ENVIRONMENTAL ISSUES IN LIVESTOCK PRODUCTION HOME STUDY COURSE

Livestock
Industry
Facilities &
Environment

The *Environmental Issues in Livestock Production* home study series was developed for livestock producers, educators, students, and others seeking to better understand potential air and water quality impacts of animal agriculture, and to learn more about management practices that can minimize these impacts.

Modules in this series include:

- *Open Feedlot Runoff;*
- *Odor Assessment and Control;*
- *Manure Application;*
- *Livestock Environmental Regulations; and*
- *Manure Treatment*

For information concerning home study course completion certificates, and supplemental teaching materials (Power Point presentations) for use in the classroom, contact Agricultural & Biosystems Engineering Extension, 207 Davidson Hall, Iowa State University, Ames, IA 50011-3080 (phone 515-294-6360), email tglanvil@iastate.edu, or visit our World Wide Web site at http://www.ae.iastate.edu.

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IOWA STATE UNIVERSITY
University Extension

Ames, Iowa

Manure Application
Home Study Lesson 3

This lesson is about proper manure application to crop producing fields. This module was developed by Mark Hanna, Extension Ag Engineer, Agricultural and Biosystems Engineering, and Gene Tinker, Extension Swine Field Specialist, Iowa State University, Ames, IA.

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Objectives:
Upon successful completion of this unit, agricultural producers and support personnel will:
- Know the different land application techniques for manure, including the equipment, time and labor involved.
- Know how to determine application rates and how to calibrate equipment.
- Be able to compare the cost of owning and using application equipment with the cost of custom application.
- Be able to schedule land application to minimize odors released and soil compaction.
- Know the differences in crop residue remaining on the soil surface following different application techniques and the effect additional residue has on the environment.

Introduction
Manure is a by-product of the livestock industry. Manure can be considered a waste, or it can be treated as a resource for crop production. If manure is substituted directly for commercial fertilizer inputs and is used to enhance soil tilth, soil structure and biological activity, then further decisions must be made on how to store, transport and apply the manure to the soil. These decisions will impact equipment and labor requirements; the nutrients added to the soil; potential odor release and possible environmental contamination. Livestock manure must be properly applied to the soil in order to minimize potential environmental damage and maximize soil improvement. The time of application and environmental conditions also have major impacts on overall soil conditions following application.

Figure 1. Manure applicator tank.

Types of application equipment

There are many different types of equipment available for hauling and applying manure to land. The characteristics of the manure often dictate the equipment that may be used to handle it. Manure with 20 percent or more solids (consistency of catsup) can be handled as a solid. Most spreaders for solid manure are box-type, but some flail-type spreaders are also used for solid manure. Manures with 4 - 15 percent solids (consistency of buttermilk) are considered semi-solids and can be handled as either liquids or solids, depending on the equipment that is available. If the semi-solid material is handled with equipment designed for solids, the unit must be watertight to prevent environmental contamination during transport to the field. If this material is handled as a liquid, the manure should be well agitated before pumping to resuspend solids that have settled out from the liquid. Sometimes special pumps are also needed to be able to handle the increased solids. Flail-type and V-shaped slinger spreaders can be used with semi-solid material. Manures with up to 4 percent solids (consistency of half-and-half) are classified as liquids, and are usually hauled in tank wagons (Figure 1) or pumped through pipelines of umbilical or irrigation equipment.

Box-type spreaders

Box-type spreaders have variable-speed aprons or front gates, which allow spreading rate to be adjusted. Flail-type spreaders are used for all types of manure; however unloading liquid material from these spreaders can take considerable time. Slinger-type spreaders have a single opening for releasing the manure. A hydraulic slide gate regulates the size of the opening and thus the rate at which the manure is released. Large augers in the spreader move the manure toward the opening. Just outside the opening is the “slinger," a series of paddles that spin to spread the manure over the land.

Tank wagons

When using tank wagons (Figure 1), application rate is varied primarily by changing travel speed. Some equipment may reduce rates by using smaller orifices in outlets or hoses or pressure may be able to be altered in a vacuum tank. Tractor-size requirements depend on tank size and rolling resistance of the tires and axles as well as use of injectors. A 150 hp tractor is commonly used for 3,000-gallon applicators and 200-225 hp tractor is used for 6,000- to 7,000-gallon applicators.

Umbilical applicators

An umbilical system pumps manure from storage through a hose to an applicator in the field. The field applicator is a tractor-towed implement. See Figure 2. This method greatly speeds clean out time, as the pump runs continuously, so no time is lost for hauling. Also there is less soil compaction, as the umbilical hose is just pulled around the field, compared to the weight of large tank wagons or trucks continuously driving over the ground. A second tractor or vehicle is frequently needed to reposition the hose so it does not block the path of the applicator. Application distance is usually limited to within one mile of the source; however, booster pumps may extend the distance up to two miles. If greater hauling distances are required for a large liquid volume, truck-mounted tanks are used (often by custom applicators).

Figure 2. Umbilical manure applicator.

Umbilical units use flexible hose typically 4 1/2 or 6 inches diameter. Hose should have a life expectancy of several years if well maintained. Purchase costs of umbilical units depend on the options purchased (e.g., the amount of feeder hose required), but can be comparable to those of large tank units. A tractor or power unit is also required at the lagoon pump. Some type of radio contact is advisable between the field operator and lagoon pump operator in case of problems

Irrigation
Irrigation disperses liquid over the soil surface and it soaks into the soil without incorporation. Irrigation is used primarily for emptying lagoons, as there are often large quantities with few solids. The type of irrigation used, such as sprinkler, flood or big gun, determines how many solids can be handled without a mechanical problem.

Application rates and calibration

Determining a desired land application rate by the equipment, based on needs determined by crop requirements and soil tests, is an important step, but outside the scope of this learning unit. Consult Pm-1599, Land Application for Effective Manure Nutrient Management or other sources for determining a desired target-application rate for a specific crop/soil situation. Proper utilization of the nutrients in livestock manure requires that the manure be applied in a uniform pattern at a desired rate that **can be used** by crops. Applying at a rate greater than what can be utilized is actually damaging to the environment, as the excess nutrients can cause surface and groundwater contamination. In order to uniformly apply manure, applicators must know how to determine application rates and how to calibrate application equipment.

