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Matching Dairy Lagoon Nutrient Application To Crop Nitrogen Uptake Using A Flow Meter And Control Valve

Marsha Campbell Mathews

University of California Cooperative Extension, 3800 Cornucopia Way, Suite A, Modesto CA 95358: mcmathews@ucdavis.edu

Eric Swenson

Creative Mechanical Solutions, 3610 Syracuse Ct., Merced, CA 95348; creatmec@elite.net

Thomas Harter, Ph. D.

University of California, 125 Veihmeyer, Davis, CA 95616-8628; thharter@ucdavis.edu

Roland D. Meyer, Ph. D.

University of California, Hoagland Hall, Davis, CA 95616-8628

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Abstract. *A system has been developed to apply targeted application rates of diluted manure nitrogen onto cropland through an irrigation system by using a control valve in conjunction with a flow meter and quick test for nitrogen. With this system, a grower performs a preliminary determination of the nitrogen concentration in his lagoon water and estimates how long it will take to irrigate a given acreage. Using a look-up table or computer spreadsheet, a target flow rate (gpm) is determined which will result in the application of the desired number of pounds of nitrogen per acre. This figure is provided to the irrigator, who adjusts a valve on the pond outlet* *until the flow meter displays the target gpm. The number of gallons displayed on the meter totalizer is recorded at the beginning and end of each field or check and samples are taken periodically during the irrigation and later analyzed to confirm that the N concentration in the pond did not changed over the course of the irrigation. Totalized flow and concentration information is entered into a computer spreadsheet that calculates the amount of nitrogen actually applied. Any deficiency or excess (due mainly to the irrigation taking longer or slower than expected) can be corrected in subsequent applications irrigations.*

Validation of this system was conducted on ten individual irrigation basins, or checks, located in three fields. The average area in each check was 4.6 acres. On nine of the ten irrigation checks total nitrogen application for the season was within 15% of the intended application rate as measured by the flow meter totalizer. Average application rates for the entire field was within 3% of the target rate on two fields and 17% off the target on the third field.

The flow meter/valve system was installed on four cooperating dairies, and the lagoon nutrient applications were managed by the irrigators. The system is proving to be sufficiently simple and practical for the average dairy producer to operate, although none of the participating dairies was able to achieve a balance of nitrogen application with uptake in the first season of use.

Yields from both the replicated and all demonstration fields where lagoon water nutrients were used exclusively were comparable to those obtained using conventional practices which supplement manure applications with commercial fertilizers. This method of using a flow meter and valve to apply targeted rates of lagoon nutrients is being implemented on a number of commercial dairies in the region.

Overall considerations for designing this and other aspects of a diluted manure transport, storage and land application system are discussed.

Keywords. Manure, nutrient management, dairy, corn, groundwater, nitrate, nitrogen cycle, dairy waste, flow meters, liquid manures, lagoons, nutrients, waste disposal, groundwater quality.

Introduction

The dairy industry is coming under increasing scrutiny from regulatory agencies and the public in accounting for the nitrogen and other constituents contained in dairy manure , and dairy operators may be required to document application rates of manure nutrients to cropland (EPA, 2000). On a typical California dairy, as much as 80% of the waste is handled using a flush system, where manure in alleyways and hard surface holding pens is washed into a lagoon (Meyer, 2000). Usually, the lagoon water is recycled by using it in the flush system many times until the lagoon effluent is applied to cropland. A recent study of 5 dairies in the Northern San Joaquin Valley indicated that cropland receiving dairy lagoon water often has elevated concentrations of nitrate contamination in the shallow groundwater below. (Harter, 1999). It has been common for growers to not fully account for the nitrogen being applied in the lagoon water when fertilizing their crops because practical methods for doing so have not been available.

In most areas of the Central Valley in California, nitrogen is generally considered to be the major potential contaminant of subsurface water. In many areas, soils are sandy and flood irrigated, making them especially subject to leaching of nutrients and there are many dairies located on such soils. Because there is potential for nitrate-form nitrogen present in the soil to be leached into the shallow groundwater during irrigation water applications, it is common for growers in these areas to inject aqua or anhydrous ammonia into the irrigation water at rates and timings that match anticipated crop uptake. To minimize groundwater contamination from dairy wastewater, we have taken this same approach by fertigating with lagoon nutrients in much the same way as has been commonly practiced with commercial fertilizer.

Both of the main forms of nitrogen in lagoon water, ammonium- and organic- (nitrogen bound in bacteria or small particles of plant material) form, will adhere in the upper few inches of the soil when first applied but are likely to leach after they are converted to nitrate, a process that can occur within a few days of application. Our goal has been to develop methods of applying lagoon water nitrogen with enough accuracy so that only the amount of nitrogen that can be taken up by the crop prior to the next irrigation is applied. This way, large amounts of nitrate are not present during irrigation and thus is less subject to leaching to groundwater, even if irrigation efficiencies are poor. While this approach is most needed on light textured soils, the same techniques may easily be adapted for use in nearly any similar situation.

This project, begun in spring 1998 and continuing through 2000, was aimed at developing methods of measuring and metering dairy lagoon water nitrogen in order to use it as a nutrient source for the corn without overapplication. The system we have developed uses a control valve in conjunction with a flow meter and quick test for nitrogen. With this system, a grower determines the nitrogen concentration in his lagoon water and estimates how long it will take to irrigate a given acreage. Using a look-up table or computer spreadsheet, a target flow rate (gpm) is determined which will give the desired pounds of nitrogen per acre. This figure is provided to the irrigator, who adjusts the valve until the flow meter displays the target gpm. The number of gallons displayed on the meter totalizer is recorded at the beginning and end of each field or irrigation set. An occasional sample is taken during the irrigation and later analyzed to confirm that the N concentration in the pond has not changed over the course of an irrigation. Totalized flow and concentration information is entered into a computer spreadsheet that calculates the amount of nitrogen actually applied. Any deficiency or excess (due mainly to the irrigation taking longer or slower than expected) can be made up for in the next irrigation.

To be most effective, this flow meter/control valve method must be integrated into a well-planned manure transfer and land application system. An overview of necessary components and consideration for the entire system is discussed in part 1 of this paper, and the results of a project to validate the effectiveness and use of the system is provided in part 2.

