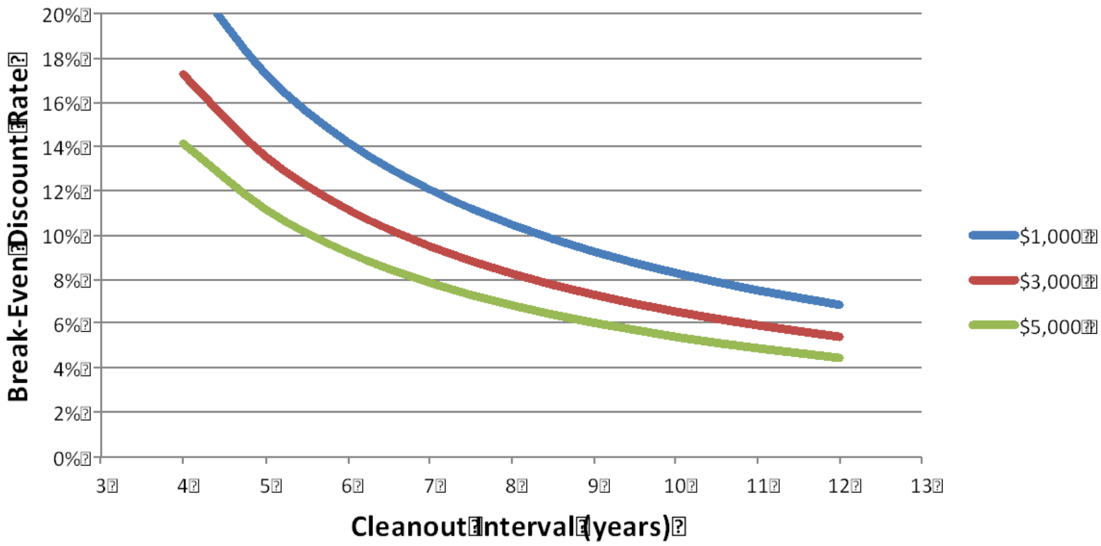

Figure 3. Break-Even Discount Rate vs. Cleanout Interval for Three Agricultural Land Prices and Two-Stage Ditch Construction Cost of \$5 ft^{-1}

Figures 1 through 3 show the break-even discount (interest) rates for various agricultural land prices, cleanout intervals, and two-stage ditch construction costs. For example, given a two-stage ditch construction cost of \$10 per linear foot (Figure 2), adjacent land value of \$3,000 per acre and an approximate conventional ditch cleanout interval of 10 years, the break-even discount rate is approximately 3%. Thus, if an interest rate of 3% (or lower) can be achieved, the two-stage ditch will be economically viable.

Achievable interest rate will have a large bearing on project feasibility (perhaps more so than cleanout frequency or land price), and small reductions in the interest rate may tip the economic analysis in favor of a two-stage channel for certain land prices and cleanout intervals. Because there is considerable uncertainty surrounding the interest rate that is expected for two-stage ditch construction practices, presenting the break-even interest rate based on other factors may be especially useful for considering the feasibility of two-stage ditch projects in the future.

EXPANDED ECONOMIC ANALYSIS WITH WATER QUALITY BENEFITS

Determining the economic value of potential water quality benefits is important for determining the role of the two-stage ditch as a BMP for reducing nutrient loading in headwater streams. Roley et al. (2008) and Tank et al. (2009) reported results from a study of channel floodplain bench denitrification in a 620-m two-stage ditch reach (Indiana, USA) before and after two-stage channel construction. Tank et al. (2009) reported a 400% increase (708 g N d^{-1} vs. 142 g N d^{-1}) in nitrogen removal on ditch floodplains benches due to increased bio-reactive area following two-stage construction. An economic analysis similar to that shown above in Table 1 is presented to analyze the cost-effectiveness of two-stage ditches for nitrogen removal.

The economic analysis carried out here considers *hypothetical* ditch dimensions and characteristics (optimal nitrogen treatment values) to illustrate potential economic benefits of nitrogen removal in two-stage ditch systems. Characteristics of the ditch will be informed by information thus far presented, but are purely intended as demonstration to show how accounting for nitrogen removal in a two-stage system may positively impact the economic analysis presented previously. While the channel dimensions and nitrogen removal characteristics will be pre-determined for the entire analysis, factors such as discount rate, cleanout interval, and the price of agricultural land taken out of production will vary as in the previous analysis presented in Table 1.

