

MU Guide

Land Application Equipment for Livestock and Poultry Manure Management

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Land application is the most desirable method for making use of the nutrients and organic matter in animal manure. The value of the manure is usually maximized if it can be substituted for the purchase of commercial fertilizer.

Under the U.S. Environmental Protection Agency's Unified National Strategy for Animal Feeding Operations, the desired outcome is for all concentrated animal feeding operations to develop and implement a *comprehensive nutrient management plan*. This plan should address, as necessary, feed management, manure handling and storage, a nutrient management plan for land application of manure, land management, record keeping, and options for making use of manure. In addition to nutrients, the plan should address other pollutants, such as pathogens, to minimize the effects of animal feeding operations on water quality and public health.

At a minimum, nutrient management should prevent the application of nutrients at rates that exceed the capacity of the soil and the anticipated needs of crops. To determine nutrient needs and content, soils and manure should be tested and nutrient removal by crop yield should be evaluated. Manure application equipment should be calibrated to ensure that the intended quantity of material is being applied. Records of crops removed annually and the total amount of manure applied should be kept to maintain the desired nutrient balance. Electronic totalizing flow-rate meters in slurry and lagoon pumping systems are frequently used by custom applicators to calibrate equipment and record the amount applied per acre. These meters can also be a component in site-specific variable-rate application. GPS guidance systems can facilitate record keeping and help in maintaining correct "swath width" for broadcast applicators, including maintaining proper separation distances from wells, streams, water impoundments, sinkholes and property lines.

Environmental comparisons

Table 1 compares various manure application systems by means of an environmental rating system

developed at the University of Nebraska and based on five important factors. The first of these is that manure application equipment should provide uniform application, similar to that of fertilizer or chemical applicators, and should be easily calibrated for the desired rate per acre. Timeliness of manure application is an important consideration because there is usually a short window of time when field conditions are suitable and losses will be minimized. Conservation of ammonium nitrogen varies with the method of storage and with weather conditions after manure is applied and before it is incorporated into the soil and used by the crop. Manure application systems vary widely in the resulting odor emissions (nuisances) after application. This is often the determining factor in the choice of application method, especially in densely populated locations.

The high volumes and weights of manure normally handled, usually during the spring and fall when the soil is wet and subject to compaction, give an advantage

Table 1. Environmental comparison of manure application systems.

	Uniformity of application	Conservation of ammonia	Odor	Compaction	Timeliness of application
Solid systems					
Box spreader: tractor pulled	F	VP	F	F	P
Box spreader: truck mounted	F	VP	F	F	F
Flail spreader	F	VP	F	F	P
Dump truck	VP	VP	F	P	F
Liquid systems: surface spread					
Liquid tanker with splash plate	P	P	P	P	F
Liquid tanker with drop hoses	F	F	G	P	F
Big gun irrigation system	P	P	VP	E	E
Center-pivot irrigation system	F	P	VP	E	E
Liquid systems: incorporation					
Tanker/knife injectors	G	E	E	P	F
Tanker/shallow incorporation	G	E	E	P	F
Drag-hose/shallow incorporation	G	E	E	G	G

E = excellent; G = Good; F = Fair; P = Poor; VP = very poor

to systems that pump the manure to the field. In general, systems treat manure as a solid or semisolid to be hauled and spread, or as a liquid (such as a slurry or lagoon effluent) that can be pumped and injected by a tractor-drawn applicator or surface applied by irrigation.

Surface application of liquid manure without immediate incorporation can result in significant losses of the available nitrogen due to ammonia volatilization. Ammonia nitrogen losses vary with application method and with soil and climate conditions from near zero to as much as 80 percent due to ammonia volatilization, depending on the time between land application and incorporation of the manure (Table 2). Without incorporation, most volatilization losses occur within the first 24 hours after land application. The Missouri Department of Natural Resources requires use of an ammonia loss factor of 40 percent on permitted facilities using the plant available nitrogen (PAN) procedure.

Slurries are much more odorous than lagoon effluent or dry solid manure. Aerosol sprays produced by mixing manure and air can carry odors for considerable distances as evidenced from the data in Table 3.

The equipment used for land application is usually determined by the solids content of the manure. The consistency of manure is usually classified as solid, semisolid, slurry or liquid, depending on its fluidity. Figure 1 relates the consistency of manure from various species to the solids content. This guide will discuss land application equipment used for each of the four classifications in Figure 1.

Solid and semisolid manure

Solid manure management systems typically handle less weight and volume than liquid systems because evaporation and separation reduce the amount of water in the manure. The volume of manure may be greater if large amounts of bedding have been added to

Table 2. Nitrogen losses during land application. Percent of total nitrogen lost within 4 days of application.

