NC STATE UNIVERSITY

January 2006

Cost and Returns Analysis of Manure Management Systems Evaluated in 2005 under the North Carolina Attorney General Agreements with Smithfield Foods, Premium Standard Farms, and Front Line Farmers

TECHNOLOGY REPORT: CONSTRUCTED WETLANDS

Prepared as Part of the Full Economic Assessment of Alternative Swine Waste Management Systems Under the Agreement Between the North Carolina Attorney General and Smithfield Foods

Prepared for:
C. M. (Mike) Williams
Animal and Poultry Waste Management Center
North Carolina State University
Campus Box 7609
Room 134 Scott Hall
2711 Founder's Drive
Raleigh, NC 27695-7608

Prepared by:
Task 1 Team
Agricultural and Resource Economics
North Carolina State University

Technical Point of Contact:
Dr. Kelly Zering (Task 1 Team Leader)
North Carolina State University
Department of Agricultural
and Resource Economics
3313 Nelson Hall
Campus Box 8109
Raleigh, NC 27695-8109
Tel: 919-515-6089
Fax: 919-515-6268
Email: kelly_zering@ncsu.edu

Administrative Point of Contact:
Dr. Michael Wohlgenant
(Project Coordinator)
North Carolina State University
Department of Agricultural
and Resource Economics
3310 Nelson Hall
Campus Box 8109
Raleigh, NC 27695-8109
Tel: 919-515-4673
Fax: 919-515-6268
Email: michael_wohlgenant@ncsu.edu

Table of Contents

Summary of Results 1
Sensitivity Analysis 2
Break-even Analysis on By-product Prices 4
1. Overview of the Constructed Wetlands Technology 5
1.1. Farm Overview 5
1.2. Technology Overview 5
2. Mass Balances and Performance Data (Tables CW.1-CW.3) 6
3. Electricity Costs at Brandon Howard Farm (Table CW.4) 7
4. Costs of the Constructed Wetlands Technology as Constructed at Brandon Howard Farm Demonstrational Facility 7
4.1. Invoiced Construction Costs at Brandon Howard Farm (Tables CW.5-CW.9) 7
4.2. Modified Construction Costs at Brandon Howard Farm (Tables CW.10-CW.11).. 8
5. Cost Modeling (Tables CW.12-CW.53) 8
5.1. Introduction 8
5.2. Standardized Modeling Assumptions (Tables CW.12) 9
5.3. Estimated Adjusted Invoice Costs for Constructed Wetlands Technology at Brandon Howard Farm (Tables CW.13-CW.19) 9
5.4. Standardized Costs for Constructed Wetlands Technology at a 4,320-Head Feeder-to-Finish Farm with Pit-Recharge System (Tables CW.20-CW.27) 10
5.5. Standardized Costs for Constructed Wetlands Technology at a 4,320-Head Feeder-to-Finish Farm with Flush System (Tables CW.28-CW.35) 10
5.6. Standardized Costs for Constructed Wetlands Technology at an 8,800-Head Feeder-to-Finish Farm (Tables CW.36-CW.43) 11
5.7. Standardized Costs for Constructed Wetlands Technology at a 4,000-Sow Farrow-to-Wean Farm (Tables CW.44-CW.51) 11
5.8. Extrapolation to Other Farm Types and Sizes (Tables CW.52-CW.53) 12
6. Summary 13
References 14
Figure CW.1. Constructed Wetlands Waste Flow Diagram 15

Tables CW.1 through CW.3: Mass Balance and Performance Data Tables for the Constructed Wetlands Technology 16
Table CW.4: Actual Electricity Costs of the Constructed Wetlands Technology as Operated at Brandon Howard Farm 17
Tables CW.5 through CW.9: Invoiced Costs for the Constructed Wetlands Technology as Demonstrated at Brandon Howard Farm 17
Tables CW.10 through CW.11: Modified Invoiced Construction Costs for the Constructed Wetlands Technology 19
Table CW.12: Modeling and Operating Assumptions for Standardized Cost Models 20
Tables CW.13 through CW.19: Costs and Returns Estimates Based on Actual Cost and Performance Data for Constructed Wetlands On-Farm System: 3,520-Head Feeder to Finish Operation with Pit-Recharge System 21
Tables CW.20 through CW.27: Costs and Returns Estimates Based on Standardized Cost and Performance Data for Constructed Wetlands Technology: 4,320-Head Feeder to Finish Operation with Pit-Recharge System 26
Tables CW.28 through CW.35: Costs and Returns Estimates Based on Standardized Cost and Performance Data for Constructed Wetlands Technology: 4,320-Head Feeder to Finish Operation with Flush System 30
Tables CW.36 through CW.43: Costs and Returns Estimates Based on Standardized Cost and Performance Data for Constructed Wetlands Technology: 8,800-Head Feeder to Finish Operation with Pit-Recharge System 34
Tables CW.44 through CW.51: Costs and Returns Estimates Based on Standardized Cost and Performance Data for Constructed Wetlands Technology: 4,000-Sow Farrow to Wean Operation with Pit-Recharge System 38
Tables CW.52 and CW.53: Predicted Costs of Retrofitting Various Representative Farm Sizes and Farm Types with the Constructed Wetlands Technology: DWQ Permitted Farms and SF/PSF Owned Farms 42

Summary of Results

Retrofit Cost per 1,000 pounds Steady State Live Weight per year: $168.05
Standardized Feeder-to-Finish Farm with 4,320 head (Tables CW.20- CW.27)
10-Year Amortization, Pit-Recharge, N limited Irrigation onto Forage

Includes:	Manure Evacuation:	$ 1.86 / 1,000 lbs. SSLW / Yr.
	Solids Separator:	$ 35.83 / 1,000 lbs. SSLW / Yr.
	Settling Basin:	$ 2.81 / 1,000 lbs. SSLW / Yr.
	Wetlands Cells:	$ 119.68 / 1,000 lbs. SSLW / Yr.
	Increased Land Application Cost:	$ 7.87 / 1,000 lbs. SSLW / Yr.

Range:	Across Farm Sizes and Types (Pit-Recharge):	$79.28 To 365.32 / 1,000 lbs. SSLW / Yr.
	Across Farm Sizes and Types (Flush):	$86.85 To 437.29 / 1,000 lbs. SSLW / Yr.

Confidence in Estimates:

Low-Medium

Full farm-scale system with evaluations extending over a period of 20 months or more. Cost invoices appear to be complete. Flow and performance data sampled periodically as separator and operation of the technology varied over time. Some flow estimates discounted due to heavy rains during the sampling period. Unusually low barn discharge volume during the sampling period.

Costs by Category:

Direct Construction:	$102.90 / 1,000 lbs. SSLW / Yr.
Contractor Overhead	$ 44.35 / 1,000 lbs. SSLW / Yr.
Total Operating:	$ 12.93 / 1,000 lbs. SSLW / Yr.
Increased Land Application Cost:	$ 7.87 / 1,000 lbs. SSLW / Yr.

Sensitivity Analysis

Effect of Expected Economic Life, Interest Rate, and Overhead Rate on Predicted Annualized Construction and Overhead Cost ($ / 1,000 lbs. SSLW)

		Overhead Rate	
Capital Recovery Factor (CRF)		20 %	43.1 %
Low-Cost Projection			
(15-year economic life, 6 % interest rate)	0.1030	$85.31	$101.74
Baseline Cost Projection			
(10-year economic life, 8 % interest rate)	0.1490	$123.48	**$147.25***
High-Cost Projection			
(7-year economic life, 10 % interest rate)	0.2054	$170.20	$202.96

* This predicted cost was calculated using the assumptions that are applied throughout the report—10-year maximum economic life, 8 % interest rate, and 43.1 % overhead rate.

Effect of Electricity Price on Predicted Annual Operating Cost ($ / 1,000 lbs. SSLW)

Electricity Price ($ / kWh)	Predicted Annual Operating Cost ($ / 1,000 lbs. SSLW)
Low-Cost Electricity ($0.06 / kWh)	$12.51
Baseline Cost of Electricity ($0.08 / kWh)	**$12.93***
High-Cost Electricity ($0.10 / kWh)	$13.35

* This predicted cost was calculated using the assumption that is applied throughout the report--$0.08 / kWh.

The sensitivity of predicted costs and returns to a few critical assumptions is illustrated above by recalculating **annualized construction and overhead cost** with lower and higher values for amortization rate (cost recovery factor) and for overhead rate. The number in bold face (**$147.25**) is the predicted annualized 2004 construction and overhead cost for the constructed wetlands technology expressed in a $ / 1,000 lbs. SSLW metric. Numbers are recalculated using two overhead rates: 20% and 43.1%, and three combinations of interest rate and maximum expected economic life: 15 year life and 6% interest rate, 10 year life and 8% interest rate, and 7 year life and 10% interest rate. The range of selected parameter values has a significant effect on the predicted value of annual construction and overhead costs.

Similarly, predicted **annual operating costs** of the constructed wetlands technology are recalculated using higher and lower prices for electricity. The 25% increase or decrease in electricity price has a small effect (+/- 3%) on the predicted annual cost per unit reflecting low use of electricity by the constructed wetlands system.

Note that the sensitivity analysis is not intended to propose alternative costs and returns estimates. It is solely intended to illustrate the sensitivity of the results to changes in parameter values.

Break-even Analysis on By-product Prices

Breakeven analysis is conducted for systems that produce potentially marketable by-products in order to determine the by-product price required to cover the cost of the system. Separated solids are the marketable product produced by the constructed wetlands technology. In the model, separated solids were assumed to be land applied.

