

Measuring Liquid Manure Application Rates

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Introduction

Knowing the amount of manure nutrients that have been applied is essential for achieving the best crop production, protecting environmental quality and meeting regulatory requirements. There are several methods that can be used to measure, or at least estimate, the amount of liquid manure applied to a field. However, in selecting a method to use, it is important to also consider if the chosen method will enable the operator to easily apply a specific desired target rate of a nutrient at the precise time that it can be best utilized by the crop.

In order to know how many pounds per acre of nitrogen or other crop nutrient are being applied in lagoon water, several types of information are needed:

- the volume of the material that went onto the field (gallons),
- the amount of nitrogen in the water (concentration), and
- the area (acres) onto which the material was applied.

To avoid either under- or over-application of nitrogen, it is necessary to have a practical method of measuring, and ideally controlling, the amount of liquid manure applied. In most cases, a flow meter installed on the lagoon pump outlet is the simplest way to measure application amounts from the lagoon. A flow meter allows the user to easily calculate the amount of liquid manure and nutrients applied and, when combined with a flow control device such as a throttling valve, also makes it easy to adjust the flow rate so that the specific amount of nitrogen called for in a nutrient management plan can be applied to the crop.

Although an installed flow meter is almost always the best choice for managing lagoon nutrients and every effort should be made to install one, in reality other methods may need to be used on a temporary or permanent basis. Each of the other ways of estimating lagoon water application rates, and each has advantages and disadvantages.

In addition to measuring the amount of lagoon nutrients applied, regulations require all other sources of water and nitrogen be measured, so methods for measuring sources such as fresh water and reappplied tailwater are also needed. If some of the water that is applied to a field runs off as tailwater and is not



To calculate the amount of nutrients applied, a sample must be taken of the same material that is being measured. This sampling spigot is well-positioned for ease of use.

returned to the same field, the amount of runoff should be measured as well so that it can be subtracted from the application amounts in order to accurately measure and report the actual rates of water and nutrients that were applied to the crop.

The method or combination of methods selected for making these measurements will be influenced by many factors including cost, irrigation system limitations, and the accuracy of nutrient applications required to maintain yields and avoid groundwater contamination and/or runoff to surface waters. In choosing a method, consider if it is adequate to simply monitor the amount of nutrients that have been or are being applied, or if it is also necessary to proactively apply a specific target nutrient application.

Measuring Volume with a Flow Meter on the Lagoon Water Discharge

Installing an in-line flow meter on the lagoon water outlet pipe is the easiest method of measuring and controlling nutrient application when using pond water nutrients. Most flow meters will display both the current gpm and the totalized gallons. The amount of nutrients applied to each field is calculated using the starting and ending total gallons from the meter along with the nitrogen concentration in the liquid manure. If both a flow meter and a control valve are installed, the meter can be used to proactively apply a specific quantity of lagoon nutrients.

Having the capacity to control the application rate and apply precise amounts of nitrogen gives the flexibility to apply the nitrogen in several smaller applications over a number of irrigations rather than in one large application during a single irrigation. Applying nitrogen in multiple smaller amounts has several advantages:

- Ensuring that the nitrogen is available to the crop during critical growth periods
- Preventing crop injury from excess salts
- Minimizing leaching losses on light and medium soils
- Minimizing denitrification losses on heavier soils
- Preventing excessive applications by being able to adjust rates in subsequent irrigations if the run time or concentration was not what was expected

To apply a specific application rate, the concentration of lagoon water nitrogen is determined and the length of time for the irrigation is estimated. Then a chart or spreadsheet is consulted which gives the target gpm for the desired nitrogen application rate. The valve on the lagoon outflow is adjusted until the flow meter readout displays the targeted gpm. The flow meter is checked periodically during the irrigation to ensure that the desired application rate is maintained.

It is essential that the right kind of flow meter is installed and that it is installed correctly. There are many types of flow



Affordable flow meters for measuring dairy lagoon water are available with solar or battery power, data loggers and wireless data transfer. The right flow meter can greatly simplify nutrient management recordkeeping, and, when installed with a throttling valve or variable frequency drive controller, make it possible to accurately apply the specific amounts of nitrogen called for in the nutrient plan.

meters available but only a few are appropriate for use in dairy lagoon water because of the presence of debris and solids which clog or foul the mechanisms. Only flow meters commonly used for sewage, pulp, or other similar applications are appropriate for use with lagoon water.

All flow meters have placement requirements to enable them to read accurately. The pipeline where they are located must always be completely full. Sometimes there is already a location where they can be placed such as a vertical pipe, otherwise a metering run must be constructed that provides a section of pipe downstream from the meter where the pipeline is at least 1 pipe diameter higher than the pipe where the sensor is located. Many flow meters also require placement on a straight section of pipe that is at least 5 pipe diameters upstream and 10 pipe diameters downstream from an elbow or tee. A pipe with a 12-inch diameter would need total of 15 feet of straight run. The meter may need to be placed even further away from active valves, which distort the flow pattern more severely than elbows. In general, insertion style electromagnetic meters which measure the velocity of the liquid at one or two points near pipe wall are more sensitive to irregular flow patterns within the pipeline, and require more straight pipe, than full bore (tube style) electromagnetic meters which have multiple sensors surrounding the pipe or wetted Doppler insertion meters that integrate the velocity across the entire cross section of the pipe. The installation of a constructed metering run that meets the placement requirements for the selected meter must be factored in to the cost of the meter.

