Proper Design of Dairy Liquid Manure Nutrient Distribution Systems to Facilitate Agronomic Applications

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Introduction

With the California Regional Water Quality Control Board's (**Water Board**) adoption of the Waste Discharge Requirements General Order for Existing Milk Cow Dairies, Order No. R5-2007-0035 (**General Order**) and the July 1, 2012 Nutrient Management Plan (**NMP**) implementation deadline, the dairy industry has seen an increased need for precision application of nutrients to crops. Under the General Order, dairies are required to implement a NMP prepared by a Certified Crop Advisor (**CCA**), professional Soil Scientist, Agronomist or NRCS certified Technical Service Provider (**TSP**).

The intent of the NMP is to provide the farmer a schedule of when to apply specified quantities of nutrient laden water from the dairy to crops in order to meet a nitrogen ratio of 1.4 (nitrogen pounds applied to nitrogen pounds removed). A properly designed dairy liquid manure nutrient distribution system provides dairies the ability to implement their NMP. Precise amounts of nutrient laden water from the dairy can be distributed to discrete mixing stations throughout the farm for crop utilization. Agronomic applications should not be limited by infrastructure, but should instead be facilitated by it.

Water Generation and Quality

A properly designed nutrient distribution system begins with understanding the quality and volume of water generated by the dairy. Daily barn water generation is a large variable needed for determining volumes. Cooling equipment, sprinklers, and floor flushing from the dairy barn can vary greatly from dairy to dairy. Other components of the total water generation are rainfall & evaporation. **Figure 1** illustrates the various components of a typical flushed dairy facility where water is generated and used.

To understand the quality of the water generated, a representative lagoon water samples will be needed. Currently the Water Board requires quarterly sampling of the lagoon water. The concentration of nutrients in the lagoon varies throughout the year. During the winter months the cooler weather inhibits microbial action in the lagoons. Also, if cows are housed in freestalls as opposed to open corrals more nutrients are collected. During the summer, many dairymen add irrigation water to their lagoons in order to flush out some of the solids built up from the winter. By doing so, this reduces the concentration of the lagoon water nutrients but increases the volume of lagoon water. By analyzing samples quarterly, differences and trends between summer and winter applications can be determined. Ultimately, the designer must design the system to handle the total volume generated, and to deliver the nutrients that the crop needs.