Application method	Type of waste	Nitrogen lost (%)
Broadcast	Solid	15–30
	Liquid	10–25
Broadcast with immediate incorporation	Solid	1–5
	Liquid	1–5
Knifing	Liquid	0–2
Sprinkler irrigation	Liquid	15–75

Table 3. Odor emission rates during land spreading of pig slurry from manure storage.

Application method	Total odor emissions*
Conventional tanker with splash plate	1,322
Irrigation	6,250
Shallow incorporation	503
Deep injection	689
Low trajectory spreader with 15 trailing hoses	130

* Odor units per 1,000 gallons of slurry applied, as measured by olfactometer.

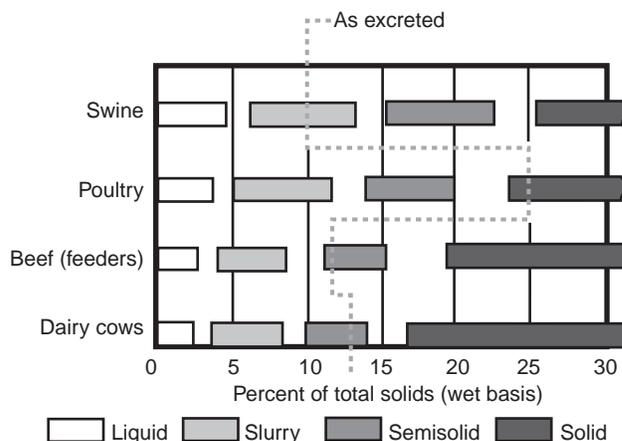


Figure 1. Relative handling characteristics of different types of manure.

increase the solids content and make the manure less fluid. Solid manure handling equipment may have lower cost and power requirements; however, the labor required for operation and management is generally greater than for other methods.

The most common equipment for applying solids to the land is a rear-discharge, box-type spreader equipped with beaters that broadcast the manure over a width of several feet (Figure 2). Usually, the manure is conveyed to the beaters at the rear by slats attached at each end to a sprocket-driven chain. Some use a powered front endgate to push the material to the beaters at the rear.



Figure 2. This box-type spreader is equipped with a chain-driven conveyor to move solid manure to the beaters for rear discharge.



Figure 3. This side-discharge, hopper-type spreader can be used for solid and semisolid manure.

To handle semisolid manure, a tight-fitting, closable rear endgate is required. Some spreaders have a side discharge; most of these have V-shaped hoppers and feed the material to the discharge with augers (Figure 3). A rotating expeller slings the material out of the discharge port. The application rate is varied by an adjustable gate opening, usually operated by a hydraulic cylinder. Flail-type spreaders have a semicircular hopper bottom and a rotating shaft with chain-suspended hammers to fling the material from the hopper. The flail-type and the side-discharge spreaders are adapted to both semisolid and solid manure.

Manure spreaders may be tractor-drawn models or they may be mounted on a truck. Most tractor-drawn spreaders are PTO operated, but some are driven from the ground wheels. Some are hydraulically powered for greater speed variation, especially for the apron drive, to vary the application rate. In the past, spreader capacities varied from about 30 to 400 cubic feet with tractor horsepower requirements ranging from 10 to more than 120. **Some newer spreaders have capacities and power requirements approximately double those figures.** Ratings may be expressed in different ways, from cubic feet struck level to bushels heaped. One bushel equals 1.25 cubic feet.

The distance between successive passes of the spreader must be properly adjusted to achieve the best uniformity of application. For details on calibrating manure spreaders and measuring manure spreader uniformity, see MU publications WQ213, *Calibrating Manure Spreaders*, and WQ214, *Measuring Manure Spreader Uniformity*.

Liquid (slurry) manure

Agitation of the manure storage before and during pumping is recommended to reduce the buildup of solids and for a consistent application of sampled nutrients. In the past, most slurry has been transported to the field in tank wagons equipped to either broadcast the slurry onto the soil surface (Figure 4) or to inject the slurry below the surface. Custom operators and large animal feeding operations may use self-propelled applicators, and tender trucks to keep the applicator operating in the field (Figures 5A and 5B). As operations become larger and the potential odor and environmental problems become greater, there is a trend toward injecting or incorporating the slurry with a drag-hose, tractor-drawn applicator (Figures 6 and 7). Injection or immediate incorporation can prevent the loss of ammonia nitrogen to the air. Where odor and erosion problems are minimal, slurry can be surface-applied by sprinkler irrigation with a choice of fixed sprinklers, hand-carried sprinklers, traveling guns or specially equipped center-pivot irrigators. High fiber slurry, such as from dairy and beef animals, may require chopper pumps. Care must be taken not to overapply manure nutrients when using sprinkler irrigation equipment with slurry manure.



Figure 4. This tank-type applicator is broadcasting slurry onto the soil surface.



Figure 5A. This self-propelled, tank-type applicator is equipped to inject slurry below the soil surface, thus reducing nutrient losses and odor emissions.