Part 1 Manure Water Distribution System Design Criteria

New approaches have been established to improve upon past practices of approximating the application rates of manure water to field crops. These new approaches allow accurate measurement of pounds of nutrients applied per acre. Experience in the field has shown that the following are key components to such an upgraded manure water distribution system:

Equipment must be simple to construct

Equipment must be simple to operate

All components must be reliable and require minimum maintenance

System construction cost must be low

Operating costs must be low

All components must be simple and quick to repair when broken

System must accurately measure flowrate of manure water

System must allow easy sampling for typical manure water composition

Systems containing these elements have been constructed and successfully operated by dairymen. These systems have only been applied at dairies that utilize manure water for lane flushing and manure transport. The following sections describe each of the elements of these systems.

Solids Separation: Two basic approaches to removing most solids have been utilized by dairymen. One approach that has been used successfully utilizes a pair(s) of settling basins. The settling basins allow the removal of significant quantities of suspended solids in the manure water. An alternate approach to solids separation is to use an inclined wedge wire screen. These screens come in a variety of configurations and slot opening sizes. Some dairy operators are currently experimenting with operating two inclined wedge wire screens, with different slot openings, in series. The separated material will be dewatered and either directly land applied by mechanical spreading or first composted and then spread. Removal of suspended solids greatly enhances the ability to control nutrient application rates by removing significant quantities of slow release nutrients from the liquid stream.

Lagoon Storage Capacity: 120 days of liquid storage is required in manure water storage lagoons in some

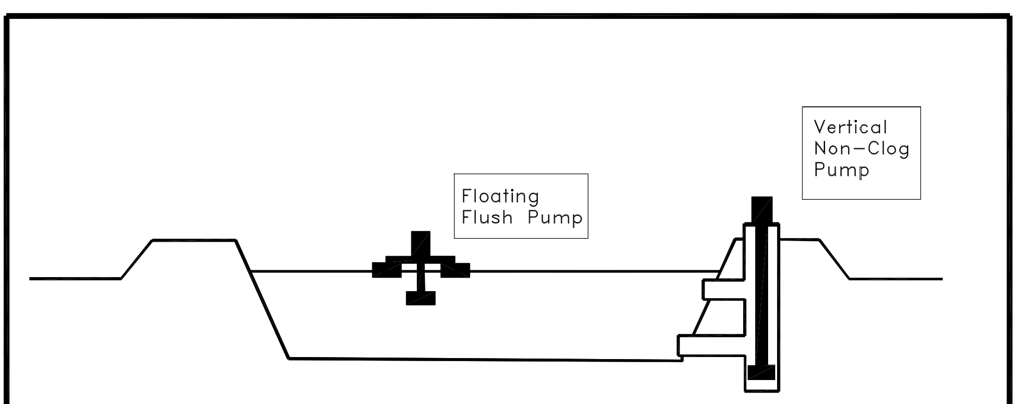

FIGURE 2

locations. A limited number of dairy operators are constructing lagoons with up to 160 days of storage. An existing facility may or may not have 120 days of storage. A dairy storage lagoon may have floating pumps or pumping systems that do not allow for the full use of all the lagoon storage capacity (see figure 2). Storage capacity must be calculated from the maximum allowed operating level (usually 2 feet of freeboard to top of berm) to the minimum operating level (often dictated by operation of flush lane pumps). Storage lagoons should have adequate capacity to store all required liquids based upon anticipated storm water and dairy operations inflows minus anticipated farming scheduling dictated outflows, in addition to meeting the legally required minimum storage capacities. Some soil types may significantly restrict the amount of liquid material that can be applied during the winter months leading to the need for additional storage.

Irrigation Water Supplies*:* One of the first steps in designing a manure water irrigation system is to understand the capabilities of the existing fresh water irrigation supplies. Water may be available from surface facilities (such as canals or rivers), private wells, or treated effluent from processing facilities. The quality, quantity, and time availability of the water sources is important. Characteristics of the soil and proposed cropping are very important. For flood and furrow irrigation in the San Joaquin Valley in California it is desirable to have a minimum of 10 gpm/acre of water available for irrigation. Peak ET is typically during late July and August. For irrigation systems other than flood and furrow, one is primarily trying to insure that peak ET can be reliably be met. In some cases it may be necessary to increase the quantity of fresh water irrigation supplies to ensure high irrigation distribution uniformity's can be obtained.

Determining Transfer Rate: Once a knowledge of the known fresh water irrigation supplies is determined, soil types are known, and cropping patterns are established, then one must estimate what the maximum desired application rate of nutrients from manure water would be for optimal plant utilization. This flow rate is then used to size pumps, flow meters, throttling devices, and other equipment. For instance it might be determined that the maximum desired application rate of nitrogen is 100 pounds per acre per irrigation. Let us further assume that based upon irrigation water supply scheduling and availability that 5 inches of water is to be applied with each irrigation. Next the minimum anticipated nitrogen available from the manure water would be estimated (this might be something like 250 ppm available nitrogen). This information taken together will allow the irrigation designer to establish a maximum application rate for manure water.

Transfer of Manure Water: Manure water can be transferred by pumping or gravity flow. Pumps are utilized to transfer manure water when gravity head is not adequate. An irrigation designer should establish the required flow and pressure characteristics of the pump. Pumps designed for "trash" type services have been used with a good success rate. These pumps are often called "Non-clog" pumps. The best service has been experienced with pumps having submerged impellers such as submersible or vertical turbine style pumps. Many of these pumps do not generate high discharge heads. Capacities of these pumps commonly found at dairies range from 1,000 to 3,000 gpm. In-line, end suction, non-clog pumps may be needed following lagoon pumps for long manure water transfer operations or where long uphill piping runs are needed. Self-priming, end suction, non-clog pumps are not recommended for lagoon pumping due to the foaming nature of some manure water which can negatively impact pump priming and operation.

