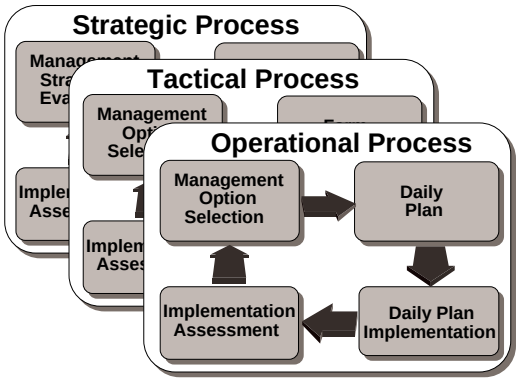
A nutrient management approach for Pennsylvania:
Nutrient management decision-making

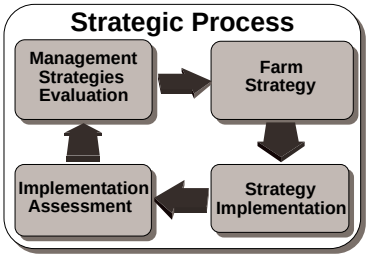
LEVELS OF NUTRIENT MANAGEMENT DECISION-MAKING

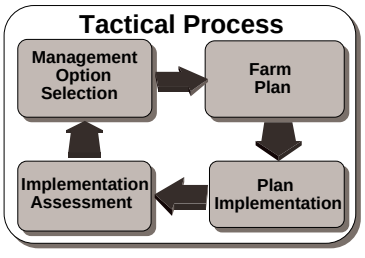
Effective nutrient management requires decisions to be made at several different levels of detail: strategic, tactical, and operational (Figure 1). Nutrient management activities for the different levels of management can range from the acceptance of a broadly-conceived environmental protection strategy to tracking individual loads of manure (Table 1). In many nonagricultural businesses the corresponding level of management would be the responsibility of several individuals, such as the chief executive officer, general manager, and operations supervisor. On farms, the strategic managers are often those who also plan and implement the tactical and operational activities.

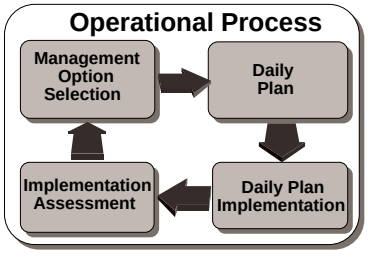
Because a single individual can be responsible for all management decisions on a farm, it is important to recognize whether the management considerations involved at a particular time are strategic goals or the details of very specific daily activities. Requirements for informed decisions and technical support will be different for each of the management levels. If assistance is needed at a strategic level, but information is provided that best fits the operational level, a successful strategic decision is unlikely. Considerable frustration for the farm manager, the technical support staff, and those who have expectations for the nutrient management outcomes may result instead.

Figure 1. Different levels of detail in nutrient management decision-making.









Strategic management

Strategic management is concerned with comprehensive planning for the success of the organization (Table 2). Strategic managers evaluate the surroundings in which the organization must succeed and formulate the general management approach. They promote the implementation of the strategy through the tactical and operational management levels, and assess the success of strategy implementation. Strategic management has a longer time-frame, and top management personnel, such as the chief executive officer and staff, establish the general organizational goals. The information used in strategic management is likely to be broad in scope and holistic in nature. A wide range of sources, each with a different type of related information, will generally be consulted by a manager in the process of strategic decision-making.

Generally the information required at this management level is more subjective than for the other management levels. It is not as accurate as that relied upon at the other levels because there are many uncertainties in the long time period and in the broad scope of the factors affecting the decisions. Examples of typical strategic decisions in nutrient management might be whether to expand livestock operations, or whether the emphasis of nutrient manage-

Table 1. Sample nutrient management activities at several management levels.

MANAGEMENT LEVEL	MANAGEMENT ACTIVITY	MANAGEMENT SUPPORT
Strategic	Managing farm so that water quality is maintained or improved benefits in improved water quality	Evaluating relative investments in production costs compared to
Tactical	Developing allocation plan for manure and supplemental fertilizer requirements	Testing soil and manure, calibrating manure spreader, assisting in calculations
Operational	Designating actual field to receive manure on a particular day	Recording spreading date, manure type, and amount applied

Table 2. General characteristics of the various management levels.

