7. Monitoring

Wastewater Land Application Program (WLAP) monitoring is a comprehensive program that provides information for managing and regulating WLAP sites. WLAP monitoring is determined by site-specific environmental and operational parameters.

This section presents guidance and provides the technical references that should be considered when designing a WLAP monitoring plan and establishing permit conditions for monitoring in a wastewater land application facility. General discussions of monitoring as well as particular discussions of commonly monitored media are also presented.

7.1 General Discussion

Several general considerations apply to all facilities in the wastewater land application permit (WLAP) program administered by DEQ:

- Monitoring Objectives
- Monitoring Parameters
- Monitoring Frequency
- Sampling and Sampling Location Determination
- Analytical Methods
- Quality Assurance and Quality Control
- Data Processing, Verification, Validation, and Reporting

Monitoring recommendations for commonly monitored media are provided in the following to assist in the development of a WLAP monitoring program. Each type of monitoring is discussed in a separate section and the discussion follows the outline of the general section.

Commonly monitored media include the following:

- General discussion (Section 7.1)
- Ground water monitoring (Section 7.2)
- Soil-water monitoring (Section 7.3)
- Soil monitoring (Section 7.4)
- Wastewater monitoring (Section 7.5)
- Crop monitoring and yield estimation (Section 7.6)

7.1.1 Monitoring Objectives

The goal of WLAP monitoring is to provide a timely and cost-effective assessment of both wastewater treatment process operations as well as the impact of operation and management activities on ground water, surface water, soil resources, and crop health. Monitoring information provides valuable feedback to determine whether wastewater land treatment changes should be made to manage environmental impacts. All permits need to specify required monitoring sufficient to yield data that are representative of the monitored activity. WLAP monitoring requirements should have well defined objectives – i.e., it should be known how the data will be used. Useful data are generated when the purposes of monitoring are understood.

The three objectives of environmental monitoring are as follows:

a) Site Characterization

It is necessary to characterize baseline conditions of ground water, soil water, surface water, soils, and other media prior to initiation of wastewater land treatment activities and for system design purposes. Characterization of variability in monitored media, particularly wastewater and ground water, is a prerequisite to establishing monitoring schedules.

b) Site Management or Process Control Monitoring

Process control monitoring involves monitoring internal components of both the wastewater land application system and other associated wastewater treatment processes to determine whether they are functioning as designed (Crites et al. 2000). This monitoring can yield information that can be used to modify ineffective management practices.

c) Compliance Monitoring

Compliance monitoring is required in regulatory instruments so that an adequate determination of whether a wastewater-land application system is complying with applicable water quality standards, permit specific limits, and other WLAP permit conditions. Compliance monitoring includes environmental parameters, such as ground water quality. It also includes monitoring of treatment parameters, such as constituent loading, which serve as a first line of monitoring to be protective of the resource (ground water for example)

Consideration of these objectives is necessary to develop a program or strategy with the combination of monitoring that will best fit the needs of a given wastewater-land application site.

A quality assurance project plan should be written as prescribed in Section 7.1.6.

7.1.2 Monitoring Parameters

All parameters with permit limits must have associated monitoring requirements in the permit. Parameters that do not have regulatory-established limits may be included to meet clearly defined monitoring objectives as required by DEQ. Media-specific monitoring parameters are discussed in respective sections below. As will be discussed further, choice of parameters to monitor is facility-specific. Not all parameters are necessary for every site.

7.1.3 Monitoring Frequency

The frequency of sampling should result in the generation of data that provide a reasonable characterization of the media. Reasonableness can be demonstrated on the basis of the value of data collected versus cost. A primary value of the data is the establishment of data variability, an important factor in calculating permit limits, determining compliance, and establishing the basis for monitoring frequency. Routine compliance monitoring frequency may be adjusted to reflect the variability - less variable parameters being sampled less frequently, while more highly variable parameters are sampled more often. The intent is to establish a frequency of monitoring that will detect most events of noncompliance without requiring needless or burdensome monitoring and associated costs.

7.1.3.1 Temporal or Spatial Variability

Variability can be temporal or spatial:

- Soils can have significant spatial variability. Monitoring considerations related to soil spatial variability are discussed in 7.4.5.2 *Sampling Location Determination*, page 7-46.
- Temporal variability of the media being monitored is one of the most important factors in establishing monitoring frequency. Therefore, the degree of monitoring frequency is dependent on the characterization of temporal variability. Various sampled media exhibit different variability. Particular parameters measured from one sampled medium can also exhibit different variability. An example of the variability over time of potato processing wastewater COD levels for one year is shown in Figure 7-1.

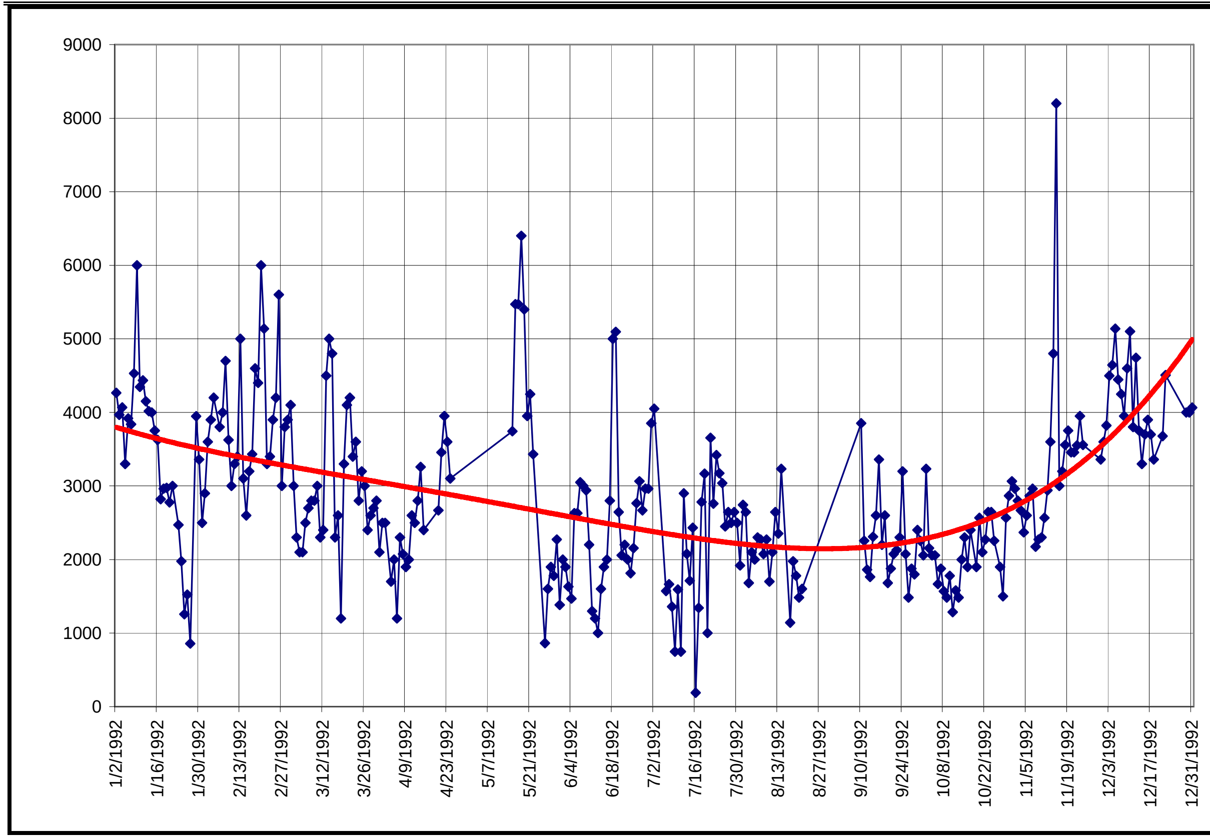

Figure 7-1. Potato processing wastewater COD levels for one year.

- Characterization of medium and parameter variability should be included as a part of the permit application (see Section 1). High frequency monitoring, usually within a tiered framework or as a special study, is recommended to characterize temporal variability of a medium. The frequencies for monitoring may be determined based on the estimated variability.

There are various statistical approaches to determining variability and sampling frequency. DEQ has developed a spreadsheet tool and explanatory text, which provides one such method for use in wastewater land treatment facility permitting. (See *Program Forms and Spreadsheets* in Section 1.9.3)

7.1.3.2 Tiered Monitoring

Tiered Monitoring is a term used to describe a reduction or increase in frequency of monitoring required in a permit. If initial (baseline) sampling shows little variability in a parameter, a reduced monitoring scheme may then apply. Likewise, if initial (baseline) sampling indicates strong variability in a parameter, a more frequent and/or more comprehensive monitoring schedule would apply. Tiered monitoring decisions are based on the results of previous monitoring. The conditions for increase and decrease should be specified in the permit.

The triggers for the tiered elements of a permit should, where possible, be well defined in the permit and explained in the staff analysis. The permit should explain to what frequency the tiered parameter will revert if not detected, not found to be at a level of concern (a trigger), or exceeding a level of concern. The numeric level of concern or other trigger should be defined in the permit and justified in the staff analysis. The reduction, elimination, or increase in monitoring should also be contingent upon formal notification from DEQ to the permittee of the monitoring change, be that a permit modification or written notification. Monitoring changes should be discussed with the permittee prior to formal notification.

7.1.4 Sampling and Sample Location Determination

Monitoring requirements in the permit should specify the sample type (grab, composite or continuous), and the analytical methods for each parameter. Sampling, sample handling, and analytical methods should conform to the guidance provided here and in the technical references cited.

7.1.4.1 Sampling

The sample type will depend on the following:

- The parameter to be monitored. To determine appropriate sample types, consult references provided for each respective media.
- The temporal and spatial variability of the media sampled.
- The type of regulatory limit that may be applied to sample results.

7.1.4.1.1 Discrete Grab or Sequential Grab Samples

A *grab sample* is an individual sample that represents "instantaneous" conditions. Use grab samples when the following is true:

- The characteristics of the media sampled are relatively constant
- The parameters to be analyzed are likely to change with storage
- The parameters to be analyzed are likely to be affected by compositing
- Information on variability over a short time period is desired
- Composite sampling is impractical, or the compositing process is liable to introduce artifacts of sampling
- The spatial parameter variability is to be determined

Another type of grab sample is sequential sampling, which is discussed in 7.5.5.1.1 Discrete Grab or Sequential Grab Samples, page 7-58.

7.1.4.1.2 Composite Samples

A *composite sample* consists of a series of individual samples collected over time and analyzed as one sample. Application of composite sampling to various monitored media is described in the respective media sections.

7.1.4.1.3 Continuous Monitoring

Continuous monitoring is another option for certain parameters and media, such as wastewater flow, pH, salinity and temperature; climate parameters; and soil moisture content. Important factors to remember about continuous monitoring include the following:

- Continuous monitoring is appropriate for a limited number of parameters.
- Reliability, accuracy and cost vary with the parameter.
- Continuous monitoring can be expensive, so the environmental significance of the variation of parameters of a given media should be compared to the cost of continuous monitoring equipment available.
- Continuous monitoring provides a considerable amount of data and its use should be clearly defined.

7.1.4.1.4 Other Sample Types

Several other types of samples can also be taken:

- *Split Sample* - A split sample is portioned into two or more containers from a single container. Portioning assumes adequate mixing to assure the split samples are, for all practical purposes, identical.
- *Duplicate Sample* - Duplicate samples are collected sequentially from the same source, under identical conditions, but into separate containers.
- *Control Sample* - A control sample is collected upstream, up-gradient, or away from the influence of a source or site to isolate the effects of the source or site on the particular medium being evaluated.
- *Background Sample* - A background sample is collected from an area, water body, or site similar to the one being studied but located in an area known or thought to be uninfluenced by site activities being regulated .
- *Sample Aliquot* - A sample aliquot is a portion of a sample that is representative of the entire sample.

7.1.4.2 Sampling Location Determination

The point at which a sample is collected can make a large difference in the monitoring results. The purpose of monitoring is to observe changes in conditions and compare them to expected or desired outcomes. For this reason, permanent sampling locations should be determined and identified in permit monitoring requirements. Monitoring data can then be compared without concern for spatial variability introduced under conditions where sampling locations are not permanent. The permit applicant should provide a description of all proposed monitoring locations in application materials. Important factors to consider in selecting the sampling station include the following:

- The volume of media at the sampling station should be adequate in order to obtain a sample.
- The sampling station should be easily and safely accessible.
- The sample should be truly representative of the media during the period monitored.

Additional sampling information is given in the *Handbook for Sampling and Sample Preservation of Water and Wastewater* (EPA, 1982):

http://yosemite.epa.gov/water/owrccatalog.nsf/e673c95b11602f2385256ae1007279fe/fe398acacbde5cf685256fc1004e5680?OpenDocument&CartID=9992-112918

7.1.5 Analytical Methods

Approved analytical methods for parameters usually include sampling and handling requirements. Media specific analytical methods are found in respective sub-sections of this section. Recommended analytical methods, in addition to information regarding sample preservation and handling, are also found in the *Ground Water and Soils Quality Assurance Project Plan Development Manual* (DEQ, 2001):

http://www.deq.state.id.us/water/data_reports/ground_water/contaminants_detected_statewide_monitoring_program.pdf

Standardization of analytical methods is important in the WLAP program, so that data can be consistently interpreted with respect to site performance and compliance with standards and/or permit-stipulated limits. Different analytical methods can yield different results: for example, a soil analysis for plant available phosphorus (P) might yield a result of 15 mg P/kg soil, while an analysis for total phosphorus (most of which is not plant available) may yield a result around 650 mg P/kg soil (Overcash and Pal, 1982; page 394). In addition, plant available phosphorus has useful agronomic interpretive value while total phosphorus does not.

Laboratory analyses have low fundamental detection limits, method detection limits (MDLs) and practical quantitation limits (PQLs):

- MDLs are the minimum concentrations that a laboratory method can measure above the instrument background noise. MDLs indicate only the minimum detection level of an analyte but do not imply any accuracy or precision in the result. As such, MDLs have little reporting value but rather reflect the standard basic capabilities of a laboratory for specified testing methods.
- PQLs are the minimum concentrations that can be reported within specified accuracy or precision criteria. PQLs can be affected by analyst skill, interferences in the sample and other operating factors. Where MDLs are typically consistent, PQLs typically vary. PQLs are always higher than MDLs, and they should be used for reporting and interpretation.

PQLs reported at or above concentrations of interest (regulatory limit, previously established lower background level, etc.) render the data useless.

For example, if the PQL for manganese (Mn) provided by a laboratory is at the ground water standard (previously the maximum contaminant level, or MCL) of 0.05 mg/L for a ground water sample, the data have no interpretive value for the entire range below the ground water standard. A method having a MDL of 0.005 mg/L, for example, would be appropriate so long as sampling protocol minimizes interferences (e.g. minimizing turbidity in ground water samples) such that the PQL is achievable.

The tables in respective sections below provides guidance regarding chemical analytical methods recommended for environmental monitoring required in WLAP permits, including ground water, soil water, soils, wastewater, and plant tissue analyses.

Standard operating procedures regarding sample collection, preservation, storage, transportation, and preparation of samples, are also important to assure sample integrity. Recommended procedures are outlined in EPA (Revised 1979 and March 1983), Greenberg et al (1992), and other relevant texts.

7.1.6 Quality Assurance and Quality Control

Data gathered in WLAP monitoring programs provides information to decision makers on the quality of ground water, soils, wastewater, leachate, etc. data collected, the adequacy of operation and maintenance procedures, and the potential for land application activities to affect the environment. If decision makers are to have confidence in the quality of environmental data used to support their decisions, there must be a structured process for quality in place. A *Quality Assurance Project Plan* (QAPP) is the environmental industry standard for a structured process for quality in the collection of environmental data.

The QAPP is the single most important quality assurance tool at the project or monitoring program level, and is necessary for all data collection and generation activities. The QAPP summarizes the DQOs (Data Quality Objectives) of the project or monitoring program and integrates technical and quality aspects, including planning, implementation, and assessment into a single document.

