Designing Dairy Liquid Manure Transfer Systems for Nutrient Management

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Introduction

A liquid manure transfer system is the pumps and pipelines that move the liquid manure from the retention pond to the point where it will be diluted with fresh irrigation water and applied to the field. The ability of the system to deliver the amount of nutrients needed by the crop and specified in the nitrogen budget is constrained by the physical limitations of the manure transfer system. When developing a budget, it is essential to determine the capabilities of an existing system to deliver nutrients and to either change the plan or the infrastructure if the application rates fall outside the system capacities.

Can Liquid Manure be Delivered to Each Field?

If a field will have liquid manure applied to it, there needs to be a pipeline connecting the liquid manure source to the irrigation system of that field. There are many instances where it is difficult or impossible to install a pipeline to a particular field due to distance from the source pond or obstacles such as non-contiguous parcels, roads, canals, rivers etc. Even if a pipeline connection does exist, it may not be usable because it is in disrepair, or because it is shared by other landowners who do not want manure water in the pipe, or because backflow prevention measures are not or cannot be installed.

It is usually possible to engineer solutions to these situations, although it may not always be economical to implement them. It is essential in developing a nitrogen budget that only fields where the liquid manure can realistically be applied be included in that portion of the plan.

After is it confirmed that there are functional pipelines to deliver liquid manure to every field, the method of delivery and mixing points need to be evaluated. Many existing dairies have only one point where the liquid manure is injected into the freshwater irrigation system. This configuration may continue to be adequate for smaller operations with few fields and relatively fast run times, because these systems seldom irrigate more than one field at a time. More commonly, however, two or more fields are irrigated simultaneously, often with differing freshwater sources, flow rates and crop nutrient requirements. If liquid manure flows are split, either before or after being mixed with fresh water, it can be difficult to determine what percentage of the flow went to each of the fields, and even more difficult to proactively adjust the amount that each field receives. Because the amount of total nitrogen that can be applied to each field is subject to regulatory limits, crop production can be expected to decline in fields that receive significantly less nitrogen than anticipated.

In a well-designed system, it should be easy and convenient to measure and apply different target application rates of nutrients to each field independently of the others, especially during the peak irrigation season. One approach to increasing the flexibility of lagoon water application system is to distribute lagoon water through a dedicated distribution system to multiple fresh water mixing points around a farm. This allows lagoon water to be applied at a distant field while applying only fresh water at a field close to the lagoon water source.

What Freshwater Sources Will be Used for Dilution?

In most cases, the lagoon water will need to be diluted prior to being applied. A adequate source of source of fresh water needs to be identified for each lagoon water application. Dilution of lagoon water prior to land application is not only necessary for appropriate rates to be applied in almost all cases, but also decreases the risk of injury to the crop from salts, reduces the risk of plugging irrigation distribution pipelines by maintaining sufficient fluid velocities to prevent solids from settling, and improves nutrient application uniformity by moving the water over the field faster. Changing the amount of lagoon water added to the fresh water also makes it possible to adjust the nitrogen rate applied.

In most cases, water for dilution comes from irrigation district canals, or pumped water from wells or rivers. The amount of lagoon water to be blended into the fresh water in the amount that will result in the application rate specified in the nitrogen budget.

Very few liquid manure application systems have the capability of delivering undiluted liquid manure to a field at rates that do not result in either too much nitrogen or salt being applied in a single application.

Ratio of lagoon water to fresh water needed to supply a target nutrient application rate

total water applied acre-inches/A	desired application rate (lbs/acre)	lagoon concentration in mg/L	lagoon concentration in lbs/ac inch	acre inches/A LW needed to supply rate	% lagoon water in blend	ratio lagoon to fresh water
3	50	200	45	1.1	37%	1:2
3	50	400	91	0.6	18%	1:4
3	50	600	136	0.4	12%	1:7
3	50	800	181	0.3	9%	1:10
3	50	1000	227	0.2	7%	1:13
3	100	200	45	2.2	73%	1:0.4
3	100	400	91	1.1	37%	1:2
3	100	600	136	0.7	24%	1:3
3	100	800	181	0.6	18%	1:4
3	100	1000	227	0.4	15%	1:6
3	200	200	45	4.4	-	-
3	200	400	91	2.2	73%	1:0.4
3	200	600	136	1.5	49%	1:1
3	200	800	181	1.1	37%	1:1.7
3	200	1000	227	0.9	29%	1:2.4
6	50	200	45	1.1	18%	1:4
6	50	400	91	0.6	9%	1:10
6	50	600	136	0.4	6%	1:15
6	50	800	181	0.3	5%	1:21
6	50	1000	227	0.2	4%	1:26
6	100	200	45	2.2	37%	1:2
6	100	400	91	1.1	18%	1:4
6	100	600	136	0.7	12%	1:7
6	100	800	181	0.6	9%	1:10
6	100	1000	227	0.4	7%	1:13
6	200	200	45	4.4	73%	1:0.4
6	200	400	91	2.2	37%	1:2
6	200	600	136	1.5	24%	1:3
6	200	800	181	1.1	18%	1:4
6	200	1000	227	0.9	15%	1:6
9	50	200	45	1.1	12%	1:7
9	50	400	91	0.6	6%	1:15
9	50	600	136	0.4	4%	1:23
9	50	800	181	0.3	3%	1:32
9	50	1000	227	0.2	2%	1:40
9	100	200	45	2.2	24%	1:3
9	100	400	91	1.1	12%	1:7
9	100	600	136	0.7	8%	1:11
9	100	800	181	0.6	6%	1:15
9	100	1000	227	0.4	5%	1:19
9	200	200	45	4.4	49%	1:1
9	200	400	91	2.2	24%	1:3
9	200	600	136	1.5	16%	1:5
9	200	800	181	1.1	12%	1:7
9	200	1000	227	0.9	10%	1:9

