EPA Regional Priority AFO Science Question Synthesis Document

Environmental Risk Management Methodologies and Approaches

Workshop Review Draft:
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6.1 Background

Animal waste has long been used on farms as a nutrient and soil conditioner. The increased concentration of animals at animal feeding operations (AFOs), however, has created new environmental challenges. A range of pollutants can be introduced to the environment from AFOs, including nutrients, pathogens, particulate matter, ammonia, and antibiotic or hormone residues. The extent to which an individual farm contributes pollutants is dependant upon a wide range of physical factors, including soils, landscape, climate, the type of animals, and farm management. If the quantity, timing, and method of manure application are not carefully managed with respect to crop need and site characteristics, excess nutrients may accumulate in the soil. The result may be nitrate leaching through the soil to contaminate groundwater or phosphorus moving in surface runoff, leading to eutrophication of surface waters. Pathogens and antibiotic or hormone residues in manure runoff can also contaminate water bodies and threaten human health.

The concentration of animal populations within relatively small geographic areas over the past few decades has upset the balance between supply and demand for animal waste. In many areas there is not sufficient cropland to receive the manure and associated waste products (e.g., bedding) generated at animal facilities. This situation creates two related technical and economic challenges to protecting the environment: spreading the animal waste safely and productively on cropland that is nearby, and processing or hauling the excess animal waste for safe use elsewhere. Thus, concerns associated with both siting and management must be addressed to minimize the movement of pollutants from AFOs and the lands upon which animal waste is applied. In the case of new AFOs, market conditions – availability of land to spread manure and/or markets for animal waste products or byproducts – may be more important than physical factors (e.g., climate, soils, or geology) as determinants of the degree to which the AFO can be managed to protect the environment.

Not all agricultural operations cause water quality problems and not all parts of the landscape contribute equally to water quality problems. A variety of assessment techniques, screening tools, and models exist that can help producers and managers identify conditions and practices that represent a high risk to water quality and other adverse environmental impacts. An attempt is made here to separate farm management planning tools and nutrient loading and water-quality models from more generalized environmental risk assessment tools, but this distinction is, in some cases, artificial due to the wide applicability of some of the tools contained in this document.

6.1.1 Farm Management Planning Tools

There are many screening tools and decision support systems available that perform farm-scale analysis useful in animal waste management. Many of these are available through state universities and extension offices. Some examples are cited below:

Model/Tool	Application	Scale	Data requirements
AFOPro	Nutrient management planning	Farm	Low
AWM	Manure production/storage Gross farm nutrient balance	Farm	Low
MMP	Manure management Sustainability	Farm	Low

- **AFOProTM** is a standalone nutrient management planning tool, with optional connections to GIS (ArcView using either AFOPro Spatial or Spatial Nutrient Management Planner as the front end) and the NRCS's Animal Waste Management (v 2.1 or higher) engineering software (De et al., 2004). The application automates manure and commercial fertilizer allocation decisions in compliance with the NRCS's 590 (nutrient management) Standard, which requires the documentation of form, source, timing, method, and placement of nutrients. The design of the application is open, transparent, and flexible which enables it to be adapted to specific state crop removals, nutrient risk ratings, and nitrogen accounting requirements. Additionally, the application uses modular Phosphorus Indices, state-specific fertility recommendations and state-specific CNMP templates. (http://www.esri.sc.edu/Projects/usda/application_development/afopro.asp#description)
- **AWM** (Animal Waste Management) is a planning/design tool for animal feeding operations that can be used to estimate the production of manure, bedding, process water and determine the size of storage/treatment facilities (USDA NRCS, 2003). The procedures and calculations used in AWM are based on the USDA NRCS Agricultural Waste Management Field Handbook. AWM develops a monthly water and waste budget for each treatment/storage component and produces a gross nutrient balance from target yields and crop acreage specified for crops listed in the crop database. (http://www.wcc.nrcs.usda.gov/awm/awm.html).
- **MMP** (Manure Management Planner) MMP is a Windows-based program developed at Purdue University used to create manure management plans for crop and animal feeding operations (Purdue Research Foundation, 2004). The user enters information about the operation's fields, crops, storage, animals, and application equipment. MMP helps the user allocate manure (where, when and how much) on a monthly basis for the length of the plan (1-10 years). This allocation process helps determine if the current operation has sufficient crop acreage, seasonal land availability, manure storage capacity, and application equipment to manage the manure produced in an environmentally responsible manner. MMP is also useful for identifying changes that may be needed for a non-sustainable operation to become sustainable, and determine what changes may be needed to keep an operation sustainable if the operation expands. (http://www.agry.purdue.edu/mmp/)

