FEBRUARY 1997 R.B. 96-13

DEVELOPING A FARM PLAN TO ADDRESS WATER QUALITY AND FARM BUSINESS OBJECTIVES: A FRAMEWORK FOR PLANNING

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ABSTRACT

This report describes a planning framework to help guide on-farm efforts that seek to address agriculture's potential to adversely affect water quality while achieving farm business objectives. Principles and concepts from modern management thought and economics underlie the framework. This report introduces the Whole Farm Planning and Implementation Process of the New York City Watershed Agricultural Program. The process embodies the planning framework and guides on-farm planning and implementation efforts in the New York City Watershed. Economic and management aspects of the process receive emphasis.

ACKNOWLEDGMENTS

This report resulted from the authors' involvement in the New York City Watershed Agricultural Program as part of Cornell University's Whole Farm Planning Team. The authors acknowledge the New York City Department of Environmental Protection for providing funding, and the Watershed Agricultural Council and Program Cooperators (See Appendix A) for their involvement in developing the Whole Farm Planning and Implementation Process described in the report.

The authors express appreciation to Professors John Brake and Nelson Bills, Department of Agricultural, Resource, and Managerial Economics at Cornell University, to Rob Halbohn, Jerry LeClar, and Alan White of the New York City Watershed Agricultural Program, to Edward Staehr, Skaneateles Lake Watershed Program, and to Rick Swenson, Natural Resources Conservation Service, for their helpful reviews of this report.

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INTRODUCTION

Society is increasingly looking to nonpoint sources[1] of water pollution for opportunities to obtain incremental improvements in water quality and/or to protect water supplies from future declines in quality.[2] As attention on pollution of water supplies from nonpoint sources increases, society is increasingly examining agriculture as a source of nonpoint source pollution. The relationships between agriculture and water quality, and approaches to address agriculture's responsibility are receiving increasing attention.

The potential to adversely affect water quality means that agricultural production practices can have consequences that go beyond the boundaries of the farm. Conflict arises between society's desire to protect public health by ensuring safe drinking water supplies and the farm manager's/owner's desire to achieve farm business objectives. Tension between the parties can follow. At the heart of the tension is the possible difference between the resource use (organization) that society prefers in order to provide a desired level of water quality protection and the manner in which the farmer currently organizes limited resources to achieve individual and farm business missions, objectives and goals.

Society has several approaches at its disposal to influence human activities, such as agriculture, that can degrade water quality. Approaches include: moral suasion and education; direct regulation; economic incentives; and research and development (Abler and Shortle). Although differing in method, each approach seeks to influence resource allocation in ways that achieve water quality objectives and goals enroute to protecting public health. Abler and Shortle describe two forms of direct regulation: design standards and performance standards. Design standards for agricultural sources involve regulations that dictate the way farm managers organize resources on the farm. The performance standard approach for agricultural sources involves establishing water quality objectives and goals. The performance standard approach provides farm managers with the opportunity to identify the allocation of resources that best achieves water quality and farm business objectives. Performance standards require and encourage individual initiative while the design standard approach requires monitoring for compliance.

Interest in addressing agriculture's potential to adversely affect water quality using approaches that emphasize voluntary participation, education, performance standards, cost sharing, and research and development exists (Watershed Agricultural Council, 1996; Skaneateles Lake Watershed Agricultural Program). Success of such efforts rests on many factors. A key factor is the ability to adequately define water quality objectives and goals. Success of such efforts also rests on the ability of owners/managers to successfully plan and implement changes in resource use that achieve water quality, economic and management objectives given available resources (on-farm and other). Other resources might include program resources designated for education, planning, incentives, and research and development. Allowing the farm owner/manager to realize and achieve

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[1] A nonpoint source is a diffuse source from which organic and inorganic materials enter surface and ground water. Effectively, any source not defined as a point source may be considered a nonpoint source. A point source is any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, concentrated animal feeding operation, or vessel, from which pollutants are or may be discharged (Porter, 1975: pp. 363 and 364). Examples of nonpoint sources include: construction sites; parking lots; other urban activities; and agriculture.

[2] Porter (1994a) discusses watershed protection efforts that seek to prevent pollution in watersheds that serve as municipal water supplies. Porter discusses protection efforts in relationship to treatment (filtration) that removes contaminants prior to consumption, but after contamination has occurred. Porter makes reference to the political, economic and scientific environments that will determine the relative roles watershed protection and treatment will assume in future efforts to ensure safe drinking water supplies.

individual and farm business missions, objectives and goals is especially critical. Allowing the farm owner/manager to satisfy wants and needs increases the likelihood that the farm manager will commit to and take ownership of the plan and its goals. The farm owner/manager will be more likely to successfully plan, implement, and monitor changes in resource use that achieve water quality objectives, thereby effecting change in water quality and/or the level of water quality protection.

Modern management thought, not surprisingly, provides valuable principles and concepts to guide efforts to address the problem of agriculture's potential to adversely affect water quality. One of the basic concepts is that management involves three functions: planning, implementation and control.[3] Of these three functions, planning is referred to as the primary function of management. A key to successful implementation is good planning. Thus, planning receives emphasis here.

The purpose of this report is to describe a planning framework that guides on-farm planning efforts that seek to address agriculture's potential to adversely affect water quality while achieving the individual and farm business missions, objectives and goals given available resources. Principles and concepts from management thought underlie the framework to increase the likelihood that objectives and goals are achieved en route to realizing the overall purpose. In this report, a background section provides context. A section that describes a planning framework follows the background section. This report then introduces a process developed around the framework. The process guides on-farm planning and implementation efforts in the New York City Watershed. Summary and conclusions close the report.

BACKGROUND

Agriculture's Potential to Adversely Affect Water Quality

Technical and management factors combine to underlie agriculture's potential to adversely affect water quality. Farmers employ nutrients in the forms of feeds, fertilizers and manures; pesticides; and other chemicals to produce marketable commodities. Also, dairy farms and other livestock farms often concentrate livestock in certain areas on farms. Livestock are potential sources of pathogens such as *Giardia* sp. and *Cryptosporidium parvum*. Also, livestock manures contain nutrients such as nitrogen and phosphorus. Depending upon a variety of conditions, runoff and subsurface movement of water have the potential to transport nutrients, pesticides, other chemicals and pathogens from the farm to water resources in amounts that may be unacceptable. Each is a potential pollutant and each may adversely affect water quality.

Pollutants in water supplies can adversely affect the health of downstream users of the water, people other than those directly involved in the production and consumption of the products from the farm -- a negative externality. An externality is an effect, a benefit or cost, of an action that accrues to someone other than the people involved in the action. Existence of a negative externality is not sufficient for inefficiency in resource use, or tension. Inefficiency and tension arise when the manager does not consider adverse effects on others when making resource allocation decisions.

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[3] Management is defined as a process that involves the coordination and integration of limited resources available to the business to achieve desired results through the efforts of oneself and other people. Management involves the following functions: planning, implementation (organizing, staffing, directing), and controlling (modification of PRO-DAIRY definitions of management (Hutt, Milligan, Kauffman, and Claypoole));

Therefore, the mission and objectives of the business underlie any inefficiency in resource use or tension.

Management reasons underlie the potential for agriculture to adversely affect water quality. Producers and consumers base their decisions to allocate limited resources among competing uses or choices upon marginal benefits and marginal costs. Pollution may impose costs on others than those who make production and consumption choices. A mechanism is seldom present by which producers and consumers are able to account for such costs in their decisions. The organization of resources that results from such decisions may not coincide with the organization desired by society. For example, a farmer who bases manure application decisions only upon the on-farm benefits and costs may apply manure in a manner that is inconsistent with how manure would be applied if he or she considered the off-farm impacts on water quality and public health, the costs to society.

Another useful way to examine the factors that underlie agriculture's potential to adversely affect water quality is in terms of unset, unmet, or conflicting objectives or goals. In agricultural production, farm managers/owners may not explicitly, or even implicitly consider water quality or other environmental objectives in their planning. The farm manager/owner who does not set such objectives will likely adopt fewer practices with the potential to enhance water quality than the farm manager/owner that sets water quality objectives.

Setting water quality objectives may not be enough. Farmers would likely have difficulty achieving some water quality objectives and goals important to society. Farmers are unlikely to have access to the workable approaches needed to consider water quality effects in their decisions and achieve water quality objectives and goals. In contrast, farmers have had success in using workable approaches that embody knowledge and science of crop and animal production to achieve farm business objectives.

Finally, suppose a farm manager does set water quality objectives and goals. Suppose too that the farmer has the necessary information to evaluate alternatives with respect to the water quality objectives and goals. Even under these conditions the owner/manager would likely at some point confront the problem that the water quality objectives or goals conflict with the individual and farm business missions, objectives and goals. Tradeoffs would exist. In the absence of regulations or incentives that place importance on water quality objectives and goals, the owner/manager would likely place greater emphasis on achieving individual and farm business missions, objectives and goals than on achieving water quality objectives and goals.

For example, suppose a farmer considers eliminating winter spreading of manure to achieve a water quality objective. The farmer may face a conflict between achieving that water quality objective by eliminating winter spreading and achieving an objective to increase profitability. When the farmer considers alternatives to daily spreading such as manure storage, the potential to decrease profitability becomes important. Expected benefits, such as reduced fertilizer purchases, may not outweigh expected costs, especially when one considers all costs including greater ownership costs associated with capital items such as a manure storage facility.

Achieving a water quality objective by eliminating winter spreading may also conflict with objectives that relate to the availability of resources. For example, the initial capital required to place the storage into use on the farm may not be compatible with the farm's access to owned or borrowed capital resources.

Addressing Agriculture's Potential to Adversely Affect Water Quality: An Important Role for Modern Management Thought

The overall purpose of efforts that seek to address agriculture's potential to adversely affect water quality can be summarized as follows: to attain an organization of available resources that best achieves water quality objectives and goals. Achievement of water quality objectives and goals leads to the realization of a desired level of water quality and public health protection. Keys to the success of such efforts include: identifying issues surrounding the current allocation of resources given objectives and goals; and effecting changes in the ways farmers manage available resources. The latter lead to the desired (needed) effects on water quality.

Efforts differ with respect to the approach preferred to effect changes in the ways farmers manage available resources. The performance standard approach is one approach whose attractiveness is being discussed with respect to agriculture. The approach would provide the farm owner/manager with the opportunity to identify the allocation of limited resources that best achieves water quality objectives, while allowing for the realization and achievement of individual and farm business missions and objectives.

Regarding nonpoint sources of water pollution and current thinking on strategies to manage nonpoint sources of water pollution, Porter writes

> "Since nonpoint sources have become a concern to water quality, only limited attempts have been made to relate their management directly to water quality criteria and objectives. Under previous versions of the Clean Water Act, the primary strategy has been to develop Best Management Practices (BMPs). It was assumed that application of BMPs either prevented pollution or decreased the pollutant load leaving the farm if BMPs constituted improved management of nonpoint sources. Therefore the BMPs assist in improving water quality.
>
> It is now considered insufficient to simply decrease the pollutant load. Increased priority is accorded to pollution prevention rather than simply reduction. Whole Farm Planning is intended to prevent pollution. Therefore, methods have been explored by which BMPs can be related directly to water quality objectives. These methods are novel and their development and testing depends in part upon field validation." (Porter, 1994b, p.1)

These comments suggest the need for methods that emphasize achieving water quality objectives and goals. The emphasis on achieving water quality objectives and goals is consistent with the performance standard approach to address agriculture's potential to adversely affect water quality.

Consider the following definition of management:

> Management is defined as a process that involves the coordination and integration of limited resources available to the business to achieve desired results through the efforts of oneself and other people. Management involves the following functions: planning, implementation (organizing, staffing, directing), and controlling (modification of PRO-DAIRY definitions of management (Hutt, Milligan, Kauffman, and Claypoole));

Consider the overall purpose that seemingly should guide efforts to address agriculture's potential to adversely affect water quality and current thinking on strategies to manage nonpoint sources of water pollution. Management thought, not surprisingly, provides valuable principles and concepts that guide and focus efforts to address agriculture's potential to adversely affect water quality.

A FRAMEWORK FOR PLANNING

Principles and Concepts from Management Thought

Planning, perhaps the most fundamental and important function of management, is the ongoing process of developing the elements of a plan enroute to achieving rewarding, productive ends. A plan is an outline or scheme that describes how to organize limited land, labor and capital resources among competing uses to realize the mission, objectives and goals of a business or organization. A plan has the following elements: mission, objectives, goals, tactics. Problem solving is an important part of the planning process whereby the planner develops tactics given objectives and goals.

Mission

If you don't know where you are going, any road will get you there.

A mission statement summarizes why the business or organization exists. A mission statement reflects the personally held values of the owner and ideally others affected by the success or failure of the organization. A mission statement also describes what products or services the business will market. Establishing a mission statement provides the foundation for the planning process. However, the value of a mission statement to a business involves much more. The mission statement establishes the frame of reference for making decisions -- all decisions that relate to the planning, implementation and control functions of management. To successfully assume this greater role, a mission statement must contain principles that everyone participates in developing. Too, everyone must agree that the principles included in the mission statement will govern his or her actions. The mission statement must reflect the emotional buy-in of all stakeholders (Covey). This view of the mission's role has implications for who should participate in the development of the mission statement.

The following discussion draws heavily on Stephen Covey's bestseller The Seven Habits of Highly Effective People and the material for the three day training based on the book.[4]

Everything we do is created twice: once in the planning stage; once in the implementation stage. Perhaps building a structure is the simplest illustration of the two creations: the blueprints are the planning stage (first creation); construction is the implementation (second creation). The structure that is built is only as good as the blueprints. The blueprints, however, are only effective in portraying the structure the planner had in mind when they accurately portray an explicit visualization by that planner. When building a house, the blueprints are much more likely to result in a satisfied homeowner when they portray a family dream house than when they represent a house with little forethought or vision. The blueprint and the final structure are more likely to result in a

[4] The seven habits of highly effective people: A video based leadership development course. 1990. The Covey Leadership Center.

satisfied homeowner when the family said "I want to build our dream house" than when they said "I want to build a house" (Table 1).

Table 1.

VISUALIZATION, PLANNING, AND IMPLEMENTATION

Visualization	Planning	Implementation
Dream Home	Blueprints	Construction
Personal Mission	Life's plan	Living life
Organizational mission	Business planning	Operations

Covey argues that effectively completing the first plan means beginning with the "End in Mind." Examples of keeping the end in mind include the dream house, the athlete determined to participate in the Olympics, or local volunteer group committed to raising the money to fulfill their dream.

When it comes to our personal lives, the visualization is best represented by a personal mission statement. Development of this statement requires searching for ones principles and values. This mission statement must be based on what it is we want to accomplish in our lives. The statement then becomes the basis of ones life's plans and of living ones life (Table 1).

Stephen Covey in his new book First Things First includes the following six items as characteristics of an empowering mission statement (Covey, Merrill, and Merrill, 1994; P.222). For each characteristic comments are added to tie it to on-farm planning:

- "focuses on contributions, or worthwhile purposes that create a collective deep burning 'Yes'." The statement should provide a focus to rally around. It is written to reflect peoples feelings and values; it is not a literary piece for others to read.

- "comes from the bowels of the organization, not from Mount Olympus." Whether involved in the development or not, everyone involved in the farm operation must feel they are an important part of attaining the mission. A mission is not something that is inflicted upon people.

- "is based on timeless principles." The mission must be a "compass" that guides the organization through good times and bad.

- "contains both vision and principle-based values." Elsewhere, Covey describes this as containing both ends and means with the vision focusing on the ends or outcomes. The mission then, also, contains means including the values (hard work, honesty, integrity, enjoyment, etc.) critical to reaching the ends.

- "address the needs of all stakeholders." A stakeholder is anyone impacted by the success or failure of the organization. Traditional stakeholders for a farm would include owners and their families, employees, suppliers of inputs, and buyers of products. Today, we are recognizing neighbors, downstream inhabitants, residents of local communities, and society as stakeholders.

- "addresses all four needs and capacities." The four needs and capacities are to live, to love, to learn, and to leave a legacy. They reflect the physical, social, psychological, and spiritual dimensions of our lives.

Any planning effort should strive to develop mission statements that possess these characteristics.

Objectives and Goals

Following the development of the mission statement, planning efforts focus on establishing objectives. Objectives are general, observable, challenging and untimed descriptions of the farm business. Objectives outline what the owner/operator wants the business to look like in the future. The mission becomes realized through the achievement of recorded objectives by oneself and other people. For example, in support of the farm's mission, two objectives could be: "achieve excellent milk production per cow " and "breed and sell registered animals." By achieving these two objectives, the farm's mission of producing and marketing high quality milk will be partially attained. Objectives are the aim given to the mission or the "big picture."

Seeing "The Big Picture" does not replace the need for more specific goals for each job. Goals are defined as being **S**pecific, **M**easurable, **A**ttainable, **R**ewarding, and **T**imed (**SMART**) statements of what is to be done en route to achieving an objective. Goals include a specific outcome, a monitoring system for control, and reward for its completion. Goals are stated in quantitative terms such as pounds, miles, or scores and provide motivation, organization and measures of progress. Frequently, the goal is of little value in itself, but it is important in supporting the achievement of objectives and providing incentives for activities that are themselves of great value. In sports, of what importance is it to get a ball in a basket or a hockey puck in a net? The answer, of course, is to get points in order to win the game! The goal makes the objective more meaningful and tangible. An example of a goal is to reduce somatic cell count to 250,000 by December 31. Accomplishing this goal will help to achieve the objective of increasing milk production.

The systematic setting of objectives and goals facilitates rational and systematic planning, because you know what you are trying to achieve. Not setting objectives and/or goals can continually result in a person responding to all the urgent tasks, leaving no additional time for those important activities that are not urgent. Routinely responding to all urgent matters is effective in emergency situations but leaves no time for the accomplishments of planned activities in support of both objectives and goals. This might explain why not setting objectives/goals is preferred by people who do not feel in control of their business.

The ways in which a business or organization uses objectives and goals influence their success. Objectives are used to plan, coordinate, and motivate individuals so that related activities can be synchronized. Objectives must define why activities are being done and they must be understood by everyone involved in attaining that objective. Goals must reflect upon the objective and they must be measurable. Evaluation becomes easier when set standards are available to measure productivity. Therefore, objectives and goals require and demand responsibility and accountability by both employee and employer.

Problem Solving

Problem solving is an important part of the planning process. A systematic approach to problem solving is critical to successful planning. Hutt, Milligan, Kauffman, and Claypoole suggest an approach to problem solving that involves forming answers to specific questions (Table 2).

Table 2.

AN APPROACH TO PROBLEM SOLVING

Step	Question to Answer
1. Problem Identification	What is the problem in terms of unmet, unset, and/or conflicting objectives?
2. Problem Diagnosis	What are the causes of the problem? What technical and management reasons underlie the problem?
3. Generating Alternatives	What are the possible solutions to the problem?
4. Decision Making	What is the best solution to the problem?
5. Tactical Planning	What action is to be taken?

Tactics

Tactics are precise, individually itemized plans for action. After completing decision making, the selected changes in resource allocation, proposed changes in the business, are known. However, the specific actions to be taken to actually make the changes are not yet specified. As an analogy, think about going on vacation. The selection of best alternatives is analogous to the decision of where to go on vacation. Once you have decided where to go, a major decision has been made, but the details of methods of transportation, route, reservations, and budgets among others that are necessary for a successful, relaxing vacation remain.

Tactical planning answers the question, "What actions are to be taken to implement the selected alternatives?" The tactical plan translates the decisions made in formulating the best alternatives into actions to be taken. Completing and writing out tactical plans help the manager clearly define the actions and tasks to be completed to accomplish the stated goals. In the process of writing a plan the planner defines more specific goals. In addition, the process of writing a plan may cause the manager to address items that might have been overlooked without going through the process.

Detailed tactical plans to achieve **SMART** goals are keys to successful implementation of the best alternatives. Tactical plans increase the likelihood that best alternatives will be successfully implemented. A format for tactical plans, examples and suggestions for use follow.

Tactical Plan Format

Tactical plans answer the following questions:

- What task is to be done?
- Who is responsible for doing it?
- Where will the task be done?
- How will it be done?
- When will it be accomplished?

A tactical plan format that has been used extensively in the PRO-DAIRY Program appears in Figure 1 (Hutt, Milligan, Kauffman and Claypoole). Note that the columns are used to answer the questions listed above.

Example Tactical Plan

Figure 1 contains a tactical plan for meeting the following dairy cattle feeding goal: to have cows reaching 150 days in milk average a body condition score of 3. Note the very specific nature of the answers that are included in the tactical plan.

Suggestions for Use

Suggestions for the development of tactical plans follow. These suggestions come from those actually involved in working with farmers to develop tactical plans.

1. Tactical plans are a tremendous attribute to actually achieving water quality goals. Because farmers are unaccustomed to considering water quality goals, tactical plans are even more crucial. Without these plans the whole farm plans could get lost in the urgency of day to day activity.

2. The items in a good tactical plan are so specific and simple that they often appear trivial at first. Do not let this reduce the importance of the tactical plan. Simple tactics executed when planned are the secret to successful goal achievement.

3. Farmers may resist writing down these tactics. Do not be tempted by their arguments that they do not need to write the plan out.

4. Many of the items essentially constitute a checklist with dates.

5. Many of the items on the tactical plan can be included in TO DO lists used by the farmer.

Figure 1.

TACTICAL PLAN FORMAT AND EXAMPLE

Goal to be actualized: *To have cows reaching 150 days in milk average a body condition score of 3 by March 1*

What task or activity is to be done?	Who is responsible?	How and/or where should the task be done?	When to perform task or activity (deadline, frequency, under what conditions)?
Take samples of all forages for testing	*Carl*	*Mail samples or give to DHI supervisor*	*Every 3rd Tuesday of the month*
Choose feed consultant/ nutritionist	*Carl & Sarah*	*Interview consultants and check references*	*By November 1, 1989*
Investigate costs and availability of alternative feedstuffs	*Sarah*	*Check prices at local mills and in "Feedstuffs" magazine*	*Before monthly meeting with nutritionist*
Balance ration	*Nutritionist*	*In his/her office; by use of computer program*	*1st of every month*
Meet with Bill and Sarah to make adjustments to feeding program		*Our kitchen*	*After breakfast on the 2nd of every month*
Inventory forages	*Bill*		*Every three months at beginning of season; every month as supplies dwindle*

Planning Framework

The planning framework below embodies principles and concepts from management thought. Using this framework as a guide for on-farm planning efforts results in the formulation of plans that have desired characteristics.

Planning framework

- Develop a mission statement.
- Identify objectives and goals (for example, farm business, individual, water quality and other environmental objectives and goals, among others).
- Identify and define problems as unset, unmet and/or conflicting objectives and/or goals.
- Determine the underlying causes of problems (diagnose problems).
- Generate alternatives, possible solutions to problems.
- Select the best alternative (decision making)
  - * develop criteria for evaluating alternatives;
  - * rate each alternative on each criterion;
  - * compare the alternatives based upon the ratings each received;
  - * rank the alternatives;
  - * choose the best alternative, or a combination of those that are highly ranked.
- Develop tactical plans.

Specific efforts to address agriculture's potential to adversely affect water quality, for example, watershed protection and management efforts, may modify and build upon the framework to develop planning processes that fulfill the programs' overall purposes, objectives and goals given available resources. The remainder of this publication focuses on a specific watershed protection and management effort, specifically the New York City Watershed Agricultural Program, to illustrate application of the planning framework.

THE NEW YORK CITY WATERSHED AGRICULTURAL PROGRAM'S WHOLE FARM PLANNING EFFORT

New York City Watershed Agricultural Program

Human activities often degrade the quality of water resources. Various efforts at the federal, state and local levels seek to ensure a high quality source of drinking water for consumers. At the federal level, the common purpose of the Safe Drinking Water Act (SDWA), its Amendments, and the Surface Water Treatment Rule (SWTR), is to protect public health. The policies seek to achieve a level of water quality that is acceptable to society. These regulations mandate minimum allowable levels of bacteria, viruses, and the protozoan *Giardia* in drinking waters.

Under the SDWA, all public water systems that draw from surface sources must filter their water or meet certain criteria established by the SWTR. If the purveyor demonstrates that criteria established by the SWTR are met, then the Environmental Protection Agency (EPA), or the enforcement authority to which the EPA has designated primary reponsibility for enforcement, may grant an avoidance of filtration. To meet the filtration avoidance criteria of the SWTR a public water system must demonstrate: 1) that their source water meets federal and state raw water standards; 2)

that adequate disinfection is in place; and 3) that an adequate watershed protection program that reduces the risk of waterborne disease can be implemented.

Three systems, the Catskill, the Delaware, and the Croton, comprise the water supply system for New York City. The entire system for New York City covers over 1,900 square miles and falls within a radius of about 125 miles of New York City. The system supplies drinking water to New York City residents, daily commuters and visitors to the city, as well as to some 60 communities in the watershed. As a public water system that draws from surface water sources, the New York City water supply system must either meet the filtration avoidance criteria established by the SWTR or implement a filtration system for its water.

New York City will filter the water produced from the Croton system. Filtration of the water produced in the Catskill and Delaware systems would require approximately $5.0 billion in construction costs, and approximately $300 million in annual operating costs (Porter, 1994a). In November 1991 the New York City Department of Environmental Protection (NYCDEP), seeking to avoid filtration and its costs in the Catskill and the Delaware systems, submitted an application for filtration avoidance for the two systems. As a precursor to this attempt to avoid filtration, the NYCDEP in September 1990 issued a Discussion Draft of revisions to its watershed regulations, under New York State Public Health Law Article 11 and New York City Administrative Code Sec. 24-302. The most recent amendments to the regulations date back to 1953. The stated purpose of the Discussion Draft was to solicit input on approaches to meet the City's overall objective of preventing degradation of the sources of its water supply. This stated purpose relates to the filtration avoidance criteria. The water supplier must demonstrate that an adequate watershed protection program that reduces the risk of waterborne disease can be implemented.

Proposed watershed wide regulations related to agriculture included: prohibiting the application of manure and fertilizer within "limiting distances" from watercourses; controlling the runoff from pastures; and prohibiting the discharge of contaminants from barnyards. (NYCDEP, 1990). Agricultural interests in the watershed responded unfavorably to the proposed regulations. The agricultural community believed that the proposed regulations threatened the continued economic viability of farms in the watershed -- especially, dairy and livestock farms. The likelihood of local cooperation under the regulatory approach appeared small. Without local cooperation, successful implementation and enforcement of the proposed regulations would be threatened. Criteria related to the watershed protection requirement aspects of the avoidance criteria would likely not be met.

Instead of taking a strictly regulatory approach to prevent degradation of the sources of its water supply from agriculture, New York City entered into partnership with the watershed agricultural community. The partnership, the New York City Watershed Agricultural Program, seeks a locally developed and administered approach that protects water quality from watershed activities that may have an adverse impact on the quality of drinking water supplied from the watershed, while maintaining or enhancing economic competitiveness and viability in the watershed.

On January 19, 1993, the EPA issued its Determination granting filtration avoidance until a further determination was made or until the City failed to meet the Determination's conditions for avoidance. The EPA limited the duration of their Determination to one year or not later than December 31, 1993. At that time the EPA determined that until a further determination was made or until December 15, 1996, whichever was earlier, NYC could avoid filtration of its Catskill and Delaware water supplies. The conditions of the determination focus on further enhancing the level

of control over activities in the watershed that may adversely affect microbiological water quality. Recently, the EPA issued an Interim Filtration Avoidance Determination until April 15, 1997. The New York City Watershed Agricultural Program with its Whole Farm Planning component is an important element of a comprehensive watershed protection effort that emphasizes management of activities in the watershed that may adversely affect water quality. The New York City Watershed Agricultural Program seeks to address potential contamination from agricultural activities, only one of several possible sources of pollution.

The Watershed Agricultural Council (WAC) and New York City are cooperating to address the potential for agriculture to affect water quality in the New York City Watershed. To help direct the program the Watershed Agricultural Council provides the mission and objectives that appear below.

The New York City Watershed Agricultural Program

Program Mission:

To assist the agricultural community in adopting operational and management techniques that environmentally protect water quality as well as enhance economic competitiveness and viability. The project will champion a Whole Farm Planning process that strengthens working relationships between landowner, New York City, local, state and federal government, and the agriculture-support infrastructure.

Primary Objectives:

Allow the New York City water supply to continually meet water quality protection policies of New York State, City and Federal law.

Promote improved understanding of impacts that innovative, practical, field-tested solutions to individual farm situations have on water quality.

Encourage a high level of voluntary project participation by demonstrating, promoting, and educating producers on the economic and environmental benefits of Whole Farm Planning.

Advance the reality that a vibrant agricultural economy of well-managed farms is preferred and compatible to maintaining and protecting water quality in the watershed.

Foster community pride, enthusiasm, and empowerment through local leadership and involvement in such a nationally-recognized, innovative, cooperative approach to a highly complex environmental situation.

Identify and develop farmland retention incentives that recognize the benefits of a strong agricultural base to the local economy and the watershed communities.

Adopted by the Watershed Agricultural Council on October 26, 1993

To achieve the above primary objectives on the way to realizing the program's mission, program participants identified environmental objectives related to water quality, soil, other water, air, plant, and animal resources. The objectives provide overall guidance and focus to the planning efforts.

