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A Framework for the Economic Analysis of Ditch System Management Alternatives

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A FRAMEWORK FOR THE ECONOMIC ANALYSIS OF DITCH SYSTEM MANAGEMENT ALTERNATIVES

Kenji Adachi, Jeffrey Apland, Steven Taff and Gary Sands[1]

Abstract

A framework for the economic analysis of alternative management plans for public drainage ditch systems is presented. The framework combines enterprise budgeting techniques with a flexible, spatially disaggregated, database framework. The approach is demonstrated with test data for public ditch JD-20 − a tile-based, agricultural drainage system which feeds into the Maple River. Integration of hydrological simulation models is discussed, including approaches to the addressing water quality outcomes.

Introduction

In this report, we provide a summary of a proposed framework for evaluating the economic consequences associated with alternative drainage ditch system management strategies. Initially developed for use in studying Judicial Ditch 20 in the Lower Maple River Watershed, this framework is designed to be flexible to a wide range of management alternatives and adaptable for use in studying different systems. Further it may readily be adapted to consider both economic and environmental outcomes associated with ditch management alternatives.

The report begins with an overview of the budgeting framework. Then, details of the model, an Excel spreadsheet, are documented. Finally, some preliminary results are reported for JD-20 in order to demonstrate the model's use and capabilities.

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Design of the Ditch Budgeting Model

The budgeting model was implemented as an Excel worksheet. Since relational databases are used for various components of the model, it is adaptable to a variety of economic and environmental analyses, levels of detail and to different ditch systems. Three commonly used budgeting frameworks are employed – enterprise budgeting, whole farm budgeting and capital budgeting. In this section of the report, the general design of the model will be presented including the general budgeting procedures. The databases in the model are made up of fields and records – basically the columns and rows of the table that makes up the database. Each field is a characteristic or piece of information kept for each record and the first row of the database table contains a label for the field. Subsequent rows in the table contain data for each member of the database or record.

The "main database" drives the organization of the data throughout the model. Records in the main database are parcels of land which are assumed to be uniform with respect to use, economic and environmental outcome, ownership and impact as a result of changes in the ditch system. For each parcel, data fields include general information about the location of the land, ownership, area in acres and the type of soil. The remaining fields contain information unique to each of several scenarios for the ditch. Currently the model is dimensioned for five alternatives – a base or current case and up to four alternatives for the system. Land use in the budgeting model is characterized by alternative enterprise budgets – a particular enterprise budget is identified for parcel and each of the system alternatives.

Enterprise budgets are widely used to represent the technical and economic outcomes of production for a particular crop and system of production. Here, the crop budgets include per acre yields and receipts and operating input and costs for the range of soils and drainage conditions in the watershed. The potential impacts of changes in drainage quality are reflected in the crop budgets. In many cases, the impacts would be yield changes only. However, more significant changes in land use such as retirement from production or a change from row crop production to a cover crop may be measured with the appropriate budgets, too. Operating costs in crop enterprise budgets typically include such items as seed, fertilizer, pesticides, fuel and other machine operating costs, and interest on operating costs. For illustration purposes, a typical crop enterprise budget is included in the appendix. By linking each parcel of land in the main database to an enterprise budget for each ditch system alternative, operating receipts and costs may be computed for that parcel under each system alternative. These receipts and costs may then be summed appropriately across parcels of land to get total receipts and operating costs for the entire system or for particular land owners of operators under each of the system alternatives.

Currently, the enterprise budgeting module in the spreadsheet is designed to produce estimates of receipts and operating expenses as performance measures for the alternative ditch management plans. It is useful to note that other performance measures, such as environmental outcomes, may be budgeted as well. By including characteristics such as nitrate loads associated with the farm production practices budgeted and for each ditch alternative, total effluent levels can be estimated for each of the alternatives, also. It should be mentioned that a proper assessment of tradeoffs between profitability and environmental performance would require developing enterprise budgets that include economical alternatives for reducing effluent levels, such as reduced rates of fertilizer use or manure application, if economic an environmental trade-offs associated with alternative ditch strategies can be accurately assessed.

