Chapter 6

6. Protocols for Land Application of Manure Nutrients

As explained in Chapter 4.1.7, any permit issued to a CAFO must include a requirement to implement an NMP that includes the BMPs necessary to meet the requirements of 40 CFR part 122.42(e)(1) and for Large CAFOs the ELG of 40 CFR part 412. The relevant content in the NMP must be integrated into the permit as enforceable terms of the permit. The *terms of the NMP* are the content of the NMP that implements the regulatory requirements in part 122.42(e)(1). One of the nine requirements in part 122.42(e)(1) are *protocols for land application.*[1] Terms of the NMP relevant to the *protocols for land application* must be incorporated as enforceable terms of any CAFO permit.

NMPs contain the technical information operations use to develop a plan that allows for maximum utilization of the nutrients in manure while minimizing the runoff of nutrients and pollutants. The maximum utilization of nutrients in manure depends on the amount of manure that the operation will have, the characteristics of that manure, the amount of land the operation will have available, and the type of crops and nutrient needs of the crops that the operation plans to grow. Although this chapter explains in more detail the specific components of the NMP that are the *protocols for land application* of manure, 40 CFR part 122.42(e)(1)(ix), it is important for a permit writer to understand the source of the information in the NMP itself and the way it is used in the NMP to develop rates of application and terms of the NMP.

Land application of manure slurry. (Photo courtesy of USDA/NRCS)

This chapter provides background information on soil fertility and plant availability of nutrients, state technical standards for nutrient management, EPA's regulatory requirements for land application of manure, the permit term *protocols for land application*, and this chapter demonstrates how to derive the permit terms for *protocols for land application* from a sample NMP.

6.1. Soil and Plant Availability of Nutrients

Soil is a pathway for nutrient flow to surface and ground water, and it is a medium for nutrient transformations. Nutrient compounds are generally dynamic, undergoing various transformations depending on the properties of the soil they are in. Because those transformations affect the amount and form of nitrogen and phosphorus available to the plant, appropriate manure and fertilizer applications in an NMP will account for many of the transformations as discussed below. Additionally, the CAFO rule requires accounting for some of those nutrient transformations as permit terms. 40 CFR §§ 122.42(e)(5)(i)(A), (e)(5)(ii)(A). Therefore, it is important for a permit writer to understand the behavior of nitrogen and phosphorus in the soil. For further supporting information regarding soil science, see Appendix A, Basic Soil Science and Soil Fertility.

6.1.1. Nitrogen Cycle

Although nitrogen in soil is essential for plant growth, it is not always available in a form for plant uptake. The largest pool of nitrogen is found in the atmosphere as an inert gas (N_2). Plants are not able to absorb gaseous nitrogen. Nitrogen must first have its form changed by biological or industrial processes. The process that converts nitrogen gas into plant available forms of nitrogen is called nitrogen fixation and is a part of the nitrogen cycle (Figure 6-1). In nature, nitrogen becomes plant available when specialized bacteria (and to a lesser extent, lightning) fix nitrogen gas. Leguminous plants, such as alfalfa and soybeans, have a symbiotic relationship with nitrogen-fixing bacteria, in which the bacteria supply sufficient nitrogen to the plant and the plant supplies carbohydrates to the bacteria. Because of that relationship, a legume crop is able to supply its own nitrogen need and enrich a soil with nitrogen for crops that follow in the rotation and therefore is considered an nitrogen credit.

The forms of nitrogen that plants typically use are ammonium (NH_4^+) and nitrate (NO_3^-). Ammonium is used less by plants because it is extremely toxic in large concentrations. Ammonium can oxidize in the soil to form nitrate through a two-step process that requires two types of soil bacteria (*Nitrosomonas* and *Nitrobacter*). Nitrate is highly mobile and easily leached as water moves through the soil profile, and can be a source of nitrogen pollution in surface and ground water if it is not utilized by growing crops.

The majority of the nitrogen in the soil (95 to 99 percent) is locked up as organic compounds (mostly as proteins) that are generally unavailable to plants. Organic nitrogen compounds become plant available through a microbial process called mineralization. While mineralization converts organic compounds into inorganic compounds, inorganic nitrogen can also be converted to organic forms through a process called immobilization. Microbes require nitrogen, as all living

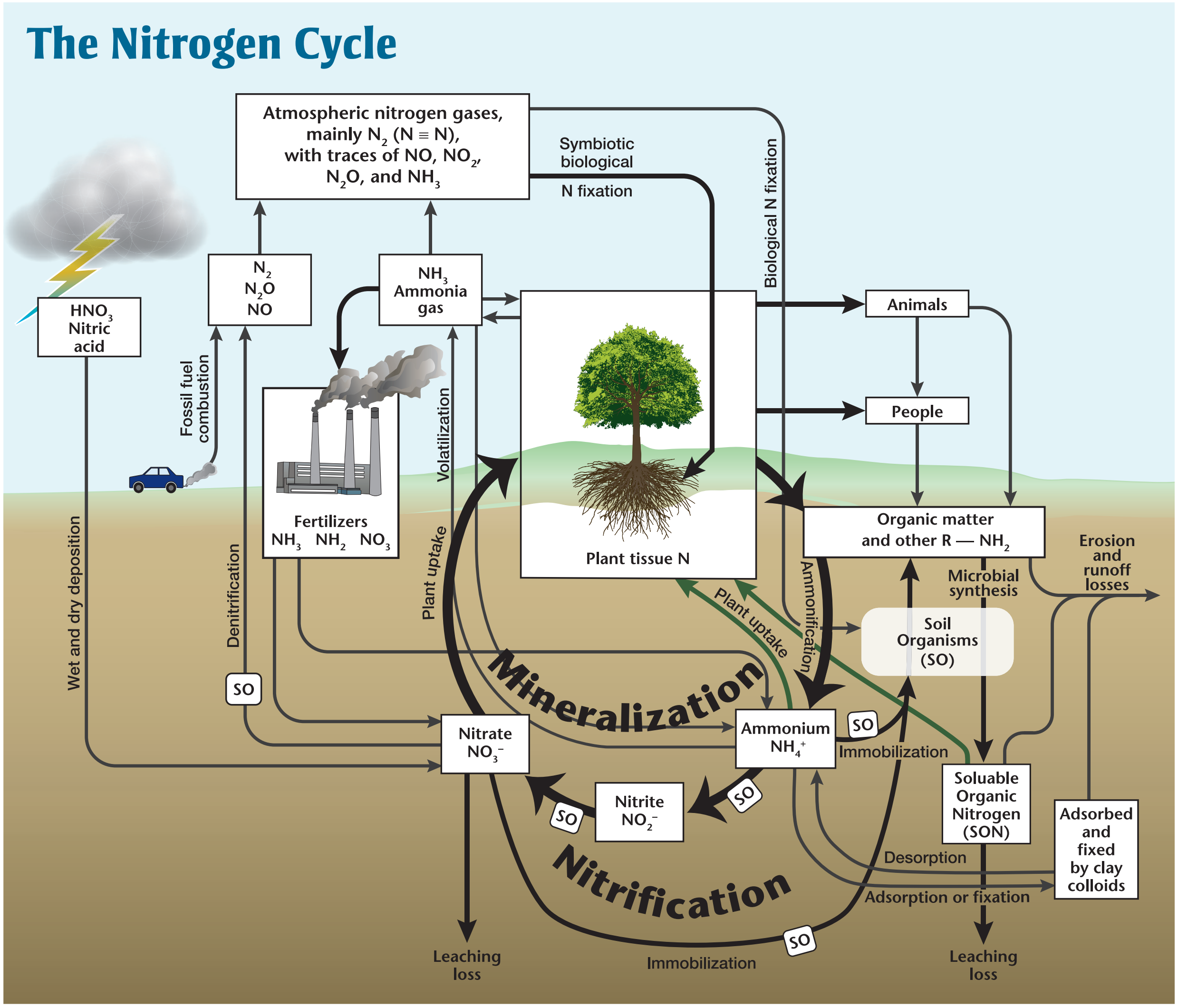

Figure 6-1. The Nitrogen Cycle.

organisms do, for basic cellular function. Nitrogen is required for microbial decomposition of organic residues. Microbes use available inorganic nitrogen from the soil, which becomes incorporated into their microbial cellular structure. That nitrogen is unavailable until the organisms die and decompose, releasing plant available inorganic nitrogen back to the soil.

Nitrogen compounds can also be released to the atmosphere as ammonia gas (NH_3) through a process called volatilization. Warm, moist soils and surface application of manure and wastewater accelerates volatilization. While ammonia can be lost to the atmosphere, it can also be removed from the atmosphere via absorption through plants. The other significant pathway for gaseous loss of nitrogen is denitrification. Denitrification is a series of bacteria-driven reduction reactions that reduce nitrate ultimately to nitrogen gas. Because denitrification is a reduction reaction, it requires an anaerobic environment, such as saturated soils. Only when soil oxygen levels are low enough will nitrate be fully reduced resulting in the formation of nitrogen gas.

6.1.2. Phosphorus Cycle

Phosphorus in soil mostly comes from weathered apatite rock. Other sources of soil phosphorus include decomposing organic matter and humus. Plant available forms of phosphorus include hydrogen phosphate (HPO_4^{-2}) and dihydrogen phosphate ($H_2PO_4^-$). Phosphorus's tendency to bond with other compounds and with the clay fraction in the soil can reduce the mobility of the nutrient. Soil pH also has a strong influence on the availability of phosphorus. The phosphorus cycle is shown in Figure 6-2.

Both the inorganic and organic phosphorus forms are distributed among three major soil pools: solution phosphorus, active phosphorus, and fixed phosphorus. The solution pool contains dissolved, soluble phosphorus that is readily available for plant uptake. While that pool is generally small, relative to the total amount of phosphorus, it is important because it is the only pool from which plants can draw nutrients. Because plants are continuously removing nutrients from this pool, it must be replenished.

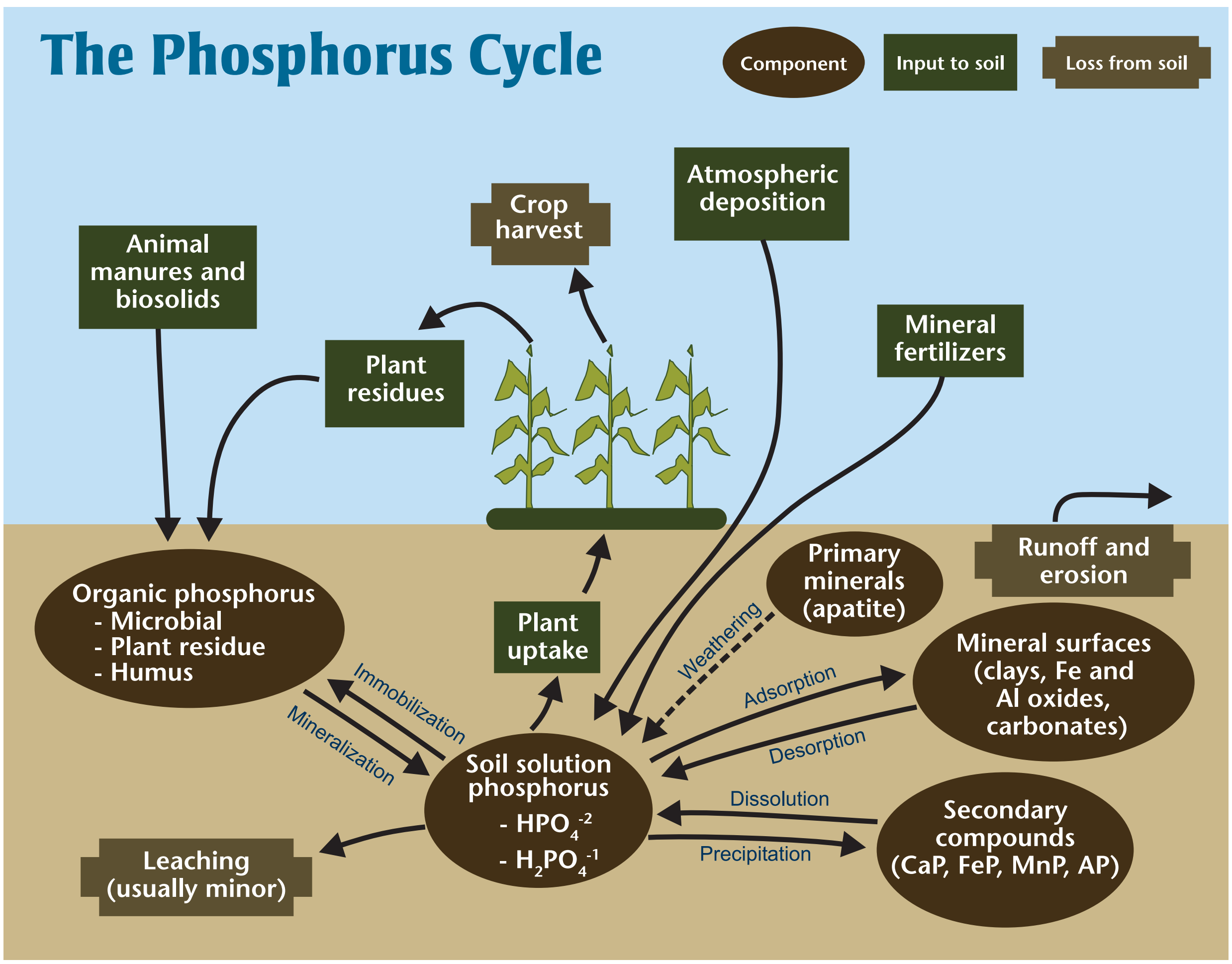

Figure 6-2. The Phosphorus Cycle.

The active pool is capable of replenishing the solution pool. The active pool contains phosphorus that is somewhat less available than the solution pool. This pool contains phosphorus in several different forms:

- Phosphorus that is loosely adsorbed to mineral surfaces, on active mineral sites.
- Phosphorus that has reacted with other elements to form somewhat insoluble compounds.
- Organic phosphorus that is easily mineralized.

While the active pool does not contain soluble phosphorus, the active pool can easily release phosphorus to the solution pool. The relationship between the solution and active pools can be described by the cycle shown in Figure 6-3. As phosphorus is added to the solution pool, more phosphorus is adsorbed to mineral surfaces and as the solution pool is depleted, the active pool will release additional phosphorus to replenish it.

Some exchange occurs between the solution and active pools. When phosphorus is initially added to a soil, it can first be held in complexes of low solubility or by temporary bonds, as part of the active pool, that can be released back to the solution pool and be made plant available. However, with time, the compounds will become more and more insoluble and contribute to the third pool—fixed phosphorus. Fixed phosphorus is extremely insoluble and can remain there for many years without becoming available to a plant and contributing minimally to a soil's fertility.

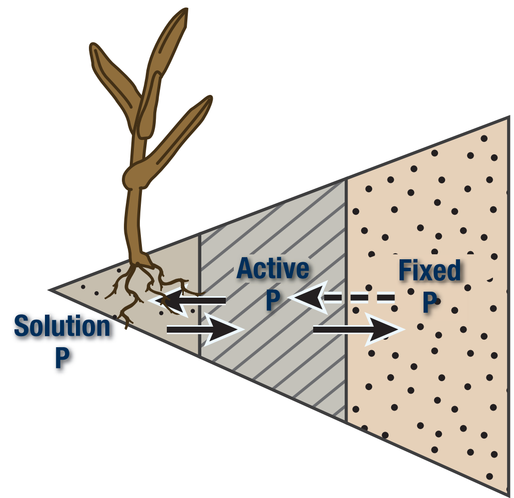

Figure 6-3. The relationship between the phosphorus solution and the active pool.

Soils have a phosphorus fixation capacity that is defined by the sites on a mineral surface that are available to react with phosphorus. Historically, there has been very little plant available phosphorus in many soils because of that fixation capacity. If enough soluble phosphorus is added to a soil, the reactive sites become occupied so that any further phosphorus that is applied will remain in the solution pool. Soils that have been regularly over-applied with phosphorus might have relatively high levels of soluble phosphorus because the soil's capacity to fix phosphorus has been overwhelmed. In those cases, dissolved phosphorus can be leached from soils and lost to groundwater through the soil profile or to surface water in runoff.

Regardless of the potential for dissolved phosphorus leaching or runoff, there is always a potential for losses of phosphorus to surface waters from erosion. Because phosphorus binds to soil particles, if soil particles are eroded from a landscape, the attached phosphorus (and any other nutrients, metals, or contaminants) are lost as well. Phosphorus can be released from the soil particle it is bound to if the chemical bond holding it together is broken. For example, the oxidized form of iron forms a strong bond with phosphorus. However, if iron is reduced, the bond will break and release phosphorus. When phosphorus is bound to soil sediments by iron and the soil is eroded to surface waters such as an anaerobic lake or pond, iron will be reduced and release iron-bound phosphorus from the soil particle to the waterbody. Agricultural management practices must consider the potential for this type of phosphorus loss. 40 CFR §§ 122.42(e)(1)(vi), 412.4(c)(2)(i).

Many factors must be considered when applying phosphate fertilizer, including soil fertility levels, crops to be grown, tillage methods, equipment, timing, slope, climate, and other management factors so that both dissolved and particulate phosphorus are adequately controlled while supplying the necessary crop nutrient requirements.

6.1.3. Soil Fertility

Soil fertility is the ability of a soil to provide nutrients for plant growth. Although soils contain most of the nutritional elements plants require, only a small percentage is available for plant uptake. Plants generally derive nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur from soil. Many factors affect the availability of nutrients in soil, including the forms of the nutrient in the soil, pH, soil aeration, soil compaction, soil temperature, and soil moisture. The essential nutrients for plant growth move through the soil profile at various rates, depending on their chemical properties. An understanding of the chemical properties of those elements and the amounts available to plants is necessary when determining the amount of fertilizer or manure to be added to a soil to prevent over application, which in time could result in surface and ground water contamination.

The ability of a soil to retain nutrients is related to its cation exchange capacity (CEC). CEC is a measure of the soil's ability to retain cations (positively charged ions) and is indicative of the soil's fertility. Soil minerals have a net surface charge, which is usually negative, that allows them to hold and retain cations against leaching. The net negative charge of a soil is largely attributed to the clay and organic matter contained in the soil. Negatively charged soil particles will naturally attract positively charged ions and repel negatively charged ions. That explains why positively charged nutrients such as ammonium, will remain adsorbed to clay particles in the soil, while negatively charged nutrients such as nitrate are easily leached out of the soil. The CEC of a soil directly affects the soil's nutrient storage capacity and, therefore, the amount of fertilizer or manure that should be used and the frequency with which fertilizer or manure should be applied.

Water runoff eroding a field. (Photo courtesy of USDA/MO NRCS)

The movement of nutrients in soil is largely controlled by the movement of water through and over a soil. Two pathways are (1) the infiltration and percolation or drainage of water through the soil profile; and (2) runoff water over the soil surface.

Percolation results in the loss of soluble compounds (leaching), thus depleting soils of needed plant nutrients. Runoff losses generally include water, appreciable amounts of soil (erosion) and any nutrients, chemicals, or compounds that are attached to the displaced soil particles.

6.2. Using Manure Nutrients

Manure is land applied because it contains nutrients (i.e., nitrogen, phosphorus and potassium) and acts as a fertilizer by supplying crop nutrient needs; it also contains organic matter, which improves the quality of the soil by decreasing compaction, increasing water-holding capacity, and, increasing the CEC, among other benefits. Typically, manure is applied so that it supplies either the nitrogen or phosphorus requirements of the crop to which it is applied. Manure is typically excreted at an nitrogen to phosphorus ratio of 2 or 3 to 1, while the typical crop's nutrient need of nitrogen and phosphorus is in a ratio ranging from 4 to 9 pounds of nitrogen per pound of phosphorus. That means that up to 3 times the needed amount of phosphorus is applied when manure is applied to meet the nitrogen requirements (disregarding nutrient losses). Table 6-1 shows typical nutrient concentrations for various types of manure. Table 6-2 shows typical nutrient requirements for some common crops. The values shown in these tables are generalized and might not be typical of all locations. When developing an NMP, site-specific values should be used where available. State-specific book values should be used where site-specific data are not available. Because of the 2 or 3 to 1 nitrogen to phosphorus ratio of manure, meeting nitrogen requirements through manure application alone can lead to a buildup of phosphorus in the soil and correspondingly high or very high soil test phosphorus levels.

Land application of dairy waste via "big gun" effluent distribution system. (Photo courtesy of USDA/NRCS)

Table 6-1. Manure nutrient content factors

Animal type	Manure nutrient content (pounds per ton of manure)			
	Nitrogen		Phosphorus*	
	As excreted	After losses	As excreted	After losses
Beef cows	10.95	3.30	3.79	3.23
Milk cows	10.69	4.30	1.92	1.65
Heifer and heifer calves	6.06	1.82	1.30	1.10
Steers, calves, bulls, and bull calves	10.98	3.30	3.37	2.86
Breeding hog and pig	13.26	3.32	4.28	3.62
Other hog and pig	11.30	2.82	3.29	2.80
Hens and pullets of laying age	26.93	18.64	9.98	8.50
Pullets over 3 months but not laying	27.20	13.60	10.53	8.95
Pullets under months	27.20	13.60	10.53	8.95
Broilers	26.83	16.10	7.80	6.61
Turkeys for slaughter	30.36	16.18	11.83	10.06
Turkeys for breeding	22.41	11.20	13.21	11.23

* Phosphorus presented here is elemental phosphorus. To convert to the orthophosphate (P_2O_5) form, multiply the elemental phosphorus by 2.29.

Table 6-2. Nutrient uptake parameters for selected crops used to estimate the assimilative capacity of cropland. *These values are for the harvested portion of the crop that is removed from the field at harvest.*

Crop	Yield unit	Pounds per yield unit	Nutrient content - pounds per yield unit	
			Nitrogen	Phosphorus
Field corn, for grain	Bushel	56	0.80	0.15
Field corn, for silage	Ton	2,000	7.09	1.05
Oats	Bushel	32	0.59	0.11
Barley	Bushel	48	0.90	0.18
Soybeans	Bushel	60	3.55	0.36
Alfalfa hay	Ton	2,000	50.40	4.72
Bermuda grass seed	Pound	1	0.040	0.005
Winter wheat harvested (soft)	Bushel	60	1.02	0.20
Winter wheat harvested (hard)	Bushel	60	1.23	0.23
Canola	Pound	1	0.035	0.006
Rice	Bag	100	1.25	0.29
Rice for grain	Bushel	56	1.07	0.18
Sorghum hay	Ton	2,000	2.39	1.01
Sugar beets for seed	Pound	1	0.024	0.020
Sugar beets for sugar (w/o crown)	Ton	2,000	4.76	0.94
Triticale	Bushel	56	1.50	0.17
Wild rice	Pound	1	0.013	0.003

In some areas, animal waste application rates might need to be based on parameters other than nitrogen or phosphorus. For example, trace metals present in animal wastes, when applied at either nitrogen- or phosphorus-based rates, provide many of the micronutrients necessary for plant growth. Excessively high levels of the trace metals, however, can inhibit plant growth. By limiting manure applications to the nitrogen- and phosphorus-based rate, CAFOs will also be limiting the rate at which metals are applied to fields and thus reduce the potential for applying excessive amounts of the trace metals. In other regions of the country where farmlands are overloaded with salt, the salt content of animal waste, often measured as electrical conductivity, might be the appropriate parameter for limiting land application rates. When using any of those alternative application rates, CAFOs must ensure appropriate agricultural use of the nutrients in the manure. In no case may manure be applied at rates greater than the annual nitrogen needs of the crop(s).

NRCS staff and landowner use the soil probe to take a soil sample on farm. (Photo courtesy of USDA/NRCS)

The animal agricultural industry has seen the consolidation of many smaller operations into a smaller number of larger operations (Kellogg et al. 2000). Many livestock and poultry producers do not have adequate land to utilize the manure nutrients generated on-site in a manner that does not exceed crops needs. Figures 6-4 and 6-5 illustrate that in some counties, the production of recoverable manure nutrients exceeds the assimilative capacity of all the cropland and pastureland available for manure application in that county.

Consolidation in the animal agriculture industry has created regional surpluses of phosphorus and a buildup of soil phosphorus levels, as indicated by Figure 6-6. Phosphorus buildup is one variable that can contribute to phosphorus loss. However, other factors can result in high phosphorus loss even when the soil test phosphorus is low. Unfortunately, problems associated with high soil phosphorus levels are aggravated by the fact that many of these agricultural soils are in states with sensitive waterbodies, such as the Great Lakes, Lake Champlain, the Chesapeake Bay and Delaware Bay, Lake Okeechobee, and the Everglades.

The overall goal of efforts to reduce phosphorus loss to water should be to balance phosphorus inputs and outputs at the farm and watershed levels while managing soil and phosphorus in ways that maintain productivity. Management strategies that minimize phosphorus loss to water can involve one or more of the following approaches: optimizing phosphorus use efficiency, refining animal feed rations, using feed additives to increase animal absorption of phosphorus, transporting manure from surplus areas to deficit areas, increasing the number of acres available

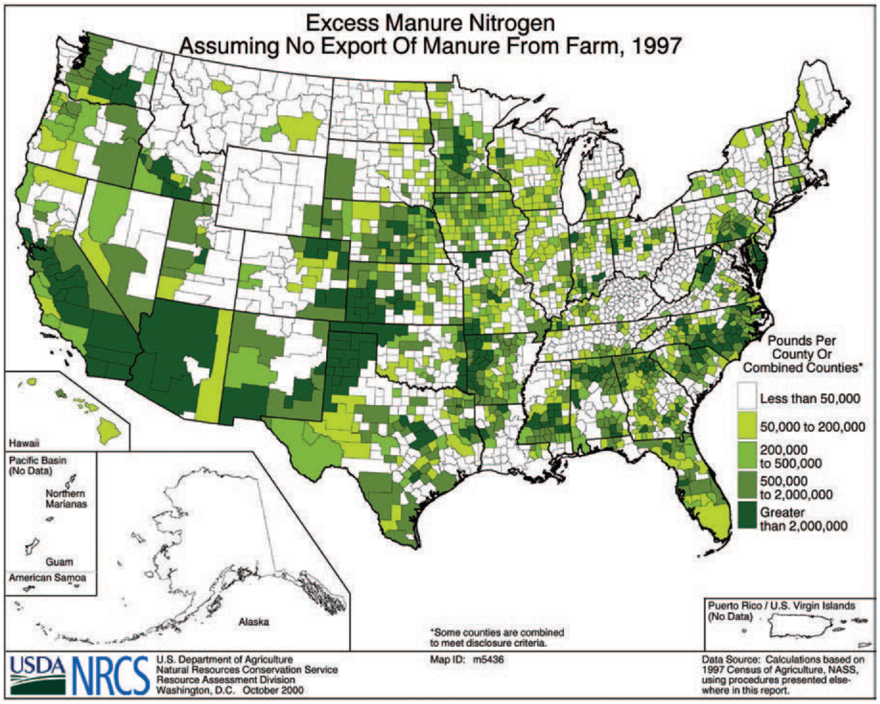

Figure 6-4. Excess manure nitrogen.

