# NUTRIENT AND SALINITY MANAGEMENT GUIDANCE FOR MANURE SUBSURFACE DRIP SYSTEMS

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Abstract

This document provides guidance for nutrient and salinity management for implementing a manure sub-surface drip irrigation system (manure SDI). A key first step is developing a whole farm nitrogen budget and nutrient management plan. Irrigation, nutrient and salinity management will need to change, as will sampling protocols. The guidance should be helpful for both dairy farmers and those who assist them in implementing a manure SDI system.

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# Contents

## 1.0 Introduction

The typical dairy irrigation system in California is flood irrigation; however, as the scarcity of water becomes more and more apparent, precision irrigation has become more and more attractive to dairy farming. Some dairies have turned to conventional sub-surface drip irrigation (conventional SDI) as a solution. A major drawback is that conventional SDI requires the use of synthetic fertilizers, limiting a dairy's ability to utilize the manure nutrients freely available.

The alternative demonstrated in the present project is a manure sub-surface drip irrigation system (manure SDI). Filtered, dairy manure effluent is delivered through subsurface drip irrigation systems supplying plants with and water nutrients. Managing a manure SDI system is different from both flood irrigation and conventional SDI, so the present report provides guidance on major factors related to nutrient and salinity management that a dairy should consider when switching to manure SDI.

The guidance is based on experience from manure SDI systems installed on three dairies in California's San Joaquin Valley. The project partnered with the growers to run the systems from 2017 through the end of 2019. Each dairy offered one field to be irrigated by the manure SDI system. The drip tape was buried at twelve inches deep with forty inch row spacing. The dairies also offered data from a flood irrigated comparison field that was managed under their typical practices. Dairies kept the all of the fields in a standard corn-wheat rotation for the entirety of the project.

Standard agronomic methods for sampling and testing provided the dairy growers the means to use the manure SDI system to match nitrogen requirements to crop growth stage, schedule irrigations, apply irrigation water and nutrients efficiently, maintain and/or increase yields, and manage soil salinity. The final section of the report is a condensed sample process a dairy could undertake to assess and implement manure SDI.

## 2.0 Qualifying a Dairy

The whole dairy farm nutrient balance needs to be evaluated to determine if a manure SDI system will be beneficial. Thus, dairies should first conduct a whole farm nutrient balance assessment and, if needed, develop a plan to address any nutrients that would be leftover after switching to manure SDI. A Comprehensive Nutrient Management Plan (CNMP) is one tool dairies can use to assess their situation and identify practices – such as increasing manure exports – that might be needed to achieve whole farm nutrient balance when switching to manure SDI.

The details for managing nutrients and salinity will be significantly different dairy to dairy, so it's not possible for the present report to provide specific guidance. Instead, the report will present areas that should be evaluated, based on the results of the three real-world manure SDI systems studied.

### 2.1 Existing Data

Review the existing nutrient management data as a starting place to determine the nutrient balance of a dairy. In California's Central Valley, dairies already have a nutrient management plan and track annual data on their whole farm nitrogen balance, summarized in annual reports to the Central Valley Regional Water Quality Control Board. Relevant data in those reports include: the number of cows, the number of acres farmed that received manure effluent, the number of acres farmed that received solid manure, the amount of nutrients applied over the entire farm, the amount of exported nutrients, including nutrients being used as bedding.

### 2.2 Whole Farm Nitrogen Balance

Develop a whole farm nutrient balance analysis, collecting additional data if needed. The NRCS' Comprehensive Nutrient Management Plan process could provide a good framework, even if not applying for EQIP cost-share; each dairy should consult with their agronomist, technical service provider, etc. about the best approach to develop a whole farm nitrogen balance evaluation.

The analysis will help determine if the amount of applied manure currently meets agronomic needs and informs a discussion of opportunities to redirect the nitrogen already being applied to the fields planned for the manure SDI system. The project sites resulted in a median of 45% less nitrogen applied when compared to the control flood fields, while maintaining similar yields. Those unused nutrients need to be properly managed, either as an export or by providing sustenance to crops in other fields.