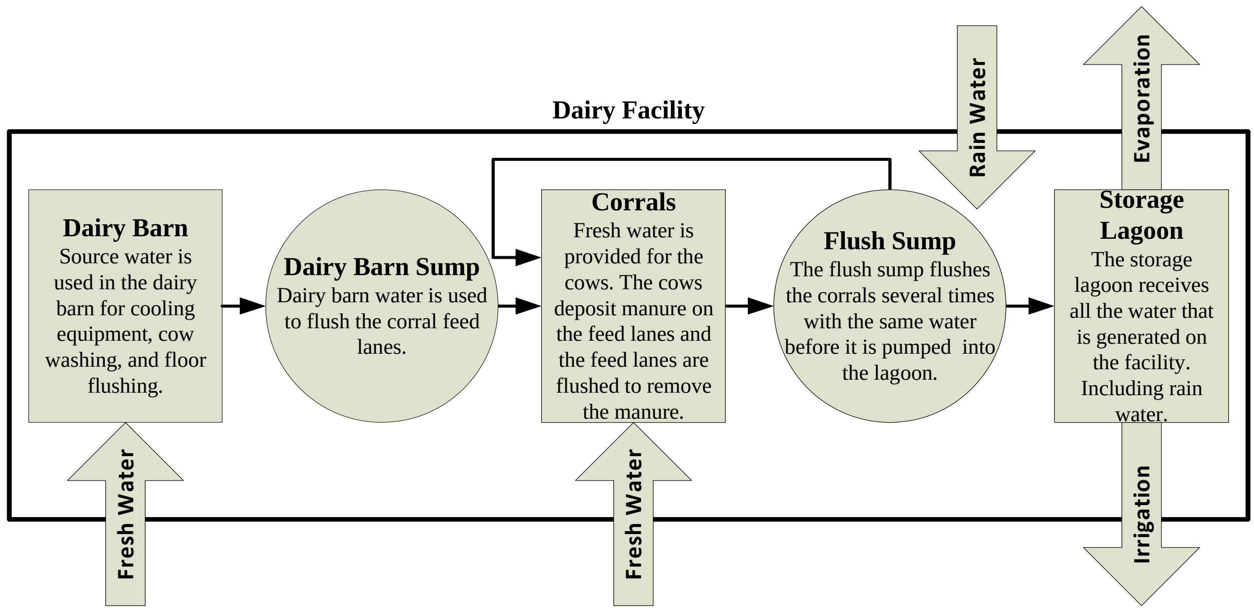

Figure 1. The diagram of the dairy facility shows the path that water takes through the different areas of the facility and its uses. The fresh water source is typically from a groundwater well. Rain water falls across the entire facility and much of it drains into the lagoon. The lagoon water is evaporated and used as irrigation water for crops.

Lagoon Management

Knowing the fill rate of the lagoon, the nutrient load within that volume, and the size of the lagoon, the number of needed irrigations throughout the year can be determined. For Central Valley dairies, the predominant crop rotation is corn in the summer months and wheat in the winter months. On a mass balance basis, dividing the total pounds of nitrogen produced by the agronomic nitrogen demand of the crops determines the total acreage needed for nutrient utilization. The calculated acreage can be reduced to reach the 1.4 nitrogen ratio. Balancing the nutrient needs and uptake timing of the crop with the lagoon capacity results in the number of irrigations needed. **Figure 2** illustrates the lagoon storage volume throughout the year for a typical properly designed system on a dairy facility.

Often times, the lagoon water is applied less frequently but in larger volumes, which may not be as beneficial to the crop. Typically the reason for this type of irrigation is because the lagoon pumps have a high flow rate (as much as 1,200 gallons per minute (**gpm**) or higher). Using a lagoon pump with a high flow rate is difficult to evenly spread across the entire field, because of the need for a large volume of additional well water. It is also difficult to apply the proper concentrations of crop nutrients evenly across the field. For instance, the volume of water delivered to a field that takes 14 days to irrigate with a 1,200 gpm pump is approximately 3.2 million cubic feet. From Figure 2 referring to the infrequent, large volume irrigations, the volume of one irrigation is approximately 2.5 million cubic feet. Applying, the lagoon water in this manner can be detrimental to the crop. Water with a high Biological Oxygen Demand (**BOD**) can deprive the crop roots of O_2, which can affect the plant's growth. Furthermore, if more nitrogen is applied than the crop needs the next irrigation will push the remaining nitrogen down below the root zone. This is the concern of the Water Board and the basis for the 1.4 nitrogen ratio. The effect of this type of application scenario on the lagoon storage capacity is illustrated in Figure 2 with the solid line. The four irrigation events results in a maximum storage volume of approximately 3.25 million gallons.

If each of the four larger irrigation events were divided into four smaller events, the maximum storage volume is reduced to approximately 1.4 million gallons; a reduction of approximately 56%. Referring to Figure 2, this type of irrigation scheduling is illustrated by the dashed line. In order to achieve the more frequent irrigation scheduling a lower flow rate pump is required.

