4

Management Measures

This guidance document is intended to provide technical information to state program managers and others on the best available, economically achievable means of reducing NPS pollution of surface and ground water from agriculture. The guidance provides background information about agricultural NPS pollution, where it comes from and how it enters the nation's waters, discusses the broad concept of assessing and addressing water quality problems on a watershed level, and presents up-to-date technical information about how to reduce agricultural NPS pollution.

Management measures for nutrient management, pesticide management, erosion and sediment control, facility wastewater and runoff from confined animal facilities, grazing management, and irrigation water management are described in Chapter 4. Also in Chapter 4 are discussions of BMPs that can be used to achieve the management measures, including cost and effectiveness information.

4A: Nutrient Management

Management Measure for Nutrients

Develop, implement, and periodically update a nutrient management plan to: (1) apply nutrients at rates necessary to achieve realistic crop yields, (2) improve the timing of nutrient application, and (3) use agronomic crop production technology to increase nutrient use efficiency. When the source of the nutrients is other than commercial fertilizer, determine the nutrient value and the rate of availability of the nutrients. Determine and credit the nitrogen contribution of any legume crop. Soil and plant tissue testing should be used routinely. Nutrient management plans contain the following core components:

1. Farm and field maps showing acreage, crops, soils, and waterbodies. The current and/or planned plant production sequence or crop rotation should be described.
2. Realistic yield expectations for the crop(s) to be grown, based primarily on the producer's actual yield history, State Land Grant University yield expectations for the soil series, or local NRCS information for the soil series.
3. A summary of the nutrient resources available to the producer, which at a minimum include:
   - ❒ Soil test results for pH, phosphorus, nitrogen, and potassium;
   - ❒ Nutrient analysis of manure, sludge, mortality compost (birds, pigs, etc.), or effluent (if applicable);
   - ❒ Nitrogen contribution to the soil from legumes grown in the rotation (if applicable); and

To reduce water pollution caused by nitrogen and phosphorus, develop and implement a broad-based nutrient management plan.

- ❒ Other significant nutrient sources (e.g., irrigation water, atmospheric deposition).

4. An evaluation of field features based on environmental hazards or concerns, such as:
   - ❒ Sinkholes, shallow soils over fractured bedrock, and soils with high leaching potential;
   - ❒ Subsurface drains (e.g., tile drains);
   - ❒ Lands near surface water;
   - ❒ Highly erodible soils;
   - ❒ Shallow aquifers;
   - ❒ Combinations of excessively well drained soils and high rainfall seasons, resulting in very high potential for surface runoff and leaching; and
   - ❒ Submarine seeps, where nutrient-laden ground water from upland areas can directly enter the ocean through tidal pumping (e.g. along the coastline of Maui, Hawaii).
5. Use of the limiting nutrient concept to establish the mix of nutrient sources and requirements for the crop based on a realistic yield expectation.
6. Identification of timing and application methods for nutrients to provide nutrients at rates necessary to achieve realistic crop yields, reduce losses to the environment, and avoid applications as much as possible to frozen soil and during periods of leaching or runoff.
7. Provisions for the proper calibration and operation of nutrient application equipment.

Management Measure for Nutrients: Description

While the nutrient management plan may have many components, the principle is simple: minimize total losses.

The goal of this management measure is to minimize nutrient losses from agricultural lands occurring by edge-of-field runoff and by leaching from the root zone. Once nitrogen, phosphorus, or other nutrients are applied to the soil, their movement is largely controlled by the movement of soil and water and must therefore be managed through other control systems such as erosion control and irrigation water management. Effective nutrient management abates nutrient movement by minimizing the quantity of nutrients available for loss (source reduction). This is usually achieved by developing a nutrient budget for the crop, applying nutrients at the proper time with proper methods, applying only the types and amounts of nutrients necessary to produce a crop, and considering the environmental hazards of the site. In cases where manure is used as a nutrient source, manure holding areas may be needed to provide capability to apply manure at optimal times.

The focus of nutrient management is to increase the efficiency with which applied nutrients are used by crops, thereby reducing the amount available to be transported to both surface and ground waters. In many instances, nutrient management results in the use of less commercial fertilizer and, therefore, a reduction in production costs. However, where there has not been a balanced use of nutrients in the past, the application of this management measure may result in more nutrients being applied.

The best approach to *minimizing nutrient transport* to surface and ground waters depends upon whether the nutrient is in the dissolved phase or is attached to soil particles. For dissolved nutrients, effective management includes source reduction and reduction of water runoff or leaching. Erosion and sediment transport controls are necessary to reduce transport of nutrients attached to soil particles. Practices that focus on controlling the transport of smaller soil particle sizes (e.g., clays and silts) are most effective because these are the soil fractions that transport the greatest share of adsorbed nutrients.

Sources of Nutrients

Nitrogen (N), phosphorus (P), and potassium (K) are the primary nutrients applied in most agricultural operations. Nutrient management plans typically focus mainly on N and P, the nutrients of greatest concern for water quality.

Nutrient management planning is enhanced by knowledge of the nitrogen and phosphorus cycles.

The major sources of nutrients include:

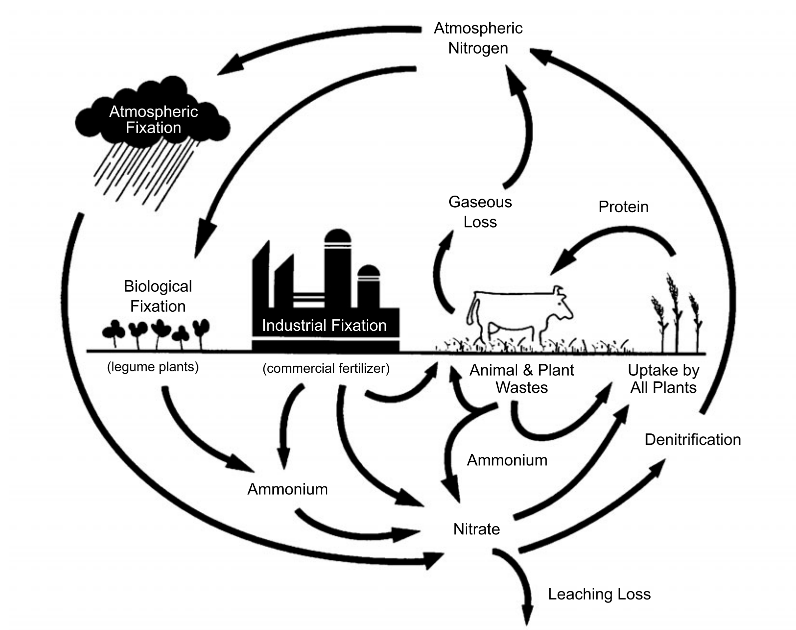
- ❒ Commercial fertilizers
- ❒ Manures, sludges, and other organic materials
- ❒ Crop residues and legumes in rotation
- ❒ Irrigation water
- ❒ Soil reserves

Because these two elements behave very differently, basic understanding of how N and P are cycled in the soil-crop system is an important foundation for effective nutrient management.

Nutrient Cycles

Nitrogen is continually cycled among plants, soil organisms, soil organic matter, water, and the atmosphere (Figure 4a-1) in a complex series of biochemical

Figure 4a-1. The nitrogen cycle (Kansas State Univ. CES & NAWG Foundation, 1994).

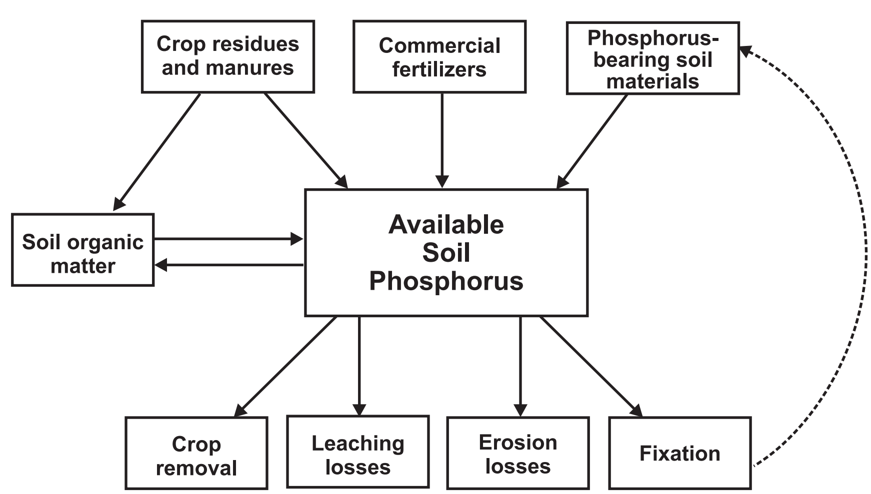


transformations. Some N forms are highly mobile, while others are not. At any given time, most of the N in the soil is held in soil organic matter (decaying plant and animal tissue) and the soil humus. *Mineralization* processes slowly transform the N in soil organic matter by microbial decomposition to ammonium ions (NH4+), releasing them into the soil where they can be strongly adsorbed and relatively immobile. Plants can use the ammonium, however, and it may be moved with sediment or suspended matter. *Nitrification* by soil microorganisms transforms ammonium ions (either mineralized from soil organic matter or added in fertilizer) to nitrite (NO2-) and then quickly to nitrate (NO3-), which is easily taken up by plant roots. Nitrate, the form of N most often associated with water quality problems, is soluble and mobile in water. *Immobilization* includes processes by which ammonium and nitrate ions are converted to organic-N, through uptake by plants or microorganisms, and bound in the soil. *Denitrification* converts nitrate (NO3) into nitrite (NO2) and then to nitrous oxide (N2O) and gaseous nitrogen (N) through microbial action in an anaerobic environment.

A nitrogen molecule may pass through this cycle many times in the same field. The processes in the nitrogen cycle can occur simultaneously and are controlled by soil organisms, temperature, and availability of oxygen and carbon in the soil. The balance among these processes determines how much N is available for plant growth and how much may be lost to ground water, surface water, or the atmosphere.

