March 31, 2010

Caution Advisory for Application of *Guidelines for Sizing Irrigation Systems for Nutrient Management* dated March 2010 by Eric Swenson, P.E.:

These guidelines describe approaches and design guidance for the installation of distributed lagoon (manure) water distribution piping to effectively deliver controlled amounts of nutrients to various fields within a medium to large farming operation associated with the operation of a dairy.

These guidelines have been developed based upon my personal experience as a design professional working in this field since approximately 1998 including two years as a technical advisor for the University of California (UC) Agricultural Extension from April 2003 through April 2005. Each dairy site typically requires a customized approach to create the optimal design to best perform the intended service for a reasonable construction cost and long term operating expense.

Certified Crop Advisors, Agronomists, and irrigation system design professionals should all be utilized to create a final system design. The Guidelines contained in the attached document can be utilized to assist in guiding a final system design.

It is my desire that these guidelines will assist in the creation of better systems for the use of lagoon water as a nutrient source for crop production.

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GUIDELINES FOR SIZING IRRIGATION SYSTEMS FOR NUTRIENT MANAGEMENT

by Eric Swenson, P.E.

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GENERAL: In sizing irrigation systems for nutrient management four things are very important:

- Providing an adequate supply of irrigation water to provide a high distribution uniformity (uniform irrigation).
- Providing primary solids separation of manure water prior to irrigated application.
- Maintaining adequate velocity in pipelines containing manure water and manure water mixed with irrigation water.
- Adequately mixing manure water with irrigation water prior to field application.

ADEQUATE WATER SUPPLY: Fresh water supplies from surface water or groundwater (well water) need to be made available to provide a uniform irrigation. Excessively long irrigation sets over irrigate and provide excessive nutrients to the upper end of a field. Fresh irrigation water supplies are needed in the winter as well as the summer when double or triple cropping is used with manure water addition. In some cases additional water supplies will have to be developed to achieve these goals.

PRIMARY SOLIDS SEPARATION: Primary solids separation is the process of removing solids greater than 0.045 inches in size. This is usually accomplished through the use of settling basins or sloped screen separators. Removal of these oversize solids helps to reduce plugging in distribution piping and drop out (settling of solids) at the top of fields.

SIZING OF MANURE WATER TRANSFER/DISTRIBUTION PIPING: A high degree of success has been experienced using PVC pipe for the distribution of lagoon water. High density polyethylene would also make an excellent distribution pipe, but is not easily modified or repaired by staff currently employed at most dairies. Many sites have significant quantities of concrete distribution piping that can require significant maintenance effort to keep operational with minimal leakage. Pipelines conveying manure water should be sized to maintain a velocity range between 2.5 to 5.0 feet per second (fps). Sizing pipelines in this velocity range can be completed as follows:

1. Select typical nitrogen application rates that you anticipate using. Summer application rates on corn are typically in the 50 pounds of available nitrogen per acre per irrigation range. Winter applications of nitrogen can range up to 130 pounds per acre per irrigation.
2. Measure typical manure water nitrogen concentrations. You will need to calculate ammonia nitrogen available and organic nitrogen content. You or your crop advisor will need to decide what percentage of your organic nitrogen you anticipate being available for the current crop cycle (50% is a default value sometimes used for this value for pipe sizing purposes). For estimating purposes:

   total nitrogen available = ammonia nitrogen + available organic nitrogen

3. Estimate the range of rates that you typically irrigate your fields. This will include both summer and winter irrigation rates. To do this take the total time required to irrigate a field and divide it by the total hours required for the irrigation:

   Irrigation rate = Irrigated Acres/Total Irrigation Time

4. Calculate manurewater flowrates required for typical summer and winter irrigations. To do this, take the typical total nitrogen available that was calculated in step 2 and the estimated irrigation rate from step 3 for summer. Take these two values and go to Table 1 attached. Enter the table with these two values and write down the value that is in the table. This value represents the flowrate of lagoon water to apply 10 pounds per acre of available nitrogen. Multiply this flowrate by 5 to get a typical summer irrigation manure water flowrate for a 50 pound per acre application. Repeat this process for a typical winter irrigation with a maximum application of 130 pounds per acre. Multiply the value in table 1 by 13 to get the flowrate for 130 pounds per acre.