6.1.2 Pollutant Loading and Water Quality Assessment Models

Over the past several decades, numerous mathematical models have been developed to understand, quantify, and simulate the movement of nonpoint source pollutants from land to water. While not all of these models are applicable in the present context, some may be used as screening tools to assess risks to water quality from agricultural operations. By understanding the fate and transport of manure pollutants and the effectiveness of management practices, producers and managers can evaluate farming operations and take steps to prevent adverse environmental impacts.

Model/Tool	Application	Scale	Data requirements
LEACHM	Nutrient leaching estimation	Field; Daily, Annual	Low
MANNER	Manure nutrient availability	Field	Low
NLEAP	Nutrient leaching estimation	Field; Daily, Annual	Moderate
RZWQM	Load estimation Management evaluation	Field; Daily, Annual	Moderate
EPIC	Soil erosion, crop yields, nutrient/pesticide movement Management evaluation	Field; Daily, Annual	Moderate
SUNDIAL	Nutrient leaching estimation	Field; Weekly	Moderate–High
GLEAMS	Load estimation Management evaluation	Field, Farm; Daily, Annual	Moderate
DAFOSYM	Nutrient cycling and balance Management evaluation Economics	Dairy Farm; Daily, Annual	Moderate
PLOAD	Load estimation Screening tool	Watershed; Annual	Low
GWLF	Load estimation Management evaluation	Watershed; Monthly, Annual	Low–Moderate
MIKE-BASIN	Load estimation Water quality assessment	Watershed; Daily, Annual	Low–Moderate
AGNPS	Load estimation Management evaluation	Watershed; Storm event and annual	Moderate
SWRRBWQ	Load estimation Management evaluation	Watershed; Annual	Moderate–High
SWAT	Load estimation Water quality assessment	Watershed; Daily, Annual	Moderate–High

	Management evaluation TMDL		
HSPF	Load estimation Water quality assessment	Watershed; Event, Hourly, Daily, Annual	Moderate–High
BASINS	Load estimation Water quality assessment Management evaluation TMDL	Watershed; Daily Annual	Moderate High

- **LEACHM** (Leaching Estimation And Chemistry Model) is a simulation model used for management and/or research into chemical movement into and below then root zone. It also examines plant uptake of these chemicals (Hutson and Wagenet, 1992). The model contains 6 submodules: a water flow module to estimate drainage, pesticide and tracer module, nitrate dynamics module; microorganisms; and an `other nutrients module.' Other nutrients that can be used includes chlorides, sulfates, and potassium. LEACHM requires several soil parameters as input (physical properties, bulk density, particle soil distribution, water retention). It also requires the amount of nitrogen and phosphate applied in manure/fertilizers, daily maximum and minimum temperature, precipitation and evapotranspiration estimates. The model predicts amount of chemical leaching below the root zone and amount taken up by the plants. The model uses a daily time step and is executed for one growing season or over a several year period. (http://www.wiz.uni-kassel.de/kww/irrisoft/drain/leachm.html)
- **MANNER** (MANure Nitrogen Evaluation Routine) is a decision support system that can be used to predict the fertilizer nitrogen value of organic manures on a field specific basis. MANNER accounts for N losses via ammonia volatilization and nitrate leaching, and accounts for mineralization of manure organic N. It calculates the amount of manure N available to the growing crop. (http://www.adas.co.uk/manner/frameset.html)
- **NLEAP** (Nitrate Leaching and Economic Analysis Package) is a computer model that can provide a rapid estimate of the potential nitrate leaching associated with agricultural practices on a field (USDA NRCS, 2004). It combines basic information about on-farm management practices, soils, and climate and then translates the results into projected N budgets and nitrate leaching below the root zone and to ground water supplies, and estimates the potential off-site effects of leaching. NLEAP can be used to conduct an annual screening, a monthly screening, or a single event analysis to determine leaching potential. (http://gpsr.ars.usda.gov/products/nleap/nleap.htm)
- **RZWQM** (Root Zone Water Quality Model) simulates major physical, chemical, and biological processes in an agricultural crop production system. RZWQM is a one-dimensional (vertical in the soil profile) process-based model that simulates the growth of the plant and the movement of water, nutrients and agrichemicals over, within and below the crop root zone of a unit area of an agricultural cropping system under a range of common management practices (RZWQM Development Team, 1992). The model includes simulation of a tile drainage system.