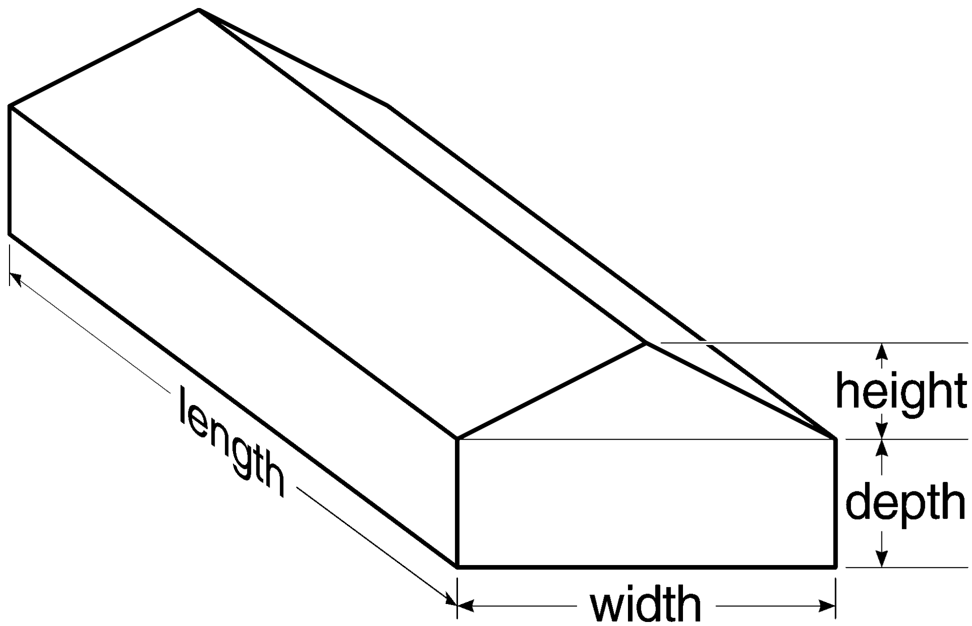
The first step in determining an application rate is to know the manure capacity of the spreader. The most reliable way to determine this is to weigh the spreader when filled. Then weigh the spreader when empty. The difference between the two weights would be the weight of the manure. Divide by 2000 pounds to get tons of manure. If a scale is not handy, a second choice is to determine the volume of the spreader and use manure density, to figure manure weight of a full spreader.

Spreader volumes

Box-type spreaders

Box-type spreaders normally range in size from 90- to 650-cubic-feet. A simple method to calculate spreader volume of a level full spreader is to multiply the dimensions of the spreader:

length (in feet) x width (in feet) x depth (in feet) = volume (in cubic feet)



If the spreader is heaped full, the formula to use is:

length (in feet) x width (in feet) x (depth + height (in feet)) x 0.8 = volume (in cubic feet)

Because it is difficult to fill a solid spreader evenly, when using these formulas measure an average manure depth within the box rather than simply using the height of the box sidewall.

Example 1:

As an example, we will calculate the volume of a box-type spreader described as a 235-bushel spreader. The dimensions of the interior of the box are 12 feet, 1 inch in length and 60 inches in width. The average manure depth is 28 inches. Since the formula is for measurements in feet, all inch measurements must be divided by 12 to convert inches to feet. Thus the calculation for volume is:

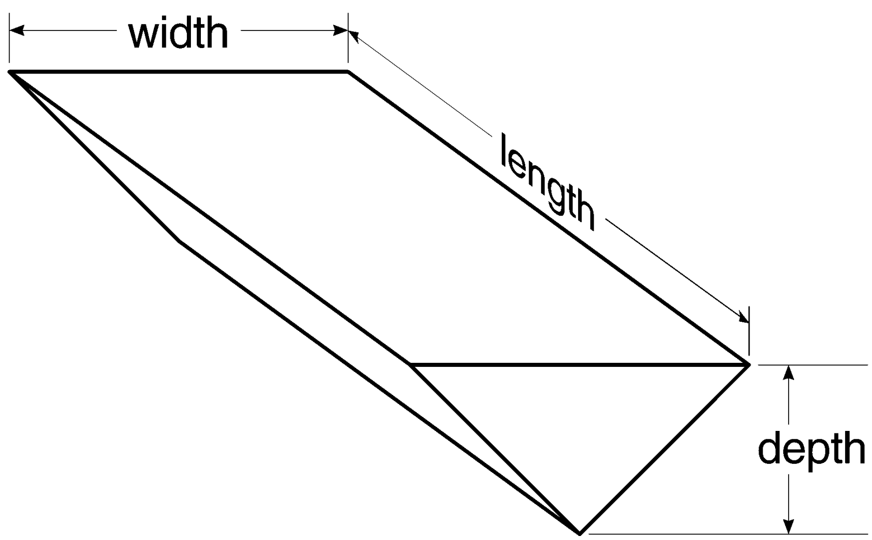
1 inch/12 = 0.08 feet
60 inch/12 = 5 feet
28 inch/12 = 2.33 feet
12.08 feet long x 5 feet wide x 2.33 feet deep = 141 cubic feet

Problem 1:
Determine the volume (in cubic feet) of a spreader that is 14 feet long, 5 1/2 feet wide, 3 feet deep and heaps the manure an additional 15 inches above the top of the box.

Volume =

Slinger-type spreaders
The volume of slinger type manure spreaders is determined with the following formula:

1/2 x depth (in feet) x width across the top (in feet) x length (in feet) = volume (in cubic feet)