Ownership costs, such as depreciation and interest on farm machinery is best measured at the whole farm level, rather than summing from unit or enterprise budgets. For many system alternatives, ownership costs will remain unchanged. Thus it would be unnecessary to address these costs in evaluating the alternatives. However, if a system change involves significant adjustments in land use which make changes in ownership costs likely, these changes must be addressed. To account for this, the model includes for each owner entries of ownership costs or receipt of payments associated with changes in the ditch system. These changes in costs and/or receipts are then added to operating costs and receipts in computing net returns for each system alternative.

Farm returns are budgeted here on an annual basis and should reflect costs and returns in a typical year under each system alternative. Changes in the ditch system, however, will typically involve a large capital outlay in one or more years for construction. Maintenance costs will be dispersed over the life of the system. To compute system costs, the budget model is set up for annual construction and maintenance costs associated with each system alternative to be entered over a thirty year planning horizon. For comparison to the net farm returns, these costs must be annualized. To do this, the net present values of capital and maintenance expenditures are computed for each system alternative and at three rates of interest. The net present values are then annualized to an equivalent thirty year annuity which may be treated as an annual payment for the system.

Details of the Spreadsheet

The components of the economic analysis spreadsheet, and the links between these components, are illustrated in Figure 1. For illustrative purposes, key portions of the worksheet are provided in the Appendix to this report. Data in these illustrations are hypothetical but representative of current development options under consideration for JD-20. In this analysis, system alternatives include:

i) improved system to today's standard

ii) Alternative I – Existing tile with upstream detention

iii) Alternative II – Existing tile with downstream detention

iv) Alternative III – Improved tile with downstream detention.

Forty acre land parcels, developed for the hydrologic analysis, were divided as necessary based on ownership to form the records in the main database. Soils within the parcels were assumed to be of uniform quality with specific characteristics corresponding to those of the dominant soil type.

Records in the Enterprise Budget Database were created to represent the relevant range of soil and drainage conditions, and alternative land uses associated with the land parcels and system alternatives in the main database. For purposes of this example, the alternative land uses included corn and soybeans in a two year rotation, continuous corn, continuous soybeans, a corn-soybean-alfalfa rotation, and a budget to represent land retired from agricultural production. Basic operating cost information for these enterprises was taken from the Center for Farm Financial Management's FINBIN database (FINBIN 2005).[2] The data were averaged over 25 and 33 operator owned farms in the Blue Earth County for corn and soybeans, respectively. Yield estimates based on the NRCS yields for the crop enterprises reflect the soils, drainage and production practices on the associated land parcels. The NRCS yields are for adequately-drained, well managed fields. Because some of

[2] Operating costs and other enterprise characteristics could be collected for individual owners and operators in the watershed. Budgets based on such data would provide results that to some degree represent predictions for individual farms and operators. However, using enterprise budgets which represent typical production practices may be better suited to analyses of drainage system alternatives.

the fields in JD20 are not adequately-drained by current standards – as measured by their drainage coefficients – we adjusted the NRCS yields on these fields. Long-term studies of crop response to drainage activities have been conducted in several regions (Wright and Sands 2001). In these studies, however, the drainage activities were categorized qualitatively, such as "very poorly drained" and "poorly drained." A more flexible measure of the effect of drainage quality on yields, such as the drainage coefficient, was needed for this project. A computer-based water management model entitled DRAINMOD was used to estimate relative yield responses for each alternative. To construct input data for DRAINMOD, some representative weather and soil data were used. Weather data was assembled for Waseca, Minnesota, and soil data for Guckeen silty clay loam, respectively. In addition, certain assumptions, such as drain depth, drain spacing, and desired planting data, were made. Our land valuation equation is based on current EMV and estimated NRCS yields, so the implicit assumption in the model is that all fields are well drained. (The County Assessor's valuations, which we use in estimating land values, are in part based upon the Crop Equivalent Ratings for each soil, and these are based upon the same assumption about current drainage conditions.) So the provision of "adequate" drainage in the alternatives has the effect of bringing some of the JD20 fields up to the wider county average land values. More study would be necessary to quantify the effect of yield response to drainage activities in specific watersheds.

To link changes in drainage efficiency to changes in land values, we first link crop yields to land values. If crop yields change with changes in drainage, then land values also change. This is consistent with basic economic theory that holds that agricultural land value is a function of expected annual returns.

