NEWTRIENT

APPLICATION FOR COMPONENT ADDITION TO NRCS

NRCS Practice Standard 629

For Acceptance of Nitrogen Interception Technology

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APPLICATION FOR COMPONENT ADDITION TO NRCS Practice Standard 629:

Nitrogen Interception Technology

REQUEST

As environmental, regulatory, and legal pressures surrounding nutrient management on dairy farms continue to grow, an increasing number of technologies are being introduced as potential solutions. However, dairy producers often navigate these options with information primarily provided by technology vendors, making it challenging to assess their effectiveness objectively. To address the needs identified by both the USDA's Natural Resources Conservation Service (NRCS) and dairy farmers, Washington State University, in partnership with Newtrient, developed a standardized evaluation protocol. This framework, adapted from the criteria outlined in Appendix A of the NRCS Conservation Practice Standard (CPS) Waste Treatment (629), is designed to provide impartial, data-driven assessments of nutrient removal technologies. By offering a structured approach, this protocol supports dairy farmers in making informed decisions when considering technology adoption on their operations.

Newtrient has utilized this standardized evaluation protocol to assess Nitrogen Interception Technology, and we are submitting this report to request its consideration for inclusion under the NRCS Conservation Practice Standard 629 (Waste Treatment). This report introduces the technology, highlights its potential benefits, and explores its relevance as a solution for nitrogen management on dairy farms. The technology has been successfully evaluated on a dairy in Florida and has demonstrated its capability to capture nitrogen-rich leachate, which significantly reduces nitrogen loading to groundwater. We believe that this technology meets the criteria outlined in the NRCS standards and should be considered for inclusion once it becomes commercially available and scalable for broader use.

BRIEF DESCRIPTION OF COMPONENT CLASS

Nitrogen Interception technology is an innovative approach designed to capture nitrogen-rich leachate before it reaches the groundwater. This system works by installing intercept wells beneath irrigation pivots to collect subsurface water, which is then either treated further or reused, reducing the need for external water sources and commercial fertilizers. This technology helps minimize nitrogen loading to both surface and groundwater, offering a sustainable solution to nitrogen management on dairy farms.

DETAILED DESCRIPTION

Nitrogen Interception technology is a cutting-edge solution aimed at addressing nitrogen runoff and leaching, addressing key environmental challenges on dairy farms. The system operates by converting an "Open System" into a "Closed System" through the installation of intercept wells beneath irrigation pivots. These wells are strategically positioned to capture nitrogen-rich leachate, before it can percolate down into the ground water.

This technology is typically used on more coarse textured soils where irrigated or surface applied nutrients from manure. Even though manure nutrients are applied according to a nutrient management plan, these soil types have a higher leaching potential lowering the retention time within the soil profile allowing nutrients such as nitrogen to leach more readily into the groundwater.

The process begins with the installation of intercept wells that have intake points at the surface of the underlying water table. The wells are designed to draw in subsurface water, creating localized cones of hydrologic depression that help capture nitrogen-rich water that has leached through the soil. Once collected, this water can either be blended with groundwater from irrigation wells for reuse or directed to a denitrification bioreactor for further treatment to lower nitrogen concentrations.

The treated or blended water is then available for reuse in irrigation, thus closing the nutrient loop and reducing nitrogen loading to surface and groundwater. This approach not only reduces the reliance on external water sources and commercial fertilizers but also supports sustainable agricultural practices by minimizing the environmental impact of excess nitrogen runoff and leaching. With its ability to intercept nitrogen and recycle water, Nitrogen Interception technology offers a valuable tool for dairy farmers seeking to improve nutrient management.

This efficiency of this technology improves the higher the water nitrate levels. It is not recommended for use with nitrate levels less than 10 parts per million.

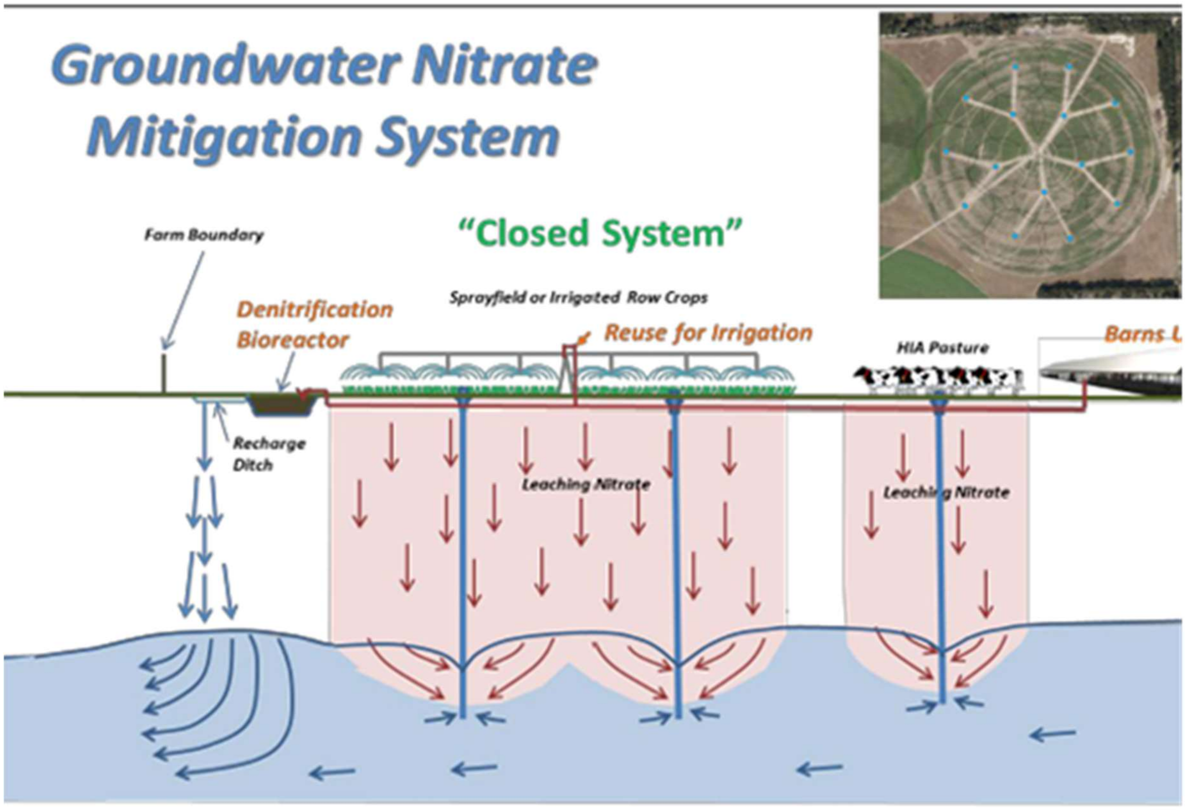


Figure 1: Cross section of theoretical dairy operation with high intensity pasture and sprayfield resulting in nitrate leaching; however, in this instance an array of intercept wells captures leachate and brings it back to the surface for reuse or treatment through a denitrification bioreactor.

THE PROCESS

The nitrogen interception technology evaluated in this study transforms an "Open System" into a "Closed System" by strategically placing intercept wells beneath irrigation pivots, or sprayfield (Figure 1). The process works in the following steps:

1. **Installation of Intercept Wells**: Intercept wells are installed beneath irrigation pivots, with intake points at the surface of the underlying water table. These wells are positioned to capture nitrogen-rich leachate, before it reaches the water table (Figure 2).

2. **Creation of Localized Cones of Depression**: The equidistantly placed intercept wells are strategically designed so that as subsurface water is drawn into the intercept wells, localized cones of hydrologic depression and potentiometric lows are created, helping to capture the nitrogen-rich water that has leached through the soil.

3. **Collection and Reuse**: The intercepted subsurface water is collected and can be either reused by blending it with groundwater from irrigation wells or treated further through a denitrification bioreactor further reducing the nitrogen loading.

4. **Nitrogen Reduction Technologies (Optional)**: In some cases, the intercepted subsurface water is directed to an optional nitrogen reduction technology or practices, such as woodchip denitrification bioreactor (CPS 605), which lowers the nitrogen concentrations before the water is either reused or discharged (Figure 3).

5. **Sustainable Water Reuse**: Once treated or blended, the water can be reused for irrigation, closing the nutrient loop and reducing nitrogen loading to both surface and groundwater.

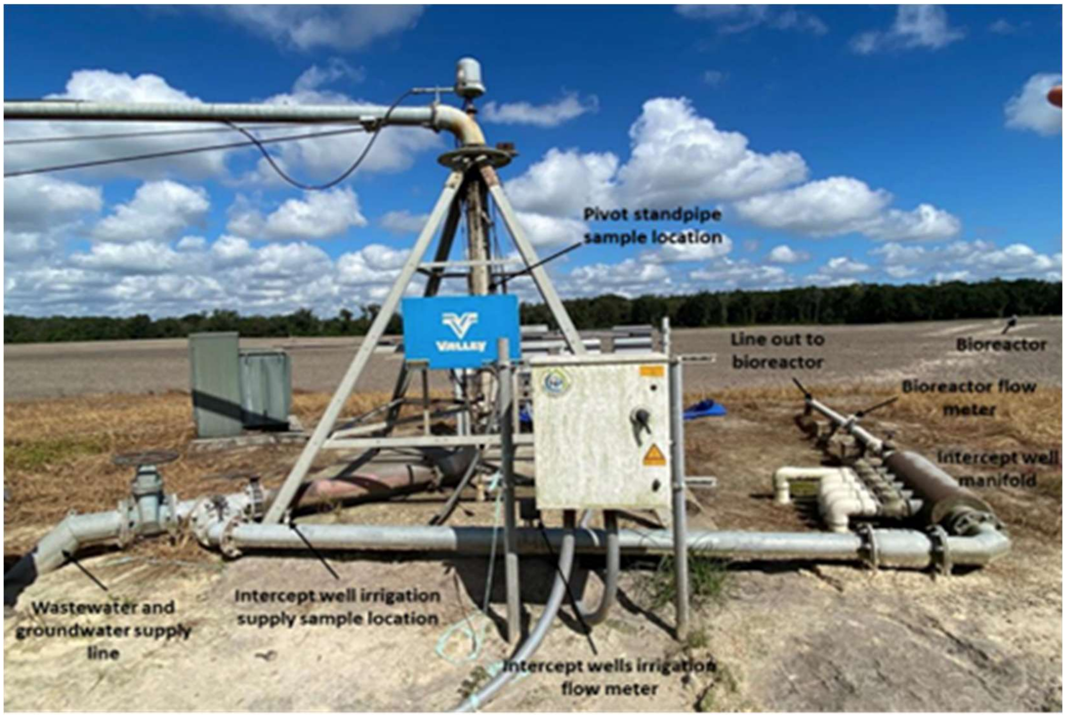


Figure 2: Layout of piping at center of pivot B indicating principal components of intercept well infeed line to irrigation pivot and line out to bioreactor and flow meters and sample collection locations.

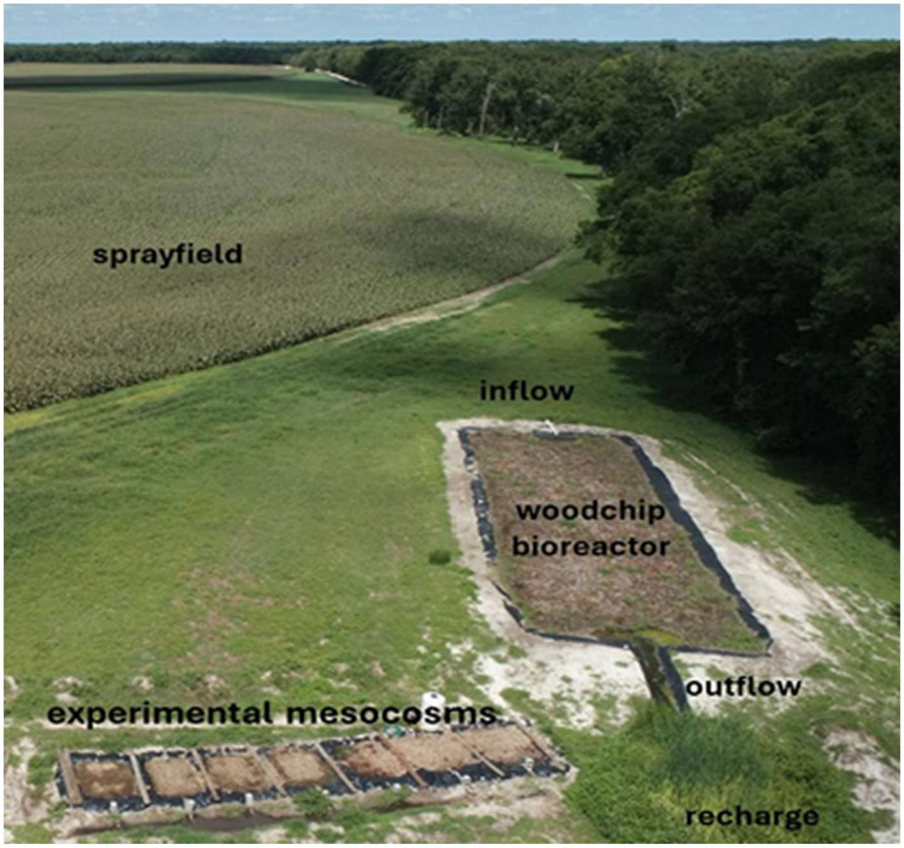


Figure 3: Aerial image showing proximity of woodchip denitrification bioreactor relative to sprayfield

HOW PROPOSED SYSTEM ACCOMPLISHES PURPOSES OF THE STANDARD

Nitrogen interception technology aligns with NRCS Waste Treatment (Code 629) by capturing and reusing nitrogen-rich leachate, helping to maintain water quality and improve nutrient management on dairy farms. This system uses strategically placed intercept wells to collect subsurface water before it reaches the surface of the underlying water table, preventing nitrogen losses, groundwater contamination, and enabling its reuse for irrigation or further treatment. By reducing nitrogen leaching and runoff, this approach minimizes the need for synthetic fertilizers to offset nitrogen losses and external water sources while also addressing environmental concerns related to surface and groundwater contamination. As a sustainable solution for dairy nutrient management, Nitrogen Interception Technology presents a strong case for inclusion under NRCS Practice Standard 629 as it gains wider adoption in U.S. agricultural systems.

Newtrient (https://www.newtrient.com/), a company sponsored by the dairy industry and committed to enhancing value and sustainability in manure management, has conducted a thorough assessment of technology systems and practices within the field, focusing on their impact on critical environmental metrics, specifically water quality. The information in this report is based on a University of Florida evaluation of the technology at Alliance Dairy Branford in Branford, Florida.

In support of this discussion, Appendix A offers a brief discussion on the significant impact of Nitrogen Interception technology on key environmental indicators related to water quality, air emissions, and other relevant factors aligned with the objectives of Standard 629. Also, Appendix B presents data from Nitrogen Interception technology evaluation, offering visual representations and nutrient profiles that demonstrate the positive influence of integrating a Nitrogen Interception technology system within a comprehensive manure management approach. Additionally, Appendix C contains the final report of the study conducted by the University of Florida, providing further insights into the effectiveness and benefits of Nitrogen Interception technology.

Reducing Nutrient Content, Organic Strength

Nitrogen interception technology reduces nutrient content and organic strength by capturing nitrogen-rich leachate before it reaches groundwater and reusing it in controlled applications. By intercepting and blending this water with irrigation sources or further treating it through additional nitrogen reduction technologies or practices, the system helps break down excess nitrogen and organic matter. This process dilutes and redistributes nutrients more effectively, reducing the overall concentration of nitrogen in the environment. Additionally, optional nitrogen reduction technologies and practices, such as woodchip denitrification bioreactor (CPS 605), can further lower nitrogen levels.

According to the University of Florida evaluation at Alliance Dairy Branford, the woodchip denitrification bioreactor played a crucial role in further reducing nitrogen levels. Over the monitoring period, the bioreactor reduced nitrate-nitrogen (NOx-N) concentrations by 24.6% and total nitrogen (TN) by 19.5%. While other components, such as the interception and reuse of groundwater and intercept well water, contributed to capturing and redistributing nitrogen, the bioreactor was the key technology that effectively reduced nutrient content and organic strength. It helped break down excess nitrogen and organic matter, further improving the system's ability to manage nutrient loads and reduce the overall environmental concentration of nitrogen.

Reducing Odor and Gaseous Emissions

Nitrogen interception technology reduces odor and gaseous emissions by capturing nitrogen-rich leachate before it infiltrates groundwater or volatilizes into the air. By preventing excess nitrogen buildup in soil and water, it minimizes ammonia volatilization—a key contributor to odor and air quality concerns. When blended with irrigation sources or additional treatment through a denitrification bioreactor, the intercepted water stabilizes nitrogen, further limiting emissions.

The University of Florida evaluation at Alliance Dairy Branford, showed that the implementation of the intercept well array and woodchip denitrification bioreactor significantly contributed to reducing nitrogen loads, which directly impacts odor and gaseous emissions. The woodchip denitrification bioreactor removed an average of 24.6% of NOx-N and 19.5% of TN, reducing emissions that contribute to ammonia volatilization and greenhouse gas (GHG) formation. Over the study period, the bioreactor removed approximately 2,930 lbs. of NOx-N and 3,458 lbs. of TN, translating to 27.7 lbs./acre of TN removal at Pivot B.

Additionally, the intercept well array intercepted 5,596 lbs. of TN, which, when combined with the bioreactor's treatment, prevented a significant portion of nitrogen from entering the groundwater. The lower nitrogen concentrations in the northern well array indicate the potential influence of groundwater movement, suggesting that strategic well placement can further optimize nitrogen capture and mitigate emissions. By intercepting nitrogen at multiple stages—through well arrays, irrigation reuse, and bioreactor treatment—this system effectively limits gaseous nitrogen emissions, reduces odor, and improves air quality in the surrounding environment.

