Chapter 5
Land Application Procedures and Equipment

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Introduction

The nature of modern animal agriculture, with its highly concentrated production facilities has raised serious questions about the effects of animal manure on the quality of our soil, water, atmosphere, and food supply. The soil is a very effective manure treatment system if manure is applied at the proper rate, time, and location. Since manure is a valuable organic fertilizer, operators who need the nutrient resource in manure tend to use it better, even those who are using land application as a waste disposal practice can do it in an environmentally sound manner provided they know the impacts of their practices.

Land application planning is a two-part process. The first step involves the process of determining the amount of manure to apply, developing a general cropping plan, and estimating the number of acres needed to properly land apply the manure. The second step deals with the implementation of this plan including knowledge of how, when, and where this manure will be applied. It covers such things as the planned times for manure applications, manure application methods, best management practices (BMPs), and records of manure applications and crop yields. Often these factors can have as much or more impact on the environment than the application amount.

Selecting Land Application Sites

Site selection is one of the major factors that directly affect an operation's success. Spend the time up front selecting the best sites for land application of manure so that future, potentially expensive environmental problems and adverse public relations can be avoided. Even though a site may look good initially, its use may result in problems that could easily have been avoided by choosing another site.

One of the most important criteria in site selection is finding a site where the soils are suitable for the crops that are intended to be grown. The goal of land application is to use the manure nutrients in crop production. If the soil does not sustain crop production, then the nutrients will probably end up in the surface or groundwater. Sometimes certain areas of land application fields do not sustain vegetation. In these areas, soil testing is an essential diagnostic tool for determining what the problem is and developing solutions for correcting the problem. You may need to consider different crops or tillage systems that will sustain vegetative growth. Remember, if the intended crop is not growing, then the nutrients are going some place else.

The soil texture and other physical characteristics are also very important. Ideally, the soils at the site would not be too sandy. The clays and organic matter in soils help hold the nutrients and metals found in the manure, thereby preventing their movement to the groundwater and maximizing the potential for plant uptake. Sandy soils are prone to groundwater contamination while heavy clay soils tend to create more runoff and surface water impacts. To prevent nitrogen (N) from leaching to groundwater, limit N applications on sandy soil and avoid soils with high water tables, tile drains, or controlled drainage. A deep soil (greater than 12 inches) that has good separation from bedrock is preferred. Shallow soils tend to produce more runoff and will not hold the nutrients in place for crop utilization.

Since phosphorus (P) is usually applied in excess of plant needs in manure land application systems, sites with low soil test P are preferred. To receive the most value from your manure, apply high-P manure to fields with the lowest soil test P levels. Economically, it also makes sense to haul the highest nutrient content manure to the farthest fields and apply the lowest nutrient content manure to the closest fields. For lagoon systems, this would usually result in irrigating the closest fields with collected runoff water and lagoon effluent and hauling sludge to fields farther away.

Animal manure should not reach surface waters or wetlands by runoff, drift, manmade conveyances (such as pipes or ditches), or direct discharge during land application. For regulated operations, EPA requirements call for a 100-ft setback or a 35-ft vegetated buffer between any application area and surface waters. Therefore, sites with least potential for surface water runoff reaching streams would be better suited for land application systems. Sites that have a deep groundwater table are also preferred. This can reduce the risk of groundwater contamination. Tile-drained systems artificially lower the water table by draining the soil. These systems are therefore more prone to nutrients seeping into the shallow groundwater and ending up in surface water.

Slopes steeper than 6% should also be avoided unless there is sufficient crop residue to prevent runoff, or unless manure is injected or incorporated into the soil. Sites that are too steep will have greater losses to runoff, will have more soil erosion, and often have shallower topsoil. In general, flatter slopes have better soils for land application and make the maintenance of a crop easier.

Odor associated with land application is unavoidable so isolated sites are better that those near neighbors or in the public view. Always check with local city and county officials for applicable regulations on zoning, health, and building codes to ensure that the site can legally have manure applied to it. Buffer or set-back restrictions can significantly reduce available land for manure application. Buffers are designed to minimize the potential for impacts to adjacent homeowners as well as to the environment. Having trees or other visual barriers around the site will also help you to avoid odor complaints. In addition, it is crucial to consider the direction of the prevailing wind in relation to the site and residential development in the area.