			Information					Characteristics		
Management level	Activity focus	Action period	User	Decision	Source	Scope	Time	Perspective	Accuracy	Character
Strategic	Planning	>5 Years	Top management	Goals	External	Very wide	Future	Holistic	Low	Subjective
Tactical	Plan/control	1 to 5 Years	↓	↓	↓	↓	↓	↓	↓	↓
Operational	Plan/control/ action	Daily to 12 months	Managers/ supervisors	Tasks	Internal	Narrow	Historic	Component	High	Objective

ment efforts on a farm should be to maximize the use of manure nutrients on the farm rather than to export manure from
the farm.

A rapid assessment of a farm operation using farm material flow as a basis for the classification can suggest the emphasis of the existing production management strategy of a farm. When based on the best information available, this assessment can be used to identify nutrient management assistance needs or to make specific decisions in the development of tactical plans.

Tactical management

Tactical management focuses on implementation. It is the management that determines how the strategic goals will be achieved. More emphasis is placed on specific information about farm characteristics, both for planning and evaluation at this management level (Table 2). The scope of the information is more focused on the farm-specific conditions than in strategic management. Development of a farm nutrient management plan to allocate the manure and to estimate the supplemental fertilizer requirements of all farm fields for a cropping season, or the period of a common crop rotation, is an example of an activity at the tactical level of management. The strategic goals to be met by the manure allocation and supplemental fertilizer use must be determined before the tactical plan is developed. Tactical management activities are often conducted by the farm manager with assistance from technical consultants who have the specialized expertise to assist the manager in meeting the goals set for the plan.

Most references to nutrient management for environmental protection generally deal with tactical management level issues or activities without recognizing the relationship of that level of management to the strategic farm management goals. Emphasis on programs and efforts to refine the tactical management process will not remedy contradictions between the strategic management goals and the expected farm performance. However, changes at the strategic level will certainly influence the outcomes of tactical management.

Operational management

Operational decision-making (Table 2) is an activity of the farm manager/supervisor that involves the direction and participation of farm labor in specific tasks. The farm operations manager is not only attuned to the tactical plan that reflects the farm strategy, but also to the particular field

conditions, labor situations, machinery status, and all the other factors that influence actual day-to-day operations. Based on the tactical plan and the current conditions, the operational manager/supervisor develops plans of action covering monthly to daily periods. An operational manager/supervisor must make quick decisions based on the most accurate information available about the very specific conditions under his or her control. Historic knowledge of specific farm components is often essential to effective operational management. Deciding if manure will be spread on a particular day and on which field it will be spread is an example of the activity at this level of management. Because the specific features of individual farm organization are so essential to good operational decision-making, off-farm information and assistance is likely to play a limited role in these decisions.

The tasks specified in the operational plan are done by the farm labor. These workers are in a good position to record the actual activities associated with implementation of the daily plan. Operational effectiveness may need to be assessed quickly or the information may be accumulated for a later evaluation. As an example of operational activities assessment, the actual nutrients supplied from animal manure, legume residual nitrogen, and/or fertilizer for a particular field can be compared to the planned supply. Discrepancies between the intentions and the actual performance may be corrected in the current growing season, such as by sidedressing applications of nitrogen to corn or topdressing alfalfa with applications of phosphorus and/or potassium, to make up a nutrient shortage. If implementation problems develop or questions about the assessment of operational effectiveness develop, off-farm assistance may be enlisted to resolve the problems.

Information describing the outcomes of the specific management operations can be used in making subsequent decisions at higher levels of management. For instance, a tactical plan may need to be revised if problems develop with implementing the plan at the operational level.

TACTICAL NUTRIENT MANAGEMENT DECISION-MAKING

The basic management process described here involves four activities: assessment, management option selection, management plan development, and plan implementation (Figure 2). These activities are connected within each management level to form an ongoing, repeating process. All the best plans in the world for achieving the most admirable goals will be meaningless if they are not implemented well. Assessment of implementation activities will provide the basis for options in the next round of management activities.