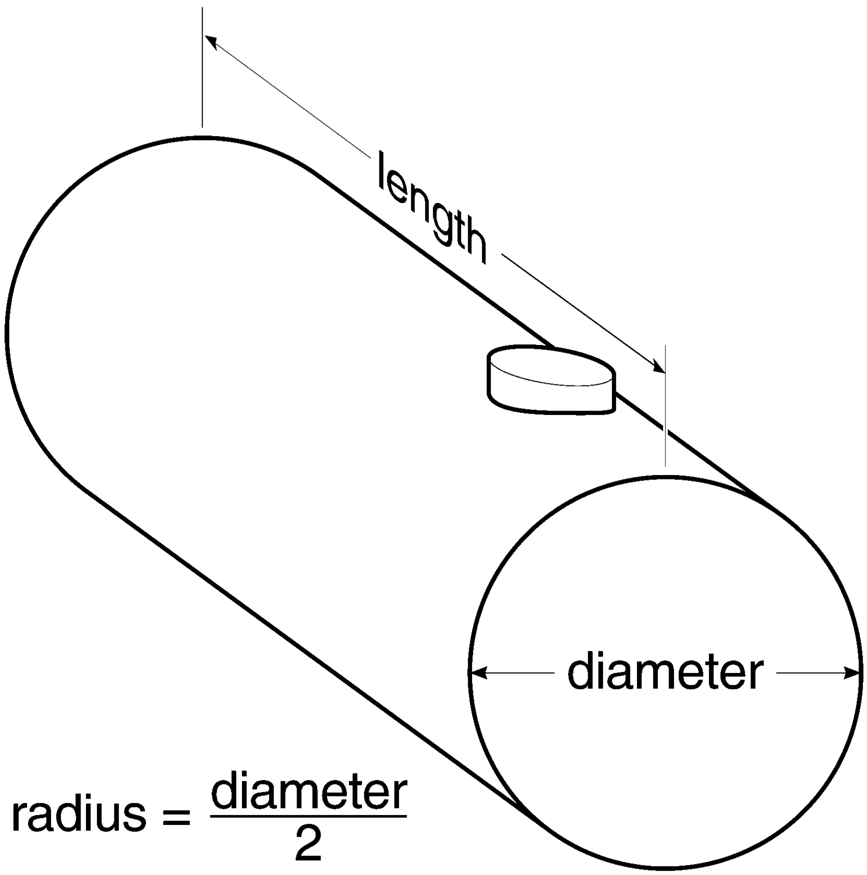


Example 2:
To demonstrate use of this formula, we will calculate the volume of a slinger spreader that is 60 inches wide across the top, 14 1/2 feet long and 35 inches deep. Converting all figures to feet and filling in the equation provides:

60 inch/12 = 5 feet
35 inch/12 = 2.92 feet
1/2 x 2.92 feet deep x 5 feet wide x 14.5 feet long = 106 cubic feet

Tank spreaders
If tank spreader capacity is unknown, it can also be calculated. Volume of tank spreaders can be determined with only two measurements, length of the tank and radius of the tank. The radius is one half of the tank diameter, which is measured on the end of the tank, with the measurement from one edge to the other edge and passing through the center of the tank end. The formula for volume is:

(radius, in feet) x (radius, in feet) x 3.14 x length (in feet) = volume (in cubic feet)



If outer tank dimensions are used and because a slight amount of residual manure may be left in the tank, assume usable tank volume to be 95 percent of that calculated with the above formula.

Flail type spreaders are basically just the bottom one half of tank spreaders, so the same formula can be used, and the volume then divided by 2.

Example 3:
Let's work through an example of determining the volume of a tank wagon. Consider a tank that is 15 feet long and has a diameter of 5 feet. Putting these figures into the formula gives:

radius = diameter/2 = 5 feet/2 = 2.5 feet

(2.5 feet) x (2.5 feet) x 3.14 x 15 feet = 294 cubic feet

Problem 2:
Determine the volume of a flail-type spreader that is 10 feet long and measures 6 feet from edge to edge on the end of the tank.

Volume =

Spreader manure capacity

We now know how to determine the volume of a spreader. The next step in determining the manure capacity of a spreader is to calculate the tons of manure per spreader load. This can be done with a 5-gallon bucket and a scale. A 5-gallon bucket of manure has 2/3 cubic feet of volume. To determine the density of the solid manure, find the weight of 5 gallons of manure. Do so by weighing the bucket empty and the bucket full of the manure to be spread. The difference is the weight of the manure. Multiplying the weight by 3/2 gives the density of the manure, in pounds per cubic foot. Repeat the process at least 3 times to get a good average. Manure density varies with the straw content and can range from 30 to 60 lb/cubic foot. The density of the manure, in pounds per cubic foot, is then multiplied by the volume of the spreader, in cubic feet, to get the pounds of manure per load. Divide by 2,000 pounds per ton to get the tons of manure per load.

Example 4:

Suppose the average weight of manure in a 5-gallon bucket is 35 pounds. Manure density would be 52.5 lb/cubic foot (= 35 x 3/2). If the slinger spreader from a previous example, capacity equal to 106 cubic feet, is filled with this manure it would contain 5,565 lbs (= 52.5 x 106) or 2.78 tons (= 5,565/2,000) of manure.

Since liquid manure is measured in gallons, the volume of liquid tank spreaders must be converted to volume in gallons. This is done by multiplying volume in cubic feet by 7.5, as there are 7.5 gallons in one cubic foot. Since flail and slinger spreaders are used for both solid and liquid manures, either calculation—volume in cubic feet or gallons—can be made for the type of manure being spread.

Problem 3:

In Example 3 we determined the tank spreader had a volume of 294 cubic feet. The tank would be able to theoretically hold 2,205 (= 294 x 7.5) gallons of liquid manure. Assuming 95 percent usable space each tankful could spread 2,095 (=2,205 x 0.95) gallons of liquid manure. How many gallons of liquid manure could be held in the flail-type spreader you determined volume for in problem 2? (Assume inner dimensions were measured and do not reduce for usable capacity.)

Gallons =

If a liquid spreader is weighed to determine the amount of manure, the density of the liquid manure must be known in order to calculate gallons of manure in the load. Most liquid manure is about 8 pounds per gallon; however, a specific sample can be checked with a 5-gallon bucket. Dividing manure weight by density gives the gallons of manure per load.

Land area determination

The second step in determining application rate is to calculate the area of land where the manure will be spread. This is a rather simple procedure for square and rectangular fields or applicator swaths. Multiply length (in feet) by width (in feet) to get square feet in the field or of the area where manure was spread. Oddly shaped fields are a bit more challenging, but the area can still be determined. The simplest method is to break odd shaped fields into areas of typical geometric shapes, such as triangles, half circles, etc. Calculate the square feet for each area and then add the square feet of the areas to determine the total field area. The area of a triangle is equal to 1/2 x base (in feet) x height (in feet) where base and height are the distances of the two sides of the area that meet at a 90-degree corner. Area, in square feet, is divided by 43,560 to determine acres.

Example 5:
Let's calculate the area at the end of a swath that is one mile long by 120 inches wide (four 30 inch rows).

The area equals 52,800 square feet (=5,280 feet x 10 feet) or 1.21 acres (= 52,800 square feet/43,500 square feet per acre).