For additional information on selecting and installing flow meters, see [Flow Meters for Measuring Dairy Lagoon Water](#) and [Installing Flow Meters on Dairies](#) in this series.

Calculating nutrients applied using flow meter data

Record the beginning and ending reading from the flow meter totalizer for each field or area to which lagoon water is applied. The flow meter totalizer is usually set to read in either hundred or thousands of gallons. Be certain you know which multiplier is being used for your meter. If your meter is set to read in hundred of gallons, multiply your readings by 10 before using the following method.

1. How many gallons were applied to the field, as thousand gallons:
$$\text{Ending totalized gallons} - \text{beginning totalized} = \text{gallons applied}$$
2. How many pounds of nitrogen were in that volume
$$\text{ppm or mg/L nitrogen} \times \text{thousand gallons} \times .008345 = \text{pounds nitrogen applied}$$
3. How much was applied to each acre
$$\text{pounds nitrogen applied} \div \text{number of acres} = \text{lbs N applied per acre}$$

Operators who have experience using flow meters report that people often make mistakes when writing down totalizer numbers. It is a good idea to also record the average gpm and run time for each field to double check that the numbers were correctly transcribed. If the flow meter has a data logger, the totalizer reading at the start and end times can be looked up off the downloaded data.

Using a flow meter to apply a specific nitrogen application rate (“Target” Application)

Applying a specific amount of lagoon nitrogen or other nutrient is simple with a flow meter and throttling valve. The flow rate of lagoon water in gallons per minute (gpm) that will result in the desired amount of nitrogen applied is calculated, and the throttling valve or pump controller is adjusted until the flow meter displays that flow rate.

The target gpm is based on the amount of nitrogen needed, the concentration in the pond, and the expected run time. The gpm can be looked up using a chart such as the one below, available at manure.ucdavis.edu, or calculated using the following method:

1. Determine the amount of nitrogen to be applied to the area to be irrigated.

$$\text{Lbs N/acre} \times \text{number of acres to be irrigated} = \text{lbs N needed}$$

2. Calculate the amount of nitrogen in the lagoon water from the analysis.

$$\text{Mg/L or ppm N} \times .008345 = \text{pounds of nitrogen per 1000 gallons}$$

3. Calculate how many gallons of lagoon water it will take to supply the amount of nitrogen to be applied (See Step 1).

$$\frac{\text{pounds of nitrogen to apply}}{\text{lbs of N per 1000 gallons} \times 1000} = \text{total number of gallons of lagoon water}$$

Gallons per minute to achieve a target application rate

lbs/Kgal	lbs/ac-in	mg/L or ppm	50 lbs N/acre							
			irrigation hours/acre			irrigation minutes/acre				
			1½	1¼	1	50	40	30	20	
1.7	45	200	333	399	499	599	749	999	1498	
2.5	68	300	222	266	333	399	499	666	999	
3.3	91	400	166	200	250	300	374	499	749	
4.2	113	500	133	160	200	240	300	399	599	
5.0	136	600	111	133	166	200	250	333	499	
5.8	159	700	95	114	143	171	214	285	428	
6.7	181	800	83	100	125	150	187	250	374	
7.5	204	900	74	89	111	133	166	222	333	

Applying a specific amount of lagoon nitrogen or other nutrient is simple with a flow meter and throttling valve. Determine the flow rate needed to obtain the desired pounds of lagoon nitrogen based on the pond concentration and expected irrigation run time. Adjust the flow with the throttling valve or pump controller until the meter displays the needed flow rate. Complete charts are available at manure.ucdavis.edu.

4. Divide the number of gallons by the number of minutes it will take to irrigate this area.

$$\frac{\text{total gallons of lagoon water}}{\text{minutes}} = \text{gallons per minute (gpm)}$$

Be careful when adjusting the flow rate to not go so low as to damage the pump or to allow solids to settle out and plug the pipeline. Determine ahead of time the minimum gpm for your pipeline and don't allow anyone to set a flow rate that is lower than that. If the required pump gpm is too low for the infrastructure to accommodate, consider redesigning the system or running the pump during only part of the irrigation as described in the pump output method section below. Additional options are discussed in [Designing Liquid Manure Transfer Systems](#) in this series.

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

Use this chart 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 value 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.

Measuring Application Volume using Pump Output and Run Time

With this method, the output of the pump (gpm) is estimated and the time the pump runs is recorded. Once the concentration of nitrogen in the lagoon water is known, a “lookup” table or simple calculation gives the total pounds of nitrogen applied. The total pounds of nitrogen applied divided by the number of acres gives the pounds of nitrogen applied per acre. This method is prone to inaccuracies and allows only limited flexibility in controlling application rates of lagoon water nutrients. Nonetheless, it avoids the expense of a flow meter and may be the only option in some circumstances.

