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Guidance for Evaluating Surface Water Quality Improvements Resulting from Dairy Waste Best Management Practices

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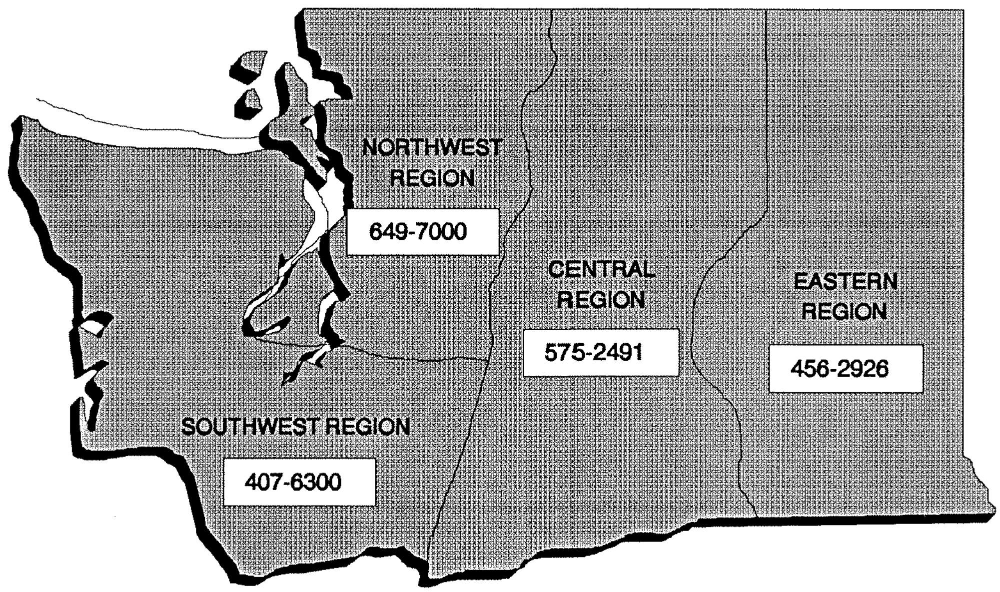

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Guidance for Evaluating Surface Water Quality Improvements Resulting from Dairy Waste Best Management Practices

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Abstract

This guidance document provides a general overview of the most significant considerations to be included in the design of a dairy waste Best Management Practices (BMP) evaluation study, and points the direction to more detailed information. The guidance emphasizes the importance of developing a comprehensive project plan, careful planning of the monitoring surveys, and evaluating both the BMP implementation and the water quality affected by the BMPs.

Summary

The Washington State Department of Ecology, in cooperation with Washington's Conservation Commission, local Conservation Districts, and the Natural Resource Conservation Service, regulates, promotes and assists the proper management of dairy animal waste through a statewide waste management program. The goal of the program is to minimize and eliminate the discharge of pollutants from dairy operations to the waters of the state by the design, installation, and operation of Best Management Practices (BMPs) within a comprehensive animal waste management plan.

A key element to a well-run and effective state dairy waste management program is adequate monitoring of the effectiveness of BMPs in producing water quality improvements. The importance of BMP evaluation and monitoring has been recognized in nationwide studies such as the Rural Clean Water Program. A few BMP evaluation studies have been conducted at specific sites, stream reaches, and sub-basins in Washington, and more can be anticipated in the future. It is important to learn from past efforts and to provide guidance so that future BMP evaluation projects are of a consistent high quality.

This guidance provides a general outline of the most significant considerations to be included in the design of a dairy waste BMP evaluation study, and points the direction to more detailed information. A comprehensive Project Plan should be developed to guide the study. Goals and objectives must be clear so that appropriate sites and methodology are selected. Monitoring must evaluate both the progress of BMPs and the quality of the associated water body. Proper monitoring design, sampling schedule, and parameter selection based on sound statistical principles are essential to meet project objectives. Consideration must be given to data quality management.

A BMP evaluation study is a complex undertaking. Each study is different, and a "cook book" approach is not possible. In order to develop and implement an effective Project Plan that will result in a successful study, the references provided in this guidance and other sources of expertise should be consulted.