Application rate

Once the total acreage the manure was spread on is known, the application rate can be determined. The number of loads spread multiplied by the tons or gallons contained in a spreader load equals the total amount of manure spread, in tons or gallons. Divide this value by the number of acres the manure was spread on to determine the application rate, in tons per acre or gallons per acre.

Example 6:
Let's evaluate the application rate for a producer who has cleaned some pens of solid manure following sale of market livestock.

The producer hauled 44 loads of manure. The spreader holds 5.4 tons of manure. The producer calculated the total acreage covered by the manure to be 13.5 acres.

The first step is to determine the total amount of manure hauled. A total of 44 loads multiplied by 5.4 tons per load totals 237.6 (= 44 x 5.4) tons of manure. Second step is to divide the total tons by the acres covered: 237.6 tons/13.5 acres = 17.6 tons of manure per acre.

Problem 4:
This producer's neighbor also just emptied an outside manure storage pit. The neighbor's tank wagon holds 3,000 gallons. This spreader was used to haul 52 loads of liquid manure and spread it on 33 acres of crop ground. Determine the application rate of this manure application.

Gallons per acre =

Calibration

The above outlined procedures determine application rate after the fact. For the applicator who desires a specific application rate, a procedure must be used to adjust, or calibrate, the application rate until the desired rate is achieved. The same procedure is used as described above, but the application rate is determined after spreading only one or two loads on a portion of a field and adjustments are made until the desired rate is achieved. There are a number of methods to adjust application rate. One way is to vary the ground speed of the application equipment, a second is to alter the unloading rate, and a third is to adjust swath overlap of broadcast spreading or the number and spacing of knives for injection.

Methods to change application rates

Adjusting ground speed of the application equipment, while leaving unloading rate constant, is an easy method to adjust application rate. This is also an important reason for the application operator to be diligent about maintaining a constant ground speed for uniform application. Practical speed range can be limited by field roughness; tractor power; excessive residue burial; and time required for disposal. A similarly easy adjustment for application rate is how far spreading swaths are overlapped. For the most uniform application, however, swaths should be overlapped to the extent that the areas to the side of the spreader receive the same application rate as the area behind the spreader. This spreading pattern, in combination with ground speed adjustment, can be used to give uniform application at the desired rate.

Unloading rate adjustment may also be done easily on some spreaders. This may be simply changing the power take-off (PTO) speed, if an appropriate spreading pattern is maintained. Unloading rate may also be changed by increasing or decreasing the discharge opening, whether that be a hydraulic end gate on a box-type or slinger spreader or the discharge valve or orifice on a tank wagon. Changing the pressure inside a tank spreader also affects the rate of unloading. In addition to the previously mentioned options, application rate of injection equipment can be adjusted by altering the number of injection points or changing the spacing between points.

Calibration steps and examples

The first step in calibrating a spreader is to establish a known application rate. Spread a load or two at a consistent ground speed. Determine the acreage that was covered and divide the acreage into the tons or gallons of manure applied. This provides the current application rate. Make changes to alter the application rate as needed and repeat the procedure until the test application equals the desired rate. Then proceed to spread the rest of the manure at that rate.

Example 6:

Consider an applicator who wants to apply liquid manure at 4,500 gallons per acre. The equipment is a 3,500 gallon tank spreader with 4 injector sweeps at the rear of the tank. Two loads were applied at a very consistent rate and the area applied to measured. The area was 1.8 acres.

Dividing the 7,000 gallons applied (2 loads) by the 1.8 acres gives an application rate of 3,889 gallons per acre. The applicator wants to increase the application rate, so evaluates the options. The tool bar does not have room to add more sweeps and driving closer to the previous pass would cause inconsistent application, so those options are not feasible. The discharge valves were already open the maximum distance and the tank pressure currently used to discharge the manure is at its maximum level. Therefore the applicator decided to decrease application ground speed in order to increase application rate. The tractor was run one gear slower, with all other variables the same, as the next two loads were spread. As expected, the distance traveled was less than when the first loads were spread. Application area measured 1.5 acres, which meant an application rate of 4,667 gallons per acre (7,000 gallons/ 1.5 acres). The applicator decided this was within 5 percent of the desired 4,500 gallons per acre (0.05 x 4500 = 225) and to use this speed.

Problem 5:
A livestock producer hauling solid manure with a box type spreader measured the land area covered by the first two loads spread. The area covered was 4/5 of an acre. The spreader holds 5.4 tons of solid manure in these heap-filled loads. The producer drove with 6 crop rows between the tractor's center line for the first two loads and noticed the area between the spreader paths did not receive as much manure as the area directly behind the spreader. The producer wants to apply about 20 tons of manure per acre. What was the application rate for the first two loads and what recommendation would you make for changes to get uniform coverage at the desired rate?

This example illustrates a frequently observed problem with broadcast manure applications. Uniform spreading requires that an approximately equal amount of manure be deposited across the broadcast swath. Lighter edges of each swath should be overlapped for even distribution. One method of checking swath distribution for uniformity is to weigh the amount of material deposited on plastic sheets spaced uniformly across the applicator travel path on the soil surface.

Once the producer in this example has adjusted the application rate to 20 tons/acre, the number of loads required for a 25 acre field can be calculated. Each load of 5.4 tons covers 0.27 acre (=5.4 tons/20 tons per acre). The number of loads required equals the number of field acres divided by the acres per load or 93 loads (= 35 acres/0.27 acres per load). If it's desired to haul fewer loads to the field, but keep application rate at 20 tons/acre, a larger capacity spreader is required.

Problem 6:
Now suppose that a producer's application rate is 3300 gallons/acre and a 6000 gallon tank is being used. How many acres should be covered by each load and how many loads are required on a field that is 1/2 mile long and 1/4 mile wide?

The driving distance required to apply one load for a given application rate and swath width can be calculated in two steps. For example, assume a 3000 gallon tank is being used to apply manure at a rate of 5500 gallons per acre. In the first step, the number of square feet covered by each tankful is calculated by dividing tank capacity by application rate and multiplying by 43,560 square feet per acre. In this instance 23,800 square feet (= 3000 gallons per tank x 43,560 square feet per acre/5500 gallons per acre) is covered by each tankful. In the second step the square feet covered by one tankful is divided by swath width to calculate driving distance for one load. In this instance, if swath width is 10 feet, driving distance equals 2,380 feet (= 23,800 square feet per tankful/10 feet).

