Handling Sand-Laden Manure

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Issues Associated With Handling Sand-Laden Manure

Sand-laden manure may be handled using a scrape or flush system. The handling systems should allow for the sand and solids to separate from the effluent. The abrasiveness of sand may create problems when mechanically handling sand-laden manure. Manure weighs about 60 pounds/cubic foot (lbs/cf) whereas sand has a density of 120 lbs/cf. Sand-laden manure will have an approximate density of 72 lbs/cf if 20% of the manure is sand. A portion of the sand will settle rapidly in a flush system by changing the velocity of the water. Since sand is heavier, it will not remain in suspension as long as manure and settles. However, a some sand and inert material will remain in suspension with any type of system. Many problems associated with handling sand-laden manure can be avoided if the sand and manure solids are stored in a different structure from the effluent.

Scrape Versus Flush

The benefits from flushing include labor reduction with automated systems, limited scraping requirements, lower operating cost, drier floors, potential reduction in odor and cleaner facilities. An optional method of handling manure may be necessary in colder weather. The disadvantages include the water requirements per cow and the initial fixed cost. Scraping may be required if the flush system is improperly designed. The ideal flush system requires no handling (scraping or restacking) of the manure until it is land applied. Flushing does not eliminate the need to apply the manure and effluent to land at environmentally acceptable levels.

Figure 1 shows there are different nutrient contents in the lagoons and solid basins when comparing scrape and flush systems on dairies using sand. If the manure has to be transported away from the immediate vicinity of the storage structures, then a scrape system may be preferred since there are more nutrients per unit volume in the solids. Dairies using recycled flush water for flushing will land in close proximity to the lagoons for irrigation purposes.

Design Parameters

Daily water requirements for flushing is a function of the width, length, bedding material, and slope of the alley. Alleys sloping 2 to 4 percent will use less flush water per day compared to those at 1-percent slope (Table 1). With composted manure bedding, at a slope of 1 percent, a minimum flush volume is 14,400 gallons per 12 feet gutter for flushing lengths of 800 feet. Design data for freestall alleys less than 150 feet suggest 100 gallons per foot of gutter width is adequate. Longer lengths require more water with a suggested maximum release of 175 gal/ft of gutter width. A study of six dairies found flush water requirements ranging from 240 to 620 gallons per cow per day (gal/cow/dy). Another design procedure suggests selecting the larger of two volumes — either 52 gal/cow/flush or 1.35 gal/square foot (sq.ft.) of alley per flush. Observations with sand-laden manure (SLM) suggest a high velocity flush system can clean alleys with less with than 1 gal/sq.ft. whereas, low velocity system may require more than 4 gal/sq.ft.

The cleanliness of an alley depends on the energy available in flush water. Present design procedures suggest the flushing wave should be 150 feet in length, 3 inches deep and moving at a velocity of 5 feet per second (fps). How these recommendations change when sand is added to the manure stream is not fully understood. Buildings longer than 450 feet require a flush wave equal at least ⅓ of the total length. If the length is less than 150 feet, then the design procedure is based on a 10 second (sec) contact time. The amount of time the flush water moves past a given selection of the alley is known as contact time. Many dairies bedding with sand are using contact times of 10 minutes or longer when flush velocities are 3 fps or less. Observations reveal many alleys are still scraped at least once per day even with the longer contact times. Other dairies using velocities of more than 7 fps are using contact times of less than 1 minute.

System Components

Properly designed flush systems use a flush device to release a volume of water at a known discharge rate and length of time. This achieves the designed flow velocity, contact time, and depth of water in the gutter to obtain adequate cleaning.

Two basic flush systems discussed in this paper are referred to high and low velocity systems. For purposes of this paper, a high velocity flush (HVF) system uses wave velocities greater than 5 fps with 7.5 fps being preferred. Low velocity flush (LVF) systems have wave velocities of

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less than 5 fps, generally around 3 fps. HVF systems store flush water in a tank or tower at the upper end of the area being flushed. A low horsepower (hp) pump is used to transfer water from the lagoon to the storage tank. Flushing tanks are 4 to 12 foot deep with a large discharge openings. Towers have depths of 20 feet or more and discharge through 12 to 24 inch diameter pipe. LVF systems are often pump flushing systems and use the lagoon for storing the flush water. A large hp pump transfers water to the upper end when flushing is desired. No additional storage is required in a flush pump system. Storage towers may be used with LVPS, however, piping losses often reduce the flow velocity.