Acknowledgments

Any value this document may have is the result of the pooled knowledge and experience of many outstanding workers in the area of nonpoint source pollution control. I am deeply appreciative of the valuable comments and suggestions given by Phil KauzLoric of Ecology's Watershed Management Section; Belinda Hovde, Bob Booth, Maryrose Livingston, Max Linden, and Jim Jacobson of Ecology's regional Water Quality sections; Diane Harvester of the Conservation Commission; Frank Easter of the Natural Resource Conservation Service; Denis Erickson of Ecology's Toxics Investigation Section; and Will Kendra, Debby Sargeant, and Keith Seiders of Ecology's Watershed Assessment Section. Barbara Tovrea did her usual inimitable job of report formatting and production.

Background

Problem Statement

Over 900 dairy farms operate in Washington State (KauzLoric, 1995), and many have the potential to discharge pollutants to surface waters of the state. The goal of Washington's dairy waste management program is to protect the waters of the state from pollution that could result from the improper management of animal waste by the state's dairy farms. To achieve that goal, dairy farms need to develop and implement holistic animal waste management plans that include a range of Best Management Practices (BMPs). The Department of Ecology (Ecology) encourages the use of federal Natural Resource Conservation Service (NRCS) standards and specifications for the BMPs.

When properly installed and managed, BMPs should prevent pollutants from reaching surface and ground waters near a dairy operation. BMPs for dairies may include over-winter storage of manure in lagoons; herd size management; land application of manure at agronomic rates; storm water and erosion management in animal holding areas (such as gutters, downspouts, or curbing); and restoring and maintaining riparian vegetative buffers on stream corridors by methods such as fencing, replanting, and restricted or remote stock watering.

Several legal instruments define the state dairy waste management program. Federal regulations require certain large dairy operations to obtain a National Pollutant Discharge Elimination System (NPDES) waste discharge permit. The Dairy Waste Management Act (Chapter 90.64 RCW) defines which farms will be covered by NPDES permits issued by Ecology, and also defines the relationship of Ecology to the local Conservation Districts (CDs) and the state Conservation Commission. This law was based on the Agricultural Compliance Memorandum of Agreement, which in 1988 established among these agencies Washington's agricultural waste management program.

On September 3, 1994, a statewide NPDES/State General Permit came into effect for dairy farms. Over 100 farms are candidates for coverage under this permit (KauzLoric, 1995). However, if a dairy operation has implemented an Animal Waste Management Plan (commonly called the "farm plan"), and no discharge is expected except in the event of a 25-year, 24-hour storm event, then coverage under the general permit is not required.

In general, dairy farms are identified for farm plan development and implementation either through voluntary compliance, complaints, or special water quality studies. Dairy farms work directly with the CDs, either voluntarily or by Ecology's referral. When Ecology investigates and verifies a compliant that a dairy is discharging pollutants, the dairy must by law develop and implement a farm plan within two years, unless the date is altered by agreement or an extension due to hardship. Dairies voluntarily requesting a farm plan will establish a schedule with the CD based on resources available to the farm and the CD.

Water quality monitoring is an essential part of any BMP implementation program to reduce nonpoint source (NPS) pollution. In their evaluation of the Rural Clean Water Program, Gale *et al.* (1992) stated that:

> "effective land treatment and water quality monitoring for NPS projects and clear, well-documented reporting of the results of such monitoring, is required to:
>
> a) document progress toward water quality goals;
> b) determine needs for further treatment;
> c) maintain the interest of project participants and staff;
> d) develop and transfer technology;
> e) reduce the number of inconclusive studies conducted;
> f) sustain Congressional support;
> g) assure credibility; and
> h) address increasing information needs."

Many, if not all, of the requirements listed above apply to the dairy waste management program in Washington State. In addition, historically some members of the public have questioned the ability of BMPs to reduce water quality impacts (KauzLoric, 1995). Very few farm-specific water quality monitoring studies have been conducted that demonstrate the effectiveness of BMPs in the Pacific Northwest. Local, site-specific information that verifies the effectiveness of BMPs would help to dispel these doubts. Clearly, the state dairy waste management program will benefit from effective monitoring and evaluation.