New York City Watershed Agricultural Program participants identified the following water quality objectives to facilitate rational and systematic planning. For each general pollutant category used in the Watershed Agricultural Program, a general statement of objective begins to describe what a whole farm plan expects to achieve from a water quality standpoint. For example, consider the pollutant category of pathogens. Statement "A" below describes an overall water quality objective for pathogens *Giardia* sp. and *Cryptosporidium parvum*. For each general pollutant category additional statements that serve as sub-objectives identify three "barriers" affecting a farm's impacts on water quality. (Statements that serve as sub-objectives are statements that help to further define objectives, but do not possess the desired characteristics of goals.) Sub-objective (1) addresses management practices that control movement of pollutants directly into a watercourse, such as livestock stream crossings. Sub-objective (2) addresses management practices that control pollutant transport from the farm, such as manure spreading on hydrologically sensitive areas. Sub-objective (3) targets the ultimate pollutant source, such as storage of pesticides; for some objectives it addresses specific items of concern (a through c).

Water quality objectives:

A: Safeguard water quality from pathogen contamination.
- 1. Reduce the risk of pathogen movement into watercourse.
- 2. Reduce the risk of pathogen transport from farm facilities.
- 3a. Reduce the risk of parasite infection in dairy animals.
- 3b. Reduce the risk of parasite transfer from one animal to another.

B: Safeguard water quality from nutrient contamination.
- 1. Reduce the risk of nutrient movement into watercourse.
- 2. Reduce the risk of nutrient transport from farm facilities.
- 3a. Reduce the risk of excess fertilizer application.
- 3b. Reduce the risk of excess manure application.

C: Safeguard water quality from pesticide contamination.
- 1. Reduce the risk of pesticide movement into watercourse.
- 2. Reduce the risk of pesticide transport from farm facilities.
- 3a. Reduce the risk of excess pesticide application.
- 3b. Minimize the need for pesticides.

D: Safeguard water quality from sediment pollution.
- 1. Reduce the risk of sediment movement into watercourse.
- 2. Reduce the volume of runoff from the farm.
- 3. Reduce the risk of erosion from hydrologically sensitive areas.

E: Safeguard water quality form other pollutants.
- 1. Reduce the risk of pollutant movement into watercourse.
- 2. Reduce the risk of pollutant transport from farm facilities.
- 3a. Reduce the risk of septic system failure.
- 3b. Reduce the risk of leakage from petroleum storage tanks.
- 3c. Reduce the risk of leakage from silage storage facilities.

In the New York City Watershed Agricultural Program's Whole Farm Planning Effort, quality criteria for soil, other water, air, plant and animal resources are other objectives that guide planning. (United States Department of Agriculture, Natural Resources Conservation Service, 1993a). Quality criteria provide planners with general descriptions of desired conditions for environmental concerns related to soil, water, air, plant and animal resources. These quality criteria establish the minimum condition required to provide both resource protection and prevent degradation. A resource condition at a level below a minimum quality criterion for that resource implies a problem. The use of the quality criteria will be consistent with federal, state, and local laws and regulations, and will further meet the performance standards of practices employed to treat the resource problem(s).

Whole Farm Planning

In the New York City Watershed Agricultural Program, the charge to farm owners and/or managers, and watershed whole farm planning staff in Phase II of the program is to "Complete a whole farm plan that solves the top priority environmental problems and includes funding to ensure that the present level of profitability is at least maintained" (Watershed Agricultural Council).[5] In the New York City Watershed Agricultural Program, the planning framework described earlier in this publication, the principles and concepts from management thought embodied in the framework and the NRCS planning procedure underlie the development of whole farm plans (New York City Waterhsed Agricultural Program, 1994b; USDA, NRCS, 1993a). Financial resources from New York City fund the planning efforts and the implementation of water quality improvements that seek to protect surface waters in the watershed from potential sources of agricultural pollution. The program also can allocate financial resources to participating farmers when implementation of a whole farm plan has the potential to adversely affect the business' level of profitability.

The development of a whole farm plan in the New York City Watershed Agricultural Program gives specific consideration to aspects of the farm business mission that relate to the environment, and to environmental objectives and goals. The program places special emphasis on water quality. Characteristics of the program's whole farm planning effort that make it the choice for addressing the overall purpose of the program include: the emphasis on establishing a mission, objectives and goals to guide plan formulation; and its integrated approach to comprehensive use of farm resources based upon objectives. If objectives and/or goals are significantly modified from the present ones, then an integrated and comprehensive reexamination of the organization of farm resources among competing uses based upon the new set of objectives and goals is preferable. This is the case for this program where water quality, and other environmental objectives and goals receive emphasis. Whole farm planning seeks an organization of resources that best meets objectives. This characteristic distinguishes whole farm planning from other approaches that emphasize the presence or absence of standard practices.

The following problem statement helps to summarize the task faced by the farm owner/manager and watershed planning staff when developing whole farm plans in the New York City Watershed Agricultural Program.

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[5] Phase II of the New York City Watershed Agricultural Program began in October of 1994. Phase II of the program emphasizes the development of whole farm plans, implementation of proposed changes in farm businesses and follow-up on farms in the watershed. Farm owner/managers sign up to participate in the program. A pilot or demonstration phase on ten farms in the watershed that began in the fall of 1992, Phase I, preceded Phase II of the program.

The purpose of the whole farm planning effort is to formulate a plan that solves the priority environmental issues for the farm (those related to water quality, soil, other water, air, plant and animal resources with an emphasis on water quality), while minimizing the funding required to implement the plan, such that:

1. the plan includes funding to ensure that the present level of profitability is at least maintained (funding compensates for any expected negative changes in profitability associated with the plan);
2. the plan is compatible with the individual and farm business missions, objectives and goals held by the farm owner/manager, and quality criteria for soil, water, air, plant and animal resources;
3. the plan is feasible given the farm resources available and the level of funding resources for water quality improvements specified for the farm.

Various program policies also guide the development and implementation of whole farm plans (Watershed Agricultural Council, 1994).

PLANNING FRAMEWORK APPLIED -- THE WHOLE FARM PLANNING AND IMPLEMENTATION PROCESS OF THE NEW YORK CITY WATERSHED AGRICULTURAL PROGRAM

To help guide and focus the development and successful implementation of whole farm plans in Phase II of the New York City Watershed Program, New York City Watershed Agricultural Program cooperators developed, and the Watershed Agricultural Council adopted, "A Whole Farm Planning and Implementation Process."[6] (For a list of cooperators involved in Phase I of the program please see Appendix A.) To develop the process, program cooperators drew from: 1) the planning framework described earlier in this publication; 2) a process developed to address water quality issues (New York City Watershed Agricultural Program, 1994b); and 3) the NRCS planning procedure (USDA, NRCS, 1993a). The steps listed below represent one element of the process. The other element consists of the methods that support the completion of each step. The underlying methods consist of elements of pathogen, nutrient, animal, crop, pesticide, water resources and farm business management, among others. All combine to support the process. (See New York City Watershed Agricultural Program, 1994c.)

[6] The planning and implementation process serves as a guide to focus efforts. In Phase II of the program, the process evolves based upon: the experiences of farmers and watershed planning staff members as they develop whole farm plans; research designed to support the whole farm planning effort; and changes in program policies and arrangements.

Whole Farm Planning and Implementation Process Steps

Step 1: Interact with farm managers to identify the farm mission and objectives for resource and business management, and to document the farm business plan.

Step 2: Inventory and analyze water, soil, air, plant and animal resource information to identify resource issues, concerns, for this farm.

Step 3: Determine the priority water quality issues for this farm taking into account New York City watershed priorities and the water quality issues identified for this farm in step 2.

Step 4: Identify alternative practices that: address the priority water quality issues from step 3 and the soil, other water, air, plant and animal concerns from step 2; and are compatible with the mission and objectives for the farm.

Step 5: Determine the expected water quality, soil, other water, air, plant and animal effects of the alternative practices.

Step 6: Identify adequate alternatives which satisfy the program's water quality criteria, and soil, other water, air, plant and animal quality criteria.

Step 7: Quantify the economic and management effects of adequate alternative practices.

Step 8: Select and integrate the practices to be included in the recommended whole farm plan, and submit to the Soil and Water Conservation Districts for technical approval and to the Watershed Agricultural Council for final approval.

Step 9: Develop tactical and control plans to insure successful implementation of the approved whole farm plan.

Step 10: Implement the plan.

Step 11: Assist, monitor and evaluate implementation and progress toward water quality, soil, other water, air, plant, animal, economic and management goals; and the farm mission and objectives.

Watershed Agricultural Council, December 1994.

The planning framework described earlier underlies the planning and implementation process. Table 3 depicts the relationships between the two.

Table 3 .
RELATIONSHIPS BETWEEN THE WATERSHED AGRICULTURAL PROGRAM'S APPROACH TO WHOLE FARM PLANNING AND THE PLANNING FRAMEWORK

WAC Approach to WFP	Planning framework
Step 1: Interact with farm managers to identify the farm mission and objectives for resource and business management, and to document the farm business plan.	Develop a mission statement. Identify objectives and goals (for example, farm business, individual and environmental among others).
Step 2: Inventory and analyze water, soil, air, plant and animal resource information to identify resource issues, concerns, for this farm.	Identify and define problems as unset, unmet and/or conflicting objectives and/or goals.
Step 3: Determine the priority water quality issues for this farm taking into account New York City watershed priorities and the water quality issues identified for this farm in step 2.	Identify and define problems as unset, unmet and/or conflicting objectives and/or goals.
Step 4: Identify alternative practices that: address the priority water quality issues from step 3 and the soil, other water, air, plant and animal concerns from step 2; and are compatible with the mission and objectives for the farm.	Determine the underlying causes of problems (diagnose problems). Generate alternatives, possible solutions to problems. Decision making.
Step 5: Determine the expected water quality, soil, other water, air, plant and animal effects of the alternative practices.	Decision making.
Step 6: Identify adequate alternatives which satisfy the program's water quality criteria, and soil, other water, air, plant and animal quality criteria.	Decision making.
Step 7: Quantify the economic and management effects of adequate alternative practices.	Decision making.
Step 8: Select and integrate the practices to be included in the recommended whole farm plan, and submit to the Soil and Water Conservation Districts for technical approval and to the Watershed Agricultural Council for final approval.	Select the best alternative, decision making.
Step 9: Develop tactical and control plans to insure successful implementation of the approved whole farm plan.	Develop tactical plans. (Developing control plans is related to the control function of management.)
Step 10: Implement the plan.	(Related to the implementation function of management.)
Step 11: Assist, monitor and evaluate implementation and progress toward water quality, soil, other water, air, plant, animal, economic and management goals; and the farm mission and objectives.	(Related to the control function of management.)

The sections that follow review the purpose, background and procedures for steps 1 through 9. Steps 1 through 9 focus on the planning function of management, the focus of this report. For information on steps 10 and 11 please refer to New York City Watershed Agricultural Program, 1994a and 1994b.

Step 1: Interact with the Farm Manager to Identify the Farm Mission and Objectives for Resource and Business Management, and to Document the Farm Business Plan

Purpose

The purpose of this step is threefold. First, this step seeks to involve the farm owner/manager in the planning process at its critical inception to insure commitment. Second, by identifying the farm mission and objectives, the farm owner/manager and watershed planning staff will have a basis for selecting alternatives that solve water quality needs and minimize the disruption to the farm's opportunity to fulfill its mission and objectives. (Hereafter, "planning team" refers to the farm owner/manager and watershed planning staff.) The likelihood of farmer ownership of the plan increases as compatibility with the individual and farm business missions and objectives increases. As farmer ownership increases, the likelihood of successful plan implementation increases. Successful implementation is critical for achieving the program's mission. Third, this step provides the planning team with an opportunity to evaluate the role of water quality and other environmental objectives.

Background

Identification of the farm mission and objectives combined with the environmental objectives of the program help to determine desired future conditions toward which the planning team is working. The farm mission and objectives are based on the wants, needs and values of the farm owner/manager, while environmental objectives of the program are based on the wants, needs and values of the farm owner/manager and other stakeholders concerning the use, treatment and management of resources.

The planning team is to develop a whole farm plan that addresses the environmental [water quality] problems on the farm with minimal disruption to the farm's opportunity to fulfill its mission and objectives. The money available to fund the plan compensates for potential loss in economic objectives. Minimizing disruptions to other objectives is addressed by the selection of alternatives to solve environmental [water quality] needs. If, for example, one farm has an objective of increasing land in forage and a second farm has an objective of reducing purchased concentrates, the recommendations might be quite different for similar water quality problems. Similarly, one farm with an objective of shifting to less intensive enterprises could have quite different recommendations from one with an objective of transferring a viable farm business to the next generation.

A second reason for the emphasis on the farm mission and objectives is to meet the goal that the plans be successfully implemented. The goal setting literature unequivocally concludes that goals are only met when the person responsible for goal attainment has ownership of the plan and its goals (Locke and Lathun). The watershed planning staff's understanding of the farm's mission and objectives is crucial to the plan reflecting the farm's mission and objectives in order to increase the likelihood of farmer ownership of the plan and its goals. Further, the discussion of the farm mission and objectives helps the farm owner(s)/manager(s) crystallize their perception of the importance of water quality and other environmental issues to their farm mission. That farm owner(s)/manager(s)

perceive the importance of water quality and other environmental issues to their farm mission is critical, since the farmer is the key to successful plan implementation.

Procedure

Modern management theory that espouses critical roles for the vision, the mission, objectives and goals in business success underlies the procedure for this step. Thus, proper completion of this step will contribute to whole farm planning success. During step 1, the watershed planning staff helps the farm family to articulate and document the farm mission, and then works with the farm owner/manager to identify and document the farm owner's/manager's objectives. The watershed planning staff discusses the program's water quality and other resource related objectives with the farm owner/manager. The farm business, water quality and other environmental objectives direct and focus planning on the farm. The farm owner's/manager's statements about issues, concerns, and opportunities related to natural resources, financial condition, or economic sustainability help to articulate objectives. The watershed planning staff and farm manager discuss desired conditions for the farm relative to existing conditions. The planning staff then works with the farm owner/manager to identify and document components of any current farm plans

The development of whole farm plans to enable farm mangers to meet water quality standards for the New York City Watershed is a unique situation due to the magnitude of the resources available for planning and implementation. The presence of these considerable off-farm resources does not diminish the need for farmer involvement in planning and implementation. Farmer involvement in the process is critical. Lack of involvement on the part of the farmer may lead to failure of the farmer to commit to the plan and its goals.

An important step in avoiding the problem of farmer failure to commit to the plan and its goals is farmer involvement in determining the mission statement and objectives. Recall the objectives of determining the farm mission and objectives: (1) to involve the farmer in the process at its crucial inception to insure commitment; (2) to understand the farm's mission and objectives so the plan can be tailored to them to the extent possible; and (3) to provide an opportunity for the farmer to evaluate the role of environmental stewardship in the farm mission and to consider environmental objectives.

The first question to be addressed is: "Who writes the mission and objectives statement — the farmer or the Whole Farm Planning Team?" Although the whole farm plan is being developed by the planning team, the vision and mission for the farm are so value-laden and personal, it is best for them to be developed and written by the farm owner, or owners, and their families. The watershed planning staff serves as facilitator, supporter, and coach. If the farmer asks for assistance, then a watershed planning staff member might do some writing or revising in certain instances. Minimal involvement by the watershed planning staff is preferred during the development of the vision and mission. The greater the farmer involvement; the greater the commitment and accuracy of the mission and objectives. Covey (1990, P. 165) argues: "Many organizations have a mission statement, but typically people aren't committed to it because they aren't involved in developing it; consequently, it's not part of the culture."

Thinking about the vision for the farm business, and writing a mission statement and objectives are foreign topics to most farmers and, consequently, will often be threatening. This situation requires that watershed planning staff members develop a process that facilitates developing a mission statement and farm objectives in a non threatening, helpful way. This process

helps the farmer develop the thoughts and information needed instead of saying "now we are going to develop a mission statement." In the New York City Watershed Agricultural Program, several activities provide examples of the processes and worksheets others have found useful in developing a farm mission statement. (See Activities 1-1 through 1-3 in Appendix B.) Planning staff members keep the characteristics of empowering mission statements in mind as they develop and implement plans for working with farm managers concerning their mission and objectives.

Following the development of the farm's mission statement, the planning team works to establish and document the farm owner's/manager's objectives.[7] The farm owner(s)/manager(s) discusses ideas about issues, concerns, and opportunities on the farm with the watershed planning staff. Discussions provide the planning team with bases for stating objectives. Initially, the planning team may only identify one or two issues/opportunities from which they can state objectives. As planning progresses and planning teams develop additional information, and as they identify other issues/opportunities, the planning team states additional objectives.

Step 2: Inventory and Analyze Water, Soil, Air, Plant and Animal Resource Information to Identify Resource Issues and Concerns for The Farm

Purpose

The purpose of this step is to identify and list the water quality, soil, other water, air, plant, and animal resource issues for the farm.

Background

Recall that the charge to a planning team in Phase II of the Watershed Agricultural Program is to "complete a whole farm plan that solves the top priority environmental problems and includes funding to ensure that the present level of profitability is at least maintained" (Watershed Agricultural Council, 1994). A problem exists when observed performance deviates from desired performance in a way that is unacceptable. Describing an identified problem in terms of unset, unmet, and/or conflicting objectives and/or goals provides additional information. With this in mind New York City Watershed Agricultural Program participants identified water quality and other environmental objectives to facilitate rational and systematic planning (See pp. 22-23).

The remaining discussion for step 2 is taken from Walter, Seitz, Rossing, O'Leary, and Scott.

To identify water quality issues for a farm, the program's whole farm planning effort focuses on areas of the farm that have high potential for transporting pollutants to drinking water supplies. By identifying areas with a high potential for transporting pollutants to drinking water supplies, management practices can be developed to minimize pollutant loading and/or the risk of transport in these areas (Walter et al.). Successful implementation of the practices by farm owners/managers will help to achieve the objectives of the program.

Walter et al. classify areas with a high potential for transporting pollutants to drinking water supplies as **hydrologically sensitive areas**. In the whole farm planning effort, two categories of hydrologically sensitive areas receive emphasis: areas which contribute surface water runoff to reservoirs; and areas which contribute subsurface flow to recharge areas for developed springs and

[7] See page 7 of this publication for a definition and characteristics of objectives.

wells. Hydrologic sensitivity is seasonal. Based on the analysis of over 50 years of data, Walter et al. identify three hydrologic seasons: winter, summer, and the spring/fall transitions.

The term **loading area** describes a location where existing or planned farm practices result in the potential for water contamination due to the application, intentional or otherwise, of contaminants to the soil or crops. For example, intentional applications occur when a farmer spreads manure on fields or applies pesticides to crops. Unintentional applications may occur when silage leachate enters a stream or concentrated pesticides are spilled in a mixing area. Identification solely as a loading area does not indicate the potential for contaminant transport into a water supply.

If a loading area is located within a hydrologically sensitive area, then there is a high potential for contaminant transport. Under these circumstances Walter et al. classify the area as a **critical management zone**. For example, if a farmer applies manure (or any other potential pollutant) to a hydrologically sensitive area, then the area becomes a critical management zone. Critical management zones become the focus of efforts to identify water quality problems.

Procedure

During this step, the planning team works to identify resource issues by collecting and studying information about present resource conditions. Through the application of step 2, planning teams use systematic methods to eliminate inconsistencies in the identification of water quality and other resource issues on farms. Planning teams complete this step guided by the information in Walter et al.

To identify water quality issues and concerns, the planning team identifies hydrologically sensitive areas, pollutant loading areas and critical management zones. The planning team accomplishes these by reviewing records, by completing and reviewing maps, by interviewing the farmer, and by performing a visual assessment of the farm. The methods used to accomplish these tasks are updated as on-going research continues to increase the understanding of the risk of transport of potential farm pollutants. Water quality issues are defined in terms of unmet objectives on critical management zones in step 3. In step 3 the planning team sets priorities to reduce risk. Water quality problems in terms of unmet goals, are defined further in step 6 using estimates of existing pollutant loads, maximum allowable loads based upon water quality criteria and reductions needed on fields with critical management zones.

In order to identify soil, other water, air, plant, and animal resource issues planning teams inventory resources, analyze resource data, and determine whether present resource conditions present problems. Here, a problem by definition is a resource condition which does not meet minimum quality criteria for that resource. The planning team determines specific resource problems by comparing the status of each resource with the quality criteria specified for the resource (USDA, NRCS 1993a and 1993b).

Preliminary Investigation

Several important maps are essential components of step 2. A planning team generates the needed maps based upon maps, records and other information that the team obtains during pre-planning activities. (See the chapter on "Pre-Planning Activities," New York City Watershed Agricultural Program, 1994a.) One map that a planning team generates on a farm is a base map of the farm, referred to here as the "Farm Map." This map should show all of the farm fields, the

farmstead area, and all other farmstead property. Although these maps are often generated from aerial photographs, it may be necessary to enlarge the size of the map so that individual points within a field, such as a drainage ditch can be clearly depicted. Several copies of this map will be needed to complete step 2 (one for each season and pollutant loading combination). The planning team also completes a farmstead sketch. This sketch is an enlarged view of the farmstead area, showing the barnyard, the farm residence and any other farm buildings.

Delineation of Hydrologically Sensitive Areas

The planning team delineates hydrologically sensitive areas through a combination of interviews, field observations, maps and other techniques. The chapter for step 2 in The WAC Approach to Whole Farm Planning -- Part II discusses, in detail, criteria and methods to delineate hydrologically sensitive areas (New York City Watershed Agricultural Program, 1994b). The watershed planning staff may delineate several potential hydrologically sensitive areas prior to the farm visit using the collected maps and records. The watershed planning staff then confirms these areas and records additional areas during the farm visit based upon the interview and field observations.

To depict seasonal variations, planning teams consider an area to be hydrologically sensitive when the area meets the criteria for hydrologically sensitive areas for the duration of the following seasons:

a. all year - all 12 months, this is identified as the most critical level;
b. October through April - the fall/spring transition months plus all winter;
c. November through March - only the 5 critical winter months or some part thereof;
d. Never - not hydrologically sensitive in any season.

Interviews with farmers are essential sources of information. Farmers can provide insight to the farm hydrology based on historical observations of flooding and other surface runoff conditions. The watershed planning staff documents information on maps as well as on forms based upon conversations with farmers. (See the following: Interview; Farm Inventory; and Field Data Table in Appendix A, New York City Watershed Agricultural Program, 1994a.)

Farmers provide historical information about hydrologic features that are easily identified (for example, springs, diversions, wells, areas prone to flooding). The findings of the interview may also highlight areas of farmer concern that are associated with water movement. For instance a barnyard may be an operational or animal health concern if a significant volume of water flows through the area. Additionally, the farmer may be familiar with areas on the farm that are inaccessible because soils are seasonally saturated. The planning team notes such concerns and assesses them further through field observations.

Often the farmers are the only source of information regarding current production practices. The Farm Inventory Form is a summary of existing farm practices. (See Attachment B, Farm Inventory, in Appendix A, New York City Watershed Agricultural Program, 1994a.) Information contained in this form includes current manure management practices, and pesticide usage. A separate working map, referred to as the "Pollutant Loading Map" contains relevant information on pollutant loading areas.

Identification of Critical Management Zones/Water Quality Concerns

The program's whole farm planning effort considers the following contaminants: pathogens; nutrients; sediment; pesticides; and fuels/other toxics. From the seasonal Farm Maps and the Field Data Sheet, the planning team checks the hydrologically sensitive areas present for each of the farm's fields. Using the Pollutant Loading Map and the Farm Inventory, the team checks the type of pollutant loading for each field. Any field which has both a hydrologically sensitive area and a pollutant loading area becomes a critical management zone (mylar overlays help to visualize this). Delineation of a field as a critical management zone does not necessarily mean that current resource use on the area presents a problem and that an alternative management plan for resource use will be required for that field. It only means that the planning team must evaluate the field further regarding the risk posed by the pollutant of being transported from the hydrologically sensitive area to a surface water body. Further evaluation occurs in step 3.

The Environmental Audit is a series of questions planning teams use to systematically examine the agricultural operation to identify water quality issues on farms. (See Attachment C, Environmental Audit, in Appendix A, New York City Watershed Agricultural Program, 1994a.) The watershed planning staff completes the Environmental Audit via interviews with the farm operator and on-site observations

Step 3: Determine the Priority Water Quality Issues for this Farm Taking into Account New York City Watershed Priorities and the Water Quality Issues Identified for this Farm in Step 2

The discussion for step 3 is taken from New York City Watershed Agricultural Program (1994b).

Purpose

This step is designed to help planning teams further define water quality issues and set priorities for designing remedial and preventive management options to meet water quality goals on farms.

Background

Every aspect of the agricultural watershed protection program depends upon a firm foundation of priorities for preventing contamination. All pollutants and potential sources of pollution cannot be given the same priority. Equal importance among categories of pollutants suggests an unlimited capacity to control sources equally effectively. In reality, with limited funds and available expertise, giving pollutants different levels of importance helps planning.

Recommended priorities are set to minimize risk (Table 4). The concept of risk is based on the relative toxicity of pollutants and the expected potential for movement to a water course under current conditions. The potential for movement is based on amounts stored or generated on, or potentially released from farms, and the risk that they will affect surface waters. Risk to surface waters partly is based on the concept of hydrologically sensitive zones. The planning team further defines water quality issues and sets priorities based on qualitative assessments of circumstances on farms.

Table 4:

CLASSIFICATION OF GENERIC POTENTIAL POLLUTANTS ACCORDING TO TYPE OF SOURCE

Type of Pollutant	Potential Cataclysmic Point Sources	Potential Concentrated Nonpoint Sources	Potential Diffuse Nonpoint Sources
Parasites (e.g. *Giardia* and *Cryptosporidium*)	(I[1]) Animal Waste Storages	(V) Runoff from feedlots, barnyards, exercise areas, calf-raising areas	(VI) Field Use of Animal Wastes (Spreading), Pastures
Phosphorus	(IV) Bulk Storage Facilities, Animal Waste Storages	(IX) Runoff from feedlots, barnyards, exercise areas, silage leachate	(VII) Fertilizer and waste applications, Pastures
Sediment		(X) Stream banks, construction sites, road cuts	(VIII) Periodically disturbed areas (fields)
Pesticides	(II) Storage Facilities, Mixing/Loading Areas		(XI) Normal Applications for Pest Control
Fuels/Other Toxics	(III) Storage Facilities		(XII) Dumps/Disposal Areas

[1]Roman numerals indicate rankings for separate categories and range from I, highest priority, to XII, lowest priority. Roman numerals also correspond to the flow diagrams that the planning teams use during this step.

Procedure

Planning teams use a series of questions presented in the form of flow diagrams to further define water quality issues and to set priorities. Flow diagrams refer to information from the environmental audit, the farm inventory, and maps and assessments of locations of hydrologically sensitive areas.[8] The flow charts identify a level of risk that should be avoided using an appropriate combination of barriers.

The coincidence of hydrologically sensitive areas and areas where any of the several classes of pollutants are (a) stored in bulk, (b) released in large quantities in small areas or (c) released in a diffuse way, both in time and space defines the level of risk. (These areas were defined and identified in step 2). In some cases, guidance from published sources defines what is meant by terms such as "bulk." In others, threshold values that provide guidance about what is "large" and "small" are not available. In such cases, values have been suggested. Each flow diagram refers the team to

[8] See Appendix A, New York City Watershed Agricultural Program, 1994a for copies of the flowcharts. See the chapter for step 3 in The WAC Approach to Whole Farm Planning -- Part II for: instructions on using the flowcharts; and methods for evaluating key components needed to use the flow charts (New York City Watershed Agricultural Program, 1994b).

problem diagnosis questions in step 4 that are relevant for the potential pollutant and source that is an issue.

Step 4: Identify Alternative Practices That: 1) Address the Priority Water Quality Issues from Step 3 and the Soil, Other Water, Air, Plant and Animal Concerns from Step 2; and 2) Are Compatible with the Mission and Objectives for the Farm.

Purpose

The purpose of this step is to generate a set of possible solutions to the priority water quality issues identified during step 3, and the other resource problems identified in step 2. During this step, the planning team also evaluates possible solutions based upon compatibility with the individual and farm business missions and objectives.

Background

Generating alternative solutions to problems immediately following problem identification and skipping the essential step of problem diagnosis, increases the likelihood that one solves a sympton of a problem rather than the real problem (Hutt, Milligan, Kauffman and Claypoole). Therefore, if the planning team is to develop a plan that solves the top priority problems, then the team needs to focus attention on problem diagnosis. Hutt et al. provide key points of problem diagnosis.

- Problem diagnosis answers the question "What are the causes of the problem?" (What happened? When? How? Why? Where?)
- Problem diagnosis attempts to get to the root cause or causes of a problem, particularly causes related to the functions of management, by asking "Why?" (repeatedly if necessary) until a cause is stated in terms of a management function.
- Anticipate multiple causes.

Procedure

This step focuses on developing possible alternative solutions to the water quality and other resource issues on the farm and on developing alternatives that take advantage of opportunities to improve the resource use on the farm given the environmental objectives of the program and the farm owner's/manager's objectives. The planning team should develop enough alternatives to provide an opportunity for the farm owner/manager to consider several possibilities. A more practical alternative formulation effort results, and the chances for successful implementation of the plan increase.