The purpose of the QAPP is to document planning efforts for environmental data collection, analyses, and data reporting to provide a project-specific “blueprint” for obtaining the type and quality of data needed for a specific decision or use. The QAPP documents the activities that will take place during the project or monitoring program, including: field and laboratory activities; data verification and validation; data storage and retrieval; data assessment; and, project or monitoring program evaluation and process improvement. The QAPP documents how QA (quality assurance) and QC (quality control) are applied to environmental data collection activities to assure that the results obtained are of the type and quality needed and expected. QA is defined as: “An integrated system of management activities involving planning, implementation, documentation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the client.” (EPA QA/R-5, March 2001). QC is defined as: “The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer;

operational techniques and activities that are used to fulfill requirements for quality." (EPA QA/R-5, March 2001).

The success of an environmental monitoring program depends on the quality of the environmental data collected and used in decision making, and this may depend significantly on the adequacy of the QAPP and its effective implementation. Data users, data producers, and decision makers should be involved in the QAPP development process for their monitoring program to ensure that their needs are adequately defined and addressed in the QAPP.

7.1.6.1 QAPP Development and Submittal Guidance

The permittee's QAPP should be developed to comply with EPA QA/R-5 *Requirements for Quality Assurance Project Plans* EPA/240/B-01/003, March 2001. QA/R-5 allows flexibility in the degree of rigor to be applied via the QAPP depending on the type of environmental monitoring to be performed, the intended use of the data, and the risk involved in using data of uncertain quality. Section 7.7.2 lists the content elements that should be addressed and included in a QAPP according to QA/R-5. The permittee's QAPP for a monitoring program should be submitted by the permit applicant as part of the application material for review and approval by DEQ.

7.1.6.2 Quality Control (Q/C) Samples for Monitoring

QC procedures should be described in the QAPP as they relate to the use or taking of QC samples during data collection activities. Field duplicate samples should be taken at a minimum rate of 5% (one duplicate for each 20 samples collected) or one duplicate per sampling event, whichever is less, to provide for determining field sampling precision. A field or equipment blank (rinsate blank) should be taken, one for each sample delivery group. Rinsate blanks shall be analyzed to determine if in-field equipment decontamination procedures are adequate. Trip blanks should be taken if there is reason to believe that a possibility of cross contamination may exist. Trip blanks provide a means to check sample collection, handling, and shipping methods to determine if cross contamination is occurring during those activities.

Laboratory QC samples should also be addressed in the QAPP and should be as specified in the applicable analytical method.

7.1.7 Data Processing, Verification, Validation, and Reporting

Data processing, data verification, and data validation are quality assurance tools used to determine if data has been collected as specified in the QAPP with respect to compliance, correctness, consistency, and completeness. In addition, these tools are used to assess the technical usability of the data with respect to the planned objectives or intention of the project or monitoring program. Although these tools are really processes, project or monitoring program specific measurement criteria for the data processing, verification, and validation should be determined during project or monitoring program planning and documented in the QAPP. Guidance for developing QAPPs and data quality objectives can be found in EPA (2002) and EPA (2000)

Data Processing includes data entry, validation, transfer, and storage. The QAPP should describe or reference specific procedures used to maintain the integrity of the data records as well as any project or monitoring program specific data storage/transmittal requirements. This process includes data formats and standards for the transfer of data to external data users. Specific data processing activities may include:

- Collection: For both manual data and computerized data acquisition systems, internal QC checks should be developed and implemented to avoid errors in the data collection process.
- Transfer: Data transfer steps should be minimized and procedures established to ensure that the data is free from errors and is not lost during transfer.
- Storage: At each stage of data processing, procedures should be established to ensure that data integrity and security are maintained. The QAPP should indicate how specified types of data will be stored with respect to format, media, conditions, location, retention time, and access.
- Reduction: Data reduction includes any process that changes either the form of expression, the numerical value of data results, or the quantity of data. This includes verification, validation, and statistical or mathematical analysis of the data. Reduction is distinct from data transfer in that it entails a change in the dimensionality of the data set. Procedures for verifying the validity of the reduction process should be described in the QAPP.

Data Verification refers to the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or permit requirements. It focuses on determining that the data have met the measurement requirements. Verification evaluates the data for basic elements such as sampling the correct sites, sample handling, chain-of-custody procedures were followed, QAPP specified analytical methods were used, the appropriate parameters were analyzed, etc. Data verification is not concerned with evaluating or assessing the quality of the data set.

Data Validation is an analyte and sample specific process that extends the evaluation of data beyond method, procedural, or permit compliance (i.e., data verification) to determine the analytical quality of a specific data set. Data validation criteria are based on the data quality objectives or measurement quality objectives specified in the QAPP.

Additional information and specific guidance and procedures for data verification and data validation can be found in the following EPA documents:

- Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8 EPA/240/R-02/004, November 2002)
- EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA540/R-99/008 October 1999)
- EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (EPA540/R-01/008 July 2002)

The first document above, and other EPA quality assurance requirements and guidance documents can be found at this EPA web site:

http://www.epa.gov/quality/qa_docs.html

The second and third documents above can be found at this EPA web site:

http://www.epa.gov/oerrpage/superfund/programs/clp/guidance.htm

Data Reporting requires that operational, wastewater quality and ground water quality records be maintained. Permits require that this information be reported to the DEQ State Office and to the appropriate DEQ Regional Office. The reporting frequency may be monthly, annual, or may correspond either to the frequency with which the information is collected or as required in the WLAP permit. Permits generally require that all monitoring data collected for required parameters be reported, even if collected at frequencies above that required in the permit. This requirement is meant to help guard against the potential of reporting bias if only certain results out of a greater pool of results are reported. If parameters other than those required in the permit are monitored, these results are not required to be reported.

It is critical that data be given to DEQ in a format suitable for the data's intended use. In all cases, the data must be presented in an organized and clear manner, and if necessary, supporting data may be required (e.g., duplicate measures, spike recoveries, etc.). The data collected as required in the permit should be submitted to DEQ in the *Annual Report* in a standardized electronic Excel spreadsheet format. This spreadsheet and accompanying instructions may be obtained from DEQ by request; they are generally provided during the permit application, issuance and renewal process.

The Annual Report is submitted to DEQ on a regular schedule stated in the permit. Special reports may be required in a permit, which frequency and format should be specified in the permit.

The monitoring data required in the permit is taken from the annual report and entered into a computerized database. This database is called the WLAP Information Management System (WLAP-IMS). The WLAP-IMS, when fully developed, will be able to generate compliance reports as well as data analyses of ground water, soils, soil water, loading rates, wastewater chemistry, trend analyses etc.

7.1.8 References

Crites, R.W., S. C. Reed, and R.K. Bastian. 2000. Land Treatment Systems for Municipal and Industrial Wastes. ISBN 0-07-061040-1. McGraw-Hill Publishers.

DEQ. Idaho Department of Environmental Quality. March 2001. Ground Water and Soils Quality Assurance Project Plan Development Manual.

EPA. U.S. Environmental Protections Agency. 1973. Handbook for Monitoring Industrial Wastewater.

EPA. U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory-Cincinnati (EMSL-Cllll), EPA-600/4-79-020. Methods for Chemical Analysis of Water and Wastes. Revised March 1983 and 1979 where applicable.

EPA. U.S. Environmental Protections Agency. 1982. Handbook for Sampling and Sample Preservation of Water and Wastewater. EPA-600/4-82-029.

EPA. U.S. Environmental Protection Agency. 1999. EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review (EPA540/R-99/008 October 1999)

EPA. U.S. Environmental Protection Agency. 2000. Guidance for the Data Quality Objectives Process – EPA QA/G-4. (EPA/600/R-96/055 August 2000)

EPA. U.S. Environmental Protection Agency. 2001. EPA Requirements for Quality Assurance Project Plans – EPA QA/R-5. (EPA/240/B-01/003 March 2001)

EPA. U.S. Environmental Protection Agency. 2002. Guidance on Environmental Data Verification and Data Validation (EPA QA/G-8 EPA/240/R-02/004, November 2002)

EPA. U.S. Environmental Protection Agency. 2002. Guidance for Quality Assurance Project Plans – EPA QA/G-5. (EPA/240/R-02/009 December 2002)

EPA. U.S. Environmental Protection Agency. 2002. EPA Contract Laboratory Program National Functional Guidelines for inorganic Data Review (EPA540/R-01/008 July 2002)

Greenberg, A.E. et al. (eds). 1992. Standard Methods for the Examination of Water and Wastewater - 18th Edition.

Overcash, M.R. and Pal, D. 1979. Design of Land Treatment Systems for Industrial Wastes-Theory and Practice.

7.2 Ground Water Monitoring

This section describes the elements of a ground water monitoring plan for wastewater land treatment facilities. (It is beyond the scope of this section to address monitoring of sites having hazardous or radionuclide constituents.)

Ground water monitoring provides data that can be used to evaluate a facility's impact on ground water as well as evaluate ground water quality changes with respect to changes in wastewater land treatment management and loading changes. Ground water monitoring also serves to assess compliance with a wastewater land application permit, including ground water quality standards as specified in the *Ground Water Quality Rule* (IDAPA 58.01.11.200) and/or permit specific limits. Ground water monitoring is necessary in most circumstances to define ambient conditions and establish a water quality baseline for the facility. Ground water monitoring often plays a major role in evaluating and modifying treatment processes, management, and loading practices to protect and maintain ground water quality.

The need and level of ground water monitoring is dependent upon facility type and size, wastewater characteristics, management, loading rates, and aquifer and site characteristics. For example, a small facility with low strength wastewater loaded at low rates would have a limited potential to contaminate ground water and may not need as extensive a monitoring program as larger and more complex facilities land applying high strength wastewater at high rates.

7.2.1 Alternatives to Ground Water Monitoring

There are circumstances where ground water monitoring may not be necessary, as in the case where wastewater constituent loading rates are *below levels of regulatory concern* (i.e., *de minimus* rates).

Although monitoring wells are the primary means of assessing ground water quality associated with land treatment systems, there are situations where their use would be impractical, such as in cases where there are long unsaturated and or saturated contaminant travel times (as a result of deep ground water, low percolate generation, and/or low permeability of vadose zone). In those cases, the time interval between land use activities and environmental response would be too large to provide timely feedback for management or compliance purposes.

Short, moderate, and long travel times are subjective, depending on the context. In a regulatory context, a long travel time might be considered to be the length of a typical 5-year permit. It could be considered *untimely* if the impacts from a management activity could not be detected through ground water monitoring beyond the life of the permit.

Other means to assess potential environmental impacts, such as soil-water monitoring, should be considered in such cases. (See Section 7.3 for additional discussion on soil-water monitoring. A simple method of estimating travel time through the vadose zone is presented by 7.7.5.2.3.)

Alternatives to ground water monitoring are considered on a case-by-case basis. A decision flowchart 7.7.1.1) serves to help determine whether ground water monitoring is practical and/or needed at a wastewater land treatment site. In general, 'de minimus loading rates' referred to in the flowchart are loading rates, which pose no regulatory concern. Specific numerical loading rates have yet to be defined and may be facility specific. The reference to *Guideline Loading Rates* refers to those generally recommended loading rates (nutrients, COD, hydraulic etc.) found in Section 4 of this guidance.

7.2.2 Monitoring Objectives

The purpose of ground water monitoring is to determine whether wastewater is being land applied and treated such that the waters of the state are protected for existing and projected future beneficial uses. Monitoring wells are preferred over other types of wells for collection of ground water quality samples. They can be located in a specific location and they can be constructed to monitor specific zones within an aquifer to isolate particular contaminants. Monitoring wells are installed specifically for assessing ground water quality.

Existing wells may be used for ground water monitoring only if the well is properly located, constructed and it is screened in the appropriate interval necessary to monitor the appropriate aquifer and the constituents of concern. Existing wells should be evaluated using the criteria provided below. Exceptions to these criteria may be made by DEQ on a case-by-case basis:

- The well is located within a reasonable distance from the wastewater land treatment facility to provide relevant ground water quality information.
- The well meets the construction requirements outlined in IDAPA 37.03.09.
- The well is completed in the uppermost aquifer.
- The screen length is appropriate for the hydrogeologic conditions and monitoring the constituents of concern.
- The well will yield water quality samples representative of background or other relevant water quality conditions.
- The water quality is not degraded by an activity between the well and the wastewater land application facility.
- The well is approved for use by DEQ.

7.2.3 Monitoring Instrumentation

This section provides guidance on monitoring well design and construction practices for wastewater land application facilities. This monitoring well construction guidance is not applicable for sites where hazardous materials are known to exist.

Monitoring wells should be designed to sample the uppermost ground water potentially affected by the activity plus any other ground water zone where contaminants may impact ground water quality. The number of wells installed should be sufficient to adequately assess background water quality and the impacts to ground water as a result of wastewater land treatment activities. Monitoring well construction is a critical component of the monitoring plan since background water quality data are used to establish baseline levels, and possibly site specific permit limits and early warning values. Each monitoring well should be designed and constructed for the specific hydrogeologic environment and the contaminants of concern.

Several goals should be achieved in monitoring well construction:

- Construct the well with minimal disturbance to the formation.
- Use materials compatible with the geochemical environment.
- Complete the well within the zone of interest.
- Adequately seal the borehole with materials that will not influence the quality of the samples.
- Sufficiently develop the well to remove additives introduced during drilling and allow unobstructed flow through the well, (EPA, 1991).
- Construct the well in such a manner that contamination from the surface will not migrate along the sides of the borehole and ensure that well is sealed properly to prevent cross contamination from other aquifers

Some general guidelines should be considered during the construction of any monitoring well. The most important of these address the following:

- regulatory requirements
- drilling methods
- screened interval
- casing materials
- seals, packing and grouting
- well development

7.2.3.1 Regulatory Requirements

All monitoring well construction must conform to the well construction rules listed in the Idaho *Administrative Procedures Act* (IDAPA) 37.03.09. Monitoring wells more than 18 feet in vertical depth that are constructed to evaluate, observe or determine the quality, quantity, temperature, pressure or other characteristics of the ground water or aquifer require a permit to be issued by the *Idaho Department of Water Resources* (IDWR). Monitoring wells 18 feet deep, or less, also should conform to the well construction rules listed in IDAPA 37.03.09

Siting of monitoring wells in relation to a wastewater land treatment site and other possible sources of contamination should be coordinated with DEQ as part of the WLAP permitting process. Proposed monitoring well designs should be submitted to DEQ for review and approval prior to well construction.

Certification that monitoring well construction is in substantial accordance with proposed monitoring well design should be submitted to DEQ. Such certification may consist of as-built diagrams stamped by an Idaho registered Professional Geologist or Professional Engineer, or prepared by someone under the direct supervision of an Idaho registered Professional Geologist or Professional Engineer. A detailed geologic log for each monitoring well should also be provided to DEQ.

7.2.3.2 Monitoring Well Construction

Specific installation procedures for ground water monitoring wells may be found in the Idaho Administrative Code, Department of Water Resources, *Well Construction Standards Rules* (JAC 2005); Ogden (1987); DEQ (March 2001); EPA (1991); and EPA (1986). Additional guidance is available from ASTM D 5092-90.

Details regarding the construction of monitoring wells are found in 7.7.3.1. Included are discussions of drilling methods; selection of screened interval depths; casing materials; seals, packing and grouting; and monitoring well development.

7.2.3.3 Monitoring Well Protection and Maintenance

The area around groundwater monitoring wells must be protected. Several practices may be employed for this. Highly visible markers may be used to warn equipment operators of the presence of the well. Using posts cemented into the ground to surround the well offers added protection against a well being damaged by equipment.

Damage from equipment includes cracked grouting, cracked or broken well piping, or broken locks or casings. This type of damage can result in the intrusion of surface water into the well and the contamination of groundwater. Such a well may have to be abandoned and another well constructed, at additional time, expense, and loss of data continuity.

Monitoring wells should be regularly maintained. Maintenance should include ensuring that caps are rust-free and locked at all times, that the outer casing is upright and undamaged, and that there is clear, unobstructed access to each well.

7.2.4 Monitoring Parameters

Table 7-1 provides general guidance for ground water monitoring analytical parameters for selected wastewater land treatment scenarios. In general, *well below guideline loading rates* (WBGLR), referred to in the table are loading rates that pose no regulatory concern. Specific numerical loading rates have yet to be defined for the WBGLR designation and may be facility specific. The reference to *Guideline Loading Rates* refers to those generally recommended loading rates (nutrients, COD, hydraulic etc.) found in Section 4 of this document. Microbiological parameters may be needed on a site-by-site basis.