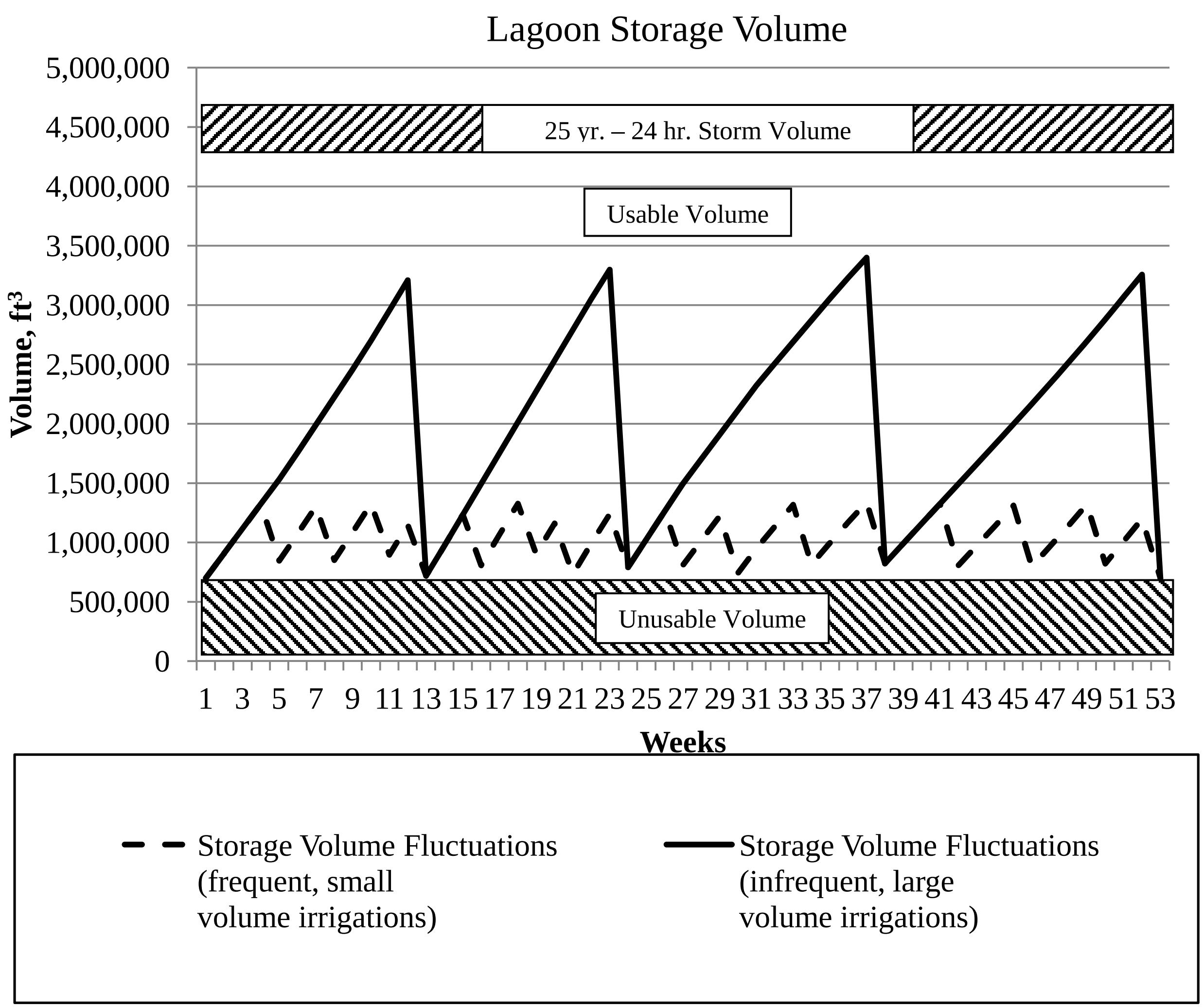

Figure 2. Lagoon storage volume graph with various components of storage. The unusable volume is due to the pump being unable to operate at a depth lower than 5 feet. The usable volume of the lagoon is the difference between the unusable volume and the 25 yr., 24 hr. storm.

Mixing Stations and Mixing Zones

When evaluating the available acreage, mixing stations and mixing zones can be determined based on the farmer's irrigation system and management style. Mixing stations should be located in conjunction with irrigation wells serving a group of fields or mixing zones. The mixing of fresh irrigation water and lagoon water is best accomplished in large standpipes. Mixing in this manner, as opposed to in a pipeline, provides adequate mixing of the two liquid streams without creating a pipeline head-to-head flow situation. The fresh water from the well can be delivered over the top of the standpipe to allow for proper air gap separation. **Figure 3** depicts the layout of a typical mixing station. Mixing of fresh water from a canal can be accomplished in much the same manner but care should be taken to prevent lagoon water from entering the canal with the use of a lift pump out of the canal and into the top of the standpipe. The lagoon water pipeline does not need an air gap and can penetrate the side of the standpipe or be delivered over the top. Adequate mixing is important so that the nutrients can be evenly distributed throughout the fields; however, measures should be taken to control the generation of foam.