1 mg/L = 1 ppm = 0.2268 lbs/ac-in

Ratios of Lagoon to Fresh Water

The ratio of lagoon water to fresh water is dependent on the concentration of the target nutrient, usually nitrogen, in the undiluted lagoon water, the total amount of water being applied, and the desired application rate of the nutrient. The needed ratio of lagoon to fresh water can vary greatly, even on the same operation. For example, a nitrogen budget may call for a light application of 30 to 50 lbs/acre nitrogen to be applied in a pre-irrigation for the corn crop to ensure enough nitrogen to encourage root growth while minimizing the risk of salt injury to the seeding plant. If the pond is concentrated (800 mg/L N) and 9 ac-inches/acre of combined fresh and lagoon water per acre are applied, one part of lagoon water to 32 parts of fresh water would result in an application rate of 50 units of N. Later in the season, an application of 100 lbs N/acre may be needed to supply a rapidly growing crop. If the pond concentration is now at 400 mg/L N and 3 ac-inches/acre of total water is applied, the dilution ratio for this application would be 1 part lagoon water to about 2 parts fresh water. Ranges of these magnitudes are common because lagoon nitrogen concentrations often fluctuate, especially if fresh water is added to the pond, and because pre- and first irrigations on surface irrigated forage crops routinely run more slowly than later irrigations, resulting in total water applications that are easily double or triple the amount of water applied for main-season irrigations.

When engineering manure transfer systems, it is imperative that an accurate assessment of the ranges of nitrogen application rates, irrigation run times and pond concentrations be made prior to designing the system.

What to Do When Dilution Water is Scarce

Winter forage crops often need nitrogen fertilization during January or February. Lagoon water applications during this time not only eliminate the need for purchased commercial fertilizer, but help decrease the amount of storage capacity needed in the retention pond. Winter applications of lagoon water are routinely made on light, well-drained soils using border check surface irrigation and crop injury only occurs when soils are waterlogged or the lagoon water is applied undiluted and/or at excessive rates. Lagoon nitrogen application rates during the mid-winter or early spring can often be somewhat higher that single-application rates put on at other times of the year. This is mainly because rainfall events typically involve far less water moving through the soil than is applied in a typical summer irrigation, so there is less potential for leaching. Slower conversion of non-leaching ammonium to leachable nitrate also helps maintain the nitrogen in the soil, and the fibrous root system of cereal forages making growth in the early spring effectively utilize the nitrogen. Because of these factors, it is often possible to apply higher rates of nitrogen - 120 – 150 lbs N/acre - in a single application in January or February on these light soils than would be advisable in the summer, and not as much dilution water is needed. .

These winter applications almost always need to be diluted with fresh water to achieve an appropriate application rate and to minimize crop injury. If, however, if an operation relies exclusively on district water for irrigation, this water source may not be available for applications to winter crops. A combination of methods may be needed to achieve the desired rate

1. One obvious solution is to install pumps and some operators will do so. However, the pump output alone may not be sufficient to move water across the field at fast enough rate.

2. Block off a portion of the irrigation canal, and fill that section with pumped water and reclaimed rain or tailwater. Irrigate a portion of the field until the canal is drawn down. Repeat as necessary until the whole field has been irrigated.

3. Divert rainfall from roofs and paved areas into the pond, and apply water from the more dilute upper portions of the pond. Some operators may also pump fresh water into the pond.

4. Irrigate during a rainfall event. The irrigation water will move over the wet soil much faster, resulting in a lower application rate. Since the nitrogen in the lagoon water is in forms that adhere to the soil, the nitrogen applied will remain in the upper root zone.

Irrigating when the ground is already wet can dramatically speed up irrigation run times, and enable applications of manure nutrients at agronomic rates so long as surface water runoff and crop waterlogging don't occur. Organic and ammonium forms of nitrogen present in lagoon water adhere to soil particles and are retained in the root zone, even if deep percolation occurs during the irrigation.

Nutrients and Salt Contributions from Freshwater

The dilution water may itself be a source of nitrogen and salts. Normally the freshwater serves to temper the adverse effects of the high salt concentration in a typical lagoon water, but if the concentration of salt in the dilution water is also high, the salt concentration of proposed blend needs to be considered and measures taken to avoid crop injury and yield reductions. Central Valley regulations require that nitrogen in freshwater be measured and reported as part of the applied nitrogen to the crop. Nitrogen in freshwater is usually in the nitrate form which moves with the water and does not adhere to soil in significant amounts as the water moves through the root zone. Although the total amount of nitrate applied is reported, only the amount that remains in the root zone of the crop with the water can be utilized by the crop. The amount of nitrate that is available to the crop will be reduced by the same proportion of applied water that is lost to deep percolation past the roots. This can be a significant amount. For example, if the freshwater irrigation source contains the drinking water limit of 10 mg/L nitrate form nitrogen, each acre-inch contains 2.27 lbs of N. A 10-inch pre-irrigation would apply about 23 lbs of N which must be included in the reported total N applied to the crop. However, on a typical sandy loam soil, only about 2.5 inches of water, containing about 5 lbs/acre N, would have actually been retained in a 3-foot root zone. Over 17 lbs N/acre of reportable N would be lost and subtracted from the total that can be applied from other sources. If deep percolation losses cannot be prevented, obtaining a source of dilution water with minimal nitrate and salt concentrations becomes a critical issue.

Choosing Manure Transfer Pipes

Newer liquid manure distribution system installations are usually constructed out of PVC pipe which has been performing well as piping for lagoon water transfer. High-density polyethylene would also make an excellent distribution pipe, but because the unions are made using heat fusion, it usually cannot be readily modified or repaired by dairy personnel. Many sites have existing concrete distribution piping that can require significant maintenance effort to keep operational with minimal leakage. PVC pipeline is smoother than concrete so the same pump head pressure will push water further because there is less friction loss.

When designing PVC constructed pipeline systems, a Hazen Williams equation (used to calculate pressure drop in pipes due to friction) C value of 140 or lower should be utilized. Caution should be exercised when sizing pumps and piping to transfer the very thick slurries found at the bottom of many storage lagoons. The density and viscosity of these slurries is significantly higher than of water.