Table 7-1. Common Ground Water Monitoring Analytical Parameters for Wastewater Land Treatment Facilities.

Facility Type — Analytical Parameter	Municipal Facility (Class A Reuse Water)	Municipal Facility (Guideline Loading Rates)	Municipal Facility (Greater than Guideline Loading Rates)	Facility (Well Below Guideline Loading Rates)	Food Processing Facility (Guideline Loading Rates)	Food Processing Facility (Greater than Guideline Loading Rates)
Common Ions[1]	O[3]	O	X	O	X	X
Field Parameters[2]	O	X	X	O	X	X
Static Water Level	O	X	X	O	X	X
NO3-N + NO2-N	O	X	X	O	X	X
Fe	O	O	?	O	?	X
Mn	O	O	?	O	?	X
TDS	O	O	X	O	X	X
COD	O	O	O	O	?	X
P	O	O	?	O	?	X
K	O	O	O	O	?	X
Cl	O	X	X	O	X	X
TC	O	?	?	O	?	?

Notes:

1. Common ions consist of the following ions: Na, K, Ca, Mg, SO_4, Cl, CO_3, HCO_3
2. Field Parameters consist of the following: pH, temperature, electrical conductivity, and dissolved oxygen
3. Symbol Definitions: X = usually monitored; ? = monitored depending upon case specific situation; O = generally not monitored.
4. TC = total coliform

7.2.4.1 Contaminants of Concern: Nitrate, Iron, Manganese, TDS and Phosphorus

Wastewater sites, if not properly loaded and managed, may impact ground water. Typical contaminants of concern include nitrate, total dissolved solids, phosphorus, metals (iron and manganese in particular). The following sections briefly discuss these constituents.

7.2.4.1.1 Nitrate

Nitrate is a primary ground water constituent, meaning there can be health related concerns at ground water levels above ground water standards (IDAPA 58.01.11.200.01a). The ground water standard for nitrate-nitrogen is 10 mg/L. Nitrate contamination at wastewater land treatment sites usually results from nitrogen overloading. Other contributing factors include aquifers with low transmissivity that do not provide the dilution volume, and so magnify the nitrogen (or other constituent) inputs from percolate.

High nitrogen loading of certain wastewaters such can often result in *low* nitrate levels in ground water. This is due to the influence of associated high loadings of chemical oxygen demanding (COD) constituents – generally organic materials. High COD loadings depress the redox state of the soil and reduce nitrate to atmospheric nitrogen or other nitrogen oxides which are lost to the atmosphere. See Section 4 for further discussion of nitrogen chemistry in the environment. Health risks associated with excessive nitrate ingestion include blue baby syndrome (methemoglobinemia) and are discussed at the following DEQ website:

http://www.deq.state.id.us/water/prog_issues/ground_water/nitrate.cfm

7.2.4.1.2 Total dissolved solids (TDS)

TDS is a secondary ground water constituent, meaning there can be aesthetic related concerns at ground water levels above ground water standards (IDAPA 58.01.11.200.01b). The ground water standard for TDS is 500 mg/L. TDS is a general term that has different interpretations depending on the media it is measured. In ground water, TDS is generally consists of inorganic salts. In wastewaters, TDS can include significant amounts of dissolved organic material. The organic TDS fraction is higher in wastewaters having higher organic constituent levels. When modeling impacts of TDS loading to ground water, it is critical to make some other measure of the inorganic constituents in wastewater to accurately assess the inorganic fraction of TDS. Such measurements include non-volatile dissolved solids (TDS less volatile dissolved solids) or total inorganic dissolved solids (TDIS, the sum of cations and anions in appreciable concentrations). Fixed dissolved solids (FDS) is another analysis which yields the inorganic content of wastewaters (Brown and Caldwell et al., 2002 p. 10-10)

TDS can often be significantly elevated down gradient of wastewater land treatment sites, especially industrial sites. Care must be taken in the interpretation of data to account for other sources of contamination as well. An effective geochemical analysis technique involves the examination of common ions, discussed in Section 7.1.4.3, to characterize chemical signatures of background, and percolate and wastewater sources to determine causes of ground water contamination.

7.2.4.1.3 Phosphorus

Phosphorus has no numeric ground water standard (IDAPA 58.01.11.200). Phosphorus loading and monitoring guidance is described in Section 4. It is a relatively immobile constituent. Concentrations in soil water and ground water are governed by complex chemistry involving sorbed, fixed (covalently bonded), precipitated, organic, and plant available pools. Elevated phosphorus in down gradient ground water can signal breakthrough of wastewater through coarse vadose material – possibly from excessive lagoon seepage or breakthrough from soils that have been loaded to capacity. This is discussed further in Section 4.

7.2.4.1.4 Metals (General)

The ground water quality standards as specified in the *Ground Water Quality Rule* (IDAPA 58.01.11.200.01ci) and the drinking water standards as specified in the Idaho *Rules for Public Drinking Water Systems* (IDAPA 58.01.08.50.01) establish criteria for total metals. Total metals analyses are used to provide an indication of the metals concentration which is available for human consumption. Drinking water wells are designed to maximize water production and minimize sediment intake whereas monitoring wells are designed to monitor changes in ground water quality. Monitoring wells are not designed to produce water for human consumption. The screened interval may not be placed in the most productive part of the formation, rather it is placed in the zone where contaminants are expected to be present which may be in a formation with finer grained sediment.

Total metals analysis measures both the metals dissolved in ground water, and metals which may be sorbed to clay or colloid sized particles suspended in ground water. Upon acidification of a ground water sample for preservation, sorbed or otherwise non-dissolved metals may solubilize. The suspended fraction may be a result of metals from the well casing (metal casing material is not approved for monitoring wells), from collected sediment within the well, or sediment from the formation. A total metals analyses may yield much higher values when wells are place in low hydraulic conductivity formations or when well development has not been properly completed. Dissolved analyses are generally more useful in evaluating the impacts of a wastewater land treatment on ground water quality, since it considers only the fraction, which are not from anthropogenic sources.

The question arises whether metals in ground water should be evaluated using the total or the dissolved fraction. On one hand, only dissolved metals truly migrate in ground water and therefore measuring total metals skews the analytical result by including metals which are adsorbed onto particles of sediment which may only be present in the well due to poor well construction or from a silty formation. On the other hand, total metals not only represent drinking water criteria, but that metals may also move by colloidal transport in ground water, thereby making the total fraction necessary to completely characterize ground water contamination.

If metals are identified as constituents of concern, it is recommended that both total and dissolved metals be analyzed. Dissolved metals should be used to interpret geochemical changes in ground water in relation to wastewater land treatment activities. Water samples analyzed for the dissolved fraction of metals should be filtered in the field, using a filter with a pore size of 0.45 microns and preserved with nitric acid prior to submission to the laboratory.

Another alternative is to measure total metals while using *low flow purge and sampling techniques* recommended by Puls and Powell, (1992). These techniques provide a characterization of both the dissolved fraction and the portion which moves by colloidal transport in ground water. Low flow pump rates allow water from the ground water formation to move into the well while overlying stagnant zones are undisturbed. In order to minimize sample disturbance during collection, a low flow rate of 0.2 to 0.3 liters/minute (not using a bailer) should be used for ground water samples collected for metals analysis with no filtration. Puls and Powell (1992) demonstrated no significant difference in metal concentrations between filtered and unfiltered samples when low flow rates were used. This provides an assessment of both the dissolved and mobile particulates associated with metals transport in ground water.

7.2.4.1.5 Metals (Iron and Manganese)

Iron (Fe) and manganese (Mn) are secondary ground water constituents, meaning there can be aesthetic related concerns at ground water levels above ground water standards (IDAPA 58.01.11.200.01b). The ground water standards for iron and manganese are 0.3 mg/L and 0.05 mg/L respectively. Iron and manganese are often found in ground water down gradient of highly loaded wastewater land treatment facilities. Associated high COD loadings and depressed redox conditions generated in the soil can reduce the valence state of iron and manganese naturally present in soils to soluble forms (see Figure 7-2.) These reduced species are mobile and can leach to ground water. Maximum contaminant levels for iron and manganese are relatively low, being 0.3 mg/L and 0.05 mg/L respectively. Elevated levels of iron and manganese cause aesthetic damage such as staining of kitchen and bathroom fixtures, siding and brickwork of dwellings, and other related damage.

REACTION	Eh AT pH 7 (V)	MEASURED REDOX POTENTIAL IN SOILS (V)
O_2 Disappearance		
$\frac{1}{2} O_2 + 2e^- + 2H^+ = H_2O$	0.82	0.6 to 0.4
NO_3^- Disappearance		
$NO_3^- + 2e^- + 2H^+ = NO_2^- + H_2O$	0.54	0.5 to 0.2
Mn^{2+} Formation		
$MnO_2 + 2e^- + 4H^+ = Mn^{2+} + 2H_2O$	0.4	0.4 to 0.2
Fe^{2+} Formation		
$FeOOH + e^- + 3H^+ = Fe^{2+} + 2H_2O$	0.17	0.3 to 0.1
HS^- Formation		
$SO_4^{2-} + 9H^+ + 8e^- = HS^- + 4H_2O$	−0.16	0 to −0.15
H_2 Formation		
$H^+ + e^- = \frac{1}{2} H_2$	−0.41	−0.15 to − 0.22
CH_4 Formation (example of fermentation)		
$(CH_2O)_n = n/2\, CO_2 + n/2\, CH_4$	—	−0.15 to − 0.22

Figure 7-2. Redox potential and its effect on the chemistry of soil constituents. Bohn et al. 1979.

7.2.4.2 Other Constituents

There are constituents that do not have ground water standard criteria in IDAPA 58.01.11.200, but which are nonetheless important to monitor in ground water. Certain of these constituents, such as COD and potassium, can serve to corroborate (i.e. support with additional evidence) the cause of constituent of concern impacts from certain wastewater land treatment practices. Other constituents serve to characterize the chemical signature of ground waters or indicate the chemical stability of the sample during the sampling event.

7.2.4.2.1 Chemical Oxygen Demand (COD)

It is typical to see COD at low levels in ground water. Sulfides and other reduced constituents will appear as an oxygen demand. COD can appear at elevated levels in down gradient ground water – usually at wastewater land treatment facilities with high COD and hydraulic loading. This serves to corroborate that COD loadings are at rates higher than the soil can filter and soil microorganisms can oxidize. It also can indicate breakthrough of wastewater to ground water, as in an excessively leaking storage structure.

7.2.4.2.2 Potassium

As with COD, potassium does not have a ground water standard, but its presence at elevated levels down gradient of potato processing facilities can indicate impacts from wastewater land treatment. For example, there are appreciable levels of potassium in potatoes. Potassium is released to wastewater upon processing of the potato and is subsequently land applied. Usually there are no other significant sources of potassium to account for the elevated levels seen down gradient. Thus, it is a corroborating constituent.

7.2.4.2.3 Major Cations and Anions

The chemical characterization of ground water quality is important when making a determination of the impacts a wastewater land treatment may have on background water quality. Ground water typically has naturally occurring concentrations of major cations and anions. Major cations and anions may not necessarily be considered constituents of concern, but data collected before and during the operation of the facility can be compared to help assess environmental impacts, (Pennino, 1988).

Major cations and anions for which analyses are typically done are shown in Table 7-2.

Table 7-2. Cations and anions for which analyses typically done.

Cations	Anions
Calcium	Bicarbonate
Magnesium	Carbonate
Potassium	Chloride
Sodium	Sulfate

Natural ground water has a distinct chemical composition, which is characteristic of the geologic formation. Minerals are dissolved in solution as they migrate through the geologic formation. Major ions can be illustrated by using graphical tools such as Stiff Diagrams or Trilinear Plots to characterize the signature of the ground water. Chemical characterization also serves in identifying cross flow between aquifers and mixing within wells. Ionic characterization data can be used to detect water quality changes and trends which may be attributed to the influence of a wastewater land treatment activity.

Common inorganic constituents can be found at elevated concentrations in most contaminant plumes. Chloride, sulfate and nitrate have a high solubility and tend to move at a similar velocity as ground water.

Inorganic constituents provide a check on the reliability of the analyses with a cation-anion balance. This is the most fundamental quality assurance/quality control (QA/QC) procedure. All waters have an equal balance of negatively and positively charged ions. The calculated error between anions and cations is generally higher for lower TDS waters. As a general rule, the sum of cations should not differ from the sum of anions by more than 2 to 3 percent. If the ratio of cations to anions does not balance, the problem is usually a typographical or analytical error; however, it can also indicate the presence of an unusual constituent which was not included in the analysis. Cation/anion analytical results with a difference of greater than 5% should be questioned. It may be an indicator that other analyses may be skewed and should be investigated for possible errors. If the relative difference between the cations and anions is small, then it is safe to assume that there are no errors in the inorganic constituents, (Hem, 1989).

Another QA/QC check is a comparison of the calculated versus the analyzed total dissolved solids values. DEQ generally has facilities analyze ground water for the major cations and anions once before permit issuance, and again near permit expiration. These analyses provide important information to evaluate impacts to ground water quality.

7.2.4.3 Field Parameters

Field parameters are ground water parameters which can be easily and accurately measured in the fieldwith portable electronic instrumentation. These include pH, electrical conductivity, temperature, dissolved oxygen and redox potential.

These field measurements serve to:

- verify when effective well purging has occurred and when ground water has stabilized to assure that the ground water sampled is representative of water in the aquifer,
- verify laboratory measurements and can indicate sample deterioration, and.
- detect abnormalities, and they can be indicative of ground water contamination, (Davis, 1988).

The preferred method of measurement is with a flow through cell which operates at the land surface and is not introduced into the borehole. If this technology is not available, then these measurements should be taken at the wellhead. Although in-situ measurements eliminate interference caused by the atmosphere, there are other interferences which may influence field measurements more dramatically. Therefore, it is recommended that field parameters be measured with a flow through cell at the land surface, or at the wellhead, (Garner, 1988).

Field measurements should stabilize to within 5% variation per casing volume removed during well purging prior to collecting ground water samples. Readings of pH, electrical conductivity, and temperature often stabilize within one casing volume while other chemical constituents take longer to stabilize. Dissolved oxygen is a better indicator of ground water stabilization since it can indicate the redox state of inorganic constituents (Puls and Powell, 1992). Dissolved oxygen is a critical field parameter to determine when representative ground water is entering the formation. Therefore, dissolved oxygen should be included in the suite of field parameters.

Redox potential is also a field parameter which provides important information on whether the ground water is in either an oxidizing or reducing condition. Field measuring devices for redox potential are not as accurate as certain laboratory methods. A qualitative method for determining reducing conditions is the use of the 2-2'dipyridyl test, which indicates the presence of ferrous iron. A positive test indicates that anaerobic conditions are present which may result in the mobilization of metals. This test is simply a screening tool. A few drops of a 0.1% 2-2'dipyridyl (or 1,10 phenathroline) solution added to a ground water sample will cause a bright red or pink reaction if ferrous iron is present, which is indicative of a reducing environment, (Heaney and Davison, 1977), (Childs, 1981). When ground water is in a reducing environment, then the sample should be field filtered rather than filtering the sample at the lab. Total digestion analysis should be requested. Metals may co-precipitate in oxidizing conditions due to a change in redox after filtration. Sampling of field parameters is discussed further in 7.7.4.1.3.

7.2.5 Monitoring Frequency

Monitoring frequency is critical to assure that samples will detect contamination if it is present, while still assuring discrete, independent samples. The frequency of ground water monitoring should be determined on a site specific basis. Factors that should be considered include information from hydrogeologic investigations, wastewater land management and loading rates, and facility type. Statistical variability of water quality data is also critical to determining monitoring frequency. For example, the maximum error about the mean, and confidence interval one is willing to accept, will determine the number of samples one needs to take in a given time period. Statistical evaluation of ground water data is discussed further in DEQ (2003).

Monitoring frequency for compliance can be adjusted during the permit cycle. It may be decreased if it can be determined that background and seasonal variations in ground water quality have been characterized and the data supports that a less frequent sampling interval will not miss significant periods over which elevated levels may be present. Certain parameters may be monitored on a less frequent basis if reasons exist which justify less frequent monitoring. Proper well purging and sampling techniques are especially critical when samples are collected on a less frequent basis, such as annually or biannually (Barcelona et al. 1989).