The framework for completing this step relates to three aspects of problem solving: problem diagnosis; generation of possible alternative solutions; and decision-making. Brief descriptions of planning activities follow.[9]

[9] For a more detailed discussion of tasks, see the chapter for step 4 in The WAC Approach to Whole Farm Planning -- Part II (New York City Watershed Agricultural Program, 1994b).

Diagnose Problems

Planning teams use worksheets to determine the natures or the causes that underlie the priority water quality issues identified for the farm. (See Worksheet 4-1, Appendix A, New York City Watershed Agricultural Program, 1994a.) Reference material describes much of the science and understanding that underlies the value of obtaining answers to questions that appear in the problem diagnosis worksheets (New York City Watershed Agricultural Program, 1994c). For example, Klausner describes the science and understanding that underlie the problem diagnosis worksheet questions that examine nutrient management. Seyler, Waldron and Rutz; Tylutki and Pell; Wade, Schaaf and Walker; Walter, Seitz, Rossing, O'Leary and Scott; Wagenet, Porter, Schwartz, and Reed; and Porter describe the science and understanding that underlie problem diagnosis worksheet questions that examine a variety of subjects including: pest and pesticide management; animal nutrition and herd health; parasite management (parasitic protozoa -- *Giardia* and *Cryptosporidium*); hydrologically sensitive areas; onsite wastewater treatment systems; and water quality criteria.

The questions included in the worksheet focus primarily on technical reasons that underlie the issues. A numerical scoring system for the problem diagnosis questions assists the planning team in its efforts to list only the most important causes that underlie the priority water quality issues. The more important underlying causes become the focus of the planning team's efforts to relate the underlying technical causes of issues to management functions and generate possible solutions that address priority water quality issues.

Generate Alternatives

The planning team seeks to produce as many possible solutions to the priority water quality issues as possible. As the number of possible solutions increases, the likelihood of identifying the best course of action to solve the problem increases. The approach suggested for the generation of alternatives is brainstorming. Reference material provides information on possible alternative solutions (New York City Watershed Agricultural Program, 1994b and 1994c).

After the brainstorming exercise, the planning team may consult suggested resources that appear in the chapter for step 4 of The WAC Approach to Whole Farm Planning -- Part II and , or reference material for possible solutions that may have been overlooked (New York City Watershed Agricultural Program, 1994b and 1994c, respectively). Watershed planning staff members, farm managers, and specialists will likely bring the perspectives from many of the resources to the brainstorming exercise, but the planning process will not be hindered by reviewing resources for possible solutions.

Evaluate Alternatives

Hopefully, a rich set of possible solutions is available for consideration by the planning team. To evaluate possible solutions relative to the individual and farm business missions and objectives in a focused manner, the planning team follows a systematic procedure outlined below. Evaluation of possible solutions based upon other criteria occurs later in the planning and implementation process. For example, evaluation based upon water quality criteria occurs in step 6.

The purpose of the procedure suggested here is to answer the question, "What solutions are compatible with the individual and farm business missions and objectives?" The following steps describe the approach:

1. determine the criteria for evaluating compatibility; and
2. evaluate each alternative, possible solution, on each of the criteria for compatibility.

The mission and objectives from step 1 provide the criteria for the evaluation. To evaluate each possible solution on each criterion, decision-making grids provide a useful tool. A blank decision-making grid suitable for this purpose appears as Worksheet 4-2 in Appendix B. The planning team may remove incompatible alternatives from further consideration. However, they may need to revisit decisions to remove a possible solution from consideration when brainstorming produces relatively few possible solutions.

Step 5: Determine the Expected Water Quality, Soil, Other Water, Air, Plant and Animal Effects of the Alternative Practices

Purpose

The purpose of this step is to determine the effects on water quality, soil, other water, air, plant, and animal resources of alternative practices identified in step 4. Planning teams quantify effects where possible or describe in qualitative terms effects that cannot be quantified. Planning teams also consider the effects on social and cultural resources during this step (USDA/NRCS, 1993b, see Section III).

Background

For water quality effects, scientific methods, current scientific understanding and ongoing research help to estimate the reductions in contaminants. For soil, other water, air, plant and animal resource concerns, and for social and cultural resources, the planning team quantifies the effects on resources, or describes in qualitative terms, effects that cannot be quantified (USDA/NRCS, 1993b).

The estimates and information produced by completing this step provide the farm owner/manager and watershed planning staff with a basis for selecting practices that best meet objectives and goals. Thus, the estimates and information aid the farm owner/manager in the decision making that occurs in step 8.

Procedure

A triple barrier approach provides the basis for the framework that planning teams use to assess water quality effects. For a detailed discussion of the procedures used to complete this step please refer to The Watershed Agricultural Council's Approach to Whole Farm Planning in the New York City Watershed: Part II -- Whole Farm Planning Water Quality Tools (New York City Watershed Agricultural Program, 1994b: Chapter for Step 5). The triple barrier approach consists of the following: controlling on-farm movement; treatment; and source control. Planning teams apply the barrier approach to the following contaminants: pathogens; nutrients, with an emphasis on phosphorous; sediment; pesticides; and fuels/other toxics.

The procedures for quantifying contaminant reductions differ by contaminant and by the type of barrier applied. For example, calculating reductions in phosphorous loading from barnyards will follow a different methodology than assessing the benefits of alternative pesticide storage and management practices. The aim of all the procedures, however, is to provide as accurate an assessment as possible of the water quality effects in order that in step 6, planning teams can compare the effects with water quality benchmarks.

Step 6: Identify Adequate Alternatives Which Satisfy the Program's Water Quality Criteria, and Soil, Other Water, Air, Plant and Animal Quality Criteria

Purpose

The purpose of this step is to identify alternative practices, or sets of practices, that satisfy water quality criteria and other criteria.

Background

Given a set of possible solutions to address an environmental problem, the farm owner/manager with support from the watershed planning staff must decide which alternative or set of alternatives best solves the problem. Evaluation of alternatives based upon a set of criteria, for example water quality criteria, provides the decision maker with information needed to select solutions from the set of alternatives.

Procedure

The outcome of this step is a list of practices that satisfies water quality criteria and quality criteria for soil, other water, air, plant and animal resources, and social and cultural resource factors.

To identify alternatives or sets of alternatives that are adequate based upon their ability to satisfy water quality criteria and thus solve problems, the planning team compares the effects of alternative practices calculated in Step 5 to the reduction in pollutant loading required on each field or area (See the chapter for step 6, New York City Watershed Agricultural Program, 1994b). For a Critical Management Zone, the difference between the existing pollutant load for a given time period and the maximum allowable pollutant load for the time period yields the required reduction. Required reductions become water quality goals. A simple mass balance approach relates the maximum allowable load to a published standard for each pollutant.

USDA/NRCS, 1993a and 1993b guide planning teams in part in their efforts to identify adequate alternatives which satisfy the program's other environmental, social, and cultural resource quality criteria.

Step 7: Quantify the Economic and Management Effects of Adequate Alternative Practices

Purpose

The purpose of this step is to estimate the expected economic and management effects of adequate alternative practices identified in step 6.

Background

In previous steps, the planning team identifies priority water quality issues for the farm. Several adequate alternatives from a water quality perspective might exist to address a water quality issue. For example, current housing facilities for calves less than six months old may allow contact among calves. Existing housing facilities may be a factor underlying the identification of the pathogens *Giardia* sp. and *Cryptosporidium parvum* as a priority water quality issue. The planning team reaches these kinds of conclusions by completing steps 2, 3 and 4. The planning team may identify several potential solutions to address the issue of calf to calf contact in the current calf housing facilities by completing step 4. Possible solutions might include: do not house calves less than six months in the current area (potentially, several options might exist here); redesign the current housing area to prevent calf to calf contact. To provide a foundation for selecting from among the set of such alternatives based upon water quality and economic and management criteria in step 8, the procedure for this step focuses on estimating expected economic and management effects associated with alternatives.

Recall the problem statement that helps to summarize the task faced by the farm owner/manager and watershed planning staff when developing whole farm plans in the New York City Watershed Agricultural Program (page 16). The problem statement dictates that the following elements be the focus of this step to quantify the economic and management effects of alternative practices: 1) the funding requirements associated with the alternative; 2) the expected effects on profitability; 3) the land, labor, and management requirements. The latter are issues related to resources.

Funding

During the whole farm planning and implementation process, planning teams consider the funding requirement associated with an alternative as a criterion to compare and evaluate alternatives. The planning team seeks to develop a plan that meets water quality objectives while minimizing the funding required to implement the plan. Also, the plan must be feasible given the level of funding resources specified for the farm (the budget constraint).[10] WAC, Inc. policies indicate that funding should cover the following: 1) the initial capital cost associated with capital items that are an integral and necessary component of practices designed to improve water quality; 2) replacement and/or major repairs for some capital items; 3) any expected negative effects on profitability attributed to implementation of the plan (Watershed Agricultural Council, 1994).

Capital items or assets are factors of production that have a useful life of more than one year. Examples include farm machinery, stream crossings, diversions, and clean water exclusions among others. Each has a purpose in the production process and a useful life greater than one year.

The decision to compensate the farmer for expected negative effects on profitability is grounded in the potential for tradeoffs between water quality and farm business objectives. For example, a whole farm plan designed to solve priority water quality issues may have an expected negative effect on the level of profits in an average future year. In this program, funding resources are available to compensate for such losses, and thus remove a disincentive to adopt the plan.

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[10] In the program, planning teams determine the financial resources available to fund plan implementation using guidelines established by the program (Watershed Agricultural Council, 1994). The section that reviews step 8 of the planning and implementation process covers the budget constraint in greater detail.

Compensation for any expected negative effects on profitability makes the plan at least as attractive as the current plan based upon a profitability criterion.

Profitability

Expected effects on profitability receive emphasis here for another reason. Planning and implementation efforts are to result in a plan that is consistent with and achieves to the greatest extent possible the individual and farm business missions, objectives, and goals. Although a variety of objectives and goals can be of special importance to individuals, profit maximization is a widely accepted goal, particularly as it contributes to and is consistent with other potential objectives and goals such as growth and business survival. Profitability becomes a criterion for decision making.

Resources

A whole farm plan must be feasible given land, labor, and capital resources available to the farm business. In this program access to owned or borrowed capital is less of a concern as a constraint because program funds provide the initial capital required for capital items associated with water quality improvements. For some capital items, program resources fund replacement and/or major repairs, as well (Watershed Agricultural Council, 1994).

The availability of adequate land resources is always a concern, but in this process the planning team designs and describes alternatives with the land resources of the farm in mind using the framework and approaches that support step 4. For example, integrated crop, animal and field management approaches lead to formulation of practices that consider the available land resources. The assumption in step 7 is that the planning team has previously defined alternatives in adequate detail, and that alternatives still being considered at this stage in the process are feasible given the available land resources.

The effects on limited labor resources remain an issue at this stage. Therefore, the planning team quantifies the effects on labor requirements associated with alternatives.

Another human resource aspect of the farm business relates to the management resource available. Planning teams need to consider the management intensity/complexity associated with an alternative practice. The relationship between the management intensity/complexity associated with an alternative and the management resource available to the farm business becomes an important criterion upon which planning teams base decision making in step 8.

Procedure

To provide a foundation for selection of alternatives based upon economic and management criteria in step 8, the procedure and approaches that comprise this step focus on estimating the following for each possible solution or alternative:

1. The initial capital cost associated with the practice;
2. The expected effect on the level of profit associated with the practice;
3. The expected effect on labor required;
4. The expected management intensity and/or complexity required.

Estimate the Initial Capital Cost Associated with the Practice

Estimating the initial capital cost is important for several reasons. First, WAC, Inc. policies indicate that the initial capital required to implement a plan on a farm will come from implementation funds. Second, planners can use estimates of the initial capital costs for items to estimate ownership (fixed) and operating (variable) costs associated with a practice. For example, initial capital cost is a basis to estimate annual charges for depreciation, interest, fixed repairs and maintenance, taxes, and insurance for capital items. Third, since the program will cover the capital cost associated with the replacement of some capital items, the initial capital cost becomes a basis for estimating the replacement component of the funding required.

Planners estimate initial capital costs for buildings, other structures, land practices, farm machinery, and farm equipment, among others, based upon: design specifications; descriptions of practices; practice requirements; and estimates from potential suppliers. The planning team's experiences with and knowledge about the costs of placing items into use on farms help in developing estimates.

Estimate the Expected Effect on Profitability Associated with the Alternative

The return (total income generated by farm operations minus total costs incurred) to management and equity capital (net worth invested in the farm business) is used as the measure of profit for the farm business.

Income can be in cash and noncash forms. Examples of cash and noncash forms of income are value of milk and crops sold, and increases in values of inventories, respectively. Costs, charges made for items used in the production of goods and services, may be cash or noncash, as well. Examples of cash and noncash costs include: purchased seed, feed, fertilizers, and fuel among others; and values of feed and supplies used out of inventory, respectively.

Describing costs as fixed or variable also is useful. Fixed costs, sometimes referred to as ownership costs, do not vary with the level of production. Consider, for example, insurance and depreciation that are independent of the level of production. Variable costs, sometimes referred to as operating costs, vary with the level of production. Producers can avoid these costs. For example, variable costs for farm machinery include fuel and lube. Depreciation, the reduction in the value of the asset over time, occurs regardless of whether the farmer uses a tractor or not, while annual fuel and lube costs for the tractor vary depending upon the number of acres in production.

The Partial Budget Approach

This discussion of the partial budget approach draws from Kay.

The planning team uses the partial budget approach to estimate the expected change in profit associated with a proposed change in the farm business. Planning teams identify proposed changes to solve problems. They solve problems enroute to achieving water quality and/or other objectives and goals. Partial budgeting is a type of marginal or incremental analysis. The analysis considers estimates of only those income and cost items that change if the farmer adopts the proposed change. Since the analysis includes only changes and not total values, the outcome is an estimate of the expected increase or decrease in profit (return to management, and equity capital).

The planner uses the partial budget approach to systematically organize answers to four questions relating to a proposed change:

1. What new or additional income will be received?
2. What current costs will be reduced or eliminated?
3. What current income will be lost or reduced?
4. What new or additional costs will be incurred?

Planners consider these questions referring to the descriptions of income and costs given above. The first two questions identify items that add to profit, while questions three and four identify items that reduce profit. Planners compute the expected change in return to management, and equity capital for an average future year by subtracting the sum of the reductions in profit from the sum of the additions to profit. A positive value indicates that the planning team expects that the alternative will increase the return to management, and equity capital.

A planning team can analyze several types of proposed changes using the partial budget approach.

Enterprise Substitution. This includes a complete or partial substitution of one enterprise for another. An example would be allocating acreage away from corn production to acres of grass production on a dairy farm to address potential adverse water quality effects of greater erosion from areas in corn production.

Input Substitution or Level. Planners can use the partial budget approach to analyze an alternative that substitutes one input for another, or an alternative that changes the level of input use. Examples include: substituting one pesticide or pest management practice for the current practice based upon the desire to reduce the potential to adversely affect water quality; and a reduction in the level of commercial fertilizer or manure used in critical management zones based upon a nutrient management plan that again attempts to solve a water quality problem.

Size or Scale of Operation. Planners might use the partial budget approach to analyze a proposed change in the farm business that requires a change in the size of the farm business. Two alternatives that correspond to a change in the size of the farm business follow. Suppose a planning team believes that current housing conditions for calves six months of age and under are factors that contributed to the conclusion that the pathogens *Giardia* sp. and *Cryptosporidium parvum* are a priority water quality problem on a farm. Given site limitations, the planning team may consider raising heifers off the farm, thus, reducing the number of livestock on the farm. Suppose a planning team faces a priority nutrient problem that they attribute to a limited amount of acreage available upon which the farmer can spread manure. The planning team may consider expanding the land base as an alternative. Each example represents a change in the size of the farm business.

Planning teams may encounter changes that have elements of all three types. The partial budget approach is applicable in these situations, as well.

The Partial Budget Format

A suggested partial budget format appears in Appendix B as Worksheet 7-1. The relationship to the four questions is evident.

Added Income. The planning team considers expected increases in cash and noncash income items. If a proposed change causes yield or production levels to increase, then an increase in income may result from the proposed change. For example, a diversion, waterway or subsurface drainage may improve yields on the area affected. A proposed change in calf raising practices to address the pathogens *Giardia* sp. and *Cryptosporidium parvum* may translate into improved performance of first calf heifers and increased milk sales. The planning team includes only the added income (value of production) expected as a result of the proposed change. Accurate estimates of expected changes in production are critical, as are accurate estimates of output prices.

Reduced Costs. The planning team considers expected reductions in cash and noncash costs, both fixed and variable, associated with the change. If the change results in eliminating or reducing investment in machinery, equipment, buildings, and/or other capital items, then fixed costs of depreciation, interest, repairs and maintenance, taxes and insurance can be less. For example, suppose the planning team determines that current conventional tillage practices underlie a priority water quality issue for the farm. Then, the planning team might consider no-till practices as an alternative to the current tillage practices. Some of the current tillage equipment may become obsolete. The farmer may decide to remove such equipment from the inventory of machinery on the farm. Since the farmer would no longer own the item with the proposed change implemented, the farmer would no longer incur annual ownership costs on the item.

The planning team may expect a change in the amount of labor required to result from implementation of the proposed change in the farm business. For partial budget analyses of practices that affect labor on the farm, planning teams adopt the following method. To estimate the change in return to management, and equity capital, the planning team accounts for the effects of reduced labor or additional labor by including them as reduced costs or added costs, respectively. If a practice requires less labor, then the farmer has the option to:

1. hire less labor,
2. use less operator and/or unpaid family member labor, and/or
3. allocate the labor freed up to other uses.

The decision is the farmer's. If a practice requires additional labor, the farmer has the option to:

1. hire additional labor,
2. use more operator and/or unpaid family labor, and/or
3. reallocate labor away from current uses to the new practice.

Reduced Returns. If the proposed change eliminates an enterprise, reduces an enterprise's size, or reduces yield or production levels, then income declines. For example, suppose a diversion or grassed waterway takes land out of production. Then, the planning team must consider the reduction in income, the value of production, from the area affected in its analysis. Since the magnitude of the reduction in income is a function of expected changes in yields, production levels, as well as the value per unit of production, planners seek the most accurate estimates of these factors as is possible.

Added Costs. The planning team may consider a proposed change that requires the purchase of additional capital items and/or operating inputs. An example that includes elements of each would be a barnyard project designed to address a water quality problem attributed to concentrations of livestock wastes that are currently subject to transport in runoff. Added ownership costs associated with the structure could combine with added operating costs in the form of increased fuel, lube, repairs, and labor costs due to a recommendation to clean the barnyard more frequently relative to the current practice.

Program funding of initial capital costs for capital items, and funding for replacement and repairs of some capital items mean that annual charges for depreciation and interest, and some repairs will not negatively affect the level of profitability. Still, including the charges in the analysis at this stage provides useful information. Including the charges helps to demonstrate and highlight those instances where potential tradeoffs between water quality objectives and business objectives exist. Expected negative impacts on profit when all costs are considered underlie the WAC, Inc.'s policies to fund initial capital costs and repair costs among others. When completing step 8 planning teams modify the estimates obtained here to reflect the fact that annual charges for depreciation and interest and some repairs will not negatively affect the level of profitability.

Planning teams may encounter situations where the labor required increases. Please refer to the discussion about "Reduced Costs" above.

Planners complete a partial budget analysis for all alternatives that are adequate given the results of step 6. A "library" of partial budgets assists the planning team in its analysis (Chapter for step 7, New York City Watershed Agricultural Program, 1994b).

Summarize the Expected Effects on Labor Required

The planning team utilizes a marginal approach to estimate the expected change in labor required associated with a proposed change in the farm business. By comparing the sum of the reductions in labor required to the sum of the additions in labor required, the planning team estimates the expected change in labor required for a proposed change in farm business for an average future year in hours. Planning teams estimate the expected change in labor required by answering the following questions:

1. What tasks will require reduced labor and in what amounts?
2. What tasks will require added labor and in what amounts?

Planning teams measure the labor required in hours. Teams consider the following types of labor: hired, family paid, family unpaid, and owner/manager. The partial budget analysis for a practice contains any estimates for reduced and added labor in hours. The planning team uses the estimates for reduced labor hours and added labor hours to complete the marginal analysis for labor in Worksheet 7-2 of Appendix B.

Estimate the Management Intensity and/or Complexity Required

The planning team uses a qualitative ranking to estimate the management intensity, and/or complexity associated with the alternative. The team uses the following ranking: 1 = very intense and/or complex; 3 = average intensity and/or complexity; and 5 = low intensity and/or complexity. The team assigns a value to each alternative. The assignment of values to an alternative is independent of the current management ability of the farm manager. The planning team assigns values based primarily on judgment. The team members use their experience regarding the level of management individuals commonly need to successfully implement the practice.

Step 8: Select and Integrate the Practices to be Included in the Recommended Whole Farm Plan, and Submit to the Soil and Water Conservation Districts for Technical Approval and to the Watershed Agricultural Council for Final Approval

Purpose

The purpose of this step is to select alternatives for inclusion in the recommended whole farm plan that best solve the priority environmental problems. Alternatives remaining at this stage of the process satisfy water quality and other resource criteria, and are compatible with the mission and objectives for the farm.

Background

Evaluation of alternatives based upon a set of criteria aids the planning team in its efforts to determine the best solution to each of the priority water quality issues. The best solution may not be a single alternative, but a set of alternatives. The program's water quality, other environmental, economic and management criteria, including those related to the mission and objectives of the farm business, and program policies help to determine the "best" solution. The farm manager, family members and other employees will implement the selected practices to achieve the program's water quality, economic and management objectives, including the objectives of the farm business.

Procedure

The first step in the methodology that the planning team uses to compare alternatives for inclusion in the plan is the creation of a decision matrix. The planning team forms a decision matrix by considering: the practices or groups of practices identified in step 6 by priority pollutant issue; the water quality, soil, other water, air, plant and animal, plus social and cultural resource effects of the practices identified in step 5; and the economic and management effects of the practices identified in step 7. The farm manager then uses the decision matrix as a basis for selecting practices or groups of practices that best solve problems.

The planning team defines the set of best solutions as the one that will achieve the water quality criteria, and the soil, other water, air, plant and animal quality criteria, while minimizing the funding required to implement the plan. If a water quality objective or goal is currently met, then the resulting whole farm plan should not disrupt this condition. The farm manager, assisted by the watershed planning team, selects practices, while minimizing any expected negative effects on profitability. The planning team confirms that the funding required to implement the plan does not exceed the funding resources, or budget allocation, for water quality improvements, specified for the farm. Watershed planning team members check to see that the selected practices, the resulting plan and associated funding are consistent with other program policies, as well (Watershed Agricultural Council, 1994).

The budget constraint, the amount of funding available for water quality improvements and implementation of the whole farm plan, affects the development of the plan. The Watershed Agricultural Council adopted a policy that established implementation cost guidelines for the whole farm planning effort (Policy #4, Appendix B). The policy established a procedure for determining the level of the budget constraint (See Implementation Cost Guidelines, Appendix B). The planning

team completes the form using information related to the level of environmental risk posed by the operation. The level of funding available is a function of environmental factors.

Select Practices

To select practices for inclusion in the plan, the planning team uses a decision matrix (Worksheet 8-1, Appendix B). The matrix includes those environmental effects by pollutant category and source (See step 3, Table 4) that are relevant for the farm, and economic and management effects on one axis. The matrix has water quality practices and/or groups of practices previously identified as adequate on the other axis. The matrix(ices) developed will be unique for each farm.

Practices that adequately address parasite (*Giardia* and *Cryptosporidium*) issues must establish the required barriers. Presently, practices for all other categories of potential pollutants must adequately establish the appropriate required barriers as well. However, as workable approaches become available, practices for all other categories of potential pollutants will require that specific, quantified, water quality related benchmarks be achieved.

The planning team completes the matrix for the first priority pollutant issue by checking the barriers that each practice establishes on the farm. The team also records the economic and management effects. Once the planning team completes the matrix, the team focuses efforts on selecting practices or groups of practices that meet the minimum water quality standards at the lowest cost possible. The team explicitly incorporates and avoids negative impacts on farm profitability. The team also considers: the labor requirements; the management intensity and/or complexity; and the farm business mission, objectives, and goals when evaluating practices. The farm owner/manager selects practices assisted by the watershed planning staff.

The planning team addresses the concerns identified in order of priority. Priorities for water quality concerns are identified in step 3 in Table 4. The planning team carries the water quality accomplishments (barriers established), costs, impacts on profit (return to management, and equity capital) and other economic and management effects forward to the worksheet that addresses the next water quality issue. The planning team seeks an expected accumulated effect on profit, adjusted for program policies that fund initial capital costs, replacement and repairs, that is non-negative. However, if it is negative, then the planning team includes this expected change in profitability in its estimate of program funds required along with any capital, replacement and repair costs of included practices. Any positive deviation in the return to management, and equity capital associated with implementing practices included as part of the plan accrues solely to the farmer owner/manager.

The planning team sums the initial capital required, replacement and repair costs, and the value of funds needed to offset any expected negative change in profit (adjusted for effects of program policies that fund initial capital required, replacement and repair costs for practices designed to improve water quality). If the present value of the sum of funding required for the whole farm plan exceeds the maximum amount available for the farm, then the planning team must scale back the plan to conform to the budget constraint. Planning teams accomplish this by first removing those practices that solve the issues that are lowest on the water quality priority list until the budget constraint is met.

Worksheet 8-2 in Appendix B specifies the computational procedure the planning team uses to determine the present value of the individual whole farm plan cost. Planning teams include the

replacement costs of items only for the years remaining in the program recognizing that funding capital costs for replacement will have major implications for the funding required given the budget constraint. The funding of replacements costs could significantly reduce the amount of funding available for other practices given the budget constraint.

Summarize Information

Completed Worksheets 8-1 and 8-2 help to summarize the expected cumulative environmental and economic impacts for the recommended whole farm plan. The information summarized provides justification for the funding requested. Also, the summarized information helps the planning team compare organizations of resources included in alternative plans based upon expected effects. Also, the worksheets provide information to evaluate the effectiveness of the plan following implementation. The chapter for step 8 in The WAC Approach to Whole Farm Planning -- Part II describes procedures for documenting the cumulative water quality effects, economic and management effects for the recommended whole farm plan in greater detail (New York City Watershed Agricultural Program, 1994b).

Submit Components of the Recommended Whole Farm Plan to the Soil and Water Conservation District for Technical Approval and to the Watershed Agricultural Council for Final Approval

The Watershed Agricultural Council through its policies provides direction and consistency to best meet program objectives and goals in a systematic and timely manner. The frame, or statement of the problem that directs and focuses efforts to formulate a whole farm plan, emphasizes and illustrates the critical role that policies play in providing direction to the planning team. To help ensure that plans are consistent with program policies, the WAC adopted policies that subject recommended plans to a review and approval process (Watershed Agricultural Council, 1994).

This part of step 8 subjects components of a recommended plan including the mission, objectives, goals, and selected practices (actions) to the review and approval process. During this step, groups responsible for administering the program have the opportunity to review, and approve or disapprove the components of a recommended plan. This part of the process increases the likelihood that an implemented plan meets the technical requirements of the local Soil and Water Conservation District (SWCD) and the policy requirements of the WAC, Inc.

This step has an important place in the whole farm planning and implementation process. The groups called upon to review and approve the plan may or may not approve the components of the plan as recommended. Disapproval suggests the need for further planning. The review and approval process adopted will help to identify areas for potential improvement in the whole farm planning process. Frequent revisions and resubmissions that share common technical and/or policy related aspects have implications for refining the way planning takes place in the program.

The materials required to complete this step include: the completed Whole Farm Plan for the farm (tactics need not be fully developed at this stage); and any of the supporting material used to complete the plan (for example, completed worksheets, and maps). A suggested format for the whole farm plan, "NYC Watershed Whole Farm Plan" appears in Appendix B.

Step 9: Develop Tactical and Control Plans to Insure Successful Implementation of the Approved Whole Farm Plan

Purpose

The purpose of this step is to insure successful implementation of the plan developed by the farm owner/manager and the watershed planning staff. The planning team develops implementation details, time schedules for implementation actions, and controls to insure successful plan implementation.

Background

Research shows that the probability of success is dramatically increased when specific goals are established. In the discussion of mission in step 1, the crucial importance of farmer ownership of water quality goals was discussed. Obtaining farmer ownership of water quality goals through farmer involvement is finalized in this step as the tactical and control plans are developed.

If you don't know where you're going, any road will get you there.

It is generally accepted both in management theory and in practice that goal setting is an effective and necessary technique for peak performance. Excellent performance, including water quality improvement, is key to meeting the farm mission and objectives. Established goals, therefore, become a key ingredient in the achievement of the vision and mission established by the organization leaders.

Goals are an excellent tool for motivating people to achieve peak performance. When the goal achievement process is used properly, the benefits can be great. Focused action, mobilized effort, and increased persistence will all contribute to improved performance. Improved performance will, in turn, translate into improved business performance and increased profits.

The following are important consequences of goal setting and achievement for the planning teams.

1. Goal setting is an important and integral part of the implementation of the plans accepted by the farmers and adopted by the WAC.

2. Planning teams seek to establish goals as part of the tactical implementation plans that are Specific, Measurable, Attainable but challenging, Rewarding, and Timed (SMART).

3. The watershed planning staff seeks to involve the farmer in establishing the SMART goals to the greatest possible extent.