Break-even Analysis on Separated Solids (per wet ton of separated solids produced)

Cost to be Recovered	**($ / 1,000 lbs. SSLW)**	**Breakeven Price @ 2.39 wet tons of separated solids / 1,000 lbs. SSLW per year**
		($ / wet ton @ 80% moisture content)
Predicted cost of solids separator	$35.83	$14.98
Predicted cost of constructed wetlands system (less land application)	$160.18	$66.96

The first line in the above table shows the break-even price for a wet ton of separated solids that is necessary to offset the annualized cost of the solids separator unit process. The second line in the table shows the break-even price for a wet ton of separated solids that is necessary to cover the annualized cost of the entire constructed wetlands system. These breakeven prices are contingent on the assumption that 2.39 wet tons of separated solids are collected per year for every 1,000 pounds of SSLW. The equivalent breakeven prices for a dry ton of separated solids (at 80% moisture content) would be:

Break-even Analysis on Separated Solids (per dry ton of separated solids produced)

Cost to be Recovered	**($ / 1,000 lbs. SSLW)**	**Breakeven Price @ 0.48 annual dry tons of separated solids / 1,000 lbs. SSLW**
		($ / dry ton)
Predicted cost of solids separator	$35.83	$74.96
Predicted cost of constructed wetlands system (less land application)	$160.18	$335.10

1. Overview of the Constructed Wetlands Technology

1.1. Farm Overview

The constructed wetlands system was evaluated at the Brandon Howard Farm near Richlands, NC (Onslow County). This is a feeder-to-finish operation with four houses each containing 880 finishing hogs, summing to a total head capacity of 3,520. The constructed wetlands system has been designed to treat the waste from all four of the houses on the Brandon Howard Farm—a steady-state live weight of 475,200 pounds.

Houses at the Brandon Howard Farm have a fully slatted floor design and incorporate a pit-recharge system for waste removal. Each house contains one pit and all pits are emptied at a frequency of once per week. The volume required to recharge each pit (and thus each house) is estimated to be 40,000 gallons, although no data on actual volumes is available.

1.2. Technology Overview

The following unit processes have been identified for the constructed wetlands technology:

1) Modifications to waste evacuation system
2) Lift station
3) Solids separator
4) Settling basin
5) Constructed wetlands
6) Storage pond
7) Return to houses
8) Land application of liquids
9) Land application of separated solids

A brief description of the constructed wetlands system of waste treatment follows:

Once per week, waste exits the houses via the removal of a pull plug. It subsequently flows to a lift station before being pumped through a central valve distribution manifold into the primary collection tank of the solids separator. The separator uses a perforated screen panel to capture solids and a paddle scraper to convey solids into a screw auger. In the screw auger, additional dewatering of separated solids occurs before the solids are ultimately discharged into a manure wagon for land application. The liquid waste stream passes through the perforated screen and enters a secondary tank. It is then pumped into a gravity-settling basin (with a 30-minute retention time) for additional clarification before flowing into either of two constructed wetland cells (inner cell and outer cell).

Periodically, gravity-settled solids are pumped from the settling basin back to the separator. Supernatant liquid undergoes additional biological treatment in the wetland plant system, which is a shallow pit planted in cattails. The wetland system is designed to allow microbial colonies in the roots of the cattails to facilitate a nitrification-denitrification process, thus achieving nitrogen reduction with less odor and ammonia emissions. The supernatant remains in the wetlands for a period of approximately 12 days, after which the treated liquid is sent to a storage pond (the original lagoon). Treated liquid is held in the storage pond until it is either land applied or returned to the houses for recharging the pits. See Figure 1 for a flow diagram of the constructed wetlands waste treatment system (Rice, et. al).

2. Mass Balances and Performance Data (Tables CW.1-CW.3)

Samples were taken at Brandon Howard Farm between the dates of November, 2001 through June, 2003. Fifteen data points were recorded during this period for each of eight sampling locations throughout the constructed wetlands system. Table CW.1 summarizes this data and reports mean values for selected nutrients and wastewater characteristics. Annual TKN loading to the system was reported at about 170 lbs. / day. The constructed wetlands system removed about 57% of TKN mass loading from the liquid stream prior to land application. Likewise, about 87% of the mass balance of total phosphorus (TP) was removed from the liquid stream before land application (Rice et. al). The concentration (ppm) of TKN in the wastewater stream was reduced by 97% and the concentration of TP was reduced by 91% (Rice et. al).

Three different solids separation methods were demonstrated and verified at Brandon Howard Farm. The first separator used was an Andritz-Ruthner, Inc. Hydrasieve static screen (0.025-inch openings). This separator removed less than 15% of total solids and produced separated solids that were too wet for on-farm management. The second separation method involved using a dissolved air floatation (DAF) unit in conjunction with the Andritz separator. This method collected more than 50% of total solids, but separated solids were difficult to contain and manage due to their foamy nature. Also, the DAF unit could not be continuously operated at Brandon Howard Farm due to maintenance issues. The third separator used was a Brome-Agri Maximizer inclined screen (0.0625-inch openings). When using this separator, average solids removal efficiency was 18%. To increase the rate of solids removal, the Brome Maximizer separator was used in conjunction with a gravity settling basin. The basin had a liquid residence time of approximately 30 minutes. By using a combination of the Maximizer separator and the settling basin, a 32% solids removal rate was achieved (Rice et. al).

Table CW.2 reports performance data and mass balances for the Brome Maximizer separator as tested for the EPA Environmental Technology Verification (ETV) program. This verification was conducted independently from the experiment at Brandon Howard Farm. The solids removal rate was 28% for the Brome Maximizer as tested for the ETV program. The separated solids contained 17.6% dry matter (82.4% moisture content). The nutrient content of the Maximizer-separated solids is also reported in Table CW.2.

Table CW.3 lists the estimated wastewater flows for the constructed wetlands system as operated at Brandon Howard Farm. Due to excessive rainfall in Onslow County during 2003, the flowmeter readings for the wetlands cells were inconclusive. The percentage of liquid volume entering the wetlands cells from the barns (as opposed to the percentage entering from precipitation) could not be directly determined using the flowmeters. After accounting for the increased liquid volume due to rainfall (and losses due to evaporation), it was estimated that 8,000 gallons per day were entering the system (Rice, et. al). Of this volume, 7,200 gallons entered the wetlands cells and 800 gallons remained in the separated solids portion of the waste stream. This compares to a standard wastewater flow rate of 23,109 gallons per day (15,013 gallons of pit-recharge liquid and 8,096 gallons of feces, urine, and wash water) for a 3,520-head finishing facility with a pit-recharge system for manure removal (Combined Appendices Report, Appendix A). The low flow rate and relatively high solids content for the constructed wetlands technology suggest that little or no pit-recharge liquid was being used in the barns.

3. Electricity Costs at Brandon Howard Farm (Table CW.4)

Table CW.4 lists the monthly electricity costs that were associated with operating the constructed wetlands technology at Brandon Howard Farm. These costs were provided by Mark Rice and are based on actual invoices. These invoices reflect electricity usage for the lift station pumps, separator system, barn recharge pump, and wetland recirculation pump. Monthly power bills were available from October, 2000 to January, 2004, which covers the entire duration of the performance verification for this system. Table CW.4 reports the electricity costs from the months of November, 2001 to June, 2003, which was the range of dates that samples were taken. Electricity costs per month ranged from $147.06 to $354.42, with an average of $263.46. Kilowatt-hours of electricity consumed per month ranged from 714 to 2,955, with an average of 1,731. The use of different separators at Brandon Howard Farm is one explanation for the fluctuation in monthly electricity costs.

4. Costs of the Constructed Wetlands Technology as Constructed at Brandon Howard Farm Demonstrational Facility

4.1. Invoiced Construction Costs at Brandon Howard Farm (Tables CW.5-CW.9)

Reported cost estimates (Tables CW.5-CW.9) were based on cost invoices provided by Cavanaugh and Associates. The invoiced costs for the constructed wetlands technology as constructed at Brandon Howard Farm were separated into unit processes by Cavanaugh. Table CW.5 reports the costs associated with the lift station. Wetlands cells construction costs are reported in Table CW.6. Table CW.7 reports the costs associated with the solids separator. Table CW.8 reports the miscellaneous costs associated with the construction of the constructed wetlands technology at Brandon Howard Farm. Finally, Table CW.9 summarizes the invoiced construction costs for the constructed wetlands system. Total invoiced cost of the constructed wetlands technology as constructed at Brandon Howard Farm was $357,666 (Table CW.9). The wetlands cells accounted for

the majority of this total invoiced cost, with a unit process cost of $236,624 (see Table CW.6), or 66.2% of the constructed wetlands system's total invoiced construction cost.

4.2. Modified Construction Costs at Brandon Howard Farm (Tables CW.10-CW.11)

Tables CW.10 and CW.11 describe cost modifications that were made to the invoiced costs listed in Tables CW.5-CW.9. These modifications were made in order to remove research-related or unnecessary expenses from the technology's invoiced costs. Determining which, if any, costs to modify was based on the discretion of the economics team after meetings with the technology providers. Table CW.10 lists the costs that were modified as well as the reason for the change. In Table CW.11, a revised invoiced cost summary is shown. The total modified invoiced costs for the constructed wetlands technology was decreased to $324,193; a $33,473 reduction (~ 9%) from the total reported in Table CW.9.

5. Cost Modeling (Tables CW.12-CW.53)

5.1. Introduction

Original invoice costs were reported detailing the construction costs of the constructed wetlands technology as it was built on the Brandon Howard Farm. These costs are reported by unit process in Tables CW.5-CW.8 and summarized in Table CW.9. Modified construction costs were also determined based on meetings between the technology providers and the economic modeling team. The modified costs are reported in Table CW.10 and total modified construction costs are summarized in Table CW.11. In the next step, the economic modeling team examined the data reported in Tables CW.5-CW.8 for missing components and outdated prices. The resulting complete estimate of construction cost is intended to approximate adjusted invoiced cost that can be compared to those for other technologies analyzed under the Agreement. These approximated invoiced costs are summarized in Tables CW.13-CW.19. In the next step, estimates of costs that would occur on standard (representative) North Carolina farms were calculated. Necessary modeling assumptions used in the cost standardization process are described in Section 5.2 and in Tables CW.12. These costs are presented in Tables CW.20-CW.27 for a 4,320-head feeder-to-finish facility with a pit-recharge manure removal system. Tables CW.28-CW.35 present the costs associated with a standard North Carolina feeder-to-finish operation with a 4,320 head capacity with a flush manure removal system. A representative NC 8,800-head feeder-to-finish facility with a pit-recharge manure removal system is reported in Tables CW.36-CW.43. The final standard NC farm described in these cost tables is a 4,000-sow farrow-to-wean operation using a pit-recharge system of manure removal (Tables CW.44-CW.51).

