Model Farms Economic Study

Final Report

TWA 14TW00000024

Prepared By:

The Balmoral Group, LLC
165 Lincoln Avenue
Winter Park, FL 32789
Phone: 407-629-2185
Fax: 407-629-2183

March 2016

Model Farms Economic Study

Executive Summary

The objective of the Model Farms Economic Study was to quantify the benefits and costs of farm-level management improvements that reduce groundwater withdrawals for average daily irrigation and cold protection, as well those that reduce Nitrogen loads to groundwater resources. The benefit and cost data can be utilized by the Southwest Florida Water Management District (SWFWMD) FARMS (Facilitating Agricultural Resource Management Systems) program to evaluate project applicants based on their expected costs and their expected groundwater withdrawal reductions or Nitrogen management improvements. The Southwest Florida Water Management District contracted with The Balmoral Group (TBG) to complete the Model Farms Economic Study.

Three tasks of the Model Farms Economic Study focused separately on average annual daily irrigation improvements (AAD), frost/freeze protection groundwater reductions (FFP), and Nitrogen reduction/retention improvements (N BMPs). The geographic scope of AAD evaluation focused on the entire SWFWMD region. The FFP evaluation was focused on production systems in the Dover and Plant City Water Use Caution Area (DPCWUCA). The N Model Farms evaluation was focused on production systems in the six counties of Levy, Marion, Citrus, Sumter, Hernando, and Pasco which contain the five springsheds of Chassahowitzka, Homosassa, Kings Bay, Rainbow, and Weeki Wachee springs.

There were three types of projects analyzed for the AAD irrigation evaluation: 1) Alternative Water Supply (farm ponds and reclaimed water), 2) Conservation (irrigation management/scheduling/control technologies), and 3) Irrigation Conversion (changing the type of application equipment). The four project types evaluated for FFP irrigation reductions were: 1) Surface Water Development, 2) Row Covers, 3) Wind Machines, and 4) Chemical Crop Protectants. There were two broad groups of Nitrogen management improvements that were evaluated: 1) N reduction (technologies that lower the amount of N fertilizer applied to fields) and 2) N retention (technologies that remove or retain N within a production system).

The general approach to the AAD, FFP, and N Model Farms evaluations was similar. The approach was to select the relevant management practices or technologies based on the project scope and literature review, quantify the expected benefits (in terms of groundwater withdrawal reductions or Nitrogen loading reductions) based on literature or system-specific simulations, and calculate costs based on vendor quotes and published cost data. Costs included all materials and installation costs based on the average farm size for particular crop groups within the geographic region being considered. Costs relative to benefits for AAD and projects were expressed as $/1000 gallons, where the 1,000 gallons represents the expected reduction in groundwater withdrawals. Costs per benefit for the FFP projects were expressed as $/1000 gallons of groundwater offset, where the groundwater offset is the estimate groundwater withdrawal reduction based on the effectiveness of the strategy and the assumed number of annual freeze events of five. Costs relative to benefits for the N management improvements were expressed as $/lb of Nitrogen, where the mass of N represents the expected reduction in loading to groundwater from the production system. This report provides a detailed account of the methods, data sources, and results of costs per benefit for AAD, FFP, and N management improvements. The Executive Summary Table provides an overview of the benefits and the costs per benefit for the aggregated project types. Conservation projects and Ponds projects have a reasonably small ratio of costs to benefits for AAD projects, given the substantial estimated benefits. Surface water projects for FFP have a large cost relative to groundwater offset; however, there is the additional possibility of further groundwater offsets for AAD irrigation that the pond for FFP can provide. Row covers seem to be a cost effective non-irrigation alternative for FFP. The N BMP project benefits are large for the N Retention projects. This is largely drive by two BMPs for dairies that have very high estimated N Retention benefits. The costs per benefit of both groups of N BMPs are similar; the N Reduction options are relatively affordable, but have a lower estimated N reduction benefit.

Executive summary table: Average benefits and costs per benefit (costs annualized using 5-year term) for the project groups for AAD, FFP, and N management.

AAD projects	Average Benefit (GPD)	$ per 1000 gallon Offset (5-yr term)
Alternative Water Source	71,314	$2.79
Alternative Water Source: Ponds	69,599	$3.51
Conservation	11,222	$0.75
Irrigation Conversion	40,405	$4.37
FFP projects	**Average Benefit (GPD)**	**$ per 1000 gallon Offset (5-yr term)**
Surface Water	7,291	$18.02
Row Covers	15,637	$2.32
Wind Machines	9,651	$7.28
Chemical Protectants	6,434	$0.11
N BMP project	**Average Benefit (lb-N/yr)**	**$ per lb of N (5-year term)**
N Reduction Strategies	167	$55
N Retention Strategies	1,202	$47

Total costs required to reduce groundwater withdrawals and Nitrogen losses can be a substantial obstacle for producers interested in improving their water and nutrient management. As agriculture is facing new environmental challenges and growing competition for water, the role of public support to implement strategies for reducing water use and improving water quality in agriculture will be increasingly important.

Table of Contents

List of Tables

List of Figures

Average Annual Daily Irrigation

Overview

The assessment of average annual daily irrigation (AAD) examined the benefits and costs of projects representative of the SWFWMD FARMS (Southwest Florida Water Management District, Facilitating Agricultural Resource Management Systems) program. The types of projects evaluated here have been aggregated into three groups: 1) Alternative Water Supply, 2) Conservation, and 3) Irrigation Conversion. Four groups of cropping systems were evaluated to represent average farm sizes and irrigation requirements: 1) Row Crops, 2) Sod/pasture, 3) Perennial crops, and 4) Container nurseries. Alternative Water Supply projects included surface water development and reclaimed water supply. Conservation projects included any equipment to improve the scheduling and management of irrigation. Irrigation Conversion projects describe the transition to a new, more efficient means of irrigating. The benefits of FARMS projects are groundwater offsets, meaning reduced groundwater withdrawals from the Upper Floridan aquifer. The costs include the materials and installation costs associated with implementing management practices for reducing groundwater withdrawals for irrigation.

Annualized costs were calculated using 5-year project terms and also using expected project lifetimes for Alternative Water Source (20 years), Conservation (10 years), and Irrigation Conversion (15 years) projects. The costs per benefit are expressed in terms of $/day per 1,000 gallons per day (GPD), or equivalently, $/1000 gallons. Using a 5-year project term, Alternative Water Source (ponds only) costs per benefit were $3.37/1000 gal, the costs per benefit for Conservation projects were $0.75/1000 gal, and the costs per benefit for Irrigation Conversion projects were $4.37/1000 gal. Conservation projects, in which producers implement some type of instrumentation to improve irrigation management, are the most affordable of the project types in terms of total costs. However, the groundwater offsets are smaller for Conservation projects. Surface water development projects are the most expensive in terms of total costs, but the potential for groundwater offsets for these types of projects are substantial.

Within any of the three project types there are numerous combinations of particular groundwater conservation strategies. Scenarios for Alternative Water Source projects include ponds of different sizes and reclaimed water supply. Scenarios for Conservation options include different types of equipment for decision support and system automation. Scenarios for Irrigation Conversion projects include different types of existing and proposed irrigation systems within each crop group. To represent the variability in costs and benefits within each project type, several scenarios of each project type were developed based on FARMS program background, peer-reviewed literature, university Extension materials, and vendor interviews. Summarizing the range of costs, benefits, and cost/benefit ratios for all scenarios within each of the project types provides the results for the 12 Model Farms.

There are numerous barriers for producers to invest in strategies to reduce irrigation water use. Of the 4,112 irrigated producers in Florida surveyed in the 2013 Farm and Ranch Irrigation Survey (FRIS 2013) by the USDA, 818 producers (20%) stated that “Improvements will not reduce costs enough to cover installation costs” and 1,415 producers (34%) stated they “Cannot finance improvements.” Total irrigation-related expenditures for Florida farmers were $73,107,000 (FRIS 2013), with only about

$11,056,655 (about 15%) spent for the primary purpose of water conservation. The largest portions of irrigation-related spending in Florida were for new expansion of irrigation and for scheduled replacement or maintenance. Agricultural producers often operate with narrow profit margins; financing improvements in irrigation efficiency can be a challenge. This highlights the importance of public-sector investments in agricultural water management improvements (Schaible and Aillery 2012).

Crop Type Groups

Typical farm sizes and irrigation systems of the four crop groups were accessed from the Florida Statewide Agricultural Irrigation Demand (FSAID 2015) databases. The FSAID 2015 farm sizes were developed from a combination of data in consumptive use permits, aerial imagery, and other sources. Annual irrigation demands were provided by SWFWMD's permitting database and from the FSAID data. A summary of the irrigated areas and irrigation requirements of the four crop groups is provided in **Table 2-1**. Row crops include all annual crops, both agronomic and horticultural crop types (examples: strawberries, peanuts, bell peppers, tomatoes). Sod/pasture describes perennial grasses that might be harvested for hay, grazed, or harvested for ornamental landscaping. Perennial crops include all cropping systems that are not replanted annually (e.g. blueberries, citrus, peach, field nurseries). Container nurseries describe any production system in which plants are grown in containers. **Figure 2-1** illustrates the spatial distribution of the four crop types in the SWFWMD.

Table 2- 1. Crop Type Characteristics

Irrigated area and annual irrigation requirements	Crop Type			
	Row crops	Sod/pasture	Perennial crops	Container nurseries
Average farm area, acres (FSAID2015)	128.0	137.8	69.3	31.1
Average field size, acres (FSAID2015)	30.7	65.7	39.6	9.4
Total SWFWMD area, acres	109,068	18,599	263,201	5,591
Irrigation, FSAID2015; in/yr	20.8	17.9	21.3	27.3
Irrigation, AGMOD; in/yr	19.3	19.3	22.3	50.5
Irrigation, AGMOD NIR; in/yr	13.8	13.8	15.2	34.4

Source: FSAID 2015 database for acreage, SWFWMD permitted irrigation amounts for AAD irrigation.

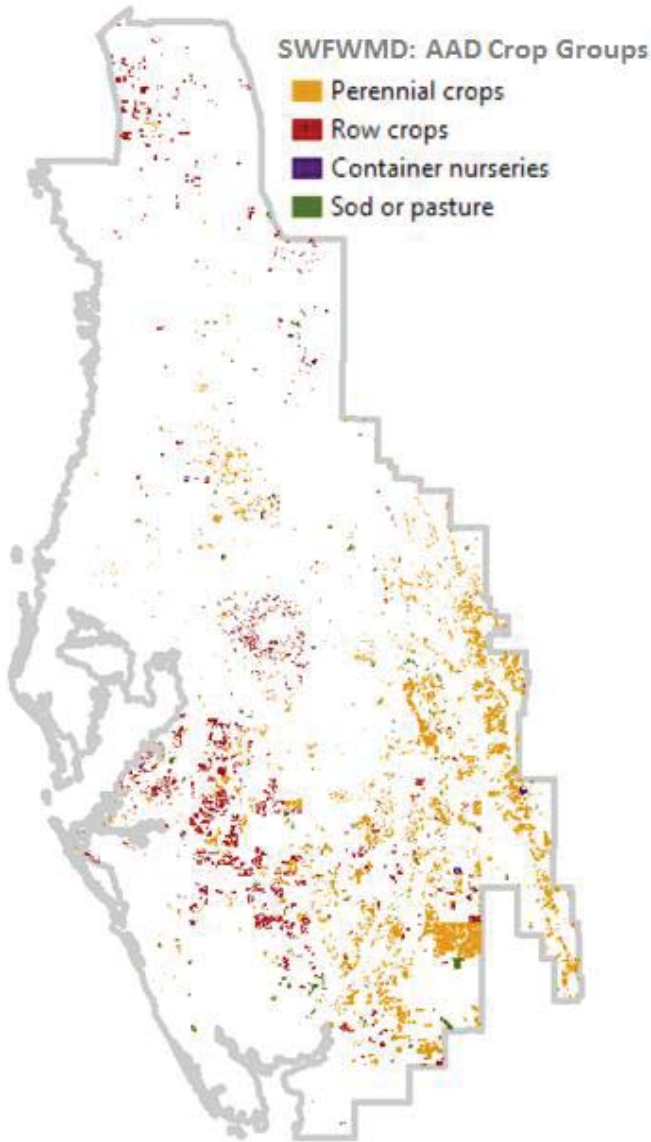


Figure 2- 1. Irrigated areas of the four crop types in the SWFWMD
Source: FSAID 2015, TBG Work Product

Project Descriptions and Methods

The costs associated with each project and crop type scenario are calculated from cost databases assembled from NRCS, FARMS projects datasets, and equipment vendors in the SWFWMD. The benefits (GPD groundwater offsets) are estimated from an adapted version of the NRC Farm Irrigation Rating Index (FIRI). Benefits for ponds projects were estimated using actual groundwater offsets observed for FARMS AAD surface water projects. The scenarios and the assumptions and methods used for each project type are described in the following sections. **Table 2-2** illustrates the project type scenarios for three project types and four crop types. A total of 16 Alternative Water Supply scenarios, 16 Conservation, and 9 Irrigation Conversion scenarios have been evaluated and summarized to provide the range of costs/benefits for the 12 Model Farms.

Table 2- 2. Project Type Scenarios for the 12 Model Farms

Project Type	Crop Type			
	Row Crops	**Sod/pasture**	**Perennial crops**	**Container nurseries**
Alternative Water Supply	• Excavated pond, average • Excavated pond, large • Existing water feature expansion • Reclaimed water supply			
Conservation	• Irrigation system automation; soil moisture sensor control • Irrigation system automation; on-site weather station control • Soil moisture sensors for decision support • Weather station for decision support			
Irrigation Conversion	• Seepage to Drip • Seepage to Center Pivot • Center Pivot to Suburface Drip	• Seepage to Center Pivot • Seepage to Subsurface Drip • Center Pivot to Suburface Drip	• Overhead to MicroSpray • Overhead to Drip	• Overhead to Micro: Nursery

Source: TBG Work Product

Alternative Water Supply

The costs and groundwater offsets for each of the AWS scenarios varies by crop type due to differences in typical farm size and irrigation requirements. With approximately 75% of FARMS AAD projects being related to surface water development, TBG analyzed costs and groundwater offsets for ponds of two different sizes and an expansion of an existing pond, for a total of three pond water supply scenarios. Reclaimed water supply is the fourth AWS scenario included in the Model Farms for AAD irrigation.

"Excavated pond, average" describes a pond volume that is sized to deliver approximately 5 days of daily irrigation applications assuming no additional inflow.

"Excavated pond, large" describes a pond sized to deliver approximately 10 daily irrigations with no additional inflow.

“Existing water feature expansion” AWS scenario accounts for existing farm ponds that might be expanded to increase irrigation capacity. For the purposes of the cost/benefit analysis, the existing water feature expansion assumes a target pond volume from the "Excavated pond, average" scenario. The result is that excavation volumes and costs are reduced by half.

“Reclaimed water” is treated municipal wastewater that is used for agricultural irrigation to supplement or replace irrigation from groundwater.

The pumping station and irrigation mainline to the existing irrigation system are two of the major costs associated with surface water development for irrigation. The pumping station includes the power unit, pump, foundation and protective structures, intake, filtration, and all necessary appurtenances. A diesel power unit and centrifugal pump were assumed. The size of the pumping station was calculated based on published average irrigation application rates and the sizes of the Model Farms for each crop type. The type of irrigation system, the topography, and the zoning utilized in an irrigation system will all impact the actual flow rates and pressures in an irrigation system. The average flow rate and power requirements (3500 GPM, 100 BHP) across the four crop groups were used to develop the cost estimate for the pumping station. A 12" PVC mainline pipe to the existing irrigation system is estimated based on flow rate and flow velocity conventions. The distance from the pond to the existing irrigation system is dependent on irrigated area (crop type); it is assumed to be the distance from the corner of the farm to the center (assuming a square farm). The same approach and mainline size was used for reclaimed water supply access. Costs for excavation, pumping stations, filtration, and irrigation mains were collected from the FY2015 NRCS EQIP Payment schedule for Florida (NRCS 2015) and from FARMS cost datasets.

Groundwater Offsets: Ponds

The total annual irrigation supplied by the ponds of different sizes and for different crop types was calculated based on the actual groundwater offsets of a subset of 36 ponds that were implemented as part of the FARMS program. This empirical approach allows for a realistic representation of both the hydrology and the management of farm ponds for irrigation in the SWFWMD. The ratio of irrigated acres to pond acres from this dataset was used to estimate the area of the ponds based on the average irrigated acreage for each of the four crop groups. The average irrigated acres per pond acre was used to estimate the average size pond, and the median irrigated acres per pond acre was used to estimate the large pond. The distribution of the ratio of irrigated acres to pond acres was positively skewed (mean substantially great than the median), and the pond sizes produced from the mean and median ratios (irrigated acres/pond acre) were similar to those produced from monthly water balance simulations used to size ponds. The following equations summarize how the FARMS dataset of groundwater offsets from AAD ponds projects were used to estimate pond areas and groundwater offsets.

$$\text{Average pond size (acres)}_{\text{crop group}} = \frac{\text{irrigated acreage}_{\text{crop group avg}}}{\text{irrigated acres per pond acre}_{\text{mean,FARMS observed}}}$$

$$\text{Large pond size (acres)}_{\text{crop group}} = \frac{\text{irrigated acreage}_{\text{crop group avg}}}{\text{irrigated acres per pond acre}_{\text{median,FARMS observed}}}$$

$$\text{Estimated groundwater offset, GPD}_{\text{crop group}} = \text{Actual offset, GPD per pond acres} * \text{pond acres}_{\text{crop group}}$$

Groundwater Offsets: Reclaimed Water

While there are a small number of agricultural users of reclaimed water (26 in SWFWMD for edible crop irrigation; FDEP 2015), the reduced groundwater withdrawals can add up to a substantial amount of water. The reclaimed water use for edible crops in 2014 for SWFWMD was 7.2 MGD (FDEP 2015). Reclaimed water groundwater offsets were estimated to be 50% of gross annual irrigation, based on historical FARMS projects and personal communication with water utilities in the SWFWMD. Project H626 had an estimated groundwater offset of 80% on 10 acres of citrus, and project H616 had an estimated groundwater offset of 75% on 42 acres of citrus (SWFWMD 2012). Given the small acreage of these FARMS projects and the uncertainty of reclaimed water supply line connection size, it was assumed that 50% of annual irrigation demand could be offset with reclaimed water. Actual groundwater offsets from reclaimed water depend largely on farm location, including the particular water utility and the distance to a supply line. Based on acreage of edible crops irrigated in SWFWMD, the water utilities with the most capacity for agricultural irrigation from reclaimed water are Manatee County, Sarasota, Pasco County, and Arcadia, with irrigated acreage of 5,383, 1,850, 491, and 466, respectively (FDEP 2015). **Table 2-3** illustrates the edible crop (EC) and other crop (OC) agricultural irrigation use of reclaimed water for each of the Water Management Districts (FDEP 2015). Total flow (million gallons per day, mgd) and total acreage irrigated are shown. SWFWMD accounts for the majority of statewide use of reclaimed water for irrigation of edible crops, representing 62% of flow and 65% of acreage for edible crop irrigation from reclaimed water.

Table 2- 3. Edible Crop and Other Crop Irrigation use by Water Management District

	EC, mgd	EC, acres	OC, mgd	OC, acres
NWFWMD	-	-	32.0	7,219.4
SFWMD	3.8	3,516.7	2.8	1,781.2
SJRWMD	0.6	1,353.9	8.3	4,310.0
SRWMD	-	-	8.7	2,804.8
SWFWMD	7.2	9,071.3	7.9	6,403.0

Source: FDEP 2015 - 2014 Reuse Inventory. http://www.dep.state.fl.us/water/reuse/inventory.htm

Conservation

Conservation projects describe any instrumentation or control system to improve the scheduling or management of irrigation. For the purposes of this analysis, the following four Conservation scenarios were considered: irrigation system automation with soil moisture sensor control, irrigation system automation with on-site weather station control, soil moisture sensors for decision support, and weather station for decision support. These four scenarios were developed from review of current and historical peer-reviewed literature, IFAS fact sheets, and equipment vendor interviews. The range possible of irrigation management strategies can be grouped into two main categories: 1) closed-loop automation and 2) data-driven interactive management. Closed-loop automation describes an irrigation management system in which irrigation events and durations are developed and implemented by control systems that are provided with data from soil moisture sensors and/or weather stations in order to determine soil water status to calculate irrigation requirements. This type of system turns pumps and valves on and off as necessary to apply the calculated irrigation depths. Data-driven interactive management describes an irrigation management system in which a producer initiates irrigation events, but irrigation decisions are informed by data from soil moisture sensors and/or weather stations which the producer interacts with through some type of user-interface to provide details about plant stress, soil moisture status, and recommended irrigation depths. These two types of systems are nearly identical in terms of the data used, but they differ in terms of producer involvement. Costs for conservation equipment were obtained from published sources and vendor quotes from AgTronix, BMP Logic, and Certified Ag Resources, which sell, install, and service equipment for irrigation system control and decision support.

Groundwater Offsets: Conservation

Estimating groundwater offsets for Conservation projects was completed using the NRCS FIRI methodology that combines rating factors for irrigation systems and management/scheduling strategies. The adapted implementation of the FIRI methodology is summarized in the following equation:

Water conserved (ac-ft/ac) = $[(SW_{proposed} + RW_{proposed}) - (SW_{initial} + RW_{initial})] + [NIR/12/FIRI\ Rating_{intial} - NIR/12/FIRI\ Rating_{proposed}]$

Where FIRI Rating = $Rating_{Irrigation\ System} * Rating_{Conservation}$, SW is surface water offset from FARMS actual offsets, RW is reclaimed water offset, NIR is net irrigation requirement (in/yr) for the crop group, FIRI Ratings for Irrigation System and Conservation are based on tabulated FIRI factors from NRCS (FIRI factors are greater than 0.5 and less than 1). The FIRI ratings used for conservation projects, including the four conservation scenarios and the existing (default irrigation management) conditions of irrigation conservation, are presented in **Table 2-4**.

Table 2- 4. Farm Irrigation Rating Index (FIRI) ratings for Conservation project scenarios

Category: FIRI[1]	Action: FIRI	Rating	Scenario
Improved Soil Moisture Monitoring and Irrigation Scheduling	Visual crop stress	0.94	Existing, average management; no decision support instrumentation
Irrigation Skill and Action	Good–lack of full attention	0.92	
Improved Soil Moisture Monitoring and Irrigation Scheduling	Continuous measurement of soil moisture or ET	1	Irrigation system automation; soil moisture sensor control
Irrigation Skill and Action	Following irrigation water management (IWM) plan	1	
Improved Soil Moisture Monitoring and Irrigation Scheduling	Continuous measurement of soil moisture or ET	1	Irrigation system automation; on-site weather station control
Irrigation Skill and Action	Following irrigation water management (IWM) plan	1	
Improved Soil Moisture Monitoring and Irrigation Scheduling	Soil moisture using moisture probe	0.98	Soil moisture sensors for decision support
Irrigation Skill and Action	Following irrigation water management (IWM) plan	1	
Improved Soil Moisture Monitoring and Irrigation Scheduling	Irrigation scheduling via weather station	0.97	Weather station for decision support
Irrigation Skill and Action	Following irrigation water management (IWM) plan	1	

Source: NRCS Farm Irrigation Rating Index ratings for irrigation management and scheduling.

Strategies to conserve irrigation water depend not only on the equipment utilized but also the quality of management and data used to make irrigation decisions. For example, a soil moisture sensor that is poorly calibrated for a particular soil type or that is installed in a non-representative location would not be expected to improve irrigation management. The implementation of irrigation water conservation strategies by trained professionals is important for realizing the water conservation potential of the conservation equipment.

Irrigation Conversion

The irrigation conversion scenarios were developed for each of the four crop groups by considering the dominant irrigation system types within a crop group from the FSAID 2015 database and using

[1] NRCS 2014. National Engineering Handbook Part 652, Chapter 5: Selecting an Irrigation Method. KS210-652-H, Amend. KS22. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_032469.pdf

professional judgment to develop realistic scenarios for existing and proposed irrigation systems. The following seven irrigation conversion scenarios were considered: Seepage to Drip, Seepage to Center Pivot, Seepage to Subsurface Drip, Center Pivot to Suburface Drip, Overhead to MicroSpray, Overhead to Drip, Overhead to Micro (nursery). **Table 2-2**, above in the Project Descriptions section, illustrates how the irrigation conversion scenarios were applied by crop group. Irrigation Conversion costs were developed from Extension Fact Sheets, an NRCS irrigation cost database, and the FY2015 NRCS EQIP Payment schedule for Florida (NRCS 2015).

Groundwater Offsets: Irrigation Conversion

Estimating groundwater offsets for Irrigation Conversion projects was completed using the NRCS FIRI methodology, described in Conservation section above. Groundwater offsets resulting from irrigation conversion to some type of microirrigation, in which the wetted area of a field is less than the total field area, are accounted for by assuming that 75% of the field is being irrigated. Therefore, in addition to the improved application efficiency represented in the FIRI rating, the reduced irrigated area is also represented here in the modified FIRI approach for these irrigation conversion scenarios. The reduction in irrigated area does not apply for subsurface-drip irrigation, which is typically used in cropping systems in which crop canopy area is approximately equal to field area. Review of wetted areas in microirrigated systems indicated a range of about 35% to 60% of field areas are irrigated (Liu et al. 2015, Bowen et al. 2012, Simonne et al. 2012), making the 75% irrigated area adjustment for conversions to microirrigation a conservative estimate. **Table 2-5** presents the FIRI ratings used for all the existing and proposed irrigation systems for the Irrigation Conversion projects.

Table 2- 5. Farm Irrigation Rating Index (FIRI) ratings for irrigation systems

Irrigation System: FIRI	Rating[2]
Seepage-subirrigated	0.75
Overhead Impact Sprinkler	0.75
Center Pivot	0.80
MicroSpray	0.85
Drip	0.90
Microirrigation, Nursery	0.90
Subsurface Drip	0.92

Source: NRCS Farm Irrigation Rating Index ratings.

Results: Costs and Benefits

The costs and benefits of the 12 Model Farms can be considered to be representative of the range of possibilities for specific production systems and types of projects. This section summarizes the results of expected costs and groundwater offsets for the Model Farms for AAD irrigation. The estimated groundwater offsets (GPD) for all Alternative Water Source, Conservation, and Irrigation Conversion project scenarios are presented in **Table 2-6**. The groundwater offsets as a percentage of the total permitted irrigation amount are shown in **Table 2-7**.

[2] NRCS 2014. National Engineering Handbook Part 652, Chapter 5: Selecting an Irrigation Method. KS210-652-H, Amend. KS22. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_032469.pdf

Table 2- 6. Benefits (groundwater offsets, GPD) for all Project Type scenarios

Project Type Scenarios	Crop Group			
	Row crops	Sod/pasture	Perennial crops	Container nurseries
	Average acreage by crop group			
	128.0	137.8	69.3	31.1
Alternative Water Source scenarios	**Groundwater offset, GPD**			
Pond size: Average	81,982	88,258	44,385	19,919
Pond size: Large	127,965	137,762	69,281	31,092
Reclaimed water: Average	91,417	98,416	57,536	58,583
Conservation project scenarios	**Groundwater offset, GPD**			
Irrigation automation; soil moisture sensor control	13,713	17,223	8,661	8,329
Irrigation automation; on-site weather station control	13,713	17,223	8,661	8,329
Soil moisture sensors for decision support	12,570	15,993	8,043	7,496
Weather station for decision support	11,427	14,762	6,805	6,663
Irrigation Conversion scenarios	**Groundwater offset, GPD**			
Seepage to Drip	73,134	-	-	-
Overhead to MicroSpray	-	-	39,595	-
Overhead to Micro: Nursery	-	-	-	44,423
Seepage to Center Pivot	36,567	38,136	-	-
Seepage to Subsurface Drip	-	38,136	-	-
Overhead to Drip	-	-	43,926	-
Center Pivot to Subsurface Drip	23,997	25,834	-	-

Source: TBG Work Product; FARMS actual offsets from AAD ponds projects, FARMS project database and FDEP 2015 for reclaimed water, FIRI for Conservation and Irrigation Conversion project types.

Table 2- 7. Benefits (groundwater offsets, % of allocation) for all Project Type scenarios

	Row crops	Sod/pasture	Perennial crops	Container nurseries
Project Type	**acreage by crop group**			
	128.0	137.8	69.3	31.1
	Permitted allocation, GPD			
	183,797	197,425	114,930	116,902
	% groundwater offset			
Alternative Water Source (ponds)	44.6%	44.7%	38.6%	17.0%
Alternative Water Source (reclaimed)	49.7%	49.8%	50.1%	50.1%
Conservation project scenarios	7.0%	8.3%	7.0%	6.6%
Irrigation Conversion scenarios	10.4%	7.4%	10.4%	5.4%

Source: TBG Work Product.

Table 2-8 presents the average costs ($, total and annualized), benefits (GPD groundwater offsets), and costs per benefit ($/1000 gal) for the three project types for AAD irrigation, with pond costs and benefits shown averaged with all AWS projects and also separately due to the feasibility and the differences in costs between ponds and reclaimed water supply.

Table 2- 8. Cost and Benefit summary for the 3 project types for AAD irrigation

Average Annualized Cost and Cost per Benefit (5 yr term)				
Option	**Average Total Cost ($)**	**Annual Cost ($), 5-yr**	**Average Benefit (GPD)**	**$ per 1000 gallon Offset**
Alternative Water Source	$286,546	$63,240	71,314	$2.79
Alternative Water Source: Ponds	$356,189	$78,610	69,599	$3.51
Conservation	$13,297	$2,935	11,222	$0.75
Irrigation Conversion	$252,281	$55,678	40,405	$4.37

Source: TBG Work Product.

Total costs among the three project types are greatest for the Alternative Water Source projects, averaging $286,546 across all AWS project scenarios and crop types ($356,189 for the ponds projects). However, the costs per groundwater offset ($/1000 gallons) for AWS projects are competitive among the 3 project types when averaged across all AWS scenarios and crop groups ($2.79/1000 gal; 5-year term). The average costs per groundwater offset for Conservation and Irrigation Conversion projects are $0.75 and $4.37 per 1000 gal (assuming a 5-year term), respectively (**Table 2-8**). The average costs per groundwater offset for the three pond AWS scenarios are $3.51/1000 gal. The costs per benefit for the AWS projects for specific crop groups (**Table 2-9**) illustrate the impact of the average farm sizes and irrigation requirements on expected costs and benefits.

Table 2- 9. Alternative Water Source Cost per Benefit Summary

Cost per Benefit Summary – Alternative Water Source				
Option	**Total Costs ($)**	**Annual Cost ($), 5-yr**	**Benefits (GPD)**	**$ per 1000 gallon Offset (5-yr term)**
		Existing Water Feature Expansion		
Row Crops	$392,460	$86,615	81,982	$2.89
Sod/Pasture	$416,500	$91,921	88,258	$2.85
Perennial Crops	$258,439	$57,037	44,385	$3.52
Container Nurseries	$167,807	$37,035	19,919	$5.09
		Excavated Pond, Average		
Row Crops	$451,985	$99,752	81,982	$3.33
Sod/Pasture	$485,267	$107,097	88,258	$3.32
Perennial Crops	$286,105	$63,143	44,385	$3.90
Container Nurseries	$178,701	$39,439	19,919	$5.42
		Excavated Pond, Large		
Row Crops	$532,643	$117,553	127,965	$2.52
Sod/Pasture	$575,280	$126,963	137,762	$2.52
Perennial Crops	$330,450	$72,930	69,281	$2.88
Container Nurseries	$198,627	$43,837	31,092	$3.86
		Reclaimed Water Supply		
Row Crops	$95,280	$21,028	91,427	$0.63
Sod/Pasture	$97,248	$21,462	98,395	$0.60
Perennial Crops	$70,702	$15,604	57,506	$0.74
Container Nurseries	$47,245	$10,427	58,513	$0.49

Source: TBG Work Product.

Costs and expected groundwater offsets of Conservation and Irrigation Conservation projects (**Table 2-10** and **Table 2-11**) show significant variability in the costs per benefit resulting from the higher costs of irrigation automation (conservation projects).