Depending on conditions, a calibrated application rate may not allow for a complete round of a spreader, or perhaps even a single pass. If wet soil causes concern with soil compaction, applicators may want to think through field patterns and minimize the travel lanes compacted with a full load. For example, when an applicator becomes empty in the middle of the field, an unfinished swath area remains. After reloading the applicator, this unfinished swath (or travel pass) might be started near the field entrance and the applicator path moved over one swath width when the treated area is encountered. Although a certain amount of dead-heading occurs with an empty applicator, compaction may be lessened by minimizing the field area trafficked by a full load. Applicators may also give consideration to adjusting the length of treated areas so that complete rounds are possible. If manure is to be applied in more remote areas of the field, however, the additional transport lanes required for this area may nullify any advantages of simply beginning at the end of the previous application area.

Occasionally an unfinished pass will result when manure storage is emptied and/or no manure will be spread for a period of several weeks in the field. The location at the end of the pass should be marked in the field and properly noted in a field record book. In this manner credit can be taken for the area where manure nutrients were applied versus the remaining area where other fertilizer sources may be used. Taking credit for field application of manure depends on good record keeping of the amount and location of applied nutrients.

Driving speed of umbilical units can be calculated from application rate, pumping rate and swath width by the following formula:

travel speed, mi/hr = (pumping rate, gal/min x 495)/ (application rate, gal/ac x swath width, ft)

Example 7:
If the application rate from a lagoon is 10,000 gallons per acre, pumping rate is 750 gallons per minute and swath width is 10 feet, travel speed should equal 3.7 mi/hr (= (750 gal/min x 495)/(10,000 gal/ac x 10 ft).

An option on some newer manure equipment actually determines the application rate while operating in the field. This is done by the use of electronic sensors to measure manure weight and distance the spreader has traveled. Such technology allows application and incorporation of exact amounts of manure; thus allowing producers' crops to maximize fertilizer benefits from the manure applied. Such technology has potential for future precision farming applications.

Economic costs

In addition to all the other aspects of manure application already discussed, the economics of the task must be considered. All costs associated with owning the proper equipment and performing the task by oneself as opposed to renting equipment or having the manure custom hauled and applied must be evaluated and considered.

Costs for the necessary equipment can be broken into primarily fixed costs and variable costs. Fixed costs are yearly costs that do not vary based on how much the equipment is used. Such items include depreciation, interest (or opportunity cost), insurance and any portion for housing and maintenance facilities that is charged to the equipment. Variable costs are also known as operating costs and are dependent upon how much the equipment is used. Such charges include repairs and maintenance and tractor costs for implements that are not self-propelled.

Fixed costs

Of all the fixed costs, depreciation makes up the greatest percentage. Yearly depreciation value is usually calculated as the difference between sale price and salvage value, divided by the expected years of useful life. Interest charge is the cost to borrow the money needed to purchase the equipment. Or if no money is borrowed, this charge is the opportunity cost - the cost of giving up the opportunity to use the money elsewhere in the operation. Insurance and housing costs can be estimated to be equal to 1 percent of implement list price. Fixed costs are a specific annual amount, but are reduced by a per hour or per unit of manure hauled with increased spreading.

Variable costs

Variable costs for a year do change based on the amount of use the equipment gets. The greater the use, the greater the expense for repairs and maintenance, fuel and labor. Also repair costs tend to increase with age. The sum of all fixed and variable costs give total cost for the season. Dividing the total cost by total hours used or total volume hauled shows the cost to own and operate the implement per unit of use.

Example 8:

To demonstrate how cost determination works, consider a 6,000-gallon vacuum tank priced at $25,000. A disk incorporation unit is added for an additional $5,000. If the expected useful life is 9 years, the salvage value of this unit might be 20 percent of list price or $6,000. This allows yearly depreciation to be calculated as ($30,000 - $6,000) / 9 years = $2,666.67 per year. Yearly interest charge is calculated as interest rate x (purchase price + salvage value)/ 2. Putting figures for the tank into this formula gives .10 x ($30,000 + $6,000) / 2 = $1,800, with a 10 percent interest rate. Insurance and housing costs of 1 percent list price would be $300. The total of all fixed costs for depreciation, interest, insurance, and housing would be $4,766.67 per year (= $2,666.67 + $1,800 + $300). If 500,000 gallons of manure were hauled and spread per year, fixed cost per gallon would be 0.95 cents per gallon ($4,766.67 / 500,000 gallons = $0.0095).

Repair costs are hard to predict, especially if a producer does not have records of past repair bills. If the total repair charges for the 9 years of service life total 24 percent of the list price, total repairs on the spreader would be $7,200. This would average $800 for the 9 years of service life. However the true repair cost per year would be less for the early years and greater for the later years. For the example, the $800 will be used. Since a tractor is needed to operate the tank, additional costs of tractor use and fuel need to be determined. The number of trips required by the tractor equals the total amount of manure being moved divided by the spreader's manure capacity. In this case it is 83 trips (= 500,000 gal/6,000 gal). If two loads can be hauled per hour, 42 hours (= 83/2) of tractor use would be required to complete the task. *The 1996 Iowa Farm Custom Rate Survey* (FM-1698) lists an average tractor rental rate of $0.137 per horsepower per hour (not including fuel or labor). If a 150 horsepower tractor is used, the cost for the tractor would be $863, determined as 150 horsepower x $.137 per horsepower per hour x 42 hours.

Fuel usage can be estimated based on tractor horsepower. *Estimating Farm Machinery Costs* (Pm-710) predicts average diesel usage (in gallons/hour) to be .044 x maximum PTO horsepower. For the example, with a 150 horsepower tractor, this would be 6.6 gallons per hour (.044 x 150). The prediction of 42 hours of usage for manure hauling and spreading gives a yearly fuel usage of 277 gallons. Assuming a cost of $.80 per gallon would give a total yearly fuel bill of $222. Although labor may be supplied by the operator, a cost must be included, as there would certainly be an opportunity cost involved. The *Custom Rate Survey* lists average farm labor for operating machinery to be $6.80. For a total of 42 hours per year, the labor charge would be $286.

Total for all variable costs for spreader repair, tractor use, fuel, and labor is $2,171 per year (= $800 + $863 + $222 + $286). On a per gallon basis, this is 0.43 cents per gallon of manure. Therefore total costs per gallon would be 1.38 cents (0.95 cents for fixed costs and 0.43 cents for variable costs). This of course is only accurate for the assumptions used (interest rate, diesel fuel price, etc.) and for the 500,000 gallons of manure hauled per year. Increasing the gallons hauled per year would decrease the fixed cost per gallon but increase variable costs per gallon if repair bills increased.