Seldom does a pump put out exactly the rated amount. Actual pump output is influenced by:

- The depth of water in the pond
- The amount of wear on the pump
- Debris on the impellor
- The distance and elevation the water is being pumped
- The type and diameter of pipeline
- How many solids are in the pumped material

The lower the water level in the pond, the less the pump output. This is true for both floating pumps and stand pumps because it is the difference in elevation between the level of water in the pond and the level of the discharge that determines the amount of energy required to pump the water through the same section of pipe.

Friction, constrictions and elbows increase the amount of head pressure or pumping pressure that it takes to move the same amount of liquid at the same velocity. If the lagoon water is in a pressurized pipeline with multiple discharge points, those discharges that are further away have more losses from friction, bends, constrictions and flatter slope, resulting in lower flow rates when pumping to far fields compared to closer ones at the same pond level.



Pump output and run time is often used as an interim method to estimate the volume of lagoon water applied in situations such as this where the close proximity of the pump and valve to the discharge make it necessary to make modifications to the pipe before a flow meter can be installed.

Measuring Flow Using a Pump Output Chart

In a pumped system, the liquid manure is often lifted from the pond and discharged into a box or standpipe and there is an air gap between the outlet of the pipe and the receiving water. If an air gap exists so that the lagoon water is pumped without backpressure from the freshwater it is mixed with, creating a chart which relates the gpm of the pump output to the depth of water in the pond will make calculating the amount applied more accurate by adjusting the gpm rate used in the calculations according to the depth of the pond at the time of the irrigation.

In a gravity or pumped system where the liquid manure is discharged directly into an underground freshwater pipeline, the lagoon flow rate can be greatly influenced by the amount of backpressure in the freshwater pipeline. There are many factors that determine the final lagoon flow rate, which is ultimately a function of the difference between the elevation of the freshwater source such as a canal, the pond level and the field discharge. This can vary throughout the irrigation for many reasons, including

- The depth of water in the pond
- The depth of water in the canal
- the number and degree of opening of the field valves
- the friction losses in the pipe as determined by distance and pipeline interior roughness
- the number of elbows or restrictions
- some fields having a different pipeline diameter
- some areas that are served by pipelines that have a flatter or steeper slope than others

Because of these factors, the flow rate from the pond discharging directly into an underground pipeline is often different for different fields and possibly within the same field even at the same pond elevation and valve opening. This method should be used with caution in a gravity system.

Methods of Measuring Pump Output

One of the difficulties in using the pump output method is determining what the lagoon pump output is. The most common way of testing freshwater pump output is to insert a pitot tube type device into the outflow of the pump. Lagoon pumps are not commonly tested with this method because lagoon water contains particles that clog the device, which somewhat resembles a drinking straw, almost as quickly as it is inserted.

The easiest way to verify the output of the lagoon pump is to temporarily install a flow meter. Even if the installation is temporary, it is still critical to choose the correct flow meter and to have the meter sited in a location that ensures that it is reading accurately. Sometimes it is possible to find a place to install a probe style insertion meter that requires only minor modifications of existing plumbing and still meet the requirements of a full pipe with the minimum length of straight run to ensure a uniform flow cross section. Sloping pipes from floating pumps and vertical pipes that discharge liquid manure into irrigation boxes often have suitable conditions. If sufficient length of straight pipe is not available, there are several options, including:

feet below full	gpm
full	1990
1	1910
2	1840
3	1770

Pump output declines as the pond is lowered. Making a chart such as this one can make pump output estimates more accurate. Remember that thick solids also can decrease the pump output by as much as half.

- Use a wetted Doppler insertion meter which requires less straight run than traditional insertion style electromagnetic meters
- Construct a metering run for installing a temporary meter with the intention of purchasing a permanent meter later
- Temporarily install a probe style magmeter and take velocity readings at multiple points in a transect across the pipe to make a custom profile factor to compensate for a less than ideal placement
- Use a different measurement method, such as the pond drop method described below.



The existing vent (left) was moved over to accommodate temporary installation of an insertion-style meter on the floating pump. The sloping pipeline ensured that the meter was in a full pipe. A PVC saddle on a vertical liquid manure pipe discharging into a concrete standpipe was not difficult to install and was capped when the temporary meter was removed. The rods on these meters allow the sensor probe to be precisely positioned to a specific depth inside the pipe.

An external Doppler meter has the advantage of being able to be strapped onto a pipe without cutting into it, but it is usually difficult to find a location on a dairy that meets the stringent conditions that this type of meter needs to be accurate.

Once a meter is installed, make a chart by recording the pump output at varying pond levels. If desired, the chart could also include the flow rates when a valve is partially closed, including the number of turns or stem height, so that the operator can have more control over application rates. The chart can be used proactively to tell the operator how much to open the valve in order to obtain a desired flow rate at a given lagoon level.

Another way to estimate lagoon pump output is by measuring pond drop (gallons) over time. First, turn off all other inflows and outflows to the pond. Record the exact starting level of the pond on a vertical pole or structure. Record the exact starting time. Run the pump until the pond has dropped a measurable distance, such as a foot. Note the exact ending time and the inches of vertical drop. Measure the dimensions of the surface water in the pond when the pond is at the mid-point of the total anticipated drop. Calculate the number of gallons that were discharged by converting pond acre-inches to gallons (1 ac-in = 27,154.3 gallons) and divide by the number of minutes to get gallons per minute. This procedure can be repeated for as many intervals as desired.