Many agencies are interested in evaluating how BMPs improve water quality, including Ecology, county governments, CDs, tribes, and other federal, state and local agencies. Ecology has developed this guidance to provide assistance and support to those efforts, and to foster consistency between the groups conducting such evaluations.

Previous and Current Evaluation Studies

A number of studies in Washington have sought to evaluate the effect of dairies and dairy waste BMPs on surface water quality. This section reviews a few of those studies.

Ecology and other agencies and academic institutions have conducted a number of water quality studies that identified impacts from dairy operations or that are evaluating BMP effectiveness. Erickson (1995a) summarized 48 of these studies. In general, the most common problems found associated with poor dairy waste management were elevated fecal coliform bacteria, depressed dissolved oxygen, and fish habitat degradation. Elevated temperatures, turbidity, and ammonia levels were also identified as problems. The information that follows comes from specific studies described in that report and from more recent work.

The Johnson Creek project in the mid-1980s (Dickes and Merrill, 1990) was designed to document water quality improvements resulting from BMP implementation. However, the project was unable to show improvement, likely due to several factors. First, the project did not specifically and quantitatively track land use and BMPs over the long term, and therefore information was not available to judge the extent of BMP implementation. From what little information was available, it appeared that many farms in the watershed did not develop farm plans and some with farm plans were not adequately implementing them. In addition, the data collected were inadequate to minimize the uncertainty in results caused by the variation in weather during the project. Thus, the project may have shown lack of improvement simply because of differences in the weather during the pre- and post-BMP sampling years.

The water quality monitoring and analysis conducted as part of the Upper Chehalis and Black River Total Maximum Daily Load (TMDL) studies in some areas found pollutants that appeared to originate from dairy operations (Pickett, 1991; 1994a,b; Coots, 1994). In these areas the study found low dissolved oxygen and increased fecal coliform bacteria, conductivity, turbidity, total organic carbon, total phosphorus, ammonia nitrogen, and organic nitrogen. These areas corresponded with areas of livestock impacts identified during the habitat degradation survey conducted by the U.S. Fish and Wildlife Service (USFWS) under the Chehalis Basin Fisheries Restoration Act (Wampler *et al.*, 1993).

Beginning in 1994, the USFWS, as part of the Chehalis Fisheries Restoration Program, began funding a BMP Evaluation Project at Ecology (Sargeant, 1994). Under this project, BMP evaluation has continued for three dairies identified in the Chehalis TMDL studies, with pre-BMP monitoring on the mainstem Chehalis River and on Beaver Creek, a tributary of the Black River, and post-BMP monitoring on the Black River. Six years of study are planned, and some initial results have been published, confirming the problems found in the TMDL studies.

Recently Erickson (1995b) completed a TMDL study on Fishtrap Creek in Whatcom County. This sub-basin is tributary to the Nooksack River, and flows through an area dominated by dairy farming. Of the 54 dairies inventoried in the sub-basin during 1993, over half have no farm plan or waste management system, and less than a quarter have fully implemented waste management systems. The study found significant problems with fecal coliform bacteria, dissolved oxygen, and ammonia nitrogen.

Although the Totten and Eld Inlet Clean Water Projects (Seiders, 1995) do not address impacts from large dairies, they do provide a detailed and thorough monitoring plan to assess nonpoint source impacts. The design of the projects comply with nonpoint source monitoring criteria specific to the U.S. EPA's National Monitoring Program (EPA, 1991a). The projects include monitoring of BMP implementation, and a detailed statistical evaluation of the water quality data to detect improvements.

Study Planning

Project Plan

For any particular evaluation project, a project plan should be developed specific to the project. The project plan should include a problem statement, project goals and objectives, a site-specific history, a study plan, and data quality objectives. A thorough description of the contents of a project plan can be found in Ecology (1991). A number of documents provide guidance on water quality assessments and nonpoint source BMP evaluation: Gale *et al.* (1992), EPA (1991a,b), Horner *et al.* (1986), Spooner *et al.* (1985), Coots (1995), and Cusimano (1994).

It is strongly recommended that a draft project plan be reviewed by Ecology or others with monitoring expertise to ensure that the study is well-planned and can meet its objectives. Peer review is always a sound principle for good quality scientific work. In addition, if it is important that the study's results be accepted by Ecology or another agency or group, then their review of the project plan will help to obtain their acceptance of the project's results.