It is desirable to have a lagoon pumping or gravity draining system that will allow the lagoon to be fully drained. Many lagoon flush pumps are mounted on floating platforms (see figure 2). These pumps often require several feet of water depth to avoid bottom scour. One approach that has been employed to avoid bottom scour is to construct a small lagoon after the settling basins and before the storage lagoon that is always maintained at a full level. The floating flush pump is then moored in this small lagoon. The manure water irrigation pump(s) can also be mounted in a pipe stand adjacent to the lagoon with one or more horizontal pipes connecting it hydraulically to the lagoon to maximize the removal of liquid from the storage lagoon. These stands can be constructed with sumps bottoms 2 to 3 feet below the bottom of the lagoon to maintain required pump submergence. Stand mounted manure water pumps work well with lagoons less than 20 feet deep.

Flow Measurement of Manure Water: In order to accurately apply a known amount of nutrients from manure water to farmland the concentration of these nutrients in manure water must be established and the rate of application of these materials must be measured. Experience and testing has shown that a real-time, continuous measurement of the flowrate of manure water can be reliably made using magnetic flow meters such as have been employed for many years in the municipal waste water industry. Anticipated accuracies of these metering installations in the field is within 5 percent of actual. Gravity flow situations may provide the opportunity for the use of open channel flow metering systems such as broad crested weirs. Unfortunately, the author is not aware of any testing of manure water with open channel metering systems. Electronic metering systems easily provide instantaneous flow readout, totalizing of flow delivered, and provide many options for additional data acquisition if desired.

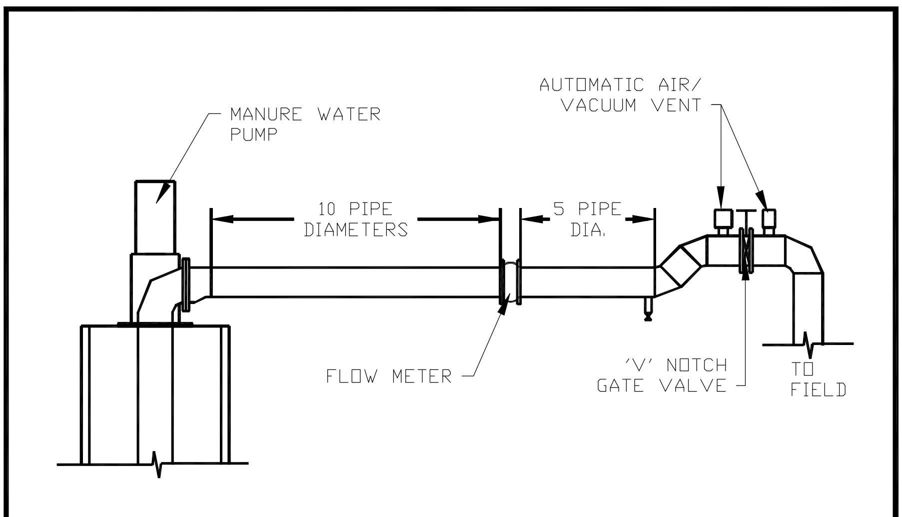

FIGURE 3

Most manure water flow metering installations require a straight run of pipe which is full of fluid. A typical installation is shown is figure 3. Optimum installation of the meter is at least 10 pipe diameters immediately downstream of the pump discharge. This would be followed by approximately 5 pipe diameters of straight run of pipe. Two 45 degree elbows can be installed after the 5 diameter long straight section to insure that the pipe is always full of water. An air vent is provided after the rise to insure that all air has been vented from the pipe. It is generally more challenging to design gravity irrigation metering runs due to the small head pressure sometimes available and the difficulty of insuring that the pipe is always full of liquid.

Flow Control of Manure Water: A flow control device is needed to regulate the flow of manure water to the field. Dairymen to date have primarily been interested in a device that is low in cost, easy to install and works reliably. The best device that fits this criteria appears to be a gate valve with a 60 degree (see figure 4) or 90 degree'V' (see figure 5) shaped orifice. This 'V' shaped valve orifice allows throttling of the flow while still providing a large cross section opening for solids and debris to travel through. The 90 degree 'V' shaped orifice has been developed to reduce full flow pressure drop, but still maintain significant plugging resistance. These valves are only somewhat more expensive than a standard gate valve and are available in a wide range of sizes. Valve opening is normally adjusted by turning a handwheel. For convenience the flow meter display is often mounted where it can be read when adjusting the handwheel.

Variable frequency drives (VFDs) can be used in place of a valve to control manure water flow. These control flow by changing the speed of the pump that results in a varying flow output. The electronics that run VFD need to be protected from excessive temperatures and dirt. Pumps that are driven by variable frequency drive must be carefully selected to insure adequate pumping head (pressure) is available at all anticipated pumping rates. An alternative means to variable speed pumping and flow control is through the use of an engine driven pump. Most variable speed pumping systems will result in lower energy usage than a throttling valve. An optimal system configuration if cost were not a significant controlling factor might be to install a VFD with a line bypass and a gate valve with a 90 degree ‘V’ shaped orifice.

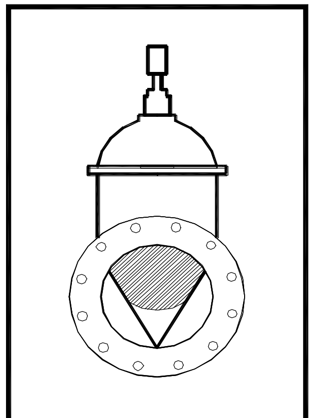
FIGURE 4

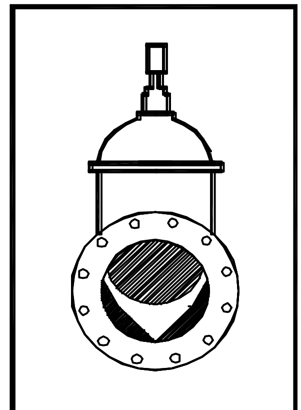
FIGURE 5

Manure Water Distribution: A high degree of success has been experienced using PVC pipe for the distribution of manure water. Polyethylene would also make an excellent distribution pipe, but is not easily modified or repaired with staff currently at most dairies. Many sites have significant quantities of concrete distribution piping that can require significant maintenance effort to keep operational with minimal leakage. Fluid velocities of 2.5 to 5.0 feet per second (fps) have been shown to be very effective at maintaining most material in suspension and conveying it to the mixing point with fresh water. Pumped systems should utilize combination air/vacuum vents and pressure reliefs that should be sized and located as would be required on a clean water irrigation pipe. Good success has been found using two individual automatic vents, at each venting location, with each vent having 2/3rds of the required total required venting capacity. With 2 vents, failure due to plugging of one vent will not lead to complete absence of any automatic venting of the pipeline.