Table 1 provides a summary of flush volume and discharge (release) rate required to meet the recommended design requirements for flushing a 12-foot alley at different slopes and lengths. The valve open time is equal to the required volume of water divided by the release rate. With high velocity units, the release rate varies from a minimum of 10 seconds to more than 60 seconds for longer buildings. Release rates can vary from 1,000 gpm to over 15,000 gpm if properly designed. Flush water pumping or low velocity systems are often limited by the pump capacity and the water release rate is from 1 to 15 minutes. Most pumping systems have a release rate of less than 3,000 gpm with 1,500 gpm being common.

Flush water is commonly released using "pop-up" or recessed valves which are controlled manually or automatically. Automated valves are pneumatically operated. Discharge rate from a value is influenced by the hydraulic characteristics from the pipeline to the valve and the initial head pressure. Common design procedures connect multiple tanks to a valve from both sides to maintain a higher head pressure and thus increase the discharge rate. The increase in discharge rate with multiple tanks requires increasing the pipe size. Many use a pump system with recessed values. Other release methods include a hinged plate, open pipe and gated pipe. Pumping losses can be reduced by using larger diameter pipes from the storage structure to the valve. For example, a 16 inch diameter pipe has 75 percent more cross-sectional area than a 12-inch pipe even though the diameter is only 33 percent larger.

The channel for controlling the flushing water is normally the freestall alley or holding pen. Flushing dairy facilities is different than swine facilities. Flushing channels in swine buildings range in width from 8 to 12 feet with secondary channel dividers located 3 to 4 foot on center. These secondary channels provide directional control of the flush water as it moves the length of the building. Channels for dairy facilities range from 8 feet to 14 feet in a freestall and up to 40 feet wide in a holding pen. Secondary channel dividers are not used because of vehicle and animal traffic.

Some scraping or manual cleaning may be needed because of amount of manure deposited along the curb to provide adequate cleaning of the alleys or channels on dairies. Alley may have ¾ to 1 inch crown in the center to direct water along the curbs in a tail to tail freestall facility. The crown will interfere with scraping, therefore, it is recommended to use level alleys or pens across the alley width with tail to tail stalls. Dairies with head to head stalls may pour the alleys with a ½ to 1-inch slope from the outside of alley to the freestall curb. This increases the depth of the flush wave along the curb and may improve sand removal.

Flush water is collected at the lower end of a building in a gutter or alley. The water flows towards a mechanical separator or gravity-settling basin. The separation allows the solids to accumulate in a basin and the liquid to drain to a lagoon.

Solid Separation

Mechanical solid separators may be inclined screen, press roller, or screw press. The inclined screen allows the liquid to pass through the screen and the solids remaining on the surface are transferred to a storage area. The inclined screen require daily cleaning to avoid solids flowing in lagoon. The press roller has the flushed material passing through a pair of rollers with the water draining away. The pressing action is designed to produce a drier material. The third mechanical separator is the screw press which uses more pressure to separate liquids and solids. A study at Mississippi State University found inclined screens removed very little of the sand from the flush water since the screen openings were larger than the diameter of the sand particles. Sand will cause additional wear on the mechanical solid separators. The abrasiveness of sand on the pumps and screens in a mechanical systems decreases the equipment life and increases maintenance cost. These increased maintenance costs may be reduced using gravity systems.

Gravity systems use a settling basin to settle out the solids and drain off the liquids. Earthen trenches or concrete basins are commonly used. The earthened trenches require a backhoe or excavation for cleaning. With gravity settling basins, the sand normally separates at the upper end of the basin. A large portion of the sand can be recovered from a gravity solids separating basin since much of it settles out near the discharge pipe. This is the location where there is the first major change in velocity of the flush wave. Generally, the sand is stacked and allowed to dry prior to reuse.