Obviously, not every site is perfect for manure applications, but knowing the limitations of potential sites is important. Evaluating the environmental suitability of your fields is one method you can use to identify those fields where manure application is most appropriate. Table 6-1 will allow you to measure the relative “risk” to the environment of various land application sites. Evaluations such as these can be done on each field and included as part of your nutrient management plan (NMP). Assessments such as Table 1 (next page) can also help you determine which fields to use if several alternatives are available.

Table 1. Field assessment for manure application.

Category	Points	Field # ____
1. Planned crop (check one)		
a. Continuous corn or corn not following legume	10	
b. Second-year corn following legume	8	
c. First-year corn following legume	1	
d. First-year corn following nonforage legume	8	
e. Nonforage legume	2	
f. Small grains (for grain)	6	
g. Small grain with seeding (removed as grain)	2	
h. Small grain with seeding (removed as hay or silage)	4	
i. Prior to direct seeding legume forage	8	
j. Topdress (good legume stand)	1	
k. Topdress (fair legume stand)	2	
l. Topdress (poor legume stand)	3	
m. Grass pasture or other nonlegumes	6	________
2. Soil test P (check one for each category)		
a. > 200 lbs/acre	1	
b. 100-200 lbs/acre	3	
c. 30-100 lbs/acre	5	
d. < 30 lbs/acre	10	
3. Site/soil limitations (check one for each category)		
a. Surface or groundwater proximity		
1. Applied and incorporated within 10-year floodplain or within 200 feet of surface water or groundwater access	1	
2. Application above these restrictions	5	
b. Slope		
1. > 12%	1	
2. 6%-12%; > 12% (incorporated, contoured, or terraced)	3	
3. 2%-6 %; 6%-12% (incorporated, contoured, or terraced)	5	
4. < 2%; <6% (incorporated, contoured, or terraced)	10	
c. Soil texture		
1. Sands, loamy sands	1	
2. Sandy loams, loams/sands, loamy sands	3	
3. Other soils	5	
d. Depth to bedrock, inches		
1. 0–10	0	
2. 10–20	1	
3. > 20	5	
4. Odor and Public Access Concerns (check one)		
a. Field along public road or near many houses without visual screening/buffer	0	
b. Field along public road or near many house with visual screen or buffer	3	
c. Field is isolated from non-farm neighbors and public view	5	+ ________
5. Total Points (Higher field score = higher priority for land application)		= ________

Timing of Manure Applications

Crop growth rates and application conditions are not uniform throughout the year. Likewise, crop nutrient requirement is not uniform among various crops. All nutrient sources should be applied at times that will maximize crop use and minimize loss. Ideally, manure nutrients should be applied to an actively growing crop or within 30 days of planting a crop. If crops for human consumption are grown, manure should not be applied within three weeks of harvest. Some common crops grown to use nutrients in manure are shown in Table 2. A cropping system with a variety of crops offers the most flexibility for manure application over many parts of the year.

Table 2. Crops useful for manure utilization and their maximum uptake period in the southeastern United States.[1]

Crop	Uptake Period[2]
Corn (grain) Corn (silage) Sorghum (grain)	Apr-July
Small grains (grain) Small grains (hay, pasture)	Feb-Apr
Soybean	July-Sept
Cotton	June-Aug
Bermudagrass (hay, pasture)	Apr-Sept
Tall fescue (hay, pasture)	Feb-Apr and Sept-Nov
Alfalfa (hay) Millet (hay, silage)	May–Aug
Annual ryegrass (hay, silage, pasture)	Feb-Apr and Sept-Oct