Careful planning of a BMP evaluation project is essential. The difficulty in monitoring the effect of BMPs is that the "signal," the improvement to be measured, is often lost in the "noise," the inherent variability of the environmental system caused by, for example, rainfall, stream baseflows, and human activities. To detect the signal, a sampling design that minimizes the noise is necessary. In other words, to measure changes in water quality that are truly from the BMPs, the effects of weather, seasonal changes, and other factors must be minimized by careful sample design.

Evaluation projects should use the appropriate statistical tools. These tools can help select the proper sample size, and will allow an objective assessment of whether significant change has occurred. Without the use of the correct statistics, any interpretation of monitoring results is conjectural. In addition, statistical tools help to determine that the data resulting from the project will be of adequate quality to support the conclusions of the study.

Key elements of BMP evaluations that are often difficult to successfully include are: finding a site that meets the requirements of the study; implementing BMPs on the site; and documenting BMP implementation. Without these elements, a study cannot evaluate the connection between the BMPs and water quality. These elements require a joint commitment from the dairy implementing the BMPs (or a significant number of the dairies in a sub-basin), the agency overseeing the BMP implementation, and the agency conducting the monitoring.

Goals and Objectives

Any project to evaluate surface water quality improvements resulting from dairy BMP implementation must have clear goals and objectives. The goal of such a project would be to document improvements in surface water quality that occur as the result of BMPs implemented through Washington's dairy waste management program.

In general, the objectives of the project should be defined taking into account the following considerations:

- Choose sites for evaluation where impacts to water quality are occurring in the absence of effective BMPs and an adequate farm plan. A substantial level of land-owner cooperation and a firm commitment from Ecology, the CD, and other involved agencies must be available. This allows the agencies to coordinate efforts and devote resources to see that farm plans are implemented and managed properly for the duration of the project. The site should usually be an individual farm. A sub-basin with dairies as the dominant land use could be studied, but areas must be chosen carefully. It may be more difficult to see improvement at the sub-basin level, since other land uses may contribute pollutants, and obtaining the concurrent cooperation from multiple farms is more challenging.

- Monitor water quality using an upstream/downstream methodology, including any significant tributaries or sources between the upstream and downstream boundaries of the study area. Monitoring should follow a schedule whose frequency, timing, and duration will minimize temporal variability not associated with dairy waste management practices. Ideally, monitoring should include several years of pre-BMP conditions and several years of conditions after BMPs are fully implemented. A gap in time between pre- and post-BMP monitoring may be necessary to allow the farm to get up to speed with the correct operation of BMPs, and to allow the recovery of the natural system.

- Document the development and implementation of a farm plan, including tracking the installation, operation, and maintenance of specific BMPs during the project for each farm-based project site and for all dairies in a project sub-basin site. Also, document land uses in the sub-basin sites and track changes in land use over the course of the project.

- Evaluate water quality monitoring and BMP implementation data to determine if water quality improvements have occurred that are associated with improved BMPs. Use quantitative statistical tools whenever appropriate, as well as evaluation of compliance with state Water Quality Standards (Chapter 173-201A WAC).

The objectives should be specific, narrowly defined, and quantitative. For example, the objective of a project might be "to determine the extent of BMP implementation specified in Farm X's animal waste management plan, and whether BMP implementation have resulted in a significant improvement in water quality in Stream Y adjacent to the farm." In this example, the objective takes into account the site chosen, the need to ensure that the farm plan is fully implemented, measurement of the level of implementation, monitoring of the water body in way that isolates the effect of the farm, comparison of the monitoring results to the level of BMP implementation, and statistical tools to determine significance.

Study Design

Monitoring Sites and Stations

Prior to conducting an evaluation project, study sites should be identified that provide the best opportunity to meet the study objectives. The final project plan should include a description of the study sites, monitoring stations, and sampling schedule.

The exact number of monitoring stations at each study site will be site-specific. Each site should have at least an upstream and downstream monitoring location. Any significant local tributary or discharge channel present should also be monitored.