(http://gpsr.ars.usda.gov/products/rzwqm.htm)

- **EPIC** (Erosion/Productivity Impact Calculator). EPIC assesses the effect of soil erosion on productivity and predicts the effects of management decisions on soil, water, nutrient, and pesticide movements and their combined impact on soil loss, water quality, and crop yields for a single field (Williams, 1997; Chung et al., 1999). The EPIC physical components include hydrology, weather simulation, erosion-sedimentation, nutrient cycling, plant growth, tillage, and soil temperature. (http://brcsun0.tamu.edu/epic/)
- **SUNDIAL** (SimUlation of Nitrogen Dynamics In Arable Land) is a dynamic computer model of nitrogen turnover in the crop/soil system. It incorporates current scientific knowledge on the individual processes of nitrogen turnover and integrates these processes to simulate what happens in the whole soil. SUNDIAL requires readily available information on soil type, cropping history and weather data as model inputs. It is widely used by scientists to interpret the results of field experiments, in particular the effects of crop management, soil type and different weather patterns on nitrate leaching. SUNDIAL is also being developed into a Fertilizer Recommendation System (SUNDIAL-FRS), a management tool for farmers, growers and advisors, which will provide nitrogen fertilizer recommendations on a field-by-field basis, aiming to minimize nitrate leaching whilst achieving the desired yield. (http://www.rothamsted.bbsrc.ac.uk/aen/sundial/sundial.htm)
- **GLEAMS** (Groundwater Loading Effects of Agricultural Management Systems) is a continuous simulation, field scale model (Knisel et al., 1993), which was developed as an extension of the Chemicals, Runoff and Erosion from Agricultural Management Systems (CREAMS) model. GLEAMS was developed to evaluate the impact of management practices (such as planting dates, cropping systems, irrigation scheduling, and tillage operations) on potential pesticide and nutrient leaching within, through, and below the root zone. It also estimates surface runoff and sediment losses from the field. GLEAMS can be used to assess the effect of farm level management decisions on water quality. (http://www.cpes.peachnet.edu/sewrl/Gleams/gleams_y2k_update.htm)
- **DAFOSYM** (Dairy Forage System Model) simulates the performance, environmental impact and economics of a dairy farm over multiple years of weather. The simulation includes the growth, harvest, handling and storage of alfalfa, grass, corn, small grain and soybean crops. Farm produced feeds are supplemented with purchased feeds to meet a given level of production for a dairy herd. Manure is returned back to the land where nutrients are lost, accumulated in the soil or used in crop production. Costs of feed production and manure handling are compared to milk, animal, and feed sales to determine a net return over those costs for the farm. Other farm costs are then included to estimate the net return or profitability of the whole farm. Major submodels include crop growth, harvest, feed storage, feed use, manure handling, tillage and economic analysis.
- **PLOAD** is a simplified, GIS-based model used to calculate pollutant loads for watersheds. PLOAD estimates nonpoint sources of pollution on an annual average basis for any user-specified pollutant using either the export coefficient or the USEPA's Simple Method approach. Optionally, best management practices (BMPs), which serve to reduce NPS loads, and point source loads, may also be included in computing total watershed loads. (http://www.epa.gov/waterscience/basins/b3docs/PLOAD_v3.pdf)