High Velocity Flush Systems

A high velocity flush system was installed in a 420-foot long freestall building with a 2% slope. The alleys were sloped 1 inch toward the freestall curb from the outside wall. The four-row barn had 168 freestalls per row. The feed alley was 14 feet wide and the cow alley was 12 feet wide. The flush system consisted of open-top flush tanks which are 10 feet in diameter and 38 feet tall. The flushing system uses a 6- to 7-foot section of 16 inch pipe exiting the tank at a right angle. The 16-inch pipe has a 45 degree sloped inlet inside the tank. Another 6 to 7 foot section of 12-inch pipe, which includes a 12-inch manual gate value, is then used to carry the water to the flush alleys. Figure 2 provides a schematic of the tank. The pipe outlet directs the water along the freestall curb. Table 2 presents the results of a study with the valve opened 90 degrees. There was a reduction in velocity from 11.5 fps to 6.7 fps as the head reduced from over 30 feet to less than 10 feet. The depth of wave also reduced about 50 percent as the initial head reduced. Based on the number of freestalls and flushing three times per day, the water usage was 48 gal/stall/flush or 140 gal/day/stall. The water usage based on a 8,500 gpm discharge rate and a 30-second flush is equal to 0.84 gal/sq. ft., giving a flow rate of 700 gpm and a water usage of 350 gal/ft width of gutter. The flush system removed the sand and manure from the alleys based on visual inspections. Flushing three times per day eliminated the need to scrape the freestall alleys. Scraping was required when flushing was reduced to twice a day.

A high velocity flush system was installed in the milk parlor using a 25 foot tall and 9 foot diameter tank. The tank was elevated such that a 12 inch entrance pipe was located about 6 ft above the milk parlor floor. The release rate in the milk parlor was 4,700 gpm with a flow velocity of 5.6 fps. The water flowed through approximately 30 feet of 12 inch pipe prior to the pipe outlet. Flushing rate could be increased by modifying where the flush water enters the transfer pipe and using long sweep elbows. Based on a 30 second flush three times per day in the milk parlor, the water usage in the milk parlor was 39 gallons per cow per day.

Guillotine Gate Flush Tank

Flush velocities have been obtained from four freestall buildings using a manual guillotine or scissor gate flush system. Two of the barns released the flush at a 90° angle to the alleys. The release was parallel to the long axis of the alleys in the other barns. The tanks were 4 feet deep with length and width dimensions of 12 feet by 16 feet. The approximate tank capacities were 5,000 gallons. The tank capacity equaled approximately 2 gallons per square ft of alley. The flush water exited the tank through an orifice measuring 8 in by 96 in at full opening. The flush velocities in the guillotine tanks were 6 to 9 fps. The tanks with the flush water exiting at right angle to the alley had a flush velocity 5 to 6 fps or about 2 fps slower than the other tanks. Energy was lost in changing the direction of the water. These design suggestions can be applied to flush alleys less than 250 feet long.

Other Considerations with High Velocity Systems

Based on visual inspection of alleys with sand bedded freestalls, the minimum flush velocity should be 5 fps with 7.5 to10 fps being preferred. Current recommendations on release rates with 400 ft alleys are adequate based on field studies. The water depth at the freestall curb should be a minimum of 3 inches with 4 inches preferred. The energy of the flush water needs to be directed along the freestall curb rather than in the center of the alley with sand bedded freestalls. This enables the flushing system to remove sand away from the curbs and minimizes scraping sand away from the curbs.

Sand Traps

Dairies using sand bedded freestalls should have a sand trap or sand separator between the freestall and the solid separating system. Gravity and mechanical separation are two basic methods for settling out the sand from the manure stream prior to solids separation. The flush tank release rate must be compatible at the upper and lower end of the alleys. If a HFVS is used, then the water channels, sand traps, or gravity solid settling basins at the lower end of the freestalls must be designed to handle the higher velocities. Any significant change in the velocity of the flush wave due to restrictions, wider channels, elbows, etc will result in some sand settling from the stream.

Gravity basins depend on the ability of the system to slow the flush velocity to 1 to 2 fps. At these velocities, the organic matter appears to remain suspended with the liquid and will discharge from the sand trap with minimal settling. Figure 3 shows the results of sampling a gravity system using a sand trap, solid basin and lagoon. This data shows that less than 3% of the solid material in the sand trap is organic material. The moisture content was 29% with 69% of the remainder being ash (sand) and 2% being organic material.

Many dairies are using sand lanes to transfer water from a freestall to a lagoon. Table 6 show data collected from two dairies based on a very limited field study in

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California. Grabs samples at various locations and times were taken and then composited prior to lab analysis. It was estimated about 40 percent of the sand in flush wave was deposited in the sand lane at Dairy 2. Less than 3% of the sand was deposit at Dairy 1. The initial concentration of inert material (sand) was much higher at Dairy 1 than Dairy 2. Table 6 does not account for the sand which was scraped into the sand lane. At both dairies, most of the settling occurs in the first 3 minutes of the flush process. This data tends to support comments by dairy producers than alleys flush better when cleaner water is used.