5.2. Standardized Modeling Assumptions (Tables CW.12)

Table CW.12 lists some of the modeling assumptions used by the economics team to estimate costs and returns of the constructed wetlands technology for standard North Carolina farms. It was assumed that a Brome Maximizer inclined screen was used with a settling basin in order to separate solids. The Maximizer has 2 motors that total to 5-HP. It was assumed that the Maximizer could process 60 gallons of wastewater per minute (3,600 gallons per hour). The Maximizer plus settling basin would combine to remove 32% of total solids, and the separated solids would contain 20% dry matter (80% moisture content) (ETV Joint Verification Report). The wetlands cells were modeled using a 12-day hydraulic retention time. A loading rate of 22 pounds of nitrogen per wetland acre per day was also used in sizing the wetlands cells. Additional cost assumptions associated with the wetlands cells are reported in Table CW.12.

5.3. Estimated Adjusted Invoice Costs for Constructed Wetlands Technology at Brandon Howard Farm (Tables CW.13-CW.19)

Table CW.13 lists the assumptions (3,520-head finishing facility with pit-recharge system) for the cost estimate calculation and also summarizes annualized costs by land application scenario (nitrogen-based application to forages, nitrogen-based application to row crops, phosphorus-based application to forages, and phosphorus-based application to row crops).[1] Annualized costs for the whole system and per 1,000 lbs. of SSLW (incremental cost) are reported. Table CW.13 presents incremental costs for each of the four land application scenarios ranging from $164.53 (nitrogen-based application to row crops) to $202.82 (phosphorus-based application to forages). Land application to forages is more costly than to row crops and phosphorus-based application is more costly than nitrogen-based application with the constructed wetlands technology as operated at Brandon Howard Farm. Tables CW.14-CW.16 summarize costs associated with individual unit processes of the constructed wetlands technology. Costs are reported for the following unit processes: manure evacuation and lift station (CW.14), solids separator (CW.15), and wetlands cells (CW.16). Table CW.16 also reports the total costs associated with the unit processes listed above. Total construction costs are predicted as $463,920, while annual operating costs are estimated as $7,164. The total annualized cost of the constructed wetlands technology before land application is estimated to be $76,301 for the 3,520-head feeder-to-finish facility at Brandon Howard Farm. Tables CW.17 (lagoon effluent) and CW.18 (solids) report land application costs associated with the constructed wetlands technology. Used in conjunction with the numbers reported at the end of Table CW.16, the total annualized and incremental cost estimates are calculated and reported in Table CW.13 for each of the four scenarios of land application. Table CW.19 details the mass balance of nutrients associated with the constructed wetlands technology. The mass balance estimates are used to derive costs in Table CW.17 and CW.18.

[1] For more on land application, see Appendix B in the Combined Appendices Report.

5.4. Standardized Costs for Constructed Wetlands Technology at a 4,320-Head Feeder-to-Finish Farm with Pit-Recharge System (Tables CW.20-CW.27)

Tables CW.20- CW.27 provide estimates of the cost of constructing and operating the constructed wetlands technology on a standard (representative) North Carolina farm. The representative farm reported in this section is a 4,320-head feeder-to-finish facility using a pit-recharge system for manure removal. Table CW.20 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for retrofitting the farm with standardized constructed wetlands technology. The standardized incremental costs range from $165.64 (nitrogen-based application to row crops) to $216.52 (phosphorus-based application to forages), with an average incremental cost of $179.29 per 1,000 lbs. SSLW per year across the four land application scenarios. In the standardized constructed wetlands model (as in the model estimating actual constructed wetlands costs), forages are more costly than row crops to land apply and phosphorus-based land application is more costly than nitrogen-based land application. Tables CW.21-CW.24 report standardized costs for the following unit processes: manure evacuation (CW.21), solids separation (CW.22), settling basin (CW.23), and wetlands cell (CW.24). Table CW.24 also summarizes the predicted total costs associated with the standardized constructed wetlands technology for a 4,320-head finishing facility with a pit-recharge system. Total construction costs are estimated at $576,254, while total annual operating costs are predicted as $7,539. Total annualized costs before land application are estimated at $93,418 for this representative farm size and type. Tables CW.25 (lagoon effluent) and CW.26 (solids) summarize the land application costs predicted for this model for each of four scenarios. Table CW.27 provides an estimated mass balance of nutrients for this representative NC farm size and type.

5.5. Standardized Costs for Constructed Wetlands Technology at a 4,320-Head Feeder-to-Finish Farm with Flush System (Tables CW.28-CW.35)

Tables CW.28- CW.35 provide estimates of the cost of constructing and operating the constructed wetlands technology on a standard (representative) North Carolina 4,320-head feeder-to-finish facility using a flush system for manure removal. The only difference between the standard farm chosen to calculate the numbers in Tables CW.28-CW.35 versus the one chosen to estimate the numbers in Tables CW.20-CW.27 is the type of manure removal system used. Table CW.28 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for the standardized constructed wetlands technology. The standardized incremental costs of retrofitting the farm with the constructed wetlands system range from $166.80 (nitrogen-based application to row crops) to $219.29 (phosphorus-based application to forages), with an average incremental cost across the four scenarios of $181.18 per 1,000 lbs. SSLW per year. Forages are more costly than row crops for land application and phosphorus-based applications are more costly than nitrogen-based applications. The use of the flush system of manure removal increases average incremental cost estimates by about 1% for a 4,320-head finishing facility as compared to using a pit-recharge system for the same facility. Tables CW.29-CW.32 list the costs of individual unit processes in this standardized model. The set of unit

processes and components are identical to those in Tables CW.21-CW.24, although some of the costs change between the two sets of tables. Table CW.32 also summarizes the total costs associated with the standardized constructed wetlands technology for a 4,320-head finishing facility with a flush system. Total construction costs are estimated at $583,690, while total annual operating costs are reported as $7,848. Total annualized costs before land application are estimated at $94,835 for this representative farm size and type. Tables CW.33 (lagoon effluent) and CW.34 (solids) summarize the land application costs associated with this standardized model for each of four scenarios. Table CW.35 provides an estimated mass balance of nutrients for the representative farm modeled in these tables.

5.6. Standardized Costs for Constructed Wetlands Technology at an 8,800-Head Feeder-to-Finish Farm (Tables CW.36-CW.43)

Tables CW.36- CW.43 provide estimates of the cost of constructing and operating the constructed wetlands technology on a standard (representative) North Carolina 8,800-head feeder-to-finish facility using a pit-recharge system for manure removal. Table CW.36 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for retrofitting a farm with the standardized constructed wetlands technology. The standardized incremental costs for the 8,800-head finishing facility range from $132.09 (nitrogen-based application to row crops) to $185.05 (phosphorus-based application to forages), with an average incremental cost of $146.68 per 1,000 lbs. SSLW per year across the four scenarios. This average incremental cost is about 18% less than that of a standardized 4,320-head finishing facility with a pit-recharge system. Based on this finding, the model suggests that economies of scale are present for the constructed wetlands technology when moving from one medium-sized farm to another. Moderate economies of scale are present within the solids separator, settling basin, and wetlands cells unit processes. The next sections show that more significant economies of scale are predicted when moving from small farms to large farms (or, to a lesser degree, small farms to medium farms). Tables CW.37-CW.40 list the costs of individual unit processes in this standardized model. The set of unit processes and components are identical to those in Tables CW.21-CW.24 and CW.29-CW.32, although some of the costs change between the sets of tables. Table CW.40 also summarizes the total costs associated with the standardized constructed wetlands technology for an 8,800-head finishing facility. Total construction costs are estimated at $963,820, while total operating costs are reported as $12,763. Total annualized costs before land application are estimated at $156,400 for this representative farm size and type. Tables CW.41 (lagoon effluent) and CW.42 (solids) summarize the land application costs associated with this standardized model for each of four scenarios. Table CW.43 provides predicted mass balance of nutrients for the representative farm modeled in this section.

5.7. Standardized Costs for Constructed Wetlands Technology at a 4,000-Sow Farrow-to-Wean Farm (Tables CW.44-CW.51)

Tables CW.44- CW.51 provide estimates of the cost of constructing and operating the constructed wetlands technology on a standard (representative) North Carolina 4,000-sow farrow-to-wean operation using a pit-recharge system for manure removal. This representative farm contains 1,732,000 pounds of SSLW: the largest of any standard farm modeled for the constructed wetlands technology. Table CW.44 provides total annualized and per unit ($ / 1,000 lbs. SSLW) costs for the standardized constructed wetlands technology. The standardized incremental costs range from $88.95 (phosphorus-based application to row crops) to $105.00 (phosphorus-based application to forages), with an average incremental cost of $94.07 per 1,000 lbs. SSLW per year across the four scenarios of land application. Land application to forages was modeled to be more costly than land application to row crops. Tables CW.45-CW.48 provide details of the costs of individual unit processes in this standardized model (as seen in previous sections). Table CW.48 also summarizes the total costs of the standardized constructed wetlands technology for a 4,000-sow farrow-to-wean operation. Total construction costs are estimated at $982,248, while total annual operating costs are reported as $19,240. Total annualized costs before land application are estimated at $165,623 for this representative farm size and type. Although SSLW at this facility is about 50% greater than at the standard 8,800-head finishing farm (1,732,000 lbs. SSLW vs. 1,188,000 lbs. SSLW), the total annualized construction costs are nearly the same ($982,248 vs. $963,820). This is a result of differences in nitrogen production rates across farm types, and the corresponding differences in wetlands cell sizes (as determined by nitrogen loading rates) for the constructed wetlands technology. Tables CW.49 (lagoon effluent) and CW.50 (solids) summarize the land application costs associated with this standardized model for each of four scenarios. Table CW.51 provides an estimated mass balance of nutrients for the 4,000-sow farrow-to-wean operation modeled for the constructed wetlands technology.