Table 2- 10. Conservation Project Cost per Benefit Summary

Cost per Benefit Summary - Conservation				
Option	**Total Costs ($)**	**Annual Cost ($), 5-yr**	**Benefits (GPD)**	**$ per 1000 gallon Offset (5-yr term)**
Irrigation System Automation (Soil Moisture Sensor Control)				
Row Crops	$23,078	$5,093	13,714	$1.02
Sod/Pasture	$23,078	$5,093	17,219	$0.81
Perennial Crops	$23,078	$5,093	8,657	$1.61
Container Nurseries	$23,078	$5,093	8,319	$1.68
Irrigation System Automation (On-site Weather Station Control)				
Row Crops	$24,647	$5,439	13,714	$1.09
Sod/Pasture	$24,647	$5,439	17,219	$0.87
Perennial Crops	$24,647	$5,439	8,657	$1.72
Container Nurseries	$24,647	$5,439	8,319	$1.79
Soil Moisture Sensors for Decision Support				
Row Crops	$1,947	$430	12,571	$0.09
Sod/Pasture	$1,947	$430	15,989	$0.07
Perennial Crops	$1,947	$430	8,038	$0.15
Container Nurseries	$1,947	$430	7,487	$0.16
Weather Station for Decision Support				
Row Crops	$3,515	$776	11,428	$0.19
Sod/Pasture	$3,515	$776	14,759	$0.14
Perennial Crops	$3,515	$776	6,802	$0.31
Container Nurseries	$3,515	$776	6,655	$0.32

Source: TBG Work Product.

Table 2- 11. Irrigation Conversion Project Cost per Benefit Summary

Cost per Benefit Summary - Irrigation Conversion				
Option	**Total Costs ($)**	**Annual Cost ($), 5-yr**	**Benefits (GPD)**	**$ per 1000 gallon Offset (5-yr term)**
Seepage to Center Pivot				
Row Crops	$224,055	$49,448	36,571	$3.70
Sod/Pasture	$241,131	$53,217	38,128	$3.82
Center Pivot to Subsurface Drip				
Row Crops	$340,182	$75,077	24,000	$8.57
Sod/Pasture	$366,110	$80,800	25,829	$8.57
Seepage to Subsurface Drip				
Sod/Pasture	$366,110	$80,800	38,128	$5.81
Seepage to Drip				
Row Crops	$273,035	$60,258	73,142	$2.26
Overhead to Drip				
Perennial Crops	$147,728	$32,603	43,902	$2.03
Overhead to Micro Spray				
Perennial Crops	$210,030	$46,353	39,574	$3.21
Overhead to Micro: Nursery				
Container Nurseries	$102,147	$22,544	44,370	$1.39

Source: TBG Work Product.

Management of irrigation systems and the specific design and implementation of these AAD irrigation improvements will determine the actual costs and benefits. As a way to represent some of the range and uncertainty in costs per benefit, a table of minimum and maximum $/1000 gallons of groundwater offset was assembled (**Table 2-12**). Maximum costs per benefit were developed using the ratio of the largest (smallest for minimum) cost estimate and the smallest (largest for minimum) groundwater offset within each project type. The maximum cost per benefit ratio, for a given crop/project combination is also shown. Data sources for costs, which include installation costs in the unit costs where applicable, are summarized in the **Appendix**.

Table 2- 12. Minimum and maximum costs per benefit

Cost per Benefit Minimum and Maximum (5 yr term)				
Option	**Maximum: $ per 1000 gallon Offset**	**Maximum $ per Minimum offset ($/1000 gal)**	**Maximum: Annual cost, $**	**Minimum: GPD offset**
Alternative Water Source	$5.42	$17.46	$126,963	19,919
Alternative Water Source: Ponds	$5.42	$17.46	$126,963	19,919
Conservation	$1.79	$2.24	$5,439	6,655
Irrigation Conversion	$8.57	$9.22	$80,800	24,000

Source: TBG Work Product.

As illustrated in the tables of costs, investments for reducing groundwater withdrawals are not trivial. Conservation projects, in which producers implement some type of instrumentation to improve irrigation management, are the most affordable of the project types by a large margin. However, the groundwater offsets are much smaller for these types of projects. While surface water development projects are the most expensive, the potential for groundwater offsets for these types of projects is substantial. For example, if we assume that 10% of the 396,459 irrigated acres (FSAID 2015) in SWFWMD were to implement a surface water project, with benefits similar to those estimated here (about 790 GPD/irrigated acre), the total groundwater offsets could be 31.2 million gallons per day (MGD).

While surface water development can provide the greatest potential groundwater offsets, the management costs might be expected to be greater for these projects, given the additional pumping station and the maintenance needs of the pond. The Conservation and Irrigation Conversion projects can potentially simplify agricultural operations, possibly saving time and money for producers. The priorities of individual producers will of course drive their decisions about investments in water conservation, and the role of public sector support for water conservation initiatives can be expected to be increasingly important as agriculture faces growing competition for water and a greater responsibility to increase productivity for an increasing population.

Frost and Freeze Protection

Overview

The Model Farms Economic Study for irrigation Frost/Freeze Protection (FFP) examines the benefits and costs of projects representative of the SWFWMD FARMS (Southwest Florida Water Management District, Facilitating Agricultural Resource Management Systems) program for reducing groundwater withdrawals for cold protection irrigation. Three groups of cropping systems have been evaluated to represent average farm sizes and irrigation requirements: 1) Non-blueberry Perennials, 2) Strawberries and Blueberries, and 3) Container Nurseries. The project types evaluated for reducing FFP irrigation requirements were Surface Water Development, Row Covers, Wind Machines, and Chemical Crop Protectants. While the total volume of groundwater withdrawals for FFP is not large relative to total irrigation withdrawals, the very short time frame during which the withdrawals occur can create hugely significant impacts from FFP irrigation, particularly in seasons having numerous consecutive freeze events. The benefits evaluated here are groundwater offsets, or reduced groundwater withdrawals from the Upper Floridan aquifer; the costs include the materials and installation costs associated with implementing management practices for reducing groundwater withdrawals for FFP irrigation.

Annualized costs were calculated using expected project life cycles of 20 years for surface water, 20 years for wind machines, 5 years for row covers, and 1 year for Chemical Protectants. Additionally, annualized costs were calculated using a 5-year project term for all projects. The average annualized costs (3.375% interest) per benefit are expressed in terms of $/ per 1,000 gallons. Using the 5-year project term for all project types, the average costs per benefit for Surface Water Development were $18.02/1000 gallons, Row Cover costs per benefit were $2.32/1000 gallons, Wind Machine costs per benefit averaged $7.28/1000 gallons, and Chemical Protectant daily costs per benefit were $0.11/1000 gallons. Chemical protectants do show substantially smaller costs per benefit than all the other project types due to their low costs, but given their limited temperature protection threshold and the limited research associated with chemical protectants for FFP, it is suggested that actual implementation of those project types would be limited.

The transition to a non-irrigation alternative for FFP can result in increased risks of crop damage and yield losses and increased labor costs for producers. However, the use of row covers in particular, shows promise for reducing groundwater withdrawals for FFP. The competitive costs per benefit and the temperature protection threshold that is well below the other non-irrigation alternatives, suggest that row covers might be the most readily implemented non-irrigation FFP alternative. With the exception of chemical protectants, which are largely unproven for regular FFP applications, the total costs for all project types are substantial.

From the database of the Florida Statewide Agricultural Irrigation Demand project (FSAID 2015), the total statewide FFP irrigation withdrawals are only about 4% of total irrigation withdrawals (FSAID 2015), but the local impacts of irrigation for cold protection can be significant due to the short time period during which FFP withdrawals occur. In the DPCWUCA, irrigation for cold protection was estimated at about 17% of AAD irrigation. **Table 3-1** shows the average annual daily irrigation (AAD) and Frost/Freeze Protection irrigation (FFP) for three different geographic extents in Florida. AAD irrigation was calculated from a bio-economic irrigation demand model developed using metered irrigation withdrawals; FFP irrigation was calculated from the historical average of five annual freeze events and crop-specific irrigation application intensities, assuming a 14-hour freeze event (FSAID 2015).

Table 3- 1. Average Annual Daily Irrigation and Frost Freeze Protection, DPCWUCA, SWFWMD and Florida Statewide

	DPCWUCA	SWFWMD	Florida, statewide
AAD irrigation, MGD	20.8	534.1	2,132.2
FFP irrigation, MGD	3.6	46.2	97.1
FFP as % of AAD	17.1%	8.7%	4.6%

The combination of the following three factors make irrigation for cold protection quite different from regular irrigation use: 1) the intensity of irrigation for cold protection (high application rate for long duration: typically exceeding 0.1 in/hr for more than 12 hours for a single freeze), 2) the geographic density of crop types that are freeze protected (for example, the large areas of strawberry and blueberry production in the DPCWUCA), and 3) the short time scale over which the irrigation withdrawals occur.

Crop Type Groups

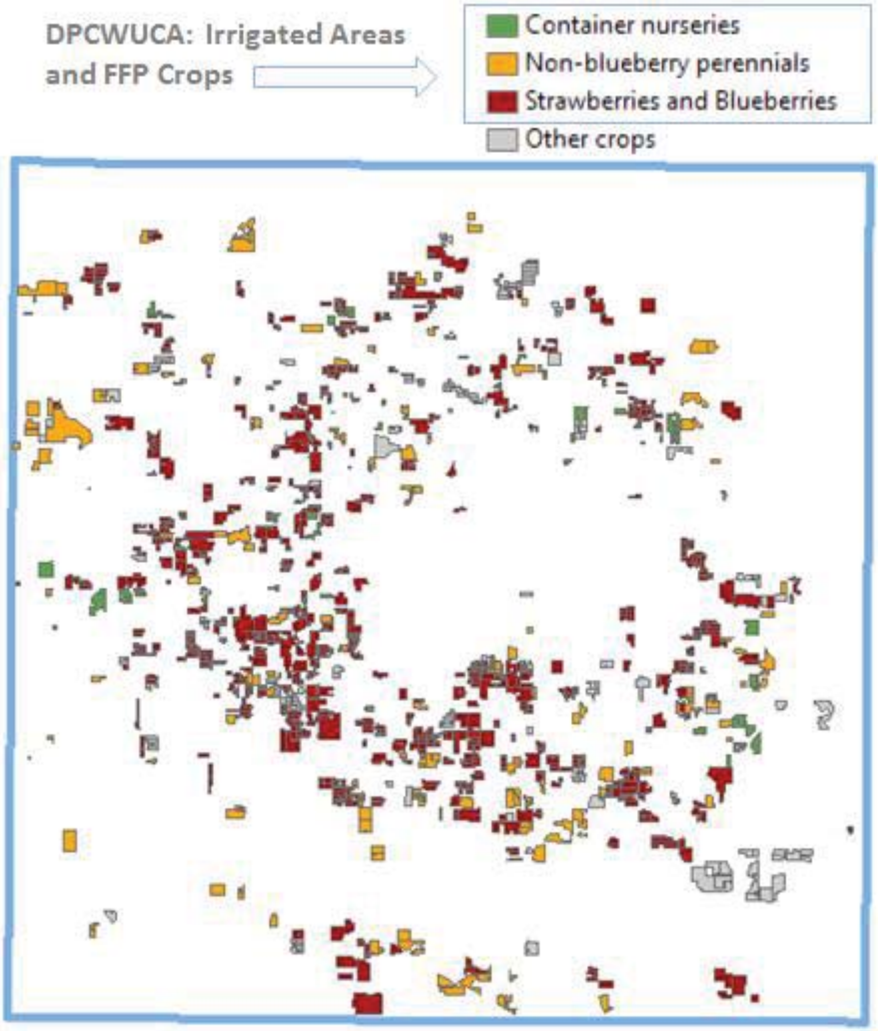
Typical farm sizes and irrigation systems of the 3 production groups within the DPCWUCA were accessed from the Florida Statewide Agricultural Irrigation Demand (FSAID 2015) databases. Strawberries represent nearly 68% of all the irrigated area in the DPCWUCA in the three crop groups. Strawberries and blueberries are grouped together because irrigation rates for FFP are similar for both crops, as both are typically protected using overhead impact sprinklers. The container nurseries category represents a wide variety of plants, including perennial fruit nurseries and ornamental landscape plants; it is assumed that container nurseries are not grown under protected cover. Non-blueberry perennials include citrus, peach, and other cold-sensitive perennials, but the acreage in this category in the DPCWUCA and in the entire SWFWMD consists largely of citrus. Production system characteristics are summarized in **Table 3-2.** **Figure 3- 1** illustrates the spatial distribution of the three crop types in the DPCWUCA.

Table 3- 2. Summary of Production System Characteristics

Irrigated area and annual irrigation requirements	Crop Types		
	Non-blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Average farm size, acres (FSAID2015)	23.9	27.2	14.8
Average field size, acres (FSAID2015)	16.5	9.2	7.0
DPCWUCA, total acres	2,919	8,087	665
FFP irrigation, in/yr	5.2	14.0	9.8
AAD irrigation (AGMOD), in/yr	17.3	33.1	53.0

Source: FSAID 2015 database for acreage, TBG Work Product for FFP irrigation, SWFWMD permitted irrigation amounts for AAD irrigation.

Figure 3- 1. All irrigated areas and FFP crops in the DPCWUCA.



Source: TBG Work Product, FSAID 2015.

Freeze Events

The terms frost and freeze are often used interchangeably, but they have different meteorological definitions. A frost describes the formation of ice crystals on near-ground surfaces that have reached a temperature below the dew point. The dew point is the temperature below which water vapor in the air condenses into liquid water (or solid water in the case of frost). Frosts can occur when thermometer readings indicate temperatures in the mid-30°F range due to radiational cooling of the ground and plant surfaces. A freeze refers to air temperatures below 32°F for a significant amount of time.

Estimated groundwater offsets for FFP irrigation require an accurate assessment of the average annual number of freeze events. A freeze event describes a situation in which a producer uses protective measures to prevent cold damage in his/her crops. The forecasted minimum temperature, dew point, wind speed, and current temperature are typically taken into consideration when a producer is deciding if and when to initiate cold protection measures. There are different critical temperatures, meaning temperatures at which yield loss or plant damage occurs, for different crops. For the purposes of this analysis of historical freeze events, it is assumed that a minimum temperature equal to or below freezing would indicate a freeze event.

Minimum temperature data from five different observation platforms were analyzed for various periods of record to estimate the average annual number of freeze events for the DPCWUCA. The longest records were available for Cooperative Observer Program (COOP) stations of the National Weather Service. These long-term stations were in Bartow, Saint Leo, and Plant City. The Florida Automated Weather Network (FAWN) station in Dover was included as well; the period of record is from 1998 to 2014. The United States Geological Survey (USGS) Geostationary Operational Environmental Satellites (GOES) reference evapotranspiration (ETo) data is a 2km gridded dataset that includes minimum temperature; these data were subset to the DPCWUCA and averaged for the entire available period of record (1996-2013). **Table 3-3** shows annual average numbers of freeze events (days having minimum temperature at or below freezing) for three different time periods for selected weather stations in and near the DPCWUCA. Based on location within the DPCWUCA, the Plant City station was selected to estimate the average number of annual freezes for the DPCWUCA. Based on historical data from Plant City, averaged across the three periods of record, there are approximately five freezes per year in the DPCWUCA.

Table 3- 3. Annual Average Number of Freeze Events

Station name	Days of Tmin <= 32 F			Total record length
	entire station record	1985-2014	1981-2010	
Bartow, COOP station	**4.0**	**2.0**	**2.5**	**1892-2015**
Saint Leo, COOP station	**3.4**	**2.9**	**3.4**	**1894-2015**
Plant City, COOP station	**5.8**	**3.7**	**4.4**	**1893-2015**
Dover, FAWN station	**3.3**			**1998-2015**
USGS GOES ETo	**2.9**			**1996-2013**

Source: TBG Work Product. Data sources: NOAA Global Historical Climatology Network for the three COOP stations, Florida Automated Weather Network for Dover FAWN station, USGS gridded reference evapotranspiration for GOES ETo.

The particular type of freeze event can greatly impact the protection provided by irrigation or any type of irrigation alternative for cold protection. The two main types of freeze events are radiative freezes and advective freezes (Perry 2001). Radiative freezes are characterized by calm winds (usually less than 3 mi/hr.) and clear skies. This creates the conditions necessary for near-surface temperature inversion, in which temperatures of land surfaces and plants can be much lower than the air temperature at higher altitudes as a result of the rapid radiational heat transfer from soils and plants near the land surface. An advective freeze is characterized by windy conditions (> 5 mi/hr.) and freezing air temperatures. Cloud cover can be either negligible or substantial; the cold air mass is sometimes associated with a frontal system. Adequate cold protection is generally easier to achieve in radiational freezes; the lower temperatures and higher winds in advective freezes create challenging conditions for successful cold protection. Part of the reason for the prevalence of irrigation for cold protection is that successful protection does not depend on the type of freeze event (assuming winds are not extreme). Wind machines and chemical protectants can only be expected to provide sufficient protection in low-wind, radiative freezes.

Project Type Descriptions and Methods

Several data sources were utilized to develop the types of projects included in this analysis for alternatives to groundwater for cold protection. FARMS annual reports, university Extension materials, and peer-reviewed literature were reviewed to develop the following four FFP alternatives to groundwater-sourced irrigation: 1) Surface Water development for irrigation, 2) Row Covers, 3) Wind Machines, and 4) Chemical Crop Protectants. The scenarios for each project type are detailed in **Table 3-4.** The groundwater offsets vary significantly among these FFP alternatives due to the temperature thresholds at which each option can provide protection. The costs associated with each scenario have been calculated from a cost database developed from FARMS project costs, Natural Resource Conservation Service (NRCS), and equipment vendors in the SWFWMD. The benefits (groundwater offsets) have been estimated from monthly water balance simulations for surface water projects and from temperature protection thresholds for the non-irrigation FFP alternatives; details of these methods are described in the following four sections. Costs per benefit are expressed in terms of cost per 1000 gallons of groundwater offset ($/1000 gallons). Conversion of the total annual volume of groundwater offset to gallons per day (GPD) is done using the estimated annual groundwater offset and dividing by 365 days/year in order for the groundwater offsets to be in units that match those of AAD projects.

Table 3- 4. Project type scenarios for the FFP Model Farms

Project Type	Crop Type		
	Non-blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Surface Water Development	• Excavated pond, average • Excavated pond, large • Existing water feature expansion		
Row Covers	Not applicable	• Row Covers • Row Covers with mechanized application/retrieval	
Wind Machines	• Wind Machines: 1 per 10 acres		
Chemical Crop Protectants	• Chemical protectants for cold protection		

Source: TBG Work Product.

Surface Water Development

Surface water development, through the excavation of an irrigation reservoir, can provide reliable cold protection through irrigation. The potential groundwater offsets depend on the size of the pond, the drainage characteristics of the farm, and the management of withdrawals from the pond. Three surface water scenarios are considered in this analysis: a large pond, an average size pond, and the expansion of an existing water feature.

"Average pond size" describes a pond sized to provide 3 days of freeze protection irrigation, based on UF/IFAS Extension recommendations for irrigation intensity and an assumed 14 hour freeze event.

"Large pond size" describes a pond sized to provide 5 days of freeze protection irrigation.

"Existing water feature expansion" describes an average pond size developed from an existing pond that is half the design volume of the average sized pond.

The pumping station and irrigation mainline to the existing irrigation system are two of the major costs associated with surface water development for irrigation. The pumping station includes the power unit, pump, foundation and protective structures, intake, filtration, and all necessary appurtenances. A diesel power unit and centrifugal pump were assumed. The type of irrigation system, the topography, and the zoning utilized in an irrigation system will all impact the actual flow rates and pressures in an irrigation system. The size of the pumping station was calculated based on the assumed irrigation application rates for FFP and the sizes of the Model Farms for each crop type (900 GPM, 50 BHP calculated as average flow and power requirements for Container Nursery and Non-blueberry Perennials; 2500 GPM, 100 BHP calculated as average flow and power requirements for Strawberries and Blueberries crop group due to the higher irrigation intensities expected there for FFP). A 12" PVC mainline pipe to the existing irrigation system is estimated based on flow rate and flow velocity conventions. The distance from the pond to the existing irrigation system is dependent on irrigated area (crop type); it is assumed to be the distance from the corner of the farm to the center (assuming a square farm). Costs for excavation, pumping stations, filtration, and irrigation mains were collected from the FY2015 NRCS EQIP Payment schedule for Florida (NRCS 2015) and from FARMS project datasets; these data are summarized in the cost summary table for FFP projects in the **Appendix**.

Groundwater Offsets: Ponds

Pond sizes were developed for each crop group following the NRCS approach of estimating pond volume to match the required irrigation volume for the desired number of freeze events. Irrigation application rates from UF/IFAS Extension materials were used: 0.07 in/hr for Non-blueberry Perennials (Parsons and Boman 2013), 0.20 in/hr for Strawberries and Blueberries (Williamson et al. 2015), and 0.14 in/hr for Container Nurseries (Olczyk 2011). Assumed initial pond volume for the monthly water balance was 50% of maximum volume. The assumed protection threshold of irrigation from surface water is the same as that of irrigation from groundwater (approximately 20°F, varying with wind speed, dew point, and irrigation rate), since the mechanism of protection has to do with the phase change of the water and not the initial water temperature.

The actual contribution of a pond to FFP irrigation requirements depends on the drainage characteristics of the farm, and the amounts and timing of rainfall that precede freeze events. To estimate the possible FFP irrigation supplied by the ponds for this analysis, a monthly water balance approach, developed by NRCS, was utilized. Monthly average rainfall was used to calculate inflow to the pond, assuming the entire farm contributes flow to the pond. Monthly average reference evapotranspiration (ETo) was used to scale total gross irrigation totals to monthly amounts to calculate withdrawals from the ponds. Seepage and evaporation losses were estimated based on monthly pond water surface area. Based on the Plant City COOP station data, the average annual number of freeze events for the DPCWUCA (five) was split into three freeze days in January and two freeze days in February. Irrigation return flow to the ponds was assumed to be 25% of the total irrigation amount the first day, 50% of irrigation on the second day, and 75% of irrigation after 3 days, assuming consecutive freeze events. FFP groundwater offsets are calculated and summarized separately, and the combined FFP and AAD groundwater offsets have also been estimated.

The following equation was used to simulate monthly storage of water in farm ponds for the purpose of estimating annual irrigation offsets supplied by the pond:

$$S = RO - Irr_{FFP} - Irr_{AAD} - DP - E \ ,$$

where S is volume of water in the pond (constrained between 0 and the maximum pond capacity), RO = runoff of rainfall and return flow of FFP irrigation, Irr_{FFP} = monthly total irrigation for frost/freeze protection (January and February only), Irr_{AAD} = average annual daily irrigation (scaled to monthly value based on ratio of monthly reference ET and annual AGMOD irrigation amount), DP = seepage losses from the pond, and E = evaporation from the pond. All units are in ac-ft per month. Runoff volume to the pond is calculated using the 30-day curve number approach:

$$RO = farm\ area * (P - 0.2 * \left(\frac{1000}{CN} - 10\right))^2 / (P + 0.8 * \left(\frac{1000}{CN} - 10\right))/12,$$

where P = rainfall (inches) and CN = Curve Number (67, for monthly balance, based on NRCS recommendations). Monthly values of pond water volume, S, were used to estimate the irrigation supplied by the pond and what would be required from groundwater to meet monthly irrigation requirements; this gives the total annual groundwater offset that might be realized with a pond.

The monthly rainfall data used for the pond water balance were the average of 32 Climate Normals (1981-2010) stations in the SWFWMD; the monthly reference evapotranspiration data (ETo) were the average of eight Florida Automated Weather Network (FAWN) stations in the SWFWMD. Monthly data summarized in **Table 3-5** were used to estimate annual water supply using monthly water balance in ponds.

Table 3- 5. Monthly Average Rainfall and Evapotranspiration

Month	Rainfall, inches	ETo, inches
January	2.5	1.9
February	2.7	2.5
March	3.6	3.6
April	2.4	4.6
May	2.8	5.4
June	8.0	5.2
July	7.9	5.3
August	8.1	5.0
September	6.8	4.1
October	2.9	3.4
November	2.0	2.2
December	2.5	1.8
Annual total	**52.3**	**45.0**

Source: TBG Work Product, Data from: 32 stations for 1981-2010 Climate Normals from NOAA, 8 FAWN stations for reference evapotranspiration.

Table 3- 6 shows the surface water supply for FFP irrigation demands for average and large size ponds; 5 annual freeze events, 14-hour protection duration per freeze. The estimated groundwater offsets from the water balance calculations for FFP irrigation from surface water for the three crop types and the two pond sizes are summarized in **Table 3-6**.

Table 3- 6. Surface Water Supply and Irrigation Requirements for FFP Irrigation Demands

		Non-blueberry perennials	Strawberries and Blueberries	Container nurseries
	Farm Size, acres	**23.9**	**27.2**	**14.8**
	FFP irrigation requirements, ac-ft	**10.3**	**31.8**	**12.1**
Average pond size	Pond Area, acres	0.6	2.4	0.7
	Pond Capacity, ac-ft	3.2	19.2	3.7
	Pond Irrigation Supply, FFP, ac-ft	4.3	12.0	5.1
	Annual losses, ac-ft	2.9	5.3	3.3
Large pond size	Pond Area, acres	0.9	3.8	1.1
	Pond Capacity, ac-ft	5.5	31.8	7.3
	Pond Irrigation Supply, FFP, ac-ft	5.4	18.3	7.0
	Annual losses, ac-ft	4.0	5.3	3.7

Source: TBG Work Product, pond monthly water balance based on NRCS irrigation reservoir methodology.

Non-irrigation Cold Protection Alternatives

Row Covers

Row covers for cold protection, for the purposes of this analysis, describe a fabric-like, non-woven material used to protect plants from cold damage. Traditionally, these fabric-like or polyethylene row covers have been used to enhance earliness in the spring and to provide protection from insect pests. Widespread use in commercial production began in the early 1980s (Hochmuth et al. 2008). Floating covers are assumed, meaning no hoops or supporting materials will be considered in the costs. This type of row cover will not cause excessive heat build-up if left in place during the day; rainfall or irrigation can drain through the covers. Also, there is only about a 15% reduction in light levels (Hochmuth et al. 2008). Row covers have been shown to effectively protect strawberries against cold damage down to 21°F (Santos et al. 2011); similar protection could be expected for other small-stature plants. The weight of the row covers (0.9 oz/yd or 0.6 oz/yd) or the position of the row covers (on plant canopies or on hoops) did not affect the level of cold protection (Santos et al. 2011). Row covers are not typically used on large plants due to the practicality of applying and retrieving them; therefore, they are being considered in this study for protection on strawberries and container nurseries. The material costs and labor costs associated with applying and retrieving covers has limited row cover use for cold protection. Equipment for applying/removing covers is considered as one of the project type scenarios to reduce labor costs for producers.

Wind Machines

Wind machines for cold protection work for a particular type of freeze event in which there is a temperature inversion: near-surface temperatures are lower than temperatures at higher altitudes. Wind machines function by mixing the warmer air with cooler air near the surface. The maximum temperature increase that can be expected is about 5°F; a single wind machine can protect about 10 acres (Williamson et al. 2015). The effectiveness of wind machines depends on temperature stratification or the amount of temperature inversion present, which is a function of wind speed. For calm nights wind machines can often provide effective cold protection, but for windy nights with freezing temperatures they are not likely to provide much protection (Georg 1958). Cold air drains work on a similar principle as wind machines, but instead of a rotating fan moving air horizontally (positioned on a tower), a cold air drain blows directly up (fan parallel to the ground surface). The near-surface coldest air layer is essentially elevated to a higher altitude where it mixes with warmer air. There was insufficient research available on the protection thresholds and applications in Florida to include cold air drains in this study. A cold air drain was implemented under FARMS Project H620; results from this project might provide data which can be used to evaluate effectiveness of these systems for future use.

Chemical Crop Protectants

Chemical crop protectants provide the lowest level of freeze protection among the irrigation alternatives of this study. It is included here because there may be potential for advances in this area that might increase protection thresholds. The most common types of chemical crop protectants for cold production are terpene polymer concentrates developed to improve adhesion and rainfastness of other crop protection chemicals. The product labels typically specify protection for frosts, but suggest no protection is provided for freezing temperatures. Research with crop protectants on strawberries found protection to be effective down to 27°F (Hernandez-Ochoa 2013). For the purposes of this study, a 30°F threshold was assumed for estimating the annual numbers of freeze events in which chemical crop protectants could provide protection.

Groundwater Offsets

Groundwater offsets from the irrigation alternatives (Row Covers, Wind Machines, and Chemical Protectants) were estimated using the protection threshold temperatures found in **Table 3-7**. These are the minimum temperatures at which the irrigation alternatives can be expected to provide successful protection against crop damage: 21°F, 27°F, and 30°F for Row Covers, Wind Machines, and Chemical Protectants, respectively. These temperature thresholds were used with the Plant City historical weather data to calculate the average number of days per year in which temperatures were below the irrigation alternative protection thresholds. This provides an estimate of the number of days per year in which irrigation for cold protection would still be required. That number of days is then used to estimate the proportion of groundwater offset for the irrigation alternative as a percent of the total irrigation requirement assuming five freezes per year.

Table 3- 7. Estimated percent water savings for the three water alternatives for FFP

water savings, % of annual FFP irrigation requirements; temperature protection thresholds					
Chemical Protectants[3]		Wind Machines[4]		Row Covers[5]	
Water savings, %	Temperature threshold, °F	Water savings, %	Temperature threshold, °F	Water savings, %	Temperature threshold, °F
40%	30°F	60%	27°F	80%	21°F

Source: TBG Work Product for water savings estimate; see footnotes for data sources for the three non-irrigation FFP alternatives

Results: Costs and Benefits

The costs and benefits of the Model Farms for FFP can be considered to be representative of the range of possibilities for various production systems and types of projects. This section provides summary tables of expected costs and groundwater offsets for the Model Farms for FFP alternatives to irrigation from groundwater.

The groundwater offsets for each of the project type scenarios are presented in **Table 3-8**. Groundwater offsets were calculated as annual total estimates converted to daily amounts by dividing by 365 days/year to align with the gal/day benefits calculated for AAD projects. The large size pond provides the greatest potential groundwater offsets, and the row covers and wind machines also show substantial benefits. **Table 3-9** shows the expected groundwater offsets as a percentage of the expected FFP amount and as a percentage of the combination of FFP and permitted AAD allocation.

Table 3- 8. Estimated groundwater offsets for all project type scenarios

Project Type Scenarios	Crop Group		
	Non-blueberry Perennials	Strawberries and Blueberries	Container Nurseries
	Average acreage by crop group		
	23.9	27.2	14.8
Surface Water scenarios	**Groundwater offset FFP, GPD (AAD basis)**		
Pond size: Average	3,839	10,713	4,553
Pond size: Large	4,821	16,337	6,249
Non-irrigation scenarios	**Groundwater offset FFP, GPD (AAD basis)**		
Row Covers	-	22,606	8,588
Wind Machines	5,553	17,015	6,474
Chemical Protectants	3,631	11,424	4,360

Source: TBG Work Product.

[3] Hernandez-Ochoa IM. 2013. Water Management Alternatives for Strawberry Transplant Establishment and Freeze Protection in Florida. University of Florida Master of Science Thesis. http://ufdc.ufl.edu/UFE0046432/00001

[4] Williamson JG, Lyrene PM, Olmstead JW. 2015. Protecting Blueberries from Freezes in Florida. UF/IFAS Extension. https://edis.ifas.ufl.edu/hs216

[5] Santos BM, Moore DN, Salame-Donoso TP, Stanley CD, Whidden AJ. 2011. Evaluation of Freeze Protection Methods for Strawberry Production in Florida. Proc. Fla. State Hort. Soc. 124: 188-190.

Table 3- 9. Estimated groundwater offsets (% of allocation) for all project type scenarios

	Non-blueberry perennials	Strawberries and Blueberries	Container nurseries
Project Type Scenarios	**FFP irrigation, GPD (AAD basis)**		
	9,177	28,358	10,790
	acreage by crop group		
	23.9	27.2	14.8
	% offset, FFP		
Alternative Water Source (ponds)	47.2%	47.7%	50.1%
Row Covers	0.0%	79.7%	79.6%
Wind Machines	60.5%	60.0%	60.0%
Chemical Protectants	39.6%	40.3%	40.4%

Source: TBG Work Product.

Total project costs are greatest for Alternative Water Source ($197,281) and Wind Machine projects ($93,333), averaged across the crop types considered here (**Table 3-10**). Benefits for Alternative Water Source projects were estimated to be 7,291 GPD and were 9,651 GPD for Wind Machine projects. The average estimated benefits are greatest for the row cover project types at 15,637 GPD. Row covers offer the most reliable protection among the non-irrigation FFP alternatives because of their lower temperature protection threshold, but they can be expensive in terms of materials and labor. The equipment for row cover application and retrieval has been included as one of the two row cover scenarios here. While the mechanization of laying and retrieving row covers can add more than 50% to total project costs, it is suggested that the labor savings provided could make row cover use a more attractive option for producers.

Table 3- 10. Cost per Benefit summary of all four FFP alternatives

	Average Total Cost ($)	Annual Cost ($), 5-yr	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Alternative Water Source	$197,281	$43,539	7,291	$18.02
Row Covers	$53,183	$11,737	15,637	$2.32
Wind Machines	$93,333	$20,598	9,651	$7.28
Chemical Protectants	$191	$211	6,434	$0.11

Source: TBG Work Product.