Problem 7:
Determine the fixed cost, variable cost, fixed cost per gallon, variable cost per gallon and total cost per gallon for a direct injection system with umbilical hose feed line.

The system costs $35,000, but a lagoon agitator and pump is also required, which costs $11,500. Consider 11 years of useful life, with a salvage value of $7,300.

Make your calculations based on cleaning a 1.7 million-gallon storage basin each year. Total repair costs for the 11 years are estimated to be 20 percent of the sale price. Interest rate is 8 percent , insurance and housing costs are 1 percent of list price. Pumping time required to empty the storage basin is 45 hours, and an additional 2 hours is needed to set up and pick up the equipment. Also, two tractors are needed, a 125 horsepower tractor to run the pump and a 175 horsepower tractor for the injection unit. Therefore, two people are also needed, at a labor cost of $6.80 per hour. Assume diesel fuel price to be $.80 per gallon.

The following formulas are needed to make the calculations:

Fixed cost = depreciation + interest + insurance and housing
Variable cost = spreader repair + tractor use + fuel + labor

Other options for obtaining services

Joint ownership may be an attractive option for lowering individual investment cost. Fixed costs are spread over more hours of use or manure applied, however, repair and maintenance costs will increase.

Another option would be to rent the spreader needed, thus replacing the fixed (ownership) costs and repair costs with a rental fee. Tractor, fuel and labor costs would remain the same, assuming the spreader rented has similar size and capabilities. For example, after checking you determine that a local rental rate for a 6,000 gallon manure spreader is $25 per hour. Using the previous example for ownership costs, although total spreading time is only 42 hours, you determine that an extra 10 hours of rental time will be required when the spreader is away from the rental dealer. Rental cost would be $1,300 (= 52 hours x $25/hour). Add to that the $863 for tractor use, $222 for fuel, and $286 for labor gives a total yearly cost of $2,671. This equates to 0.53 cents per gallon of manure hauled and spread, or about 40 percent of the cost of ownership and upkeep. Of course there are some disadvantages to renting equipment, including availability of the equipment when desired and that it is in good working condition.

One other option for manure spreading, especially with larger amounts of manure, is to hire the task done by custom operators. A common charge is 0.75 cents per gallon, with an additional charge of 0.25 cents per gallon for hauling more than 1/2 mile. This option would not require any additional equipment to be owned or rented, such as tractors, and no additional labor would need to be supplied. On the other hand, this option is dependent upon when the custom applicators can get to the job. Also of concern is the care custom applicators use around the farmstead and the uniformity with which they apply the manure. The livestock producer must realize that the custom applicator may not do everything exactly as they would do it themselves. On the other hand, the volume custom applicators haul allows them to have additional equipment, such as injection attachments, that the livestock producer may not own. With both custom application and equipment rental, the livestock producer may have more concern about disease transmission. There are definite pros and cons to all manure application options.

So far all discussion has been directed at the costs of manure application. There are also benefits to be obtained from the application of livestock manure to crop land. These benefits include improved soil tilth, soil structure and biological activity, in addition to the value of the nutrients supplied by the manure. An important part of maximizing this benefit is to develop an application plan that maximizes soil improvement and crop utilization of the nutrients. The amount of nutrients contained in manure varies due to the type of manure, how it was stored, how applied, etc. Therefore the value of the nutrients is variable, and the economic benefits are influenced by the cost of nutrients available from commercial fertilizer products.

One fallacy is to expect the nutrient value of livestock manure to totally offset the costs of hauling and applying the manure. This philosophy doesn't allow the manure to be hauled very far and still be cost effective. The result is that environmental contamination can occur if the manure is continuously applied to the land closest to the buildings. The livestock operation produces the manure, so it is appropriate for the livestock operation to stand at least part of the cost of hauling and applying the manure. There would be charges for equipment and labor to remove the manure even if it was not applied to the soil for its benefits. Therefore it is justified to budget this expense to the livestock operation and any additional expense due to using the manure as a beneficial soil additive, such as hauling further distances, be charged to the agronomic operation. In addition to the nutrients supplied by the manure, the improvement in soil structure and tilth due to manure application should be considered.

Odor concerns and application timing

Manure application involves additional issues that are important to environmental protection, time management and crop production. An important issue in today's society is to reduce the nuisance of manure odor due to land application as much as possible. There are numerous management techniques that can decrease this potential problem. One technique is to incorporate the manure into the soil as soon as possible after broadcast spreading. Liquid manure can actually be injected below the soil surface so that it is not exposed to the air, thus reducing the potential for odor. Injection or broadcast with incorporation not only decreases odor intensity, but also prevents runoff and decreases the amount of nitrogen lost from the manure through volatilization. Manure that has been broadcast should be incorporated as soon after spreading as possible. Ideally, manure should be incorporated into the soil within 12 hours of spreading for maximum nitrogen efficiency.

Proper selection of the time to apply manure can have a major impact on public reaction to the odor released. Avoid spreading manure at times when odor would be most objectionable to neighbors, such as just prior to holidays or weekends when they may have outside activities planned. Select days when the wind is not blowing toward neighbors or populated areas. Spread after morning commuter traffic and during the day when the air is warming and rising. This allows the manure to dry quickly, which reduces odors. Also try to spread on days with low humidity and with high wind velocity. For any type of broadcast spreading, including irrigation, a low spray trajectory will decrease the amount of odor released.

Maintaining good communication with neighbors can be a key to successful application. Consider contacting neighbors a few days before a major spreading activity to ask if there will be problems with selected dates. Informal discussion or an open house might be ways to let neighbors know more about the operation.

Optimum frequency of manure spreading is dependent on the unique characteristics of each situation. Fresh livestock manure often is perceived to have a less offensive odor, which indicates manure should be spread as frequently as possible, especially during warm weather. However, neighbors may be more accepting of odor with greater intensity, but lesser frequency, such as for only a few days during spring and fall. In such a situation, it may be best to construct a manure storage structure of adequate size to contain the manure until the specific spreading times. Further information on sizing manure storage can be found in Pm-1599, *Land Application for Effective Manure Nutrient Management*. All factors must be considered for each individual situation to determine the best application plan.

It is also important to keep equipment and facilities as clean as possible. Any spills should be cleaned up as soon as possible, especially if near a public roadway. Public perception plays a big part in whether an odor is considered to be a nuisance.