From a set of 940 Blue Earth County quarter-quarter sections in the project vicinity, we regressed the weighted County Assessor's 2004 estimated per-acre land values on the weighted NRCS corn yield for the unit. The resulting OLS estimate was:

$$\text{Value} = 1486 + 6.46 * \text{yield}$$

In the model, then, corn yields for each ownership unit were multiplied by 6.46 to estimate the land value for the unit under each scenario.

Appendix Tables A1 and A2 summarize system cost data and annualized costs for a current "base" plan and up to four system development alternatives. The base plan and each alternative are characterized by a stream of annual maintenance costs and capital expenditures for a thirty year planning horizon, as shown in Table A1. Absent a petition for improvement, the county ditch authority is required to maintain the system in its current working order. With older systems such as JD20, this can mean frequent pipe replacement (but not enlargement, else the Repair becomes an Improvement). In our model, the current system is assumed to continue to function as is, given the stated annual repair costs and required investment. The JD-20 infrastructure cannot be maintained without a significant investment in the not so distant future. The engineer estimated current-value cost of $1.1 million. Maintenance costs shown here are constant over the planning period; however, the model will accommodate other patterns over time. Alternatives shown here involve only capital expenditures occurring at the beginning of the planning period. However, again, other schedules may be analyzed such as multi-year construction projects or phased development schemes involving capital outlays in two or more years. The net present values of these maintenance and capital expenditure cost streams appear at the bottom of Table A1 for three used defined interest rates. The same interest rates are used to compute annual capital recovery costs – a value which can be accurately compared to changes in annual farm returns.[3] Table A2 provides a summary of annualized maintenance, capital and total system costs for each development alternative.

The Main Report of the model is shown in Table A3 of the Appendix. It includes brief descriptions of the ditch development scenarios, farm costs and returns for all owner operators, capital and maintenance costs, and overall net returns. For illustrative purposes, a table of environmental impacts is included, also. Operating receipts and costs are computed by summing the values in the main database over all land parcels in the watershed. Ownership costs and other farm receipts for all land owners and farm operators are taken from data on individual owner/operators.

These entries are designed of account for changes in ownership costs, such as property taxes or new machinery, or receipts in addition to operating receipts, such as transfer payments for land retirement, associated with system alternatives. Property tax is assessed as a fixed percent of estimated land value in the current analysis, so it rises as property values increase with drainage improvements. Another example, payments to land owners to retire land for use in storage ponds, is included in the

[3] The net present value and annualized capital cost calculations are made using the NPV and PMT worksheet formulas in Excel.

current analysis. Storage ponds are assumed to be purchased from the current owner at $2,500 per acre, regardless of the land value for the property. This price is built into the system cost estimate, so the cost of land acquisition is spread over the entire project life and paid by all properties in the system. The purchase price is paid to the landowner on an annualized basis, entering as other receipts in the owner/operator accounts. No property tax and no subsidies are paid on the pond. The owner of the pond property pays the apportioned part of the cost of pond acquisition because we do not model redetermination of benefits: all system costs are assessed according to the original benefits schedule.

Farm subsidies are included as other receipts. Subsidies are calculated on the basis of production. If yield, and hence production, increases as a result of drainage improvements, subsidies are unchanged in our model. This reflects the operation of current federal farm programs. Annualized system costs are subtracted from net farm returns to get overall net returns.

Individual land owners may be identified in order to produce a summary of farm costs and returns, system costs, and overall net returns for that land owner. This report is shown for a representative land owner in Appendix Table A4. The original benefits assigned in JD-20 upon project initiation have remained largely untouched over the intervening 90 years. Benefits are based upon relative gains from drainage, not upon relative property wealth (as is the property tax system). Benefits in JD-20 are assigned to the landowner, not to the individual field, and they are not proportional to the acres of land actually in the system. In this study, however, we necessarily assumed that all benefits associated with each landowner apply just to land within the system. If total net returns for a given alternative is negative, that's the subsidy (from outside the system) necessary to make the land-owners "whole" under the alternative. Otherwise, the landowners would be better off financially not making any changes to the drainage system. If the total net returns are positive but some individual net returns are negative, these are the transfers (from inside the system) necessary to make these landowners whole. The project "winners" can pay off the "losers" and still be better off financially than under the current system. Figure 2 shows the effect on net revenues for each landowner under the improvement alternative (compared to the current system).