The average daily costs per benefit ($/1000 gallons) for Alternative Water Source, Row Cover, Wind Machine, and Chemical Protectant project types are $18.02, $2.32, $7.28, and $0.11 per 1000 gallons, respectively. However, it should be noted that the actual project life for Alternative Water Source and Wind Machine projects would be closer to 20 years, which would substantially decrease the costs/benefit if the project lifetime is considered rather than the 5-year term. Chemical protectants do show substantially smaller costs per benefit than all the other project types, but given their limited temperature protection threshold and the limited experience and research associated with chemical protectants for FFP, it is suggested that actual implementation of those project types would be limited. Costs and benefits for Alternative Water Source projects of each of the three groups illustrate the impact of typical irrigation intensity on the ratio of costs to benefits (**Table 3-11**). The Strawberries and

Blueberries crop group typically would utilize overhead, impact sprinklers with an application rate of at least 0.2 in/hr. This high intensity corresponds to a higher expected groundwater offset due to the pond sizing approach based on numbers of freeze events.

Table 3- 11. Surface Water project Cost per Benefit summary

Cost per Benefit Analysis Summary – Alternative Water Source				
Option	**Total Cost ($)**	**Annual Cost ($), 5-yr**	**Benefits (GPD Offset)**	**Cost per Benefit: $ per 1000 gallons**
Existing Water Feature Expansion				
Non-Blueberry Perennials	$135,618	$29,931	3,839	$21.36
Strawberries and Blueberries	$208,390	$45,991	10,713	$11.76
Container Nurseries	$128,265	$28,308	4,553	$17.03
Excavated Pond, Average				
Non-Blueberry Perennials	$152,107	$33,570	3,839	$23.96
Strawberries and Blueberries	$279,267	$61,634	10,713	$15.76
Container Nurseries	$155,707	$34,364	4,553	$20.68
Excavated Pond, Large				
Non-Blueberry Perennials	$160,433	$35,407	4,821	$20.12
Strawberries and Blueberries	$373,079	$82,338	16,337	$13.81
Container Nurseries	$182,660	$40,313	6,249	$17.67

Source: TBG Work Product.

Wind machines show a somewhat large cost per benefit (**Table 3-12**), especially for the Non-Blueberry Perennials ($11.55/1000 gallons), due to the lower estimated FFP water requirement that would be offset. This results from the assumed use of microsprinklers at lower irrigation intensity than the other crop groups.

Table 3- 12. Wind Machine Cost per Benefit summary

	Cost per Benefit Analysis Summary – Wind Machines			
Option	**Total Cost ($)**	**Annual Cost ($), 5-yr**	**Benefits (GPD Offset)**	**Cost per Benefit: $ per 1000 gallons**
Non-Blueberry Perennials	$105,000	$23,173	5,498	$11.55
Strawberries and Blueberries	$105,000	$23,173	16,990	$3.74
Container Nurseries	$70,000	$15,449	6,465	$6.55

Source: TBG Work Product.

Row covers have a relatively small cost per benefit (as low as $1.39/1000 gallons) due to their low temperature protection threshold and moderate costs (**Table 3-13**). Row covers are assumed to not be applicable for Non-Blueberry Perennials and Blueberries due to plant size and logistics of cover application.

Table 3- 13. Row Cover Cost per Benefit summary

Cost per Benefit Analysis Summary – Row Covers				
Option	**Total Cost ($)**	**Annual Cost ($), 5-yr**	**Benefits (GPD Offset)**	**Cost per Benefit: $ per 1000 gallons**
Non-Blueberry Perennials	$0	$0	-	$0
Strawberries and Blueberries	$52,227	$11,526	22,654	$1.39
Container Nurseries	$28,388	$6,265	8,620	$1.99
Row Covers with Mechanized Application/Retrieval				
Non-Blueberry Perennials	$0	$0	-	$0
Strawberries and Blueberries	$77,977	$17,209	22,654	$2.08
Container Nurseries	$54,138	$11,948	8,620	$3.80

Source: TBG Work Product.

The costs per benefit for chemical crop protectants are unusually low due to the very low costs (**Table 3-14);** however, chemical protectants have had limited applications and testing for cold protection. Also, there are high labor and management costs associated with repeated applications.

Table 3- 14. Chemical Protectants Cost per Benefit summary

Cost per Benefit Analysis Summary – Chemical Protectants				
Option	**Total Cost ($)**	**Annual Cost ($), 5-yr**	**Benefits (GPD Offset)**	**Cost per Benefit: $ per 1000 gallons**
Non-Blueberry Perennials	$208	$230	3,665	$0.17
Strawberries and Blueberries	$237	$261	11,327	$0.06
Container Nurseries	$129	$142	4,310	$0.09

Source: TBG Work Product.

The actual costs per benefit of FFP groundwater offset projects will of course depend on the specific design, implementation, and management of systems. In order to represent some of the uncertainty associated with the cost and benefit estimates, a table was assembled to show the maximum daily $/1000 gallons of groundwater offset (**Table 3-15**) for the given crop/option combinations. Maximum costs per benefit are shown based on the ratio of maximum daily $ to the minimum offset for a given option across all crop groups. The **Appendix** summarizes the data sources used for all costs.

Table 3- 15. Maximum costs per benefit by project type

Cost per Benefit Minimum and Maximum (5 yr term)				
Option	**Maximum: ($ / 1000 gal)**	**Maximum $ per Minimum offset: ($ / 1000 gal)**	**Maximum: Annual cost, $**	**Minimum: (GPD offset)**
Alternative Water Source	$23.96	$58.76	$82,338	3,839
Row Covers	$3.80	$5.47	$17,209	8,620
Wind Machines	$11.55	$11.55	$23,173	5,498
Chemical Protectants	$0.17	$0.20	$261	3,665

Source: TBG Work Product.

For producers deciding about FFP alternatives to irrigation from groundwater, they are weighing both the costs and the benefits. While the groundwater offsets might not be among the primary benefits from the standpoint of producers, many of the FFP project types evaluated here can provide savings in energy costs. Additionally, these FFP alternatives might provide some assurance that producers can remain in compliance with their consumptive use permits by reducing groundwater withdrawals for FFP. Compared with irrigation for FFP, whether from groundwater or surface water, the non-irrigation alternatives for FFP could bring increased risks for crop damage and yield or quality losses. The prevalence of irrigation for cold protection is evidence of the management challenges and risks associated with the non-irrigation alternatives for cold protection. However, it is expected that producers implementing a non-irrigation FFP project will also be able to irrigate for FFP if needed. The use of non-irrigation FFP methods in combination with irrigation for more severe freezes can provide sufficient protection while still reducing groundwater withdrawals for FFP. A major management challenge, particularly for chemical protectants and wind machines (given their higher temperature thresholds for protection), is deciding when a non-irrigation alternative can safely be applied. The current quality of weather forecasts and producers' understanding of minimum temperatures in their fields compared to weather forecasts can provide producers with a reasonable amount of confidence for making decisions about non-irrigation alternatives for FFP.

Nitrogen Management Improvements

Overview

Agricultural systems can be significant sources of Nitrogen (N) to groundwater and surface waters (Canfield et al. 2010; Foley et al. 2011) as a result of the N inputs on farms. The climate and soils of Florida make our agricultural systems especially vulnerable to N losses. The low water-holding capacity and nutrient holding capacity of sandy soils together with frequent high-intensity rain events can lead to substantial N leaching, which is the draining of Nitrogen below plant root zones where it is ineffective for production and contributes to groundwater nutrient loads.

Nitrogen is one of the 17 elements essential for crop growth. The goal of Nitrogen management in agricultural systems is to provide sufficient N to maximize economic returns while minimizing N losses from the system. N can leave crop production systems along several possible pathways: through runoff of soluble reactive N (typically nitrate, NO_3^-) to lakes or streams, through leaching of soluble reactive N to groundwater, or through atmospheric losses through various types of N-containing gases. The generally high hydraulic conductivity of soils in Florida results in N leaching to groundwater being the most prevalent form of N loss from Florida agriculture.

The Model Farms Economic Study for Nitrogen was designed to quantify the cost-effectiveness of management strategies for reducing flows of N from agricultural systems to groundwater and surface water. The region of interest within the Southwest Florida Water Management District (SWFWMD) is the 6 county area of Levy, Marion, Citrus, Sumter, Hernando, and Pasco Counties, containing parts of the 5-springshed region of the Chassahowitzka, Homosassa, Kings Bay, Rainbow, and Weeki Wachee springs.

Production Systems

The types of farming systems included in the N Model Farms BMP analysis were based on recommendations from the SWFWMD FARMS program and from the most prevalent areas of agricultural lands in the study region based on datasets of the Florida Statewide Agricultural Irrigation Demand (FSAID). The resulting 7 cropping systems used here for the purposes of representative farm sizes and relevance of BMPs are:

- Horse farms
- Livestock grazing
- Dairies
- Hay
- Field crops (cotton, peanut, corn)
- Vegetables
- Perennial fruits (citrus and blueberry).

Figures 4-1 and **4-2** summarize the spatial distribution and total acreage of irrigated and non-irrigated agricultural lands in the 6 county area. **Table 4-1** summarizes which BMPs might be utilized for each type of production system. The majority of agricultural lands in the study area are non-irrigated pastures (**Figures 4-1** and **4-2**); these systems are quite variable in their environmental impacts due to the differences in proximity to surface water, the differences in groundwater recharge, and the differences in fertilization and grazing intensity. There are significant areas of irrigated field crops, particularly in the Rainbow springshed. The Weeki Wachee and Rainbow springsheds have substantial areas of irrigated vegetable systems. These irrigated systems, both in field crops and vegetables, are important because they can be expected to have higher Nitrogen application rates than in non-irrigated areas.

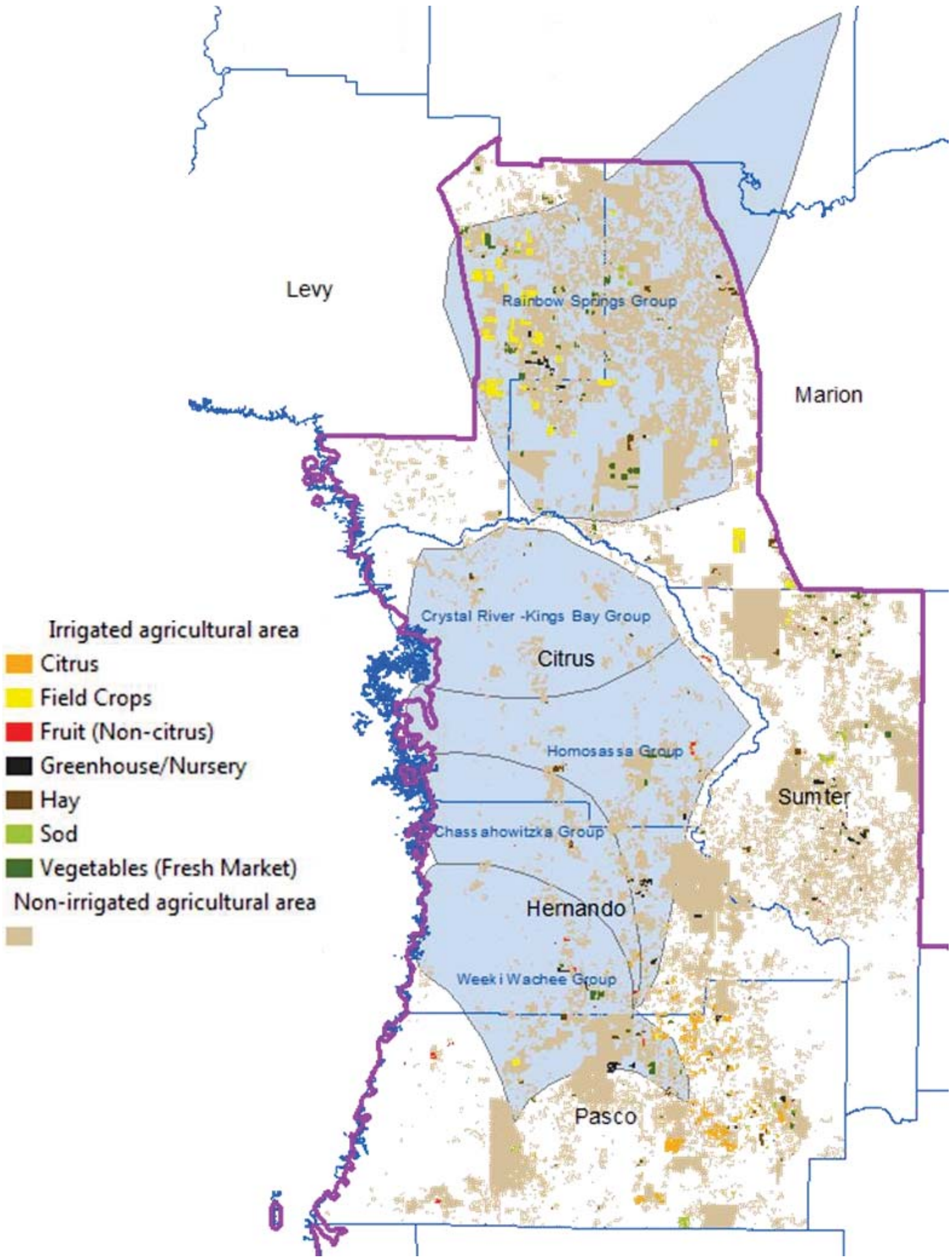


Figure 4- 1. Irrigated and non-irrigated crops in the 6 county region

The 6 counties containing the 5 springshed area are shown in **Figure 4-1**, with irrigated (colored regions) and non-irrigated agricultural areas (brown regions) represented as shaded fields. Spatial datasets of agricultural areas are from the FSAID (Florida Statewide Agricultural Irrigation Demand) databases.

Figure 4- 2. Acres of irrigated and non-irrigated agricultural areas based on FSAID datasets in the 6 County region

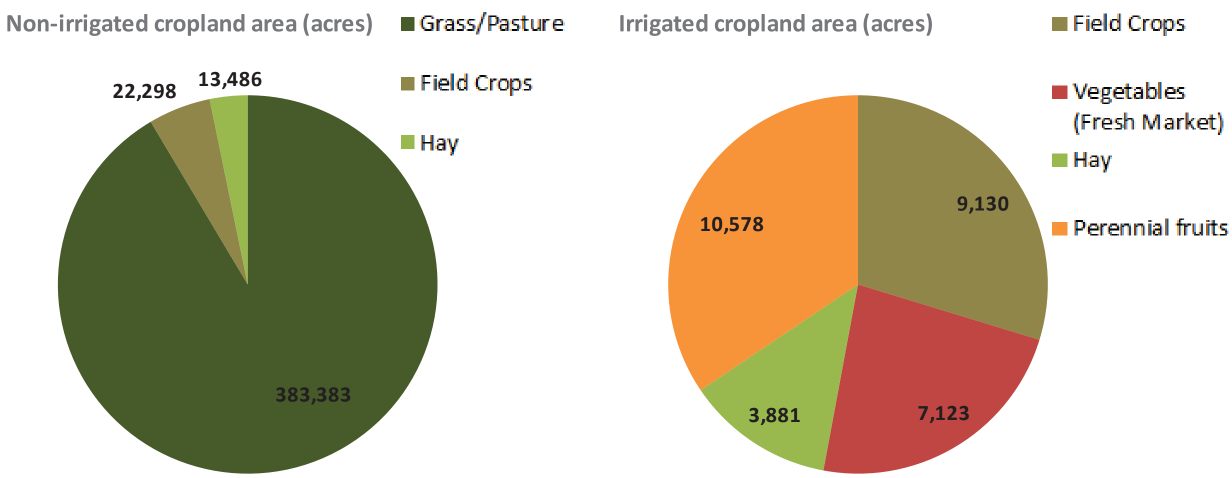


Table 4- 1. Production systems considered in the N Model Farms Assessment

	Production Systems, total and average farm acreage						
	Horse farms	Livestock grazing	Dairy	Hay	Field crops	Vegetables	Perennial fruits
Total acreage, 5 Springsheds	**19,819**	**160,757**	**243**	**8,208**	**15,760**	**4,697**	**1,349**
Average farm size, 5 Springsheds	**21**	**100**	**80**	**87**	**179**	**109**	**24**
Total acreage, 6 Counties	**60,344**	**383,383**	**325**	**17,367**	**31,429**	**7,123**	**10,578**
Average farm size, 6 Counties	**21**	**107**	**80**	**62**	**155**	**91**	**47**

Applicable N management BMPs

		Horse farms	Livestock grazing	Dairy	Hay	Field crops	Vegetables	Perennial fruits
N Application Reduction	**Variable rate N**				O	O		
	N balance simulation				O	O	O	O
	Fertigation					O	O	O
	Equipment guidance system				O	O		
N Removal/Retention	**Vegetative Filter Strips**	O	O	O	O	O	O	O
	Tailwater Recovery			O		O	O	O
	Manure storage buildings	O	O					
	De-nitrification wall	O	O	O				
	Treatment wetland	O	O	O				
	Wastewater pond liner			O				
	Interceptor well/bioreactor			O				

Source: TBG Work Product.

Nitrogen BMP descriptions

The two groups of Nitrogen BMPs considered here are those that reduce N applications and those that increase N retention or removal. The type of production system and the priorities of producers will determine which BMPs are applicable in a given system. An important distinction should be noted between the N application reduction BMPs and the N retention BMPs. The reduced input costs from the N application reduction BMPs can typically improve a producer's profitability, while also having positive environmental outcomes. The economic returns at the farm level are less likely for N retention BMPs; however, the environmental outcomes can have substantial public economic benefits.

The data sources for costs included equipment vendor quotes, NRCS EQIP payment schedules, and published cost data for the BMPs. The main sources used to quantify N management benefits were peer-reviewed publications and University Extension service fact sheets that described measured impacts on N removal or reduction by the BMPs included in this study. Peer-reviewed publications were also used to develop relationships between reduced N applications and reduced N leaching. Special attention was given to studies in Florida and in regions with comparable soils, climate, and agricultural management in order for the data on benefits and costs to applicable for projects in the SWFWMD. Nitrogen recommendations from UF-IFAS production handbooks were used in calculations to estimate N retention benefits for selected BMPs where literature values were not applicable.

Nitrogen Application Reduction

Variable-rate N Application

Varying the rate of N Application within a field can be done using two possible approaches: real-time sensor-based crop sensing or map-based prescriptions using management zones. A sensor-based system adjusts N application rates based on real-time vegetation monitoring mounted on the application equipment. These systems measure "greenness" of the crop and adjust N rates based on crop-specific algorithms. The map-based approach uses management zones within fields to adjust N application rates. These management zones could be developed from soil maps, harvest maps, topography, aerial imagery, producer knowledge, or some combination of data sources. These data are analyzed to produce N prescription maps that are utilized by a GPS-linked variable-rate N application system. Both approaches require substantial investments in equipment and installation. Several recent studies, varying the Nitrogen application rates based on soil differences or vegetation indices (Scharf et al. 2011; Borghetti 2012; Longchamps and Khosla 2015), demonstrated N reductions on the order of 29 lb N/ac/yr. Variable-rate application of any type of input will generally only result in resource conservation and returns on investment if there is sufficient variability in the soils or management within fields. To determine the applicability of variable-rate N, gridded soil sampling should be completed to test for variability in texture, pH, or other properties within fields that could be utilized in developing site-specific N application rates.

N Simulation Software

Decision-support systems for estimating movement of Nitrogen in a field have been recently commercialized. These work by tracking N movement in a field based on simulations in an effort to better inform producers about N requirements. These are typically mobile-based applications that require user inputs about field location, planting date, crop type, and fertilizer application rate and source. The application simulates N leaching, runoff, volatilization, and crop uptake to recommend the timing and amounts of in-season N applications. Daily weather data are automatically retrieved and utilized for N balance simulations. There are few studies that have documented the N application reductions resulting from these types of systems. The reported results suggest optimistic N application savings of about 60 lb N/ac/yr (Li et al. 2009; Moebius-Clune et al. 2014). Presently, the commercially available systems are not applicable in Florida; however, the data requirements for these systems can be met in Florida. The low cost and potentially substantial N application reductions mean that a Florida-specific implementation of a N Simulation Software may be of interest to the SWFWMD. It was assumed that a system that can operate in Florida would be developed in the coming years.

Fertigation

Applying Nitrogen dissolved in irrigation water can allow for more frequent applications of lower amounts of N, potentially reducing leaching losses. However, as nitrate moves with the wetted front, it is important that irrigation and fertigation are carefully managed to avoid increasing the leaching of nitrate. The majority of fertigation experiments compare the leaching or yield and quality impacts of varying N application rates; few studies report the differences in N application rates or leaching resulting from the major advantage afforded by fertigation, that of splitting N application into a larger number of operations. Realistically, if a producer is applying N using application equipment in the field, it is unlikely that more than two post-planting applications of N would be made. However, in a fertigated system, there is little additional cost associated with more numerous applications of N; this allows for lower amounts of N in the soil, reducing the risk of leaching events. A review of fertigation literature (Ng Kee Kwong et al. 1999; Quemada et al. 2013) suggests that about 22 lb N/ac/yr could be reduced using fertigation compared to conventional N application methods.

Equipment Guidance Systems

Equipment guidance systems can be as simple as providing visual cues to improve operator performance or as sophisticated as automatically steering the equipment to provide inch-level accuracy in field operations. Such approaches reduce N applications by minimizing swath overlap. This is an attractive technology for producers because it can reduce material inputs, save time, and allow for more flexibility in labor. The reported N application reductions are small relative to the other strategies considered here. N reductions of about 8 lb N/ac/yr might be expected using a guidance system (Groover and Grisso 2012; John Deere 2015).

Nitrogen Retention

Vegetative Filter Strips

Vegetative filter strips (VFS) provide a buffer primarily for surficial runoff that may be Nitrogen-rich. The filters are generally grassed but may incorporate other types of vegetation. VFS function by several means: (1) slowing runoff velocities and filtering out sediment and adsorbed pollutants, (2) providing infiltration of N into underlying soils, and (3) nutrient uptake. With sufficient width and optimal grades, VFS can provide relatively high removal of N at low cost. However, where maintaining sheet flow is problematic, the VFS may be "short circuited" by more concentrated flows and therefore provide only nominal treatment. Where the uptake of N into the vegetation dominates the design, harvesting of biomass must be included in the costs of operation.

Denitrification Wall

Denitrification (reduction of labile nitrate to Nitrogen gas) occurs in naturally saturated conditions, such as wetlands and riparian zones. However, the denitrifying microbial communities depend on sufficient availability of carbon, which may be in short supply in sandy soils or groundwater. A form of bio-reactor, denitrification walls are environments for denitrifying microbial activity enhanced by added carbon, typically in the form of wood chips or sawdust. The “walls” are trenches filled with carbon-rich material that intercept groundwater flow. Customized filtration media have been developed to optimized nutrient removal (Suntree Tech 2015). Shallow installations at the edges of fields are referred to as denitrification beds and intercept surface runoff and shallow subsurface flow such as achieved by vegetative filter strips. Where Nitrogen has leached from the vadose zone into the unconfined aquifer, a denitrification wall of sufficient depth is necessary to provide any measure of treatment; otherwise nitrogen-rich groundwater may bypass the installation.

Treatment Wetland

As with natural wetlands, treatment (constructed) wetlands support denitrifying microbial communities and can be managed to enhance their effectiveness. Treatment wetlands take advantage of natural functions of vegetation, soil, and associated organisms, and emulate wetland functions including acting as biofilters, removing sediments and adsorbed pollutants from water received. In addition to uptake of nutrients (including Nitrogen), decaying matter provides carbon for denitrification of residual nitrate. Rates of N removal can be controlled by facility design (flow behavior), size, and choices of vegetation. Treatment wetlands can be established on soils with higher percentages of clay. Treatment wetlands also can mineralize ammonia from animal waste, a step towards eventual denitrification. The nutrient and solids concentrations in the water to be treated are important in determining the size and number of cells in a treatment wetland. For treating wastewater effluent from a dairy operation, there would typically be settling basins and multiple wetland cells to allow for solids removal in upstream cells. Treating runoff from a grazing area could be achieved through simpler wetland design or by restoring an existing wetland by plugging ditch flow. Based on sizing recommendations (Miller et al. 2003, Schaafsma et al. 1999, Tanner and Kloosterman 1997) and the average farm system sizes represented here, a 1 acre treatment wetland size was used as a representative size for cost and benefit calculations. It was assumed that there is existing water conveyance infrastructure, through ditching or pipes, to route drainage water to the treatment wetland.

Tailwater Recovery

Tailwater is surface runoff resulting from crop irrigation. Flood irrigation or sprinkler irrigation in excess of the infiltration rate of the soil may generate tailwater. Excess water, particularly from sloped fields, can discharge to a channel, natural water body, or constructed facility. While often a strategy to conserve water through reuse, tailwater recovery systems also reduce Nitrogen leaving farms by one of two means: re-used water circulates Nitrogen back to the field (as might be done via fertigation) for further uptake by crops or the water collected and stored can be treated for nutrient removal via chemical or biological means before discharge. For the former (and more typical) strategy, tailwater recovery systems must convey the tailwater from the storage facility to the point of re-entry for the irrigation system. This may require a pump and pipe to return the water to the upper portion of the site, or may consist of a gravity outlet and ditch to convey the water to lower sections of the farm. It was assumed that drainage water conveyance through channels or pipes exists in farm systems where tailwater recovery would be applicable.

Manure Storage Buildings

Applicable primarily for horse farms and grazing operations with occasional animal confinement, storage buildings provide for removal of manure (and associated N) from the landscape until transported elsewhere or processed onsite. Manure storage structures are designed to replace manure piles stored in the open where rainfall can leach nutrients from the pile. The roof and concrete floor and walls assumed for the manure storage structures in this analysis effectively prevent any leaching losses from stored manure piles. After sufficient composting in the storage structure, it is assumed that manure leaves the farm through local pickup or some type of marketing for off-farm use.

Wastewater Pond Lining

Lining of manure storage ponds is applicable in dairy production systems without onsite liquid manure storage or having earth-lined existing storage ponds. The goal of lining a manure storage pond is to eliminate nutrient leaching losses during the storage/treatment of manure before it enters secondary treatment or is applied to an irrigated sprayfield, areas of grass or cereal crops typically utilized as part of the dairy feedstock.

Interceptor Wells and Bioreactor

Using interceptor or scavenger wells to collect shallow groundwater can be utilized by irrigated sprayfields in dairy systems. Interceptor wells are installed at a density of about 15 to 20 acres/well and the extracted nutrient-enriched water is pumped to the bioreactor; however, this water can be pumped to the irrigation system during irrigation events. The wells are plumbed together to deliver water to the bioreactor either at a slow rate when not irrigating or at a higher rate during irrigation events. A submerged bioreactor (of about 400 cubic yards for an 80 acre system) consists of a plastic lined pond that is filled with wood chips which are the substrate for bacteria populations that are especially effective at denitrifying water. The bioreactor is maintained in a saturated condition by the low-flow, continuous pumping of the interceptor wells. These systems have been successfully utilized in dairy production systems in Gilchrist County, Florida.

Nitrogen Benefit Methods

N Reduction Strategies

The mass of N in the cost per benefit is how much Nitrogen is not entering the groundwater or surface water as a result of the implementation of a BMP. For the N Retention BMPs these removal amounts are based on literature values with any necessary unit adjustments. For the N Application Reduction BMPs, the literature values of N reductions were adjusted based on several leaching studies (Paramasivam et al. 2001; Zotarelli et al. 2007; Zotarelli et al. 2009). The combined results from these studies showed that leaching reductions were about 8% of total N reductions. For example, if an N reduction BMP averages a 20 lb/acre/year N reduction, we would expect a 1.6 lb/acre/year (1.6 = 20 * 0.08) leaching reduction. This allows for the benefit from both groups of N BMPs to be of the same type: less N loading to water resources.

N Retention Strategies

The size of the manure storage structure was based on farm area (here the average horse farm size of 21 acres was used). Assuming 3.5 acres of grazing area per horse, the typical horse farm in the 6-county region would have about 6 horses. Typical manure production amount used was 0.9 cu-ft per day per horse (FDEP, 2013). Storage duration assumed was 180 days before moving to adjacent bin or removing from the shed. Two additional bins were added to the square footage estimate to increase storage capacity, creating the 900 square foot estimate used here. The leaching rates from open manure heaps (Chadwick 2005; Titonell et al. 2010) were used with estimated heap size to calculate the N retention of the storage structure compared to an open heap. The average annual leaching loss used was 0.85 lb of nitrate per 1,000 lb of dry weight of manure. Using the average farm size and stocking rate, this leaching amount per acre is 0.75 lb of nitrate per acre. It was assumed no leaching of N from manure in the storage structure can occur as a result of the roof and concrete floor and walls. The more stable forms of Nitrogen in composted would substantially reduce N leaching losses of composted manure. It is estimated that leaching losses from an open composted manure pile would be about 20% of those from an open, fresh manure pile, based on nitrate leaching amounts resulting from field applications of manure and compost (Bruno and Ritchie 2005). Management of manure in the storage bins can hasten the composting process through regular mixing and additions of carbon-rich materials.

N removal from vegetative filter strips and treatment wetlands were based on average N loadings and % removal rates from the BMP effectiveness study of Soil and Water Engineering Technology, Inc. (SWET 2008). Tailwater recovery N retention benefits depend on the soils and irrigation and nutrient management of the particular system. It was assumed that the soil differences in systems where tailwater recovery is applicable will result in runoff losses rather than leaching losses, and the fraction of applied N contained in runoff was based on the same 8% fraction used from the leaching studies. N application recommendations from UF-IFAS (134 lb-N/acre across all applicable farm types) were used to calculate the N retention in the tailwater system. It is assumed that fertilizer applications would be adjusted to account for the additional N in irrigation water withdrawn from the tailwater system. Size of the tailwater recovery pond was based on the sizing methodology utilized for the Average Annual Daily (AAD) Irrigation Model Farms Economic Study, with adjustments based on the production system areas utilized here.

Denitrification wall benefits (estimated at 5.3 lb N/acre/year; based on total farm acreage) were based on measured effectiveness of woodchip bioreactors (Christianson et al. 2012; Schmidt and Clark 2012). Treatment wetland benefits (estimated at 2.4 lb N/acre/year; relative to farm acreage) were developed from using an assumed 10% N removal rate (SWET 2008) and the average loading rates of 21.1 lb N/acre/year for Horse Farms and 26.4 lb N/acre/year for Dairies (SWET 2008).

The N removal benefits of the Interceptor wells/bioreactor (34.5 lb N/acre/year) were estimated using a reported 75% N removal efficiency (Del Bottcher, personal communication; system designer and Glenn Horvath, SRWMD; Project Manager) and an estimated sprayfield N leaching rate of 43.1 lb/acre/year, based on 11.7 in/year of deep percolation (Vecchioli et al. 1990) and sprayfield deep percolation N losses averaged from three studies (Newton et al. 1995; Newton et al. 1998; Woodard et al. 2003). The leaching contribution of unlined manure storage ponds on dairies was estimated at 33.1 lb N/acre/year based on total N lagoon concentrations (550 mg/l; Harter et al. 2002; Pettygrove et al. 2009) and 16 in/yr of lagoon seepage (Fulhage and Pfost 1993; Pettygrove et al. 2009).

Results: Costs and Benefits

The N reduction/removal benefits and systems costs were combined to provide estimates of costs relative to benefits. The following tables describe the expected costs per benefit of Nitrogen BMPs based on average values summarized from literature and technical documents and vendor quotes. The estimated N Reduction (reduced N losses from the farm) amounts in lb/acre/year for each of the five N Reduction options are summarized in **Table 4-2**.

Table 4- 2. Unit benefits (N Reductions) adjusted to leaching reductions for N Reduction BMPs

N Reduction strategy	Units	N Reduction
Variable rate N; Sensor-based	lb/acre/yr	2.4
Variable rate N; Map-based	lb/acre/yr	1.4
N Simulation Software	lb/acre/yr	5.0
Fertigation	lb/acre/yr	1.8
Equipment Guidance System	lb/acre/yr	0.6

Source: TBG Work Product, data from peer-reviewed literature

The estimated N Retention/Removal amounts in lb/acre/year for each of the seven N Retention options are summarized in **Table 4-3**. The very large values for pond lining and interceptor wells result from both high loads (in dairy waste lagoons and dairy sprayfields) and high retention rates.

Table 4- 3. Unit benefits (N Retention) for N Retention BMPs, where acres are whole-farm acres averaged across the applicable production systems

N Retention strategy	Units	N Retention
Vegetative Filter Strips	lb/acre/yr	0.6
Tailwater Recovery	lb/acre/yr	11.9
Manure Storage Buildings	lb/acre/yr	0.75
Denitrification Wall	lb/acre/yr	5.3
Treatment Wetland	lb/acre/yr	2.4
Pond lining	lb/acre/yr	33.1
Interceptor wells/bioreactor	lb/acre/yr	32.3

Source: TBG Work Product, data from peer-reviewed literature

Table 4-4 shows the costs and benefits of N Reduction strategies: annualized costs (5-years at 3.375%), benefits in total leaching reduction of Nitrogen lb/yr scaled up to the average farm sizes listed in **Table 4-1**.