Experience has shown that use of 100-foot head rated PVC pipe results in significant installation and repair problems. Installations using 63 PIP pipe in 18 inch and larger sizes in field areas and 80 PIP in smaller pipes have been successful. Road crossing or in-road piping should have applied loads evaluated and determination made if heavier piping is needed at these locations. As a general rule it has been effective to select piping meeting exterior imposed loads (soil and traffic) to also be selected to have a pressure rating of at least twice the anticipated maximum operating pressure.

Sizing Lagoon Transfer Pipelines

To ensure good crop production, it is essential that the crop is supplied with the nutrients it needs at the time they are needed. Nitrate is the most prevalent form of plant available nitrogen in the soil and it is the form most susceptible to losses to the air or the groundwater. The risk of nitrate loss through leaching from excess water application or denitrification in waterlogged soils will dictate how far in advance of crop utilization manure or commercial fertilizer nitrogen applications may be made. Where risk of leaching losses are high, it is often necessary to split the total amount of nitrogen needed for the season into multiple smaller applications of a lagoon water that has most of the nitrogen in the ammonium form and relatively little in the organic form. Application rates for these plans are usually between 30 and 80 lbs available N/acre for a summer corn crop, and somewhat higher, usually around 120-150 lbs N/A for mid-winter application. To achieve this application rate, the lagoon pump is usually throttled back using a "V" notch gate valve, and a flow meter is used to monitor the specific amount of liquid manure injected into the fresh irrigation water going to a field. The application infrastructure system needs to be designed so that an appropriate application rate can be applied.

A manure collection and distribution system that can deliver these rates and form of liquid manure can be very different than what is needed in a situation where leaching losses can be controlled. In low loss conditions, such as under sprinkler irrigation, fewer, larger applications may be possible. Some situations are a combination of these extremes, where several times more water are applied during pre and first irrigations than is applied during later crop irrigations, resulting in high leaching losses at the beginning of each crop but relatively little later in the season. Under these conditions, the system may or may not need the ability to apply very low rates, depending on the manure products available and the how they are specified in the nitrogen budget.

Two different pipe sizes were installed in the same trench to accommodate the range of application rates required by this operation.

In addition to knowing the ranges of nitrogen that need to be applied, in designing a liquid manure transfer system it is also critical to know what liquid manure concentrations can be expected at different times of the year and how long it takes to irrigate each field or area for winter, summer and pre-irrigations. These factors are needed to calculate the velocity of the water in the pipeline along with the size and amount of solids in the water will govern whether the pipeline will plug when the flow rate is throttled back in order to apply the specified nitrogen application rate. Fluid velocities of 2.0 to 5.0 feet per second (fps) in the pipe that conveys liquid manure from the pond to the point where it will be mixed with fresh water will usually maintain most lagoon solids in suspension.

Once the needed range of flowrates have been calculated, select a pipe size (normally PVC) that will deliver that gpm while maintaining velocity in the pipe within the 2.0 to 5.0 feet per second (fps) range. If possible maintain a minimum fluid velocity of 2.5 fps. Typical ranges of sizes of lagoon water transfer pipes in the Central Valley are 8 to 15 inches in diameter. Pipes as small as 4-inch diameters have been found operating in the field transferring lagoon water, although a more comfortable minimum would be 8 inches. Long runs of lagoon water transfer pipe smaller than 8 inches in diameter tend to result in excessive pressure drops. If calculations result in transfer pipe sizing smaller than 8 inches, consider implementing some of the alternatives described below. Sometimes it is not possible for a single size pipeline to accommodate the range of application rates needed, and systems have been installed with two different sizes of pipe in the same trench.

<u>Calculating flow rates and velocity</u>

The amount of lagoon water to inject into the irrigation water depends on

1) the size of the field (acres)
2) the amount of nutrients you want to apply
3) amount of time it takes to irrigate the field
4) the nitrogen concentration in the liquid manure

The target GPM (gallons per minute) to set the pump to deliver can be calculated using this formula:

Target GPM =
{(lbs N/A desired / estimated min/A run time) /
(ppm lagoon water N x .008345)} x 1000

The velocity of the water in the pipeline can also be calculated:

Velocity in pipe=
gpm / (pipe cross-section area in sq ft x 449)

Dealing With Pipeline Velocity Limitations

Designing a system that can facilitate the application of agronomic rates of liquid manure can be challenging. For example, if a field takes 15 minutes to irrigate one acre and the concentration of nitrogen in the pond is 350 mg/L, then a flow rate of 1140 gpm from the lagoon pump is needed to apply 50 lbs of nitrogen per acre. If, however, it takes an hour to irrigate one acre, then the lagoon pump must put out 290 gpm to achieve the same 50 lb/A application rate. If the concentration in the pond doubles to 700 mg/L, then the flow rate must be 140 gpm. This gpm is not only less than most manure pumps will apply, but will result in a velocity of less than 2 ft/sec in a 6 inch pipe. This pipe would be prone to plugging because the NRCS minimum recommended velocity needed to keep solids from settling is 2-5 ft/sec for 4 to 10% solids in solution.

	Dilute lagoon (350 mg/L N)			Concentrated lagoon (700 mg/L N)		
minutes to irrigate one acre	**15**	**30**	**60**	**15**	**30**	**60**
Target GPM to apply 50 lb/A N	1140	570	290	570	290	140
Velocity in 10" ID pipe (ft/sec)	4.7	2.3	**1.2***	2.3	**1.2***	**0.6***
Velocity in 6" ID pipe (ft/sec)	13.0	6.5	3.2	6.5	3.2	**1.6***

*velocity in pipe too low

The more concentrated the liquid manure, the smaller the pipeline needed to maintain a velocity sufficient to prevent solids from settling and plugging the pipeline.