5. Size your manure water transfer pipe by selecting a pipe size that maintains a velocity (V) between 2.5 and 5.0 feet per second. Take the two flowrates from step 4 and size a pipe from table 2 that maintains the correct velocity range. Many times an exact fit is not possible and the size closest to the range is used. Pipelines successfully carrying manure in the field have not been found smaller than 4 inches in size and any pipeline smaller than 8 inches in size should be selected with great care due to high risk of pluggage.

Pumped pipeline 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[i]. Good success has been found using two individual automatic vents with each having 2/3rds of the required total venting capacity. With 2 vents, failure due to plugging of one vent will not lead to complete absence of any automatic venting of the pipeline. Caution should be exercised when sizing pumps and piping to transfer very thick slurries found at the bottom of many storage lagoons. The density and viscosity of these slurries is significantly higher than for water.

MANURE WATER/FRESH WATER MIXING: It is desirable to fully mix lagoon and fresh water prior to application to the crop. This can be done in a number of fashions. One simple approach that has been employed is to discharge the lagoon water into an open standpipe at the beginning of an irrigation system, prior to the first irrigation outlet in the field. Another approach that has been used successfully is to construct round, pressure rated, steel, mixing chambers with automatic air vents where lagoon and fresh water mix prior to field application. Simple pipe tees where the lagoon water is introduced at 90 degrees to the main irrigation flow have also been used effectively.

DILUTION OF LAGOON WATER PRIOR TO LAND APPLICATION:

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

- Allows better distribution uniformity of nutrients over the field.
- Decreases the maximum salt loading on the crop.
- Allows reasonable velocities (2-5 ft./sec.) in irrigation distribution piping.

Dilution ratios of up to 10 parts fresh water to 1 part lagoon water have been noted in the field to achieve agronomic application rates of material. Summer dilution ratios can be in the 5 to 10 parts fresh water to 1 part lagoon water where winter dilutions are often 2 to 3 parts fresh water to 1 part lagoon water. Winter dilution rates are often lower due to the lack of availability of fresh water and the desire to dilute the lagoon water somewhat to reduce nutrient loading, improve nutrient distribution uniformity to the crop, and reduce crop exposure to high salt concentrations.

Some older lagoon water application systems only have one location for mixing lagoon water with fresh water. For land application areas in excess of approximately 300 acres for a single dairy, that have multiple sources of fresh water, it may be difficult to uniformly apply lagoon water during the peak irrigation season. One approach to increasing the flexibility of lagoon water application 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 still applying fresh water only at a field close to the lagoon water source.

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 a surface water canal should suffer 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.

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[i] See *The Surface Water Irrigation Manual* by Dr. Charles Burt published by Waterman Industries, Inc.

Calculation Sheet for Sizing Manure Water Transfer/Distribution Piping:

Step 1: Select typical nitrogen application rates in pounds/acre per irrigation:	50 pounds/ac	1.0a
Typical rates used are 50 and 130 pounds/acres		
	130 pounds/ac	1.0b
Divide Value in (1.0a) above by 10 and enter here:	5	1.1a
Divide value in (1.0b) above by 10 and enter here:	13	1.1b
Step 2: Measure typical manure water nitrogen concentation:		
Enter value for Total Kendal Nitrogen (ppm)	ppm	2.0
Enter value for ammonia nitrogen (ppm)	ppm	2.1
Subtract (2.1) from (2.0) to yield organic nitrogen (ppm)	ppm	2.2
Estimate total available nitrogen by adding 2.1 to 2.2 divided by 2:	ppm	2.3

$$\text{Total avialable nitrogen} = \frac{\text{ammonia nitrogen (2.1)} + \text{organic nitrogen (2.2)}}{2}$$