Table 4- 4. Costs and benefits of N Reduction strategies

N Reduction Strategies Option	Total costs ($)	Annualized Cost ($)	Benefits (Nitrogen in lb/yr)	Cost per Pound of N
Variable Rate N: Sensor-based				
Hay	$49,459	$10,915	151	$72
Field Crops	$50,203	$11,080	378	$29
Variable Rate N: Map-based				
Hay	$29,459	$6,501	89	$73
Field Crops	$30,203	$6,666	224	$30
N Simulation Software				
Hay	$1,995	$440	309	$1
Field Crops	$2,739	$604	773	$1
Vegetables	$2,227	$491	454	$1
Perennial Fruits	$1,875	$414	234	$2
Fertigation				
Field Crops	$4,500	$993	286	$3
Vegetables	$4,500	$993	168	$6
Perennial Fruits	$4,500	$993	87	$11
Equipment Guidance System				
Hay	$27,448	$6,058	39	$156
Field Crops	$27,448	$6,058	97	$62

Source: TBG Work Product, data from calculations and peer-reviewed literature

Table 4-5 shows the costs and benefits of N Retention strategies: annualized costs (5-years at 3.375%), benefits in total leaching reduction of Nitrogen lb/yr scaled up to the average farm sizes listed in **Table 4-1**. Annualized costs and annual N reduction are divided to give provide $/lb of N.

Table 4- 5. Costs and benefits of N Retention/Removal strategies

N Retention Strategies				
Option	**Total costs ($)**	**Annualized Cost ($)**	**Benefits (Nitrogen in lb/yr)**	**Cost per Pound of N**
Vegetative Filter Strips				
Horse Farms	$293	$65	12	$5
Livestock Grazing	$662	$146	64	$2
Dairy	$572	$126	48	$3
Hay	$504	$111	37	$3
Field Crops	$796	$176	92	$2
Vegetables	$610	$135	54	$2
Perennial Fruits	$439	$97	28	$3
Tailwater Recovery				
Dairy	$390,397	$86,160	952	$91
Field Crops	$488,409	$107,791	1,845	$58
Vegetables	$404,772	$89,332	1,083	$82
Perennial Fruits	$347,271	$76,642	559	$137
Manure Storage Buildings				
Horse Farms	$13,608	$3,003	16	$191
Livestock Grazing	$13,608	$3,003	80	$37
Denitrification Wall				
Horse Farms	$17,841	$3,938	110	$36
Livestock Grazing	$17,841	$3,938	562	$7
Dairy	$17,841	$3,938	420	$9
Treatment Wetland				
Horse Farms	$34,195	$7,547	50	$151
Livestock Grazing	$34,195	$7,547	255	$30
Dairy	$55,708	$12,295	190	$65
Pond Lining (Plastic)				
Dairy	$314,981	$69,516	2,648	$26
Pond Lining (Concrete)				
Dairy	$447,198	$98,696	2,648	$37
Interceptor Wells/Bioreactor				
Dairy	$91,107	$20,107	2,586	$8

Source: TBG Work Product, data from calculations and peer-reviewed literature

The costs per benefit, summarized across all the production system types and management strategies result in overall averages of $55/lb-N for N Reduction options and $47/lb-N for N Retention options (**Table 4-6**).

Table 4- 6. Costs and benefits of N Reduction strategies and N Retention strategies averaged across all applicable production systems.

Average Annualized Cost				
N Model Farm type	Total costs ($)	Average Annualized Cost ($)	Average Benefits (Nitrogen in Pounds)	Average Annualized Cost per Pound of N
N Reduction Strategies	$27,902	$6,158	167	$55
N Retention Strategies	$166,796	$36,812	1202	$47

Source: TBG Work Product, data from calculations and peer-reviewed literature

Maximum costs per benefit were developed using both the highest $/lb-N for each project type across all applicable production systems (**Table 4-7**) and also using the ratio of the highest cost relative to the lowest benefit for a given strategy across all production systems. This was done to give some representation of the range and uncertainty in estimated costs and benefits, as the specific system designs and implementation and management will determine the actual costs and benefits. Unit costs and data sources are summarized in the **Appendix.**

Table 4- 7. Maximum costs per benefit for N BMPs

Cost per Benefit Minimum and Maximum (5 yr term)				
Option	**Maximum costs per benefit ($/lb N)**	**Maximum $ per Minimum benefit ($/lb N)**	**Maximum: Annual cost, $**	**Minimum: benefit, lb N**
N Reduction				
Variable Rate N: Sensor-based	$72	$73	$11,080	151
Variable Rate N: Map-based	$73	$75	$6,666	89
N Simulation Software	$2	$3	$604	234
Fertigation	$11	$11	$993	87
Equipment Guidance System	$156	$156	$6,058	39
N Retention				
Vegetative Filter Strips	$5	$14	$176	12
Tailwater Recovery	$137	$193	$107,791	559
Manure Storage Buildings	$191	$191	$3,003	16
Denitrification Wall	$36	$36	$3,938	110
Treatment Wetland	$151	$246	$12,295	50
Pond Lining (Plastic)	$26	$26	$69,516	2,648
Pond Lining (Concrete)	$37	$37	$98,696	2,648
Interceptor Wells/Bioreactor	$8	$8	$20,107	2,586

The groundwater in the 6 county area of the SWFWMD is sensitive to Nitrogen loading from a variety of sources, including agriculture. Employing BMPs to reduce contributions of N, especially as NO_3^- (nitrate) from agricultural lands can improve water quality within the basins of these major springs.

The average $/lb-N for variable-rate N management is about $51/lb-N, with little difference in the ratio if a real-time sensor based or a static map-based approach is utilized to develop the N rate prescriptions. N simulation software does show the lowest cost per pound of N, but the limited data on benefits (N reductions) associated with this suggests that there might be some overestimation of the benefits. Also, these software applications are currently not accessible in Florida, but this will likely change in the coming years. Fertigation average cost per benefit was $7/lb-N; this is the most cost effective of the currently accessible technology options for reducing N applications. However, careful irrigation and nutrient management is required to achieve the expected N reductions.

Vegetative filter strips ($3/lb-N), denitrification walls ($17/lb-N), and the interceptor wells with the bioreactor ($8/lb-N) have some of the lowest $/lb-N of the N-retention BMPs considered here. For irrigated systems, tailwater recovery shows high costs relative to benefits (about $92/lb-N averaged across applicable production systems), but this option has the additional benefit of reducing groundwater withdrawals for irrigation. Similarly, the costs relative to N retention are large for constructed wetlands (about $82/lb-N), but this includes cost estimates to construct a wetland in a suitable area where there is no existing wetland. In systems where an existing wetland feature can be expanded or restored, costs could be considerably lower.

The tables presented here provide representative values for N reduction and retention benefits and costs for production systems in the 6 county area. While improving Nitrogen-use efficiency on the farm is a common goal of producers, the costs required are sometimes larger than the savings in fertilizer costs. This is one of the reasons that publicly funded programs to share the costs of N-management improvements can be valuable both for improving environmental outcomes and for improving profitability on farms.

Conclusions

This Model Farms Economic Study provides datasets of benefits, costs, and cost/benefit for strategies to reduce groundwater consumption or N loads to groundwater. The costs and benefits reported are representative of the production systems that are common in the regions analyzed for the study. This included the entire SWFWMD for AAD, the DPCWUCA for FFP, and the 6 counties (Levy, Marion, Citrus, Sumter, Hernando, and Pasco County) containing the 5 springsheds (Chassahowitzka, Homosassa, Kings Bay, Rainbow, and Weeki Wachee) for N management. The spreadsheets developed to summarize costs and benefits for this study can be utilized to review or update unit costs, units, expected benefits, or other values in order to develop a project-specific assessment of cost/benefit.

Management changes to reduce groundwater withdrawals or decrease Nitrogen loads to groundwater can have significant costs for equipment and design/installation. The impacts of reduced groundwater consumption and reduced N loads have benefits beyond the farm-scale by improving water resource sustainability, ecosystem health, and economic outcomes. Public sector funding to initiate changes in equipment and management on farms in the SWFWMD is an important way to realize the benefits to the water resources and ecosystems of Florida.

References

Bowen P, Bogdanoff C, Estergaard B. 2012. Effects of converting from sprinkler to drip irrigation on water conservation and the performance of Merlot grown on a loamy sand. American Journal of Enology and Viticulture 63(3): 385-393.

FDEP (Florida Department of Environmental Protection). 2015. 2014 Reuse Inventory. http://www.dep.state.fl.us/water/reuse/inventory.htm

FRIS (Farm and Ranch Irrigation Survey). 2013. Census of Agriculture of the United States Department of Agriculture – issued November 2014. http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Farm_and_Ranch_Irrigation_Survey/fris13.pdf

FSAID (Florida Statewide Agricultural Irrigation Demand). 2015. Florida Department of Agriculture Office of Agricultural Water Policy in cooperation with The Balmoral Group. http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Water-Policy/Agricultural-Water-Supply-Planning

Knox JW, Kay MG, Weatherhead EK. 2012. Water regulation, crop production, and agricultural water management: Understanding farmer perspectives on irrigation efficiency. Agricultural Water Management 108: 3-8.

Liu G, Williamson J, England G, Whidden A. 2015. How to Calculate Fertigation Injection Rates for Commercial Blueberry Production. UF/IFAS Extension Publication https://edis.ifas.ufl.edu/hs1197

NRCS (Natural Resource Conservation Service). 2014. National Engineering Handbook Part 652, Chapter 5: Selecting an Irrigation Method. KS210-652-H, Amend. KS22. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_032469.pdf

NRCS (Natural Resource Conservation Service). 2015. State of Florida EQIP FY 2015 Payment Schedule. http://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1265795&ext=pdf

Schaible GD, Aillery MP. 2012. Water Conservation in Irrigated Agriculture: Trends and Challenges in the Face of Emerging Demands, EIB-99, U.S. Department of Agriculture, Economic Research Service.

Simonne E, Hochmuth R, Breman J, Lamont W, Treadwell D, Gazula A. 2014. Drip-irrigation systems for small conventional vegetable farms and organic vegetable farms. UF/IFAS Extension Publication http://edis.ifas.ufl.edu/hs388

SWFWMD (Southwest Florida Water Management District). 2012. Facilitating Agricultural Resource Management Systems (FARMS) Program: 2011 Annual Report. https://www.swfwmd.state.fl.us/files/database/site_file_sets/35/2011_FARMS_Annual_Report_-_FINAL_FOR_WEB_POSTING.pdf

van der Kooija S , Zwarteveena M, Boesvelda H, Kuperb M. 2013. The efficiency of drip irrigation unpacked. Agricultural Water Management 123: 103-110.

Ward FA, Pulido-Velazquez M. 2008. Water conservation in irrigation can increase water use. Proceedings of the National Academy of Sciences: 18215-18220.

ENGAGE Agro USA. Desikote ® Product Label. http://www.engageagrousa.com/pdf/Desikote%20label.pdf

FSAID (Florida Statewide Agricultural Irrigation Demand). 2015. Florida Department of Agriculture Office of Agricultural Water Policy in cooperation with The Balmoral Group. http://www.freshfromflorida.com/Divisions-Offices/Agricultural-Water-Policy/Agricultural-Water-Supply-Planning

Georg JG. 1958. Wind Machines for Frost Protection in Florida. Proceedings of the Florida State Horticultural Society 71: 92-94.

Hernandez-Ochoa IM. 2013. Water Management Alternatives for Strawberry Transplant Establishment and Freeze Protection in Florida. University of Florida Master of Science Thesis. http://ufdc.ufl.edu/UFE0046432/00001

Hochmuth GJ, Hochmuth RC, Kostewicz S, Stall W. 2015. Row Covers for Commercial Vegetable Culture in Florida. UF/IFAS Extension. https://edis.ifas.ufl.edu/cv201

Olczyk T. 2011. Cold Protection for Nursery Crops. http://miami-dade.ifas.ufl.edu/pdfs/disaster/Cold%20protection%20for%20Nursery%20Crops.pdf

Parsons LR, Boman BJ. 2013. Microsprinkler Irrigation for Cold Protection of Florida Citrus. UF/IFAS Extension. http://edis.ifas.ufl.edu/ch182

Perry K. 2001. Frost/Freeze Protection for Horticultural Crops. NC State University Extension, Horticulture Information Leaflet 705. http://content.ces.ncsu.edu/frostfreeze-protection-for-horticultural-crops.pdf

Santos BM, Moore DN, Salame-Donoso TP, Stanley CD, Whidden AJ. 2011. Evaluation of Freeze Protection Methods for Strawberry Production in Florida. Proc. Fla. State Hort. Soc. 124: 188-190.

Williamson JG, Lyrene PM, Olmstead JW. 2015. Protecting Blueberries from Freezes in Florida. UF/IFAS Extension. https://edis.ifas.ufl.edu/hs216

Variable-Rate N

Borghetti, E. 2012. Evaluating nitrogen variable rate technology on cotton (Gossypium hirsutum L.) in Georgia (USA). University of Padova. Doctoral Disseration.

Harmel, R. D., Kenimer, A. L., Searcy, S. W., & Torbert, H. A. 2004. Runoff water quality impact of variable rate sidedress nitrogen application. Precision Agriculture, 5(3), 247-261.

Koch, B., Khosla, R., Frasier, W. M., Westfall, D. G., & Inman, D. 2004. Economic feasibility of variable-rate nitrogen application utilizing site-specific management zones. Agronomy Journal, 96(6), 1572-1580.

Link, J., Graeff, S., Batchelor, W. D., & Claupein, W. 2006. Evaluating the economic and environmental impact of environmental compensation payment policy under uniform and variable-rate nitrogen management. Agricultural Systems, 91(1), 135-153.

Longchamps, L., and R. Khosla. 2015. Improving N use efficiency by integrating soil and crop properties for variable rate N management. In 'Precision agriculture '15'. (Ed. John V. Stafford) pp. 249-255. (Wagenngen academic publishers: The Netherlands).

NRCS. 2015. EQIP Florida Statewide Payment Schedule. http://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=stelprdb1265795&ext=pdf

Porter, W., Khalilian, A., Dourte, D., Fraisse, C. 2012. Agricultural Management Options for Climate Variability and Change: Sensor-Based, Variable-Rate Nitrogen Management. UF/IFAS Extension. http://edis.ifas.ufl.edu/ae487

Scharf, P. C., Shannon, D. K., Palm, H. L., Sudduth, K. A., Drummond, S. T., Kitchen, N. R., Oliveira, L. F. 2011. Sensor-based nitrogen applications out-performed producer-chosen rates for corn in on-farm demonstrations. Agronomy Journal, 103(6), 1683-1691.

Thompson, L. J.; Ferguson, R. B.; Kitchen, N.; Frazen, D. W.; Mamo, M.; Yang, H.; Schepers, J. S. 2015. Model and Sensor-Based Recommendation Approaches for In-Season Nitrogen Management in Corn. Agronomy Journal 107(6): 2020-2030

N Simulation Software

Li, F., PR, J., Pearson, A., Fletcher, A., Jamieson, P., Brown, H., & Zyskowski, R. (2009). AmaizeN: A decision support system for optimizing nitrogen management of maize. NJAS-Wageningen Journal of Life Sciences, 57, 93-100.

Moebius-Clune, B., Ball, M., van Es, H., Melkonian, J. 2014. Adapt-N Boosts Profits and Cuts N Losses in Three Years of On-Farm Trials in New York and Iowa. What's Cropping Up? Vol. 24. No. 5: 57-60.

Thompson, L. J.; Ferguson, R. B.; Kitchen, N.; Frazen, D. W.; Mamo, M.; Yang, H.; Schepers, J. S. 2015. Model and Sensor-Based Recommendation Approaches for In-Season Nitrogen Management in Corn. Agronomy Journal 107(6): 2020-2030

Fertigation

Ng Kee Kwong, K.F., Paul, J.P., Deville, J. 1999. Drip-fertigation - A Means for Reducing Fertilizer Nitrogen to Sugarcane. Experimental Agriculture, 35: 31-37.

Quemada, M., Baranski, M., Nobel-de Lange, M.N.J., Vallejo, A., Cooper, J.M. 2013. Meta-analysis of strategies to control nitrate leaching in irrigated agricultural systems and their effects on crop yield. Agric. Ecosyst. Environ., 174: 1-10.

Equipment guidance

Groover, G., Grisso, R. 2012. Investing in GPS Guidance Systems? Virginia Tech Cooperative Extension. https://pubs.ext.vt.edu/448/448-076/448-076.html

John Deere. 2015. Guidance you can grow with: The GreenStar Lightbar System. https://www.deere.com/common/docs/products/equipment/agricultural_management_solutions/guidance_systems/brochure/en_GB_yy1114823_e.pdf

Nitrogen application relationship to Nitrogen leaching

Gheysari, M., Mirlatifi, S. M., Homaee, M., Asadi, M. E., & Hoogenboom, G. 2009. Nitrate leaching in a silage maize field under different irrigation and nitrogen fertilizer rates. Agricultural water management, 96(6), 946-954.

Paramasivam, S., Alva, A. K., Fares, A., & Sajwan, K. S. 2001. Estimation of nitrate leaching in an Entisol under optimum citrus production. Soil Science Society of America Journal, 65(3), 914-921.

Scholberg, J. M., Zotarelli, L., Dukes, M. D., Ozores-Hampton, M., Liu, G., & Tittonell, P. 2013. Enhancing fertilizer efficiency in high input cropping systems in Florida. In Sustainable Agriculture Reviews (pp. 143-174). Springer Netherlands.

Zotarelli, L., Dukes, M. D., Scholberg, J. M. S., Munoz-Carpena, R., & Icerman, J. 2009. Tomato nitrogen accumulation and fertilizer use efficiency on a sandy soil, as affected by nitrogen rate and irrigation scheduling. Agricultural Water Management, 96(8), 1247-1258.

Zotarelli, L., Scholberg, J. M., Dukes, M. D., & Muñoz-Carpena, R. 2007. Monitoring of nitrate leaching in sandy soils. Journal of environmental quality, 36(4), 953-962.

Nitrogen application recommendations

Krewer, G., Ruter, J. 2012. Fertilizing Blueberries in Pine Bark Beds UGA Extension. http://extension.uga.edu/publications/detail.cfm?number=B1291

Newman, Y.C., Vendramini, J.M.B., Johnson, F.A. 2014. Bermudagrass Production in Florida. https://edis.ifas.ufl.edu/aa200

UF/IFAS. 2011. Nutrition of Florida Citrus Trees. http://edis.ifas.ufl.edu/pdffiles/SS/SS47800.pdf

UF/IFAS. 2015. Nutrient Management of Vegetables and Row Crops. http://edis.ifas.ufl.edu/pdffiles/ss/ss63900.pdf

Nitrogen retention/removal strategies

Baca, B., et al. "Economic Analyses of Wetlands Mitigation Projects in the Southeastern U.S." Report prepared for the Maryland International Institute for Ecological Economics.

Canfield, D. E., Glazer, A. N., & Falkowski, P. G. 2010. The evolution and future of Earth's nitrogen cycle. science, 330(6001), 192-196.

Chesapeake Bay Commission. 2004. Cost-Effective Strategies for the Bay, 6 Smart Investments for Nutrient and Sediment Reduction. Annapolis, MD.

Doering, O., et al. Evaluation of the Economic Costs and Benefits of Methods for Reducing Nutrient Loads to the Gulf of Mexico: Topic 6 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico. NOAA Coastal Ocean Program Decision Analysis Series No. 20. NOAA Coastal Ocean Program, Silver Spring, MD. 115 pp.

FDEP. 2013. Florida Department of Environmental Protection. Small Scale Horse Operations: Best Management Practices for Water Resource Protection in Florida. https://www.dep.state.fl.us/water/nonpoint/docs/nonpoint/SmScaleHorseOps.pdf

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., & Zaks, D. P. 2011. Solutions for a cultivated planet. Nature, 478(7369), 337-342.

Hansen, L, J. Delgado, M. Ribaudo, and W. Crumpton. Minimizing costs of reducing agricultural nitrogen loadings: choosing between on- and off-field conservation practices. Environmental Economics, Volume 3, Issue 4, 2012

Hansen, L, et al. 2015. *Targeting Investments to Cost Effectively Restore and Protect Wetland Ecosystems: Some Economic Insights,* ERR-183, U.S. Department of Agriculture, Economic Research Service.

Jones, C., et al. 2010. How Nutrient Trading Could Help Restore the Chesapeake Bay. WRI Working Paper. World Resources Institute, Washington DC. http://www.wri.org/stories/2009/12/how-nutrient-trading-can-helprestore-chesapeake-bay

Newton, G. L., Nordstedt, R. A., French, E. C., Kidder, G. K., Graetz, D. A., & Chambliss, C. G. 1998. Dairy manure management: strategies for recycling nutrients to recover fertilizer value and avoid environmental pollution. University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS.

Newton, G. L., J. C. Johnson, Jr., J. G. Davis, G. Vellidis, R. K. Hubbard, and R. Lowrance. 1995. Nutrient recoveries from varied year-round application of liquid dairy manure on sprayfields. P. 113 to 123 in Proc. Florida Dairy Production Conf., Dairy and Poultry Sci. Dept., Univ. Florida, Gainesville.

Ribaudo, M., et al. 2011. *Nitrogen in Agricultural Systems: Implications for Conservation Policy. ERR-127.* U.S. Dept. of Agriculture, Econ. Res. Serv.

Suntree Technologies, Inc. 2015. Bold and Gold ® Filtration Media. http://www.suntreetech.com/Products/Bold+and+Gold/default.aspx

Sweeney, J. Pennsylvania Nonpoint Source BMP Effectiveness: Cost-Effectiveness and Potential for Reducing Loads. University of Maryland. Presentation to the PA Chesapeake Bay Advisory Committee Meeting, Harrisburg, PA, June 3, 2004.

SWET 2008. Nutrient Loading Rates, Reduction Factors and Implementation Costs Associated with BMPs and Technologies. Soil and Water Engineering Technology, Inc. Report for the South Florida Water Management District.

The European Nitrogen Assessment, ed. Mark A. Sutton, Clare M. Howard, Jan Willem Erisman, Gilles Billen, Albert Bleeker, Peringe Grennfelt, Hans van Grinsven and Bruna Grizzetti. Cambridge University Press, 2011. Chapter 22, Costs and benefits of nitrogen in the environment.

Constructed Wetlands

Campbell, Craig and Ogden, M. Constructed Wetlands in the Sustainable Landscape. John Wiley and Sons. 1999.

Collins, A. and N. Gillies. 2014. Constructed Wetland Treatment of Nitrates: Removal Effectiveness And Cost Efficiency. Journal of The American Water Resources Association, Volume 50, No. 4.

EPA. 2000. Manual: Constructed Wetlands Treatment of Municipal Wastewaters. United States Environmental Protection Agency – Office of Research and Development. http://www.ewb-usa.org/files/2015/05/ConstWetlandManual.pdf

Gouriveau, F. 2009. Constructed Farm Wetlands (CFWs) designed for remediation of farmyard runoff: an evaluation of their water treatment efficiency, ecological value, costs and benefits. School of GeoSciences, The University of Edinburgh.

Miller B.K., MacGowan, B.J., Reaves R.P. 2003. Are Constructed Wetlands a Viable Option for Your Waste Management System? Purdue Extension Fact Sheet. https://www.extension.purdue.edu/extmedia/fnr/fnr-202.pdf

Pennsylvania Stormwater Management Manual. "Structural BMP Criteria. BMP #: Constructed Wetlands." Section 5 – Structural BMPs. 2004.

Schaafsma, J. A., Baldwin, A. H., & Streb, C. A. 1999. An evaluation of a constructed wetland to treat wastewater from a dairy farm in Maryland, USA. Ecological Engineering, 14(1), 199-206.

Tanner, C.C. and Kloosterman V.C. 1997. Guidelines for Constructed Wetland Treatment of Farm Dairy Wastewaters in New Zealand. NIWA Science and Technology Series No. 48. https://www.niwa.co.nz/sites/niwa.co.nz/files/import/attachments/st48.pdf

Tsihrintzis, A. C Akratos, G. Gikas, D. Karamouzis and A. Angelakis. " Performance and cost comparison of a FWS and VSF constructed wetland system." Environmental Technology, Vol. 28. pp 621-628

Denitrification Walls

Christianson, L., A. Bhandari and M. Helmers. 2012. A Practice-oriented Review of Woodchip Bioreactors for Subsurface Agricultural Drainage. Agricultural and Biosystems Engineering, Iowa State University.

Gold, A, L. Schipper and K. Addy. 2012. Denitrifying Bioreactors: Opportunities and Challenges for Managing Offsite Nitrogen Losses

Schmidt, C. and M. Clark. 2012. Evaluation of a Denitrification Wall to Reduce Surface Water Nitrogen Loads. J. Environ. Qual. 41:724–731

Manure Storage

Basso, B., & Ritchie, J. T. 2005. Impact of compost, manure and inorganic fertilizer on nitrate leaching and yield for a 6-year maize–alfalfa rotation in Michigan. Agriculture, ecosystems & environment, 108(4), 329-341.

Chadwick, D. R. 2005. Emissions of ammonia, nitrous oxide and methane from cattle manure heaps: effect of compaction and covering. Atmospheric environment, 39(4), 787-799.

NRCS, June 2003. Costs Associated with Development and Implementation of Comprehensive Nutrient Management Plans Part I—Nutrient Management, Land Treatment, Manure and Wastewater Handling and Storage, and Recordkeeping.

Tittonell, P., Rufino, M. C., Janssen, B. H., & Giller, K. E. 2010. Carbon and nutrient losses during manure storage under traditional and improved practices in smallholder crop-livestock systems—evidence from Kenya. Plant and soil, 328(1-2), 253-269.

Vegetated Filter Strips

Helmers, M.J., Isenhart, T., Dosskey, M., Dabney, S. Stock, J. 2006. Buffers And Vegetative Filter Strips. http://water.epa.gov/type/watersheds/named/msbasin/upload/2006_8_24_msbasin_symposia_ia_session4-2.pdf

Interceptor wells/bioreactor

Bottcher, D. 2015. Personal Communication. System Designer of dairy sprayfield interceptor well/bioreactor. SWET, Inc.

Vecchioli, C.H. Tibbals, A.D. Duerr, and C.B. Hutchinson. 1990. Ground-Water Recharge in Florida-A Pilot Study in Okaloosa, Pasco, and Volusia Counties. USGS Water- Resources Investigations Report 90-4195.

Woodard, K.R., French, E.C., Sweat, L.A., Graetz, D.A., Sollenberger, L.E., Macoon, B., Portier, K.M., Rymph, S.J., Wade, B.L., Prine, G.M. and Van Horn, H.H. 2003. Nitrogen removal and nitrate leaching for two perennial, sod-based forage systems receiving dairy effluent. Journal of environmental quality, 32(3), 996-1007.

Pond lining for manure storage ponds

Harter, T., Davis, H., Mathews, M. C., & Meyer, R. D. 2002. Shallow groundwater quality on dairy farms with irrigated forage crops. Journal of Contaminant Hydrology, 55(3), 287-315.

Fulhage, C.D. and Pfost, D.L. 1993 Earthen Pits (Basins) for Liquid Dairy Waste. University of Missouri Extension fact sheet. http://extension.missouri.edu/p/WQ305

Pettygrove, G.S., Heinrich, A.L., Crohn, D.M. 2009. Manure Nitrogen Mineralization. Manure Technical Bulletin Series. http://manuremanagement.ucdavis.edu/files/134367.pdf University of California Cooperative Extension.

Appendix

Data sources for costs utilized for AAD cost and benefit analyses

Description	Unit cost ($)	Unit name	Cost data source(s)
Surface Water			
Description	**Unit cost ($)**	**Unit name**	**Cost data source(s)**
Excavation cost	2.64	CuYd	NRCS EQIP FY2015 - Florida: Practice Code 436 - Irrigation Reservoir
Grading and hydroseeding	805.30	acres	NRCS EQIP FY2015 - Florida: Practice Code 342 - Critical Area Planting; Grass Hydroseeding
Flashboard riser	1.33	DialnFt	NRCS EQIP FY2015 - Florida: Practice Code 587 - Structure for Water Control; Flashboard Riser, Metal
Culvert	40	ft, 24 in metal	NRCS EQIP FY2015 - Florida: Practice Code 587 - Structure for Water Control; Culvert
Pump station (diesel) > 70 hp	297.66	bhp	NRCS EQIP FY2015 - Florida: Details: Practice Code 533 - Pumping Plant
Shed/pad for pump station	7,000.00	system	SWFWMD FARMS cost datasets
Fuel tank	3,400.00	system	SWFWMD FARMS cost datasets
Meter	3,000.00	system	SWFWMD FARMS cost datasets
Fittings, valves, misc.	$110.83	acres	SWFWMD FARMS cost datasets
Suction screen, self-cleaning	2,004.00	system	Yardney suction screeen quote: 12" connection, self-cleaning stainless steel suction screen
Filtration system, automated backflush	10,696.00	system	Yardney filter system quote: Maxi-Flush Automatic Backwashing Screen Filter
Pipe to irrigation system (12", PVC)	11.12	ft	NRCS EQIP FY2015 - Florida: Practice Code 430 - Irrigation Pipeline: PVC (12" Iron Pipe Size)
Design and installation costs	1,196.00	acres	SWFWMD FARMS cost datasets
Reclaimed water			
Description	**Unit cost ($)**	**Unit name**	**Cost data source(s)**
Filtration system, automated backflush	10,696.00	system	Yardney filter system quote: Maxi-Flush Automatic Backwashing Screen Filter
Supply line (12", PVC)	11.12	ft	Practice Code 430 - Irrigation Pipeline: PVC (12" Iron Pipe Size)
Conservation			
Description	**Unit cost ($)**	**Unit name**	**Cost data source(s)**
Central control station; pump automation	21,131.65	system	AgTronix quote: Motorola system pump automation with field unit for soil moisture and/or weather station input
Soil moisture sensor with telemetry	1,946.60	system	Average of quotes from BMP Logic, Certified Ag Resources, and AgTronix: Sentek, GroPoint, Ag Sense soil moisture sensors
Weather station with telemetry	3,515.00	system	Average of quotes from BMP Logic and AgTronix: RainWise and Wireless Vantage Pro2 weather stations
Data/subscription fees	295.00	year	Average of quotes from BMP Logic and Certified Ag Resources
Irrigation Conversion			
Description	**Unit cost ($)**	**Unit name**	**Cost data source(s)**
Center pivot	1,750.23	acres	NC State (http://goo.gl/IIKAb8) and Kansas State (http://goo.gl/4Xa8aH) irrigation cost databases; FARMS project database
Microspray	3,032.35	acres	NRCS EQIP FY2015 - Florida: Practice Code 441 - Irrigation System, Microirrigation; Microjet; FARMS projects database

Drip	2,132.85	acres	NRCS EQIP FY2015 - Florida: Practice Code 441 - Irrigation System, Microirrigation; Drip; FARMS project database
Subsurface drip	2,657.38	acres	Average of NRCS EQIP FY2015 - Florida: Practice Code 441 - Irrigation System, Microirrigation; Drip & Kansas State (http://goo.gl/4Xa8aH) irrigation cost databases & CO State Extension (http://goo.gl/oh9oFi) ; FARMS project database
Microirrigation - container nursery	3,288.38	acres	NRCS EQIP FY2015 - Florida: Practice Code 441 - Irrigation System, Microirrigation; surface PE with emitters (Nursery) ; FARMS project database

Source: TBG Work Product; cost data sources listed in table.

