Selecting the Appropriate Land Application Method

The land application of livestock manure is facing growing scrutiny because of potential surface water and groundwater contamination as well as odor nuisances. As a result, when selecting and operating manure application equipment, producers must consider environmental issues along with materials handling and economic factors. When issues related to land application equipment are discussed in this lesson, producers are encouraged to evaluate their own sampling and record-keeping program. This can be done with the aid of the Regulatory Compliance Assessment (see Appendix A).

In the following pages, we will consider those (1) features of manure application systems that enhance a producer's ability to use the nutrients in manure and (2) methods of calibrating manure application rates. Key considerations for minimizing the nuisances that neighbors experience during manure application will also be discussed.

Environmental considerations

Manure spreader as a fertilizer applicator. The fundamental principle underlying both best management practices and future regulatory requirements for manure application will be efficient crop use of applied nutrients. Manure spreaders will need to be managed like any other fertilizer or chemical applicator. Spreaders and irrigation equipment will need to apply manure uniformly, provide a consistent application rate between loads, and offer a simple means of calibration. Appropriate equipment selection and careful operator management will contribute to the efficient use of manure nutrients.

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Nitrogen conservation. The availability of the nitrogen and phosphorus in applied manure is usually out of balance with crop needs. Typically, high soil phosphorus levels result from long-term applications of manure. The ammonium fraction, originally representing roughly half of the potentially available nitrogen, is lost by the long-term open lot storage of manure, anaerobic lagoons, and the surface spreading of manure. Systems that conserve ammonium nitrogen and provide nutrients more in balance with crop needs increase the manure's economic value.

Odor nuisances. Odor nuisances are the primary driving factor behind more restrictive local zoning laws for agriculture. Better management of manure nutrients through increased reliance on manure storage and land application of manure in narrow windows of time may add to or reduce odor complaints due to weather conditions or the location and your relationship with neighbors. Manure application systems that minimize odor deserve consideration and preference when neighbors live near application sites.

Soil compaction. Manure spreaders are heavy. In a 3,000-gallon liquid manure tank, the manure alone weighs more than 12 tons. In addition, manure is often applied during the year, late fall and early spring, when high soil moisture levels and the potential for compaction are common. The impact of manure application on potential soil compaction requires consideration.

Timeliness of manure nutrient applications. The ability to move large quantities of manure during short periods of time is critical. Limited opportunities exist for the application of manure to meet crop nutrient needs and minimize nutrient loss. Investments and planning decisions that enhance the farm's capacity to move manure or to store manure in closer proximity application sites will facilitate the improved timing of manure applications.

Table 36-1. Environmental rating of various manure application systems.

Type of System	Uniformity of Application	Nitrogen (Ammonium) Conservation (no incorporation)	Odor Nuisances	Soil Compaction	Timeliness of Manure Application
Solid Systems					
Box spreader: tractor pulled	poor	very poor	fair	fair	poor
Box spreader: truck mounted	poor	very poor	fair	fair	fair
Flail-type spreader	fair	very poor	fair	fair	poor
Side discharge spreader	fair	very poor	fair	fair	poor
Spinner spreader	fair	very poor	fair	fair	fair
Dump truck	very poor	very poor	fair	poor	fair
Liquid Systems: Surface Spread					
Liquid tanker with splash plate	poor	poor	poor	poor	fair
Liquid tanker with drop hoses	fair	fair	good	poor	fair
Big gun irrigation system	good	very poor	very poor	excellent	excellent
Center pivot irrigation system	excellent	very poor	very poor	excellent	excellent
Liquid Systems: Incorporation					
Tanker with knife injectors	good	excellent	excellent	poor	fair
Tanker with shallow incorporation	good	excellent	excellent	poor	fair
Drag hose with shallow incorporation	good	excellent	excellent	good	good

Manure of 20% solids or more is typically handled by box-, side discharge, or spinner-type spreaders.

Solid manure application systems

Manure of 20% solids or more is typically handled by box-, side discharge, or spinner-type spreaders. Box-type spreaders range in size from under three tons (100 cubic ft) to 20 tons (725 cubic ft). Box spreaders provide either a feed apron or a moving gate for delivering manure to the rear of the spreader. A spreader mechanism at the rear of the spreader (paddles, flails, or augers) distributes the manure. Both truck-mounted and tractor-towed spreaders are common.

Flail-type spreaders provide an alternative for handling drier manure. They have a partially open top tank with chain flails for throwing manure out the spreader's side. Flail units have the capability of handling a wider range of manure moisture levels ranging from dry to thick slurries.

Side-discharge spreaders are open-top spreaders that use augers within the hopper to move wet manure toward a discharge gate. Manure is then discharged from the spreader by either a rotating paddle or set of spinning hammers. Side-discharge spreaders provide a uniform application of manure for many types of manure with the exception of dry poultry litter.