Phosphorus lacks an atmospheric connection (although it can be transported via airborne soil particles) and is much less subject to biological transformation, rendering the P cycle considerably simpler (Figure 4a-2). Most of the P in soil occurs as a mixture of mineral and organic materials. A large amount of P (50–75%) is held in soil organic matter which is slowly broken down by soil microorganisms. Some of the organic P is released into soil solution as phosphate ions that are immediately available to plants. The phosphate ions released by decomposition or added in fertilizers are strongly adsorbed to soil particles and are rapidly immobilized in forms that are unavailable to plants. The equilibrium

Figure 4a-2. The phosphorus cycle (Buckman and Brady, 1969).



level of dissolved P in the soil solution is controlled by the chemical environment of the soil (e.g. pH, oxidation-reduction, iron concentration) and by the P content of the soil.

Commercial Fertilizers

Fertilizers represent the largest single source of N, P, and K applied to most cropland in the U.S. Major commercial fertilizer N sources include anhydrous ammonia, urea, ammonium nitrate, and ammonium sulfate. Major P fertilizer sources include monoammonium phosphate, diammonium phosphate, triple superphosphate, ammonium phosphate sulfate, and liquids. The predominant source of potassium (K) fertilizer is potassium chloride. Descriptions of common fertilizer materials are given in Table 4a-1. The use of any particular material or blend is governed by the characteristics of the formulation (such as volatilization potential and availability rate), suitability for the particular crop, crop needs, existing soil test levels, economics, application timing and equipment, and handling preferences of the producer. An example of general fertilizer

Table 4a-1. Common fertilizer minerals.

Common Name	Chemical Formula	Analysis (%) N	P_2O_5	K_2O
Nitrogen materials				
Ammonium nitrate	NH_4NO_3	34	0	0
Ammonium sulfate	$(NH_4)_2SO_4$	21	0	0
Ammonium nitrate-urea	$NH_4NO_3+(NH_2)_2CO$	32	0	0
Anhydrous ammonia	NH_3	82	0	0
Aqua ammonia	NH_4OH	20	0	0
Urea	$(NH_2)_2CO$	46	0	0
Phosphate materials				
Superphosphate	$Ca(H_2PO_4)_2$	0	20-46	0
Ammoniated superphosphate	$Ca(NH_4H_2PO_4)_2$	5	40	0
Monoammonium phosphate	$NH_4H_2PO_4$	13	52	0
Diammonium phosphate	$(NH_4)_2HPO_4$	18	46	0
Urea-ammonium phosphate	$(NH_2)_2CO+(NH_4)_2HPO_4$	28	28	0
Potassium materials				
Muriate of potash	KCl	0	0	60
Monopotassium phosphate	KH_2PO_4	0	50	40
Potassium hydroxide	KOH	0	0	70
Potassium nitrate	KNO_3	13	0	45
Potassium sulfate	K_2SO_4	0	0	50

Source: Pennsylvania State University. 1997. *The Penn State Agronomy Guide, 1997-1998,* University Park, PA. Cornell Cooperative Extension. 1997. *1997 Cornell Recommendations for Integrated Field Crop Management.* Resource Center, Cornell University, Ithaca, NY.

Precision Farming

A New Era of Production

The Precisely Tailored Practice

Precision farming, also known as site-specific management, is a fairly new practice that has been attracting increasing attention both within and outside the agricultural industry over the past few years. It is a practice concerned with making more educated and well-informed agricultural decisions. Precision farming provides tools for tailoring production inputs to specific plots (or sections) within a field. The size of the plots typically range from one to three acres, depending on variability within the field and the farmer's preference. By treating each plot as much or as little as needed, farmers can potentially reduce the costs of seed, water, and chemicals; increase overall crop yields; and reduce environmental impacts by better matching inputs to specific crop needs. Rather than applying fertilizer or pesticides to an entire field at a single rate of application, farmers first test the soil and crop yields of specific plots and then apply the appropriate amount of fertilizer, water, and/or chemicals needed to alleviate the problems in those sections of the field. Precision farming requires certain technology, which is an added cost, as well as increased management demands.

Precision farming is changing the way farmers think about their land. They are increasingly concerned not with the average needs of the entire field, but with the actual needs of specific plots, which can fluctuate from one square meter to the next. The practice of precision farming acknowledges the fact that conditions for agricultural production vary across space and over time. With this in mind, precision farmers are now making management decisions more specific to time and place rather than regularly scheduled and uniform applications.

The Computer-Aided Approach

The approach of precision farming involves using a wide range of computer-related information technologies, many just recently introduced to production agriculture, to precisely match crops and cultivation to the various growing conditions. The key to successfully using the new technologies available to the precision farmer to maximize possible benefits associated with this approach is *information*. Data collection efforts begin before crop production and continue until after the harvest. Information-gathering technologies needed prior to crop production include grid soil sampling, past yield monitoring, remote sensing, and crop scouting. These data collection efforts are even further enhanced by obtaining precise location coordinates of plot boundaries, roads, wetlands, etc., using a global positioning system (GPS).

Other data collection takes place during production through "local" sensing instruments mounted directly on farm machinery. Variable rate technology (VRT) uses computerized controllers to change rates of inputs such as seed, pesticides, and nutrients through planters, sprayers, or irrigation equipment. For example, soil probes mounted on the front of fertilizer spreaders can continuously monitor electrical conductivity, soil moisture, and other variables to predict soil nutrient concentrations and accordingly adjust fertilizer application "on-the-fly" at the rear of the spreader. Other direct sensors available include yield monitors, grain quality sensors, salinity meter sleds, weather monitors, and spectroscopy devices. Optical scanners can be used to detect soil organic matter, to recognize weeds, and to instantaneously alter the amount or application of herbicides applied.

The precision farmer can then take the information gathered in the field and analyze it on a personal computer. The personal computer can help today's farmer organize and manage the information collected more effectively. Computer programs, including spreadsheets, databases, geographic information systems (GIS), and other types of application software, are readily available. By tying specific location coordinates obtained from the GPS in with the other field data obtained, the farmer can use the GIS capability to create overlays and draw analytical relationships for site-specific patterns of soils, crop yields, input applications, drainage patterns, and other variables of interest over a particular distance or time period.

GIS can also be integrated with other decision support systems (DSS), such as process models and artificial intelligence systems, to simulate anything from crop growth and financial expectations to the generation and movement of nutrients and pesticides through the environment. Today's precision farmer can also use expert systems, information systems based on input from human experts, to retrieve advice on when to spray for specific pests, when to till, and so forth. These systems are continuously modified for the farmer's field based on past, current, and expected conditions represented by soil, weather, pest level, and other data input from the GIS.

The Technology-Driven Future

Further technological advances will make the coming years decisive for the precision farming industry. There's no saying what the future holds for this new era of agricultural production. Listed below are just a few of the technological advances projected to hit this industry in the years to come.

- ❒ Onboard grain quality analyzers will check both physical and chemical attributes (including smell).
- ❒ High-precision soil testing will move from the lab to the field, with fiberoptic spectrometers attached to real-time onboard computers.
- ❒ Micro-ecology will be tested along with water runoff and air samples.
- ❒ Immunochemical assays will measure chemical residues on leaf surfaces or monitor plant health and productivity.
- ❒ A wide range of sensors, monitors, and controllers such as shaft monitors, pressure transducers, and servo motors will be used to collect accurate data.
- ❒ Weather monitors will be mounted on sprayers, or "talk" directly to local weather station networks as they simultaneously change droplet size or spray patterns, as well as rates and products, on the go.
- ❒ Remote imaging technologies will be used to assess crop health and management practice implementation.
- ❒ Guidance on control systems will guarantee straight rows, control depth, and optimize inputs.
- ❒ Crop models will optimize economic and environmental variables. Farmers will buy insurance directly from the underwriter, who will also rely on remote sensing and risk modeling.
- ❒ Wearable computers with voice recognition and head-mounted displays will guide farmers through equipment maintenance and crop scouting.

Although precision farming has not yet been widely adopted to date, this practice continues to attract increasing attention both on and off the farm. Much of the off-the-farm enthusiasm for precision farming can be attributed to the eminent good sense of matching input application to plant needs. Precision farming is simply a more finely tuned version of the kinds of BMPs already recommended at the field level. Because this technology is still somewhat new to the industry, there is much more to learn about the potential overall impact of precision farming on water and air quality relative to conventional techniques. But one thing is certain: precision farming has the potential to enhance economic return (by cutting costs and raising yields) and to reduce environmental risk (by reducing the impacts of fertilizers, pesticides, and erosion).

Table 4a-2. Fertilizer recommendations for corn in New York State (Cornell Cooperative Extension, 1997).