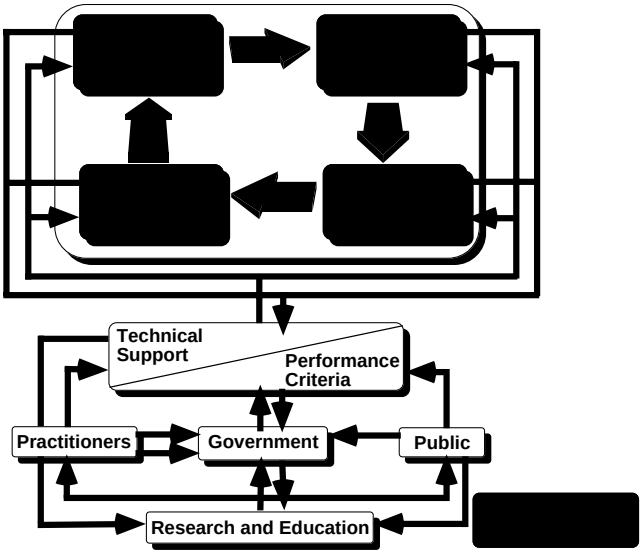
Since management at each level is related to the management at another, the farm organization will not function smoothly when the communications between management levels break down. The tactical level of management decision-making will be discussed in detail below. The tactical level has been selected for additional explanation because it is the most common level supported by off-farm technical management assistance (Table 2).

Nutrient management assessment

Implementation assessment is a technique to evaluate the outcome of a process, much as a thermostat senses the temperature in a room. Nutrient management assessment can be done at several levels of farm operations — individual fields, groups of fields, and whole farms. It can be done routinely with a substantial amount of detail to evaluate specific operations, or it could be done periodically according to more general guidelines in order to classify farms at a strategic management level. Farm classification can be the basis to identify appropriate management strategies, and different nutrient management assistance requirements for various groups of farms. The classification could serve as a starting point in the development of a tactical nutrient management plan for a cropping season. The decisions shaping the tactical nutrient management plan will be different on farms with abundant nutrients than those farms with deficiencies in nutrients.

Descriptions of actual field activities are used to measure the success of the tactical nutrient management plan for a particular farm. Such an assessment is commonly done on an annual time-frame. Nutrient applications from various sources to meet the nutrient management performance criteria for individual fields are prescribed in the plan. For instance, the number of loads of manure of a particular type to be applied is determined for a specific field as part of the plan. Actual farm activities related to nutrient supply and crop utilization in the fields are recorded as the plan is implemented. In the case of manure application, the actual number of loads of manure and the actual composition of the manure as spread should be recorded. The total nutrients actually supplied are compared to the planned amounts. Any discrepancies between planned and actual nutrients supplied would be investigated. For example, the ability to deliver manure to distant fields in a timely manner may be not be realistic based on

Figure 2. The tactical level of the nutrient management decision-making process.



the poor success of manure spreading activities during a particular year. The problem may have been due to unusual weather conditions that limited field work so the future plan to spread manure on the fields far away does not need to be changed. Or, if the problem was related to inadequate manure spreader size that required too many loads to be hauled in the limited time available, the decision in the next plan may be to use the manure on nearby fields and to rely on commercial fertilizer for the distant fields.

The outcomes of nutrient management assessments will rarely agree exactly with the nutrient management plans. Therefore, judgements must be made to determine how close the correspondence between the plan and the activities must be before some remedial action is required for the next repetition of the management process. The bottom line is that the actual activities, not the planned activities, determine nutrient management performance and the potential impact of the farm on the environment. Assessment is critical in evaluating the performance of the nutrient management process and in identifying the need for changes.

The appropriate physical and management level for a nutrient management assessment of a farm operation should be determined before information is collected. For example, if the target performance criterion is that the farm as a whole must be in balance, then field by field assessment of nutrient balance is unnecessary; gross information on nutrient inputs and outputs to the whole farm would be adequate. On the other hand, if the performance criterion requires each field on the farm to be in balance, detailed information on inputs and outputs from each individual field would be required for the assessment. Performance criteria are critical in determining the information to be collected and in indicating when change is necessary.

Management option selection

Management option selection is guided by the outcome of the nutrient management assessment, but the outcome must be put together with information from other farm management activities in order to develop effective management options.