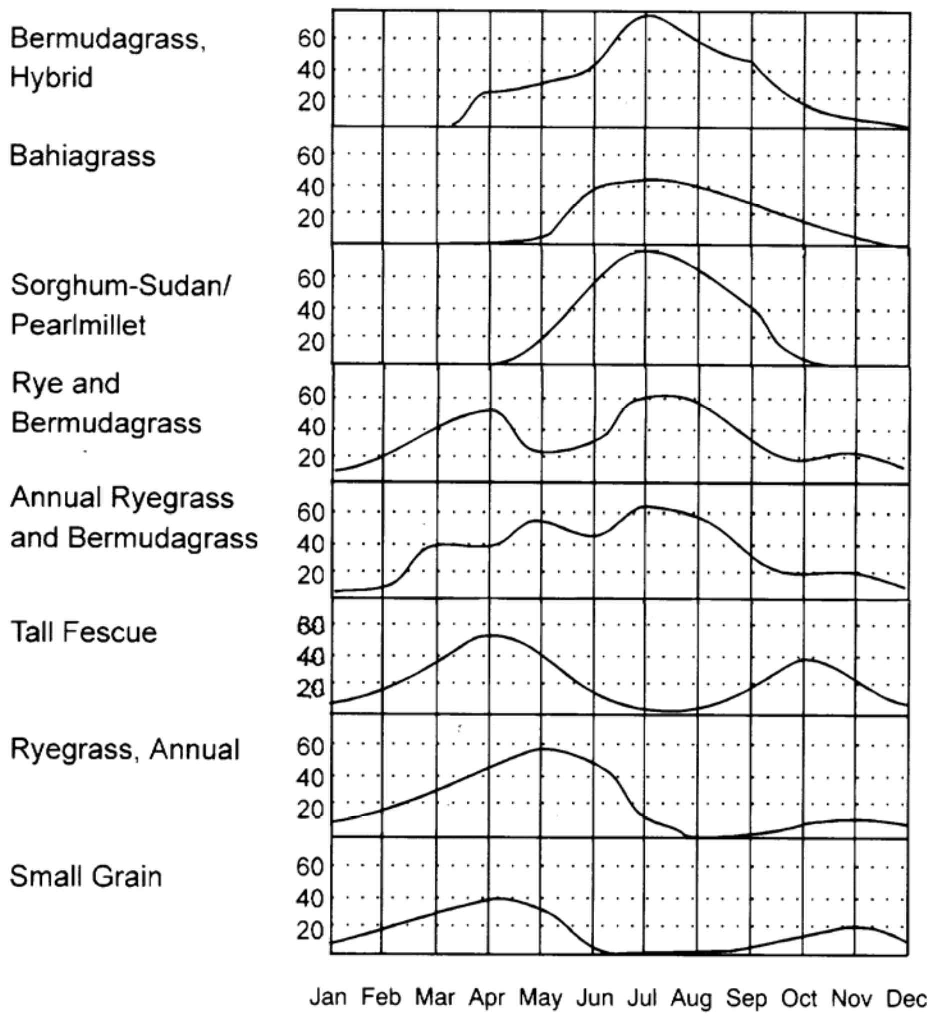
[1]Relevant crop growth periods for your local area should be substituted in this table.
[2]Application should occur no more than 30 days before planting or green up of perennial forages.

As seen in Figure 1, there are several months during the year when most crops are dormant. For example, bermudagrass is dormant in January and February, and growth is "slow" during March, November, and December. These would be periods prone to nutrient losses when manure application would not be recommended. The risk of encountering an emergency situation can be significantly reduced by utilizing a cropping system that provides the flexibility of extending the application season throughout most of the year. For example, if bermudagrass is overseeded with rye in the winter, you have a cropping system in place that can accept some manure almost all the time.

Manure should not be applied to saturated soils, during rainfall events, or when the soil surface is frozen. Timing is most important for nutrients applied to soils with a high leaching potential. Applying N to a sandy soil when there is no crop to remove it will almost certainly result in loss of N to the shallow groundwater. Manure with the highest N content should be applied in the spring to take advantage of lower temperatures. You must also plan for significant wet weather periods if you live in an area that normally receives abundant rainfall in certain months.

In some cases, manure storage capacity dictates the frequency of manure applications. Insufficient manure storage capacity will require frequent applications and year-round cropping systems, while larger storage volumes may facilitate less frequent applications to a single crop. Many storage structures are designed for 180 to 270 days of temporary storage, which means that an actively growing crop must be present in both summer and winter. Because manure production and storage capacity determine the maximum amount of time between manure applications, these factors strongly influence crop selection and land requirements.

Figure 1. Growth rate of selected forage crops. Growth is expressed as pounds of forage produced per day per acre.



Application Methods and Equipment

Different application equipment offers advantages and disadvantages over other equipment. While most operators do not have the luxury of being able to select among several types of equipment, it is important to be aware of the limitations your equipment may have on your system. Table 3 (page 7) lists the environmental performance of common application equipment. The criteria for these comparisons is given below.