Calculating nutrients applied from GPM and run time

Once the flow rate is known, the rate of nitrogen application can be calculated based on the concentration of the nitrogen in the lagoon water. It may be helpful to estimate ahead of time what that application rate is likely to be using a chart such as the one to the right. The time that the irrigation ran on each field or area must be recorded accurately. The pond level and amount of solids should also be recorded

so that the gpm can be adjusted accordingly. After the application, the amount of water and nutrients that were applied can be calculated using this method:

1. How many gallons were applied to the field, as thousand gallons:

$$\text{Gallons per minute (gpm)} \times \text{hours} \times 60 \text{ minutes/hour} = \text{gallons applied}$$

$$\text{Divide by 1000 to get thousand gallons}$$

$$\text{Gallons applied} \div 1000 = \text{thousand gallons}$$

Pounds of Nitrogen per Hour											
concentration of N in lagoon	lbs per thsd gal	lbs/ac-in	mg/L or ppm	gallons per minute (GPM)							
				250	500	750	1000	1250	1500	1750	2000
	1.7	45	200	25	50	75	100	125	150	175	200
	2.5	68	300	38	75	113	150	188	225	263	300
	3.3	91	400	50	100	150	200	250	300	350	401
	4.2	113	500	63	125	188	250	313	376	438	501
	5.0	136	600	75	150	225	300	376	451	526	601
	5.8	159	700	88	175	263	350	438	526	613	701
	6.7	181	800	100	200	300	401	501	601	701	801
	7.5	204	900	113	225	338	451	563	676	789	901

Use a chart such as this one to estimate the rate of nutrient application based on the pond concentration and pump gpm. Complete charts are available at manure.ucdavis.edu

2. How many pounds of nitrogen were in that volume

$$\text{ppm or mg/L nitrogen} \times \text{thousand gallons} \times .008345 = \text{pounds nitrogen applied}$$
3. How much was applied to each acre

$$\text{pounds nitrogen applied} \div \text{number of acres} = \text{lbs N applied per acre}$$

Applying Targeted Amounts of Nitrogen Using the Pump Output (GPM) Method

A limitation of using pump output to measure application rates is the difficulty in adjusting application rates that are too high. If a throttling valve is used to restrict the flow, it will no longer be possible to determine the amount of liquid and nutrients applied unless a different method such as a temporary flow meter, is used to revise the pump output chart to include the pump output at that valve opening for various pond levels.

Another way to decrease the application rate is to run the pump at the full amount but only turn the pump on during the last portion of each irrigation set or check. This method allows the pump to be run at full capacity but for a shorter period of time. The uniformity of the application is also improved, especially in situations where the water takes a long time to move across the field and the upper portions of the field have water on them for a much longer period of time than the lower portions. Turning on the lagoon water pump later into the irrigation also minimizes the solids buildup around the valves by helping to spread the solids out over the whole field.

Since the lagoon pump must be turned on and off for each check or set, if the run times or acres in each set or check are not all the same, the pump run time will need to be calculated individually each time the water is used. Calculate the amount of nitrogen that each area will need to receive by multiplying the desired application rate in pounds per acre by the number of acres to be irrigated. Divide this amount by the pounds of nitrogen per hour that the pump is applying (from chart) to determine the number of hours to run the pump on that check.

Applying Lagoon Water in Only the Last Portion of an Irrigation		
Field study: field length = 1200', avg. irrigation amount = 7.1"		
Liquid manure added	Nitrogen applied (lbs N/ac)	Application uniformity
During entire irrigation	242	+
When freshwater advance was at 75% of field length	86	++
When freshwater advance was at 85% of field length	31	++++

Schwankl & Frate 2004

Turning on the lagoon pump for only the last portion of each check or irrigation set not only resulted in a lower application rate without throttling back the pump, but also greatly improved the application uniformity in this study.

Important note on this method:

When the lagoon pump is turned on or off the lagoon water at the discharge of a pressurized system will start or stop immediately because the water in the pipe is a continuous column. However, it may take a long time for the lagoon water to travel from where it is introduced into the fresh water until it actually reaches the field and the irrigation for that check may be over by the time the lagoon water arrives. This lag time needs to be considered and accounted for when determining when to turn on and off the pump.

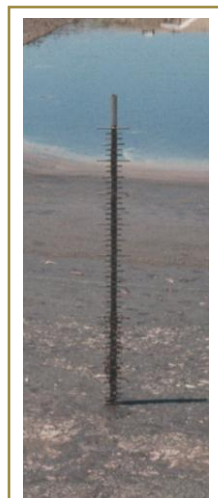
How long to run the pump on each check or set Run time for lagoon pump to achieve a target application rate

		lbs of nitrogen per hour from pump					
		100	200	300	400	500	600
lbs N for this set	250	2 h 30 m	1 h 15 m	0 h 50 m	0 h 38 m	0 h 30 m	0 h 25 m
	500	5 h 0 m	2 h 30 m	1 h 40 m	1 h 15 m	1 h 0 m	0 h 50 m
	750	7 h 30 m	3 h 45 m	2 h 30 m	1 h 53 m	1 h 30 m	1 h 15 m
	1250	12 h 30 m	6 h 15 m	4 h 10 m	3 h 8 m	2 h 30 m	2 h 5 m
	1500	15 h 0 m	7 h 30 m	5 h 0 m	3 h 45 m	3 h 0 m	2 h 30 m
	1750	17 h 30 m	8 h 45 m	5 h 50 m	4 h 23 m	3 h 30 m	2 h 55 m

Multiply the target application rate (lbs per acre) by the acres in the set to get the total amount of nitrogen needed for this area. Divide this amount by the pounds of nitrogen per hour that the pump is applying (from chart above) to determine the number of hours to run the pump on that check, or use a chart like this, available at manure.ucdavis.edu.