Facilitating Desirable Waste Handling and Storage

Nitrogen interception technology itself does not directly facilitate waste handling and storage in the traditional sense. Its primary function is to capture nitrogen-rich leachate, in the form of nitrates, before it reaches groundwater, reducing the environmental impact of excess nitrogen. However, it indirectly supports better waste management by improving the nutrient cycle through a closed-loop system. By intercepting and blending nitrate-laden water with irrigation sources or further treating it through a denitrification bioreactor, this technology helps reduce nitrogen concentrations in the environment. This process contributes to more efficient nutrient redistribution, which can alleviate the pressure on waste storage systems by reducing the need for additional fertilizer inputs to offset nitrogen losses.

Producing Value Added Byproducts that Facilitate Manure and Waste Utilization

Nitrate interception technology does not directly produce value-added byproducts that facilitate manure and waste utilization. However, by reducing nitrogen concentrations in water sources and enabling more controlled applications—such as blending with irrigation water or further treatment—the technology also facilitates the reuse of water. This creates a closed-loop system, where nitrogen and water are more effectively managed and cycled within the operation. The closed-loop approach reduces the need for additional fertilizer inputs to offset nitrogen losses, optimizes the use of water, and helps alleviate pressure on manure and waste storage systems.

RANGE OF VOLUMETRIC AND MASS FLOW CAPACITIES AS WELL AS HYDRAULIC RETENTION TIME

The following section provides an overview of key parameters related to the performance of the Nitrogen Interception system in manure management:

- *Volumetric Flow*: The water from the well flowed nearly continuously at an estimated rate of 50 gallons per minute (GPM) into the 12,000-cubic-foot woodchip denitrification bioreactor. This volumetric flow ensures that the nitrogen interception system operates efficiently by matching the annual leaching volume from rainfall in the region, directing the intercepted water into the bioreactor for treatment.

- *Mass Flow*: The average mass flow rate for NOx-N removal in the woodchip denitrification bioreactor is approximately 8.02 lbs/day, and for TN removal, it is approximately 9.47 lbs/day, assuming the system operates over a full year.

- *Hydraulic Retention Times (HRT):* The HRT for the water flowing through the 12,000-cubic-foot woodchip denitrification bioreactor is approximately 29.9 hours.

DESIRED FEEDSTOCK CHARACTERISTICS

For nitrogen interception technology, the ideal feedstock would be nitrate-rich groundwater or intercepted leachate that contains nitrogen compounds. The technology is designed to capture and treat excess nitrogen from various sources, and the feedstock can come from:

1. **Groundwater with elevated nitrogen levels**: This includes water from irrigation wells or other groundwater sources that have been impacted by excess nitrogen from agricultural practices (e.g., fertilizer runoff or manure leaching).

2. **Leachate from agricultural lands**: Nitrogen-rich leachate can be intercepted by wells and treated before it reaches the groundwater.

3. **Surface runoff**: While not directly mentioned in the description, interception of surface runoff that carries excess nitrogen from agricultural fields could also be a potential feedstock for interception technology.

EXPECTED SYSTEM PERFORMANCE

The Nitrogen Interception technology is designed to improve nutrient management by efficiently capturing and treating nitrogen-rich water sources, such as groundwater and leachate, before they reach the environment. The system's performance can be assessed by its ability to reduce nitrogen concentrations in water, enhance nutrient reuse for agricultural applications, prevent groundwater contamination, and support the mitigation of environmental impacts on both water and air quality.

- *Changes in form or handling characteristics*
    - The Nitrogen Interception technology does not directly alter the physical form or handling characteristics of manure. Instead, it focuses on capturing and treating nitrogen-rich water sources, reducing the concentration of nitrogen before it enters the environment. By addressing nutrient overload, this technology indirectly contributes to more efficient manure and wastewater management, as it helps prevent excess nutrients from negatively impacting air and water quality.
- *Nutrient fate or end use projections*
    - The Nitrogen Interception technology plays a key role in managing nutrient fate by capturing nitrogen-rich water and reducing its concentration before it reaches groundwater. The treated water, with reduced nitrogen levels, can be safely reused for irrigation or other agricultural purposes, helping to redistribute nutrients more efficiently.
- *Macro-nutrient reductions or transformations*
    - While Nitrogen Interception technology focuses on nitrogen, its processes may also indirectly affect the cycling of other macro-nutrients, like phosphorus, by altering the nutrient dynamics in the water. However, nitrogen is the primary target, and significant transformations or reductions of other macro-nutrients like phosphorus or potassium have not been a key focus or reported outcome of this specific technology.
- *Pathogen reductions or eliminations*

- The nitrogen interception technology indirectly supports pathogen reduction, primarily through the treatment processes that help to improve the overall quality of intercepted water. While the system itself does not directly target pathogens, the denitrification bioreactor can reduce the risk of pathogens in the treated water by promoting microbial activity. In the bioreactor, the microbial populations that break down nitrogen compounds can also help degrade organic material, which may include some pathogens. However, it is important to note that pathogen elimination is not the primary function of this system, and the technology's main focus is on nutrient management, particularly nitrogen.

- *Air emissions*

  - Nitrogen Interception technology can contribute to mitigating air emissions, specifically in terms of reducing the release of nitrogen-based compounds such as ammonia (NH_3) and nitrous oxide (N_2O). By intercepting and treating nitrogen-rich leachate before it reaches groundwater, the system limits the potential for these nitrogen compounds to volatilize into the air.

    The denitrification bioreactor, a key component of the system, plays an important role in further reducing these emissions. Through microbial denitrification, the bioreactor converts nitrates (NO_3^-) into nitrogen gas (N_2), which is harmlessly released into the atmosphere. This process significantly reduces the potential for N_2O emissions, a potent GHG, which is often associated with excess nitrogen in agricultural systems.

    In the Florida-based study conducted at Alliance Dairy Branford, the bioreactor achieved a reduction of approximately 24.6% in NOx-N concentrations and 19.5% in TN concentrations. While the study did not provide direct measurements of air emissions like NH_3 or N_2O, these reductions in nitrogen concentrations indicate the system's potential to reduce emissions that would otherwise contribute to environmental air quality problems. This aligns with broader efforts to improve nitrogen management practices, which can help mitigate air pollution and GHG impacts associated with agricultural operations.

- *Water emissions*

  - Nitrogen Interception technology addresses excess nitrogen loading to groundwater, particularly in regions where nitrogen leaches vertically through the soil and is at risk of entering the water table. By utilizing an intercept well array placed below the sprayfield irrigation area, this technology intercepts nitrogen-rich leachate before it reaches the groundwater. The intercepted water is either reused for irrigation or further treated through processes such as denitrification in a bioreactor. This approach reduces the nitrogen concentrations in water sources and limits the movement of excess nutrients into the environment, thus reducing water quality concerns. This technology effectively captures nitrogen and redistributes it, improving nutrient management and reducing the overall environmental impact of nitrogen leaching and runoff.

In the Florida-based study at Alliance Dairy Branford, the technology's impact on water quality was closely evaluated. The intercept well array intercepted a total of 5,596 lbs. of TN for reuse, and an additional 3,458 lbs. of TN was removed through treatment in the bioreactor. Elevated nitrogen concentrations in the main groundwater well, likely due to the well's location within the nitrogen leachate plume, resulted in an additional 43,054 lbs. of TN being intercepted for reuse. Overall, the combined total of intercepted and treated nitrogen was 52,108 lbs., or 417 lbs. per pivot acre. The study further projected that under ideal conditions, with no nitrogen in the main groundwater well, the technology could intercept up to 38,353 lbs. of TN, and with elevated nitrogen concentrations similar to those observed in the study, the potential intercept load could increase to 59,880 lbs. These findings highlight how this technology not only intercepts leached nitrogen but also facilitates its reuse and treatment, significantly improving water quality and reducing nutrient loading to the environment.

PROCESS MONITORING AND CONTROL SYSTEM REQUIRMENTS

Process monitoring and control systems are crucial for optimizing the performance of Nitrogen Interception technology. These systems enable real-time monitoring and control of key parameters, ensuring efficient and effective operation.

- *Required monitoring*— To ensure the optimal performance of Nitrogen Interception technology, several parameters must be continuously monitored, including:
    - **Water Quality** – Continuous monitoring of nitrogen levels (nitrate, nitrite, and ammonium), pH, and other contaminants in intercepted water to ensure effective treatment and reuse.

- **Flow Rates** – Monitoring the flow rates through intercept wells, pumps, and bioreactors to ensure proper operation and to detect potential blockages or inefficiencies.
- **System Pressure** – Regular checks on the pressure in the pipes and systems to prevent malfunction or damage to components such as valves and pumps.
- **Bioreactor Functionality** – If applicable, monitoring the condition and efficiency of the denitrification bioreactor, ensuring the degradation of nitrogen compounds and the proper flow of water.
- **Water Reuse Rates** – Tracking the volume of treated water being reused for irrigation, ensuring the system is successfully closing the nutrient loop and reducing the need for external resources.
- **Environmental Monitoring** – Periodic soil, manure, irrigation water, and groundwater testing within and around the system to confirm the system's effectiveness in reducing nitrogen leaching and environmental impacts.
- **System Calibration** – Regular calibration of sensors, flow meters, and other monitoring equipment to maintain data accuracy and operational reliability.

- *Required control*— Nitrogen Interception technology must include controls for the following aspects:
  - **Flow Regulation** – Manual or basic automated controls to ensure consistent water flow through the intercept wells and piping, preventing overflows or underperformance.
  - **Water Treatment Control** – Simple controls to manage the routing of intercepted water to either be reused or directed to a bioreactor for treatment, depending on water quality and nutrient needs.
  - **Pressure Management** – Basic pressure monitoring to ensure the system remains within operational limits, using pressure gauges and simple manual adjustments as needed.
  - **Bioreactor Water Distribution** – Manual or semi-automated control over water flow through the denitrification bioreactor to ensure sufficient processing time for nitrogen removal.

- **Pump and Valve Adjustment** – Basic control of pumps and valves to regulate water distribution, likely requiring regular checks and manual adjustments to ensure proper function.
- **Irrigation System Coordination** – Coordination between treated water flow and the farm's irrigation system to ensure water is reused efficiently for irrigation without complex automation.
- **Alarms and Alerts** – Simple visual or auditory alarms to indicate system malfunctions or irregularities in water quality, allowing operators to address issues promptly.

- *Equipment included for monitoring*— The Nitrogen Interception system is equipped with several key monitoring devices:
  - **Pressure Gauges** – Used to monitor water pressure at various points in the system to ensure proper flow and avoid blockages.
  - **Water Flow Meters** – Basic meters to track the amount of water being intercepted and treated, ensuring system efficiency.
  - **Visual Inspection Points** – Simple observation points along the system to allow operators to manually check for clogs or irregularities.
  - **Water Quality Test Kits** – Basic field kits for testing water quality (e.g., nitrogen levels) to determine if the water needs further treatment.
  - **Level Indicators** – Simple gauges or float systems to monitor water levels in the intercept wells and bioreactors to avoid overflows or underutilization.
- *Equipment included for controlling*— The system is designed with equipment to manage various operational parameters:
  - **Flow Control Valves** – Simple manual or automated valves to regulate the flow of intercepted water through the system, ensuring balanced distribution.
  - **Pressure Regulators** – Used to maintain optimal pressure within the system, preventing excessive pressure that could cause leaks or inefficiencies.

- **Gate Valves** – Basic valves to control the opening and closing of water channels, allowing operators to isolate sections of the system for maintenance or adjustments.
- **Bypass Valve** – Allows water to be directed around the bioreactor or other treatment components if needed, based on water quality or operational needs.
- **Air Vent Systems** – Basic vents to prevent airlocks in the pipes, ensuring smooth water flow and avoiding blockages.

TYPICAL OPERATIONS/MAINTENANCE PLAN WITH MONITORING REQUIREMENTS AND REPLACEMENT SCHEDULE

The Nitrogen Interception system is designed to effectively capture and treat nitrogen-rich leachate from agricultural operations, transforming an open system into a closed loop to minimize nitrogen loss and reduce environmental impact, specifically air and water quality. Proper operation and maintenance are crucial to ensure the system runs efficiently, supports water reuse, and contributes to sustainable nutrient management. Below is a typical operations and maintenance plan for the Nitrogen Interception system, outlining monitoring requirements and a recommended replacement schedule for key components.

System Monitoring

1. **Water Quality Testing**: Regularly test the water quality from intercept wells, bioreactors, and irrigation sources. Key parameters to monitor would include nitrogen concentration (nitrate levels), pH, dissolved oxygen, and overall nutrient content. Testing should occur every 3-6 months to ensure proper and optimal system function.

2. **Flow Rate Monitoring**: Install flow meters at key points (e.g., intercept wells, bioreactor input/output) to monitor the volume of water being intercepted, treated, and reused. This data should be collected monthly to track system efficiency and detect any changes in performance.

3. **System Performance Logs**: Maintain daily or weekly logs of system operation, including pump status, water usage, and treatment system performance (e.g., bioreactor function). Any anomalies, downtimes, or issues should be recorded, and corrective actions documented.

4. **Bioreactor Condition**: Check the denitrification bioreactor bed condition every 6 months. Monitoring should include looking for signs of clogging or depletion of the woodchips or other medium and assessing water quality after treatment.

5. **Filter and Equipment Inspections**: Perform visual inspections of intercept well filters, pipes, pumps, and valves every 3-6 months to ensure they are functioning properly. Clean or replace parts as needed.

6. **Maintenance Scheduling**: Develop a routine maintenance schedule based on system components, as described in the replacement parts schedule. This should include periodic checks on electrical systems, sensors, and physical infrastructure to ensure everything is operating optimally.

Replacement Schedule

1. **Pumps**: Depending on usage and wear, pumps may need to be replaced or overhauled every 5-7 years. Routine maintenance would involve checking seals, impellers, and electrical connections annually.

2. **Intercept Well Filters**: The filters in the intercept wells, designed to prevent clogging, might need to be cleaned or replaced every 2-3 years, depending on water quality and sediment levels.

3. **Denitrification Bioreactor (Woodchip Beds)**: Woodchip beds in the bioreactor may require replacement or replenishment every 5-7 years due to gradual decomposition of the chips and reduced efficacy in nitrogen removal. Periodic monitoring of water quality is recommended.

4. **Piping and Valves**: The pipes and valves may need inspections every 2 years and replacement or repair every 5-10 years, depending on exposure to elements and wear from water flow.

5. **Sensors/Monitoring Equipment**: Sensors that measure water quality or flow rates may need to be replaced every 3-5 years, as they can degrade over time due to environmental exposure.

6. **Electrical Components**: Electrical connections, wiring, and control panels should be inspected every 1-2 years for signs of wear or corrosion, with replacement needed every 7-10 years, depending on the environmental conditions.

CHEMICAL INFORMATION

- Nitrogen Interception technology does not use any chemicals in its operation.

ESTIMATED INSTALLATION AND OPERATION COST

<u>Equipment and Installation Capital Costs</u>

As of 2025, the initial capital cost of a nitrogen interception system is approximately $1,173 per acre. This includes an estimated $821 per acre for the interceptor wells and irrigation reuse system and $352 per acre for the woodchip bioreactor (Bottcher & Clark, 2021). These costs were adjusted for inflation based on the 2021 publication by Bottcher and Clark. Costs may vary based on regional rainfall volume, irrigation design and capacity, total acreage, and project requirements.

<u>Operation and Maintenance Costs (O&M)</u>

- ***Electrical—*** Detailed electricity cost data for operating the Nitrogen Interception technology is not currently available. However, there would likely be some electrical consumption for the nitrogen interception system, primarily for pumps that move water through the intercept wells and bioreactor, if one is used. Overall energy consumption would likely be relatively low compared to traditional irrigation or large-scale systems, as the technology focuses more on passive water and nutrient flow management.
- ***Labor—*** Detailed labor cost data for operating for Nitrogen Interception technology is not currently available. However, ongoing maintenance will likely include periodic inspections of the system, such as checking for blockages or leaks, and testing water quality, which may require a few hours per week or month. Additionally, if used, woodchips in the bioreactor will need to be replaced every 1-2 years, and any repairs or troubleshooting would require labor on an as-needed basis. Overall, the labor demand will be moderate, with more intensive work during setup and occasional repairs.
- ***Maintenance Replacement—*** Specific maintenance cost data for Nitrogen Interception technology is not available. However, over time, the intercept wells may require inspection to ensure they are functioning properly and that there are no blockages or deterioration in the well components. The denitrification bioreactor will require periodic replenishment of woodchips or other medium, as the denitrification process consumes the material. The system's piping, pumps, and other infrastructure used to collect and direct the intercepted water will

need regular maintenance to prevent clogs, leaks, or mechanical failure. Additionally, regular testing of water quality will be necessary to ensure the system is effectively reducing nitrogen concentrations before water is reused or discharged. Routine checks on the localized cones of depression and the overall functioning of the system should also be part of a proactive maintenance schedule.

EXAMPLE WARRANTY

Warranty information for Nitrogen Interception technology is not currently available. However, a typical equipment warranty may include:

1. Warranty Coverage – This warranty covers defects in materials and workmanship for the Nitrogen Interception system for a period of 2-3 years from the date of installation or purchase.

2. What Is Covered

- **System Components**: Any parts of the nitrogen interception system that malfunction or fail due to manufacturing defects.
- **Repair or Replacement**: If a covered issue arises, the manufacturer will repair or replace defective parts at no cost to the purchaser, excluding shipping or installation fees.

3. What Is Not Covered

- **Damage Due to Improper Use**: Any damage caused by misuse, neglect, or failure to follow maintenance instructions.
- **External Factors**: Damage caused by external factors, such as natural disasters, flooding, or fire.
- **Wear and Tear**: Normal wear and tear due to regular operation and use.
- **Third-Party Modifications**: Any issues caused by modifications, repairs, or alterations made by someone other than an authorized technician.

Actual warranty terms would need to be confirmed with Soil Water and Engineering Technology, Inc. (SWET) upon commercial availability.