5.8. Extrapolation to Other Farm Types and Sizes (Tables CW.52-CW.53)

Table CW.52 summarizes the per unit incremental costs ($ / 1,000 lbs. SSLW) of retrofitting the constructed wetlands technology onto each of the 25 size of farm / type of operation combinations. This table uses the representative farm size for a permitted North Carolina farm within a size / type combination. Incremental costs are shown for both pit-recharge and flush systems and Table CW.52's costs assume nitrogen-based land application to forages. Table CW.53 is analogous to Table CW.52, but uses representative farm sizes for Smithfield Foods/Premium Standard Farms (SF/PSF) owned farms only. Incremental costs are again shown for both pit-recharge and flush systems. As in Table CW.52, the costs in Table CW.53 assume that a nitrogen-based land application to forages is chosen. Tables CW.52 and CW.53 illustrate that predicted incremental costs decrease as the size of the farm increases. These economies of scale are present across all five types of operations, and are the most significant when moving from the smallest size category (0-500,000 lbs. SSLW) to the next smallest size category (500,000-1,000,000 lbs. SSLW). Within their farm size categories, wean-to-feeder operations are the most expensive types of farms on which to construct and operate the constructed wetlands technology (on a $ / 1,000 lbs. SSLW / year basis). It is also

apparent in Tables CW.52 and CW.53 that retrofits of farms with flush systems of manure removal are predicted to be more costly than those with pit-recharge systems for any size of farm/type of operation category.

6. Summary

The constructed wetlands technology was installed on the Brandon Howard farm in full scale. Based on estimates reported by Rice et al., the wetlands system treated 8,000 gallons per day of effluent from four pit-recharge type finishing barns each with 880 head capacity. Performance evaluation occurred between November, 2001 and June, 2003. The system includes a lift station, a solids separator, a settling basin, two parallel wetlands cells, and a storage pond. Three solids separation devices were tested during the project. Samples of nutrient and solids concentration in the liquid at various points in the system were reported. Percent of solids separated and moisture content of that material were reported. Some flow data were discounted due to excessive rainfall during the evaluation. The effluent from the storage pond had 97% lower concentration of TKN and 91% lower TP concentration than the barn effluent (Table CW.1.). The initial investment predicted for installation of the Wetlands system on a standardized 4,320-head flush type finishing farm is $583,690. The annual operating costs for the system are predicted at $7,848 and total annualized cost of the system is predicted at $170.57 per 1,000 pounds Steady State Live Weight per year over a 10-year amortization period. A considerable range of predicted costs ($79 to $437 per 1,000 pounds SSLW per year) occurs across different sizes and types of farms reflecting predicted economies of size and scale in construction of the system and reflecting differences in TKN loading per 1,000 pounds SSLW across different types of farms.

References

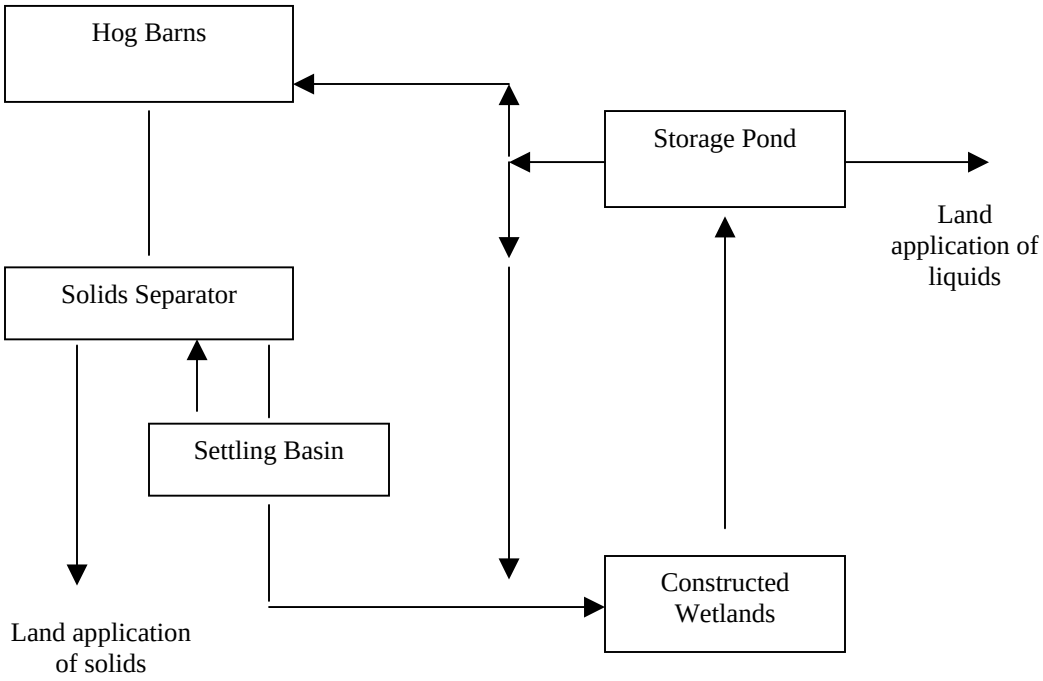
Cavanaugh and Associates. Data submitted by and/or personal communication with Jason Wilson. 2003-2004.

ETV Joint Verification Statement. USEPA. “Maximizer Separator Max 1016.” 03/01/WQPC-SWP. September, 2003.

Rice, Mark. North Carolina State University. Personal Communication. 2003-2005.

Rice, Mark, Frank Humenik, Craig Baird, and Diana Rashash. “Draft Final Report: Solid Separation/Constructed Wetland System for Swine Wastewater Treatment.” April 21, 2005.

Figure CW.1. Constructed Wetlands Waste Flow Diagram



Tables CW.1 through CW.3: Mass Balance and Performance Data Tables for the Constructed Wetlands Technology

Table CW.1. Nutrient and Total Solids Concentration of the Constructed Wetlands Wastewater Stream at Various Sampling Points (Rice, et. al)

Sampling Point	TKN (ppm)	TP (ppm)	Total Solids (%)
Inflow to separator	2,564	509	1.90
Inflow to settling basin	2,553	506	1.41
Outflow from settling basin	2,354	452	1.03
Inflow to inner wetlands cell	2,154	348	0.82
Inflow to outer wetlands cell	1,535	296	0.78
Outflow from inner wetlands cell	130	100	0.20
Outflow from outer wetlands cell	90	37	0.20
Holding pond	77	46	0.18
Concentration reduction (ppm) for the system	97%	91%	--
Mass reduction (lbs. / day) for the system*	57%	87%	--

* Mass reduction for the system is based on the amount of nutrients in the flushed effluent (pounds per day leaving the barn) as compared to the amount of nutrients in the recycled influent to the barns (pounds per day entering the barn). A mass balance breakdown of nutrients at sampling points throughout the system was not available.

Table CW.2. Recovered Separated Solids Characteristics—Brome Maximizer Separator (ETV Joint Verification Statement)

Solids recovery rate (dry weight mass basis)	28%
Dry matter content of separated solids	17.6% (82.4% moisture content)
Total nitrogen (ppm) (dry weight)	4,400
Total phosphorus (ppm) (dry weight)	2,530
Potassium (ppm) (dry weight)	628

Table CW.3. Estimated Flow Rates for the Constructed Wetlands System at Brandon Howard Farm (Rice)

Total volume leaving the barns	8,000 gallons per day
Wastewater entering solids separator	8,000 gallons per day
Wastewater entering constructed wetlands cells	7,200 gallons per day

Table CW.4: Actual Electricity Costs of the Constructed Wetlands Technology as Operated at Brandon Howard Farm

Table CW.4. Actual Electricity Costs of the Constructed Wetlands Technology as Operated at Brandon Howard Farm (Rice)

Month	Kilowatt-Hours	Electricity Cost
November ‘01	1,886	$302.02
December ‘01	2,004	$273.73
January ‘02	2,078	$307.42
February ‘02	714	$205.05
March ‘02	1,985	$283.69
April ‘02	1,111	$254.14
May ‘02	892	$234.52
June ‘02	2,955	$354.42
July ‘02	2,268	$312.85
August ‘02	2,720	$327.59
September ‘02	2,145	$296.70
October ‘02	1,121	$239.00
November ‘02	1,754	$280.27
December ‘02	1,360	$260.52
January ‘03	942	$225.72
February ‘03	1,004	$216.43
March ‘03	1,969	$212.38
April ‘03	1,581	$147.06
May ‘03	2,211	$318.50
June ‘03	1,920	$217.00
Averages	**1,731**	**$263.46**

Tables CW.5 through CW.9: Invoiced Costs for the Constructed Wetlands Technology as Demonstrated at Brandon Howard Farm (Construction Occurred Between May, 2000 and November, 2000)

Table CW.5. Invoiced Lift Station Construction Costs for Constructed Wetlands

Component	Invoiced Cost
Ditching	$1,525.00
Plumbing	$36,965.39
Wetwells	$5,029.50
Piping	$510.92
Hardware	$1,174.10
Electrical (labor and materials)	$3,586.28
Total Cost of Lift Station	**$48,791.19**

Table CW.6. Invoiced Wetlands Cells Construction Costs for Constructed Wetlands (2000)

Component	Invoiced Cost
Excavation	$84,540.75
Loading/unloading	$2,275.00
Fill	$9,000.00
Discing, seeding, and mulching dikes	$7,600.00
Plumbing	$56,241.98
Bentonite (liner material)	$59,248.78
Geological investigation	$7,441.11
Cattails	$2,351.50
Junction box	$833.16
Hardware	$1,751.38
Spreading bentonite	$2,250.00
Equipment rental/repair	$1,483.96
Liner testing	$1,606.00
Total Cost of Wetlands Cells	**$236,623.62**

Table CW.7. Invoiced Solids Separator Construction Costs for Constructed Wetlands (2000)

Component	Invoiced Cost
Andriz separator	$10,387.51
Rock	$277.47
Plumbing	$1,314.00
Labor	$8,125.00
Water tiles	$1,080.00
Hardware	$740.13
Concrete	$3,969.37
Stop logs and grooves	$5,940.00
Welding	$1,860.11
Metals USA	$3,823.95
Flex hose and fitting for recycle pump	$1,260.64
Total Cost of Solids Separator	**$38,778.18**

Table CW.8. Invoiced Miscellaneous Expenses for Constructed Wetlands (2000)

Component	Invoiced Cost
Miscellaneous expenses (meals, hotels, car rentals, etc.)	$16,432.14
Irrigation pipe from storage pond	$17,040.90
Total Cost of Miscellaneous Expenses	**$33,473.04**

Table CW.9. Summary of Invoiced Construction Costs for the Constructed Wetlands Technology (2000)

Component	Invoiced Cost	% of Total Cost
Lift station	$48,791.19	13.64 %
Wetlands	$236,623.62	66.16 %
Solids separator	$38,778.18	10.84 %
Miscellaneous expenses	$33,473.04	9.36 %
Total Invoiced Cost of Constructed Wetlands	**$357,666.03**	**100.00 %**

Tables CW.10 through CW.11: Modified Invoiced Construction Costs for the Constructed Wetlands Technology

Table CW.10. Modifications to the Invoiced Construction Costs for the Constructed Wetlands Technology

Unit Process	Component	Reason for Modification
Miscellaneous expenses	Meals, hotels, car rentals, etc.	research-related expenses
Miscellaneous expenses	Irrigation pipe from storage pond*	not part of wetlands system

* Pipe was used for land application at Brandon Howard Farm. It was assumed that all land application infrastructure would be in place at representative farms (since the existing lagoon is used as a storage pond in the constructed wetlands system).