Data sources for costs utilized for FFP cost and benefit analyses

Description	Unit cost ($)	Unit name	Cost data source(s)
Surface Water			
Excavation cost ($ per cubic yard)	2.64	CuYd	NRCS EQIP FY2015 - Florida: Practice Code 436 - Irrigation Reservoir
Grading and hydroseeding ($)	805.30	acres	NRCS EQIP FY2015 - Florida: Practice Code 342 - Critical Area Planting; Grass Hydroseeding
Flashboard riser ($)	1.33	DialnFt	NRCS EQIP FY2015 - Florida: Practice Code 587 - Structure for Water Control; Flashboard Riser, Metal
Culvert ($)	40	ft, 24 in metal	NRCS EQIP FY2015 - Florida: Practice Code 587 - Structure for Water Control; Culvert
Pump station (diesel) ($) > 70 hp	297.66	bhp	NRCS EQIP FY2015 - Florida: Details: Practice Code 533 - Pumping Plant
Pump station (diesel) ($) > 50, < 70 hp	385.96	bhp	NRCS EQIP FY2015 - Florida: Details: Practice Code 533 - Pumping Plant
Shed/pad for pump station	7,000.00	system	SWFWMD FARMS cost datasets
Fuel tank	3,400.00	system	SWFWMD FARMS cost datasets
Meter	3,000.00	system	SWFWMD FARMS cost datasets
Fittings, valves, misc.	$110.83	acres	SWFWMD FARMS cost datasets
Suction screen, self-cleaning	2,004.00	system	Yardney suction screeen quote: 12" connection, self-cleaning stainless steel suction screen
Filtration system, automated backflush	10,696.00	system	Yardney filter system quote: Maxi-Flush Automatic Backwashing Screen Filter
Pipe to irrigation system (assume 12")	11.12	ft	NRCS EQIP FY2015 - Florida: Practice Code 430 - Irrigation Pipeline: PVC (12" Iron Pipe Size)
Design and installation costs	1,529.00	acres	SWFWMD FARMS cost datasets
Row Covers			

Description	Unit cost ($)	Unit name	Cost data source(s)
Row Cover material	0.31	lnft x 7' width	Average of quotes from FarmTek Growers Supply and RainFlo Irrigation
Row Cover layer/retriever	25,750	system	Strickland Brothers Row Cover assist quote; includes spools for storing row covers
		Wind Machine	
Description	**Unit cost ($)**	**Unit name**	**Cost data source(s)**
Wind Machine, diesel, stationary tower	35,000	system	Quote from TWC Distributors: Orchard Rite wind machine, stationary tower; includes install and concrete pad. Diesel powered.
		Chemical Protectants	
Description	**Unit cost ($)**	**Unit name**	**Cost data source(s)**
Desikote concentrate	105	gallons	Quote from: http://shop.techterraenvironmental.com /desikote/ 2x2.5 gallon case - Rate: 5.3 oz/acre, mix with 21 gal per acre

Source: TBG Work Product, cost data sources listed in table.

Data sources of itemized costs utilized for N BMP costs and benefits analyses

Description	Unit cost ($)	Unit name	Cost data source(s)
N reduction strategies			
Variable rate N: sensor-based			
Reflectance Sensors	$20,000	system	Supplier quote: Everglades Farm Equipment; Kyle Norton
Variable rate spray controller	$2,298	system	Supplier quote: Everglades Farm Equipment; Kyle Norton. NRCS EQIP database.
GPS receiver	$25,665	system	Supplier quote: Everglades Farm Equipment; Kyle Norton
Installation/Setup	$1,000	install	Supplier quote: Everglades Farm Equipment; Kyle Norton
soil sampling	$8	acre	University of Florida Soil Lab fees
Variable rate N: map-based			
Variable rate spray controller	$2,298	system	Supplier quote: Everglades Farm Equipment; Kyle Norton. NRCS EQIP database.
GPS receiver	$25,665	system	Supplier quote: Everglades Farm Equipment; Kyle Norton
Installation/Setup	$1,000	install	Supplier quote: Everglades Farm Equipment; Kyle Norton
soil sampling	$8	acre	University of Florida Soil Lab fees
N simulation software			
smartphone or tablet	$500	system	Industry average
annual subscription	$999	license fee	Adapt-N Grower Pro; annual license

soil sampling	$8	acre	University of Florida Soil Lab fees
Fertigation			
tank	$500	quantity	Supplier quote: TriEst Irrigation; Mark Burgess
injection pump	$2,000	quantity	Supplier quote: TriEst Irrigation; Mark Burgess
valves	$250	quantity	Supplier quote: TriEst Irrigation; Mark Burgess
controller	$1,000	quantity	Supplier quote: TriEst Irrigation; Mark Burgess
Installation/Setup	$750	install	Supplier quote: TriEst Irrigation; Mark Burgess
Equipment guidance system			
lightbar with DGPS receiver	$3,448	system	Virginia Tech Extension: https://pubs.ext.vt.edu/448/448-076/448-076.html
autosteer with RTK GPS receiver	$23,250	system	Virginia Tech Extension: https://pubs.ext.vt.edu/448/448-076/448-076.html
Installation/Setup	$750	install	Virginia Tech Extension: https://pubs.ext.vt.edu/448/448-076/448-076.html
N retention strategies			
Vegetative Filter Strips			
Design and Establishment	$222.54	acres of VFS	NRCS EQIP FY2015 Florida Payment Schedule
Tailwater recovery			
Excavation cost ($ per cubic yard)	$2.64	CuYd	NRCS EQIP FY2015 - Florida: Practice Code 436 - Irrigation Reservoir
Grading and hydroseeding ($)	$805.30	acres	NRCS EQIP FY2015 - Florida: Practice Code 342 - Critical Area Planting; Grass Hydroseeding
Flashboard riser ($)	$1.33	Dia(in)*Ft	NRCS EQIP FY2015 - Florida: Practice Code 587 - Structure for Water Control; Flashboard Riser, Metal
Culvert ($)	$40.00	ft, 24in metal	NRCS EQIP FY2015 - Florida: Practice Code 587 - Structure for Water Control; Culvert
Pump station (diesel) ($) > 75 hp	$297.66	bhp	NRCS EQIP FY2015 - Florida: Details: Practice Code 533 - Pumping Plant
Shed/pad for pump station	$7,000.00	system	SWFWMD FARMS cost datasets
Fuel tank	$3,400.00	system	SWFWMD FARMS cost datasets
Meter	$3,000.00	system	SWFWMD FARMS cost datasets
Fittings, valves, miscellaneous	$110.83	acres	SWFWMD FARMS cost datasets
Suction screen, self-cleaning	$2,004.00	system	Yardney suction screeen quote: 12" connection, self-cleaning stainless steel suction screen

Filtration system, automated backflush	$10,696.00	system	Yardney filter system quote: Maxi-Flush Automatic Backwashing Screen Filter
Pipe to irrigation system (assume 12")	$11.12	ft/acre	NRCS EQIP FY2015 - Florida: Practice Code 430 - Irrigation Pipeline: PVC (12" Iron Pipe Size)
Design and installation costs	$1,196.00	$/acre	SWFWMD FARMS cost datasets
Manure storage buildings			
Slab	$4.00	SqFt	Industry standard
Shed	$4.00	SqFt	Industry standard
Denitrification wall			
Wall excavation	$2.64	CuYd	NRCS EQIP FY2015 Florida Payment Schedule
Organic matrix, woodchips	$60.00	CuYd	Schmidt and Clark 2012; Bottcher (SWET, Inc)
Treatment wetland			
Excavation	$2.64	CuYd	NRCS EQIP FY2015 Florida Payment Schedule
Vegetation	$0.89	each	EPA Constructed Wetlands Manual
Plumbing	$11,127.60	ls	EPA Constructed Wetlands Manual
Control structures	$10,385.76	ls	EPA Constructed Wetlands Manual
Pond lining (plastic)			
Excavation cost ($ per cubic yard)	$2.64	CuYd	NRCS EQIP FY2015 Florida Payment Schedule
Flexible membrane liner	$42.73	SqYd	NRCS EQIP FY2015 Florida Payment Schedule; Practice Code 521A - Pond sealing or lining
Large diameter PVC, waster transfer pipe	$31.27	ft	NRCS EQIP FY2015 Florida Payment Schedule; Practice Code 634 - Waste Transfer
Pond lining (concrete)			
Excavation cost ($ per cubic yard)	$2.64	CuYd	NRCS EQIP FY2015 Florida Payment Schedule
Reinforced concrete liner (4 in. thick)	$64.10	SqYd	Utah State Extension Document
Large diameter PVC, waster transfer pipe	$31.27	ft	NRCS EQIP FY2015 Florida Payment Schedule; Practice Code 634 - Waste Transfer
Interceptor wells/bioreactor			Del Bottcher, system designer (SWET, Inc.)
Wells (4" dia, 60' deep)	$4,000	ea	
Electric pump (20 gpm/well)	$700	ea	
Wiring/Control Panel	$1.50	ft	
Piping (2" PVC)	$2.76	ft	
Piping (3" PVC)	$3.70	ft	
Piping (4" PVC)	$4.31	ft	
Pond excavation	$3.00	CuYd	
Plastic Lined Pond	$1.00	SqFt	
Organic Matrix	$60.00	CuYd	

Sand/Gravel	$25.00	CuYd
Under drainpipes	$0.60	ft
pond cover	$0.33	SqFt
Fencing	$2.00	ft
Infiltration Ditch	$1.00	ft
Flowmeter/stage records	$1,000.00	ea
Sample Collection	$100.00	ea
Analytical costs	$50.00	ea
Design, oversight	$150	hrs

Source: TBG Work Product, data from vendor quotes, published costs

Nitrogen Management System Schematics

Schematics of systems for reducing N applications on farms

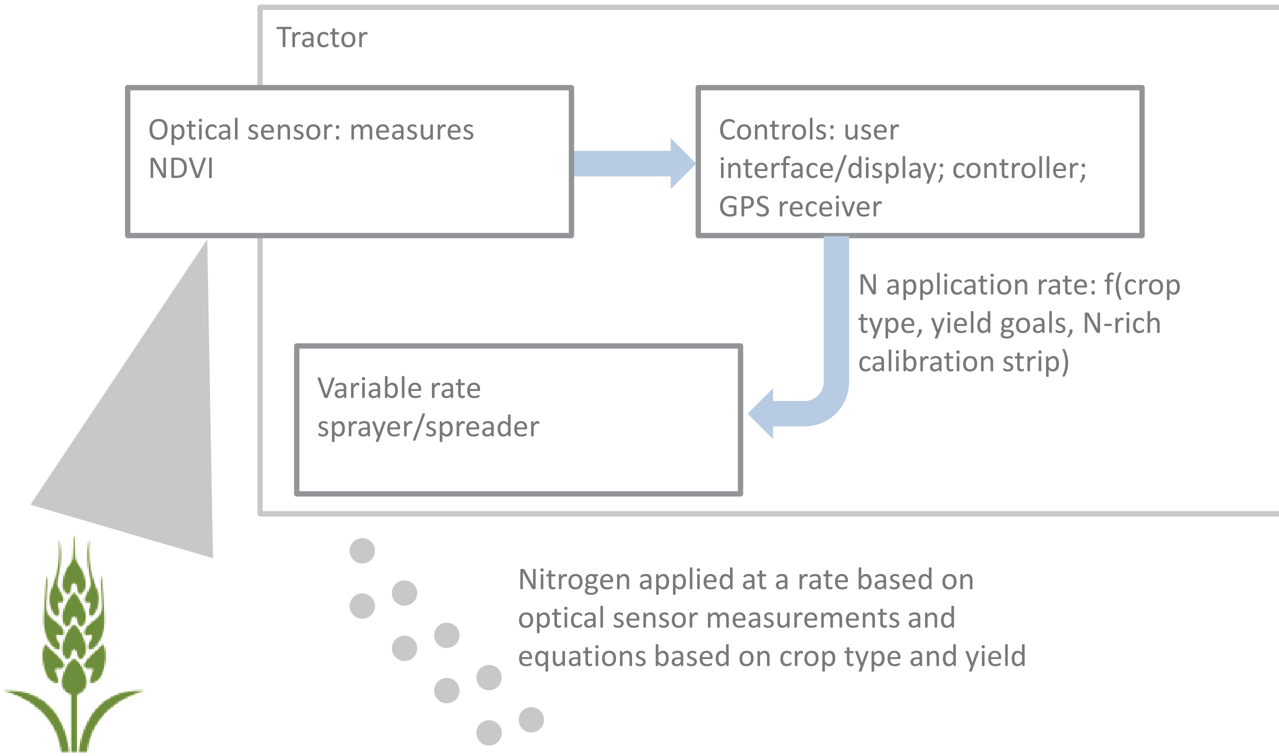
= Information, Data flow

= Water, Nutrient, Material flow

New component of system

Existing component of system

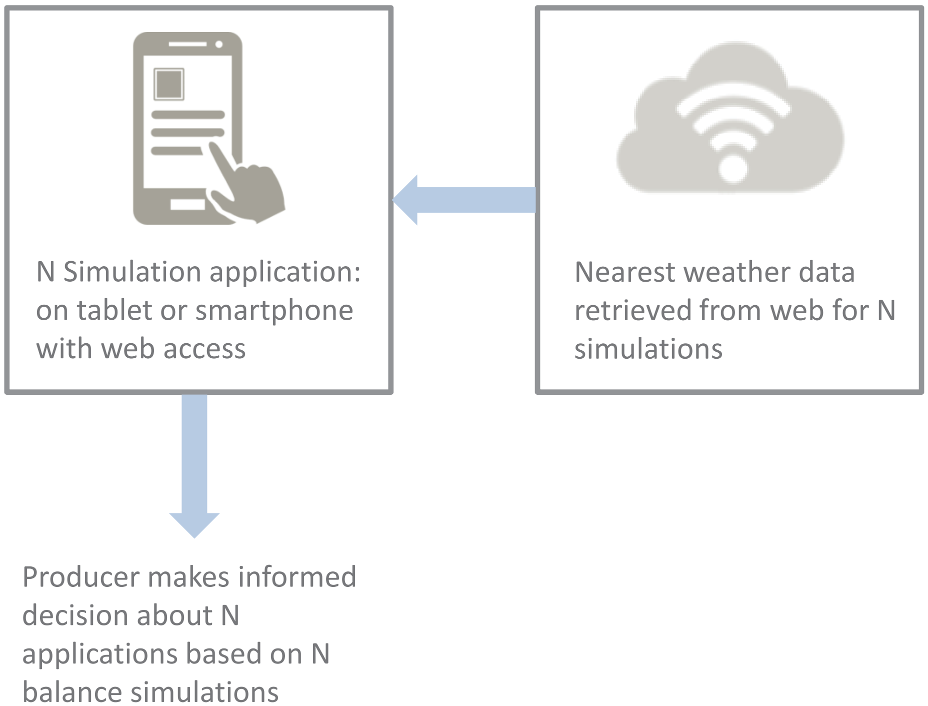
Sensor-based, Variable-Rate N applications



How it works:

- Active light sensors mounted on the spray equipment measure the red and near-infrared reflectance of a crop to calculate the Normalized Difference Vegetation Index (NDVI), which is a measure of crop “greenness”.
- Real-time NDVI maps are utilized in combination with crop management information to make automated adjustments to N application rates on the fly.
- Vendors or consultants will likely need to assist with system setup and calibration.

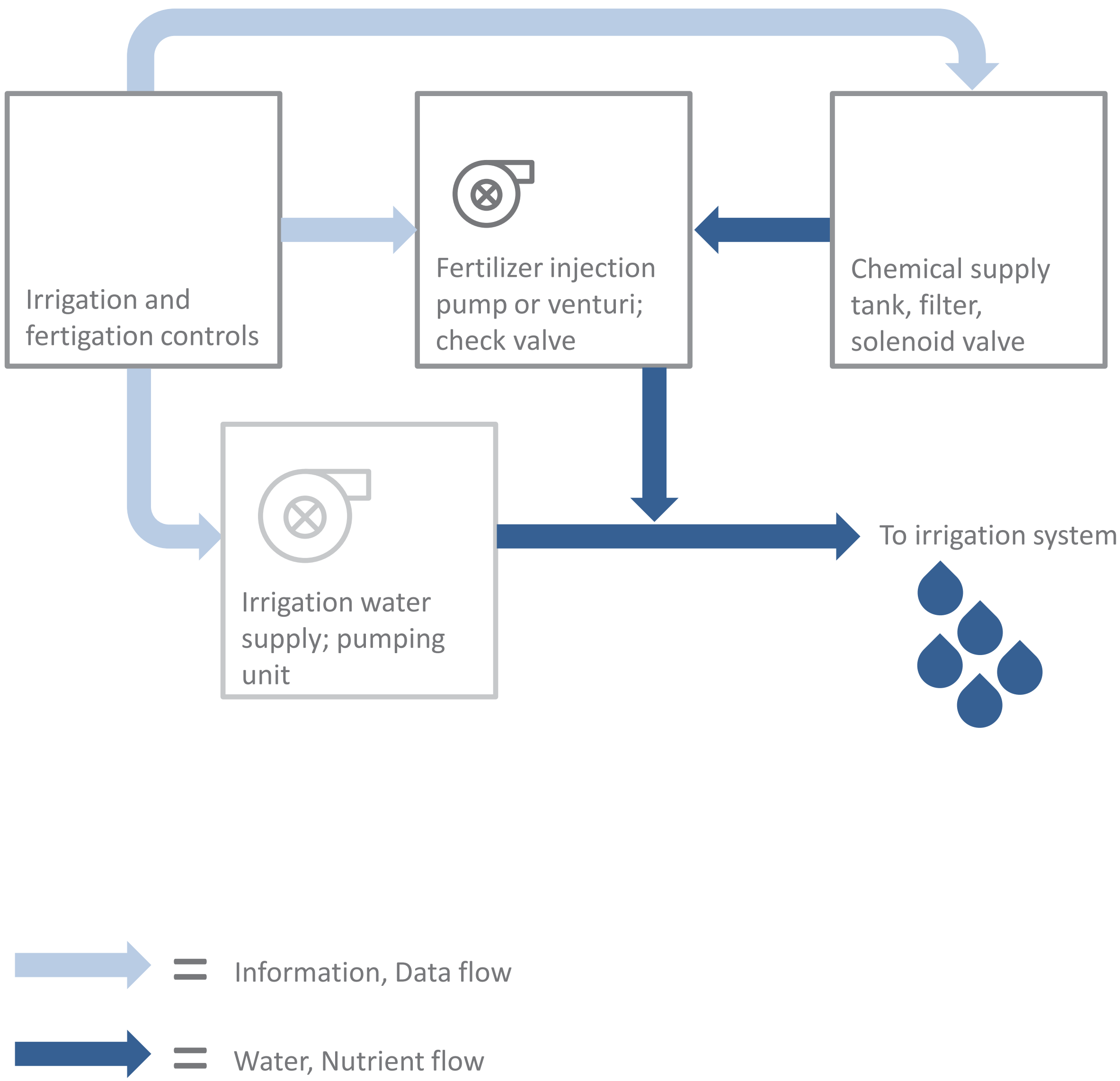
N Simulation for Decision Support



How it works:

- Nitrogen balance is simulated by a software application on a producer's computer, tablet, or phone. Data requirements include soils, weather, crop management, and yield goals. Soils and weather data are automatically retrieved based on location.
- The way in which this leads to improved N management is that a producer can be better informed about N movement (uptake, leaching, runoff) and can more confidently make decisions about the timing and rate of N applications.

Fertigation

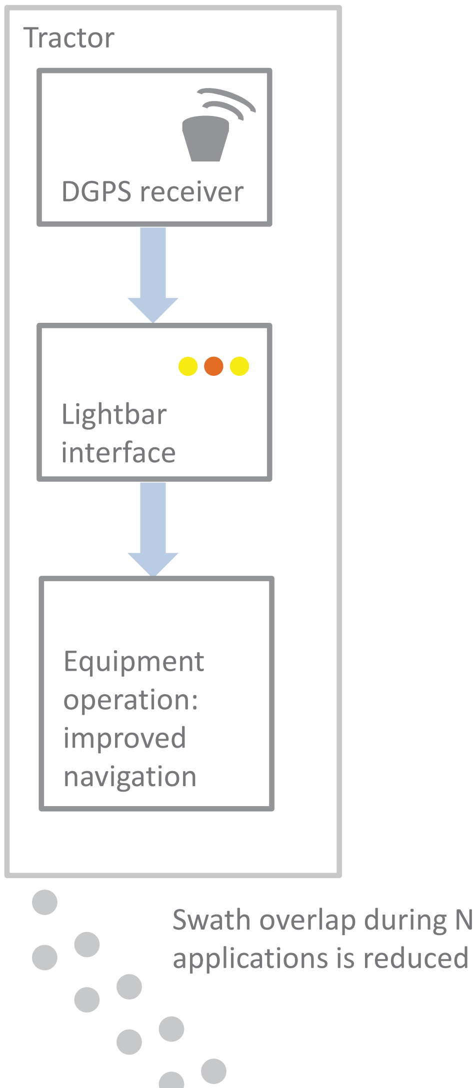


How it works:

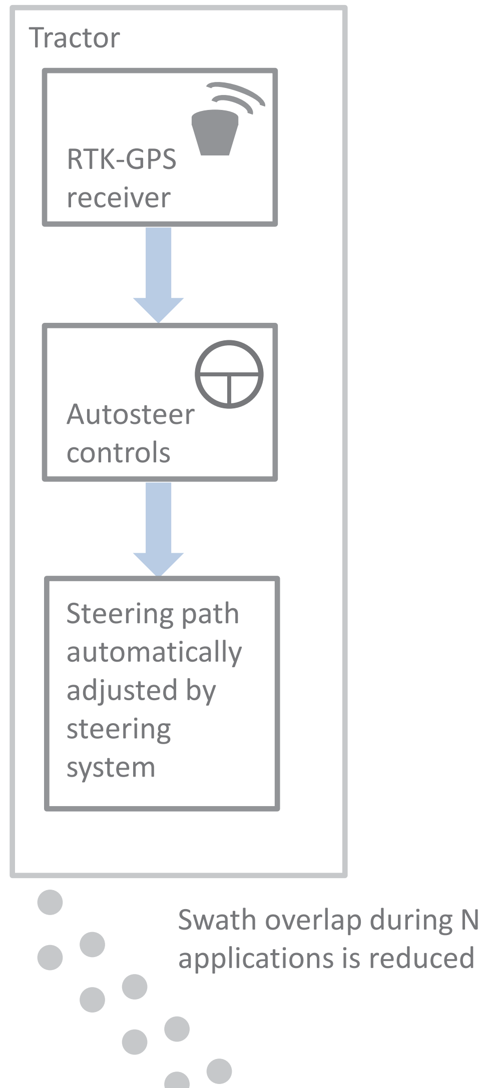
- Fertigation can reduce Nitrogen applications by facilitating the frequent applications of small amounts of nutrients delivered through an irrigation system.

Equipment guidance systems

Manual-steer system



Auto-steer system



How it works:

- Equipment guidance reduces N applications by avoiding or reducing spreader/sprayer overlap during field operations. Two levels of guidance are proposed here.
- The manual-steer guidance systems is affordable and easy to implement, requiring a DGPS receiver and a lightbar interface. The lightbar uses a strip of lights on a screen or as LEDs to signal steering inputs to the operator. Equipment swath width is the only input required, and the DGPS receiver tracks equipment position in the field.
- The auto-steer guidance systems provides steering inputs directly to the tractor through a hydraulic or electric interface. Auto-steer systems are typically utilized with the more precise RTK GPS receivers.

Schematics of systems for N removal or retention on farms

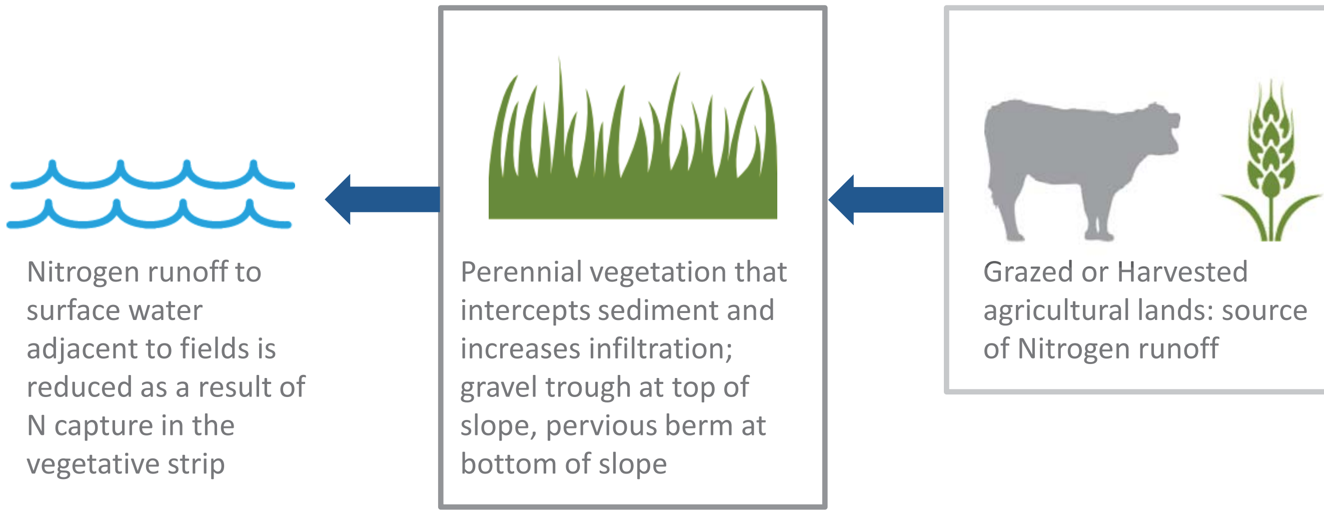
= Information, Data flow

= Water, Nutrient, Material flow

New component of system

Existing component of system

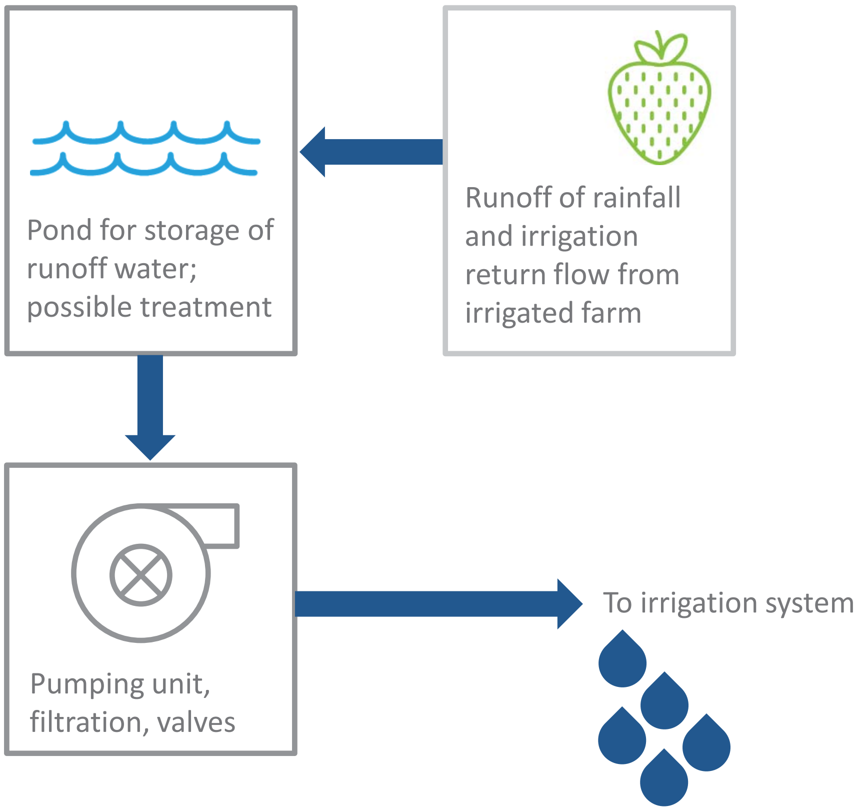
Vegetative Filter Strips



How it works:

- A vegetative filter strip (VFS) works by slowing the movement of runoff water from agricultural fields.
- The flow resistance in the VFS allows for more time for water infiltration (retaining N in solution) and the surface roughness captures sediments (retaining N attached to soil).
- A VFS is typically utilized at the edges of fields where runoff (that is not channelized) flows to a surface water body.

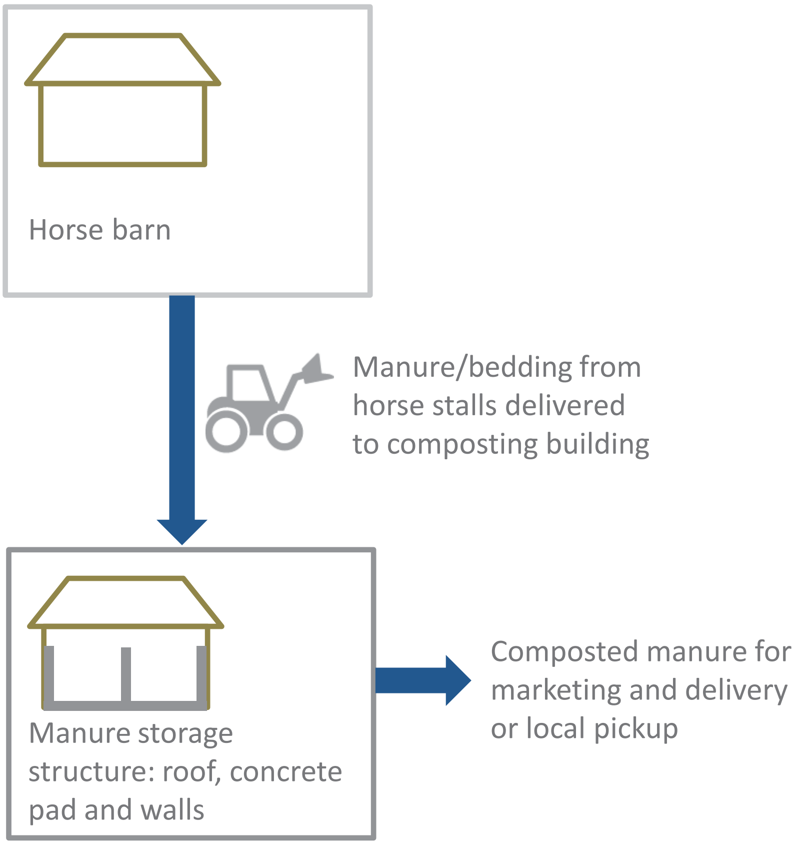
Tailwater Recovery



How it works:

- Tailwater recovery retains Nitrogen in farming systems by capturing and re-using runoff water from the farm that has

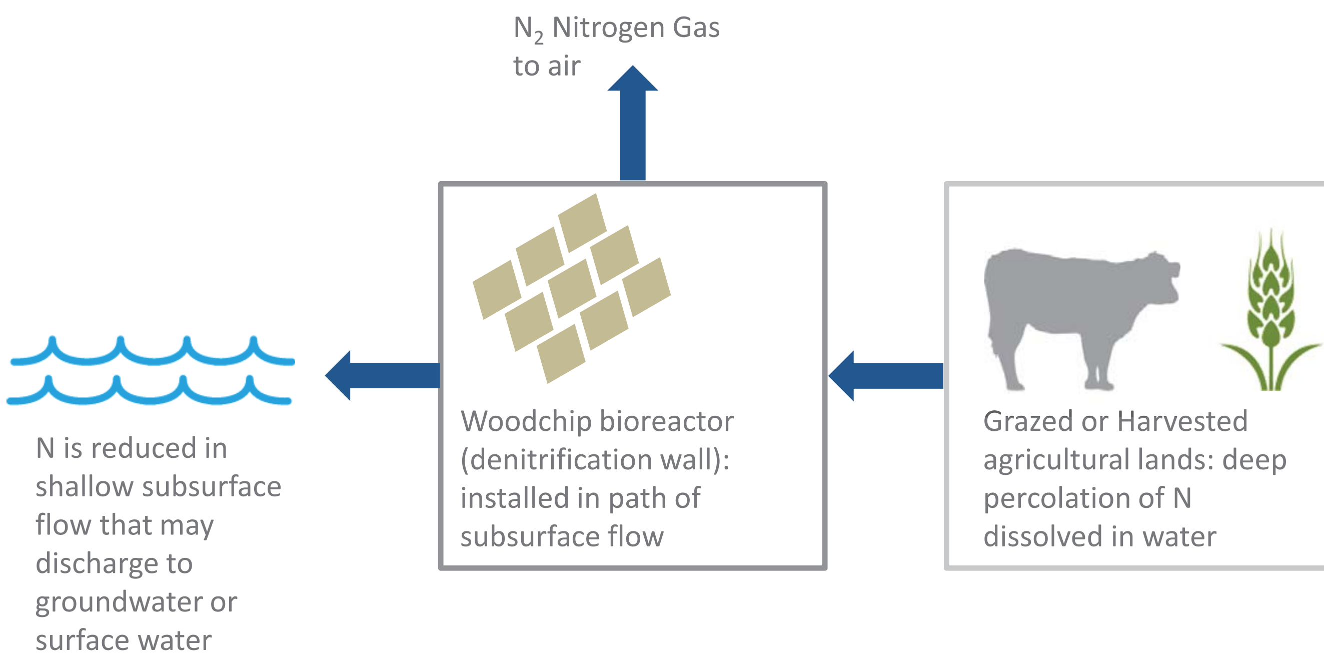
Manure Composting Structure



How it works:

- Manure composting structures retain Nitrogen in a system by storing manure and disposed animal bedding on a concrete pad with walls under a roof to eliminate leaching of nutrients from a manure pile.
- The roof prevents rainfall from saturating the manure and leaching nutrients. This also helps regulate moisture content for enhanced composting.
- This is generally applicable for horse farms or other systems in which a small number of animals spend some of their time in confinement.