### 2.3 Infrastructure and Management

Effective implementation of the manure SDI system relies on sufficient infrastructure and management. For example, a secondary or tertiary lagoon is recommended to reduce solids loading to the manure SDI system. And there is a learning curve for operating the system, so that should be taken into consideration. The technical report "Considerations for Switching from Flood to Manure Subsurface Drip Irrigation for Forage Production" provides details on major factors to consider when switching from flood irrigation to manure SDI.

## 3.0 Irrigation and Nitrogen Management

### 3.1 Irrigation Scheduling

Ideally, irrigation scheduling should be based on both real time crop evapotranspiration ($ET_c$) requirements and soil moisture monitoring data. Weekly $ET_c$ and soil moisture monitoring data are helpful tools in managing the manure SDI system and can improve the water use efficiency of each field, but are not absolutely necessary. Each dairy will have to evaluate which method of tracking soil moisture matches their needs and available resources.

Crop coefficient ($K_c$) values are available for wheat and corn from published biweekly data (Hanson 1987; Pruitt 1999), which can be extrapolated out to weekly crop $K_c$ values. These $K_c$ values can then be matched to weekly ET projections from National Weather Service (NOAA) to determine weekly crop water requirements.

### 3.2 Nitrogen Scheduling

The manure SDI system allows growers to spoon feed crops nitrogen to precisely meet the crops' agronomic needs, enabling improvements to both nitrogen use efficiency and the nitrogen applied-to-removed ratio.

Manure effluent samples are necessary to calibrate the nitrogen application calculations. The nitrogen within manure effluent is in different forms and only some forms are available to the plant immediately. Given the delay, it is important to stay ahead of the crop's nitrogen demand: Time the manure effluent applications early enough that the manure nitrogen becomes plant available by the time the crop needs it, but not so early that the plant available nitrogen leaches out of the root zone.

The decision of whether to apply solid manure to the field depends on the anticipated crop demand for nitrogen, the pre-plant soil nutrient analysis, the anticipated amount of manure effluent available during the upcoming cropping season and the amount of solid manure available for field application.

Other tools for monitoring plant nutrient status and crop growth are pre-plant and in season soil samples as well as crop tissue samples collected at specific crop growth stages.

### 3.3 Overall Nitrogen and Irrigation Scheduling

An overall crop growing season nitrogen budget should be developed through an NMP based on the growing history of the field using anticipated yields and historical sample results from manure effluent, fresh water, soils, and solid manure applied. The overall seasonal nitrogen budget can then be broken down into crop growth stages and monthly, bi-weekly, or weekly nitrogen requirement schedules.

The weekly crop nitrogen and irrigation water requirements should be compared to the manure SDI application rates. Based on the comparison, each dairy will need to adjust the current week’s application rate based on the previous week’s actual applications. Contact your agronomist, TSP, etc. to help with this process if needed.

## 3.4 Soil Moisture Monitoring

Soil moisture monitoring provides data on how deep the irrigation water is moving and the rate at which the crop uses soil moisture. Soil moisture monitoring provides important information about when and how long to irrigate, which is powerful when paired with the precision application of manure SDI. The manure SDI allows the grower to act on the monitoring data to better match crop demand.

Many different real time soil moisture monitoring systems are available. The equipment for these systems are expensive and need to be installed after planting and removed before harvest to avoid damage to the equipment. Less expensive systems such as tensiometers, gypsum blocks or neutron probes are also available, but only provide weekly or biweekly soil moisture data. Checking soil moisture by hand probing is also an option but would also provide more subjective data and is much more labor intensive. Each dairy needs to evaluate whether these systems provide enough value and are compatible with the farm's needs.