Spinner-type spreaders, used to apply dry poultry litter, are similar to the hopper-style spreaders used to apply dry commercial fertilizer or lime. Manure placed in the storage hopper is moved toward an adjustable gate via a chain drive. Manure then falls out of the spreader onto two spinning discs that propel the litter away from the spreader. Uniform application can easily be achieved with spinner spreaders by either varying the spinner speed or angle.

Application rates can be adjusted by changing the travel speed and opening or closing the opening on the spreader gate.

With the growing concern about the manure contamination of water and air resources, spreaders must be capable of performing as fertilizer spreaders. Typically, such equipment has been designed as disposal equipment with limited ability to calibrate application rates or maintain uniform, consistent application rates. Several considerations specific to solids application equipment follow:

- The operator must control the application rate. Feed aprons or moving push gates, hydraulically driven or power takeoff (PTO) powered, impact the application rate. Does the equipment allow the operator to adjust the application rate and return to the same setting with succeeding loads?
- Uniformity of manure application is critical for fertilizer applicators. Variations in application rate are common both perpendicular and parallel to the direction of travel. Uniformity can be checked by laying out several equal-sized plastic sheets and weighing the manure falling on each sheet (Figure 36-1). The variation in net manure weights represents a similar variation in crop-available nutrients.
- Transport speed and box or tank capacity impact timely delivery of manure. Often 50% or more of the time spent hauling manure is for transit between the feedlot or animal housing and field. Truck-mounted spreaders can provide substantial time savings over tractor-pulled units for medium and long-distance hauls. Trucks used for manure application must also be designed to travel in agriculture fields. Available four-wheel drive and duel or flotation-type tires should be considered for trucks that will apply manure. Increased box or tank capacities speed delivery. Spreaders must be selected to move and apply manure quickly.
- Substantial ammonia is lost from solid manure that is not incorporated. Most of the ammonia nitrogen, representing between 20% and 65% of the total available nitrogen in manure, will be lost if not incorporated within a few days. Practices that encourage the incorporation of manure into the soil on the same day that it is applied will reduce ammonia losses but may increase soil erosion.

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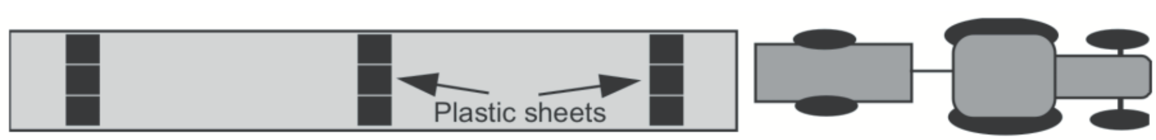


Figure 36-1. The strategic location of several equal-sized plastic sheets can indicate solid manure's uniformity of application.

Alternative delivery systems that speed the movement of manure, offer options for incorporating manure, and minimize the mixing of manure and air enhance the liquid application of manure.

Flexible hose systems distribute manure at rates up to 1,000 gallons per minute.

Liquid manure application systems

Tank wagons have traditionally performed the application of liquid or slurry manure. While this method has facilitated the disposal of manure at a relatively low capital cost, it has included some hidden costs including soil compaction, loss of ammonium nitrogen, and odor. Recently, many unique approaches to land application of liquid or slurry livestock manure have appeared. Alternative delivery systems that speed the movement of manure, offer unique options for incorporating manure, and minimize the mixing of manure and air enhance the liquid application of manure. A discussion follows of some potential features to be included in a manure application system.

Remote manure storages. Remote manure storage (or storages) is (are) an integral part of many unique delivery systems. Locating the manure storage near the fields that will receive the manure as opposed to near the animal housing has several potential advantages. Manure is transported via pump or tanker to the remote storage throughout the year, minimizing the labor required to move manure during field application. Remote sites may provide location options where odor or visual nuisances are less of a concern or reduce storage construction costs.

Weigh cells. The recent commercial application of weigh cells to manure tank wagons provides the equipment operator with information on the weight of manure applied. Weigh cells enhance the operator's ability to accurately estimate application rates and thus more accurately predict the nutrients available from the manure application. The addition of weigh cells to a manure spreader demonstrates this equipment's transition from waste disposal to fertilizer application.

Shuttle tankers. The standard 2,000- to 4,000-gallon tractor-pulled tanker cannot move manure fast enough for some livestock operations. In some regions, over-the-road tankers are being used to shuttle manure from storage areas to the edge of a field. Manure is then transferred to separate liquid application equipment or remote storage. Often, used semi-tractor milk or fuel tankers with capacities of 6,000 gallons or more are purchased for shuttle duty. Before implementing this approach, check licensing and inspection requirements and the carrying capacity of local bridges.