- **GWLF** (Generalized Watershed Loading Function). The GWLF model was developed at Cornell University to assess the point and nonpoint loadings of nitrogen and phosphorus from a relatively large, agricultural and urban watershed and to evaluate the effectiveness of certain land use management practices (Haith and Shoemaker, 1987). GWLF is easy to setup and makes extensive use of default parameters. A Windows version of GWLF can be downloaded from http://www.vims.edu/bio/vimsida/bsabout.html or http://www.avgwlf.psu.edu
- **MIKE-BASIN** MIKE-BASIN is a GIS-based water resource modeling software for integrated river basin planning and management. It accommodates a basin wide representation of water availability, sector water demands, multi-purpose reservoir operation, transfer/diversion schemes, and possible environmental constraints (DHI, 2003). It includes a water quality module that simulates ammonia, nitrate, oxygen, total phosphorus, E. coli, COD, BOD, and a user-defined substance. (http://www.dhisoftware.com/mikebasin/index.htm)
- **AGNPS** (Agricultural Nonpoint Source Pollution). Developed by the USDA Agricultural Research Service, AGNPS addresses potential impacts of point and nonpoint source pollution on surface and groundwater quality (Young et al., 1989). It was designed to quantitatively estimate pollution loads from agricultural watersheds and to assess the relative effects of alternative management programs. The model simulates surface water runoff along with nutrient and sediment constituents associated with agricultural nonpoint sources, and point sources such as feedlots, wastewater treatment plants, and stream bank or gully erosion. (http://www.sedlab.olemiss.edu/agnps.html).
- **SWRRBWQ** (Simulator for Water Resources in Rural Basins – Water Quality). SWRRBWQ was developed for simulating hydrologic and related processes in rural basins (Arnold et al., 1990). The objectives of the model are to predict the effect of management decisions on water, sediment, nutrient, and pesticide yields with reasonable accuracy for ungaged rural basins throughout the U.S. The model is physically based and uses readily available inputs and is capable of computing the effects of management changes on outputs over long time periods. (http://www.cee.odu.edu/model/swrrbwq.php)
- **SWAT** (Soil and Water Assessment Tool) is a watershed scale model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over long periods of time (Arnold et al., 1998; Neitsch et al., 2001). SWAT also simulates instream biological and nutrient processes including algal growth, death, and settling, oxygen in water, aeration and photosynthesis, and changes in water temperature. (http://www.brc.tamus.edu/swat/)
- **HSPF** (Hydrological Simulation Program - Fortran) is a comprehensive model for simulating watershed hydrology and water quality for a wide range of conventional and toxic organic pollutants (Bicknell et al., 1997). It simulates for extended periods of time the hydrologic, and associated water quality, processes on pervious and impervious land surfaces and in streams and well-mixed impoundments. HSPF uses continuous rainfall and other meteorological records to compute streamflow hydrographs and pollutographs. (http://water.usgs.gov/software/hspf.html)

- **BASINS** (Better Assessment Science Integrating point and Nonpoint Sources). BASINS is a multipurpose environmental analysis system for use by regional, state, and local agencies in performing watershed and water quality based studies (Lahlou et al., 1996). This software can be used to quickly assess large amounts of point source and nonpoint source data and to assess water quality at selected stream sites or throughout an entire watershed. It integrates environmental data, analytical tools, and modeling programs (SWAT, HSPF, PLOAD, QUAL2E) to support development of cost-effective approaches for protecting water environment. BASINS' databases and assessment tools are directly integrated within an ArcView GIS environment. (http://www.epa.gov/waterscience/basins/basinsv3.htm)

It should be noted that not all models are appropriate tools for agricultural risk assessment. Because of complexity and requirements for data and expertise, sophisticated physical process simulation models are often difficult to apply in real world situations.

6.1.3 Feed Management and Water Quality Modeling

It is well known that the different feed management strategies have an effect on the amount of livestock manure produced and the intensity of odors. A ration with lower amounts of non-digestible materials will have fewer materials passing through the animal and out as manure. Since many odors are related to nitrogen and sulfur, a ration that reduces N or crude protein in the manure will produce lower amounts of odor. As part of the CNMP, feed management activities may be used to reduce the nutrient content of manure resulting in less land being required to effectively utilize the manure. Feed management activities are usually dealt with as a planning consideration and not as a requirement that addresses specific criteria. However, AFOs owners are encouraged to incorporate feed management as part of their nutrient management strategy.