Manure/Fresh Water Mixing: It is desirable to fully mix manure and fresh water prior to application to the field. This can be done in a number of fashions. One simple approach that has been employed is to discharge the manure water into an open pipe stand at the beginning of an irrigation system, prior to the first irrigation outlet in the field. Another approach that has been used successfully is to construct round, pressure rated, steel, mixing chambers with automatic air vents where manure and fresh water mix prior to field application.

Dilution of manure water with fresh water does several positive things:

- Allows better distribution uniformity of nutrients over the field.
- Decreases the maximum salt loading on the crop.
- Allows reasonable velocities in irrigation distribution piping.

Dilution ratios of 1 to 5 parts fresh water to 1 part manure water have been noted in the field.

Some older manure water application systems only have one location for mixing manure water with fresh water. For land application areas in excess of approximately 300 acres for a single dairy, that have multiple sources of fresh water, it may be difficult to uniformly apply manure water during the peak irrigation season. One approach to increasing the flexibility of manure water application is to distribute manure water through a dedicated distribution system to multiple fresh water mixing points around a farm. This allows manure water to be applied at a distant field while still applying fresh water only at a field close to the manure water source.

It is very important that some effective method of backflow prevention be installed between fresh water sources and manure water mixing locations. If a well should shut down or a surface water canal should suffer a failure without backflow prevention, the potential for pumped or gravity transferred manure water to flow down a well or into a surface water conveyance facility may exist. For well systems, screened and pumped surface water, or other relatively clean, pressurized water sources, double check anti-siphon (chemigation) check valves have been utilized. Standard swing check valves on unscreened surface water can be subject to jamming by floating debris such as tree limbs of various sizes. Backflow prevention approaches for surface water, low-head, deliveries based upon overflow weirs to prevent backflow with minimal head loss are currently being developed.

Determination of Lagoon Nutrient Concentration: In many instances it is adequate simply to measure the amount of lagoon nutrients that have been applied after they are applied. Under these circumstances, laboratory determination of lagoon nutrients after application may be most useful. In other instances, such as situations where nutrients are highly susceptible to leaching, it may be necessary to apply a predetermined amount of lagoon nutrients so that the capacity of the crop to take up the nutrients is not exceeded, or to insure that sufficient nutrients are applied for optimal crop performance. Since nitrogen concentration often does not remain constant over the course of a season or sometimes even over the course of an irrigation event (Mathews, 2001), it is important to have an accurate estimate of the concentration of nutrients in the lagoon water just prior to and sometimes even during an irrigation event.

We have developed a quick test for nitrogen that can return an analysis for ammonium and an estimate of organic-form nitrogen in the field in about five minutes. (Mathews, 1999, 2001). Use of this or another rapid test for nutrients allows the applicator to make adjustments in application rates just prior to and/or during irrigation. Installation of a sampling spigot near the pump simplifies collection of samples during irrigation. A one inch spigot with a short length of hose attached that allows excess flow to be directed directly back into the pump box has been performing well.

Tail/Storm Water Collection and Pumping: It has been suggested that to optimize flood irrigation of land with border check irrigation systems that 15% of supplied irrigation flow be collected at the end of the check.[i] In order to achieve high irrigation distribution uniformities with most flood or furrow irrigation systems, some tail water will collect in the low areas of the field. Rainfall on many manured fields will also result in runoff to low collection areas of fields. At these locations tail water collection and transport systems must be constructed. These systems must be sloped to avoid standing water. In some locations, if standing water remains at tail water collection basins, then these basins must be constructed to the same standards as manure water storage lagoons. Often it is necessary to provide a pumping system that will lift the tail/storm water and convey it through a pipeline. It is convenient to the dairyman if this water can be applied to the field that is currently being irrigated. Storm water collected from manured fields must be conveyed to an appropriate storage location until it can be irrigated on ground that will allow it to infiltrate.

Tail/storm water collection and transfer systems must be properly sized to collect and transport the required flows of water. An engineer can be utilized to calculate the anticipated runoff from various storm events and make recommendations on rates and volumes of water that can be anticipated. There is additional collection of storm water from corrals and feed storage facilities that should be integrated into this system. Irrigation specialists who are familiar with the local soil type and irrigation methods can assist landowners with the design of tail water collection and transport systems for irrigation water.

Section 2: Validation of Flow Meter Systems for Lagoon Nutrient Application

Overview of existing system: The typical method of field crop irrigation within the Turlock and Modesto Irrigation Districts is border check with the crops, including the corn, planted flat between the borders. An average check in the area would be between 100 and 300 feet wide by 600 to 1200 feet long. Irrigation water flows by gravity from the canal system through underground pipelines from 30 to 42 inches diameter. The entire pipeline system is charged with water whenever any field on that pipeline is being irrigated, and the underground pipeline is completely full. Flow onto a particular check is controlled by alfalfa valves, usually 24 inches in diameter, which open into a box which opens onto a check. Typically each check is serviced by two valves which are both opened to allow water to flow into the check. The irrigation district supplies flows typically between 15 to 20 CFS. On the project fields, it took from 1-1/2 to less than an hour to irrigate each 4-5 acre check.

Researcher Managed Systems

Project Layout: A field was selected on a cooperating dairy south of Turlock, CA which was divided into border check irrigation basins. Four of nine checks (each measuring approximately 150 feet wide by 1200 feet long) were farmed according to a common practice of applying a single large application of lagoon water in the preirrigation followed by multiple split applications of water run anhydrous ammonia at rates sufficient to supply all the needs of the as the sole source of commercial nitrogen for the crop. The remaining four checks were farmed using dairy lagoon water as the primary nitrogen source. Treatments were assigned in a randomized complete block design with four replications.