Flexible hose systems. Flexible hose delivery systems tied to a tractor-pulled field implement or injector unit move liquid manure quickly (Figure 36-2). A common approach begins with a high-volume, medium-pressure pump located at the liquid manure reservoir. Manure is delivered to the edge of the field (at the field's midpoint) by standard 6- or 8-inch irrigation line. At this point, a connection is made to a 660 ft long, 4 inch in diameter soft irrigation hose. Often two lengths of hose are used. Manure is delivered to a tractor with toolbar-mounted injectors or splash plates immediately in front of a tillage implement.

Flexible hose systems distribute manure at rates up to 1,000 gallons per minute (gpm). Thus, a one million gallon storage can be emptied in a 24-hr pumping period. Comparatively, using 3,000 gallon or greater tankers increases soil compaction. However, the high cost of capital equipment makes it affordable only to larger livestock operations and custom applicators.

Pumping liquid manure from the manure storage to the field is becoming increasingly common. Manure of up to 8% solids is being pumped several miles to a remote storage or to field application equipment. Pipe friction is the primary limiting factor. Manure with a solids content below 4% can be treated

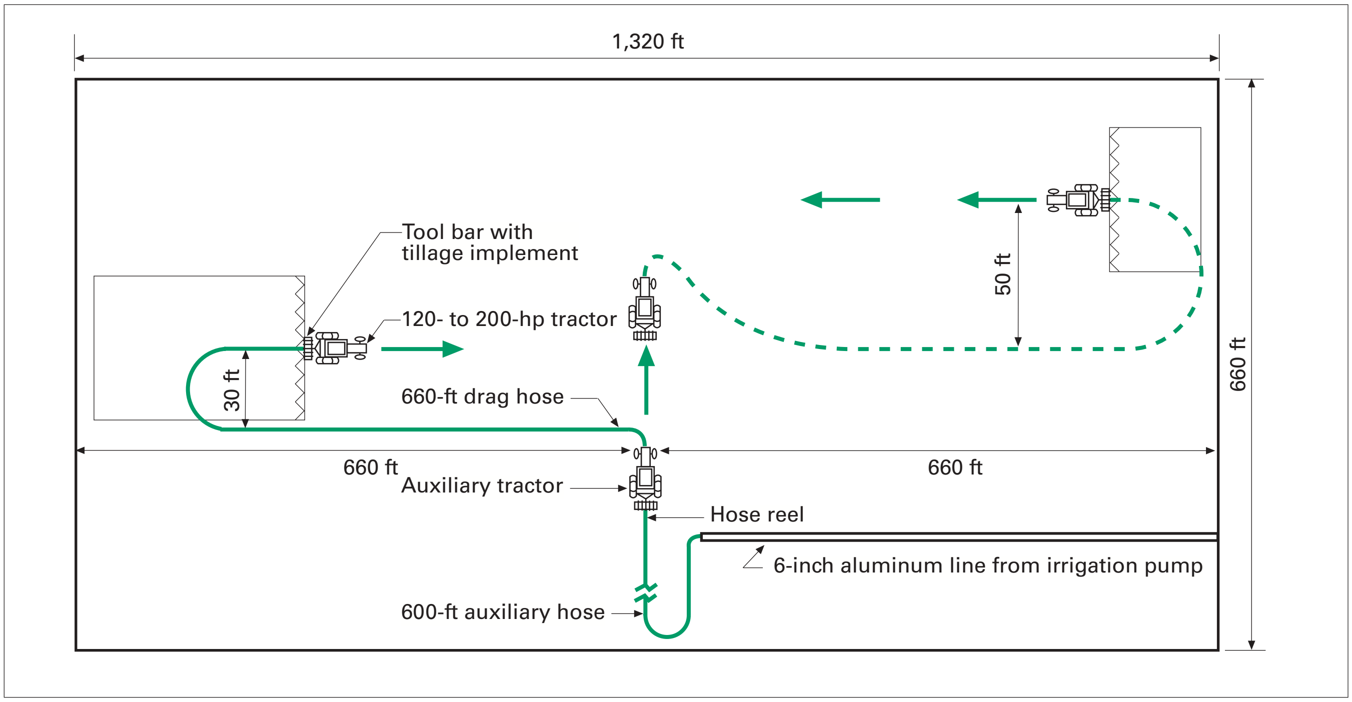


Figure 36-2. Drag hose setup for 20-acre field. Towed hose systems move manure from storage to field via a pump, pipeline, and soft hose that are pulled behind the tractor and application equipment.
Source: NRAES-89.

as water in estimating friction losses. However, an additional allowance for friction loss is required to pump manure with above 4% solids content. Manure-handling systems that involve the addition of significant dilution water or liquid-solids separation equipment provide a slurry that is most appropriate for this application.