Denitrification Wall



How it works:

- A denitrification wall, sometimes called a woodchip bioreactor, describes a system in which a substantial volume of woodchips are deposited in a large trench excavated across that path of shallow groundwater flow above a confining layer.
- The bacteria that survive on saturated woodchips are much more effective at Nitrogen than those present in soil; therefore, the woodchip media is an important element in the N removal efficiency of denitrification walls.

Treatment wetland

N concentrations in surface water are reduced; this decreases N loads to groundwater and surface waters near the system

Treatment wetland: restored or newly-developed wetland for N uptake/retention

Grazed or Harvested agricultural lands: runoff or designed drainage of dissolved or adsorbed N

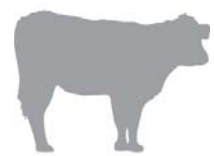
How it works:

- A treatment wetland reduces Nitrogen loadings by facilitating settling of nutrients and plant-uptake of nutrients by wetland species.
- The soils of wetlands generally have a substantial capacity for nutrient storage.

Manure storage pond lining

After sufficient storage/treatment, the liquid manure is applied by an irrigation system to a field of grass or cereal crops. Secondary lagoon or wetland treatment could precede field applications.

Primary treatment lagoon (newly excavated or newly lined) utilizes a reinforced concrete or flexible plastic liner to eliminate nitrate leaching

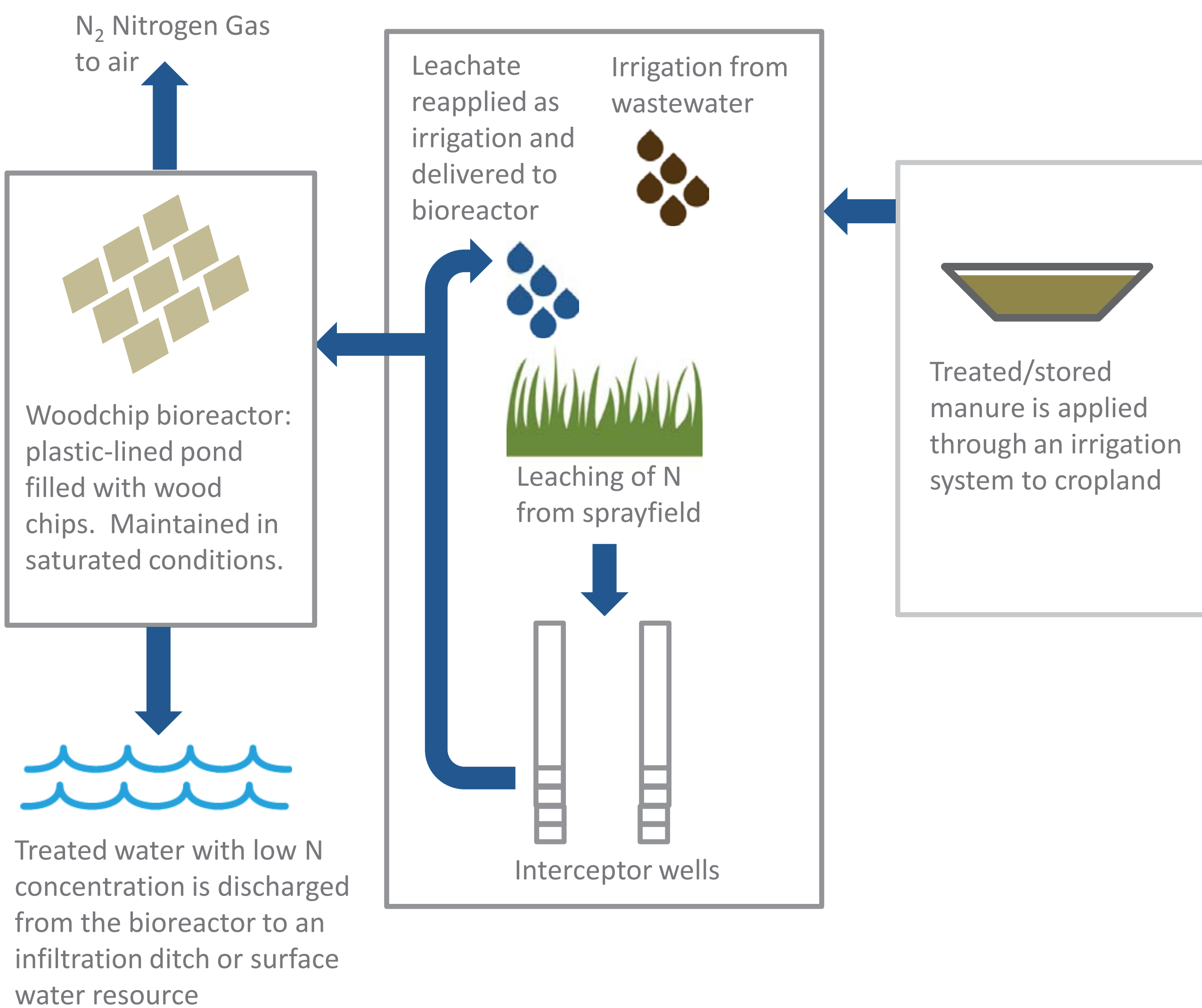


Liquid manure from dairy structures is conveyed to a storage lagoon where biological treatment occurs during storage

How it works:

- Manure storage lagoons are designed to minimize nutrient leaching, but lining with concrete or flexible membranes ensures that nutrient losses through drainage are eliminated.
- Lining a manure storage lagoon could be applicable when a producer is restoring capacity to an established lagoon or when a new lagoon is being constructed to replace or supplement an existing lagoon.

Interceptor Wells and De-N Bioreactor



How it works:

- Leached water from an irrigated sprayfield on a dairy is collected by distributed interceptor or scavenger wells (15 to 20 acres per well).
- This water, typically having elevated nitrate levels, is delivered to a woodchip bioreactor or it can be delivered to the irrigation system to be reapplied to the sprayfield.
- The bioreactor is a plastic-lined pond filled with woodchips that are saturated with high-nitrate water. Flow rates and sizes should be designed to allow for about 4 hours of residence time for sufficient nitrate reduction.
- The bioreactor drains to an infiltration ditch to discharge the treated water.

Cost per Benefit: Detailed Spreadsheet Tables

Analysis Summary

Average Annualized Cost and Cost per Benefit (project lifetime)

Option	Average Total Cost ($)	Annual Cost ($), project lifetime	Average Benefit (GPD)	$ per 1000 gallon Offset
Alternative Water Source	$286,546	$19,934	71,314	$0.88
Alternative Water Source: Ponds	$356,189	$24,779	69,599	$1.11
Conservation	$13,297	$1,589	11,222	$0.41
Irrigation Conversion	$252,281	$21,710	40,405	$1.71

Analysis Summary

Alternative Water Source

Option	Total Cost ($)	Annual Cost ($), project lifetime	Benefits (GPD Offset)	$ per 1000 gallon Offset (project lifetime)
Existing Water Feature Expansion				
Row Crops	$392,460	$27,303	81,982	$0.91
Sod/Pasture	$416,500	$28,975	88,258	$0.90
Perennial Crops	$258,439	$17,979	44,385	$1.11
Container Nurseries	$167,807	$11,674	19,919	$1.61
Excavated Pond, Average				
Row Crops	$451,985	$31,444	81,982	$1.05
Sod/Pasture	$485,267	$33,759	88,258	$1.05
Perennial Crops	$286,105	$19,904	44,385	$1.23
Container Nurseries	$178,701	$12,432	19,919	$1.71
Excavated Pond, Large				
Row Crops	$532,643	$37,055	127,965	$0.79
Sod/Pasture	$575,280	$40,021	137,762	$0.80
Perennial Crops	$330,450	$22,989	69,281	$0.91
Container Nurseries	$198,627	$13,818	31,092	$1.22
Reclaimed Water Supply				
Row Crops	$95,280	$6,628	91,427	$0.20
Sod/Pasture	$97,248	$6,765	98,395	$0.19
Perennial Crops	$70,702	$4,919	57,506	$0.23
Container Nurseries	$47,245	$3,287	58,513	$0.15

Analysis Summary

Conservation

Option	Total Cost ($)	Annual Cost ($), project lifetime	Benefits (GPD Offset)	$ per 1000 gallon Offset (project lifetime)
Irrigation System Automation (Soil Moisture Sensor Control)				
Row Crops	$23,078	$2,758	13,714.05	$0.55
Sod/Pasture	$23,078	$2,758	17,219.18	$0.44
Perennial Crops	$23,078	$2,758	8,656.82	$0.87
Container Nurseries	$23,078	$2,758	8,319.37	$0.91
Irrigation System Automation (On-site Weather Station Control)				
Row Crops	$24,647	$2,945	13,714.05	$0.59
Sod/Pasture	$24,647	$2,945	17,219.18	$0.47
Perennial Crops	$24,647	$2,945	8,656.82	$0.93
Container Nurseries	$24,647	$2,945	8,319.37	$0.97
Soil Moisture Sensors for Decision Support				
Row Crops	$1,947	$233	12,571.22	$0.05
Sod/Pasture	$1,947	$233	15,989.24	$0.04
Perennial Crops	$1,947	$233	8,038.47	$0.08
Container Nurseries	$1,947	$233	7,487.43	$0.09
Weather Station for Decision Support				
Row Crops	$3,515	$420	11,428.38	$0.10
Sod/Pasture	$3,515	$420	14,759.30	$0.08
Perennial Crops	$3,515	$420	6,801.79	$0.17
Container Nurseries	$3,515	$420	6,655.50	$0.17

Analysis Summary

Irrigation Conversion

Option	Total Cost ($)	Annual Cost ($), project lifetime	Benefits (GPD Offset)	$ per 1000 gallon Offset (project lifetime)
Seepage to Center Pivot				
Row Crops	$224,055	$19,281	36,570.81	$1.44
Sod/Pasture	$241,131	$20,751	38,128.19	$1.49
Center Pivot to Suburface Drip				
Row Crops	$340,182	$29,274	23,999.60	$3.34
Sod/Pasture	$366,110	$31,506	25,828.77	$3.34
Seepage to Subsurface Drip				
Sod/Pasture	$366,110	$31,506	38,128.19	$2.26
Seepage to Drip				
Row Crops	$273,035	$23,496	73,141.62	$0.88
Overhead to Drip				
Perennial Crops	$147,728	$12,713	43,902.43	$0.79
Overhead to Micro Spray				
Perennial Crops	$210,030	$18,074	39,574.02	$1.25
Overhead to Micro Irrigation				
Container Nurseries	$102,147	$8,790	44,369.98	$0.54

Analysis Summary

Irrigation Conversion

Option	Total Cost ($)	Annual Cost ($), 5-yr	Benefits (GPD Offset)	$ per 1000 gallon Offset (5-yr term)
Seepage to Center Pivot				
Row Crops	$224,055	$49,448	36,571	$3.70
Sod/Pasture	$241,131	$53,217	38,128	$3.82
Center Pivot to Suburface Drip				
Row Crops	$340,182	$75,077	24,000	$8.57
Sod/Pasture	$366,110	$80,800	25,829	$8.57
Seepage to Subsurface Drip				
Sod/Pasture	$366,110	$80,800	38,128	$5.81
Seepage to Drip				
Row Crops	$273,035	$60,258	73,142	$2.26
Overhead to Drip				
Perennial Crops	$147,728	$32,603	43,902	$2.03
Overhead to Micro Spray				
Perennial Crops	$210,030	$46,353	39,574	$3.21
Overhead to Micro Irrigation				
Container Nurseries	$102,147	$22,544	44,370	$1.39

Analysis Summary

Conservation

Option	Total Cost ($)	Annual Cost ($), 5-yr	Benefits (GPD Offset)	$ per 1000 gallon Offset (5-yr term)
Irrigation System Automation (Soil Moisture Sensor Control)				
Row Crops	$23,078	$5,093	13,714	$1.02
Sod/Pasture	$23,078	$5,093	17,219	$0.81
Perennial Crops	$23,078	$5,093	8,657	$1.61
Container Nurseries	$23,078	$5,093	8,319	$1.68
Irrigation System Automation (On-site Weather Station Control)				
Row Crops	$24,647	$5,439	13,714	$1.09
Sod/Pasture	$24,647	$5,439	17,219	$0.87
Perennial Crops	$24,647	$5,439	8,657	$1.72
Container Nurseries	$24,647	$5,439	8,319	$1.79
Soil Moisture Sensors for Decision Support				
Row Crops	$1,947	$430	12,571	$0.09
Sod/Pasture	$1,947	$430	15,989	$0.07
Perennial Crops	$1,947	$430	8,038	$0.15
Container Nurseries	$1,947	$430	7,487	$0.16
Weather Station for Decision Support				
Row Crops	$3,515	$776	11,428	$0.19
Sod/Pasture	$3,515	$776	14,759	$0.14
Perennial Crops	$3,515	$776	6,802	$0.31
Container Nurseries	$3,515	$776	6,655	$0.32

Analysis Summary

Alternative Water Source

Option	Total Cost ($)	Annual Cost ($), 5-yr	Benefits (GPD Offset)	$ per 1000 gallon Offset (5-yr term)
Existing Water Feature Expansion				
Row Crops	$392,460	$86,615	81,982	$2.89
Sod/Pasture	$416,500	$91,921	88,258	$2.85
Perennial Crops	$258,439	$57,037	44,385	$3.52
Container Nurseries	$167,807	$37,035	19,919	$5.09
Excavated Pond, Average				
Row Crops	$451,985	$99,752	81,982	$3.33
Sod/Pasture	$485,267	$107,097	88,258	$3.32
Perennial Crops	$286,105	$63,143	44,385	$3.90
Container Nurseries	$178,701	$39,439	19,919	$5.42
Excavated Pond, Large				
Row Crops	$532,643	$117,553	127,965	$2.52
Sod/Pasture	$575,280	$126,963	137,762	$2.52
Perennial Crops	$330,450	$72,930	69,281	$2.88
Container Nurseries	$198,627	$43,837	31,092	$3.86
Reclaimed Water Supply				
Row Crops	$95,280	$21,028	91,427	$0.63
Sod/Pasture	$97,248	$21,462	98,395	$0.60
Perennial Crops	$70,702	$15,604	57,506	$0.74
Container Nurseries	$47,245	$10,427	58,513	$0.49

Analysis Summary

Average Annualized Cost and Cost per Benefit (5 yr term)

Option	Average Total Cost ($)	Annual Cost ($), 5-yr	Average Benefit (GPD)	$ per 1000 gallon Offset
Alternative Water Source	$286,546	$63,240	71,314	$2.79
Alternative Water Source: Ponds	$356,189	$78,610	69,599	$3.51
Conservation	$13,297	$2,935	11,222	$0.75
Irrigation Conversion	$252,281	$55,678	40,405	$4.37

Analysis Summary

Cost per Benefit Minimum and Maximum (5 yr term)

Option	Maximum: $ per 1000 gallon Offset	Maximum $ per Minimum offset ($/1000 gal)	Maximum: Annual cost, $	Minimum: GPD offset
Alternative Water Source	$5.42	$17.46	$126,963	19,919
Alternative Water Source: Ponds	$5.42	$17.46	$126,963	19,919
Conservation	$1.79	$2.24	$5,439	6,655
Irrigation Conversion	$8.57	$9.22	$80,800	24,000

Analysis Summary

Alternative Water Source

Costs	Units	Unit Price	Existing Water Feature Expansion								Excavated Pond, Average							
			Costs								Costs							
			Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries		Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Excavation cost	$/CuYd	$3.31	17,983	$59,525	20,775	$68,767	8,358	$27,665	3,291	$10,894	35,967	$119,050	41,551	$137,533	16,716	$55,331	6,582	$21,787
Grading and hydroseeding	$/Acre	$805	2.10	$1,691	2.2	$1,772	1.1	$886	0.5	$403	2.10	$1,691	2.20	$1,772	1.10	$886	0.50	$403
Flashboard riser	$/DialnFt	$1.33	45	$60	45	$60	45	$60	45	$60	45	$60	45	$60	45	$60	45	$60
Culvert	$/DialnFt	$40.00	400	$16,000	400	$16,000	400	$16,000	400	$16,000	400	$16,000	400	$16,000	400	$16,000	400	$16,000
Pump station (diesel) > 75 hp	$/BHP	$298	125	$37,208	125	$37,208	125	$37,208	125	$37,208	125	$37,208	125	$37,208	125	$37,208	125	$37,208
Shed/pad for pump station	$/System	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000
Fuel tank	$/System	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400
Meter	$/System	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000
Fittings, valves, miscellaneous	$/Acre	$111	128	$14,188	138	$15,269	69	$7,676	31	$3,443	128	$14,188	138	$15,269	69	$7,676	31	$3,443
Suction screen, self-cleaning	$/System	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004
Filtration system, automated backflush	$/System	$10,696	4	$42,784	4	$42,784	3	$32,088	2	$21,392	4	$42,784	4	$42,784	3	$32,088	2	$21,392
Pipe to irrigation system (12" PVC)	$/Ft	$11	4,723	$52,496	4,900	$54,464	3,474	$38,614	2,326	$25,853	4,723	$52,496	4,900.00	$54,464	3,474.00	$38,614	2,326.00	$25,853
Supply line (12" PVC)	$/Ft	$11	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0
Design and Installation	$/Acre	$1,196	128	$153,105	138	$164,774	69	$82,839	31	$37,151	128	$153,105	138	$164,774	69	$82,839	31	$37,151
Costs Total:				$392,460		$416,500		$258,439		$167,807		$451,985		$485,267		$286,105		$178,701
Total Annual Amortized Cost (5 yr term):				$86,615		$91,921		$57,037		$37,035		$99,752		$107,097		$63,143		$39,439
Total Annual Amortized Cost (lifetime of project):				$27,303		$28,975		$17,979		$11,674		$31,444		$33,759		$19,904		$12,432

Benefits	Units	Unit Price	Existing Water Feature Expansion								Excavated Pond, Average							
			Benefits								Benefits							
			Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries		Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Groundwater offset (GPD)	GPD	-	-	81,982	-	88,258	-	44,385	-	19,919	-	81,982	-	88,258	-	44,385	-	19,919
Benefits Total:				81,982		88,258		44,385		19,919		81,982		88,258		44,385		19,919

Results	Existing Water Feature Expansion								Excavated Pond, Average							
	Results								Results							
	Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries		Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries	
Daily Cost per 1,000 GPD Offset (5 yr term):		$2.89		$2.85		$3.52		$5.09		$3.33		$3.32		$3.90		$5.42
Daily Cost per 1,000 GPD Offset (lifetime of project):		$0.91		$0.90		$1.11		$1.61		$1.05		$1.05		$1.23		$1.71

Analysis Summary

Alternative Water Source

Excavated Pond, Large — Costs

Costs	Units	Unit Price	Row Crops Quantity	Row Crops Total	Sod/Pasture Quantity	Sod/Pasture Total	Perennial Crops Quantity	Perennial Crops Total	Container Nurseries Quantity	Container Nurseries Total
Excavation cost	$/CuYd	$3.31	60,067	$198,822	68,429	$226,500	29,968	$99,192	12,529	$41,472
Grading and hydroseeding	$/Acre	$805	3.20	$2,577	3.5	$2,819	1.7	$1,369	0.8	$644
Flashboard riser	$/Dia(in)*Ft	$1.33	45	$60	45	$60	45	$60	45	$60
Culvert	$/ft, 24"metal	$40.00	400	$16,000	400	$16,000	400	$16,000	400	$16,000
Pump station (diesel) > 75 hp	$/BHP	$298	125	$37,208	125	$37,208	125	$37,208	125	$37,208
Shed/pad for pump station	$/System	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000
Fuel tank	$/System	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400
Meter	$/System	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000
Fittings, valves, miscellaneous	$/Acre	$111	128	$14,188	138	$15,269	69	$7,676	31	$3,443
Suction screen, self-cleaning	$/System	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004
Filtration system, automated backflush	$/System	$10,696	4	$42,784	4	$42,784	3	$32,088	2	$21,392
Pipe to irrigation system (12" PVC)	$/Ft	$11	4,723	$52,496	4,900	$54,464	3,474	$38,614	2,326	$25,853
Supply line (12" PVC)	$/Ft	$11	-	$0	-	$0	-	$0	-	$0
Design and Installation	$/Acre	$1,196	128	$153,105	138	$164,774	69	$82,839	31	$37,151
Costs Total:				$532,643		$575,280		$330,450		$198,627
Total Annual Amortized Cost (5 yr term):				$117,553		$126,963		$72,930		$43,837
Total Annual Amortized Cost (lifetime of project):				$37,055		$40,021		$22,989		$13,818

Reclaimed Water Supply — Costs

Costs	Units	Unit Price	Row Crops Quantity	Row Crops Total	Sod/Pasture Quantity	Sod/Pasture Total	Perennial Crops Quantity	Perennial Crops Total	Container Nurseries Quantity	Container Nurseries Total
Excavation cost	$/CuYd	$3.31	-	$0	-	$0	-	$0	-	$0
Grading and hydroseeding	$/Acre	$805	-	$0	-	$0	-	$0	-	$0
Flashboard riser	$/Dia(in)*Ft	$1.33	-	$0	-	$0	-	$0	-	$0
Culvert	$/ft, 24"metal	$40.00	-	$0	-	$0	-	$0	-	$0
Pump station (diesel) > 75 hp	$/BHP	$298	-	$0	-	$0	-	$0	-	$0
Shed/pad for pump station	$/System	$7,000	-	$0	-	$0	-	$0	-	$0
Fuel tank	$/System	$3,400	-	$0	-	$0	-	$0	-	$0
Meter	$/System	$3,000	-	$0	-	$0	-	$0	-	$0
Fittings, valves, miscellaneous	$/Acre	$111	-	$0	-	$0	-	$0	-	$0
Suction screen, self-cleaning	$/System	$2,004	-	$0	-	$0	-	$0	-	$0
Filtration system, automated backflush	$/System	$10,696	4	$42,784	4	$42,784	3	$32,088	2	$21,392
Pipe to irrigation system (12" PVC)	$/Ft	$11	-	$0	-	$0	-	$0	-	$0
Supply line (12" PVC)	$/Ft	$11	4,723	$52,496	4,900	$54,464	3,474	$38,614	2,326	$25,853
Design and Installation	$/Acre	$1,196	-	$0	-	$0	-	$0	-	$0
Costs Total:				$95,280		$97,248		$70,702		$47,245
Total Annual Amortized Cost (5 yr term):				$21,028		$21,462		$15,604		$10,427
Total Annual Amortized Cost (lifetime of project):				$6,628		$6,765		$4,919		$3,287

Benefits

Benefits	Units	Unit Price		Excavated Pond, Large: Row Crops Quantity	Row Crops Total	Sod/Pasture Quantity	Sod/Pasture Total	Perennial Crops Quantity	Perennial Crops Total	Container Nurseries Quantity	Container Nurseries Total
Groundwater offset (GPD)	GPD	-		-	127,965	-	137,762	-	69,281	-	31,092
Benefits Total:					127,965		137,762		69,281		31,092

Benefits	Units	Unit Price		Reclaimed Water Supply: Row Crops Quantity	Row Crops Total	Sod/Pasture Quantity	Sod/Pasture Total	Perennial Crops Quantity	Perennial Crops Total	Container Nurseries Quantity	Container Nurseries Total
Groundwater offset (GPD)	GPD	-		-	91,427	-	98,395	-	57,506	-	58,513
Benefits Total:					91,427		98,395		57,506		58,513

Results

Results	Excavated Pond, Large: Row Crops	Sod/Pasture	Perennial Crops	Container Nurseries	Reclaimed Water Supply: Row Crops	Sod/Pasture	Perennial Crops	Container Nurseries
Daily Cost per 1,000 GPD Offset (5 yr term):	$2.52	$2.52	$2.88	$3.86	$0.63	$0.60	$0.74	$0.49
Daily Cost per 1,000 GPD Offset (lifetime of project):	$0.79	$0.80	$0.91	$1.22	$0.20	$0.19	$0.23	$0.15

Analysis Summary

Conservation

			Irrigation System Automation (Soil Moisture Sensor Control)								Irrigation System Automation (On-site Weather Station Control)							
			Costs								Costs							
			Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries		Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries	
Costs	**Units**	**Unit Price**	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Central control station; pump automation	$/System	$21,132	1	$21,132	1	$21,132	1	$21,132	1	$21,132	1	$21,132	1	$21,132	1	$21,132	1	$21,132
Soil moisture sensor w/ all telemetry, installed	$/System	$1,947	1	$1,947	1	$1,947	1	$1,947	1	$1,947	-	$0	-	$0	-	$0	-	$0
Weather station	$/System	$3,515	-	$0	-	$0	-	$0	-	$0	1	$3,515	1	$3,515	1	$3,515	1	$3,515
		Costs Total:		$23,078		$23,078		$23,078		$23,078		$24,647		$24,647		$24,647		$24,647
		Total Annual Amortized Cost (5 yr term):		$5,093		$5,093		$5,093		$5,093		$5,439		$5,439		$5,439		$5,439
		Total Annual Amortized Cost (lifetime of project):		$2,758		$2,758		$2,758		$2,758		$2,945		$2,945		$2,945		$2,945

			Irrigation System Automation (Soil Moisture Sensor Control)								Irrigation System Automation (On-site Weather Station Control)							
			Benefits								Benefits							
			Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries		Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries	
Benefits	**Units**	**Unit Price**	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Groundwater offset (1,000 GPD)	GPD (000s)	-	-	13,714.05	-	17,219.18	-	8,656.82	-	8,319.37	-	13,714.05	-	17,219.18	-	8,656.82	-	8,319.37
		Benefits Total:		13,714.05		17,219.18		8,656.82		8,319.37		13,714.05		17,219.18		8,656.82		8,319.37

	Irrigation System Automation (Soil Moisture Sensor Control)								Irrigation System Automation (On-site Weather Station Control)							
	Results								Results							
Results	Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries		Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries	
Daily Cost per 1,000 GPD Offset (5 yr term):		$1.02		$0.81		$1.61		$1.68		$1.09		$0.87		$1.72		$1.79
Daily Cost per 1,000 GPD Offset (lifetime of project):		$0.55		$0.44		$0.87		$0.91		$0.59		$0.47		$0.93		$0.97

Analysis Summary

Conservation

			Soil Moisture Sensors for Decision Support								Weather Station for Decision Support							
			Costs								Costs							
Costs	Units	Unit Price	Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries		Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Central control station; pump automation	$/System	$21,132	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0
Soil moisture sensor w/ all telemetry, installed	$/System	$1,947	1	$1,947	1	$1,947	1	$1,947	1	$1,947	-	$0	-	$0	-	$0	-	$0
Weather station	$/System	$3,515	-	$0	-	$0	-	$0	-	$0	1	$3,515	1	$3,515	1	$3,515	1	$3,515
Costs Total:				$1,947		$1,947		$1,947		$1,947		$3,515		$3,515		$3,515		$3,515
Total Annual Amortized Cost (5 yr term):				$430		$430		$430		$430		$776		$776		$776		$776
Total Annual Amortized Cost (lifetime of project):				$233		$233		$233		$233		$420		$420		$420		$420

			Soil Moisture Sensors for Decision Support								Weather Station for Decision Support							
			Benefits								Benefits							
Benefits	Units	Unit Price	Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries		Row Crops		Sod/Pasture		Perennial Crops		Container Nurseries	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Groundwater offset (GPD)	GPD	-	-	12,571.22	-	15,989.24	-	8,038.47	-	7,487.43	-	11,428.38	-	14,759.30	-	6,801.79	-	6,655.50
Benefits Total:				12,571.22		15,989.24		8,038.47		7,487.43		11,428.38		14,759.30		6,801.79		6,655.50

	Soil Moisture Sensors for Decision Support				Weather Station for Decision Support			
	Results				Results			
Results	Row Crops	Sod/Pasture	Perennial Crops	Container Nurseries	Row Crops	Sod/Pasture	Perennial Crops	Container Nurseries
Daily Cost per 1,000 GPD Offset (5 yr term):	$0.09	$0.07	$0.15	$0.16	$0.19	$0.14	$0.31	$0.32
Daily Cost per 1,000 GPD Offset (lifetime of project):	$0.05	$0.04	$0.08	$0.09	$0.10	$0.08	$0.17	$0.17

Analysis Summary

Irrigation Conversion

			Seepage to Center Pivot				Center Pivot to Suburface Drip				Seepage to Subsurface Drip		Seepage to Drip		Overhead to Drip		Overhead to Micro Spray		Overhead to Micro Irrigation	
			Costs				Costs				Costs		Costs		Costs		Costs		Costs	
Costs	Units	Unit Price	Row Crops		Sod/Pasture		Row Crops		Sod/Pasture		Sod/Pasture		Row Crops		Perennial Crops		Perennial Crops		Container Nurseries	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Center pivot	$/Acre	$1,750	128	$224,055	138	$241,131	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0
Micro spray	$/Acre	$3,032	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0	69	$210,030	-	$0
Drip	$/Acre	$2,133	-	$0	-	$0	-	$0	-	$0	-	$0	128	$273,035	69	$147,728	-	$0	-	$0
Subsurface drip	$/Acre	$2,657	-	$0	-	$0	128	$340,182	138	$366,110	138	$366,110	-	$0	-	$0	-	$0	-	$0
Micro irrigation (container nursery)	$/Acre	$3,288	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0	31	$102,147
Costs Total:				$224,055		$241,131		$340,182		$366,110		$366,110		$273,035		$147,728		$210,030		$102,147
Total Annual Amortized Cost (5 yr term):				$49,448		$53,217		$75,077		$80,800		$80,800		$60,258		$32,603		$46,353		$22,544
Total Annual Amortized Cost (lifetime of project):				$19,281		$20,751		$29,274		$31,506		$31,506		$23,496		$12,713		$18,074		$8,790

			Seepage to Center Pivot				Center Pivot to Suburface Drip				Seepage to Subsurface Drip		Seepage to Drip		Overhead to Drip		Overhead to Micro Spray		Overhead to Micro Irrigation	
			Benefits				Benefits				Benefits		Benefits		Benefits		Benefits		Benefits	
Benefits	Units	Unit Price	Row Crops		Sod/Pasture		Row Crops		Sod/Pasture		Sod/Pasture		Row Crops		Perennial Crops		Perennial Crops		Container Nurseries	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Groundwater offset (GPD)	GPD	-	-	36,570.81	-	38,128.19	-	23,999.60	-	25,828.77	-	38,128.19	-	73,141.62	-	43,902.43	-	39,574.02	-	44,369.98
Benefits Total:				36,570.81		38,128.19		23,999.60		25,828.77		38,128.19		73,141.62		43,902.43		39,574.02		44,369.98

	Seepage to Center Pivot				Center Pivot to Suburface Drip				Seepage to Subsurface Drip		Seepage to Drip		Overhead to Drip		Overhead to Micro Spray		Overhead to Micro Irrigation	
	Results				Results				Results		Results		Results		Results		Results	
Results	Row Crops		Sod/Pasture		Row Crops		Sod/Pasture		Sod/Pasture		Row Crops		Perennial Crops		Perennial Crops		Container Nurseries	
Daily Cost per 1,000 GPD Offset (5 yr term):		$3.70		$3.82		$8.57		$8.57		$5.81		$2.26		$2.03		$3.21		$1.39
Daily Cost per 1,000 GPD Offset (lifetime of project):		$1.44		$1.49		$3.34		$3.34		$2.26		$0.88		$0.79		$1.25		$0.54

Reference Values
Alternative Water Source

Benefits	Units	Row Crops	Sod/Pasture	Perennial Crops	Container Nurseries
Existing Water Feature Expansion	GPD	81,982	88,258	44,385	19,919
Excavated Pond, Average	GPD	81,982	88,258	44,385	19,919
Excavated Pond, Large	GPD	127,965	137,762	69,281	31,092
Reclaimed Water Supply	GPD	91,427	98,395	57,506	58,513

Costs	Unit	Unit Price	Row Crops	Sod/Pasture	Perennial Crops	Container
Excavation cost, Existing	CuYd	$3.31	17,983	20,775	8,358	3,291
Excavation cost, Average	CuYd	$3.31	35,967	41,551	16,716	6,582
Excavation cost, Large	CuYd	$3.31	60,067	68,429	29,968	12,529
Grading and hydroseeding, Existing and Average	Acres	$805	2.1	2.2	1.1	0.5
Grading and hydroseeding, Large	Acres	$805	3.2	3.5	1.7	0.8
Flashboard riser	Dia(in)*Ft	$1.33	45	45	45	45
Culvert	ft, 24in meta	$40.00	400	400	400	400
Pump station (diesel) > 75 hp	bhp	$298	125	125	125	125
Shed/pad for pump station	System	$7,000	1	1	1	1
Fuel tank	System	$3,400	1	1	1	1
Meter	System	$3,000	1	1	1	1
Fittings, valves, miscellaneous	Acres	$111	128	138	69	31
Suction screen, self-cleaning	System	$2,004	1	1	1	1
Filtration system, automated backflush	System	$10,696	4	4	3	2
Pipe to irrigation system (assume 12")	Ft	$11	4,723	4,900	3,474	2,326
Supply line (assume 12")	Ft	$11	4,723	4,900	3,474	2,326
Design and Installation	Acres	$1,196	128	138	69	31

Reference Values
Conservation

Benefits	Units	Row Crops	Sod/Pasture	Perennial Crops	Container Nurseries
Irrigation system automation; soil moisture sensor control	GPD	13,714	17,219	8,657	8,319
Irrigation system automation; on-site weather station control	GPD	13,714	17,219	8,657	8,319
Soil moisture sensors for decision support	GPD	12,571	15,989	8,038	7,487
Weather station for decision support	GPD	11,428	14,759	6,802	6,655

Costs	Unit	Unit Price	Row Crops	Sod/Pasture	Perennial Crops	Container
Central control station; pump automation	Station	$21,132	1	1	1	1
Soil moisture sensor w/ all telemetry, installed	Station	$1,947	1	1	1	1
Weather station	System	$3,515	1	1	1	1

Reference Values
Irrigation Conversion

Benefits	Units	Row Crops	Sod/Pasture	Perennial Crops	Container Nurseries
		Seepage to Drip	Seepage to Center Pivot	Overhead to MicroSpray	Overhead to Micro
Irrigation Conversion	GPD	73,142	38,128	39,574	44,370
	Units	**Seepage to Center Pivot**	**Seepage to Subsurface Drip**	**Overhead to Drip**	**--**
Irrigation Conversion	GPD	36,571	38,128	43,902	-
	Units	**Center Pivot to Suburface Drip**	**Center Pivot to Suburface Drip**	**--**	**--**
Irrigation Conversion	GPD	24,000	25,829	-	-

Costs	Unit	Unit Price	Row Crops	Sod/Pasture	Perennial Crops	Container
Center pivot	Acres	$1,750	128.01	137.77	69.26	31.06
Microspray	Acres	$3,032	128.01	137.77	69.26	31.06
Drip	Acres	$2,133	128.01	137.77	69.26	31.06
Subsurface drip	Acres	$2,657	128.01	137.77	69.26	31.06
Microirrigation - container nursery	Acres	$3,288	128.01	137.77	69.26	31.06

Source	Units	Row Crops	Sod/Pasture	Perennial Crops	Container Nurseries
FSAID 2015; Acres, by Permit ID	Acres	128.01	137.77	69.26	31.06
FSAID 2015; Acres, by polygon	Acres	30.69	65.72	39.60	9.35
FSAID; irrigation, in/yr	in/yr	20.80	17.94	21.30	27.32
AGMOD; irrigation, in/yr	in/yr	19.30	19.26	22.29	50.53
AGMOD NIR; irrigation, in/yr	in/yr	13.79	13.76	15.20	34.45
Most common irrigation system		Drip	Gravity System	Micro Spray	Container Nursery

Amortization Factor			
Irrigation Type	Year	Interest Rate	Reference
FFP	1	3.375%	Chemical Protectants (Desikote)
FFP	5	3.375%	Row Covers
AAD	10	3.375%	Conservation
AAD	15	3.375%	Irrigation Conversion
AAD, FFP	20	3.375%	Alternative water source, Surface Water, Wind machine
AAD, FFP	5	3.375%	5 year contract length
AAD, FFP	30	3.375%	30 year contract length
Amortization Factor	HP 12C amortization formula (http://h20331.www2.hp.com/Hpsub/downloads/HP12Camortization.pdf)		
	Algebraic amortization formula (http://www.vertex42.com/ExcelArticles/amortization-calculation.html)		

$$A = P\frac{i(1+i)^n}{(1+i)^n-1} = \frac{P \times i}{1-(1+i)^{-n}} = P\left(i + \frac{i}{(1+i)^n-1}\right)$$

Where:

A = periodic payment amount

P = amount of principal, net of initial payments, meaning "subtract any down-payments"

i = periodic interest rate

n = total number of payments

This formula is valid if i > 0. If i = 0 then simply A = P / n.