Application uniformity

To manage manure nutrients as a resource, your application equipment must provide uniform and controllable applications. Uneven distribution of nutrients results in reduced crop production where application is deficient and in increased nutrient losses where nutrients exceed crop requirements.

Timeliness of application

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

Conservation of N

The ammonium fraction of manure, which could represent more than half of the potentially available N, is lost by long-term, open lot storage of manure, anaerobic lagoons, and surface spreading of manure. Systems that conserve ammonium N and provide nutrients more in balance with crop needs increase the economic value of manure.

Odor nuisances

Odor nuisances are the primary driving factor behind more restrictive local zoning laws for agriculture. Manure application systems that provide you with more flexibility in application timing and location can reduce odor nuisances. Application systems that minimize odor deserve consideration and preference when neighbors live close to application sites.

Soil compaction

Manure spreaders are heavy. The manure in a 3,000-gallon liquid manure tank weighs more than 12 tons. In addition, manure is often applied at times of the year, late fall and early spring, when high soil moisture levels and the potential for compaction are common. Soil compaction can reduce yields and increase surface water runoff.

Table 3. Environmental rating of various manure application systems.

	Uniformity of Application	Conservation of Ammonium*	Odor	Compaction	Timeliness of Manure Application
Solid Systems					
Box spreader: tractor pulled					poor
Box spreader: truck mounted	poor				fair
Flail-type spreader		very poor	fair	fair	
Side-discharge spreader					poor
Spinner spreader	fair				
Dump truck	very poor			poor	fair
Liquid Systems: Surface Spread					
Liquid tanker with splash plate	poor	poor	poor		
Liquid tanker with drop hoses	fair	fair	good	poor	fair
Big gun irrigation system	good				
Center pivot irrigation system	excellent	very poor	very poor	excellent	excellent
Liquid Systems: Incorporation					
Tanker with knife injectors					
Tanker with shallow incorporation	good	excellent		poor	fair
Drag hose with shallow incorporation				good	good

*Solid or liquid manure applications may be followed by immediate incorporation to improve ammonia conservation.

Equipment Calibration

A NMP is of little use if the designed application rate cannot be met. Calibration of manure application equipment is essential because it lets you know the amount of manure and wastewater you are applying to an area. More specifically, the calibrated rate and nutrient concentration of manure lets you know the amount of plant-available nutrients you are applying. Then you can adjust your application rate to avoid over fertilization and resulting nutrient losses. Calibration will:

- Verify actual application rates.
- Troubleshoot equipment operation.
- Determine appropriate overlaps.
- Evaluate the uniformity of application.
- Monitor changes in equipment operations (age and “wear and tear”).
- Alert you to changes in manure consistency or “thickness."

Detailed procedures for calibrating almost any type of application equipment can be obtained from equipment manuals or the Cooperative Extension Service. Operators should establish written calibration procedures to be used on their operation and schedule calibration activities on a regular basis. Georgia regulations require some type of calibration documentation for custom or professional applicators. At a minimum, annual calibration is recommended for all application equipment on a farm.

Best Management Practices (BMPs)

The term Best Management Practices refers to a combination of practices determined to be effective economical approaches to preventing or reducing pollution generated by nonpoint sources. Even under ideal conditions with properly calculated, well timed, and appropriately placed applications, land application systems will have losses to ground or surface water, so BMPs are necessary to minimize the impacts of these losses. BMPs can be structural like in the construction of terraces, sedimentation basins, vegetated waterways, or fencing or they can be managerial like crop rotation, plant tissue analysis, and conservation tillage. Both types of BMPs require good management to effectively reduce the generation or delivery of pollutants from agricultural activities. In an NMP, it is important to indicate the BMPs that will be used on all land application areas.

Factors Controlling BMP Effectiveness

Best Management Practices use a variety of mechanisms that result in varying degrees of effectiveness. Often, operators will need the assistance of a conservation planner such as your local Natural Resources Conservation Service (NRCS) staff, Soil and Water Conservation District (SWCD) officer, Extension agent, or crop advisor to select and develop a conservation plan for each field. When selecting BMPs, you should use a systematic approach to ensure that the practice you select will solve your problem. The following questions can help you in the selection process:

What pollutants are contributing to the problem?
Sediment, nutrients, bacteria, etc.
Where are the pollutants being transported?
Surface or groundwater
How are the pollutants being delivered?
Availability, transport paths, in the water, or on sediment

The most effective plan will probably consist of several different BMPs that target different mechanisms. Some BMPs may solve a surface water quality problem but create a groundwater quality problem. An expert trained in these systems should design (and review the installation of) the BMPs for your operation. Finally, if a BMP is not economically feasible and well suited for the site, you probably should not use it. When selecting BMPs, consider all the of costs including effects on yield, production and machinery costs, labor and maintenance, and field conditions. Often a very effective BMP will rapidly become a problem if all the costs are not considered before implementation.