Design parameters for gravity sand traps have not been fully determined. Some data suggest the flush water has to be slowed to less than 1.5 fps to allow the sand to settle out before the effluent and manure is transferred to the mechanical or gravity separators. Velocities in the sand lanes on four western dairies were measured. The velocity on all of the dairies was 2 to 3 fps. Design data suggest the velocities could be reduced to 1 to 1.5 fps to settle additional sand without settling organic matter. Using Manning's equation, a 1.5 fps velocity may be obtained with a sand lane sloping at 0.25 percent and 12 feet wide with a release rate of 2,000 gpm. The key principle to remember is to change or slow down the velocity of the flush.

A mechanical separator has been developed by Wedel and Bicket (1996, 1998) and is marketed by McLanahan[2]. The separator has the ability to remove or recycle 90% or more of the sand from the waste stream. The sand is much cleaner than from a gravity separator since it is washed. The mechanical separator works better with coarse sand than fine sand. Burcham et al. (1997) found an inclined screen was not effective in separating the sand from the waste stream. The screen openings were larger than the sand particles. Sand also had a tendency to settle out up stream of the inclined separator as the flush wave velocity was reduced. Mechanical separators must be part of the total system and not a bottleneck. Bottlenecks within a sand system tend to result in settling sand at undesirable places.

Comments Related to Low Velocity Systems

Many flushing systems utilize purchased components using pop-up valves or plates and underground piping. However, it is questionable whether an adequate release rate of the water can be obtained with long freestall buildings based on current engineering recommendations when piping losses are considered. Dairies are utilizing these low velocity systems by increasing the contact (flushing) time. However, observation also reveals they are scraping alleys at least once per day. Normally, the scraping process is part of the freestall maintenance routine.

The challenge is to minimize the energy lost in moving the flush water through the pipes. Table 3 shows the estimated flow rate through a 12 inch PVC pipe with a friction coefficient of 0.02. As the equivalent pipe length is increased, the flow rate is reduced unless more head pressure is utilized. This may be accomplished by using a taller tower or larger pump. Table 4 shows the equivalent length of pipe for different fittings. For example in a four row barn, there may be 100 feet of pipe, 3 elbows, and 3 tees. In this case the water would have to flow through the equivalent of 315 feet of pipe. Therefore, the flow velocity is reduced by 35% by just moving the water through the fittings. If pop up valves are used, it is better to use 16 inch or larger pipe and not reduce the pipe size until at the valve.

Table 5 shows the theoretical flow rate for different pump sizes operating at 50 percent efficiency against various pressure losses. The pressure losses not only have to include the friction losses through the pipe but also the vertical lift of the water. Pumping water from the lower end to the upper end of a 1,000 foot free stall building on a 2% slope requires a minimum vertical left of 20 feet. Realistically it may be closer to 40 feet when vertical length from the lagoon is considered.

General Guidelines for Sand-laden Manure

There are some general guidelines to remember when working with sand:

1. Sand-laden manure will not stack or pile up like manure mixed with organic material such as straw or paper. It tends to spread and move away particularly in wet weather. Naturally, sand-laden manure does not appear stack more than 12 to 18 inches deep. Therefore, before it can be handled, you have to contain it.
2. Based on experience, observations and comments by dairy producers, the longer it is contained in a storage structure other than a lagoon, the easier it is to handle. It is recognized that weather does impact the handling characteristics.
3. It is easier to handle sand-laden manure if it is contained in a structure other than the lagoon or holding pond. Difficulties in retrieving and handling occur once the sand moves into a liquid storage area such as a lagoon or holding pond.
4. Utilize the forces of nature as much as possible. Begin the waste handling system design by taking as much advantage of gravity as possible. Only use pumps and

[2]Mention of trade names does not imply endorsement of the product nor criticism of similar products not mentioned by the authors or Kansas State University.

augers as a last resort in moving the manure stream from the end of the freestalls to the holding structures.