Minimum gpm to maintain velocity in pipe to prevent solids from settling

feet per second	manure pipeline diameter (inches) 2	4	6	8	10	12	15	16	18	20	24	30	36
2	20	78	176	313	489	705	1101	1253	1585	1957	2819	4404	6342
2.3	23	90	203	360	563	810	1266	1441	1823	2251	3241	5065	7293
3	29	117	264	470	734	1057	1652	1879	2378	2936	4228	6606	9513
4	39	157	352	626	979	1409	2202	2505	3171	3915	5637	8808	12,684
5	49	196	440	783	1223	1762	2753	3132	3964	4893	7047	11,010	15,855

Table 2. Use this table to determine the minimum gpm that will maintain a high enough velocity to prevent solids from settling out and plugging the pipeline. NRCS recommends a minimum of 2-5 ft/sec for 4-10% suspended solids. Use the higher or lower velocity depending on your solids level, the slope and roughness of the pipeline, and how difficult it would be to clean out your pipeline should plugging occur.

These physical relationships put hard-and-fast constraints on the nutrient application rates that can be applied through a given plumbing system. It is essential to estimate what the working concentration of the pond will be and how much nitrogen should be put out in a single application. Since a typical application rate for the summer may not be the same as in the winter, both situations need to be evaluated when designing a system. Once the infrastructure is installed, it may not be possible to deviate much from the concentrations and flow rates used to design the system so it is imperative to anticipate what the system will need to deliver.

What to do When the Flow Rate You Need is Less Than Your System Will Deliver

Here are some methods that to achieve a lower application rate in a situation where the needed flow rate is excessively low include

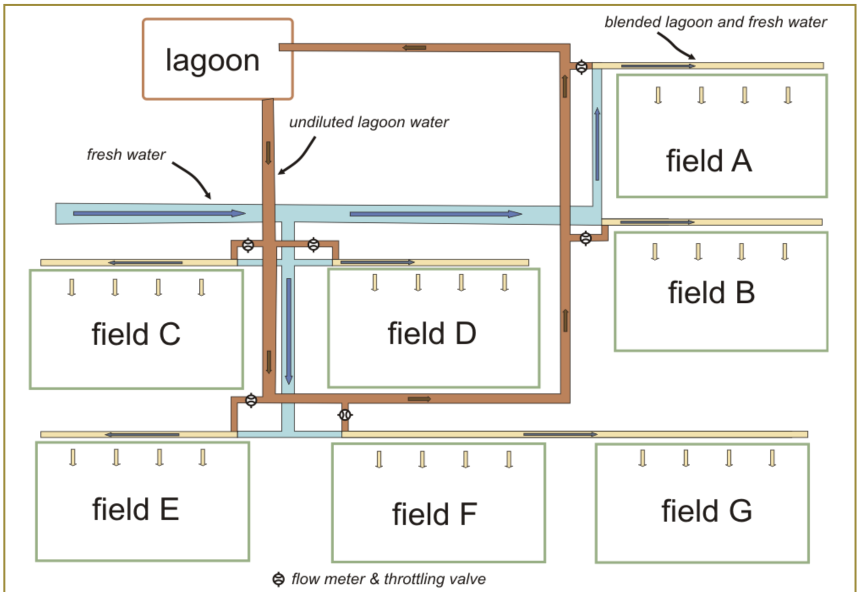
1. Blend the pond water with fresh water just after it leaves the pond and pumping the more dilute water to the mixing point with the irrigation water in a larger pipeline. This will need a source of fresh water such as a pump or canal that is situated near the pond. This method is most easily implemented in situations where liquid manure applications are made to only one field at a time. If this is the case, the flow meter should be installed so that only the undiluted lagoon water is measured and the metering run and short stretch pipeline and any metering run and pipeline that carries the undiluted should have provision made for easy cleanout in case of plugging.

2. If two or more fields are irrigated simultaneously, the stream going to each field must be measured and throttled independently. The calculated target gpm for each field would be based on the concentration of nitrogen in the diluted water, so either the diluted lagoon water needs to be sampled for management purposes, or the undiluted lagoon concentration and exact amount of dilution would need to be known. Regulations require that the concentration and volume of undiluted process wastewater be sampled and reported so additional calculations will be needed if there are flow meters only on the blended water.

3. Installing a dedicated pipeline that recirculates a large flow of liquid manure around the ranch that can be tapped into by several fields simultaneously.

4. Changing the irrigation system to reduce nitrogen losses so that larger applications of N may be applied at one time

5. Install a dedicated liquid manure pipeline that recirculates a large volume of lagoon water in a pipe that loops around the farm with access by every field so that several fields can be supplied simultaneously with the low flow rates they need while maintaining a higher velocity in the main pipeline. Each field would need its own metering and throttling system for lagoon water, and a system of measuring freshwater application rate will also be necessary. In addition to the expense of installing a dedicated pump and pipeline, and multiple flow metering and throttling systems, there would also be the ongoing energy costs to maintain pressure in the high volume pipeline.

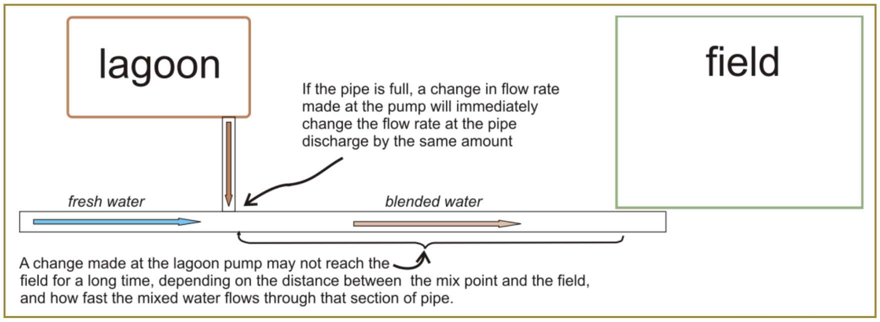


A high volume of lagoon water is circulated throughout the farm so that the low flow rate that is needed for each field can be supplied to several fields at the same time. A separate flow meter and control valve is needed for each field that will be irrigated at the same time. In this example, fields F and G are never irrigated simultaneously so a single flow meter can be used on each.

6. Apply the lagoon nutrients during only part of an irrigation set. This technique is especially effective when the irrigation flow rates are low and run times are long. Under these conditions, it is common for more water to infiltrate towards the head of the field and less towards the middle and end. Injecting the nutrients into the fresh water during only the last portion of the irrigation set not only enables low application rates at higher lagoon flow rates, but also the distribution uniformity of the nutrients is dramatically improved.