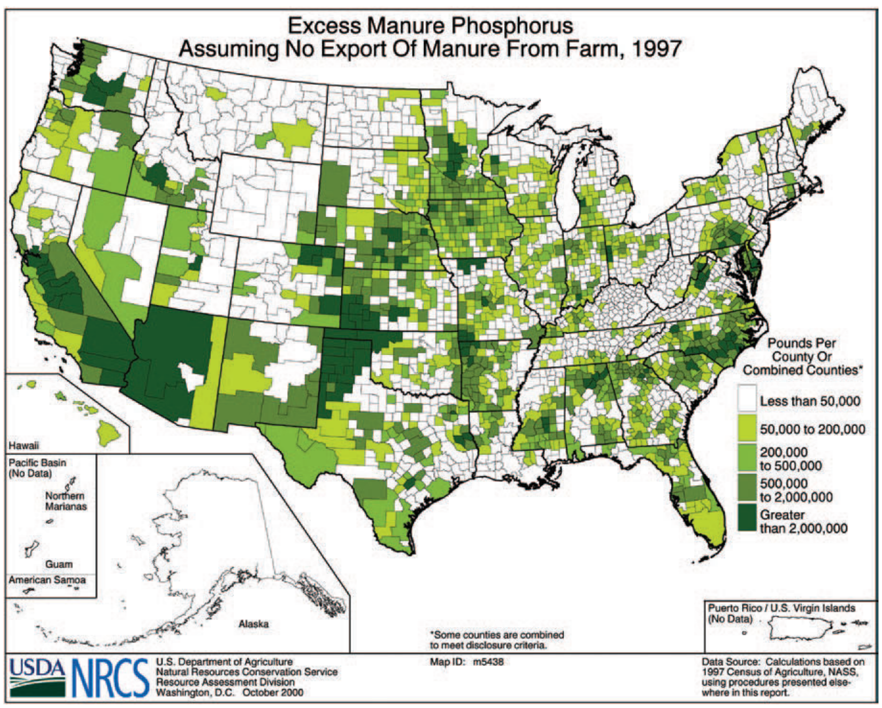

Figure 6-5. Excess manure phosphorus.

to an operation for land application, and applying conservation practices like reduced tillage, buffer strips, and cover crops in critical areas of phosphorus export from a watershed.

Because of the potential for phosphorus buildup where manure utilization plans are based on nitrogen, soils in fields receiving livestock manure should be tested regularly with close monitoring of phosphorus levels as well as the risk for phosphorus transport from the field.

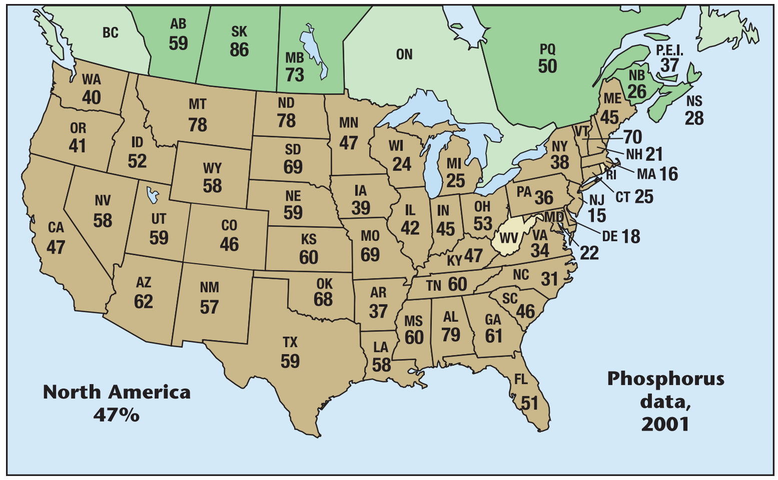

Figure 6-6. Percent of soils testing medium or low in phosphorus. (Source: USDA/NRCS)

6.3. Standards for Nutrient Management

Utilizing manure nutrients can be a beneficial practice that improves the health of the soil and replaces the use of purchased commercial fertilizer. However, that requires proper management of the amount, form, source, timing, and placement of the nutrients. Various standards exist for the management of nutrients. USDA-NRCS develops national conservation practice standards for nutrient management. Each state's NRCS office adopts and may modify those practices that are applicable in that state. Some state NRCS offices also develop state-specific standards that are not found in the national handbook. For standards to which NPDES permit writers and inspectors can refer, see Appendix K, NRCS Conservation Practice Standards. NRCS Conservation Practice Standard Code 590,[2] Nutrient Management, is intended to guide the proper land application of nutrients. The standard states that nutrient application rates are to be established that consider current soil tests, realistic yield goals and management capabilities. In cases where manure is the source of applied nutrients, the rate also must be based on an analysis of the nutrient content of the manure, NRCS book values, or historical documented records.

NRCS conservation practice standards often rely on guidelines established by the state's land grant university. Land grant universities establish guidelines for many procedures involved with nutrient management. Some examples can include

- Crop yield goals.
- Fertilizer recommendations.
- Manure excretion rates.
- Field risk assessment tools for nitrogen, phosphorus, and erosion.
- How to calibrate equipment.

Chicken litter spreading. (Photo courtesy of USDA/NRCS)

- Nutrient use efficiency strategies.
- Emerging technologies.

Private industries also develop some of their own standards. For instance, many private soil and manure testing labs develop their own nutrient recommendations on the basis of soil test analyses. Those private standards might or might not be recognized by the land grant university in a state.

6.3.1. EPA's State Requirements for Land Application

The CAFO regulations require states to establish technical standards for nutrient management that are consistent with 40 CFR part 412.4(c)(2). 40 CFR § 123.36. The regulation at 40 CFR part 412.4(c)(2) requires that those technical standards include a field-specific assessment of the potential for nitrogen and phosphorus transport from the field to waters of the U.S. In addition, the standards must address the form, source, amount, timing, and method of application of nutrients on each field to achieve realistic production goals while minimizing nitrogen and phosphorus movement to waters of the U.S. Id.

40 CFR § 412.4(c)(2)
Best Management Practices (BMPs) for Land Application of Manure, Litter, and Process Wastewater

Determination of application rates

Application rates for manure, litter, and other process wastewater applied to land under the ownership or operational control of the CAFO must minimize phosphorus and nitrogen transport from the field to surface waters in compliance with the technical standards for nutrient management established by the Director. Such technical standards for nutrient management shall:

(i) Include a field-specific assessment of the potential for nitrogen and phosphorus transport from the field to surface waters, and address the form, source, amount, timing, and method of application of nutrients on each field to achieve realistic production goals, while minimizing nitrogen and phosphorus movement to surface waters; and

(ii) Include appropriate flexibilities for any CAFO to implement nutrient management practices to comply with the technical standards, including *consideration of multi-year phosphorus application* on fields that do not have a high potential for phosphorus runoff to surface water, phased implementation of phosphorus-based nutrient management, and other components, as determined appropriate by the Director.

Requirements for State Technical Standards

All technical standards must identify an appropriate field-specific assessment method for determining nutrient transport to be used when developing rates for land application. Technical standards for nutrient management also establish methods and criteria for determining application rates that must appropriately balance the nutrient needs of crops and potential adverse water quality impacts, in accordance with the risk of nutrient transport. 40 CFR § 412.4(c)(1). To achieve that objective, technical standards must address the source, amount, timing and method of application for each form of manure nutrients. 40 CFR § 412.4(c)(2)(i).

Nutrient Transport Risk Assessment

The field-specific assessment provides CAFOs with the information needed to determine whether manure nutrients should be applied at an nitrogen- or phosphorus-based rate, or if manure application is not appropriate. CAFOs may apply a combination of conservation practices, BMPs, and management activities, which in aggregate can reduce a field's vulnerability of phosphorus transport to waters of the U.S. Regardless of what assessment method is required by a state, it must at least include an analysis of soil phosphorus. 40 CFR §§ 122.42(e)(5), 412.4(c)(3). As discussed in Chapter 5, sample handling can affect soil test results and extraction procedures used for different analysis are typically tailored to a region. Therefore, technical standards need to also address how soil samples are to be collected, the extraction procedures, methods or laboratories that are to be used for analyzing different nutrients and the frequency with which the analyses should occur.

Form and Source

The form and source of the manure must be identified for all manure that is planned for land application. 40 CFR § 412.4(c)(2)(i). The term *form* of manure may be identified as solid, liquid, semi-solid, or slurry. The term *source* refers to the specific storage structure or location at which manure is held until it is land applied. The manure's form will directly determine the type of storage needed. Liquid and semi-solid or slurry manures are typically stored in a type of lagoon or holding pond. Solid manures are typically stored in sheds or stockpiles, which can be on a concrete pad or other impervious material. For further discussion of manure types and storage, see Chapter 4 of EPA's development document for the 2003 CAFO rule revisions (EPA-821-R-03-001) (USEPA 2003).

Turkey litter stockpile. (Photo courtesy of USDA/NRCS)

Amount

Because the amount of manure to be applied relies on the amount of nutrients in the manure, technical standards need to ensure that manure nutrient analyses represent the manure that is applied. Similar to soil testing, the handling of a sample can affect the outcome of the test results. For example, some manure nitrogen is lost through volatilization during the handling and storage of the manure. The manure nutrient analysis accounts for volatilization losses that have occurred up to the time at which the samples for the analysis are taken. Therefore, technical standards need to address appropriate sampling methods and acceptable methods or laboratories that should be used for performing the analyses to ensure the results represent the nutrient content of the material that will be applied to a field.

A separate manure analysis needs to be provided for each form (e.g., stockpiled solids, separated solids, lagoon or pond liquid, lagoon or pond sludge) of animal manure stored on-site where the manure nutrient content is expected to vary to have test results that accurately reflect the nutrients in the manure that is land applied. See 40 CFR parts 412.4(c)(1) and (c)(3). Not only will the composition of the forms be different, they often are applied to the land separately from each other. For example, liquids from a holding pond could be irrigated weekly to a field, whereas the solids might be land applied just once or twice per year to remotely located fields. There could be circumstances where sampling of every single source might be less important. For example it could be reasonable to expect a dairy with multiple barns that are each designed, operated, and managed under the same set of variables would generate manure with similar nutrient content. When each barn houses the same number of cows, the cows are fed the same diet and are on the same milking schedule, and each barn is designed to handle and store manure in the same manner (e.g., freestall barns with push pits at the end of each barn), sampling of both pits is probably not necessary. For more information on manure testing protocols, see Chapter 5.9.

The amount of nutrients to be applied, from both organic and inorganic sources also depends on the realistic production goals, and the nutrient needs for a given crop to meet the realistic yield goal. The criteria for deriving realistic yield goals including criteria for adjusting yield goals on the basis of actual crop yields should be provided by the technical standard as that will affect the amount of nitrogen and phosphorus that will be applied to the land. It might be insufficient for the technical standard to simply require development of realistic yield goals; the specific basis(es) for the yield goals should be described. Unrealistic yield goals will result in an over-application of nutrients.

Residual plant available nitrogen (PAN) in the soil affects the amount of additional nutrients that should be applied to meet crop nitrogen needs. Because organic forms of nitrogen typically become plant available when they are converted to inorganic forms, such as nitrate and ammonium, crediting generally identifies the amount of organic nitrogen likely to be converted to inorganic forms that will be plant available. Crediting for all residual nitrogen in the field that will be plant available, as a result of prior additions, should be done in accordance with the directions provided in the technical standards. That will include appropriate mineralization rates to be used in determining the amount of available nitrogen that has slowly become available from previous manure applications and the amount of PAN from a prior legume crop.

The amount of available nutrients will also fluctuate with the method of land application (e.g., spray irrigation, surface application, with or without incorporation). The method of land application will affect the amount of nitrogen that will volatilize, thus affecting the amount of manure that needs to be applied to meet realistic yield goals. Therefore, volatilization rates to be applied to various application methods should be provided by the technical standards.

Timing

Heavy frost on a stream buffer. (Photo courtesy of USDA/NRCS)

Under certain circumstances, usually related to seasonal conditions, CAFO land application areas might be more likely to generate runoff that reaches waters of the U.S. Accordingly, technical standards must address *timing* considerations as to when land application should be delayed and/or prohibited to minimize nutrient movement to surface waters. 40 CFR § 412.4(c)(2)(i). To minimize movement of nutrients to waters of the U.S., technical standards for nutrient management should prohibit application of manure and process wastewater to saturated ground where appropriate. The technical standards should prohibit surface application of manure and process wastewater during rainfall and when rainfall is expected soon after a planned application, if the rainfall might produce runoff and the runoff might enter waters of the U.S. The standards should either prohibit application of manure and process wastewater on snow, ice, and frozen ground, or include specific protocols that CAFO owners or operators, nutrient management planners, and inspectors will use to conclude whether application to a frozen or snow- or ice-covered field (or a portion thereof) poses a reasonable risk of runoff. Where there is a reasonable risk, the standards should prohibit application to the field or relevant portion thereof during times when the risk exists or could arise. Manure storage structures need to include adequate capacity to store material that accumulates during those times when, under the technical standards for nutrient management, land application would be prohibited. 40 CFR § 122.42(e)(1)(i).

For example, in Michigan, the technical standard for nutrient management includes an explicit prohibition of manure application under certain conditions :

1. CAFO waste shall not be applied on land that is flooded or saturated with water at the time of land application.
2. CAFO waste shall not be applied during rainfall events.
3. CAFO waste shall not be surface applied without incorporation to frozen or snow-covered ground, except in accordance with the Department 2005 Technical Standard for the Surface Application of CAFO Waste on Frozen or Snow-Covered Ground without Incorporation or Injection.
4. CAFO waste application shall be delayed if rainfall exceeding one-half inch, or less if a lesser rainfall event is capable of producing an unauthorized discharge, is forecasted by the National Weather Service (NWS) during the planned time of application and within 24 hours after the time of the planned application. Forecast models to be used are at *http://www.weather.gov/mdl/synop/products.php*.

The ELG does not establish national requirements prohibiting manure application to frozen, snow-covered, or saturated ground, or before forecasted rain. Runoff associated with such application could depend on a number of site-specific variables, including soil type, topographic variability (i.e., slope of the land), and distance to waters of the U.S. States are better able to tailor their technical standards to reflect the site-specific conditions that warrant prohibitions or limitations on manure applications to frozen, snow-covered, or saturated ground, or before forecasted rain. In general, EPA strongly encourages states to prohibit application to frozen, snow-covered, or saturated ground, and when the forecast calls for rain in an amount that is likely to produce runoff because crops are unable to utilize the nutrients during such conditions and, therefore, typically results in runoff of nutrients. For additional guidance on addressing winter spreading, see Appendix G, Winter Spreading Technical Guidance and Appendix E, Minimum Depth of Rain at Which Runoff Begins.

If technical standards for nutrient management do not prohibit manure application on frozen, saturated, or snow covered ground, the *protocols for land application* under those circumstances should account for the form of the manure to be applied (e.g., liquid, semi-solid, or dry manure), the time at which the manure would be applied relative to periods when runoff may occur, the fraction of precipitation that runs off the land in melt water and in response to winter rains (as affected, in part, by whether soil is frozen), the time it takes runoff to travel to waters of the U.S. (as affected by the slope of the land, distance to waters, roughness of the land surface, and whether runoff is in contact with land surface), and other relevant factors, as appropriate.

Flexibility to Implement Nutrient Management Practices

Technical standards for nutrient management can allow certain flexibilities for implementing nutrient management practices. 40 CFR § 412.4(c)(2)(i). The CAFO regulations specifically allow for the *consideration of multi-year phosphorus application* on fields that do not have a high risk for phosphorus runoff to waters of the U.S. Id. Multi-year phosphorus application is an approach that allows a single application of manure phosphorus to be applied at a rate equal to the recommended phosphorus application rate or phosphorus removal in harvested plant biomass for the crop rotation for multiple years in the crop sequence. However, under any multi-year phosphorus application, the rate at which manure nutrients are applied cannot exceed the annual nitrogen recommendation of the year of application. 68 FR 7,210 (Feb. 12, 2003). The field must also not receive additional phosphorus until the amount applied in the single year has been removed through plant uptake and harvest. 40 CFR § 412.4(b)(3).

Additional Standards

While the state's technical standards need to be detailed in addressing the form, source, amount, timing and method of application for the use of each form of manure nutrients, they may also contain additional requirements that the state chooses to address. Those could include specific requirements that address animal feed management, additional soil testing (i.e., nitrogen testing requirements), implementing specific BMPs (i.e., cover crops), or any other practices the state deems necessary to minimize nitrogen and phosphorus transport to surface waters. Additional considerations necessary for protecting surface waters are left to the discretion of the state Director when establishing technical standards. 68 FR 7,198 (Feb. 12, 2003).

6.4. EPA's CAFO Requirements for Land Application

Any permit issued to a CAFO must include the requirement to implement a nutrient management plan that includes *protocols for land application*. 40 CFR § 122.42(e)(1). As discussed in Chapter 4.1.3 of this Manual, permitted Large CAFOs subject to ELG subparts C and D must land apply manure nutrients in accordance with certain practices defined by the ELG. 40 CFR § 412.4. Those include following the state's technical standards for nutrient management[3] as discussed in Section 6.3.1. Id.; at § 4(c). Briefly the ELG require the following:

- A field-specific assessment of the potential for nitrogen and phosphorus transport from each field where manure is to be applied and using the results in developing application rates. 40 CFR § 412.4(c)(2)(i).
- Land application of manure, litter, and process wastewater at application rates that minimize phosphorus and nitrogen transport from the field to waters of the U.S. in compliance with the technical standards for nutrient management. 40 CFR § 412.4(c)(2).
- Consideration of the manure and soil analyses in the development of the application rates. 40 CFR § 412.4(c)(3).
- Inspections of equipment used for land application. 40 CFR § 412.4(c)(4).
- Development of appropriate setbacks and buffers. 40 CFR § 412.4(c)(5).
- Documentation of appropriate BMPs as well as other necessary record keeping requirements. 40 CFR § 412.37(c).

As discussed throughout this chapter, numerous variables, including those listed above, are considered when developing appropriate land application rates for manure, litter and process wastewater. Technical standards, as discussed above, form the foundation for determining the appropriate rates of application.

A nutrient management planner reviews field conditions and implementation of BMPs to conduct a field risk assessment and calculate appropriate land application rates. (Photo courtesy of USDA/NRCS)

A Note on the Orientation of Chapter 6:

Section 6.5 of this chapter provides an in-depth discussion of *protocols for land application* and discusses how a permit writer can derive permit terms for *protocols for land application* from an NMP, as required in 40 CFR part 122.42(e)(1). As discussed in Chapter 4.1.7, a permit writer may identify the *protocols for land application* as a permit term by using one of three methods. Section 6.6 illustrates how a permit writer can derive terms for *protocols for land application* from an NMP, using the third method discussed in Chapter 4, which specifically describes each term of the NMP in detail. A permit writer taking that approach would extract from the NMP all the relevant values for all the components that together encompass the term *protocols for land application*.

6.5. Protocols for Land Application

The CAFO regulations require site-specific terms of an NMP to be included in a CAFO's NPDES permit. Technical standards form the basis for critical elements of the site-specific terms of the NMP because they are the foundation from which an NMP is developed. EPA has clarified what a technical standard should include to adequately meet the requirements of 40 CFR part 412.4(c)(2) when used to develop an NMP that contains all the required terms of the NMP (See Appendix I, NPDES CAFO Technical Standard Review Checklist).

Land application of manure using lay-flat hose system. (Photo courtesy of USDA/NRCS)

Land application rates in NMPs are uniquely developed for each field and must be included in the permit as site specific permit terms. 40 CFR § 122.42(e)(5). Fields and field-specific rates of application of manure cannot be captured with broadly applicable permit conditions. (For an introduction of the concepts of broadly applicable versus site-specific terms, see Section 4.1.7.) The remainder of this chapter discusses and provides example permit terms that should be used as guidance for understanding what in the NMP should be identified as a permit term under both the linear and narrative rate approach.

With respect to rates of application, a CAFO permit must be written to express the terms of the NMP for *protocols for land application* using either the linear or narrative rate approach. 40 CFR § 122.42(e)(5). Many NMPs are developed such that the permit terms may be written to meet either the linear or narrative rate approach. In essence, both approaches require the same information. However, the linear and narrative rate approaches differ in the way the site-specific land application rates and the information used to develop them are expressed in the NMP and incorporated as terms of the permit. Under the linear approach, certain required information is captured as permit terms, while under the narrative rate, much of the same information is captured as part of a complex term, identified in the CAFO regulations as the *methodology*. Under the linear approach, the NMP as submitted with the NOI is the NMP that is to be implemented over the 5 years of permit coverage. The rates, methods, timing, and source of manure nutrients (among other items) are to be applied as predicted by the NMP. The linear approach is for operators who do not anticipate that the NMP will change once it is developed. The narrative rate approach allows the NMP the flexibility for some changes to occur as it is implemented over 5 years of permit coverage. The source of manure and the rates, methods, and timing of application are some of the elements that may change over the life of the permit without requiring changes to the terms of the NMP.

Cover crop BMPs can reduce the risk of phosphorus transport by minimizing soil erosion. (Photo courtesy of USDA/NRCS)

For each approach, the CAFO rule identifies the required, minimum terms of the NMP specific to that approach. The linear approach expresses field-specific maximum application rates in terms of the amount (in pounds) of nitrogen and phosphorus from manure allowed to be applied. 40 CFR § 122.42(e)(5)(i). The narrative rate approach expresses the field-specific application rates by identifying the way in which the site-specific NMP determines how to calculate the amount of manure allowed to be applied while including limits on the maximum amounts of nitrogen and phosphorus derived from all sources of nutrients. Id at (e)(5)(ii). Under either approach, the projected amount of manure to be land applied is not a permit term because it depends on the concentration of nutrients in the manure. However, specifying the actual amount of manure applied must be reported in the annual report. Id. Under both approaches, the amount of manure to be land applied is a projected amount that must be recalculated at least once a year. 40 CFR §§ 122.42(e)(5)(i)(B), (5)(ii)(D).

There is more than one way for the permit writer to adequately express the terms of the NMP as permit requirements, particularly given the flexibilities provided by the narrative rate approach. As discussed, state-specific requirements for nutrient management vary from one state to another. Field risk assessment tools differ in the site characteristics they include and the frequency with which they are run. Some states' risk assessment tools factor in current and previous manure applications while others do not. Some states require nitrogen soil testing in addition to phosphorus soil testing, and soil testing frequency can range from 1 to 5 years. Those types of variation affect how agronomic rates are developed in an NMP. Section 6.5 provides one approach for writing narrative rate permit term requirements. Permit writers need to understand their state's regulatory requirements and technical standards for nutrient management, as well as the minimum requirements of the linear and narrative rate approaches, so they can develop site-specific permit terms that meet the requirements of their state-specific CAFO programs.

6.5.1. Site-Specific Terms: Linear and Narrative Rate Approaches

Table 6-3 outlines the terms associated with *protocols for land application* for each approach. As shown in Table 6-3, six site-specific terms apply to both the linear and narrative rate approaches for expressing land application rates in NMPs. 40 CFR §§ 122.42(e)(5)(i)(A), 122.42(e)(5)(ii)(A). Six additional permit terms apply when using the linear approach. 40 CFR § 122.42(e)(5(i)(A). Those additional linear approach permit terms address site-specific information that is also addressed under the narrative rate approach. The difference is that, in the narrative rate approach, the linear approach permit terms are factors of the *methodology*, rather than terms of the NMP. The factors are not themselves required to be terms in the narrative rate approach, but the *methodology* used to account for them in the CAFO's NMP is a term. Under the narrative rate approach, the *methodology* is the enforceable permit term, rather than the factors that it must encompass. Sections 6.5.1, as follows, 6.5.2, and 6.5.3 discuss in depth the elements listed in Table 6-3 and the important role each plays in the NMP, regardless of whether they are captured under the linear or narrative rate approach.

Table 6-3. Field-specific land application protocol terms

NMP Components	Term linear approach	Term narrative rate
Fields available for land application	X	X
Timing limitations for land application	X	X
Outcome of the field-specific assessment of the potential for nitrogen and phosphorus transport from each field	X	X
Planned crops or other use	X	X
Realistic annual crop yield goal	X	X
Total nitrogen and phosphorus recommendations per crop	X	X
Credits for plant available nitrogen	X	
Consideration of multi-year phosphorus application	X	
Accounting for all other additions of plant available nitrogen and phosphorus to the field	X	
Method and timing of land application	X	
Form and source of manure, litter, and process wastewater	X	
Maximum pounds of nitrogen and phosphorus from manure, litter, and process wastewater	X	
Methodology to account for the amount of nitrogen and phosphorus in the manure to be applied	X	
Maximum amount of nitrogen and phosphorus from all sources		X
Alternative crops		X

Table 6-3. Site-specific and field-specific land application protocol terms *(continued)*

NMP Components	Term linear approach	Term narrative rate
Methodology to account for • Soil test results • Credits for plant available nitrogen in the field • The amount of nitrogen and phosphorus in the manure, litter, and process wastewater to be applied • Consideration of multi-year phosphorus application • Accounting for all other additions of plant available nitrogen and phosphorus to the field • Form and source of manure, litter, and process wastewater • Timing and method of land application • Volatilization of nitrogen and mineralization of organic nitrogen		X

Fields Available for Land Application

The NMP must identify each field where land application will occur. The CAFO regulations require each field included in the NMP to be a site-specific term of the permit. 40 CFR § 122.42(e)(5). Each field should have a unique name or code and include the number of acres making up the field. Field maps that are appropriately labeled should also be included in the NMP. The labels from the field maps should be easily matched to all fields listed through the NMP. Otherwise, it might be difficult to correlate other terms associated with each field, thus making it difficult for the permit writer to correctly establish the terms of the NMP.

Technical standards may limit the allowable size of a field by setting limits on the acres that a soil sample can represent. Many standards set limits ranging from 10 to 30 acres. For example, if the soil sample shows that a 30-acre portion of a 100-acre field has significantly different soil nutrient content than the rest of the field, that 30-acre portion should be managed separately to meet the objective of nutrient management planning. Conversely, many standards allow fields with similar allowable application rates to be combined. For example, Missouri's technical standard requires the average field area represented by a soil sample to be approximately 20 acres or less. The Missouri standard allows adjoining 20-acre field areas to be combined, to a limit

Implementing the nutrient management plan. (Photo courtesy of USDA/NRCS)

of 80 acres, when recommendations are within 10 percent (or 10 pounds per acre, whichever is greater). A permit writer needs to be aware of such limitations and conditions in a technical standard to ensure that field sizes are set appropriately in an NMP.

Timing Limitations for Land Application

The term *timing limitations* requires the permit writer to establish permit restrictions for land applying manure under certain conditions. State technical standards need to identify when applications should be prohibited or delayed. These could include, for example, times when fields are saturated or frozen, or when other conditions prevent the use of appropriate land application practices. Such timing limitations may be seasonal; for example, restrictions barring winter application such as between November and February. EPA encourages CAFOs to ensure adequate storage so that manure is never applied to frozen ground.

The term *timing limitations* should be distinguished from the term *timing and method of land application*. *Timing and method of land application* refers to the availability of nutrients for crop uptake because that can vary with the timing and the method of land application. Under the linear approach, *timing and method of land application* is a term in addition to *timing limitation*. Under the narrative rate approach, *timing and method of land application* is a factor of the term, *methodology*. *Timing and method of land application* is further discussed in Section 6.5.2.

Outcome of the Field-Specific Assessment of the Potential for Nitrogen and Phosphorus Transport from Each Field

Application rates for manure applied to land under the ownership or operational control of a permitted CAFO must minimize phosphorus and nitrogen transport from the field to surface waters using a field-specific risk assessment. 40 CFR § 412.4(c)(2)(i). Therefore, the *outcome of the field-specific assessment of the potential for nitrogen and phosphorus transport from each field* (from here forward, the term will be referred to as *outcome of the field-specific risk assessment*) is a term.