## 3.5 Germination

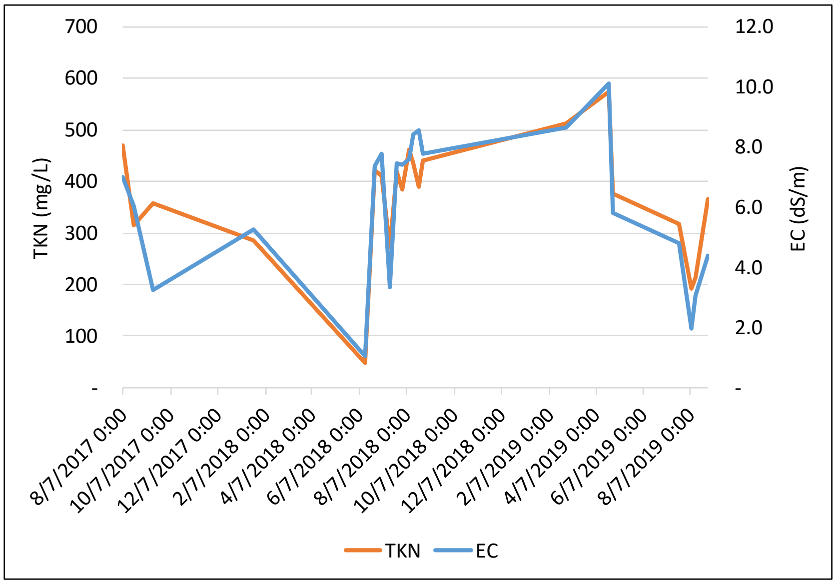
In the manure SDI fields studied, attempts to use the drip tape for germination were unsuccessful, resulting in poor seedling development. However, uniform and successful crop germination was achieved by using either flood or sprinklers to provide the initial water for seedling development. These irrigation methods also provide an opportunity to flush salts within the soil, presented in further detail the "Salinity Management" section of the present report.

## 3.6 Managing Manure Effluent and Freshwater Blend Ratios

Manure SDI uses an electrical conductivity (EC) sensor to monitor and manage the blend of manure effluent and freshwater (blend). The EC sensor dictates the blended ratio of manure and fresh water put through the filters by adjusting a butterfly valve at regular intervals on the manure effluent inlet pipe based on a preset EC value. Although salts and nitrogen trend lines are in the same direction, there was not enough data to show a statistical correlation between the two (Figure 1); further data collection or research may help explore this relationship, if there is one. The potential relationship warrants further study, to see if a model to use EC as a proxy for manure effluent nitrogen can be developed.

Currently, manure SDI uses the EC sensor to restrict salt loading to the fields; this is discussed further in the "Salinity Management" section. Restricting solids loading to the system is also important, to limit the time the filtration system is in back-flush. For further discussion on solids loading, please refer to the report

"Considerations for Switching from Flood to Manure Subsurface Drip Irrigation for Forage Production."

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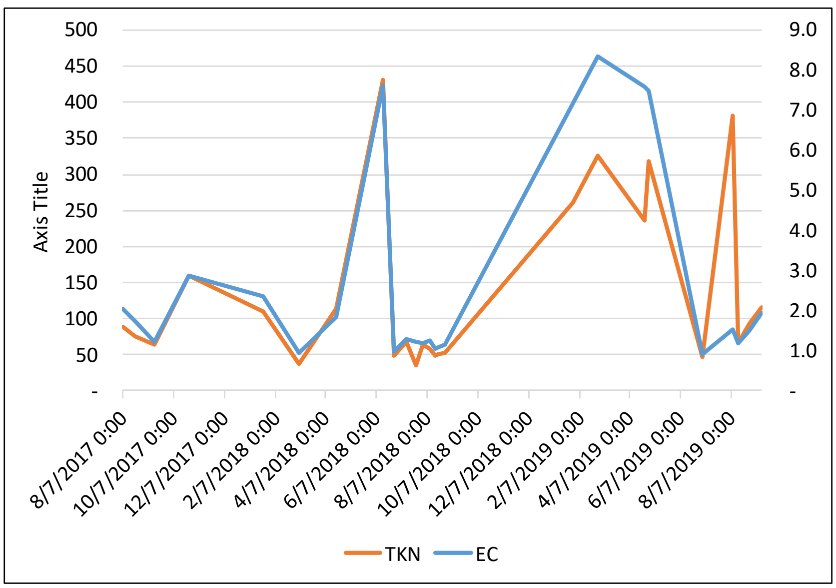