4. More importantly, farmer commitment to attaining the goals is key to successful implementation of the plan. In other words farmers must have ownership of the goals.

5. In addition to the financial support from the WAC, the watershed planning staff must provide support in the form of training so that farmers understand what the achievement of goals requires.

6. The watershed planning staff and the WAC provide both positive and constructive feedback concerning progress toward goal achievement.

Procedure

The first eight steps in the process produce most of the elements that comprise a whole farm plan. The plan includes New York City funding to meet the established water quality criteria and other program objectives. At this stage in the process the plan contains the recommended changes in the farm operation and the expected outcomes associated with the reorganization of resources. However, at this stage in the process the plan does not include implementation details and time schedules for implementation actions. This section outlines a framework for developing those details, and discusses the development of controls to insure successful implementation of the plan.

Developing Tactical Plans

After the planning team develops the whole farm plan and after the WAC accepts the plan, the practices to be added, deleted, and modified are known. However, the specific actions to be taken to actually make the changes are not yet specified. The tactical plan translates the decisions made in developing the whole farm plan in to actions to be taken. Tactical plans map activities to be accomplished in order to meet goals

The planning team develops tactical plans to achieve goals established in the plan guided by the framework for developing tactical plans described earlier in this publication. Please refer to the discussion beginning on page 8, including Figure 1. With the elements of a whole farm plan now complete, the planning team documents the whole farm plan that contains the necessary elements: mission, objectives, goals and tactics ("NYC Watershed Whole Farm Plan," Appendix B).

Developing Control Plans

To provide a foundation for successful implementation of the whole farm plan, and evaluation of progress in steps 10 and 11 of the whole farm planning and implementation process, respectively, the planning team develops control plans. The WAC Approach to Whole Farm Planning -- Part II, in the chapter for step 9 introduces control as a function of management, and details control plans (New York City Watershed Agricultural Program, 1994b). That chapter describes the four step controlling process that follows. This section provides a very brief outline of the process.

Four step process for controlling:

1. Establish control standards based on the goals;
2. Develop a control plan (please see Figure 11-5, Appendix A, New York City Watershed Agricultural Program, 1994a);
3. Monitor and report the performance data;
4. Evaluate performance against control standards and interpret the need for corrective action.

This publication focuses on the planning function of management as it relates to addressing agriculture's potential to adversely affect water quality. Therefore, more information on the remaining aspects of step 9, and steps 10 and 11 of the New York City Watershed Agricultural Program's whole farm planning and implementation process can be found in the chapters for steps 9, 10, and 11, respectively, The WAC Approach to Whole Farm Planning -- Part II, (New York City Watershed Agricultural Program, 1994b).

SUMMARY AND CONCLUSIONS

The report describes a planning framework that is grounded in principles and concepts from management thought. On-farm planning efforts can use the framework to address agriculture's potential to adversely affect water quality. A planning effort that follows the framework produces a plan that outlines the organization of limited resources that best meets water quality objectives and goals, and the mission, objectives and goals of the farm business. The New York City Watershed Agricultural Program developed a planning and implementation process that embodies the planning framework described here to guide its whole farm planning effort. The New York City Watershed Agricultural Program designed the whole farm planning effort to achieve the program's water quality, other environmental, economic and management objectives, including the objectives of farm businesses. The program's effort evolves based upon the experiences of the whole farm planning teams and based upon research. Researchers study agriculture's effects on water quality, and resource allocation on watershed farms given farm business and water quality objectives.

Any on-farm planning effort that is grounded in and embodies principles and concepts from modern management thought will establish the mission, objectives, goals and tactics as key elements of a plan. The mission, objectives, and goals provide direction. That is, they describe what the planning effort seeks to achieve. Identification of the mission, objectives and goals are critical to completing the other aspects of the planning process: problem solving and developing tactics. The task of establishing objectives and goals, especially water quality objectives and goals, that possess the desired characteristics may be difficult in a watershed protection program. However, the importance of completing that task can not be overemphasized. If a program successfully establishes water quality, economic and management objectives and goals, then on-farm planning efforts will possess needed direction and focus. On-farm planning efforts will likely be more systematic, less frustrating to those involved in the planning, and more likely to realize the desired purposes.

A watershed protection program will have a finite amount of farm and program resources for planning and implementation efforts. How much can be done enroute to achieving water quality, economic and management objectives and goals, and the best means for achieving objectives and goals depends upon the availability of these resources. Limitations on the availability of program resources to plan and fund water quality improvements compel a program to prioritize water quality issues and establish policies to guide the allocation of program funds through the planning effort. The tradeoffs that likely exist between water quality objectives and goals, and farm business objectives and goals may well influence how a program allocates limited funds. Tradeoffs can be significant.

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APPENDIX A

List of Program Cooperators, Phase I of the
New York City Watershed Agricultural Program

PROGRAM ACKNOWLEDGMENT

Watershed Agricultural Council

Appointed Members:

Richard Coombe, Chairperson (Sullivan County)
David Taylor, Vice-Chairperson (Delaware)
Peter Clark (Delaware)
William Coleman (Delaware)
John A. Cook (Delaware)
Gail Dale, Executive Director (Delaware)
Sandra Dawson (Delaware)
Raymond Denman (Sullivan)
Thomas Donnelly (Delaware)
Steven Fleming (Delaware)
Dennis Hill (Delaware)
Dave Holley (Delaware)
Fred Huneke (Delaware)
Floyd B. Many (Delaware)
William Murphy (Delaware)
Howard Nichols (Delaware)
David Post (Delaware)
Howard Tuttle (Greene)
Barbara Wilkens (Westchester)

Ex-Officio Members

Floyd Duger ..... Acting State Executive Director, US Department of Agriculture, Agricultural Stabilization and Conservation Service
Marilyn Gelber ..... Commissioner, NYC Department of Environment Protection
Philip Griffen ..... Chair, NYS Soil & Water Conservation Committee
Carla Hagerman ..... US Environmental Protection Agency
Kenneth Markert ..... Coalition of Watershed Towns
Richard McGuire ..... Commissioner, NYS Department of Agriculture & Markets
Philip Nelson ..... Acting State Conservationisht, US Department of Agriculture, Soil Conservation Service
Keith Porter ..... Director, NYS Water Resources Institute at Conell University
William Stasiuk ..... Director, Center for Environmental Health, NYS Department of Health
Langdon Marsh ..... Commissioner, NYS Department of Environmental Conservation
Gerald Skoda ..... Association Director, Cornell Cooperative Extension of Sullivan County

Demonstration Farmers for Phase I

Delaware County

Paul and Gwen Deysenroth, Bloomville
Wayland Gladstone, Jr., Andes
R. Thomas Hutson, DeLancey
Paul and Candice Menke, Meredith
Bruce and Scott Rasmussen, Delhi
James and Barbara Robertson, Bloomville

Green County

J.J. Farber, Jack and John Verhoeven, East Jewett

Schoharie County

William Proudman, Conesville

Sullivan County

George Dean, Neversink

Ulster County

George and Gail Hillriegel, Hardenbergh

County Project Teams and Other County Staff

Delaware County
Gerald Clark (SWCD)
Brian Danforth (SWCD)
Jeannie Darling (CCE)
Dean Frazier (CCE)
Robert Halbohm (SCS)
Lorinda Pierce (SWCD)
Peggy Pilch (SWCD)
Larry Underwood (SWCD)
Rick Weidenbach (SWCD)
Debbie Wilcox (SWCD)

Greene County
René van Schaak (SWCD)
Peter Kavakos (SWCD)
James Calhoun (SCS)
Robert Beyfuss (CCE)

Schoharie County
Steve Hoerz (SWCD)
Lisa Fields (CCE)
Leonard Prezorski (SCS)

Sullivan County
Richard Ehrmann (SWCD)
Cheryl Marion (CCE)
Mary Muhlig (SWCD)
George Stang (SCS)
Alan White (CCE)

Ulster County
Gary Capella (SWCD)
Kathy Capella (SCS)
Lydia Reidy (CCE)
Kristine Walters (SWCD)

NYS Soil & Water Conservation Committee: Lead Administrator/Coordinator of Phase I

Tonia Hayes
Richard Lewis, Watershed Agricultural Program Administrator
David Pendergast, Executive Director

Technical Support Group

NYS Dept. of Environmental Protection
Robert Alpern
Albert Appleton (former Commissioner)
Laurence Beckhardt
Walter W. Faber, Jr.
Frank Pavia
Donald Pierson
David A. Stern

US Dept. of Agriculture, Soil Conservation Service
Richard Crowe
Paul Dodd, State Soil Conservationist (Ret.)
Gary Lamont
Steven Machovec
Paul Ray
Joseph DelVecchio

NYS Dept. of Environmental Conservation
Patricia Longabucco
Michael Rafferty

NYS Dept. of Agriculture & Markets
David Dodge
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Cornell University

Cornell Principals

William C. Ghiorse ..... Microbiology
Stuart D. Klausner ..... Soil, Crop and Atmos. Sciences
Wayne A. Knobluach ..... Ag., Resource, and Managerial Economics
Robert A. Milligan ..... Ag., Resource, and Managerial Economics
Hussni O. Mohammed ..... Veterinary Clinical Sciences
Alice N. Pell ..... Animal Science
Keith S. Porter ..... NYS Water Resources Institute
Donald A. Rutz ..... Pest Management Education
Susan E. Wade ..... Veterinary Diagnostic Laboratory
J. Keith Waldron ..... Integrated Pest Management
Mark J. Walker ..... NYS Water Resources Institute
Michael F. Walter ..... Ag. & Biological Engineering

Cornell Associates

Lynne J. Anguish ..... Microbiology
Juliet E. Bryant ..... Animal Sciences
John J. Hanchar ..... Ag. Resources, and Managerial Economics
Thomas F. Kilcer ..... Soil, Crop and Atmos. Sciences
Brian C. Rineer ..... NYS Water Resources Institute
Stephanie L. Schaaf ..... Vet. Diagnostic Laboratory
Karen A. Seitz ..... Ag. & Biological Engineering
Linda A. Seyler ..... Integrated Pest Management and Education Programs
Stanley W. Telega ..... PRO-DAIRY Program
Thoms Tylutki ..... Animal Sciences

Other Cornell Staff

Kathie R. Burdick ..... NYS Water Resources Institute
Jahae (Terry) Koo ..... NYS Water Resources Institute
Catherine J. Lance ..... NYS Water Resources Institute
Cynthia Malvicini ..... NYS Water Resources Institute
Steven Pacenka ..... NYS Water Resources Institute
Mary Jane Porter ..... NYS Water Resources Institute
Brigitte Y. Perigard ..... NYS Water Resources Institute
John J. Schwartz ..... NYS Water Resources Institute

Others

American Farmland Trust

APPENDIX B

Worksheets and Other Material, Economic and Management Aspects, New York City Watershed Agricultural Program Whole Farm Planning and Implementation Process

Workshop Activity 1-1.

VISION/MISSION OF FARM OWNERS DIRECTIONS

Workshop Activity Objectives:

1. To give farm owners, family members and employees an improved understanding of what is needed in a farm vision and mission statement.

2. To give farm owners, family members and employees an improved understanding of the process of developing a farm vision and mission statement.

3. To provide farm owners, family members and employees an opportunity to develop their farm vision and mission statement.

Workshop Activity Directions:

1. Begin by explaining that what you are giving them is a process that can help them in developing their farm vision and then in articulating a farm mission statement.

2. Explain that items A. - C. obtain information about their current operation. Have them complete this page. Be available to answer questions and help. Having refreshments available is a good idea.

3. Explain that items D. and E. are concerned with future directions, hopes, dreams, etc. and with what they hold to be important or values. Have them complete this page. Be available to answer questions and help.

4. The member of the farm unit should now share their answers with each other especially questions C., D., and E. They can use the space after step F. to note similarities and differences. Make a strong point that in their discussions now and later they must be seeking a consensus.

5. They should now use item G. to begin writing the mission statement. They should continue to discuss and refine as they continue to reach consensus on their vision. Emphasize that this is not a simple process or one that can be hurried.

Workshop Activity 1-1.

VISION/MISSION OF OWNERS

A. Describe the business you are in: products, services, what specifically does the business produce, type of marketing.

B. Describe the size and productivity of your business: production units, levels of production, sales volume, family members, involved employees.

C. Describe your views on environmental stewardship and water quality.

D. What changes in the business are expected: enterprises, growth, specialization, diversification.

E. What is important to the owners: integrity, growth, excellence, family time, personal growth, etc.

F. Discuss the answers to A-D until a consensus emerges on the vision for the business. Make notes below.

G Further articulate the consensus vision by writing a mission statement for the business.

Workshop Activity 1-2.

MISSION STATEMENT DEVELOPMENT DIRECTIONS

Workshop Activity Objectives:

1. To give farm owners, family members and employees an improved understanding of what is needed in a farm vision and mission statement.

2. To give farm owners, family members and employees an improved understanding of the process of developing a farm vision and mission statement.

3. To provide farm owners, family members and employees an opportunity to develop their farm vision and mission statement.

Workshop Activity Directions:

1. In the square in the middle of Worksheet Activity 1-4 have each participant write a phrase that describes the farm business from his or her perspective.

2. In the outer circles of Workshop Activity 1-4 have each participant jot down things that as a farm business are:

   a. are important to them
   b. are valued
   c. indicate their view of the future of the farm.

3. Ask each participant to use one or two remaining circles to jot down thoughts concerning water quality and environmental stewardship.

4. The member of the farm unit should now share their notes with each other. They can use some space on the next page to note similarities and differences. Make a strong point that in their discussions now and later they must be seeking a consensus.

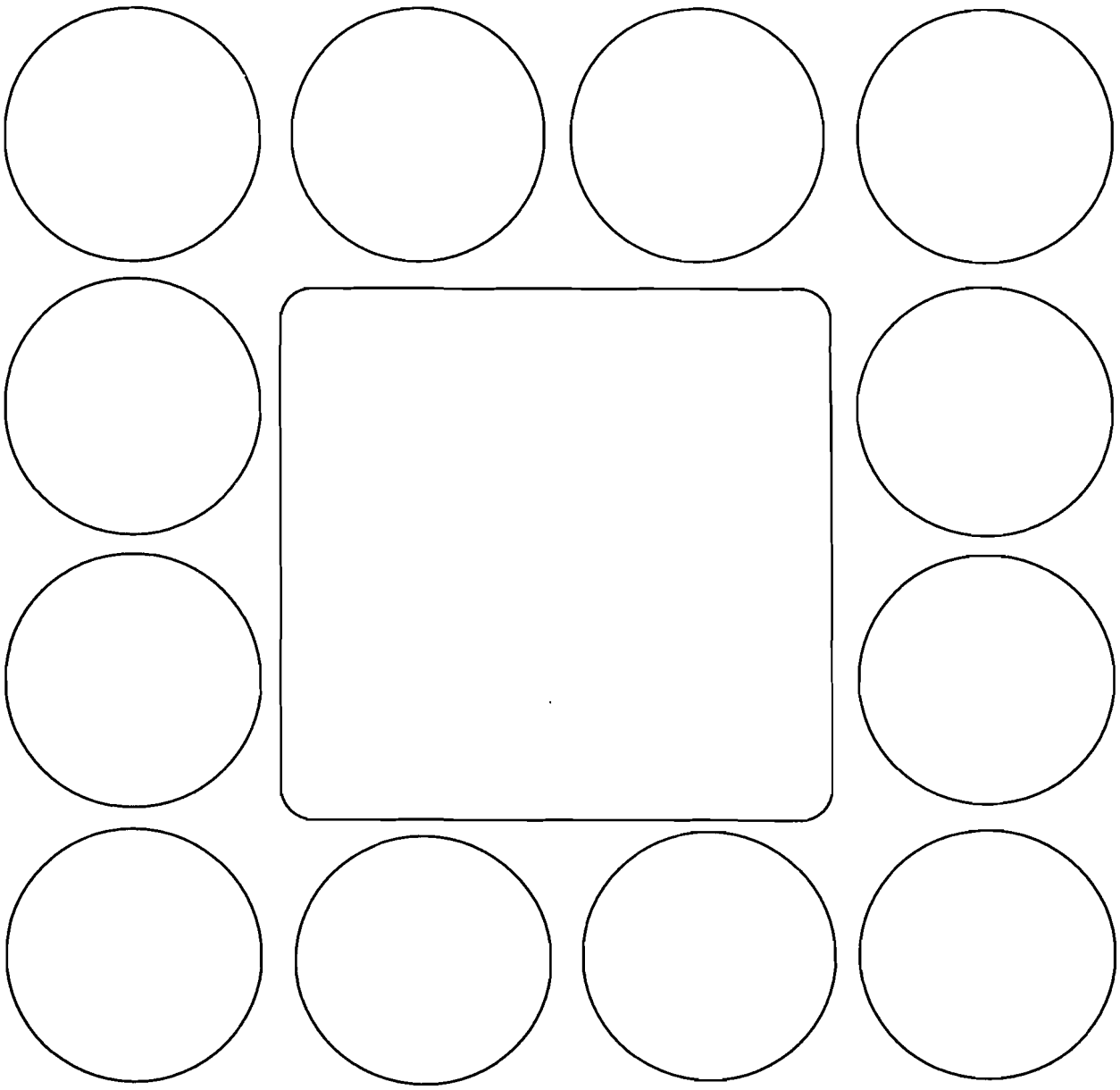
5. They should now use remainder of the second page to begin writing the mission statement. They should continue to discuss and refine as they continue to reach consensus on their vision. Emphasize that this is not a simple process or one that can be hurried.

Workshop Activity 1-2.

MISSION STATEMENT DEVELOPMENT

1. In the square, write a phrase which describes your farm business, the type of farm business you are in.

2 In the outer circles, jot down things that, as a farm business:
   a. are important to you
   b. are valued
   c. indicate your future direction



Workshop Activity 1-2.

MISSION STATEMENT DEVELOPMENT (CONTINUED)

Using the analysis on the previous page, prepare a brief (maximum 4 sentences or 50 words) statement which describes the purpose, philosophy and mission of your farm business.

Workshop Activity 1-3.

DEVELOPING A BUSINESS MISSION STATEMENT DIRECTIONS

Workshop Activity Objectives:

1. To give farm owners, family members and employees an improved understanding of what is needed in a farm vision and mission statement.

2. To give farm owners, family members and employees an improved understanding of the process of developing a farm vision and mission statement.

3. To provide farm owners, family members and employees an opportunity to develop their farm vision and mission statement.

Workshop Activity Directions:

1. In the spaces below question 1 of Worksheet Activity 1-5 have each participant write phrases that describe what the person is in business to do from his or her perspective.

2. In the space below question 2 of Workshop Activity 1-5 have each participant jot down what they would like their business to be:

   a. Position in the industry
   b. Strengths of the business.
   c. Qualities of products and people.
   d. Environmental stewardship and water quality.

3. In the space below question 3 of Workshop Activity 1-5 have each participant write down values that serve as a foundation for their business.

4. The members of the farm unit should now share their notes with each other. They can use a blank piece of paper to note similarities and differences. Make a strong point that in their discussions now and later they must be seeking a consensus.

5. They should now use another piece of paper to begin writing the mission statement. They should continue to discuss and refine as they continue to reach consensus on their vision. Emphasize that this is not a simple process or one that can be hurried.

Workshop Activity 1-3.

DEVELOPING A BUSINESS MISSION STATEMENT

1. What I am in business to do. Products/services my business provides. My purposes for being in business.

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

2. What I'd like my business to do. Position in the industry and community. Strengths of my business. Qualities of my products/people.

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

3. Values I choose as a foundation for my business.

_____ _____
_____ _____
_____ _____
_____ _____
_____ _____

Worksheet 4-2.

DECISION MAKING GRID FOR DETERMINING COMPATIBILITY

To use this worksheet planning teams list the mission and objectives determined in step 1 on the left hand side of the worksheet. Then, the planning team determines whether an alternative is, or is not compatible using values of 0 or 1, where 0 means incompatible, and 1 means compatible.

Problem:

Ratings: 0 = not compatible
1 = compatible

Alternatives

Criteria				

Worksheet 7-1.

FORM FOR COMPLETING A PARTIAL BUDGET ANNALSIS

PARTIAL BUDGET ANALYSIS

Analysis:

ITEMS THAT INCREASE PROFIT	ITEMS THAT REDUCE PROFIT
Added Income	**Reduced Income**
$	$
Total $	Total $
Reduced Costs	**Added Costs**
$ FIXED (OWNERSHIP): VARIABLE (OPERATING):	$ FIXED (OWNERSHIP): VARIABLE (OPERATING):
Total $	Total $
Total: Added Income and Reduced Costs (A) = $	**Total: Reduced Income and Added Costs (B)** = $
	Change in Profit (A minus B) = $

Worksheet 7-2.

FORM FOR ESTIMATING THE EXPECTED EFFECT ON LABOR REQUIRED

MARGINAL ANALYSIS OF LABOR

Analysis:

ITEMS THAT DECREASE LABOR REQUIRED	ITEMS THAT INCREASE LABOR REQUIRED
Reduced Labor	**Added Labor**
Hours	**Hours**
Total: Reduced Labor (A) **= Hours**	**Total: Added Labor (B)** **= Hours**
	Change in Labor Required (B minus A) **= Hours**

Note: A positive value for the estimate of the expected change in labor required indicates that the proposed change in the farm business will require more labor hours when compared to the current situation. A negative value for the estimate indicates that the proposed change in the farm business will require fewer labor hours when compared to the current situation.

Policy #4
Year 1 BMP Implementation Cost Guidelines

The Watershed Agricultural Program will annually establish implementation cost guidelines in order to help staff members develop Whole Farm Plans that are consistent with the financial resources available. Permanent livestock housing structures and other production facilities will not be eligible for Program funding.

Staff Guidelines for Policy #4

1. Farms will be rated for potential environmental impact based upon criteria similar to those used for demonstration farm selection (See Attachment A). Animal density and cropping intensity will be considered. Farms will be rated for potential impact on the basis of high, medium or low.

2. Total Farm Plan Implementation Guidelines can be developed by using either the animal unit method or the gross agricultural income method. Planning teams should use the methods that result in the higher guideline.

3. Greenhouses constructed for the purpose of calf pathogen control will be considered a non-permanent structure and will be exempt from the "no buildings" clause of this policy. Maintenance and repair of calf greenhouses will be considered a production expense to be borne by the Landowner and/or Producer.

Potential Environmental Impact on Farm (See Attachment A)	Low	Medium	High
Animal Unit Method	$350-$500 per animal unit	$500-$750 per animal unit	$750-$1000 per animal unit
Gross Agricultural Income Method	40% of Gross Agricultural Income	60% of Gross Agricultural Income	80% of Gross Agricultural Income

Attachment A.

Implementation Cost Guidelines
Policy #4 Documentation

Farmer: _____

WATERSHED PROJECT TEAM POTENTIAL ENVIRONMENTAL IMPACT

Definition: Upland farm classified with greater than 30 percent of cropland with slopes in excess of 5 percent.

Score

1. Acreage of cropland classified as "highly Erodible Land" (HEL)
   1._____
   - a. 0-70 acres =5
   - b. 71-140 =10
   - c. 140+ acres =15

2. Total acres of row crops on HEL
   2._____
   - a. 0-45 acres =10
   - b. 46-100 =20
   - c. 100+ acres =30

3. Distance of barn from nearest stream
   3._____
   - a. 200 feet =5
   - b. 100-200 feet =10
   - c. 0-100 feet =15

4. Distance of barnyard from nearest stream
   4._____
   - a. 200 feet =5
   - b. 100-200 feet =10
   - c. 0-100 feet =15

5. Calf mortality rate in past year
   5._____
   - a. 0-5% =5
   - b. 5-10% =10
   - c. 10%+ =15

6. Calves are raised in:
   6._____
   - a. Outside hutches =5
   - b. Individual stalls =10
   - c. Group stalls =15
   - d. Outdoors =15

7. Cows walk in a stream to get to pasture or drinking water

7._____

a. No =1
b. Yes =5

8. Cropping system

8._____

a. All hay =1
b. Row crops =5

9. Milkhouse waste handling system

9._____

a. Lagoon or storage =5
b. Septic =10
c. Direct pipe =15

10. Number of years since the majority of fields have been soil sampled

10.____

a. 1-3 years =5
b. 4-6 years =10
c. 6+ =15

11. Livestock density

11.____

	Density	Rating
a. Grass Hay only	<2.25	=10 low
a._____		
	2.25-2.5	=20 medium
	>2.50	=30 high
b. Corn-Grass	<1.5	=10 low
b._____		
	1.5-2.25	=20 medium
	>2.25	=30 high
c. Corn Legume	<1	=10 low
c._____		
	1-1.5	=20 medium
	>1.5	=30 high

12. Potential Environmental Impact Risk Rating TOTAL SCORE

12.____

Score _____ Rating _____

Rating Scale:		
	Low	0-77
	Medium	78-128
	High	129-175

EXAMPLES FOR COST IMPLEMENTATION GUIDELINES

75 Cow Dairy

75 cows * 1300 lbs.	=	97,500
57 heifers * 600 lbs. average	=	34,200
		131,700
132,000/ 1000 lbs. /unit	=	132 units

Animal Unit Method

$500 * 132 units	**$ 66,000**
$750 * 132 units	**$ 99,000**
$1000 * 132 units	**$132,000**

---

75 Cow Dairy

16,000 lb. Herd Average	
12,000 cwt @ 12.00	144,000
sell 20 cull cows	10,000
30 bob calves	2,500
ASCS or hay sales	2,000
Gross Ag Income	$158,500

Gross Income Method

Low Impact	40% of gross	**$ 63,400**
Medium Impact	60% of gross	**$ 95,100**
High Impact	80% of gross	**$126,800**

Worksheet 8-1.

WHOLE FARM PLAN DECISION MATRIX

Type of Pollutant by Source: (See step 3, Table 4)
Issue:

Pollutant by Source by Barrier Required[1]	Practice(s) 1	2	3	4	5
	Water Quality Effect[2]				
e.g. I. Parasites -- Potential Cataclysmic Point Sources. a. Source barrier required					

--- continued on next page

Worksheet 8-1 --- continued.

Economic and Management Effect

Expected Changes in:

Capital Required[3]					
Return to Management, and Equity Capital[4]					
Repair Cost[5]					
Labor[6]					
Management Intensity and, or Complexity[7]					

Notes for Worksheet 1: Whole Farm Plan Decision Matrix.

1 Listed from highest to lowest water quality priority.

2 Measure in the units as specified in Steps 5 and 6.

3 Capital cost required to implement the practice(s).

4 Obtained from the partial budgets developed in Step 7 and adjusted for program policies regarding funding of initial purchase, replacement and repair costs for capital items of practices that improve water quality (WAC, 1994).

5 Annual replacement & repair costs are paid by the program for access roads(10), barnyard water management(15), calf manure composting facilities(15), cover crop(1), diversion(10), grassed waterway(10), livestock crossing(10), livestock exclusion(10), livestock watering facility(10), manure storage(15), milkhouse waste treatment(15), petroleum storage(10), riparian forest buffer(10), silage leachate treatment(15), stone lined waterway(10), stream channel stabilization(10), subsurface drainage(10), surface drainage(10), and underground outlet(10). The farmer pays for replacement and maintenance of conservation cropping sequence(1), conservation tillage(1), grasses/legumes in rotation(specified in plan), pasture and hayland planting(specified in plan), short duration grazing system(10), and farm equipment(10). No maintenance or replacement is needed for nutrient management(1), pest management(1) or stripcropping(10). Numbers in ()'s indicate required maintenance life.

6 Additional hours of operator, family and other employee labor required.

7 Management intensity or complexity, 1 = very intense or complex, 3 = average and 5 = low intensity or management not required.

Worksheet 8-2.

PRESENT VALUE OF CURRENT AND FUTURE PROGRAM COSTS

Year	Initial Capital Cost	Replacement and Repair Cost	Return to Management, and Equity Capital	Total	PV Factor[2]	Present Value
1	$	$	$	$	1.000	$
2	$	$	$	$	0.9709	$
3	$	$	$	$	0.9426	$
4	$	$	$	$	0.9151	$
5	$	$	$	$	0.8885	$
6	$	$	$	$	0.8626	$
7	$	$	$	$	0.8375	$
8	$	$	$	$	0.8131	$
9	$	$	$	$	0.7894	$
10	$	$	$	$	0.7664	$
11	$	$	$	$	0.7441	$
12	$	$	$	$	0.7224	$
13	$	$	$	$	0.7014	$
14	$	$	$	$	0.6810	$
15	$	$	$	$	0.6611	$

Total $

Notes for Worksheet 2: Present Value of Current and Future Program Costs.

1 Adjusted for effects of program policies that fund initial capital required, replacement and repairs costs for practices designed to improve water quality.