As previously discussed, the field-specific risk assessment should be identified in the state's technical standard. EPA provides examples of the different types of field-specific risk assessment methods. Those examples are based on the risk assessment methods that were included in USDA's NRCS Nutrient Management Conservation Practice Standard, Code 590 (August 2006) which EPA referenced in the 2003 CAFO rule. That NRCS practice standard describes three methods: (1) Soil Test Phosphorus Level; (2) Soil Phosphorus Threshold Level; and (3) P-Index. Those three tools assess the risk of phosphorus loss.[4]

The *outcome of the field-specific risk assessment* reflects the terminology typically associated with the use of the P-Index, which reflects the risk assessment method described by the January 2012 NRCS conservation practice standards 590 and the supporting National Instruction Document NI-190-302. NRCS conservation practice standard 590 (and elaborated on below). However, in the CAFO rule and this Manual this phrase is to reflect the results of whichever method is required by the technical standards established by the Director, including the soil test phosphorus method and the phosphorus threshold method.

Terraces, buffers, and conservation tillage are among the practices being used in water quality improvement projects. (Photo courtesy of USDA/NRCS)

The field-specific risk assessment for nitrogen evaluates whether the manure application rate supplies excess nitrogen that could be lost to the environment. An nitrogen loss risk assessment should consider the nitrogen requirement of the crop to be grown according to the operation's soil type, crop, and realistic crop yields. Once the nitrogen requirement for the crop is established, the manure application rate is generally determined by subtracting any other sources of nitrogen available to the crop from the crop's nitrogen requirement. The other sources of nitrogen can include residual nitrogen in the soil from previous applications of organic nitrogen, nitrogen credits from previous crops of legumes, crop residues, or applications of commercial fertilizer, irrigation water, and biosolids. Application rates are based on the nitrogen content in the manure and should also account for application timing and methods, such as incorporation, and other site-specific practices. 68 FR 7,211 (Feb. 12, 2003). As long as nitrogen needs are not exceeded, the risk is assumed to be minimized.

USDA's NRCS Nutrient Management Conservation Practice Standard, Code 590, also recommends utilizing a leaching index to assess the risk of NO_3^- leaching from a field. Nitrate is a highly mobile nutrient. As water moves through the soil profile, NO_3^- is not utilized by the crop may readily leach to groundwater. ELG have not been developed for discharges to groundwater, and therefore permit authorities are not required to write a permit term to address groundwater contamination; however, state permitting authorities may impose NPDES permit conditions for these discharges. 68 FR 7,216 (Feb. 12, 2003). Where surface waters have a direct hydrological link to groundwater, a nitrogen leaching index would be an appropriate tool for the permitting authority to include as part of the permit term. Additionally, while a nitrogen leaching index is not a requirement under this CAFO rule, many states have chosen to make the index a state-specific requirement in their technical standards.

If a state's technical standard for nutrient management incorporates a version of the NRCS 590 practice standard that allows more than one assessment method, the permitting authority has the discretion to determine which method or other state-approved alternative method may be used. Additionally, when a standard identifies more than one allowable method, the method used at the time of permit coverage must be used throughout the 5 years of permit coverage (unless the CAFO permit is revised). If a CAFO operator decided to change assessment methods in the middle of permit coverage, the operator would be subject to the requirements associated with a substantial permit modification. 40 CFR § 122.42(e)(6)(iii). The field risk assessment provides CAFOs with the information needed to determine if manure nutrients should be applied at an nitrogen or phosphorus based application rate, or if no manure application is appropriate. Changing the tool that is the basis for determining appropriate manure application rates is a change to the term of the NMP and should be considered a substantial permit modification (see Chapter 4.1.7).

Soil Test

In this option, manure application rates are based on the soil test recommendations for optimum crop production. In other words, the amount of phosphorus in the soil based on the phosphorus soil test dictates whether the application of manure can be made to meet the nitrogen needs of the crop, the phosphorus needs of the crop, or whether no manure nutrients should be applied.

Soil Test Example—Indiana

Indiana includes the soil test method as an option for determining application rates for manure, biosolids, and other phosphorus-containing material, as shown in the table below.

Soil test method P risk assessment for Indiana

Soil test phosphorus level (Bray P1/Mehlich 3ppm)	Basis for nutrient application
≤50	Nitrogen based
51–100	Not to exceed 1.5 × crop P_2O_5 removal
101–200	Not to exceed crop P_2O5 removal
>200	No phosphorus application

Source: Indiana NRCS. 2001. Conservation Practice Standard, Nutrient Management, Code 590. Indiana Natural Resources Conservation Service Field Office Technical Guide—July 2001.

The soil sampling depth will impact the outcome of the phosphorus soil test. According to USDA-ARS publication, *Agricultural Phosphorus and Eutrophication*, it is the top few centimeters of soil with which surface runoff interacts. Therefore, when using soil test results for environmental purposes, the soil sampling depth should always be considered. For more discussion on soil sampling, see Chapter 5.

Soil Phosphorus Threshold

Many states have considered developing recommendations for phosphorus applications based on the potential for phosphorus loss in agricultural runoff to address environmental concerns. What makes such a determination challenging is the identification of a phosphorus soil test that estimates when soil phosphorus concentrations becomes high enough to result in unacceptable concentration of phosphorus enrichment of agricultural runoff. The phosphorus threshold approach recommends nitrogen-based manure application on sites on which the soil phosphorus test levels are below a set threshold value and phosphorus-based rates or no manure application on sites on which soil phosphorus test levels meet or exceed the set threshold value.

Soil Phosphorus Threshold Example— Idaho Phosphorus Threshold (IDPTH)

The 590 conservation practice standard adopted by Idaho NRCS establishes thresholds for determining application rates to

- Determine the method for developing the nutrient budget. This could be either crop uptake or recommended application rate cited in the University of Idaho Crop Specific Fertilizer Guide.
- Track trends in soil phosphorus concentrations over time and to assess environmental risk.

Soil samples taken soon after manure, biosolids or other organic by-product application could produce erroneous soil test results for phosphorus. Soil samples taken for the Idaho Phosphorus Threshold (IDPTH) should be delayed for 9 to 12 months after organic amendment applications. The on-site surface or ground water resource concern will determine the appropriate depth of the soil sample taken (Table A) for comparison to the IDPTH:

- Surface water concerns exist when surface runoff leaves the field(s) from average annual precipitation, rain on snow or frozen ground, or irrigation.
- Groundwater concerns exist when surface water (from any source) does not leave the field. A high water table, fractured bedrock, poor irrigation water management, cobbles, gravel, or coarse-textured soils can contribute to downward movement of water and nutrients.*

**Note: EPA's NPDES CAFO program does not regulate discharges to groundwater.*

Table A. Required soil sample depth for the IDPTH

Primary resource concern	IDPTH soil sample depth (inches)
Surface Water	0–12
Ground Water	18–24

When both a surface and ground water concern exist, the surface water concern governs NMP development. If neither concern exists, the NMP is developed on the basis of the IDPTH for the groundwater concern to maintain soil quality and long-term sustainability.

IDPTH concentrations by resource concern are listed in Table B. The primary resource concern identified and site characteristics are used to determine the appropriate IDPTH for the site.

Table B. IDPTH concentration by resource concern

Primary resource concern	IDPTH concentration (ppm)		
	Olsen	Bray-1	Morgan
Surface Water	40	60	6
Ground Water			
Water <5 feet	20	25	2.5
Water >5 feet	30	45	4.5

Soil Phosphorus Threshold Example—Idaho Phosphorus Threshold (IDPTH) *(continued)*

Table C. Phosphorus application rates based on the IDPTH

Soil test phosphorus (ppm)	Phosphorus application rate
< IDPTH	Fertilizer Guide or Crop Rotational Phosphorus uptake
≥ IDPTH	Crop Rotational Phosphorus uptake

Nitrogen-based manure applications are allowed on sites where the soil test phosphorus levels are below the IDPTH (Tables B and C). The nitrogen availability of the planned application must match plant uptake characteristics as closely as possible, taking into consideration the timing of nutrient application(s) to minimize leaching and atmospheric losses. The management activities and technologies used must effectively utilize mineralized nitrogen and minimize nitrogen losses through denitrification and ammonia volatilization.

Phosphorus-based applications are allowed on sites where soil phosphorus levels equal or exceed threshold values. Where phosphorus-based applications are made, the application rate must

- Not exceed the recommended nitrogen application rate for the current crop during the year of application.
- Not be made on sites considered vulnerable to off-site phosphorus transport unless appropriate conservation practices, BMPs, or management activities are used to reduce the vulnerability.

Source: Information taken from Idaho NRCS Conservation Practice Standard, Nutrient Management, Code 590 (June 2007 version).

The Phosphorus Index[5]

Another approach advocated by researchers is to link critical areas of surface runoff and high phosphorus content in a watershed. When environmental sources of phosphorus (e.g., high soil concentrations, manure or fertilizer applications) are transported to a sensitive location (through processes such as leaching, runoff, and erosion) water quality can be heavily impacted. A field with high soil phosphorus levels but little opportunity for transport may not always constitute an environmental threat, even though there is no agronomic need for additional phosphorus. Likewise, a field where there is a high potential for transport but no source of phosphorus to move might be of little threat. The concern and emphasis on management practices should be focused on areas where these two conditions—phosphorus sources and transport mechanisms—coincide. Such areas are called critical source areas.

The Concept of a Phosphorus Site Index

The purpose of the Phosphorus Site Index (P-Index) is to provide field personnel, watershed planners, and land users with a tool to assess various landforms and management practices for potential risk of phosphorus movement to waterbodies. The P-Index ranking identifies sites where the risk of phosphorus movement might be higher than that of other sites. When the parameters of the index are analyzed, it should become apparent that an individual parameter or parameters could be influencing the index disproportionately. Those identified parameters can be the basis for planning corrective soil and water conservation practices and management techniques. If successful in reducing the movement of phosphorus, the potential for phosphorus enrichment of surface waters will also be reduced.

The Procedures for Making an Assessment

The site characteristics addressed by the P-Index are weighted by the reasoning that some characteristics might be more influential than others in allowing phosphorus movement from the site. There is scientific basis for concluding that these relative differences exist; however, the absolute weighting factors given are based on professional judgment. Examples of weighted site characteristic factors are

- Soil erosion (1.5).
- Irrigation erosion (1.5).
- Runoff class (0.5).
- Soil phosphorus test (1.0).
- Phosphorus fertilizer application rate (0.75).
- Phosphorus fertilizer application method (0.5).
- Organic phosphorus source application rate (1.0).
- Organic phosphorus source application method (1.0).

The value categories are rated using a log base of 2. The greater the ratings, the proportionally higher are the values. The higher the value, the higher potential for significant problems related to phosphorus movement. Examples of value ratings are as follows:

- None = 0.
- Low = 1.
- Medium = 2.
- High = 4.
- Very high = 8.

To make an assessment using the P-Index, a rating value is selected for each site characteristic using the categories NONE, LOW, MEDIUM, HIGH, or VERY HIGH. The site characteristic weight factor is multiplied by the rating value to get the weighted value for each characteristic. The sum of the weighted values for all eight characteristics is compared with the site vulnerability chart.

Note that each state has the ability to adopt the P-Index and make state-specific adaptations. Some states might not consider all factors listed above, and they could weight each factor differently. Therefore, ratings in each state might not follow the 0 through 8, *none* to *very high* risk rating system. Some states might have more or fewer rating categories and use alternative numbering systems for describing each category.

An example using the P-Index	
Soil erosion (weight = 1.5) is 7.5 ton/ac/yr (= MEDIUM, value = 2)	1.5 x 2 = 3.0
Irrigation erosion (weight = 1.5) is not applicable (= NONE, value = 0)	1.5 x 0 = 0
Runoff class (weight = 0.5) is LOW (value = 1)	0.5 x 1 = 0.5
Soil phosphorus test (weight = 1.0) is 82 lb P (= HIGH, value = 4)	1.0 x 4 = 4.0
Phosphorus fertilizer application rate (weight = 0.75) is 25 lb/ac (= LOW, value = 1)	0.75 x 1 = 0.75
Phosphorus fertilizer application method (weight = 0.5) is placed with planter (= LOW, value = 1)	0.5 x 1 = 0.5
Organic phosphorus source application rate is 95 lb/ac (= VERY HIGH, value = 8)	1.0 x 8 = 8.0
Organic phosphorus source application method (weight = 1.0) is surface applied a month before no-till planting (= HIGH, value = 4)	1.0 x 4 = 4.0

Sum total of all weighted values = 20.75
Site vulnerability is HIGH

Total of weighted rating values site vulnerability

<8 LOW
8–14 MEDIUM
15–32 HIGH
>32 VERY HIGH

Using the Phosphorus Index as a Permit Term

The phosphorus site index is the most commonly used field-specific risk assessment tool. Because many state technical standards require the use of a P-Index for nutrient management, an extended discussion on this risk assessment tool and its use as a permit term, is provided below.

States that use a P-Index adapt the tool to accommodate local conditions, thereby creating variation among state phosphorus site indices (Osmond et al. 2006)].[6] Some state P-Indices use a specific risk loss category, such as low, medium or high risk, to describe the quantitative weighted value of the risk. In others, only the quantitative weighted value is used to describe the risk. In many states, an appropriate application rate basis (such as nitrogen-based, phosphorus-based, or no application) is also applied to each risk. When a state's P-Index is used as the field-specific risk assessment tool, it is important that the permit term include the risk and the recommended nutrient basis for land application.

Scientist notes excellent corn growth on manured soil treated with alum residue, which cuts phosphorus losses in runoff water. (Photo courtesy of USDA/ARS)

Two different risk categories may have the same recommendation for land application. For instance a state could recommend nitrogen-based manure application for fields that have low risk and medium risk for phosphorus transport. Even if the application rate basis for a field does not change with a change in the risk rating, the operator (or planner) needs to know when the risk for a field is increasing. The reason for this is that any increase to the *outcome of the field-specific risk assessment* is a substantial change to a term that necessitates a permit modification. Even though both low and medium risk ratings might recommend an nitrogen-based application rate, the change from low to medium is indicative of some other change in the current management or conditions on the field, which is resulting in an increased risk of phosphorus runoff. Therefore, the permit term needs to capture the risk category or other rating in addition to specifying the recommended application rate basis.

The factors that are considered in calculating a P-Index often include variables that fluctuate over time, such as application rates and methods of application for inorganic and organic nutrient sources, the timing of each application, conservation practices implemented or the actual crops planted (among others). Those variables can fluctuate with each crop grown on a field and also depend on how and how often manure is applied. Over the course of a 5-year permit cycle, a P-Index risk rating could theoretically fluctuate from a low to high risk on a single field. The linear approach inherently accommodates the variation in risk over the life of the permit because the NMP reflects the actual crops and associated manure application rates that will be used. The narrative rate approach allows that implementation of the NMP could differ from what was anticipated when the plan was written. Methods of nutrient applications might fluctuate or nutrient applications might occur at different times than when they were originally planned, particularly if crop rotations change (as is accommodated under the narrative rate approach). Given those anticipated changes, a field's actual risk for an individual crop year might change during the period of permit coverage and might not reflect the risk that was calculated at the beginning of the permit cycle. That situation could require permit modifications during the 5-year permit term, depending on how the *outcome of the field-specific risk assessment* is written as a permit term.

The *outcome of the field-specific risk assessment* is required to be reported by field, but not for each individual crop grown in the field. Nevertheless, even though the permit term is not crop-specific, the outcome of the assessment depends on the management of each specific crop (i.e., accounting for the manure application rate and method for each crop) and, thus, is indirectly crop specific.

This Manual describes two possible methods for developing the term *outcome of the field-specific risk assessment*. In the first method, the term reflects the field risk for each crop-year in the plan. This method is described as *multiple risk levels* over the planning period. That method meets the CAFO rule requirement for reporting the risk for each field for each year covered by the NMP but restricts the operator in the sense that any management changes during the planning period must maintain the risk identified for each crop-year. This method aligns with the requirements of the linear approach.

In the second method, the term is described as a *single risk level* for a field over the entire planning period. It is based on the highest risk calculated for any individual crop year. This method accounts for the inherent relationship between the P-Index and the management of each crop and allows each individual year's risk to fluctuate as long as the highest risk over the planning period is not exceeded. This second approach reconciles inconsistencies between the multiple risk level method and the flexibility intended by the narrative rate approach.

It is important to note that, while EPA has determined that the two methods described below are consistent with the requirements of the CAFO rule, they are not necessarily the only valid methods for capturing the term *outcome of the field-specific risk assessment*. Permitting authorities may identify other approaches consistent with the regulatory requirements.

As mentioned above, the single risk level approach accommodates the flexibilities provided under the narrative rate approach. Unlike the linear approach, the narrative rate approach allows CAFOs to adjust their manure nutrient application rates without requiring the permit to be modified. 73 FR 70,449 (Nov. 20, 2008). The predicted form, source, amount, timing and method of application of manure, litter and process wastewater set forth in the NMP are not permit terms under the narrative rate approach so the actual inputs may differ from what was projected in the NMP. Additionally, the narrative rate approach allows the flexibility to include alternative crops that might be planted over the course of the permit. Because changing any of those inputs could result in a change to the risk in an individual crop year, the single risk level approach sets the permit term as the highest risk (i.e., the risk that results in the most stringent nutrient basis for land application) anticipated over the course of permit coverage. Actual inputs for factors such as the crop planted or the form, source, timing and method of nutrient application can fluctuate, as anticipated under the narrative rate approach, as long as the field's risk for any individual crop year does not increase above this highest predicted rating. That avoids the requirement for a permit modification based on a substantial change to the NMP that might otherwise be needed if the permittee is restricted to the risk predicted in the NMP for each individual crop year. The implications of this approach with respect to the allowable land application rates are discussed in Section 6.5.3 under the discussion on the *maximum amount of nitrogen and phosphorus from all sources*.

Example of two approaches to expressing the term *outcome of the field-specific risk assessment for nitrogen and phosphorus transport*

In a CAFO's NMP, Field A results in the following risk ratings and associated nutrient basis for land application for a corn-soybean rotation.

Crop Year 1: Medium—Nitrogen-based application

Crop Year 2: Medium—Nitrogen-based application

Crop Year 3: High—Application at 1.0 x crop phosphorus removal rate

Crop Year 5: Medium—Nitrogen-based application

Method 1 (Multiple Risk Levels)

The permit term could be reported for every year on every field. Under this approach, the field will have multiple risks, each corresponding to a particular crop year.

Field	Year	Crop	Risk	Recommended rate basis
1	2010	Corn	Medium	Nitrogen-based Application
	2011	Soybean	Medium	Nitrogen-based Application
	2012	Corn	High	1 times crop phosphorus removal
	2013	Soybean	High	1 times crop phosphorus removal
	2014	Corn	Medium	Nitrogen-based Application

Under the multiple risk method, where the permit term includes the individual risk for each crop year under permit coverage, the operator must not exceed a medium risk in crop years 1, 2 and 5 and a high risk in crop years 3 and 4. For example, the operator could substitute an alternative crop in Year 1, which allows a higher manure application rate as long as the change does not cause the risk rating to increase to high in year 1 year 2, or year 5.

Method 2 (Single Risk Level)

The permit term could be reported as a single risk for the field. In this case, the highest risk rating for the field for the planning period (usually corresponding to a 5-year permit period) would be reported as the permit term.

Field	Risk	Recommended rate basis
1	High	1 times crop phosphorus removal

Under the single risk method, the term would reflect the high risk rating for the entire permit period. The operator would have more flexibility to make changes in years 1, 2, and 5 that might increase the risk rating as long as the change does not cause the risk rating to exceed the high risk in any year.

Additional Considerations for Implementing the *Outcome of the Field-Specific Risk Assessment* when Utilizing a Phosphorus Site Index

In many states, an appropriate application rate for manure (e.g., nitrogen-based, phosphorus-based, or no application) is associated with the risk estimated by a state-specific P-Index. Additionally, many state P-Indices include the planned application rate of manure as a variable in calculating the risk in the P-Index. A CAFO's planned application rate could result in a risk rating that would not recommend the planned rate to be applied. Planned rates of manure application must always align with the recommended rate associated with the estimated risk. Therefore, determining the appropriate land application rate is an iterative process because it is necessary to analyze the planned rate of manure application in the calculation of the P-Index until the planned rate aligns with the recommend rate as defined by the P-Index. An example is given below.

A state-specific P-Index is as follows:

P-Index rating	Risk	Recommended nitrogen and phosphorus application rates
0–5	Low	Nitrogen-based
6–10	Medium	Crop phosphorus removal
11–15	High	No application

An operator may plan to apply manure at an nitrogen-based rate on his field the first year of operation. When the P-Index is calculated, which takes the nitrogen-based rate into consideration, the P-Index rating is 7, and the risk for runoff is medium. The recommended application rate for manure, when the risk is 7 should not exceed the crop phosphorus removal rate. The planned nitrogen-based rate does not align with the recommended rate. The P-Index indicates that an nitrogen-based manure application increases the risk for phosphorus runoff on this particular field and therefore should not be applied. The rate needs to be adjusted to lower the risk. (Another variable influencing the risk could also be adjusted or conservation practices could be implemented that would also reduce the risk to low, and then the planned nitrogen-based rate could be applied because it would align with the recommended rate, but this example assumes that other factors are held constant.)

No matter how the term for the *outcome of the field-specific risk assessment* is identified in the permit, planned rates of application should not exceed the recommended rates based on the P-Index or other risk assessment method used.

Planned Crop or Other Use

An NMP is predicated on the use of manure as a source of nutrients for a crop. Land application of manure that is not intended for crop uptake is simply waste disposal. Without a crop to actively utilize nutrients and prevent erosion, nutrients applied in manure can be washed directly into surface streams or leached into the groundwater. The vegetative cover that a crop provides reduces the potential for runoff and erosion from an area. The root system of a crop holds soil together and provides a network of openings, or pores, for water to infiltrate soil rather than run off. When selecting a crop, the operator should consider factors including:

- Adaptation to the local climate.
- Ability to use nutrients when manure applications are made.
- Harvest requirements.
- Marketability and profitability.
- Yield.
- Suitability to soil conditions.
- Pest management.

Crops growing in a Missouri field. (Photo courtesy of USDA/ MO NRCS)

Among the most common cropping practices that receive manure applications are a corn/ soybean rotation (i.e., corn is grown in one year and soybeans the next year), continuous corn (i.e., corn is grown every year), a corn/soybean/wheat rotation (i.e., three crops are grown in 2 years), and forage (i.e., hay or grass). Yet depending on the region, manure application is commonly used for many different crops. Specific data about the appropriateness of manure application and local application rates should always be outlined in the state's technical standards and often follow the guidance of local agronomists, NRCS experts, a Cooperative Extension Service, or land grant university. Those experts help operators select sustainable cropping practices, and they make nutrient application recommendations.

A CAFO's NMP must identify the crop or crops that are planned for each field for every year of permit coverage. Alternate crops may be specified for NMPs developed using the narrative rate approach, as described in Section 6.5.3.

Crop Rotations and Crop Nutrient Requirements

To develop appropriate land application practices, CAFOs should identify planned crop rotations. A rotation is the growing of a sequence of crops to optimize yield and crop quality, minimize the cost of production, and maintain or improve soil productivity. CAFOs should describe their planned sequence of crops (e.g., corn for silage, soybeans) preferably for 5 years. That should include planting and harvesting dates and residue management practices. Crop rotation is important in calculating total nutrient needs over the period of the rotation, nutrient buildup, and nutrient removal via harvesting.

Benefits of Crop Rotations

A cropping sequence with a variety of crop types (grasses, legumes) and rooting characteristics (shallow roots, deep roots, tap roots) better uses available soil nutrients. Following a shallow-rooted crop with a deep-rooted crop helps scavenge nutrients that might have moved below the root zone of the first crop.

Realistic Annual Yield Goals

The realistic yield goal is the estimated potential for crop yield for a given field. The total nutrient requirements for fields are largely based on the CAFOs expected crop yields; generally, the higher the yield expectation, the higher the nutrient requirement. An unrealistic estimate can result in either a deficiency or an excess of nutrients being applied. In addition to crop variety and climate, crop yields are influenced by field-specific factors including, among others, soil fertility, soil type, crop management and, pest control. Thus, estimated yields can be expected to vary for different fields. State technical standards for nutrient management need to identify acceptable methods and data sources for establishing realistic yield goals.

The best way to estimate yield potential is to consider production practices given the relationship between crop yields and site-specific management and field conditions. For example, the average of the three highest yields of the five most recent years that the specific crop was grown in the field could be used. Increased yields from the use of improved varieties and hybrids should be considered when yield goals are set for a specific field.

Where records are not available, as is the case with most new operations, another method of estimating yield is needed. NRCS, in conjunction with state agricultural and Cooperative Extension Service specialists, establish realistic yields for specific crops on different agricultural soils. Those values are based on inherent soil properties and long-term observations. They should be viewed only as estimates because they might not reflect irrigation, new cultivars, and improved management tools. That information is available through county NRCS field offices. Local farmers, fertilizer dealers, and custom harvest companies might also be able to provide yield data. Field-to-field and farm-to-farm differences can easily result in a ±20 percent difference in realistic yield expectations from those published by state and Cooperative Extension Service specialists and should be considered normal. Further differences might also exist because of practices such as supplemental irrigation or no-till planting although local specialists might have information to document those differences.

States should establish in their technical standards criteria for deriving realistic yield goals including criteria for adjusting yield goals according to actual crop yields. CAFO operators of Large CAFOs subject to subparts C and D should follow the criteria established in the technical standards for deriving a realistic yield goal for a given crop. CAFO operators must follow the criteria in the technical standards and should have sufficient data and records to demonstrate that the yield goals used as the basis for developing application rates are realistic. 40 CFR § 412.4(c)(2). The permit term for *realistic annual yield goal* is the yield goal identified in the NMP for each crop grown in each field for each year of the planning period. See 40 CFR sections 122.42(e)(5)(i)(A) and 122.42(e)(5)(ii)(A).

While the basis for establishing the yield goal is not part of the permit term, EPA recommends that the basis (e.g., historical records, data source for book values) be identified in the NMP. In any event, the permitting authority has the authority to request the basis for the yield goal that was used. 40 CFR § 122.23(h). Additionally, upon subsequent permit issuance, the public will have the opportunity to review yield goals in light of actual yields reported by the CAFO in its annual reports. Id.; § 122.42(e)(4)(viii).

Once a realistic yield expectation is determined for a crop, the amount of nutrients required to achieve that yield can be determined.

Total Nitrogen and Phosphorus Recommendations for Each Crop

A key factor in determining the amount of manure to apply to a crop is the amount of nitrogen and phosphorus required for a crop to achieve a given yield. The *total nitrogen and phosphorus recommendation* for specific crops should be identified by each state's technical standards for nutrient management.