RECOMMENDED RECORD-KEEPING FOR NITROGEN INTERCEPTION TECHNOLOGY

Effective record-keeping is essential for ensuring the optimal performance, reliability, and longevity of the Nitrogen Interception system. Below are the recommended record-keeping practices:

1. System Performance Monitoring

- **Date and Time of Operation**: Log when the system is activated and deactivated. This helps track overall system usage.
- **Nitrogen Reduction**: Track any measurable nitrogen reductions over time (e.g., monthly or seasonally). This can help assess if the system is meeting its expected performance goals.
- **Water Flow Rate**: Record basic flow rate data when the system is operating, detailed readings are not necessary unless there are performance issues.

2. Water and Nutrient Recycling

- **Water Reuse**: Keep a simple log of how often water is being recycled for reuse within the system. This helps confirm the system's efficiency in reusing water.
- **Nutrient Recycling Overview**: Track any changes in the nutrient levels, particularly nitrogen, but keep it basic (e.g., record when major adjustments are made or if the system shows noticeable improvements or increases).

3. Maintenance and Calibration

- **Maintenance Logs**: Record basic details of any maintenance or repairs (e.g., what was fixed, the date of the maintenance). This keeps the system running smoothly.
- **Calibration Notes**: If you notice performance issues, make a note of any calibration adjustments made to sensors or flow meters.

4. Cost and Economic Tracking

- **Operational Costs**: Track any major operational costs, such as energy or replacement parts, to ensure the system is cost-effective.
- **Savings from Fertilizer and Water**: If possible, keep a rough estimate of savings from reduced fertilizer or water purchases. This doesn’t need to be thoroughly detailed but can help assess the economic impact of the system.

ALTERNATIVES FOR THE USE OF BYPRODUCTS

The Nitrogen Interception system works by capturing excess nitrogen from dairy manure, wastewater, or runoff, which can then be processed into valuable by-products. The technology focuses on intercepting nitrogen before it leaches into the groundwater, helping keep water sources clean while also creating opportunities for resource recovery.

1. Water Reuse

Nitrogen captured from the system can also be incorporated into water management systems, such as treating water for reuse in irrigation or other agricultural needs. By recycling water that has been filtered through the nitrogen interception process, farms can reduce their dependency on external water sources, conserving water and improving operational efficiency. This contributes to more sustainable water management practices, particularly in areas where water scarcity is a concern.

INDEPENDENT VARIFIABLE DATA DEMONSTRATING RESULTS/CREDENTIALS

Appendix A is a summary of the expert opinion and technical data available for this class of technology and how it relates to key performance indicators within NRCS Standard 629. This information is available through Newtrient.

Appendix B provides a summary of data from a Newtrient-managed third-party review of Nitrogen Interception unit at Alliance Dairy Branford in Branford, FL. The data comes from a system performance analysis conducted by the University of Florida but has not been peer-reviewed.

Appendix C contains the full University of Florida report detailing the third-party review at Alliance Dairy Branford.

CONTACT INFORMATION—VENDOR

The list below includes a single company based in Florida, as this is a novel technology that is not yet commercially available.

1. **Soil and Water Engineering Technology, Inc.**
   Address: 3448 N.W. 12th Ave., Gainesville, FL 32605
   Phone: 352-378-7372
   Website: https://www.swet.com/
   Company Information: Soil and Water Engineering Technology, Inc. provides consulting in the areas of water resource modeling, pollution abatement practices, agricultural best management practice implementation programs, and

animal waste management design solutions. We provide a full range of services for public and private clients throughout Florida and the southeast.

CONTACT INFORMATION—USER

Commercial facilities presently operating in the U.S. with this class of technology are identified below. The list is a best effort but may not be completely inclusive of all installations.

Nitrogen Interception Technology

Alliance Dairies-Branford – Branford, Florida

OTHER CONSIDERATIONS

The NRCS documentation specifies that a third-party review shall contain 15 specific items that comprise the report above, but as part of working with the farm(s) and the technology provider during the evaluation period there are often other important and valuable learnings that may be helpful for NRCS and others as they consider this technology. Below is a list of Other Considerations that should be included in the evaluation of this technology:

1. Operational Limitations:

One common challenge in implementing nitrogen interception systems is the occurrence of operational limitations that can affect overall system performance. In particular, technical malfunctions or equipment failures, such as issues with water blending controllers or other key components, can disrupt the intended functioning of the system. For example, if the blending of intercepted water from the wells and fresh groundwater is not properly regulated, the system may fail to achieve optimal nutrient recycling and water efficiency. These limitations can result in suboptimal nitrogen interception and less effective reuse of water, which in turn reduces the anticipated environmental and economic benefits. To maximize the system's effectiveness, regular maintenance and monitoring of key components are essential to ensure that all parts of the system are functioning as designed and that any issues are identified and resolved promptly.

2. Variations in Nitrogen Concentrations

Another significant challenge is the variability in nitrogen concentrations across different zones of the system. Nitrogen levels in intercepted water can fluctuate due to several factors, including soil characteristics, water movement, and external environmental influences. In systems with varying concentrations, it can be difficult to predict nitrogen load reductions with accuracy, especially when certain areas experience higher concentrations than others. For example, the proximity of certain intercept wells to groundwater sources like rivers or karst features may introduce additional nitrogen or dilute concentrations. This variation complicates the management of the system, as it requires more precise monitoring and adjustments to ensure consistent performance. As a result, managing nitrogen concentrations across different zones of the system can require a more adaptive approach to optimize treatment and prevent nutrient imbalances.

Conclusion

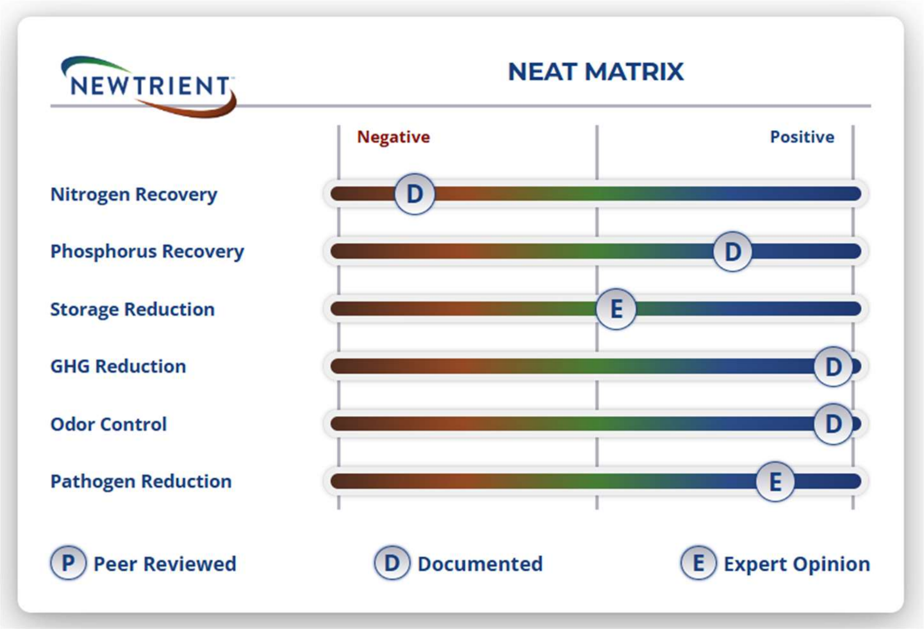
The Nitrogen Interception technology evaluated in this report has shown promising potential in reducing nitrogen loads from dairy operations, particularly in regions vulnerable to nitrogen leaching into groundwater. By using intercept wells to capture nitrogen-rich leachate before it reaches the water table and directing it through a denitrification bioreactor for further treatment, this technology effectively intercepts nitrogen, reduces water contamination, and improves water quality.

The integration of intercept wells and the optional of additional nitrogen reduction technologies or practices promotes sustainable water reuse and nutrient management, creating a closed-loop system that maximizes resource efficiency and minimizes nitrogen accumulation. This method has the potential to reduce the need for external water sources and fertilizers, ultimately leading to cost savings and contributing to a more sustainable dairy operation.

While challenges such as operational limitations and variations in nitrogen concentrations across the system may be encountered, the technology's overall effectiveness in intercepting and treating nitrogen demonstrates its significant contribution to improving water quality, reducing runoff and leaching, and promoting efficient resource use. With further refinement, the system could become a key tool in enhancing nutrient management practices, ensuring both dairy farm efficiency and the protection of vital water resources.

Appendix A

NEWTRIENT CRITICAL INDICATOR ANALYSIS – NITRIFICATION DENITRIFICATION



Overall Summary

Nitrogen Interception technology is an innovative approach designed to manage and reduce nitrogen contamination in groundwater, particularly in agricultural regions with porous soils or karst geology, where rapid water movement increases the risk of nutrient leaching. By addressing nitrogen leaching and runoff, this technology helps protect water quality, mitigate greenhouse gas (GHG) emissions, and promote healthier ecosystems.

The primary function of this technology is to intercept and recycle nitrogen that would otherwise migrate below the soil surface, preventing it from contaminating sensitive water systems or contributing to atmospheric emissions. In regions with high vulnerability to groundwater leaching but limited opportunities for in-ground nutrient treatment, this system offers a practical and scalable solution to safeguard environmental health.

At the core of the technology is the strategic installation of intercept wells below irrigation sprayfields. These wells are designed to create localized cones of depression, drawing leached nutrients back to the surface before they can infiltrate deep into groundwater reserves. This closed-loop system not only protects water quality but also helps reduce nitrogen losses to the atmosphere, which can contribute to the formation of nitrous oxide — a potent GHG.

Once intercepted, the nutrient-rich water can be managed in two primary ways:

1. **Reuse for Irrigation:** The extracted water, blended with fresh groundwater, can be reused for crop irrigation, allowing plant-available nutrients to be absorbed by crops rather than escaping into the environment. This approach also reduces the overall demand for freshwater resources.
2. **Treatment Through a Denitrification Bioreactor:** Alternatively, the intercepted water can be processed through a nitrogen reduction technology or practice, such as woodchip denitrification bioreactor (CPS 605), which can further lower nitrogen levels.

This dual-purpose approach — nutrient recovery and enhanced treatment — not only minimizes the environmental impact of nitrogen leaching but also supports sustainable water management practices. By capturing leached nitrogen before it reaches groundwater, protecting surface water quality from nitrogen runoff, and minimizing nitrogen losses to the air through volatilization, nitrogen interception technology helps dairy farms protect natural resources and maintain productive, sustainable operations.

Appendix B

Third-Party Review of Nitrogen Interception Technology at Alliance Dairy – Branford, FL (Report Summary)

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FEBRUARY 2025

BACKGROUND

Dairy farming plays a vital role in agriculture, providing essential products while supporting local economies and communities. The industry is committed to sustainable practices, recognizing the need to balance food production with environmental stewardship, economic viability, and social responsibility. Like all agricultural operations, dairy farms must carefully manage nutrients to protect precious natural resources. One area of ongoing focus in nutrient management is the nitrogen cycle, as nitrogen compounds from manure applications can leach into groundwater and surface water, potentially affecting water quality.

While traditional nutrient management strategies, such as optimizing irrigation and fertilizer application rates, have been effective in reducing nitrogen losses in many cases, knowledge gaps remain—particularly regarding nitrogen interception once it moves below the vadose zone. Addressing these gaps is crucial, especially in regions where local geology presents unique challenges. For example, in Branford, Florida, the absence of clay confining layers between the surface and the Floridan Aquifer increases groundwater vulnerability. This geology allows nitrogen-rich leachate to move more rapidly into the aquifer, while the area's karst features, including springs, create additional pathways for nitrogen transport to connected water bodies.

INTRODUCTION

This study specifically aimed to address nitrogen leaching into groundwater, specifically in the form of nitrates, a critical environmental challenge for the dairy industry. In regions like Branford, Florida, where the lack of clay confining layers and the presence of karst features heighten groundwater vulnerability, nitrogen from manure applications can readily move into the aquifer and connected water bodies. Traditional best management practices have successfully reduced surface nitrogen loads; however, they offer limited solutions for intercepting nitrogen after it leaches below the vadose zone.

To fill this gap, this study evaluated a nitrogen interception technology at Branford-Alliance Dairy in Branford, FL, designed to capture nitrogen-rich subsurface water before it reaches the aquifer. This innovative approach includes the installation of a series of intercept wells beneath irrigation pivots, allowing the recovered water to be reused by blending it with groundwater for irrigation or treating it through a denitrification bioreactor.

By assessing the system's performance and effectiveness in decreasing nitrogen loads, this research determined the feasibility of transforming these vulnerable "Open Systems" into more sustainable "Closed Systems." The findings have the potential to inform future nutrient management practices, contributing to both dairy farm productivity and the protection of critical water resources.

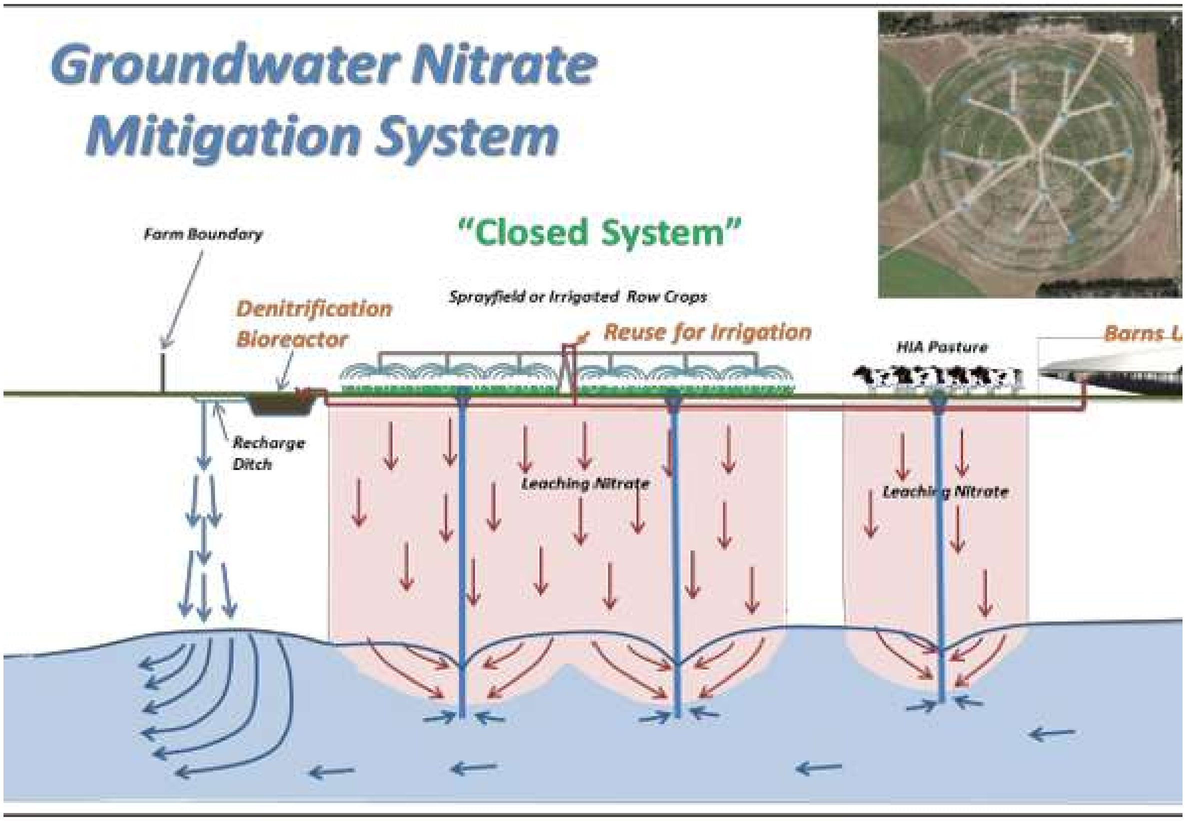


Figure 1: Cross section of theoretical dairy operation with high intensity pasture and sprayfield resulting in nitrate leaching; however, in this instance an array of intercept wells captures leachate and brings it back to the surface for reuse or treatment through a denitrification bioreactor.

THE PROCESS

The nitrogen interception technology evaluated in this study transforms an "Open System" into a "Closed System" by strategically placing intercept wells (Figure 1). The process works in the following steps:

1. **Installation of Intercept Wells**: Intercept wells are installed beneath irrigation pivots, with intake points at the surface of the underlying aquifer. These wells are positioned to capture nitrogen-rich leachate before it reaches the aquifer (Figure 2).

2. **Creation of Hydrologic Localized Cones of Depression**: The equidistantly placed intercept wells are strategically designed so that as subsurface water is drawn into the intercept wells, localized hydrologic cones of depression and potentiometric lows are created, helping to capture the nitrogen-rich water that has leached through the soil.

3. **Collection and Reuse**: The intercepted subsurface water is collected and can be either reused by blending it with groundwater from irrigation wells or treated further through the woodchip denitrification bioreactor for higher nutrient quality.

4. **Bioreactor Treatment (Optional)**: In some cases, the intercepted subsurface water is directed to a denitrification bioreactor, which lowers the nitrogen concentrations before the water is either reused or discharged (Figure 3).

5. **Sustainable Water Reuse**: Once treated or blended, the water can be used for irrigation, closing the nutrient loop and reducing nitrogen loading to both surface and groundwater.