Step 3: Estimate Range of Irrigation Rates:		
Winter:		
Slowest Irrigating Field (Divide Acres/Time in Hours)	Acres/Hr	3.1
Fastest Irrigating Field (Divide Acres/Time in Hours)	Acres/Hr	3.2
Summer:		
Slowest Irrigating Field (Divide Acres/Time in Hours)	Acres/Hr	3.3
Fastest Irrigating Field (Divide Acres/Time in Hours)	Acres/Hr	3.4

Step 4: Calculate Manure Water Flowrates:

Winter:

Maximum Flowrate:			
Use value from (3.2) and (2.3) to enter Table 1 & Enter GPM Value Here:	____	GPM	4.1
Enter Value from Step 1.1b Above	13		4.2
Multiply (4.1) by (4.2) and enter value here:	____	GPM	4.3
Minimum Flowrate:			
Use value from (3.1) and (2.3) to enter Table 1 & Enter GPM Value Here:	____	GPM	4.4
Enter Value from Step 1.1a Above	5		4.5
Multiply (4.5) by (4.5) and enter value here:	____	GPM	4.6

Summer:

Maximum Flowrate:			
Use value from (3.4) and (2.3) to enter Table 1 & Enter GPM Value Here:	____	GPM	4.7
Enter Value from Step 1.1a Above	5		4.8
Multiply (4.7) by (4.8) and enter value here:	____	GPM	4.9
Minimum Flowrate:			
Use value from (3.3) and (2.3) to enter Table 1 & Enter GPM Value Here:	____	GPM	4.10
Enter Value from Step 1.1a Above	5		4.11
Multiply (4.10) by (4.11) and enter value here:	____	GPM	4.12

Step 5: Size Your Manure Water Transfer Pipe:

Winter Flows:

Maximum: Pick the smallest pipe size in Table 2 where V=5.0 FPS and the value in this column is greater than (4.3).

Enter Pipe Size= ______ Inches 5.1

Minimum: Pick the largest pipe size in Table 2 where V=2.5 FPS and the value in this column is less than (4.4).

Enter Pipe Size= ______ Inches 5.2

Note: Enter 4 if (4.4) is less than 110 GPM

Summer Flows:

Maximum: Pick the smallest pipe size in Table 2 where V=5.0 FPS and the value in this column is greater than (4.8).

Enter Pipe Size= ______ Inches 5.3

Minimum: Pick the largest pipe size in Table 2 where V=2.5 FPS and the value in this column is less than (4.12).

Enter Pipe Size= ______ Inches 5.4

Note: Enter 4 if (4.4) is less than 110 GPM

Step 5b: Select the smaller of the values from (5.3) and (5.4) and enter here: ______ Inches 5.5

Step 5c: Select the smaller of the values from (5.1) and (5.2) and enter here: ______ Inches 5.6

Step 5d: If (5.5) and (5.6) are the same size, this is your final pipe size, **stop here**.

If (5.5) and (5.6) are not the same, enter the larger of these two values here: ______ Inches 5.7

Find the pipe size one size larger than (5.7) in Table 2 and enter here: ______ Inches 5.8

This is your final pipe size selection.

Target gpm calculator

Location	**field 1**	
Acres	28.0	← **For Acres per Hour - Enter Rate Here**
expected run time (hou	11.2	← **For Acres per Hour - Enter 1 Here**
Target N/A	100	

enter lab data		← **Enter Lab Data Here**
NH4-N (mg/L)	100	
Org-N (mg/L)	150	

OR

←

% org-N available	50
mg/L available N	175

Target GPM **2,853** ← **Flowrate to Set at Lagoon Discharge**

calculator for quick checks of application rates

Actual GPM	1100	} **This will not function if you enter Acres per Hour above**
actual hours	11.2	
N/acre	39	
min/acre	24	