While the total amount of nutrients required to achieve a given yield may be met by drawing from all available sources, recommendations for a crop might or might not account for available nutrients already present in the soil. State recommendations may be based solely on quantity of nutrients needed to achieve the given yield goal or may be based on the amount of nutrients needed in addition to those available to a crop from the soil needed to achieve the given yield goal. The latter is commonly referred to as the crop's fertilizer recommendation. Fertilizer recommendations can account for the availability of existing nutrients and how nutrients (existing and added) will behave with time, management practices, and other environmental conditions that affect their availability to a plant. Phosphorus fertilizer recommendations account for existing available nutrients and, therefore, must always consider the results of a soil analysis. That is less common for nitrogen fertilizer recommendations because nitrogen compounds are highly mobile and undergo rapid transformations in soil (see Section 6.1.1 on the nitrogen cycle). Providing an accurate and representative soil analysis of plant available nitrogen is more difficult than for phosphorus because the samples need to be taken close to the time when nutrients will be land applied. Therefore, nitrogen fertilizer recommendations often represent the entire quantity of plant available nitrogen needed from all sources to achieve the yield goal.[7]

Cropland fertilized with hog manure. (Photo courtesy of USDA/NRCS)

Instead of using a fertilizer recommendation to quantify the nutrients needed to achieve a certain yield, some technical standards express the *total nitrogen and phosphorus recommendation* in terms of the crop's nutrient removal rate. When a crop is harvested, the nutrients in the harvested portion of the plant that the crop extracted from the soil, are removed from the field. Standard values have been calculated for specific crops to quantify the amount of nutrients removed on the basis of the yield unit that is harvested. Crop yield units for the most common grain and forage crops are bushels/acre and tons/acre, respectively. The nutrient content of common crops is shown in Table 6-2 . The values in Table 6-2 are generalized national data. Local crop nutrient content is not expected to differ greatly from that shown in Table 6-2 but should be based on local NRCS, Cooperative Extension Service, or land grant university data. Such local data should be used for planning purposes. A crop's nutrient removal rate is determined by multiplying the nitrogen or phosphorus per yield unit by the expected yield.

Nitrogen

Total nitrogen recommendation is almost always based on the fertilizer recommendation. The recommendation defines the amount of nitrogen needed by the crop and application rates are derived considering the various sources of nitrogen available to meet the total nitrogen need.

The exception to that approach is when the crop is a legume. Legumes can supply and meet their own nitrogen needs through nitrogen fixation. However, some states' technical standards allow for manure to be applied to legumes, because legumes will use nitrogen that has been supplied externally to the extent that it meets the plant's needs, rather than fixing nitrogen to meet that need. In states that allow manure application to legumes, typically it is allowed at the crop's removal rate. The nitrogen removal rate will determine the amount of nitrogen expected in harvested biomass for a given crop and yield. Where states allow that, the nitrogen removal rate can be reported for legume crops as the crop nitrogen recommendation. In all other cases, the crop nitrogen fertilizer recommendation should be used.

Phosphorus

Total phosphorus recommendations can follow either the phosphorus removal rate or the phosphorus fertilizer recommendation (based on the soil phosphorus test level). When the soil test for phosphorus is low, operators will most likely follow the phosphorus fertilizer recommendation, rather than the removal rate, because it allows a higher phosphorus application rate, which will build up the soil phosphorus level to improve the fertility of the field. When the phosphorus fertilizer recommendation is followed, the soil test level increases with time, and subsequently the phosphorus recommendation should decrease.

The phosphorus fertilizer recommendation is based on the amount of phosphorus that is needed beyond what is already available in the soil to grow a given yield of a specific crop. A soil sample is analyzed to determine the amount of phosphorus that can be removed from the sample; the ability to remove phosphorus from the sample represents the plant availability of phosphorus.

Fertilizer recommendations based on soil test phosphorus levels are designed to achieve an *optimum* available soil phosphorus level (see Figure 6-7 and Section 5.9.3 Soil Test Protocols). When the soil test is low, the recommendation is to apply more than what the crop will remove with the intention to build up the soil test level so that the soil can supply the crop and subsequent crop's phosphorus need. Conversely, when the soil test level is high, the recommendation is less than the removal rate because the intention is to draw down the phosphorus level in the soil to achieve an optimum level. When the phosphorus fertilizer recommendation is used as the term for *total phosphorus recommendation*, the term will inevitably change because the intent of the recommendation is to increase the amount of phosphorus in the soil (or to decrease the amount of phosphorus in soil when soil tests are high) to achieve an optimum level of phosphorus soil fertility.

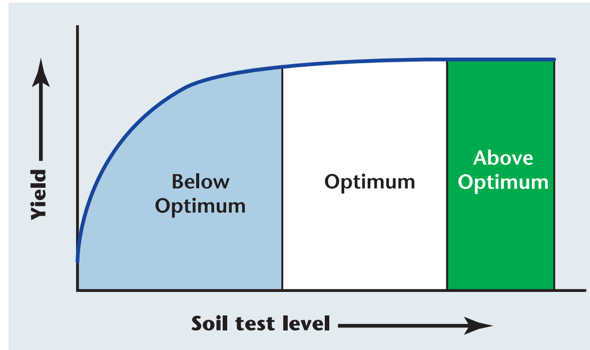

Figure 6-7. Yield response curve illustrating the soil test interpretation levels.

An application based on a crop phosphorus removal rate will maintain the current soil phosphorus test level because the removal rate supplies only enough phosphorus to replace the phosphorus that is removed with harvest. The amount of plant available soil phosphorus will have no bearing on the amount of additional nutrients to apply. When the crop phosphorus removal rate is used as the term for *total phosphorus recommendation*, the term will be consistent over time for a specific crop unless the crop yield goal is adjusted.

Figure 6-8 provides an example of how the recommended pounds of P_2O_5 to apply can differ when following either a soil test fertilizer recommendation or a crop phosphorus removal rate.

The site-specific information captured for the term, *total nitrogen and phosphorus recommendations for each crop*, will depend on what the state's technical standards require. In many cases, the state's technical standards will allow for either the fertilizer recommendation or the crop removal rates, in which case, the higher rate will typically be used to calculate manure nutrients to be applied.

Removal Rates vs. Fertilizer Recommendations

Nutrients removed in harvested portions of corn silage.

Crop	Unit of yield	Nutrient removed per unit of yield	
		P_2O_5	K_2O
		lb/unit	
Corn			
Silage	ton	3.30	8.00

Phosphate (P_2O_5) recommendations for corn silage.

Soil test	Yield potential—tons per acre				
	20	22	24	26	28
ppm (lb/acre)	lb P_2O_5 per acre				
5 (10)[1]	115	125	130	135	140
10 (20)	90	100	105	110	115
15-30 (30-60)[2]	65	75	80	85	90
35 (70)	35	40	40	45	45
40 (80)	0	0	0	0	0

[1] Values in parentheses are lb/acre.
[2] Maintenance recommendations are given for this soil test range.

Figure 6-8. Removal rates versus fertilizer recommendations. (Source: TriState Fertilizer Recommendations)

Understanding Substantial Changes with Low Phosphorus Soil Test Results

Various applications for the result of the soil phosphorus analysis are discussed throughout this chapter, which include how they are applied in deriving:

- *Outcome of the field-specific risk assessment*.
- *The total phosphorus recommendation for each crop*.
- *The maximum amount of phosphorus to be applied*.
- *The methodology* (under the narrative rate approach).

With respect to the above terms, any changes to the field-specific maximum amounts of phosphorus and any changes that are likely to increase the risk of nitrogen and phosphorus transport to waters of the U.S. as determined by the *outcome of the field-specific risk assessments* are substantial changes to the terms of an NMP.

As just discussed, when soil tests are low, the operator will likely follow the phosphorus fertilizer recommendation over the removal rate if given a choice. Following the fertilizer recommendation will increase the soil test value and subsequently decrease the corresponding fertilizer recommendation.* Thus, over a period the permit term, *total phosphorus recommendation,* is likely to change.

In many cases, when the phosphorus soil test is low, the risk for runoff will also be low and manure will most likely be applied at an nitrogen-based rate. As a result, the phosphorus recommendation is likely to be become obsolete. The phosphorus fertilizer recommendation is not followed when land applying using an nitrogen-based rate. While the fluctuating term, *total phosphorus recommendation* would be considered a permit modification, it has no bearing on the *maximum amount of phosphorus that can be applied* and thus it would not be a **substantial** permit modification.

However, it is possible for a field to have a high risk for runoff (generally limiting application to a phosphorus-based rate) and a low phosphorus soil test. In this case, the fertilizer recommendation is most likely followed. In this case, the *maximum amount of phosphorus* will be the amount directly determined by the fertilizer recommendation. Over time, the phosphorus soil test will increase and subsequently the fertilizer recommendation will decrease. Because that field has a high risk for runoff, as the recommendation declines, less phosphorus should be applied, thereby decreasing the *maximum amount of phosphorus* that can be applied. With every change to the *total phosphorus recommendation* (in this case the fertilizer recommendation), *the maximum amount of phosphorus* changes triggering a **substantial** permit modification. EPA believes that is necessary to ensure that phosphorus is not over-applied as the soil phosphorus levels build on such high-risk sites.

***Note:**
There are many ways to read a soil test analysis, which could lead to confusion when discussing the change to the fertilizer recommendation. Phosphorus fertilizer recommendations are typically given as the pounds of phosphorus to be applied to a crop for a given soil test range. Therefore, for a range of soil test results, the recommendation will be the same. For example, a quantitative range of soil test results (i.e., 0–50, 50–100, 100–150 ppm) will be qualitatively described (0–50 = low, 50–100 = optimum, 100–150 = high). Different phosphorus recommendations for the amount of additional phosphorus to be applied will be provided for each qualitative soil test range. If a soil test is taken more than once over the course of a 5-five year permit term, a change to the crop recommendation term would occur only if a new soil test recommendation is applied.

6.5.2. Additional Site-Specific Terms: Linear Approach

Because the linear approach specifies the maximum amount of nutrients that will be supplied from manure, the permit must include terms for the variables and data that are used to derive that value. In addition to the terms that apply to both approaches, which are discussed in Section 6.5.1 above, the CAFO regulations require the terms described in this section for application rates expressed using the linear approach.

Credits for Plant Available Nitrogen in the Field

Once the nitrogen recommendation for a crop is known, the manure application rates can be determined by subtracting from the total nitrogen recommendation the amount of nitrogen that will be available to the crop from all other sources. One of these sources is nitrogen that is already in the field. These in-field nitrogen sources of PAN are referred to as nitrogen credits. Two common credits for PAN are organic nitrogen from prior manure applications that mineralizes to available nitrogen compounds over the course of the planning period and nitrogen supplied from legume crops. Quantifying these sources of PAN is part of the methodology for calculating application rates for the narrative rate approach and a permit writer should ensure this is specified in the NMP. Under the linear approach, the credits themselves are a term.

Nitrogen Credits from Mineralization

Not all nitrogen in manure that CAFOs apply is available to the crop during the year of application. Some nutrients require organic material decomposition before they are available for plants. An accurate estimate of the amount of organic nitrogen that will become available in the years after a manure application event is considered a part of the credits for PAN in the field. The availability of organic nitrogen from manure application will vary according to the degradability of organic nitrogen compounds in the manure and other environmental conditions. Organic nitrogen in different types of manure (e.g., dairy, poultry, beef) mineralizes at different rates. Varying environmental conditions associated with the timing of application (fall versus spring), such as soil temperature and moisture, affect the ability of microorganisms to mineralize organic nitrogen compounds in the manure into plant available forms. Availability coefficients are applied to the amount of organic nitrogen, as determined from the manure analysis. Coefficients typically are used for calculating nitrogen availability in the first, second and third year after application. (See section 6.1.1 and Appendix A, Basic Soil Science and Soil Fertility, for more details on the nitrogen cycle and nitrogen mineralization.)

State technical standards should provide mineralization coefficients that are based on the type of manure being applied and the time of year that application is occurring. Most states consider nutrients to be 50 to 75 percent available in the first year. Typical rates are provided in Table 6-4, but state-specific rates should be reflected in a CAFO's NMP.

Table 6-4. General mineralization rates for nitrogen[a]

Waste and management	Years after initial application		
	1	2	3
	Percent available (accumulative)		
Fresh poultry manure	90%	92%	93%
Fresh swine or cattle manure	75%	79%	81%
Layer manure from pit storage	80%	82%	83%
Swine or cattle manure stored in covered storage	65%	70%	73%
Swine or cattle manure stored in open structure or pond (undiluted)	60%	66%	68%
Cattle manure with bedding stored in roofed area	60%	66%	68%
Effluent from lagoon or diluted waste storage pond	40%	46%	49%
Manure stored on open lot, cool-humid	50%	55%	57%
Manure stored on open lot, hot-arid	45%	50%	53%

Source: Table 11-9, USDA-NRCS, 1999

a. Table assumes annual applications on the same site. If a one-time application, the decay series can be estimated by subtracting year 1 from year 2 and year 2 from year 3. For example, the decay series for fresh poultry manure would be 0.90, 0.02, 0.01. The decay rate becomes essentially constant after 3 years.

The permit writer should be aware that the estimate for residual manure nitrogen in the field, which, in the linear approach, contributes to the permit term, *credits for PAN in the field* is estimated from the manure analysis used to develop the NMP. Therefore, the requirement for Large CAFOs to sample and analyze their manure annually could result in changes in the value of PAN in the field. Medium and Small CAFOs are subject to BPJ requirements and might be able to account for the nutrient content of manure using standard book value estimates. Standard estimates will not reflect fluctuations of the manure analysis and associated changes to the PAN credits in the field. The narrative rate approach accommodates for those types of fluctuations.

Temporal fluctuations in the manure nutrient content can be great for uncovered lagoons and pits because seasonal variations in temperature and precipitation can alter nutrient content through dilution, evaporation, and volatilization. Manure analyses from under-barn concrete pits or covered aboveground tanks will not vary as much because there is limited exposure to the environment.

Nitrogen Credits from Legumes

As described in the discussion above on *total nitrogen recommendations*, legumes can fix atmospheric nitrogen to supply their own nitrogen need and add nitrogen to the soil. The state's technical standards for nutrient management need to describe how to account for nitrogen credits from a previous legume crop so the NMP can properly account for them. Two examples from Montana and Iowa are provided below. Montana's technical standard provides legume credits that vary with plant species and growing conditions (Table 6-5):

Iowa's technical standard sets an upper limit of total nitrogen credits that can be derived from a soybean crop. Credits for nitrogen that are to be carried over into the following year are calculated as follows:

- Last year's soybean crop: 1 lb nitrogen per bushel of yield, maximum of 50 lb nitrogen per acre credit.
- Legume forage crop:
  - Last year's crop with 50 to 100 percent alfalfa or other legume in stand: 100 to 140 lbs nitrogen per acre.
  - Last year's crop with 20 to 50 percent alfalfa or other legume in legume/grass mixture: 50 to 80 lbs nitrogen per acre.
  - Two years ago crop with 50 to 100 percent alfalfa or other legume in stand: 30 lbs nitrogen per acre.
- Last year's legume green manure crop: 100 lbs nitrogen per acre.

Nitrogen credits are a term even for a field with a phosphorus-based rate because the nitrogen credit is needed to calculate the appropriate amount of supplemental nitrogen to be added to the field to ensure that the crop's nitrogen requirement is not exceeded.

Consideration of Multi-Year Phosphorus Application

A multi-year phosphorus application consists of applying a single application of manure at a rate equal to the recommended phosphorus application rate (whether based on soil test levels or crop removal) for multiple years in the crop sequence. In some situations a multi-year phosphorus application is used because the application equipment might not be able

Table 6-5. Legume nitrogen credits for Montana

Legume	Nitrogen fixation (lbs/acre)*
Alfalfa (after harvest)	40–80
Alfalfa (green manure)	80–90
Spring Pea	40–90
Winter Pea	70–100
Lentil	30–100
Chickpea	30–90
Fababean	50–125
Lupin	50–55
Hairy Vetch	90–100
Sweetclover (annual)	15–20
Sweetclover (biennial)	80–150
Red Clover	50–125
Black Medic	15–25

*The maximum nitrogen fixation in lbs/acre should be used unless appropriate justification is given showing lower nitrogen fixation is appropriate. In all cases, the nitrogen fixation used must be within the ranges specified above.

An example of no till farming where young soybean plants thrive in the residue of a wheat crop. (Photo courtesy of USDA/NRCS) to apply manure at the recommended phosphorus application rate because that rate is lower than the spreading capability of the equipment. In other cases, it might be more practical and economical to *bank* phosphorus by applying manure at rates higher than the crop's phosphorus needs for that year.

The use of multi-year phosphorus application is a flexibility that the Director can provide to CAFOs when establishing the state's technical standards for nutrient management. 40 CFR § 412.4(c)(2)(ii). However, that flexibility is allowed only on fields that do not have a high potential for phosphorus runoff to surface waters. Id. Such flexibility is not needed when the *outcome of the field-specific risk assessment* permits an nitrogen-based application rate because an nitrogen-based application rate already provides 2 to 4 times the amount of phosphorus that a crop typically needs. Therefore, *consideration of multi-year phosphorus application* will never be a term for any field with an nitrogen-based limit. It is a flexibility to be considered once the *outcome of the field-specific risk assessment* restricts application to a phosphorus-based rate.

The term for *consideration of multi-year phosphorus application* should identify the field, crop, and year that the multi-year phosphorus application will occur. Because a multi-year phosphorus application should never exceed the annual nitrogen rate for the year of application, the plan should demonstrate that the amount of nitrogen being applied does not exceed the allowable nitrogen recommendation for that crop during the year that the multi-year phosphorus application is made.

When a multi-year phosphorus application is allowed, CAFOs must not apply additional phosphorus to those fields until the amount applied in the single year has been removed through plant uptake and harvest. 40 CFR § 412.4(c)(1). Therefore, the permit writer should ensure that no manure application is planned for the number of years covered by the multi-year application. The number of years will depend on how many years' worth of phosphorus was applied in a single application [68 FR 7,210 (Feb. 12, 2003)].

Accounting for All Other Additions of Plant Available Nitrogen and Phosphorus

For many fields where manure is land applied, other sources of nutrients are also land applied. The term, *accounting for all other additions of plant available nitrogen and phosphorus*, is to capture those sources of nutrients. The nutrient sources can include chemical fertilizers, biosolids, nutrients in water used for irrigation, or any other additions to the field but would not include mineralization of nitrogen from previous land application events or legume nitrogen credits.

Pound for pound, animal manure does not have the same nutrient value as commercial fertilizer, and commercial fertilizer can be customized and blended to meet specific nutrient requirements. Farmers often supplement animal manure applications with commercial fertilizer or biosolids. Furthermore, because animal manure contains relatively high concentrations of phosphorus, crops are generally not supplied with enough nitrogen when manure is applied on a phosphorus basis. Therefore, CAFOs might need commercial nitrogen fertilizer to meet the crop's total nitrogen requirements when manure is applied at less than the nitrogen rate.

Irrigation water, especially from shallow aquifers, contains some nitrogen in the form of NO_3-N. Also, water from runoff ponds and storage lagoons contains nutrients. CAFOs must include those nutrient sources in the NMP. To calculate the amount of nitrogen applied with irrigation water, CAFOs must conduct a nutrient analysis to determine the concentration of nitrogen and phosphorus in the water, typically reported as NO_3-N and soluble phosphorus in ppm or mg/L.

The permit term is not the actual amount of the nutrient source to be applied the field. The CAFO rule describes the term as accounting for additions of plant available nutrients to indicate how those other nutrient sources are included as additions for meeting crop needs. That is to say that they must be identified in the NMP, and the amount of nutrients they contribute must be included in the calculation of the total nutrients to meet the nutrient recommendation. Therefore, while the permit term could be captured in the permit as a specific type of fertilizer, the actual amount of fertilizer applied can fluctuate year to year. The plan should include the nutrient content of the sources that are accounted for (e.g., the N-P-K value of supplemental fertilizer or the nitrogen and phosphorus concentration in biosolids or irrigation water).

Example term *accounting for all other additions of plant available nitrogen and phosphorus*

A Large permitted CAFO plans to apply 100 lbs/acre of nitrogen from manure and 50 lbs/acre of nitrogen from a 25-0-0 commercial fertilizer to Field A in each year of the permit.

The permit term for *accounting for all other additions of plant available nitrogen and phosphorus* means that the plan includes the additions of commercial fertilizer to field A. (For an illustration, see the example provided in section 6.6.2 under *Accounting for all other additions of plant available nitrogen and phosphorus*.) In year 2 of the permit, the manure test indicates the concentration of nitrogen in the manure has decreased because of a change in the feed ration. Using all the manure generated at the CAFO supplies only 90 lbs/acre of nitrogen, and the amount of commercial fertilizer used must be increased. That is an acceptable change to make because the actual amount of fertilizer being applied is not the permit term. However, if the CAFO operator wanted to use biosolids to supplement the nitrogen supplied by manure this would be considered a change to the NMP and would need to be submitted to the Director because that source was not accounted for in the NMP.

Form and Source of Manure that Is Land Applied

The form and source of manure are closely related. The form of manure will dictate the type of storage structure or source. The *form and source of manure* are required terms for the linear approach because they relate to the method of application, which is also a term and is discussed in more detail below. 40 CFR § 122.42(e)(5)(i)(A).

An automated lagoon waste management system for a 900-head hog farm. (Photo courtesy of USDA/NRCS)

Manure handled as a solid, such as broiler and turkey manure, is typically surface applied to cropland using either tractor-drawn or truck-mounted, box-type manure spreaders. Manure handled as a semi-solid or slurry, such as dairy cow manure removed from free-stall barns by scraping, is typically applied to cropland using tractor-drawn or truck-mounted tanks. That type of manure typically can be surface applied and incorporated into the soil by disking or plowing, or can be directly injected into the soil. Manure handled as a liquid, such as lagoon wastewater, could be applied to cropland using tractor-drawn or truck-mounted tanks or irrigation systems. Because of the volume of manure when handled as a liquid, irrigation is a fairly common method for land application of this form of manure because it reduces labor requirements. Liquid manure is either applied on the soil surface and incorporated shortly after application or can be directly injected into the soil. Incorporation or injection helps to control loss of volatile ammonia and odors. Incorporation is very effective at controlling runoff of manure nutrients from land application if done within a few hours after application. A soil injector applies liquid manure directly into the soil to a depth of 6 to 9 inches as the tanker passes over the field.

The term *form* refers to the form of the manure (solid, semi-solid, slurry, and liquid) and the term source refers to the storage structure containing the manure. Multiple applications of manure can be made to a single field in one season. Each application could come from a different source and be of a different form. For example, in March solid manure from a manure stack might be land applied to a field. That same field could receive an additional manure application the next month in the form of an injection of liquid manure from a lagoon. Each form and source of manure application should be identified in the NMP and as the permit term for *form and source of manure* in the linear rate approach.

Timing and Method of Land Application

The timing and method of land application of manure have a direct impact on the amount of nutrients that will be available to the growing crop. Therefore, the CAFO regulations specify that those are required site-specific terms when using the linear approach.

The time of year that manure is applied can influence nitrogen availability because of seasonal changes in conditions that influence mineralization rates. As a term of the NMP, *timing* depends on the specific way in which timing affects nutrient availability in the application rate calculation.

For example, *spring* or *fall* would be sufficient if the nitrogen value for that application is the same no matter when during the spring or fall manure is applied. On the other hand, the term might be as specific as "within two weeks before planting" if that is critical to determining the availability of nitrogen to the growing crop. An operator might prefer to specify the timing of an application relative to a seasonal time frame for use as a permit term, even if the plan specifies a specific day or month. (Note that most nutrient management planning software requires identification of a specific date of application; EPA does not expect that permit terms would dictate a specific date for manure application). EPA believes that capturing application timing over the course of a season would be appropriate even if the NMP is more specific, as long as the specific timing is not critical to determining nutrient availability.

The term *method* refers to the equipment used (e.g., big gun, injector, sprinkler, broadcast spreader) to apply the manure. The method of application can affect nutrient availability, the efficiency of crop use, and the likelihood of nutrient loss from the soil. Surface-applied nutrients are more likely to be lost with erosion, particularly during heavy rains, if adequate erosion controls are not in place. Phosphorus loss can also occur in the absence of soil erosion with runoff of dissolved, soluble phosphorus. Nitrogen loss can also occur in the absence of soil erosion because of volatilization and/or leaching losses. Fresh or stored manure contains nitrogen in the form of ammonium, which is subject to loss because it volatilizes as ammonia gas. Incorporation into the soil reduces volatilization; however, there can be a tradeoff because erosion potential increases after disturbing the soil surface. Solid manures like feedlot pen manure contain very little ammonium, making incorporation less critical for conserving nitrogen lost from volatilization (although still desirable for controlling manure nutrients that can be lost from runoff and erosion). Nevertheless, incorporation within the root zone increases plant availability of nutrients. Uniformity of nutrient applications and distance from the root system can also influence crop response to nutrient applications. Manure and wastewater should also be applied at rates and with methods that consider and account for all pathways for loss.

The land application method used at a CAFO often depends on the type of application equipment available or the method that is most cost- or time-effective. Many growers choose to broadcast nutrient application because of fewer time constraints and lower cost. The handling system and therefore the form of manure might also dictate the application method that is used. For example, solid or semi-solid materials cannot be effectively injected into the soil or applied through an irrigation system, while lagoon liquids are most economically applied through an irrigation system.

Land application of manure by injection. (Photo courtesy of USDA)

If the rates associated with a method rely on incorporating the manure after a certain number of days, the number of days should be captured with the method and as part of the timing requirement because the timing, as it specifically relates to the method of application, will affect the amount of nitrogen that will volatilize after manure is land applied.

Volatilization coefficients, which correspond with different methods and timing of application, can be applied to the appropriate nitrogen compounds from the manure analysis where technical standards account for this type of nitrogen loss. Typical rates are provided in Table 6-6.

Table 6-6. **Percentage of nitrogen in applied manure still potentially available to the soil (ammonia volatilization causes the predicted losses)**

Application method	Percentage remaining/delivered		
Injection	95%		
Sprinkling	75%		
Broadcast (fresh solids)	*Soil Conditions*		
Days between application and incorporation:	*Warm dry*	*Warm wet*	*Cool wet*
1	70%	90%	100%
4	60%	80%	95%
7 or more	50%	70%	90%

Source: Table 11-6, USDA-NRCS Agricultural Waste Management Field Handbook, (after Willrich et al. 1974)

Manure spreading or spraying activities should be planned and managed to prevent nuisances and an adverse impact on groundwater, surface water, public health, and plants. Degradation of any aspect of the environment could warrant reevaluation of the use of a selected manure application system.

Method

CAFOs should always apply manure uniformly and at the approved application rates. Under the effluent guidelines, CAFOs must record the data (day, month, year) and method of each manure application. 40 CFR § 412.37(c). Although many equipment options exist, there are basically two methods of application: subsurface application and surface application. CAFOs must record weather conditions (e.g., rainfall amounts) at the time of application and for the 24-hour period before and after application. 40 CFR § 412.37(c)(3). The operator must also periodically inspect equipment used for land application of manure, litter, or process wastewater. 40 CFR § 412.4(c)(4). Though the CAFO rules do not specify the frequency of the inspections, EPA recommends inspections every time the equipment is used. This allows CAFOs to detect and then correct any potential problems before they cause adverse environmental impacts.

- **Subsurface Application.** Solid, semisolid, and liquid manure can all be applied using this method. When feasible, this is the preferred method of manure application.