Table CW.11. Summary of Modified Invoiced Construction Costs for the Constructed Wetlands Technology

Component	Invoiced Cost	% of Total Cost
Lift station	$48,791.19	15.05 %
Wetlands	$236,623.62	72.99 %
Solids separator	$38,778.18	11.96 %
Total Modified Invoiced Cost of Constructed Wetlands	**$324,192.99**	**100.00 %**

Table CW.12: Modeling and Operating Assumptions for Standardized Cost Models

Table CW.12. Modeling and Operating Assumptions for Standardized Cost Models

Solids separator used	Brome Maximizer (inclined screen) and settling basin
Separator horsepower	5-HP
Separator capacity	60 gallons / minute
Separator efficiency	32% total solids removal
Moisture content of separated solids	80%
Retention time in constructed wetlands cells	12 days
Loading rate for constructed wetlands cells	22 lbs. of N / acre
Bentonite liner cost	$0.146 / square foot
Cost of planting cattails	$800 / acre of wetland base
Cost of planting media fill	$2,600 / acre of wetland base
Wetlands plumbing cost	$2,311 / acre of wetland base

Tables CW.13 through CW.19: Costs and Returns Estimates Based on Actual Cost and Performance Data for Constructed Wetlands On-Farm System: 3,520-Head Feeder to Finish Operation with Pit-Recharge System

Table CW.13. Constructed Wetlands Technology Assumptions and Total Annualized Costs: Actual Costs and Performance Data

Number of Animals	**3,520**		
Type of Operation	**Feeder-Finish**		
Barn Cleaning System	**Pit-Recharge**		
Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
	If Nitrogen-Based Application	**$ 78,899.12**	**$ 78,182.73**
	If Phosphorus-Based Application	**$ 96,379.72**	**$ 78,913.27**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost per Unit		Forages	Row Crops
	If Nitrogen-Based Application	**$ 166.03**	**$ 164.53**
	If Phosphorus-Based Application	**$ 202.82**	**$ 166.06**

Note: Daily volume discharged from barns is 23,109 gallons / day including recharge liquid.
SSLW equals 475,200 pounds.

Table CW.14. Constructed Wetlands Technology Manure Evacuation and Lift Station Costs: Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Ditching	$ 1,525.00	$ 227.27
Plumbing	$ 36,965.39	$ 5,508.93
Wetwells	$ 4,919.50	$ 733.15
Piping	$ 510.92	$ 76.14
Welding	$ 110.00	$ 16.39
Hardware	$ 1,174.10	$ 174.98
Electrical Materials	$ 3,586.28	$ 534.46
Contractor & Engineering Services & Overhead	$ 21,029.00	$ 3,133.94
Total Construction Cost	$ 69,820.19	$ 10,405.27
Electric Power Cost		$ 192.44
Maintenance Cost		$ 2,199.67
Property Taxes		$ 247.86
Total Operating Cost		$ 2,639.98
TOTAL ANNUALIZED COST OF MANURE EVACUATION AND LIFT STATION		**$ 13.045.24**

Table CW.15. Constructed Wetlands Technology Solids Separator Costs: Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Rock	$ 277.47	$ 41.35
Plumbing	$ 1,314.00	$ 195.82
Labor	$ 8,125.00	$ 1,210.86
Water Tiles	$ 1,080.00	$ 160.95
Hardware	$ 740.13	$ 110.30
Concrete	$ 3,969.37	$ 591.55
Stop Log and Grooves	$ 5,940.00	$ 885.24
Welding	$ 1,860.11	$ 277.21
Screen Separator	$ 10,387.51	$ 1,548.05
Aluminum Frame for Pump	$ 3,030.84	$ 451.68
Steel Tower	$ 2,053.75	$ 306.07
Contractor & Engineering Services & Overhead	$ 16,713.40	$ 2,490.79
Total Construction Cost	$ 55,491.58	$ 8,269.88
Electric Power Cost		$ 801.85
Maintenance Cost		$ 881.94
Property Taxes		$ 197.00
Total Operating Cost		$ 1,880.78
TOTAL ANNUALIZED COST OF SOLIDS SEPARATOR		**$ 10,150.67**

Table CW.16. Constructed Wetlands Technology Wetlands Cells Costs: Actual Costs and Performance Data

Component	Total Cost	Annualized Cost
Excavation	$ 69,165.75	$ 10,307.74
Resloping/Recutting	$ 15,375.00	$ 2,291.33
Loading/Unloading	$ 2,275.00	$ 339.04
Planting Media Fill	$ 9,000.00	$ 1,341.27
Disc, Seed, and Mulch Dikes	$ 7,600.00	$ 1,132.62
Plumbing	$ 56,241.98	$ 8,381.71
Bentonite (liner material, liner spreading, and liner testing)	$ 63,104.78	$ 9,404.48
Geological Investigation	$ 7,441.11	$ 1,108.94
Cattails	$ 2,351.50	$ 350.44
Junction Box	$ 833.16	$ 124.17
Hardware	$ 1,551.38	$ 231.20
Float Logs	$ 200.00	$ 29.81
Equipment Rental	$ 1,483.96	$ 221.16
Contractor & Engineering Services & Overhead	$ 101,984.78	$ 15,198.74
Total Construction Cost	$ 338,608.40	$ 50,462.64
Maintenance Cost		$ 1,440.73
Property Taxes		$ 1,202.06
Total Operating Cost		$ 2,642.79
TOTAL ANNUALIZED COST OF WETLANDS CELLS		**$ 53,105.42**

TOTAL CONSTRUCTION COST OF CONSTRUCTED WETLANDS TECHNOLOGY	**$ 463,920.17**
TOTAL OPERATING COST INCLUDING ROYALTIES OF CONSTRUCTED WETLANDS TECHNOLOGY	**$ 7,163.55**
TOTAL ANNUALIZED COSTS OF CONSTRUCTED WETLANDS TECHNOLOGY WITHOUT LAND APPLICATION	**$ 76,301.33**

Table CW.17. Constructed Wetlands Technology Predicted Liquid Application Costs for Four Land Application Scenarios: Actual Costs and Performance Data

Annual Cost of Applying Lagoon Effluent		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	7,062.54	$	6,264.32
If Phosphorus-Based Application	$	6,865.19	$	6,532.18
Acres Needed For Assimilation		**Forages**		**Row Crops**
If Nitrogen-Based Application		11.48		37.21
If Phosphorus-Based Application		14.65		40.03
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	688.94		
If Phosphorus-Based Application	$	878.72		
Irrigation Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	6,373.60	$	7,035.98
If Phosphorus-Based Application	$	5,720.19	$	7,411.72
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application			$	(771.65)
If Phosphorus-Based Application			$	(879.54)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application		-		
If Phosphorus-Based Application	$	266.28		

Note: 6,114,188 gallons / year of effluent land applied at Brandon Howard Farm

Table CW.18. Constructed Wetlands Technology Predicted Solids Application Costs for Four Land Application Scenarios: Actual Costs and Performance Data

Annual Cost of Applying Solids		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	10,491.34	$	8,141.33
If Phosphorus-Based Application	$	30,866.25	$	9,494.06
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		16.15		52.35
If Phosphorus-Based Application		106.12		283.52
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	969.14		
If Phosphorus-Based Application	$	6,367.30		
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	8,650.69	$	9,178.89
If Phosphorus-Based Application	$	9,956.32	$	12,467.64
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application			$	(1,037.56)
If Phosphorus-Based Application			$	(2,973.58)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	871.50		
If Phosphorus-Based Application	$	14,542.62		

Note: 1,776,148 lbs. / year of solids land applied at Brandon Howard Farm

Table CW.19. Summary and Mass Balance of Generated and Land Applied Nutrients: Actual Costs and Performance Data

Nutrient Balance	Nitrogen (lbs/ year)	Phosphorus (lbs / year)	Potassium (lbs / year)
Generated At Barn	71,244.80	20,416.00	35,024.00
Removed in Separated Solids	7,815.05	4,493.65	1,115.42
Entering Constructed Wetlands	63,429.75	15,922.35	33,908.58
Removed in Constructed Wetlands	44,400.82	13,852.44	5,086.29
Entering Storage Pond	19,028.92	2,069.90	28,822.29
Removed in Storage Pond	12,362.33	1,344.73	18,724.69
Land Applied in Liquid Effluent	6,666.59	725.17	10,097.60

Source: Rice et. al

Tables CW.20 through CW.27: Costs and Returns Estimates Based on Standardized Cost and Performance Data for Constructed Wetlands Technology: 4,320-Head Feeder to Finish Operation with Pit-Recharge System

Table CW.20. Constructed Wetlands Technology Assumptions and Total Annualized Costs: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Number of Animals	**4,320**		
Type of Operation	**Feeder-Finish**		
Barn Cleaning System	**Pit-Recharge**		
Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
	If Nitrogen-Based Application	**$ 98,007.06**	**$ 96,601.48**
	If Phosphorus-Based Application	**$ 126,273.67**	**$ 97,368.56**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost per Unit		Forages	Row Crops
	If Nitrogen-Based Application	**$ 168.05**	**$ 165.64**
	If Phosphorus-Based Application	**$ 216.52**	**$ 166.96**

Note: Daily volume discharged from barns is 28,361 gallons / day including recharge liquid.
SSLW equals 583,200 pounds.