Control of soil erosion is probably the best opportunity for preventing pollution from land application areas since sediment is not only a pollutant but can also carry nutrients or pesticides with it. While soil erosion is a natural process, it is accelerated by any activity that disturbs the soil surface. The amount of soil erosion that occurs is a function of the rainfall and runoff generated from the site, the soil erodibility, the slope length and steepness, the cropping and management of the soil, and any support practices that are implemented to prevent erosion. Knowledge of rainfall patterns will allow operators to ensure that the soil is protected during the periods of the year when it receives the largest amounts of rainfall.

Your primary control of soil erosion is through modifications in slope steepness and slope length and in cropping, tillage and residue management, and support practices. Steeper slopes produce more soil erosion, and methods of reducing slope length or steepness such as the construction of levies and terraces can reduce soil erosion. Practices such as strip cropping and vegetated waterway construction can be used to reduce runoff velocities and slope length. Crop canopy and surface cover or residue act as a buffer between the soil surface and the raindrops, absorbing much of the rainfall energy and ultimately reducing soil erosion. Therefore, crops that produce more vegetative cover, have longer growing seasons, or produce a persistent residue will have less soil erosion. Any cropping system with less tillage or greater amounts of vegetative production will result in less sediment leaving the field. Support practices are structural BMPs such as terraces that are proven to reduce soil erosion. These practices are often more expensive than management and cropping changes but may be required on some fields.

While most BMPs reduce soil erosion and transport, some BMPs use other mechanisms to reduce the impact of a pollutant. The three stages of the pollutant delivery process are availability, detachment, and transport. Availability is a measure of how much of a substance in the environment can become a pollutant. For example, an effective BMP for reducing the amount of animal manure entering surface water may be to simply decrease the amount that you are land applying to an area so that less is available. Once a substance is available, it must be detached from the target site to become a pollutant. Pollutants may be detached as individual particles in the water or attached to soil particles. For example, dry manures applied to the surface are more easily detached than the same amount of liquid manure that has soaked into the soil. Incorporation of the dry manure into the soil is therefore a BMP that limits detachment. Transport is the final link in the pollutant delivery chain. To cause a problem, nutrients or other pollutants must travel from the point where they were applied to the surface or groundwater. For instance, using a filter strip to collect sediment before it enters a stream is an example of reducing pollutant transport.

Land Application BMPs

When properly carried out, BMPs improve water quality. Best management practices relating to manure management are those practices that optimize nutrient uptake by plants and minimize nutrient impact on the environment. They will change over time as technology and understanding of the complex environment improves. Likewise, BMPs are very site specific, and a BMP in one place may not be useful for another location. Key BMPs for land application are listed in Table 4 (next page).

Table 4. Common BMPs for land application of manure.

BMP	Mode of Action
Soil, manure or plant analysis	Ensures that proper crop nutrient requirements are met and manure is not over applied: Amount
Nutrient management plan	
Calibration of application equipment	
Manure treatments such as alum	Reduces availability of nutrients to runoff: Availability
Manure injection or incorporation	Places nutrients in the root zone and reduces availability to runoff: Availability
Critical area protection/Vegetated waterways	Removes areas prone to runoff and erosion from production and manure application: Availability
Water diversions	Diverts water from running onto fields: Availability
Terraces or contour planting	Reduces erosion and encourages infiltration: Transport
Riparian buffers or filter strips	Acts as trap to remove pollutants before entering waterways: Transport
Cover crops, "scavenger crops, or crop rotation	Reduces erosion and encourages infiltration, improves soil quality and provides additional uptake: Transport and availability
Conservation or reduced tillage	
Ponds or retention structures	Acts as trap to remove pollutants before entering waterways: Transport
Rotational grazing/Pasture management	Reduces runoff and erosion, increases plant uptake: Transport and availability