Equipment Calibration

Once the method of land application is determined, the manure-spreading equipment needs to be calibrated to ensure that the actual manure application rate matches the planned manure application rate. Equipment calibration is determining the appropriate setting and speed necessary for a piece of land application equipment to apply a calculated rate of manure per acre. Calibration helps a producer to ensure that application at appropriate rates by determining appropriate overlaps, evaluating application uniformity, monitoring usage and *wear and tear* in equipment, and determining application settings based on manure consistency. At a minimum, equipment used to apply manure, litter, or process wastewater should be calibrated annually.

During calibration, the required or appropriate overlap can be determined. Overlap distances and travel lane widths are best determined by measuring the distribution of applied material across the spread pattern. Rain gauges, tarps, or disposable baking pans can be used to collect the applied manure before it is weighed or measured. Many times, visual estimates of desired overlap can be misleading. Because of variations in spreader volume and changes in manure moisture content and density, this is especially true when calibrating litter or solid manure spreaders. Sprinkler overlaps, typically calculated to be the points where an area is receiving less than half of the average volume across the spread width, generally vary between 50 to 80 percent, depending on sprinkler type and wind conditions.

Application equipment should be maintained and operated so it applies a given application rate as evenly as possible across a field. *Hot spots* or areas of over-application due to operator error, non-calibrated or worn equipment can increase the occurrence of runoff or ponding, accumulation of nutrients, or excessive nutrients moving into shallow groundwater. Areas of low application might not produce the realistic yield that could be achieved on the site, potentially leaving unused nutrients that accumulate or are lost to the environment.

As equipment is used and becomes older, it loses efficiency, increasing the need for calibration. That is compounded by the solids, acidity, and salts found in manure, litter, and wastewater that can accumulate in equipment with use. To monitor system performance, irrigation systems that pump liquids with high solids or with significant crystal (iron or calcium carbonate/lime) buildup should be calibrated regularly.

Finally, equipment should be calibrated in response to changes in manure consistency and nutrient content. When a manure storage structure is emptied, a higher amount of solids will be removed and applied to fields than when only wastewater from the surface of the storage structure is applied. As the manure density increases, the equipment should be recalibrated to ensure that the application rate is within acceptable limits. Spreaders should also be recalibrated when a material that is wetter or drier than the litter or manure spread during the previous calibration is applied. Different manure sources will require equipment calibration to account for changes in nutrient content.

Manure spreader calibration. (Photo courtesy of USDA/NRCS)

CAFOs use this method by mechanically incorporating or injecting the manure into the soil. Mechanical incorporation can be performed using moldboard plows, chisel plows, or heavy discs. To reduce nutrient losses, CAFOs should incorporate wastes applied to the land surface before it dries, usually within 2 days of application. Injection requires a liquid manure spreader and equipment to inject manure below the soil surface. To prevent nutrient losses, CAFOs should close the openings made by the injectors following application.

Immediately incorporating manure in the spring will increase the amount of PAN by reducing ammonia loss. Incorporation in soils with low runoff potential can help prevent the movement of nutrients and pathogens from animal manure to surface waters. Where soil erosion is a problem, however, tillage might result in unacceptable losses of soil and nutrients.

Injection is likely the best method of incorporating liquid and semi-solid animal manure in reduced-till or no-till cropping systems because crop residues left on the surface act as a mulch, and the exposed soil surface is minimum.

- **Surface Application of Liquid Manure (Irrigation).** The three predominant systems used for surface application of liquid animal manure (irrigation) are solid sets, center pivots, and traveling guns. Solid set systems are a series of sprinklers generally supplied by underground pipe. Center pivot systems are generally used in large fields and must be able to travel in a circle. Traveling guns are high-pressure, high-output, single-nozzle systems that crawl down travel lanes in the field. Liquid wastes can also be surface applied with tank spreaders.

  Irrigation can save considerable amounts of time and labor when applying large volumes of wastewater or liquid animal manure. Sometimes, CAFOs might need to dilute animal manure with fresh water for salinity or other plant requirements, or to facilitate application via irrigation. Irrigation provides flexibility in applying animal manure during the growing season and has the added advantage of supplying water during the growing season's drier periods. Infiltrating liquid can carry much of the easily volatilized ammonia into the soil, although some ammonia will still be lost from the spray before it reaches the soil.

  The irrigation system should, however, be matched to the topography, cropping program, nutrient and water needs of the crops, as well as infiltration, percolation rate, and water holding capacity of the soil. CAFOs should not use irrigation to apply animal wastes unless solids have been removed or chopped very fine. If solids are present, the nozzles will clog and the system will not operate properly. Irrigation also can produce aerosol sprays that can cause odor problems.

- **Surface Application of Dry, Solid Manure.** This application method is very effective at applying dry, bulky animal wastes such as poultry litter. Box spreaders with a chain-drag delivery to a fan or spreader mechanism, or tank wagons equipped with splash plates typically are used for surface applications.

Although this is a relatively easy method for applying animal manure and wastes to the land, it has several disadvantages. First, when manure is applied to the surface of the soil without incorporation, most of the unstable, rapidly mineralized, organic nitrogen from the manure is lost through the volatilization of ammonia gas. Volatilization increases with time, temperature, wind, and low humidity. Surface application without incorporation also increases the likelihood of nutrient losses via surface runoff. Surface runoff losses are more likely on soils with high runoff potential, soils subject to flooding, soils that are snow-covered or frozen (via runoff once the snow melts or soil thaws), and soils with little or no vegetative cover. Second, aerosol sprays produced by mixing manure and air during this type of application can carry odors considerable distances. Third, this application method provides poor distribution of nutrients, which can be aggravated by heavy winds. In addition, precision application of manure and waste, such as poultry litter, with a geared box spreader can be difficult.

CAFOs can reduce nutrient losses when using surface application by implementing soil conservation practices such as contour strip cropping, crop residue management, cover crops, diversion terraces, vegetative buffer strips, and grass waterways. More information about conservation practices is available from the local soil and water conservation district and USDA's NRCS.

- **Irrigation Technologies.** Irrigation application systems can be grouped under two broad system types: gravity flow and pressurized. Gravity-flow systems are particularly predominant in the arid west. Many irrigation systems rely on gravity to distribute water across the field. Land treatments (such as soil borders and furrows) are used to help control lateral water movement and channel water flow down the field. Water losses are comparatively high under traditional gravity-flow systems due to percolation losses below the crop-root zone and water runoff at the end of the field.

  Pressurized systems—including sprinkler and low-flow irrigation systems—use pressure to distribute water. Sprinkler system use is highest in the Pacific Northwest, northern plains, and in eastern states. Center-pivot technology serves as the foundation for many technological innovations—such as low-pressure center pivot, linear-move, and low-energy precision application systems—that combine high application efficiencies with reduced energy and labor requirements. For more detail on irrigation water management, see ARS' Irrigation Water Management in Agricultural Resources and Environmental Indicators at *http://www.ers.usda.gov/publications/ah712/AH7124-6.pdf*.

Gravity-Flow Irrigation

Water is conveyed to the field by means of open ditches, above-ground pipe (including gated pipe) or underground pipe, and released along the upper end of the field through siphon tubes, ditch gates, or pipe valves. Such systems are generally designed for irrigation water, and many CAFOs have not traditionally accounted for the irrigated manure nutrients. Some irrigation systems may offer nutrient management challenges to CAFOs including: uneven nutrient distribution, flooding and pooling, excessive volatilization of nitrogen, excessive leaching, and other potential difficulties in meeting technical standards established in their state.

Timing

Timing of manure application is an important consideration for nutrient availability. The longer manure nutrients are in the soil before crops take up the nutrients, the more those nutrients can be lost through volatilization, denitrification, leaching, and surface runoff. CAFOs should consider the hydrological cycle and hydrological sensitivity of each field when making management decisions.

- **Spring Applications.** Applications made during this time can conserve nutrients if nutrients are applied in coordination with plant crop needs because it is just before the period of maximum crop uptake, allowing for more efficient nutrient utilization. In these cases the threat of surface runoff and leaching can be diminished. However, nutrients added in early spring can also be quite vulnerable to loss. Increased precipitation, snow melts, and warming soils contribute to saturated soils that can result in high nutrient loss unless applications are timed appropriately with crop nutrient uptake.

- **Summer Applications.** Early summer is a good time to apply manure because it is generally the time of maximum crop uptake. One consideration is that improper manure application rates and methods can damage growing crops. Options for applying manure in the early summer include side-dressing manure by injecting it between row crops, irrigating liquid manure over corn rows when the corn is 3 to 12 inches tall (taller corn stalks can suffer more leaf damage), or applying manure to forages such as hay fields and grasses after the first and second cuttings or to pastures with small stubble. CAFOs can also apply nutrients to harvested stubble fields in mid- to late-summer. Nitrogen in the manure stimulates more growth of cover crops, especially non-legume species that require nitrogen. The cover crop takes up the nutrients and holds them in an organic form in the plant, preventing them from leaching or being tied up in the soil complex. The nutrients are then more available for subsequent years' crops when the crop residue breaks down.

- **Fall Applications.** Fall application of manure generally results in greater nutrient losses, especially if manure is applied to a soil without any vegetative cover. Increased nutrient losses occur because mobile nutrients such as nitrogen leaching out of the soil. Many of the non-leachable nutrients react with the soil to form insoluble compounds that build soil fertility, but some are bound so tightly that they might not be available for the next crop. In fall, manure is best applied at low rates to fields that will be planted in winter grains or cover crops. If winter crops are not planted, CAFOs should apply manure to the fields containing the most vegetation or crop residues. Sod fields to be plowed the next spring are also acceptable, but fields where corn silage is removed and a cover crop not planted are undesirable sites.

- **Winter Applications.** The greatest nutrient losses typically occur with winter manure applications to frozen, snow-covered, or saturated soils. Research indicates that winter applications increase pollutants in runoff during spring thaw and rainfall events. Most of the seasonal runoff occurs during snowmelt in late winter or early spring. Manure applied in winter generally does not have the opportunity to dry and anchor to the soil surface or to be incorporated into the soil. CAFOs that apply manure during the winter must do so in compliance with the state's technical standards unless winter application is prohibited by the state technical standards. Such protocols must account for the form of material that would be applied (e.g., liquid, semi-solid, or dry manure). In addition, such standards should address the time at which the materials would be applied relative to periods when runoff could occur, the fraction of precipitation that runs off the land in meltwater and in response to winter rains (as affected, in part, whether the soil is frozen or not), the time it takes runoff to travel to waters of the U.S. (as affect by slope, distance to waters, roughness of the land surface, and whether runoff is in contact with the land surface), and other relevant factors, as appropriate.

Nutrient applications should be managed in a way that accounts for the right amount, the right source (manure/fertilizer), the right placement, and most important the right timing. While different seasons can be more or less favorable for crop nutrient utilization, the right timing should ultimately be coordinated with planted crop needs for efficient nutrient utilization and to minimize nutrient loss. CAFOs should check their state regulations to determine whether fall or winter land application is allowed. Manure, litter, and wastewater storage structures should include adequate capacity to store materials that accumulate during those times when, under the technical standards for nutrient management, land application would be prohibited.

The Maximum Amount of Nitrogen and Phosphorus from Manure, Litter and Process Wastewater

For the linear approach, the enforceable term for the land application rate is the *maximum amount of nitrogen and phosphorus from manure, litter, and process wastewater* in pounds per acre, per year, in chemical forms determined to acceptable to the Director. 40 CFR § 122.42(e)(5)(i)(A). That value does not include residual nutrient credits or nutrients available from other sources because under the linear approach, the nutrients from those sources are already accounted for as separate permit terms. The maximum application rate must be calculated for each crop on each field to be used for land application for each year of permit coverage.

The purpose of the term, *outcome of the field-specific risk assessment* (in both the linear and narrative rate approaches) is to determine the appropriate limiting nutrient for developing land application rates (i.e., whether phosphorus or nitrogen limits the amount of manure, litter, or process wastewater that can be applied or whether land application is to be avoided altogether). Therefore, the field-specific risk assessment plays an important role in determining the appropriate amount of both nitrogen and phosphorus to apply. Therefore, what constitutes the term, **maximum** *amount of nitrogen and phosphorus from manure, litter, and process wastewater*, depends on the term *outcome of the field-specific risk assessment.* Section 6.5.1 describes two methods for writing the permit term, outcome of the *field-specific risk assessment,* when the assessment tool is a phosphorus site index. The first method, the *multiple risk level*, lends itself to the linear approach.

The maximum amount of nitrogen from manure, litter, and process wastewater is the maximum amount of nitrogen from manure that can be applied to a field for the specified crop. The amount is calculated on the basis of the terms for the total nitrogen recommendation minus the nitrogen credits and any other additions of PAN. The amount must also account for the form, source, method, and timing of application, all of which are terms under the linear approach. Where the risk assessment allows nitrogen-based application, the maximum amount of nitrogen from manure should supply the difference between the crop's nitrogen fertilizer recommendation (or for legumes, the crop nitrogen removal or other state-specific nitrogen recommendation) and other sources of PAN.

The maximum amount of phosphorus from manure, litter, and process wastewater will be determined for every crop according to each year's field risk rating. *The maximum amount of phosphorus from manure, litter, or process wastewater* can be calculated as the quantitative value for the allowable application rate determined for a field by the field-specific risk assessment. The *maximum amount of phosphorus from manure, litter, or process wastewater* needs to be reported only for years where land application is limited to a phosphorus-based rate. For example, assuming that the operator is only using manure as a nutrient source, if the field-specific risk assessment determines that manure application should be limited to the annual crop phosphorus removal rate in year 1, the crop removal rate will define the value that constitutes the term *maximum amount of phosphorus from manure, litter, or process wastewater*. If in the second year the risk is reduced so that manure could be applied at an nitrogen-based rate, the maximum amount of phosphorus from manure that could be applied could be reported as nitrogen-based without quantitatively defining the phosphorus limit. For every field, there will be an individual nitrogen and phosphorus limit for every crop that is based on the crop(s) planned to be grown each year in the NMP and that year's risk assessment outcome.

Hog manure sampling for nutrient analysis. (Photo courtesy of USDA/NRCS)

The Methodology to Account for the Amount of Nitrogen and Phosphorus in the Manure to be Applied

Permitted CAFOs must calculate the maximum amount of manure to be land applied at least once each year on the basis of the results of the manure nutrient analysis. 40 CFR §§ 122.42(e)(5)(i)(A), (ii)(D). The tons or gallons of manure to be applied are not the enforceable permit term. The enforceable term is the *maximum number of pounds of nitrogen and phosphorus from the manure to be applied*. The operator is held to that rate when calculating the tons or gallons of manure to be land applied. Although the rate constitutes a numeric limit in the permit, the operator may apply fewer nutrients from manure but may not exceed the *maximum amount of nitrogen and phosphorus from manure, litter, and process wastewater* that is established as a term of the NMP.

Under the linear approach, the methodology that is used to account for the amount of nitrogen and phosphorus in the manure that is to be applied is a permit term. 40 CFR § 122.42(e)(5)(i)(A). As mentioned above, operators of permitted Large CAFOs must calculate the actual amount of manure to be applied annually to supply the calculated amount of nutrients to be applied from manure. The amount of nitrogen and phosphorus in the calculated amount of manure can be determined with the use of the manure test results. For more on how to read and interpret a manure analysis, see Chapter 5.9.1. Large CAFOs must use the results of the most recent representative manure tests for nitrogen and phosphorus taken within at least 12 months of the date of land application. Medium and Small CAFOs must apply manure consistent with BPJ-based requirements established in the permit for accounting for the nutrient content of the manure. The NMP must describe the calculations that will be used to translate the pounds of nitrogen and phosphorus to be applied into an application rate for manure, litter, or process wastewater.

6.5.3. Additional Site-Specific Terms: Narrative Rate Approach

The narrative rate approach allows rates of nutrient application from manure to be expressed in a narrative as long as it includes the *maximum amount of nitrogen and phosphorus derived from all sources*. The six site-specific terms described in Section 6.5.1 must be terms of the permit when using either the linear or narrative rate approach for expressing land application rates in NMPs. They are

- *The fields available for land application.*
- *Timing limitations for land application.*
- *Outcome of the field-specific risk assessment.*
- *Planned crops or other use.*
- *Realistic crop yield goals.*
- *Total nitrogen and phosphorus recommendation for each crop.*

In addition to those six permit term requirements, three additional site-specific permit term requirements apply only to the narrative rate approach.

- *The maximum amount of nitrogen and phosphorus from all sources.*
- *Alternative crops.*
- *The methodology used to derive the actual amount of manure that is applied.*

The Maximum Amounts of Nitrogen and Phosphorus from All Sources

Unlike the linear approach, where land application rates are expressed in terms of the amount of nutrients to be applied from manure, the narrative rate approach sets an upper limit on the amount of nutrients to be applied from all sources. The term is *the maximum amounts of nitrogen and phosphorus derived from all sources of nutrients* for each crop identified in the NMP in chemical forms determined to be acceptable to the Director, in pounds per acre, for each field. 40 CFR § 122.42(e)(5)(ii)(A). An additional distinction between the maximum limits required by the linear and narrative rate approach is that in the linear approach, the maximum limit must be identified for each year manure is applied; in the narrative rate approach, the maximum limit is identified only for each crop but does not need to be reported each year that crop is planted. 40 CFR §§ 122.42(e)(5)(i) and (5)(ii).

The *outcome of field-specific risk assessment* is used to determine the appropriate limiting nutrient for developing land application rates (i.e., whether phosphorus or nitrogen limits the amount of manure, litter, or process wastewater that can be applied or whether land application is to be avoided altogether). However, in the narrative rate approach, the term *maximum amount of nitrogen and phosphorus from all sources* should not be exclusively dependent on the *outcome of the field-specific risk assessment for the potential for nitrogen and phosphorus transport* as the maximum limit was described for the linear approach.

The *maximum amount of nitrogen from all sources* under the narrative rate approach is based on the maximum amount of nitrogen that can be applied to a field for the specified crop based on crop type, yield goal, and current soil test (where states rely on nitrogen soil testing). That is the crop's fertilizer recommendation or for legumes, the crop nitrogen removal rate, or other state-specific nitrogen limit for legumes. That value is the same value that is reported for the term, *total crop nitrogen recommendation*.

To preserve the flexibility of the narrative rate approach, the *maximum amount of phosphorus from all sources* can be set for each crop according to the maximum amount of phosphorus applied in any one year for any one crop as dictated by the *outcome of the field-specific risk assessment*. For example, the *maximum amount of phosphorus from all sources* applied in one given year may be the amount of phosphorus in an nitrogen-based application.

The same crop may be planted more than once over the course of a 5-year NMP. Each time the crop is planted it can receive different amounts of nitrogen and phosphorus (i.e., a legume may or may not have manure applied to it. A *maximum amount of nitrogen and phosphorus from all* *sources* does not need to be identified each time the crop is planted and associated with a specific crop year. This is illustrated in the following example.

The NMP illustrated in Figure 6-9 shows a corn-soybean rotation with varying rates of manure application and a risk that varies with each crop and management of that crop. As discussed in Section 6.5.1 under the subsection *Additional Considerations for Implementing the Outcome of the Field-Specific Risk Assessment when Utilizing a Phosphorus Site Index*, planned rates of application should not exceed the recommended rates identified by the phosphorus site index. Given that the risk fluctuates with different crops and years, different rates of manure are applied that follow the P-Index recommended rates. Therefore, in year 1, an nitrogen-based rate is applied to corn but in year 3, because the risk increases, manure is applied at the crop phosphorus removal rate as recommended by this state-specific P-Index. More phosphorus is applied in an nitrogen-based rate than in a rate that supplies the crop phosphorus removal; therefore, the maximum amount of phosphorus that is applied to a corn crop in this NMP is the amount applied under the nitrogen-based rate. The soybean crop is planted twice in this NMP. In the second year, manure is applied at the soybean phosphorus removal rate and in year 4, no phosphorus is applied. Therefore, the maximum amount of phosphorus applied to soybeans is the soybean phosphorus removal rate.

The field-specific assessment plays an important role in determining the appropriate amount of both nitrogen and phosphorus to apply each year and can result in different amounts of nutrients applied each time the same crop is planted. Disassociating the amount recommended by the risk assessment from a specific crop-year in the NMP allows flexibility to change the crop rotation or the crops grown as intended under the narrative rate approach. In addition to changing the sequence that crops are planted, the narrative rate approach also allows a change in actual crops grown as long as the nitrogen and phosphorus application rates are calculated in accordance with the approved methodology (see the section below on alternative crops).

Permitted CAFOs must comply with all limits and conditions of their permits. That includes the *outcome of the field-specific risk assessment*. Therefore, manure and other nutrient sources can be applied up to the identified *maximum amount of nitrogen and*

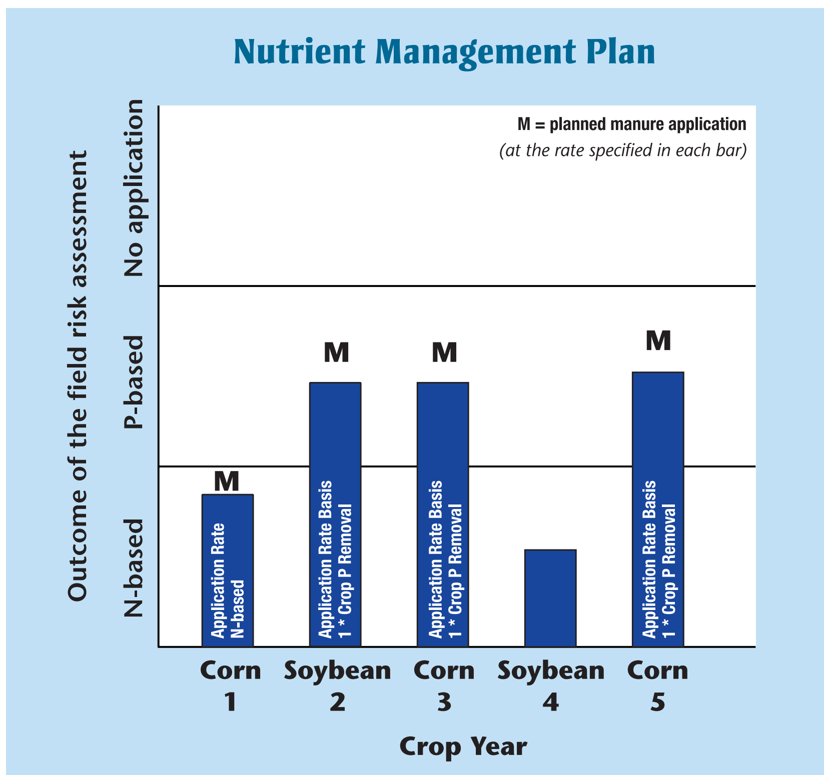

Figure 6-9. An illustration of a 5-year NMP for a corn-soybean rotation.

phosphorus from all sources limits identified in the permit so long as the field risk rating is maintained as well as all other established permit limits and conditions (For ways in which application rates can be changed without incurring a substantial permit modification, see Section 6.5.1 under the subsection *Additional Considerations for Implementing the Outcome of the Field-Specific Risk Assessment when Utilizing a Phosphorus Site Index* and Section 6.5.4).

Alternative Crops

A key difference between the linear and narrative rate approaches that allows for greater flexibility under the narrative rate approach, is that the narrative rate approach allows the NMP to include alternative crops that may be planted in lieu of those included in the planned rotation. If *alternative crops* are included, the NMP must also identify for each alternative crop realistic yield goals and nitrogen and phosphorus recommendations from sources specified by the Director. The term alternative crops includes the alternative crops listed in the NMP, along with their associated yield goals and nitrogen and phosphorus recommendations. 40 CFR § 122.42(e)(5)(ii)(B).

If an alternative crop is used, the *maximum amounts of nitrogen and phosphorus from all sources* and the amount of manure to be applied must be determined in accordance with the *methodology* that is included as an enforceable permit term (as discussed below). The terms and factors associated with *alternative crops* would be the same as the terms and factors required for the crops included in the planned rotation in the NMP.

It is important to recognize that any increase in an *outcome of the field-specific risk assessment* that results from incorporating an alternative crop into the planned crop rotation will still be considered a substantial change to the plan. 40 CFR § 122.42(e)(6)(iii)(D). The amount and timing of nutrients to be applied is likely to change with a change in the planned crop rotation. As discussed in Section 6.5.1, this type of change could affect the *outcome of the field-specific risk assessment* for an individual crop year. A CAFO operator must ensure that there is no increase the *outcome of the field-specific risk assessment* when implementing an alternative crop; otherwise, the operator must follow the substantial change procedures for revising a plan.

Sunflower crop. (Photo courtesy of USDA/ARS)

It is also important to recognize that when alternative crops are used, application rates might need to be adjusted for all years after implementing the alternative crop. That is especially important if a legume crop is added or removed from a rotation because of the change in PAN credits that are accounted for in the methodology. Additionally, if a manure application rate is adjusted because of an alternative crop, mineralization credits for future years could also change. Those changes are accommodated by the flexibility allowed to an operator when using the narrative rate approach and would not be considered substantial changes.

The Methodology by which the NMP Calculates the Amount of Manure to be Land Applied

Rates of application that are expressed using either the linear and narrative rate approach must include the *methodology* for calculating the amount of manure to be land applied; that *methodology* is captured as an enforceable term. 40 CFR §§ 122.42(e)(5)(i)(A), (ii)(A). Under, the narrative rate approach, the *methodology* must account for the following factors part 122.42(e)(5)(ii)(A):

- Credits for PAN in the field.
- The amount of nitrogen and phosphorus in the manure to be applied.
- Consideration of multi-year phosphorus application.
- Accounting for all other additions of plant available nitrogen and phosphorus to the field.
- Form and source of manure, litter, and process wastewater.
- Timing and method of land application.
- Soil test results.
- Volatilization of nitrogen and mineralization of organic nitrogen.

A Global Positioning Satellite (GPS) navigation system facilitates accurate planting, fertilization, and harvesting. (Photo courtesy of USDA/FSA)

The factors listed above are not themselves considered permit terms, but the *methodology* used to account for them in the CAFO's permit is a term. Thus, the CAFO operator will be bound by the methodology and the way in which the above factors are accounted for in calculating the rates of manure application. As long as the methodology prescribed in the NMP is followed and includes all the listed factors, the calculated amount of manure, litter, or process wastewater can change from year to year.

The first six factors listed above are terms under the linear approach. 40 CFR § 122.42(e)(5)(i)(A). Regardless of whether they are expressed as permit terms under the linear approach or as factors of the *methodology* under the narrative rate approach, the information is typically used in the same manner when calculating rates of manure application. Therefore, the discussions of these terms under the linear approach (see the discussion above in Section 6.5.2) also apply here, and the factors are not further discussed in this section. The difference is that, unlike the linear approach, where the factors are terms, the narrative rate approach allows flexibility for the factors to fluctuate from year to year without notifying the Director. As described in Chapter 4.2.3, some of this information must be included in the annual report for CAFOs that use the narrative rate approach to assure the permitting authority and the public that the CAFO is operating within the limits established by the permit given the flexibility of the narrative rate approach permit terms. 40 CFR § 122.42(e)(4).

Results of the Soil Test

The annual calculation of the amount of manure to be applied must account for the results of the most recent soil test conducted in accordance with sampling requirements approved by the Director. Soil sampling requirements should be included in the technical standards for nutrient management. The ELGs specify that Large CAFOs subject to subparts C and D must test their soil for phosphorus at least once every 5 years. Some states' technical standards require sampling to be done more frequently (e.g., annually or 2 to 3 years). Some states require more frequent sampling on fields that have reached higher soil test phosphorus levels. The annual calculation of the amount of manure to be applied must rely on the results of the most recent soil test; even if sampling is conducted more frequently than required by the Director. If a soil test is taken only once over the course of a 5-year permit term, the amount of plant available soil phosphorus indicated by that analysis is assumed on an annual basis. Some states may also require testing for soil nitrogen. The methodology for calculating the amount of manure to be land applied should take that into account.