   To achieve a desired application rate, calculate what percent of the total run time for the set the pump must run based on the minimum gpm the system will deliver and the expected lagoon nitrogen concentration. The irrigator will need to then determine what time the pump needs to be turned on based on the anticipated run time for each set. This can be a limitation for this system, since not all irrigators will be able to make these calculations in field, especially if the acreage and run times for each set are not equal.

Also, turning pumps on and off frequently can cause premature wear on the pump, and it does require labor to be more frequently available during the irrigation.



7. Another limitation of this method is that there may be a lag time between the time the pump is turned on or off and the time that these changes are reach the field. Assuming the lagoon water transfer pipe is remains full, lagoon water will start flowing out of the other end of the pipe as soon as the pump is turned on. The lag time between when the pump is turned on and the time the blended water to travel from the mixing point to the application field can be significant. This lag time may vary from field to field and even within the same field because this distance and possibly also the flow rates are different. Since applying the correct rate may entail the lagoon water running in as little as only the last 20% of the total run time, underestimating the lag time or overestimating the run time can easily result not enough nutrients being applied to the intended field. Running the pump during only during the last portion of an irrigation set. This method will require additional management and frequent starting and stopping of the pump. For more information on this technique, see Measuring Liquid Manure Application Rates.

8. Maintain a more dilute pond concentration. If nutrients in a pond are less concentrated, it is easier to maintain faster flow rates. Clearly, adequate pond capacity is essential for this method. In addition to being easier to apply lagoon nitrogen at agronomic rates, maintaining a more dilute pond assists with odor control because dilute ponds often are more conducive to the formation of a purple sulfur bacteria (“red water”) layer near the pond surface which captures and converts hydrogen sulfide gas generated deeper in the pond.

It is often not possible to expand pond capacity. However, it may be possible to add dilution water to second pond or portion of an existing pond and irrigate out of it. Another alternative could be to add pumped fresh water or diverted roof or barn water to the top of the main pond and draw the water used for irrigation from the upper portion of the pond. It is difficult to maintain a consistent nutrient product with this system but it may make applications possible during times of the year when otherwise the pond would be too concentrated.

9. Operating remote “nurse” ponds closer to the point of application.

   Although it may not usually be feasible to install a new pond, in some situations there may already be an existing pond can be used for this purpose. A larger pipeline is used to transfer the undiluted liquid manure to the remote pond. Smaller diameter transfer pipe can be used for the shorter runs because there is less friction loss over short distances.

10. Remove most solids from the liquid so that pipelines do not plug at lower flow rates

    This solution is effective but not without some risk. There is always some solids accumulation even with the best solids separation systems and there is potential for someone to open the wrong valve or let a floating pump get too close to the bottom. Providing access for cleanout at intervals along the pipeline may be prudent.

11. Increase head pressure at the pump.

    This will come at a higher energy cost. The amount of pressure that can be effectively used is limited in low pressure systems that utilize open air vents.

12. Control water application to minimize leaching losses.

    If losses due to leaching and denitrification can be controlled, higher rates of nitrogen can be applied in a single liquid manure application. Then, nitrogen that mineralizes from organic nitrogen during times of limited crop removal can be stored in the soil for later use, making it easier to effectively utilize dry manure or high solids liquid manure in the management plan. The convenience of operation, and ability to stay within regulatory nitrogen application limits by efficiently utilizing manure nitrogen and savings on water and labor costs has made lateral move or pivot sprinkler systems an attractive option for some dairy producers despite their high installation and energy costs.

13. Convert to a scrape system or injected slurry system.

    This should be done with caution and is not recommended in situations where leaching and denitrification losses cannot be minimized. In a system where manure can be applied only between crops, it may be necessary to apply some supplemental commercial fertilizer during times of peak demand in order to maintain crop yields. This in turn increases the land base required to stay within regulatory N application limits.

14. Design a cropping pattern and nitrogen budget that avoids making small applications. The most straightforward method of meeting crop nitrogen needs while avoiding leaching losses is to either minimize leaching by reducing water application or to split many small applications of mainly commercial or low-organic nitrogen liquid manure applied just prior to the time that the crop needs them. Both of these solutions are impractical in many situations. If it is necessary to utilize a significant amount of organic form nitrogen in a moderate to high leaching situation, a computer model has been developed by UC that solves for the most efficient application strategy for the types of manures on the farm and their associated application constraints. The model takes leaching and organic nitrogen mineralization and returns the application strategy that is predicted to meet crop nitrogen demands while minimizing losses. Using this model, it

may be possible to design a nitrogen budget that incorporates larger amounts of strategically timed applications of organic form nitrogen without requiring low application rates.

Additional Measures to Prevent Pipeline Plugging

In addition to maintaining sufficient velocity in the pipeline and open conveyances to prevent solids from settling out, there are other reasons that pipelines can plug. Sands and sludges can be pumped into systems if pump inlets are allowed to get close to lagoon bottoms or sand/solids islands.

Do not reduce the size of manure water transfer pipes in the direction of flow so that the diameter of the upstream pipe is larger than the pipe downstream

Remove sand prior to allowing liquid manure or flush water to enter the transfer system. It is desirable to have the ability to flush the manure transfer pipe in the reverse direction with clean water.

A v-notch valve is best for plugging prevention if flow rates must be throttled back severely because the opening is larger at the same degree of throttling than the narrow sliver created by a standard knife gate valve when it is nearly closed. Pinch valves provide the largest possible diameter opening for throttling but would usually be too costly in a dairy application compared to other choices.

Pipe distribution systems typically have multiple outlets and branches. Shutoff valves should be installed on both sides of pipe tees where flow directions can be diverted. This is especially important if a seldom used manure pipeline tees off of one that is used more frequently. Solids will tend to settle out in the pipe stub and over time can completely pack that section of pipe. Installing block valves at branching locations to isolate the pipe stub with low or no flow is a good practice. A common example of this situation is where a flush pump operates on the same pipeline that goes to the field. If the pipeline to the field is not isolated especially during long periods of disuse, it can become plugged with solids from the flush.