Because soils in this area are prone to leaching, the common practice is to apply all or most of the water-run anhydrous ammonia in several split applications onto the corn in the irrigations prior to tassel emergence. The cooperating grower followed this practice but also added one to two additional applications after tassel to better supply the crop with nitrogen during grain fill. Lagoon water nitrogen application rates and timings followed the grower’s commercial nitrogen application rates as closely as possible. Nitrogen was applied in 5 to 6 of the 9 to 10 crop irrigations.

In the first year, dairy lagoon water was applied to three of the four anhydrous checks during the preirrigation according to a flow rate set by the grower. It was not possible to get lagoon water through the pipeline to the fourth anhydrous check because the flows of the district and lagoon waters come from opposite directions. The lack of lagoon water on this check in the preirrigation had no discernable impact on the yields from this check. In years 2 and 3, all anhydrous N checks received a lagoon water preirrigation.

In addition to the replicated field (Rep field), fertilization of corn using lagoon water was done on an entire field of about 25 acres on a different dairy nearby and under the same management. An additional field of about the same size was managed using solely anhydrous ammonia for the crop irrigations. Originally, we had intended to manage this field also with lagoon nutrients. Since the district water and pond water on this field were coming from opposite directions, each check was split with a border so that only one valve was run at a time, so that the lagoon water could mix with the district water at the valve. However, we discovered during the preirrigation that adequate mixing did not occur at the valve, but that each flow kept to its own side of the check. This meant that one side of the check was receiving straight lagoon water while the other side was getting almost pure district water. Achieving uniform application of nutrients to the crop was therefore impossible without compromising groundwater quality. During the first year of the project, anhydrous ammonia only was used for fertilization and the grower's flow and N application monitored. This situation was corrected in years 2 and 3 of the project by installing a pump and piping the lagoon water approximately ¾ mile so that it was mixed with the incoming fresh water well before being applied to fields.

Flow Measurement: During the initial year of the project, we used a Marsh McBirney Flo-mate electromagnetic flow meter to measure velocity of the mixed lagoon and fresh water in the underground pipeline. The sensor was mounted on a pole and inserted it down existing 12 inch concrete air vents into the main pipeline. During the 1998 and part of the 1999 season, we measured velocity at the .2, .4 and .8 diameter locations in the pipe. Starting partway through the 1999 season, we measured velocity at 13 points from bottom to top of the pipe and calculated the relative contribution of the velocity and area in each of 7 concentric rings to the total flow in the pipe.

During the 2nd and 3rd years of the project, the final mixed flow was measured using both the hand-held electromagnetic meter and also a Marsh-McBirney Flo-Tote Model 260II B datalogging open channel flow meter, which recorded fluctuations in the flow at one-minute intervals. Four samples of the mixed lagoon and fresh water were taken from each check. Nitrogen application rates were determined using the nitrogen concentrations and flow rates for the mixed lagoon and fresh water. Results obtained from both the flow methods were averaged together to obtain a single application rate at the field.

Flow rates of the undiluted lagoon water were measured using a Marsh McBirney model 282 insertion style electromagnetic flow meter and/or an installed ISCO Unimag electromagnetic flow meter. At least one sample per check was taken using an installed spigot near the pump outlet. Total number of gallons applied to each check were recorded and used with the analysis of the undiluted lagoon water to determine application rates as measured at the pump.

Flow Regulation: In year one of the project, lagoon water from each of the lagoons was regulated by adjusting the opening of the 24 inch sidegate on the intake of the pipeline going from the lagoon to the field. In year two of the project, pumps and piping were installed on both locations to transport the lagoon water to a point near the beginning of the pipeline to effect proper mixing of lagoon and fresh water prior to application to all the fields. A butterfly valve with a ratchet-style controller was installed on the pond associated with the replicated study field, and a v-notch gate valve was installed on the demonstration field pond. By year three, a v-notch gate valve had also been installed on the pond associated with the replicated field.

Determination of Lagoon Nitrogen Concentration: To measure the concentration of nitrogen of either the mixed lagoon and fresh water or the undiluted pond water, an in-field quick test was developed by modifying the Nessler's method (HACH, 1997) for measuring ammonium nitrogen. This method uses a syringe to accurately dilute a 1cc sample of lagoon water in 200 cc of water. Dispersing and mineral stabilization reagents are added to minimize interferences. Nessler's reagent is added to a subsample and, after the appropriate time for color development, the absorbance is read using a hand-held 420 nm colorimeter. Because diluted lagoon water also absorbs light at 420 nm, a reading of the absorbance of the diluted lagoon water is taken prior to adding the Nessler's reagent and this reading is subtracted from the final absorbance figure. We have correlated the absorbance of this diluted lagoon sample to the organic nitrogen concentration (Mathews, 2001) to provide a quick test that will estimate concentrations of both ammonium and organic form nitrogen.

In-field nitrogen tests were supplemented with laboratory analysis of lagoon nitrogen using a conductimetric method (Carlson, 1978) (years 1 and 2) or standard distillation (year 3) for ammonium, and standard total Kjeldahl nitrogen (years 2 and 3) for TKN. Organic form nitrogen is considered to be TKN minus ammonium. Year 1 organic nitrogen samples were lost, and organic nitrogen application were estimated from the ammonium concentration by assuming that the ratio of organic to ammonium form nitrogen was the same for both years.

Obtaining Targeted Nitrogen Application Rates: During the first two years of this project, we determined the rate of ammonium-form nitrogen being applied to the field by measuring the flow with the hand-held flow meter as described above, and adjusting a valve on the lagoon outlet until a predetermined concentration (based on flow rate, desired N application rate, anticipated run time, and acreage irrigated) of lagoon ammonium was obtained in the mixed lagoon and fresh water flows. Flow meters and v-notch valves were installed in the second year on the demonstration field and in the third year on the replicated field. When using this system, the valve was adjusted to obtain a predetermined flow rate from the lagoon pump. The needed flow rate was calculated based on concentration of the undiluted pond water, the desired application rate, the anticipated run time and the acreage irrigated.

During 1998 and 1999, only ammonium form nitrogen was measured or considered in determining application rates for lagoon nutrients. By year three, the method for in-field estimation of organic nitrogen had been developed, and application rates were determined using the assumption the all of the ammonium and 70% of the organic form nitrogen would be available during the cropping season.