Soil Management Group	Years Following Sod	Fertilizer Nutrients to Be Added (lb/A)[4] — NITROGEN (N)[5], [6], [7] — Type of Plowed Sod — Grass		Less than 50% Legume		Greater than 50% Legume		PHOSPHORUS (P_2O_5) — Soil Test Phosphorus Levels [8]					POTASSIUM (K_2O) — Soil Test Potassium Levels [8]				
		No Manure	*Manure*	*No Manure*	*Manure*	*No Manure*	*Manure*	*Very Low*	*Low*	*Medium*	*High*	*Very High*	*Very Low*	*Low*	*Medium*	*High*	*Very High*
Soil group I–Clayey soils, fine-textured soils in northern New York, near lakes and along the Hudson River. Examples: Vergennes, Kingsbury, Hudson, Rhinebeck, Schoharie, Odessa.	1	10–30	10–30	10–30	10–30	10–30	10–30										
	2	50–100	10–40	30–80	10–20	20–70	10–30										
	3	70–110	10–50	60–100	10–40	60–100	10–40	70	60	40	20	0	50	40	30	20	0
	4 or more	80–120	20–60	80–120	20–60	80–120	20–60										
Soil group II–Silty soils, medium- to moderately fine-textured soils of the central region. Examples: Cazenovia, Hilton, Honeoye, Lima, Ontario, Lansing, Mohawk, Chagrin, Teel.	1	10–30	10–30	10–30	10–30	10–30	10–30										
	2	60–100	10–40	50–90	10–30	40–80	10–30										
	3	80–120	10–60	70–110	10–50	70–110	10–50	70	60	40	20	0	60	60	40	20	0
	4 or more	90–130	30–70	90–130	30–70	90–130	30–70										
Soil group III–Silt loam soils, moderately coarse-textured acid soils of the Southern Tier, glacial outwash. Examples: Barbour, Chenango, Palmyra, Tioga, Mardin, Langfor, Tunkhannock.	1	10–30	10–30	10–30	10–30	10–30	10–30										
	2	60–100	10–40	40–90	10–30	30–80	10–30										
	3	80–120	20–60	70–110	10–50	70–110	10–50	70	60	40	20	0	80	70	50	25	0
	4 or more	90–130	30–70	90–130	30–70	90–130	30–70										
Soil group IV–Loamy soils, coarse- to medium-textured soils of northern New York and the Hudson Valley. Examples: Bombay, Broadalbin, Copake, Empeyville, Madrid, Sodus, Worth.	1	10–30	10–30	10–30	10–30	10–30	10–30										
	2	60–110	10–50	50–90	10–30	40–90	10–30										
	3	80–120	10–60	70–120	10–60	70–110	10–50	70	60	40	20	0	120	80	50	25	0
	4 or more	90–130	30–70	90–130	30–70	90–130	30–70										
Soil group V–Sandy soils, very coarse-textured soils on beach ridges, deltas, and sandy or gravelly outwash near mountains and the Hudson Valley. Examples: Alton, Colton, Windsor, Colonie, Elmwood, Junius, Suncook.	1	10–30	10–30	10–30	10–30	10–30	10–30										
	2	40–100	10–40	20–80	10–20	20–70	10–30										
	3	60–110	10–50	50–100	10–40	50–100	10–40	70	60	40	20	0	120	90	60	30	0
	4 or more	70–120	20–60	70–120	10–60	70–120	10–60										

[1]A more specific recommendation will be obtained from a complete soil test analysis

recommendations for corn is shown in Table 4a-2. Commercial fertilizers offer the advantage of allowing exact formulation and delivery of nutrient quantities specifically tailored to the site, crop, and time of application in concentrated, readily available forms.

Organic Nutrient Sources

Organic nutrient sources, such as manure, sludge, and compost, can supply all or part of the N, P, and K needs for crop production. Organic nutrient sources offer additional advantages because they also contain secondary nutrients and micronutrients (e.g. iron, boron), add organic matter to the soil, provide nutrients to crops for several years after application, and provide a practical outlet to recycle manure and other farm organic materials. The use of manure is particularly important on livestock and poultry farms because nutrients can build up in the soil, be lost to the atmosphere, leach into ground water, or runoff to surface waters as more nutrients are brought onto the farm than leave in products sold. Table 4a-3 shows examples of estimated N and P mass balances for several New York dairy farms.

Table 4a-3. N and P mass balances on several New York dairy farms.

	Nitrogen Size (# of cows)			Phosphorus Size (# of cows)		
	45	85	120	45	85	120
	—tons of N/yr— -			—tons of P/yr—-		
INPUT						
purchased fertilizer	1.0	2.2	4.6	1.2	0.9	1.3
purchased feed	3.8	9.7	21.4	1.0	1.7	5.4
legume N fixation	1.3	1.1	3.2	—	—	—
Total:	6.1	13.0	29.2	2.2	2.6	6.7
OUTPUT						
milk	2.0	3.8	6.3	0.4	0.7	1.1
meat	0.1	0.4	0.6	<0.1	0.1	0.2
crops sold	0.1	0.5	—	<0.1	<0.1	—
Total:	2.2	4.7	6.9	0.4	0.8	1.3
REMAINDER	**3.9**	**8.3**	**22.3**	**1.8**	**1.8**	**5.4**
remaining on farm	**64%**	**64%**	**76%**	**81%**	**69%**	**81%**

Source: Klausner, S. 1995. Nutrient Management: Crop Production and Water Quality. 95CUWFP1, Cornell University, Ithaca, NY.

The nutrient content of manure and other organic materials can vary greatly according to the type of animal, type of feed, storage and handling procedures, climate, and management. In order to use them efficiently, these materials must be analyzed for their nutrient content. Examples of average values for nutrient content of organic materials are shown in Table 4a-4; however, it is important to note that the nutrient content of manure even on neighboring farm operations may vary widely from the average.

A difficulty in using organic nutrient sources is that their nutrient content is rarely balanced for the specific soil and crop needs. For example, the ratio of N:P in applied manure is usually around 3 or less, while the ratio at which crops

Table 4a-4. Representative values for nutrients in manure, sludge, and whey, as applied.

		Total N	P_2O_5 [1]	K_2O [1]
SOLID MANURE				
Species	**% dry matter**		**——lb/ton——**	
Dairy cattle	18-22	6-17	4-9	2-15
Beef cattle	15-50	11-21	7-18	10-26
Swine	18	8-10	6-9	7-9
Poultry	22-76	20-68	16-64	12-45
Sheep	28	14-18	9-11	25-26
Horse	46	14	4	14
LIQUID MANURE				
Species	**% dry matter**		**——lb/1000 gal——**	
Dairy cattle	1-8	4-32	4-18	5-30
Beef cattle	1-11	4-40	9-27	5-34
Veal calf	3	24	25	51
Swine	1-4	4-36	2-27	4-22
Poultry	13	69-80	36-69	33-96
DIGESTED SLUDGE			**——lb/1000 gal——**	
		20	12	1
WHEY			**——lb/1000 gal——**	
		12	9	18

1Convert values for P2O5 and K2O to P and K by multiplying by 0.43 and 0.83, respectively.

Sources: Midwest Plan Service. 1985. *Livestock Waste Facilities Handbook.* Iowa State University, 1991a. Ames, IA. Klausner, S. 1995. *Nutrient Management: Crop Production and Water Quality.* 95CUWFP1, Cornell University, Ithaca, NY. University of Wisconsin-Extension and Wisconsin Dept. of Agriculture, Trade, and Consumer Protection. 1989. *Nutrient and Pesticide Best Management Practices for Wisconsin Farms.* WDATCP Technical Bulletin ARM-1, Madison, WI. University of Vermont. 1996. *Agricultural Testing Laboratory – Manure Analysis Averages, 1992-1996.* Dept. of Plant & Soil Science, University of Vermont, Burlington, VT.

use nutrients typically ranges from 5 to 7. Therefore, when manure is applied at rates based solely on N analysis and crop need for N, excess amounts of P are added. Because the amounts of P added in manure exceed the amounts removed by crops, continuous manure usage can result in accumulations of excess P in the soil, increasing the potential for P to be transported in runoff and erosion (Daniel et al., 1997).

Credits for previous year manure applications and nitrogen-fixing crops should be considered in the plan for nitrogen management.

Another difficulty in efficient use of manure nutrients involves nutrient availability. Not all nutrients in manure are immediately available for crop uptake. The organic N in manure, for example, must be mineralized before it can be used by plants, a process that may take 3 or more years to complete. Examples of average amounts of nutrients available for crop growth in the first year of application in Wisconsin are shown in Table 4a-5. Actual quantities of available nutrients at a specific site will depend on initial nutrient content of the manure, soil type, temperature, and soil moisture. Failure to account for this slow availability can result in under-supply of nutrients in a given year of manure application. Perhaps more critically, it must be recognized that when manure is applied to the same field over the years, each succeeding year requires the addition of

Table 4a-5. Nutrients available for crop use in the first year after spreading manure.

Animal	SOLID N incorp.	SOLID N not incorp.	SOLID P_2O_5	LIQUID N incorp.	LIQUID N not incorp.	LIQUID P_2O_5
	lbs/ton			bs/1000 gal		
Dairy	4	3	3	10	8	8
Beef	4	4	5	12	10	14
Swine	5	4	3	15	12	6
Poultry	15	13	14	41	35	38

Source: University of Wisconsin-Extension and Wisconsin Dept. of Agriculture, Trade, and Consumer Protection. 1989. *Nutrient and Pesticide Best Management Practices for Wisonsin Farms.* WDATCP Technical Bulletin ARM-1, Madison, WI.

Table 4a-6. Quantity of livestock or poultry manure needed to supply 100 kg of Nitrogen over the cropping year with repeated applications of manure (Schepers and Fox, 1989).

Number of years applied	Quantity (metric tons) needed for manure with these percent N: 0.25	1.0	2.0	4.0
1	154	22	7	1.4
2	79	16	6	1.4
3	54	13	5	1.4
4	41	11	5	1.3
5	33	10	4	1.3
10	17	7	3.7	1.3
15	12	6	3.3	1.2
20	9	5	3.0	1.2

less N to maintain an adequate supply of plant available N (Table 4a-6). Failure to consider this N carryover could lead to excessive application of N.

Since organic nutrient sources contain valuable nutrients and have soil-conditioning properties, application to land should never be considered disposal. In cases where organic nutrient sources are disposed of as waste with no regard given to their N and P content, excessive levels of available nutrients and losses to surface or ground waters are likely to occur.

Because of their ability to "fix" atmospheric nitrogen, legumes grown in rotation can represent a significant input of N into the soil of a crop field. Alfalfa has been reported to fix from 60 to 530 lb N/ac (pounds of nitrogen per acre); soybeans may fix from 13 to 275 lb N/ac. Some of this fixed N is removed in harvest, but some remains in crop residue or in the soil and is available for subsequent crops. Table 4a-7 shows representative values for residual N contributions from legume crops. Failure to account for such added N could result in excessive application of N from other sources.

Table 4a-7. Representative values for first-year nitrogen credits for previous legume crops.

Crop	Nitrogen Credit (lb N/ac)
Forages	
Alfalfa[a]	
>50%	80 – 120
25-50%	50 – 80
<25%	0 – 40
Red Clover and Trefoil[a]	
>50%	60 – 90
25-50%	40 – 60
<25%	0 – 30
Soybeans	1 lb N/ac for each bu/ac harvested up to 40 lb N/ac
Green Manure Crops (plowed down after growing season of seeding year)	
Sweet clover	80 - 120
Alfalfa 60 - 100	
Red clover	50 - 80
Vegetable Crops (residue not removed)	
Peas, snap beans, lima beans	10 - 20

[a] The percentage of stand of the particular crop.