2 A real discount rate of 3 percent is specified.

NYC Watershed Whole Farm Plan

Farm Name:_____

Farm Owner(s):_____

Mailing Address:_____

_____

_____

Telephone Number: _____

Date Plan Completed: _____

Personnel Assisting in Plan Development:_____

_____

Farm Mission Statement (highlight environmental component)[Step 1]:

_____

_____

_____

_____

_____

_____

_____

Individual and Business Objectives and Goals of the Farm Manager/Owner (Objectives and goals reflect areas of opportunity) [Step 1]

_____

_____

_____

_____

_____

Water Quality Priorities for this Farm (Steps 2 and 3)

Area	Farm Status	Watershed/Program Standard

Water Quality Priorities for this Farm (Steps 2 and 3) -- continued

Area	Farm Status	Watershed/Program Standard

Tactics by Priority Area (Outcome of Steps 4 through 10)

The US Department of Agriculture, Soil Conservation Service framework known as RECORD OF COOPERATOR'S DECISIONS AND PROGRESS IN APPLICATION will provide the basis here to describe the organization of resources by pollutant priority area that best meets the objectives and goals given the available resources. (Watershed whole farm planning team members will work to modify the standard format to create the ability to present practices by pollutant area.)

Funding Requested by Priority Area (Step 8)

Include a summary table indicating the funding requested by priority area by practice. Indicate funding requested for initial capital item purchase and funding requested to compensate any expected negative impacts on annual profitability associated with implementation of the Whole Farm Plan. Provide justification for latter requests for funding with the partial budget analysis of the Whole Farm Plan in Attachment 5 (Result of Step 8).

To provide justification for the funding requests in terms of the expected impacts on water quality, planning teams document the expected impacts of practices on water quality by priority area (Step 8).

Goals for First Year

The RECORD OF COOPERATOR'S DECISIONS AND PROGRESS IN APPLICATION with its computer software component (CAMPS) will be used to track activities, implementation date goals, and actual implementation dates.

Water Quality Goals

Measure	Current Level	End of First Year

Attachments include the following:

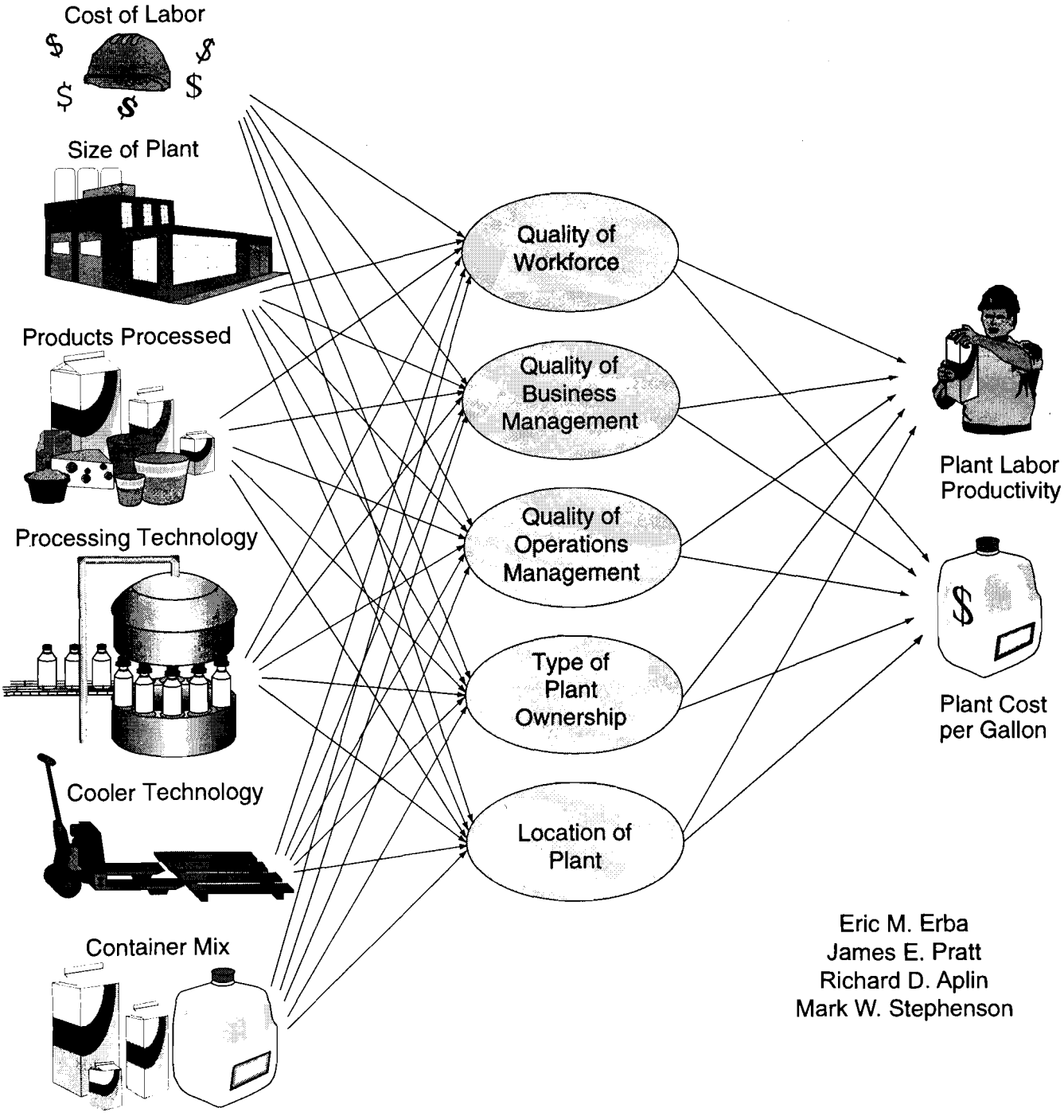
1. Crop Rotation Plan by Year
2. Nutrient Management Plan
3. Whole Farm Plan Map with Legend
4. Field, Soil Listing Index
5. Partial Budget Analysis of the Whole Farm Plan

OTHER A.R.M.E. RESEARCH BULLETINS

No. 96-05	The Magnitude of and Factors Influencing Product Losses in 141 Fluid Milk Plants in the United States	Mark W. Stephenson Jay Mattison Richard D. Aplin Eric M. Erba
No. 96-06	Dairy Department Procurement Dynamics The Role of the Supermarket Buyer	Edward W. McLaughlin Debra J. Perosio
No. 96-07	Integrating Knowledge to Improve Dairy Farm Sustainability	Caroline N. Rasmussen, ed.
No. 96-08	A Descriptive Analysis of the Characteristics and Financial Performance of Dairy Farms in Michigan, New York, Ontario, Pennsylvania and Wisconsin	S. Ford R. Gardner S. Gripp S. Harsh W. Knoblauch A. Novakovic L. Putnam M. Stephenson A. Weersink R. Yonkers
No. 96-09	The Feasibility of a Mid-Hudson Valley Wholesale Fresh Product Facility: A Buyer Assessment	Craig Robert Kreider Edward W. McLaughlin
No. 96-10	Impact of National Dairy Advertising on Dairy Markets, 1984-95	Harry M. Kaiser
No. 96-11	Dairy Farm Management Business Summary New York State 1995	Stuart F. Smith Wayne A. Knoblauch Linda D. Putnam
No. 96-12	A Spatial Equilibrium Model for Imperfectly Competitive Milk Markets	Tsunemasa Kawaguchi Nobuhiro Suzuki Harry Kaiser

September 1996 R. B. 96-13

Comparisons of Costs and Efficiencies Between Cooperative, Proprietary, and Captive Fluid Milk Processors: A Neural Network Approach



Eric M. Erba
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A Publication of the
Cornell Program on Dairy Markets and Policy

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Acknowledgments

Eric M. Erba is a Ph. D. candidate, James E. Pratt is a Senior Research Associate, Richard D. Aplin is a Professor Emeritus, and Mark W. Stephenson is a Senior Extension Associate in the Department of Agricultural, Resource, and Managerial Economics at Cornell University.

We are grateful to the personnel from each of the participating dairy companies who invested many hours to research and report data from all aspects of their respective organizations. Without their efforts, this study would not have been possible. We wish to thank Tetra Pak, Inc. for generously providing a portion of the funding to conduct this research.

This publication was prepared under contract to the Rural Business and Cooperative Development Service/ Cooperative Services Programs, United States Department of Agriculture (#58-RDA-CS-4-0027).

HIGHLIGHTS

Labor Productivity and Costs in 35 Fluid Milk Plants

This report focuses on labor productivity and costs in 35 fluid milk plants in 15 states. We targeted medium and large plants that are well-managed and have a significant market presence. The 35 operations are highly respected in the industry and are thought to be among the best fluid milk plants in the country. Of the 35 plants in the study, 8 are owned and operated by supermarket companies (i.e., captive plants), 5 are owned and operated by farmer-owned milk marketing cooperatives, and the remaining 22 are independently owned and operated. Participating plants submitted data from a recent 12-month period. Most plants submitted data from 1993 or 1994 calendar years.

Key Characteristics of Survey Plants

The following table allows for comparisons of key characteristics among all plants in the study. The figures in the column labeled "High 3 Average" ("Low 3 Average") represent the average values of the three highest (three lowest) plants calculated for each characteristic. High and low averages for each characteristic were computed independently. For example, the plants that comprise the "High 3 Average" for the number of pounds of fluid products processed are not necessarily the same three plants that comprise the "High 3 Average" for SKUs processed, labor cost per hour, or any other category.

Plant Characteristic	Average of 35 Plants	Low 3 Average	High 3 Average	Details On Page No.
All fluid products, million lbs. per month	27.8	13.3	51.4	5
SKUs processed[1]	148	26	367	6
SKUs in cooler	250	40	539	7
Number of labels	11	2	34	7
Labor cost, including benefits, $ per hour	20.19	13.12	27.92	12
Electricity, ¢ per kwh	6.7	2.2	13.2	13
Natural gas, ¢ per therm	42.6	18.1	66.0	13
Level of processing & filling technology (1 to 10; 10 = highest)	7.4	4	9	7
Level of cooler & load out technology (1 to 10; 10 = highest)	5.9	1	10	7

[1] SKUs are stock keeping units, and each SKU denotes a different product. For example, skim, 2% milkfat, and whole milk packaged in half-gallon paperboard and gallon plastic jugs under 4 different labels constitute 3x2x4 = 24 SKUs.

Labor Productivity and Costs

This report contains detailed reporting of the following measures of performance on a per gallon basis:

- plant labor productivity
- plant labor costs
- utility costs
- total plant costs excluding depreciation
- total plant costs including depreciation

We offer the following reminders and caveats:

- The productivity and unit costs were calculated on a gallon equivalent basis which included ALL beverage products processed and packaged in the plant. Items other than fluid milk products included creamers, juices, drinks, bottled water, and ice cream mixes.

- Labor hours and labor costs reflect direct labor from the raw milk receiving bays through the cooler and load out area. Labor from the following areas was also included: maintenance, plant quality control, plant office support, and plant management. The blow mold area was excluded from plant cost and productivity measures.

- Labor hours and labor costs did NOT include any labor dedicated to production of soft products (e. g., cottage cheese, sour cream, and yogurt). Raw milk procurement, distribution, selling, and general and administrative expenses were also excluded.

- The plant with the highest labor productivity or the lowest cost per gallon is not necessarily the most profitable. Many factors affect profitability, and we have not attempted to analyze profitability in this report.

The following table enables comparisons of labor productivity and plant costs for all plants in the study.

Plant Characteristic	Average of 35 Plants	Low 3 Average	High 3 Average	Details On Page No.
Labor productivity, gallons/hr	174	107	286	11
Labor cost, ¢/gallon	12.3	7.7	17.1	13
Cost of utilities, ¢/gallon	2.6	1.7	4.2	14
Plant cost (depreciation excluded), ¢/gallon	18.2	11.5	24.0	15
Plant cost (depreciation included), ¢/gallon	21.2	13.1	27.3	15

Comparisons of Plant Descriptors and Plant Performances by Type of Ownership

When grouped by type of ownership, (i.e., plant is owned by vertically integrated supermarket company, milk marketing cooperative, or independently owned and operated), we found that there were significant differences among the three groups. The following table allows for comparisons of means of basic plant descriptors, such as plant size, cost of labor, and number of products processed by the plant.

	Averages by Plant Ownership Type			
Descriptor	Captive	Proprietary	Cooperative	Details On Page No.
Volume, 10^6 galons/month	3.55	3.36	2.28	16
Plant capacity utilized, %	77	76	77	16
Labels processed	3	13	18	16
SKUs processed	48	178	160	16
SKUs in cooler	70	299	332	16
Labor cost, $/hr	22.42	19.83	19.05	16
Electricity, ¢/kwh	7.2	6.4	7.4	16
Natural gas, ¢/therm	47.2	45.4	32.4	16

We also found that plants owned by supermarket companies were more productive and lower cost than either proprietary plants or cooperative plants. Although cooperative plants and proprietary plants typically operate as full-line plants, proprietary plants were slightly more productive and lower cost than cooperative plants. The following table allows for comparisons of means of cost and labor productivity measures grouped by type of plant ownership.

	Averages by Plant Ownership Type			
Descriptor	Captive	Proprietary	Cooperative	Details On Page No.
Labor productivity, gallons/hr	261	153	128	20
Cost of utilities, ¢/gallon	2.7	2.7	3.1	20
Cost of labor, ¢/gallon	8.6	13.1	15.1	20
Variable costs, ¢/gallon	13.8	18.9	22.2	21
Total plant costs, ¢/gallon	17.1	22.3	24.1	21

A Neural Network Approach to Determining the Effects of Various Factors on Labor Productivity and Cost per Gallon

Neural network methods encompass a broad class of flexible nonlinear regression and discriminant models, data reduction models, and nonlinear dynamical systems. Neural networks "learn" from examples and can exhibit some capability for generalization beyond the training data. The "learning" in this context is analogous to "estimation" in more traditional statistical analysis. Similarly, "training" data is analogous to "observed" data. Neural networks are useful for classification and function approximation problems which are tolerant of some imprecision, but to which strict rules cannot be easily applied. For example, neural networks are well-suited for pattern recognition, trend prediction, and image analysis. We used a neural network model to predict the effect of different factors on plant labor productivity and cost per gallon and to determine if factor effects differed by type of plant ownership. Our analysis revealed that:

- Plant size, as measured by actual monthly volume processed, was predicted to increase labor productivity and decrease cost per gallon for the three types of plant ownership.

- Higher labor cost per hour was expected to increase labor productivity for the three types of plant ownership but with an associated increase in cost per gallon.

- Regardless of type of ownership, plants were predicted to be more productive and lower cost without unionized labor.

- Increases in percent of products packaged in gallon and half-gallon containers and percent of plant capacity utilized were predicted to increase labor productivity and decrease cost per gallon.

- Plants with more advanced equipment in the processing and filling area had slightly higher labor productivity with little impact on costs per gallon. Plants with more advanced equipment in the cooler and load out area had significantly higher labor productivity and slightly lower costs per gallon.

- More intensive use of pallets was predicted to increase labor productivity and decrease cost per gallon, but a large increase in the percent of volume handled on pallets was necessary to produce these effects.

- Processing more stock keeping units was predicted to decrease labor productivity and increase plant cost per gallon, but a large increase in the number of products processed was necessary to produce these effects.

- Without exception, changes in the various inputs impacted labor productivity in cooperative plants considerably less than what was predicted for captive or proprietary plants.

- Labor productivity and cost per gallon in cooperative plants were predicted to respond well to increases in plant capacity utilization, decreases in the number of products processed, increases in the volume of product handled on pallets, and improvements in cooler technology.

INTRODUCTION

Objectives

This report details the findings of a survey of 35 fluid milk plants believed to be among the best operations in the United States. The objectives of the study were to determine the costs of processing and distributing fluid milk products and to identify and to quantify the factors which contribute to differences in labor productivity and costs among plants under different ownership categories.

Research Justification

The fluid milk industry is the largest single-product sector of the U.S. dairy industry, representing about 37% of the usage of U.S. milk production. Approximately 500 companies and 645 plants produce fluid milk products which have an annual wholesale value of about $23 billion. As is generally true in the dairy industry, the number of products processed and handled by fluid milk plants shows tremendous variability.

The main (perceived) role of milk marketing cooperatives has been to balance milk supply, but changing market conditions have resulted in cooperative ownership of fluid processing facilities. In 1992, 29 cooperatives owned fluid milk plants, and about one-third of the cooperatively owned fluid milk plants accounted for about 90% of total fluid milk volume processed by cooperative plants (15). Thus, although most butter/powder plants are owned and operated by cooperatives, a small number of fluid milk operations are also owned and operated by cooperatives. Since 1980, the volume of packaged fluid milk products distributed by cooperatives relative to all fluid milk processors has held constant at about 16% (15).

Uncertain impacts of the Dairy Title of the 1995 farm bill leaves cooperatives concerned about the future. Cooperative ownership of fluid milk plants may become increasingly important as the dairy industry moves toward less governmental intervention and regulation. It is necessary to understand the differences in productivity and cost of processing between ownership types – cooperative, proprietary, and vertically integrated supermarket plants – if cooperatives are to be successful owner/operators of fluid milk plants.

Outline of Report

The report is divided into three major sections, each with subsections detailing specific topics. The first section addresses general characteristics of the plants studied, including the reported volume of milk and other beverage milk products processed, percent plant capacity utilization, number of labels and stock keeping units (SKUs) processed, plant and cooler evaluations, filling equipment, and product handling.[1] Plant labor productivity, labor costs, cost of utilities, and processing costs are also reviewed. The second section reviews differences among the 35 plants based on type of plant ownership. The third section uses a neural network model to quantify the effects of various factors on labor productivity and cost per gallon.

---

[1] Stock keeping unit (SKU) was defined as a specific product with a specific label in a specific package size.

Background Information On Fluid Milk Plants

In 1857, Louis Pasteur, a French chemist and bacteriologist, discovered that heating milk postponed milk spoilage. Not coincidentally, commercialized firms that processed and marketed fluid milk products began to emerge soon after Pasteur's findings. Before the times of commercialized fluid milk processing and packaging, dairy farmers prepared and distributed milk. As they became more involved in milk production, these tasks became the responsibility of organizations specializing in milk processing and marketing (10).

In the mid to late 1800s, fluid milk processing and packaging was a relatively new industry, and improved techniques or mechanical innovations were rare. The introduction of returnable glass quart milk bottles marked the beginning of several technologies introduced to increase the efficiency and safety of fluid milk processing. In 1886, automatic filling and capping equipment was developed for milk bottlers, and in 1911, automatic rotary bottle filling and capping equipment was perfected for large scale use which further increased the speed and efficiency of bottling plants (22). Between 1930 and 1950, high temperature-short time (HTST) continuous flow pasteurization replaced vat pasteurization as the primary method of preparing fluid milk for bottling. As bottling plants soon discovered, automation of fluid milk processing and filling equipment led to substantial increases in labor productivity and plant efficiency. The relatively recent developments of plastic-coated paper containers, plastic jug containers, clean-in-place (CIP) systems, case stackers, conveyors, and palletizers contributed further to efficiency gains of fluid bottlers.

Although fluid milk processing plants may differ in size and in form, the functional aspects are relatively consistent. As with any manufacturing plant, raw materials are transformed into finished products through process applications as the products "flow" through the plant. The raw material in this case is milk which arrives at the plants via bulk milk trucks or tractor-trailers. In the receiving bays of the plant, the milk is pumped from the bulk transport tanks and passes through a plate cooler which reduces the temperature of the milk to 35° F before it reaches the raw milk storage tanks or silos. From the silos, HTST processing, which passes milk through a heat exchange plate, pasteurizes the milk. The process heats the milk to temperatures of 163° F to 170 ° F for 15 to 18 seconds, killing most of the microorganisms the milk may contain. After pasteurization, a separator removes the milkfat component from the skim portion of the milk. Excess cream may be stored for future processing, but it is often sold in bulk to ice cream or butter manufacturing plants. In-line standardization allows the removed cream to be added back to the skim portion as the milk continues to flow from the pasteurization area to the homogenizer. A homogenizer contains a series of high-speed pistons that break down milkfat particles; this process prevents cream from separating from the skim portion of milk. After homogenization, milk flows to pasteurized storage tanks. From these tanks, milk is either pumped or gravity-fed to filling equipment where it is packaged in plastic-coated paper containers, plastic jug containers, or polybags. Packaged milk is placed (usually automatically) into plastic, wire, or cardboard cases for further handling. The traditional milk case has been a 16-quart plastic case, but the introduction of disposable, nonreturnable corrugated cardboard cases has allowed for growth of one-way shipments of milk. After the packaged milk has been placed in cases, the product must move immediately into a cooler to prevent rapid spoilage. Most plants use equipment to automatically form stacks of 5 to 7 cases. The stacked cases travel on a track conveyor which transports the product to the cooler where it is stored temporarily until it is loaded on a delivery vehicle for distribution to retail outlets.

In an attempt to use the facility as efficiently as possible, most fluid milk plants process other products which might include juices; flavored drinks; light, medium, and heavy creams; half and half; buttermilk; ice cream mixes; and bottled water. Generally, these items use the same plant equipment as fluid milk products. Some plants may also have soft dairy product processing capabilities and produce cottage cheese, yogurt, sour cream, and ice cream in addition to the beverage products.

Previous Studies of Fluid Milk Plants

Results from fluid milk processing and distribution cost studies have a variety of uses. Fluid milk plant management and executive personnel may apply the results to their own operations to gauge or bench mark the performance of their operations against other similar milk plants. Such studies may also reveal which aspects of fluid milk operations offer the most benefit from internal restructuring or capital investments. The results may also be useful for regulatory purposes, especially for states that regulate milk prices at the wholesale or retail level. At the academic level, cost of processing and distribution studies have been an invaluable component for modeling the dairy industry and projecting structural changes in milk markets.

In the past 35 years, the cost of processing fluid milk has been analyzed several times. Studies by Blanchard et. al. (5) and Bond (6) partitioned plants into separate cost centers and used cost data to analyze differences in efficiencies among participating plants. Other research has investigated processor sales, costs of goods sold, operating costs, and gross and net margins for moderate-sized fluid milk plants (1, 13, 14, 18). Because of difficulties encountered in recruiting participants for processing cost studies or lack of an adequate number of representative plants, economic engineering studies have served as an alternative method of estimating minimum achievable processing costs per gallon and investigating the consequences of various plant volume capacities on per unit processing costs (8, 11, 12, 17, 20).

Studies that attempt to identify the factors that affect plant productivity and the cost of processing are less common. Thraen et. al. (21) estimated a functional relationship between total plant cost and plant volume based on data from 15 cooperatively owned and operated fluid milk plants, suggesting that per unit costs decrease with increases in plant processing volume. Metzger (16) found that, among 21 Maine dealers, plants with larger processing volumes were associated with lower per unit costs of processing and distributing fluid milk products. Aplin (2, 3) indicated that economies of scale, utilization of plant processing capacity, product mix, and level of technology in the processing and cooler areas were expected to influence the cost of processing as well as plant labor productivity.

Profile of Fluid Milk Operations Studied

This study targeted medium and large fluid milk operations that are well-managed, have high labor productivity, and maintain a significant market presence. Our list of "benchmark" operations was constructed by consulting with fluid milk industry executives and Federal Milk Marketing Order Administrators to identify the fluid operations that are highly respected. Thus, the plants did not represent a random sample of all fluid milk plants throughout the country. A high percentage of the plants identified for the study agreed to participate.

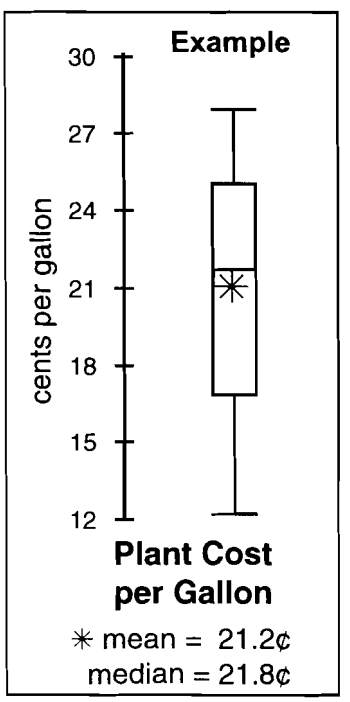
Data Collection Period

Plants were requested to submit data on plant operations for a recent 12-month period. The data collection period spanned just over 2 years, with the oldest data representing plant activities in January 1993 and the most recent representing activities in March 1995. Although most plants submitted data for 12 consecutive months, a few plants submitted quarterly or annual data.

Much of the data submitted were aggregated into monthly averages to simplify the report. Some plants submitted information based on different time frames (for example, 13 4-week periods or 12 weekly periods with a 4-4-5 week allocation). These data were converted to corresponding monthly figures to allow for comparisons among all plants. In several of the plants, soft manufactured dairy products (e. g., sour cream, cottage cheese, and yogurt) were produced in addition to the fluid beverage products. These plants reported neither the monthly production of these products nor their associated production costs.

Using Boxplots to Report Results

Boxplots are used as descriptors of data points in many instances in this report. The following explanation regarding the information that they contain may help to interpret their meaning. The boxplot to the right illustrates plant cost per gallon for the 35 plants in the survey. Plant cost includes the costs of direct processing and filling labor, cooler and load-out labor, and all other plant labor, electricity, gas, water and sewage, building and equipment depreciation (excluding any depreciation charged to blow mold equipment), leases, repairs, parts, cleaners and lubricants, plant supplies, pest control, refuse collection, taxes, and insurance.



Boxplots are a method of displaying the central point and dispersion of data. The information is broken down into quartiles (25% of the ranked observations fall into each quartile). The center "box" which is composed of the two middle quartiles outlines the middle 50% of the observations. The horizontal line within the box indicates the median value of the data set. The median is the midpoint of the data. In other words, 50% of the observations lie above the median, and 50% of the observations lie below the median. Here, the median plant cost is 21.8¢ per gallon. The sample mean, the location of which is represented in the boxplot by the starburst (✳), is the average value of the collected data. For this data set, the sample mean is 21.2¢ per gallon. The mean and the median are close in magnitude for this example which implies that the mean plant cost per gallon is not unexpectedly skewed toward a higher or lower cost per gallon. The sample mean and median need not be closely matched in magnitude as will be encountered in some of the following analyses.

Correlation Coefficients

Correlation is a measure of the degree of association between two variables. Correlations range from -1 to +1 and are denoted by the symbol "r". A correlation of +1 indicates a perfect linear relationship, i.e., the "movement" of the two variables matches precisely in direction, but not necessarily in magnitude. A correlation of -1 indicates that the variables are "moving" in exactly opposite directions. A correlation of 0 means that no linear relationship exists between the two variables. Correlations imply nothing about the causal relationship between two variables. For example, a correlation coefficient of 0.8 between plant labor productivity and average employee height would not necessarily imply that taller employees increase plant labor productivity. It merely indicates that the two variables are positively related in a relatively strong manner.

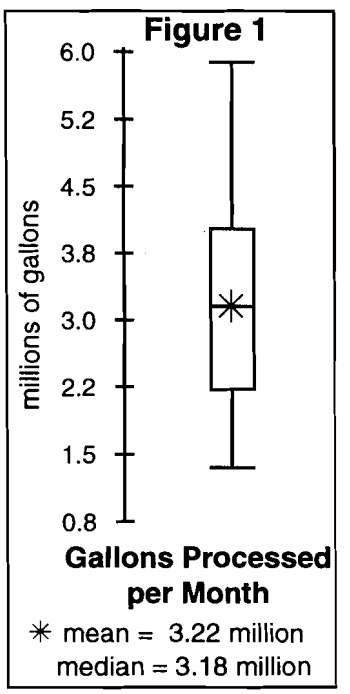
GENERAL CHARACTERISTICS OF PLANTS STUDIED

Plant Location and Ownership

The plants participating in the study were widely dispersed throughout the United States. Although 14 of the plants were located in the Northeast, 7 plants were located in Western and Mountain states, 7 were located in the Middle Atlantic and Southeast, and 7 were located in the Upper Midwest. Of the 35 plants in the study, 5 were owned and operated by milk marketing cooperatives, 8 were owned by vertically integrated supermarket chains (i. e., captive plants), and the remaining 22 were owned and operated by proprietary firms.

Volumes Processed

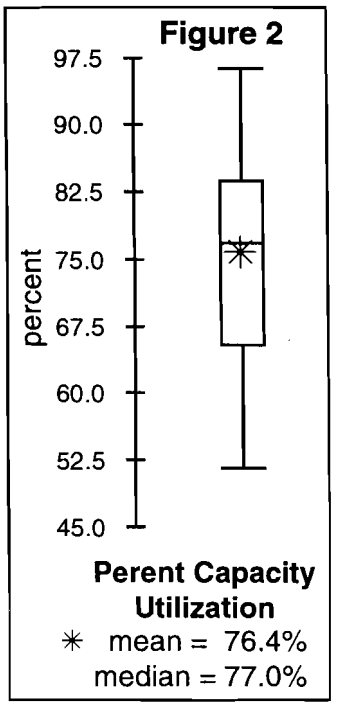
Figure 1 shows the average monthly volume of beverage milks and other fluid products processed by the 35 plants. Fluid products included all white and flavored milk products, half and half, heavy cream, buttermilk, ice cream mix, juices, drinks, and bottled water. Other products, such as sour cream, yogurt, cottage cheese, and carbonated drinks were not included. Participating plants processed an average of 3.22 million gallons (27.8 million pounds) of products per month with a median of 3.18 million gallons (27.4 million pounds). Processing volume for all plants ranged from 1.36 million gallons to about 5.97 million gallons per month (11.7 million pounds to 51.4 million pounds).