Figure 5B. The self-propelled, tank-type applicator shown in Figure 5A is being refilled from a tender truck.



Figure 6. This drag-hose applicator can inject liquid and slurry below the soil surface.



Figure 7. The aggressiveness of this incorporating applicator can be increased by angling the tine shaft.



Figure 8. This PTO-powered, high-pressure centrifugal pump fed by a submersible chopper pump, is typical of pumps used with irrigation systems and drag-hose applicators handling slurry manure.

An open-impeller centrifugal pump capable of handling large solids up to 1 inch in diameter may be selected for pumping livestock slurry to minimize clogging problems. Open impeller pumps may handle liquids with solids content up to 15 percent. They often have a sharp rotating blade at the pump inlet to chop large material such as bedding, hay, or silage.

Used for liquids with high solids content, foot valves can leak, thus requiring re-priming of centrifugal pumps used for livestock waste. To avoid priming problems, install the pump below the reservoir level. To reduce the risk of overland flow in case of a piping failure, the pump may be installed in a dry well.

Irrigating high-fiber slurry may require large sprinkler nozzles to prevent clogging. More details on pumps and irrigation can be found in the following section on applying lagoon effluent.

Injector-type applicators (either tanker mounted or tractor-mounted and hose-fed) usually have chisels or sweeps spaced at least 20 inches apart on a toolbar. Use of wide sweeps for injection results in a more uniform application of manure than knives. Generally, injecting with wide sweeps operating 4–5 inches below the surface takes less fuel and may have an advantage in sandy soils to place the nutrients near the root zone to minimize leaching. Knife injectors may have an advantage

in heavy soils if subsoiling is needed to break up a clay pan. Large amounts of manure applied in a knife channel a short time before planting may result in damage to seedling root development.

Some injectors have paired disks or other furrow closing or covering devices to lessen the chance for odor emission or erosion of the slurry from the slot. Manufacturers are striving to develop applicators that create minimal disturbance of sod or residue cover (to aid in soil conservation compliance). Each opener may require from 10 to 30 or more horsepower, depending on soil, depth, opener design and speed.

The incorporating-type applicators mix the slurry with the surface soil layer using rotating spikes (e.g., an Aer-Way type, Figure 7) or knives (e.g., a rotary tiller). These applicators may take considerably less power than the injector-type, depending on the degree of incorporation. More odor may be emitted from incorporated manure than from injected manure.

Liquid manure and lagoon effluent

Land application by sprinkler irrigation or by a drag-hose, tractor-mounted applicator are the current practical methods of transporting and applying large volumes of lagoon effluent or ponded lot runoff. Drag-hose applicators can decrease odor problems and the loss of ammonia nitrogen to the air by incorporating the manure. The advantages of irrigation include reduced cost and lower power and labor requirements. However, land application of manure slurry and lagoon effluent with irrigation equipment requires a higher level of management than other methods of spreading in order to avoid pollution and nuisance problems. Labor costs are reduced by permanently installed underground pipes to sprinkler risers, center-pivot irrigators or hose attachment points for traveling guns or drag-hose applicators.

Pump selection

Solids size and content and the required pumping pressure and flow rate are major factors in selecting a waste-handling pump. Fewer pumping problems result if solids are settled out (as in a lagoon), mechanically separated, or if dilution water is added (as by rain on a lagoon or feedlot). Semi-open impellers can handle water with small solids, such as swine lagoon liquid. Large closed-impeller pumps are efficient for high-pressure application of effluent without solids, such as municipal lagoons and others where the solids have been settled or separated out.

Pressure requirements vary considerably with the application — sprinkler irrigation requires high pressures, typically from 40 to 120 psi at the sprinkler, depending on the nozzle diameter. Towed-hose, tractor-drawn applicators require sufficient pressure to overcome the friction losses in the conduit from the intake of the conduit to the applicator and in the applicator manifold. Many custom pumpers of livestock lagoons

Table 4. Solids content for various liquid manure handling systems.

System	Solids content, percent
Manure pit	
Swine	4–8
Cattle	10–15
Holding pond	
Pit overflow	1–3
Feedlot runoff	less than 1
Dairy barn washwater	less than 1
Lagoon	
Single or first stage	
Swine	½–1
Cattle	1–2
Second stage	Less than ½

use a hydraulically driven, submersible chopper pump to feed a centrifugal booster pump at the side of the lagoon (Figure 8). This system eliminates priming and inlet screen problems.

Solids content of livestock waste varies with livestock type, housing, and waste collection system. Table 4 shows the typical solids content for various liquid livestock waste handling systems. Figure 1 shows the relative handling characteristics of different types of manure and percent total solids for various species.