The timing of manure application also affects the benefits acquired by the manure addition to the soil. Applying manure when soil moisture content is near field capacity may actually have a net decrease in benefit if compaction occurs. Such compaction is especially a concern with large tanks and spring field conditions, as the tremendous weight of a full tank can cause considerable compaction on wet soils. Applying manure to frozen or snow covered ground greatly increases the potential for runoff. These issues must all be considered with the time required to haul manure. Operations without storage facilities must haul more often, so there may not be options based on these concerns. These operations will need ground on which to haul, however, where the manure can provide a benefit.

Whether storage facilities are available or not, a certain amount of time is required to haul and apply the manure. Storage facilities just allow more flexibility in when application can be done. Finding the time to haul can be difficult. Consider the equipment example used previously. Forty-two hours were required to haul and apply the manure. These 40 hours would be an addition to regular daily and weekly activities. Finding those additional hours may be difficult, especially in spring and fall when ground is available for application, but other field activities must be completed also. In the example, if the producer was only able to put an additional 4 hours per day toward manure removal, it would take 10 days to complete this task. Finding 10 days when all conditions are "right" for application can be difficult. Options would be to purchase or rent bigger equipment so the job does not take as long, or to hire a custom applicator.

In general, the amount of time required to haul a given amount of manure can be calculated as follows. Divide the given amount of manure by the hauling capacity per load to obtain a number of loads required. The total hours required can then be obtained by dividing this number of loads by the average number of loads hauled per hour. For irrigation and umbilical hose application systems, the time required to move a given number of gallons of manure is equal to this gallonage of manure divided by the pumping rate expressed in gallons per hour.

Example 9:
To empty 1.5 million-gallons from a lagoon with a pumping rate of
500 gallons/minute or 30,000 gallons/hour (= 500 gallons/minute x 60 minutes/hour)
would take 50 hours (= 1,500,000/30,000).

Although it is ideal to apply manure between crop seasons, such may not be a possibility, as with operations without storage capabilities. These situations may require that manure be applied to land with growing crops. Proper equipment may allow manure to be applied to row crops if wheel spacings are compatible with row spacings and the crop is still short. If manure is to be injected between crop rows, care must be taken to minimize root pruning. Any surface application method, such as dribbling manure between rows, should avoid splashing manure onto leaf tissue, which can be detrimental to plant health.

Grass crops, such as corn, respond efficiently to manure because of the nitrogen available. However, sometimes application to such crops may not be feasible when manure needs to be applied. If manure is to be applied to hay fields, consider selecting the oldest stands. Such fields normally have more grass, which will benefit more from the nitrogen in the manure. Apply the manure immediately after removing a cutting so the manure contacts soil rather than foliage. Doing so reduces the risk of burning the plant and avoids palatability problems when the next crop is harvested. Limit application to no more than 3000 gallons of liquid or 10 tons of solid manure per acre. Adjust solid spreaders to break up large chunks of manure that could smother regrowth or be picked up in harvest of the next cutting. Also try to apply just before a rain, which will wash manure off any regrowth that has occurred and carry the manure into the soil. Avoid spreading when soils are not firm in order to limit soil compaction or damaging plant crowns.

The other season when daily spreading is a concern is during the winter. Environmental contamination is a possible hazard when manure is applied to frozen, snow covered land. Such manure is prone to run off the field during rapid spring thaw.

Use caution when applying manure near sensitive areas such as: sinkholes, cisterns, abandoned wells, unplugged agricultural drainage wells, ag drainage well surface tile inlets, drinking water wells, or lakes or farm ponds. Current state regulations require that manure not be applied to cropland within 200 feet of these types of sensitive areas, unless the manure is applied by injection or is incorporated within 24 hours of broadcast spreading. Failure to abide by such regulations could cause major environmental contamination, as the manure could be transported throughout some large water supplies. Illegal application is subject to fines and penalty.

Residue cover

Prevention of field runoff on sloping ground is a primary goal of conservation and environmental protection plans. Field runoff not only causes soil erosion, but also moves manure that has been applied to fields. Experience has shown that increased amounts of field crop residue will decrease the amount of field runoff. Therefore the more residue that can be left for field cover on sloping land, the fewer problems one should experience with environmental contamination from manure that has moved off the fields.

This presents a dilemma, as residue is desired to prevent erosion and runoff, but the tillage practices to incorporate manure spread on fields and manure injection methods all reduce the amount of surface residue. Therefore it is important to evaluate tillage and injection methods to determine which methods maximize manure incorporation yet retain adequate surface residue.

Different injection methods also leave varying residue amounts. A number of field trials have been conducted to evaluate these differences. Table 1 presents a brief summary of some trials conducted during fall applications in Iowa and Illinois.

Table 1. Results of injection methods at fall field trials in Iowa and Illinois.

Implement	Residue remaining after injection, %
Chisel points	60 - 80
Sweeps	50 - 70
Covering discs	60 - 80
Broadcast and incorporate or discharge in front of light disk or field cultivator	40 - 80

Figure 3. Sweep injectors operated in soybean residue.

All observations were made on corn residue, with the starting residue value at about 95 percent. The chisel points basically leave the manure in vertical bands within the field. Sweeps (Figure 3) distribute the manure more uniformly in horizontal bands beneath the soil surface. Covering discs mound soil up around the manure as it is discharged from the tank. With the broadcast and incorporate implements, the manure was either broadcast on the field in a separate operation prior to the tillage pass, or the manure was discharged just in front of the implement during the same field pass. One must remember that the presented ranges are only for comparison and do not indicate that similar types of injection or incorporation during different times of the year will give the same reduction of surface residue. For example, weathered surface residue in the spring may break up more easily with less resulting cover. Ranges listed indicate results vary due to operator adjustment and operation of the equipment. More fragile soybean residue would have less residue present after injection.

In addition to evaluating the amount of residue remaining after injection or incorporation, one must consider other effects on the field. Implements can leave bunches of stalks that have accumulated in front of the tillage shanks or rough surface topography that requires further tillage. Each implement must be evaluated for how it would fit in with the planned cropping system. If the system calls for planting without any further tillage operations, one would want the field to be left smooth enough to prevent any planter operation problems. If another tillage pass is used prior to planting, the condition of the field surface after manure application is less critical. But all injection or incorporation methods should cover the manure adequately and uniformly disperse the manure within the soil. The spacing of injection shanks and consistent driving during application are important for application consistency.