Corn Yield Measurement: Yields were measured by weighing every silage truck coming from each project check and exactly measuring the harvested area. The entire check was weighed with the exception of the first rows along the borders and the headlands at either end. Two to three samples were taken from the silage pit or from silage deliberately blown into a small pile on the ground. These were weighed and dried to determine moisture and yields adjusted accordingly. Total nitrogen concentration of the samples was determined by laboratory analysis.

Farmer Managed Systems

To determine how well the growers could manage the flow meter/valve nutrient application system, Marsh-McBirney model 282 insertion style flow meters were installed at each of 4 dairies. In most cases, project personnel assisted the growers with calculations during the first season while all irrigation and recordkeeping was performed by the grower and their irrigators. Samples were collected periodically during the irrigations and analyzed using both quick test and laboratory methods. At each of the dairies, at least one field was selected on which to apply target rates of lagoon nutrients to silage corn during the 2000 growing season. Complete nitrogen, phosphorus and potassium application and uptake information was collected for the corn crop at three sites. Partial application information was collected at a fourth site because of an initial difficulty in setting up and managing the flow measurement system.

Results and Discussion

Regulating Flow Rates:

<u>Side Gate on a Gravity Flow System</u>: On the demonstration field pond, a 1 to 1 ½ inch side gate opening (as measured by the threaded stem) was needed to obtain the target concentration. On the smaller pond, the proper opening was between 1 ½ and 1 ¾ inches. Adjustments of ¼ to 1/8 inch were necessary to keep the quick test reading within 10 ppm of the target (usually between 45 and 65 ppm). It was not possible to get closer than within 10 ppm of the target. Because there was around two inches of play in the side gate stem handle, it was necessary to first raise the side gate by at least 2 inches and close it down to the desired opening each time an adjustment was made. The same side gate opening did not necessarily give the same quick test reading over the course of an irrigation because 1) the play in the valve made it impossible to be certain subsequent settings were equivalent; 2) plugging of portions of the opening changed the amount of flow coming through; and 3) head pressure decreased as the water level in the pond dropped. In addition to this, the narrow opening resulted in frequent plugging on the pond where the outlet was at the bottom, especially in the first irrigations of the season. On one occasion, the entire pipeline from the pond to outlet plugged, necessitating a difficult clean out.

<u>Butterfly Valve on a Pressurized System:</u> During the 1999 season, a 12 inch butterfly valve with a ratchet style controller was used to regulate the lagoon water flow from the pump. This system proved to be even more difficult to adjust than the side gate on the gravity system used the previous season. The proper opening was between notch 8 and 8 ½ on the handle position where notch 9 is fully closed. The opening on the valve was less than ¼ inch and was very prone to plugging. Because of the distance between the pump and the outlet to the field, there was at least a half-hour lag between the time an adjustment could be made and the time the full effect of that adjustment could be measured at the field. Since many of the checks irrigated in just about an hour, it was very difficult to make adjustments at the pump in time to have the effect of that change be seen in the field during the period that check was still being irrigated.

Although we were successful in applying our target application rates in years 1 and 2 of the project, the method of applying targeted application rates by measuring flow and concentration of the mixed lagoon and fresh water was far too labor intensive and awkward to be practical in most situations.

<u>V-notch Gate Valve on a Pressurized System:</u> Unlike the side gates used in 1998 and butterfly valve used on the replicated field in 1999, the v-notch gate valve was designed for controlling flow. It allowed precise adjustments in flow rate to be made without clogging, and was easy to use even at low flow rates. We experienced no clogging problems with this valve. These

experiences underscore the importance of selecting the correct valve to use with the flow meter system.

Accuracy in Achieving Targeted Rates Using a Flow Meter and Valve on Pumped Lagoon Water: Validation of this system was conducted on ten individual irrigation basins, or checks, located in three fields. The average area in each check was 4.6 acres. On each check of the replicated field, seasonal nitrogen application rates differed by less than 10% from the season target as calculated using quick test concentrations and totalized gallons from the installed flow meter. The overall average for the entire field was 275 lbs N/A—only 5 lbs off from the target rate of 270 lbs N/A (Table 1). The West demonstration field averaged 310 lbs with a target of 300 lbs N/A while the East demonstration field had an average application rate of 256 lbs N/A, 44 lbs less than desired (Tables 2 and 3). The East field has some characteristics that make it difficult to predict how fast an irrigation will run, leading to over or under application of the lagoon nutrients.

On the replicated field, N/A measured at the pump was different then N/A measured at the point where the mixed lagoon and fresh waters were applied to the field to each check (Table 4). The average difference between the valve measurement and the field measurement was about 15%. However, if all the checks were averaged together, the difference was only 3%. This would indicate that both methods of determining nitrogen were performing satisfactorily. The discrepancy between the two measurements is due to the time lag between the time an adjustment is made at the valve and the time the effects of that adjustment reaches the field. On the West demonstration field, the average N/A was 7% different between the two methods with individual checks ranging as high as 60% different between the two methods. The East demonstration field was the highest difference (34%), probably because the irrigation sequence usually begins in this location and it takes a long time for the pipeline to clear from its prior usage.

***Yield, N Application and N Uptake*:** Over the three year study, there was little difference between the yields of corn grown exclusively with lagoon nutrients and that grown with commercial anhydrous ammonia (Table 7). During the first two years of the project, nitrogen application greatly exceed uptake on both the lagoon nutrient and commercial fertilizer plots. The excess nitrogen on the commercial fertilizer treatments came from the large amount of lagoon nitrogen applied during the preirrigation. The excess nitrogen on the lagoon nutrient checks came from not taking into account the contribution of the organic form of nitrogen. In this case, the organic nitrogen comprised about half of the total nitrogen in the crop. During the third year of the study, 70% of the lagoon organic form nitrogen was accounted for when determining application rates. Nitrogen application rates for the lagoon nutrient checks were within a few pounds of crop uptake and there was no apparent detriment to yields.