Source	Units	Row Crops	Sod/Pasture	Perennial Crops	Container Nurseries
FSAID 2015; Acres, by Permit ID	Acres	128.01	137.77	69.26	31.06
FSAID 2015; Acres, by polygon	Acres	30.69	65.72	39.60	9.35
FSAID; irrigation, in/yr	in/yr	20.80	17.94	21.30	27.32
AGMOD; irrigation, in/yr	in/yr	19.30	19.26	22.29	50.53
AGMOD NIR; irrigation, in/yr	in/yr	13.79	13.76	15.20	34.45
Most common irrigation system		Drip	Gravity System	Micro Spray	Container Nursery

Amortization Factor			
Irrigation Type	Year	Interest Rate	Reference
FFP	1	3.375%	Chemical Protectants (Desikote)
FFP	5	3.375%	Row Covers
AAD	10	3.375%	Conservation
AAD	15	3.375%	Irrigation Conversion
AAD, FFP	20	3.375%	Alternative water source, Surface Water, Wind machine
AAD, FFP	5	3.375%	5 year contract length
AAD, FFP	30	3.375%	30 year contract length
Amortization Factor	HP 12C amortization formula (http://h20331.www2.hp.com/Hpsub/downloads/HP12Camortization.pdf)		
	Algebraic amortization formula (http://www.vertex42.com/ExcelArticles/amortization-calculation.html)		

$$A = P\frac{i(1+i)^n}{(1+i)^n - 1} = \frac{P \times i}{1-(1+i)^{-n}} = P\left(i + \frac{i}{(1+i)^n - 1}\right)$$

Where:

A = periodic payment amount

P = amount of principal, net of initial payments, meaning "subtract any down-payments"

i = periodic interest rate

n = total number of payments

This formula is valid if i > 0. If i = 0 then simply A = P / n.

Source	Units	Row Crops	Sod/Pasture	Perennial Crops	Container Nurseries
FSAID 2015; Acres, by Permit ID	Acres	128.01	137.77	69.26	31.06
FSAID 2015; Acres, by polygon	Acres	30.69	65.72	39.60	9.35
FSAID; irrigation, in/yr	in/yr	20.80	17.94	21.30	27.32
AGMOD; irrigation, in/yr	in/yr	19.30	19.26	22.29	50.53
AGMOD NIR; irrigation, in/yr	in/yr	13.79	13.76	15.20	34.45
Most common irrigation system		Drip	Gravity System	Micro Spray	Container Nursery

Amortization Factor			
Irrigation Type	Year	Interest Rate	Reference
FFP	1	3.375%	Chemical Protectants (Desikote)
FFP	5	3.375%	Row Covers
AAD	10	3.375%	Conservation
AAD	15	3.375%	Irrigation Conversion
AAD, FFP	20	3.375%	Alternative water source, Surface Water, Wind machine
AAD, FFP	5	3.375%	5 year contract length
AAD, FFP	30	3.375%	30 year contract length
Amortization Factor	HP 12C amortization formula (http://h20331.www2.hp.com/Hpsub/downloads/HP12Camortization.pdf)		
	Algebraic amortization formula (http://www.vertex42.com/ExcelArticles/amortization-calculation.html)		

$$A = P\frac{i(1+i)^n}{(1+i)^n - 1} = \frac{P \times i}{1-(1+i)^{-n}} = P\left(i + \frac{i}{(1+i)^n - 1}\right)$$

Where:

A = periodic payment amount
P = amount of principal, net of initial payments, meaning "subtract any down-payments"
i = periodic interest rate
n = total number of payments

This formula is valid if i > 0. If i = 0 then simply A = P / n.

Analysis Summary

Alternative Water Source

Option	Total Cost ($)	Annual Cost ($), project lifetime	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Existing Water Feature Expansion				
Non-Blueberry Perennials	$135,618	$9,435	3,839	$6.73
Strawberries and Blueberries	$208,390	$14,497	10,713	$3.71
Container Nurseries	$128,265	$8,923	4,553	$5.37
Excavated Pond, Average				
Non-Blueberry Perennials	$152,107	$10,582	3,839	$7.55
Strawberries and Blueberries	$279,267	$19,428	10,713	$4.97
Container Nurseries	$155,707	$10,832	4,553	$6.52
Excavated Pond, Large				
Non-Blueberry Perennials	$160,433	$11,161	4,821	$6.34
Strawberries and Blueberries	$373,079	$25,954	16,337	$4.35
Container Nurseries	$182,660	$12,707	6,249	$5.57

Analysis Summary

Wind Machines

Option	Total Cost ($)	Annual Cost ($), project lifetime	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Wind Machines				
Non-Blueberry Perennials	$105,000	$7,305	5,498	$3.64
Strawberries and Blueberries	$105,000	$7,305	16,990	$1.18
Container Nurseries	$70,000	$4,870	6,465	$2.06

Analysis Summary

Row Covers

Option	Total Cost ($)	Annual Cost ($), project lifetime	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Row Covers				
Non-Blueberry Perennials	$0	$0	-	$0
Strawberries and Blueberries	$52,227	$11,526	22,654	$1.39
Container Nurseries	$28,388	$6,265	8,620	$1.99
Row Covers with Mechanized Application/Retrieval				
Non-Blueberry Perennials	$0	$0	-	$0.00
Strawberries and Blueberries	$77,977	$17,209	22,654	$2.08
Container Nurseries	$54,138	$11,948	8,620	$3.80

Analysis Summary

Chemical Protectants

Option	Total Cost ($)	Annual Cost ($), project lifetime	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Chemical Protectants				
Non-Blueberry Perennials	$208	$215	3,665	$0.16
Strawberries and Blueberries	$237	$245	11,327	$0.06
Container Nurseries	$129	$133	4,310	$0.08

Analysis Summary

Alternative Water Source

Option	Total Cost ($)	Annual Cost ($), 5-yr	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Existing Water Feature Expansion				
Non-Blueberry Perennials	$135,618	$29,931	3,839	$21.36
Strawberries and Blueberries	$208,390	$45,991	10,713	$11.76
Container Nurseries	$128,265	$28,308	4,553	$17.03
Excavated Pond, Average				
Non-Blueberry Perennials	$152,107	$33,570	3,839	$23.96
Strawberries and Blueberries	$279,267	$61,634	10,713	$15.76
Container Nurseries	$155,707	$34,364	4,553	$20.68
Excavated Pond, Large				
Non-Blueberry Perennials	$160,433	$35,407	4,821	$20.12
Strawberries and Blueberries	$373,079	$82,338	16,337	$13.81
Container Nurseries	$182,660	$40,313	6,249	$17.67

Analysis Summary

Wind Machines

Option	Total Cost ($)	Annual Cost ($), 5-yr	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Wind Machines				
Non-Blueberry Perennials	$105,000	$23,173	5,498	$11.55
Strawberries and Blueberries	$105,000	$23,173	16,990	$3.74
Container Nurseries	$70,000	$15,449	6,465	$6.55

Analysis Summary

Row Covers

Option	Total Cost ($)	Annual Cost ($), 5-yr	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Row Covers				
Non-Blueberry Perennials	$0	$0	-	$0
Strawberries and Blueberries	$52,227	$11,526	22,654	$1.39
Container Nurseries	$28,388	$6,265	8,620	$1.99
Row Covers with Mechanized Application/Retrieval				
Non-Blueberry Perennials	$0	$0	-	$0.00
Strawberries and Blueberries	$77,977	$17,209	22,654	$2.08
Container Nurseries	$54,138	$11,948	8,620	$3.80

Analysis Summary

Chemical Protectants

Option	Total Cost ($)	Annual Cost ($), 5-yr	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Chemical Protectants				
Non-Blueberry Perennials	$208	$230	3,665	$0.17
Strawberries and Blueberries	$237	$261	11,327	$0.06
Container Nurseries	$129	$142	4,310	$0.09

Analysis Summary

Average Total and Annualized Costs and Cost per Benefit (Project Life)

Option	Average Total Cost ($)	Annual Cost ($), project lifetime	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Alternative Water Source	$197,281	$13,724	7,291	$5.68
Row Covers	$53,183	$11,737	15,637	$2.32
Wind Machines	$93,333	$6,493	9,651	$2.29
Chemical Protectants	$191	$198	6,434	$0.10

Analysis Summary

Average Annualized Cost and Cost per Benefit (5 yr term)

Option	Average Total Cost ($)	Annual Cost ($), 5-yr	Benefits (GPD Offset)	Cost per Benefit: $ per 1000 gallons
Alternative Water Source	$197,281	$43,539	7,291	$18.02
Row Covers	$53,183	$11,737	15,637	$2.32
Wind Machines	$93,333	$20,598	9,651	$7.28
Chemical Protectants	$191	$211	6,434	$0.11

Analysis Summary

Cost per Benefit Minimum and Maximum (5 yr term)

Option	Maximum: ($ / 1000 gal)	Maximum $ per Minimum offset: ($ / 1000 gal)	Maximum: Annual cost, $	Minimum: (GPD offset)
Alternative Water Source	$23.96	$58.76	$82,338	3,839
Row Covers	$3.80	$5.47	$17,209	8,620
Wind Machines	$11.55	$11.55	$23,173	5,498
Chemical Protectants	$0.17	$0.20	$261	3,665

Analysis Summary

Surface Water

Costs	Units	Unit Price	Existing Water Feature Expansion: Non-Blueberry Perennials Quantity	Total	Strawberries and Blueberries Quantity	Total	Container Nurseries Quantity	Total	Excavated Pond, Average: Non-Blueberry Perennials Quantity	Total	Strawberries and Blueberries Quantity	Total	Container Nurseries Quantity	Total	Excavated Pond, Large: Non-Blueberry Perennials Quantity	Total	Strawberries and Blueberries Quantity	Total	Container Nurseries Quantity	Total
Excavation cost	$/CuYd	$3.31	4,981	$16,489	21,413	$70,877	8,291	$27,442	9,963	$32,977	42,826	$141,754	16,582	$54,885	12,444	$41,191	70,844	$234,495	24,622	$81,500
Grading and hydroseeding	$/Acre	$805	0.7	$596	2.4	$1,949	1.1	$886	0.7	$596	2.4	$1,949	1.1	$886	0.9	$709	3.8	$3,020	1.5	$1,224
Flashboard riser	$/DialnFt	$1.33	144	$192	144	$192	144	$192	144	$192	144	$192	144	$192	144	$192	144	$192	144	$192
Culvert	$/DialnFt	$40.00	150	$6,000	150	$6,000	150	$6,000	150	$6,000	150	$6,000	150	$6,000	150	$6,000	150	$6,000	150	$6,000
Pump station (diesel) > 75 hp	$/BHP	$298	-	$0	100	$29,766	-	$0	-	$0	100	$29,766	-	$0	-	$0	100	$29,766	-	$0
Pump station (diesel) ($) > 50, < 70 hp	$/BHP	$386	50	$19,298	-	$0	50	$19,298	50	$19,298	-	$0	50	$19,298	50	$19,298	-	$0	50	$19,298
Shed/pad for pump station	$/System	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000	1	$7,000
Fuel tank	$/System	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400	1	$3,400
Meter	$/System	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000	1	$3,000
Fittings, valves, miscellaneous	$/Acre	$111	24	$2,651	27	$3,018	15	$1,640	24	$2,651	27	$3,018	15	$1,640	24	$2,651	27	$3,018	15	$1,640
Suction screen, self-cleaning	$/System	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004	1	$2,004
Filtration system, automated backflush	$/System	$10,696	2	$21,392	2	$21,392	2	$21,392	2	$21,392	2	$21,392	2	$21,392	2	$21,392	2	$21,392	2	$21,392
Pipe to irrigation system (12" PVC)	$/Ft	$11	1,531	$17,017	1,634	$18,162	1,204	$13,382	1,531	$17,017	1,634	$18,162	1,204	$13,382	1,531	$17,017	1,634	$18,162	1,204	$13,382
Design and Installation	$/Acre	$1,529	24	$36,579	27	$41,631	15	$22,629	24	$36,579	27	$41,631	15	$22,629	24	$36,579	27	$41,631	15	$22,629
Costs Total:				$135,618		$208,390		$128,265		$152,107		$279,267		$155,707		$160,433		$373,079		$182,660
Total Annual Amortized Cost (5 yr term):				$29,931		$45,991		$28,308		$33,570		$61,634		$34,364		$35,407		$82,338		$40,313
Total Annual Amortized Cost (lifetime of project):				$9,435		$14,497		$8,923		$10,582		$19,428		$10,832		$11,161		$25,954		$12,707

Benefits	Units	Unit Price	Existing Water Feature Expansion: Non-Blueberry Perennials Quantity	Total	Strawberries and Blueberries Quantity	Total	Container Nurseries Quantity	Total	Excavated Pond, Average: Non-Blueberry Perennials Quantity	Total	Strawberries and Blueberries Quantity	Total	Container Nurseries Quantity	Total	Excavated Pond, Large: Non-Blueberry Perennials Quantity	Total	Strawberries and Blueberries Quantity	Total	Container Nurseries Quantity	Total
Groundwater offset (GPD)	gal/day	-	-	3,839	-	10,713	-	4,553	-	3,839	-	10,713	-	4,553	-	4,821	-	16,337	-	6,249
Benefits Total (FFP):				3,839		10,713		4,553		3,839		10,713		4,553		4,821		16,337		6,249

Results: FFP Benefits	Existing Water Feature Expansion: Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries	Excavated Pond, Average: Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries	Excavated Pond, Large: Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Daily Cost per 1,000 GPD Offset (5 yr term):	$21.36	$11.76	$17.03	$23.96	$15.76	$20.68	$20.12	$13.81	$17.67
Daily Cost per 1,000 GPD Offset (lifetime of project):	$6.73	$3.71	$5.37	$7.55	$4.97	$6.52	$6.34	$4.35	$5.57

Analysis Summary

Wind Machines

Costs	Units	Unit Price	Wind Machines: Costs — Non-Blueberry Perennials Quantity	Non-Blueberry Perennials Total	Strawberries and Blueberries Quantity	Strawberries and Blueberries Total	Container Nurseries Quantity	Container Nurseries Total
Wind Machine, diesel, stationary tower	$/System	$35,000	3	$105,000	3	$105,000	2	$70,000
Costs Total:				$105,000		$105,000		$70,000
Total Annual Amortized Cost (5 yr term):				$23,173		$23,173		$15,449
Total Annual Amortized Cost (lifetime of project):				$7,305		$7,305		$4,870

Benefits	Units	Unit Price	Wind Machines: Benefits — Non-Blueberry Perennials Quantity	Non-Blueberry Perennials Total	Strawberries and Blueberries Quantity	Strawberries and Blueberries Total	Container Nurseries Quantity	Container Nurseries Total
Groundwater offset (GPD)	gal/day	-	-	5,498	-	16,990	-	6,465
Benefits Total:				5,498		16,990		6,465

Results	Wind Machines: Results — Non-Blueberry Perennials		Strawberries and Blueberries		Container Nurseries	
Daily Cost per 1,000 GPD Offset (5 yr term):		$11.55		$3.74		$6.55
Daily Cost per 1,000 GPD Offset (lifetime of project):		$3.64		$1.18		$2.06

Analysis Summary

Row Covers

Costs	Units	Unit Price	Row Covers – Costs: Non-Blueberry Perennials Quantity	Non-Blueberry Perennials Total	Strawberries and Blueberries Quantity	Strawberries and Blueberries Total	Container Nurseries Quantity	Container Nurseries Total	Row Covers with Mechanized Application/Retrieval – Costs: Non-Blueberry Perennials Quantity	Non-Blueberry Perennials Total	Strawberries and Blueberries Quantity	Strawberries and Blueberries Total	Container Nurseries Quantity	Container Nurseries Total
Row cover material	lnft x 7' width	$0.31	-	$0	169,433	$52,227	92,095	$28,388	-	$0	169,433	$52,227	92,095	$28,388
Row cover layer/retriever	System	$25,750	-	$0	-	$0	-	$0	-	$0	1	$25,750	1	$25,750
Weighted bags	Bags	$0	-	$0	-	$0	-	$0	-	$0	-	$0	-	$0
Costs Total:				$0		$52,227		$28,388		$0		$77,977		$54,138
Total Annual Amortized Cost (5 yr term):				$0		$11,526		$6,265		$0		$17,209		$11,948
Total Annual Amortized Cost (lifetime of project):				$0		$11,526		$6,265		$0		$17,209		$11,948

Benefits	Units	Unit Price	Row Covers – Benefits: Non-Blueberry Perennials Quantity	Non-Blueberry Perennials Total	Strawberries and Blueberries Quantity	Strawberries and Blueberries Total	Container Nurseries Quantity	Container Nurseries Total	Row Covers with Mechanized Application/Retrieval – Benefits: Non-Blueberry Perennials Quantity	Non-Blueberry Perennials Total	Strawberries and Blueberries Quantity	Strawberries and Blueberries Total	Container Nurseries Quantity	Container Nurseries Total
Groundwater offset (GPD)	gal/day	-	-	-	-	22,654	-	8,620	-	-	-	22,654	-	8,620
Benefits Total:						22,654		8,620				22,654		8,620

Results	Row Covers – Results: Non-Blueberry Perennials		Strawberries and Blueberries		Container Nurseries		Row Covers with Mechanized Application/Retrieval – Results: Non-Blueberry Perennials		Strawberries and Blueberries		Container Nurseries	
Daily Cost per 1,000 GPD Offset (5 yr term):				$1.39		$1.99				$2.08		$3.80
Daily Cost per 1,000 GPD Offset (lifetime of project):				$1.39		$1.99				$2.08		$3.80

Analysis Summary

Chemical Protectants

Costs	Units	Unit Price	Non-Blueberry Perennials Quantity	Non-Blueberry Perennials Total	Strawberries and Blueberries Quantity	Strawberries and Blueberries Total	Container Nurseries Quantity	Container Nurseries Total
			Chemical Protectants – Costs					
Desikote concentrate	Gallons	$105	1.98	$208	2.25	$237	1.23	$129
Costs Total:				$208		$237		$129
Total Annual Amortized Cost (5 yr term):				$230		$261		$142
Total Annual Amortized Cost (project lifetime):				$215		$245		$133

Benefits	Units	Unit Price	Non-Blueberry Quantity	Non-Blueberry Total	Strawberries and Quantity	Strawberries and Total	Container Nurseries Quantity	Container Nurseries Total
			Chemical Protectants – Benefits					
Groundwater offset (GPD)	gal/day	-	-	3,665	-	11,327	-	4,310
Benefits Total:				3,665		11,327		4,310

Results	Non-Blueberry	Strawberries and	Container Nurseries
	Chemical Protectants – Results		

Reference Values
Surface Water

Benefits	Units	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Existing Water Feature Expansion	GPD	3,839	10,713	4,553
Excavated Pond, Average	GPD	3,839	10,713	4,553
Excavated Pond, Large	GPD	4,821	16,337	6,249

Costs	Unit	Unit Price	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Excavation cost, Existing	CuYd	$3.31	4,981	21,413	8,291
Excavation cost, Average	CuYd	$3.31	9,963	42,826	16,582
Excavation cost, Large	CuYd	$3.31	12,444	70,844	24,622
Grading and hydroseeding, Existing and Average	Acres	$805	0.7	2.4	1.1
Grading and hydroseeding, Large	Acres	$805	0.9	3.8	1.5
Flashboard riser	Dia(in)*Ft	$1.33	144	144	144.0
Culvert	ft, 24in metal	$40.00	150	150	150
Pump station (diesel) > 75 hp	BHP	$298	-	100	-
Pump station (diesel) ($) > 50, < 70 hp	BHP	$386	50	-	50
Shed/pad for pump station	System	$7,000	1	1	1
Fuel tank	System	$3,400	1	1	1
Meter	System	$3,000	1	1	1
Fittings, valves, miscellaneous	Acres	$111	24	27	15
Suction screen, self-cleaning	System	$2,004	1	1	1
Filtration system, automated backflush	System	$10,696	2	2	2
Pipe to irrigation system (assume 12")	Ft	$11	1,531	1,634	1,204
Design and Installation	Acres	$1,529	24	27	15

Reference Values
Wind Machines

Benefits	Units	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Wind Machines (27 F)	GPD	5,498	16,990	6,465
Wind Machines (29 F)	GPD	3,665	11,327	4,310

Costs	Unit	Unit Price	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Wind Machine, diesel, stationary tower	Station	$35,000	3	3	2

Reference Values
Row Covers

Benefits	Units	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Row Covers	GPD	7,331	22,654	8,620
Row Covers with mechanized application/retrieval	GPD	7,331	22,654	8,620

Costs	Unit	Unit Price	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Row cover material	lnft x 7' width	$0.31	0.00	169,433	92,095
Row cover layer/retriever	System	$25,750	0.00	1.00	1.00
Weighted bags	Bags	$0	0.00	0.00	0.00

Reference Values
Chemical Protectants

Benefits	Units	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Chemical Crop Protectants for FFP alternative (30 F)	GPD	3,665	11,327	4,310
Chemical Crop Protectants for FFP alternative (28 F)	GPD	5,498	16,990	6,465

Costs	Unit	Unit Price	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
Desikote concentrate	Gallons	$105	1.98	2.25	1.23

Source	Units	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
FSAID 2015; Acres, by Permit ID	Acres	23.9	27.2	14.8
FSAID 2015; Acres, by polygon	Acres	16.5	9.2	7.0
DPCWUCA, acres	Acres	2,919.0	8,087.0	665.0
Average freeze events per year	Events	5.0	5.0	5.0
Freeze protection duration, hours/event	Hours/event	14.0	14.0	14.0
FFP irrigation, in/yr	in/yr	5.2	14.0	9.8
AGMOD; irrigation, in/yr	in/yr	17.3	33.1	53.0
AGMOD NIR; irrigation, in/yr	in/yr	12.3	23.7	36.1

Amortization Factor			
Irrigation Type	Year	Interest Rate	Reference
FFP	1	3.375%	Chemical Protectants (Desikote)
FFP	5	3.375%	Row Covers
AAD	10	3.375%	Conservation
AAD	15	3.375%	Irrigation Conversion
AAD, FFP	20	3.375%	Alternative water source, Surface Water, Wind machine
AAD, FFP	5	3.375%	5 year contract length
AAD, FFP	30	3.375%	30 year contract length
Amortization Factor	HP 12C amortization formula		
	Algebraic amortization formula (http://www.vertex42.com/ExcelArticles/amortization-		

$$A = P\frac{i(1+i)^n}{(1+i)^n - 1} = \frac{P \times i}{1-(1+i)^{-n}} = P\left(i + \frac{i}{(1+i)^n - 1}\right)$$

Where:

A = periodic payment amount
P = amount of principal, net of initial payments, meaning "subtract any down-payments"
i = periodic interest rate
n = total number of payments

This formula is valid if i > 0. If i = 0 then simply A = P / n.

Source	Units	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
FSAID 2015; Acres, by Permit ID	Acres	23.9	27.2	14.8
FSAID 2015; Acres, by polygon	Acres	16.5	9.2	7.0
DPCWUCA, acres	Acres	2,919.0	8,087.0	665.0
Average freeze events per year	Events	5.0	5.0	5.0
Freeze protection duration, hours/event	Hours/event	14.0	14.0	14.0
FFP irrigation, in/yr	in/yr	5.2	14.0	9.8
AGMOD; irrigation, in/yr	in/yr	17.3	33.1	53.0
AGMOD NIR; irrigation, in/yr	in/yr	12.3	23.7	36.1

Amortization Factor			
Irrigation Type	Year	Interest Rate	Reference
FFP	1	3.375%	Chemical Protectants (Desikote)
FFP	5	3.375%	Row Covers
AAD	10	3.375%	Conservation
AAD	15	3.375%	Irrigation Conversion
AAD, FFP	20	3.375%	Alternative water source, Surface Water, Wind machine
AAD, FFP	5	3.375%	5 year contract length
AAD, FFP	30	3.375%	30 year contract length
Amortization Factor	HP 12C amortization formula		
	Algebraic amortization formula (http://www.vertex42.com/ExcelArticles/amortization-		

$$A = P\frac{i(1+i)^n}{(1+i)^n - 1} = \frac{P \times i}{1-(1+i)^{-n}} = P\left(i + \frac{i}{(1+i)^n - 1}\right)$$

Where:

A = periodic payment amount

P = amount of principal, net of initial payments, meaning "subtract any down-payments"

i = periodic interest rate

n = total number of payments

This formula is valid if i > 0. If i = 0 then simply A = P / n.

Source	Units	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
FSAID 2015; Acres, by Permit ID	Acres	23.9	27.2	14.8
FSAID 2015; Acres, by polygon	Acres	16.5	9.2	7.0
DPCWUCA, acres	Acres	2,919.0	8,087.0	665.0
Average freeze events per year	Events	5.0	5.0	5.0
Freeze protection duration, hours/event	Hours/event	14.0	14.0	14.0
FFP irrigation, in/yr	in/yr	5.2	14.0	9.8
AGMOD; irrigation, in/yr	in/yr	17.3	33.1	53.0
AGMOD NIR; irrigation, in/yr	in/yr	12.3	23.7	36.1

Amortization Factor			
Irrigation Type	Year	Interest Rate	Reference
FFP	1	3.375%	Chemical Protectants (Desikote)
FFP	5	3.375%	Row Covers
AAD	10	3.375%	Conservation
AAD	15	3.375%	Irrigation Conversion
AAD, FFP	20	3.375%	Alternative water source, Surface Water, Wind machine
AAD, FFP	5	3.375%	5 year contract length
AAD, FFP	30	3.375%	30 year contract length
Amortization Factor	HP 12C amortization formula		
	Algebraic amortization formula (http://www.vertex42.com/ExcelArticles/amortization-		

$$A = P\frac{i(1+i)^n}{(1+i)^n - 1} = \frac{P \times i}{1-(1+i)^{-n}} = P\left(i + \frac{i}{(1+i)^n - 1}\right)$$

Where:

A = periodic payment amount

P = amount of principal, net of initial payments, meaning "subtract any down-payments"

i = periodic interest rate

n = total number of payments

This formula is valid if i > 0. If i = 0 then simply A = P / n.

Source	Units	Non-Blueberry Perennials	Strawberries and Blueberries	Container Nurseries
FSAID 2015; Acres, by Permit ID	Acres	23.9	27.2	14.8
FSAID 2015; Acres, by polygon	Acres	16.5	9.2	7.0
DPCWUCA, acres	Acres	2,919.0	8,087.0	665.0
Average freeze events per year	Events	5.0	5.0	5.0
Freeze protection duration, hours/event	Hours/event	14.0	14.0	14.0
FFP irrigation, in/yr	in/yr	5.2	14.0	9.8
AGMOD; irrigation, in/yr	in/yr	17.3	33.1	53.0
AGMOD NIR; irrigation, in/yr	in/yr	12.3	23.7	36.1

Amortization Factor			
Irrigation Type	Year	Interest Rate	Reference
FFP	1	3.375%	Chemical Protectants (Desikote)
FFP	5	3.375%	Row Covers
AAD	10	3.375%	Conservation
AAD	15	3.375%	Irrigation Conversion
AAD, FFP	20	3.375%	Alternative water source, Surface Water, Wind machine
AAD, FFP	5	3.375%	5 year contract length
AAD, FFP	30	3.375%	30 year contract length
Amortization Factor	HP 12C amortization formula		
	Algebraic amortization formula (http://www.vertex42.com/ExcelArticles/amortization-		

$$A = P\frac{i(1+i)^n}{(1+i)^n - 1} = \frac{P \times i}{1 - (1+i)^{-n}} = P\left(i + \frac{i}{(1+i)^n - 1}\right)$$

Where:

A = periodic payment amount

P = amount of principal, net of initial payments, meaning "subtract any down-payments"

i = periodic interest rate

n = total number of payments

This formula is valid if i > 0. If i = 0 then simply A = P / n.