5. Do not judge the effectiveness of a system designed to handle sand by what is seen on the surface. Generally, the top surface will be a slurry and initially emptying a solids storage basin takes time. Once the slurry is removed, the rest of the material in the structure will be at less than 80 percent moisture.
6. Flushing systems work better when the energy created by the water depth or head pressure in the flush water tower (and pumps) is used to move manure and sand rather than flush water through the pipes and elbows. A certain amount of energy is lost for every foot of pipe the flush water has to move through. When flushing sand, it is better to purchase more storage towers and move them closer to the alleys than to buy pipes and elbows. If the piping system is desired, then use a larger pipe for the manifold system and do not reduce down to the pop up valve size until after the last elbow or tee joint.
7. Recycling sand for bedding in the near future will require mechanically separating and washing sand, if clean sand and biosecurity are primary concerns. Some producers are experimenting with stock piling gravity separated sand. Most are partially blending the dirty sand with clean sand. The stocked piled period ranges from 1 to 6 months prior to reuse. If a dairy is expanding, the gravity separated sand may be used in construction projects. The run off from the sand pile should be contained and transferred to the lagoon. In a recycled flush water system, the additional drainage area may be beneficial in providing some extra flush water.

Summary

Flushing can be a viable alternative to scraping of dairy manure. Existing facilities can be constructed for the addition of flushing systems at a latter date even if scraping is planned for in the immediate future. This requires placing the buildings at 2 to 3 percent slope. It is recommended to slope the alleys ¾ to1-inch towards the curbs. If a minimal amount of scraping is desired, the flush velocities need to be a minimum of 5 fps with 7.5 fps preferred. Sand will settle from the waste stream by reducing the wave velocity to less than 2 fps. A 6 to 8 foot difference in elevation between the lower end of the flushed areas and the lagoon freeboard will be necessary for inclusion of separation equipment and transfer collection gutters. Inclusion of flushing systems in existing buildings has to be determined on an individual bases. An adequate water supply for fresh water flushing of the milk parlor and holding pen must also be available.

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Table1. Volume of flush water (gal) required for gutters 12 feet wide based on gutter length and slope.

	Gutter Slope (%)				
Gutter Length (ft)	0.5	1	2	3	4
150 ft or less	4,700	2,700	1,550	1,150	1,300
200	6,300	3,600	2,100	1,500	1,500
300	9,400	5,400	3,100	2,250	2,250
400	12,550	7,200	4,150	3,000	3,000
500	15,700	9,000	5,200	3,800	3,800
600	18,800	10,800	6,200	4,500	4,500
800	25,100	14,400	8,300	6,000	6,000
1000	31,340	18,000	10,400	7,500	7,500
Discharge Rate (gpm)	28,200	16,200	9,300	6,800	7,700

Table 2. Characteristics of flushing system with valve 90 degrees open

Initial Head (ft)	No. of Rep	Velocity (fps)	Flow Rate[1] (gpm)	Flow Depth (in)	Contact Time[2] (sec)
>30	3	11.5	9,740	3.6	11.2
26–30	3	10.8	8,630	3.6	11.9
21–25	2	9.4	7,760	3.0	13.4
16–20	3	8.3	7,390	3.3	15.4
11–15	3	7.6	5,940	3.0	16.3
6–10	3	6.7	5,010	2.5	20.0

[1] Average flow rate based on from opening to closing of valve.
[2] Estimated based on released rate, flow depth, velocity.

Table 3. Estimated flow rate (gpm) through a 12 inch PVC pipe with a friction coefficient of 0.02 for varying pipe lengths and water pressures.

Equivalent Pipe Length (ft)	Average Feet of Water Pressure					
	10	15	20	25	30	40
100	5,200	6,320	7,300	8,200	8,900	10,300
200	4,000	4,900	5,700	6,300	6,900	8,000
300	3,400	4,100	4,800	5,300	5,900	6,800
400	3,000	3,700	4,200	4,700	5,200	6,000
500	2,700	3,300	3,800	4,300	4,700	5,400
750	2,200	2,700	3,200	3,500	3,900	4,500
1000	2,000	2,400	2,800	3,100	3,400	3,900

Table 4. Equivalent feet of pipe for different fittings and valves for 12-inch diameter PVC pipe.

Fitting or Valve Opening	Equivalent Pipe Length (ft)
Gate Valve fully opened	7 ft
Gate valve ½ opened	30 ft
Gate valve ¼ opened	200 ft
90° Elbow	35 ft
90° Long Sweep Elbow	20 ft
Tee w/ Straight through Flow	20 ft
Tee w/ vertical Flow	70 ft

Table 5. Estimated flow rate (gpm) for different pumps sizes and water pressures.