Table 1

GPM Required for 10 pound per acre application of nitrogen

Irrigation Rate Acres/Hour	Total Nitrogen Available in ppm															
	50	**100**	**150**	**200**	**250**	**300**	**350**	**400**	**450**	**500**	**550**	**600**	**650**	**700**	**750**	**800**
0.1	40.0	20.0	13.3	10.0	8.0	6.7	5.7	5.0	4.4	4.0	3.6	3.3	3.1	2.9	2.7	2.5
0.2	80.0	40.0	26.7	20.0	16.0	13.3	11.4	10.0	8.9	8.0	7.3	6.7	6.2	5.7	5.3	5.0
0.3	120	60	40	30	24	20	17	15	13	12	11	10	9	9	8	7
0.4	160	80	53	40	32	27	23	20	18	16	15	13	12	11	11	10
0.5	200	100	67	50	40	33	29	25	22	20	18	17	15	14	13	12
0.6	240	120	80	60	48	40	34	30	27	24	22	20	18	17	16	15
0.7	280	140	93	70	56	47	40	35	31	28	25	23	22	20	19	17
0.8	320	160	107	80	64	53	46	40	36	32	29	27	25	23	21	20
0.9	360	180	120	90	72	60	51	45	40	36	33	30	28	26	24	22
1	400	200	133	100	80	67	57	50	44	40	36	33	31	29	27	25
1.2	480	240	160	120	96	80	69	60	53	48	44	40	37	34	32	30
1.4	560	280	187	140	112	93	80	70	62	56	51	47	43	40	37	35
1.6	640	320	213	160	128	107	91	80	71	64	58	53	49	46	43	40
1.8	720	360	240	180	144	120	103	90	80	72	65	60	55	51	48	45
2	800	400	267	200	160	133	114	100	89	80	73	67	62	57	53	50
2.2	880	440	293	220	176	147	126	110	98	88	80	73	68	63	59	55
2.4	960	480	320	240	192	160	137	120	107	96	87	80	74	69	64	60
2.6	1,040	520	347	260	208	173	149	130	116	104	95	87	80	74	69	65
2.8	1,119	560	373	280	224	187	160	140	124	112	102	93	86	80	75	70
3	1,199	600	400	300	240	200	171	150	133	120	109	100	92	86	80	75
3.2	1,279	640	426	320	256	213	183	160	142	128	116	107	98	91	85	80
3.4	1,359	680	453	340	272	227	194	170	151	136	124	113	105	97	91	85
3.6	1,439	720	480	360	288	240	206	180	160	144	131	120	111	103	96	90
3.8	1,519	760	506	380	304	253	217	190	169	152	138	127	117	109	101	95
4	1,599	800	533	400	320	267	228	200	178	160	145	133	123	114	107	100
5	1,999	1,000	666	500	400	333	286	250	222	200	182	167	154	143	133	125
6	2,399	1,199	800	600	480	400	343	300	267	240	218	200	185	171	160	150
7	2,799	1,399	933	700	560	466	400	350	311	280	254	233	215	200	187	175
8	3,199	1,599	1,066	800	640	533	457	400	355	320	291	267	246	228	213	200
9	3,598	1,799	1,199	900	720	600	514	450	400	360	327	300	277	257	240	225
10	3,998	1,999	1,333	1,000	800	666	571	500	444	400	363	333	308	286	267	250

Table 2

Pipe Type	Nominal Pipe Size (inches)	Inside Diameter (inches)	Flowrate V=2.5 FPS (gpm)	Flowrate V=5.0 FPS (gpm)
100 IPS	4	4.26	111	222
100 IPS	5	5.27	170	340
100 IPS	6	6.27	241	481
80 PIP	8	7.81	373	747
80 PIP	10	9.77	584	1168
80 PIP	12	11.72	841	1681
80 PIP	15	14.65	1313	2627