Special provisions should be made for acreages being developed for wastewater land treatment. If possible, ground water monitoring should be conducted on such sites for a sufficient amount of time in order to adequately characterize baseline potentiometric and chemical characteristics of ground water *prior to initiating wastewater land treatment activities*.

7.2.6 Sampling and Sample Location Determination

Effective monitoring requires sampling, with samples taken from pre-determined locations.

7.2.6.1 Sampling

An effective system for monitoring a land application site for potential sources of ground water contamination should be capable of detecting contamination. This is done through appropriate sampling and analysis from properly designed, located, and constructed monitoring wells. This section discusses well sampling protocols and sampling location determination.

The data collected in a WLAP ground water sampling program must be of sufficient quality to allow proper analysis and interpretation and to provide evidence for the presence or absence, extent, degree, and source of contamination. For these reasons it is essential that sampling be conducted such that the data collected are precise, accurate, representative, comparable and complete.

The goal of ground water monitoring is to sample water from the geologic formation with minimal disturbance. Representative samples should indicate the condition of ambient ground water and any changes in quality as a result of the wastewater land treatment. The facility should have a monitoring plan that includes sampling and analytical protocol to assure ground water samples will be collected and analyzed properly.

The facility is responsible for having samples collected and analyzed as required in the permit. However, DEQ reserves the right to conduct site inspections and collect samples for determining compliance. It is important to assure that the resulting analytical data will adequately represent the conditions in ground water. Therefore, it is critical that sampling and analytical protocol be properly planned to assure that the sample will not be compromised by personnel, the atmosphere, the sample container, preservatives, filtering, sampling equipment, transport, or the laboratory.

The following items should be addressed in the facility's monitoring plan:

- Sampling Supplies and Equipment
- Well purging
- Sample collection
- Decontamination
- QA/QC procedures

Specific guidance related to sampling supplies and equipment, well purging, sample collection, sample packing and shipping, and decontamination are discussed in 7.6.5.

7.2.6.2 Compliance Determination and Confirmatory Sampling

Ground water quality compliance is based on results from routine sample analysis at each compliance monitoring point identified in the facility's WLAP permit. The number of samples collected, testing frequency and constituent analysis stated in the WLAP permit are minimum requirements unless otherwise stated.

Ground water quality permit violations occur when a compliance sample analysis result exceeds a level specified in the permit whether a ground water quality standard or alternate permit limit. Permits may be written such that a first exceedance will not generate enforcement action or penalties. An exceedance may be treated as a warning signal that prompts further actions such as: assessment of wastewater management practices, evaluation of the treatment capabilities and maintenance of the land application system, and assistance from qualified experts. Statistical analyses can be utilized to determine whether there are temporal or other trends in ground water. (See DEQ, June 2003). In the event a continuing violation occurs, DEQ will determine if enforcement action is warranted.

If laboratory results from compliance sampling show an exceedance of a permit limit, then confirmatory sample collection is recommended. Confirmatory samples can validate the analytical results from the previous sample and should be taken as soon as initial exceedances are known or suspected. If confirmatory samples are not collected, then the laboratory results from the original sample may be used for compliance determination. Confirmatory sampling requirements should be included in permit requirements.

Confirmatory sampling may also be conducted and used to establish trends in ground water quality or to monitor a continuing ground water quality violation. Finally, confirmatory samples are recommended, but not required, for samples collected for purposes other than compliance.

7.2.6.3 Sampling Location Determination

A monitoring network should be designed based on the information from a hydrogeologic investigation. A properly designed monitoring network is essential. Ground water monitoring wells must be properly sited to provide areal coverage of the affected site. Wells must be constructed and sampled to obtain representative water quality samples. Sample variability can result from temporal and spatial variability in ground water or from influences during well pumping, purging, and recharge. Therefore, monitoring well location, design, construction, and sampling should be carefully planned initially to help assure that all samples will be useful and representative of ground water quality. The monitoring plan should be facility-specific.

Monitoring well locations must be approved by DEQ prior to installation to help ensure that the wells will be sited, designed, and constructed properly to assess wastewater land treatment impacts.

The number of wells must be sufficient to ensure a high probability of detecting contamination when it is present. Specifically the placement and number of monitoring wells will depend on both aquifer and facility characteristics. Aquifer related characteristics include the ground water gradient and the site hydrogeology. Information on ground water flow direction is essential in siting wells. Aquifer hydraulics may cause spatial and temporal variability in samples, (Barcelona et al. 1989); therefore, monitoring well locations should be carefully considered prior to installation.

Facility characteristics include the volume and quality of wastewater land applied, and the fate and transport characteristics of potential contaminants. The size and configuration of the facility and land treatment acreage are particularly important. Generally, large land application sites with complex hydrogeology may require more monitoring wells than sites that are small or hydrogeologically simple. The number of wells also depends on the type of monitoring requirements. Land application sites with a long down gradient boundary perpendicular to the ground water flow direction may require additional monitoring wells.

Up gradient wells (un-impacted by the facility's activities) define ambient ground water quality, and are necessary to compare background water quality to down gradient water quality (water potentially impacted by the facility's activities). Ideally, up gradient wells should be located along the ground water flowpath toward the site. In Figure 7-3, wells 1, 2, and 3 are improperly located; wells 4, 5, and 6 are properly located.)

Background water quality characterization from up gradient wells will reduce the probability of attributing to wastewater land treatment any contamination originating off-site from other sources, or vice versa. At least one up gradient well is necessary to characterize background water quality.

Location and number of down gradient wells should be determined based on the designated point of compliance. Compliance wells must be located hydraulically down gradient of the wastewater land treatment site, along the flowpath of ground water discharging from the site. Down gradient wells must be reflective of the activity's impacts to ground water quality. At least two down gradient well are necessary in addition to an up gradient well to assess impacts and triangulate ground water flow.

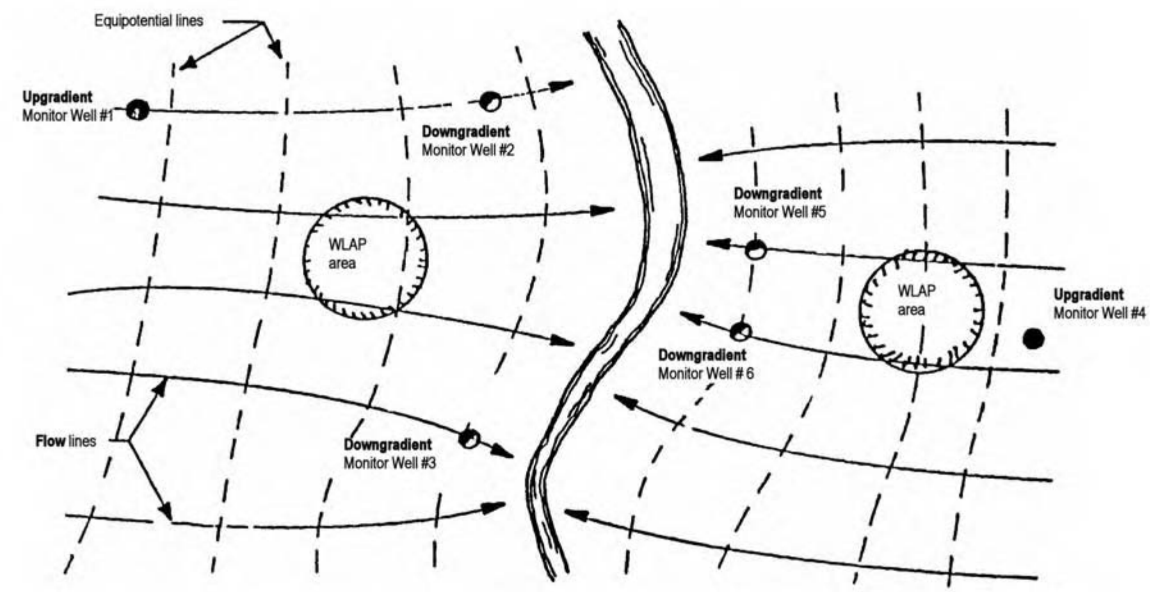

Figure 7-3. Improper and Proper Locations for Groundwater Monitoring Wells (State of North Carolina, 2001).

Ground water monitoring should be conducted in the uppermost saturated zone in addition to any other zones potentially affected by the wastewater land treatment activity. Significant water quality changes will occur in the uppermost saturated zone sooner; however, hydraulic connections between aquifers can cause contamination in lower aquifers. Ground water quality trends are determined by monitoring specific wells consistently over time.

7.2.7 Ground Water Compliance Points Monitoring

Ground water compliance monitoring involves sampling and testing ground water from approved collection points for compliance with permit conditions. Ground water compliance monitoring may not be necessary for every wastewater land treatment site (see Figure 7-5). If ground water compliance monitoring is required, compliance points for sampling and testing must be identified in the facility's WLAP permit. The number, location and frequency of sampling of compliance points are determined through the permit process.

The *point, or points, of compliance are* the locations where the facility must be in compliance with either ground water quality standards as specified in the *Ground Water Quality Rule* (IDAPA 58.01.11.200) or permit specific limits (IDAPA 58.01.11.400.05). Such standards and limits are the maximum allowable contaminant concentrations allowed at a point of compliance.

The point, or points, of compliance are determined by DEQ on a site specific basis for each facility. The point of compliance provides information to assess ground water conditions related to current and reasonable future uses of the ground water.

Ground water is typically designated as the medium where the point of compliance must be achieved since it is the primary resource that is being protected. If the point of compliance is determined to be in ground water, the following criteria should be considered in locating a point, or points, of compliance:

- The point should be as near the wastewater land treatment activity as technically feasible.
- A monitoring well must be used as the device to measure compliance.
- The monitoring wells must be located hydraulically downgradient of the wastewater land treatment activity.
- The monitoring wells must be properly constructed and screened in the uppermost ground water zone.
- If other ground water zones may be affected, then these should also be monitored by separate monitoring wells.
- The monitoring well(s) must measure the impacts of the facility's wastewater land treatment activity on ground water quality.

One well may not be adequate to measure compliance. Therefore, the point of compliance is not necessarily limited to one well, but may include an array of wells if it is determined that the information would provide a better representation of ground water conditions. Additional wells may be required if there are multiple compliance points, if the wastewater is being land applied over a large surface area, if multiple aquifers may be affected, or if the ground water flow direction varies seasonally.

Site specific conditions may warrant setting a ground water point of compliance in an alternate location to assure protection of public health and the environment. DEQ may establish alternate ground water compliance monitoring points if provided sufficient justification. A permit limit should be established in ground water at the point(s) of compliance *unless* one of the following conditions exist:

- A monitoring well will not adequately allow measurement of the impacts a wastewater land treatment activity will have on ground water quality (e.g. screened too deep, not along down gradient flow path etc.).
- The initial point where the leachate from wastewater land treatment reaches ground water cannot be determined. For example, in fractured basalt the wastewater may move along preferential pathways making it difficult to determine the location of its entry into ground water.
- The limit established for ground water at the point of compliance is met prior to release into the environment.

If it is economically infeasible or technically impractical to locate the point of compliance in ground water, monitoring limits can be established in the vadose zone directly under the wastewater land treatment site. Modeling can be done to determine what percolate concentration for a given volume would be expected to result in ground water exceeding ground water quality standards as specified in the *Ground Water Quality*

Rule (IDAPA 58.01.11.200), or permit specific limits. See discussion in Section 7.7.5.2. Thus, vadose zone monitoring can still be used to measure compliance when ground water monitoring is not feasible.

7.2.8 Analytical Methods

IDAPA 58.01.11.200.c requires that analytical procedures to determine compliance shall be in accordance with Environmental Protection Agency, Code of Federal Regulation, Title 40, Parts 141 and 143, revised as of July 2001, or another method approved by the Department. Table 7-19, presents chemical analytical methods recommended for ground water samples. Where more than one method is given, employ the method appropriate for the type of sample, its concentration range, the availability of equipment, and necessary detection limit. Note that detection limits are generally an order of magnitude less than the Ground Water Quality Rule (IDAPA 58.01.11.200) standards for constituents assigned such numerical limits.

7.2.9 Quality Assurance and Quality Control

As discussed in Section 7.1.6.1, the facility should have a quality assurance project plan (QAPP) that includes instructions for field parameter stabilization. For more information on the development of a QAPP, refer to Section 7.1.6.

7.2.10 Data Processing, Verification, Validation, and Reporting

As with other types of monitoring, the facility's permit will specify what parameters to monitor, when to monitor, and when results must be submitted. When reporting ground water monitoring data, describe the well location and use the monitoring serial numbers designated in the permit.

7.2.11 References

ASTM. American Society for Testing and Materials. Designation D 5092 – 90. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. Reapproved 1995.

ASTM. American Society for Testing and Materials. Designation D 6089 – 97. Standard Guide for Documenting a Ground-Water Sampling Event. Reapproved 2003.

Barcelona, M.J., H.A. Whehrmann, M.R. Schock, M.E. Sievers, and J.R. Karney. 1989. Sampling Frequency for Ground-Water Quality Monitoring. EPA Project Summary EPA/600/S4-89/032, Las Vegas, NV, 6p.

Brown and Caldwell, Kennedy Jenks, and Konnex H2O Science. 2002. Final Report: Manual of Good Practice for Land Application of Food Process / Rinse Water for California League of Food Processors.

Childs, C.W. 1981.Field Tests for Ferrous Iron and Ferric-organic Complexes (on Exchange Sites or in Water Soluble Forms) in Soils. Aust. J. Soil Res., 19, pp. 175-180.

Davis, S.N. 1988. Where are the Rest of the Analyses? Ground Water, Vol 26, No. 1, pp. 2-5.

DEQ. Idaho Department of Environmental Quality. 2007. Idaho Rules for Public Drinking Water Systems (IDAPA 58.01.08).

DEQ. Idaho Department of Environmental Quality. 2007. Ground Water Quality Rule (IDAPA 58.01.11).

EPA. U.S. Environmental Protection Agency, 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. 208 p.

EPA. U.S. Environmental Protection Agency, 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. EPA/600/4-89/034, Washington, DC, 221 pp.

EPA. U.S. Environmental Protection Agency. Methods for Chemical Analysis of Water and Wastes. EPA Environmental Monitoring Systems Laboratory-Cincinnati (EMSL-Cllll), EPA-600/4-79-020. Revised March 1983 and 1979 where applicable.

Garner, S. 1988. Making the Most of Field-Measurable Ground Water Quality Parameters. In Ground Water Monitoring Review, Summer Edition, pp. 60-66.

Heaney, S.I, and W. Davison, 1977. The Determination of Ferrous Iron in Natural Waters with 2,2"Dipyridyl. Limnol. Oceanogr. 22, pp. 753-760.

Hem, J.D. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water – 3rd Edition. US Geological Survey Swater-Supply Paper 2254. United States Government Printing Office. 264 pages.

Idaho Administrative Code (IAC), Department of Water Resources, Well Construction Standards Rules. 2005.

Idaho Department of Environmental Quality (DEQ). March 14, 2001. Ground Water and Soils Quality Assurance Project Plan Development Manual. 121 pages.

Idaho Department of Environmental Quality (DEQ). June 2003. DRAFT Wastewater Land Application Statistical Guidance for Ground Water Quality Data. Idaho Department of Environmental Quality.

Ogden, A. E. 1987. A Guide to Groundwater Monitoring and Sampling. Idaho Department of Health and Welfare, Division of Environment. Boise, Idaho. Water Quality Report No. 69.

Pennino, J.D. 1986. There's no Such Thing as a Representative Ground Water Sample. In Ground Water Monitoring Review, Summer Edition, pp. 4-9.

Puls, R.W., and R.M. Powell. 1992. Acquisition of Representative Ground Water Quality Samples for Metals. Ground Water Monitoring Review, Summer, pp. 167-176.

State of North Carolina, 2001. Spray Irrigation System Operators Training Manual.

7.3 Soil-water (Vadose) Monitoring

The vadose zone is defined, for the purposes of this document, as occupying the soil and geologic units lying between the bottom of the root zone and the top of the water table. Water samples representing water in the vadose zone are collected with lysimeters.