Farmer Managed Systems Dairy operators at each of the four sites were pleased with how well the flow meter/valve/quick test system performed for them, and they were especially pleased to not have to purchase commercial fertilizer for their corn. Table 9 shows the yield and number of acres monitored at each of the sites where yields were measured. Yields were acceptable at each of the three sites where yields were measured.

The flow meter/valve/quicktest system allowed reasonable rates of nitrogen to be applied in each irrigation. On dairies A and D, the total amount of nitrogen applied (excluding the last irrigation) were 275 and 248 lbs. available lagoon N/acre, respectively. If the last irrigation had not been applied, total season application rates would have approximated crop uptake by the crop for the season (table 12). In both of these instances, lagoon water was mistakenly applied in an additional irrigation at rates higher than desired. Total amounts of nitrogen applied from all sources on these two dairies exceeded the crop uptake. Table 11 shows the total amount of nitrogen applied from all sources. The cooperating dairy operator at dairy A was initially not convinced that the lagoon water nutrients would be sufficient; so he applied commercial fertilizer in addition to the lagoon water. The commercial nitrogen he had applied when combined with nitrogen in the lagoon water totaled 470 lbs/acre, far exceeding the crop uptake of 229 lbs/acre. This coming season he is planning to apply only minimal amounts of commercial fertilizer on all but a small part of his acreage, and instead is planning to grow as much corn as possible using only lagoon nutrients.

Application rates at Dairy B were less than desired because limited pond capacity forced the dairy operator to empty his pond in the winter and spring so that the pond water was relatively dilute during the summer corn season. In addition, it was later discovered that a 5 gallon bucket was stuck in the pump intake, greatly reducing the output of the pump and making it impossible to apply enough nutrients in each irrigation.

Application data from dairy C is incomplete because of difficulties getting the meter installed in time for the irrigation season. A Currently, it is unknown how much of the amount of organically bound nitrogen will become available during the current cropping season. Since 30 to 66 percent of the total nitrogen is in the organic form, and it is unreasonable to assume that all of this will be available the first year, it is difficult to determine the total amount of lagoon nitrogen can be applied without compromising groundwater quality.

Conclusions

The method of using a flow meter and control valve on the outlet of the lagoon, used in conjunction with a relatively accurate nitrogen quick test, can provide the average dairy operator with the practical tools necessary to easily apply targeted amounts of lagoon nutrients to crops. This can help to shift from the all-too-common practice of treating lagoon water as a disposal problem to one which views lagoon nutrients as a valuable fertilizer resource for themselves and for their neighbors.

The ability to accurately apply targeted amounts of lagoon nutrients has many advantages for the dairy operator including:

- The ability to rely completely on lagoon nutrients without sacrificing yield while protecting groundwater quality by eliminating the need to overapply to ensure that sufficient nitrogen will be available for the crop

- The ability to have confidence in the amounts of nutrients being applied reduces reliance on commercial fertilizers and

- Full utilization of cropland available for land application by being able to apply the entire amount needed by the crop without overapplication

- The ability to use manure nutrients on salt sensitive crops such as fruit and nut trees, or crops which are adversely affected by excessive nitrogen such as cotton or grapes.

- The potential to minimize adverse affects of dairy nutrient applications on groundwater even on highly leachable soils with shallow groundwater

- The ability to easily keep accurate records of nutrient application rates and plan for future applications

There are many interrelated factors that must be considered when setting up a functional lagoon nutrient management and application system. Many of these have been discussed. One important issue not addressed in this presentation is the uniformity of the irrigation distribution system, because the uniformity of that system will determine the uniformity of application of the nutrients carried in the water. Another issue where reliable data is lacking is an understanding of the rate at which lagoon organic form nitrogen becomes available to the crop. It is difficult to determine the appropriate targets without this information.

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References

Carlson, R. M. 1978. Automated separation and conductimetric determination of ammonia and dissolved carbon dioxide. *Anal. Chem. 50*:1528-1531.

EPA, 2000, National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitations Guidelines and Standards for Concentrated Animal Feeding Operations, Proposed Revisions, December 15, 2000; http://www.epa.gov/owm/afos/proposedrule.htm

Hach Company, Nessler Method for Ammonia Nitrogen, method 8038, Water Analysis Handbook, 1997 p 825

Harter T., R. D. Meyer, M. C. Mathews. 1999. Shallow groundwater quality under dairies in Merced and Stanislaus County, *Proceedings, 1999 California Plant and Soil Conference*, 122-127, California Chapter of American Society of Agronomy.

Mathews, M. C., R. D. Meyer, T. Harter. 2001, Composition, sampling, and analysis of dairy lagoon water, *Proceedings, 2001 California Plant and Soil Conference*, California Chapter of American Society of Agronomy.

Meyer, D. and L. J. Schwankl. 2000. Liquid dairy manure utilization in a cropping system: A case study; *in*: *Land Application of Agricultural, Industrial and Municipal By-Products*, SSSA Book Series No. 6, 409-422, Madison, Wisconsin.

Pritchard, Terry UC Davis, comments made during Spring 2000 Seminar at UC Extension shortcourse entitled: **Using Dairy Lagoon Water Nutrients for Crop Production.**

Table 1. Comparison of lbs N/A Applied vs Intended Target, Replicated Field, 2000

Check 1	Target N/A this irrigation	N/A QT avg pump NH4+.7 Org N	pump % different from target
1st irrig.	45	27	-69%
2nd irrig	75	78	4%
3rd irrig.	58	70	18%
4th irrig.	35	42	17%
6th irrig.	47	43	-9%
7th irrig.	40	38	-6%
total	**270**	**298**	**9%**
Check 4			
1st irrig.	45	74	39%
2nd irrig.	20	18	-9%
3rd irrig.	44	53	17%
4th irrig.	28	31	10%
6th irrig.	39	40	3%
7th irrig.	40	36	-10%
total	**270**	**253**	**-7%**
Check 5			
1st irrig.	45	51	13%
2nd irrig.	60	65	7%
3rd irrig.	65	69	6%
4th irrig.	31	29	-6%