Off-farm considerations must also be combined with on-farm activities to determine the appropriate action in the next repetition of the nutrient management process. Specific future nutrient management options for on-farm nutrient management will depend on the agreement between the plan and the implementation and the interests of those involved in the comparison.

Choosing appropriate management options may be difficult because the on-farm and off-farm stakeholders view them differently. From an environmental water quality protection perspective, it is generally better that the balance of nutrients (inputs-outputs) is negative. That is, more nutrients are removed from each management unit, such as a crop, a field or a farm, than are added. A negative balance is likely to indicate less potential nutrient losses to the environment than a highly positive balance. A negative balance will be interpreted differently from an agricultural production perspective. If nutrient supply does not keep pace with crop demand for nutrients, crop production can be limited. This may be undesirable for the farmer, and could even affect the consumers if crop production does not meet market demands. On the other hand, reactions to positive nutrient balance in the pathways managed by environmentalists and farmers are almost opposite to the concerns for negative balances. A positive balance will generally not hinder farm production, but it might result in negative environmental effects.

These differing perspectives among farmers, environmentalists, and perhaps even consumers, should be addressed at the strategic level of nutrient management. The decisions made at this level will influence the management options considered for the tactical nutrient management plans. As management options are evaluated, it may be necessary to revise performance criteria, identify more appropriate technical support, or promote changes in the nutrient management expectations.

The selection of prospective management options must be as broad as possible and include both on-farm and off-farm options in order to meet the performance criteria. On-farm options may be developed, for example, after identifying locations of positive balances within the farm. Additions of nutrients to a farm in feeds will need to be addressed differently than unrealistically high rates of fertilizer applications to cropland. Specific activities in the targeted management unit will need to be evaluated. If the specific management units with excess nutrients are identified, nutrient management improvements can be accurately targeted. Generic guidelines or lists of the “best” practices are not likely to adequately address the specific requirements of particular farms. There is a contradiction in delivering a general list of recommendations to address very specific problems. General, widely applicable information is much more appropriate to strategic management than to tactical management. Off-farm options to remedy nutrient imbalances might include cost sharing to redistribute any excess nutrients from farms, rather than to institute a best management practice to conserve nutrients most “efficiently.”

After the appropriate management options have been tailored to meet the revised performance criteria or to adjust farm operations to better meet the prevailing expectations, appropriate changes can be made to the tactical farm plan in preparation for the next repetition of nutrient management.

Nutrient management planning

Implementing nutrient management plans for crop production *and* environmental protection will be most successful if modifying the farmer’s current program to address the new concerns for the environment is the focus rather than coming up with something totally different. This is one reason why having a good assessment of the current strategy and/or on-going nutrient management activities is so important in choosing the management options around which the tactical nutrient management plan will be

developed.

The first activity in developing a tactical plan is collecting the necessary information. This includes an inventory of manure produced on the farm, nutrient analysis of the manure, characteristics of the manure handling system, soil test information for the farm fields, and farm management capabilities.

Next, the fields are prioritized for manure application. This is usually based on the characteristics of the crops to be grown on each field and their nutrient needs, the levels of nutrients already in the soil based on the soil tests, field characteristics such as soil type, slope, and proximity to water sources, and farmer specified management constraints such as land tenure or proximity to neighbors.

Once the fields have been prioritized, the inventory of manure nutrients is allocated to the fields in the priority order. The rate of manure planned for each field is based on not exceeding the amount needed by the crop for the priority nutrient. Usually these maximum rates are based on not exceeding the nitrogen requirements of this year's crop and/or the phosphorus requirements for all of the crops to be grown in the crop rotation. The actual planned rate should be equal to or less than the maximum and will be determined by the practical constraints of the farmer's management and equipment capabilities.

Finally, the need for additional nutrients in the form of fertilizer to meet the crop needs should be determined as the difference between the crop nutrient requirement and the planned nutrient application in the manure.

A computerized farm nutrient management worksheet is available to estimate the amount of manure produced by animal groups on farms, and to assist in the allocation of manure and fertilizers to fields based on their soil test recommendations and farmer priorities. The output from this computer-assisted worksheet is not a plan in itself. It simply organizes the basic information and does many of the calculations that are useful to the planner in developing the actual nutrient management plan for a farm.