Table 2. Dimensions, Nitrogen Removal Rates, and Cleanout Cost of Hypothetical Ditch.

Dimension/Characteristic	Conventional Ditch (Before Two-Stage Construction	Two-Stage Channel
Floodplain Width (m)	1.22	6.10
Overall Ditch Width (m)	13	17.88
Channel Length (m)	2000	2000
Reach Nitrogen Removal (g d^{-1})	458(1)	2284(1)
Marginal Nitrogen Removal due to Two-Stage Channel (kg d^{-1})	1.83	
Marginal Nitrogen Removal due to Two-Stage Channel (kg y^{-1})	666.5	
Conventional Ditch Cleanout Cost ($ per linear meter)	9.84	-
Two-Stage Ditch Construction Cost ($ per linear meter)	-	32.80

(1) estimates based on values presented by Tank et al. (2009) and increased from literature values due to increased ditch reach length.

Selected ditch dimensions, nitrogen removal rates before and after two-stage construction, and cleanout cost for the pre-existing conventional ditch are presented in Table 2. The floodplain widths before and after two-stage construction are the same as those presented by Roley et al. (2008), as are the nitrogen removal rates per unit area of floodplain and the overall increase in floodplain area. Conventional ditch cleanout cost is $3 per linear foot ($9.84 per linear meter). Two-stage channel construction cost is $10 per linear foot ($32.80 per linear meter). The spreadsheet used for these calculations (Lazarus, 2009) has the option of including water quality benefits as an annual benefit ($ km^{-1}). The net present value of annual benefits is calculated over the project life and subtracted from the two-stage ditch construction costs to calculate the total net present value for the two-stage option. Nitrogen removal costs are based on the removal rate (Table 2) and the total water quality benefit necessary to equalize the net present value of the conventional and two-stage ditches, given land price, cleanout interval, and discount rate. Note that negative break-even nitrogen removal costs correspond to situations where a two-stage ditch was already the economically preferred option without the inclusion of water quality economic benefits.

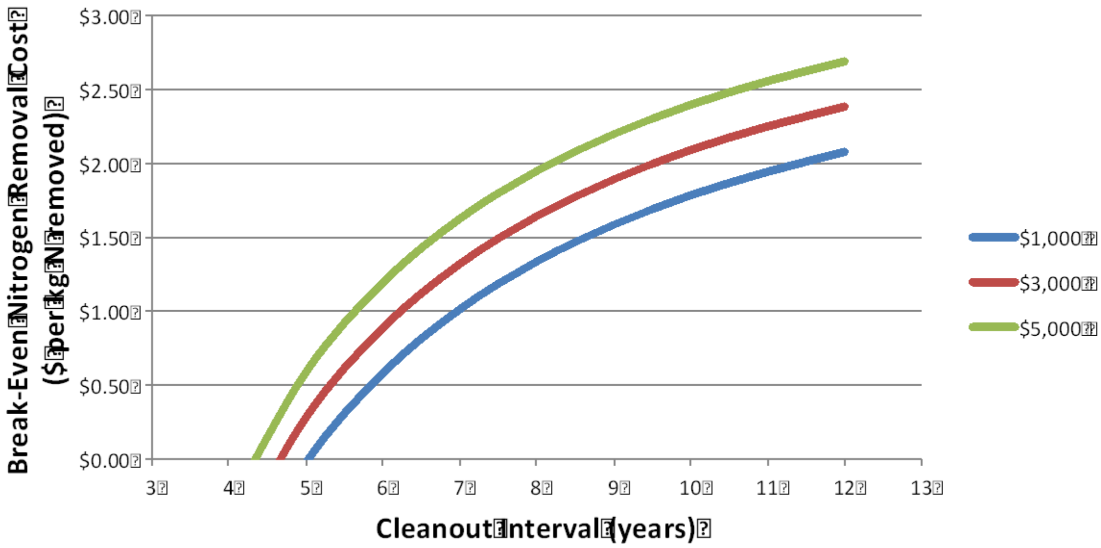

Figure 4. Break-Even Nitrogen Removal Costs at a Discount Rate of 7 Percent for Various Agricultural Land Costs and Conventional Ditch Cleanout Intervals.