Stations should be positioned as close as possible to the farms associated with the site (to eliminate the influence of non-target pollutant sources), but far enough away for the study site to be representative. For example, the upstream station should be close enough to the study site to be below other sources of pollutants, but far enough away to be unaffected by the study site. Similarly, the downstream station should be far enough downstream for any pollutant inputs from the study site to be fully mixed across the width and depth of the stream, but still avoiding if possible the influence of non-target sources.

Each station is usually monitored at mid-stream below the water surface, and if possible sampling should be from upstream to downstream. Some knowledge of the stream's travel time between sampling stations can be useful in the interpretation of results.

Monitoring Schedule

Based on the recommendations of Gale *et al.* (1992), the ideal evaluation project should last at least six years, with the possibility of one to four years additional work depending on the status of BMP implementation, weather conditions during the study, and other factors affecting the ability of the study to meet its objectives.

Monitoring should consist of two components: BMP implementation monitoring, and water quality monitoring. Only by comparing these two components can the relationship of BMPs to water quality be determined with certainty.

To determine the best water quality monitoring schedule, one must return to the concept of detecting the "signal" of water quality change due to BMPs, as distinct from the "noise" of variability due to causes other than BMPs. As discussed earlier, spatial variability due to sources other than the project site was addressed through careful positioning of sampling stations. Temporal variability creates noise due to the variations in weather from day-to-day and year-to-year. Certain parameters may be reduced more dramatically due to the source and transport mechanism of the pollutants. And the detectable signal may occur more strongly during certain patterns of rainfall, such as during the early stages of a significant storm.

The simplest approach to a water quality monitoring survey is to develop a regularly spaced pre-determined time schedule, with adjustments made to the schedule as a result of severe weather, monitoring logistics, or personnel considerations. For example, monitoring surveys could be scheduled twice per month, at least two weeks apart, for a total of 24 surveys per year. This results in what amounts to a "random" sampling from all possible weather conditions. The advantage of this approach is its simplicity and predictability in terms of sampling logistics. However, it requires a large number of sampling points over a large period of time to get enough data to adequately characterize the distribution of data and detect differences due to BMPs.

If data are available that identify a critical season when impacts are most severe, then monitoring could be focused on that time period. Also, if certain parameters are identified that represent the most significant problem, it is appropriate to focus on those parameters. However, the total number of surveys per year should ideally still be 20 or more. For example, the Totten-Little Skookum National Monitoring Project described in Seiders (1995) consists of 20 weekly surveys during the wet season.

The number of years included in the project or samples per year may be reduced from what is recommended here, if consideration is given to the statistical design of the project, knowledge of data variability from previous studies, critical weather or flow conditions, an anticipated large reduction in pollutant loading, or other factors. If the anticipated data variability can be estimated, statistical tools are available to estimate the optimal sample size for a given power of detection. However, reducing the number of years in the project should be approached with caution, since fewer samples over a shorter time frame generally means a lower chance of detecting a change in water quality due to BMP activities and a greater chance of seasonal weather changes strongly influencing data variability.

If sufficient information is available about the response of pollutant loading to rainfall events, monitoring in response to a rainfall event may be appropriate. For example, if data is available that shows that 0.5 inches of rain in 48 hours results in a rising water level in the stream under study, and these conditions produce the highest pollutant levels, then the schedule can be based on those specified antecedent conditions as a trigger for sampling. This approach can allow more focused sampling and the collection of added information about "worst-case" runoff. However, rainfall-driven sampling is logistically difficult (for example, laboratories may be limited in their flexibility to accept samples on short notice), and can produce biased results if collected data are not statistically representative.

An important consideration in the scheduling of the monitoring surveys is that the pre-BMP monitoring must be comparable to the post-BMP monitoring. Both data sets must be taken from the same sampling population and must be subject to the same preconditions. For example, it would be incorrect to compare a data set collected at weekly intervals to a data set collected in response to rainfall events. However, it may be appropriate to select data from the weekly sampling with the same antecedent conditions as the rainfall event sampling, and then compare those two data sets (if other requirements of the statistical test are also met).

Another survey design that is available as an alternative to the strategy described above is a paired watershed study design. This is a powerful evaluation method, but technically complex and potentially more costly, so it is only mentioned here briefly. A detailed description of the paired watershed method is presented in EPA (1993).