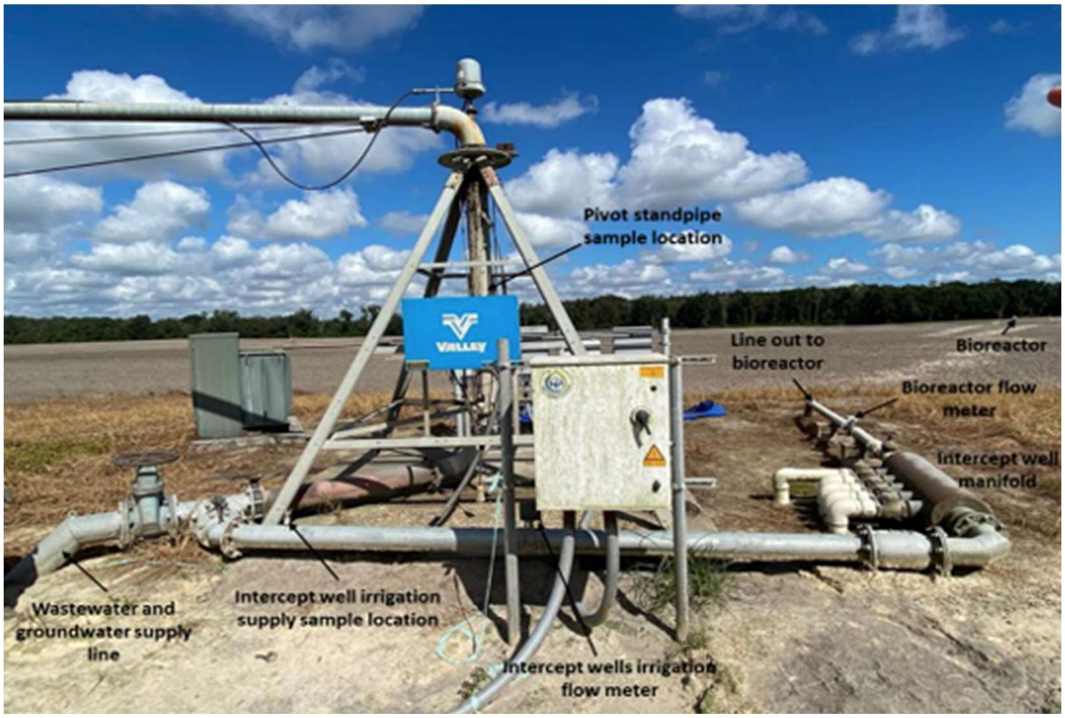


Figure 2. Layout of piping at center of pivot B indicating principal components of intercept well infeed line to irrigation pivot and line out to bioreactor and flow meters and sample collection locations.

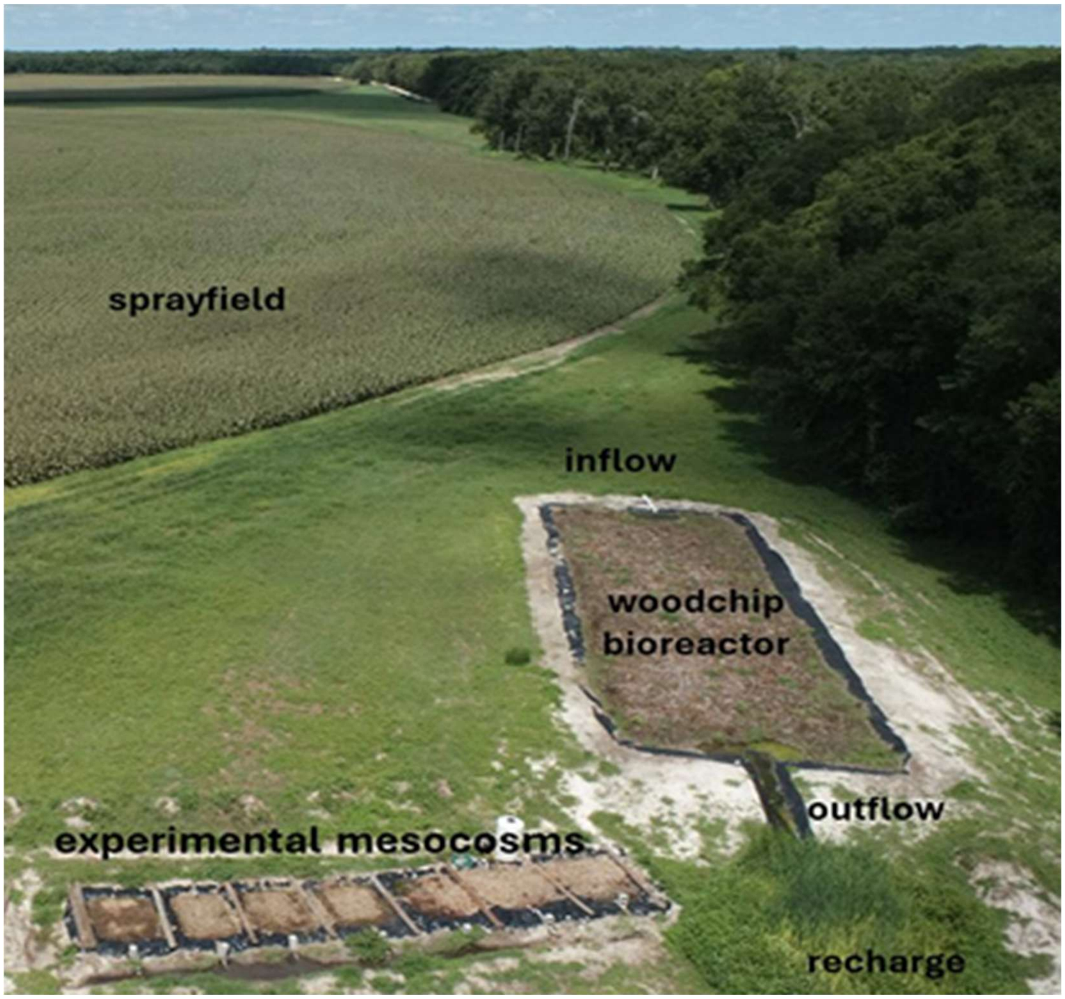


Figure 3: Aerial image showing proximity of woodchip denitrification bioreactor relative to sprayfield.

METHODOLOGY

Sample Collection and Monitoring:

Over the course of the study, water samples were collected weekly, typically on Mondays, to monitor flow from the intercept wells to the woodchip denitrification bioreactor (M-line) and to the center pivot (IW-I line). A water sample was collected from the standpipe to the sprayfield pivot when either fresh groundwater (FW) or wastewater (WW) was in use, with the valve being flushed for three minutes before collection. The main freshwater irrigation well was drilled to 100 feet, and the intercept wells were installed to 50-60 feet below the surface. During most of the monitoring period, the controller regulating the mixing of FW and IW-I water was offline, therefore only one sample event captured the combined water quality. However, other events were documented using water from the intercept well array. Three sampling events (9/16/2022, 4/24/2023, and 8/10/2023) were conducted for all 15 intercept wells to estimate water quality from the intercept wells during irrigation.

Weekly water samples were also taken from the inlet and outlet of the woodchip denitrification bioreactor, with flow volumes monitored by the M-line meter. All samples were collected in 250 ml polyethylene containers, placed on ice, and transported to the laboratory for analysis. Parameters tested included pH, conductivity, nitrate-N, ammonium-N, phosphorus, potassium, calcium, and other elements, with total nitrogen calculated from nitrate and total Kjeldahl nitrogen (TKN) concentrations.

Woodchip Denitrification Bioreactor:
The woodchip denitrification bioreactor (100’ x 30’ x 4’) received a continuous flow of water (~50 gallons per minute) from an intercept well, entering through a multilevel diffuser. Water flowed through the bioreactor and infiltrated back into the soil, contributing to nitrogen reduction before returning to the aquifer.

Load, Intercept, and Treatment Calculations:
Input nitrogen loads were calculated for wastewater (WW), fresh groundwater (FW), and intercept well water (IW-I) applications. Wastewater loads were determined using producer-recorded volumes and nitrogen concentrations from the nearest temporal sample at the center pivot. Groundwater loads were based on producer-provided volumes and corresponding nitrogen concentrations. Intercept well nitrogen loads were estimated using IW-I flow meter data and either direct center pivot measurements or average concentrations from intercept well array samples.

Intercept loads represented nitrogen quantities that would have been lost to the environment without interception. These were calculated using IW-I flow meter data and nitrogen concentrations from direct or averaged intercept well sampling. Additionally, groundwater nitrogen loads and denitrification bioreactor inlet loads were determined based on producer records, flow meter readings (M-line), and weekly inflow sample concentrations.

Treatment loads quantified nitrogen reductions achieved by the denitrification bioreactor. The reduction was calculated by comparing inflow nitrogen loads (based on M-line meter volumes and inflow concentrations) with outflow concentrations from weekly bioreactor sampling.

DISCUSSION OF RESULTS

This evaluation offers valuable insights into the effectiveness of nitrogen interception technology for improving nutrient management practices in dairy farming. This analysis examines the performance of the intercept well array and woodchip denitrification bioreactor in capturing nitrogen-rich leachate and reducing nitrogen concentrations in water, ultimately assessing their potential for enhancing water quality and promoting sustainable farming practices.

KEY BENEFITS OF THE NITROGEN INTERCEPTION TECHNOLOGY

Improved Nitrogen Management: The study highlights the significant benefit of nitrogen interception through a combination of intercept wells and a woodchip denitrification bioreactor. By using intercept wells, nitrogen species such as Nitrogen Oxides-Nitrogen (NOx-N), Ammonium-Nitrogen (NH_4-N), and Total Kjeldahl Nitrogen - Nitrogen (TKN-N) are intercepted and redirected, reducing nitrogen concentrations in the irrigation water. This process minimizes the potential for nutrient leaching and runoff into surrounding environments, particularly important in areas with sensitive water systems. The woodchip denitrification bioreactor further enhances this by removing NOx-N and total nitrogen (TN) concentrations at rates of approximately 25% and 20%, respectively. This removal leads to a marked reduction in nitrogen loads — combining the groundwater and intercept wells, TN load intercepted and returned for reuse totaled 48,650 lbs. or 392 lbs./acre at pivot B (Tables 1 and 2).

Table 1. Nutrient load, load intercepted, or load treated at Pivot B during the monitoring period.

Water source	NOx -N , lbs	NH4-N, lbs	TKN-N, lbs	TN, lbs
Wastewater	2	83,290	183,972	183,974
Groundwater	29,257	30	13,797	43,054
Intercept Wells	4,273	3	1,323	5,596
Denitrification Bioreactor	2,930	1	528	3,458

Table 2. Nutrient load, load intercepted, or load treated at Pivot B normalized per acre.

Water source	NOx -N , lbs/acre	NH4-N, lbs/acre	TKN-N, lbs/acre	TN, lbs/acre
Wastewater	0	672	1,484	1,484
Groundwater	236	0	111	347
Intercept Wells	34	0	11	45
Denitrification Bioreactor	23	0	4	28

Improved Water Quality: By significantly reducing nitrogen concentrations in the irrigation water, the technology helps mitigate risks associated with excess nitrogen leaching, such as eutrophication in downstream water bodies. The bioreactor's reduction of NOx-N and TKN-N — averaging a 19.5% decrease in TN across all water sources (Table 3) — directly contributes to improved water quality and promotes enhanced soil conditions. This targeted approach provides a sustainable solution to managing agricultural runoff and leachate, optimizing both water and ecosystem health.

Table 3: Mean + 1SD of nutrient concentration of water sources monitored. Values represent weighted average during assessment period.

Water source	NOx -N , mg/L	NH4-N, mg/L	TKN-N, mg/L	TN, mg/L
Wastewater	0.05 + 0.00	370 + 69.2	814 + 153	814 + 153
Groundwater	49.8 + 11.8	0.05 + 0.00	22.7 + 10.8	72.5 + 18.3
Intercept Wells	68.0 + 11.2	0.07 + 0.05	48.4 + 50.5	116.3 + 44.9
Denitrification Bioreactor inflow	58.9 + 25.3	0.06 + 0.04	37.5 + 23.3	96.4 + 36.4
Denitrification Bioreactor outflov	44.4 + 22.3	0.05 + 0.01	33.2 + 23.2	77.6 + 29.1

Enhanced Resource Efficiency and Closed-Loop Nutrient Management: The intercept well system, in conjunction with the woodchip denitrification bioreactor, plays a pivotal role in promoting resource reuse and creating a closed-loop nutrient management system. This technology maximizes the use of available water resources, including wastewater, groundwater, and intercept wells, to optimize irrigation efficiency. By recycling water and nutrients within the system, the approach reduces the need for costly external water sources and commercial fertilizers and minimizes nitrogen accumulation in the environment. Under ideal conditions, with intercept wells operating as originally designed, approximately 50% of the water used for irrigation would be sourced from the intercept wells, with the remaining half drawn from groundwater. This diminishes overall water demand while simultaneously lowering the nitrogen load in the irrigation process.

EVALUATION KEY CHALLENGES AND ISSUES

Operational Limitations: A significant challenge during this study was the malfunction of the system's blending controller, which disrupted the intended 50:50 blend between the intercept wells and groundwater irrigation. While the intercept wells continued to successfully intercept nitrogen as designed, the malfunction prevented the system from receiving enough water from the wells. As a result, only about 10% of the total irrigation volume came from the intercept wells, well below the intended 50% capacity. This limitation meant that the total amount of nitrogen being intercepted and redirected into the irrigation system was much smaller than anticipated. However, the study still provided useful insights into the potential impacts of a fully functional system, estimating up to 59,880 lbs of TN could be intercepted under optimal conditions (Table 4).

Table 4: Projected nitrogen loads that could be intercepted by main groundwater well and intercept well array if blended 50:50 by volume. The two scenarios vary by the nitrogen concentration allocated to the main groundwater well. Scenario 1 assumes no nitrogen in the main groundwater well, Scenario 2 assumes concentrations would remain as measured.

		Concentrations		Intercepted load			
Water source	**Pumped volume, 1000 gal.**	**NOx-N, mg/L**	**TN, mg/L**	**NOx -N, lbs**	**TN, lbs**	**NOx -N, lbs/acre**	**TN, lbs/acre**
Scenario 1							
Groundwater	44,388	0.0	0.0	0	0	0	0
Intercept Wells	44,388	68.0	116.3	22,425	38,353	179	307
Total	88,776	34.0	58.2	22,425	38,353	179	307
Scenario 2							
Groundwater	44,388	49.8	72.5	14,628	21,527	117	172
Intercept Wells	44,388	68.0	116.3	22,425	38,353	179	307
Total	88,776	34.0	58.2	37,053	59,880	296	479

Variation in Nitrogen Concentrations: Another challenge involves the variation in nitrogen concentrations across the intercept well array. Concentrations of NOx-N ranged from 3.6 mg/L to 137.5 mg/L, with noticeable variation between different zones in the field. Wells on the northern side of the pivot exhibited considerably lower concentrations, likely due to external groundwater influences, such as the proximity to the Sante Fe River and its karst geology. These variations in nitrogen levels can complicate the process of accurately predicting nitrogen load reductions, making it difficult to manage the system with precision in areas of inconsistent nitrogen input (Table 5).

Table 5. Weighed average nitrogen concentrations for the Pivot B intercept well array during the study period.

Water source	NOx -N , mg/L	NH4-N, mg/L	TKN-N, mg/L	TN, mg/L
Intercept Wells	68.0 + 11.2	0.07 + 0.05	48.4 + 50.5	116.3 + 44.9

IMPLICATIONS

The nitrogen interception technology has demonstrated significant potential in reducing nitrogen loads in irrigation water, with substantial removals achieved during the study period. Total nitrogen (TN) loads intercepted by the system amounted to 48,650 lbs (392 lbs per acre), with the main groundwater well alone contributing 43,054 lbs of TN. The woodchip denitrification bioreactor further enhanced the system's effectiveness by removing 2,930 lbs of NOx-N and 3,458 lbs of TN, with removal rates of 23.4 and 27.7 lbs per acre, respectively. When considering the nitrogen intercepted by both groundwater and intercept wells, the system achieved a reduction in nitrogen load applied via wastewater by approximately 20-33%. While operational challenges and variability in nitrogen concentrations persist, the results underscore the considerable impact of this technology in mitigating excess nitrogen in agricultural runoff. Under full functionality, this system offers a promising solution for improving water quality and operational efficiency in agricultural settings.

For additional information on the vendor, environmental impacts, financial implications, and nitrogen interception technology, visit the Soil and Water Engineering Technology, Inc. Vendor Snapshot on the Newtrient website.

This study was funded by the Natural Resources Conservation Service (NRCS) through a Conservation Innovation Grant (CIG). The views and findings presented in this publication are those of the author(s) and do not necessarily reflect the official views or policies of NRCS or the U.S. Department of Agriculture.

Appendix C

Third-Party Review of Nitrogen Interception Technology at Alliance Dairy – Branford, FL (Full Report)

Third Party Evaluation of Nitrogen Interception at Branford-Alliance Dairy, Branford, Florida

Work completed
for Newtrient
September 2024

By Mark Clark

Soil, Water and Ecosystem Sciences Department

University of Florida / Institute of Food and
Agricultural Sciences Gainesville, FL

1.0 Purpose

Nitrogen has found its way to groundwater in many locations around the country. Some sources have been traced back to manure applications on crop and pasture lands.

This study's intent is to evaluate the performance and water quality advantages of an innovative subsurface nitrogen interception technology at the Branford-Alliance Dairy in Branford, FL.

Subsurface water is intercepted and re-applied on cropland or pastureland reducing the nitrogen load reaching ground and surface waters.

The primary objective of this study is to evaluate the system performance and determine its effectiveness in reducing the nitrogen load in subsurface water from applied liquid animal waste.

2.0 Study Site

The study was conducted at a free stall dairy operation in Branford, Florida. The operation consists of five whole or partial radius sprayfield pivots (Figure 1). The geology at this location has no clay confining layers between the surface and the underlying groundwater. This makes the site less vulnerable to surface runoff, but highly vulnerable to groundwater leaching and entrainment of potential contaminants into the Floridan Aquifer (Figure 2). This type of connectivity with the environment is often considered an "Open System" due to an inability to intercept potential contaminant loads. This area has numerous karst features including many springs. Unlike nutrient best management practices targeting surface nutrient loads that can be intercepted and treated, leaching and subsurface loading to groundwater have traditionally only been managed through optimization of irrigation and fertilizer application rates with limited opportunity to intercept losses once they leach below the vadose zone.

The innovative technology being evaluated here is the placement of an array of intercept wells below an irrigation pivot with intake at the surface of the underlying water table. This would effectively create a "Closed System" where nutrients could be intercepted and reused (Figure 3). Total pumped volumes are designed to equal the annual leaching volume from rainfall. Placement of wells equidistant under the sprayfield and pump rate are designed to create localized cones of depression and potentiometric lows such that leaching volumes are intercepted and directed back to the surface for reuse or treatment (Figure 4).