Irrigation pumps for liquid wastes

Effluents from manure lagoons, feedlot runoff holding ponds, and milkhouses (less than 4 percent solids content) can often be handled by conventional irrigation pumps and equipment. Large quantities of these wastes are usually encountered in a system. Pipeline transport is most common because it is impractical to transport such highly dilute manure by tank wagon or truck. Single-stage, standard closed-impeller centrifugal pumps work well. Semi-open impeller pumps are sometimes desirable to reduce clogging. Large solids should be screened out at the pump inlet. The screen area should be as large as possible to minimize velocities into



Figure 9. To prevent intake of floating debris, suspend an irrigation pump intake about 2 feet below the surface of a lagoon.

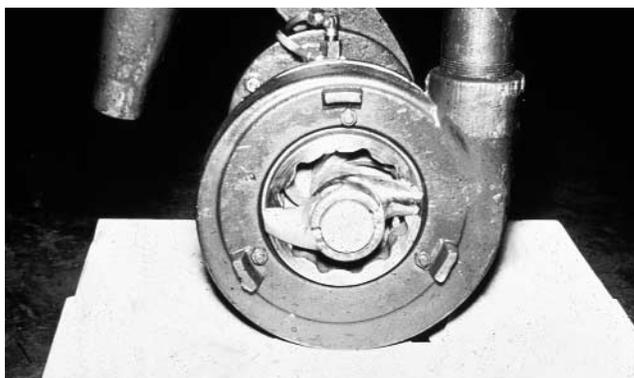


Figure 10. Chopper blades on the intake of a centrifugal pump.

the screen and to eliminate plugging. A trash guard with a 5- to 15-foot radius encircling the screen is often beneficial. The guard can be constructed with small-diameter woven or meshed wire. When large sprinkler nozzles are used, most operators float the intake 18 to 24 inches below the surface and do not use an intake strainer (Figure 9). This keeps the intake free of floating debris, and above the sludge layer at the bottom of the lagoon. The pump should be located as far as is practicable from the inlet pipe to a livestock lagoon. If the lagoon is located in an area where there is a prevailing wind direc-

Table 5. Typical manure pump characteristics.

Pump type	Maximum solids content percent	Pumping rate gpm	Pumping head, feet of water	Power requirements hp	Applications
Centrifugal					
Open & semi-open impeller					
Vertical shaft chopper	10–12	1000–3000	25–75	65+	Gravity irrigation Tanker filling Pit agitation Transfer to storage
Inclined shaft chopper	10–12	3000–5000	30–35	60+	Earth storage agitation Gravity irrigation Tanker filling
Closed impeller	4–6	500+	200+	50+	Sprinkler irrigation Recirculation
Helical screw	4–6	200–300	200+		Sprinkler irrigation
Self-loading tanker					
Centrifugal, open impeller	6–8	200–300	N/A	75+	Tanker loading
Vacuum pump	8–10	200–300	N/A	50+	Tanker loading

tion, the pump should be located on the upwind side of the lagoon since solids tend to migrate to the downwind side by wind and wave action.

Swine, beef and dairy manure as excreted contains about 10–12 percent solids, whereas sheep and poultry manure contains about 25 percent solids. To be pumped with conventional irrigation pumps, the solids content should be diluted to 4 percent or less. Because of dilution from rainfall, water (effluent) pumped from lagoons typically contains less than 1–2 percent solids and presents no special pumping problem if no large or fibrous solids are present. If long, fibrous solids are present in the liquid being pumped, a chopper pump may be required (Figure 10). The larger the pump size, the larger the solid particles it can pump.

Positive displacement helical screw pumps can handle liquids with high solids content, but they must be free of hard abrasive solids such as nails, sand or stones. Do not operate these pumps dry. A common practice is to add a small stream of fresh water directly into the pump inlet to ensure lubrication during operation. With positive displacement pumps, monitor line pressure when sprinkler irrigating directly out of liquid

manure pits. If irrigation nozzles clog, pressure buildup can burst pipes.

Some high-capacity centrifugal pumps have two discharges, one to fill a tanker, the other a nozzle to agitate a pit or lagoon to suspend the solids (Figure 11). All-steel pumps are less susceptible to corrosion than pumps with brass impellers. Flushing the system with clean water after use prolongs equipment life by reducing corrosion. Table 5 shows data on several common types of manure pumps.

Pipelines

As a general rule, pipelines should be sized to limit fluid velocities in the pipe to 5 fps (feet per second) to reduce water hammer and excessive friction losses. Size pump suction lines so that velocities are less than 2 to 3 fps. Table 6 shows capacities and friction loss for various pipe sizes based on maximum velocity of 5 fps.

Table 7 contains friction loss data for portable aluminum pipe with couplings at 30 foot intervals and for PVC pipe. For 20-foot lengths of aluminum pipe, increase values by 7 percent. Table 8 lists recommended pipe sizes for various flow rate ranges.

Table 6. Friction loss in feet of head per 100 feet of pipe for flow rates with velocities limited to 5 fps.