Sources: Pennsylvania State University. 1997. The Penn State Agronomy Guide, 1997-1998, University Park, PA. University of Wisconsin-Extension and Wisconsin Dept. of Agriculture, Trade, and Consumer Protection. 1989. Nutrient and Pesticide Best Management Practices for Wisconsin Farms. WDATCP Technical Bulletin ARM-1, Madison, WI.

Irrigation Water

Irrigation water, if drawn from already nutrient-enriched sources, can supply significant amounts of N. In the Central Platte River Valley in Nebraska, ground water used to irrigate corn contributed an average of 41 lb N/ac, nearly one-third of the N fertilizer requirement (Schepers et al., 1986). Ground water used to irrigate potatoes in Wisconsin contributed an average of 51 lb N/ac, or 25% of the N added as fertilizer (Saffigna and Keeney, 1977). Table 4a-8 shows guidelines for calculating the N contribution from irrigation water.

Table 4a-8. Calculating N contributions from irrigation water.

	Water Application Rate (acre-feet)			
N in water (mg/l)	0.5	1.0	1.5	2.
	lb N/ac			
2	3	5	8	11
4	5	11	16	22
6	8	16	24	32
8	11	13	32	43
10	13	27	40	54

Source: Kansas State University Cooperative Extension System and The National Association of Wheat Growers Foundation. 1994. Best Management Practices for Wheat. NAWG Foundation, Washington, D.C.

Soil Nutrients

The release of N, P, K, and micronutrients from soil reserves provides an additional source of plant-available nutrients. The amount of nutrient release depends on soil moisture, aeration, temperature, pH, and the amount of organic matter in the soil. The magnitude of this source can be assessed accurately only through soil testing.

Atmospheric Sources

Finally, atmospheric deposition can significantly contribute nutrients, especially N, to the soil. Because of the atmospheric linkages of the N cycle and industrial additions of N to the atmosphere, N loading from atmospheric deposition can be significant. From 1983-1994, average annual inorganic N deposition over the Chesapeake Basin ranged from 3.5 to 7.7 kg N/ha; average annual NO3+NH4 atmospheric deposition loading rates ranged from 6.7 to 7.8 kg N/ha (Wang et al., 1997). McMahon and Woodside (1997) cite wet NO3 and NH4 deposition rates of 9.8 kg N/ha/yr and 2.8 kg N/ha/yr, respectively, for the Albemarle-Pamlico Drainage Basin in North Carolina and Virginia. Examples of atmospheric deposition rates for various forms of N across the U.S. are given in Table 4a-9.

Table 4a-9. N loading in atmospheric deposition, NADP/NTN data, 1996.

Location	Station	NH_4-N	NO_3-N	Inorganic N
		kg N/ha/yr		
Vermont	Mt. Mansfield (VT99)	1.78	2.95	4.73
North Carolina	Mt. Mitchell (NC45)	2.39	2.92	5.31
Florida	Quincy (FL14)	1.06	1.60	2.66
Wisconsin	Popple River (WI09)	1.93	2.16	4.10
Indiana	Purdue Ag Res Ctr (IN41)	3.29	3.64	6.94
Arkansas	Fayetteville (AR27)	2.55	2.24	4.80
Nebraska	North Platte Ag Exp Sta (NE99)	2.54	1.58	4.12
California	Davis (CA88)	2.18	0.82	3.00
Alaska	Poker Creek (AK01)	0.05	0.11	0.16
Hawaii[1]	Mauna Loa (HI00)	0.05	0.05	0.10

all data reported as N

[1] 1993

Source: National Atmospheric Deposition Program (NRSP-3)/National Trends Network (June 24, 1998). NADP/NTN Coord. Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820.

Atmospheric deposition of P is generally very small. Ahl (1988) cited atmospheric deposition of 0.05–0.5 kg P/ha/yr in Canada. Annual P loading rates to the Chesapeake Basin have been estimated at 0.16 to 0.47 kg/ha (Wang et al., 1997). A similar P deposition rate of 0.16 kg/ha/yr has been measured in the Lake Champlain basin (VTDEC and NYS DEC, 1997). An estimated annual load of 0.66 kg P/ha by atmospheric deposition has been cited for the Albemarle-Pamlico Basin (McMahon and Woodside, 1997).

The most comprehensive collection of data on precipitation chemistry and atmospheric deposition is available from the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) at: http://nadp.sws.uiuc.edu/. Data are available for precipitation chemistry, annual and seasonal wet deposition totals, isopleth maps of precipitation chemistry and wet deposition, and other variables for over 200 sites in the continental U.S., Alaska, Hawaii, Puerto Rico, and the Virgin Islands. While deposition data from the NADP network may not be exactly applicable to a specific site due to local factors such as elevation, air movement, or industrial emissions, NADP data can help provide an initial screening estimate of the possible significance of atmospheric nutrient sources. If atmospheric inputs are estimated to be significant, specific local data can be sought from university or agency research activities.

Nutrient Movement into Surface and Ground Water

Some general principles govern nutrient movement. Site specific crop history, climate, soils, watershed, and farming characteristics result in specific local nutrient pathways and transformations.

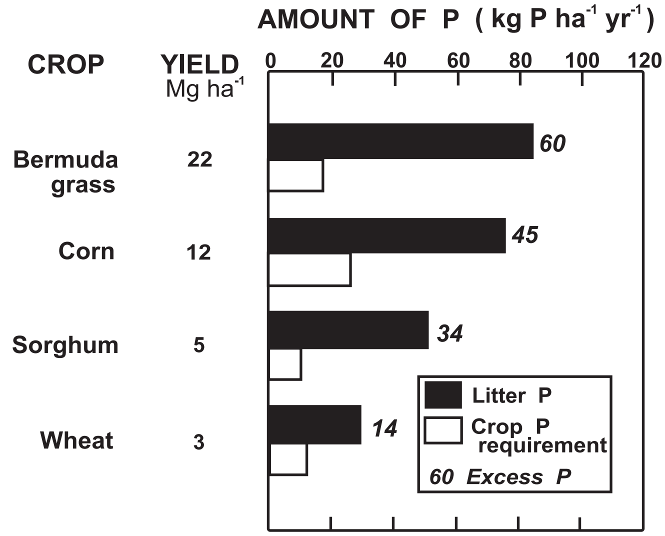
Nutrients in harvested crops typically represent the largest single component of nutrient output from agricultural land. Table 4a-10 gives representative values for annual crop nutrient removal. However, crop uptake of added N and P is by no means complete. Overapplication of nutrients relative to crop need results in build-up of N and P surplus in agricultural soils. Nutrient surpluses have been documented at both the farm scale (Klausner, 1995) and the watershed scale (McMahon and Woodside, 1997; Cassell et al., 1998). Soil test values show that soil P in many areas is excessive, relative to crop requirements; the greatest concern occurs with animal-based agriculture, where farm and watershed-scale P surpluses and over-application of P to soils are common. (Breeuwsma et al., 1995; Lander et al., 1998; Sims et al., 2000). Accumulation of P in cropland soils may be especially high if the N requirement of the crop is met with animal waste, adding P in excess of crop P uptake (Figure 4a-3). The magnitude of potential loss of nutrients to surface and ground waters is directly related to accumulation of excessive nutrient levels in soils.

Table 4a-10. Crop nutrient removal.

Crop	Yield /ac	N	P
		—— lb/ac ——	
Corn	125 bu	95	22
Corn silage	21 t	190	46
Grain sorghum	125 bu	65	33
Soybeans	40 bu	130	18
Wheat/rye	60 bu	90	26
Oats	80 bu	90	31
Barley	75 bu	105	20
Alfalfa	5 t	250	33
Orchardgrass	6 t	300	44
Tall fescue	3.5 t	135	29
Sugar beets	30 t	275	37

Sources: Pennsylvania State University. 1997. *The Penn State Agronomy Guide 1997-1998*, University Park, PA; Midwest Plan Service. 1985. *Livestock Waste Facilities Handbook*. Iowa State University, Ames, IA.

Figure 4a-3. P added in poultry litter compared with crop requirements (Sharpley et al., 1994).



Amount of P added in poultry litter compared with crop P requirements, if litter application rates are determined by crop N requirements.

N and P not removed in the harvested crop can become available for transport to surface and ground waters. The movement of applied nutrients is primarily driven by the movement of water and eroded soil, but the specific transport pathways are largely determined by the characteristics of the nutrient source, soil characteristics, and related environmental conditions (e.g., soil temperature). As noted in the earlier discussion of nutrient cycles, readily soluble nitrate moves easily in the liquid phase. Due to its strong affinity for soil particles, phosphorus usually moves primarily with eroding soil particles. Nitrogen can volatilize directly from fertilizers such as urea and ammonia and from surface-applied manure; N lost to the atmosphere in this way may be washed from the atmosphere by rain a great distance away. Nitrogen can also be lost to the atmosphere as harmless nitrogen gas through denitrification. Other factors influencing nutrient movement include topography, precipitation patterns, and, of course, land use and management.

Movement to Surface Waters

Transport of nutrients to surface waters depends on the availability of nutrients in the upper soil zone, how easily the nutrients and/or associated soil particles are detached, whether the chemical is transported in the dissolved form or attached to soil, and any deposition that may occur before delivery to a waterway. Nutrients are most susceptible to runoff loss while they are in a thin (<3 cm) layer at the soil surface where overland flow, chemicals, and soil intermix during runoff. Once nutrients are below this mixing zone, they are usually less vulnerable to ordinary runoff losses. Nitrate is an exception, as it can be readily leached through the soil.