Reuse in this case is by blending water from the intercept well array with water from an irrigation groundwater well. This mixed source was necessary since the intercept wells below a single sprayfield are not sufficient to meet the pivot volume demand. If other sprayfields were set up with intercept wells, then pivot irrigation volume demand could be met by combining intercept well flows from multiple fields, thus eliminating a main irrigation well. Treatment in this case is being implemented using a woodchip denitrification bioreactor that is continuously loaded from one of the intercept wells (Figure 5).

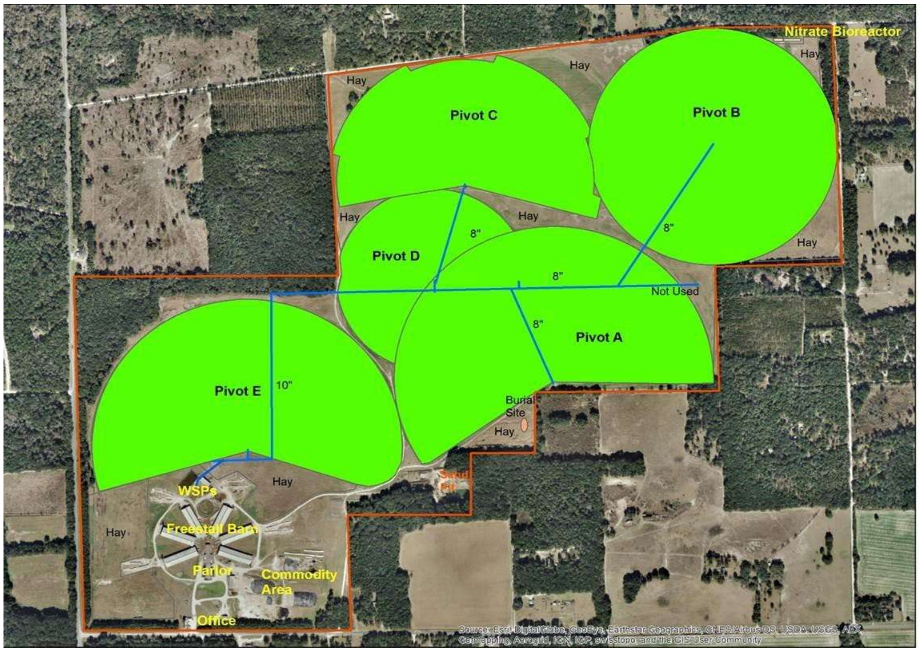


Figure 1. Dairy operation used for this study, specifically pivot B in the upper right of image.

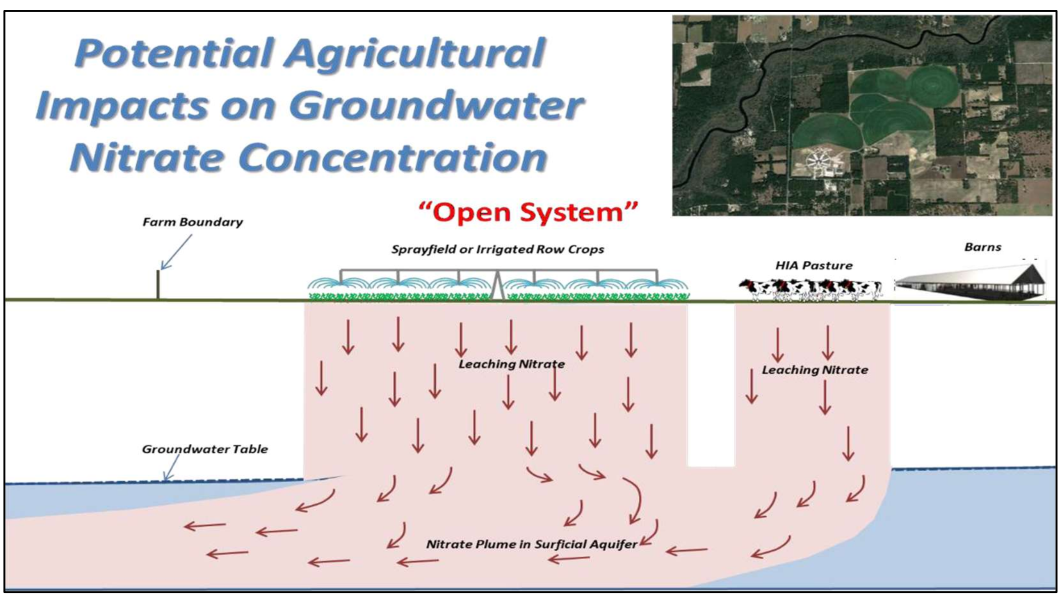


Figure 2. Potential impact to groundwater from leaching of nitrate below high intensity use areas and irrigated crops in unconfined karst geologies.

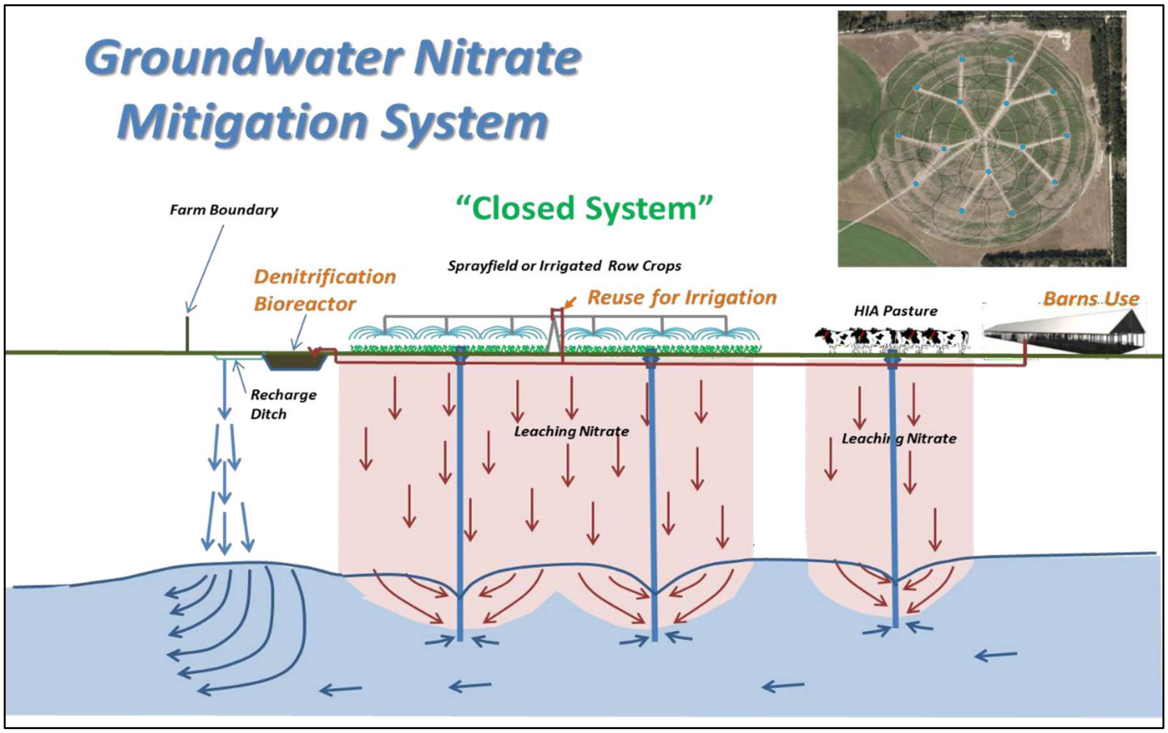


Figure 3. Cross section of theoretical dairy operation with high intensity pasture and sprayfield resulting in nitrate leaching; however, in this instance an array of intercept wells captures leachate and brings it back to the surface for reuse or treatment through a denitrification bioreactor.

3.0 Methods

3.1 Sample collection and intercept well array

Water sample collection and flow meter monitoring was conducted once per week, typically on a Monday. A meter that monitored flow from the intercept wells to the denitrification bioreactor (identified as "M-line") and a meter monitoring flow from intercept wells to center pivot (identified as "IW-I line") were logged weekly. If irrigation of "fresh" groundwater (identified as "FW") or wastewater (identified as "WW") was occurring when meters were logged, a water sample was collected from the standpipe going out to the sprayfield pivot via a valved port (Figure 6). When sampling, the valve was left open for 3 minutes to completely flush the line prior to sample collection.

The main freshwater irrigation supply well was drilled to 100 feet deep and cased to 55'. Wells associated with the groundwater intercept array were installed to a depth of 50-60 feet below the surface or approximately 10 feet below the seasonal low groundwater table.

When groundwater was being irrigated, the designed water supply with intercept wells would be an approximate 50:50 mix of water from the main groundwater supply well (FW) and water from the intercept array (IW-I line) to supply the pivot. However, for 9 months during the monitoring period the controller that regulated mixing was offline and only one sampling event captured the combined FW and IW-I line water quality. However, there were still multiple events that utilized water from the intercept well array as documented by the producer and quantified on the flow meter. There was also a nearly continuous flow of water from one of the intercept wells to the denitrification bioreactor. Since only one sampling event captured the combined concentration of all intercept wells, three sampling events of all 15 intercept wells were conducted during the monitoring period (9/16/2022, 4/24/2023 and 8/10/2023). Samples at each well were conducted by turning the pump on, allowing it to flow for 60 seconds (approximately 50 gal or 25 well casing volumes). The average concentration of intercept wells during these three sampling events were then used to estimate the concentration of combined intercept well water being applied whenever the IW-I line flow meter indicated irrigation from the intercept well array had occurred.

Weekly water samples were also collected at the inlet (pilot-inflow) and outlet (pilot-outflow) of the denitrification bioreactor with weekly flow volumes based on the M-line meter at the center pivot.

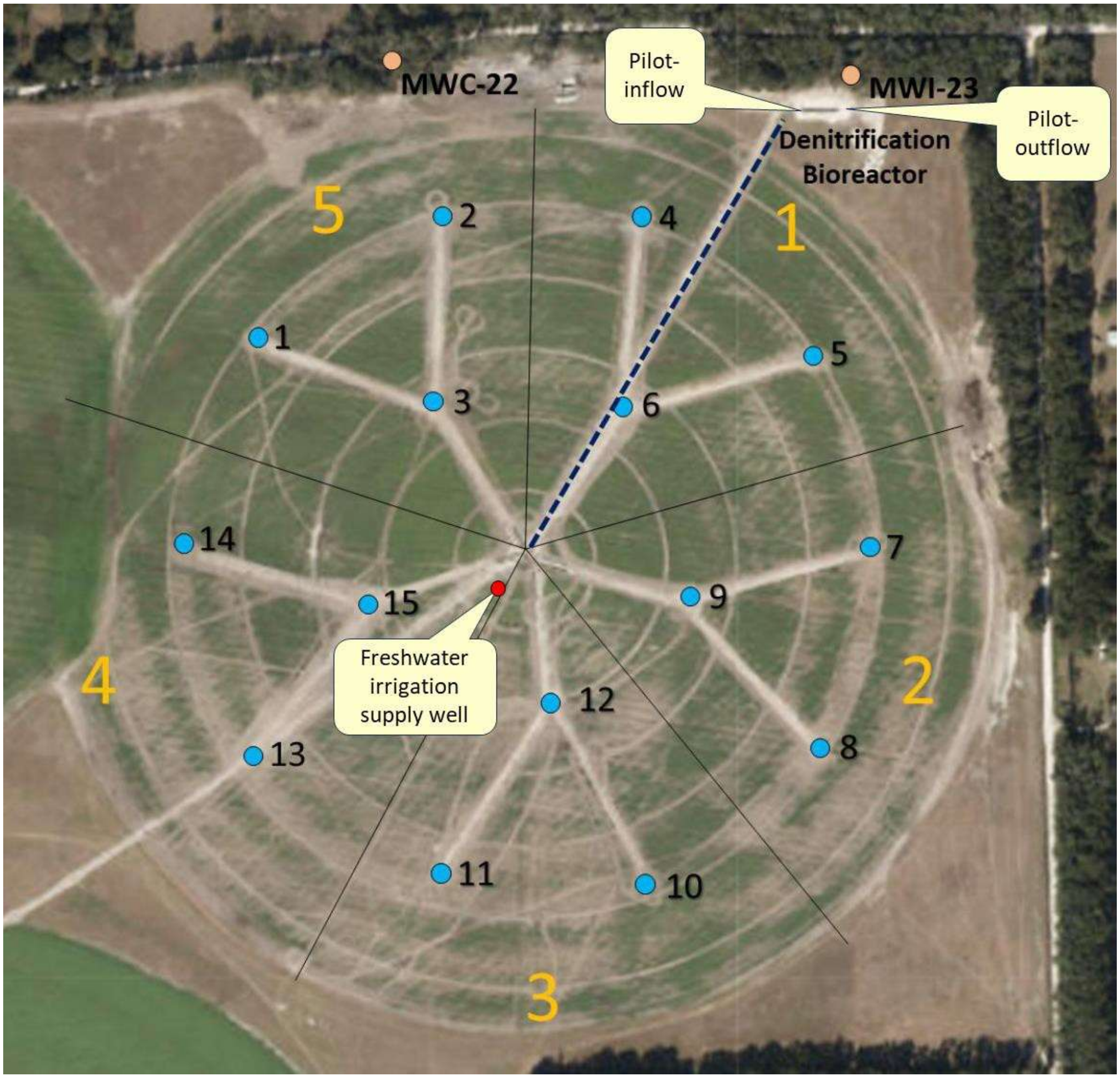


Figure 4. Location of intercept well array in Pivot B sprayfield and pilot denitrification bioreactor (upper right). Numbers 1-5 in orange indicate zones of three wells each within the sprayfield, numbers 1-15 in black identify the individual intercept wells. Dendritic pattern originating from center of sprayfield identify trenching used to place pipes. Pilot-inflow and Pilot outflow sampling locations at denitrification bioreactor and freshwater irrigation supply well location also noted.

Figure 5. Aerial view of Pivot B with milking barns in the distance and denitrification bioreactor in the foreground. Open patches within the sprayfield identify the location of each well in the intercept well array below the field.

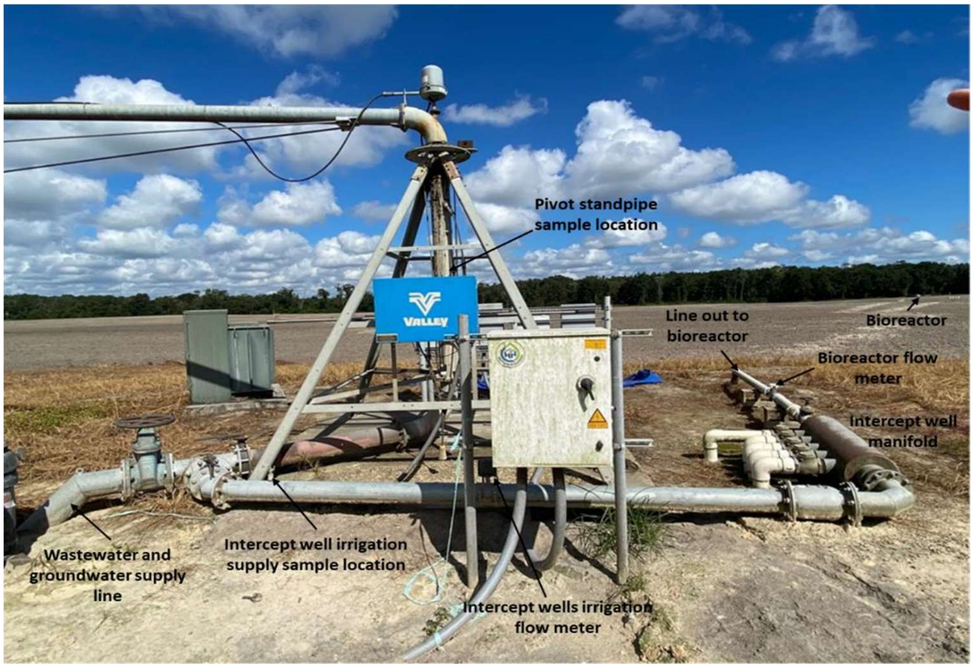


Figure 6. Layout of piping at center of pivot B indicating principal components of intercept well infeed line to irrigation pivot and line out to bioreactor and flow meters and sample collection locations.

All water samples were collected in 250 ml polyethylene containers and immediately placed on wet ice for transport to the laboratory. Once in the laboratory, samples were placed in a freezer and frozen to approximately -18° C.

All sample analysis for this study was conducted at A&L Great Lakes Laboratory. Frozen samples were shipped 2nd day delivery in well insulated boxes. Testing of shipment method indicated that samples would remain frozen for a period of up to 3 days when ambient average

temperature during the period remained below 32° C. Analysis at the laboratory consisted of: Ph, Conductivity, Nitrate-N (NOx), Ammonium-N (NH4), Phosphorus, Potassium, Calcium, Magnesium, Sodium, Aluminum, Sulfur, Zinc, Manganese, Iron, Copper, Boron, Chloride, Molybdenum, Silicon and Total Kjeldahl Nitrogen (TKN). Total nitrogen (TN) was determined by adding NOx-N and TKN-N concentrations together.

3.2 Denitrification Bioreactor

The denitrification bioreactor received a continuous flow (~50gpm) of water from one of the intercept wells. Water entered a lined woodchip bioreactor (100 x 30 x 4 feet, L x W x D) via a multilevel inlet diffuser and was collected at the opposite end and allowed to overflow the reactor and infiltrate into the soil back to the water table. (Figure 7).