Monitoring of this kind is referred to in this section as *soil-water monitoring* or *vadose zone monitoring*. Vadose zone monitoring is intended to be a means of providing early detection of migrating contaminants before they reach ground water.

Definitions and characteristics of soil water are discussed in EPA (1993, Section 9). This discussion is excerpted/summarized in this paragraph. Three major types of soil water can be identified in the context of sampling soil water: (1) Macropore or gravitational water, which flows through the soil relatively rapidly in response to gravity (excess of 0.1 to 0.2 bars suction); (2) soil-pore or capillary water, which is held in the soil at negative pressure potentials (suction) from around 0.1 to 31 bars of suction; and (3) hygroscopic water that is held at tensions greater than 31 bars suction. Soil-pore water moves through the vadose zone, but at much slower rates than gravitational water, whereas hygroscopic water moves primarily in the vapor form. The term soil solute or solution sampling has been used loosely in the literature to describe most sampling methods, whereas the term soil pore liquid is typically used in a more restricted sense to apply to sampling of capillary water. The chemistry of the soil solute sample can differ significantly, depending on the sampling method used. Concentrations of inorganic species generally increase as the matric potential increases (i.e. concentration is inversely related to soil pore water volume).

Vadose zone monitoring offers certain advantages for monitoring environmental response to wastewater land treatment activities. Lysimeters are less expensive and easier to install than monitor wells. Lysimeter samples (from gravity lysimeters) reflect percolate quality after wastewater has received treatment in the root zone. Vadose monitoring can provide important information regarding potential impacts of percolate to ground water in a much more timely fashion than monitoring wells if vadose and/or aquifer travel times are long. However, a disadvantage is the difficulty both in obtaining samples on a regular basis, obtaining representative samples, and interpretation of results. Instrumentation can be unreliable. Variations in soils and other factors contribute to high variability and poor reproducibility in data obtained.

Vadose zone monitoring can be used in both a management and regulatory context. For example, a threshold soil water percolate constituent concentration can be calculated above which down gradient ground water constituent concentrations would exceed acceptable levels. Such a threshold leachate concentration can be back-calculated from assumed values of ground water flow, up gradient ground water concentration, and leachate volume. This calculated threshold percolate concentration can then be compared to sample concentration data from lysimeters for management or regulatory purposes. Further discussion of utilization of lysimeter data is found in 7.7.5.2. Further discussion of when vadose zone monitoring is appropriate is found in Section 7.1 and Figure 7-5.

The remainder of this section discusses soil water monitoring objectives, instrumentation, monitoring parameters, sampling, analytical methods, QA/QC and Data Validation. Supplemental data use and interpretation is also included.

7.3.1 Monitoring Objectives

Site and management conditions that would indicate soil-water monitoring as the preferred alternative to ground water monitoring are discussed in 7.2.1. Soil-water monitoring can serve to collect early warning information about strength and volume of percolate and its potential to contaminate ground water. This is especially useful where both depth to ground water is great and percolate travel times are long, making it impractical to wait many years for indicators of contamination to appear in ground water.

7.3.2 Monitoring Instrumentation

Instrumentation is available to 1) collect soil water samples under unsaturated conditions, 2) collect soil water samples and measure percolate loss under saturated flow conditions, and 3) measure soil water content only. These types of instrumentation are discussed below. See EPA (1993, Section 9) for further details.

7.3.2.1 Soil Water Sample Collection Instrumentation

There are two basic types of soil-water monitoring instrumentation: pressure-vacuum (suction) lysimeters (hereafter pressure-vacuum samplers) and free-gravity lysimeters. This section discusses these in addition to ‘wick’ lysimeters and another recently developed sampler.

7.3.2.1.1 Pressure-Vacuum Samplers

The pressure-vacuum samplers withdraw a soil-water sample by vacuum from the soil profile. The sample is then collected by pressurizing the sampler, which forces the water sample to the surface. One of the advantages of pressure-vacuum samplers is they can collect a soil-water sample during unsaturated soil conditions when downward movement of soil-water percolate is unlikely. These lysimeters are easy to install and, for pressure-vacuum samplers, there is no depth limitation for installation. Recently developed ‘advanced tensiometers’ also have no depth limitation and are described in DOE (2002).

There is the possibility of sorption or other interferences from ceramic, or other non-ceramic, cup materials through which the soil water sample must pass. Certain organic chemicals, microorganisms, volatile chemicals and metals may present problems in this regard (EPA, 1993, p. 9-3). See also further discussion in 7.3.3.

Soil water chemistry and quantity information can be valuable to assess the effectiveness of site operations but may have limited utility for compliance purposes. The data collected from pressure-vacuum samplers will allow the evaluation of soil-water quality at the time of sample collection. The constituent concentration will depend highly on the moisture status of the soil at the time of sampling. Such samples may not be representative of percolate unless the sample was taken under free drainage conditions. If the sample was taken under unsaturated conditions, the constituent concentration would likely be higher than under saturated conditions. It would be invalid to assume samples taken under unsaturated conditions represented saturated conditions.

7.3.2.1.2 Free-Gravity (Pan) Lysimeters

Free-gravity or pan lysimeters can only collect a sample when soil-water is percolating downward. The sample collected represents the quality and quantity of soil-water percolate losses below the crop root zone.

Pan lysimeters provide information for system performance and potential ground water impacts from free drainage. A disadvantage of pan lysimeters is that no sample is collected unless soil moisture is high enough to allow for percolate losses. The lack of significant percolate accumulation, under the appropriate circumstances, may also provide important information regarding the likelihood of contaminant transport. Lack of sample can also mean that by-pass is occurring.

By-pass occurs when soil water freely drains around the lysimeter. Soil matric potential (suction or tension) around the lysimeter then increases relative to the soil matric potential above the lysimeter. Soil water then flows in response to the matric potential gradient generated and often moves laterally away from the lysimeter surface and toward the freely drained soil, thus causing lysimeter by-pass.

Other disadvantages of pan lysimeters are that installation can be complex and time consuming, and location is limited to relatively shallow depths (EPA, 1993).

7.3.2.1.3 Other Soil Water Samplers

In addition to the two types of lysimeters described above, there is also the "wick" lysimeter. The wick lysimeter collects both free drainage liquid as well as liquid held at tensions up to 0.4 bars. It offers the advantage of gathering real-time samples. Further information regarding soil water monitoring instrumentation, including method description, selection considerations, frequency of use, standard methods and guidelines, and sources of additional information can be found in EPA (1993, Section 9)

A recently developed lysimeter incorporates both the ability to obtain a soil water sample as well as capacity to measure soil water flux without the complication of by-pass. The vadose zone fluxmeter with solution collection capability is described further in Gee et al. (2003).

Table 7-3 provides a summary of soil monitoring instrumentation, including the advantages and disadvantages of each method (CLFP, 2002).

Table 7-3. Summary of soil water sampling instrumentation).

Method	Description	Advantages/Disadvantages
Soil Sampling	Soil samples are collected and analyzed for pH, ECe, Cl, NO3-N	+ Simple and reliable -Samples totals, not just solution fraction -Destructive sample -Requires a soil water balance calculation to determine whether flow occurs
Suction Lysimeter	A porous ceramic tube is placed in the soil so soil solution samples can be collected and analyzed	+ Inexpensive, simple technique to implement -Extracts soil solution that is not mobile -Known to have large measurement variability -Requires a soil water balance calculation or correlation with soil moisture to determine whether flow occurs
Pan Lysimeter	A small collection pan (1-5 ft2) is buried at a selected depth so that soil solution samples can be collected via gravity drainage for analysis. Side wall extending above the device may improve performance	+ Extracts soil solution during flow events + Provides a measure of both flow and water quality + Installation can approximate undisturbed conditions + Moderate variability among replicate samples -Relatively expensive installation costs -Will not result in samples in unsaturated soil
Basin Lysimeter	A large collection pan (50-400 ft2) is constructed and covered with soil so that soil solution samples can be collected via gravity drainage for analysis	+ Extracts soil solution during flow events + Provides a measure of both flow and water quality -Installation creates disturbed soil conditions + Large sample decreases variability -Long-term installation generally done prior to starting a project
Wick Lysimeter	A porous wick designed to match the water retention characteristics of the soil is buried at a selected depth so that solution samples can be collected using a low negative pressure.	+ Extracts soil solution at near zero water potential + Installation can approximate undisturbed conditions -Requires a soil water balance calculation to determine whether flow occurs

From CLFP (2002)

7.3.2.2 Soil Water Measurement Instrumentation

Measurement of soil water content can be done in both the crop root zone and the vadose zone. Soil moisture measurement in the root zone is typically done for irrigation scheduling purposes. Soil moisture is often measured somewhat qualitatively to determine when sufficient root zone depletion of water has taken place to require irrigation.

Measurement of soil water content in the vadose zone for contaminant fate and transport purposes requires more quantification, and is discussed in Ley et al. (2002) and in EPA (1993, Section 9). This latter discussion is excerpted/summarized in the following two paragraphs. Water state in the subsurface is measured in terms of hydraulic head in the saturated zone and negative pressure potential or suction in the vadose zone. Water movement in the vadose zone is determined by the interaction of three major types of energy potentials: (1) matric potential (the attraction of water to solids in the subsurface), (2) osmotic potential (the attraction of solute ions to water molecules), and (3) gravitational potential (the attraction of the force of gravity toward the earth's center). Water flow in the vadose zone is strongly influenced by the moisture content (or matric potential, which is a function of moisture content), with hydraulic conductivity and resulting flow decreasing exponentially as moisture content decreases.

EPA (1993) provides information on six major techniques for measuring soil water potential and several methods for measuring soil moisture content. The measurement of soil water potential and moisture content in the vadose zone are intimately connected, and a specific measurement technique measures either potential or moisture content. Either measurement can be used to obtain the other if a moisture characteristic curve has been developed (see EPA, 1993; Section 6.3.1). Soil water instrumentation and measurement are also discussed in an agronomic context in Ley, et al. (2002).

Porous cup tensiometers are the most commonly used method for measuring soil water potential in the vadose zone. The gravimetric method is most commonly used to measure moisture content from soil samples, and the neutron probe and gamma methods are most commonly used for in situ measurement of soil moisture. Dielectric or capacitance sensors provides accuracy similar to the neutron probe without some of the disadvantages of nuclear methods. Similarly, time domain reflectometry is becoming more widely used with the advent of commercially available units. Further information regarding soil water content measurement instrumentation, including method description, selection considerations, frequency of use, standard methods and guidelines, and sources of additional information can be found in EPA (1993, Section 6). In addition, ASTM D 6642-01 (2001) can also be consulted for quantification of soil water flux.

7.3.3 Monitoring Parameters

Table 7-4 provides general guidance for soil water monitoring analytical parameters for selected wastewater land treatment scenarios. It should be noted that certain parameters can be sampled with pan lysimeters and should not be sampled with pressure-vacuum lysimeters due to interferences from either ceramic or non-ceramic materials of the porus cup. Wilson et al. (1995), Table 26.3 summarizes potential chemical interferences of various porus cup materials. Table 26.2 summarizes physical properties of porus cup materials.

Table 7-4. Common Soil Water Monitoring Analytical Parameters for Wastewater Land Treatment Facilities

Facility Type Analytical Parameter	Municipal Facility (Class A Reuse Water)	Municipal Facility (Guideline Loading Rates)	Municipal Facility (Greater than Guideline Loading Rates)	Facility (Well Below Guideline Loading Rates)	Food Processing Facility (Guideline Loading Rates)	Food Processing Facility (Greater than Guideline Loading Rates)
Common Ions[1]	O[2]	O	?	O	?	?
pH	O	O	X	O	X	X
Electrical Conductivity	O	O	X	O	X	X
NO_3-N + NO_2-N	O	X	X	O	X	X
Fe	O	O	?	O	X	X
Mn	O	O	?	O	X	X
TDS	O	O	X	O	X	X
COD	O	O	O	?	?	X
P	O	O	?	?	?	X
K	O	O	O	?	?	X
Cl	O	X	X	X	X	X

Notes:
1. Common ions consist of the following ions: Na, K, Ca*, Mg*, SO_4, Cl, CO_3, HCO_3. These ions help characterize the chemical signature of the percolate, which can be compared to up and down gradient ground water in the determination of potential impacts.
2. Symbol Definitions: X = usually monitored; ? = monitored depending upon case specific situation; O = generally not monitored.

7.3.4 Monitoring Frequency

Frequency of monitoring should be addressed on a case-by-case basis. Lysimeters should be sampled at appropriate intervals to monitor for the changes in soil-water percolate quantity and quality. These sampling events do not necessarily need to be at regular intervals. More frequent sampling may be advisable at sites that anticipate large percolate losses within specific months, such as during the spring flush coinciding with snowmelt.

The timing of sample collection is very important to obtain representative data when using suction samplers. Pressure-vacuum samplers should be sampled to represent the largest soil-water percolate flux in order to maximize the potential to obtain samples. Sampling can be timed concurrent with irrigation and precipitation events. Timing for obtaining samples from pan lysimeters is not so critical. Percolate will accumulate in the pan lysimeter until it is sampled at the end of the quarter, or monthly, depending on the soil-water percolate storage capacity of the instrument.

7.3.5 Sampling and Sample Location Determination

7.3.5.1 Sampling

Lysimeter sampling methods are described in EPA 1993, Sections 9.2 (suction methods) and 9.3 (other methods).

7.3.5.2 Sampling Location Determination

Lysimeters for soil-water sampling should be installed below the anticipated crop root zone in order to collect percolate, which may contribute to deep drainage and potentially impact ground water. By collecting samples at this point, it is assumed that most of the treatment has already occurred in the crop root zone. This is a conservative assumption that does not account for the treatment potential in the vadose zone.

Soil-water status can vary widely over a land application site due to variations in irrigation application rates, soil hydraulic properties, and seasonally with changes in the evapotranspiration demand. The number of lysimeters on a land treatment field is dependent upon spatial and temporal variability, and acceptable quality of the data given the site-specifics and use of the data. Areas that are significantly contrasting with respect to soil type, topography, texture, and other properties should be sampled separately.

The data from each lysimeter sampling point, monitored over time, can be compared with site management to look for changes in percolate quality and volume in response to management practices, so that management/response relationships can be established. Such responses will likely be more qualitative and relative in nature.

7.3.6 Analytical Methods

Table 7-20 presents analytical methods recommended for soil water samples. Where more than one method is given, employ the method appropriate for the type of sample, its concentration range, the availability of equipment, and necessary detection limit. Note that detection limits reported by the laboratory should be significantly less than the ground water standard for constituents, which have regulatory limits.

Soil water sample volumes will vary depending on instrumentation used and time of year. It is recommended that there be a priority for testing established in the QAPP. For example, nitrate and EC require little sample volume compared with TDS, which requires about 100 ml. A reasonable priority would be to conduct nitrate-N and EC analyses first followed by COD, and TDS. Other analyses can then be added depending on the concerns of the site.

7.3.7 Quality Assurance and Quality Control

As discussed in Section 7.1.6.1, the facility should have a quality assurance project plan (QAPP). For more information on the development of a QAPP, refer to Section 7.1.6.

7.3.8 Data Processing, Verification, Validation, and Reporting

As with other types of monitoring, the facility's permit will specify what parameters to monitor, when to monitor, and when results must be submitted. When reporting soil water monitoring data, describe the lysimeter location and use the monitoring serial numbers designated in the permit.

7.3.9 References

ASTM. American Society for Testing and Materials. May 2001. Standard Guide for Comparison of Techniques to Quantify the Soil-Water (Moisture) Flux – Designation: D 6642-01.

CLFP. California League of Food Processors. September 20, 2002. Final Report: Manual of Good Practice for Land Application of Food Process/Rinse Water for California League of Food Processors. Brown and Caldwell, Kennedy Jenks, Komex H_2O Science.

DOE. U.S. Department of Energy. September 2002. Advanced Tensiometer for Vadose Zone Monitoring. Characterization, Monitoring, and Sensor Technology Crosscutting Program sand Subsurface Contaminants Focus Area. Innovative Technology Summary Report. DOE/EM-0639.