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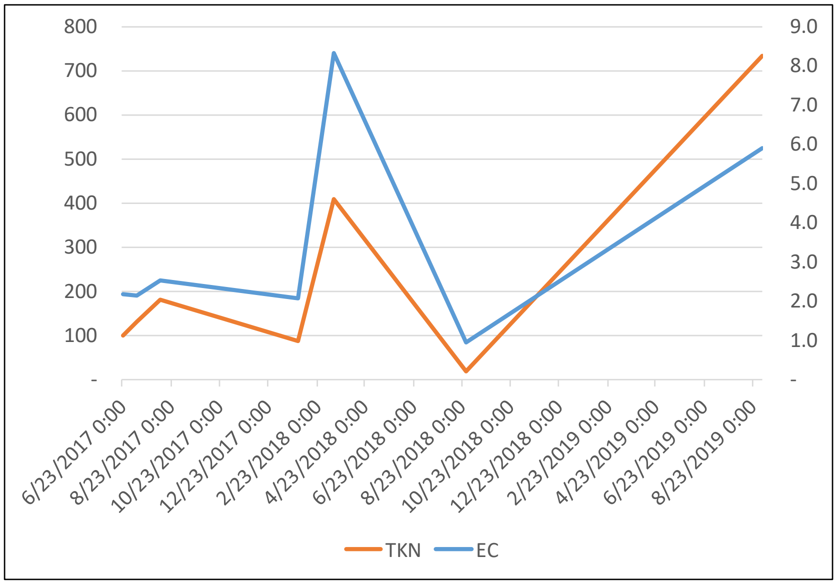


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Figure 1. The TKN and EC values of manure effluent collected at a) Dairy #1, b) Dairy #2, and c) Dairy #3.

## 4.0 Salinity Management

The soil salinity results from the manure SDI fields showed no overall increase in soil salinity. Salinity accumulation at the surface is a potential concern to monitor, but so far does not appear to be much different from the flood irrigated blocks. For more details, see the technical report "Evaluation of the Agronomic and Environmental Impacts of Manure Subsurface Drip Irrigation."

Just as in any farming, the monitoring and management of salts within the soil is recommended. Factors that affect soil salinity include: soil type, initial soil salinity, fresh water salinity contribution (district or well water), manure effluent salinity contribution and other loading of salts as related to crop nitrogen requirements. The manure SDI fields were germinated using sprinklers or flood, which may have helped flush salts out of the soil. Additional flushing can be executed by applying fresh water through the drip lines. Soil moisture monitoring can be used as a tool to determine when satisfactory flushing has been accomplished.

Over the two corn-wheat crop cycles, the manure SDI fields did not require special action for salinity management compared to flood irrigation. Further studies and continual monitoring is worthwhile; however, to make sure that there are no long-term effects that could be not be detected within the project's timespan.

## 5.0 Sampling Recommendations

The recommended constituent tests to include for each sample are summarized in Table 1. Any sampling for the manure SDI system should be coordinated with applicable regulatory requirements to assure the dairy is not collecting unnecessary samples.

Table 1. Constituents to test for each sample type.

| Manure effluent | Fresh water | Blend | Soils | In-season |
|---|---|---|---|---|
| pH | pH | pH | Sp | N |
| EC | EC | EC | pH | P |
| NO3-N | NO3-N | NO3-N | EC | K |
| NH4-N | NH4-N | NH4-N | Ca | |
| TKN | TKN | TKN | Mg | |
| P | P | P | Na | |
| K | K | K | ESP | |
| CO3 | CO3 | CO3 | Gypsum or Lime Requirements | |
| HCO3 | HCO3 | HCO3 | Lime Presence | |
| Cl | Cl | Cl | B | |
| SO4 | SO4 | SO4 | NO3-N | |
| Ca | Ca | Ca | PO4-P | |
| Mg | Mg | Mg | K | |
| Na | Na | Na | Zn | |
| TDS | TDS | TDS | NH4-N | |
| FDS | FDS | FDS | TKN | |
| TSS | TSS | TSS | | |
| FSS | FSS | FSS | | |