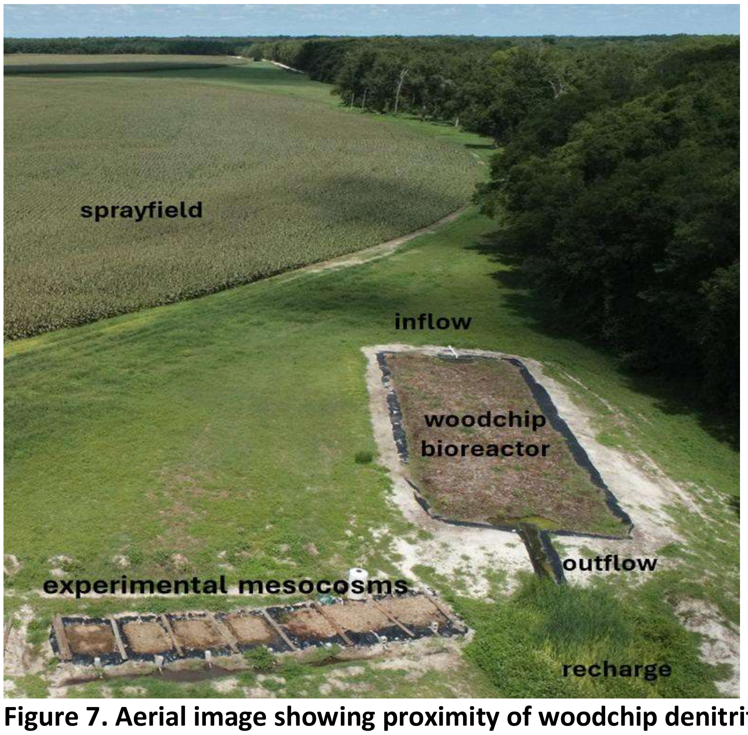


Figure 7. Aerial image showing proximity of woodchip denitrification bioreactor relative to sprayfield.

3.3 Load, Intercept and Treatment calculations

Input loads were defined as any nitrogen load related to the application of wastewater (WW), groundwater (FW) and or intercept well water (IW-I). These loads were calculated based on the following:

- Wastewater load – volume pumped based on producer records; nitrogen concentration based on closest temporal sample collected at the center pivot.
- Groundwater load - volume provided by producer records, nitrogen concentration based on closest temporal sample collected at the center pivot.
- Intercept well nitrogen load - volume based on IW-I flow meter, concentration based on either direct measurement at center pivot or average concentration of individual well samples collected from the intercept well array during the closest temporal sampling.
- Denitrification bioreactor inlet load – volume based on metered flow into reactor (M- line), concentration based on weekly inflow samples.

Intercept loads are defined as any nitrogen load intercepted that would have otherwise been lost to the environment.

- Intercept well nitrogen load - volume based on IW-I flow meter, concentration based on either direct measurement at center pivot or average concentration of individual well samples collected from the intercept well array during the closest temporal sampling.
- Groundwater nitrogen load - volume provided by producer records, nitrogen concentration based on closest temporal sample collected at the center pivot.
- Inlet load to denitrification bioreactor - volume based on metered flow into reactor (M- line), concentration based on weekly inflow samples.

Treatment load

- Load reduced by treatment in the denitrification bioreactor - The change in nitrogen load between inflow and outflow at the denitrification bioreactor. Inlet loads are defined above, Outlet loads from the denitrification bioreactor are based on inlet volumes from M-line meter and concentration of samples collected weekly at the outflow of bioreactor.

4.0 Results and Discussion

Results will be covered in four sections: 1) Overall nitrogen loads, 2) Intercept well array nitrogen, 3) Denitrification bioreactor, and 4) Measured and projected intercept nitrogen loads.

4.1 Overall nitrogen loads

Four components of nitrogen load were evaluated during this study, wastewater inputs, groundwater inputs from irrigation well, intercept well water used for irrigation, and intercept well water sent to the denitrification bioreactor for treatment. Concentration of the various water sources varied in nitrogen species and concentration (Table 1). Wastewater NOx-N concentrations were negligible, while wastewater NH4-N, TKN-N and TN concentrations were an order of magnitude greater than the other three water sources. Groundwater irrigation well NOx-N and TKN-N concentrations were unexpectedly high. These concentrations were still less than concentrations for the intercept well array but suggest that the main groundwater irrigation well is acting like the intercept wells to intercept NOx-N and TKN-N and bring it back to the surface for reuse. NOx-N concentration change in the denitrification bioreactor averaged 14.5 mg/L or a 24.6% reduction of NOx-N and total nitrogen concentration decreased 18.8 mg/L for a 19.5% reduction for TN on average over the monitoring period.

Table 1. Mean ± 1SD of nutrient concentration of water sources monitored. Values represent weighted average during assessment period.

Water source	NOx -N , mg/L	NH4-N, mg/L	TKN-N, mg/L	TN, mg/L
Wastewater	0.05 + 0.00	370 + 69.2	814 + 153	814 + 153
Groundwater	49.8 + 11.8	0.05 + 0.00	22.7 + 10.8	72.5 + 18.3
Intercept Wells	68.0 + 11.2	0.07 + 0.05	48.4 + 50.5	116.3 + 44.9
Denitrification Bioreactor inflow	58.9 + 25.3	0.06 + 0.04	37.5 + 23.3	96.4 + 36.4
Denitrification Bioreactor outflo	44.4 + 22.3	0.05 + 0.01	33.2 + 23.2	77.6 + 29.1

Pumped water volumes associated with these four water sources were in the millions to tens of millions of gallons during the monitoring period (Table 2). Groundwater for irrigation had the greatest volume pumped, with intercept wells used for irrigation being only 10% of that volume. If the intercept well array had been integrated into the groundwater irrigation process as designed, approximately half the water used for irrigation would have come from the groundwater well and the other half from the intercept wells. Therefore, intercept well loads presented represent what occurred during this monitoring effort; however, they are significantly lower than what would have occurred had the system been operated as design. The fourth part of the results section will address this and provide a projected estimate of nitrogen that would have been intercepted had the system been operated as designed.

Table 2. total volume and volume per acre of water applied or treated at Pivot B.

Water source	1000 gal	1000 gal/acre
Wastewater	31,039	248
Groundwater	80,497	644
Intercept Wells	8,278	66
Denitrification Bioreactor inflow	25,223	202

Nitrogen loads associated with the four water sources are provided in Table 3. Total nitrogen loads were two orders of magnitude greater for wastewater and one order of magnitude greater for groundwater then the nitrogen load intercepted by the intercept array for irrigation or what was sent to the bioreactor and removed through denitrification. Normalizing these load values over the 125 acres of pivot B we can see input TN loads from wastewater are over 4 times greater than groundwater, and groundwater TN loads are almost 8 times greater than TN loads for irrigation from intercept wells (Table 4). Combining the groundwater and Intercept wells, TN load intercepted and returned for reuse totaled 48,650 lbs. or 392 lbs./acre at pivot B.

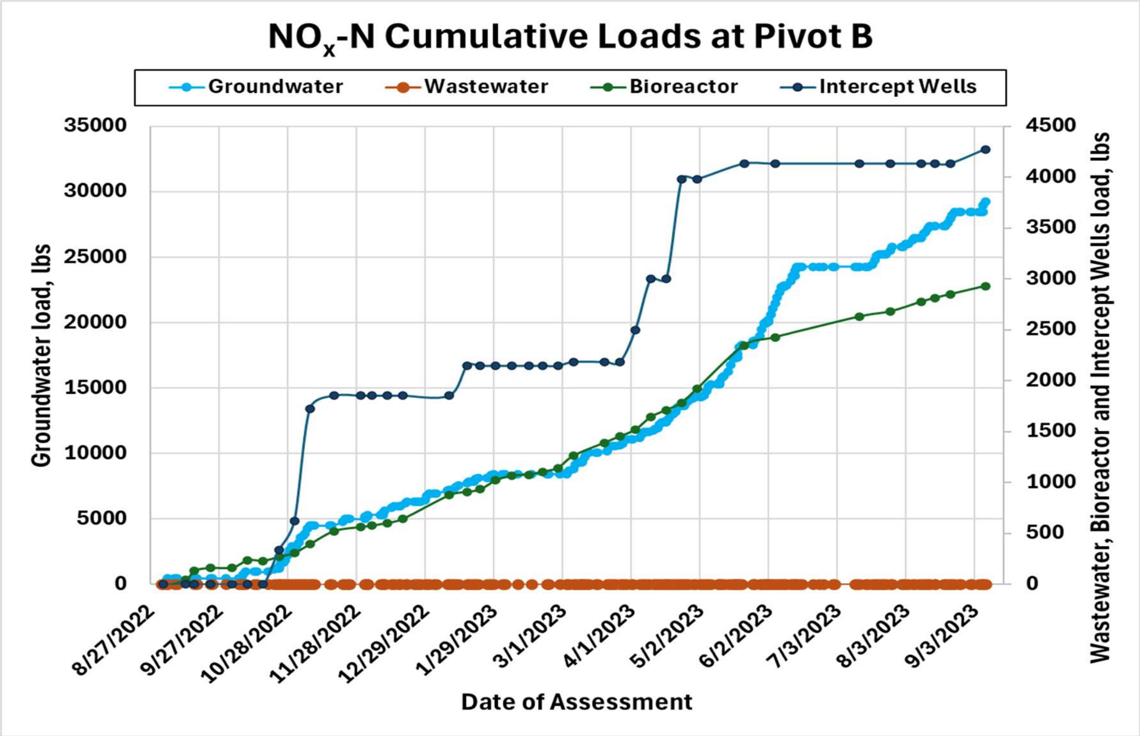
Figures 8-11 illustrate the cumulative load for each water source and nitrogen species during the one-year monitoring period.

Table 3. Nutrient load, load intercepted or load treated at Pivot B during the monitoring period.

Water source	NOx -N , lbs	NH4-N, lbs	TKN-N, lbs	TN, lbs
Wastewater	2	83,290	183,972	183,974
Groundwater	29,257	30	13,797	43,054
Intercept Wells	4,273	3	1,323	5,596
Denitrification Bioreactor	2,930	1	528	3,458

Table 4. Nutrient load, load intercepted or load treated at Pivot B normalized per acre.

Water source	NOx -N , lbs/acre	NH4-N, lbs/acre	TKN-N, lbs/acre	TN, lbs/acre
Wastewater	0	672	1,484	1,484
Groundwater	236	0	111	347
Intercept Wells	34	0	11	45
Denitrification Bioreactor	23	0	4	28



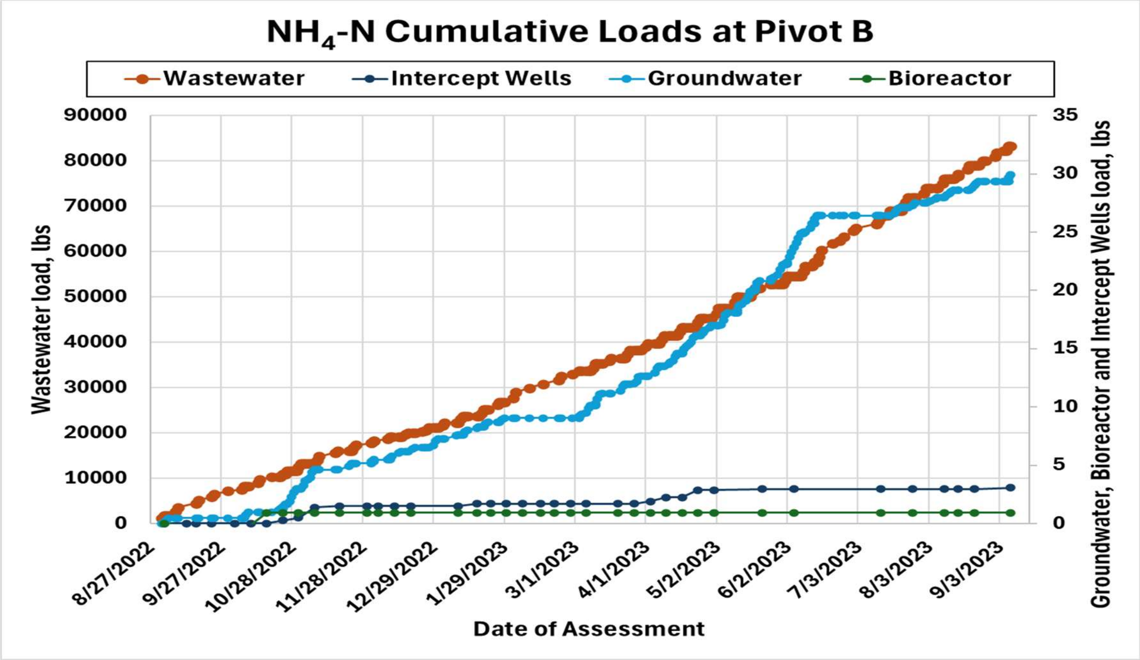
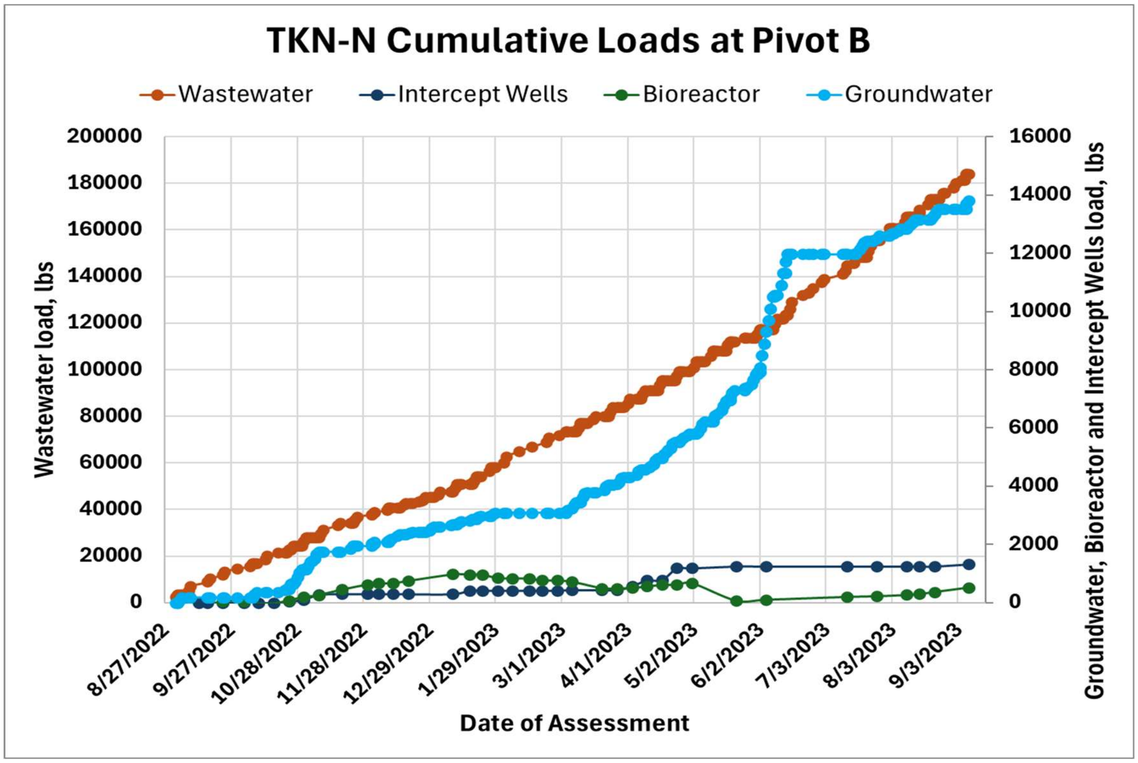


Figure 8 and 9. Cumulative NOx-N and NH4-N load for the four water sources.



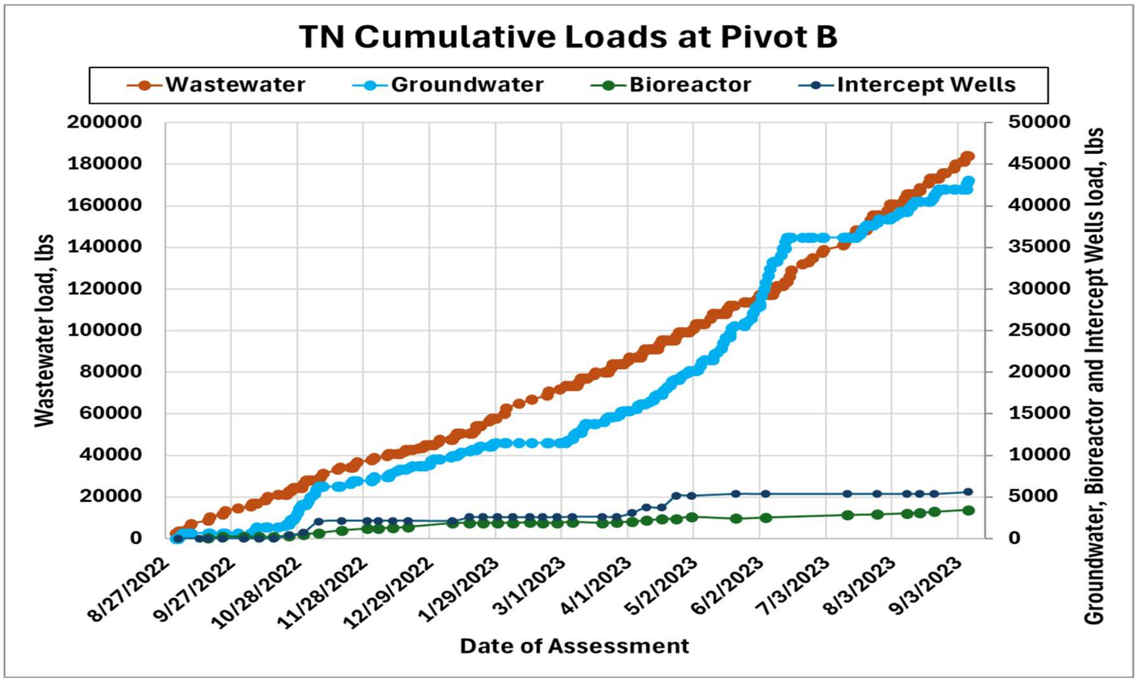


Figure 10 and 11. Cumulative TKN-N and TN load for the four water sources.

4.2 Intercept well array nitrogen dynamics

As described in the methods section, the intercept well array consisted of 15 wells arranged in five zones as groups of three. Samples were collected from each operational well three times. Figures 12, 13 and 14 show individual well NOx-N concentrations with an average NOx-N of 50.84 + 23.04 mg/L (9/16/2022), 78.21+ 25.03mg/L (4/24/2023) and 58.17 + 25.30 mg/L (8/10/2023). NOx-N concentrations typically ranged an order of magnitude or more among the wells with lower concentrations generally occurring in the north and northwest side of the pivot and highest concentrations occurring around the center or southern side of the pivot. The NOx-N concentration among all wells and across the monitoring period ranged from 3.6 to 137.5 mg/L. Average nitrogen concentrations for the intercept well array can be found in table 5.