EPA. U.S. Environmental Protection Agency. Subsurface Characterization and Monitoring Techniques: A Desk Reference Guide – Volume II: The Vadose Zone, Field Screening and Analytical Methods Appendices C and D. EPA Office of Research and development, Washington DC. EPA/625/R-93/003b. May 1993.

Gee, G.W., Z.F. Zhang, and A.L. Ward. 2003. A Modified Vadose Zone Fluxmeter with Solution Collection Capability. Vadose Zone Journal 2:627-632. Soil Science Society of America Publisher.

Ley, T.W., R.G. Stevens, R.R. Topielec, and W.H. Neibling. February 1, 2002. Soil Water Monitoring & Measurement. Washington State University. Publication No. PNW0475. Available on-line at the following web site: http://cru.cahe.wsu.edu/CEPublications/pnw0475/pnw0475.html

Wilson, L.G., L.G. Everett, and S.J. Cullen. 1995. Handbook of Vadose Zone Characterization and Monitoring. Lewis Publishers, 730 pages.

7.4 Soil Monitoring

Successful treatment of wastewater through land application takes place through an agronomic mechanism. Soil monitoring is a basic component of wastewater-land application monitoring and is generally necessary for continued agronomic operation and management of a land application site.

The schedule for monitoring and the parameters to be measured will depend on the type of wastewater being applied. Soil monitoring is utilized for both nutrient management and characterizing soil quality. Soil monitoring is usually not utilized for compliance purposes.

Section 7.7.7 discusses soil monitoring as used for grazing management purposes.

7.4.1 Monitoring Objectives

Soil monitoring has a dual purpose within the wastewater-land application program. The first is a *nutrient management* purpose, which is discussed in Section 4. Testing for macro-nutrients such as nitrogen, phosphorus, and potassium; pH; and micro-nutrients, are needed so that nutrient loading through wastewater and/or fertilizer can be managed to maximize both crop growth and the efficiency with which nutrients are being utilized. Extensive research on crop nutrient needs, crop response to fertilization given soil-specific nutrient status, crop health, and economic yield has been done by the University of Idaho Extension Service and others. Fertility guides and other publications are available which should be utilized in the management of wastewater land treatment facilities. Crops that appear unhealthy or for which production is noticeably decreased may indicate a need to further investigate the soil crop system to determine the problem area. For example, soils should be monitored for excessive wetness prior to subsequent application of wastewater (particularly during the wet season). Excessive wetness can effect crop growth, nutrient uptake and mobility of nutrients and metals.

The second purpose of soil monitoring is to assess soil quality. This involves characterizing the chemical and physical properties of soils of wastewater-land application sites initially during site characterization as well as over time. Soil data can be used for determining initial permit loading and management conditions, or can indicate whether loading or management changes may be indicated during the permit cycle. Long term soil characterization can reflect effects of particular land use activities. Trend data of parameters such as available nitrogen, electrical conductivity, sodium adsorption ratio (SAR), concentrations of phytotoxic constituents, salinity, and concentrations of redox sensitive species (iron and manganese) can serve as indicators of excessive wastewater loading when compared to ambient levels in agricultural soils not used for land treatment. Soil quality monitoring can signal the accumulation of constituents which may constitute a risk to ground water, given leaching conditions. Soil data can then be utilized to determine appropriate loading rates and management. Monitoring of soils should also include metals and a periodic infiltration study, if SAR levels or operational observation indicate increased runoff or runoff potential.

7.4.2 Monitoring Instrumentation

Ferguson et al. (1991) provides a description of common soil sampling equipment, and is paraphrased here. The soil probe or tube is the most desirable tool for collecting soil samples. It will give a continuous core with minimal disturbance of the soil. The cores can be divided for the various depths. There should be very little contamination of subsoil sample with surface soil when using a soil probe. A soil probe cannot be used when the soil is too wet, too dry, or frozen. If the soil is frozen, the frozen layer will need to be fractured before a probe can be used. Soil probes cannot be used in soils that contain gravel.

'The soil auger can be used in soils that are frozen or contain gravel; however great care must be taken to obtain representative samples and to avoid mixing of soil from different depths. The use of a soil auger in wet, sticky soils will result in mixing soil from different depths. A soil auger will not effectively gather dry, powdery soils. Use a soil auger only when a soil probe cannot be used.' A spade can also be used for surface samples, but is not satisfactory for subsoil samples. 'A post hole digger can be used for collecting deep samples , but its use requires some special techniques.' Galvanized, brass, bronze, or soft steel equipment should not be used as they may contaminate the sample with metals which are important micronutrients (Self and Soltanpour, 2004). Stainless steel or chrome plated tools and plastic buckets are recommended. Equipment should be clean. Wiping equipment clean between samples is generally sufficient, but washing with non-phosphate detergent and a triple rinse in de-ionized water can also be done (CES, 1997). See DEQ (2001) for further details.

DEQ (2001), Appendix 'C' provides soil sampling SOPs (standard operating procedures). SOPs reference monitoring instrumentation. Mahler and Tindall (1990), page 3, discuss sampling equipment. EPA (1991), Section 1 provides a complete list soil sampling equipment which may be needed. Section 4 of the same document provides a description of both hand held and power driven soil sampling equipment.

7.4.3 Monitoring Parameters

Table 7-5 shows common wastewater-land application facility types and analytical parameters recommended for on-going soil monitoring. For initial characterization of baseline soil conditions, the entire suite of analyses is recommended for all facility types.

Not included in the table are other macro- and micro-nutrients which would be monitored by facility land treatment operators or agronomists as needed to determine nutrient status of constituents which are not usually of environmental concern and wastewater land treatment sites. These include sulfate, calcium, magnesium, zinc, boron, copper, chloride and molybdenum.

Table 7-5. Common Soil Monitoring Analytical Parameters for Wastewater Land Treatment Facilities

Facility Type / Analytical Parameter	Municipal Facility (Class A Reuse Water)	Municipal Facility (Guideline Loading Rates)	Municipal Facility (Greater than Guideline Loading Rates)	Facility (Well Below Guideline Loading Rates)	Food Processing Facility (Guideline Loading Rates)	Food Processing Facility (Greater than Guideline Loading Rates)
pH	O[3]	O	?	O	X	X
Organic Matter	O	?	X	O	X	X
NH_3-N	O	X	X	?	X	X
NO_3-N + NO_2-N	O	X	X	?	X	X
DTPA-Fe[2]	O	O	?	O	X	X
DTPA-Mn[2]	O	O	?	O	X	X
Sodium Adsorption Ratio (SAR)	O	?	?	?	X	X
Specific Conductivity	O	O	X	?	X	X
P	O	O	X	?	X	X
K	O	O	O	?	?	X
Cl	O	?	?	O	?	X
Cation Exchange Capacity[1]	O	X	X	X	X	X
Texture (USDA)[1]	O	X	X	X	X	X

Note:
1. Commonly done once during each permit cycle.
2. Commonly done both at the beginning and end of the permit cycle.
3. X = usually monitored; ? = monitored depending upon case specific situation; O = generally not monitored.

A description of the analytes shown and the rationale for monitoring are provided below:

Cation Exchange Capacity (CEC): Cation exchange capacity is a measure of a soils ability to retain and exchange positively charged ions on colloidal surfaces (Bohn et al. 1979). The finer the texture (i.e. greater surface area) and the greater the OM content of the soil, the greater the CEC will generally be. The greater the CEC, the more cations, including crop nutrients, the soil can retain~~s~~. Higher CEC in soils generally indicates higher fertility.

Chloride (Cl): Chloride is commonly found in municipal and industrial wastewaters. It can move substantially un-attenuated through the soil to ground water (i.e. the ion is conservative). As such, chloride is a good indicator of contaminant movement through soil. Certain industrial wastewaters can have significant chloride concentration and may be loaded at high rates to the soil. Chloride toxicity to crops may result if concentration in the soil exceeds certain threshold levels, depending on the sensitivity of the crops. The following crop tolerance ranges are given in Biggar (1981) (in meq/L of saturated extract): low – 10 to 20; medium – 20 to 25; and high – 25 to 90+.

DTPA Extractable Iron and Manganese (DTPA Fe/Mn): Plant available iron and manganese are extracted by the chelating agent diethylenetriaminepentaacetic acid (DTPA). Fe and Mn extracted by this method are in a reduced valence state (i.e. Fe^{2+} and Mn^{2+}). Soils which have been overloaded hydraulically and/or chemically (COD) may develop reducing conditions. Reducing conditions change oxidized forms of Fe and Mn naturally resident in the soil profile to mobile forms. These forms may then leach to ground water under certain conditions. The presence of high levels of the above reduced species in soils may reflect reduced soil conditions brought on by hydraulic and/or COD overloading.

High levels of soil Fe and Mn, with respect to crop utilization, typically range from 4.1 to 10 mg/kg and 2.6 to 8.0 mg/kg respectively (Stukenholtz no date).

Sodium Adsorption Ratio (SAR): Sodium Adsorption Ratio serves as an index of the potential sodium influence in the soil. SAR values above thirteen (13) classify soils as sodic or alkali (Robbins and Gavlak, 1989), have sodium as the dominant cation, and may possibly experience infiltration problems due to deflocculation of soil colloids. Certain textures of soils can become affected at values lower than 13 (David Argyle, Hibbs Analytical Laboratories, personal communication c. 1993).

Electrical Conductivity (EC): The electrical conductivity of a water extraction of a soil is an indirect measure of the salt content in the soil. High loadings of inorganic TDS may cause salt build-up in the soil leading to crop yield decreases.

Electrical conductivities of the saturated paste extract values greater than 4 dS/m indicate saline conditions in the soil. Other *proposed* limits for defining saline soils are 2 dS/m (Bohn et al. 1979). A general soil test interpretive guide from Stukenholtz Laboratory shows ECs of 0 to 1.0 dS/m being low, 1.0 to 4.0 dS/m being medium, and 4.1 to 8.0 dS/m being high (Stukenholtz, no date).

Nitrate and Ammonium (NO_3^-/NH_4^+): common nitrogen species which are plant available and important in determining the resident nutrient status of soils. Nitrate is very mobile in the soil and is subject to leaching. Excessive nitrate leaching may cause adverse impacts to ground water.

Organic Matter (OM): Organic matter mineralizes over time to yield plant available nitrogen. It is common in crop nutrient guides to correlate the percent of organic matter with the pounds of nitrogen which will be mineralized during the growing season. This mineralization should be taken into account in wastewater land treatment site nitrogen balance calculations. Rules of thumb vary as to the amount of nitrogen released for each percent of organic matter in the soil. Taberna (no date) cites values of 50 pounds of nitrogen per acre for each percent of organic matter released for southwest Idaho, 40 for the Magic Valley, and 35 for eastern Idaho. Extension fertility guides take soil organic matter into account when assessing the need for nutrient addition.

Texture: Soil textures are reported in the Natural Resource Conservation Service Soil Survey reports for many areas. Soil textures can be determined in the laboratory or by manual field methods if no soil survey reports are available, or to verify existing soil survey reports. Available water holding capacity, a very important parameter with respect to non-growing season wastewater loading, is a function of soil texture. Also, cation exchange capacity is correlated with soil texture (see below). Soil textures need only be determined once, since texture is a physical property of the soil and does not normally change over time.

Phosphorus: Phosphorus is relatively non-mobile in the soil and is an essential crop macronutrient~~s~~. Phosphorus is an important species which can cause eutrophication of surface waters, and associated water quality degradation problems. Phosphorus is discussed at length in Section 4.8.

Potassium: Potassium is relatively non-mobile in the soil, and is an essential crop macronutrient~~s~~. Sites which are overloaded with respect to potassium not only show very high levels in the soil profile, but distinct potassium increases from ambient ground water concentrations can often be seen down gradient.

pH: pH is a measure of the acidity/alkalinity of the soil. Generally the pH of soils does not exceed 8.3, this limit reflecting the dominating effect of carbonate on the soil chemistry. When soil pH exceeds this value, a sodic soil condition may be indicated (Robbins and Gavlak, 1989). Soil pH has an important influence on availability of crop nutrients. Productive agricultural soils generally exhibit a pH range of 6.5 to 7.5.

7.4.4 Monitoring Frequency

The frequency of soil monitoring is dependant on the type of facility, wastewater land treatment management, loading rates, and site specific factors. Table 7-6 provides recommendations for soil monitoring frequencies.

In cases where soil sampling is needed, sampling in early spring is generally indicated. Early spring sampling is done to assess the nutrient status of the soil near the commencement of the crop growing season. Fertility guides can be used to interpret the result and provide recommendations for nutrient addition for the cropping year. Soil quality status (i.e. status of non-nutrient parameters affecting crop growth and/or the environment) can also be assessed through spring sampling. Comparing spring sampling data from one year to the next can be used to estimate leaching losses of constituents such as salts. If initial and final soil concentrations are known, crop ash (inorganics) uptake and removal is known, and salts applied with wastewater, irrigation water, waste solids etc. are known, leaching losses can be estimated by difference.

Fall soil sampling after the cropping season is sometimes necessary, as Table 7-6 indicates. Additional fall sampling can be useful at facilities for which nutrient budgets (particularly nitrogen) must be closely monitored. By comparing spring and fall soil nutrient status; nutrient additions from wastewater, waste solids, and fertilizer; and crop uptake and removal; one can estimate by difference the losses of a nutrient to the environment during the growing season. In the case of nitrogen those losses would include leaching, volatilization, and denitrification. By estimating volatilization and denitrification losses, one can arrive at a growing season leaching loss estimate.

The same is true by comparing fall and spring soil nutrient status over the non-growing season, only the nutrient additions would not include fertilizer; and there would not be crop uptake and removal. One can estimate by difference the losses of a nutrient to the environment as described for the growing season. In the case of nitrogen, estimates of volatilization and denitrification may be much more tenuous because other factors, such as organic constituent and hydraulic loading and temperature, influence soil redox potential and microbial metabolic rates, which affect denitrification. This increased uncertainty makes the nitrogen leaching loss estimate more uncertain as well.

Sampling depth intervals for common types of wastewater land treatment facilities are given in the table. To characterize nutrient status for non-mobile species, such as phosphorus and potassium, crop fertility guides typically recommend sampling the 0-12 inch depth. To characterize nitrogen status, both the 0-12 inch and 12-24 inch depths are recommended.

As discussed in Section 4.2, NO_3^- is a mobile constituent. In general, shallower depths are sampled for relatively immobile nutrients. Deeper depths should be sampled for more mobile species. Depending on the type of facility, management, and loading rates, deeper layers of the soil profile should be sampled to obtain qualitative indication of movement of constituents below the crop root zone. In Table 7-6, facilities with higher loading rates, with legacy sites, and industrial facilities generally sample at depths greater than 24 inches. Recommended sampling intervals in Table 7-6 are in 12 inch increments (i.e. 0 – 12 inches; 12 – 24 inches; etc.). It is not generally recommended to select pedogenic horizons to sample; such as A, B and C horizons; since these likely occur at variable depths in a field, and may not be readily distinguishable when sampling. Also, calculating soil constituent content from concentration data is greatly simplified when a 12 inch interval is selected, as the following formula shows:

$$Soil\ \ Content\ \ (lb/acre) = Soil\ \ Constituent\ \ Concentration\ \ (mg/kg) * 4$$

Note: The factor of 4 is approximate and appropriate for many soils, but is dependant on the bulk density of the soil. A more versatile and accurate means of obtaining soil constituent content requires additional inputs of both soil depth considered and soil bulk density. The equation is as follows:

$$M = 0.225 * d * C * D_b$$

Where:

M = soil nutrient content (lb/acre)

d = soil depth considered (inches)

C = soil constituent concentration (mg/kg)

D_b = soil bulk density (g/cm^3)

It should be noted that if monitoring is performed more frequently than required by the permit, the results of this additional monitoring are required to be included in the annual report. If additional parameters are monitored which are not required in the permit, these data do not have to be reported.

Table 7-6. Soil Monitoring Frequency Recommendations for Common Types of Wastewater Land Treatment Facilities.