Gate valves are the preferred shutoff valve compared to butterfly valves for lagoon water due to the full open cross section and shearing action when the gate is closed. However, for sampling ports, a ball valve is the best choice because it is easy to regulate the flow rate and small gate valves tend to become packed with debris and solids and become difficult to close completely.

Provision for pipe cleanout at frequent strategic locations is always a good idea.

There is a greater risk of pipeline plugging when flow rates of lagoon water are throttled back. Installing cleanout ports at intervals is good insurance.

Manure Transfer Pipe Venting

All piping systems designed for distribution of lagoon water and fresh water should be designed with adequate air/vacuum venting and pressure relief. The venting for liquid manure distribution systems should utilize combination air/vacuum vents and pressure reliefs that are sized and located as would be required on a clean water irrigation pipe. Closed, automatic, air/vacuum venting systems coupled with automatic pressure relief are commonly installed on pumped systems. Ideally, the system should be designed using two individual automatic vents, each having two-thirds of the total required venting capacity. With two vents, failure of one vent due to plugging will not lead to complete absence of automatic venting of the pipeline.

For more information reference *Pressure Relief Valves and Air Vents* by Charles Burt, Professor, Cal Poly SLO, 1980.

Flow meters on pressurized pipe are calibrated to assume the pipe is full. Continuous acting air vents to remove entrained air that can build up and displace water in the pipe in the vicinity of the meter are an essential component of a non-vertical metering run.

Air vents associated with valves will often spit out manure water. At a minimum, point the vent opening away from operators and sensitive equipment such as metering devices. Even better, divert the discharge back to the pond or pump box. This prevents muddy, messy conditions in the area, and avoids the potential for seepage to the groundwater.

Gravity Systems

Dairy operators generally prefer to use a gravity system rather than a pumped system if at all possible because these are less expensive in terms of equipment needed and energy cost to operate them. However, control of nutrient application rates can be difficult and complicated in a gravity system for several reasons.

Typically the liquid manure joins the stream of fresh irrigation water in an underground pipeline. The backpressure of the freshwater has a large influence on the inflow rate of the liquid manure. The amount of backpressure can vary considerably over the course of an irrigation due to fluctuations in canal level, the elevation of the irrigation pipeline at different points in the field, the number of opened field valves and the degree of opening. The depth of water in the pond will also vary and will interact with the irrigation backpressure to influence the final flow rate of liquid manure. With these influences on flow rate, it can be difficult to obtain a uniform flow rate without constant adjustment of the valve.

It is typical for existing gate valves to be used for flow control in these situations. Many of these valves have a considerable amount of "play" in the controller wheel, making it difficult to calibrate be number of turns open or inches of stem. Also, if an existing gate valve is throttled down to a small opening to facilitate appropriate application rates, the corners of the valve opening may alternately plug and unplug with solids from the pond, further complicating flow control and measurement. A v-notch valve in these situations would be ideal as far as throttling and flow control are concerned, however cast iron v notch valves that are constantly in contact with liquid manure have corroded rapidly. A valve failure at the bottom of a gravity fed lagoon can be disastrous.

Access to valves at the bottom of the pond, or installation of a flow meter on a pipeline exiting the bottom of the pond, requires that the pond be emptied. If there is only a single pond on a flush dairy, it can be difficult to arrange a time when the pond can be empty long enough to perform these installations.

Liquid Manure Pumps

Install a Dedicated Pump for Field Applications

Many existing dairies utilize the same pump for irrigation and flushing. In almost all cases, this makes appropriate application of nutrients impossible because the irrigation needs to be stopped when the pump is needed for flushing or portions of the field will not receive the nutrients needed for the crop. Also, the size of the pump needed for flushing may be very different than one sized for optimal land application. <u>A separate irrigation pump should be installed wherever possible</u>.

Pump Selection

Pumps designed for "trash" type services are typically used for liquid manure applications. 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. Appropriate nutrient application rates often require installation of pumps with higher discharge heads at lower flow rates than have commonly been used in the past for similar applications. Self-priming, end suction, non-clog pumps are not recommended for lagoon pumping. Liquid manure often tends to foam and this foaming causes major problems with the priming of self-priming pumps.

It is critical that appropriate field application rates be determined prior to sizing the pump. It may not be possible to design a system that applies the entire range of application rates desired for agronomic purposes and the impact of compromises on the nutrient budget need to be carefully evaluated.

If very low flow rates are required, consider:

1. Installing a second, smaller pump, and co-mingling this flow with a larger freshwater flow to send to the field as described above.

2. Installing a bypass so that the output of a larger pump is split, with some of the flow directed back into the pond to protect the pump at lower flow rates

Pump Placement

The most basic decision to be made is whether to install a stand pump or a floating pump.

Stand Pumps

The main advantage of stand pumps is the ability to completely empty the pond, and utilize all of the pond's capacity.

A disadvantage of stand pumps is that they will tend to pump sludge from the bottom of the lagoon during the initial startup period. If the sludge layer is thick, the sludgy discharge can be applied for a significant

Newly installed vertical stand pump.

proportion of the irrigation, potentially applying many times the intended rate of nutrients, especially nitrogen and phosphorus, to those fields or portions of fields that are irrigated first. These over-applications can adversely impact groundwater quality. The system should be designed with the ability to return the initial discharge to the pond at a location not near the intake until the pumped product is more uniform in solids content.

The stand pumps typically used in the dairy industry are typically low efficiency (50% or less) and designed for trash service. Most stand pumps are limited to approximately 20 feet in overall length due to construction and installation issues. Construct the pump stand with sumps 2 to 3 feet deeper than the low point of the lagoon so that the lagoon can be totally emptied.

Removal of bottom sludge through the irrigation system may not be possible from large lagoons with stand pumps unless the pond is flushed with large quantities of fresh water. However, adding fresh water to the pond during an irrigation may not be desirable because it is difficult to accurately apply nutrients when the pond concentration varies greatly throughout the course of the irrigation. If fresh water is added during an irrigation, it will require constant monitoring of concentrations and frequent adjustments in flow rates to avoid under fertilizing crops and jeopardizing crop yields.