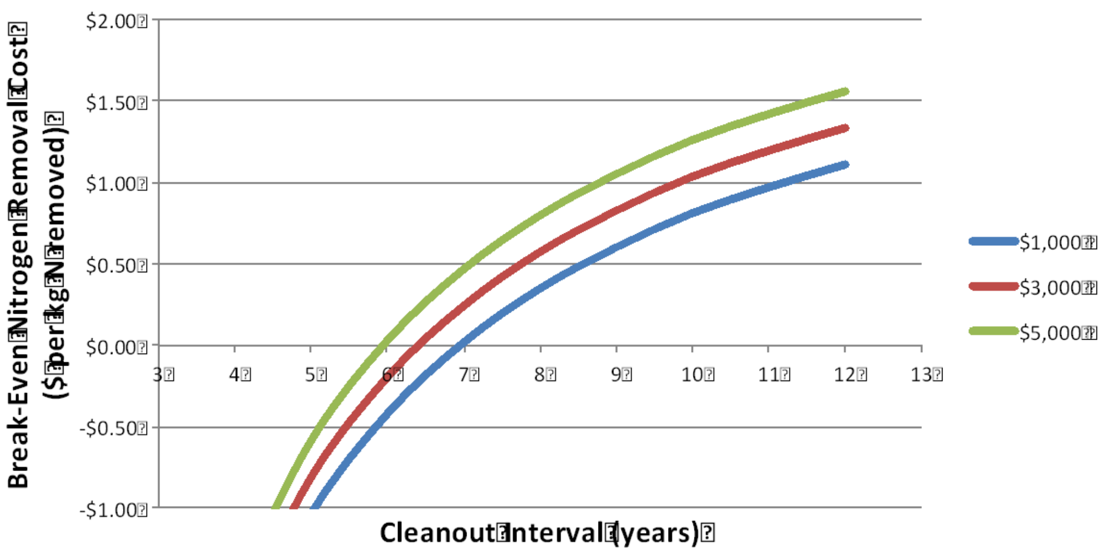

Figure 5. Break-Even Nitrogen Removal Costs at a Discount Rate of 5 Percent for Various Agricultural Land Costs and Conventional Ditch Cleanout Intervals.

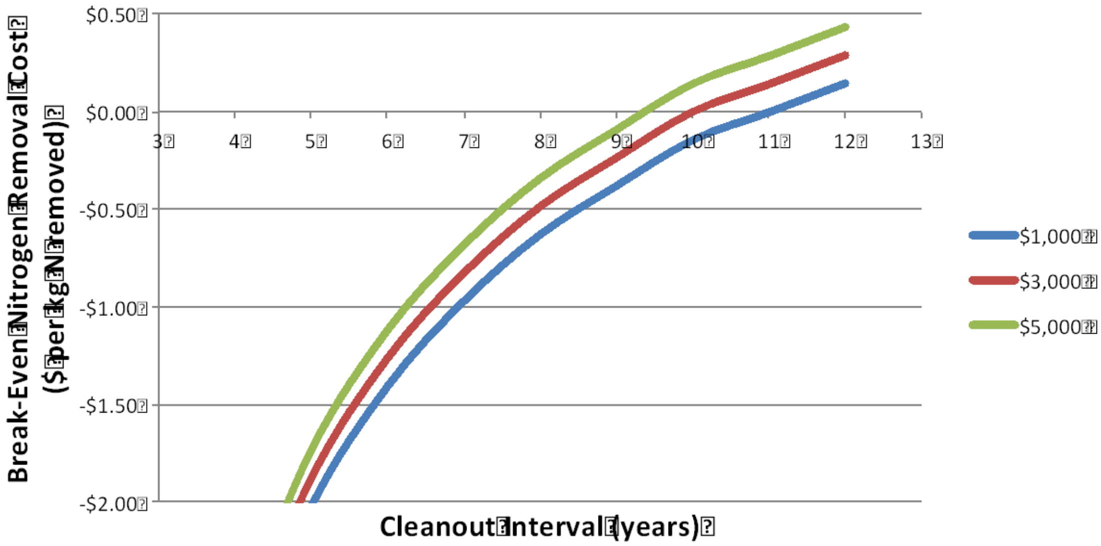

Figure 6. Break-Even Nitrogen Removal Costs at a Discount Rate of 3 Percent for Various Agricultural Land Costs and Conventional Ditch Cleanout Intervals.