To pump manure (> 4% solids) longer distances requires heavy-duty equipment. Aggressive chopper units are often installed just before the pump when solids separation equipment is not used. Industrial slurry pumps are selected to overcome the pipe friction losses and avoid potential wear problems. Buried PVC piping with a high pressure rating (e.g., 160 psi) is generally selected. Because manure leaks are far more hazardous than water leaks, joints must be carefully assembled and tested. Special care must also be given to piping crossing streams and public roads. If public roads will be crossed, appropriate local governments maintaining these roads should be contacted early in the planning process.

Surface broadcast of liquid manure. Surface application of liquid slurries provides a low-cost means of handling the manure stream from many modern confinement systems. Tank wagons equipped with splash plates are commonly used to spread manure. However, surface application suffers from several disadvantages including ammonia loss, odor, and poor uniformity.

- Ammonia losses. Surface application of slurries results in losses of 10% to 25% of the available nitrogen due to ammonia volatilization (Table 36-2).
- Odor. Aerosol sprays produced by mixing manure and air carry odors considerable distances (Table 36-3).
- Uniformity. Splash plates and nozzles provide poor distribution of manure nutrients. Wind can add to this challenge.

. . .surface application suffers from several disadvantages including ammonia loss, odor, and poor uniformity.

Table 36-2. Nitrogen losses during land application. Percent of total nitrogen lost within 4 days of application.

Application Method	Type of Manure	Nitrogen Lost, %
Broadcast	Solid Liquid	15-30 10-25
Broadcast with immediate incorporation	Solid Liquid	1-5 1-5
Knifing	Liquid	0-1
Sprinkler irrigation	Liquid	0-1

Source: Livestock Waste Facilities Handbook, MWPS-18.

Table 36-3. Odor emission rates during land spreading of pig slurry from manure storage.

Application Method	Total Odor Emissions[1]
Irrigation	6,250
Conventional tanker with splash plate	1,322
Deep injection	689
Shallow incorporation	503
Low-trajectory spreader with 15 trailing hoses	130

[1]Odor units per 1,000 gallons of slurry applied as measured by olfactometer.
Source: Phillips et al. 1991, Odour and Ammonia Emissions from Livestock Farms.

Locating the manure higher in the soil profile minimizes potential leaching, decreases the number of hot spots that affect plant growth, and reduces power requirements.

A few recent developments attempt to address these concerns. For the first time, boom-style application units for attachment to tank wagons or towed irrigation systems are appearing commercially. These systems use nozzles or drop hoses to distribute slurry. They tend to reduce odor concerns and improve uniformity of distribution. Other systems are under development.

Direct incorporation of liquid manure. The options for direct incorporation of liquid manure are increasing (Figure 36-3). Injector knives have been the traditional option. Knives, often placed on 20- to 25-inch centers, cut 6- to 8-inch deep grooves in the soil into which the manure is placed. High power requirements and limited mixing of soil and manure are commonly reported concerns.

Injector knives with sweeps that run four to six inches below the soil surface facilitate manure placement in a wider band at a shallower depth. Manure is placed immediately beneath a sweep (up to 18 inches wide), which improves the mixing of soil and manure. Locating the manure higher in the soil profile minimizes potential leaching, decreases the number of hot spots that affect plant growth, and reduces power requirements. Sweeps can be used to apply a higher rate of manure than a conventional injector knife.

Other shallow incorporation tillage implements (s-tine cultivators and concave disks) are increasingly available options on many liquid manure tank wagons. These systems are most commonly used for pre-plant application of manure. Manure is applied near the tillage tool, which immediately mixes the manure into the soil. Speed of application, low power requirements, and uniform mixing of soil and manure have contributed to the growing popularity of this approach. In addition, such systems are being used to

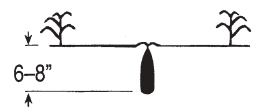
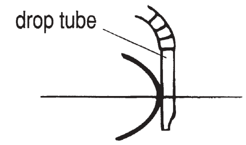
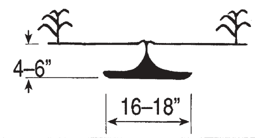
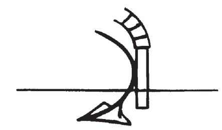
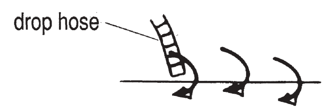
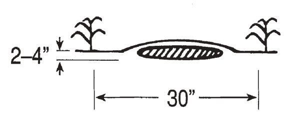
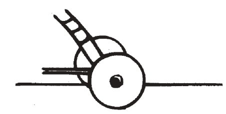
Row Crop Application Method	Placement of Manure (not to scale)	Application Implement (side views)
a) Injection: vertical knife/chisel		
b) Injection: horizontal sweep		
c) Shallow incorporation: s-tine cultivator (staggered)		
d) Shallow incorporation: concave disks		

Figure 36-3. Options for manure incorporation into the soil.
Adapted from Jokela and Cote 1994.

sidedress manure on row crops without foliage damage. Sidedressing expands the season during which manure can be applied and increases the use of manure nutrients. All soil incorporation systems also offer the advantage of ammonia conservation and minimal odors.