Though the effectiveness of feed management in changing the nutrient composition is well recognized, actual net effects on water quality are not yet well documented. Studies on coupling feed management with the water quality models are very limited. Little information is available about such models. A few models such as AFOPro (De, et al., 2004) and DAFOSYM (Rotz et al., 1989) have the capability of incorporating feed management in manure loading predictions. Limited information is known about the field application studies of AFOPro. Rotz et al (2001) used the DAFOSYM model to study the long-term effects of changes in feeding, cropping, and other production strategies on phosphorous loading from two farms in southeastern New York. Also, models like SWAT (Arnold et al., 1998) have the capability of receiving inputs like the amount of manure with specified nutrient and pathogen concentrations applied on the agricultural land. Based on the knowledge about the effect of feed management strategies, the manure nutrient contents can be manually modified and the model can be reevaluated. Santhi et al. (2001) have applied SWAT to predict the impact of management practices on water, sediment and agricultural chemical yields in the Bosque River Watershed in Texas, incorporating the feed strategies.

6.2 Risk Index Tools

Farmers, consultants, and watershed authorities have access to a variety of tools for evaluating farming operations to determine their contributions toward causing or preventing adverse environmental impacts. Some of these tools are simple index tools, some represent distinct exercises (e.g., Farm*A*Syst), and some are incorporated within the context of normal farm management (e.g., CNMPs). The specific application and utility of these tools will necessarily depend upon local needs and objectives.

6.2.1 The Phosphorus Index

The Phosphorus Index, or P Index is a tool used to estimate the potential or risk for phosphorus (P) movement from individual fields based on soil and field characteristics and on management practices (USDA NRCS, 1994). The P Index considers both field characteristics like soil test P and fertilizer or manure applications that influence potential P movement to surface waters and transport factors such as field location, conservation practices, precipitation, runoff, and artificial drainage that influence delivery of P to surface waters. Using weighting factors, the P Index calculates a relative ranking of a field's potential P loss from Low to Very High. A Low ranking, for example, suggests that if farming practices are maintained at current level, the probability of an adverse impact to surface water resources from P losses from this site would be low. A ranking of Very High indicates a very high probability for an adverse water quality impact. Remedial action is required to reduce the risk of P movement. All necessary soil and water conservation practices plus a phosphorus management plan must be put in place to reduce the potential for water quality degradation.

The original P Index developed by USDA NRCS uses eight site (field) characteristics:

Soil erosion	P fertilizer application rate
Irrigation erosion	P fertilizer application method
Runoff class	Organic P source application rate
Soil test P	Organic P source application method

Since the introduction of the original P Index, many states have adopted the concept in their agricultural P management programs and have modified the index to address the particular concerns and conditions of their states. Iowa, Maryland, Texas, and Vermont are examples of states that have developed their own P Index systems (Sharpley et al., 2003). Heathwaite et al. (2003) recently developed a new GIS tool, called "P indicators Tool" to help identify risk of P pollution. The tool uses three interlinked "data layers", i.e. loss-potential indicator, transfer indicator, and delivery indicator to illustrate transport of P from agricultural land and its potential impact to the environment.

6.2.2 Nitrogen Leaching Index

Although runoff losses of nitrogen (N) are of concern in some parts of the U.S., the primary water quality issue over N concerns leaching of nitrate-N out of the crop root zone and into groundwater. On a national and regional scale, maps have been published that describe vulnerability to nitrate leaching based on soil and climate, such as the Manure N Leaching Vulnerability Index map published by the USDA NRCS (http://www.nrcs.usda.gov/technical/land/lgif/m2126l.gif).

At the local or field level, several specialized management tools are available to assist producers who farm in areas of high vulnerability to N leaching:

- **The Nitrogen Leaching Index** (NLI) was developed by the USDA NRCS to estimate the average annual percolation below the root zone and is based on the hydrologic soil group, and the amount of seasonal precipitation. It is a simplified procedure for estimating the leaching potential for a given climate and soil type based on monthly average rainfall.
- **NLEAP** (Nitrate Leaching and Economic Analysis Package) is a field-scale computer model developed to provide a rapid and efficient method of determining potential nitrate leaching associated with agricultural practices (USDA NRCS, 2004). (See more description in section "Pollutant Loading and Water Quality Assessment Models" of this report) (http://gpsr.ars.usda.gov/products/nleap/nleap.htm)
- **NPURG** (National Pesticide/Soils Database and User Decision Support System for Risk Assessment of Ground and Surface Water Contamination) is a screening tool that provides the leaching potential and the surface loss potential for a selected soil and a selected pesticide. The model can also be used to determine the Nitrate Leaching Index and the US EPA groundwater contamination classification (USDA NRCS, 1991).