Nitrogen can be delivered to surface waters through runoff, erosion, and subsurface flow. Some N in the form of ammonium can be lost by erosion along with organic N attached to soil particles. Soluble N can be carried in surface runoff, but most soluble nitrate is lost via leaching through the soil. Leached nitrate may move into surface waters through shallow subsurface flow or be transported to deeper ground water. Drainage tiles may provide an important short circuit for delivery of N from shallow subsurface flow to surface waters. Concentrations of nitrate in tile drain flow are normally higher than levels found in surface runoff.

The majority of phosphorus lost from agricultural land is transported via surface runoff, mostly in particulate form attached to eroded soil particles. Because P is so strongly adsorbed to soil particles, the P level in the soil is a critical factor in determining loads of P delivered to surface waters (Daniel et al., 1997). Increased residual P levels in the surface soil can lead to increased P loadings to surface water, both attached to soil particles and in dissolved form. Soluble P losses from cropland can also be significant if runoff occurs very soon after heavy addition of phosphate fertilizer.

Runoff of Dissolved P

Phosphorus can be exported from agricultural land in particulate and dissolved forms. In most cases, the majority of P loss occurs in surface runoff in particulate form. However, dissolved P carried in surface runoff or subsurface flow may be a critical consideration because dissolved P tends to be immediately available to stimulate growth in receiving waters.

- Loss of dissolved P in runoff is often directly related to the P content of surface soils — linear relationships have been observed between dissolved P concentration in runoff and P content of surface soils in cropped and grassed watersheds (Daniel et al., 1997; Pote et al., 1999; Schoumans and Groenendijk, 2000).
- P losses from grassland may be high, particularly because fertilizers and animal waste are not usually incorporated into the soil. Significant phosphorus export has been measured in surface runoff and interflow from grazed grassland, with losses of over 0.5 kg P/ha during major storm events, especially when events closely followed inorganic fertilizer application (Haygarth and Jarvis, 1997).
- Soluble P losses may be greater from pasturelands than from croplands due to the presence of animal waste on the land surface, P release from plant decomposition, and low amounts of suspended sediment to sorb dissolved P (Baker et al., 1978; Sharpley and Menzel, 1987; Sharpley et al., 1992).
- In the Chesapeake Basin, dissolved P concentrations in storm runoff were higher from pastureland than from either cropland or forest (Correll et al., 1995).

Movement to Ground Water

The magnitude of nutrient loss to ground water, especially through leaching, depends on the availability of the chemical in the soil profile, the ease with which the nutrient form is detached from the soil, the rate and path of downward transport or percolation of water and chemicals, and any possible removal or deposition of the chemical before it reaches ground water. Nutrients may be introduced to ground water by direct routes such as abandoned wells, irrigation wells, sinkholes, or back-siphoning of nutrients when filling tanks. Such pathways are especially significant because transport through soil is bypassed, eliminating any opportunity for adsorption or uptake. While it is important to protect all ground water through the proper use of nutrients, in areas where ground water quality problems are known to exist, special emphasis should be placed on nutrient management planning and the careful use of nutrients.

Leaching of soluble nutrients to ground water can occur as chemicals are carried with precipitation or irrigation water moving downward past the root zone to the ground water table. Over-application of irrigation water can enhance leaching of nutrients to ground water by carrying dissolved nutrients quickly below the root zone. Ponded water in surface depressions due to large runoff events can be a significant source of nutrient transport to ground water, as ground water mounds underneath the depression (Zebarth and DeJong, 1989). Summer fallow may have a higher ground water contamination risk than continuous cropping because of the increased water storage in soil profiles that may increase deep percolation (Campbell et al., 1984; Bauder et al., 1993). Finally, idling of cropland either due to normal rotations or to commodity or conservation programs can in some cases initially increase nutrient leaching to ground water as nutrients are not taken up by growing plants and are available for leaching loss (Webster and Goulding, 1995).

Increasing efficiency and reducing nutrient losses is founded upon the development of sound soil and water conservation principles.

Nitrogen in the form of nitrate is normally the nutrient most susceptible to leaching to groundwater. Nitrate not used by crops or denitrified by soil bacteria, is subject to leaching. Leaching potential is a function of soil type, crop, climate, tillage practices, fertilizer management, and irrigation and drainage management. Coarse textured soils pose a greater potential problem than fine textured soils, and crops with poor nitrogen use efficiencies present a greater hazard. In some studies, no-till systems have been shown to reduce nitrate leaching over conventional tillage, as well as proper crop rotation, especially those including a nitrogen-fixing crop (Meek et. al, 1995). However, other studies have shown that conservation tillage increases the infiltration rate of soils (Baker, 1993). Soil macroporosity and the proportion of rainfall moving through preferential flow paths often increase with the adoption of conservation tillage, potentially increasing the transmission of nitrates and other chemicals available in the upper soil to subsoils and shallow groundwater (Shipitalo et al., 2000). Over-irrigation, particularly on sandy soils, is a primary cause of nitrate leaching to groundwater.

Leaching of phosphorus to ground water is generally not a significant problem. However, organic soils and sandy soils, which lack the iron and aluminum oxides important for P adsorption, are exceptions; P losses in leaching from intensive cropping on such soils can be large. The degree of leaching will vary with soil structure, geologic conditions, climate, and management practices. Recent reports document phosphorus leaching in areas of intensive manure application to highly enriched soils over shallow water tables (Breeuwsma et al., 1995), or in areas of artificial drainage or preferential flow through soil macropores (Simard et al., 2000).

Nutrient Management Practices and Their Effectiveness

Nutrient Management Principles

There are several fundamental principles that should be applied to managing nutrients for both crop production and water quality protection. These principles focus on improving the efficiency of nutrient use and thereby reducing the potential for nutrient loss to surface or ground waters:

- ❒ Determine realistic yield goals, preferably on a field-by-field basis
- ❒ Account for available nutrients from all sources before making supplemental applications
- ❒ Synchronize nutrient applications with crop needs; N is needed most during active crop growth and N applied at other times may be lost
- ❒ Reduce excessive soil-P levels by balancing P inputs and outputs

Because of the complex cycling and multiple sources of N in the soil-crop system, careful accounting for all sources is often the most critical step in improving N management. Since the level of P in the soil is a major factor determining the amount of P lost from agricultural land, reducing soil P levels will ultimately reduce P delivery to surface and ground waters.

Additional practices may be needed to reduce detachment and transport of N and P and delivery to surface or ground waters. Erosion control practices are particularly critical to reduce losses of P and sediment-bound forms of N. Efficient water management can reduce leaching of soluble N from irrigated cropland, and improved irrigation practices can reduce water, sediment, and nutrient transport in tailwaters. Crop failure due to a lack of water leaves nutrients in the soil, rendering them vulnerable to leaching or runoff loss.

Nutrient Management Practices

Numerous practices are available to address the above principles. Many of these are specific to the cropping system, soils, climate, and management activities associated with particular crops and regions of the country. Readers are encouraged to contact their State Land Grant universities, NRCS, cooperative extension offices, State agriculture departments, or producer organizations for more site specific practices.

Soil and Water Conservation Districts, NRCS, or Extension offices can assist growers with the selection of nutrient management practices.

Following are practices, components, and sources of information that should be considered in the development of a nutrient management plan:

1. Use of soil surveys in determining soil productivity and identifying environmentally sensitive sites. Aerial photographs or maps and a soil map should be used. If the agricultural lands lie within a watershed that has been designated as having impaired surface or ground water quality associated with nutrients, then nutrient management plans should include an assessment of the potential for N or P from the agricultural lands to be contributing to the impairment.
2. Use of producer-documented yield history and other relevant information to determine realistic crop yield expectations. Appropriate methods include averaging the three highest yields in five consecutive crop years for the planning site or other methods based on criteria used

in developing the State Land Grant University's nutrient recommendations. Increased yields due to improved management and/or the use of new and improved varieties and hybrids should be considered when yield goals are set for a specific site.

Soil, tissue, and manure testing provide useful information for nutrient management planning.

3. Application of N and P at recommended rates for realistic yield goals. Through remote sensing and precision farming techniques, yield and fertilization can be optimized. Accurately located (e.g. via Global Positioning System, GPS) soil testing can help evaluate soil variability between and within fields, and use of on-the-go yield monitors and GPS-driven variable rate application can match inputs to soil and field variations and place nutrients where increased yield potential exists. Limit manure and sludge applications to phosphorus crop needs, supplying any additional nitrogen needs with nitrogen fertilizers or legumes.

   It may be necessary in some cases to route excess phosphorus in manures or sludge to fields that will be rotated into legumes, to other fields that will not receive manure applications the following year, or to sites with low runoff and low soil erosion potential.

   USDA has developed P application guidelines for situations where animal manure or other agricultural by-products are applied (see Table 4a-11). Producers unable to meet the P-based application rate requirement of the standard initially are encouraged to do so in a reasonable period of time using progressive planning approaches.

4. Soil testing for pH, phosphorus (Figure 4a-4), potassium, and nitrogen (Figure 4a-5). Preplant or midseason soil profile nitrate testing (e.g., a pre-sidedress nitrate test) should be used when appropriate. Sub-soil sampling for residual nitrate may be needed for irrigated croplands. Surface layer sampling (0-2 inches) for elevated soil P and soil acidity may be needed when there is permanent vegetation, non-inversion

Table 4a-11. Allowable P Application Rates for Organic By-products (e.g., manure) A–NRCS, 1977, revised 1999).

The following guidelines are contained in USDA's Conservation Practice Standard 590 for Nutrient Management.

For phosphorus, one of the following options should be used to establish acceptable phosphorus application rates when manure or other organic by-products are applied:

- **Phosphorus Index (PI) Rating.** Nitrogen based manure application on Low or Medium Risk sites, phosphorus based or no manure application on High and Very High Risk Sites.**
- **Soil Phosphorus Threshold Values.** Nitrogen based manure application on sites on which the soil test phosphorus levels are below the threshold values. Phosphorus based or no manure application on sites on which soil phosphorus levels equal or exceed threshold values.**
- **Soil Test.** Nitrogen based manure application on sites on which there is a soil test recommendation to apply phosphorus. Phosphorus based or no manure application on sites on which there is no soil test recommendation to apply phosphorus.**

** Acceptable phosphorus based manure application rates shall be determined as a function of soil test recommendation or estimated phosphorus removal in harvested plant biomass. Guidance for developing these acceptable rates is found in the NRCS General Manual, Title 190, Part 402 (Ecological Sciences, Nutrient Management, Policy), and the National Agronomy Manual, Section 503).