How the soil test is factored into the methodology under the narrative rate approach may differ from state to state. Soil tests should be included as a variable in the field risk assessment method. Different assessments use the soil test differently. The examples of assessment methods provided in Section 6.5.1 show that some states use soil test thresholds while others rely on a P-Index. Soil test thresholds directly rely on the soil test value to determine if manure nutrients should be applied at an nitrogen-based rate, phosphorus-based rate, or not applied at all while P-Indices use the soil test along with many other variables to make that determination. Each state has the flexibility to determine which assessment method it uses and how that assessment incorporates the soil test results.

When states require a soil test to be taken more frequently than once over the course of a 5-year permit cycle, the CAFO operator should recalculate the field-specific risk assessment so that the outcome is based on the result of the most recent test. If soil test levels for phosphorus are increasing, the potential for phosphorus to be transported from a field could be increasing as well. The CAFO operator should be aware of such a change so that changes in manure application rates or conservation practices can be implemented and updated in the NMP to minimize losses and maintain the risk rating captured as a term for that field. EPA encourages frequent soil testing and reevaluation of the field risk assessment for all CAFO operators, regardless whether they are using the linear or narrative rate approach. The CAFO operator should always be aware of the current field conditions to ensure the minimization of nutrient transport from each field using the most recent data.

Mineralization of Organic Nitrogen and Volatilization of Nitrogen

As with the linear approach, the narrative rate approach must rely on and incorporate the results of the most recent representative manure tests taken within 12 months of the date of land application when calculating the rates of application.

The amount of manure to be land applied is determined on the basis of the amount of plant available nutrients in the manure. A manure analysis provides the amount of nitrogen (typically as total nitrogen, ammonium and phosphorus) contained in the manure samples that were submitted (see Chapter 5). The manure analysis is used to determine the amount of PAN. PAN is determined by accounting for both nitrogen losses (volatilization) and nitrogen gains (mineralization). State technical standards for nutrient management should identify appropriate volatilization and mineralization rates; those rates are a part of the *methodology* under the narrative rate approach to ensure proper calculation of appropriate manure application rates.

Losses of nitrogen from volatilization vary depending on the form, source, timing and method of application. Gains of PAN as a result of mineralization will vary depending on the timing of application and the type of manure that is being used (e.g., dairy, beef, poultry, or swine). Some organic nitrogen will be available the year it is applied, and some will become available in the years following a land application event. Approximately 50 to 75 percent of the total nutrients applied are likely to be plant available during the first year. Nitrogen not used by the crop(s) planted following an application is available for subsequent crops or they are subject to loss by erosion or leaching. It is therefore important to time manure applications to coincide with peak nutrient uptake by the crop.

The volatilization and mineralization rates identified by the state technical standards must be applied to the appropriate manure nitrogen fractions to determine the amount of PAN, supplied from the manure to be added to a field for a crop. In general, volatilization factors are applied to the ammonium result from the manure analysis. Mineralization factors are applied to the organic nitrogen results. If the manure analysis provides only total nitrogen and ammonium, the amount of organic nitrogen can be determined as the difference between the two (total N – NH_4^+).

Land application of manure by a honeywagon. (Photo courtesy of USDA/NRCS)

In practice, the narrative rate approach (and the linear approach) will require that amounts of manure to be land applied be translated from pounds of nutrients into tons or gallons of manure to be applied. The information presented to the public in the CAFO's NMP will include the projected tons or gallons of manure for the planned crop rotation for

Applying volatilization and mineralization factors to the annual manure analysis results will provide an adequate estimate for calculating the tons or gallons of manure to be applied to supply the appropriate amount of nitrogen to the crop. While this estimate is generally adequate, the volatilization and mineralization coefficients that are the basis for those values include certain assumptions about environmental conditions that affect the processes; actual conditions, and therefore actual volatilization and mineralization rates, could differ from those estimated.

Plant tissue testing and pre-sidedress nitrate testing might be effective tools for more accurately determining nitrogen deficiencies (and the need for supplemental nitrogen application) and for determining excess nitrogen. Plant tissue tests and pre-sidedress nitrate tests are typically taken after a portion of the manure or fertilizer applications have been made on a field. The tests should be used to adjust the amount of additional manure or fertilizer that needs to be applied to meet the crop needs. A CAFO's NMP may include plant tissue testing as part of the CAFO's methodology as long as it is done consistently with state technical standards.

each field. That provides the permitting authority and the public an opportunity to review, before permit issuance, the adequacy of the CAFO's methodology. Additionally, the permitting authority and public can review the way the CAFO uses the methodology to calculate the appropriate amount of manure to be applied. Again, the planned crop rotations and projected amounts are not terms, because they will need to be recalculated each year on the basis of updated information; however, the projections will allow the public to see how the *methodology* (which is a term) is applied to a projected set of facts to calculate the amounts to be land applied.

The narrative rate approach provides additional flexibility. In addition to addressing changes in the management of the operations, CAFOs can adjust their rates of application because of fluctuations in any of the factors addressed by the narrative rate methodology. For example, if the NMP projects an amount of manure to be applied according to incorporation of solid manure, the operator could instead apply process wastewater from a lagoon. Form, source, and method of application are all factors affected when an operation makes that type of change. Factors of the *methodology* can change and possibly result in a change to the projected tons of manure to be applied to gallons of wastewater to be land applied. The flexibility is allowed by the narrative rate because the new amount of manure to be applied will be predictably and accurately calculated according to the required *methodology*.

If an NMP is developed by hand or using software that either is not documented publicly or has not been determined to satisfy all the factors in accordance with the state's technical standard, the methodology must be documented in the NMP itself. The *methodology* may; however, be embedded in a software program if the permitting authority determines that the program adequately accounts for the required factors in accordance with the state's technical standards. In addition, documentation that fully expresses how the software accounts for each of the listed factors must be available to the Director and to the public to satisfy the public review requirements of the CAFO rule. Section 6.6 should serve as guidance for permitting authorities as to what EPA expects in nutrient management planning programs to ensure that it encompasses all the factors of the *methodology* listed above.

6.5.4. Substantial Changes

The *outcome of the field-specific risk assessment and the maximum amount of nitrogen and phosphorus from all sources or the maximum amount of nitrogen and phosphorus from manure, litter, or process wastewater* are site specific permit terms. Changes to these terms (any **increase** to the *outcome of the field-specific risk assessment* and **any change** to the *maximum amount of nitrogen and phosphorus*) are considered substantial changes that trigger a permit change. 40 CFR § 122.42(e)(6)(iii)(B). Given the relationship between the amount of nutrients to be applied and the field-specific risk assessment, it is necessary for CAFOs to recalculate the *outcome of field-specific risk assessment* when there are changes to any variables that are used in calculating the *outcome of the field-specific risk assessment*. That becomes more apparent when the field-specific risk assessment is a P-Index because of the numerous variables used by that tool for determining risk. Because a P-Index often includes the manure application rate as one of the variables; this would include changes to the planned rate of manure application, even if the new planned rate does not exceed the maximum limit identified in the permit. Figure 6-10, below illustrates when a phosphorus site index would need be recalculated when NMP implementation deviates from what was planned when the NMP was first developed.

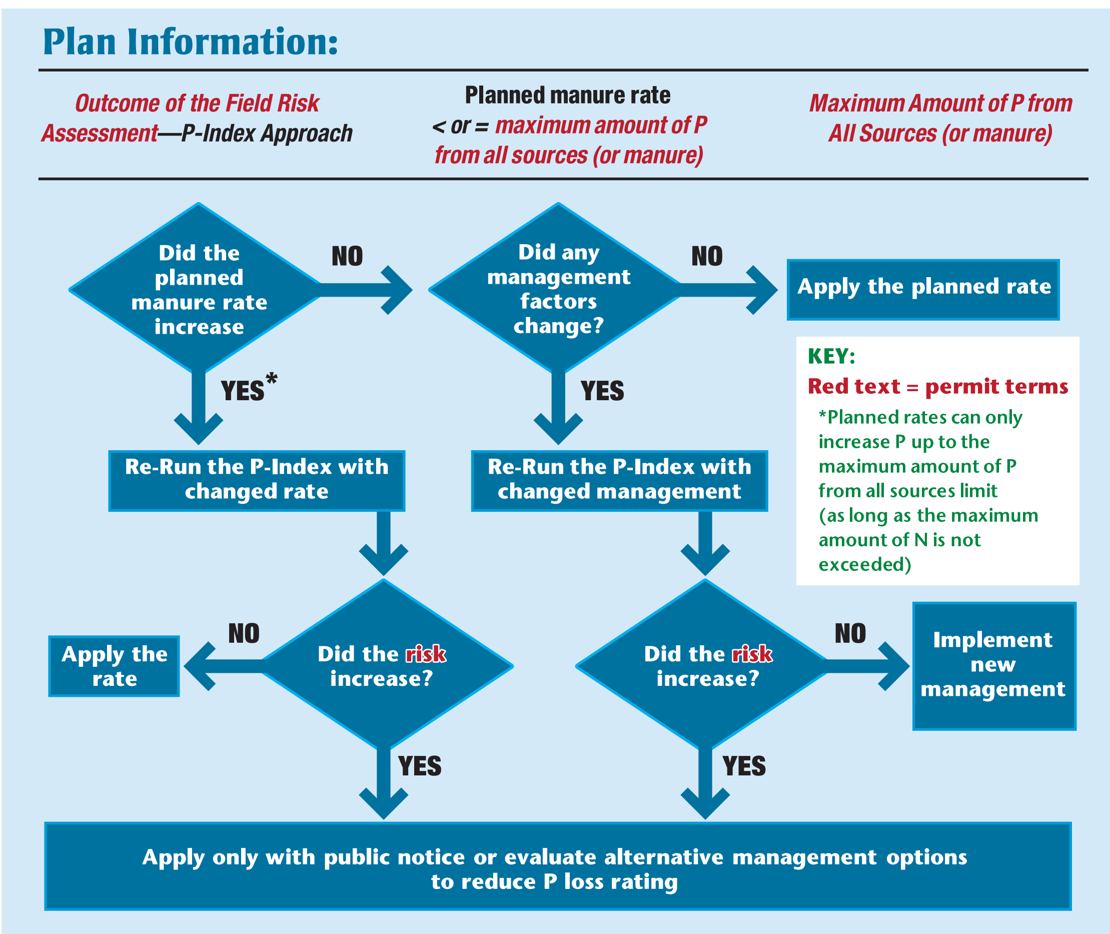

Figure 6-10.

The permit term for the *outcome of the field-specific risk assessment* can be written in various ways. Two have been discussed in this Manual. The process illustrated in Figure 6-10 is applicable regardless of how the permit term for the *outcome of the field-specific risk assessment* is written. When a single overall risk for a field is used (the highest risk), only changes that result in an exceedance of that risk are substantial. When multiple risks are used for a field (typically associated with each crop year) any change that results in an exceedance of any one risk over the course of the NMP is substantial.

The CAFO operator is responsible for ensuring that any changes in management that deviate from what was proposed in the submitted NMP do not increase the field risk rating beyond the rating included as a term in the permit. If an operator's NMP plans for the land application of nutrients at rates below the limits established by the permit term *maximum amount of nitrogen and phosphorus from all sources* (e.g., planned application of manure at the crop phosphorus removal rate when the risk assessment allows for an nitrogen-based rate), the operator can choose to apply at rates that are higher than planned without violating the permit, as long as the rates do not exceed the *maximum amount of nitrogen and phosphorus from all sources (or from manure, litter, and process wastewater* under the linear approach) and as long as the increased application rate does not increase the field risk beyond that allowed by the permit term *outcome of the field-specific risk assessment*.

6.6. Permit Terms for Land Application Protocols Using a Sample NMP

This section uses a sample NMP (Appendix P, Sample Nutrient Management Plan) to identify example permit terms under each approach. Because many permit terms are based on the technical standard for nutrient management, a sample technical standard is also provided with the sample permit (Appendix O, Sample Site-Specific NPDES General Permit). The sample technical standard that is attached to the sample permit was developed by EPA for illustrative purposes only and is not a state Director-identified and approved technical standard for any state.

The permit writer needs to be familiar with the state's technical standards to properly determine that permit terms based on information in a CAFO's NMP are developed in accordance with the state's requirements. To help illustrate the importance and relationship that technical standards play in developing permit terms, a reference to the sample technical standard is given for the example, where appropriate. Additionally, for each term, the location in the plan is identified. While the NMP contains 16 fields and is developed for 5 years, permit terms are not illustrated for each field for all 5 years because many of the terms are identical and the information is repetitive.

As described above, this section provides guidance to permitting authorities on EPA's expectations as to what needs to be addressed by automated nutrient management planning tools to ensure that they encompass all the terms and factors required by the CAFO rule. The sample plan referenced in this section was developed using Manure Management Planner (MMP). EPA recognizes that many states use different programs, which may encompass all of what is described below. Data may be contained in program files and not explicitly provided to an operator as not all the information is necessary to an operator in the day-to-day management of his operation. No matter how the data are stored or displayed, to obtain permit coverage, it is the CAFO's responsibility to ensure that the information is provided to the permit writer.

The sections below follow the order of the discussion of site-specific permit terms for land application protocols in Section 6.5. For each of the terms identified in the CAFO rule, Section 6.6 identifies the site-specific information from the sample NMP that would be captured as permit terms.

6.6.1. Site-Specific Terms: Linear and Narrative Rate Approaches

Fields Available for Land Application

Data sources:

1. Sample NMP: Table 6.1 Field Information and Field Maps
2. Technical Standards reference: Appendix A9 of the Iowa DNR, Manure Management Plan Form, 65.17(16) - *Soil sampling requirements for fields where the P-Index must be used*

Example term:

Field ID	Subfield ID	Total spreadable acres
Bob's Farm-North	8N	56.4
Bob's Farm-South	8S	79.6

A note on using the sample NMP and technical standard to develop the permit term:
As discussed in Chapter 6.5.1, technical standards may limit the allowable size of a field by setting limits on the acres that a soil sample can represent. This sample technical standard does not prohibit grouping soil test results from soil samples. Therefore, field acres represented by similar analyses have been grouped in the sample NMP.

Timing Limitations for Land Application

Data sources:

1. Sample NMP:
   - Table 6.1 Field Information and Field Maps
     - ▹ for field slopes
   - Table 6.6 Manure Application Planning Calendar
     - ▹ for timing restrictions
2. State Technical Standard reference: State NRCS Conservation Code 590 (December 2008).

Text from the state-specific NRCS code 590:

Nutrients and organic nutrient sources shall not be surface applied to frozen, snow covered ground, or saturated soil if a potential risk for runoff exists. A potential risk for runoff exists on slopes greater than 5% unless erosion is controlled to soil loss tolerance levels (T) or less. Manure may be surface applied to frozen, snow covered or saturated ground if a potential risk for runoff exists only under one of the following conditions.

- Where manure storage capacity is insufficient and failure to surface apply creates a risk of an uncontrolled release of manure.
- On an emergency basis.

Example term:

Field ID	Subfield ID	Year	Limitations
Bob's Farm South	8S	2010	The slope is 7%, therefore: Manure may only be surface applied to this field when the ground is frozen, snow covered or saturated if one of the following conditions exists: 1. Where manure storage capacity is insufficient and failure to surface apply creates a risk of an uncontrolled release of manure 2. On an emergency basis
		2011	
		2012	
		2013	
		2014	

In contrast, an example of a field with a slope of less than 5 percent, the term could be illustrated as

Example term:

Field ID	Subfield ID	Year	Limitations
Sample	*Sample-1*	2010	The slope is 3.5%, therefore: No limitations. Manure may be applied year round.
		2011	
		2012	
		2013	
		2014	

A note on using the sample NMP and technical standard to develop the permit term:
Although in emergency situations, the sample technical standards allow for application to occur on frozen, snow covered, and saturated ground, EPA encourages that no application occur by any method to any ground that is frozen, snow covered, or saturated. EPA points out that while a standard may allow for that type of application to occur, the plan writer may choose that it is not the best management practice and write a more protective limit into the permit.

Outcome of the Assessment of the Potential for Nutrient and Phosphorus Transport for Each Field

Data source:

1. Sample NMP: Table 5.3, Nitrogen and Phosphorus Risk Analysis—Iowa Phosphorus Index
2. Technical Standard:
   - Appendix A9 of the Iowa DNR, Manure Management Plan Form, Chapter 567—65.17(17)

Example term when using multiple risks for a field that are based on each crop year's risk

Field ID	Subfield ID	Year	P loss risk	Allowable manure application rate
Bob's Farm South	8S	2010	Low	Manure shall not be applied in excess of the nitrogen needs of the crop.
		2011	Medium	Manure shall not be applied in excess of two times the crop phosphorus removed with crop harvest over the period of the crop rotation.
		2012	Medium	Manure shall not be applied in excess of two times the crop phosphorus removed with crop harvest over the period of the crop rotation.
		2013	Medium	Manure shall not be applied in excess of two times the crop phosphorus removed with crop harvest over the period of the crop rotation.
		2014	Medium	Manure shall not be applied in excess of two times the crop phosphorus removed with crop harvest over the period of the crop rotation.

Or

Example term when using a single risk outcome for a field based on the highest risk for all crop years

Field ID	Subfield ID	P loss risk	Allowable manure application rate
Bob's Farm South	8S	Medium	Manure shall not be applied in excess of two times the crop phosphorus removed with crop harvest over the period of the crop rotation.

A note on using the sample NMP and technical standard to develop the permit term:
The allowable manure application rate associated with each risk level is not provided in the NMP output Table 5.3. The allowable manure application rate basis was pulled from the state technical standards [Appendix A9 of the Iowa DNR, Manure Management Plan Form, Chapter 567—65.17(17)] to develop the complete and appropriate permit term.

Planned Crops or Other Use (Fallow, Pasture, etc.) for Each Field and Each Year

Data source:

1. Sample NMP: Table 6.5, Planned Crops and Fertilizer Recommendation
2. Technical Standard reference: Not applicable

Example term:

Field ID	Subfield ID	Year	Crop
Bob's Farm South	8S	2010	Soybean
		2011	Corn
		2012	Soybean
		2013	Corn
		2014	Soybean

Realistic Annual Crop Yield Goal for Each Field

Data sources:

1. Sample NMP: Table 6.5, Planned Crops and Fertilizer Recommendation
2. Technical Standard Reference: Appendix A9 of the Iowa DNR, Manure Management Plan Form, Chapter 567—65.17(6) - *Optimum crop yield and crop schedule.*

Example term:

Field ID	Subfield ID	Year	Crop	Yield goal	Units
Bob's Farm South	8S	2010	Soybean	61	bu/acre
		2011	Corn	195	bu/acre
		2012	Soybean	61	bu/acre
		2013	Corn	195	bu/acre
		2014	Soybean	61	bu/acre

A note on using the sample NMP and technical standard to develop the permit term:
According to Appendix A9 of the Iowa DNR, Manure Management Plan Form, Chapter 567—65.17(6) - *Optimum crop yield and crop schedule*, optimum crop yield goals could have determined in accordance with one of the following methods:

- Soil Survey Interpretation Record
- USDA county crop yields
- Proven Yield Methods

In this case, USDA county crop yields were used. Appendix A8 of the Iowa DNR, Manure Management Plan Form, contains Agriculture Statistics on County Corn and Soybean Yield Averages.

Total Nitrogen and Phosphorus Recommendations for Each Crop by Field and Year

Data sources

1. Sample NMP: Table 6.5, Planned Crops and Fertilizer Recommendations
   - Provides fertilizer recommendations and removal rates
2. Technical Standard References:
   - Appendix A5 of the Iowa DNR, Manure Management Plan Form, Crop Nitrogen Usage Rates Factors for Various Crops
   - Appendix A6 of the Iowa DNR, Manure Management Plan Form, Nutrient Removal for Iowa Crops
   - IA NRCS 590 conservation code (December 2008), Manure and Organic By-Product Nutrient Application Rates, Section A. Nitrogen Application
     - Manure application to legumes

Example term:

Field ID	Subfield ID	Year	Crop	Total N	Total P_2O_5
Bob's Farm South	8S	2010	Soybean	232 lbs/A	49 lbs/A
		2011	Corn	210 lbs/A	73 lbs/A
		2012	Soybean	232 lbs/A	49 lbs/A
		2013	Corn	210 lbs/A	73 lbs/A
		2014	Soybean	232 lbs/A	49 lbs/A

A note on using the sample NMP and technical standard to develop the permit term:
In Table 6.5 of the sample NMP, the crop nitrogen recommendation for legumes is zero. However, the IA NRCS 590 conservation code (December 2008) allows for manure or other organic by-products may be applied on legumes at rates equal to the estimated removal of nitrogen in the harvested portion of the crop that is removed from the field in that growing season. Therefore, the permit term for nitrogen for soybeans is reported according to the removal rate of 3.8 lbs N/bu of soybean harvested and the yield goal. In addition to being reported in the NMP, it is provided in Appendix A6 of the Iowa DNR, Manure Management Plan Form.

The nitrogen recommendation as reported in MMP in Table 6.5 of the sample NMP indicates that corn, following soybeans has a recommendation of only 160 lbs/acre. That is 50 lbs less than the typical, 210 lbs/acre recommendation for corn (based on the recommendation for a corn crop following a corn crop. This rotation with this recommendation is not shown in the simplified NMP of Appendix P). The recommendation is lowered to account for nitrogen credit generated from the legume crop. For this term, the 50 lbs/acre is included in the total nitrogen recommendation because the credit is accounted for in the term *credits for plant available nitrogen in the field by year* for the linear approach. See Section 6.6.2 below under, Credits for Plant Available Nitrogen and step 6 of the Methodology in Section 6.6.3 for an example of how this credit was accounted for.

The phosphorus fertilizer recommendation for all crops is 0 lbs P_2O_5/acre. This is based on the high phosphorus soil tests (Tables 6.3 of the sample NMP). Because the soil test recommendation is zero and the appropriate nutrient rate basis, as defined by *the outcome of the field specific risk assessment,* allows for phosphorus to be applied at a phosphorus removal rate, the term for the *total phosphorus recommendation* is based on removal rate for each specific crop.

6.6.2. Additional Site-Specific Terms: Linear Approach

Credits for Plant Available Nitrogen

Data sources:

1. Sample NMP:
    a. Table 6.8, Field Nutrient Balance
        i. For legume and residual credits
    b. Table 6.9, Field Nutrient Status Details
        i. Also identifies residual manure Nitrogen credits
        ii. Also can be used to identify adjustments to crop Nitrogen recommendations for legume credits
2. Technical Standard:
    a. Footnote "t" of the Iowa DNR Manure Management Plan Form
        i. For legume credit values
    b. Appendix B3 of the Iowa DNR, Manure Management Plan Form. Note Appendix B3 is the Iowa State University Extension publication PMR1033 (September 2008) - Using Manure Nutrients for Crop Production.
        i. For residual Nitrogen credit values

Example term:

Field ID	Subfield ID	Year	Crop	PAN credits(lbs/acre)
Bob's Farm South	8S	2010	Soybean	0
		2011	Corn	50†
		2012	Soybean	0
		2013	Corn	50† + 2*= 52
		2014	Soybean	0

† - Legume credits
* - Residual manure Nitrogen credits

A note on using the sample NMP and technical standard to develop the permit term:
When the first year of an NMP contains 0 lbs of PAN/acre, it is assumed that the field has not received manure or been planted in legumes in recent history. For most existing fields, the first year of the plan will include a PAN credit. For permit renewals, permit writers should check the first-year PAN credit to ensure that it is consistent with the known cropping and land application history for the field as reflected under the previous permit.

MMP accounts for legume credits by adjusting the crop nitrogen recommendation. Here, the legume nitrogen carryover from the prior legume crop is captured as part of the term, *PAN credits*.

The methodology describes in greater detail how the numeric values for both legume and residual manure nitrogen credits were derived for each year. (See Step 6 of the methodology in Section 6.6.3.)

Consideration of Multi-Year Phosphorus Application

Data sources:

1. Sample NMP: Table 6.7, Planned Nutrient Applications; Table 6.8, Field Nutrient Balance
2. Technical Standard Reference: Appendix A9 of the Iowa DNR, Manure Management Plan Form, Chapter 567—65.17(19)

Example term:

Field ID	Year	Crop	Consideration of multi-year phosphorus
Bob's Farm South – 8S	2010	Soybean	No
	2011	Corn	Yes
	2012	Soybean	N/A
	2013	Corn	N/A
	2014	Soybean	No

A note on using the sample NMP and technical standard to develop the permit term:
Manure was applied in the fall of 2010. (See Table 6.7, Planned Nutrient Applications). The application is shown here as occurring in 2011 because the fall application is nutrients for the crop planted in the spring of 2011. Table 6.8 of the sample NMP, Field Nutrient Balance, does not state that the manure application is considered a multi-year application with a yes or no as it is shown in the table above. What Table 6.8 illustrates is that phosphorus balance remains after a manure application had been made to meet the crop phosphorus removal rate. Therefore, more phosphorus has been applied than was removed by the crop. What also should be noted in Table 6.8 is that additional manure is not applied until the balance returns to zero.

The methodology describes in greater detail how this manure application meets the state requirements for applying a multi-year phosphorus application. (See Step 9 of the methodology in Section 6.6.3.)

Accounting for All Other Additions of Plant Available Nitrogen and Phosphorus to the Field

Data sources:

1. Sample NMP: Table 6.7, Planned Nutrient Applications
2. Technical Standard Reference: Not applicable

Example term:

Field ID	Subfield ID	Date	Other additions of PAN	Available N (Lbs/Acre)	Available P_2O_2 (Lbs/Acre)
Bob's Farm South	8S	2010	None	0	0
		2011	Commercial fertilizer (28-0-0)	128	0
		2012	None	0	0
		2013	Commercial fertilizer (28-0-0)	158	0
		2014	None	0	0

A note on using the sample NMP and technical standard to develop the permit term:
The only additional plant available nutrients that are applied to this field are nitrogen fertilizer. The amount of available nitrogen from nitrogen fertilizer is shown in the table below, but the value of available nitrogen is not part of the term and may fluctuate from year to year. The term is the source of additional nutrients planned for each year and the fact that it is an additional amount of nutrients necessary to ensure crop yield goals are met without exceeding maximum limits, that is taken into consideration.

Form and Source of Manure that is Applied

Data source:

1. Sample NMP:
   a. Table 6.7 Planned Nutrient Applications
      i. Nutrient source
   b. Table 2.3 Manure Storage
      i. Type of storage
2. Technical Standard Reference: Not applicable

Example term:

Field ID	Subfield ID	Timing	Form	Source
Bob's Farm South	8S	Fall 2010	Solid	E Lots Stack #1
		Fall 2014	Solid	W Lots Stack #2

A note on using the sample NMP and technical standard to develop the permit term:
Timing is not a component of the term *form and source of manure, litter, and process wastewater to be land applied*, but is included here to clarify the form and source to be applied at different times during each crop year. For example, if the facility planned to apply liquid manure in the spring of 2011 and solid manure in the fall of 2011, the terms for *timing and form* would work in conjunction to clarify the details for each manure application.