Figures 4 through 6 show the break-even nitrogen removal costs for various discount rates, land prices, and ditch cleanout intervals. Break-even nitrogen removal costs are presented as the cost per kg of nitrogen removed based on maximum annual nitrogen removal efficiency from Tank (2009). Figure 4 shows that nitrogen removal rates (given a discount rate of seven percent) for cleanout intervals in the range of 8 to 12 years are on the order of $1.50 to $2.50 per kg N removed. A substantial reduction is seen as the discount rate is reduced to five percent (Figure 5). Cleanout intervals of ten years or less all have a corresponding nitrogen removal cost of $1.25 per kg or less in this situation. The best reduction in removal cost occurs with a three percent discount rate (Figure 6). Even for a ditch with a cleanout interval of 12 years, the nitrogen removal costs is less than $.50 per kg for land prices of $5,000 and less. However, actual annual nitrogen removal rates will vary by location and season across the Midwest.

For purposes of comparison, literature values were obtained for nitrogen removal costs from various proposed projects and BMPs, and are presented in Table 3. Edge-of-field N-less reduction costs reported by CENR (2000) were as low as $0.88 per kg N removed, and showed an exponential increase in removal cost as load reduction targets increased. CENR (2000) also showed that a 20% reduction in nitrogen loads could be achieved at a cost of just $0.69 per kg N removed through reduced fertilizer use alone. Nitrogen removal costs associated with wetland restoration in the Mississippi River basin was also reported, and were $6.06 per kg N removed for the first one million acres restored. It is important to point out, that these are average nitrogen removal cost for the most cost-effectively restored one million acres, and that there are likely many areas where wetlands could reduce nitrogen loading for far less than $6.06 per kg. Several values from this study are also given in Table 3, and are similar to the costs reported in the literature presented here. However, it must be stressed again how important the discount rate is in determining the nitrogen removal cost associated with a two-stage ditch.

Table 3. Comparison of Nitrogen Removal Cost for Various Treatments and BMPs.

Nitrogen Reduction Method	Net Cost Within Agricultural Sector ($ per kg N removed)
Edge-of-field N-loss reductions(1)	
20% load reduction	0.88
30% load reduction	1.90
40% load reduction	3.37
50% load reduction	5.20
60% load reduction	7.48
Through reductions in fertilizer use alone (1)	
20% load reduction	0.69
45% load reduction	2.85
500% fertilizer tax	14.54
Wetland restoration in the Mississippi basin(1)	
1,000,000 acres	6.06
5,000,000 acres	8.90
10,000,000 acres	10.57
18,000,000 acres	11.93
Riparian buffers (27,000,000 acres)(1)	26.03
River diversion to coastal wetlands(1)	~6
Wastewater nitrogen removal(1)	~40
407,000 acres of wetland restoration in the Illinois River basin(2)	0.60
Hennepin Levee District floodplain restoration, Illinois(2)	2.87
Two-stage ditch results presented in this study, land price = $5000 per acre	
Interest rate = 3%, cleanout interval = 10 years	0.14
Interest rate = 3%, cleanout interval = 12 years	0.43
Interest rate = 5%, cleanout interval = 8 years	0.80
Interest rate = 5%, cleanout interval = 10 years	1.26

Interest rate = 7%, cleanout interval = 8 years	1.95
Interest rate = 7%, cleanout interval = 10 years	2.40

(1) taken from CENR (2000), (2) taken from TWI (2001)

SUMMARY

The results presented here, although approximated, suggest that two-stage ditches may be able to compete with other nitrogen removal BMPs. Interest rates play an important role in determining the economic feasibility of a two-stage ditch. However, even at higher interest rates there are likely ditches (such as those with very low cleanout intervals or low adjacent land values) that may provide the optimal economic conditions for cost savings and nutrient reductions through the implementation of a two-stage ditch. In unstable geologic settings where cleanout is required often, the two-stage ditch offers a potential long-term cost saving option.

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