The tactical planning process must be flexible and based on integrating the appropriate on-farm or off-farm management options as suggested by an assessment of the existing nutrient status on the farm. There can obviously be no one "nutrient management plan" that will fit all farms. In some cases, a field-based tactical nutrient management plan will not be adequate to meet the performance criteria set for the farm. In these cases, such as when a large proportion of the feed requirements of the livestock come from off the farm, the on-farm field-based plan may be a minor component of the total nutrient management program and the major emphasis of the nutrient management plan may be on transporting manure to other farms, treatment of manure, or marketing of manure.

Repetition is an essential feature of the nutrient management approach (Figure 1). Updates of the tactical farm nutrient management plan are based on the outcomes of the plan implementation assessment and the selection of appropriate options in response to the assessment outcomes. The options may be changes to existing practices or the implementation of new practices in order to better meet the goal of environmental protection. The performance criteria by which the effectiveness of the process is measured may be revised. The tactical plan will need to be updated on an annual basis as a minimum. However, nutrient management decisions at the operational level will be made routinely during the year as on-farm conditions change.

Plan implementation

Implementation of a farm nutrient management plan to protect the environment is an essential feature of the nutrient management process. A nutrient management plan for crop production and environmental protection cannot do either well unless it is properly implemented. Implementation of the planned nutrient management activities can be limited by a variety of controllable and uncontrollable factors. Planning and preparation apply equally well to nutrient management plan implementation as to other management activities. It does little good to have a sound nutrient management plan that calls for the application of particular rates of manure if the manure spreader is not calibrated before spreading starts or some alternative method to determine the rates of application is not in place.

Uncontrollable factors that reduce the effectiveness of nutrient management, such as weather conditions or unforeseen machinery problems, usually cannot be anticipated. However, an effective nutrient manager will be prepared with contingency plans for the difficulties created by these uncontrollable factors. These contingency plans will need to be as sensitive to environmental protection as is the primary plan. When operations are not going as anticipated, it may be tempting to put environmental considerations at a lower priority than getting the management job done. As experience is gained in managing nutrients to protect the environment, some of the hurdles that are encountered early in the adoption of the new management activities will be overcome and become less troublesome.

The sometimes contradictory messages that farmers receive from environmentalists and from many traditional agricultural interests may seem to be as uncontrollable for the individual nutrient manager as is the weather. If the economies of mass production are encouraged so that the concentration of animals in larger and larger operations is promoted while environmentalists hold the farmer responsible for managing the resulting manure in an environmentally sensitive way, conflicts between economic success and environmental protection may develop in the implementation of nutrient management plans.

Farm managers may require different kinds of assistance to implement nutrient management plans for environmental protection than has traditionally been provided for crop production. The consequences of management actions for the environment are often not as obvious as the effectiveness of new products that contribute to crop production.

Information about production and about other aspects of the farm operation may be required to adequately describe potential environmental impacts of the farm. Nutrient losses by leaching through the soil may be more sensitive to the overabundance of nutrients than is yield, and even economic returns, of field crop production.

Collecting and managing more and different information may require not only management assistance to determine the appropriate information to collect, it may require different types of assistance to collect the information and any necessary samples, and assistance in the management of the resulting information.

Since plant nutrients are part of almost every material that moves on a farm, information collection is likely to involve recording the relevant day-to-day activities that are a routine part of farming and organizing the information into a format to be used in an assessment of the activity performance. Materials move to, from, and within farms for various reasons, to meet animal feed requirements, to add fertilizer nutrients to fields, or to distribute manure on the cropland. If the nutrients are to be balanced for the farm, decisions must be made for which management unit (fields, livestock, farm) information will be collected and how that information will be used to determine if the nutrient management performance criteria are being met.

Information dealing with material movement that is part of the plan and for which performance criteria have been established must be collected in a reliable manner. The reliability of the information will depend both on the measurements to be made and the performance criteria to be met. If the criteria are general ranges, less information about the farm operation will be necessary than if the criteria are very closely specified. Further, more information will need to be collected if the next repetition of the nutrient management activity is expected to change the outcome significantly; less information will be needed if a simple improvement will be acceptable to all involved. Some criteria may be met in a following year, while achieving some may require several years.