The sample NMP does not specify the form of manure to be applied; however, according to the information in Tables 2.3 (Manure Storage) and 6.7 (Planned Nutrient Applications), the permit writer is able to determine the form of manure that is stored in each source.

Method and Timing of Land Application of Manure for Each Field

Data source:

1. Sample NMP: Table 6.7, Planned Nutrient Applications
2. Technical Standard Reference: Not applicable

Example term:

Field ID	Subfield ID	Timing in NMP	Timing term	Method
Bob's Farm South	8S	Nov 2010	Fall 2010	Dry Box Spreader, Not incorporated
		Sept 2014	Fall 2014	Dry Box Spreader, Not incorporated

A note on using the sample NMP and technical standard to develop the permit term:
MMP reports timing of applications on a monthly basis. Other tools might report an exact date of application. That information can be captured more broadly as the permit term. Here, it is captured on a seasonal basis. For this example, spring is defined as March, April, and May. Summer is defined as June, July, and August. Fall is defined as September, October, and November. Winter is defined as December, January, and February.

Maximum Amount of Nitrogen and Phosphorus from Manure, Litter, and Process Wastewater

Data source:

1. Sample NMP: Table 6.7, Planned Nutrient Applications
2. Technical Standard Reference: Not applicable

Example term:

Field ID	Subfield ID	Crop year	Crop	Max N from manure applied (lbs/acre)	Max P_2O_2 from manure applied (lbs/acre)
Bob's Farm South	8S	2010	Soybean	0	0
		2011	Corn	32	190
		2012	Soybean	0	0
		2013	Corn	0	0
		2014	Soybean	0	0

As indicated above, although the NMP shows the first manure application on this field in the fall of 2010, that application is made for the corn crop to be planted in the spring of 2011, so the limits are associated with the 2011 crop year. That is also true for the September 2014 manure application. (Note that the *Target Crop* indicated in Table 6.7 for the November 2010 and September 2014 manure applications are corn, whereas the crops grown in 2010 and 2014 are soybeans.)

The permit term for the linear approach is the manure nutrients predicted by the NMP to be applied expressed as pounds of nitrogen and phosphorus for each year of permit coverage. Note that this value does not include residual nitrogen from previous application(s).

The operator has chosen not to meet crop needs solely with manure nutrients. Manure could have been applied to the soybean crops, but the operator has chosen not to apply nutrients in those three crop years (additionally, this plan has utilized the flexibility of a multi-year phosphorus application which restricted any additional phosphorus from being applied until the phosphorus from the multi-year application had been utilized by the crops). Also, the NMP shows that commercial fertilizer will be applied to this field in addition to manure in 2011 and 2013. So, although the plan could have been written to allow more nutrients from manure to be applied, the operator has chosen to limit manure application on this field. As described in Section 6.5 under the linear approach, the NMP that is submitted with the NOI is the NMP that is to be implemented over the 5 years of permit coverage. The permit terms are written to reflect what is predicted by the submitted NMP. For the linear approach, the CAFO's permit will limit manure application on the basis of the amount of manure nutrients to be applied as predicted in the submitted NMP, unless the operator follows the substantial change procedures to increase this term.

Methodology to Account for the Amount of Nitrogen and Phosphorus in the Manure to be Applied

The term is the set of calculations used by the MMP software program to account for the amount of nitrogen and phosphorus in the manure that is to be applied. That is the methodology used to derive the amount of manure to be applied according to the term *maximum pounds of nitrogen and phosphorus from manure* and the manure nutrient analysis. In this specific example, for the 2011 corn crop, 1,514 tons of dry box spreader manure from E Lots Stack #1 (that was not incorporated) was able to supply 32 pounds of nitrogen and 190 pounds of phosphorus. The permitting authority has determined that this program accounts for the nitrogen and phosphorus in the tons of manure to be applied. The term that is captured in the permit would be *Use of Manure Management Planner, version 0.29*. If the result of the annual manure nutrient analysis is different from that used to develop the plan, the CAFO operator would use MMP to recalculate the amount of manure to apply in 2010 and 2014 based on the term *maximum amount of nitrogen and phosphorus from manure*.

For this example field, the methodology for the linear rate approach is encompassed within the methodology for the narrative rate approach. For a more detailed discussion on how the amount of nitrogen and phosphorus in the manure applied is calculated, see steps 7.1 through 7.3.4 of the methodology in Section 6.6.3.

Data source/Location in NMP:

1. Sample NMP: If MMP or other software is used, the methodology can be cited as use of the program, if the permitting authority determines that the program adequately accounts for the nitrogen and phosphorus in the manure to be applied.

Putting together all the terms that are applicable to the linear approach :

The *methodology* is expressed within MMP version 0.29. The permitting authority determined that the methodology used by MMP was developed in accordance with the state's technical standard. Additional site-specific permit terms for expressing protocols for land application under the linear approach are shown below. (Note that in this example, the permit term for the *outcome of the field risk assessment*, was written so that a single risk was applied to the entire field.) For this example, the terms are shown only for the field Bob's Farm South, Subfield 8S, but a permit writer for this facility would identify terms for all fields identified in the NMP.

Fields available for land application		Crop year	Total acres	Timing limitations for a land application	Outcome of the assessment of the potential for nutrient transport		Planned crops or other use	Realistic annual yield goal	Total nitrogen and phosphorus recommendations for each crop on each field
Field	Sub-field				P loss risk	Allowable manure application rate			
Bob's Farm South	8S	2010	79.6	Field slope 7%. Manure may only be surface applied to this field when the ground is frozen, snow covered or saturated if one of the following conditions exists: 1. Where manure storage capacity is insufficient and failure to surface apply creates a risk of an uncontrolled release of manure 2. On an emergency basis	Low	Manure shall not be applied in excess of the nitrogen needs of the crop	Soybean	61 bu/acre	Soybean recommendations 232 lbs N/acre 49 lbs P_2O_5/acre Corn recommendations 210 lbs N/acre 73 lbs P_2O_5/acre
		2011			Medium	Manure shall not be applied in excess of two times the crop phosphorus removed with crop harvest over the period of the crop rotation	Corn	195 bu/acre	
		2012			Medium		Soybean	61 bu/acre	
		2013			Medium		Corn	195 bu/acre	
		2014			Medium		Soybean	61 bu/acre	

Subfield	Crop year	Credits for PAN lbs/acre	Consideration of multi-year phosphorus application	Accounting for all other additions of plant available nitrogen and phosphorus to the field	
				PAN	P_2O_5
8S	2010	0	No	None	None
	2011	50	Yes; 3 years' worth of manure phosphorus is applied, and no additional phosphorus is applied for the next two years.	Commercial fertilizer (28-0-0)	None
	2012	0	Continued	None	None
	2013	52	Continued	Commercial fertilizer (28-0-0)	None
	2014	0	No	None	None

Subfield	Crop year	Form of manure applied	Source of manure applied	Timing of land application	Method of land application	Maximum amount of nitrogen and phosphorus from manure	
						N (lbs/acre)	P_2O_5 (lbs/acre)
8S	2010	Solid	E Lots Stack #1	Fall	Dry Box Spreader, not incorporated	0	0
	2011	No manure applied	No manure applied	No manure applied	No manure applied	32	190
	2012	No manure applied	No manure applied	No manure applied	No manure applied	0	0
	2013	No manure applied	No manure applied	No manure applied	No manure applied	0	0
	2014	Solid	W Lots Stack #2	Fall	Dry Box Spreader, not incorporated	0	0

6.6.3. Additional Site-Specific Terms: Narrative Rate Approach

As previously mentioned, six site-specific terms apply when using either the linear or narrative rate approach for expressing land application rates in NMPs. Those six terms are (1) *the fields available for land application,* (2) *timing limitations for land application,* (3) *the outcome of the nitrogen and phosphorus transport risk assessment,* (4) *planned crops or other use,* (5) *realistic annual crop yield goal,* and (6) *total nitrogen and phosphorus recommendations for each crop.* Those permit terms for this sample NMP are identified in Section 6.6.1. The only exception is for how *the outcome of the nitrogen and phosphorus transport risk assessment* would be reported. Under the narrative rate approach, a single risk method would likely be utilized by the permit writer. In addition to those six permit terms, the narrative rate approach has three additional site-specific permit term requirements that are as follow:

Maximum Amount of Nitrogen and Phosphorus from All Sources of Nutrients

Data Source:

1. Sample NMP: Table 6.7. Planned Nutrient Applications

Example term:

Field ID	Subfield ID	Year	Crop	Max N Derived from all sources (lbs/acre)	Max P_20_5 Derived from all sources (lbs/acre)
Bob's Farm South	8S	2010	Soybean	Soybeans = 0 lbs N/acre Corn = 210 lbs N/acre	Soybeans = 0 lbs P_20_5/acre Corn = 190 lbs P_20_5/acre
		2011	Corn		
		2012	Soybean		
		2013	Corn		
		2014	Soybean		

The maximum amount of phosphorus from all sources in any single year is shown in Table 6.7 as 190 lbs/acre. (There is a 2014 fall application of manure that contains 200 lbs P_2O_5/acre but that is targeted for crop in the next permit cycle.) The state's P-Index interpretation of the medium risk category is two times the crop phosphorus removed with crop harvest over the period of the crop rotation. That would be 2 × (49 lbs P_2O_5/acre for soybeans plus 73 lbs P_2O_5/acre for corn) or 244 lbs P_2O_5/acre (see step 4.4 of the methodology in Section 6.6.3 below). The NMP was not submitted with any one crop receiving an application rate with 244 lbs P_2O_5/acre being applied. Therefore, while a maximum amount of phosphorus from all sources could have been set at 244 lbs P_2O_5/acre for any one crop, the plan was submitted with a maximum application rate of phosphorus at 190 lbs P_2O_5/acre. Additionally, the state's technical standards allow manure or other organic by-products to be applied on legumes at rates equal to the estimated removal of nitrogen in the harvested portion of the crop that is removed from the field in that growing season (Iowa NRCS 590). In this case, that would be 232 lbs nitrogen/acre for the soybean crop. Therefore, a maximum amount of nitrogen could have been set at 232 lbs nitrogen/acre for soybeans. The NMP was not submitted with any soybean crop receiving an application rate with 232 lbs nitrogen/acre being applied. Therefore, while a maximum amount of nitrogen from all sources could have been set at 232 lbs nitrogen/acre for soybeans, the plan was submitted with a maximum application rate of nitrogen at 0 lbs nitrogen/acre.

As noted in Section 6.5.3, the maximum rates of nitrogen and phosphorus are not associated with a particular year. They are associated only with a particular crop. The rates could be applied in any one year as long as no other permit terms or conditions are violated.

Alternative Crops

The term is the alternative crops (in addition to the planned crops) listed in the NMP. In this plan, there are no alternative crops being grown.

Data source: N/A – The example plan does not include any alternative crops. However, if it were to include crops, the term could be reported as follows:

Example term:

Field	Subfield	Potential alternative crop(s)	Yield goal (unit/acre)	N rec. (lbs/acre)	P_2O_5 rec. (lbs/acre)
Bob's Farm South	8S	Wheat	78 bu/acre	88	41
		Alfalfa	4.1 ton/acre	205	51

Methodology

Data source: In the sample NMP, the methodology is expressed within MMP version 0.29. The permitting authority determined that the methodology used by MMP encompasses all the factors of the methodology, and the plan was developed in accordance with the state's technical standard.

The steps described below review development of the application rates for the entire permit cycle for the field Bob's Farm South, Subfield 8S from the sample NMP. The steps review the entire process of calculating land application rates to show how the methodology should account for the required narrative rate factors; therefore, the steps repeat some of the information on narrative rate approach terms described above. In addition, the methodology presented here is useful to illustrate the general process for calculating land application rates, regardless of whether the linear or narrative rate approach is used.

Several of the narrative rate factors are addressed in multiple steps in the process below, as follows:

Factor	Step(s)
Soil test results	3.1
Credits for PAN in the field	6
Total amount of nitrogen and phosphorus in the manure to be applied	7
Consideration of multi-year phosphorus application	9
Accounting for all other additions of plant available nitrogen and phosphorus to the field	5
Form and source of manure	7.1
Timing and method of land application	7.3.2
Volatilization of nitrogen and mineralization of organic nitrogen	7.3.2 and 6.2

These steps should serve as guidance for permitting authorities as to what EPA expects of various nutrient management planning programs to ensure that they encompass all the required factors of the methodology. The methodology can be rather complicated, and a step by step approach does not necessarily always need to be written out in its entirety as a permit term. As stated earlier, it is common for much of the methodology to be embedded within many state software programs. However, the process below and the type of information that it captures should be contained within all methodologies. In addition, software documentation that clearly describes the methodology should be made publicly available.

The steps below outline the process to account for the required factors of the narrative rate methodology; therefore, the term *outcome of the nitrogen and phosphorus transport risk assessment* is expressed as a single risk rating for a field according to the highest crop year's risk.

Step 1: Identify the Technical Standards Applicable to the Plan for Developing Rates of Application

The sample plan is for a facility in Sioux, Iowa. The sample technical standard that applies to this location is in Appendix O, Sample Site-Specific NPDES General Permit.

Step 2: Identify the Fields where Manure Nutrients Will be Applied

Manure is planned to be land applied in crop years 2011 and 2015, with actual application in the fall of 2010 and 2014, or permit years 1 and 5 (2010–2014) to Bob's Farm South Subfield 8S (field 8S from here onward).

Field	Subfield	Crop year	Application rate	Units
Bob's Farm South	8S	2010	0	N/A
		2011	1,514	Tons
		2012	0	N/A
		2013	0	N/A
		2014	0	N/A
		2015	1,500	Tons

These values are found in Table 6.7, Planned Nutrient Application of the sample NMP. In Table 6.7, two applications are shown to occur in November of 2010 and November of 2014. Those are considered nutrient applications for the following calendar year; spring crop 2011 and spring crop 2015. While 2015 is not part of this permit cycle and would not be captured as part of this permit's permit terms, it is shown here as it would be necessary to account for that information during the next permit cycle. The nutrient applications are not themselves a term; however, the methodology for calculating them is. The tons or gallons of manure applied should follow the basic methodology:

Manure nutrients applied ≤ Max nitrogen or phosphorus from all sources – other additions of plant available nutrients – available in field nutrients

The required factors of the narrative rate methodology can be found within those four variables. Calculating the value of each variable above takes into consideration the other required factors of the narrative rate approach. The process below illustrates how all the factors of the methodology are included in the NMP and used in calculating the tons and gallons of manure to be applied.

Step 3: Identify the Allowable Basis for Calculating an Application Rate

Because manure, litter and process wastewater contain both nitrogen and phosphorus, the application of manure to each field will be made so that the appropriate amount of nutrients are supplied to meet either the nitrogen or phosphorus requirement of the crop being grown on that field. This is determined by the outcome of field specific assessment for the potential of phosphorus transport from each field. The specific risk assessment used is provided in the sample state technical standard for nutrient management. Because the sample NMP is based on an operation that is in Iowa, the sample technical standard used for Iowa requires that the Iowa P-Index (as specified by the USDA NRCS Iowa Technical Note no. 25) be used to determine the nutrient basis for all manure applications. The Iowa P-Index calculations result in a numerical value that corresponds to one five risk assessments:

Total points from index	Interpretation of points	Basis for application rate
0–1	Very Low	Manure shall not be applied in excess of an nitrogen-based rate in accordance with 65.17(18)
> 1–2	Low	Manure shall not be applied in excess of an nitrogen-based rate in accordance with 65.17(18)
> 2–5	Medium	Manure shall not be applied in excess of two times the phosphorus removed with crop harvest over the period of the crop rotation.*
> 5–15	High	Manure shall not be applied until practices are adopted which reduce the P-Index to at least the medium risk category.
> 15	Very High	Manure shall not be applied.

* Regulations 65.17(17) describe the manure application rate requirements for fields that are assigned the P-Index site vulnerability ratings described by the Iowa P-Index. The sample technical standard does not always restrict applications on a field with a medium risk rating to 2 times the crop phosphorus removal rate. However, for this example, 2 times the phosphorus removed with crop harvest over the period of the crop rotation is set as the upper limit for all medium risk ratings.

The Iowa P-Index uses source and transport factors to approximate phosphorus loads to surface waters. The source factors are arranged in a multiplicative manner within three components that represent the main transport mechanisms: (1) Erosion Component (sediment loss), (2) Runoff Component (water loss), and (3) Subsurface Drainage Component (water movement through tile or coarse subsoil/substrata). The Iowa P-Index is calculated as follows:

Erosion component + Runoff component + Subsurface drainage component = P-Index

The three components are composed of the following variables:

1. Erosion =
   Gross erosion × (sediment trap factor or delivery ratio) × buffer factor × enrichment factor × Soil Test Phosphorus (STP) erosion factor

2. Runoff =
   Runoff factor × precipitation × (STP runoff factor + phosphorus application factor)

3. Subsurface drainage =
   Precipitation × flow factor × STP drainage factor

Step 3.1: Use the Soil Test Results to Calculate the Outcome of the Risk Assessment

STP, a required factor of the methodology, is considered in all three transport components of the Iowa P-Index.

The soil test results are shown in Table 6.3, Soil Test Data, of the sample NMP. The results are as follows:

Field	Subfield	Test year	P concentration	Units	Test analysis
Bob's Farm South	8S	2009	32	ppm	Bray P1

The outcome of the assessment is provided Table 5.3, Nitrogen and Phosphorus Risk Analysis, of the sample NMP. In this example, the P-Index is run each year for each crop on the field. The permit term is based on the highest risk for each crop over the course of the 5 years of permit coverage. In this case, the highest risk is a medium risk (for both corn and soybeans), which limits application rates to two times the phosphorus removed with crop harvest over the period of the crop rotation.

Field ID	Subfield ID	Year	Risk	Basis for application rate*
Bob's Farm South	8S	2010	Low	Nitrogen-based
		2011	Medium	2 times the phosphorus removed with crop harvest over the period of the crop rotation.
		2012	Medium	2 times the phosphorus removed with crop harvest over the period of the crop rotation.
		2013	Medium	2 times the phosphorus removed with crop harvest over the period of the crop rotation.
		2014	Medium	2 times the phosphorus removed with crop harvest over the period of the crop rotation.

* The basis for the allowable application rate is not provided in Table 5.3 of the sample NMP. The appropriate rate basis was identified from the technical standard and applied to the appropriate risk category.

Step 4: Derive the Crop Nutrient Requirements

Crop nutrient requirements are derived from the planned crops, their realistic yield goals, and the total nitrogen and phosphorus recommendation for each crop identified in the planned crop sequence. The permit terms for field 8S, for *planned crops, yield goals, and total nitrogen and phosphorus recommendations* are shown below. Table 6.5 in the sample NMP identifies the Planned Crops and Fertilizer Recommendations as well as the crop removal rates. Steps 4.1 through 4.3 illustrate how the values in total nitrogen and phosphorus recommendations were determined.

Year	Field crop	Yield goal (bushels/ acre)	Total recommended nitrogen (lbs/acre)	Total recommended phosphorus (lbs per/acre)
2010	Soybean	61	232	N/A
2011	Corn	195	210	73
2012	Soybean	61	232	49
2013	Corn	195	210	73
2014	Soybean	61	232	49

Step 4.1: Derive the Realistic Annual Yield Goals

All crop recommendations are based on a realistic yield goal for the crop. The yield goal typically represents the expected optimum yield for that crop. The example plan, as written, does not provide a specific reference for how the yield goal was determined. The regulations do not require that an NMP provide the basis for the yield goal; however, the permit writer has the authority to request the source of that information, which might be necessary if the values appear to be unrealistic. The sample technical standard provides multiple options for calculating an optimum yield goal. Those include the following:

- Soil survey interpretation record.
- USDA county crop yields.
- Proven yield methods. Proven yield methods may be used only if a minimum of the most recent three years of yield data for the crop is used. Those yields can be proven on a field-by-field or farm-by-farm basis. Crop disaster years may be excluded when there is a 30 percent or more reduction in yield for a field or farm from the average yield over the most recent five years. Excluded years shall be replaced by the most recent non-disaster years. Proven yield data used to determine application rates shall be maintained with the current manure management plan.

A review of the yield goals provided in the sample NMP shows that USDA county crop yields were used. The sample technical standard contains Iowa Ag Statistics for County Corn and Soybean Yields. The 5-year average yield, the 5-year average yield +10 percent and the average yield of the four highest years are provided. For Sioux County, the location of the facility for which the sample plan was developed, the 5-year average yield +10 percent is 195.3 bu/acre for corn and 60.7 bu/acre for soybeans, which matches the reported sample NMP yield goals for corn and soybeans.

Step 4.2: Derive the Crop Nitrogen Recommendations

The sample technical standard provides Crop Nitrogen Usage Rate Factors for Various Crops. For corn, those nitrogen usage rate factors are based on the expected yield goal and the appropriate geographic zone where corn is being grown. The standard outlines three geographic zones for different soil associations. The sample NMP is written for an operation in Sioux County, which is in both zones 1 and 2. The nitrogen usage rate factor for zone 1 is 0.9 lbs N/bu, and the nitrogen usage rate factor for zone 2 is 1.1 lbs N/bu. The estimated yield goal for corn is 195 bu/acre.

Zone 1 Nitrogen Usage Rate = 195 bu/acre × 0.9 lbs N/bu = 176 lbs N

Zone 2 Nitrogen Usage Rate = 195 bu/acre × 1.1 lbs N/bu = 215 lbs N

The NMP includes an nitrogen recommendation of 210 lbs nitrogen/acre. Because Sioux county contains both zone 1 and zone 2 nitrogen usage factors, a nitrogen recommendation of 210 appears to be appropriate. If the permit writer believes that the nitrogen or phosphorus recommendation in the NMP is significantly different than that which can be derived from the technical standard, it is a good idea to ask the operator or planner to explain the basis for the rate.

Note that Table 6.5 of the sample NMP does not show a corn nitrogen recommendation of 210 lbs nitrogen/acre. When corn follows a legume, the crop need is shown as 50 lbs less than the total nitrogen recommendation. That is because the nitrogen credits from the legume crop are directly factored into the recommendation in Table 6.5. For purposes of identifying permit terms, the *total nitrogen recommendation* will still be identified as 210 lbs nitrogen/acre. The 50 lbs of nitrogen credit from the legumes will be accounted for under the factor *all other plant available credits in the field*, shown in step 6 below.

Step 4.2.1: Derive the Crop Nitrogen Removal Rates

The sample technical standard allows for manure or other organic by-products to be applied on legumes at a rate equal to the estimated amount of nitrogen in the harvested portion of the crop that is removed from the field in that growing season (i.e., crop nitrogen removal). The nitrogen removal for soybeans is 3.8 lbs nitrogen/bushel (found in sample technical standard, Appendix A6 of the Manure Management Plan Form). MMP's Initialization File Summary Report also includes that information and could be provided with the CAFO's NMP (see Section 8.3 of the sample NMP). Given the expected yield goal of 61 bushels/acre, the allowable nitrogen application is 232 lbs/acre.

3.8 lbs N/bushel × 61 bushels/acre = 232 lbs N/acre

Table 6.5 in the sample NMP also provides that removal rate for soybeans. Although the fertilizer nitrogen recommendation for soybeans is 0 lbs of nitrogen, the permit term *Total nitrogen recommendation* is 232 lbs nitrogen/acre based on the technical standard allowance for nitrogen application on legume crops.

Step 4.3: Derive the Crop Phosphorus Recommendations

The term *total phosphorus recommendation* is based on the removal rate of each crop. Removal rates are found in the sample technical standard, Appendix A6 of the Manure Management Plan Form and in MMP's Initialization File Summary Report (see Section 8.3 of the sample NMP). For corn, the removal rate is 0.375 lbs P/yield unit, and for soybeans it is 0.8 lbs P/yield unit.

Corn
0.375 lbs P_2O_5/bushel × 195 bushels = 73 lbs P_2O_5

Soybean
0.8 lbs P_2O_5/bushel × 61 bushels = 49 lbs P_2O_5/acre

Table 6.5 of the sample NMP also provides those removal rates for corn and soybeans.

Step 4.4: Determine the Maximum Amount of Crop Nutrient from All Sources

The methodology relies on the maximum amount of crop nutrients that **could** be applied from all sources for illustrating the basic methodology:

Manure nutrients applied ≤ Max nitrogen or phosphorus from all sources—other additions of plant available nutrients—available in field nutrients

The permit term is based on what is shown in the NMP as submitted with for permit coverage. As discussed in Section 6.6.3, it was identified that for this field, nutrient application rates were not set as the maximum possible rate as allowed under the state's technical standard. The maximum amount of nutrients that **could** have been applied is used to illustrate that permit terms are in compliance with the state's technical standards for nutrient management.

The maximum amount of nitrogen that can be applied from all sources is equal to the amount of nitrogen identified for the permit term, *total nitrogen recommendation*.

The maximum amount of phosphorus from all sources that can be applied is based on the term, *outcome of the field-specific risk assessment*. For field 8S, the Iowa P-Index results in a medium risk. The state standards define the phosphorus limit for medium-risk fields as two times the crop phosphorus removed over the crop rotation. Field 8S shows a corn, soybean rotation.

Corn:
73 lbs P_2O_5 removed/acre

Soybean:
49 lbs P_2O_5 removed/acre

2 × (49+73 lbs P_2O_5/acre) = 244 lbs P_2O_5/acre

Applying those values to the basic methodology is described as

Manure nutrients applied ≤ Max nitrogen or phosphorus $_{\text{from all sources}}$ - other additions of plant available nutrients—available in field nutrients

Crop Year 2010, 2012, and 2014: Soybeans

X lbs N/acre $_{\text{from manure}}$ ≤ 232 lbs N/acre - commercial fertilizer applied lbs N/acre - N available in field lbs/acre

X lbs P_2O_5/acre $_{\text{from manure}}$ ≤ 244 lbs P_2O_5/acre - commercial fertilizer applied lbs P_2O_5/acre - P_2O_5 available in field lbs/acre

Crop Year 2011 and 2013: Corn

X lbs N/acre $_{\text{from manure}}$ ≤ 210 lbs N/acre - commercial fertilizer applied lbs N/acre - N available in field lbs N/acre

X lbs P_2O_5/acre $_{\text{from manure}}$ ≤ 244 lbs P_2O_5/acre - commercial fertilizer applied lbs P_2O_5/acre - P_2O_5 available in field lbs/acre

Step 5: Determine Other Sources of Nutrients Applied

The term *accounting for all other additions of plant available nitrogen and phosphorus to the field* captures the amount of nutrients from sources other than manure. Those nutrients are applied to the total amount required to meet the crop's need. That includes nutrient sources such as commercial fertilizers, biosolids, or irrigation water. According to the sample NMP, commercial fertilizer is the only source of nutrients added besides manure. That can be found in Table 6.7 of the sample NMP. Commercial fertilizer is added to subfield 8S in years 2011 and 2013. Adding that to the basic methodology is as follows (with the amount of nutrients from sources other than manure shown as the second element of the expression):

Crop Years 2010, 2012, and 2014: Soybeans

X lbs N/acre $_{\text{from manure}}$ ≤ 232 lbs N/acre - 0 lbs N/acre - N available in field lbs/acre

X lbs P_2O_5/acre $_{\text{from manure}}$ ≤ 244 lbs P_2O_5/acre - 0 lbs P_2O_5/acre - P_2O_5 available in field lbs/acre

Crop Year 2011: Corn

X lbs N/acre $_{\text{from manure}}$ ≤ 210 lbs N/acre - 128 lbs N/acre - N available in field lbs/acre

X lbs P_2O_5/acre $_{\text{from manure}}$ ≤ 244 lbs P_2O_5/acre - 0 lbs P_2O_5/acre - P_2O_5 available in field lbs/acre

Crop Year 2013: Corn

X lbs N/acre $_{\text{from manure}}$ ≤ 210 lbs N/acre - 158 lbs N/acre - N available in field lbs/acre

X lbs P_2O_5/acre $_{\text{from manure}}$ ≤ 244 lbs P_2O_5/acre - 0 lbs P_2O_5/acre - P_2O_5 available in field lbs/acre

Step 6: Determine the Available in Nutrients in the Field

This step accounts for the PAN that is already in the soil from prior legume crops, previous manure applications, and other sources. Credits for PAN in the sample NMP come from legumes, which contribute nitrogen to the soil, and from the mineralization of organic nitrogen from previous years' manure applications.