A summary of other BMP principles related to land application practices that enhance surface water and groundwater quality are as follows:

1. Application of nutrients at rates corresponding to crop uptake requirements is one of the most important management practice used for reduction of off site transport of nutrients.
2. Maintaining good crop-growing conditions will reduce both surface runoff losses and subsurface losses of plant nutrients. Preventing pest damage to the crop, adjusting soil pH for optimum growth, providing good soil tilth for root development, planting suitable crop varieties, and improving water management practices will increase crop efficiency in nutrient uptake.
3. Timing of nutrient application to coincide with plant growth requirements increases uptake efficiency and reduces exposure of applied nutrients to surface runoff and subsurface leaching. The optimum time of application depends on the type of crop, climate, soil conditions, and chemical formulation of fertilizer or manure. Consult a certified crop advisor or professional agronomist to discuss when manure/nutrients should be applied to maximize crop uptake.
4. Certain soil and water conservation practices will reduce sediment-associated nutrient losses. By reducing sediment transport, contouring, terraces, sod-based rotations, conservation tillage, and no-tillage reduce edge-of-field losses of sediment-bound-N and sediment-bound-P.
5. Proper selection and calibration of equipment will ensure proper placement and rate of nutrient delivery. Improper calibration and equipment maintenance will result in over or under application of nutrients or uneven nutrient distribution. Appropriate handling and loading procedures will prevent localized spills and concentration of manure nutrients.

6. Crop sequences, cover crops, and surface crop residues are useful tools for reducing runoff and leaching losses of soluble nutrients. Winter cover crops may theoretically capture residual nutrients after harvest of a summer crop. Nutrient credits for "green manures" and cover crops must be taken into account to determine the appropriate rate of additional manure application. On soils with a high potential for leaching, multiple applications of manure at lower rates should be used.
7. Deep-rooted crops, including alfalfa and to a lesser extent, soybeans, will scavenge nitrate leached past the usual soil-rooting zone. Used in crop rotation following shallow-rooted or heavily fertilized row crops, deep-rooted crops will recover excess nitrate from the soil and reduce the amount available for leaching to groundwater.
8. Use commercial fertilizer only when manure does not meet crop requirements.
9. Manure should not be applied more than 30 days prior to planting of the crop or forages breaking dormancy. Incorporate manure to reduce N loss, odors, and nutrient runoff for crops where tillage is normally used.
10. Applications of animal manure should not be made to grassed waterways. If applications are made, they should be conducted at agronomic rates and during periods of low rainfall to minimize runoff from the site.
11. On manure application sites that are grazed, reduce the N rate by 25% or more to account for nutrient cycling through the grazing animals. Use proper stocking rates so that the vegetative cover is not damaged, which could result in increased soil erosion. Controlling animal traffic patterns can help to prevent bare spots that could lead to the formation of gullies.
12. The use of sediment basins or small ponds is a method of preventing off-farm pollution. A sediment basin is a barrier or dam constructed across a waterway to reduce the velocity of the runoff water so that much of the sediment and associated nutrients settle to the basin bottom. Small sediment basins require regular sediment removal while larger basins can almost appear to be a pond and may support fish and wild life. A well-placed pond can collect all of the runoff from an operation and have a positive impact on water quality. It acts as a detention basin by removing sediment and nutrients from the flow and reducing the volumes of flow occurring at peak conditions. It can also filter many nutrients if aquatic vegetation or fish are used. Finally, the pond can act as a buffer between the operation and the external environment.

Note: This module was adapted from the Livestock and Poultry Environmental Stewardship (LPES) curriculum, Lesson 30 authored by Pat Murphy, Kansas State University; Lesson 31 authored by Karl Shaffer, North Carolina State University; Lesson 32 authored by Ron Sheffield, now at the University of Idaho; Lesson 33 authored by Ron Sheffield, now at the University of Idaho, and Pat Murphy, Kansas State University; Lesson 34 authored by Andrew Sharpley, USDA-Agricultural Research Service, and Ron Sheffield, now at the University of Idaho; Lesson 35 authored by Karl Shaffer, North Carolina State University, and Ron Sheffield, now at the University of Idaho; and Lesson 36 authored by Ron Sheffield, now at the University of Idaho, courtesy of MidWest Plan Service, Iowa State University, Ames, Iowa, 50011-3080.