For example, a pump that is putting out 400 lbs of nitrogen per hour will need to be run 1 hour 15 minutes to apply 50 lbs/ac of nitrogen on 10 acres (500 lbs total)

Measuring Application Volume Using the Pond Drop Method



This staff gauge has metal cross bars. Painted markings become difficult to read when coated with scum.

The concept behind the pond drop method is to determine the surface area of the pond in acres, then multiply the pond surface acreage by the number of inches of vertical drop as the pond is used to irrigate a field of known size. Multiplying the area of the pond (in acres) by the drop (in inches) gives the acre-inches of pond water that went out during the irrigation. Acre-inches multiplied by the pounds of nutrient per acre-inch gives the total pounds of nitrogen applied. The pounds of nitrogen applied per acre are determined by dividing the total applied by the number of acres irrigated.

While the pond drop method may appear to be simple and straightforward, in practice it is often challenging to obtain accurate application volumes using this technique. There are many reasons pond drop volumes may be difficult such as odd pond shapes, non-uniform side slopes, the presence of irregular areas of built up solids, other inflows to the pond (the capacity of a flush pump is typically much higher than that of the irrigation pump), two or more interconnected ponds, the difficulty of establishing and using a measuring pole, and the short distance a large pond drops when low rates are applied to a small field. If fresh water is introduced into the pond at the same time as the pond is being drawn down, using pond drop as a method of estimating nutrient application is especially difficult. Irrigations that begin and/or end during the middle of the night can be a problem if the measuring

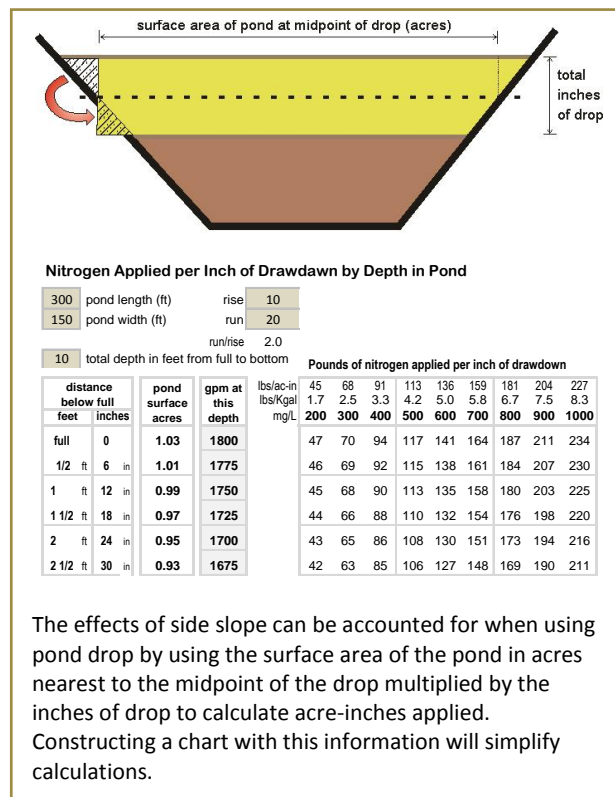
pole cannot be read in the dark by a competent person. Devices for accurately measuring the depth of the pond exist, however, the more economical choice would usually be to invest in a flow meter.

Despite the potential inaccuracies, the pond drop method is often used on dairies to determine how much water has been applied because this method is relatively simple and requires few capital inputs. And there are some situations where the pond drop method can provide very accurate information and can be used not only for measuring application amounts but also to check the accuracy of other

measurement methods. The pond drop concept is useful for other purposes such as calculating the volume applied from tailwater return ponds.

Because the sides of most ponds are sloped, an inch of drop when the pond is full is not the same volume applied as when the pond drops an inch when the pond is lower. If the slope of the pond is fairly uniform, the pond surface area (length x width in acres) at the half way depth of the drop multiplied by the total inches of drop will give an accurate estimation of the acre-inches of water applied. Having a chart for the pond which gives the surface area of the pond at different depths can simplify calculations. Make the chart either by measuring the pond surface length and width at intervals as the pond is drawn down, or by entering the dimensions of the pond and run and rise of the slope into an Excel template available at manure.ucdavis.edu.

It can be difficult to achieve a target application rate using the pond drop method because of the large amount of acreage that must be irrigated before the rate of drop can be established and adjusted. Constructing a chart which gives the estimated pump output (in gpm) from the pond at different pond levels can be helpful in proactively estimating if a planned application will result in an appropriate application rate.