Figure 4a-4. Example of soil test report (Pennsylvania State University, 1992a).

07/31/84	0004	700234	SOMERSET	25	NPBUU1	READINGTON
DATE	LAB NO.	SERIAL NO.	COUNTY	ACRES	FIELD	SOIL

THE PENNSYLVANIA STATE UNIVERSITY
COLLEGE OF AGRICULTURE
MERKLE LABORATORY - SOIL & FORAGE TESTING
UNIVERSITY PARK, PA 16802

SOIL TEST REPORT FOR:

P.A. PENN
RD1
ANYTOWN, PA 10000

COPY SENT TO:

ACME FERTILIZER CO.
MAIN STREET
ANYTOWN, PA 10000

SOIL NUTRIENT LEVELS:

				LOW	OPTIMUM	HIGH	EXCESSIVE
Soil pH		6.2		XXXXXXXXXXXXXX			
Phosphate	(P_2O_5)	114	lb/A	XXXXXXXXXXXX			
Potash	(K_2O)	178	lb/A	XXXXXXXXXXX			
Magnesium	(MgO)	230	lb/A	XXXXXXXXXXXXXX			

RECOMMENDATIONS FOR: *PLANTING CORN FOR GRAIN* (For other crops see ST 2 column 1) — See Back For Comments

YIELD GOAL 125.0 BUSHELS (PER ACRE) — 1,2

LIMESTONE: *3400* lb/A Calcium Carbonate Equivalent — 3,4

PLANT NUTRIENT NEEDS:

NITROGEN (N)	PHOSPHATE (P_2O_5)	POTASH (K_2O)	MAGNESIUM (MgO)	
130 lb/A	*70* lb/A	*90* lb/A	*10* lb/A	5,11

MESSAGES:

- USE A STARTER FERTILIZER — 6,7
- LIMESTONE RECOMMENDATION, IF ANY, IS TO BRING THE SOIL PH TO 6.0 - 6.5. MULTIPLY THE EXCHANGABLE ACIDITY BY 1000 TO ESTIMATE THE LIME REQUIREMENT FOR PH 6.5 - 7.0.
- RECOMMENDED LIMESTONE CONTAINING .2% MGO WILL MEET THE MG REQUIREMENT.
- IF MANURE WILL BE APPLIED, SEE ST-10 "USE OF MANURE" — 9

LABORATORY RESULTS:

6.2	50	4.1	0.19	0.6	7.8	12.6	1.5	4.7	61.5
SOIL pH	P lb/A	ACIDITY	K	Mg	Ca	CEC	K	Mg	Ca
		EXCHANGEABLE CATIONS (meq/100 g)					% SATURATION		

OTHER TESTS: ORGANIC MATTER - 2.2 %

Figure 4a-5. Example of Penn State's soil quicktest form (Pennsylvania State University, 1992a).

PENNSTATE

1855

PRE-SIDEDRESS SOIL NITROGEN TEST FOR CORN
QUICKTEST EVALUATION PROJECT

- SOIL TEST INFORMATION AND REPORT FORM -

GROWER (PLEASE PRINT)

↑ NAME ↑

↑ STREET OR R. D. NO. ↑

↑ CITY, STATE, AND ZIP ↑

↑ COUNTY ↑

DATE:

ANALYZED BY:

↑ AREA CODE ↑ - ↑ TELEPHONE NO. ↑

Best time to call (8 am - 4:30 pm): ________

Please answer all of the following questions about this field:

1. What is the field ID (name or number)? ______________ Corn Height __________in.
2. What is the expected yield of the corn crop (bu/A or ton/A) in this field? __________
3. What was the previous crop? ____________________________

   If this was a forage legume what was the % stand?

   (check one): ☐ 0-25% ☐ 25-50 % ☐ 50-100%
4. Was manure applied to this field? ☐ Yes ☐ No If "yes" answer the following questions:

   When? ☐ Fall ☐ Spring ☐ Both ☐ Daily

   Type? ☐ Cattle ☐ Poultry ☐ Swine ☐ Horse ☐ Sheep

   Estimate manure rate: _____ tons/acre - OR - _____ gallons/acre

   If incorporated how many days were there between spreading and incorporation? ______
5. What is the tillage program on this field? ☐ Conventional Tillage ☐ Minimum Tillage ☐ No-till
6. What would be your normal N fertilizer application rate for this field? ______ lbs. N/acre

Do not write below the line (to be completed by the analyst)

Quicktest Analysis Result & Recommendation

Individual Meter Readings	Average meter reading		Conversion factor		Average standard reading		Soil Nitrate-N (ppm)
☐ ☐ ☐ →	☐	x	20	÷	☐	=	☐

Sidedress N Fertilizer Recommendation ☐ **lbs. N/acre**
(See table and guidelines on back of form)

If you have any questions about this test contact your Penn State Cooperative Extension Office

White copy- Grower
Yellow copy- Analyst
Pink copy- Agronomy Extension

5/91

tillage, or when animal manure or other organic by-products are broadcast or surface-applied.

5. Plant tissue testing, e.g. chlorophyll testing in corn.
6. Manure, sludge, mortality compost, and effluent testing.
7. Quantification of nutrient impacts from irrigation water, atmospheric deposition, and other important nutrient sources.
8. Use of proper timing, formulation, and application methods for nutrients that maximize plant utilization of nutrients and minimize the loss to the environment. This includes split applications and banding of the nutrients, use of nitrification inhibitors and slow-release fertilizers, and incorporation or injection of fertilizers, manures, and other organic sources. In addition, fall application of N fertilizer on coarse-textured soils should be avoided. Manure should be applied uniformly in accordance with crop needs, but surface application to no-till cropland should be avoided.
9. Coordination of irrigation water management with nutrient management. For example, in-field measurement of crop and soil N status during the growing season can be coupled with high-frequency irrigation to match N applications with crop needs and reduce N losses (Onken et al., 1995). Irrigation should also be managed to minimize leaching and runoff.
10. Use of small grain cover crops or deeply-rooted legumes to scavenge nutrients remaining in the soil after harvest of the principal crop, particularly on highly leachable soils. Consideration should be given to establishing a cover crop on land receiving sludge or animal waste if there is a high leaching potential. Sludge and animal waste should be incorporated or subsurface injected.
11. Use of buffer areas or intensive nutrient management practices to address concerns on fields where the risk of environmental contamination is high, such as:
    - ❐ Karst topographic areas containing sinkholes and shallow soils over fractured bedrock,
    - ❐ Subsurface drains (e.g., drain tile),
    - ❐ Lands near surface water,
    - ❐ High leaching index soils,
    - ❐ Irrigated land in humid regions,
    - ❐ Highly erodible soils,
    - ❐ Lands prone to surface loss of nutrients, and
    - ❐ Shallow aquifers and drinking water supplies.

    For example, nitrification inhibitors may be needed when conditions promote leaching, and banding or ridge application may render applied N or P less susceptible to leaching. Manure should not be applied to frozen or saturated soils, to shallow soils over fractured bedrock, or to excessively drained soils.
12. Use of soil erosion control practices to minimize runoff and soil loss.
13. Calibrate nutrient application equipment regularly.

14. A narrative accounting of the nutrient management plan that explains the plan and its use.

The best means for implementing and coordinating many of the above activities is through a comprehensive, site-specific nutrient management plan. Nutrient management plans should be reviewed annually to determine if modifications are needed for the next crop, and a thorough review of the plan should be done at least once every 5 years or once per crop rotation period. Application equipment should be calibrated and inspected for wear and damage periodically and repaired when necessary. Records of nutrient use and sources should be maintained along with other management records for each field. This information will be useful when it is necessary to update or modify the management plan.

A list of the required nutrient management plan elements for confined animal operations in the Pequea-Mill Creek (PA) National Monitoring Program project is shown Table 4a-12. Table 4a-13 shows a set of nutrient recommendations from a Vermont Crop Management Association. Table 4a-14 shows two summary tables from a sample plan.

Practice Effectiveness

Following is a summary of information regarding pollution reductions that can be expected from installation of nutrient management practices.

- The State of Maryland estimates that average reductions of 34 pounds of nitrogen and 41 pounds of P2O5 applied per acre can be achieved through the implementation of nutrient management plans (Maryland Department of Agriculture, 1990). These average reductions may be high because they apply mostly to farms that use animal wastes; average reductions for farms that use only commercial fertilizer may be lower.
- As of July 1990, the Chesapeake Bay drainage basin states of Pennsylvania, Maryland, and Virginia had reported that approximately 114,300 acres (1.4% of eligible cropland in the basin) had nutrient management plans in place (EPA, 1991a). The average nutrient reductions of TN and TP were 31.5 and 37.5 pounds per acre, respectively. The States initially focused nutrient management efforts on animal waste utilization. Because initial planning was focused on animal wastes (which have a relatively high total nitrogen and phosphorus loading factor), estimates of nutrient reductions attributed to nutrient management may decrease as more cropland using only commercial fertilizer is enrolled in the program.
- In Iowa, average corn yields remained constant while nitrogen use dropped from 145 pounds per acre in 1985 to less than 130 pounds per acre in 1989 and 1990 as a result of improved nutrient management. In addition, data supplied from nitrate soil tests indicated that at least 32% of the soils sampled did not need additional nitrogen for optimal yields (Iowa State University, 1991b).
- Data from the 66,640-acre Big Spring ground water basin in northeastern Iowa indicate that reduced application of nitrogen fertilizer associated with the 1983 payment-in-kind set-aside program resulted in reduced nitrate levels in ground water two years later (Hallberg et al., 1993). Based upon this analysis, it is postulated that water quality improvements at the watershed level will be definable over time in

Table 4a-12. Required nutrient management plan elements for confined animal operations in the Pequea-Mill Creek National Monitoring Program project, Pennsylvania.