Next Steps

The model is adaptable and expandable in several possible directions, given the decision environment within which ditch system managers operate.

1. The model could be enlarged to deal with considerable scientific and natural system uncertainty that systems such as these exhibit.
2. We could approximate the implications of a redetermination procedure, under which costs of a major system change are reallocated according to the benefits received under the new regime. This could mirror the decision process of system Viewers, who would actually conduct a redetermination.
3. The model does not cover many smaller conservation practices that might, in reality, be proposed for a system such as this. Inclusion would require addition work by the engineers to determine how each practice affects environment conditions like flow and water quality.
4. The model does not calculate off-system costs and benefits such as flooding or water quality changes, because the physical estimates were not calculated by the engineers. Future work could greatly expand our ability to talk about downstream benefits and costs.
5. Because both physical and economic systems evolve over time, it makes sense to expand the current model into some sort of multi-year framework, to better assess long-run adjustments.

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Figure 1: Analysis Framework

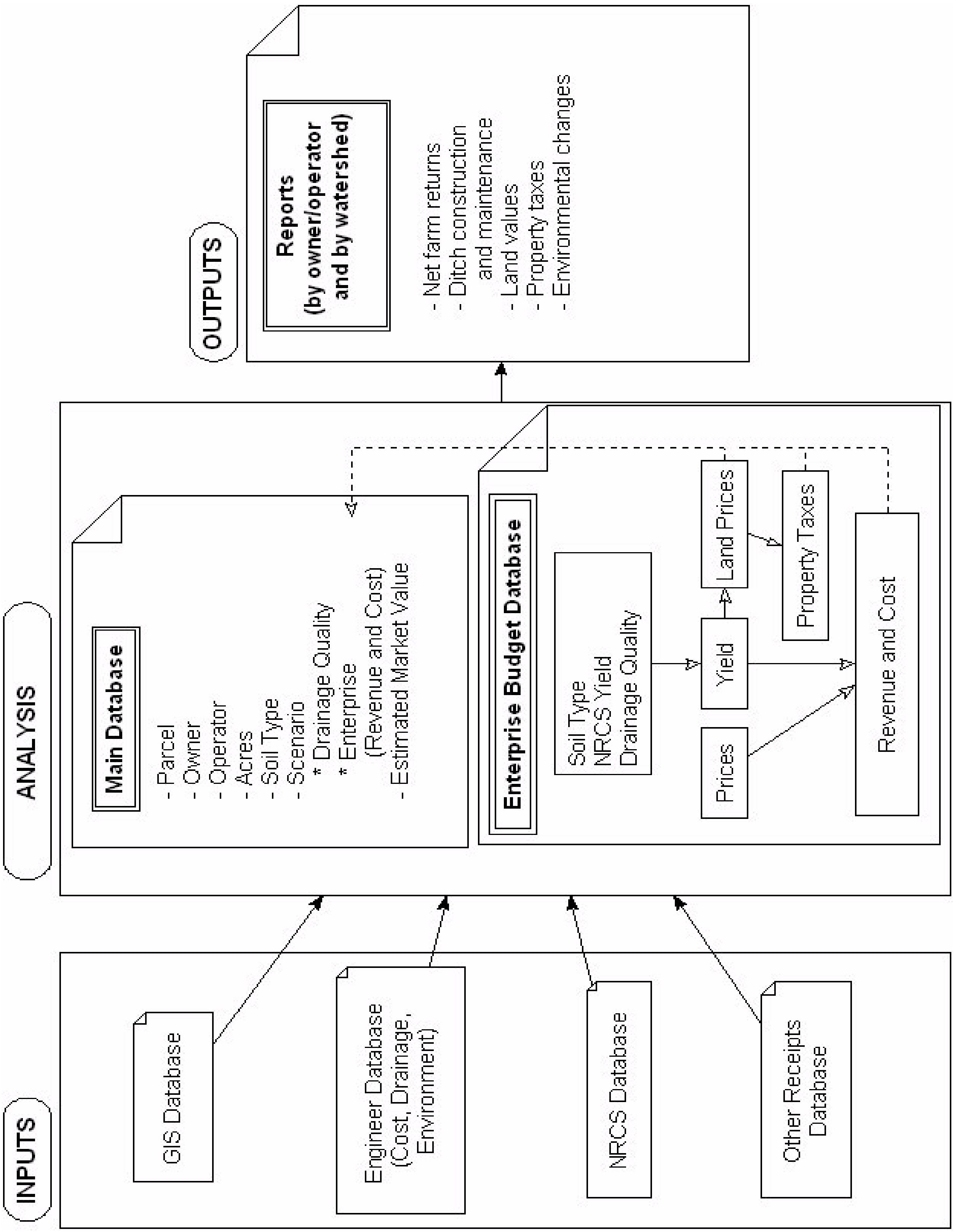
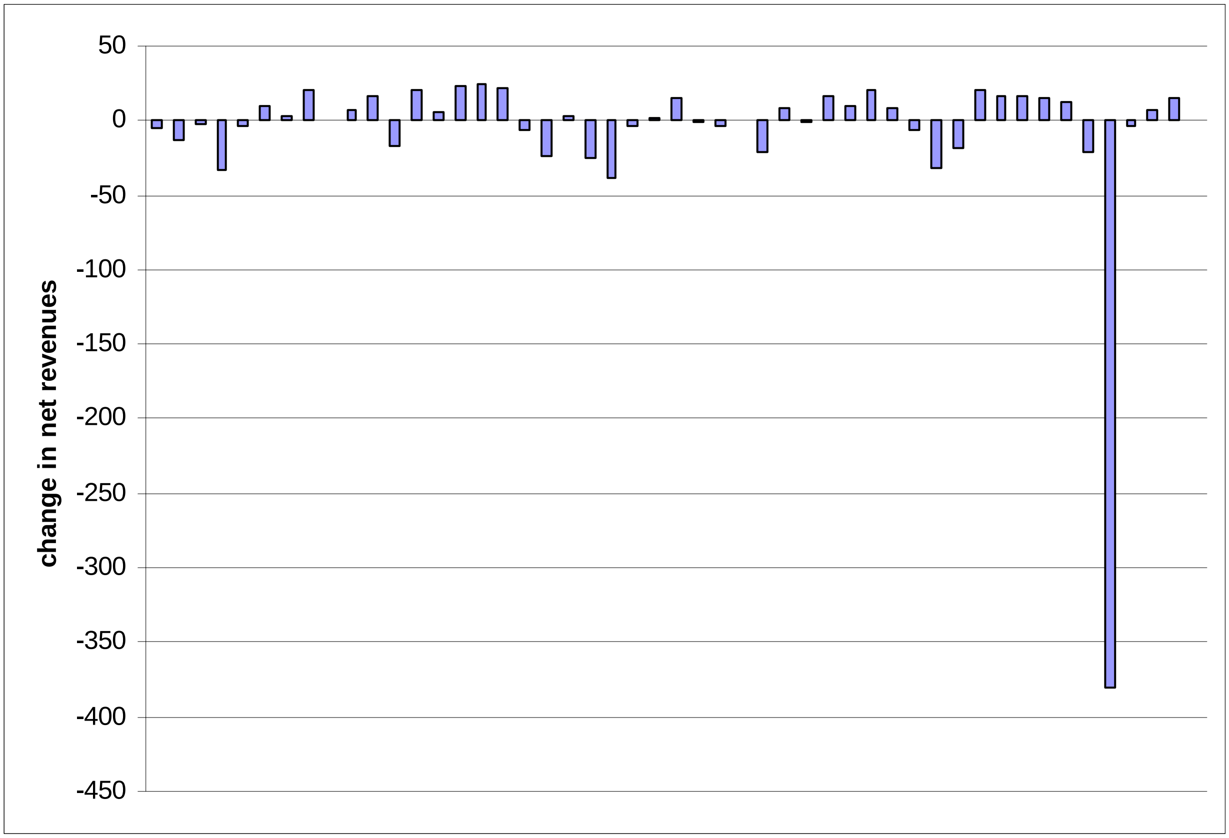


Figure 2: Effect of improvement alternative on individual landowner net revenues



Appendix

Table A1: Capital and Maintenance Cost of System by Scenario and Year, and Net Present Values and Annualized Costs by Interest Rate.