Plant Capacities

The maximum capacity rating of each plant was defined as the level of processing that could be sustained without changing the existing equipment, buildings, product mix, or customer mix. Additional shifts of labor or additional processing days were allowed. Using the maximum capacity rating and the actual gallon equivalents of fluid products processed each month, a measure of capacity utilization was estimated. All monthly estimates for plant capacity utilization were averaged to produce a single number (Figure 2). Capacity utilization ranged from about 51.8%

to 96.5% with an average of 76.4%. It was evident that a number of facilities were operating far below their maximum sustainable capacity, and as a consequence, had excess plant capacity for several months throughout the year. Consistently low capacity utilizations were calculated for plants that process large amounts of non-beverage products because only beverage products were considered when determining gallon equivalents processed each month. Consequently, plants that processed large volumes of soft products were not included in the calculation of plant capacity utilization.



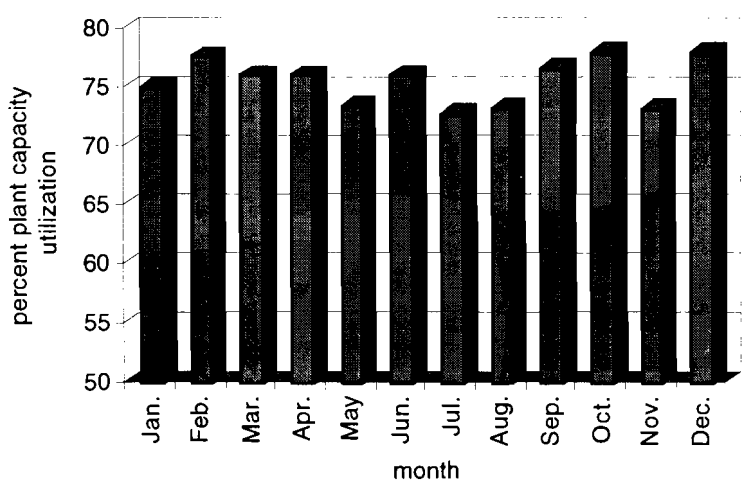
We compared plant capacity utilization by month. We calculated daily productions for each plant and then standardized all production data to 30.5 days to avoid potential bias encountered by comparing months of unequal lengths. The results revealed that there were small differences in average monthly plant capacity utilization (Figure 3).

Plant capacity utilization was not expected to be high during the summer months. Milk supply typically increases during the spring and early summer, but demand for beverage dairy products tends to be lower. Although farm milk production typically drops off during the late fall and early winter, high capacity utilization was anticipated because of increased consumption of beverage milk products and production of seasonal beverages. This hypothesis was supported by the results. On average, plant capacity utilization was highest in December, followed by October, February, and September. Plant capacity was utilized the least in July, May, and August.

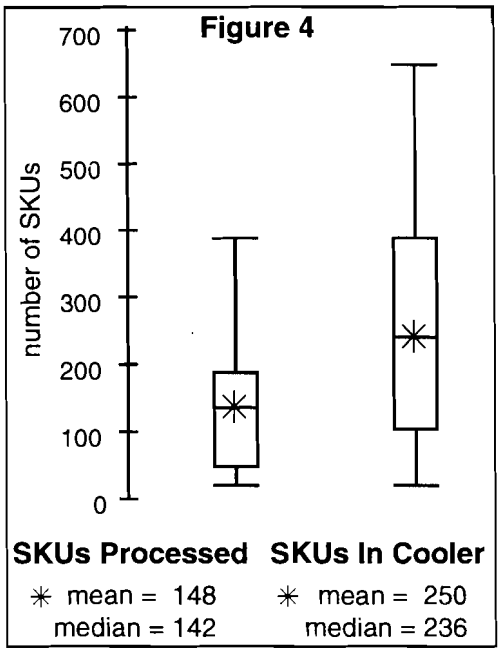
Number of Products, Labels, and SKUs Processed

None of the plants in the study was strictly a fluid milk plant, i. e., a plant that only processed beverage milk products. Many products were processed, packaged and stored

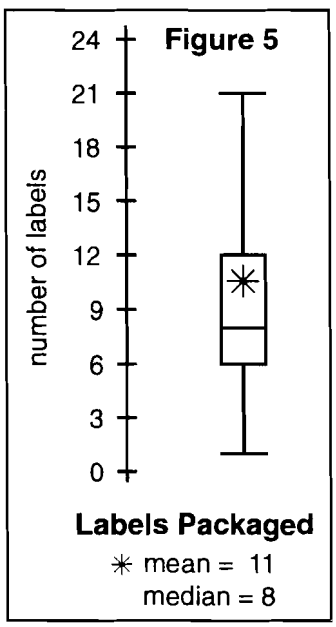
Figure 3. Average percent plant capacity utilization by month



along with the variety of beverage milk products. Very few plants processed and packaged UHT products, and the most common products processed with UHT technology were coffee creamers; half and half; and light, medium, and heavy creams. A few plants processed and packaged soft dairy products, such as sour cream, cottage cheese, and yogurt. Nearly all plants brought finished products into their coolers from other food manufacturers which were then distributed to wholesale or retail outlets with the products processed by the plant. However, a few plants did not bring any finished purchased products into their coolers. Figure 4 illustrates the range of stock keeping units (SKUs) that were plant-processed and the range of SKUs handled in the cooler. On average, plants processed 148 SKUs and stored about 250 SKUs in the cooler. The data for each category was quite disperse with SKUs processed ranging from about 20 to nearly 400. The number of SKUs stored in the cooler ranged from 25 to 650.



Most plants indicated that they packaged products under multiple labels (Figure 5). Seven plants processed four or fewer labels, and six plants processed twenty or more labels. On average, the plants packaged beverage products under 11 labels. The number of SKUs processed was influenced by the number of labels processed. The correlation coefficient for labels and monthly volume processed was weak (r = 0.17), indicating that plants processing and packaging beverage products for a large number of labels were not necessarily large operations. The correlation coefficient for SKUs processed and monthly volume processed was also weak (r = 0.27), indicating that large facilities were not necessarily the plants processing and packaging a large number of SKUs.



Plant and Cooler Evaluation

A number of questions were posed in the survey to characterize the level of technology and automation. Automation and technology in the processing and filling area and in the cooler and load-out were evaluated by the plant manager at each plant. The managers were asked to use a 10-point scale to self-assess the levels of technology in the two areas of the plant (1 = the lowest level of technology, and 10 = the latest, most innovative technology). Similarly, cooler size and cooler design were assessed on 10-point scales (1 = too small; poor layout, and 10 = spacious; convenient design).

Automation and technology in the processing and filling area averaged 7.4 and ranged from 4 to 9 (Table 1). About 83% of the plants rated the technology and automation in their processing and filling area 7 or better. Automation and technology in the cooler and load-out area was more variable, ranging from 1 to 10 and averaged 5.9.

Table 1. Ratings of plant and cooler characteristics by plant managers[1]

Characteristic rated:	Mean	Median	Minimum	Maximum
Processing and filling area	7.4	8	4	9
Cooler and load-out area	5.9	7	1	10
Cooler size	5.7	6	1	10
Cooler design and layout	6.3	7	2	10

[1] Automation and technology, cooler size, and cooler layout were evaluated by the plant manager at each facility. The managers were asked to use a 10-point scale to assess the levels of technology ("1" = older technology, and "10" = innovative technology). Similarly, cooler size and cooler design were assessed on 10-point scales ("1" = too small; poor layout, and "10" = spacious; convenient design).

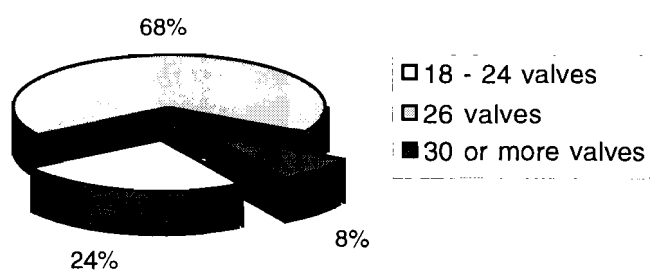
About 50% of the plants rated the automation and technology in their cooler and load-out area 7 or better. The correlation between processing and filling technology and cooler and load-out technology was surprisingly low (r = 0.20), indicating that high ratings for technology in the processing and filling area were only weakly associated with high ratings for technology in the cooler and load-out area.

Ratings for cooler size and cooler design followed the same dispersed pattern as shown by cooler and load-out technology (Table 1). Among the 35 participating plants, cooler size averaged 5.7, and cooler design averaged 6.3. About one-third of the plants rated both the size and layout of their coolers 4 or less. Correlation coefficients among cooler and load-out technology, cooler size, and cooler design ranged from mildly strong to strong. The correlation between cooler size and cooler design indicated that larger coolers were also likely to be more conveniently designed (r = 0.63). The correlation between cooler and load-out technology and cooler design indicated that coolers with more automation were very likely to be more conveniently designed (r = 0.81). The correlation between cooler and load-out technology and cooler size indicated that coolers with more automation were likely be more spacious (r = 0.62).

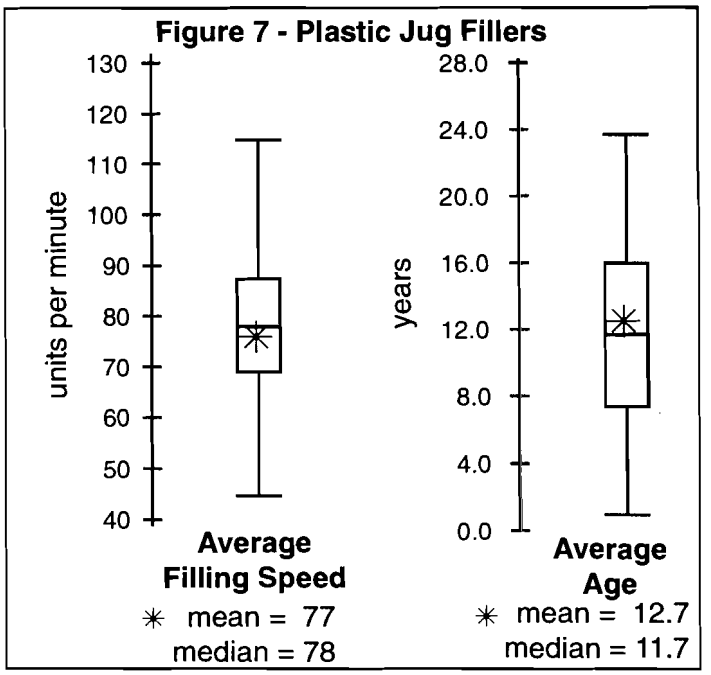
Plastic Jug Filling Equipment

All plants operated plastic jug filling equipment and most operated paperboard container filling equipment as well. Plastic jug fillers were almost exclusively manufactured by Federal, although a small percentage of jug fillers were manufactured by Fogg. The size of plastic jug fillers, as measured by the number of valves per machine, was variable, but over two-thirds of jug fillers were equipped with 26 valves (Figure 6). Fillers with 18-valves were generally reserved for filling half-gallon jugs, but it was not unusual for plants to fill gallon and half-gallon jugs on a single machine. The average age of

Figure 6. Percent of gallon and half-gallon plastic jug fillers by number of valvles

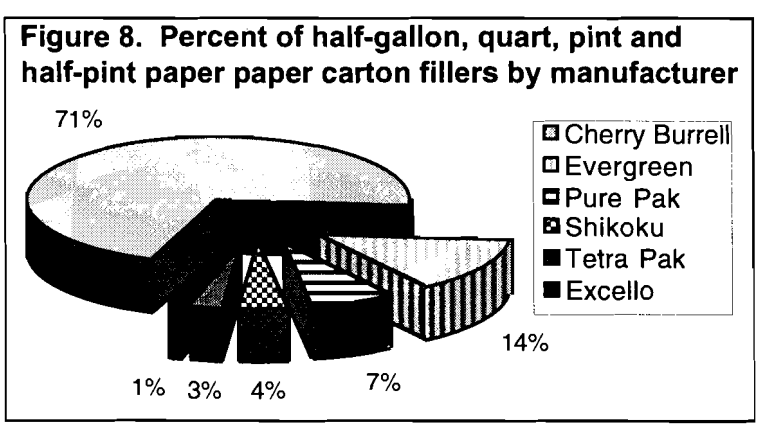


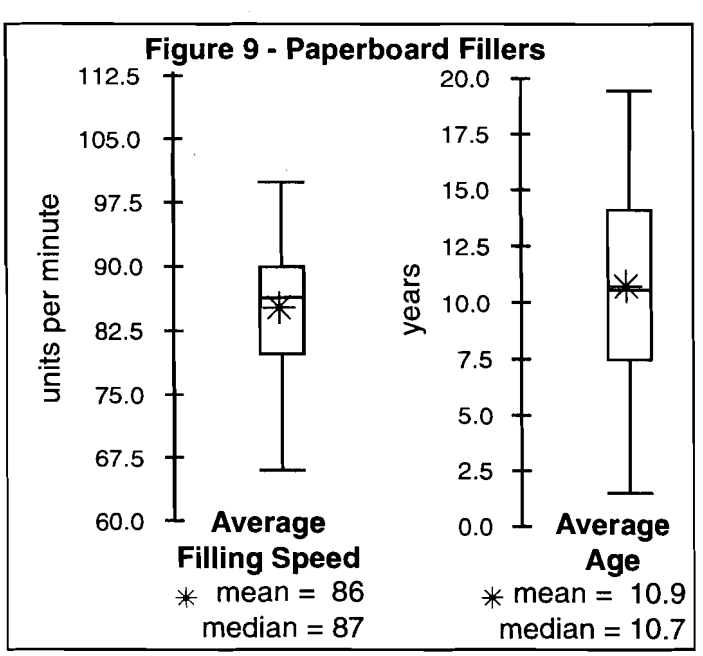
all plastic jug fillers was 12 years and ranged from 1 year to 24 years (Figure 7). Actual filling speeds, as opposed to manufacturers' ratings, were reported for machinery used to fill gallon jugs. Plastic gallon jug filling equipment averaged 77 units per minute and ranged from 45 units per minute to 115 units per minute (Figure 7). The correlation coefficient for gallon jug filling speed and age of plastic gallon jug fillers indicated that older machines were somewhat more likely to operate at slower rates (r = -0.43).



Paperboard Filling Equipment

Manufacturers of paperboard fillers were more numerous than plastic jug fillers, but Cherry Burrell was clearly the dominant manufacturer of paperboard filling equipment in the participating plants (Figure 8). Forty-three percent of paperboard fillers were used exclusively for filling half-gallon containers. The other fillers were capable of handling a variety of package sizes. About 45% were capable of filling quart, pint, and half-pint containers, and the remaining 12% were used to package half-pint and 4-ounce NEP containers. The average age of all paperboard filling equipment was 10.9 years and ranged from 1 year to 19 years (Figure 9). Actual filling speeds, as opposed to manufacturers' ratings, were reported for half-gallon paperboard filling equipment. The average filling speed was 86 units per minute, and the range was 65 units per minute to 100 units per minute (Figure 9). The correlation coefficient for half-gallon paperboard filling speed and age of half-gallon paperboard fillers indicated that older machines were somewhat more likely to operate at slower speeds (r = -0.47).

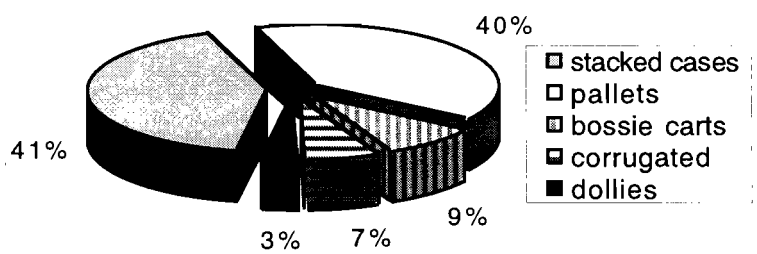




Product Handling In the Cooler and Loading

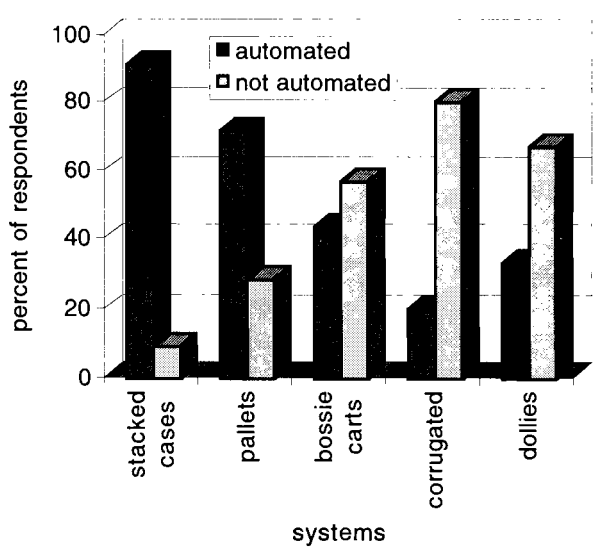
A wide variety of product handling systems were used in the coolers of the 35 participating plants: stacked cases, corrugated boxes, bossie carts, dollies, and pallets. All but five of the plants used two or more of these product handling systems in their coolers. Product handled on pallets was packed in plastic cases, wire cases, or corrugated boxes prior to loading on a pallet. To eliminate any confusion with these different product handling systems, stacked cases or corrugated boxes placed on pallets were classified as pallets. Stacked cases and corrugated boxes refers only to the product handled in individual stacks. Pallets and stacked cases accounted for the largest shares of volume handled by the various systems (Figure 10). On average, 41% of the plants' volumes were handled using stacked cases, and 40% were handled on pallets. Bossie carts accounted for about 9% of the volume handled, and corrugated boxes and dollies combined for about 10% of the volume handled.

Figure 10. Percent of plants using various product handling methods in the cooler



To characterize the handling systems and associated assembly processes, each product handling system of each plant was categorized as "automated" or "not automated". For example, case stackers and palletizers indicated automated product handling processes. Ninety percent of the plants using stacked cases to handle product indicated that mechanical case stackers were used (Figure 11). Three-fourths of the plants using pallets to handle product indicated that pallets were loaded by automated equipment. More than 55% of the plants using bossie carts responded that the carts were loaded manually. Similarly, corrugated boxes and dollies were less likely to be automated processes. For the less popular product handling systems, automation appeared to be associated with the volume of product handled. In other words, a plant that handles 5% of its volume on bossie carts may find it difficult to justify purchasing an automated cart loader whereas another plant that handles 30% of its volume on bossie carts may be able to justify an automated cart loader.

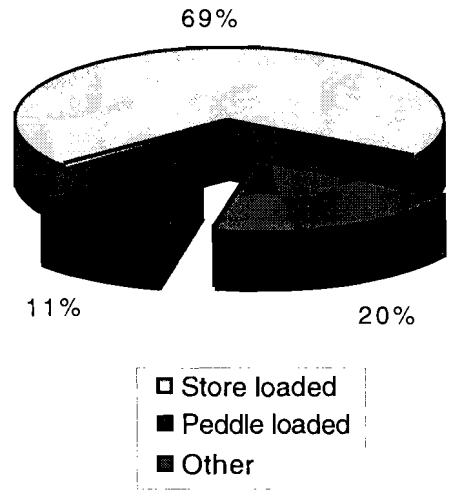
Figure 11. Percent of respondents using automated product handling systems



When placed into the delivery vehicles, product is organized largely by customer (store loaded) or by product (peddle loaded). "Store loaded" means that orders are pre-picked in the cooler and then arranged on

delivery vehicles by the customers receiving orders on the route. "Peddle loaded"means that orders are not pre-picked, and the driver is responsible for assembling the order at the time of delivery. As such, products are arranged on the delivery vehicle to simplify order filling at the time of delivery. About 89% of all routes operated by the 35 plants were either store loaded or peddle loaded (Figure 12). The remaining 11% of the routes were loaded by other methods. The most popular alternative method was bulk loading, usually reserved for trucks and trailers destined for warehouses or other drop points.

Figure 12. Percent of all distribution routes loaded by various methods

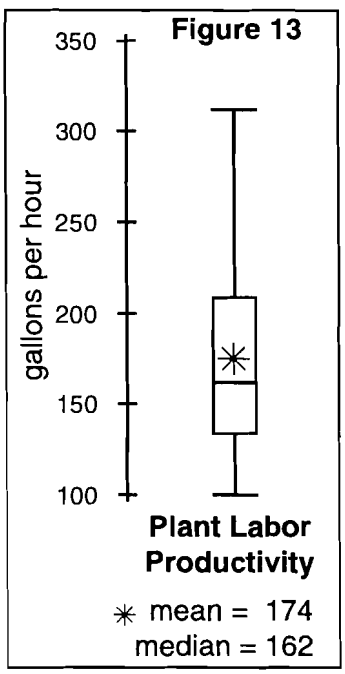


Plant Labor Productivity

Plant labor productivity is one measure of plant efficiency. Plant labor productivity for the 35 plants reflected the volume processed, in gallon equivalents, relative to the hours worked by direct plant, cooler, and all other plant labor. All milks, creams, buttermilks, juices, drinks, bottled water, and ice cream mixes were included in the calculation of volume processed. Direct processing labor included all processing plant employees from the receiving bay to the cooler wall, and cooler labor included employees in the cooler and load-out areas as well as any jockey labor.[2] "All other plant labor" was a general plant labor category that included maintenance, engineers, plant quality control, plant office support, and plant management. Plant labor productivity did not include any labor from the blow mold area, nor did it include any labor used in producing soft dairy products (e. g., cottage cheese, sour cream, and yogurt). Hours worked in milk procurement, research and development, distribution, selling, and general and administrative personnel were also excluded.

Plant labor productivity ranged from about 100 gallons per hour to over 320 gallons per hour (Figure 13). The top ten plants, eight of which were captive supermarket plants, averaged more than 210 gallons per hour. These highly productive plants influenced the average plant labor productivity as evidenced by the large difference between the mean and median (174 gallons per hour versus 162 gallons per hour). Twenty-two of the 35 plants fell in the range of 100 gallons per hour to 170 gallons per hour.

Figure 13



[2] Jockey labor moves distribution trucks and trailers into and out of the loading bays.

Plant Labor Costs

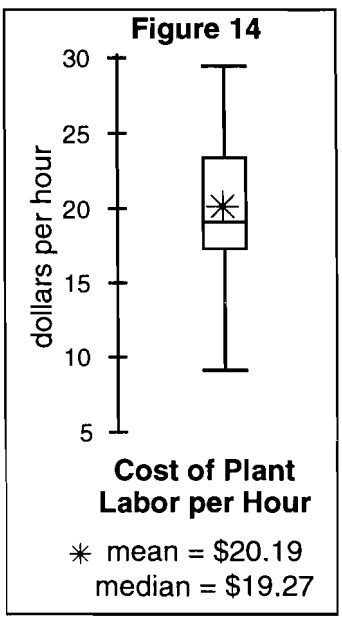
Hourly Cost of Labor

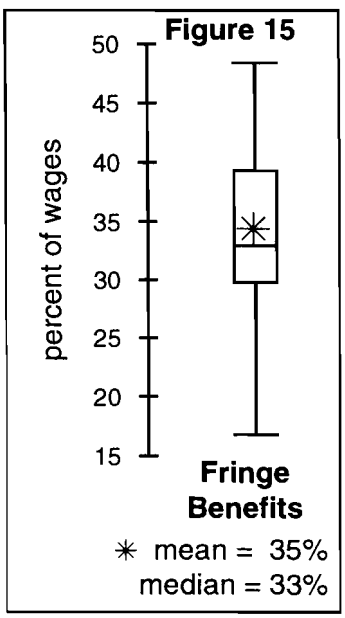
Labor cost per hour (wages and fringe benefits) was calculated by dividing the sum of the direct plant, cooler, and all other plant labor costs by the total number of hours worked in the plant. Labor assigned to the blow mold, research and development, distribution, selling, general and administrative personnel was not included in this category.

Cost of plant labor averaged about $20.19 per hour, but there was a tremendous range among plants (Figure 14). Plant location and the availability of other competitive occupational opportunities may explain some of the variation in cost of labor per hour. For example, New York City Metropolitan Area plants paid an average of $24.88 per hour for plant labor while the cost of labor in all other plants averaged $19.42 per hour.

Fringe Benefits

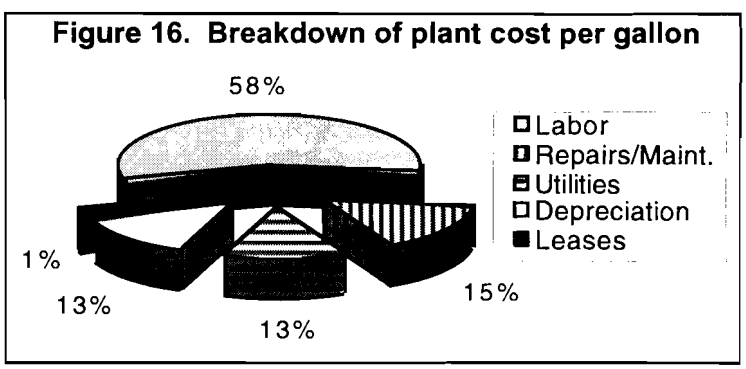
Fringe benefits included employer contributions to medical insurance, employees' pension fund, vacation, and gifts as well as the mandatory contributions to FICA, workman's compensation, and unemployment insurance. Not all plants contributed to all benefit categories. Benefits as a percentage of labor wages ranged from about 17% to 48% with an average of 35%, but 85% of the plants fell in the range of 18% to 40% of wages (Figure 15).





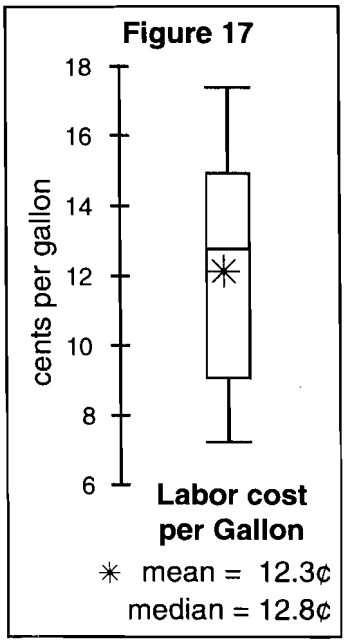
Labor Cost per Gallon

The cost of labor was the largest single factor in determining plant cost per gallon (Figure 16). The percent of plant cost per gallon attributable to labor costs ranged from 41% to 70% with a mean of 58%. The average labor cost was 12.3¢ per gallon of fluid products processed, and the median labor cost was 12.8¢ per gallon (Figure 17). Labor cost per gallon was influenced by a number of factors, including plant location. For example, plants in and around New York City tended to have higher labor costs per gallon than plants in other parts of the country. Plants around the New York City Metropolitan Area averaged 14.3¢ per gallon for labor costs, and all of the plants outside this area averaged 12.1¢ per gallon.



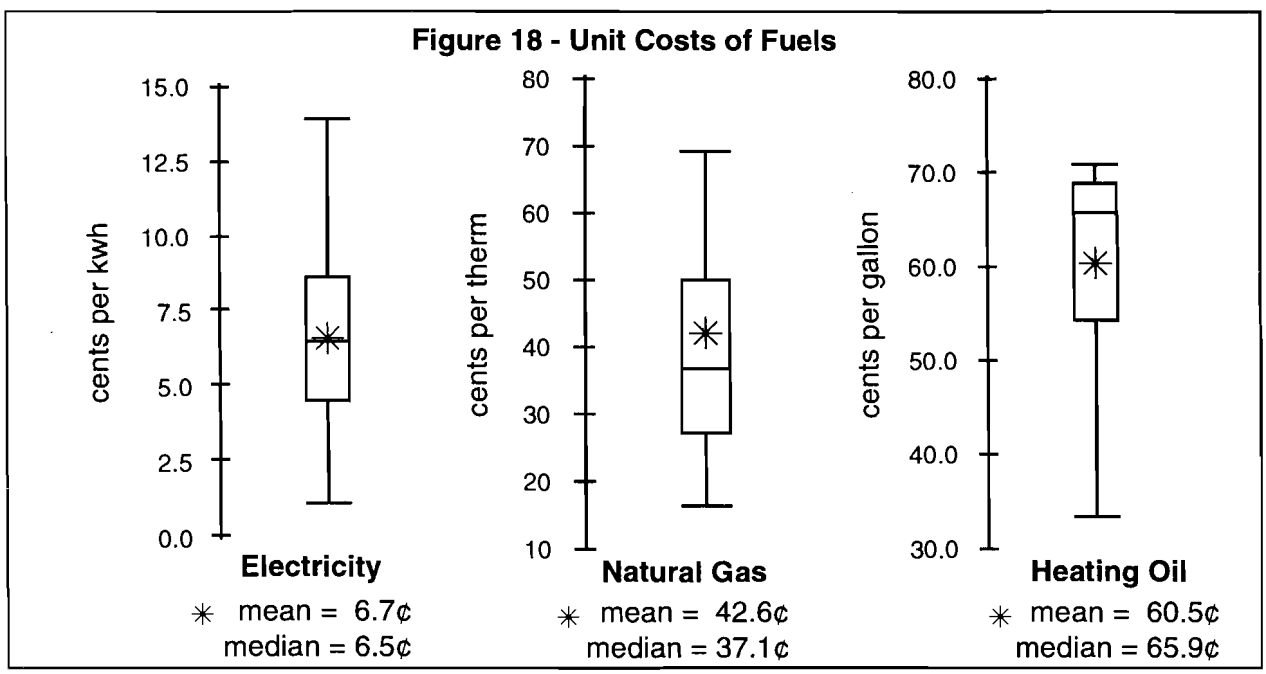
Cost of Utilities

All 35 participating plants reported per unit electricity and natural gas costs. Heating oil and liquid propane were also used as fuels but far less frequently than electricity and natural gas. The common unit of measure of electricity was kilowatt-hour (kwh), but natural gas was measured in therms, decitherms, hundred cubic feet (ccf), and thousand cubic feet (mcf). To make meaningful comparisons, all unit costs for natural gas were converted to cents per therm.