Pump (hp)	Average Feet of Head					
	20	40	60	80	100	120
10	1,485	743	495	371	297	248
20	2,970	1,485	990	743	594	495
30	4,455	2,228	1,485	1,114	891	743
40	5,940	2,970	1,980	1,485	1,188	990
50	7,425	3,713	2,475	1,856	1,485	1,238
75	11,138	5,569	3,713	2,784	2,228	1,856
100	14,850	7,425	4,950	3,713	2,970	2,475

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Table 6. Concentration (ppm) of inert material (sand) in the flush wave at different times and locations of wave entering and exiting a sand lane and of the initial recycled flush water. Data does not include the amount of sand scraped from the alleys prior to flushing.*

Location and Time of Sample	Dairy 1	Dairy 2
Water at pop-up valve	5,500	1,800
30 sec after flush wave reached end of freestall alley	14,000	27,400
210 sec after flush wave reached end of freestall alley	6,500	8,000
390 sec after flush wave reached end of freestall alley	6,100	3,500
30 sec after flush wave exited the sand lane	13,400	18,200
210 sec after flush wave exited the sand lane	6,100	6,200
390 sec after flush wave exited the sand lane	6,300	3,100
Estimate of sand deposited in lane during 390 seconds**	3%	40%

*Data based on a limited field study in which grab samples were obtained while flushing on two western dairies.
**Based on estimated weight difference between beginning and end of the sand lanes during time period and using release rates of 1,300 gpm release rate at dairy 2 and 2,000 gpm at dairy 1.

Figure 1.

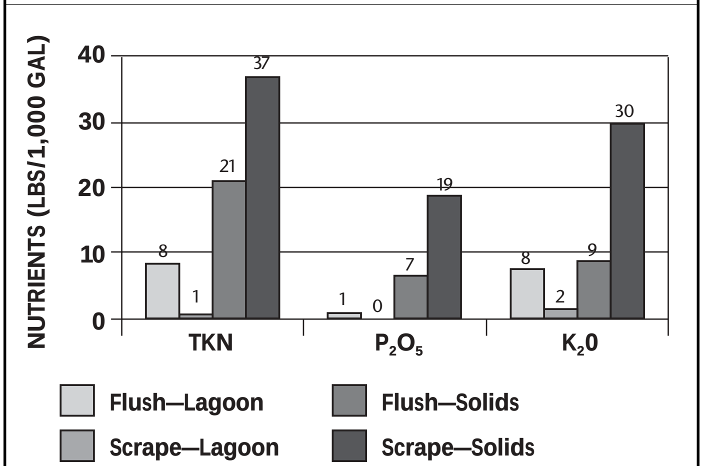


Figure 3.