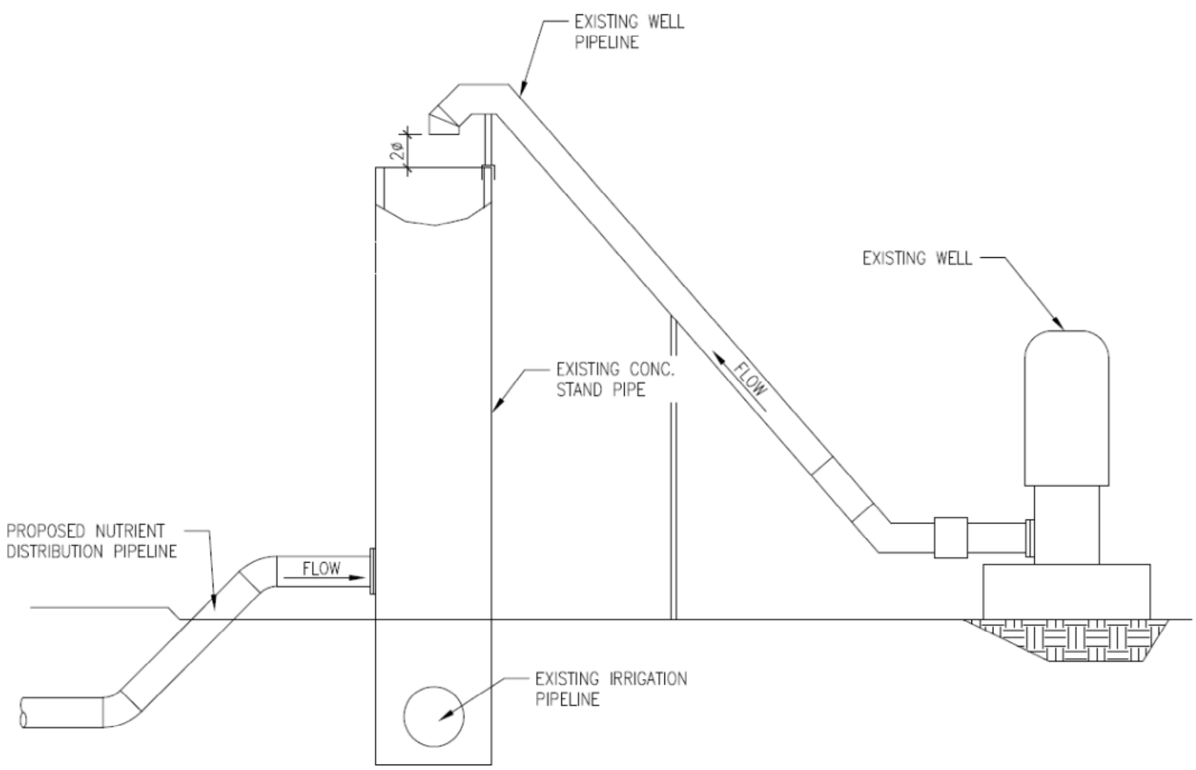

Figure 3. Mixing station layout with air gap to prevent contamination of well.

After locating the mixing stations and mixing zones, the farming practices are analyzed. Some of the information gathered includes the advance rate of the water across the field, the amount of water applied per irrigation, and the number of irrigations per season. This information is used to determine the operation and performance of the system. Also, the NMP is reviewed and the agronomist is consulted to determine the agronomic demands of the crops, and nutrient applications to correspond with the needed irrigation schedule.

Pipeline Appurtenances

Robust and redundant equipment like valves and air vents are important for the system to function properly. Two combination air/vacuum relief vents are installed at each location along the pipeline to ensure protection in case one of them becomes plugged. Air vents are placed at high points, after pump check valves, and every 1,320 feet. Although a properly designed system minimizes the likelihood of plugging, installing clean outs and/or designing the system to back flush can reduce overall operation and maintenance costs. The use of V-notch gate valves allow the flow to be throttled with the benefit of minimizing the potential for plugging. A V-notch gate valve changes the cross section of the valve from circular to triangular. The triangular cross section leaves a larger opening when the valve is closed. **Figure 4** illustrates the cross sectional opening of a V-notch gate valve versus a typical gate valve with a circular cross section.