Monitoring of BMP implementation is the second major component of BMP evaluation that must not be neglected. For each concentrated dairy animal feeding operation located at a study site, the status of BMP and farm plan development and implementation should be reviewed and documented on a regular basis, such as quarterly, semi-annually, or annually. It is better to select the measures and monitor BMP implementation closely during the study, rather than waiting until much later to try to find historical data or search foggy memories.

For sub-basin study areas, in addition to the specific measures of BMP implementation, the land use patterns of the sub-basin should be documented during the first year of the study, and reviewed annually to document any significant changes in land use. If resources are available, land use data can be managed with a Geographic Information System (GIS).

Monitoring Parameters

Monitoring parameters should be selected based on their association with dairy waste pollution problems and the possible impact to the water body. Table 1 shows the monitoring parameters commonly affected by dairy activities in past surface water studies, and examples of BMP implementation measures. The parameters marked with an asterisk (*) are considered the most important for most projects, and the others are desirable or may be significant in a given situation. Parameters are also marked to indicate whether they are a problem in a particular season.

Dissolved oxygen, temperature, pH, and conductivity are best measured in the field at each station during each survey using a portable measurement device appropriate to the range and accuracy required for the study. Flows should be measured at monitoring stations with a current meter using standard USGS methods if feasible, or by other appropriate methods.

At each station, all laboratory samples should be collected as grabs for analysis at an accredited laboratory. At all times with bacteria samples, and whenever possible with other parameters, samples should be collected directly into the bottle supplied by the laboratory. Samples must be stored on ice immediately after collection and shipped to the laboratory for analysis within holding times. Samples should only be analyzed at accredited laboratories, so that standard analytical methods will be used (APHA, 1992; EPA, 1983) and regulatory standards for quality will be met. Always try to use the same method, and if possible the same laboratory, for each parameter.

For the monitoring of BMP implementation, specific activities should be tracked or quantitatively measured, such as the operation and maintenance of the waste management system. Land application of manure may be a critical component of BMP monitoring, and data collected can include the time, location, and amount of manure applied to fields. Associated hydrologic measures may be important, such as precipitation or field soil moisture. It may be desirable to have the farm operator keep a regular log of activities. The amount of fencing or re-vegetation, the head-to-acreage ratio, or other specific measures of BMPs can be included.

Table 1. Monitoring Parameters

Water Quality Parameters		
Lab Parameter	Field Parameter	BMP Implementation Parameters
Fecal Coliform Bacteria (*, S, W)	Temperature (*, S)	Streambank fenced (length or %)
Turbidity (*,W)	Dissolved Oxygen (*, S)	Streambank re-vegetated (length or %)
Total Suspended Solids (W)	Flow (*, S, W)	Manure managed (tons/year)
Total Persulfate Nitrogen	pH (S)	Fields agronomically managed (acres)
Ammonia Nitrogen (S)	Conductivity	Rainfall or runoff diverted (acre-in/yr)
Nitrate/Nitrite	Precipitation (*, W)	Head-to-acreage ratio
Total Organic Carbon		Head under BMPs (# or % of total)

(*) = key parameter; (S) = usually summer problem; (W) = usually winter problem

Data Quality and Management

As discussed above, the main difficulty in determining the effect of BMPs is separating the changes in the water quality due to the BMPs from any other causes of variability in the water quality data. Project design and monitoring protocols can help minimize the variability due to site characteristics, temporal changes, and monitoring methods. Quality assurance/quality control (QA/QC) procedures also help to reduce the variability due to sample collection and analysis and provide a measure of that variability.

For field measurements, meters and other equipment must be properly maintained, calibrated according to manufacturer's instructions, and operated correctly. A meter should be selected that measures field parameters in a range and with the accuracy necessary for the conditions that are expected in the field. The project plan should specify the equipment to be used, as well as the precision and range of the instruments.

Field meters should be checked with standards if possible at least once per day, and as a "post-calibration" at the end of the survey. Standards checks should be made more frequently if the field conditions, meter operation, or unusual readings suggest a check is warranted. Each meter has its unique features and quirks, and the operator should be familiar with the proper operation and maintenance of the meter. In addition, measurements can be periodically verified by using two separate methods, if possible. For example, if conductivity is measured in the field, samples can also be analyzed at the lab for that parameter.