Pipe size ² @ gpm	Friction loss in feet of head for pipe material ¹		
	Steel	Aluminum	PVC
4 inch @ 200	4.4	3.1	2.1
6 inch @ 400	2.7	2.0	1.3
8 inch @ 750	1.7	1.2	0.8
10 inch @ 1200	1.4	1.0	0.7
12 inch @ 1750	1.2	0.8	0.5

1. To convert head in feet of water to pounds per sq inch (psi), multiply feet by 0.43. To convert psi to feet of head, multiply psi by 2.31.
2. Nominal inside pipe diameter.



Figure 11. This PTO-powered, high-capacity pump can either fill tankers or bypass effluent to agitate a lagoon, or both.

Table 7. Friction loss, feet of head per 100 feet of pipe.

Flow rate (gpm)	4-in.		6-in.		8-in		10-in.		12-in.	
	Aluminum	PVC	Aluminum	PVC	Aluminum	PVC	Aluminum	PVC	Aluminum	PVC
100	0.90	0.60								
150	1.80	1.20	0.20	0.20						
200	3.00	2.10	0.40	0.30	0.1	0.1				
250	4.80	3.20	0.60	0.40	0.1	0.1	0.1			
300	6.20	4.30	0.80	0.60	0.2	0.1	0.1			
400	10.6	7.20	1.50	1.00	0.3	0.2	0.1	0.1		
500	17.1	11.4	2.40	1.60	0.6	0.4	0.2	0.1	0.1	0.1
750	36.3	24.1	5.00	3.40	1.3	0.8	0.4	0.3	0.1	0.1
1,000	61.8	41.1	8.60	5.70	2.1	1.4	0.7	0.5	0.3	0.2
1,250	93.3	62.1	13.0	8.60	3.2	2.1	1.1	0.7	0.4	0.3
1,500	130.7	87.0	18.2	12.1	4.5	3.0	1.5	1.0	0.6	0.4
1,750	173.9	115.7	24.2	16.1	6.0	4.0	2.0	1.3	0.9	0.6
2,000	222.5	148.1	31.0	20.6	7.7	5.1	2.6	1.7	1.1	0.7

Note: Flow rates below the values in boldfaced type for each pipe size exceed the recommended 5 feet per second velocity.

Source: *Livestock Waste Facilities Handbook*, MWPS-18, Table 8-2.

Table 8. Recommended pipe sizes for ranges of flow rates in gallons/minute.

Pipe diameter	Aluminum		PVC	
	Flow rate range*	Maximum**	Flow rate range*	Maximum**
2"	0 – 25	35	0 – 30	40
3"	25 – 80	100	30 – 90	115
4"	80 – 170	200	90 – 200	245
5"	170 – 300	370	200 – 350	440
6"	300 – 480	600	350 – 575	715
8"	480 – 1000	1250	575 – 1225	1525
10"	1000 – 1900	2300	1225 – 2200	2740
12"	1900 – 3000	3800	2220 – 3560	4440

* Flow rate range was calculated based on a maximum pipe friction loss of approximately 1 psi/100 feet of pipe.

**Maximum flow rate was calculated based on a maximum pipe friction loss of approximately 1.5 psi/100 feet of pipe.

Note: This table provides general guidelines only. Larger pipe size may be required to keep total operating pressure within reason for long lengths of pipeline or large elevation differences between the pump and the application area.



Figure 12. Hose carts provide a compact, fast means to transport, lay out and take up flexible drag hose or feeder hose.

Hoselines

Custom operators of traveling guns and drag-hose applicators frequently use feeder hoses in lieu of rigid pipe for ease in loading the conduit for transport with a reel rather than loading pipe onto a trailer (Figure 12). Because of the high cost of hose, operators may tolerate higher pressure losses with hose than with pipe. Estimated pressure losses due to friction are shown in Table 9. Traveling guns may use either a soft hose or a hard hose. Hard-hose travelers are more convenient for fields with varying lengths of travel but have higher friction losses with a given hose diameter.

Calculating pump horsepower

Pump power requirements are determined by flow rate, pump efficiency and total head (the sum of total lift, friction losses, and the required pressure at the irrigator, expressed in feet) as follows:

$$\text{Horsepower} = \frac{\text{gpm} \times \text{total head in feet}}{3960 \times \text{pump efficiency (decimal)}}$$

Table 9. Estimated pressure loss in psi (due to friction) for 100 feet of soft hose*/for 100 feet of hard hose.**

Flow (gpm)	Nominal inside diameter in inches				
	2.5	3.0	4.0	4.5	5.0
100	1.6/2.8				
150	3.4/6.0	1.4/2.5			
200	5.6/10.2	2.4/4.2			
250	—	3.6/6.2	0.9/1.8		
300	—	5.1/8.8	1.3/2.4	0.6/1.2	
400	—	—	2.3/3.7	1.3/2.1	
500	—	—	3.5/5.8	2.1/3.2	1.1/1.9
600	—	—	4.9/8.0	2.7/4.5	1.6/2.7
700	—	—	—	3.6/6.0	2.1/3.6
800	—	—	—	4.6/7.7	2.7/4.6
900	—	—	—	—	3.4/5.9
1,000	—	—	—	—	4.2/7.0

* Estimated loss when operated at about 100 psi, contact the manufacturer for more accurate data. Some operators add about 10% to the soft hose pressure loss for pumping slurry to an injector because of less hose expansion at less than 100 psi .