Technical support

Practitioners provide the technical expertise to support all phases of decision-making in nutrient management (Figure 2). The technical assistance required will also be different for each participating farm depending upon the essentially unique situations that will be involved. Those who provide technical support for nutrient management are not likely to be required to do the same thing on every farm. This support must be flexible in order to meet the specific needs. Technical services to describe the physical movement of farm materials could include manure sampling, manure spreader calibration, and yield estimates. Other services may be more directly involved in management decision-making by providing recommendations.

Some technical assistance such as making recommendations, developing plans, or interpreting nutrient management performance assessments will require agronomic and management expertise on the part of the practitioner. Other field activities to collect information about nutrient management activities will require good communications skills and the ability to be in the field when the activities occur. Qualified technical assistance with different skills will be critical to the success of any nutrient management program to balance crop production *and* environmental protection.

Performance criteria

Performance criteria for each phase of the nutrient management process will provide guidelines for farm managers, the technical support practitioners, government agencies, and the public to measure the success of nutrient management efforts (Figure 2). Performance criteria are outcomes to be achieved through nutrient management, such as nutrient balance for certain management units of the farm operation. These clearly established outcomes can specify the intent of nutrient management to protect the environment, yet promote solutions to meet the environmental challenges and localized conditions faced by farmers.

Research and education

Research and education in nutrient management can contribute to nutrient management in many ways, although many of them are indirect (Figure 2). Both the delivery of technical support and the character of performance criteria may need to be modified if achieving farm performance expectations becomes difficult. An example of the possibilities in research for technical support could be the development of new tools to help implement the nutrient management plans or evaluate possible performance scenarios to create a stronger foundation for the performance criteria. Research on management options might include developing new treatment processes for manure or modifying cropping systems to better utilize manure nutrients. Biophysical and social science research may be essential to understand the problems that will be encountered. Government agencies should consider the latest research results as they develop nutrient management regulations and other activities affecting the future of agriculture. A primary objective of research in nutrient management could be to develop a wide variety of management options that farmers can integrate into improved nutrient management plans.

Unique educational programs in nutrient management will be critical in addressing the differing needs of the groups involved in nutrient management, from farmers to government officials to the general public. As farmers are informed of the environmental protection considerations and those become part of the management portfolio on their farms, they can be expected to include related performance criteria in their plans when it is feasible. Extensive educational programs will be needed to develop and maintain a solid base of public and private personnel to provide technical support for nutrient management. Nontraditional educational programs will be needed for those, such as government officials, who will be involved in developing legislation, performance criteria, programs such as manage-

ment incentives, or regulations.

Finally, the general public could learn about nutrient management through programs emphasizing insights into the nutrient management issues that have been gained by research. As the public develops a greater appreciation of the nutrient management process on farms and in agriculture, they may call upon public officials to enact appropriate legislation or they may call for modifications of the marketing of farm products so that they can purchase products that are produced on farms managed in particular environmentally-sensitive ways.

Participation and feedback

The nutrient management process does not occur in isolation. It will involve participation from field practitioners who provide technical support and the government agencies, and the public who will influence the performance criteria. Not only is there participation in the process, but the outcomes of the process can provide feedback for those involved (Figure 2). The feedback can indicate which approaches work well and which things do not. It can be a source of ideas for new research and education programs. It can also be a source of insight for government agencies and the public into how farm operations are really functioning. This information will provide a better basis for the formulation of performance criteria than speculation and even representative farm surveys.

SUMMARY

This fact sheet describes three management levels and the tactical approach to nutrient management decision-making as it has been developed in Pennsylvania. The management process described influences the movement of materials to, from, and within a farm and emphasizes the application of appropriate performance criteria for crop production *and* environmental quality.

This fact sheet is one of a set of three dealing with nutrient management. The other two are: Agronomy Facts 38-A, *Introduction to the Concepts,* and Agronomy Facts 38-B, *Plant Nutrient Stocks and Flows.* These fact sheets are available from the Publications Distribution Center, 112 Agricultural Administration Building, University Park, PA 16802-2602

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