Sampling for laboratory analysis must be conducted with the correct bottles. Sampling equipment such as Van Dorn bottles or buckets must be adequately cleaned and rinsed between samples, and not used for sensitive parameters such as bacteria. Samples must be preserved properly and transported to the laboratory within holding times. Procedures for sampling should be specified in the project plan.

To measure the sampling variability, samples can be collected in replicate for a certain percentage of samples. Replicates are two or more samples taken at roughly the same time at the same location under the same conditions (duplicates are two replicates). As a rule of thumb, replicate samples should be collected for 10% of the total number of samples, but for some parameters with poorer precision, such as fecal coliform bacteria, a higher replicate rate is warranted. Replicates may also be used to reduce the "noise" introduced by random sampling variability - for a highly variable parameter like fecal coliform bacteria, a 100% duplicate rate might be desirable. Replicate rates should be specified in the project plan, and identified for specific sites in the samplers' field instructions.

The laboratory should also follow QA/QC procedures. For example, the lab can split samples for duplicate analysis, which will allow assessment of laboratory variability. The lab should provide a summary of those procedures, and they may provide different levels of QA/QC for different costs. Communication with the laboratory is important to establish the appropriate level of QA/QC and to ensure that no misunderstandings occur that could result in poor quality data. Laboratory arrangements can be documented in the project plan.

Data quality objectives for water quality monitoring should be specified in the project plan, including the method, precision, lower reporting limit, and expected range for each parameter that is achievable with the equipment and laboratory to be used. It is important that the laboratory agrees to these objectives.

Similarly, data quality objectives should be specified for the BMP implementation monitoring. These objectives should address the specific BMP implementation and land use parameter, the unit and scale of measure, method of collection, and collection frequency. For example, a BMP implementation parameter might be stream fencing (that protects the affected surface water), measured in feet in place and maintained each month. Fencing data would be collected through review of the farm plan with the local CD and the owner, which would take place annually.

A final element of the project is adequate data management, which relates to project management in general. All field data, observations, and laboratory analytical results must be recorded carefully and consistently, and transferred to data storage without error. If several people will be collecting data, then training and instructions must be provided to ensure adequate and consistent quality of data collection. Responsibilities should be clearly defined, including a single project manager who will be accountable for achieving the overall project goals and objectives. Project and data management responsibilities should be specified in the project plan.

Analysis and Reporting

Once the data have been collected, the data must first be assessed and validated with respect to the data quality objectives. If any of the data do not fully meet objectives, then the qualifications for that data should be reported, or the data should not be used. The data quality must be taken into consideration in the analysis of results.

The "Project Plan" section discussed the importance of statistical methods, and the references mentioned in that section describe a number of those methods. Examples include the use of boxplots, linear regressions, and non-parametric comparisons of two data sets. These methods can be used to evaluate the relationship of upstream to downstream water quality, changes in the water quality at downstream sites over time, changes in the relationship of upstream to downstream sites over time, and the relationship of BMP implementation measures to water quality parameters.

The importance of using appropriate statistical methods, and designing the monitoring to provide data that can be analyzed with those methods, cannot be stressed enough. Statistical methods should be evaluated prior to the study and specified in the project plan as part of the project design, in order to ensure that sufficient data is collected to apply the appropriate statistic. The statistical evaluation of data is a complex area that is beyond the scope of this document to address in detail. Researchers planning a BMP evaluation study or analyzing data are encouraged to consult other references and people with expertise.

In addition to statistical measures, evaluating improvements in Water Quality Standards compliance is also important. In many cases, under pre-BMP conditions water quality will be degraded relative to the levels defined in the water quality criteria. Comparison to the standards allows an assessment of the support for the water's beneficial uses (such as swimming, fisheries, or other resources). In these cases it is particularly important to document compliance with criteria and the restoration of beneficial uses as BMPs are implemented.

Finally, the data and analysis should be reported in a way that makes it clear how the project has met its objectives. Simple, vivid graphics usually are an effective way to show success. After all, the overall goals of monitoring, as discussed earlier, are to document the successes of dairy waste management in protecting water quality, to build credibility, and to maintain political support. Achievement of those goals will be possible both through a good evaluation study and effective communication of the results.

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