	Scenario									
	Current		Improved		I		II		III	
Year	Mainte nance	Capital Cost	Mainte nance	Capital Cost	Mainte nance	Capital Cost	Mainte nance	Capital Cost	Mainte nance	Capital Cost
0	0	1,162,100	0	1,483,200	0	1,162,100	0	1,162,100	0	1,642,400
1	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
2	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
3	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
4	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
5	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
6	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
7	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
8	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
9	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
10	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
11	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
12	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
13	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
14	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
15	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
16	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
17	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
18	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
19	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
20	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
21	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
22	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
23	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
24	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
25	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
26	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
27	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
28	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
29	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
30	10,000	0	10,000	0	10,000	0	10,000	0	10,000	0
	Net Present Value									
5.0%	153,725	1,162,100	153,725	1,483,200	153,725	1,162,100	153,725	1,162,100	153,725	1,642,400
7.5%	118,104	1,162,100	118,104	1,483,200	118,104	1,162,100	118,104	1,162,100	118,104	1,642,400
10.0%	94,269	1,162,100	94,269	1,483,200	94,269	1,162,100	94,269	1,162,100	94,269	1,642,400
	Annualized Cost									
5.0%	10,000	75,596	10,000	96,484	10,000	75,596	10,000	75,596	10,000	106,840
7.5%	10,000	98,396	10,000	125,584	10,000	98,396	10,000	98,396	10,000	139,064
10.0%	10,000	123,275	10,000	157,337	10,000	123,275	10,000	123,275	10,000	174,225

Appendix

Table A2: Annualized Capital and Maintenance Cost of System by Scenario and Interest Rate.

	Scenario				
	Current	Improved	I	II	III
Total Capital Cost	1,162,100	1,483,200	1,162,100	1,162,100	1,642,400
Years	30	30	30	30	30
	Annualized Capital Cost				
5.0%	75,596	96,484	75,596	75,596	106,840
7.5%	98,396	125,584	98,396	98,396	139,064
10.0%	123,275	157,337	123,275	123,275	174,225
	Annual Maintenance Cost				
5.0%	10,000	10,000	10,000	10,000	10,000
7.5%	10,000	10,000	10,000	10,000	10,000
10.0%	10,000	10,000	10,000	10,000	10,000
	Annualized Capital Cost + Maintenance Cost				
5.0%	85,596	106,484	85,596	85,596	116,840
7.5%	108,396	135,584	108,396	108,396	149,064
10.0%	133,275	167,337	133,275	133,275	184,225

Appendix

Table A3: Main Report.

JD-20 Economic Analysis: Main Report	
Scenario Labels and Descriptions:	
Scenario	Description . . . .
Current	Current system. Maintenance costs only.
Improved	Improved system.
Alt I	Current system with upstream detention.
Alt II	Current system with downstream detention.
Alt III	Improved system with downstream detention.

Farm Costs and Returns: All Land Owners/Farm Operators

	Scenario				
	Current	Improved	I	II	III
Operating Receipts:	$634,035	$657,722	$633,427	$633,364	$656,637
Operating Costs:	$343,879	$343,879	$342,409	$334,227	$334,227
Net Operating Income:	$290,156	$313,843	$291,018	$299,137	$322,410
Change in Net Operating Income:	---	$23,687	$862	$8,981	$32,254
Ownership Costs, Land Owners:	$37,284	$38,735	$37,117	$36,266	$37,679
Ownership Costs, Farm Operators:	$0	$0	$0	$0	$0
Other Receipts, Land Owners:	$84,161	$84,161	$83,761	$81,942	$81,942
Other Receipts, Farm Operators:	$0	$0	$0	$0	$0
Net Farm Returns:	$337,033	$359,269	$337,662	$344,813	$366,673
Change in Net Farm Returns:	---	$22,236	$629	$7,779	$29,640

	Scenario				
Interest Rate	Current	Improved	I	II	III
5.0%	$85,596	$106,484	$85,596	$85,596	$116,840
7.5%	$108,396	$135,584	$108,396	$108,396	$149,064
10.0%	$133,275	$167,337	$133,275	$133,275	$184,225