Irrigation systems

A properly designed irrigation system uniformly applies wastewater at agronomic rates without direct runoff from the site. However, a “good design” does not guarantee proper land application. Poor management can compromise the performance of a well-designed system; likewise, a poorly designed system can sometimes provide good performance with proper, intensive management. To keep your system in proper operating condition, you should be familiar with your system components, range of operating conditions, and maintenance procedures and schedules.

Various sprinkler systems are described and illustrated in the next few pages. 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 and holding basins generally facilitates the use of smaller, less costly systems. It also is possible to use an application system for both effluent and freshwater irrigation. The type of irrigation system chosen may depend on the particle size of the effluent solids, the amount of available capital, and how much time and labor is available for pumping. The system capacity selected may also depend on the amount of available capital and how much time and labor is available for pumping. Table 36-4 gives the labor requirement for irrigating with various systems.

To keep your system in proper operating condition, you should be familiar with your system components, range of operating conditions, and maintenance procedures and schedules.

Caution: Irrigation equipment used to apply manure or lagoon effluent and also connected to a freshwater source must be fitted with a check valve assembly.

Table 36-4. Operating characteristics of some sprinkler irrigation systems.

System Type	Labor Requirement, hr/acre/irrigation event	Sprinkler Pressure[1], psi	Field Shape[2]
Stationary			
Hand move	0.6-1.0	40-60	Any shape
Solid set	0.1-0.5	40-90	Any shape
Moving			
Traveling gun	0.2-0.4	50-100	Any shape
Linear move	0.1-0.3	5-80	Rectangle, square
Center pivot	0.05-0.2	5-80	Circular, square, rectangle

[1]Pressure supplied to the initial sprinkler/nozzle. Pressure at the inlet to the system must be higher to compensate for friction losses and elevation differences within the field.
[2]A range of field shapes are possible; however, some shapes may limit the total acres that can be irrigated or the suitability of specific system types.
Source: MWPS-30.

Caution: Irrigation equipment used to apply manure or lagoon effluent and also connected to a freshwater source must be fitted with a check valve assembly. The check valve assembly should be located between the freshwater source and the point of manure entry into the irrigation system. The check valve prevents the backflow of manure into the freshwater source. Check valves are commonly placed on irrigation systems used for fertilizer or chemical application.

Effluent irrigation systems

As with water irrigation, no one system is superior to another system. The following systems can be used for effluent irrigation:

- Stationary volume gun
- Solid-set sprinkler
- Traveling gun
- Center pivot and linear move
- Hand-move sprinkler
- Side roll
- Furrow or gated pipe irrigation

Stationary volume gun. This system can be used in many small effluent application systems (Figure 36-4). The system includes a pump and a main line similar to the hand-move system but with a single or multiple large-volume gun sprinklers. Advantages of the volume gun system include larger flow rates and a larger wetted area so less labor is required to move the sprinkler. Some volume guns are wheel mounted to facilitate moving the unit. Stationary volume guns typically have nozzle sizes that range from 0.5 to 2 inches and operate best at pressures of 50 to 120 psi. Coverage areas of 1 to 4 acres can be obtained with the proper selection of nozzle size and operating pressure. Gun sprinklers typically have relatively high application rates; therefore, adjacent guns should not be operated at the same time (referred to as “head to head”). Although stationary volume guns cost more than smaller hand-carry systems, the reduced labor cost and higher flow rates may offset the higher cost.

A typical volume gun that discharges 330 gpm at 90 psi of pressure wets a 350 ft in diameter circle (2.2 acres) with an application rate of 0.33 inches per hr. The power requirement is about 30 horsepower (hp). This system must be manually moved from one set or location to another, ensuring that the soil does not become saturated, which results in runoff.

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

Limitations:

- Moderate to high initial investment
- Water application pattern is easily distorted by wind.
- Significant odor source
- Tendency to over-apply effluents with high nutrient concentrations such as livestock lagoon effluent

Solid-set sprinkler. Stationary systems for land application of lagoon liquid are usually permanent installations (lateral lines are PVC pipes permanently installed below ground). One of the main advantages of solid-set sprinkler systems is that they are well suited to irregularly shaped fields. Thus, it is difficult to give a standard layout, but there are some common features between systems. To provide proper overlap, sprinkler spacings are normally 50% to 65% of the sprinkler wetted diameter. Sprinkler spacing, typically in the range of 80 ft by 80 ft using single-nozzle sprinklers, is based on nozzle flow rate and desired application rate. A typical layout for a permanent irrigation system is shown in Figure 36-4. Most permanent systems use Class 160 PVC plastic pipe for mains, submains, and laterals and either 1-inch galvanized steel or Schedule 40 or 80 PVC risers near the ground surface where an aluminum quick coupling riser valve is installed. In grazing conditions, all risers must be protected (stabilized) if left in the field with animals.