## 5.1 Manure Effluent

Past lagoon samples can help evaluate variability and potential loading of nitrogen, solids, and salts. In addition to looking at past samples, lagoon samples should be taken twice per month during the first summer crop cycle that the manure SDI system is operational to determine nutrient variability of the manure effluent. Lagoon sampling can then be reduced to either monthly or once every two months, depending on that variability. The monitoring program needs to remain flexible enough to adapt to ongoing changes within the lagoon and agronomic needs of the crop.

Occasional samples of the outgoing blend of fresh water and manure effluent, taken at the beginning and the middle of the crop cycle, should be taken to confirm that the loading calculations are correct and to verify the manure SDI filtration control system is functioning properly. Samples of the blend are important to confirm nutrient loading post-application but not for calculating loading rates ahead of time, since the values for one blend ratio will not necessarily translate to the next.

## 5.2 Fresh Water

Fresh water samples should be collected from both district and well water supplies annually. Review past supply water data to determine if there is any variability. Typically, fresh water qualities are relatively stable, but circumstances can cause changes. For example, in the project, well conditioning led to an increase in solids loading from one of the fresh water wells, which increased the back-flushing needed from the manure SDI filtration system.

## 5.3 Soil

Soil samples should be collected for each field or management zone (a field or area able to be controlled independently) after each crop is harvested and prior to any application of manure effluent, solid manure or soil amendments. That provides a baseline of the nutrient content in the soil to inform the next season's NMP.

## 5.4 In-Season Tissue

In season tissue samples (analyzed for N, P, and K) are helpful to monitor crop nutrient status at specific growth points. These samples are not essential, but can provide good information as a dairy is adapting manure SDI to their operation.

## 6.0 Conclusions

The whole farm nitrogen balance is an essential first step to evaluating whether manure SDI can work for a dairy. Manure SDI allows a grower to grow a crop with significantly less water and manure nitrogen, so a plan needs to be put in place to manage that excess available nitrogen. The manure SDI requires support of infrastructure and management, so that also needs to be in place for a successful implementation.

To enjoy the benefits of the greater precision offered by manure SDI, growers should monitor the forms of nitrogen in the manure effluent. That requires more monitoring of the manure effluent in the first year, to understand the variability of the manure effluent nitrogen content, then can taper off. Solid manure can be a good option for some dairies, but that needs to be evaluated for each dairy. Based on current data, EC is not a strong enough proxy for nitrogen, so growers should calculate and compare the actual applications to the planned applications, adjusting the applications throughout the season. The EC meter is useful to limit salts and solids loading.

Salinity management does not seem to vary from flood irrigation, though further study is needed. Sampling recommendations are also similar to a flood system, though with some additional samples and tests. Overall, the specific details of how to implement manure SDI needs to be worked out by each dairy as it best suits the details of their specific operation. A summarized suggested process is described in Appendix A.

## Appendix A: Guidance for fertigation of crops using the manure SDI system

In order to fertigate crops using the manure SDI system, a water and nutrient blend that is designed to efficiently meet crop growth requirement is needed. To determine the appropriate blends at different points during the cropping season, irrigation and nutrient management plans are needed.

Ideally, irrigation scheduling should be based on both real time crop evapotranspiration (ETc) requirements and soil moisture monitoring data. Weekly ETc and soil moisture monitoring data are helpful tools in managing the manure SDI system and can improve the water use efficiency of each field, but are not absolutely necessary. Each dairy will have to evaluate which method of tracking moisture match their needs and available resources.

Similar to irrigation scheduling, nutrient scheduling is key to successful implementation. The demonstration fields performed best when nutrient applications were monitored weekly, with the difference between the planned applications and the actual applications were measured. That allowed the growers to adjust the following week's nutrient applications to keep up with the crops' nutrient demands.