** Estimated loss, values vary due to differences in inside diameter, contact the manufacturer for more accurate data.

Example: You want to calculate the power required for a traveling gun with 90 psi (208 ft) pressure at the discharge (at the nozzle) operating 40 feet above the lagoon water surface at 700 gpm flow rate with total pipe friction losses for 3,000 feet of 8" x 30' aluminum pipe at about 35 feet (or 15 psi) and hose friction for a hard hose 4.5" x 1200' at 72 psi (or about 166 feet). Assume the pump efficiency is 70 percent.

$$\begin{aligned} \text{Horsepower} &= \frac{700 \text{ gpm} \times (208 + 40 + 35 + 166 = 449)}{3960 \times 0.70 \text{ pump efficiency}} \\ &= 113.4 \text{ horsepower} \end{aligned}$$

Note: If the pump is operating near the water level, almost the entire 449 feet of head will apply at the pump discharge, subjecting the pipe to about 194 psi pressure, which may exceed the pressure rating of the pipe. If so, the pumping rate may have to be reduced to a point where the pipe will tolerate the operating pressure. This will result in a smaller coverage by the gun; thus, the travel lane spacing must be reduced.

Sprinkler systems

Although the equipment required for pumping and distributing lagoon effluent may be similar to conventional irrigation equipment, the smaller volume of water handled in most livestock lagoons generally allows the use of smaller and less costly systems. The type of sprinkler system chosen may depend on the particle size of the solids in the waste. The system capacity and type selected may depend on the capital available and the annual time window and labor available for pumping. Table 10 shows the estimated annual lagoon pumpdown time in hours for various animal species and systems.

Table 10. Pumping time required to irrigate the annual average pumpdown volume for lagoons.

Animal type and capacity	Volume acre-inches per year	System flow rate gpm	Average pumping time, hrs	Pipe size (aluminum) inches
Beef, total confinement, per 100 head	5.0	100	22.5	3-4
		300	7.5	5
		500	4.5	6
Beef, open dirt lot, per 100 head	19.0	100	85.5	3-4
		300	28.5	5
		500	17.1	6
Swine, total confinement, per 1,000 finishing hogs	16.0	100	72.0	3-4
		300	24.0	5
		500	14.4	6
Dairy, per 100 cows	28.0	100	126.0	3-4
		300	42.0	5
		500	25.2	6
Poultry, total confinement, per 10,000 layers	3.6	100	16.2	3-4
		300	5.4	5
		500	3.2	6

Table 11. Labor and number of sets for 10 sprinkled acres.

System	No. of sets/ 10 acres	Labor/set (minutes)	Labor/10 acres (hours)
Hand-move ^a	5.5	70	6.4
Stationary big gun ^b	4.5	70	5.2
Traveling big gun ^c	1.0	60	1.0

a. ¼-mile lateral with 60' between sets
b. 350' wetted diameter
c. 350' wetted diameter and ¼ mile travel
Source: *Livestock Waste Facilities Handbook*, MWPS-18, Table 9-8.

Table 11 gives the labor requirement and the number of sets for sprinkling 10 acres with various systems.

Hand-move sprinkler systems. The simplest and least costly sprinkler systems are the hand-carry or hand-move types that require labor input for setting up and moving the system. These systems usually have a 4-inch or 6-inch mainline pipe with one or more laterals, which tee off the main line at appropriate intervals. The laterals are assembled from 20-, 30-, or 40-foot sections of aluminum pipe and with sprinklers that cover 60- to 80-foot circles.

As the pump runs, a strip is sprinkled as long as the lateral and as wide as the cover diameter of an individual sprinkler. That strip is one **set**. After that set is irrigated, the pump is shut off and the pipe is disassembled, moved to a new location, reassembled, and the new set is sprinkled.

With a typical system, a ¼-mile lateral covers 1.8 acres with each 60-foot move; 32 sprinklers can discharge 10 gpm each for a total 320 gpm pumped through 5-inch pipe. The application rate is 0.4 in/hr and the power required is about 20 hp.



Figure 13. The use of aluminum pipe requires more labor than flexible hose requires.



Figure 14. Small sprinklers (up to ¾-inch diameter) can be used to irrigate lagoon effluent onto irregularly shaped fields.



Figure 15. Small hand-set sprinklers require more labor than other systems but may be more economical for small operations.