The suction pipe from the lagoon to the pump stand should not be sized overly large so that adequate velocity to transport suspended solids can be maintained. Remember, that the pump output when lifting thick solids can be half of what it would be otherwise.

The ability to backflush pump suction stands and inlet pipes with fresh water is desirable. It is common to place check valves near the discharge of stand pumps (unless backflush with fresh water is provided for).

A single stand pump may be installed between two adjacent lagoons to allow easy suction from either or both lagoons.

Typical floating lagoon pump

Floating Pumps

Many dairy irrigation and flush pumps are located on floating platforms. The major disadvantage to floating pumps is that these pumps often require several feet of water depth to avoid bottom scour. This can prevent the large storage lagoon from completely emptying. Floating pumps with very shallow draft are available and can help to avoid this problem.

Shallow draft floating pumps can increase the usable capacity of the pond compared to traditional floating pumps which require 2 to 3 feet of liquid depth.

Another approach that has been used successfully to avoid this is to construct a small lagoon after the settling basins (or adjacent to the screen separator) 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 lagoon water irrigation pump(s) can then be installed in the larger storage lagoon as either a floating pump or a stand mounted pump.

It is desirable to have ‘feet’ on the bases of these floating pumps to avoid burying the pump suction into the bottom at shallow liquid depths. Another feature that is desirable is to have a suction diffuser plate attached to the ‘feet’ to keep from boring holes in the lagoon bottom at shallow liquid depths.

The connection hoses from floating pumps to shore are typically one size smaller than the shore side fixed piping. Floating pumps can have multiple connection points from discharge hoses to fixed piping systems at the bank. It is advantageous to be able to move the floating pumps around the storage lagoon during periods of fine solids removal either through agitation or mixing with fresh water.

When selecting hoses and end clamps for floating pumps, be aware many existing floating pumps have typically operated at a maximum of 30-40 feet of discharge head. New low volume systems may have system discharge heads in the range of 50-60 feet so it may be necessary to upgrade the hose and fittings when replacing an older pump.

Check valves are often installed at the location where the discharge hoses are connected to the shore side piping. Adequate anchorage should also be provided where the hose and pipe meet to resist lateral loads.

Supply Pressure Requirements:

Factors that determine the supply pressure the pump needs to generate:

- GPM needed to apply the desired range of nutrient application rates
- Length of pipe
- Roughness of the pipe walls
- Number of disruptions in flow pattern from elbows, tees, valves, or changes in diameter
- Difference in elevation between the lowest pond pumping level and the highest point in the manure transfer pipeline

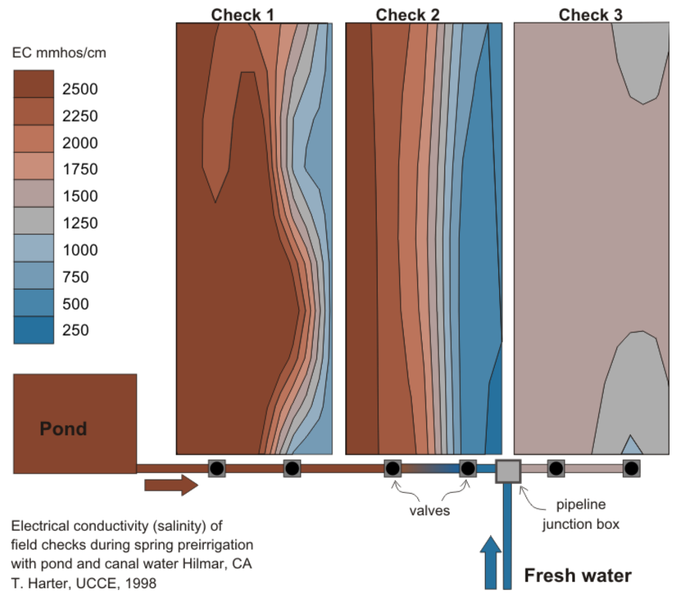
The correct pump size depends not only on the desired gpm to achieve the target application rate, but also the friction loss in the pipe.. The longer the pipeline, the more the water will slow down due to friction from the walls. The smaller the pipeline diameter, the more pronounced the friction loss will be because a larger proportion of the total flow is affected by the drag on the pipe walls. The roughness of the pipe will also affect the amount of friction loss. Any disruption in the flow pattern, such as valves, elbows or changes in pipe diameter will also reduce the head pressure, and slow the flow of the material through the pipe. These head losses will impact the amount of head pressure the pump needs to generate to push the water through the pipeline, and place a lower limit on the size of the pipeline that can be installed, especially on longer runs.

To calculate the supply pressure requirements to the pipeline you will need to know:

1. Desired range of flow rates as specified in the nutrient budget
2. Elevation change = maximum discharge elevation minus the minimum pumping elevation
3. Friction loss in pipeline (or pipeline+hose for a floating pump)
4. Valve and fitting losses.

These losses should be calculated for both high and low viscosity cases. The effective viscosity of lagoon water changes significantly as a function of temperature and solids content. Pumping rates may decrease by more than 50% with composition changes, such as pumping heavier solids content lagoon water.

A commonly used method of calculating supply pressure requirements is by using the Hazen-Williams equation to calculate the amount of head loss due to friction. Engineering software is often used by engineers to solve these equations and there are also on-line calculators. Engineers with experience in designing dairy systems recommend that the initial PVC pipeline calculations be made using a Hazen Williams coefficient of C=140 for a low solids case and C=100 for high solids case. Use C=100 for all floating pump flexible rubber hose applications. PVC pipe fittings are typically segmented or step reducers, so use conservative K factors when assessing fitting losses. Be sure to evaluate the pressure losses using flow rates that will result in appropriate nitrogen application rates for both low and high solids lagoon water.