A method is described below as an example of how to manage the manure SDI system to meet crop irrigation and nutrient demand. Dairy producers and their agronomist should use the example method below as guidance to determine the most appropriate method for their operations, ideally in combination with a tracking sheet (see **Error! Reference source not found.** below for a tracking sheet example).

1. Determine weekly evaporation transpiration demand
    a. A weekly irrigation schedule is developed based on crop evapotranspiration requirement from plant to harvest date. Crop coefficient (Kc) values are available for wheat and corn from published biweekly data (Hanson 1987; Pruitt 1999), which can be extrapolated out to weekly crop Kc values. These Kc values can then be matched to weekly ET projections from National Weather Service (NOAA) to determine weekly crop water requirements.
2. Estimate weekly crop nitrogen required to achieve yield objectives
    a. The total pounds of nitrogen required to achieve yield objectives will first need to be determined. Nitrogen requirements are typically variety dependent, so should be discussed with a seed company agronomist.
    b. Based on the nitrogen requirements during the various reproductive growth stages of the crop, develop a weekly nitrogen demand schedule. It is important to adhere to the weekly nitrogen application plan, since it is difficult to make up for nutrient deficits with a manure SDI system.
3. Evaluate available nitrogen sources.

   a. Testing is done to determine nitrogen contribution from various sources needed to meet crop demand. Deduct residual soil and fresh water nitrogen in order to determine remaining nitrogen contribution needed from manure effluent.
   b. Soil – Soil samples should be collected for each field or management zone (a field or area able to be controlled independently). That provides a baseline of the nutrient content in the soil.
   c. Fresh water – Fresh water samples should be collected from both district and well water supplies annually. Review past fresh water data to determine if there is any variability. Typically, fresh water qualities are relatively stable, but circumstances can cause changes.
   d. Manure effluent – Manure effluent samples should be taken twice per month during the first crop cycle the manure SDI system is operational to determine the nutrient variability of the manure effluent. Manure effluent sampling can then be reduced to either monthly or once every two months, depending on that variability. The monitoring program needs to remain flexible enough to adapt to ongoing changes to an NMP.
4. Determine the blend ratio of manure effluent and irrigation water needed to achieve weekly nitrogen and crop ET requirement.
   a. The blend ratio determines the combination of manure effluent and irrigation water needed to meet crop water and nitrogen demand. The ratio of manure effluent to irrigation water will continue to increase and peak around tasseling in silage corn. The system must have the capacity to meet peak demand for water and nutrients.
   b. The volume of blended manure effluent needed to achieve weekly fertigation objectives is determined by a variety of factors (e.g. crop genetics, growing degree units). System specifications will be provided to enable calculation of pump run times listed on the table. The number of pumping hours is an important measure of progress towards achieving irrigation and nutrient management objectives.
   c. The blend ratio may be limited by the filtration capacity as a result of the presence of solids. Therefore, it is important to understand the system's limitation in order to ensure that the filtration system maintains desired flow rates. The system installer should provide guidelines on sand media filter flow rates and the frequency of backflushing that is acceptable for efficient system operation.
5. Monitor and adjust the blend ratio
   a. The flow of fresh water is controlled by a variable frequency drive that throttles up or down as needed. The manure effluent flow is controlled with a butterfly valve on the manure effluent inlet pipe. Flowmeters measure volume and flow rate from both fresh and manure effluent inlet pipes. The flow of blend is also tracked with a flowmeter at the outlet pipe going to the field, post filtration.

b. The manure SDI system uses a sensor to monitor the EC of the blend and regulate the blend of manure effluent and freshwater so that it stays under a target EC the grower sets. The system maintains the EC by automatically adjusting a butterfly valve that increases or reduces the amount of manure effluent in the blend.
c. In order to adjust the system to meet a target blend ratio, the grower needs to determine what blend ratios will likely occur at different EC values. Since this will vary based on manure effluent characteristics, the grower first needs to run the system at different EC values and document a range of resulting blend ratios (e.g. "Based on prior experience, when the manure SDI system is set to a target EC of 1.5 dS/m, the blend is typically between X% and Y% manure effluent). With that knowledge, the grower can set the target EC as a way to control the blend ratio. These ranges can be further refined as the grower collects more data points from running the system over time.