...solid-set sprinkler systems... are well suited to irregularly shaped fields.

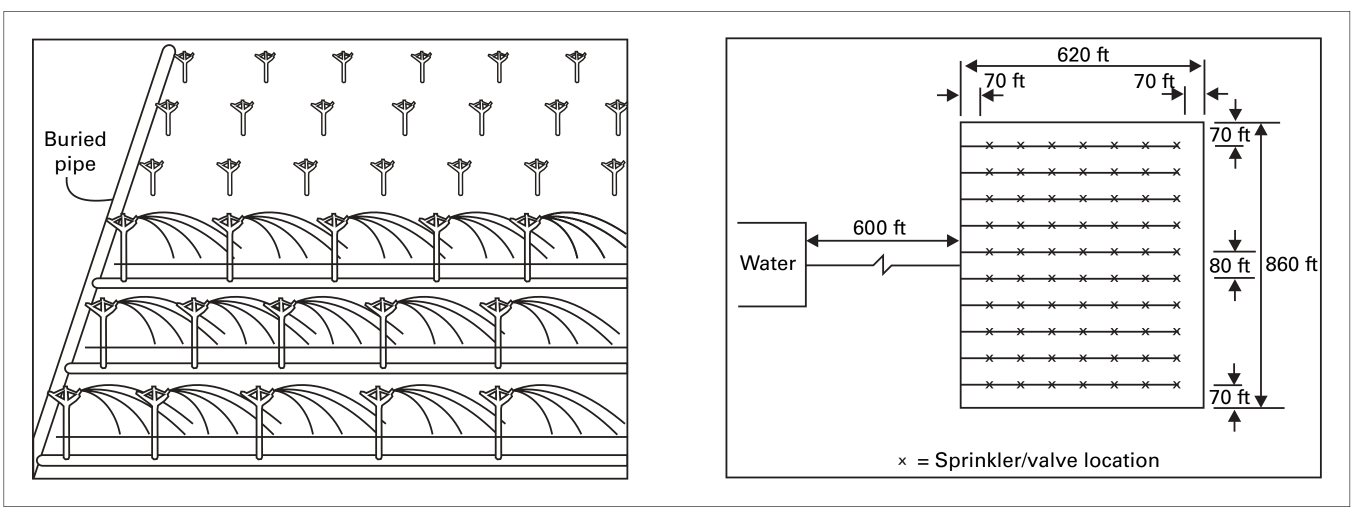


Figure 36-4. Schematic layout of a permanent irrigation system used to apply liquid manure.

The minimum recommended nozzle size for wastewater is 1/4 inch, and the typical operating pressure at the sprinkler is 50 to 60 psi. While sprinklers can operate full or partial circle, the system should be zoned (all sprinklers operated at the same time constitute one zone) so that all sprinklers are operating on about the same amount of rotation and thus achieve uniform application.

Advantages:
- Good for small or irregularly shaped fields
- Do not have to move equipment.

Limitations:
- Higher initial cost
- Must protect from animals in fields
- Small-bore nozzles likely to get plugged or broken
- No flexibility to move to other (new) field

Traveling gun. Traveling gun sprinkler systems are either cable-tow or hard-hose drag travelers. The cable-tow traveler consists of a single gun sprinkler mounted on a trailer with water supplied through a flexible, synthetic fabric, rubber-coated, or PVC-coated hose. The pressure rating on the hose is normally 160 psi. A steel cable is used to guide the gun cart, a wheel or sled-type cart.

Regardless of the drive mechanism, travelers should be equipped with speed compensation... .

The hose drag traveler consists of a hose drum, a high-density polyethylene hose, and a gun-type sprinkler. The hose drum is mounted on a multi-wheel trailer or wagon and rotated by a water turbine, water piston, water bellows, or by an internal combustion engine. Regardless of the drive mechanism, travelers should be equipped with speed compensation so that the gun cart travels at a uniform speed from the beginning of the pull until the hose is fully wound onto the hose reel. If the solids content of the wastewater exceeds 1%, an engine drive should be used.

The hose supplies wastewater to the gun sprinkler and also pulls the gun cart toward the drum. The distance between adjacent pulls is referred to as the lane spacing. To provide proper overlap, the lane spacing is normally between 70% to 80% of the gun's wetted diameter.

The gun sprinkler is mounted on the gun cart. Normally, only one gun is mounted on the gun cart. A typical layout for a hard-hose drag traveler irrigation system is shown in Figure 36-5.

Gun sprinklers have a ring, taper ring, or taper bore nozzle.