Measuring Lagoon Flow Rate using Dilution

If only the freshwater flow rate can be measured, it is possible to estimate the flow rate of lagoon water by sampling the combined lagoon and fresh water and the undiluted lagoon water, and then analyzing both samples for a constituent that is not present in the fresh water. Potassium is a good constituent to use for this purpose since it occurs in only one form in water and is not commonly present in greater than trace amounts in freshwater. Some “fresh” water sources that do contain significant amounts of potassium or sodium include manured tailwater, some tile drain water, canal water that receives tile drain water, and most municipal or food processing wastewaters. In these situations, the fresh water source will need to be analyzed in addition to the lagoon and blended water. Ammonium is another constituent that can be

Calculating lagoon flow rate from dilution

Example:

The measured freshwater flow rate is 1300 gpm. The concentration of soluble K in the freshwater is negligible.

The concentration of soluble K (potassium) in the lagoon water is 490 mg/L and 160 mg/L in the blended water.

$160 \div 490 = .33$ or 33% of the total flow came from the lagoon.

If 33% came from the lagoon, then 67% came from the freshwater.

$1300 \text{ gpm} \div .67 = 1930 \text{ gpm}$ combined flow rate.

$1930 \text{ gpm} - 1300 \text{ gpm} = 630 \text{ gpm}$ lagoon flow rate

analyzed for dilution but it can volatilize or change form under some circumstances. Other constituents such as sodium would work as well as potassium but may require analyses that or otherwise not required.

Both lagoon and blended water samples should be taken at the same time and as close as possible to the time that the flow was measured to minimize the effect of fluctuations in flow rates or concentrations. Be sure that the flow from the lagoon has run long enough to have cleared out water from previous applications. Where pipeline runs are long, this can take a long time.

To calculate the flow rate of the lagoon water, divide the concentration of potassium in the mixed water by the concentration in the lagoon water to find what percent of the total flow came from the lagoon. The percent that came from the freshwater is 100% minus the lagoon flow percentage. Divide the measured freshwater flow rate by the freshwater percentage to calculate what the total flow rate must have been. Subtract the freshwater flow rate from the total flow rate to determine the lagoon flow rate.

The freshwater flow rate can be measured with a flow meter on the freshwater pump, a recent pump test, or by using a hand-held velocity meter inserted down a vent or standpipe. If an accurate measurement of the blended fresh and lagoon flow can be obtained, this method can be adapted to estimate both the fresh and lagoon flow rates. It can also be adapted for use in other difficult situations, such as measuring tailwater runoff.

The dilution method is somewhat cumbersome for most dairy operators to use regularly but is useful when it is not feasible to make permanent changes to the system. Also, any method such as this one that measures the flow rate at a single point in time assumes that the flow rate from the district and the pond is the same throughout an irrigation, which is often not true. Even if the district or pump flow rate is uniform, the flow rate for a particular field, or portion of a field, may vary due to differences in pipeline characteristics such as slope, pipe length and diameter, in addition to the number and degree of opening of valves. For this reason, this method can be considered only an estimate of actual flow rates.



Measuring velocity in an underground pipe with an electromagnetic meter mounted on aluminum concrete finishing poles that can be snapped together to obtain the length needed.

Measuring Lagoon Water Flow Rate by Difference

If it is not possible to directly measure the flow rate of the lagoon water but it is possible to measure the flow rates of both the fresh water and the combined fresh and lagoon water, the flow rate of the lagoon water can be calculated by subtracting the freshwater flow rate from the combined water flow rate.

For example, if the blended water flow rate is 1500 gpm and the freshwater flow rate is 500 gpm, then the lagoon water flow rate is $1500 \text{ gpm} - 500 \text{ gpm} = 1000 \text{ gpm}$.

If only the blended water flow rate can be measured, turning off the pond pump and comparing the blended flow rate to the freshwater only flow rate will not usually provide an accurate measure of the lagoon flow rate unless the blended water is measured in an open channel or in a pipeline that is not

full. Both the velocity and level of the water must be measured. If When the blended water to be measured is in a full pipeline and the pond water pump is turned off, part of the original mixed flow may be taken up by additional fresh water, giving an erroneously low estimation of the difference between the total flow and the fresh water flow.



The trajectory of water being discharged from an open pipe may be used to estimate flow rate.

This method may be useful as a temporary estimate, however it may be awkward to do in the dark and is less convenient for throttling purposes. For charts and additional information on this method, see “Hanson and Schwankl, Measuring Irrigation Water Flow Rates.”

Another option is simply to record the amount of time it takes for the discharge to fill a container of known volume, such 5 gallon bucket, and calculate the gallons per minute (gpm). This method works best when the expected flow rate is less than about 30 gpm.

Measuring Freshwater and Blended Fresh and Lagoon Water with Flow Meters

Accurate measurement of fresh water applied is important for many reasons in addition to being required. Inexpensive mechanical meters such as propeller type meters are often used when pumping groundwater. If the meter must be located near an elbow or valve, propeller meters that measure the entire cross section of the pipe are more accurate than those that measure only a portion of the flow. Accuracy can also be improved by placing the meter in a standard metering run. Other types of meters, such as electromagnetic flow meters, can be used to measure fresh or blended water but are considerably more expensive.