Facility Type	Municipal Facility (Class A Reuse Water)	Municipal Facility (Guideline Loading Rates)	Municipal Facility (Greater than Guideline Loading Rates)	Food Processing Facility[1] (De-Minimus Loading Rates)	Food Processing Facility (Guideline Loading Rates)	Food Processing Facility (Greater than Guideline Loading Rates)
Soil Monitoring Frequency	none	Annually: Early Spring	Annually: Early Spring	Annually: Early Spring	Annually: Early Spring	Semi-Annually: Early Spring and Fall
Sampling Depths (inches)	none	0 - 12 & 12 - 24 or refusal	0 - 12 & 12 - 24 & 24 – 36 or refusal	0 - 12 & 12 - 24 or refusal	0 – 12; 12 – 24 & 24 – 36 or refusal	0 – 12; 12 – 24 & 24 – 36 or refusal

1) Common food processing facilities in Idaho include potato (fries and dehydrated products), sugar beet, cheese, and whey processing plants. Potato fresh pack facilities, although not a food processing operation, would be included in this category.

7.4.5 Sampling and Sample Location Determination

7.4.5.1 Sampling

Soil sampling protocols for crop nutrient assessment in soils are discussed in Mahler and Tindall (1990). Sampling protocols are summarized in WLAP permits which require soil monitoring. DEQ (2001) provides soil sampling SOPs (standard operating procedures) in (DEQ 2001) Appendix 'C'. Included are SOPs for the following:

- Collecting representative surface soil samples
- Collecting representative subsurface soil samples with hand augers, split spoon samplers, and from pits and trenches
- Decontaminating soil sampling equipment

Soil sampling should be done when there is sufficient time to complete sampling. Sampling should not be done when soils are excessively wet because compositing is difficult. Soils should not be sampled when snow covered; or have had recent fertilizer, lime, or manure applications (Oklahoma State University Extension, September 2003; Mahler and Tindall, 1990). In general, several sub-samples from several locations are taken from each sampling interval (see further discussion below) and are composited by depth in a clean plastic bucket to yield a composite sample for chemical or physical analysis. If taking soil cores, the entire core from the particular depth interval should be included as a sub-sample. As described in Mahler and Tindall (1990), soil samples 'need special handling to ensure accurate results and minimize changes in nutrient levels because of biological activity. Keep moist soil samples cool at all times during and after sampling. Samples can be frozen or refrigerated for extended periods of time without adverse effects.' Samples can then be transported to the laboratory in a cooler.

Directions for air drying of soil samples in the following paragraph are paraphrased from A&L Plains Labs, Inc. (no date) unless noted otherwise. Samples can be air dried by spreading the sample in a thin layer on a (clean) plastic sheet. Clods should be broken up and soil spread in a layer about ¼ inch deep. The sample should be dried at room temperature. If a circulating fan is available, position it to move the air over the sample for rapid drying. Do not dry where agricultural chemical or fertilizer fumes or dust will come in contact with the samples. Do not use artificial heat in drying. When soil samples are dry, mix the soil thoroughly, crushing any coarse lumps. Take from the sample about 1 pint (roughly 1 pound) of well-mixed soil and place it in a sample bag or other sturdy, spill-proof container (generally provided by the laboratory) which has sample number, depth, date, time, field number and sampler's name (Mahler and Tindall, 1990). Documentation having sample identification describing the sample and associated information should be written. An example of a soil sample information sheet is in 7.7.6 (Iowa State University, 1997).

7.4.5.2 Sampling Location Determination

Soil monitoring units (SMUs) are specified in wastewater land application permits. SMUs are the predefined areas from which soils are sampled and composite samples are prepared. SMUs are designed so that, in as much as possible, soil properties, cropping practices and wastewater application rates are similar (CES, 1997). Obtaining representative samples is critical to getting valid and interpretable analytical results. Areas should be sampled that are similar in topography, soils, land use and management. Mahler and Tindall (1990), as excerpted and summarized here, recommend that the sampler avoid unusual areas such as eroded sections, dead furrows, fence lines, burn-row areas, wood pile burn areas, gate areas, old building sites, old manure and urine spots, areas of poor drainage, fertilizer bands where row crops have been grown, areas of fertilizer spills, and other unusual areas which would not be representative of SMU soils.

Soil samples should be taken from several different locations in the SMU. Taberna (1992) recommends taking subsamples no closer than 40 feet from the edge of the field. The sampling pattern recommended there is along a transecting loop diagonal (45 degrees) to the field (a diamond shaped transect within a square field). Mahler and Tindall (1990) recommend a zigzag meander pattern to randomly collect samples, being sure to collect samples throughout the unit. Other sampling methods besides a simple random sampling include stratified random sampling, sampling at predetermined locations based upon soil mapping, and using a systematic grid pattern. These are discussed further in CES (1997) and Jacobson (1999).

Special sampling protocols are necessary for furrow irrigated fields, areas where fertilizer has been banded, and on reduced tillage or no tillage fields. These protocols are discussed in Mahler and Tindall (1990)

It is important to note that sampling for nutrient assessment, while adequate for fertility assessment under routine farm management, introduces too much variability for monitoring practices. Soil monitoring should be performed at established locations over time to monitor for changes over time. Valid comparisons over time are not possible if sampling collects from different locations each time. In general, individual locations, grids, or sampling transects should be established to monitor for land application system performance over time.

Table 7-7 gives a recommended number of subsamples to collect based on the size of the field and purpose of sampling:

Table 7-7. Recommended Number of Soil Subsamples.

Field Size in Acres	U of I Recommended Number of Subsamples for Agronomic Nutrient Characterization[1]	DEQ Recommended Number of Subsamples for Regulatory Reconnaissance Characterization
<5	15	5
5-10	18	5
10-15	20	5
15-25	20	10
25-50	25	10
>50	30	10

1) from Mahler and Tindall, 1990

7.4.6 Analytical Methods

Table 7-24 presents analytical methods recommended for soil monitoring. Of particular importance are methods outlined in the Web site:

http://isnap.oregonstate.edu/WCC103/Soil_Methods.htm

This website consists of the on-line version of the Western States Plant, Soil, and Water Analysis Manual, Second Edition, 2003 (hereafter Gavlak et al., 2003).

Where more than one method is given, employ the method appropriate for the type of sample, its concentration range, the availability of equipment, and necessary detection limit. Note that detection limits reported by the laboratory should be significantly less than the ground water standard for constituents that have regulatory limits. Other references which may be consulted for useful soil analytical information include Black et al. (1965), Horneck et al. (1989), Miller and Amacher (1994), and Page et al. (1982).

7.4.7 Quality Assurance and Quality Control

It is recommended that soil testing laboratories utilized for permit required soil analyses are participants in the North American Proficiency Testing Program (NAPT) program for soil, planed and water analyses. The NAPT program is based on the quarterly submission to participating laboratories of six soil and/or three plant materials for chemical analysis using reference methods of analysis described in the four Regional Soil Work Group publications of the Northeast Coordinating Committee on Soil Testing (NEC-67), North Central Regional Soil Testing Committee (NCR-13), Southeast Regional Soil Testing Committee (SERA-6), Nutrient Management and Water Quality Team (WERA-103) and methods outlined in the *Methods Manual for Forest Soil and Plant Analysis* (Forestry Canada.)

Participating laboratories complete sample analysis and provide results to the NAPT program coordinator for statistical evaluation. Quarterly, each laboratory will provide an evaluation of their individual performance on each of the methods listed. Annually, the program will provide a report to each participant of the performance of the individual laboratory and that of the agricultural laboratory industry. An extension outreach program to aid participating laboratories in improving the quality of their analytical results will be implemented in cooperation with regional soil and plant analysis work groups and individual state, regional and provincial representatives from the Web site:

http://www.soiltesting.org/proficiencytesting.html

The following Web site has information regarding quality assurance in the agricultural laboratory:

http://isnap.oregonstate.edu/WCC103/Methods/WCC-103-Manual-2003-Lab%20Quality%20Control.PDF

7.4.8 Quality Assurance and Quality Control

As discussed in Section 7.1.6.1, the facility should have a quality assurance project plan (QAPP). For more information on the development of a QAPP, refer to Section 7.1.6.

7.4.9 Data Processing, Verification, Validation, and Reporting

As with other types of monitoring, the facility's permit will specify what parameters to monitor, when to monitor, and when results must be submitted. When reporting soil monitoring data, describe the soil monitoring unit location and use the monitoring serial numbers designated in the permit.

7.4.10 References

A & L Plains Labs, Inc. (No Date). Best Sampling Procedures website. (get site address)

Argyle, David. 1993. Hibbs Analytical Laboratories, personal communication.

Biggar, J.W. 1981. Water Quality for Agriculture and Related Uses. Course Syllabus, University of California, Davis. Chapter 8.

Black, C.A., et al. (eds). 1965. Methods of Soil Analysis, Part 1, Physical and Mineralogical Properties, including Statistics of Measurement and Sampling. ASA SSSA Publication, Madison WI #9 in monograph Series.

Bohn, H. L., B. L. McNeal, and G. A. O'Connor, 1979. Soil Chemistry. Wiley Interscience. 329 Pages.

CES. Cascade Earth Sciences. October 1997. Process Water Irrigation Systems: Design and Management. Soil and Crop Monitoring.

DEQ. Idaho Department of Environmental Quality. March 14, 2001. Ground Water and Soils Quality Assurance Project Plan Development Manual. 121 pages.

EPA. U.S. Environmental Protection Agency. November 1991. Description and Sampling of Contaminated Soils – A Field Pocket Guide. EPA/625/12-91/002 Technology Transfer. 122 pp.

Ferguson, R.B., K.D. Frank, G.W. Hergert, E.J. Penas, and R.A. Wiese. February 1991. Guidelines for Soil Sampling. University of Nebraska NebGuide. 7 pp.

Gavlak, R., D. Horneck, R.O. Miller, and J. Kotuby–Amacher, 2003. Soil, Plant and Water Reference Methods for the Western Region. Second Edition. WCC-103 Publication.

Horneck, D. A., Hart, J. M., Topper, K., and Koespell, B. September 1989. Methods of Soil Analysis Used in the Soil Testing Laboratory at Oregon State University. Agricultural Experimental Station, Oregon State University, SM 89:4.

Iowa State University, January 1997. University Extension Soil Sample Information Sheet: St-8 Revised January 1997.

Jacobson, J.S. 1999. Soil Sampling. MontGuide MT 8602 Agriculture. 6 pp.

Kalra, U.P., D.G. Maynard. 1991. Methods Manual for Forest Soil and Plant Analysis. Forestry Canada, Northwest Region, Edmonton, Alberta, Canada. Ifn. Rep. NOR-X-319.

Mahler, R. L., and T.A. Tindall 1990. Soil Sampling. University of Idaho Cooperative Extension Bulletin N. 704 (Revised).

Miller, R. O. and Amacher, J. 1994 version 1.00. Western States Agricultural Laboratory Exchange Program: Suggested Soil and Plant Analytical Methods.

Oklahoma State University Extension, September 2003. Take a Good Soil Sample to Help Make Good Decisions. 4 pp.

Page, A.L., R.H. Miller and D.R. Kenney (eds). 1982. Methods of Soil Analysis, Part 2, Chemical and Microbial Properties, 2nd Edition. Edited by ASA SSSA Publication, Madison WI. #9 in monograph Series.

Robbins, C. W., and R. G. Gavlak, 1989. Salt and Sodium Affected Soils. Cooperative Extension Service Bulletin No. 703.

Self, J.R., and P.N. Soltanpour. August 2004. Soil Sampling. Colorado State University Cooperative Extension. 3 pp.

Stukenholtz Laboratory, Inc. Twin Falls, Idaho. No Date. Soil Test Levels – General Evaluation Table. 1 page.

Taberna, J.P. 1992 revised. Taking a Soil Sample According to Taberna. Western Laboratories, Inc. Parma, ID.

Taberna, J.P. No Date. Useful Conversions and Tables for Western Laboratories Reports. Western Laboratories, Inc. Parma, ID.

7.5 Wastewater Monitoring

The quality and quantity of the effluent applied to the land treatment area should be monitored on a regular basis. Wastewater sampling and analysis plans are determined based on individual wastewater characteristics, site specific considerations, and regulatory requirements (see Section 2 and Section 7.1.6).

This section provides wastewater monitoring guidance for both municipal and industrial wastewater land application permits and includes wastewater monitoring objectives, instrumentation, monitoring parameters, sampling, analytical methods, quality assurance/quality control and data processing, verification, validation, and reporting.

7.5.1 Monitoring Objectives

The goal of wastewater monitoring at a wastewater-land application facility is to provide a timely and cost-effective assessment of the adequacy of wastewater treatment unit process operations and operation and management procedures. Wastewater chemical and flow monitoring is also critical for constituent loading calculations for permit compliance purposes.

7.5.2 Monitoring Instrumentation

The following section discusses sample collection equipment and flow measurement instrumentation.

7.5.2.1 Sample Collection Equipment

There are various types of wastewater samplers, which are designed to collect sample types described in Section 7.4.4. Refrigerated samplers are designed to take daily composite samples and keep samples at appropriate temperatures for preservation. There are other portable samplers, which can collect hourly composite samples, and can be readily moved to different locations (Metcalf and Eddy, 2003). Some composite samplers can take time-weighted samples, taking identical sample volumes over time. Other samplers can take flow-weighted samples, taking different volumes of sample proportionate to measured flows over time.

7.5.2.2 Flow Measurement

The accurate and precise measurement of wastewater flow is critical for the operation of wastewater land treatment facilities for many reasons. In-plant wastewater treatment processes, which will not be addressed here, rely on flow measurement. Important from a regulatory standpoint is flow measurement to determine both hydraulic loading and constituent loading rates for site management and permit compliance.

Flow measurement is discussed at length in various wastewater engineering texts and the reader is referred there. Important topics to consider regarding flow measurement include:

- Type and application of the flow measurement (metering) device
- Selection criteria for metering devices, and
- Maintenance of metering devices.

Metcalf and Eddy (1991), Tables 6-2, 6-3, and 6-4 provide summary information regarding application, selection criteria, and characteristics of flow metering devices respectively. Flow measurement for industrial facilities is discussed in EPA (1973).

Table 7-8, from CLFP (2002), provides a convenient summary of flow measurement devices and advantages and disadvantages.

Table 7-8. Flow Measurement Examples.

Method	Alternatives	Advantages/Disadvantages
Intrusive flow meters	Impeller, paddle wheel Hot wire anemometer	- Intrusive devices can clog with solids or from biological growth - higher friction loss/pressure drop - Low pH or high Electrical Conductivity can cause failure of sensing components resulting in higher maintenance
Non-intrusive flow meters	Magnetic Ultrasonic/Doppler	+ These sensors have no parts in the flow - Higher capital cost + Often, these are used at main pump station and alternate methods are used for individual fields
Open channel flow measurements	Weir-type Parshall flume	- Requires controlled channel to establish proper conditions for measurement + Simple, reliable operation + measurements can be recorded continuously
Incoming water supply correlation	Discharge volume is estimated as a percentage of incoming water consumption	+ Supply water is clean and relatively simple to measure using meters - A correlation between incoming flow, in-plant loss, and process/rinse water discharge is required
Pump run time and output calculation	Flow for individual fields can be estimated proportionally from total flow	- Requires a master pump station flow meter or some calibration - Irrigation fields must be maintained so they operate according to specifications - Primarily applicable to sprinkler irrigation systems or surface irrigation using siphon tubes or gated pipe
In-field methods	Rain gauge/catch cans in individual fields Use of soil water measurements to calculate net irrigation	+ Approximates net irrigation (amounts actually received) rather than gross irrigation delivered - Assumptions in water budget method make method approximate; - calibration required. - Measurement of soil moisture at bottom of root zone provides useful information related to leaching - Rain gauges are applicable to sprinkler irrigation only

From CLFP (2002).

Both wastewater and irrigation water flows need to be measured. Irrigation water generally comes from one source, but can come from multiple sources (well, diverted surface irrigation water). In the latter case, each source should be metered. Irrigation water should be metered at every hydraulic management to measure application rates.

Total wastewater flow to land treatment acreage should be metered from the facility. As with irrigation water, each hydraulic management unit should be metered to measure wastewater application.

Flow data is not compromised by sample contamination, but data verification is important to consider when collecting flow measurements. In some cases flow measurements cannot be safely verified because of the position of the flow measurement device. In other cases the flow measurement device may not be properly constructed, so there is doubt about the measurements produced by the device. For example, a weir may not be level, thus the original engineering calculations used to gauge flow on the weir may not be appropriate for use with the structure as built. Data verification for flow devices should be approached carefully, because in many cases the cost of verification can be great. In some cases documentation showing proper calibration can be presented as a flow verification. All flow meters should be maintained regularly, according to manufacturer's recommendations, and should be calibrated at least once each year to insure both accurate and precise measurements are being taken.