For uniform distribution, nozzle sizes on gun-type travelers are 1/2 to 2 inches in diameter and require operating pressures of 50 to 100 psi at the gun. Gun sprinklers have a ring, taper ring, or taper bore nozzle. The ring nozzle provides better breakup of the wastewater stream, which results in smaller droplets with less impact energy (less soil compaction). But, for the same operating pressure and flow rate, the taper bore nozzle throws water about 5% further than the ring nozzle, i.e., the wetted diameter of a taper bore nozzle is 5% wider than the wetted diameter of a ring nozzle. Taper bore nozzles also provide better application uniformity throughout the wetted radius, resulting in about a 10% larger wetted area than the ring nozzle. Thus, the precipitation rate of a taper bore nozzle is approximately 10% less than that of a ring nozzle.

A gun sprinkler with a taper bore nozzle is normally sold with only one size of nozzle. A ring nozzle, however, is often provided with a set of rings ranging in size from 1/2 to 2 inches in diameter, giving the operator the

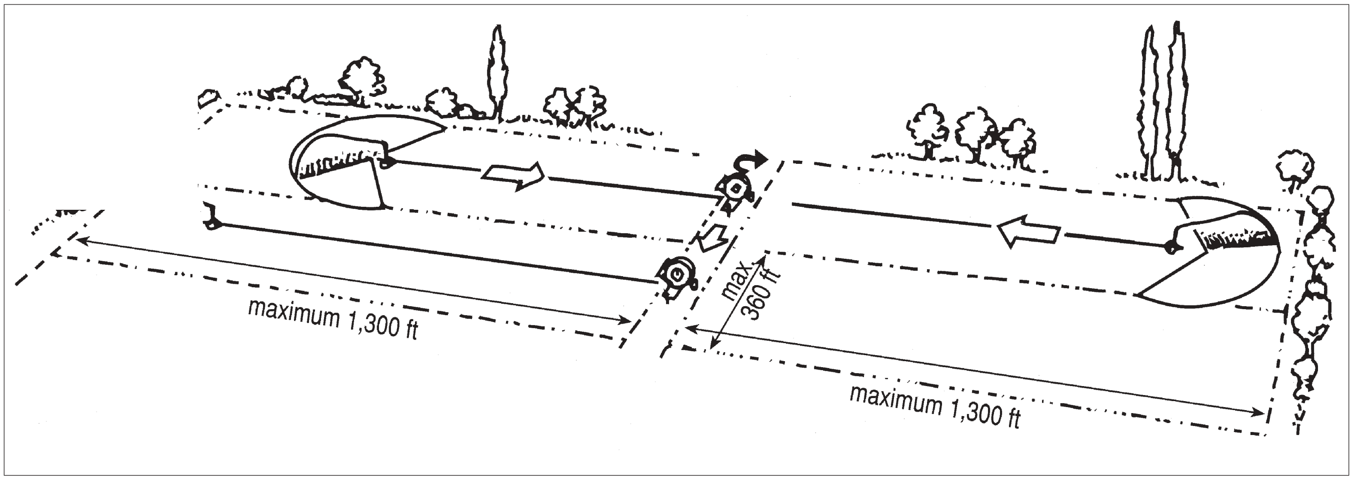


Figure 36-5. Layout of a hard-hose drag traveler. Travel lanes are 100-300 ft apart, depending on sprinkler capacity and diameter coverage.
Courtesy of The Irrigation Association, Fairfax, VA.
Source: NRAES 89.

flexibility to adjust flow rate and throw diameter without sacrificing application uniformity. However, a misconception exists that using a smaller ring with a lower flow rate will reduce the precipitation rate. This is not normally the case. Rather, the precipitation rate remains about the same because a smaller nozzle results both in a lower flow and in a smaller wetted radius or diameter. The net effect, therefore, is little or no change in the precipitation rate. Furthermore, on water drive systems, the speed compensation mechanism is affected by flow rate, and a minimum threshold flow is required for proper operation of the mechanism. If the flow drops below the threshold, the travel speed becomes disproportionately slower, resulting in excessive application even though a smaller nozzle is being used. Thus, system operators should be knowledgeable of the relationships between ring nozzle size, flow rate, wetted diameter, and travel speed before interchanging different nozzle sizes. As a general rule, operators should consult with a technical specialist before changing nozzle size(s) to a size different than that specified by the system design.

Advantages:
- Moderate labor requirements
- Few or no plugging problems with the large nozzle
- Flexible with respect to land area

Limitations:
- Higher initial cost than the previous systems
- High power requirement
- More mechanical parts than the other systems, especially with an auxiliary engine
- High rate of application

Center pivot and linear move. The use of center pivot systems for wastewater irrigation is increasing. Center pivots are available in both fixed pivot point and towable machines. They range in size from single tower

...operators should consult with a technical specialist before changing nozzle size(s)... .