Advantages:

- Low initial investment; consider a used system.
- Few mechanical parts to malfunction.
- Low power requirement (50 psi at the sprinklers).
- Adaptable to field shape. Different lengths can be set and run in any direction to get isolated corners.

Disadvantages:

- High labor requirement; individual pipe sections are moved, which can be an unpleasant task with manure (Figure 13).
- Small sprinklers can plug.

Nozzle sizes for these systems are generally in the



Figure 16. Stationary big gun on wheels to facilitate moving.

$\frac{1}{2}$ to 1-inch range (Figure 14) and typically cover $\frac{1}{2}$ to 2 acres per sprinkler depending on nozzle size and system operating pressure. Although labor input is required, these systems may be applicable for small lagoons (Figure 15).

Stationary big gun. This system is applicable to many waste disposal systems. The system includes a pump and a main line similar to the handmove system, but with one or more large volume gun sprinklers replacing small hand-move sprinklers. Advantages of the big gun system include larger flow rates and a larger wetted area so less labor is required in moving the sprinkler. Some big guns are wheel mounted to facilitate moving the unit (Figure 16). Stationary big guns typically have nozzle sizes ranging from 1–2 inches, and operate best at pressures of 80–120 psi. Coverage areas of 2.5–6.0 acres can be obtained with proper selection of nozzle size and operating pressure. Although stationary big guns cost more than smaller hand-carry systems, the reduced labor cost and higher flow rates may offset the higher cost.

A typical big gun discharging 330 gpm sprinkles a 350' diameter circle (2.2 acres) at 0.33 in/hr and 90 psi. The power requirement is about 30 hp.

Advantages:

- Few mechanical parts to malfunction.
- Few plugging problems with large nozzle.
- Flexible with respect to land area.

- Pipe requirements are slightly less than with small sprinklers.
- Moderate labor requirement.

Disadvantages:

- Moderate to high initial investment.
- High power requirement (90 psi at the sprinkler).
- Uneven distribution in windy areas.

Sprinkler systems require labor for movement from one set or location to another to ensure that the soil does not become saturated.

Traveling big gun. The traveling big gun is justifiable on large acreages irrigated several times a year. A single conventional gun sprinkler is mounted on a running gear that is pulled across the field. This self-propelled unit covers larger areas than stationary sprinklers of the same size and has variable speeds to control application depths. Generally, a water-driven winch on the machine pulls the traveling gun across the ground by a cable anchored at the end of the field (a soft-hose traveling gun, Figure 17), or the gun is pulled by a hard hose feeding the water to the traveling gun. A small engine may also drive the winch (on some models). Such an arrangement prevents solids from plugging the water turbine. However, plugging problems are minimal when pumping effluent from properly sized and operated lagoons. An engine-driven cable winch on a soft-hose traveler can be mounted on the traveler or anchored at the far end of the field.

Effluent is usually carried from the lagoon to the point of attachment in the field by portable aluminum pipe (Figure 18) or underground plastic pipe. Traveling guns require pressure ranging from 75–120 psi with flow rates from 100–800 gpm. Pressure required at the pump may range from 80–200 psi, normally being higher for hard-hose travelers than for soft-hose traveling guns. Soft-hose traveling guns usually travel either 660' or 1320' on each set. The hose is a major cost item on a traveling gun. Typical coverages range from 4 acres per set for small traveling guns to 13 acres per set for large traveling guns, depending on nozzle diameter, operating pressure, sprinkler angle and hose length.



Figure 17. Soft-hose traveling big gun irrigators are frequently the system of choice for land application of lagoon effluent.



Figure 18. Portable aluminum pipe is available in a variety of sizes for use as a low-friction feeder conduit for irrigators and tractor-drawn, drag-hose applicators and injectors.

Large traveling guns are too costly for pumping typical livestock lagoons, unless also used for crop irrigation or for custom application of effluent. A common size irrigates 10 acres per set compared to about 2 acres for a stationary gun. Most manufacturers of traveling guns now make small units that are competitive in cost with the hand-move or stationary big gun sprinklers. These units are adaptable to the rolling terrain often encountered near lagoons and are easily transported.

Advantages:

- Lower labor requirements other systems listed.
- Few or no plugging problems with large nozzle.
- Flexible with respect to land area.

Disadvantages:

- Higher initial cost than the previous systems.
- High power requirement.
- More mechanical parts than the other systems, especially with an auxiliary engine.

Center-pivot irrigation systems. Center-pivot systems (Figure 19), which move around in a circle like the spokes of a wheel, have been used for some large livestock operations and are customarily used for irrigating effluent from municipal systems. Center-pivot irrigators are becoming more common for land application of livestock manure as the size of operations increases. Center pivots offer almost complete automation. Disadvantages include high initial cost, small sprinklers, and a fixed area of coverage. Systems with nozzles less than 1/4-inch diameter are not recommended because solids in the effluent could plug them.