Step 6.1: Accounting for Legume Credits

Soybeans are the only legume planted in field 8S. As mentioned in step 4, MMP accounted for nitrogen credits from legumes by adjusting the recommendation for corn in years following a soybean crop. Footnote 't' of the Manure Management Plan Form in the sample technical standard contains the appropriate credits for legume crops. Credits for nitrogen carryover from prior year legume crops are calculated as follows:

- Credit 1 lb nitrogen per bushel of yield for the previous year's soybean crop.
- A maximum credit of 50 lb nitrogen per acre is allowed.

Year	Field crop	Yield goal (bushels/acre)	Total nitrogen legume credit (lbs/acre)
2010	Soybean	61	0
2011	Corn	195	50
2012	Soybean	61	0
2013	Corn	195	50
2014	Soybean	61	0

Step 6.2: Accounting for Manure Mineralization Credits

Residual manure nitrogen credits are identified in the Field Nutrient Status Detail Custom Report, provided in Section 6.9 of the sample NMP. Mineralization rates for organic nitrogen are defined in the sample technical standard under Iowa State University Extension publication PMR1033 - Using Manure Nutrients for Crop Production (September 2008). The technical standard provides mineralization rates for the year of application and two years following manure application.

Animal type	1st year nitrogen availability	2nd year nitrogen availability	3rd year nitrogen availability
Beef cattle (solid)	35%	10%	5%

The fraction of nitrogen from manure that will be available in year 1, when the manure is applied, is not captured as a part of this credit. Credits are derived from only what is carried over from a previous year's application. Mineralized nitrogen available during the year of application is accounted for in step 7 below.

On subfield 8S, manure is first applied in 2011, which provides residual manure credits for years 2012 and 2013. Manure is also applied in year 2014, which creates credits for year 2015 and 2016. Credits for year 2015 and 2016 fall under a new permit cycle and will be accounted for then.

Application		Nitrogen availability		
Application year	Total manure N* (tons/acre)	1st year availability (35%)	2nd year availability† (10%)	3rd year availability† (5%)
2010	0	2010	2011	2012
		0	0	0
2011	133	2011	2012	2013
		32	10	4
2012	0	2012	2013	2014
		0	0	0
2014	0	2013	2014	2015
		0	0	0
2015	140	2014	2015	2016
		34	10	5

* To calculate the total manure nitrogen applied, which is needed to determine residual manure credits, the manure analysis is used. Derivation of this value is described in step 7.3.2.

† The second and third year availability estimates of 10 and 5 percent cannot be applied directly to the total manure nitrogen applied to the field to determine nitrogen availability for the second and third years after land application. Volatilization losses associated with manure application in year 1 must be accounted for first. Step 7.3.2 calculates the manure nitrogen available after application, which accounts for volatilization losses and the first year manure nitrogen availability. The second and third year availability estimates of 10 and 5 percent are applied to this nitrogen value after volatilization.

Combining the total PAN credits from step 6.1 and 6.2 (legumes and 2nd and 3rd year mineralization credits) for each year as follows:

Permit year	Field crop	Total N credit (as calculated) (lbs/acre)	Total N credit (available) (lbs/acre)
2010	Soybean	0	0
2011	Corn	50	50
2012	Soybean	10*	0
2013	Corn	54*	52
2014	Soybean	0	0
2015	Unknown	0	0
2016	Unknown	10	10
2017	Unknown	5	5

* Residual credits are calculated as available in years 2012 and 2013 from the fall 2010 manure application. However, MMP assumes that if the crop does not utilize the available nitrogen in the year that it is made available, it is lost. Table 6.8, Field Nutrient Balance of the sample NMP shows a positive nitrogen balance of 2 extra lbs of nitrogen/acre in year 2013. Those two excess nitrogen credits are assumed lost because they are not necessary to meet the corn crop needs. Therefore, only the 52 lbs of nitrogen credit/acre are utilized and reported.

Years 2015–2017 are shown in the table above to capture residual manure nitrogen credits that will be available from the 2014 fall application. These values are not included as part of this permit cycle but will be important to know if this facility reapplies for a second permit cycle. Credits for PAN available in the field are shown as the third element in the expressions below.

Crop Year 2010 and 2014: Soybean

$X \text{ lbs N/acre}_{\text{from manure}} \leq 232 \text{ lbs N/acre} - 0 \text{ lbs N/acre} - 0 \text{ lbs N/acre}$

$X \text{ lbs } P_2O_5\text{/acre}_{\text{from manure}} \leq 244 \text{ lbs } P_2O_5\text{/acre} - 0 \text{ lbs } P_2O_5\text{/acre} - 0 \text{ lbs } P_2O_5\text{/acre}$

Crop Year 2011: Corn

$X \text{ lbs N/acre}_{\text{from manure}} \leq 210 \text{ lbs N/acre} - 128 \text{ lbs N/acre} - 50 \text{ lbs N/acre}$

$X \text{ lbs } P_2O_5\text{/acre}_{\text{from manure}} \leq 244 \text{ lbs } P_2O_5\text{/acre} - 0 \text{ lbs } P_2O_5\text{/acre} - 0 \text{ lbs } P_2O_5\text{/acre}$

Crop Year 2012: Soybean

$X \text{ lbs N/acre}_{\text{from manure}} \leq 232 \text{ lbs N/acre} - 0 \text{ lbs N/acre} - 0 \text{ lbs N/acre}$

$X \text{ lbs } P_2O_5\text{/acre}_{\text{from manure}} \leq 244 \text{ lbs } P_2O_5\text{/acre} - 0 \text{ lbs } P_2O_5\text{/acre} - 0 \text{ lbs } P_2O_5\text{/acre}$

Crop Year 2013: Corn

$X \text{ lbs N/acre}_{\text{from manure}} \leq 210 \text{ lbs N/acre} - 158 \text{ lbs N/acre} - 52 \text{ lbs N/acre}$

$X \text{ lbs } P_2O_5\text{/acre}_{\text{from manure}} \leq 244 \text{ lbs } P_2O_5\text{/acre} - 0 \text{ lbs } P_2O_5\text{/acre} - 0 \text{ lbs } P_2O_5\text{/acre}$

Step 7: Meeting the Remaining Nutrient Need with Manure

The preceding steps have illustrated how to calculate the amount of nutrients to be applied from manure. The equations can now be simplified to

Crop Year 2010: Soybean

$X \text{ lbs N/acre}_{\text{from manure}} \leq 232 \text{ lbs N/acre}$

$X \text{ lbs } P_2O_5\text{/acre}_{\text{from manure}} \leq 244 \text{ lbs } P_2O_5\text{/acre}$

Crop Year 2011: Corn

$X \text{ lbs N/acre}_{\text{from manure}} \leq 32 \text{ lbs N/acre}$

$X \text{ lbs } P_2O_5\text{/acre}_{\text{from manure}} \leq 244 \text{ lbs } P_2O_5\text{/acre}$

Crop Year 2012: Soybean

$X \text{ lbs N/acre}_{\text{from manure}} \leq 232 \text{ lbs N/acre}$

$X \text{ lbs } P_2O_5\text{/acre}_{\text{from manure}} \leq 244 \text{ lbs } P_2O_5\text{/acre}$

Crop Year 2013: Corn

$X \text{ lbs N/acre}_{\text{ from manure}} \leq 0 \text{ lbs N/acre}$

$X \text{ lbs } P_2O_5\text{/acre}_{\text{ from manure}} \leq 244 \text{ lbs } P_2O_5\text{/acre}$

Crop Year 2014: Soybean

$X \text{ lbs N/acre}_{\text{ from manure}} \leq 232 \text{ lbs N/acre}$

$X \text{ lbs } P_2O_5\text{/acre}_{\text{ from manure}} \leq 244 \text{ lbs } P_2O_5\text{/acre}$

Steps 7.1 through 7.4 use the remaining factors of the methodology to illustrate how the remaining nutrient needs can be satisfied with the nutrients from manure applications. The remaining factors include the form and source of the manure that is applied, the timing and method of manure application, the amount of nitrogen that volatilizes, and the nitrogen and phosphorus in the manure analysis.

Step 7.1: Identify the Form and Source of the Manure that is Applied

The form and source of manure to be applied to must be identified in the NMP. One reason is to ensure that the appropriate manure analysis is used. The form and source of manure is in Table 2.3, Manure Storage of the sample NMP. The results are as follows:

Source	Form
E Lots Stack #1	Solid
E SetldSolidBasin #3	Solid
E Storage Pond #1	Liquid
W Lots Stack #2	Solid
W SetdSolidBasin #4	Solid
W Storage Pond #2	Liquid

The form can be identified as a liquid or a solid depending on the rate at which it is applied, pounds or tons for solid and gallons for liquids as is indicated in the planned nutrient application table.

Field 8S has two applications, one in the fall of 2010 and one in the fall of 2014. As mentioned, both of those applications are credited toward the next year's spring crop and are therefore considered applications for the permit year 2011 and 2015. The fall 2010 application comes from the solid manure held in the E Lots Stack #1, and the fall 2014 application comes from the solid manure held in the W Lots Stack #2.

Step 7.2: Reading the Manure Analysis

The amount of nitrogen and phosphorus contained in the manure is determined by the manure analysis. The manure analysis is in Table 6.4 of the sample NMP. A manure analysis is provided for each manure source. In this sample NMP, for field 8S, manure is used from E Lots Stack #1 and W Lots Stack #2. These two manure storage structures have the same manure analysis. The manure analyses for all manure sources are as follows:

Source	Measured total nitrogen	Measured NH_4-N	Measured Total P_2O_5	Units
E Lots Stack #1	7.0	2.6	10.0	lbs/ton
W Lots Stack #2	7.0	2.6	10.0	lbs/ton

Step 7.3: Calculate the First Year Nitrogen Availability

The nitrogen content that is measured by the manure analysis is not what is available to the crops when applied to the field. Only a portion of the nitrogen will mineralize and become available in year 1 (as discussed in step 6.2). Additionally, the amount of nitrogen that is applied is subject to volatilization losses. The following steps go through each of those processes to determine the amount of nitrogen that is applied and available to the crops for uptake.

Step 7.3.1: Accounting for the Storage and Handling of Manure

Volatilization of nitrogen will occur during the handling and storage and the manure. Those losses are already accounted for in the measured manure analysis shown above. As discussed in Chapter 5, the manure analysis should be taken as close to the time of application as possible to accurately assess the nutrient content just before field application to reflect these types of losses.

Step 7.3.2: Accounting for the Timing and Method of Land Application

Different methods of land application affect the amount of nitrogen that will volatilize. This must be taken into consideration so the concentration of available nitrogen in the manure that is being land applied can be estimated accurately. It is important to remember that only the ammonium fraction of the total nitrogen value volatilizes. However, the applicable technical standard for the sample NMP applies the volatilization factor to the total nitrogen value from the manure analysis. This is not necessarily how all technical standards calculate nitrogen availability.

Year	Manure applied (tons)	Total manure nitrogen* (lbs/acre)	Method of application	Timing of application	Volatilization correction factor†	Manure nitrogen after application (lbs/acre)‡
2010	0	0	N/A	N/A	N/A	0
2011	1,514	133	Dry Box Spreader	Not incorporated	0.7	93
2012	0	0	N/A	N/A	N/A	0
2013	0	0	N/A	N/A	N/A	0
2014	0	0	N/A	N/A	N/A	0
2015	1,500	140	Dry Box Spreader	Not incorporated	0.7	98

* Total Manure Nitrogen is calculated as follows:

(Tons applied × Total Manure Nitrogen analysis)/acres manure spread

Example: Year 2011 total manure nitrogen = (1,514 tons × 7.0 lbs N/ton) / 79.7 acres = 133 lbs N/acre

† From the sample technical standard, Iowa State Extension PMR 1003 – Using Manure Nutrients for Crop Production provides volatilization rates for manure application. PMR 1003 specifies that when solid manure is broadcast and not incorporated the manure total nitrogen rate applied should be multiplied by the volatilization correction factor of 0.70 to 0.85 to determine the portion of total manure nitrogen remaining. Because manure applied in year 2011 was not incorporated, MMP applied a 0.70 volatilization correction factor.

‡ Step 7.3.2 accounts for the ammonium nitrogen that volatilizes from the total manure nitrogen because of the method of application. Step 7.3.3 shows how to calculate the portion of organic nitrogen that mineralizes in year 1 and is available for plant uptake.

Step 7.3.3: Calculating the Mineralization of Nitrogen

The nitrogen in manure is available over multiple years. The sample technical standard uses Iowa State University Extension publication PMR1033 (September 2008), Using Manure Nutrients for Crop Production, to estimate the amount of manure nitrogen, by animal source, that is available over the course of three years. This nitrogen availability must be taken into consideration when determining the tons of manure to apply to meet the crop needs.

The technical standard includes a mineralization factor of 35 percent for the first year of application. The first year mineralization estimate of 35 percent was applied the total manure nitrogen after application as derived in step 7.3.2. The year 1, total available manure nitrogen values are directly provided in the sample NMP, in Table 6.7 Planned Nutrient Applications (Manure-Spreadable Area). It is important to remember that only the organic fraction of the total nitrogen value mineralizes. (The organic nitrogen fraction can be calculated by subtracting the ammonium nitrogen value from the total nitrogen value.) However, the applicable technical standard for the sample NMP applies the mineralization rate to the total nitrogen remaining after volatilization. This is not necessarily how all technical standards calculate manure nitrogen availability.

Year	Manure nitrogen after application (lbs/acre)*	First year nitrogen availability for beef cattle manure	Year 1 plant available manure nitrogen (lbs N/acre)
2010	0	N/A	0
2011	93	35%	32
2012	0	N/A	0
2013	0	N/A	0
2014	0	N/A	0
2015	98	35%	34

* Values calculated in step 7.3.2.

Step 7.3.4: Determining the Availability of Manure Phosphorus

The sample technical standard, Iowa State University Extension publication PMR1033 (September 2008), Using Manure Nutrients for Crop Production, indicates that phosphorus from beef cattle manure is 60 to 100 percent available in the first year of application. For this example, based on the methodology used in MMP, 100 percent of the total phosphorus from the manure nutrient analysis is assumed to be plant available.

Year	Manure applied (tons)	Total manure P_2O_5 after application (lbs/acre)*	First year N availability for beef cattle manure	Year 1 plant available manure P_2O_5 (lbs/acre)
2010	0	0	N/A	0
2011	1,514	190	100%	190
2012	0	0	N/A	0
2013	0	0	N/A	0
2014	0	0	N/A	0
2015	1,500	200	100%	200

* Total Manure P_2O_5 after application is calculated as follows:
(Tons applied × Total Manure Phosphorus analysis)/acres manure spread
Example: Year 2011 total manure phosphorus = (1,514 tons ×10.0 lbs P_2O_5/ton)/79.7 acres = 190 lbs P_2O_5/acre

Step 8: Meeting the Remaining Crop Needs for Crop Years 2010 and 2011

Step 7 illustrated how to determine the actual amount of nutrients from the manure applied that would be available after land application to meet the crop nutrient needs along with nutrients available from other sources. Step 8 illustrates how the pounds of nutrients are converted to tons of manure and how the manure that is planned to be applied is in compliance with the maximum permit limits.

Step 8.1: Calculate Manure Application Rate for Crop Year 2010

As shown in Step 2, the NMP indicates that no manure will be applied in year 2010. Therefore,

$$0 \text{ Tons of manure} = 0 \text{ lbs N/acre}$$

and

$$0 \text{ Tons of manure} = 0 \text{ lbs } P_2O_5\text{/acre}$$

The NMP demonstrates compliance with the permit terms with respect to manure application because**:**

$$0 \text{ lbs N/acre} < 232 \text{ lbs N/acre}$$

$$0 \text{ lbs } P_2O_5\text{/acre} < 244 \text{ lbs } P_2O_5\text{/acre}$$

Step 8.2: Calculate Manure Application Rate for Crop Year 2011

As shown in Step 5, commercial fertilizer application is planned for the 2011 corn crop. At the beginning of Step 7, the equations demonstrate that manure nutrients could be used to supply up to 32 lbs[8] of nitrogen needed by the corn crop as long as the manure application is in compliance with the medium field risk assessment **and** does not contain more than 244 lbs of P_2O_5.

$$X \text{ lbs of N/acre}_{\text{ from manure}} \leq 32 \text{ lbs N/acre}$$

and

$$X \text{ lbs } P_2O_5\text{/acre from manure} \leq 244 \text{ lbs } P_2O_5\text{/acre}$$

As shown step 7, the NMP indicates that the CAFO plans to apply 1,514 tons of manure which will supply 32 pounds of nitrogen per acre.

$$1{,}514 \text{ Tons of manure} = 32 \text{ lbs manure N/acre}$$
$$32 \text{ lbs manure N/acre} = 32 \text{ lbs N/acre}$$

Step 7 also shows that 1,514 tons of manure supplies 190 lbs of phosphorus therefore:

$$1{,}514 \text{ tons manure} = 190 \text{ lbs } P_2O_5\text{/acre}$$

$$190 \text{ lbs } P_2O_5\text{/acre} < 244 \text{ lbs } P_2O_5\text{/acre}$$

On the basis of that check, the 1,514 tons of manure planned for application is in compliance with the permit limits. However, the permit writer should be aware that, although the crop phosphorus removal rate for corn is 73 lbs of phosphorus, 190 lbs of phosphorus are being applied. Before moving on to the remaining years, it will be imperative to determine that this application rate is in compliance with the state's technical standards for multi-year phosphorus application.

Step 9: Accounting for Multi-Year Phosphorus Application in Crop Year 2011

The technical standards allow multi-year phosphorus application on fields that are limited to a phosphorus-based application rate. The sample technical standard establishes the following requirements for multi-year phosphorus application.

1. No single manure application shall exceed the nitrogen-based rate of the planned crop receiving the manure application.
2. No single manure application shall exceed the rate that applies to the expected amount of phosphorus removed with harvest by the next four anticipated crops in the crop schedule.
3. If the actual crop schedule differs from the planned crop schedule, any surplus or deficit of phosphorus shall be accounted for in the subsequent manure applications.

In 2011 on Subfield 8S, 1,514 tons of manure is planned to be applied to a corn crop; the manure supplies 190 lbs/acre of P_2O_5. A single year of phosphorus removal for growing 195 bushels of corn is 73 lbs/acre of P_2O_5. EPA defines multi-year phosphorus application as phosphorus applied to a field in excess of the crop needs for that year. 190 lbs/P_2O_5 is more phosphorus than the crop needs for 2011. However, this application appears to meet the state's requirements for a multi-year application based on the following:

1. The 1,514 tons of manure that is applied in November 2010 for the 2011 crop year supplies 32 lbs/acre of nitrogen which, in conjunction with other sources of PAN, does not exceed the 210 lbs/acre of nitrogen recommended for this corn crop.
2. Assuming the crop rotation of soybean–corn continues with soybeans in year 2015, the total amount of phosphorus removed by the crops for the next 4 years would total

   Years 2012 soybeans = 0.8 lbs P_2O_5/bu × 61 bu/acre = 49 lbs/acre P_2O_5

   Year 2013 corn = 0.375 lbs P_2O_5/bu × 195 bu/acre = 73 lbs/acre P_2O_5

   Years 2014 soybeans = 0.8 lbs P_2O_5/bu × 61 bu/acre = 49 lbs/acre P_2O_5

   Year 2015 corn = 0.375 lbs P_2O_5/bu × 195 bu/acre = 73 lbs/acre P_2O_5

   TOTAL = 244 lbs/acre P_2O_5 allowed

   The applied 190 lbs/acre P_2O_5 does not exceed this limit.

3. 190 lbs/acre P_2O_5 contains approximately the next 3 years' worth of phosphorus that is expected to be removed and from this NMP, it is shown that no additional phosphorus will be applied for the next two years so that 2011, 2012, and 2013 crops can use the phosphorus that was applied in 2011.

Step 10: Calculate the Manure Application Rate for Crop Years 2012 and 2013

On the basis of step 9, no additional manure should be applied for the next two years after the 2011 multi-year phosphorus application. As indicated by the sample NMP (Table 6.7, Planned Nutrient Applications), no nutrients from manure are applied in year 2012 or 2013:

Crop Year 2012: Soybean

0 lbs N/acre $_{\text{from manure}}$ ≤ 232 lbs N/acre

0 lbs P_2O_5/acre $_{\text{from manure}}$ ≤ 244 lbs P_2O_5/acre

Crop Year 2013: Corn

0 lbs N/acre from manure ≤ 0 lbs N/acre

0 lbs P_2O_5/acre from manure ≤ 244 lbs P_2O_5/acre

Step 11: Calculate the Manure Application Rate for Crop Year 2014

Because no phosphorus will be applied in 2012 and 2013 because of the 3-year phosphorus application in year 2011, manure nutrients can be applied again in year 2014. As shown in steps 1–7, the sample NMP indicates that no other sources of nitrogen will be applied in crop year 2014. In steps 1 through 7, the amount of nutrients to be applied from manure was calculated as follows:

X lbs of N/acre $_{\text{from manure}}$ ≤ 232 lbs N/acre

and

X lbs P_2O_5/acre $_{\text{from manure}}$ ≤ 244 lbs P_2O_5/acre

Manure nutrients can be used to supply 232 lbs of N/acre to the soybean crop as long as the manure application is in compliance with the medium field risk **and** does not contain more than 244 lbs of P_2O_5/acre. As shown in step 7, the NMP indicates that no additional manure will be applied for crop year 2014. Therefore, the NMP demonstrates compliance with the permit terms with respect to manure application because

0 tons manure = 0 lbs N/acre

0 lbs N/acre < 232 lbs N/acre

and

0 lbs P_2O_5/acre < 244 lbs P_2O_5/acre

Table 6.7, Planned Nutrient Applications in the sample NMP shows that in September of 2014, 20 tons/acre of W Lots Stack #2 manure will be surface applied with a dry box spreader. A soybean crop is planted in year 2014, and those nutrients are not to supply the nutrient needs of the soybean crop. That is a fall application (and it is indicated in Table 6.7) that the nutrients are applied to supply the next spring's corn crop. Those nutrients should be credited to the next year's permit cycle.

Putting together all the terms that are applicable to the narrative rate approach:
The methodology is expressed within MMP version 0.29. The permitting authority has determined that the methodology used by MMP encompasses all the factors of the methodology, and the plan was developed in accordance with the state's technical standard. Additional site-specific permit terms for expressing protocols for land application under the narrative rate approach include the following:

Fields available for land application					Outcome of the assessment of the potential for nutrient transport				
Field	Sub-field	Crop year	Total acres	Timing limitations for a land application	P loss risk	Allowable manure application rate	Planned crops or other use	Realistic annual yield goal	Total nitrogen and phosphorus recommendations for each crop on each field
Bob's Farm South	8S	2010	79.6	Field slope 7%. Manure may only be surface applied to this field when the ground is frozen, snow covered or saturated if one of the following conditions exists: 1. Where manure storage capacity is insufficient and failure to surface apply creates a risk of an uncontrolled release of manure 2. On an emergency basis	Low	Manure shall not be applied in excess of the nitrogen needs of the crop	Soybean	61 bu/acre	Soybean recommendations 232 lbs N/acre 49 lbs P_2O_5/acre Corn recommendations 210 lbs N/acre 73 lbs P_2O_5/acre
		2011			Medium	Manure shall not be applied in excess of two times the crop phosphorus removed with crop harvest over the period of the crop rotation	Corn	195 bu/acre	
		2012			Medium		Soybean	61 bu/acre	
		2013			Medium		Corn	195 bu/acre	
		2014			Medium		Soybean	61 bu/acre	

Subfield	Crop year	Max lbs N derived from all sources	Max lbs P_2O_5 derived from all sources	Alternative crop			
				Alternative crop	Yield goal	Total N recommendation	Total P_2O_5 recommendation
8S	2010	Soybeans = 0 lbs N/acre Corn = 210 lbs N/acre	Soybeans = 0 lbs P_2O_5/acre Corn = 190 lbs P_2O_5/acre	Wheat	78 bu/acre	88	41
	2011						
	2012						
	2013			Alfalfa	4.1 ton/acre	205	51
	2014						

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Endnotes

[1] All terms of the NMP are italicized in this chapter.

[2] Notice of proposed changes to the national handbook of conservation practices (including the 590 standard) for the Natural Resources Conservation Service was published in the Federal Register on January 11, 2011. (See *http://edocket.access.gpo.gov/2011/pdf/2011-373.pdf*) Revisions to the 590 conservation standard were finalized in January 2012 and are available at *http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/landuse/crops/npm*

[3] Land application of manure is often handled differently than land application of industrial waste or biosolids. 40 CFR part 503 subpart B provides information for land application of biosolids to agricultural land. Many states use similar regulations for other industrial wastes. Those rules often require tracking of many nutrients, metals, and other potential contaminants. They also usually require crediting for nutrient availability over multiple years. Usually, they do not require any type of phosphorus risk analysis. Animal waste is typically a much more homogenous and consistent source of nutrients. Nitrogen or phosphorus is almost always the limiting constituent for determining manure application rates. When application rates are based on those nutrients, the accumulation of metals in the soil is rarely a problem. The nutrients in manure are also more readily available than the nutrients in most industrial wastes. Given those differences, care should be taken when comparing the land application of manures to regulations on land application of other wastes.

[4] The January 2012 revised NRCS 590 conservation standard requires the use of an NRCS approved nitrogen and phosphorus risk assessment tool. An NRCS approved risk assessment tool meets the technical criteria outline in the National Instruction Document NI-190-302 (located: *http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1046435.pdf*).

[5] Portions of the information in this section are extracted or adapted from NRCS, The Phosphorus Index, A Phosphorus Assessment Tool (August 1994) at *http://www.nrcs.usda.gov/technical/ecs/nutrient/pindex.html*.

[6] State indices can vary so much in fact, that P-indices should not be used in states other than that for which they were developed, and risk categories are generally not comparable state to state.

[7] An exception is for nitrogen recommendations provided with soil analysis reports. Analytical labs often make nitrogen recommendations according to the results of the soil analysis. The recommendations consider the yield goal and the soil nutrient content. Some state technical standards allow use of laboratory recommendations for nutrient management planning.

[8] Note that, because the amount of nutrients to be supplied from manure is not a term under the narrative rate approach, the operator is not limited to 32 lbs of nitrogen from manure. If the amount of commercial fertilizer is decreased, more manure could be applied as long as the total amounts of nitrogen and phosphorus applied do not exceed the term *maximum amount of nitrogen and phosphorus to be applied from all sources*.