The use of center pivot systems for wastewater irrigation is increasing.

machines that cover around 10 acres to multitower machines that can cover several hundred acres. Center pivot manufacturers offer almost completely automated systems that use rotary sprinklers, small guns, or spray nozzles. Their disadvantages include high cost, small sprinklers, and fixed land area covered. Drop-type spray nozzles offer the advantage of applying wastewater close to the ground at low pressure, which results in little wastewater drift due to wind.

Linear move systems are similar to center pivot systems, except that they travel in a straight line. Depending on the type of sprinkler used, operating pressure ranges from 10 to 50 psi. Low-pressure systems reduce drift at the expense of higher application rates and greater potential for runoff. Low-pressure systems in the 20-psi range with nozzles less than 1/4 inch in diameter are not recommended for livestock effluent because the effluent solids could plug the system.

Advantages:
- High uniformity of coverage
- Low labor requirement
- Flexible with respect to land area

Limitations:
- Used for low solids and well-screened liquids only
- Not applicable for irregularly shaped fields
- High initial cost

Hand move sprinkler. The least expensive sprinkler systems for effluent irrigation are the hand move types that must be set up and moved by hand. Although considerable labor input is required, these systems may be preferable for small lagoons. Used hand move systems may be available, but their small sprinkler nozzles may not be suited for effluent irrigation. A screened inlet pipe, however, will reduce problems with small nozzles.

An example of such a system is a 1/4-mile lateral covering 1.8 acres with each 60-ft move. A total of 32 sprinklers would discharge 10 gpm each, for a total of 320 gpm pumped through a 5-inch pipe. The application rate would be 0.4 inches per hr.

Nozzle sizes used for moderately to heavily loaded lagoons are generally in the 1/2- to 1-inch range, and the nozzles typically cover 1/2 to 2 acres per sprinkler, depending on nozzle size and system operating pressure.

Advantages:
- Low initial investment, especially with a used system
- Few mechanical parts to malfunction
- Low power requirement (50 psi at the sprinkler)
- Adaptable to field shape. To get isolated corners, different lengths can be set and run almost any direction.

Limitations:
- High labor requirement; individual pipe sections are moved, which can be a very unpleasant task with effluent.
- Small sprinklers can plug.
- Tendency to overapply effluents with high nutrient concentrations, such as livestock lagoon effluent.

Side roll. This system rolls sideways across a rectangular field but is limited to low-growing crops. Crop clearance is slightly less than 1/2 of the wheel's diameter. These systems use small sprinklers, require rectangular fields, and have several mechanical devices.

Furrow or gated pipe irrigation. These systems consist of a pump or gravity flow arrangement from a lagoon storage basin to a distribution pipe that has holes at regular intervals along its length. Effluent is discharged through the holes at a rate compatible with the land slope and soil infiltration rate. The gated distribution pipe usually is laid as level as possible across the upper end of a sloped soil-plant filter or manure receiving area. Gated pipe systems are suitable for land with 0.2 to 5.0 percent slope; they do not perform well on uneven or steeply sloped land. Flatter slopes result in ponding, or manure accumulating at the discharge point of the gated pipe, while steeper slopes cause effluent runoff with little opportunity for soil infiltration.

The advantages of gated pipe systems are relatively low cost, low operating pressures, and even effluent distribution if the pipe holes are properly located and sized. The disadvantages of these systems are high labor and management to ensure that they operate properly. Traditionally, gated pipe systems have been used to irrigate row crops. However, properly designed and managed gated pipe systems have also been successfully used to apply lagoon effluent to grassed areas.

Issues when irrigating manure slurry. The direct irrigation of manure slurry through a large-diameter sprinkler nozzle is an alternative for farms that produce large quantities of manure and have nearby pasture or cropland. The irrigation of liquid manure requires less labor, time, and operating expense than hauling and does not incur soil compaction problems.

Centrifugal pumps that can deliver at least 30 psi of pressure at the sprinkler nozzle are needed for irrigation. In addition, due to the slurry's high solids content, a lift pump similar to the chopper-agitator pump already described is needed to maintain the centrifugal pump's prime. Internal pump chopper mechanisms can help prevent clogging.

Slurries with more than 4 percent solids cause higher friction losses in pipes, requiring more pump pressure and hp. After pumping slurry, the irrigation lines must be flushed with clean water. With proper management, slurry manure up to 7 percent total solids can be irrigated.

The overapplication of nutrients is a concern with slurry irrigation systems. However, frequently moving sprinklers helps to minimize this concern. Thus, traveling irrigators are recommended. Hose drag travelers are less labor intensive and apply manure more uniformly than other traveling systems. Because the high solids content clogs other types of drives, the hose reel should be driven by an auxiliary engine. Gun sprinklers operate at higher pressures, resulting in greater potential for misting and wind drift.

Gated pipe systems are suitable for land with 0.2 to 5.0 percent slope; they do not perform well on uneven or steeply sloped land.

After pumping slurry, the irrigation lines must be flushed with clean water.