Table CW.21. Constructed Wetlands Technology Manure Evacuation Modification Costs: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Waste Evacuation/Plumbing Cost	$ 4,555.00	$ 678.83
Contractor & Engineering Services & Overhead	$ 1,963.21	$ 292.58
Total Construction Cost	$ 6,518.21	$ 971.40
Maintenance Cost		$ 91.10
Property Taxes		$ 23.14
Total Operating Cost		$ 114.24
TOTAL ANNUALIZED COST OF MANURE EVACUATION MODIFICATIONS		**$ 1,085.64**

Table CW.22. Constructed Wetlands Technology Solids Separator Costs: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Mechanical Solids Separator	$ 66,606.00	$ 9,926.26
Concrete Basin	$ 8,558.08	$ 1,275.41
Contractor & Engineering Services & Overhead	$ 32,395.72	$ 4,827.92
Total Construction Cost	$ 107,559.79	$ 16,029.58
Electric Power Cost		$ 984.09
Maintenance Cost		$ 3,501.46
Property Taxes		$ 381.84
Total Operating Cost		$ 4,867.39
TOTAL ANNUALIZED COST OF SOLIDS SEPARATOR		**$ 20,896.97**

Table CW.23. Constructed Wetlands Technology Settling Basin Costs: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Settling Basin	$ 6,863.20	$ 1,022.82
Contractor & Engineering Services & Overhead	$ 2,958.04	$ 440.83
Total Construction Cost	$ 9,821.24	$ 1,463.65
Maintenance Cost		$ 137.26
Property Taxes		$ 34.87
Total Operating Cost		$ 172.13
TOTAL ANNUALIZED COST OF SETTLING BASIN		**$ 1,635.78**

Table CW.24. Constructed Wetlands Technology Wetlands Cells Costs: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Excavation	$ 124,835.53	$ 18,604.18
Resloping/Recutting	$ 47,437.50	$ 7,069.59
Bentonite Liner	$ 74,344.79	$ 11,079.57
Wetland Plants	$ 7,233.25	$ 1,077.97
Disc, Seed, and Mulch Dikes	$ 9,041.56	$ 1,347.46
Plumbing	$ 20,895.05	$ 3,113.98
Planting Media Fill	$ 23,508.06	$ 3,503.39
Geological Investigation	$ 8,815.52	$ 1,313.77
Contractor & Engineering Services & Overhead	$ 136,243.96	$ 20,304.37
Total Construction Cost	$ 452,355.22	$ 67,414.27
Maintenance Cost		$ 779.56
Property Taxes		$ 1,605.86
Total Operating Cost		$ 2,385.42
TOTAL ANNUALIZED COST OF WETLANDS CELLS		**$ 69,799.69**

TOTAL CONSTRUCTION COST OF CONSTRUCTED WETLANDS TECHNOLOGY	**$ 576,254.46**
TOTAL OPERATING COST INCLUDING ROYALTIES OF CONSTRUCTED WETLANDS TECHNOLOGY	**$ 7,539.18**
TOTAL ANNUALIZED COSTS OF CONSTRUCTED WETLANDS TECHNOLOGY WITHOUT LAND APPLICATION	**$ 93,418.09**

Table CW.25. Constructed Wetlands Technology Predicted Liquid Application Costs for Four Land Application Scenarios: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Annual Cost of Applying Lagoon Effluent	Forages	Row Crops
If Nitrogen-Based Application	$ 7,566.95	$ 7,342.06
If Phosphorus-Based Application	$ 7,512.80	$ 7,416.66
Acres Needed For Assimilation	**Forages**	**Row Crops**
If Nitrogen-Based Application	13.61	44.10
If Phosphorus-Based Application	16.55	45.25
Opportunity Cost of Land	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 816.34	
If Phosphorus-Based Application	$ 993.20	
Irrigation Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 6,750.61	$ 8,251.35
If Phosphorus-Based Application	$ 6,271.44	$ 8,410.79
Savings From Not Having To Buy Fertilizer	**Forages**	**Row Crops**
If Nitrogen-Based Application		$ (909.29)
If Phosphorus-Based Application		$ (994.13)
Extra Fertilizer Purchase Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	-	
If Phosphorus-Based Application	$ 248.16	

Note: 7,247,779 gallons / year of effluent modeled to be land applied

Table CW.26. Constructed Wetlands Technology Predicted Solids Application Costs for Four Land Application Scenarios: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Annual Cost of Applying Solids		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	13,840.27	$	10,086.92
If Phosphorus-Based Application	$	45,702.93	$	11,923.85
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		25.37		82.24
If Phosphorus-Based Application		166.71		445.38
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	1,522.43		
If Phosphorus-Based Application	$	10,002.45		
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	10,948.79	$	11,716.83
If Phosphorus-Based Application	$	12,855.34	$	16,595.08
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application			$	(1,629.91)
If Phosphorus-Based Application			$	(4,671.23)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	1,369.05		
If Phosphorus-Based Application	$	22,845.14		

Note: 2,790,167 lbs. / year of solids modeled to be land applied

Table CW.27. Summary and Mass Balance of Generated and Land Applied Nutrients: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Pit-Recharge)

Nutrient Balance	**Nitrogen (lbs/ year)**	**Phosphorus (lbs / year)**	**Potassium (lbs / year)**
Generated At Barn	87,436.80	25,056.00	42,984.00
Removed in Separated Solids	12,276.73	7,059.12	1,752.22
Entering Constructed Wetlands	75,160.07	17,996.88	41,231.78
Removed in Constructed Wetlands	52,612.05	15,657.28	6,184.77
Entering Storage Pond	22,548.02	2,339.59	35,047.61
Removed in Storage Pond	14,648.55	1,519.94	22,768.64
Land Applied in Liquid Effluent	7,899.47	819.65	12,278.37

Tables CW.28 through CW.35: Costs and Returns Estimates Based on Standardized Cost and Performance Data for Constructed Wetlands Technology: 4,320-Head Feeder to Finish Operation with Flush System

Table CW.28. Constructed Wetlands Technology Assumptions and Total Annualized Costs: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Number of Animals	**4,320**
Type of Operation	**Feeder-Finish**
Barn Cleaning System	**Flush**

Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
	If Nitrogen-Based Application	**$ 99,476.27**	**$ 97,277.29**
	If Phosphorus-Based Application	**$ 127,888.21**	**$ 98,018.13**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost per Unit		Forages	Row Crops
	If Nitrogen-Based Application	**$ 170.57**	**$ 166.80**
	If Phosphorus-Based Application	**$ 219.29**	**$ 168.07**

Note: Daily volume discharged from barns is 33,505 gallons / day including recharge liquid.
SSLW equals 583,200 pounds.

Table CW.29. Constructed Wetlands Technology Manure Evacuation Modification Costs: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Component	Total Cost	Annualized Cost
Waste Evacuation/Plumbing Cost	$ 9,110.00	$ 1,357.66
Contractor & Engineering Services & Overhead	$ 3,926.41	$ 585.13
Total Construction Cost	$ 13,036.41	$ 1,942.81
Maintenance Cost		$ 182.20
Property Taxes		$ 46.28
Total Operating Cost		$ 228.48
TOTAL ANNUALIZED COST OF MANURE EVACUATION MODIFICATIONS		**$ 2,171.29**

Table CW.30. Constructed Wetlands Technology Solids Separator Costs: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Component	Total Cost	Annualized Cost
Mechanical Solids Separator	$ 66,606.00	$ 9,926.26
Concrete Basin	$ 9,199.46	$ 1,370.99
Contractor & Engineering Services & Overhead	$ 32,672.15	$ 4,869.11
Total Construction Cost	$ 108,477.61	$ 16,166.36
Electric Power Cost		$ 1,162.58
Maintenance Cost		$ 3,514.29
Property Taxes		$ 385.10
Total Operating Cost		$ 5,061.96
TOTAL ANNUALIZED COST OF SOLIDS SEPARATOR		**$ 21,228.32**

Table CW.31. Constructed Wetlands Technology Settling Basin Costs: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Component	Total Cost	Annualized Cost
Settling Basin	$ 6,863.20	$ 1,022.82
Contractor & Engineering Services & Overhead	$ 2,958.04	$ 440.83
Total Construction Cost	$ 9,821.24	$ 1,463.65
Maintenance Cost		$ 137.26
Property Taxes		$ 34.87
Total Operating Cost		$ 172.13
TOTAL ANNUALIZED COST OF SETTLING BASIN		**$ 1,635.78**

Table CW.32. Constructed Wetlands Technology Wetlands Cells Costs: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Component	Total Cost	Annualized Cost
Excavation	$ 124,835.53	$ 18,604.18
Resloping/Recutting	$ 47,437.50	$ 7,069.59
Bentonite Liner	$ 74,344.79	$ 11,079.57
Wetland Plants	$ 7,233.25	$ 1,077.97
Disc, Seed, and Mulch Dikes	$ 9,041.56	$ 1,347.46
Plumbing	$ 20,895.05	$ 3,113.98
Planting Media Fill	$ 23,508.06	$ 3,503.39
Geological Investigation	$ 8,815.52	$ 1,313.77
Contractor & Engineering Services & Overhead	$ 136,243.96	$ 20,304.37
Total Construction Cost	$ 452,355.22	$ 67,414.27
Maintenance Cost		$ 779.56
Property Taxes		$ 1,605.86
Total Operating Cost		$ 2,385.42
TOTAL ANNUALIZED COST OF WETLANDS CELLS		**$ 69,799.69**

TOTAL CONSTRUCTION COST OF CONSTRUCTED WETLANDS TECHNOLOGY	**$ 583,690.48**
TOTAL OPERATING COST INCLUDING ROYALTIES OF CONSTRUCTED WETLANDS TECHNOLOGY	**$ 7,847.99**
TOTAL ANNUALIZED COSTS OF CONSTRUCTED WETLANDS TECHNOLOGY WITHOUT LAND APPLICATION	**$ 94,835.09**

Table CW.33. Constructed Wetlands Technology Predicted Liquid Application Costs for Four Land Application Scenarios: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Annual Cost of Applying Lagoon Effluent	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 7,619.16	$ 6,600.87
If Phosphorus-Based Application	$ 7,710.35	$ 6,649.23
Acres Needed For Assimilation	**Forages**	**Row Crops**
If Nitrogen-Based Application	13.32	37.33
If Phosphorus-Based Application	14.01	38.30
Opportunity Cost of Land	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 799.39	
If Phosphorus-Based Application	$ 840.72	
Irrigation Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 6,819.77	$ 7,370.56
If Phosphorus-Based Application	$ 6,659.57	$ 7,490.74
Savings From Not Having To Buy Fertilizer	**Forages**	**Row Crops**
If Nitrogen-Based Application		$ (769.69)
If Phosphorus-Based Application		$ (841.51)
Extra Fertilizer Purchase Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	-	
If Phosphorus-Based Application	$ 210.06	