One factor likely influencing the lower nitrogen concentration of intercept wells in the north-northwestern side of the pivot is the proximity of the spray field to the Sante Fe River and the karst geology of the area. High water levels in the river can result in reversal of the groundwater gradient and where springs exist along the river there can be a flow of river water into the spring and movement of that water though groundwater conduits for considerable distances. When sampling the well array on 9/16/2022, groundwater sampled from wells in zone 5 showed considerable color indicating tannins in the water. NOx-N concentrations at these wells were also considerably lower than the rest of the pivot intercept wells. The same condition occurred when sampling on 8/10/2023 where NOx-N concentrations in well #1 were at least ten times lower than all other wells. It is likely that wells on the northern side of the pivot are influenced by reversals in groundwater due to high water periods in the river during which time water from outside the direct leachate zone of the pivot move under the pivot resulting in lower NOx-N concentrations. The higher concentrations in the center of the pivot are likely due to a lack of dilution that is occurring to some extent in the perimeter wells of the intercept array.

Table 5. weighted average nitrogen concentrations for the Pivot B intercept well array during the study period.

Water source	NOx -N , mg/L	NH4-N, mg/L	TKN-N, mg/L	TN, mg/L
Intercept Wells	68.0 + 11.2	0.07 + 0.05	48.4 + 50.5	116.3 + 44.9

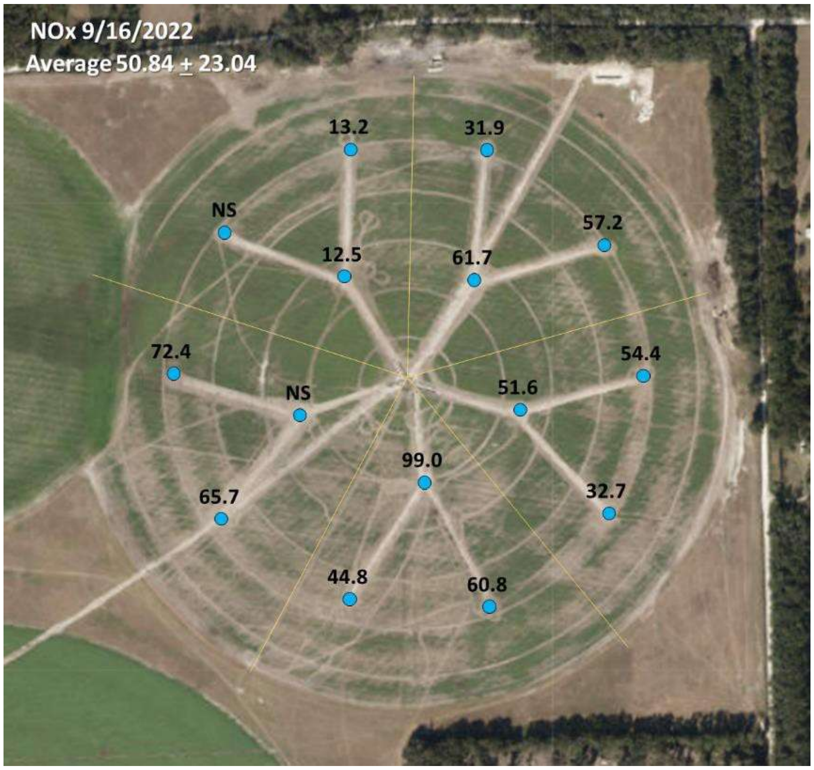

NOx 9/16/2022
Average 50.84 ± 23.04
13.2
31.9
NS
57.2
12.5
61.7
72.4
54.4
NS
51.6
99.0
65.7
32.7
44.8
60.8

Figure 12. NOx concentrations on 9/16/2022 at each well of the intercept well array at pivot B.

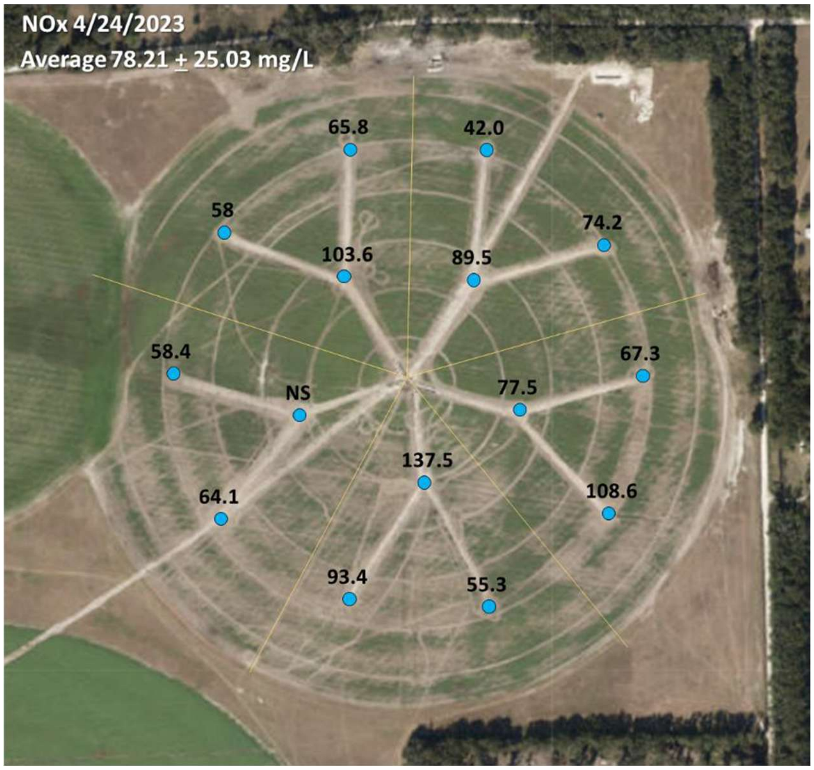


Figure 13. NOx concentrations on 4/24/2023 at each well of the intercept well array at pivot B.

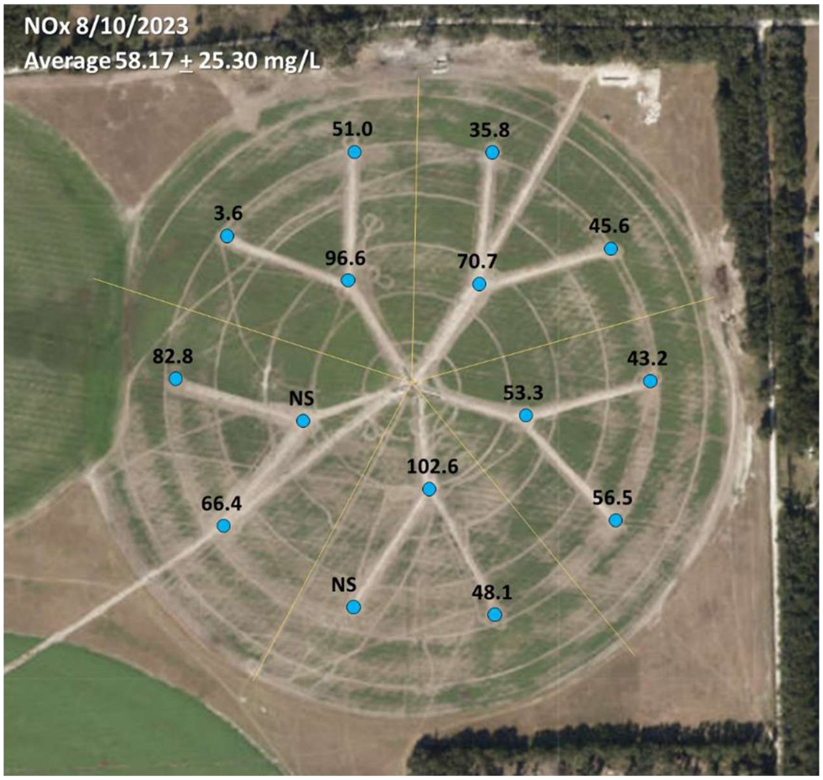


Figure14. NOx concentrations on 8/10/2023 at each well of the intercept well array at pivot B.

4.3 Denitrification Bioreactor

The denitrification bioreactor received a total of 25.2 million gallons of intercepted groundwater at an average flow rate of ~50 gpm. Inflow, outflow and change in water concentrations can be found in table 6 and figures 15 and 16. Nitrate concentrations were removed at a rate of ~25% and TN was removed at a rate of ~20%. The total load of NOx-N and TN removed in the denitrification bioreactor during the study period was 2,930 lbs. and 3,458 lbs. (Table 7 and Figures 17 and 18) or 23.4 and 27.7 lbs./pivot acre, respectively.

Table 6. Average inflow, outflow and change in concentration at the denitrification bioreactor.

Inflow concentration				**Outflow concentration**			
NOx, mg/L	**NH4, mg/L**	**TKN, mg/L**	**TN, mg/L**	**NOx, mg/L**	**NH4, mg/L**	**TKN, mg/L**	**TN, mg/L**
58.9 ± 25.3	0.06 ± 0.04	37.5 ± 23.3	96.4 ± 36.4	44.4 ± 22.3	0.05 ± 0.01	33.2 ± 23.2	77.6 ± 29.1

Concentration change

NOx, mg/L	**NH4, mg/L**	**TKN, mg/L**	**TN, mg/L**
14.5 ±10.9	0.01 ± 0.04	4.28 ± 18.2	18.8 ± 20.2

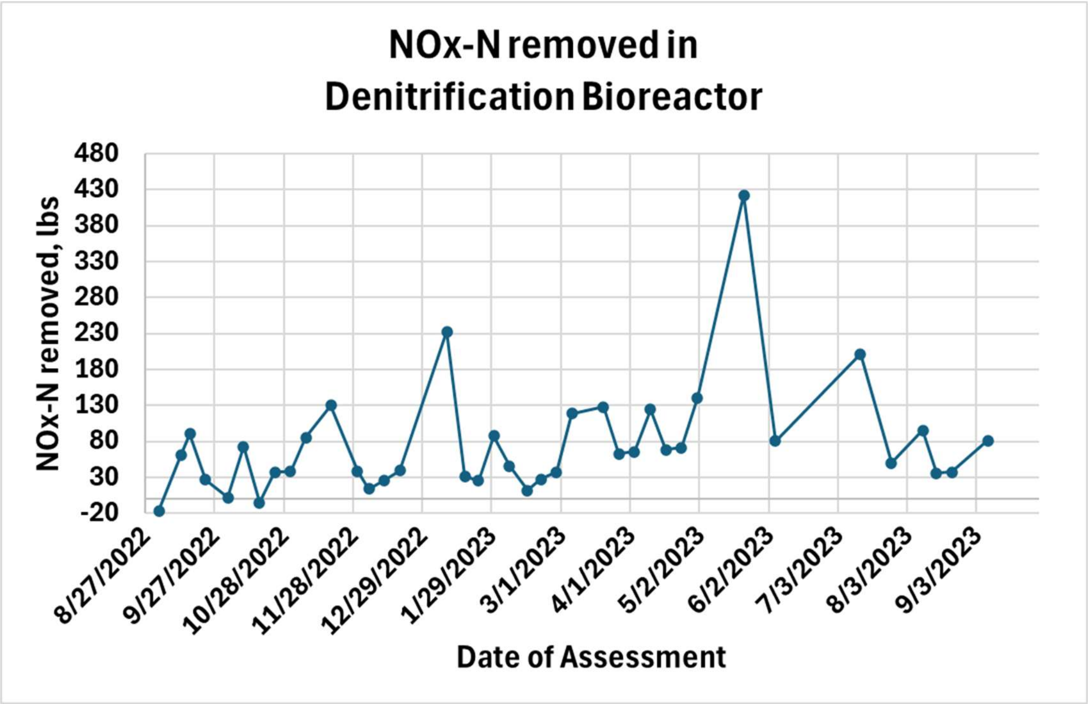


Figure 15. NOx-N removed in denitrification bioreactor during the study period.

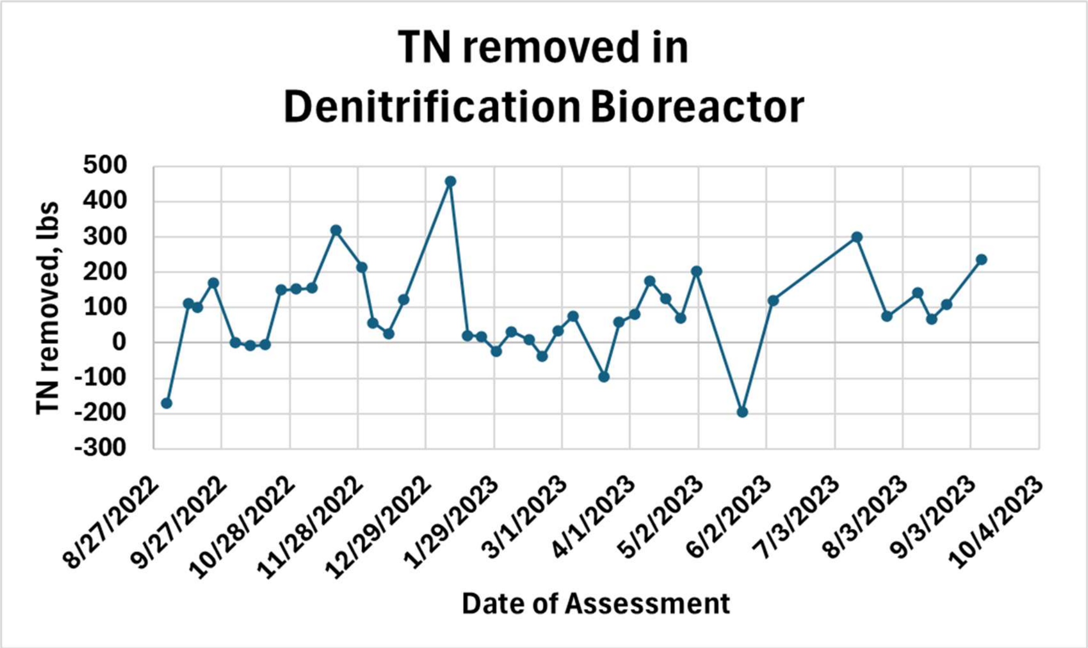


Figure 16. TN removed in denitrification bioreactor during the study period.

Table 7. Total nitrogen load removed from Pivot B in denitrification bioreactor and normalized removal rate per acre.

Total load removed				Total load removed per acre			
NOx-N, lbs	NH4-N, lbs	TKN-N, lbs	TN, lbs	Nox-N, lbs/acre	NH4-N, lbs/acre	TKN-N lbs/acre	TN lbs/acre
2930	1	528	3458	23.4	0.0	4.2	27.7

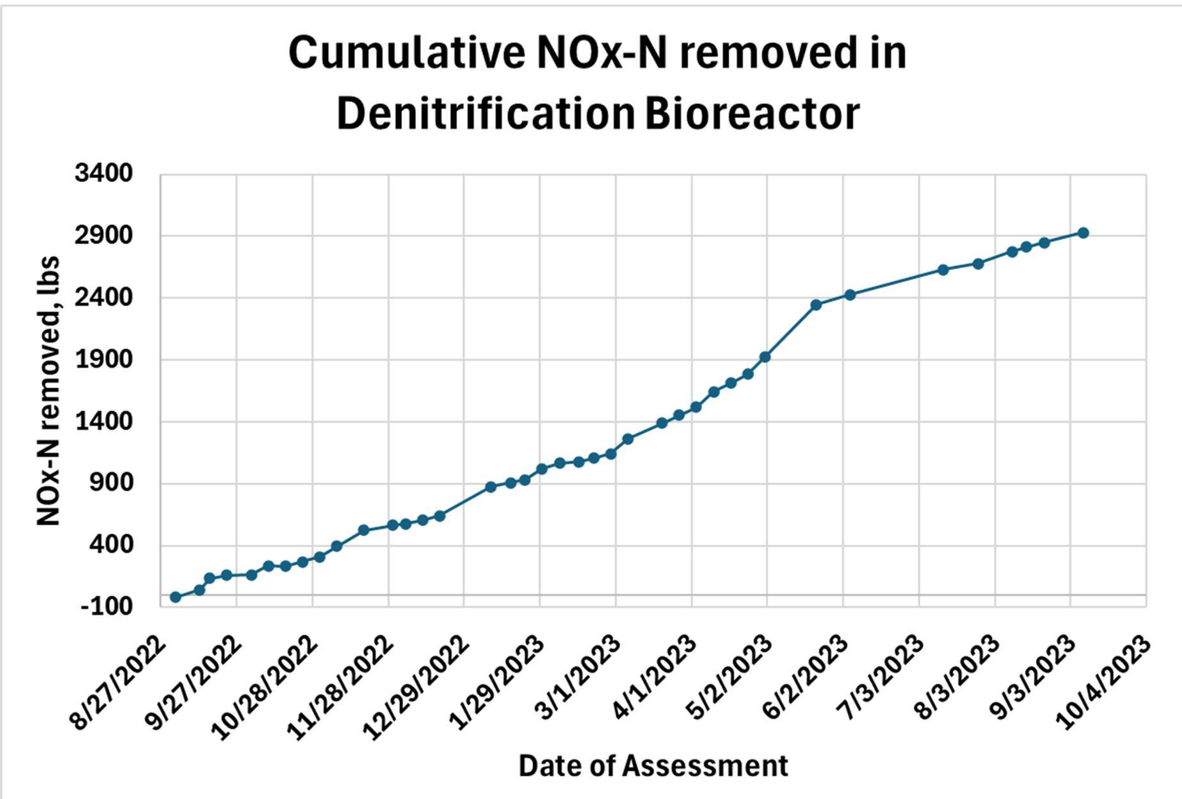


Figure 17. Cumulative NOx-N removed in denitrification bioreactor during the study period.