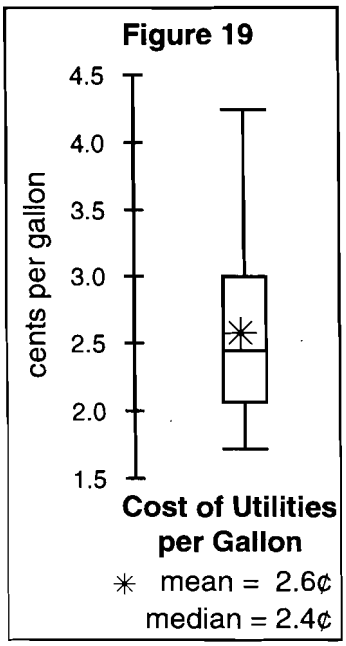
There were substantial differences among the lowest and highest per unit costs for electricity and natural gas (Figure 18). Cost of electricity averaged 6.7¢ per kwh with a median of 6.5¢ per kwh. About 85% of the plants reported units costs between 3.5¢ per kwh and 10.0¢ per kwh. Natural gas costs ranged from 17¢ per therm to 70¢ per therm. The average cost of natural gas was 42.6¢ per therm with a median of 37.1¢ per therm. The data was uniformly distributed around the median, i. e., reported per unit costs did not tend to cluster around any certain costs. Plants that paid high per unit costs for electricity were likely to pay high per unit costs for natural gas (r = 0.60).

Unit costs for electricity and natural gas were dependent on plant location. For example, plants in and around New York City reported higher unit costs than plants in other parts of the country. Plants around the New York City Metropolitan Area averaged 9.9¢ per kwh and 53.4¢ per therm, and all of the plants outside this area averaged 6.2¢ per kwh and 36.8¢ per therm.



Only a handful of plants used fuel oil, and the majority of those plants did not specify which grade of fuel oil was used in the plant. Therefore, the average and median prices paid per gallon reflected the reported costs of all grades of fuel oil. Oil prices averaged 60.5¢ per gallon and were influenced by plant location as well as grade. The use of fuel oil in fluid milk plants was generally limited to late fall and winter months, and other fuel sources were used in plant operations during the remainder of the year.

The total cost of utilities per gallon processed varied widely (Figure 19). Cost of utilities per gallon was calculated as the 12-month average cost of utilities divided by the 12-month average volume processed by the plant. Utilities included electricity, natural gas, heating oil and other fuels, water, and sewage. Cost of utilities ranged from 1.7¢ per gallon to 4.3¢ per gallon and averaged 2.6¢ per gallon of product processed. Two-thirds of the plants had utility costs between 2.0¢ per gallon and 3.7¢ per gallon.



Plant Costs

Two measures were developed to assess the cost of operating each of the 35 fluid plants. Both measures represented plant cost per gallon of fluid product processed, but while one measure included the cost of depreciation, the other did not. Depreciation is an expense, albeit a non-cash expense, and it could be argued that depreciation costs should be included to paint a more accurate and complete portrait of plant costs and asset replacement. On the other hand, including reported depreciation costs in the calculation may be misleading because depreciation costs as reported in this study are based on bookkeeping methods. For older equipment and older plants, depreciation costs are low if the building and much of the equipment is fully depreciated. In addition, depreciation costs for new equipment and new plants may be determined on an accelerated basis which shows up as a higher depreciation cost than the actual consumption of capital in the early stages of the useful life of the assets.

The true economic cost of the investment in these fluid milk plants is not the accounting depreciation that was reported. Rather, it is the economic depreciation of the assets based on current replacement costs and the cost of capital tied-up in the assets (opportunity cost of capital). Unfortunately, neither economic depreciation nor opportunity cost information lent itself well to straightforward assessments by accounting personnel or controllers at the participating plants.

To avoid bias associated with bookkeeping depreciation in plant cost comparisons, we included two separate measures of plant cost per gallon. Specifically, one measure of plant cost accounted for the costs of labor, electricity, gas, water, sewage, building and equipment depreciation (excluding any depreciation charged to blow molding equipment), leases, repairs, maintenance, parts, cleaners, lubricants, plant supplies, pest control, refuse collection, taxes, and insurance relative to the volume processed in gallon equivalents. The second measure summarized variable costs and included all of the above items except depreciation expenses. The true plant cost per gallon would likely be bounded from below by the plant cost which excludes depreciation and from above by the plant cost which includes depreciation.

Ingredient costs were not included in either the calculation of total plant costs per gallon or variable costs per gallon. We excluded packaging costs from both of the plant cost measures because we found that unit purchase prices followed a time-series progression, i.e., the plants that submitted plant data in the early stages of the study had significantly lower packaging material prices than the plants that submitted plant data toward the end of the study. Any labor used in producing soft dairy products (e. g., cottage cheese, sour cream, and yogurt) was also excluded, as well as the costs of milk procurement, research and development, distribution, selling, and general and administrative personnel.

Plant Cost per Gallon

Among the 35 plants, plant cost per gallon, including depreciation, showed large variability, ranging from 12.3¢ per gallon to 28.0¢ per gallon (Figure 20). The average cost was 21.2¢ per gallon. About 65% of the plants fell within the range of 15¢ per gallon to 25¢ per gallon. One-third of the plants had calculated plant costs of less than 18¢ per gallon.

When depreciation expenses were excluded, variable costs per gallon dropped to an average of 18.2¢ per gallon and ranged from 10.9¢ per gallon to 26.2¢ per gallon (Figure 20). About three-fourths of the plants fell within the range of 13¢ per gallon to 23¢ per gallon.

When depreciation expenses were included, labor costs constituted 58% of plant cost per gallon (Figure 21). Building and equipment depreciation accounted for 13%, and the cost of water, sewage, electricity, and other fuels accounted for an additional 13%. As a group, repairs, maintenance, parts, cleaners, lubricants, plant supplies, pest control, refuse collection, taxes, and insurance totaled 15% of plant cost per gallon. Leases accounted for about 1% of plant cost per gallon.

Figure 20 - Plant Cost per Gallon

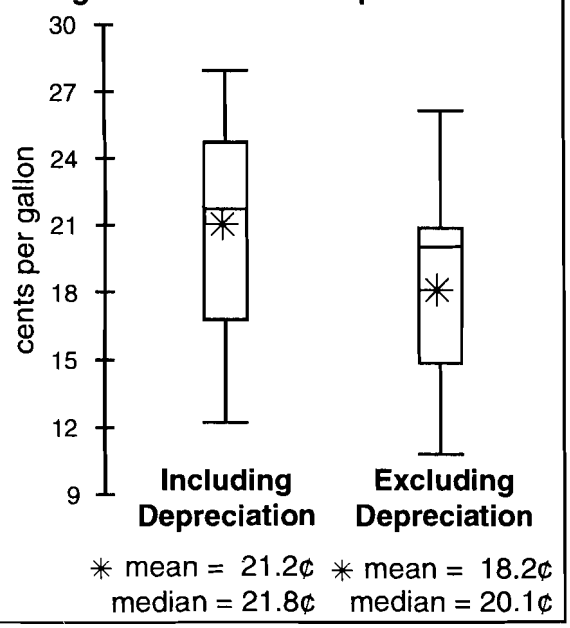
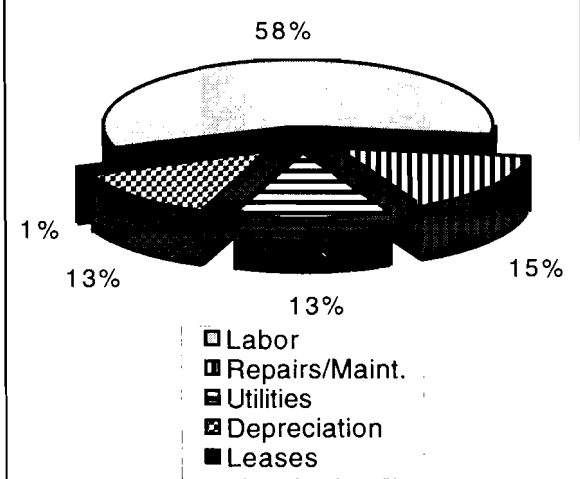


Figure 21. Breakdown of plant cost per gallon by percentage



COMPARISONS BASED ON TYPE OF PLANT OWNERSHIP

Overview

The second objective of this study was to investigate differences among the participating plants based on type of plant ownership. Although the majority of the plants in the study were independently owned and operated (63%), 14% of the plants were owned and operated by milk marketing cooperatives, and 23% of the plants were owned and operated by supermarket companies.

In this section, we present comparisons of basic plant information and efficiency measures by plant ownership with the appropriate statistical tests for differences among means. We emphasize comparisons of captive and proprietary plants against cooperative plants.

Statistical Test

We used heteroscedastic Student's t-Tests to evaluate differences among plants by type of ownership. Each test requires two distinct samples and assumes that the variances of both samples of data are unequal. Because we were investigating the profiles and performances of cooperative plants relative to other plants, we used two t-tests. One test compared captive plants and cooperative plants, and the second test compared proprietary plants and cooperative plants.

The results of the test are given in the form of probabilities. For example, $P = 0.05$ means that there is a 5% chance that the samples come from two underlying populations with the same mean. Conversely, $P = 0.05$ indicates that there is a 95% probability that the true means of all plants in each type of ownership class, including those plants not sampled, are different.

General Plant Comparisons

Comparing captive plants and cooperative plants revealed many statistically significant differences (Table 2). However, comparing cooperative plants and proprietary plants revealed few statistically significant differences.[3] Although we found few statistically significant differences between means of cooperative and proprietary plants, most of the comparisons favored proprietary plants.

To summarize Table 2, we provide a brief description of the results of the pairwise comparisons. On average, captive plants and proprietary plants were significantly larger than cooperative plants as measured by gallon equivalents of product processed per month. There were only small and insignificant differences among the means for plant capacity utilization among the three types of plant ownership. On average, captive plants processed many fewer labels and SKUs than cooperative plants and proprietary plants. Furthermore, captive plants stored very few SKUs in their coolers as compared to plants under different ownership. Relative to cooperative plants, proprietary plants processed

[3] By convention, P=0.05 is choosen as the level to indicate "statistical significance". If the computed probability is 0.05 (or less), then there is a 95% (or greater) chance that the means are different.

Table 2. Comparisons of means of basic plant information by plant ownership

Descriptor	Captive plant mean	Proprietary plant mean	Cooperative plant mean	*P* cap:coop[1]	*P* pro:coop[1]
Volume, x10^6 gal/mo	3.55	3.36	2.28	0.05	0.01
Plant capacity utilized, %	77	76	77	0.96	0.83
Labels processed	3	13	18	0.03	0.34
SKUs processed	48	178	160	0.03	0.67
SKUs in cooler	70	299	332	0.04	0.74
Labor cost, $/hr.	22.42	19.83	19.05	0.16	0.71
Electricity, ¢/kwh	7.2	6.4	7.4	0.91	0.66
Natural gas, ¢/therm	47.2	45.4	32.4	0.09	0.18

[1] Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

fewer labels and stored fewer SKUs in their coolers, but they processed slightly more SKUs than cooperative plants. The comparisons of SKUs and labels among proprietary and cooperative plants were not statistically significant. Labor cost per hour was higher in captive plants than proprietary or cooperative plants on average. These differences may be a function of plant location, rather than an intrinsic feature of captive plants. Proprietary plants paid employees slightly more per hour than cooperative plants. Cost of electricity and natural gas was mixed for the three plant types. Cooperatives had the highest unitary cost for electricity, but the lowest unitary cost for natural gas. Unit electricity and natural gas costs for captive plants were curiously high relative to other plants, but, again, this may be a function of plant location.

Plant and Cooler Comparisons

Although the plants in the study were considered to be among the best in the U.S., differences in plant age and capital investments in processing equipment and cooler machinery were evident. We attempted to assess technology and automation as well as obtain some measures of satisfaction with cooler design and layout. We asked the plant manager at each plant to use a 10-point scale to assess plant and cooler technology ("1" = the lowest level of technology, and "10" = the latest, most innovative technology). Similarly, cooler size and cooler design were assessed on 10-point scales ("1" = too small; poor layout, and "10" = spacious; convenient design). Table 3 summarizes the comparisons of the mean responses to four plant and cooler evaluation questions.

Comparing captive plants and cooperative plants revealed three statistically significant differences. However, comparing cooperative plants and proprietary plants revealed no statistically significant differences (Table 3). Although the differences among cooperative plants and proprietary plants were not large enough to be statistically significant, all of the comparisons favored proprietary plants.

While we found only small differences in processing technology ratings among the groups of plants, cooler evaluations were much more varied. On average, captive plant

Table 3. Comparisons of means of plant and cooler ratings by plant ownership

Descriptor[1]	Captive plant mean	Proprietary plant mean	Cooperative plant mean	*P* cap:coop[2]	*P* pro:coop[2]
Processing technology	7.3	7.4	7.0	0.74	0.37
Cooler technology	7.5	5.5	4.8	0.01	0.42
Cooler size	6.8	5.5	4.4	0.10	0.39
Cooler design & layout	8.3	5.8	5.0	0.03	0.53

[1] Automation and technology, cooler size, and cooler layout were evaluated by the plant manager at each facility. The managers were asked to use a 10-point scale to assess the levels of technology ("1" = older technology, and "10" = innovative technology). Similarly, cooler size and cooler design were assessed on 10-point scales ("1" = too small; poor layout, and "10" = spacious; convenient design).

[2] Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

managers appeared more satisfied with cooler technology, cooler size, and cooler layout and design than managers of other plants. When comparing evaluations for the three cooler characteristics, responses by managers of captive plants were higher and statistically different (when using reasonable levels of significance) than those of cooperative plant managers. Cooperative plant managers appeared to be the least satisfied with cooler size when compared to the responses given by managers of proprietary or captive plants.

Comparisons of Filling Machinery

When constructing the survey, we chose not to collect much descriptive data on specific processing equipment used in each plant. We did, however, obtain data on the filling machinery used by the plants (Table 4). We compared actual filling speeds in units per minute and age of equipment in years for both plastic gallon jug fillers and half-gallon paper carton fillers. These two types of fillers were used by nearly every plant. In general, other types of filling machinery, such as quart, pint, and half-pint paper carton fillers and plastic half-gallon jug fillers were not used by captive plants and did not allow us to make comparisons based on type of plant ownership.

Age of equipment did not show much variation among the three groups of plants, and comparing means among the three groups of plants led to mixed results. However, none of the paired comparisons was statistically significant. Captive plants and proprietary plants operated the oldest plastic jug filling equipment on average, and cooperative plants operated newer plastic jug filling equipment. However, a comparison of age of paper half-gallon carton fillers revealed that these positions were reversed - cooperative plants operated the oldest fillers on average, and captives and proprietary plants operated newer fillers.

While age of filling equipment was not greatly different among the three groups, filling speed varied considerably. Captive plants operated both plastic jug and paper carton fillers at speeds that were considerably higher (and statistically different) than those of cooperative plants. For example, captive plants filled an average of 24 plastic gallon jugs and 32 half-gallon paper cartons per minute per machine more than cooperative

Table 4. Comparisons of means of filling machinery age and speed by plant ownership

Descriptor[1]	Captive plant mean	Proprietary plant mean	Cooperative plant mean	*P* cap:coop[2]	*P* pro:coop[2]
Age of plastic jug fillers	12.6	12.4	11.2	0.78	0.75
Age of paper carton fillers	10.8	10.6	12.0	0.65	0.59
Plastic jug filling speed	89	75	65	0.06	0.37
Paper carton filling speed	97	88	65	0.04	0.09

[1]Comparisons were based on plastic gallon jug fillers and half-gallon paper carton fillers. Actual filling speeds in units per minute and age of equipment in years were compared.
[2]Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

plants. Proprietary plants also operated both types of filling equipment at faster speeds than cooperative plants. On average, proprietary plants filled 10 plastic gallon jugs and 23 half-gallon paper cartons per minute per machine more than cooperative plants. Although the speed of operation for plastic gallon jug fillers was not statistically significant, the speed of operation for paper half-gallon carton fillers was.

Product Loading

When placed into the delivery vehicles, product was organized largely by store (store loaded) or by product (peddle loaded). As a reminder, "store loaded" means that orders are pre-picked in the cooler and then arranged on delivery vehicles by the customers receiving orders on the route, and "peddle loaded" means that orders are not pre-picked, and the driver is responsible for assembling the order at the time of delivery. Although store loading and peddle loading were the most frequently used methods, most plants used bulk loading as an alternative method when delivering to warehouses or other drop points.

An average of 93% of all orders were store loaded by captive plants (Table 5). Because a captive plant usually serves only the stores owned by the supermarket com-

Table 5. Comparisons of means of product loading methods by plant ownership

Descriptor	Captive plant mean	Proprietary plant mean	Cooperative plant mean	*P* cap:coop[2]	*P* pro:coop[2]
Store loaded orders, %	93	68	36	0.02	0.08
Peddle loaded orders, %	0	22	43	0.04	0.17
Other loading, %	7	10	21	0.28	0.36

[1]Store loading refers to orders that are pre-picked in the cooler and then arranged on delivery vehicles by the stores receiving orders on the route. Peddle loading refers to orders that are not pre-picked, and the driver was responsible for assembling the order at the time of delivery.
[2]Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

pany, this result was not a surprise. On average, proprietary plants used store loading for about 68% of their orders, but cooperative plants used store loading for only 36% of the orders. Conversely, peddle loading was the loading method of choice for an average of 43% of the orders filled by cooperative plants. While proprietary plants peddle-loaded their delivery vehicles on about one-fifth of all orders filled, captive plants reported no use of peddle loading for any of the orders. Cooperative plants reported an average of 21% of their orders were loaded by other methods, but bulk loading was the most common alternative to store or peddle loading. Proprietary plants and captive plants used other methods of loading for only a small percentage of the orders.

Comparison of Costs and Labor Productivity

Overview

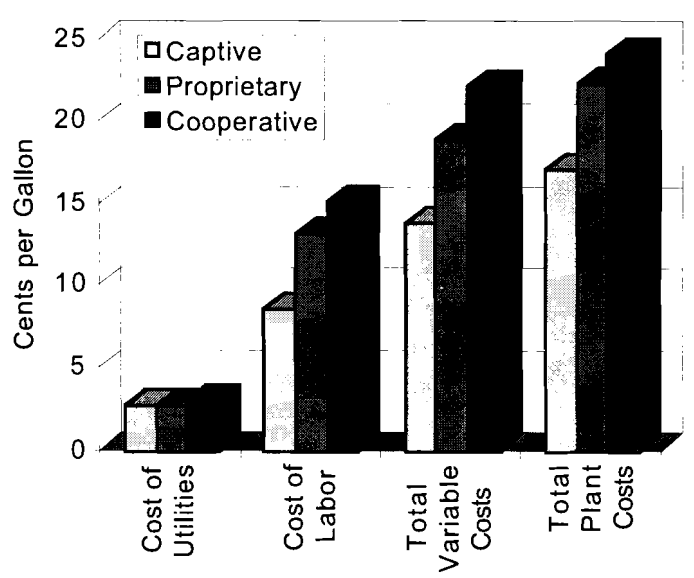
We present five measures for comparison of plant costs and labor productivity: gallon equivalents processed per hour of labor, cost of utilities per gallon, labor cost per gallon, variable costs per gallon, and total plant costs per gallon. We used the same definitions presented earlier for each measure.

As might be suspected given the results of the previous comparisons by plant ownership, captive plants bettered the other plants in every cost and labor productivity category (Figure 22 and Table 6). While proprietary plants and cooperative plants were closer in magnitude for each pairwise comparison, proprietary plants had, on average, lower costs per gallon and higher productivity per hour of labor.

Plant Labor Productivity

Labor productivity in captive plants far exceeded that of proprietary or cooperative plants. On average, captive plants processed and packaged 108 gallons per hour more than proprietary plants, and 133 gallons per hour more than cooperative plants. The difference in means of captive plants and cooperative plants was highly significant from a statistical viewpoint. Although proprietary plants outperformed cooperative plants by 25 gallons per hour, the difference in means was not statistically significant at the 5% level.

Figure 22. Comparison of various costs by type of plant ownership



Cost of Utilities and Cost of Labor per Gallon

In combination, the cost of labor and utilities accounted for 55% to 75% of plant cost per gallon, including depreciation. Labor cost was clearly the dominant cost and accounted for 40% to 70% of plant cost per gallon. Although the com-

Table 6. Comparisons of means of cost and labor productivity by plant ownership

Descriptor[1]	Captive plant mean	Proprietary plant mean	Cooperative plant mean	*P* cap:coop[2]	*P* pro:coop[2]
Plant labor productivity, gal/hr	261	153	128	<0.01	0.18
Cost of utilities, ¢/gal	2.7	2.7	3.1	0.52	0.52
Cost of labor, ¢/gal	8.6	13.1	15.1	<0.01	0.08
Variable costs, ¢/gal	13.8	18.9	22.2	<0.01	0.04
Total plant costs, ¢/gal	17.1	22.3	24.1	<0.01	0.23

[1]Plant labor productivity reflected the total volume processed, in gallon equivalents, relative to the hours worked by direct plant, cooler, and all other plant labor. Cost of utilities per gallon included the cost of electricity, natural gas, heating oil and other fuels, water, and sewage relative to the total volume processed. Labor cost per gallon reflected the cost of wages and benefits for direct plant, cooler, and all other plant labor relative to the total volume processed. Variable costs per gallon included the cost of labor, repairs, maintenance, cleaners, lubricators, and other supplies, and utilities relative to the total volume processed. Total plant cost included all variable costs as well as equipment leases and building and equipment depreciation for the plant and the cooler relative to the total volume processed.

[2]Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

parisons of utility costs revealed no statistical differences, cooperative plants had higher utility costs per gallon than captive plants or proprietary plants. On the other hand, comparisons of labor cost per gallon showed that captive plants and proprietary plants had advantages over cooperative plants. For example, labor cost per gallon in captive plants was 60% lower than that of cooperative plants, and labor cost per gallon in proprietary plants was 15% lower than that of cooperative plants. Both of these differences were statistically significant.

Variable and Total Plant Costs per Gallon

Variable costs included the cost of labor, repairs, maintenance, cleaners, lubricators, and other supplies, and utilities relative to the total volume processed. Total plant cost included all variable costs as well as equipment leases and building and equipment depreciation for the plant and the cooler. Variable costs for captive plants averaged 13.8¢ per gallon, far less than cooperative plants (22.2¢ per gallon) and proprietary plants (18.9¢ per gallon). The differences among means of plants were statistically significant. When leases and depreciation expenses were included, captive plants were still significantly lower cost operations than cooperative plants. Although proprietary plants had lower total plant costs per gallon than cooperative plants, the difference was not statistically significant.

Comparisons of Cost Breakdowns by Percentage

As a final comparison among plants under different ownership, we present a breakdown of total plant costs per gallon for each group (Table 7 and Figure 23). Relative to cooperative plants, the cost of labor in captive plants makes up a smaller percentage of total plant cost, but, on an individual category comparison basis, depreciation, utilities, repairs and maintenance, and leases accounted for a larger percentage of total plant cost. Similarly, labor cost and repairs and maintenance costs in proprietary plants contributed to

Table 7. Comparisons of means of plant cost categories by plant ownership

Descriptor[1]	Captive plant mean	Proprietary plant mean	Cooperative plant mean	*P* cap:coop[2]	*P* pro:coop[2]
Labor cost, %	51.0	60.2	63.1	0.03	0.52
Utilities cost, %	15.8	12.3	12.4	0.15	0.99
Repair & Maint. cost, %	17.2	13.8	16.4	0.82	0.45
Cost of leases, %	1.3	0.8	0.8	0.65	0.97
Cost of depreciation, %	14.7	12.9	7.4	<0.01	<0.01

[1] Labor cost per gallon included the cost of wages and benefits for direct plant, cooler, and all other plant labor. Cost of utilities per gallon included the cost of electricity, natural gas, heating oil and other fuels, water, and sewage. Repairs and maintenance included any expenses for purchased labor and parts, supplies, laundry and uniforms, cleaners, and lubricators, pest control, refuse collection, and property taxes. Cost of leases included all equipment leases maintained by the plant on processing, filling, or cooler equipment. Depreciation included costs of all building and equipment (except depreciation on blow mold equipment) depreciation reported during the 12 month data collection period.

[2] Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

a smaller percentage of total plant costs per gallon, but depreciation costs accounted for a higher percentage of total plants costs, relative to cooperative plants.

Describing Captive Plants

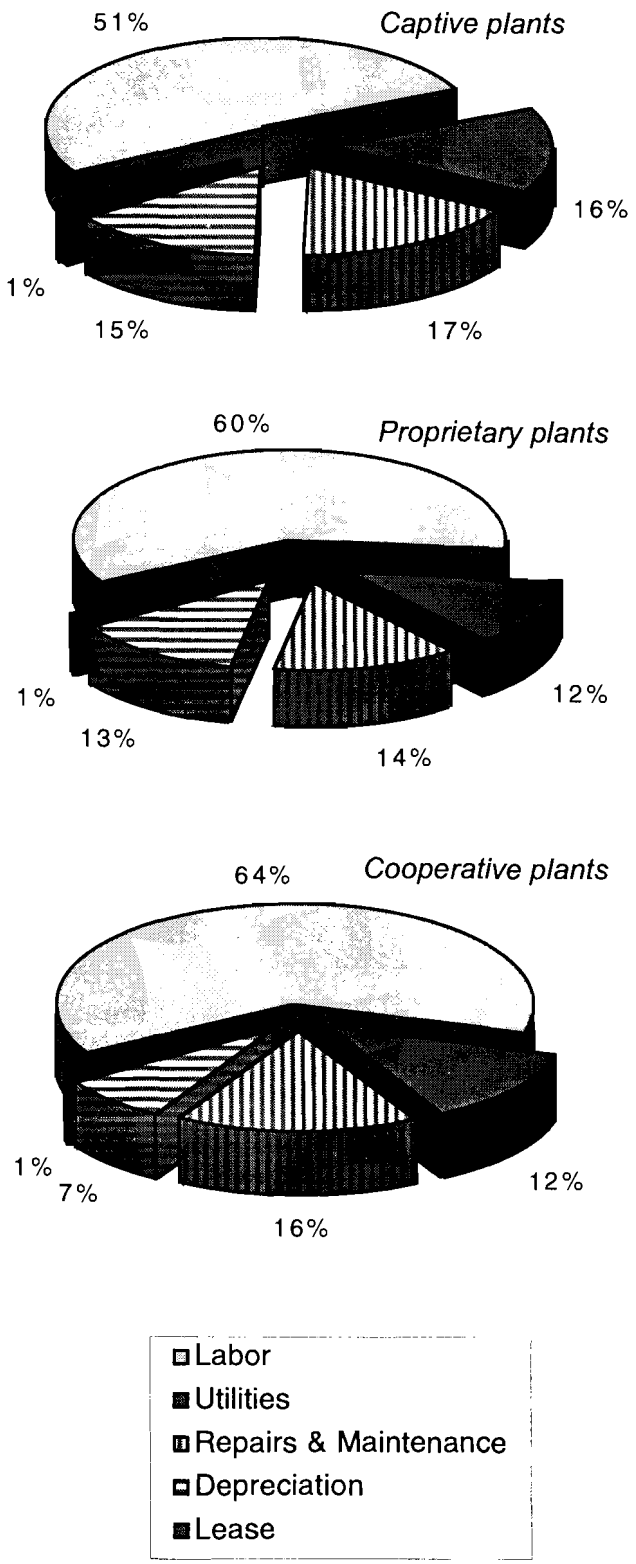
For those who are not familiar with captive plants, it may be insightful to review some of the differences between captive plants and full-line dairies. Some of the differences in how these plants operated may help to explain why they have lower costs per gallon and higher labor productivity.

Captive plants typically maintain narrower product mixes, i. e., they process fewer products under fewer labels and use fewer packaging sizes. Furthermore, most products are packaged in gallon and half-gallon containers, and only a small percentage of products are packaged in quart, pint or half-pint containers. Because captives only serve their own stores, there is a greater opportunity to handle products on less labor intensive systems, such as bossie carts and pallets. Relative to the total number of products handled, few (if any) finished products from outside sources are brought into the coolers of captive plants for distribution, reducing the number of products in the cooler and simplifying filling of orders and load-out procedures. On the distribution side, captives serve supermarket stores that place orders for similar mixes of products with little variation in order size. In combination, the characteristics described point toward operations with high product turnover and high labor productivity, which are inherently, less complex and easier to manage.

Describing Cooperative Plants

Like proprietary plants, cooperative plants tend to operate as full-line processing facilities, but the analysis of the 35 participating plants suggested that cooperative plants achieved lower labor productivity and higher costs per gallon than proprietary plants. Several reasons may offer insight as to why the disparity existed. The structure of a cooperatively owned and operated business may not be a valid reason; some of the top food processing businesses in the U. S. are cooperatives, such as Sunkist, Ocean Spray and Welch's.