	Scenario				
Interest Rate	Current	Improved	I	II	III
5.0%	$251,437	$252,785	$252,066	$259,217	$249,833
Change in Annual Net Return:	---	$1,348	$629	$7,779	($1,604)
7.5%	$228,637	$223,685	$229,266	$236,417	$217,609
Change in Annual Net Return:	---	($4,952)	$629	$7,779	($11,028)
10.0%	$203,758	$191,932	$204,387	$211,538	$182,448
Change in Annual Net Return:	---	($11,826)	$629	$7,779	($21,310)

	Scenario				
	Current	Improved	I	II	III
Nitrogen, Tons/Year:	0.0	0.0	0.0	0.0	0.0
Change in Annual Nitrate Loss:	---	0.0	0.0	0.0	0.0
Phosphorus, Tons/Year:	0.0	0.0	0.0	0.0	0.0
Change in Annual Phosphate Loss:	---	0.0	0.0	0.0	0.0
Sediment, Tons/Year:	0.0	0.0	0.0	0.0	0.0
Change in Annual Sediment Loss:	---	0.0	0.0	0.0	0.0
10-year peak flow rate, cfs:	34.7	80.6	34.6	20.7	45.9
Change in 10-year peak runoff rate:	---	45.9	(0.1)	(14.0)	11.2

Appendix

Table A4: Land Owner Report.

JD-20 Economic Analysis: Land Owner Report		ID =	JD20-046	
Scenario Labels and Descriptions:				
Scenario	Description			
Current	Current system. Maintenance costs only.		151.52	Total acre (approx.)
Improved	Current system with upstream detention.			
Alt I	Current system with downstream detention.		0	acre to detention
Alt II	Improved system.		27.7	acre to detention
Alt III	Improved system with downstream detention.		27.7	acre to detention

Farm Costs and Returns for Owner/Operator:

	Scenario				
	Current	Improved	I	II	III
Operating Receipts:	$39,751	$41,425	$39,751	$39,467	$40,815
Operating Costs:	$22,274	$22,274	$22,274	$18,202	$18,202
Net Operating Income:	$17,477	$19,151	$17,477	$21,265	$22,613
Change in Net Operating Income:	---	$1,674	$0	$3,789	$5,136
Ownership Costs, Land Owners:	$2,384	$2,487	$2,384	$1,955	$2,038
Ownership Costs, Farm Operators:	$0	$0	$0	$0	$0
Other Receipts, Land Owners:	$20,408	$21,980	$20,408	$4,380	$4,380
Other Receipts, Farm Operators:	$0	$0	$0	$0	$0
Net Farm Returns:	$20,408	$21,980	$20,408	$23,690	$24,955
Change in Net Farm Returns:	---	$1,572	$0	$3,282	$4,546

Annualized Capital and Maintenance Costs for Owner/Operator:

	Scenario				
Interest Rate	Current	Improved	I	II	III
5.0%	$6,899	$8,583	$6,899	$6,899	$9,417
7.5%	$8,737	$10,928	$8,737	$8,737	$12,015
10.0%	$10,742	$13,487	$10,742	$10,742	$14,848

Annual Net Returns for Owner/Operator:

	Scenario				
Interest Rate	Current	Improved	I	II	III
5.0%	$13,509	$13,398	$13,509	$16,791	$15,537
Change in Annual Net Return:	---	($112)	$0	$3,282	$2,028
7.5%	$11,672	$11,052	$11,672	$14,953	$12,940
Change in Annual Net Return:	---	($619)	$0	$3,282	$1,269
10.0%	$9,666	$8,493	$9,666	$12,948	$10,106
Change in Annual Net Return:	---	($1,173)	$0	$3,282	$440

Annual Effluent Loads for Owner/Operator:

	Scenario				
	Current	Improved	I	II	III
Nitrogen, Tons/Year:	0	0	0	0	0
Change in Annual Nitrate Loss:	---	0	0	0	0
Phosphorus, Tons/Year:	0	0	0	0	0
Change in Annual Phosphate Loss:	---	0	0	0	0
Sediment, Tons/Year:	0	0	0	0	0
Change in Annual Sediment Loss:	---	0	0	0	0
10-year peak flow rate, cfs:	0	0	0	0	0
Change in 10-year peak runoff rate:	---	0	0	0	0