6. In-season nitrogen tests and monitoring
   a. In season tissue samples are helpful to monitor crop nutrient status at specific growth points. Testing will enable you to determine and refine nitrogen uptake requirements at various stages of crop growth. These samples are not essential, but can provide good guidance for successful operation, especially when the manure SDI system is first installed and the dairy is learning how to run manure SDI on their specific circumstances.

Table 2. Example fertigation schedule.

| Manure SDI Irrigation Schedule<br>Field: | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Week** | **Dates** | | **ET** (inches/day) | **cKo** | **Inches per week** | **Hours** | **Number of sets** | **Hours of Runtime** (actual) | **% total N** | **# N need / week** | **inches / acre lagoon** | **Blend Ratio** |
| 25 | 19-Jun | 25-Jun | 0.3 | 0.5 | 1.13 | 66 | 4 | | 2% | 6 | 0.13 | 12% |
| 26 | 26-Jun | 2-Jul | 0.31 | 0.5 | 1.17 | 69 | 4 | | 5% | 15 | 0.33 | 28% |
| 27 | 3-Jul | 9-Jul | 0.32 | 0.6 | 1.45 | 85 | 4 | | 5% | 15 | 0.33 | 23% |
| 28 | 10-Jul | 16-Jul | 0.32 | 0.7 | 1.69 | 99 | 4 | | 8% | 24 | 0.52 | 31% |
| 29 | 17-Jul | 23-Jul | 0.31 | 0.8 | 1.87 | 110 | 4 | | 10% | 29 | 0.65 | 35% |
| 30 | 24-Jul | 30-Jul | 0.31 | 0.9 | 2.10 | 124 | 4 | | 10% | 29 | 0.65 | 31% |
| 31 | 31-Jul | 6-Aug | 0.3 | 1 | 2.26 | 133 | 4 | | 15% | 44 | 0.98 | 43% |
| 32 | 7-Aug | 13-Aug | 0.285 | 1 | 2.15 | 126 | 4 | | 15% | 44 | 0.98 | 46% |
| 33 | 14-Aug | 20-Aug | 0.27 | 1 | 2.03 | 120 | 4 | | 10% | 29 | 0.65 | 32% |
| 34 | 21-Aug | 27-Aug | 0.26 | 1 | 1.96 | 115 | 4 | | 8% | 24 | 0.52 | 27% |
| 35 | 28-Aug | 3-Sep | 0.25 | 1 | 1.88 | 111 | 4 | | 8% | 24 | 0.52 | 28% |
| 36 | 4-Sep | 10-Sep | 0.23 | 1 | 1.73 | 102 | 4 | | 4% | 12 | 0.26 | 15% |
| 37 | 11-Sep | 17-Sep | 0.22 | 1 | 1.66 | 97 | 4 | | 4% | 12 | 0.26 | 16% |
| 38 | 18-Sep | 24-Sep | 0.2 | 1 | 1.51 | 89 | 4 | | 0% | 0 | 0.00 | 0% |
| 39 | 25-Sep | 1-Oct | 0.18 | 1 | 1.35 | 80 | 4 | | 0% | 0 | 0.00 | 0% |
| 40 | 2-Oct | 8-Oct | 0.15 | | | | | | | | | |
| 41 | 9-Oct | 15-Oct | 0.15 | | | | | | | | | |
| 42 | 16-Oct | 22-Oct | 0.12 | | | | | | | | | |
| 43 | 23-Oct | 29-Oct | 0.12 | | | | | | | | | |
| 44 | 30-Oct | 5-Nov | 0.1 | | | | | | | | | |
| | | | | | | | | Total | 104% | 306 | 6.80 | 24% |

| | |
|---|---|
| | #NO3/acre-inch |
| Lagoon water | 45 |
| Yield Goal | 32 |
| N Removal/ton | 9.2 |
| | |
| Total # N/acre | 294 |
| Total acre-inches/acre lagoon | 6.54 |

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