A. **Farm Identification**
including location, receiving waters, size of operation, and farm maps of fields, soils, and slopes

B. **Summary of Plan**
- Manure summary, including annual manure generation, use, and export
- Nutrient application rates by field or crop
- Summary of excess manure utilization procedures
- Implementation schedule
- Manure management and stormwater BMPs

C. **Nutrient Application**
- Inventory of nutrient sources
- Animal populations
- Acreage and expected crop yields for each crop group
- Nutrients necessary to meet expected crop yields
- Nutrient content of manure
- Nitrogen available from manure
- Residual N from legumes and past manure applications
- Planned manure application rate
- Target spreading rates for manure application
- Nitrogen balance calculation
- Winter manure spreading procedures (if applicable)

D. **Alternative Manure Use**
Amount, destination, and use of manure exported to other landowners, brokers, markets, or used in other than agricultural application

E. **Barnyard Management**

F. **Storm Water Runoff Control**

Source: Penn State Cooperative Extension. 1997. *Pequea-Mill Creek Information Series.* Smoketown, PA.

Table 4a-13. Missisquoi Crop Management Association 1997 nutrient recommendations.

Crop	Field Name	Acres	Manure Applied In Fall	Recom. Manure Rate	Loads /Field 3375 gal	Recommended Fertilizer lb/A	N	P_2O_5	K_2O	Micronutrients	After Manure & Fertilizer —Remaining Need— N	P_2O_5	K_2O	Mg	Lime Need
Corn	#7	9.7	9742	0	0	150	10	20	20	with 1.33% Zinc	47	0	0	0	
				or 3737 11	150	10	20	20	with 1.33% Zinc		0	0	0	0	
	#9A	11.3	2000	5226	17	150	10	20	20	with 1.33% Zinc	0	0	0	0	
	#11	20.0	5625	8798	52	250	10	20	20	with 0.8% Zinc	0	0	0	0	2.0
Alfalfa New Seeding	Spooner 3	4.3		3333				NONE			0	0	0	0	2.0
				or 0		300	5	10	30	with 0.6% Boron	0	0	0	0	2.0
Grass 1st Cut	#1	10.0		4135	12			NONE			0	0	26	0	1.0
				or 0		200	23	0	30		0	0	40	0	
	#3	10.8	7986	0				NONE			6	0	0	0	
Grass 2nd Cut	#1	10.0		0		200	23	0	30		0	0	0	0	
	#3	10.8		3755	12			NONE			0	0	0	0	

Table 4a-14. Plan Summary from a Sample Plan (Pennsylvania State University Cooperative Extension, 1997).

Manure Summary Table

Manure Source	Generated on the Farm	Used on the Farm	Exported from the Farm
liquid dairy	523,000 gal	523,000 gal	0 gal
uncollected solid dairy	263 tons	263 tons	0 tons
collected solid dairy	175 tons	175 tons	0 tons
solid poultry	1,860 tons	0 tons	1,860 tons

Nutrient Application Rates by Crop Group

Crop Group	Acres	Starter Fertilizer Nutrients (lbs per acre) N	P_2O_5	K_2O	Planned Manure Application Rate/ac.	When Manure Applied (incorp. time)	Additional Chemical Fertilizer Nutrients Applied N	P_2O_5	K_2O
Corn, grain (liquid manure)	32	10	20	10	9,000 gal	spring (2-4 days)	0	0	0
Corn, grain (liquid manure)	18	10	20	10	9,000 gal	fall (2-4 days)	50	0	0
Corn, silage (liquid manure)	12	20	20	10	6,000 gal	fall (2-4 days)	0	0	0
Corn, silage (solid manure)	9	20	20	10	20 tons	fall/spring (2-4 days)	0	0	20
Alfalfa (new)	21	10	20	10	0	–	0	40	230
Alfalfa	53	0	0	0	0	–	0	120	200

– All numbers rounded off recognizing the built-in variation in figures used.
– **Manure application is restricted in the following areas:**
a) within 100 feet of the farm well (field A-13) and the neighbor's well (field A-7), where surface flow is towards the well (unless the manure is incorporated within 24 hours of application, in which case manure application rates and supplemental fertilizer needs may need to be adjusted)
b) within 100 feet of Little Fishing Creek when the ground is frozen, snow-covered, or saturated (fields A-2 and A-3)
c) within the grassed waterway when the ground is frozen, snow-covered, or saturated (fields A-1 and A-2)

responsive ground water systems if significant changes in nitrogen application are accomplished across the watershed.

- In a pilot program in Butler County, Iowa, 48 farms managing 25,000 acres reduced fertilizer nitrogen use by 240,000 pounds by setting realistic yield goals based on soils, giving appropriate crop rotation and manure credits, and some use of the pre-sidedress soil nitrate test (Hallberg et al., 1991). Other data from Iowa showed that in some areas fields had enough potassium and phosphorus to last for at least another decade (Iowa State University, 1991b).
- In Garvin Brook, Minnesota, fertilizer management on corn resulted in nitrogen savings of 29 to 49 pounds per acre from 1985 to 1988 (Wall et al., 1989). In this Rural Clean Water Program (RCWP) project, fertilizer management consisted of split applications and rates based upon previous yields, manure application, previous crops, and soil test results.

- Baker (1993) concluded that the downward trends in total and soluble phosphorus loads from Lake Erie tributaries for the period from the late 1970s to 1993 indicate that agricultural controls have been effective in reducing soluble phosphorus export. Tributary nitrate concentrations increased, however, possibly due to adoption of conservation tillage, which enhances water percolation into the soil, and the extensive use of tile drainage systems in the watersheds.
- Berry and Hargett (1984) showed a 40% reduction in statewide nitrogen use over 8 years following introduction of improved fertilizer recommendations in Pennsylvania. Findings from the RCWP project in Pennsylvania indicated that, for 340 nutrient management plans, overall recommended reductions (corn, hay, and other crops) were 27% for nitrogen, 14% for phosphorus, and 12% for potash (USDA–ASCS, 1992a). Producers achieved 79% of the recommended nitrogen reductions and 45% of the recommended phosphorus reductions. In the same project area, Hall (1992) documented 8 to 32% decreases in median nitrate concentrations in ground water samples following decreases of 39–67% in N application rates under nutrient management.
- Base flow concentrations of dissolved nitrate-nitrite from a 909-acre subwatershed under nutrient management decreased slightly relative to a 915-acre paired subwatershed in the Little Conestoga Creek watershed in Pennsylvania, suggesting that nutrient management had a positive impact on water quality (Koerkle et al., 1996). Nutrient applications in the 909-acre treated subwatershed (study site) decreased in the period 1986-1989 by about 30% versus the period 1984-1986 (pre-implementation) as 85% of the land was placed under nutrient management. Less than 10% of the land was under nutrient management in the 915-acre untreated subwatershed (control site). The study was extended for two years to improve upon the findings, but implementation at the control site resulted in nutrient management on 40% of agricultural land, while implementation for the study site stood at 90% (Koerkle and Gustafson-Minnich, 1997). Nitrogen applications for the period 1989-1991 were about 7% less than for the period 1984-1986 at the study site, a much smaller decrease than the 30% decrease reported for the period 1986-1989. Nutrient application data were not available for the control site. The lack of statistically significant reductions in dissolved nitrate-nitrite for the period 1989-1991 versus 1984-1986 is interpreted as an indication that a reduction in nitrogen input of 30% (as achieved in 1986-1989) is needed to cause a 0.5 mg/L decrease in dissolved nitrate-nitrite.

  A related study in the Conestoga River headwaters, Pennsylvania, showed that nutrient management caused statistically significant decreases in nitrate concentrations in ground water (Hall et al., 1997). Changes in nitrogen applications to the contributing areas of five wells were correlated with nitrate concentrations in the well water on a 55-acre crop and livestock farm in carbonate terrain. Lietman et al. (1997) showed that terracing decreased suspended-sediment yield as a function of runoff, but also increased nitrate-nitrite yields in runoff, and increased nitrate concentrations in ground water at 4 of the wells on a 23.1-acre site.
- A 6-year study in the 403-acre Brush Run Creek watershed in Pennsylvania showed that monthly and annual base flow loads of total

nitrogen, dissolved nitrite-nitrate, total ammonia plus organic nitrogen, and total and dissolved phosphorus and orthophosphorus decreased during the 3-year period when nutrient management was implemented (Langland and Fishel, 1996). However, stormflow discharges of total nitrogen and total phosphorus increased by 14 and 44%, respectively, while nitrogen and phosphorus applications were reduced by 25 and 61%. Fewer storms were sampled during two of the three years under nutrient management due to a significant decrease in precipitation during the growing seasons. Maximum total nitrogen concentrations were 21 mg/L above the tile drains before nutrient management, and 2,400 mg/L in the tile drains before nutrient management (Langland and Fishel, 1996). Median concentrations of total nitrogen and dissolved nitrite-nitrate were reduced from 3.3 and 1.2 mg/L, respectively, to 2.5 and 0.90 mg/L when nutrient management was applied above the tile drains. Nutrient management in this tile-drained watershed resulted in a 14% decrease in nitrogen and 57% decrease in phosphorus applied as commercial and manure fertilizer.

❒ In Vermont, research suggested that a newly introduced, late spring soil test resulted in about a 50% reduction in the nitrogen recommendation compared to conventional technologies (Magdoff et al., 1984). Research in New York and other areas of the nation documented fertilizer use reductions of 30 to 50% for late spring versus preplant and fall applications, with yields comparable to those of the preplant and fall applications (Bouldin et al., 1971).

❒ Improved nutrient management on a case-study group of 8 United States Department of Agriculture (USDA) Demonstration Projects (DP) and 8 Hydrologic Unit Area (HUA) Projects resulted in reported nitrogen application reductions ranging from 14 to 129 lb/ac and phosphorus

Table 4a-15. Reported changes in average annual nutrient application rates on land with practice adoption in 19 USDA Demonstration and Hydrologic Unit Area Projects, 1991-1995.