6.3 Risk Assessment Programs

*Farm*A*Syst*

Farm*A*Syst is an agricultural self-assessment resource for operators to determine the risk their operation may pose to water quality. It uses a series of fact sheets and questionnaire worksheets to help a producer identify the effectiveness of his/her management practices, identify alternative measures, and prioritize areas that need improvement. Because Farm*A*Syst is voluntary and confidential, it is up to the operator to determine the level of technical expertise they may wish to pursue (University of Wisconsin et al., 1991).

On Farm Assessment and Environmental Review (OFAER)

The America's Clean Water Foundation (ACWF) On Farm Assessment and Environmental Review (OFAER) is an assessment program for livestock producers to have certified professionals determine their operation's environmental risks. The procedure is free and confidential. The assessment tools focus on overall site management, building and lot management, manure storage and handling, mortality management, and nutrient management (ACWF, 2004).

6.4 Incentive Programs

A wide variety of incentive programs exist at both the Federal and State level that can help producers manage the risks of environmental impacts from their operations. Many of these incentive programs include both technical assistance in identifying risks, problems, and solutions and cost-share assistance for implementing changes in management. Examples of Federal incentive programs include:

USDA NRCS Animal Feeding Operations (AFO)

The Natural Resources Conservation Service helps AFO owners and operators to achieve their production and natural resource conservation goals through development and implementation of comprehensive nutrient management plans (CNMPs).

USDA NRCS Conservation Security Program (CSP)

Through CSP, NRCS provides financial incentives and technical assistance to farmers and ranchers who develop conservation plans on their working lands. The program provides payments for producers who historically have practiced good stewardship on their agricultural lands and incentives for those who want to do more.

USDA NRCS Environmental Quality Incentives Program (EQIP)

EQIP provides technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial manner. Cost-share payments may be made to implement one or more eligible conservation practices, including animal waste management facilities and nutrient management. Many states operate their own incentive or cost-share programs to promote good animal waste management statewide or in special project areas.

Comprehensive Nutrient Management Plans (CNMPs)

While not truly an assessment tool, a CNMP (USDA NRCS, 2004a) is in many ways equivalent to a self-assessment tool such as Farm*A*Syst because it requires that the operator document and evaluate farm conditions within the context of developing a nutrient management plan that incorporates environmental protection.
Under the final CAFO rule, USEPA established requirements for animal waste and nutrient management on large CAFOs (http://cfpub.epa.gov/npdes/afo/cafofinalrule.cfm). These requirements call on producers to:

Implement a comprehensive nutrient management plan;
Submit annual reports to your permitting authority;
Keep permits current; and
Keep records of your nutrient management practices for at least 5 years.

CNMPs should address, as necessary, feed management, manure handling and storage, land application of manure, land management, record keeping, and other waste utilization options. While nutrients are often the major pollutants of concern, CNMPs also address risks from other pollutants, such as pathogens, to minimize water quality and public health impacts from AFOs. Best management practices (BMPs) are also a part of a CNMP, including managing the farm to reduce soil erosion and improve soil tilth through conservation tillage, planting cover crops to catch excess nutrients or using filter strips and buffers to protect water quality. Preventative maintenance, record keeping, mortality management and emergency response plans may also be included in a CNMP for livestock and poultry operations.

Nutrient management plans for all CAFOs must include provisions for:

Assuring adequate manure storage capacity;
Proper handling of dead animals and chemicals;
Diverting clean water from the production area;
Keeping animals out of surface water;
Using site-specific conservation practices;
Developing ways to test manure and soil;
Assuring appropriate use of nutrients when you spread manure; and
Keeping records of your nutrient management practices.