Analysis Summary

N Reduction Strategies; Total and 5-year Annualized Costs

Option	Total costs ($)	Annualized Cost ($)	Benefits (Nitrogen in lb/yr)	Cost per Pound of N
Variable Rate N: Sensor-based				
Hay	$49,459	$10,915	151	$72
Field Crops	$50,203	$11,080	378	$29
Variable Rate N: Map-based				
Hay	$29,459	$6,501	89	$73
Field Crops	$30,203	$6,666	224	$30
N Simulation Software				
Hay	$1,995	$440	309	$1
Field Crops	$2,739	$604	773	$1
Vegetables	$2,227	$491	454	$1
Perennial Fruits	$1,875	$414	234	$2
Fertigation				
Field Crops	$4,500	$993	286	$3
Vegetables	$4,500	$993	168	$6
Perennial Fruits	$4,500	$993	87	$11
Equipment Guidance System				
Hay	$27,448	$6,058	39	$156
Field Crops	$27,448	$6,058	97	$62

Analysis Summary

N Retention Strategies; Total and 5-year Annualized Costs

Option	Total costs ($)	Annualized Cost ($)	Benefits (Nitrogen in lb/yr)	Cost per Pound of N
Vegetative Filter Strips				
Horse Farms	$293	$65	12	$5
Livestock Grazing	$662	$146	64	$2
Dairy	$572	$126	48	$3
Hay	$504	$111	37	$3
Field Crops	$796	$176	92	$2
Vegetables	$610	$135	54	$2
Perennial Fruits	$439	$97	28	$3
Tailwater Recovery				
Dairy	$390,397	$86,160	952	$91
Field Crops	$488,409	$107,791	1,845	$58
Vegetables	$404,772	$89,332	1,083	$82
Perennial Fruits	$347,271	$76,642	559	$137
Manure Storage Buildings				
Horse Farms	$13,608	$3,003	16	$191
Livestock Grazing	$13,608	$3,003	80	$37
Denitrification Wall				
Horse Farms	$17,841	$3,938	110	$36
Livestock Grazing	$17,841	$3,938	562	$7
Dairy	$17,841	$3,938	420	$9
Treatment Wetland				
Horse Farms	$34,195	$7,547	50	$151
Livestock Grazing	$34,195	$7,547	255	$30
Dairy	$55,708	$12,295	190	$65
Pond Lining (Plastic)				
Dairy	$314,981	$69,516	2,648	$26
Pond Lining (Concrete)				
Dairy	$447,198	$98,696	2,648	$37
Interceptor Wells/Bioreactor				
Dairy	$91,107	$20,107	2,586	$8

Analysis Summary

Average Total and Annualized Costs, 5-year term

Option	Total costs ($)	Annualized Cost ($)	Benefits (Nitrogen in lb/yr)	Cost per Pound of N
N Reduction				
Variable Rate N: Sensor-based	$49,831	$10,997	264	$ 51
Variable Rate N: Map-based	$29,831	$6,584	156	$ 51
N Simulation Software	$2,209	$488	442	$ 1
Fertigation	$4,500	$993	180	$ 7
Equipment Guidance System	$27,448	$6,058	68	$ 109
N Retention				
Vegetative Filter Strips	$554	$122	48	$ 3
Tailwater Recovery	$407,712	$89,981	1110	$ 92
Manure Storage Buildings	$13,608	$3,003	48	$ 114
Denitrification Wall	$17,841	$3,938	364	$ 17
Treatment Wetland	$41,366	$9,129	165	$ 82
Pond Lining (Plastic)	$314,981	$69,516	2648	$ 26
Pond Lining (Concrete)	$447,198	$98,696	2648	$ 37
Interceptor Wells/Bioreactor	$91,107	$20,107	2586	$ 8

Analysis Summary

Project Lifetime Annualized Costs

Option	Total costs ($)	Annualized Cost ($)	Benefits (Nitrogen in lb/yr)	Cost per Pound of N
N Reduction				
Variable Rate N: Sensor-based	$49,831	$5,954	264	$ 23
Variable Rate N: Map-based	$29,831	$3,564	156	$ 23
N Simulation Software	$2,209	$488	442	$ 1
Fertigation	$4,500	$538	180	$ 3
Equipment Guidance System	$27,448	$3,280	68	$ 48
N Retention				
Vegetative Filter Strips	$554	$66	48	$ 1
Tailwater Recovery	$407,712	$28,364	1,110	$ 26
Manure Storage Buildings	$13,608	$947	48	$ 20
Denitrification Wall	$17,841	$1,535	364	$ 4
Treatment Wetland	$41,366	$2,878	165	$ 17
Pond Lining (Plastic)	$314,981	$21,913	2,648	$ 8
Pond Lining (Concrete)	$447,198	$31,110	2,648	$ 12
Interceptor Wells/Bioreactor	$91,107	$6,338	2,586	$ 2

Analysis Summary

Average Total and Annualized Costs, 5-year term

Option	Total costs ($)	Average Annualized Cost ($)	Average Benefits (Nitrogen in Pounds)	Average Annualized Cost per Pound of N
N Reduction Strategies	$27,902	$6,158	167	$55
N Retention Strategies	$166,796	$36,812	1202	$47

Analysis Summary

5-year Annualized Costs

Option	Maximum costs per benefit ($/lb N)	Maximum $ per Minimum benefit ($/lb N)	Maximum: Annual cost, $	Minimum: benefit, lb N
N Reduction				
Variable Rate N: Sensor-based	$72	$73	$11,080	151
Variable Rate N: Map-based	$73	$75	$6,666	89
N Simulation Software	$2	$3	$604	234
Fertigation	$11	$11	$993	87
Equipment Guidance System	$156	$156	$6,058	39
N Retention				
Vegetative Filter Strips	$5	$14	$176	12
Tailwater Recovery	$137	$193	$107,791	559
Manure Storage Buildings	$191	$191	$3,003	16
Denitrification Wall	$36	$36	$3,938	110
Treatment Wetland	$151	$246	$12,295	50
Pond Lining (Plastic)	$26	$26	$69,516	2,648
Pond Lining (Concrete)	$37	$37	$98,696	2,648
Interceptor Wells/Bioreactor	$8	$8	$20,107	2,586

Analysis Summary

N Reduction Strategies

			Horse Farms		Livestock Grazing		Dairy		Hay							
Costs	Units	Unit Price	Costs N/A		Costs N/A		Costs N/A		Costs Variable Rate N: Sensor-based		Costs Variable Rate N: Map-based		Costs N Simulation Software		Costs Equipment Guidance System	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Variable Rate N: Sensor-based																
Reflectance Sensors	Each	$20,000							1	$20,000						
Variable Rate Spray Controller	Each	$2,298							1	$2,298						
GPS Receiver	Each	$25,665							1	$25,665						
Installation/Setup	Install	$1,000							1	$1,000						
Soil Sampling	Acre	$8							62	$496						
Variable Rate N: Map-based																
Variable Rate Spray Controller	Each	$2,298									1	$2,298				
GPS Receiver	Each	$25,665									1	$25,665				
Installation/Setup	Install	$1,000									1	$1,000				
Soil Sampling	Acre	$8									62	$496				
N Simulation Software																
Smartphone or Tablet	Each	$500											1	$500		
Annual Subscription	License Fee	$999											1	$999		
Installation/Setup	Install	$0											1	$0		
Soil Sampling	Acre	$8											62	$496		
Fertigation																
Tank	Each	$500														
Injection Pump	Each	$2,000														
Valves	Each	$250														
Controller	Each	$1,000														
Complete System	Each	$4,225														
Installation/Setup	Install	$750														
Soil Sampling	Acre	$0														
Equipment Guidance System																
Lightbar with DGPS Receiver	Each	$3,448													1	$3,448
Autosteer with RTK GPS Receiver	Each	$23,250													1	$23,250
Installation/Setup	Install	$750													1	$750
Soil Sampling	Acre	$0													62	$0
Costs Total:				$0		$0		$0		$49,459		$29,459		$1,995		$27,448
Total Annual Amortized Cost (5-year):				$0		$0		$0		$10,915		$6,501		$440		$6,058
Total Annual Amortized Cost (project lifetime):				$0		$0		$0		$5,910		$3,520		$440		$3,280

	Field Crops										Vegetables				Perennial Fruits			
Costs	Costs Variable Rate N: Sensor-based		Costs Variable Rate N: Map-based		Costs N Simulation Software		Costs Fertigation		Costs Equipment Guidance System		Costs N Simulation Software		Costs Fertigation		Costs N Simulation Software		Costs Fertigation	
	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Variable Rate N: Sensor-based																		
Reflectance Sensors	1	$20,000																
Variable Rate Spray Controller	1	$2,298																
GPS Receiver	1	$25,665																
Installation/Setup	1	$1,000																
Soil Sampling	155	$1,240																
Variable Rate N: Map-based																		
Variable Rate Spray Controller			1	$2,298														
GPS Receiver			1	$25,665														
Installation/Setup			1	$1,000														
Soil Sampling			155	$1,240														
N Simulation Software																		
Smartphone or Tablet					1	$500					1	$500			1	$500		
Annual Subscription					1	$999					1	$999			1	$999		
Installation/Setup					1	$0					1	$0			1	$0		
Soil Sampling					155	$1,240					91	$728			47	$376		
Fertigation																		
Tank							1	$500					1	$500			1	$500
Injection Pump							1	$2,000					1	$2,000			1	$2,000
Valves							1	$250					1	$250			1	$250
Controller							1	$1,000					1	$1,000			1	$1,000
Complete System							0	$0					0	$0			0	$0
Installation/Setup							1	$750					1	$750			1	$750
Soil Sampling							155	$0					91	$0			47	$0
Equipment Guidance System																		
Lightbar with DGPS Receiver									1	$3,448								
Autosteer with RTK GPS Receiver									1	$23,250								
Installation/Setup									1	$750								
Soil Sampling									155	$0								
Costs Total:		$50,203		$30,203		$2,739		$4,500		$27,448		$2,227		$4,500		$1,875		$4,500
Total Annual Amortized Cost (5-year):		$11,080		$6,666		$604		$993		$6,058		$491		$993		$414		$993
Total Annual Amortized Cost (project lifetime):		$5,998		$3,609		$604		$538		$3,280		$491		$538		$414		$538

			Horse Farms		Livestock Grazing		Dairy		Hay							
Benefits	Units	Nitrogen Reduction	Benefits N/A		Benefits N/A		Benefits N/A		Benefits Variable Rate N: Sensor-based		Benefits Variable Rate N: Map-based		Benefits N Simulation Software		Benefits Equipment Guidance System	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Variable rate N; Sensor-based	lb/acre/yr	2.44							62	151						
Variable rate N; Map-based	lb/acre/yr	1.44									62	89				
N Simulation Software	lb/acre/yr	4.99											62	309		
Fertigation	lb/acre/yr	1.84														
Equipment Guidance System	lb/acre/yr	0.63													62	39
Benefits Total:				0		0		0		151		89		309		39

	Field Crops										Vegetables				Perennial Fruits			
Benefits	Benefits Variable Rate N: Sensor-based		Benefits Variable Rate N: Map-based		Benefits N Simulation Software		Benefits Fertigation		Benefits Equipment Guidance System		Benefits N Simulation Software		Benefits Fertigation		Benefits N Simulation Software		Benefits Fertigation	
	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Variable rate N; Sensor-based	155	378																
Variable rate N; Map-based			155	224														
N Simulation Software					155	773					91	454			47	234		
Fertigation							155	286					91	168			47	87
Equipment Guidance System									155	97								
Benefits Total:		378		224		773		286		97		454		168		234		87

	Horse Farms		Livestock Grazing		Dairy		Hay							
Benefits	Results N/A		Results N/A		Results N/A		Results Variable Rate N: Sensor-based		Results Variable Rate N: Map-based		Results N Simulation Software		Results Equipment Guidance System	
Cost per Pound of Nitrogen Reduction:		$0		$0		$0		$327.38		$329.47		$6.45		$707.28
Cost per Pound of Nitrogen Reduction (5 year):		$0		$0		$0		$72.25		$72.71		$1.42		$156.09
Cost per Pound of Nitrogen Reduction (Project Lifetime):		$0		$0		$0		$39.12		$39.37		$1.42		$84.51

	Field Crops										Vegetables				Perennial Fruits			
Benefits	Results Variable Rate N: Sensor-based		Results Variable Rate N: Map-based		Results N Simulation Software		Results Fertigation		Results Equipment Guidance System		Results N Simulation Software		Results Fertigation		Results N Simulation Software		Results Fertigation	
Cost per Pound of Nitrogen Reduction:		$132.92		$135.12		$3.54		$15.74		$282.91		$4.91		$26.81		$8.00		$51.91
Cost per Pound of Nitrogen Reduction (5 year):		$29.34		$29.82		$0.78		$3.47		$62.44		$1.08		$5.92		$1.77		$11.46
Cost per Pound of Nitrogen Reduction (Project Lifetime):		$15.88		$16.14		$0.78		$1.88		$33.80		$1.08		$3.20		$1.77		$6.20

Analysis Summary

N Retention Strategies

Costs	Units	Unit Price	Horse Farms								Livestock Grazing							
			Costs		Costs		Costs		Costs		Costs		Costs		Costs		Costs	
			Vegetative Filter Strips		Manure Storage Buildings		Denitrification Wall		Treatment Wetland		Vegetative Filter Strips		Manure Storage Buildings		Denitrification Wall		Treatment Wetland	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Vegetative Filter Strips																		
Land, Design & Vegetation	Acres	$223	1.32	$293							2.97	$662						
Tailwater Recovery																		
Excavation Cost	CuYd	$3																
Grading and Hydroseeding	Acre	$805																
Flashboard Riser	Dia(in)*Feet	$1																
Culvert	Feet, 24in Metal	$40																
Pump Station (Diesel) > 75 hp	bhp	$298																
Shed/pad for Pump Station	Each	$7,000																
Fuel Tank	Each	$3,400																
Meter	Each	$3,000																
Fittings, Valves, Miscellaneous	Acre	$111																
Suction Screen, Self-cleaning	Each	$2,004																
Filtration System, Automated Backflush	Each	$10,696																
Pipe to Irrigation System (Assume 12")	Feet/Acre	$11																
Design and Installation	Acre	$1,196																
Manure Storage Buildings																		
Slab	SqFt	$6			900	$4,968							900	$4,968				
Shed	SqFt	$10			900	$8,640							900	$8,640				
Denitrification Wall																		
Excavation (Structure)	CuYd	$3					504	$1,332							504	$1,332		
Wood Chips	CuYd	$60					275	$16,510							275	$16,510		
Treatment Wetland																		
Excavation	CuYd	$3							6,441	$17,004							6,441	$17,004
Vegetation	Each	$1							19,312	$17,191							19,312	$17,191
Plumbing	Each	$11,128							1	$11,128							1	$11,128
Control Structures	Each	$10,386							1	$10,386							1	$10,386
Pond Lining (Plastic)																		
Excavation	CuYd	$3																
Flexible Membrane Liner	SqYd	$43																
Large Diameter PVC, Waster Transfer	Feet	$31																
Pond Lining (Concrete)																		
Excavation	CuYd	$3																
Reinforced Concrete Liner (4 in. thick)	SqYd	$64																
Large Diameter PVC, Waster Transfer	Feet	$31																
Interceptor Wells/Bioreactor																		
Wells (4" dia, 60' deep)	Each	$4,000																
Electric Pump (20 gpm/well)	Each	$700																
Wiring/Control Panel	Feet	$2																
Piping (2" PVC)	Feet	$3																
Piping (3" PVC)	Feet	$4																
Piping (4" PVC)	Feet	$4																
Pond Excavation	CuYd	$3																
Plastic Lined Pond	SqFt	$1																
Organic Matrix	CuYd	$60																
Sand/Gravel	CuYd	$25																
Under Drainpipes	Feet	$1																
Pond Cover	SqFt	$0																
Fencing	Feet	$2																
Infiltration Ditch	Feet	$1																
Flowmeter/Stage Records	Each	$1,000																
Sample Collection	Each	$100																
Analytical Costs	Each	$50																
Design, Oversight	Hours	$150																
Costs Total:				$293		$13,608		$17,841		$34,195		$662		$13,608		$17,841		$34,195
Total Annual Amortized Cost (5-year):				$65		$3,003		$3,938		$7,547		$146		$3,003		$3,938		$7,547
Total Annual Amortized Cost (project lifetime):				$35		$947		$1,535		$2,379		$79		$947		$1,535		$2,379

Costs	Dairy													
	Costs		Costs		Costs		Costs		Costs		Costs		Costs	
	Vegetative Filter Strips		Tailwater Recovery		Denitrification Wall		Treatment Wetland		Pond Lining (Plastic)		Pond Lining (Concrete)		Interceptor Wells/Bioreactor	
	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Vegetative Filter Strips														
Land, Design & Vegetation	2.57	$572												
Tailwater Recovery														
Excavation Cost			45,400	$150,274										
Grading and Hydroseeding			3	$2,013										
Flashboard Riser			144	$192										
Culvert			400	$16,000										
Pump Station (Diesel) > 75 hp			125	$37,208										
Shed/pad for Pump Station			1	$7,000										
Fuel Tank			1	$3,400										
Meter			1	$3,000										
Fittings, Valves, Miscellaneous			80	$8,866										
Suction Screen, Self-cleaning			1	$2,004										
Filtration System, Automated Backflush			2	$21,392										
Pipe to Irrigation System (Assume 12")			3,900	$43,368										
Design and Installation			80	$95,680										
Manure Storage Buildings														
Slab														
Shed														
Denitrification Wall														
Excavation (Structure)					504	$1,332								
Wood Chips					275	$16,510								
Treatment Wetland														
Excavation							6,441	$17,004						
Vegetation							19,312	$17,191						
Plumbing							1	$11,128						
Control Structures							1	$10,386						
Pond Lining (Plastic)														
Excavation									17,963	$47,422				
Flexible Membrane Liner									6,188	$264,432				
Large Diameter PVC, Waster Transfer									100	$3,127				
Pond Lining (Concrete)														
Excavation											17,963	$47,422		
Reinforced Concrete Liner (4 in. thick)											6,188	$396,648		
Large Diameter PVC, Waster Transfer											100	$3,127		
Interceptor Wells/Bioreactor														
Wells (4" dia, 60' deep)													6	$24,000
Electric Pump (20 gpm/well)													6	$4,200
Wiring/Control Panel													3,780	$5,670
Piping (2" PVC)													2,520	$6,955
Piping (3" PVC)													1,260	$4,662
Piping (4" PVC)													891	$3,840
Pond Excavation													426	$1,278
Plastic Lined Pond													1,913	$1,913
Organic Matrix													284	$17,040
Sand/Gravel													71	$1,775
Under Drainpipes													220	$132
Pond Cover													1,913	$631
Fencing													200	$400
Infiltration Ditch													360	$360
Flowmeter/Stage Records													1	$1,000
Sample Collection													15	$1,500
Analytical Costs													15	$750
Design, Oversight													100	$15,000
Costs Total:		$572		$390,397		$17,841		$55,708		$314,981		$447,198		$91,107
Total Annual Amortized Cost (5-year):		$126		$86,160		$3,938		$12,295		$69,516		$98,696		$20,107
Total Annual Amortized Cost (project lifetime):		$68		$27,159		$1,535		$3,876		$21,913		$31,110		$6,338

Costs	Hay		Field Crops				Vegetables				Perennial Fruits			
	Costs		Costs		Costs		Costs		Costs		Costs		Costs	
	Vegetative Filter Strips		Vegetative Filter Strips		Tailwater Recovery		Vegetative Filter Strips		Tailwater Recovery		Vegetative Filter Strips		Tailwater Recovery	
	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Vegetative Filter Strips														
Land, Design & Vegetation	2.26	$504	3.58	$796			2.74	$610			1.97	$439		
Tailwater Recovery														
Excavation Cost					45,400	$150,274			45,400	$150,274			45,400	$150,274
Grading and Hydroseeding					3	$2,013			3	$2,013			3	$2,013
Flashboard Riser					144	$192			144	$192			144	$192
Culvert					400	$16,000			400	$16,000			400	$16,000
Pump Station (Diesel) > 75 hp					125	$37,208			125	$37,208			125	$37,208
Shed/pad for Pump Station					1	$7,000			1	$7,000			1	$7,000
Fuel Tank					1	$3,400			1	$3,400			1	$3,400
Meter					1	$3,000			1	$3,000			1	$3,000
Fittings, Valves, Miscellaneous					155	$17,179			91	$10,086			47	$5,209
Suction Screen, Self-cleaning					1	$2,004			1	$2,004			1	$2,004
Filtration System, Automated Backflush					2	$21,392			2	$21,392			2	$21,392
Pipe to Irrigation System (Assume 12")					3,900	$43,368			3,900	$43,368			3,900	$43,368
Design and Installation					155	$185,380			91	$108,836			47	$56,212
Manure Storage Buildings														
Slab														
Shed														
Denitrification Wall														
Excavation (Structure)														
Wood Chips														
Treatment Wetland														
Excavation														
Vegetation														
Plumbing														
Control Structures														
Pond Lining (Plastic)														
Excavation														
Flexible Membrane Liner														
Large Diameter PVC, Waster Transfer														
Pond Lining (Concrete)														
Excavation														
Reinforced Concrete Liner (4 in. thick)														
Large Diameter PVC, Waster Transfer														
Interceptor Wells/Bioreactor														
Wells (4" dia, 60' deep)														
Electric Pump (20 gpm/well)														
Wiring/Control Panel														
Piping (2" PVC)														
Piping (3" PVC)														
Piping (4" PVC)														
Pond Excavation														
Plastic Lined Pond														
Organic Matrix														
Sand/Gravel														
Under Drainpipes														
Pond Cover														
Fencing														
Infiltration Ditch														
Flowmeter/Stage Records														
Sample Collection														
Analytical Costs														
Design, Oversight														
Costs Total:		$504		$796		$488,409		$610		$404,772		$439		$347,271
Total Annual Amortized Cost (5-year):		$111		$176		$107,791		$135		$89,332		$97		$76,642
Total Annual Amortized Cost (project lifetime):		$60		$95		$33,977		$73		$28,159		$52		$24,159

Benefits	Units	Nitrogen Retention	Horse Farms								Livestock Grazing							
			Benefits		Benefits		Benefits		Benefits		Benefits		Benefits		Benefits		Benefits	
			Vegetative Filter Strips		Manure Storage Buildings		Denitrification Wall		Treatment Wetland		Vegetative Filter Strips		Manure Storage Buildings		Denitrification Wall		Treatment Wetland	
			Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Vegetative Filter Strips	lb/acre/yr	0.60	21	12							107	64						
Tailwater Recovery	lb/acre/yr	11.90																
Manure Storage Buildings	lb/acre/yr	0.75			21	16							107	80				
Denitrification Wall	lb/acre/yr	5.25					21	110							107	562		
Treatment Wetland	lb/acre/yr	2.38							21	50							107	255
Pond Lining (Plastic)	lb/acre/yr	33.10																
Pond Lining (Concrete)	lb/acre/yr	33.10																
Interceptor Wells/Bioreactor	lb/acre/yr	32.33																
Benefits Total:				12		16		110		50		64		80		562		255

Benefits	Dairy													
	Benefits		Benefits		Benefits		Benefits		Benefits		Benefits		Benefits	
	Vegetative Filter Strips		Tailwater Recovery		Denitrification Wall		Treatment Wetland		Pond Lining (Plastic)		Pond Lining (Concrete)		Interceptor Wells/Bioreactor	
	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Vegetative Filter Strips	80	48												
Tailwater Recovery			80	952										
Manure Storage Buildings														
Denitrification Wall					80	420								
Treatment Wetland							80	190						
Pond Lining (Plastic)									80	2,648				
Pond Lining (Concrete)											80	2,648		
Interceptor Wells/Bioreactor													80	2,586
Benefits Total:		48		952		420		190		2,648		2,648		2,586

Benefits	Hay		Field Crops				Vegetables				Perennial Fruits			
	Benefits		Benefits		Benefits		Benefits		Benefits		Benefits		Benefits	
	Vegetative Filter Strips		Vegetative Filter Strips		Tailwater Recovery		Vegetative Filter Strips		Tailwater Recovery		Vegetative Filter Strips		Tailwater Recovery	
	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total	Quantity	Total
Vegetative Filter Strips	62	37	155	92			91	54			47	28		
Tailwater Recovery					155	1,845			91	1,083			47	559
Manure Storage Buildings														
Denitrification Wall														
Treatment Wetland														
Pond Lining (Plastic)														
Pond Lining (Concrete)														
Interceptor Wells/Bioreactor														
Benefits Total:		37		92		1,845		54		1,083		28		559

Benefits	Horse Farms				Livestock Grazing			
	Results	Results	Results	Results	Results	Results	Results	Results
	Vegetative Filter Strips	Manure Storage Buildings	Denitrification Wall	Treatment Wetland	Vegetative Filter Strips	Manure Storage Buildings	Denitrification Wall	Treatment Wetland
Cost per Pound of Nitrogen Retention:	$23.46	$864.00	$161.83	$684.18	$10.39	$169.57	$31.76	$134.29
Cost per Pound of Nitrogen Retention (5 year):	$5.18	$190.68	$35.71	$151.00	$2.29	$37.42	$7.01	$29.63
Cost per Pound of Nitrogen Retention (Project Lifetime):	$2.80	$60.11	$13.93	$47.60	$1.24	$11.80	$2.73	$9.34

Benefits	Dairy						
	Results	Results	Results	Results	Results	Results	Results
	Vegetative Filter Strips	Tailwater Recovery	Denitrification Wall	Treatment Wetland	Pond Lining (Plastic)	Pond Lining (Concrete)	Interceptor Wells/Bioreactor
Cost per Pound of Nitrogen Retention:	$12.02	$410.08	$42.48	$292.59	$118.95	$168.88	$35.23
Cost per Pound of Nitrogen Retention (5 year):	$2.65	$90.50	$9.38	$64.57	$26.25	$37.27	$7.77
Cost per Pound of Nitrogen Retention (Project Lifetime):	$1.44	$28.53	$3.66	$20.35	$8.28	$11.75	$2.45

Benefits	Hay	Field Crops		Vegetables		Perennial Fruits	
	Results	Results	Results	Results	Results	Results	Results
	Vegetative Filter Strips	Vegetative Filter Strips	Tailwater Recovery	Vegetative Filter Strips	Tailwater Recovery	Vegetative Filter Strips	Tailwater Recovery
Cost per Pound of Nitrogen Retention:	$13.66	$8.64	$264.79	$11.27	$373.79	$15.68	$620.90
Cost per Pound of Nitrogen Retention (5 year):	$3.01	$1.91	$58.44	$2.49	$82.49	$3.46	$137.03
Cost per Pound of Nitrogen Retention (Project Lifetime):	$1.63	$1.03	$18.42	$1.35	$26.00	$1.87	$43.19

Reference Values

N Reduction Strategies

Benefits	Units	Nitrogen Reduction	Description
Variable rate N; Sensor-based	lb/acre/yr	2.44	Reduced leaching N
Variable rate N; Map-based	lb/acre/yr	1.44	Reduced leaching N
N Simulation Software	lb/acre/yr	4.99	Reduced leaching N
Fertigation	lb/acre/yr	1.84	Reduced leaching N
Equipment Guidance System	lb/acre/yr	0.63	Reduced leaching N

Costs	Unit	Unit Price	Quantity
Variable Rate N: Sensor-based			
Reflectance Sensors	Each	$20,000	1
Variable Rate Spray Controller	Each	$2,298	1
GPS Receiver	Each	$25,665	1
Installation/Setup	Install	$1,000	1
Soil Sampling	Acre	$8	Farm acres
Variable Rate N: Map-based			
Variable Rate Spray Controller	Each	$2,298	1
GPS Receiver	Each	$25,665	1
Installation/Setup	Install	$1,000	1
Soil Sampling	Acre	$8	Farm acres
N Simulation Software			
Smartphone or Tablet	Each	$500	1
Annual Subscription	License Fee	$999	1
Installation/Setup	Install	$0	1
Soil Sampling	Acre	$8	Farm acres
Fertigation			
Tank	Each	$500	1
Injection Pump	Each	$2,000	1
Valves	Each	$250	1
Controller	Each	$1,000	1
Complete System	Each	$4,225	0
Installation/Setup	Install	$750	1
Soil Sampling	Acre	$0	Farm acres
Equipment Guidance System			
Lightbar with DGPS Receiver	Each	$3,448	1
Autosteer with RTK GPS Receiver	Each	$23,250	1
Installation/Setup	Install	$750	1
Soil Sampling	Acre	$0	Farm acres

Production Systems	Total Acreage	Average Farm Size
Horse Farms	60,344	21
Livestock Grazing	383,383	107
Dairy	325	80
Hay	17,367	62
Field Crops	31,429	155
Vegetables	7,123	91
Perennial Fruits	10,578	47

Amortization Factor

HP 12C amortization formula (http://h20331.www2.hp.com/Hpsub/downloads/HP12Camortization.pdf)

Algebraic amortization formula (http://www.vertex42.com/ExcelArticles/amortization-calculation.html)

$$A = P\frac{i(1+i)^n}{(1+i)^n - 1} = \frac{P \times i}{1-(1+i)^{-n}} = P\left(i + \frac{i}{(1+i)^n - 1}\right)$$

This formula is valid if i > 0. If i = 0 then simply A = P / n.

Where:
A = periodic payment amount
P = amount of principal, net of initial payments, meaning "subtract any down-payments"
i = periodic interest rate
n = total number of payments

Year	Interest Rate
1	3.375%
5	3.375%
10	3.375%
15	3.375%
20	3.375%
30	3.375%

Reference Values

N Retention Strategies

Benefits	Units	Nitrogen Reduction	Description
Vegetative Filter Strips	lb/acre/yr	0.60	N export minimized; uptake
Tailwater Recovery	lb/acre/yr	11.90	N maintained onsite; reuse
Manure Storage Buildings	lb/acre/yr	0.75	N maintained onsite; assume 900 sqft
Denitrification Wall	lb/acre/yr	5.25	N export minimized; NO3 => N2
Treatment Wetland	lb/acre/yr	2.38	N export minimized; NO3 => N2
Pond Lining (Plastic or Concrete)	lb/acre/yr	33.10	N leaching reduced
Interceptor Wells/Bioreactor	lb/acre/yr	32.33	N maintained onsite; reuse, treat

Costs	Unit	Unit Price	Quantity
Vegetative Filter Strips			
Design and Establishment	Acres	$223	Acres of VFS = 2*SQRT(Farm acres*43560)*30/43560
Tailwater Recovery			
Excavation Cost	CuYd	$3.31	45,400
Grading and Hydroseeding	Acre	$805	3
Flashboard Riser	Dia(in)*Feet	$1	144
Culvert	Feet, 24in Metal	$40	400
Pump Station (Diesel) > 75 hp	bhp	$298	125
Shed/pad for Pump Station	Each	$7,000	1
Fuel Tank	Each	$3,400	1
Meter	Each	$3,000	1
Fittings, Valves, Miscellaneous	Acre	$111	Farm acres
Suction Screen, Self-cleaning	Each	$2,004	1
Filtration System, Automated Backflu	Each	$10,696	2
Pipe to Irrigation System (Assume 12	Feet/Acre	$11	3,900
Design and Installation	Acre	$1,196	Farm acres
Manure Storage Buildings			
Slab	SqFt	$5.52	900
Shed	SqFt	$9.60	900
Denitrification Wall			
Wall Excavation	CuYd	$3	504
Organic Matrix, Wood Chips	CuYd	$60	275
Treatment Wetland			
Excavation	CuYd	$3	6,441
Vegetation	Each	$1	19,312
Plumbing	Each	$11,128	1
Control Structures	Each	$10,386	1
Pond Lining (Plastic)			
Excavation	CuYd	$3	17,963
Flexible Membrane Liner	SqYd	$43	6,188
Large Diameter PVC, Waster	Feet	$31	100
Pond Lining (Concrete)			
Excavation	CuYd	$3	17,963
Reinforced Concrete Liner (4 in.	SqYd	$64	6,188
Large Diameter PVC, Waster	Feet	$31	100
Interceptor Wells/Bioreactor			
Wells (4" dia, 60' deep)	Each	$4,000	6
Electric Pump (20 gpm/well)	Each	$700	6
Wiring/Control Panel	Feet	$2	3,780
Piping (2" PVC)	Feet	$3	2,520
Piping (3" PVC)	Feet	$4	1,260
Piping (4" PVC)	Feet	$4	891
Pond Excavation	CuYd	$3	426
Plastic Lined Pond	SqFt	$1	1,913
Organic Matrix	CuYd	$60	284
Sand/Gravel	CuYd	$25	71
Under Drainpipes	Feet	$1	220
Pond Cover	SqFt	$0.33	1,913
Fencing	Feet	$2	200
Infiltration Ditch	Feet	$1	360
Flowmeter/Stage Records	Each	$1,000	1
Sample Collection	Each	$100	15
Analytical Costs	Each	$50	15
Design, Oversight	Hours	$150	100

Production Systems	Total Acreage	Average Farm Size
Horse Farms	2,882	21
Livestock Grazing	383,383	107
Dairy	325	80
Hay	17,367	62
Field Crops	31,429	155
Vegetables	7,123	91
Perennial Fruits	10,578	47

Amortization Factor

HP 12C amortization formula (http://h20331.www2.hp.com/Hpsub/downloads/HP12Camortization.pdf)

Algebraic amortization formula (http://www.vertex42.com/ExcelArticles/amortization-calculation.html)

The planning horizon for all calculations is 5 years.

Inflation is estimated at 4.875% annually.

$$A = P\frac{i(1+i)^n}{(1+i)^n - 1} = \frac{P \times i}{1-(1+i)^{-n}} = P\left(i + \frac{i}{(1+i)^n - 1}\right)$$

This formula is valid if i > 0. If i = 0 then simply A = P / n.

Where:
A = periodic payment amount
P = amount of principal, net of initial payments, meaning "subtract any down-payments"
i = periodic interest rate
n = total number of payments

Year	Interest Rate
1	3.375%
5	3.375%
10	3.375%
15	3.375%
20	3.375%
30	3.375%