Project	Purpose[1]	Nitrogen Reductions (lb/ac)	Phosphorus Reductions (lb/ac)
AL HUA	N, P	129	106
IN HUA	N, P	21	30
MI HUA	N, P	41	18
NY HUA	N, P	14	21
UT HUA	P	—	0
DE HUA	N, P	118	96
IL HUA	N, P	117	36
OR HUA	N	52	—
MD DP	N, P	43	42
NC DP	N, P	72	n/a
WI DP	N, P	78	18
FL DP	N, P	14	3
MN DP	N, P	30	21
NE DP	N	21	—
TX DP	N, P	21	18
CA DP	N, P	47	11

1 Nutrients to be controlled as project objective: N=nitrogen, P=phosphorus

—- = data not applicable

n/a = data not available

Source: Meals, D.W., J.D. Sutton, and R.H. Griggs. 1996. *Assessment of Progress of Selected Water Quality Projects of USDA and State Cooperators.* USDA–NRCS, Washington, D.C.

application reductions of 0 to 106 lb/ac (Table 4a-15). The case study group included both animal and crop agriculture and both irrigated and non-irrigated cropland.

Additional results from evaluations of practice effectiveness may exist for specific practices in particular regions. Potential sources of such documentation include the USDA MSEA/ADEQ (Management Systems Evaluation Areas/ Agricultural Systems for Environmental Quality) Programs (http://www.nps.ars.usda.gov/) and the US EPA Section 319 National Monitoring Program (http://h2osparc.wq.ncsu.edu/319index.html).

A summary of the literature findings regarding the effectiveness of nutrient management in controlling nitrogen and phosphorus is given in Table 4a-16.

Table 4a-16. Relative effectiveness[a] of nutrient management (Pennsylvania State University, 1992b).

Practice	Percent Change in Total Phosphorus Loads	Percent Change in Total Nitrogen Loads
Nutrient Management[b]	-35	-15

a Most observations from reported computer modeling studies
b An agronomic practice related to source management; actual change in contaminant load to surface and ground water is highly variable.

Factors in Selection of Management Practices

Effective nutrient management will not transfer problems from surface to ground water, or vice versa.

The movement of available nutrients to surface and/or ground waters depends on the properties of the nutrients involved, climate, soil and geologic characteristics, and land management practices such as crops grown, fertilizer applications, erosion control, and irrigation water management. These factors determine which specific strategies and practices should be selected to reduce nutrient movement in a given situation. Land management practices such as selection of fertilizer formulation or rate and method of application can be controlled, while environmental factors such as climate cannot. Other factors, such as crop selection and farming equipment, are governed to varying degrees by economic considerations and may therefore limit nutrient management options in some cases.

Care should be taken that practices to control surface runoff do not increase the risk of ground water contamination, and vice versa. In general, practices that increase the efficiency of nutrient use and thereby reduce availability of nutrients for loss are the first line of defense in nutrient management. Control of detachment and transport of nutrients in the particulate phase and of runoff and leaching of soluble forms may be achieved with other practices or management measures, including erosion and sediment control and irrigation water management.

The characteristics of the agricultural operation are critical considerations in selection of appropriate practices for nutrient management. Specific nutrient management practices will differ markedly, for example, between a large grain farm, where all nutrients are supplied by purchased fertilizer and can be applied by precision farming methods, and a small dairy farm, where nutrients are supplied by animal waste, legumes, and purchased fertilizer, and exact nutrient balance is difficult to achieve. The equipment and facilities available to the producer, such as manure or fertilizer application equipment and the type of waste storage system influence both the form of the nutrients and the producer's ability to efficiently manage the nutrients.

Climatic and other environmental conditions such as soils and geology are key determinants in the selection of practices. For example, the need for irrigation to grow crops in the Columbia Basin of Washington places a premium on careful scheduling of fertigation to protect ground water below sandy soils (Annandale and Mulla, 1995), whereas the yield variability in midwestern claypan soils makes "on-the-go" changes in fertilizer application rates essential to maximizing the efficiency of N uptake (Kitchen et al., 1995). In addition, local environmental factors, such as the presence of sensitive or protected waterbodies, may require additional practices such as buffer strips or vegetative filter strips to reduce delivery of nutrients lost from agricultural land.

Local and regional agricultural economies and land use mix can also be important factors in selecting nutrient management practices. In livestock agriculture, the available land base with respect to animal populations may limit the potential for full use of manure nutrients on farm land and require efforts to export manure from an area in order to follow a nutrient management plan. Proximity to residential and urban centers can offer opportunities for exporting manure nutrients, but may also limit some forms of nutrient management due to odor problems or other perceived nuisances.

Finally, a range of issues such as the availability of soil, manure, and plant testing services; the availability of nutrient management consultants; the opportunity for producer training; the availability of rental equipment for specialized operations; and State, Tribal, and local laws and regulations may all affect the selection of best management practices for any given location.

Cost and Savings of Practices

Costs

In general, most of the costs documented for this management measure are associated with technical assistance to landowners to develop nutrient management plans. Some costs are also involved in ongoing nutrient management activities such as soil, manure, and plant tissue testing. Technical assistance in nutrient management is typically offered by universities, farm service dealers, and independent crop consultants. Rates vary widely depending on the extent of the service and type and value of the crop. Fees can range from about $5 per acre for basic service up to $30 per acre for extensive consultation on high-value crops (NAICC, 1998).

Typical nutrient management costs for Vermont dairy farms begin with a $150 fixed charge for a nutrient management plan. There is an additional $6 per acre for corn land, which includes record-keeping for manure, fertilizer, and pesticide applications, soil analysis for each field, manure test, and a PSNT; cost for grassland is $4 per acre, which includes the same services as for corn fields except the PSNT (Stanley, 1998).

In Pennsylvania, where state law requires extensive nutrient management planning, charges for development of a plan range from $400 to $900. Specific costs vary from around $3 to $4 per acre for a "generic" plan without soil sampling or weed and insect control recommendations, up to $8 to $12 per acre for a complete plan with full scouting (Craig, 1998).

In Maryland, again subject to a recent state law requiring all farms to have nutrient management plans, average costs across the state are about $3 per acre, which includes writing the plan, technical recommendations on fertilization and waste management, maps, and record-keeping (Maryland Dept. of Agriculture, 1998). Soil and manure testing are additional costs, at $2 to $5 per analysis.

Charges listed by an Illinois crop consultant range from $5 to $15 per acre for services including scaled maps, manure analysis, soil testing, and site specific recommendations for fertilizer and manure applications (Cochran, 1998).

A Wisconsin agronomic service charges $5 to $8 per acre for nutrient management services that include farm aerial maps; identification of fields with manure spreading restrictions; soil test reports; animal inventory with manure analysis; written plans for each field specifying crop to be grown, previous crop grown, fertilizer recommendations, legume and manure credits, manure application rates, and record-keeping sheets; and regular field scouting (Polenske, 1998).

In Nebraska, a crop consulting service charges $5 per acre for basic soil fertility and pest and water management, another $4 per acre for precision-farming GPS grid samples, plus a separate soil analysis charge (Michels, 1998).

Savings

In many instances landowners can actually save money by implementing nutrient management plans. For example, Maryland estimated (based on the over 750 nutrient management plans that were completed prior to September 30, 1990) that plan recommendations would save the landowners an average of $23 per acre per year (Maryland Dept. of Agriculture, 1990). This average savings may be high because most of the 750 plans were for farms using animal waste. Savings for farms using commercial fertilizer may be less.

In the South Dakota RCWP project, the total cost (1982–1991) for implementing fertilizer management on 46,571 acres was $50,109, or $1.08 per acre (USDA–ASCS, 1991a). In the Minnesota RCWP project, the average cost for fertilizer management for 1982–1988 was $20 per acre (Wall et al., 1989). Assuming a cost of $0.15 per pound of nitrogen, the savings in fertilizer cost due to improved nutrient management on Iowa corn was about $2.25 per acre as rates dropped from 145 pounds per acre in 1985 to about 130 pounds per acre in 1989 and 1990 (Iowa State University, 1991a).

USDA/NRCS *Comprehensive Nutrient Management Planning Technical Guidance*, December 1, 2000.

The goal of the NRCS *Comprehensive Nutrient Management Planning Technical Guidance* is to promote voluntary actions that will minimize water pollution from the production areas of animal feeding operations (AFOs) and the land application of manure and organic by-products. To accomplish this goal, NRCS envisions that AFOs will develop and implement technically sound, economically feasible, and site-specific Comprehensive Nutrient Management Plans (CNMP) using a conservation planning process.

The document explains that conservation planning is a natural resource problem-solving process, that integrates ecological (natural resource), economic, and production considerations meeting both the operator's objectives and the public's resource protection needs. This approach emphasizes identifying desired future conditions, improving natural resource management, minimizing conflict, and addressing problems and opportunities. The plan will help AFO owners and operators manage manure and organic by-products by combining conservation practices and management activities into a conservation system that, when implemented, will protect or improve water quality.

The guidance identifies six elements that must be considered when developing a CNMP. These elements include:

1. **Manure and Wastewater Handling and Storage**
2. **Land Treatment Practices**
3. **Nutrient Management**
4. **Record Keeping**
5. **Feed Management**
6. **Other Utilization Activities**

The specific criteria that each of these elements should address is presented in the guidance. The guidance also states that practices in CNMPs should meet requirements of NRCS Field Office Technical Guide conservation practice standards.

The technical guidance also provides information on the expertise required to prepare CNMPs. As a minimum, the three elements that address Manure and Wastewater Handling and Storage, Land Treatment Practices, and Nutrient Management must be developed by certified specialists. Because of the diversity and complexity of specific skills associated with each element of the CNMP, it is envisioned that most individuals will pursue "certification" for only one of the elements. Therefore, to develop a CNMP could require the interaction of three separate certified specialists, each addressing only one element. NRCS envisions that a certified conservation planner, assisting the AFO owner/operator, would facilitate the CNMP development process, with "certified specialists" developing the detailed specifics associated with the element they are certified to produce.

The CNMP Technical Guidance is available at *www.policy.nrcs.usda.gov/scripts/lpsis.dll/H/H_180_600_E5.htm*.