Note: 7,247,779 gallons / year of effluent modeled to be land applied

Table CW.34. Constructed Wetlands Technology Predicted Solids Application Costs for Four Land Application Scenarios: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Annual Cost of Applying Solids		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	13,840.27	$	10,086.92
If Phosphorus-Based Application	$	45,702.93	$	11,923.85
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		25.37		82.24
If Phosphorus-Based Application		166.71		445.38
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	1,522.43		
If Phosphorus-Based Application	$	10,002.45		
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	10,948.79	$	11,716.83
If Phosphorus-Based Application	$	12,855.34	$	16,595.08
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application			$	(1,629.91)
If Phosphorus-Based Application			$	(4,671.23)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	1,369.05		
If Phosphorus-Based Application	$	22,845.14		

Note: 2,790,167 lbs. / year of solids modeled to be land applied

Table CW.35. Summary and Mass Balance of Generated and Land Applied Nutrients: Standardized Quantities and Prices (4,320-Head Feeder-Finish with Flush)

Nutrient Balance	**Nitrogen (lbs/ year)**	**Phosphorus (lbs / year)**	**Potassium (lbs / year)**
Generated At Barn	87,436.80	25,056.00	42,984.00
Removed in Separated Solids	12,276.73	7,059.12	1,752.22
Entering Constructed Wetlands	75,160.07	17,996.88	41,231.78
Removed in Constructed Wetlands	52,612.05	15,657.28	6,184.77
Entering Storage Pond	22,548.02	2,339.59	35,047.61
Removed in Storage Pond	15,861.31	1,645.78	24,653.67
Land Applied in Liquid Effluent	6,686.71	693.82	10,393.34

Tables CW.36 through CW.43: Costs and Returns Estimates Based on Standardized Cost and Performance Data for Constructed Wetlands Technology: 8,800-Head Feeder to Finish Operation with Pit-Recharge System

Table CW.36. Constructed Wetlands Technology Assumptions and Total Annualized Costs: Standardized Quantities and Prices (8,800-Head Feeder-Finish with Pit-Recharge)

Number of Animals	**8,800**
Type of Operation	**Feeder-Finish**
Barn Cleaning System	**Pit-Recharge**

Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
	If Nitrogen-Based Application	**$ 162,448.17**	**$ 156,919.31**
	If Phosphorus-Based Application	**$ 219,835.78**	**$ 157,803.10**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost per Unit		Forages	Row Crops
	If Nitrogen-Based Application	**$ 136.74**	**$ 132.09**
	If Phosphorus-Based Application	**$ 185.05**	**$ 132.83**

Note: Daily volume discharged from barns is 57,772 gallons / day including recharge liquid.
SSLW equals 1,188,000 pounds.

Table CW.37. Constructed Wetlands Technology Manure Evacuation Modification Costs: Standardized Quantities and Prices (8,800-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Waste Evacuation/Plumbing Cost	$ 9,110.00	$ 1,357.66
Contractor & Engineering Services & Overhead	$ 3,926.41	$ 585.15
Total Construction Cost	$ 13,036.41	$ 1,942.81
Maintenance Cost		$ 182.20
Property Taxes		$ 46.28
Total Operating Cost		$ 228.48
TOTAL ANNUALIZED COST OF MANURE EVACUATION MODIFICATIONS		**$ 2,171.29**

Table CW.38. Constructed Wetlands Technology Solids Separator Costs: Standardized Quantities and Prices (8,800-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Mechanical Solids Separator	$ 99,909.00	$ 14,889.39
Concrete Basin	$ 17,433.12	$ 2,598.05
Contractor & Engineering Services & Overhead	$ 50,574.45	$ 7,537.08
Total Construction Cost	$ 167,916.57	$ 25,024.52
Electric Power Cost		$ 2,004.63
Maintenance Cost		$ 5,344.11
Property Taxes		$ 596.10
Total Operating Cost		$ 7,944.85
TOTAL ANNUALIZED COST OF SOLIDS SEPARATOR		**$ 32,969.37**

Table CW.39. Constructed Wetlands Technology Settling Basin Costs: Standardized Quantities and Prices (8,800-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Settling Basin	$ 10,294.80	$ 1,534.23
Contractor & Engineering Services & Overhead	$ 4,437.06	$ 661.25
Total Construction Cost	$ 14,731.86	$ 2,195.48
Maintenance Cost		$ 205.90
Property Taxes		$ 52.30
Total Operating Cost		$ 258.19
TOTAL ANNUALIZED COST OF SETTLING BASIN		**$ 2,453.67**

Table CW.40. Constructed Wetlands Technology Wetlands Cells Costs: Standardized Quantities and Prices (8,800-Head Feeder-Finish with Pit-Recharge)

Component	Total Cost	Annualized Cost
Excavation	$ 182,106.26	$ 27,139.20
Resloping/Recutting	$ 69,200.38	$ 10,312.90
Bentonite Liner	$ 142,469.59	$ 21,232.17
Wetland Plants	$ 14,884.83	$ 2,218.28
Disc, Seed, and Mulch Dikes	$ 18,606.04	$ 2,772.85
Plumbing	$ 42,998.55	$ 6,408.05
Planting Media Fill	$ 48,375.69	$ 7,209.40
Geological Investigation	$ 18,140.89	$ 2,703.53
Contractor & Engineering Services & Overhead	$ 231,353.14	$ 34,478.44
Total Construction Cost	$ 768,135.36	$ 114,474.82
Maintenance Cost		$ 1,604.21
Property Taxes		$ 2,726.88
Total Operating Cost		$ 4,331.09
TOTAL ANNUALIZED COST OF WETLANDS CELLS		**$ 118,805.91**

TOTAL CONSTRUCTION COST OF CONSTRUCTED WETLANDS TECHNOLOGY	**$ 963,820.19**
TOTAL OPERATING COST INCLUDING ROYALTIES OF CONSTRUCTED WETLANDS TECHNOLOGY	**$ 12,762.61**
TOTAL ANNUALIZED COSTS OF CONSTRUCTED WETLANDS TECHNOLOGY WITHOUT LAND APPLICATION	**$ 156,400.24**

Table CW.41. Constructed Wetlands Technology Predicted Liquid Application Costs for Four Land Application Scenarios: Standardized Quantities and Prices (8,800-Head Feeder-Finish with Pit-Recharge)

Annual Cost of Applying Lagoon Effluent	Forages	Row Crops
If Nitrogen-Based Application	$ 10,735.64	$ 9,592.73
If Phosphorus-Based Application	$ 11,691.73	$ 9,451.81
Acres Needed For Assimilation	**Forages**	**Row Crops**
If Nitrogen-Based Application	27.72	89.83
If Phosphorus-Based Application	33.72	92.18
Opportunity Cost of Land	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 1,662.92	
If Phosphorus-Based Application	$ 2,023.19	
Irrigation Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 9,072.72	$ 11,444.99
If Phosphorus-Based Application	$ 9,163.03	$ 11,476.89
Savings From Not Having To Buy Fertilizer	**Forages**	**Row Crops**
If Nitrogen-Based Application		$ (1,852.25)
If Phosphorus-Based Application		$ (2,025.08)
Extra Fertilizer Purchase Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	-	
If Phosphorus-Based Application	$ 505.51	

Note: 14,321,581 gallons / year of effluent modeled to be land applied

Table CW.42. Constructed Wetlands Technology Predicted Solids Application Costs for Four Land Application Scenarios: Standardized Quantities and Prices (8,800-Head Feeder-Finish with Pit-Recharge)

Annual Cost of Applying Solids		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	22,554.06	$	14,807.78
If Phosphorus-Based Application	$	87,253.27	$	18,399.82
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		51.69		167.52
If Phosphorus-Based Application		339.59		907.26
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	3,101.25		
If Phosphorus-Based Application	$	20,375.35		
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	16,664.01	$	18,127.96
If Phosphorus-Based Application	$	20,341.52	$	27,915.29
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application			$	(3,320.18)
If Phosphorus-Based Application			$	(9,515.46)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	2,788.80		
If Phosphorus-Based Application	$	46,536.40		

Note: 5,683,674 lbs. / year of solids modeled to be land applied

Table CW.43. Summary and Mass Balance of Generated and Land Applied Nutrients: Standardized Quantities and Prices (8,800-Head Feeder-Finish with Pit-Recharge)

Nutrient Balance	**Nitrogen (lbs/ year)**	**Phosphorus (lbs / year)**	**Potassium (lbs / year)**
Generated At Barn	178,112.00	51,040.00	87,560.00
Removed in Separated Solids	25,008.16	14,379.69	3,569.35
Entering Constructed Wetlands	153,103.84	36,660.31	83,990.65
Removed in Constructed Wetlands	107,172.69	31,894.47	12,598.60
Entering Storage Pond	45,931.15	4,765.84	71,392.06
Removed in Storage Pond	29,839.63	3,096.18	46,380.56
Land Applied in Liquid Effluent	16,091.52	1,669.66	25,011.50

Tables CW.44 through CW.51: Costs and Returns Estimates Based on Standardized Cost and Performance Data for Constructed Wetlands Technology: 4,000-Sow Farrow to Wean Operation with Pit-Recharge System

Table CW.44. Constructed Wetlands Technology Assumptions and Total Annualized Costs—Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Pit-Recharge)

Number of Animals	**4,000**		
Type of Operation	**Farrow-Wean**		
Barn Cleaning System	**Pit-Recharge**		
Annualized Cost ($ / Year)			
Total Annualized Cost		Forages	Row Crops
	If Nitrogen-Based Application	**$ 159,354.01**	**$ 156,399.51**
	If Phosphorus-Based Application	**$ 181,854.33**	**$ 154,062.05**
Per Unit Cost ($ / 1,000 lbs. of SSLW)			
Total Annualized Cost per Unit		Forages	Row Crops
	If Nitrogen-Based Application	**$ 92.01**	**$ 90.30**
	If Phosphorus-Based Application	**$ 105.00**	**$ 88.95**