4.4 Measured and projected nitrogen loads intercepted

The original expectation was that only the intercept wells would have significant concentrations of nitrogen and therefore would be the primary mass of intercepted nitrogen for reuse. However, we also found high concentrations of nitrogen in the main groundwater irrigation well water. Concentrations in the main groundwater well were somewhat lower than the combined concentration of intercept wells (Table 8), but due to the significantly larger volume of water pumped from the groundwater irrigation well vs. intercept wells, the groundwater well resulted in a significantly greater total mass of nitrogen intercepted than what was recovered by the intercept wells. Total mass of NOx-N and TN intercepted by the intercept well array was 4,273 and 5,596 lbs respectively or 34 and 45 lbs/pivot acre. NOx-N and TN mass intercepted by the main groundwater irrigation well was 29,257 lbs. and 43,054lbs. or 234 and 344 lbs/pivot acre respectively.

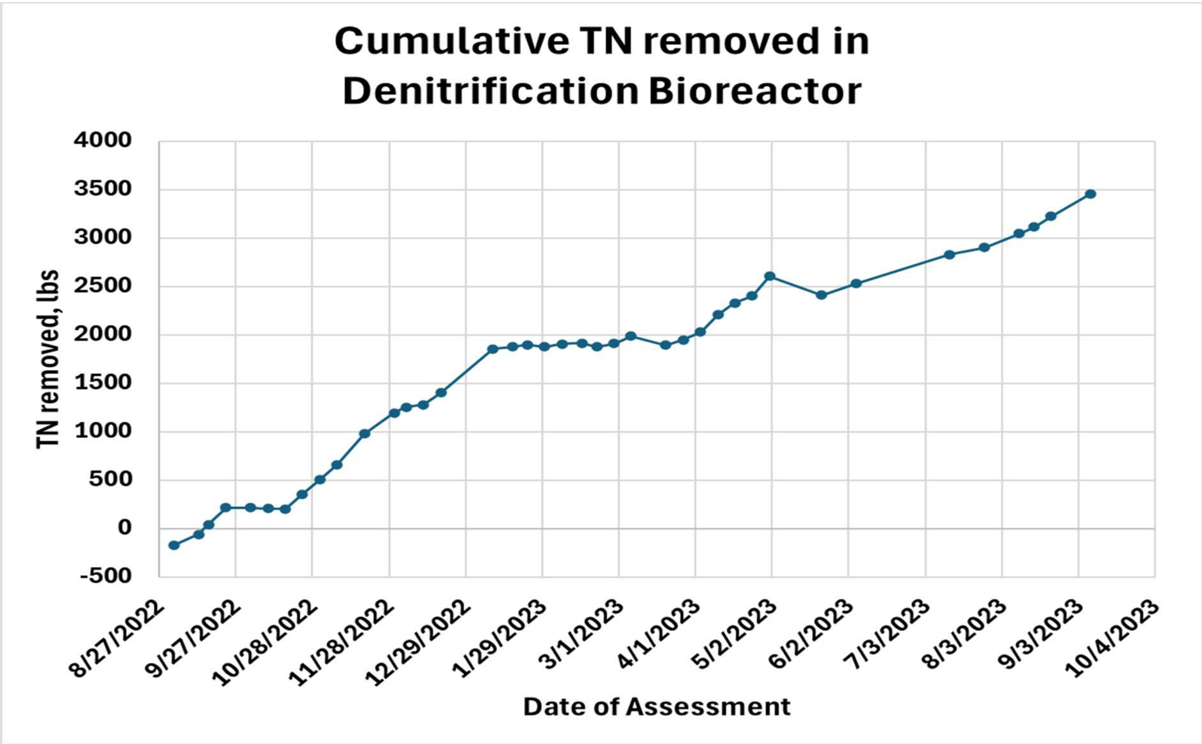


Figure 18. Cumulative TN removed in denitrification bioreactor during the study period.

As designed, water from the intercept well array would be blended approximately 50:50 by volume with the main groundwater irrigation well whenever irrigation from a source other than wastewater was necessary. Unfortunately, the controller that would typically facilitate the blend of the two water sources was compromised for a significant portion of the monitoring period and therefore only about 10% of the total irrigation volume was sourced from the intercept wells. Since directly measuring this 50:50 blend was not possible, an estimated 50:50 blend of the intercept well array and the main groundwater was applied under two scenarios (Table 9). In scenario one, it was assumed that there is no nitrogen in the groundwater well supply and that the only nitrogen intercepted is from the intercept wells. In scenario two, it was assumed that nitrogen concentrations in the groundwater were as measured in this study. In both scenarios, the total non-wastewater irrigation volume applied during the study period (88.78 million gallons) was partitioned 50:50 between the groundwater well and the intercept well array.

Under these two scenarios the TN load intercepted and reapplied was 38,353 lbs (scenario 1) and 59,880 lbs (scenario 2) or 307 and 479 lbs/pivot acre, respectively. That is 20.8% and 32.5% of the TN load applied from wastewater. If we assume 20-30% of applied wastewater nitrogen is lost through volatilization and a nitrogen uptake by the triple crop of Corn, Sorghum and Cereal Rye for silage of 400-500 lbs/pivot acre, these intercepted loads would be approximately equal to the residual wastewater nitrogen load applied that was not lost to volatilization or taken up by the crop.

Table 8. Measured loads intercepted by main groundwater well and intercept well array and used for irrigation.

Water source	Pumped volume, 1000 gal.	Concentrations NOx-N, mg/L	TN, mg/L	Loads NOx -N, lbs	TN, lbs	NOx -N, lbs/acre	TN, lbs/acre
Groundwater	80,497	49.8	72.5	29,257	43,054	234	344
Intercept Wells	8,279	68.0	116.3	4,273	5,596	34	45
Total	88,776	51.5	76.6	33,530	48,650	268	389

Table 9. Projected nitrogen loads that could be intercepted by main groundwater well and intercept well array if blended 50:50 by volume. The two scenarios vary by the nitrogen concentration allocated to the main groundwater well. Scenario 1 assumes no nitrogen in the main groundwater well, scenario 2 assumes concentrations would remain as measured.

Water source	Pumped volume, 1000 gal.	Concentrations NOx-N, mg/L	TN, mg/L	Intercepted load NOx -N, lbs	TN, lbs	NOx -N, lbs/acre	TN, lbs/acre
Scenario 1							
Groundwater	44,388	0.0	0.0	0	0	0	0
Intercept Wells	44,388	68.0	116.3	22,425	38,353	179	307
Total	88,776	34.0	58.2	22,425	38,353	179	307
Scenario 2							
Groundwater	44,388	49.8	72.5	14,628	21,527	117	172
Intercept Wells	44,388	68.0	116.3	22,425	38,353	179	307
Total	88,776	34.0	58.2	37,053	59,880	296	479

Corroborating the increased recycling of nitrogen through the intercept well array and the entrainment by the main groundwater irrigation well were decreases observed in NOx-N concentration at several groundwater monitoring wells along the northern edge of pivot-B

(Figure 19). This decrease in edge of field NOx-N concentrations would suggest that although the nitrate concentrations below the spray field are still quite high, a significant

portion of that mass is being intercepted and reused, thereby at least partially starting to close the system what was previously open.

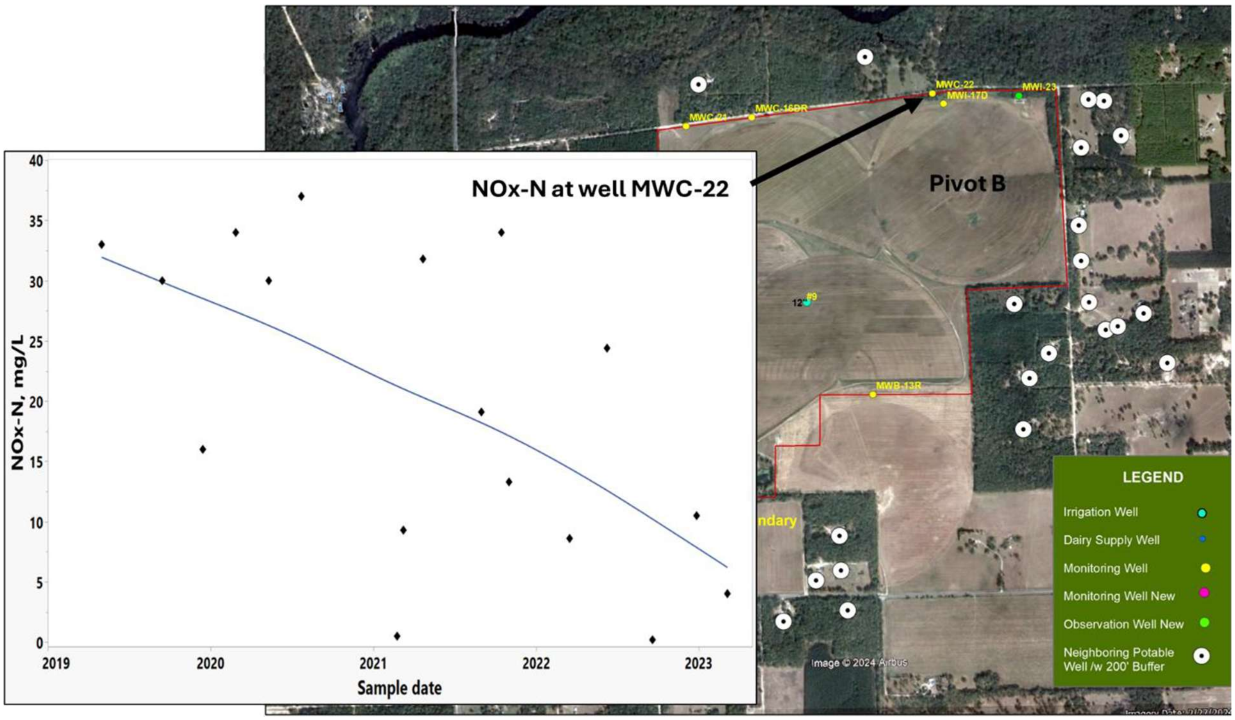


Figure 19. NOx-N concentration at monitoring well MWC-22 located along the northern edge of Pivot B sprayfield, which is generally downgradient. The intercept array was brought online in May 2019.

5.0 Conclusions

Excess nitrogen loading to groundwater, especially in the form of NOx-N, can be significant in karst geological areas where there is little or no confinement between the surface and the underlying water table. Use of conventional edge of field best management practices to intercept surface flows for treatment or reuse are not applicable to operations where the principal pathway for water is leaching vertically below the field. In this investigation, a novel intercept well array below a typical sprayfield irrigation area was monitored to determine what the potential was to intercept and reuse or treat nitrogen that had leached below the sprayfield.

Findings indicate that the intercept well array intercepted 5,596 lbs. of TN for reuse and 3,458 lbs. were removed through treatment. It was also determined that nitrogen concentrations in the main groundwater well were also elevated in nitrogen, likely due to the well being within the nitrogen leachate plume below the sprayfield. This resulted in an additional TN intercept for reuse of 43,054 lbs. In total, the combined intercept and treated TN load was 52,108 lbs. or 417 lbs./pivot acre. Because the blending of intercept well water with groundwater could not be monitored as intended, a projection of this technology's potential to intercept and reuse leached nitrogen was estimated under two scenarios. Scenario 1 with no nitrogen in the main groundwater well would result in an intercept TN load of 38,353 lbs. In scenario 2, with nitrogen concentrations in the main groundwater well equal to that measured in this study, the potential intercept TN load could be as high as 59,880 lbs. To this intercepted load directed for reuse, an additional 3,458 lbs. of TN could be removed in the denitrification bioreactor. These findings indicate this technology could significantly reduce excess nutrient loads to the environment by intercepting the hydrologic flow path below the sprayfield and redirect that volume and associated nutrients for reuse.

6.0 Acknowledgements

I would like to acknowledge the willingness of the Branford-Alliance Dairy to allow us access to their property and to monitor nutrient loads at Pivot B. Also, for their willingness to share data and respond quickly if there were any issues we encountered. In addition, if it were not for their progressive interest in nutrient reuse and reducing impacts to the environment, this technology may still be a concept on paper.

I would also like to acknowledge Dr. Del Bottcher for his development of this technology and passion for finding creative solutions and investigating better ways to utilize nutrient resources and minimize impacts to the environment. His insights and collaboration on this and other similar projects are unmatched.

Lastly, I would like to thank Dr. Lauren Griffiths and Dr. Elix Hernandez for their monitoring of the system and troubleshooting when needed.

7.0 Appendix A

Example of A&L Great Lakes Laboratories Water Quality Report

Account Number
63570
Report Number
F23055-8001

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3505 Conestoga Dr.
Fort Wayne, IN 46808
260.483.4759
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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

FOR: UNIVERSITY OF FLORIDA

Purchase Order: UNIVERSITY OF FLORID

Attn: MARK STOERMAN
Sample ID: N-PILOT-OUTFLOW
Lab Number: 26606

Page: 1 of 4
Date Sampled: 02/14/2023
Date Received: 02/24/2023
Date Reported: 02/27/2023

REPORT OF ANALYSIS

ANALYSIS	UNIT	RESULT
pH	s.u.	6.9
Conductivity (Soluble Salts)	mmho/cm	0.46
Nitrogen - Nitrate (NO3-N)	mg/L	3.4
Nitrogen - Ammonium (NH4-N)	mg/L	< 0.1
Nitrogen - Total Kjeldahl	mg/L	28
Phosphorus (P)	mg/L	< 0.1
Potassium (K)	mg/L	11
Calcium (Ca)	mg/L	66
Magnesium (Mg)	mg/L	11
Sodium (Na)	mg/L	11
Sulfur (S)	mg/L	16
Zinc (Zn)	mg/L	< 0.01
Manganese (Mn)	mg/L	< 0.01
Iron (Fe)	mg/L	0.01
Copper (Cu)	mg/L	< 0.01
Boron (B)	mg/L	0.04
Aluminum (Al)	mg/L	< 0.1
Molybdenum (Mo)	mg/L	< 0.01
Silicon (Si)	mg/L	4
Chloride (Cl)	mg/L	17

Report Approved By: David Henry - Agronomist / Technical Services - CCA

Approval Date: 2/27/2023

Account Number
63570
Report Number
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FOR: UNIVERSITY OF FLORIDA

Purchase Order: UNIVERSITY OF FLORID

Attn: MARK STOERMAN

Sample ID: N-PILOT-INFLOW

Lab Number: 26607

Date Sampled: 02/14/2023
Date Received: 02/24/2023
Date Reported: 02/27/2023

REPORT OF ANALYSIS

ANALYSIS	UNIT	RESULT
pH	s.u.	7.0
Conductivity (Soluble Salts)	mmho/cm	0.43
Nitrogen - Nitrate (NO3-N)	mg/L	7.1
Nitrogen - Ammonium (NH4-N)	mg/L	< 0.1
Nitrogen - Total Kjeldahl	mg/L	27
Phosphorus (P)	mg/L	< 0.1
Potassium (K)	mg/L	7
Calcium (Ca)	mg/L	63
Magnesium (Mg)	mg/L	11
Sodium (Na)	mg/L	9
Sulfur (S)	mg/L	14
Zinc (Zn)	mg/L	< 0.01
Manganese (Mn)	mg/L	< 0.01
Iron (Fe)	mg/L	0.01
Copper (Cu)	mg/L	< 0.01
Boron (B)	mg/L	0.02
Aluminum (Al)	mg/L	< 0.1
Molybdenum (Mo)	mg/L	< 0.01
Silicon (Si)	mg/L	4
Chloride (Cl)	mg/L	17

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Attn: MARK STOERMAN

Date Sampled: 02/20/2023
Date Received: 02/24/2023
Date Reported: 02/27/2023

Sample ID: N-PILOT-OUTFLOW
Lab Number: 26608

REPORT OF ANALYSIS

ANALYSIS	UNIT	RESULT
pH	s.u.	7.0
Conductivity (Soluble Salts)	mmho/cm	0.44
Nitrogen - Nitrate (NO3-N)	mg/L	0.3
Nitrogen - Ammonium (NH4-N)	mg/L	< 0.1
Nitrogen - Total Kjeldahl	mg/L	27
Phosphorus (P)	mg/L	< 0.1
Potassium (K)	mg/L	6
Calcium (Ca)	mg/L	63
Magnesium (Mg)	mg/L	11
Sodium (Na)	mg/L	9
Sulfur (S)	mg/L	13
Zinc (Zn)	mg/L	< 0.01
Manganese (Mn)	mg/L	< 0.01
Iron (Fe)	mg/L	< 0.01
Copper (Cu)	mg/L	< 0.01
Boron (B)	mg/L	0.02
Aluminum (Al)	mg/L	< 0.1
Molybdenum (Mo)	mg/L	< 0.01
Silicon (Si)	mg/L	4
Chloride (Cl)	mg/L	15

Account Number
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Report Number
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Attn: MARK STOERMAN

Sample ID: N-PILOT-INFLOW

Lab Number: 26609

Page: 4 of 4

Date Sampled: 02/20/2023

Date Received: 02/24/2023

Date Reported: 02/27/2023

REPORT OF ANALYSIS

ANALYSIS	UNIT	RESULT
pH	s.u.	7.3
Conductivity (Soluble Salts)	mmho/cm	0.44
Nitrogen - Nitrate (NO3-N)	mg/L	7.0
Nitrogen - Ammonium (NH4-N)	mg/L	< 0.1
Nitrogen - Total Kjeldahl	mg/L	11
Phosphorus (P)	mg/L	< 0.1
Potassium (K)	mg/L	7
Calcium (Ca)	mg/L	68
Magnesium (Mg)	mg/L	11
Sodium (Na)	mg/L	9
Sulfur (S)	mg/L	14
Zinc (Zn)	mg/L	< 0.01
Manganese (Mn)	mg/L	< 0.01
Iron (Fe)	mg/L	0.01
Copper (Cu)	mg/L	< 0.01
Boron (B)	mg/L	0.02
Aluminum (Al)	mg/L	< 0.1
Molybdenum (Mo)	mg/L	< 0.01
Silicon (Si)	mg/L	4
Chloride (Cl)	mg/L	15