The electrical conductivity of applied irrigation water was mapped during this preirrigation for corn. There were two valves on each 200-foot wide check. On checks 1 and 2, the lagoon water came from one direction and the fresh water came from the other. There was very little mixing of the two streams. The first check received a higher proportion of lagoon water mainly because it was irrigated first when the pond was higher, in addition to being closer to the pond. The third check received a more uniform application of lagoon water because the fresh and lagoon came together in a concrete junction box prior being applied to the field.

Mixing of Lagoon Water With Freshwater

If lagoon water is introduced into the freshwater such that the two flows are not mixed before the stream is applied to the field, part of the field with receive all or most of the nutrients and the other will get little or none. This is most pronounced when lagoon and fresh water are introduced into the pipeline from opposite directions. If more than one valve is open, the valve or valves that are on the lagoon pipe will receive only lagoon water and while those on the freshwater side will only have freshwater. If only one valve is open and the two flows are coming from opposite directions in the pipe, it is is unlikely that the two flows will mix well enough as they are coming out of the valve to assure a uniform application.

Uniformity of application is critical to the success of a nutrient management program that relies on lagoon nutrients for crop production. One simple approach to assure adequate mixing is to discharge the lagoon water into an open standpipe or box 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,


Round steel mixing chamber


Installed mixing chamber

pressure rated, steel mixing chambers with automatic air vents where lagoon and fresh water mix prior to field application. The lagoon water is introduced at right angles (usually the top) to the fresh water flow (usually the side) with the combined flow leaving out the side(s).

Simple pipe tees, where the lagoon water is introduced at 90 degrees to the main irrigation flow, have also been used effectively, although in rare instances there may be insufficient turbulence or transit distance to assure that each open valve receives a uniform blend.

Backflow Prevention

It is very important to install an effective method of backflow prevention between fresh water sources and lagoon water mixing locations. If a well should shut down, or if a surface water canal suffers a failure without backflow prevention, the potential for pumped or gravity transferred lagoon 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. Irrigation districts have a variety of standard required backflow prevention measures and should be consulted prior to equipment installation.

Field Application

Field application is often made through flood irrigation valves. Flood irrigation valves typically come in two styles: (1) solid arch and (2) removable arch. Experience has shown that the solid arch valves are a better choice due to a thicker support arch metal cross section, which does not corrode as quickly to an unusable state as does a removable arch. An alternate water application system to utilize for furrow irrigation is a thin plastic tube pipe that is rolled out and becomes inflated with water as it is used. The water is applied directly into individual furrows through 2-inch plastic valves without the need for the leveling basins that are often used with siphon pipes. There is less personal contact with the manure water with this system than with siphon pipes.

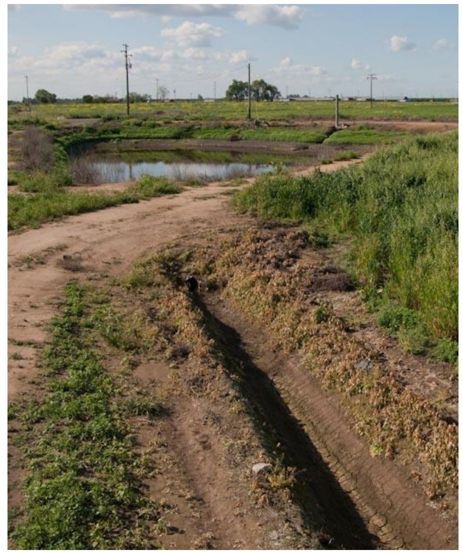
Tailwater Return Systems

If the potential for tailwater runoff exists for manured fields, a tailwater return system is a necessity. In many cases, some runoff is inevitable and desirable especially where soils are tight and water must remain long enough for enough infiltration to occur to refill the root zone. Some runoff may also help to achieve higher distribution uniformity in some situations. If this tailwater contains manure or manure has been applied recently, it cannot be allowed to come in contact with surface waters.

A volume of 15 to 25% of the combined fresh and lagoon water on flow is a typical rough estimate of the amount of tailwater runoff, however this value may vary considerably. Tailwater is often recovered in a small basin in the low corner of the field or in a small basin drained by ditch or pipeline from the low corner of a field or fields. In some cases the size of the basin can be minimized if the lower end of the field can hold the tail water until it can be removed. Sizing of pumping and storage should be such that the tail water can be fully removed within 48 hours. Tail water pumps can be configured to return flow to irrigation pipes actively conveying water to fields or back to the lagoon water retention pond. If tailwater is to be returned to the lagoon, ensure that there is adequate capacity in the pond to accommodate this water.

Tailwater ponds that are pumped need to have a minimum amount of water remaining to operate the pump without damage by pulling up mud and debris on the bottom of the pond. The pond should be constructed with a metal or concrete pump stand that has an intake sump two feet below the level of the bottom of the pond so that the pond can be drained completely. Completely draining tailwater ponds is desirable not only minimize seepage of nitrates, but also to prevent any pesticides that may have been picked up in the runoff from moving into the groundwater. Trash racks or screens should be provided to protect pump suctions.

Tailwater that leaves the field and is not returned to that same field should be subtracted from the total amount of water applied to the field along with the nutrients that the water contains. An accurate assessment of the volume of tailwater that leaves the field is needed in order to document that the field did not actually receive these nutrients. When designing a tailwater return system, consider how the runoff volume will be measured and make provision for this to be easily accomplished. A variety of methods may be used to do this. One common method is to record the tailwater pump output and run time as it pumps water from a sump to the retention pond or next field. The volume of the tailwater pond may also be used but only if tailwater from the first field has completely drained before the application to the next field begins, only one field at a time is entering the pond, and losses due to seepage from the sump or transfer ditches are minimal. Additional information on this topic is in Measuring Liquid Manure Applications.



Irrigation water and nutrients that runs off of the end of the field as tailwater need to be measured and subtracted from the amount that was applied to the crop in order to obtain accurate application rates.

If tailwater from one field is picked up and transferred to a different field, that water in turn becomes a water and nutrient source for the receiving field which must be recorded and reported as a freshwater source. Sampling of this water will be needed for reporting purposes.