Summary

Livestock manure is truly a resource. It contains many vital nutrients and enhances the physical properties of soil. But it must be handled with care. The potential for contamination of the environment is always a possibility. Proper manure application to crop producing fields involves many aspects. The selection, calibration, and use of land application methods is an important decision. Economics, labor availability, and determination of application rates are all a part of this decision making process. All livestock producers should evaluate their operations and determine the best system based on their particular operation. This includes determination of the cost to own and operate equipment as compared to the costs in their area of renting equipment or hiring custom application. A major component of the decision making process is the availability of labor to properly apply the manure in the appropriate manner. The final decision should be based on the most economical method of achieving maximum benefit from livestock manure with the least possible chance of any environmental contamination and without disruption of other production activities.

For additional information on calibration see: *Manure Spreader Calibration*; *and Manure Happens...Take Credit!*

For additional information on determining desired application rates and sizing storage see: Pm-1599, *Land Application for Effective Manure Nutrient Management*

For additional information on economics see: Pm-1609, *You Can't Afford Not to Haul Manure*; Pm-710, *Estimating Farm Machinery Costs*; and FM-1698, *Iowa Farm Custom Rate Survey*

Answers to problems:

Problem 1: Volume = 14 ft x 5.5 ft x (3 ft + 1.25 ft) x 0.8 = 262 cu ft

Problem 2: Volume = 3 ft x 3 ft x 3.14 x 10 ft x 0.5 = 141 cu ft

Problem 3: Gallons = 141 cu ft x 7.5 = 1060 gal

Problem 4: Gallons = 52 x 3000 gal = 156,000 gal
Gallons/acre = 156,000 gal / 33 ac = 4730 gal/ac

Problem 5: Tons = 2 x 5.4 ton = 10.8 ton
Tons/acre = 10.8 ton / 0.8 ac = 13.5 ton/ac
Since ratio of 13.5 : 20 approximately equals ratio of 4 : 6,
recommend a 4-row spread pattern

Problem 6: Acres/load = 6000 gal / 3300 gal/ac = 1.82 ac/load
Acres = (0.5 x 5280 ft) x (0.25 x 5280 ft) / 43,560 = 80 ac
Loads = 80 ac / 1.82 ac/load = 44 loads

Problem 7: Fixed cost = depreciation + interest + insurance & housing
Initial cost = $35,000 + $11,500 = $46,500
Depreciation = ($46,500 - $7,300) / 11 years = $3563
Interest = 0.08 x ($45,500 + $7,300) / 2 = $2152
Insurance & housing = 0.01 x $46,500 = $465
Fixed cost = $3563 + $ 2152 + $465 = $6180
Fixed cost/gallon = $6180 / 1,700,000 gal = $0.0036/gal or 0.36 cents/gal
Variable cost = spreader repair + tractor use + fuel + labor
Spreader repair = 0.20 x $46,500 / 11 yr = $845
Tractor use = 45 hr x $0.137 x (125 hp + 175 hp) = $1850
Fuel = 45 hr x 0.044 x (125 hp + 175 hp) x $0.80/gal = $475
Labor = 2 x 45 hr x $6.80/hr = $612
Variable cost = $845 + $1850 + $475 + $612 = $3782
Variable cost/gallon = $3782 / 1,700,000 gal = $0.0022/gal
or 0.22 cents/gal
Total cost/gallon = 0.36 + 0.22 = 0.58 cents/gal

Test Questions

Lesson 3, Manure Application

1. Describe the best time to spread livestock manure, including desirable environmental conditions.

2. List two advantages and two disadvantages of injecting or incorporating livestock manure.

3. Give three reasons why proper livestock manure application is important.

4. Describe potential strategies to use to avoid neighborhood perceptions of an odor problem.

(Optional for your own use)
5. Using your own or another livestock producer's manure spreader,
a) calibrate the spreader; and
b) determine its cost per gallon or ton of application this year.
Using a specific application rate:
    c) how many loads would be applied to a field area that has a length and width of 1/4 mile?

Answers to Lesson 3 Manure Application

Test Question 1: At times when neighbors are not expected to spend significant time outdoors; when wind blows away from neighbors and populated areas; after morning commuter traffic and during the day when air is warm and rising; when humidity is low and wind is brisk.

Test Question 2:
Advantages: reduced odor, reduced manure runoff, incorporation of plant nutrients.

Disadvantages: decreased residue cover, secondary tillage may be required before planting, increased tractor-power required for tillage/injection.

Test Question 3:
Maximize use of plant nutrients in manure; minimize environmental effects on water quality such as nitrate loss in runoff; minimize odor production; maintain good relations between animal operations and neighbors; enhance soil tilth; minimize soil compaction.

Test Question 4:
Plan odor-producing activities for time periods least offensive to neighbors; consult with neighbors before major spreading activity to determine acceptable dates/times; use informal discussion or perhaps an open house to show the operation and odor-reduction techniques being used.

Home Study Module Evaluation

Environmental Issues in Livestock Production - Manure Application

Thank you for participating in the Iowa State University *Environmental Issues in Livestock Production* home study series. Please take a few minutes to give us your suggestions for improving these materials, and to guide our development of new home study materials. If you wish to obtain a certificate of completion for this module, mark the certificate request line at the bottom of this form, fill in your name and address, and attach your answers to the homework problems for this module. (Note: your answer sheet will NOT be returned)

Describe your objective(s) for completing this module:

___Personal interest in environmental issues ___Background for other class work
___To evaluate and/or modify your livestock enterprise ___Background for your profession
___Other (please specify)____
____

Do you feel that you met your objectives? ___Yes ___No

The content of this module was:

___too easy ___somewhat easy ___about right ___somewhat difficult ___too difficult

It took me about ______ hours to complete this module.

What did you learn from this module that was of greatest value to you?

Your suggestions for improving this module.

Please suggest other subject(s) you would like to have home study materials on.

___I would like a certificate of completion from Iowa State University for the *Manure Application* module. **My answers sheet for the homework problems in this module are enclosed as proof of completion**, and my name and mailing address are as follows:

Your name: ________________ Address:____

Return this form to: Livestock & Environment Home Study Project, Department of Agricultural & Biosystems Engineering, 207 Davidson Hall, Iowa State University, Ames, Iowa 50011-3080, OR FAX to L&E Home Study Project at 515-294-9973, OR email your responses to tglanvil@iastate.edu.