In some cases, an irrigation reservoir also serves as the lagoon receiving livestock waste. In such cases, take care that the reservoir does not overflow, or that the overflow does not violate pollution laws and regulations.

If a lagoon and an irrigation reservoir are located close together, a properly designed pump intake system may allow simultaneous withdrawal of liquid from both the irrigation reservoir and the lagoon. If the irrigation water source and the lagoon are some distance apart, a pump at the lagoon will probably be required to inject the lagoon effluent into the pipe downstream from the



Figure 19. Center-pivot irrigator. Source: Valmont Slurry Manager.

pump serving the center-pivot system. This method may also be used to inject manure pit effluent into an irrigation system. Another alternative is to pump or drain the lagoon effluent into the irrigation reservoir provided there is sufficient volume available.

Special center-pivot systems are available with sequencing big guns for irrigating undiluted manure from pits and storage ponds.

Side-roll systems, which roll sideways across a rectangular field, are more adaptable than center-pivot systems but are limited to low-growing crops. Crop clearance is slightly less than half the diameter of the wheel at each lateral joint. Side-roll systems require rectangular fields and have small sprinklers and several mechanical devices to deal with.

Solid-set systems throughout a field are generally



Figure 20. Gated pipe systems are occasionally fed by gravity from a lagoon at a higher elevation.

too expensive to install, except perhaps for small systems using small-diameter plastic pipe, or for year-round effluent disposal fields. The risers and sprinklers are always in place and must be avoided with machinery and protected from animals. Solid-set sprinkler systems are the most flexible and labor-saving of all systems. If automation is desired, remote control valves can be programmed to operate separate laterals or blocks in sequence.

Gated pipe systems (Figure 20) can provide low-pressure application at low cost and with low energy requirements. Labor requirements, however, may be high, and uniformity of application may be low.

Application rate and depth:

Three performance characteristics are critical to proper land application of wastewater by irrigation. These performance characteristics are determined by site conditions and requirements as shown in the table that follows.

Performance characteristic	Determined by
Sprinkler application rate	Soil infiltration rate or soil permeability
Depth of application per irrigation event	Soil water-holding capacity (depends on soil type and moisture content at time of irrigation)
Total depth of effluent applied annually	Amount of nitrogen or other limiting nutrient allowed annually under nutrient management plan

Sprinkler application rate is a characteristic of sprinkler hardware and operating parameters (nozzle type, size, trajectory, pressure). Hence, sprinklers should be selected to be compatible with soil infiltration rate or permeability. If the sprinkler application rate is higher than the soil infiltration rate, the probability of runoff

increases. Since runoff must be prevented when irrigating with wastewater, sprinklers are often selected for the lowest application rate possible.

The maximum allowable rate of application (inches/hour) to prevent runoff depends on the intake rate of the soil. The intake rate of an initially dry soil typically decreases at a high rate as water is added and approaches the permeability of the soil. County soil surveys give the permeability of soils in inches per hour and the available water-holding capacity in inches/inch. Contact your local Natural Resources Conservation Service office for a current soil survey.

Depth of application per irrigation event should be matched to the water holding capacity of the soil. If soil surveys are not available, the data in EQ327, *Calibration of Lagoon Irrigating Equipment*, may be used as a guide. The total amount (inches) of an application depends on the water holding capacity (moisture deficit) of the soil at the time of application.

Exceeding the water-holding capacity of the soil can result in runoff and contamination of surface water or percolation into groundwater. Depth of application is determined by duration of operation in the case of stationary sprinklers, and by travel speed in the case of traveling sprinklers.

The total depth of effluent applied annually should provide the target amount of nutrients to the receiving management plan area. This may be accomplished in a single irrigation event, or may require several separate applications, depending on site conditions and annual depth of application. See MU publication EQ327 for more information about determining sprinkler application rate and the depth of application per irrigation event and calculating the total depth of effluent to be applied annually.

For further information

Agricultural Waste Management Field Handbook, Part 651, National Engineering Handbook. 1992. Washington, D.C.: Natural Resources Conservation Service.

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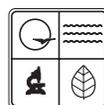
G 1157 *Lagoon Pumping and Irrigating Equipment*
G 1158 *Recycling Lagoon Water for Manure Flushing Systems*
EQ 201 *Reduce Environmental Problems with Proper Land Application of Animal Wastes*
EQ 202 *Land Application Considerations for Animal Wastes*
EQ 219 *Separation Distances for Livestock Manure Management Systems*
EQ 327 *Calibration of Lagoon Irrigating Equipment*
WQ 324 *Solids Removal from Livestock Manure Lagoons*

Midwest Plan Service publications

MWPS-18 *Livestock Waste Facilities Handbook*
MWPS-30 *Sprinkler Irrigation Systems*

Northeast Regional Agricultural Engineering Service publications

NRAES-89 *Liquid Manure Application Systems Design Manual*



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