Table 2. Comparison of lbs N/A Applied vs Intended Target

East Demonstration Field, 2000

	Original target N/A	**East Field Check 1**	**East Field Check 2**	**East Field Check 3**	Avg.
1st irrig.	60	56	70	63	
2nd irrig.	60	52	45	56	
3rd irrig.	50	47	50	22	
4th irrig.	50	37	46	52	
6th irrig.	40	41	32	26	
7th irrig.	40	33	20	18	
total	**300**	**266**	**264**	**237**	**256**
% different from target		11%	-14%	-27%	-17%

Table 3. Comparison of lbs N/A Applied vs Intended Target

West Demonstration Field, 2000

	Original target N/A	**West Field Check 1**	**West Field Check 2**	**West Field Check 3**	Avg.
1st irrig.	60	102	64	52	
2nd irrig.	60	57	64	78	
3rd irrig.	50	44	29	18	
4th irrig.	50	56	64	63	
6th irrig.	40	63	40	55	
7th irrig.	40	24	25	31	
total	**300**	**345**	**287**	**298**	**310**
% different from target		13%	-5%	-1%	3%

Table 4. Pounds per acre of lagoon nitrogen applied as measured by at the pump outlet compared to as measured at the outlet of the mixed lagoon and fresh waters onto the field. Replicated field, 2000

Check 1	Lab N/A applied as measured at pump	Lab N/A applied as measured in field	valve % difference from pump
1st irrig.	25	22	14%
2nd irrig	73	27	63%
3rd irrig.	65	25	61%
4th irrig.	40	26	35%
6th irrig.	45	43	3%
7th irrig.	38	43	-13%
total	**285**	**185**	35%
Check 4			
1st irrig.	74	82	-10%
2nd irrig.	17	19	-12%
3rd irrig.	52	52	-1%
4th irrig.	30	45	-48%
6th irrig.	36	48	-33%
7th irrig.	37	40	-9%
total	**247**	**287**	-16%
Check 5			
1st irrig.	53	33	37%
2nd irrig.	62	71	-14%
3rd irrig.	65	76	-17%
4th irrig.	28	37	-33%
6th irrig.	40	35	12%
7th irrig.	41	44	[illegible]

Table 5. Pounds per acre of lagoon nitrogen applied as measured by at the pump outlet compared to as measured at the outlet of the mixed lagoon and fresh waters onto the field. East demonstration field, 2000

East Field Check 1	lbs N/A (lab) applied as measured at pump	lbs N/A (lab) applied as measured at field outlet	outlet % different from pump (lab N)
1st irrig.	53	66	-24%
2nd irrig.	55	77	-40%
3rd irrig.	41	45	-10%
4th irrig.	23	31	-35%
6th irrig.	25	33	-34%
7th irrig.	34	43	-26%
total	**231**	**296**	-28%
East Field Check 2			
1st irrig.	47	59	-25%
2nd irrig.	35	45	-31%
3rd irrig.	25	30	-22%
4th irrig.	48	71	-48%
6th irrig.	21	30	-44%
7th irrig.	25	18	30%
total	**201**	**253**	-26%

Table 6. Pounds per acre of lagoon nitrogen applied as measured by at the pump outlet compared to as measured at the outlet of the mixed lagoon and fresh waters onto the field. West demonstration field, 2000

West Field Check 1	lbs N/A (lab) applied as measured at pump	lbs N/A (lab) applied as measured at field outlet	Field outlet % different from pump (lab N)
1st irrig.	84	49	42%
2nd irrig.	55	62	-12%
3rd irrig.	38	55	-46%
4th irrig.	36	57	-59%
6th irrig.	61	35	42%
7th irrig.	34	25	25%
total	**308**	**284**	**8%**
West Field Check 2			
1st irrig.	37	47	-28%
2nd irrig.	59	57	3%
3rd irrig.	30	44	-49%
4th irrig.	47	77	-63%
6th irrig.	34	45	-30%

Table 7 Replicated Field lbs N/A Application and lbs N/A Uptake

Corn Silage 1998 - 2000

Lagoon nitrogen	commercial NH4-N lb/A applied	lagoon NH4-N lb/A applied	lagoon Org-N lb/A applied	Total-N lb/A applied	Yield T/A @ 70%	Lbs/A N removed
1998		279	567	846	41.6	381
1999		222	469	691	33.3	312
2000		186	107	293	35.7	285
anhydrous						
1998	266	117	328	621	43.1	417
1999	254	108	253	615	34.8	315
2000	271	114	335	721	32.9	292

Table 8 Demonstration Field lbs N/A Application and lbs N/A Uptake

Corn Silage 1998 - 2000

East field	NH4-N lb/A applied	Org-N lb/A applied	Total-N lb/A applied	Yield T/A @ 70%	Lbs/A N removed
1998	206	183	388	36.6	326
1999	222	273	494	29.3	235
2000	169	78	247	32.8	268
West field					
1998	187	166	353	30.2	329
1999	217	235	452	30.3	278
2000	212	93	305	29.6	230

1998 both laboratory and quick test ammonium values, organic N is estimated

1999 and 2000 are laboratory values

Table 9. Yield and Acreage of Demonstration Sites				
Dairy	A	B	C	D
Yield(T/A) @ 70% moist	28.9	29.7	na	33.6
moisture @ harvest	72.6	71.0	na	71.8
acres monitored	37.8	75.2	48.1	75.9

Table 10. Average nitrogen applied each irrigation				
Dairy	A	B	C	D
1st irrigation	79	29	na	46
2nd irrigation	69	22	na	49
3rd irrigation	75	32	14	54
4th irrigation	52	32	37	38
5th irrigation	72	21	29	61
6th irrigation		23	69	81
Total lagoon available* N applied	348	159	149	329
*assume 50% of organic-form N is available				

Table 11. Total nitrogen applied by source				
Dairy	A	B	C	D
lagoon NH_4-N	306	140	91	235
lagoon Org-N	84	38	118	174
commercial N	80			
total	470	178	209	409

Table 12. Lagoon nutrient application and uptake				
		N	P_20_5	K_20
Dairy A	lb/A applied	428	142	998
	lb/A removed	229	100	404
Dairy B	lb/A applied	159	69	322
	lb/A removed	270	132	367
Dairy D	lb/A applied	329	164	604
	lb/A removed	265	142	367