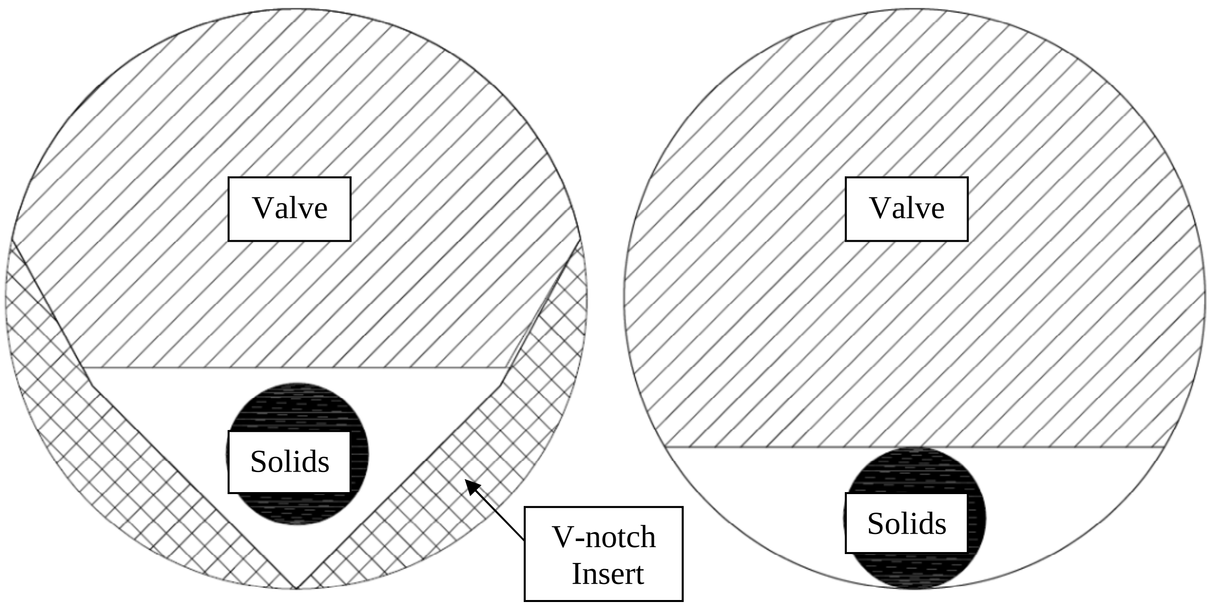

Figure 4. The illustration shows the cross sections of a V-notch gate valve (left) and a regular gate valve (right). The horizontal line is the bottom of the gate. Both openings have the same cross sectional area; however, the V-notch gate valve can allow larger diameter solids to pass compared to the regular gate valve. In this illustration the solid material (depicted as a circle) has a 2 inch diameter and fits through the V-notch gate valve easier than the circular gate valve.

Flow Rate Significance

The most significant characteristic of the system is the flow rate. It determines the diameter of the pipeline, the horsepower of the pump, and the nitrogen application rate (lbs per acre). There are several factors that go into calculating the flow rate including: the advance rate of the fresh water across the field, the total volume of water generated, and the acreage needed for nutrient utilization. The variable in the calculation for the flow rate is the number of irrigations per year with the lagoon water. The final flow rate selection is based on: the crops maximum nitrogen application in a single irrigation and the cost of the system. The maximum nitrogen application in a single irrigation for corn and wheat is approximately 80 pounds per acre. Knowing the concentration of the nitrogen in the lagoon water and the nitrogen application rate will lead you to the maximum flow rate.

Using the flow rate, the diameter of the pipeline is calculated based on minimum and maximum velocity guidelines of 2 feet per second and 5 feet per second. The minimum velocity is to prevent solids from settling out and plugging the pipeline. The maximum velocity is to protect the pipeline from damage caused by water hammer, excessive friction loss and higher energy costs. The maximum velocity will result in a smaller pipeline while the minimum velocity will result in a larger diameter; if the flow rate is small enough.

With the pipeline sized and the flow rate determined, the hydraulics of the system can be calculated for the various scenarios. The pump is selected based on the system curve, which is a plot of energy versus flow rate for each scenario. Although a smaller pipeline will cost less than a larger pipeline; the pumping cost will be greater due to higher pressures required to overcome friction losses. For both pipeline options the velocities for all the scenarios should be analyzed for adequacy and a cost analysis performed before the design is finalized.

Conclusion

There are many benefits for a dairy facility to have an efficient and effective nutrient distribution system. Applying the lagoon water frequently in smaller amounts minimizes the facility's required lagoon storage capacity. Through the efficient application of nutrients, significant savings from the reduction of commercial fertilizer and the benefits from increased yields are realized. A properly designed system also simplifies the irrigator's job, which can reduce operator error when following the NMP.