Measuring Lagoon Flow Rate from a Pipe Discharge

If there is a location where the liquid manure discharges from an accessible pipe, and the flow rate is not high, there are a couple of inexpensive options for measuring the flow rate. If the pipe is horizontal, the output can be estimated by measuring the distance from the pipe at the point where the output stream has dropped 4 inches from horizontal. The flow rate is estimated from this distance and the pipe diameter using a table. Similar charts exist for pipes that are not horizontal.



The flow rate of this liquid manure discharge could be estimated by timing how many seconds it takes to fill a 5 gallon bucket. If it takes 10 seconds, or $10 \div 5 = 2$ seconds per gallon, then in 60 seconds (1 minute), $60 \div 2 = 30$ gallons or 30 gpm would be pumped. Or, calculate gpm by dividing 300 by the number of seconds it takes to fill 5 gallons.

On freshwater pumps with minimal variation in pumping levels, the pump output, verified by an accurate pump test, can be used along with pump run time to calculate the volume applied with sufficient accuracy for most purposes.

When measuring water pumped from a canal or river, however, propeller type meters may not be the best choice because water weeds or other stringy debris can interfere with any sort of meter which is installed inside or protrudes far into the pipe. Screened intakes can help but may need to be frequently cleaned. Electromagnetic or Doppler meters with minimal protrusions are preferred for these situations but are more expensive.

Water received from a district is usually delivered in open canals. Travel from the district turnout to the fields may be in underground pipeline or it may be in an open channel.

The easiest way to measuring the flow of water in a large underground pipeline is with an electromagnetic or wetted Doppler meter with a debris shedding sensor mounted to the inside wall of the pipe. On pipes less than about 30 inches in diameter, the sensor is often mounted to a band that fits snugly inside the pipe. On larger pipes where access to the inside of pipe is possible, affixing a bracket to the inside wall of the pipe to hold the sensor may be preferable. In either case, it is critical that the sensor, bracket and interior cable be configured tight to the wall in such a way that water weeds and debris cannot be trapped and interfere with the reading.

Pipes that do not run full and open channels will require that both the velocity of the water, as measured by the flow meter velocity sensor, and the depth of water in the pipe or canal, be simultaneously measured. Flow meters measure the velocity of the water but the flow rate is determined by both the velocity (the number of feet a water particle travels per second) of the water and the cross sectional area (square feet) that the water travels through. Combined, these two pieces of information give the volume (cubic feet) passing through that cross sectional area per second (cubic feet per second, or cfs).

Open air space in the top of the pipe, and silt or debris in the bottom of the pipe change the area of the pipe. The depth of the silt layer may change even during the irrigation of an individual field depending on the velocity of the water in the pipe, which can be affected by a variety of factors including the number of valves open or the elevation of the irrigation valves in comparison to the height of the canal.

Both an estimate of depth of the silt in the pipe and the depth of water in the pipe are necessary to calculate the volume of water flowing through the pipe in a non-pressurized system This can be done by



The flow meter sensor above is mounted to the inside wall of a large diameter pipeline. If the pipe does not always run full, another sensor to detect the water level in the pipe will be needed in addition to the velocity sensor. The level and velocity sensor may be integrated on the same mount, or they may be separate devices. The installation in the photo below has a ultrasonic level sensor mounted at the top of the pipe and a velocity sensor through the side, with no wires inside the pipe.

Photos: Mace USA LLC



using a sensor mount that has a capacitive pressure diaphragm which measures the weight of the water above it, or with a separate downward looking ultrasonic depth sensor mounted at the top of the pipe. The pressure diaphragm method is suitable in situations where the sensor will be wet. The downward looking depth sensor is mounted above the fluid and does not come in direct contact with it, making it ideal for very dirty or debris laden water. Both methods of measuring and recording water levels are useful for a variety of other purposes, such as turning on a sump pump or recording the depth of water in lagoons, open channels or weirs.

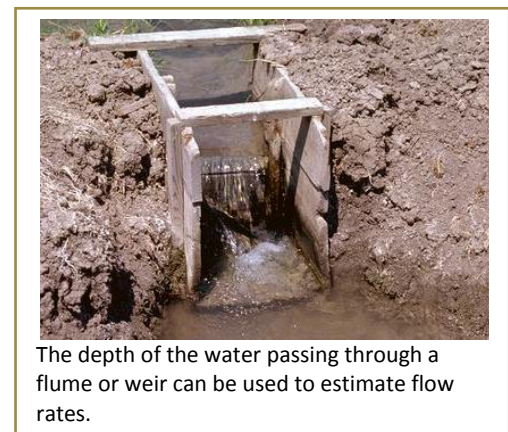
Computer software that will calculate the flow rate from the velocity and cross sectional area is essential and is generally supplied by the meter manufacturer. When selecting a meter and depth sensor, be sure that that you will be able to understand and use whatever additional software is needed to determine flow rate.

The same meters and level sensors that are used to measure flow rate in partially full pipes can also be used for the same purpose in open channels such as canals. If a temporary metering solution is needed, an electromagnetic meter on a lightweight pole can be used to obtain a velocity reading at a single point in time. Access to straight stretch of pipeline through a vent is necessary. Either an electromagnetic velocity meter or wetted Doppler insertion meter can be used as a temporary meter for blended liquid manure in open channel canals and irrigation ditches.