Figure 23. Total cost per gallon breakdown by percentage



Moreover, some of the most efficient and well-run cheese plants and butter/powder plants throughout the U. S. are owned and operated by dairy cooperatives. Consequently, other explanations must be sought to offer some insight as to why cooperative plants were found to be less labor efficient and more costly on a unit basis than plants under different ownership.

Several reasons may help to address the lower labor productivity and higher unit costs experienced by cooperative plants. First, cooperative plants tend to be smaller than proprietary plants and captive plants. Although we have not specifically investigated the effect of plant size on labor productivity and plant costs per gallon, economic theory contends that larger plants realize economies of size. Second, cooperative plants tend to process more products and handle more products in their coolers. We propose that the more SKUs processed, the more complicated the logistics of changing processing lines, switching labels, and changing container sizes and types. We also contend that plants that stored a large number of SKUs in the cooler experience a decrease in cooler and load-out labor productivity because of the logistics involved in coordinating the storage and retrieval of a large number of products. These added complications would lead to lower labor productivity and higher labor costs per unit. Third, because the primary owners of a dairy cooperative are dairy farmers, raising equity capital to invest in new equipment and increased automation in fluid milk facilities can be difficult. This seems to be supported by the lower levels of satisfaction with plant and cooler facilities expressed by cooperative plant managers. Lastly, cooperatives typically undertake milk supply balancing functions in a given market for the economic benefit of their members, and performing this balancing function results in additional costs, and perhaps, less efficient use of labor and facilities.

NEURAL NETWORK MODELS

Introduction

Differences among plants based solely on type of plant ownership, as shown in the previous section, spawn questions about the effects of the factors on labor productivity and cost per gallon. For example, how much effect does increasing the number of SKUs processed have on labor productivity and cost per gallon? Does the magnitude of the factor effects differ by type of plant ownership? Traditional statistical methods are available to answer these type of questions, but such methods also have limitations, such as selecting an appropriate functional form and specifying a (parsimonious) model. Neural networks, a form of data mining, do not have these restrictions.

Neural network methods encompass a broad class of flexible nonlinear regression and discriminant models, data reduction models, and nonlinear dynamical systems. Precise (and disparate) definitions for neural networks abound, but most researchers who use this method of data analysis would agree that a neural network is a collection of many simple and highly interconnected processors or "neurons" that process information in parallel. The communication channels ("connections") that link the neurons carry numeric as opposed to symbolic data. The neurons operate only on their local data and on the inputs they receive via the connections.

Most neural networks have an input layer, an output layer, and an unspecified number of "hidden layers", ranging from one to many (Figure 24). The hidden layer is so named because it has no direct connection to the outside world. The function of the hidden layers is to make the associations between the inputs and the outputs. Each layer of neurons receives its input from the previous layer or, in the case of the input layer, from outside the network.

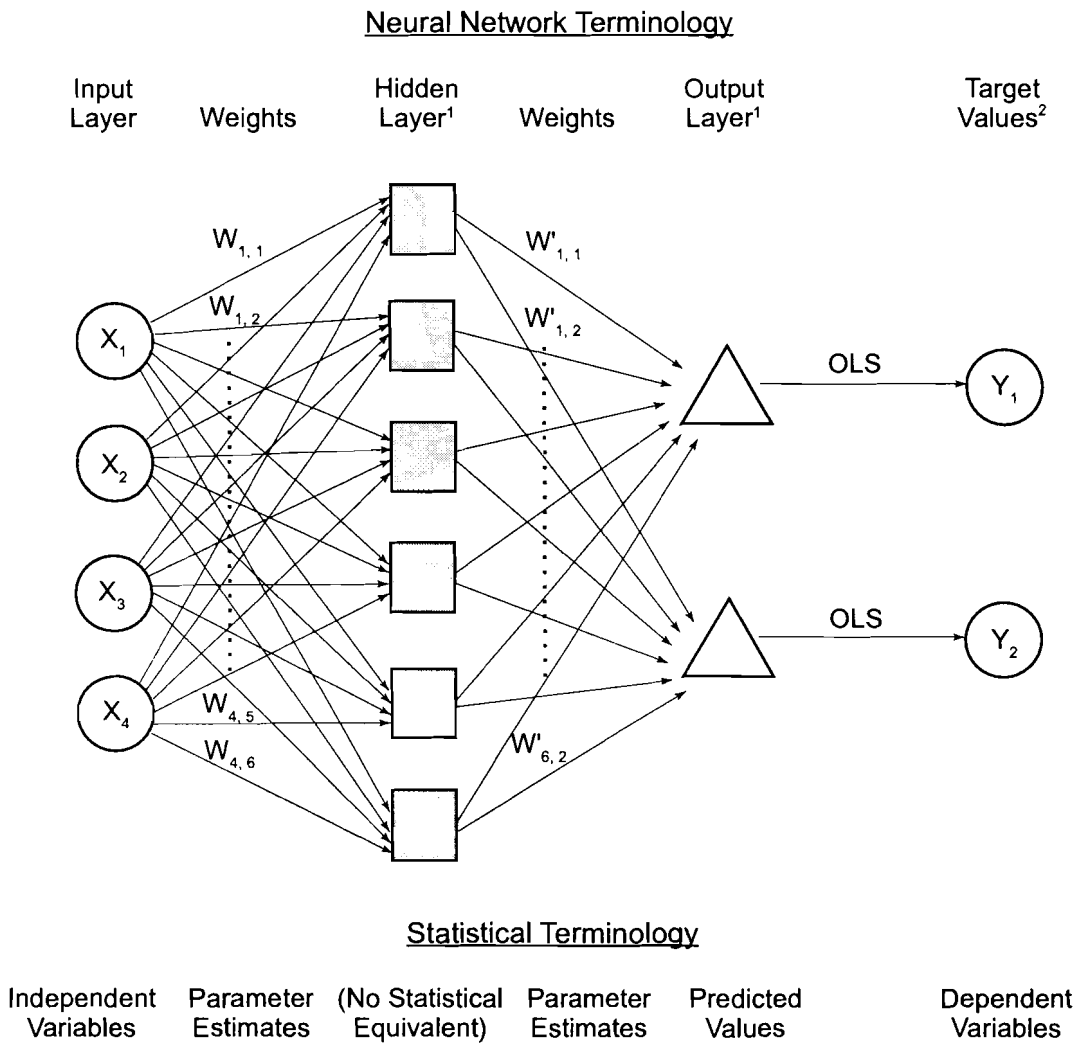
Neural networks "learn" from examples and can exhibit some capability for generalization beyond the training data. The learning in this sense is analogous to "estimation" in more traditional statistical analysis. Similarly, "training" data is analogous to "observed" data. Most neural networks have a training rule whereby the weights of connections are adjusted on the basis of data. The network learns (estimates) by adjusting the weights to minimize the sum of the squared error of the outputs (predicted values) relative to the target values (observed data). The schematic in Figure 24 may help to clarify the relationships of the various neural network components.

Although the name "neural networks" seems to imply a biological connection, neural networks are not limited to modeling biological phenomenon. Neural networks are useful for classification and function approximation problems which are tolerant of some imprecision, but to which strict rules cannot be easily applied. For example, neural networks are well-suited for pattern recognition, trend prediction, and image analysis. These applications may appear unrelated, but they all share the ability to make associations between known inputs and outputs.

Classification and Description

Neural network models are especially appealing when there is little knowledge about the form of the relationship between the independent and dependent variables. Part of

Figure 24. Conceptual framework of a 3-layer neural network with 4 input neurons, 6 hidden layer neurons, and 2 output neurons



[1] The hidden layer(s) and output layer contain activation functions which are usually sigmoidal or linear.
[2] Ordinary least squares (OLS) is typically used to fit the values generated by the output layer to the target values.

the reason for the flexibility of neural network models is explained by the hidden layer(s). Activation functions for the units in the hidden layer(s) are used to introduce nonlinearity into the network, making them less restrictive and more useful as universal approximators (25). The capability to represent nonlinearity makes neural networks with hidden layers powerful. Almost any nonlinear function can be used for the activation function although it must be differentiable for back propogation learning. Sigmoidal functions (i.e., logistic and Gaussian functions) are the most common choices for activation functions. Activation functions for the output units should be selected based on the distribution of the target values. For example, bounded activations functions are more useful when the target values have a bounded range.

Neural networks may be classified into two broad categories — feedforward and feedback. A feedforward network is such that a neurons' output does not depend on the output of subsequent neurons. Signals only flow in one direction, and outputs are dependent on only the signals incoming from the neurons in the previous layer. On the other hand, feedback networks have looping features built into the system.

Feedforward networks are a subset of the class of nonlinear regression and discrimination models. Feedforward networks with one hidden layer are closely related to projection pursuit regression. Many results from the statistical theory of nonlinear models apply directly to feedforward networks.

Neural Networks and Statistics

There is considerable overlap between the fields of neural networks and statistics. Many neural network models are similar or identical to popular statistical techniques such as generalized linear models and polynomial regression, especially when the emphasis is on prediction of complicated phenomena rather than on explanation (23, 24). Despite the overlap between statistical models and neural network models, the terminology prevalent in neural network discussion differs considerably from that used in statistics. Table 8 provides a brief list of corresponding terms.

With the tremendous number of tried-and-true statistical models available, there may be some question as to why neural network models would be used. Standard regression models start out with a specified functional form (e.g., linear, polynomial, logarithmic) which may include interaction terms in addition to the independent variables. Ordinary least squares (OLS) seeks to minimize the sum of the squared differences between the

Table 8. Corresponding terms between statistics and neural networks.

Statistics Jargon	Neural Networks Jargon
independent variable	input
predicted value	output
dependent variable	target (or training) value
residual	error
estimation	training, learning, or adaptation
parameter estimates	(synaptic) weights
observations	patterns
hold-out sample	test set
iteration	epoch
interpolation or extrapolation	generalization
prediction	forward propagation
computation of the error gradient for a feedforward network by use of derivatives	back propogation
a category of neural networks in which connections flow in one direction	feedforward network

regression line (or curve) and the data points. In other words, after the functional form is specified, OLS tries to find estimates for the model parameters that produce the best fit to the line or curve. With neural network models, a similar process is used with the exception of specifying a functional form; there are no assumptions concerning the form of the model. Simply put, neural network models let the data reveal the shape that best fits the data rather than forcing the data to fit a pre-specified shape. In general, regression analysis requires that the researcher theorize how a variable enters a model and guess as to which variables are relevant for the model. Neural network models do not require these tasks of the researcher. The network decides which variables are important and how best to use each relevant variable. Works by Cheng and Titterington (7) and Ripley (19) provide a more comprehensive discussion of neural networks viewed from a statistical perspective.

Speed of Calculation

Nonlinear regression algorithms can fit most neural network models orders of magnitude faster than the standard neural network algorithms. Part of the difference in speed of calculation has to do with data storage (23). Neural network algorithms are often designed for situations where the data are not stored, but each observation is available transiently in a real-time environment. In statistical applications, the data are usually stored and are repeatedly accessible so statistical algorithms can be faster and more stable than neural network algorithms. Many neural networks converge to a set of weights slowly or not at all, depending on the restrictions imposed by the operator.

Polynomial regression models are linear in the parameters, and, as a results, they can be fit quickly. However, numerical accuracy problems can result with fourth degree (or higher) polynomial models. Multiple layer neural networks with nonlinear activation functions are genuinely nonlinear in the parameters, and therefore take much more computer time to fit than polynomial models.

Neural Network Model of Fluid Milk Plants

Our objective was to obtain quantitative measures of the effects of various factors on labor productivity and cost per gallon. We used Windows Neural Network (WinNN), a Windows-based neural network simulator with back propogation learning to find the weights which best described the data set (9). We specified three layers for our neural network model – an input layer, one hidden layer, and an output layer. We selected 11 factors to serve as input neurons and 2 factors to serve as output neurons (Table 9). Three of the input neurons were used as identification inputs to distinguish captive plants, cooperative plants, and plants with unionized labor.

Set Up

WinNN accepts a variety of activation functions to transfer data from the hidden layer to the output layer (9). We selected logistic activation functions in the hidden layer and the output layer because bounded activations functions are more appropriate when the target values have a bounded range. The logistic activation function was described as

$$act(x) = (1 + e^{-x})^{-1}$$

Because we included both labor productivity and cost per gallon as outputs and used logistic activation functions, our model was the statistical equivalent of a multivariate

multiple nonlinear simultaneous regression model (23).

Normalizing (rescaling) input data is fairly common when working with multilayer neural network models. The reason is that data sets often contain numbers that are out of the effective range of the activation functions. The logistic activation functions in the hidden and output layers required that the target values fall within a meaningful range. We normalized the input data so that all of the elements fell between -3 and 3 and the output data such that all observations fell between 0 and 1.

Table 9. Inputs and outputs for neural network model

Inputs	Outputs
Plant size	Labor productivity
Captive plant	Plant cost per gallon
Cooperative plant	
Labor cost	
Unionization of workforce	
Plant capacity used	
Product in gallon and half-gallon containers	
Processing technology	
Cooler technology	
SKUs processed	
Product on pallets	

Another relatively common practice is to assign a small amount of error randomly to input data when training the network to help avoid local minima in the weight surface and to make the trained network less sensitive to changes in the input values. The assignment of random error also helps to avoid the problem of "inconsistent" data where two or more identical sets of inputs generate different outputs. We assigned a "noise" of 0.05 to the normalized input values.

The training of the network and associated adjustments of the weights necessitates specification of a convergence criterion. Although it is theoretically possible to specify an allowable error of zero, speed of convergence is adversely affected as the allowable error is reduced. We made a compromise between speed of convergence and accuracy of the solution weights when setting the convergence criteria. We specified that an acceptable solution was obtained when all of the output values were within 4% of their corresponding target values.

Results and Discussion of Neural Network Model

Model Plants

One of the challenges we encountered was to explain the results of a neural network application in meaningful economic terms. The solutions obtained from neural network models are in the form of synaptic weights. These weights are definitionally similar to parameter estimates in traditional statistical models, but neural network models do not quantify the effects of the inputs explicitly. Furthermore, interaction among the input variables and the basic nonlinearity of the activation functions introduce additional complications when interpreting the meaning of the weights.

Our approach to the problem of interpreting results was to train the network using monthly observations for each of the 35 plants. After obtaining the weights, we constructed model plants for the three types of plant ownership (Table 10). The model plants

Table 10. Numerical description of model plants by type of ownership

Descriptor	Type of Ownership		
	Captive	Proprietary	Cooperative
Plant size, x10^6 gal/month	3.0	3.5	2.5
Labor cost, $/hr	25	20	18
Plant capacity used, %	85	75	77
Product in gallon and half-gallon containers, %	91	84	72
Processing technology, score	8	7	7
Cooler technology, score	7.5	5.5	4.5
SKUs processed	40	165	180
Product on pallets, %	80	50	20

were based on profiles of actual plants, but none of the model plants duplicated an actual plant. Using the model plants as a guide, we built a test data set by varying each of the inputs listed in Table 10 by 10% (+ and -). We standardized the results to produce coefficients which indicated the impact of changing the input by one-half of a standard deviation (Table 11). This standardization process allowed us to draw conclusions about the relative importance of changing input variables over "equally likely" ranges of input variables. As such, the figures represented the expected change in labor productivity or plant cost per gallon for a small change in the input for each type of plant ownership. For example, a $2.23 per hour increase labor cost in captive plants, a one-half standard deviation change, increased labor productivity by 18.89 gallons per hour and increased plant cost by 0.74¢ per gallon.

The exception to this type of interpretation of the results reported in Table 11 was the impact of non-unionized labor. All three model plants were constructed under the assumption of a unionized workforce. The figures reported in Table 11 for non-unionized workforce reflected the expected change in labor productivity and plant cost per gallon with a non-unionized workforce in place of the unionized workforce. For example, a non-unionized workforce was expected to increase labor productivity in captive plants by 15.05 gallons per hour and decrease plant cost by 0.49¢ per gallon.

Overview of Results

In general, the effects of each factor varied appreciably across type of plant ownership. Plant size, as measured by actual monthly processing volumes, had similar implications for all model plants — increasing plant size was predicted to increase labor productivity and decrease cost per gallon. Higher labor cost per hour was expected to increase labor productivity in all model plants but with an associated increase in cost per gallon. All model plants were predicted to be more productive and have lower costs without unionized labor. Increases in percent of products packaged in gallon and half-gallon containers and percent plant capacity utilization were predicted to increase labor productivity and decrease cost per gallon simultaneously. Plants with more advanced equipment in the processing and filling area had slightly higher labor productivity with little associated change

in cost per gallon. Plants with more advanced equipment in the cooler and load out area had significantly higher labor productivity and slightly lower in costs per gallon. The large variation in use of pallets and SKUs processed helped to amplify their effects on labor productivity and cost per gallon. More intensive use of pallets was predicted to increase labor productivity and decrease cost per gallon, but processing more SKUs was predicted to decrease labor productivity and increase plant cost per gallon.

Although most of the coefficients followed what intuition would suggest, a few of the results appeared counter-intuitive and invited discussion. One such unexpected result was the estimated effect of labor cost on cost per gallon. Hiring plant labor at $2.23 per hour more than the model plants increased labor productivity but had a small impact on cost per gallon. A $2.23 per hour increase in labor cost was be expected to increase cost per gallon in captive plants by 0.74¢ per gallon, by 1.13¢ per gallon in proprietary plants, and by 1.00¢ per gallon in cooperative plants. It is likely that the neural network discerned some other subtle and hidden interactions between wages, labor productivity, and cost

Table 11. Predicted performance measures and calculated coefficients for various plant descriptors by type of ownership[1]

	Type of Ownership					
	Captive		Proprietary		Cooperative	
Descriptor	Productivity (gal/hr)	Cost (¢/gal)	Productivity (gal/hr)	Cost (¢/gal)	Productivity (gal/hr)	Cost (¢/gal)
Plant performance	300.07	13.05	153.19	18.15	125.58	20.74
Plant size, 0.66 million gal/month	12.19	-0.02	7.40	-0.03	4.42	-0.02
Labor cost, $2.23/hr	18.89	0.74	11.50	1.13	6.87	1.00
Non-unionized labor[2]	15.05	-0.49	9.88	-0.71	5.99	-0.61
Plant capacity used, 5.3%	7.42	-0.23	4.50	-0.36	2.69	-0.31
Product in gallon and half-gallon containers, 5.4%	0.36	-0.31	0.22	-0.47	0.13	-0.42
Processing technology, 0.66 score	1.31	-0.01	0.79	-0.01	0.47	-0.01
Cooler technology, 1.33 score	5.67	-0.03	3.43	-0.05	2.05	-0.04
SKUs processed, 50 SKUs	-7.78	0.32	-4.71	0.49	-2.81	0.43
Product on pallets, 21.4%	11.18	-0.54	6.80	-0.82	4.05	-0.73

[1]Each coefficient represents the expected change in labor productivity or plant cost per gallon for the specified change in the input for each type of plant ownership. The specified changes reflect a one-half standard deviation increase in the input value. For example, a $2.23 per hour increase in labor cost increased labor productivity by 18.89 gallons per hour and increased plant cost by 0.74¢ per gallon in captive plants, increased labor productivity by 11.50 gallons per hour and increased plant cost by 1.13¢ per gallon in proprietary plants, and increased labor productivity by 6.87 gallons per hour and increased plant cost by 1.00¢ per gallon in cooperative plants.

[2]All model plants were constructed with unionized labor. The reported number reflects the impact of non-unionized labor on labor productivity and plant cost per gallon. For example, the effect of a non-unionized workforce on captive plants was an increase of 15.05 gallons per hour in labor productivity and a decrease of 0.49¢ per gallon in plant cost. Similar results were obtained for proprietary and cooperative plants. These results were not induced by a change in cost of labor per hour. Simply put, if all factors listed in Table 11 were held constant, including labor cost per hour, then a nonunionized workforce would increase labor productivity and decrease cost per gallon.

per gallon such that cost per gallon did not increase as much as one might expect naively. A second unexpected result was the minor effect of packaging more product in gallon and half-gallon containers. Although the results indicated that more volume packaged in gallon and half-gallon containers decreased cost per gallon appreciably, the associated increase in labor productivity was negligible. Perhaps the neural network detected some interactions between plant capacity utilization, percentage of volume packaged in gallon and half-gallon containers, and labor productivity such that labor productivity did not increase as one might anticipate.

Two other factors gave results which were not unexpected but warrant mentioning nonetheless. The results suggested that plants that process a large number of SKUs were adversely affected by their diverse product mix. Not only was cost per gallon higher in the model plants that processed a larger number of SKUs, but labor productivity was lower as well. The model captive plant, which had a very narrow product mix, was affected more than the proprietary plant or cooperative plant. Specifically, by adding another 50 SKUs to the product mix of the captive plant, labor productivity decreased by 7.8 gallons per hour and cost increased by 0.32¢ per gallon.

A second result suggested that plants without unionized labor were more productive and had lower cost per gallon than plants with unionized labor. Unionized labor has been criticized for defining narrow job descriptions, imposing jurisdictional limitations, developing work rules, and reducing workforce flexibility, all of which would lead to decreased labor productivity and increased cost per gallon. However, labor unions also lead to lower job turnover rates, to more experienced and skilled workers, and to more stability and order in the work environment. On the management side, unions may compel company executives to become better managers. Although the negative effects of unionized labor are probably true and are highly publicized, the more positive aspects of labor unions are not well-known. We expected that the effect of unionized labor encompassed a combination of both the positive and the negative effects. However, the results indicated that the negative effects apparently outweighed the positive effects in this study. Captive plants realized the largest gains in labor productivity by using non-unionized labor (15.1 gallons per hour), and proprietary plants realized the largest decrease in cost per gallon (0.71 ¢ per gallon).

Factor Effects and Type of Plant Ownership

We recognize that the "model" cooperative plant described in Table 10 had the lowest values for all input variables except SKUs processed. These values were chosen in an attempt to represent the profile of the cooperative plants in the study accurately. However, without exception, changes in the various inputs impacted labor productivity in cooperative plants in the same direction but with considerably less magnitude than what was predicted for captive or proprietary plants. From Table 11, increasing plant size by 0.66 million gallons per month over and above that specified for the model plants was predicted to increase labor productivity by 12.2 gallons per hour for captive plants, 7.4 gallons per hour in proprietary plants, and only 4.4 gallons per hour in cooperative plants. Hiring plant labor at $2.23 per hour more than that specified for model plants was predicted to increase labor productivity by 18.9 gallons per hour in captive plants, by 11.5 gallons per hour in proprietary plants, and only 6.9 gallons per hour in cooperative plants. A 5.3% increase in the percentage of plant capacity utilized was predicted to increase

labor productivity by 7.4 gallons per hour in captive plants, 4.5 gallons per hour in proprietary plants, and only 2.7 gallons per hour in cooperative plants.

Similar comparisons of the coefficients for cost per gallon did not reveal the same systematic differences. Furthermore, the coefficients appeared to be more similar for proprietary and cooperative plants. For example, replacing unionized labor with non-unionized labor was predicted to decrease cost per gallon by 0.49¢ per gallon in captive plants, 0.71¢ per gallon in proprietary plants, and 0.61¢ per gallon in cooperative plants. Increasing plant capacity utilization and the percent of product packaged in gallon and half-gallon containers were also expected to have the larger impacts on cost per gallon for proprietary plants and cooperative plants than for captive plants.

Cooperative Plant Performance Under A Captive Plant Profile

The results presented in Table 11 generate questions concerning the performance of cooperative plants relative to captive plants and proprietary plants. We specified a second model cooperative plant with characteristics identical to those of the captive plant with the exception of type of ownership (Table 10). Although none of the cooperative plants in the study were similar operationally to a captive plant, the exercise was revealing (Table 12). Efficiency measures for the model cooperative plant improved remarkably. Labor productivity increased by 37.8%, and plant cost per gallon decreased by 8.9%. Despite the impressive gains in plant performance, the model cooperative plant did not match the efficiency measures predicted for the model captive plant.

Differences in the effects for the individual coefficients also persisted. When comparing the calculated coefficients, the captive plant was predicted to realize larger changes in labor productivity than the cooperative plant for identical changes in the inputs. For example, increasing plant size by 0.66 million gallons processed per month was predicted to increase labor productivity by 12.2 gallons per hour in the captive plant, but by only 9.1 gallons per hour in the cooperative plant. Furthermore, a $2.23 increase in labor cost per hour was expected to increase labor productivity by 18.9 and 14.2 gallons per hour in the captive plant and the cooperative plant, respectively.

The same systematic differences were not evident when comparing the coefficients for cost per gallon. The increase of $2.23 in labor cost per hour was expected to increase cost per gallon by 0.74¢ per gallon and 0.97¢ per gallon in the captive plant and the cooperative plant, respectively. Increasing plant capacity utilization by 5.53% decreased plant cost by 0.23 and 0.31¢ per gallon in the captive plant and the cooperative plant, respectively. We expect that the differences in the effects of the inputs for the two nearly identical plants were attributable to differences in immeasurable plant characteristics, such as quality of workforce, and operations and business management. It is also likely that different business objectives for cooperatively-owned and privately-owned plants are contributing factors.

Table 12. Predicted performance measures and calculated coefficients for various plant descriptors for a cooperative plant under captive plant profile[1]

	Type of Ownership			
	Captive		Cooperative	
Descriptor	Productivity (gal/hr)	Cost (¢/gal)	Productivity (gal/hr)	Cost (¢/gal)
Plant performance	300.07	13.05	173.07	18.90
Plant size, 0.66 million gal/month	12.19	-0.02	9.13	-0.02
Labor cost, $2.23/hr	18.89	0.74	14.18	0.97
Non-unionized labor[2]	15.05	-0.49	12.06	-0.60
Plant capacity used, 5.3%	7.42	-0.23	5.56	-0.31
Product in gallon and half-gallon containers, 5.4%	0.36	-0.31	0.27	-0.41
Processing technology, 0.66 score	1.31	-0.01	0.98	-0.01
Cooler technology, 1.33 score	5.67	-0.03	4.23	-0.05
SKUs processed, 50 SKUs	-7.78	0.32	-5.82	0.49
Product on pallets, 21.4%	11.18	-0.54	8.39	-0.82

[1]Each coefficient represents the expected change in labor productivity or plant cost per gallon for the specified change in the input for captive plant ownership and cooperative plant ownership. The specified changes reflect a one-half standard deviation increase in the input value. For example, a $2.23 per hour increase in labor cost increased labor productivity by 18.89 gallons per hour and increased plant cost by 0.74¢ per gallon in captive plants and increased labor productivity by 6.87 gallons per hour and increased plant cost by 1.00¢ per gallon in cooperative plants.

[2]Both model plants were constructed with unionized labor. The reported number reflects the impact of non-unionized labor on labor productivity and plant cost per gallon. For example, the effect of a non-unionized workforce on captive plants was an increase of 15.05 gallons per hour in labor productivity and a decrease of 0.49¢ per gallon in plant cost.

CONCLUSION

Labor productivity and plant operating costs are determined in a complex system of interrelated variables. Input variables undoubtedly have complex and nonlinear relationships with the output variables, and the levels of some input variables impact the importance of others. For example, labor cost per hour impacts labor productivity and cost per gallon, but labor cost per hour is also likely to determine the degree of mechanization in labor-intensive areas of the plant and the extent to which the plant's capacity is utilized. Labor cost per hour may also play a role in determining the extent of subsequent investments in plant expansions and renovations.

Traditional regression analysis requires the researcher to explicitly specify the functional form of the model and interactions among the variables prior to the analysis. Neural network methods use a "data mining" approach to numerical analysis and rely on observations to reveal these intricacies. While the input variable weights are not as directly usable as their counterparts from regression analysis, they capture much more of the potential complexities hidden in a system such as fluid milk processing operations.

Although the research revealed a number of differences in plant profiles across type of ownership, the neural network model showed that only a subset of those characteristics had any meaningful impact on plant labor productivity or cost per gallon for equally likely changes in the various inputs. For example, cooperatives and proprietary plants packaged a smaller percentage of product in gallon and half-gallon containers than captive plants, but the predicted effect on labor productivity and cost per gallon of doing so was small.

The results also showed that differential effects were predicted for some characteristics and were dependent on the type of plant ownership. For example, the predicted effect of increasing plant size by an equal amount for the three types of ownership increased labor productivity in all plants but by different amounts with the cooperative plant realizing the smallest gains. This result is particularly intriguing considering that a 0.66 million gallon increase in processing capacity represented a 26% increase in plant size for the model cooperative plant and only a 19% and 22% increase in plant size for proprietary plants and captive plants, respectively. Furthermore, when a model cooperative plant was constructed using a captive plant profile excepting of type of ownership, the predicted labor productivity and cost per gallon did not match those predicted for the captive plant. This suggests that cooperative plants are deleteriously impacted by variables not explicitly included in the analysis.

Opportunities for cooperative plants to decrease plant cost per gallon and increase labor productivity were evident from the analysis. Increasing the percentage of plant capacity utilized, decreasing the number of SKUs processed, increasing the percentage of product handled on pallets, and de-unionizing plant labor stand out as a potential means of simultaneously increasing labor productivity and decreasing cost per gallon. Investments in the cooler area may also increase labor productivity without affecting cost per gallon adversely.

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