State permitting authorities may set additional requirements for any size CAFO. While specific requirements may vary by livestock type, in general, requirements for large CAFOs apply to both the production area where animals are housed and manure is stored and to the land where manure is applied.

Whole Farm Planning

Whole Farm Planning is a process that can be used by a producer and his/her family to balance the quality of life they desire with the farm's resources, the need for production and profitability, and long-term stewardship. This kind of planning effort can address multiple concerns of family, profitability, and environmental risk.

When focused on environmental risk management, whole farm planning is a locally developed, comprehensive, multi-agency effort to control agricultural sources of pollution and to promote the economic viability of the agricultural operation. Each farmer creates a whole farm plan tailored to the individual farm's needs, with a schedule of implementation, maintenance, and operation of recommended best management practices to meet water quality objectives. The concept was pioneered in the New York City Watershed Project (http://www.nycwatershed.org/).

6.5 Agricultural Environmental Management Systems

An Environmental Management System (EMS) is a comprehensive environmental management approach developed for business and industry by the International Organization for

Standardization (ISO), known as the statute ISO 14001. An EMS is a voluntary, proactive, flexible, and individualized way for an industry to meet environmental and economic constraints, and documenting their environmental stewardship. The EMS process has been adapted to agriculture in recent years (http://www.uwex.edu/AgEMS/EMSbookletFINAL.pdf). Many agricultural operations may already have management plans in place and an EMS can aid in organizing these efficiently to help gain farm sustainability and achieve environmental goals (USDA CSREES, 1992).

An EMS can be seen as a series of steps that incorporates feedback loops, in which operators are continually learning and growing, and improving their management structure to optimize efficient environmental protection:

- A Farm Environmental Policy Statement should be written to discuss pollution prevention measures, and continued dedication to environmental improvement.
- A Management Plan should be developed to set priorities and identify the most critical areas in need of improvement, with the help of assessment resources such as Farm*A*Syst (University of Wisconsin et al., 1991) or On Farm Assessment and Environmental Review (ACWF, 2004). - The plan should also include a comprehensive nutrient management plan to properly manage animal waste production and use (discussed above).
- Plan Implementation requires effective communication between all stakeholders (farmer managers, employees, regulators, consultants, neighboring farmers/other farmers in same watershed, public). Water quality monitoring, implementation of management practices, and implementation schedules should all be properly documented.
- Check and Correct involves comparing documentation and record-keeping procedures with standardized industry checklists and to insure that all important parameters are monitored
- Review and Approve includes an annual review of all documentation and records to determine success and failure and to identify changes or improvements needed in the EMS.

Other Agricultural Management Resources.

Many other resources exist to assist producers and managers identify and mitigate environmental risk. Some of these are:

- The Livestock and Poultry Environmental Stewardship curriculum, workshops for producer-targeted product education and support. (http://www.LPES.org)
- A Farmer's Guide To Agriculture and Water Quality Issues, National Agriculture Compliance and Assistance Center. (http://www.cals.ncsu.edu/wq/wqp/index.html)
- The American Soybean Association’s “Best Management Practices Handbook/Workbook” shows how to take a close look at farming operations, select appropriate best management practices (BMPs), set practical and economical goals, and develop a comprehensive action plan. (http://www.soygrowers.com/?v2_group=0&p=498)

- Ontario Environmental Farm Plan, farmer-driven, voluntary assessment program, highlights farm's environmental strengths and sets goals for improvements. (http://www.gov.on.ca/OMAFRA/english/environment/efp/efp.htm)
- Natural Resources Conservation Service's Conservation Planning Procedures Handbook, provides guidance on the planning process the NRCS uses to help develop, implement, and evaluate conservation plans for individuals, and area-wide conservation plans or assessments for groups. (http://policy.nrcs.usda.gov/scripts/lpsiis.dll/H/H_180_600.htm)
- Stream and Riparian Area Management: A Home Study Course for Managers. Designed specifically for livestock producers, this course offers effective stream and riparian management principles and technique. (http://www.homepage.montana.edu/~stream)

6.6 Research Needs

The greatest needs in this area are the validation of models for use in risk assessment and the proper application of models in assessment. Consideration of runoff contributing areas in combination with the P Index would improve the assessment of P export risk on a watershed level and improve the ability to target land treatment to important source areas.

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