Measuring Freshwater and Blended Fresh and Lagoon Water without using a flow meter

There are a variety of ways to measure irrigation water being applied to or running off of fields without using a flow meter. These involve portable flumes, various constructed weirs or the size and number of siphon pipes being used. All of these methods measure the depth of water in or difference in depth of water on either side of a constriction of specific shape and size. The flow rate is usually read off a chart for that device. These methods do not usually require expensive devices and are especially useful when exact volumes are not essential. They are most appropriate in situations where the flow rates are fairly constant, unless multiple readings are taken. A data logging depth sensor can provide a log of the height of the water passing through a flume or weir. This may be a cost effective solution if the depth sensor can be accommodated by an existing data logging controller box. An excellent reference for these and other method is Detailed information on these methods is “Hanson and Schwankl, 2010. Measuring Irrigation Water Flow Rates”



Measuring Tailwater Runoff

A method to measure or estimate the amount of tailwater runoff from fields is essential to avoid over estimating the amount of nutrients applied to the field and to avoid over reporting of nutrients and salts when calculating application amounts in relation to crop removal.

Allowing some of the water applied to run off the field as tailwater is often necessary on fields where infiltration is slow. On these fields, 15 to 25% of the total water applied is allowed to run off in order for the water to remain on the surface long enough to wet through the root zone. This runoff water is collected and either pumped back on to the same field, to a different field or to the retention pond. If this runoff is not reapplied back to the same field, that portion of water and nutrients that ran off needs to be subtracted from the application amount.

If the runoff is applied to the same field and the re-applied water contains significant concentrations of nutrients, the portions of the field that received the additional tailwater may receive more nutrients than portions that did not unless adjustments are made.

There are several options for measuring the volume of tailwater runoff.

As with undiluted lagoon water, using a suitable flow meter is the easiest and most accurate method of measuring runoff. Solar or battery powered datalogging wetted Doppler or electromagnetic flow meters are ideal for this purpose if the water can be routed through a length of pipe that is configured so that it will always run full. If the water is in a pipeline or open channel that is not full, the flow meter velocity reading can be used in conjunction with a level sensor to calculate the flow. It may be possible to use a temporary meter to obtain percent runoff estimates that can be used at other times.

If the runoff drains into a sump out of which water is pumped, the volume pumped can be estimated by multiplying the length of time the pump ran by the pump output. The pump output in gpm can be determined by stopping the inflows to the sump and timing how long it takes for the pump to draw down a

known volume. At a minimum, the pump should have a run time meter and the hours of runoff for each field recorded. A totalizing flow meter on the pump discharge would be more accurate.



Water and nutrients that run off the field and are not re-applied to that same field should be measured and subtracted from what was applied so that the crop is not inadvertently shorted of nutrients and so that application amounts are not over—reported.

Calculating flow rate by sump fill time

Example:

A 5 foot deep tailwater sump is 8 feet wide and 10 feet long when it is halfway full.

$8 \text{ ft} \times 10 \text{ ft}$ is 800 square feet surface area, or $800 \div 43560 \text{ ft}^2/\text{ac} = .001837$ acres

The pond is 5 feet deep or $5 \times 12 \text{ in/ft} = 60$ inches deep

Measuring the pond surface area when the pond is half full, or 2.5 feet below full accounts for the side slope of the pond.

The pond capacity is $.001837 \text{ acres} \times 60 \text{ inches} = .110193 \text{ acre inches}$.

$1 \text{ ac-in} = 27,154.3 \text{ gallons}$

$.110193 \text{ acre inches} \times 27,154 \text{ gallons/ac-in} = 2,992 \text{ gallons in the pond}$.

If it takes 30 minutes to fill the pond, the inflow rate is

$2992 \text{ gallons} \div 30 \text{ minutes} = 100 \text{ gpm}$.

Another way to estimate the runoff flow rate is to record the length of time it takes to fill a sump of known volume and use this to calculate the flow rate. Ideally, this should be done several times over the course of the irrigation to confirm that the flow rate is constant. The flow rate is then multiplied by how long the entire flow ran to calculate the total volume of runoff for that field. The more variable the flow rate and uncertain the start and end times of the runoff, the less accurate this method will be for a particular irrigation and field.



Many of the same methods that are used to measure flows from wastewater lagoons can also be used to measuring the flow into and out of tailwater retention ponds like this one.

If there is a tailwater retention pond, measuring the volume of water in that pond is useful only if the entire runoff from a single field is captured in the pond, and if the pond is not being drawn down at the same time as it is being filled. If the runoff from only one field it may be possible to calculate the runoff rate.

Ideally, a tailwater pump sumps and tailwater retention ponds should be constructed in a way that facilitates a way to measure or estimate the amount of runoff that occurred, and to measure the amount of tailwater that was re-applied onto a different field.

References

Hanson, B. R. and L. J. Schwankl. 2010. Measuring Irrigation Water Flow Rates. University of California Agriculture and Natural Resources Publication 21644

Schwankl, L. and C. Frate. 2004. Alternative techniques improve irrigation and nutrient management on dairies. California Agriculture. Vol 50 NO. 3 pp 159-163