Note: Daily volume discharged from barns is 142,682 gallons / day including recharge liquid.
SSLW equals 1,732,000 pounds

Table CW.45. Constructed Wetlands Technology Manure Evacuation Modification Costs: Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Pit-Recharge)

Component	Total Cost	Annualized Cost
Waste Evacuation/Plumbing Cost	$ 6,377.00	$ 950.36
Contractor & Engineering Services & Overhead	$ 2,748.49	$ 409.61
Total Construction Cost	$ 9,125.49	$ 1,359.97
Maintenance Cost		$ 127.54
Property Taxes		$ 32.40
Total Operating Cost		$ 159.94
TOTAL ANNUALIZED COST OF MANURE EVACUATION MODIFICATIONS		**$ 1,519.90**

Table CW.46. Constructed Wetlands Technology Solids Separator Costs: Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Pit-Recharge)

Component	Total Cost	Annualized Cost
Mechanical Solids Separator	$ 166,515.00	$ 24,815.65
Concrete Basin	$ 35,896.31	$ 5,349.61
Contractor & Engineering Services & Overhead	$ 87,239.27	$ 13,001.22
Total Construction Cost	$ 289,650.58	$ 43,166.48
Electric Power Cost		$ 4,950.89
Maintenance Cost		$ 9,043.68
Property Taxes		$ 1,028.26
Total Operating Cost		$ 15,022.83
TOTAL ANNUALIZED COST OF SOLIDS SEPARATOR		**$ 58,189.31**

Table CW.47. Constructed Wetlands Technology Settling Basin Costs: Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Pit-Recharge)

Component	Total Cost	Annualized Cost
Settling Basin	$ 17,158.00	$ 2,557.05
Contractor & Engineering Services & Overhead	$ 7,395.10	$ 1,102.09
Total Construction Cost	$ 24,553.09	$ 3,659.13
Maintenance Cost		$ 343.16
Property Taxes		$ 87.16
Total Operating Cost		$ 430.32
TOTAL ANNUALIZED COST OF SETTLING BASIN		**$ 4,089.46**

Table CW.48. Constructed Wetlands Technology Wetlands Cells Costs: Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Pit-Recharge)

Component	Total Cost	Annualized Cost
Excavation	$ 166,033.99	$ 24,743.96
Resloping/Recutting	$ 63,092.92	$ 9,402.71
Bentonite Liner	$ 116,580.32	$ 17,373.90
Wetland Plants	$ 11,944.14	$ 1,780.03
Disc, Seed, and Mulch Dikes	$ 14,930.18	$ 2,225.04
Plumbing	$ 34,503.64	$ 5,142.06
Planting Media Fill	$ 38,818.46	$ 5,785.09
Geological Investigation	$ 14,556.92	$ 2,169.41
Contractor & Engineering Services & Overhead	$ 198,458.50	$ 29,576.17
Total Construction Cost	$ 658,919.05	$ 98,198.37
Maintenance Cost		$ 1,287.28
Property Taxes		$ 2,339.16
Total Operating Cost		$ 3,626.44
TOTAL ANNUALIZED COST OF WETLANDS CELLS		**$ 101,824.81**

TOTAL CONSTRUCTION COST OF CONSTRUCTED WETLANDS TECHNOLOGY	**$ 982,248.21**
TOTAL OPERATING COST INCLUDING ROYALTIES OF CONSTRUCTED WETLANDS TECHNOLOGY	**$ 19,239.53**
TOTAL ANNUALIZED COSTS OF CONSTRUCTED WETLANDS TECHNOLOGY WITHOUT LAND APPLICATION	**$ 165,623.48**

Table CW.49. Constructed Wetlands Technology Predicted Liquid Application Costs for Four Land Application Scenarios: Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Pit-Recharge)

Annual Cost of Applying Lagoon Effluent	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 11,743.14	$ 9,212.54
If Phosphorus-Based Application	$ 12,127.25	$ 9,411.45
Acres Needed For Assimilation	**Forages**	**Row Crops**
If Nitrogen-Based Application	30.76	34.72
If Phosphorus-Based Application	30.76	41.76
Opportunity Cost of Land	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 1,845.66	
If Phosphorus-Based Application	$ 1,845.66	
Irrigation Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	$ 9,897.49	$ 9,942.67
If Phosphorus-Based Application	$ 9,897.49	$ 10,328.80
Savings From Not Having To Buy Fertilizer	**Forages**	**Row Crops**
If Nitrogen-Based Application		$ (730.13)
If Phosphorus-Based Application		$ (917.35)
Extra Fertilizer Purchase Costs	**Forages**	**Row Crops**
If Nitrogen-Based Application	-	
If Phosphorus-Based Application	$ 384.10	

Note: 16,733,966 gallons / year of effluent modeled to be land applied

Table CW.50. Constructed Wetlands Technology Predicted Solids Application Costs for Four Land Application Scenarios: Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Pit-Recharge)

Annual Cost of Applying Solids		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	15,274.95	$	10,887.59
If Phosphorus-Based Application	$	52,316.89	$	12,957.40
Acres Needed For Application		**Forages**		**Row Crops**
If Nitrogen-Based Application		29.53		95.71
If Phosphorus-Based Application		194.03		518.37
Opportunity Cost of Land		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	1,771.93		
If Phosphorus-Based Application	$	11,641.66		
Application Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	11,909.61	$	12,784.61
If Phosphorus-Based Application	$	14,086.19	$	18,394.15
Savings From Not Having To Buy Fertilizer		**Forages**		**Row Crops**
If Nitrogen-Based Application			$	(1,897.02)
If Phosphorus-Based Application			$	(5,436.76)
Extra Fertilizer Purchase Costs		**Forages**		**Row Crops**
If Nitrogen-Based Application	$	1,593.41		
If Phosphorus-Based Application	$	26,589.04		

Note: 3,247,424 lbs. / year of solids modeled to be land applied

Table CW.51. Summary and Mass Balance of Generated and Land Applied Nutrients: Standardized Quantities and Prices (4,000-Sow Farrow-Wean with Pit-Recharge)

Nutrient Balance	**Nitrogen (lbs/ year)**	**Phosphorus (lbs / year)**	**Potassium (lbs / year)**
Generated At Barn	117,000.00	37,040.00	77,000.00
Removed in Separated Solids	14,288.67	8,215.98	2,039.38
Entering Constructed Wetlands	102,711.33	28,824.02	74,960.62
Removed in Constructed Wetlands	71,897.93	25,076.90	11,244.09
Entering Storage Pond	30,813.40	3,747.12	63,716.53
Removed in Storage Pond	24,593.80	2,990.78	50,855.52
Land Applied in Liquid Effluent	6,219.60	756.35	12,861.00

Tables CW.52 and CW.53: Predicted Costs of Retrofitting Various Representative Farm Sizes and Farm Types with the Constructed Wetlands Technology: DWQ Permitted Farms and SF/PSF Owned Farms

Table CW.52. Predicted Costs ($ / 1,000 Pounds of Steady-State Live Weight (SSLW) per Year) of Retrofitting DWQ Permitted Representative Farm Type / Farm Size Combinations: Constructed Wetlands Technology

	Farm Size (1,000 pounds SSLW)				
	0-500	**500-1000**	**1000-1500**	**1500-2000**	**> 2000**
Farm Type					
Farrow-wean					
Rep. # of sows	752	1,540	2,400	4,000	6,000
Pit-recharge system	$119.33	$108.39	$100.57	$92.01	$82.60
Flush system	$127.15	$115.08	$106.49	$97.11	$87.05
Farrow-feeder					
Rep. # of sows	500	1,200	2,000	3,600	5,500
Pit-recharge system	$136.56	$119.03	$108.01	$95.01	$87.94
Flush system	$165.81	$159.18	$138.48	$122.28	$110.21
Farrow-finish					
Rep. # of sows	150	500	1,000	1,200	2,000
Pit-recharge system	$181.32	$137.44	$112.94	$110.24	$95.65
Flush system	$186.04	$141.25	$123.63	$114.07	$102.89
Wean-feeder					
Rep. head capacity	3,840	20,000	N/A	N/A	N/A
Pit-recharge system	$321.95	$208.88	N/A	N/A	N/A
Flush system	$389.53	$305.67	N/A	N/A	N/A
Feeder-finish					
Rep. head capacity	2,448	5,280	8,800	12,240	17,136
Pit-recharge system	$179.68	$155.98	$136.74	$118.85	$112.95
Flush system	$182.22	$158.45	$139.10	$127.04	$115.10

Table CW.53. Predicted Costs ($ / 1,000 Pounds of Steady-State Live Weight (SSLW) per Year) of Retrofitting Smithfield Foods/Premium Standard Farms Representative Farm Type / Farm Size Combinations: Constructed Wetlands Technology

	Farm Size (1,000 pounds SSLW)				
	0-500	**500-1000**	**1000-1500**	**1500-2000**	**> 2000**
Farm Type					
Farrow-wean					
Rep. # of sows	650	1,700	2,400	4,000	7,000
Pit-recharge system	$126.30	$104.13	$100.57	$92.01	$79.28
Flush system	$134.46	$110.60	$106.49	$97.11	$86.85
Farrow-feeder					
Rep. # of sows	675	1,200	2,000	3,419	5,500
Pit-recharge system	$123.30	$119.03	$108.01	$97.48	$87.94
Flush system	$178.90	$159.18	$138.48	$125.69	$110.21
Farrow-finish					
Rep. # of sows	N/A	500	1,000	1,200	2,000
Pit-recharge system	N/A	$137.44	$112.94	$110.24	$95.65
Flush system	N/A	$141.25	$123.63	$114.07	$102.89
Wean-feeder					
Rep. head capacity	2,808	N/A	N/A	N/A	N/A
Pit-recharge system	$365.32	N/A	N/A	N/A	N/A
Flush system	$437.29	N/A	N/A	N/A	N/A
Feeder-finish					
Rep. head capacity	1,240	5,100	8,800	12,246	17,136
Pit-recharge system	$226.29	$158.06	$136.74	$118.82	$112.95
Flush system	$229.45	$160.60	$139.10	$127.01	$115.10