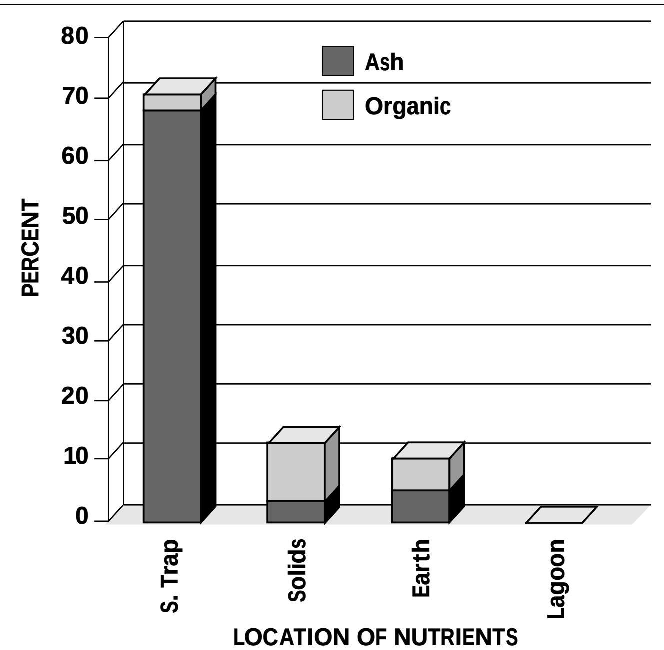
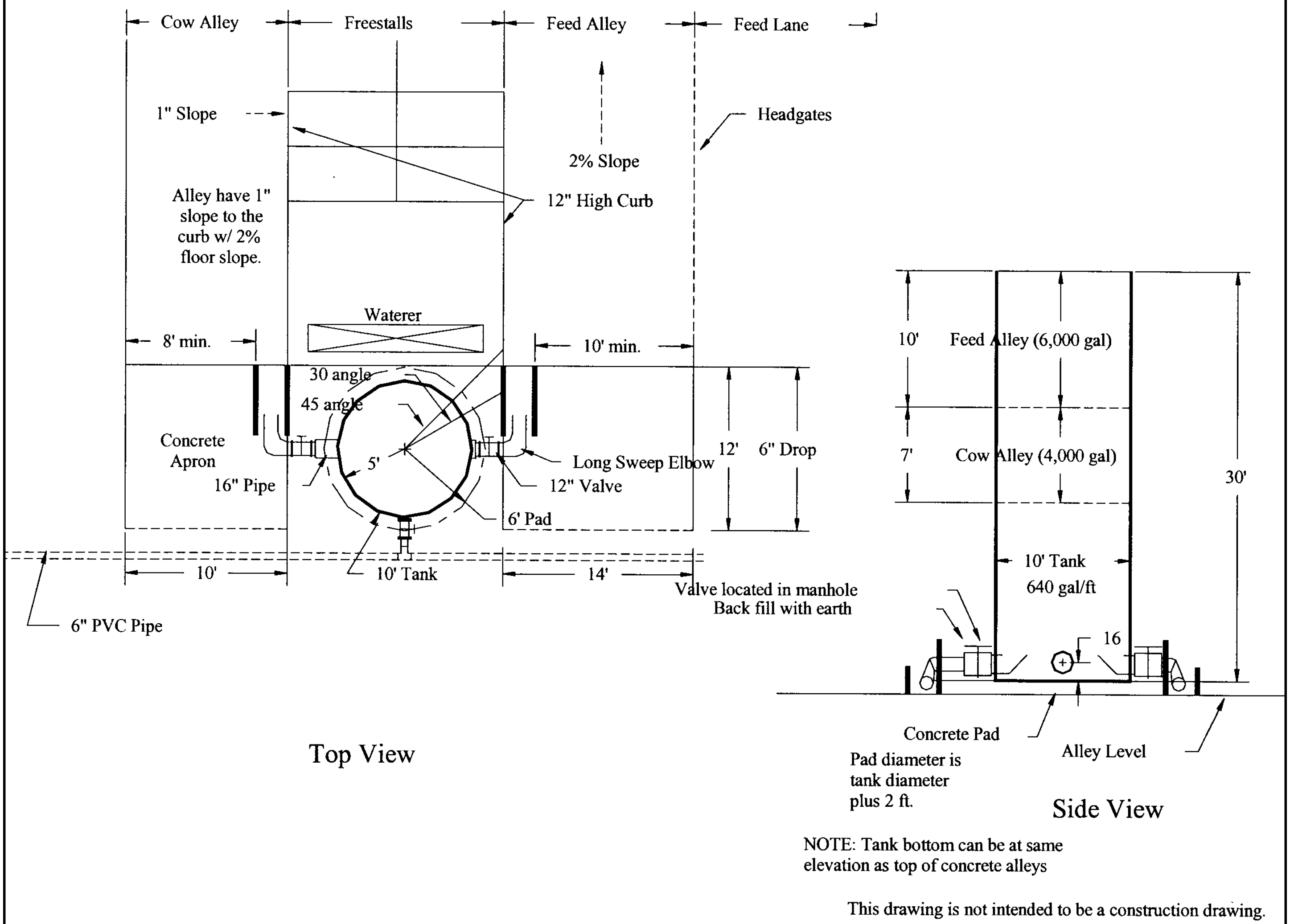


Figure 2.



Cow Alley
Freestalls
Feed Alley
Feed Lane
1" Slope
Headgates
2% Slope
Alley have 1" slope to the curb w/ 2% floor slope.
12" High Curb
Waterer
8' min.
10' min.
30 angle
45 angle
Concrete Apron
5'
Long Sweep Elbow
12'
6" Drop
16" Pipe
12" Valve
6' Pad
10'
10' Tank
14'
Valve located in manhole
Back fill with earth
6" PVC Pipe
Top View
10'
Feed Alley (6,000 gal)
7'
Cow Alley (4,000 gal)
30'
10' Tank
640 gal/ft
16
Concrete Pad
Pad diameter is tank diameter plus 2 ft.
Alley Level
Side View
NOTE: Tank bottom can be at same elevation as top of concrete alleys
This drawing is not intended to be a construction drawing.