Further discussion of flow measurement and an in-depth discussion regarding the evaluation of flow measurement devices and records for regulatory purposes is found in EPA (2004), Chapter 6. This chapter is included in this guidance in the supplementary information (Section 7.7.8), and is available at the following Web site:

http://www.epa.gov/compliance/resources/publications/monitoring/cwa/inspections/npdesinspect/npdesmanual.html

7.5.3 Monitoring Parameters

This section discusses typical chemical monitoring parameters for wastewater, irrigation water, and operations and unit process monitoring.

7.5.3.1 Chemical Monitoring Parameters

Wastewater chemical analytical parameters to be monitored in wastewater are determined from permit application data, history of the facility wastewater generation, wastewater characteristics of similar facilities and other factors. The permit may require monitoring of constituents in the wastewater for reasons other than to determine compliance with loading or other regulatory limits. Additional parameters to monitor may include toxic chemicals or substances that could upset the treatment system. These substances could be introduced from raw materials, compounds resulting from chemical interactions, or impurities in raw materials including solvents.

Municipal systems typically monitor for total suspended solids (TSS) and biochemical oxygen demand (BOD_5). These parameters are useful as an indicator of treatment performance prior to land application.

Table 7-9 shows common wastewater monitoring analytical parameters for wastewater land treatment facilities.

Table 7-9. Table of Common Wastewater Monitoring Analytical Parameters for Wastewater Land Treatment Facilities.

Facility Type Analytical Parameter	Municipal Facility (Class A Reuse Water)	Municipal Facility (Guideline Loading Rates)	Municipal Facility (Greater than Guideline Loading Rates)	Facility (Well Below Guideline Loading Rates)	Food Processing Facility (Guideline Loading Rates)	Food Processing Facility (Greater than Guideline Loading Rates)
Flow	X[2]	X	X	X	X	X
Total Settleable Solids	X	X	X	?	?	?
Total Suspended Solids	X	X	X	?	?	?
Turbidity	X	O	O	O	O	O
pH	X	X	X	X	X	X
Alkalinity	?	?	?	?	?	?
Sodium	O	O	?	?	?	X
NO3-N + NO2-N	X	X	X	X	X	X
TKN	X	X	X	X	X	X
BOD	?	?	?	O	O	O
SO4	O	O	O	?	X	X
Total Dissolved Inorganic Solids[1]	O	O	O	?	?	X
VDS	O	O	?	O	?	?
TDS	O	O	X	?	?	?
FDS/NVDS	O	O	?	?	?	?
Electrical Conductivity	O	X	X	X	X	X
COD	O	O	O	?	?	X
P	O	O	X	?	X	X
K	O	O	O	?	X	X
Cl	O	X	X	X	X	X
Total Coliform	X	X	X	?	?	?
Other Micro-organisms	?	?	?	?	?	?

Notes:
1. Total Dissolved Inorganic Solids generally consist of the following ions: Na, K, Ca, Mg, SO_4, Cl, CO_3, HCO_3 and other species in appreciable concentration.
2. Symbol Definitions: X = usually monitored; ? = monitored depending upon case specific situation; O = generally not monitored.

Irrigation water quality is often measured at wastewater land treatment facilities, where there is need to account for constituent loading from this source. In cases where irrigation water does not vary appreciably during the water year, nor between water years, sampling and analysis during the spring and fall of the first water year of the permit cycle is usually considered sufficient. For cases where there is more variability, additional monitoring may be necessary for chemical characterization. Typical constituents of concern are salts (as measured by TDS analysis) and total nitrogen (as measured by TKN plus nitrate-nitrogen analyses). Chloride may be necessary for sites where ground water modeling is being, or may be, conducted. Chloride is a conservative constituent (i.e. does not undergo chemical transformations in an agronomic soil environment) and can be used for modeling calibration purposes.

7.5.3.2 Operations and Unit Process Monitoring

Operations monitoring is an important component of the wastewater monitoring program. Operations monitoring includes monitoring performance of irrigation systems including inspection and cleaning of sprinklers. Observation during both growing and non-growing season during wastewater irrigation for runoff, ponding, vectors, ice build-up and other irregularities is important. Precipitation and evapotranspiration should also be monitored.

Cumulative constituent and hydraulic loadings onto hydraulic management units should be monitored throughout the application season so that sound wastewater land treatment management decisions can be made.

Lagoon water levels need to be monitored. Lagoon berms need to be inspected regularly for rodent damage and for weed control. Operation of pumps, clarifiers, screens, filter presses, centrifuges and other unit processes must be closely monitored. Ground water mounding around lagoons should also be monitored using piezometers.

Table 7-10, adapted from CLFP (2002), summarizes operations monitoring in a checklist for routine maintenance for use at a wastewater land treatment facility.

Table 7-10. Routine Maintenance Inspection Checklist for Land Application Sites Monitoring.

Feature	**Condition**	**Recommended Action**
Facility Discharge	Check primary screens for solids accumulation, amount of flow, evidence of unusual conditions	
Lagoon or Pond	Pond level, odor, scum on surface, presence of excessive solids, berm inspection for rodent damage and weed control	
Residuals Stockpile	Amount, need for land application, odor	
Main Pump Station	Current operations, flow, pressure, odor, leaks, mechanical concerns	
Transmission Piping	Leaks, odor, pressure at intermediate locations	
Booster Pumps	Current operations, flow pressure, odor, leaks, mechanical concerns	
Other Unit Processes	Monitoring of clarifier, filter presses, centrifuges, etc.	
Fields irrigated	For each field: list irrigation run times, process water or supplemental water supply, odor	
Constituent Loading	Cumulative constituent and hydraulic loadings throughout growing and non-growing seasons	
Fields condition	For each field: assess irrigation uniformity, runoff, erosion, irrigation system condition, odor, solids on surface, ice buildup, ponding, vectors,	
Crop Condition	For each field: general crop health, need for farming activities	
Samples Collected	List samples taken	

Adapted from CLFP (2002).

7.5.4 Monitoring Frequency

Wastewater monitoring frequency is determined based on the measured or estimated variability (see Section 7.1.3). Other factors for determining sampling frequency include the following:

- Size and design capacity of facility
- Type of treatment
- Compliance history
- Number of pollutant sources from a facility
- Cost of monitoring relative to the facility's capability and benefits obtained
- Environmental significance of wastewater constituents
- Detection limits and analytical precision/accuracy
- Production schedule of the facility (seasonal, daily, year round, etc.)
- Plant washdown or cleanup schedule
- Batch type process and discharge or continuous operation

The number of samples necessary to determine compliance for total coliform is related to the degree of public exposure, as rated by total coliform counts in wastewater (see Table 7-11). The WLAP rule (IDAPA 58.01.17.600.07) specifies the use of the median sample value for the last three to seven test results to determine compliance, depending on the effluent classification.

Table 7-11. Total Coliform Testing Frequency and Compliance Determination for Municipal Systems

Wastewater Category	Median Coliform Limit	Single Sample Maximum Value**	Recommended Sampling Frequency	Compliance Determination Method
Class A	Filtered, Total Coliform limit: 2.2/100 ml *	23/100 ml	Daily when land application system is in operation, or project specific	O&M manual must include provisions to divert effluent or shut down application system whenever bacterial excursions occur or may occur; Median value of last 7 results, rolling basis
Class B	Total Coliform limit: 2.2/100 ml	23/100 ml	Twice per week when land application system is in operation	Median value of last 7 results, rolling basis
Class C	Total Coliform limit: 23/100 ml	240/100 ml	Weekly when land application system is in operation	Median value of last 5 results, rolling basis
Class D	Total Coliform limit: 230/100 ml	2400/100 ml	Twice per month when land application system is in operation	Median value of last 3 results, rolling basis
Class D	Too Numerous to Count – Not Applicable	Not Applicable	Twice per month when land application system is in operation	Not Applicable

Notes:
* This category requires filtration performance standards (turbidity or TSS) prior to disinfection.
** The facility shall include provisions to divert effluent or shut down application system whenever bacterial excursions occur or may occur

Municipal wastewater land application permits should include a total coliform maximum limit, in addition to the median limit. For compliance, using the median value allows a certain number of individual samples to have unlimited bacteria counts. Including a single sample maximum value provides needed public health protection, and requires facilities to monitor their disinfection systems more closely. See Table 7-11 for suggested maximum limits according to wastewater category.

Municipal permits typically have hydraulic loading rates be calculated on a monthly basis. If a system is having problems managing the site properly, a weekly basis may be more appropriate.

Frequency of wastewater constituent monitoring for industrial wastewater land application facilities is summarized in Table 7-27. Frequency of wastewater constituent monitoring for municipal wastewater land application facilities is summarized in Table 7-28.

7.5.5 Sampling and Sample Location Determination

7.5.5.1 Sampling

Detailed information for developing a wastewater sampling program is found in Section 7.1.6 in the context of development of the quality assurance project plan (QAPP). The publication, *Monitoring Industrial Wastewater,* EPA, 1973, can also be consulted. The information is also applicable to municipal wastewaters. There are several types of wastewater samples that can be collected: *grab*, *composite*, and *continuous sampling*, all of which are discussed in the following.

The wastewater sample type will depend on several factors:

- The parameter to be monitored.
- The temporal and spatial variability of the wastewater sampled; and
- The type of limit. Limits based on instantaneous or one hour values may be sampled using grab sampling techniques. Limits based on average values or daily maximums may be sampled using time or flow proportional composite samples. This is acceptable for certain conventional pollutants, nutrients, and bio-accumulative pollutants, for which percent removal and total loading to the receiving water are of concern.

7.5.5.1.1 Discrete Grab or Sequential Grab Samples

A wastewater grab sample is an individual sample collected in less than 15 minutes time. It represents more or less "instantaneous" conditions as discussed in Section 7.1.4. Grab samples should be used when:

- Wastewater characteristics are relatively constant.
- The parameters to be analyzed are likely to change with storage such as temperature, dissolved gasses, residual chlorine, soluble sulfide, cyanides, phenols, microbiological parameters and pH.
- The parameters to be analyzed are likely to be affected by the compositing process such as oil,grease, and volatile organic compounds.
- Information on variability over a short time period is desired.
- Composite sampling is impractical or the compositing process is liable to introduce artifacts of sampling.
- The spatial parameter variability is to be determined. For example, variability through the cross section and/or depth of a stream, lagoon or other large body of water.
- Wastewater flows are intermittent from well-mixed batch process tanks. Each batch dumping event should be sampled.

Another type of grab sample is sequential sampling. A special type of automatic sampling device collects relatively small amounts of a sampled stream, with the interval between sampling either time or flow proportioned. Unlike the automatic composite sampler, the sequential sampling device automatically retrieves a sample and holds it in a bottle separate from other automatically retrieved samples. Many individual samples can be stored separately in the unit, unlike the composite sampler, which combines aliquots in a common bottle. This type of sampling is effective for determining variations in media characteristics over short periods.

7.5.5.1.2 Composite Samples

As discussed in Section 7.1.4, a composite sample consists of a series of individual samples collected over time into a single container, and analyzed as one sample. Composite sampling is employed when time or flow-weighted constituent concentration averages are needed (see below), or when mass per unit time information is needed. There are two general types of composite samples.

- **Time composite samples** collect a fixed volume at equal time intervals and are acceptable when flow variability is not excessive. Automatically timed composited samples are usually preferred over manually collected composites. Composite samples collected by hand are appropriate for infrequent analyses and screening. Composite samples can be collected manually if subsamples have a fixed volume at equal time intervals when flow variability is not excessive.
- **Flow-proportional compositing** is usually preferred when Wastewater flow volume varies appreciably over time. The equipment and instrumentation for flow-proportional compositing have more downtime due to maintenance problems. When manually compositing Wastewater samples according to flow where no flow measuring device exists, use the influent flow measurement without any correction for time lag. The error in the influent and wastewater flow measurement is insignificant except in those cases where extremely large volumes of water are impounded, as in reservoirs. Use composite samples when either determining average concentrations, or calculating mass loading/unit of time.

There are numerous cases where composites are inappropriate. Samples for some parameters such as pH, residual chlorine, temperature, cyanides, volatile organic compounds, microbiological tests, oil and grease, and total phenols should not be composited. They are also not recommended for sampling batch or intermittent processes. Grab samples are needed in these cases to determine fluctuations in wastewater quality.

The compositing time period and frequency of aliquot collection should be determined. Whether collected by hand or by an automatic device, the time frame within which the sample is collected should be specified in the permit. The number of individual aliquots which compose the composite should also be specified. A minimum of four aliquots during a 24-hour period is common for wastewater composite samples.

7.5.5.1.3 Continuous Monitoring

Continuous monitoring is another option for a limited number of parameters such as total organic carbon (TOC), temperature, pH, conductivity, fluoride and dissolved oxygen. Reliability, accuracy and cost vary with the parameter. Continuous monitoring can be expensive, and has limited applicability to wastewater land treatment facilities. The environmental significance of the variation of any of these parameters in the wastewater should be compared to the cost of continuous monitoring equipment available.

Process control monitoring has been generally discussed both in Section 7.1.1 and Section 7.4.3.2. It refers to monitoring of internal waste streams in order to verify that proper waste treatment or control practices are being maintained. The wastewater treatment process will determine the types of process control monitoring needed.

Additional sampling information is given in the *Handbook for Sampling and Sample Preservation of Water and Wastewater*, EPA (1982).

7.5.5.2 Sampling Location Determination

Permanent sampling locations should be determined and identified in permit application materials. The permit applicant should provide a description of the wastewater sampling station location and in most cases, a line drawing and description of the flows and processes involved in wastewater treatment.

The point at which a sample is collected can make a large difference in the monitoring results. Important factors to consider in selecting the sampling station are:

- The flow at the sampling station should be measurable.
- The sample should be representative of the wastewater during the time period which is monitored.
- If possible, the sample should be collected where the wastewater is well-mixed. Therefore, the sample should be collected near the center of the flow channel, at a depth of approximately half the total depth, where the turbulence is at a maximum and the possibility of solids settling is minimized. Acceptable sampling locations can include near a Parshall flume or at a location in a sewer with hydraulic turbulence. Weirs tend to enhance the settling of solids immediately upstream and the accumulation of floating oil or grease immediately downstream. Such locations should be avoided for sampling.
- Skimming the water surface or dragging the bottom should be avoided.
- In sampling from a mixing zone, cross-sectional sampling should be considered. Dye may be use as an aid in determining the most representative sampling points.
- If manual compositing is employed, the individual sample bottles must be thoroughly mixed before pouring the individual aliquots into the composite container.

It is often convenient to combine a flow measurement station with a sampling station. When flumes are used for flow measurement, the sample is usually well mixed. Wastewater samples should be collected at a location which represents wastewater quality which is to be land applied. More than one wastewater sampling station may be necessary for two separate wastewater streams which are not mixed, but are land applied separately.

7.5.6 Analytical Methods

Table 7-29 presents analytical methods which are recommended for wastewater monitoring. Where more than one method is given, employ the method appropriate for the type of sample, its concentration range, the availability of equipment, and necessary detection limit. As discussed in Section 7.1.5, practical quantitation limits (PQLs) reported by the laboratory should be appropriate for constituents which have regulatory limits. The following references can be consulted for further information on wastewater analytical methods; EPA (1979/1983), Greenberg et al. (1992), Bordner and Winter (1978), and AOAC (1990).

For chlorine residual "free" chlorine should be specified. Metcalf & Eddy (1991) states "the main reason for adding enough chlorine to obtain a free chlorine residual is that usually disinfection can then be ensured." Chlorine residual monitoring and monthly reporting should be required in permits.

7.5.7 Quality Assurance and Quality Control

As discussed in Section 7.1.6.1, the facility should have a quality assurance project plan (QAPP). For more information on the development of a QAPP, refer to Section 7.1.6.

7.5.8 Data Processing, Verification, Validation, and Reporting

As with other types of monitoring, the system's permit will specify what parameters to monitor, when to monitor, and when results must be submitted. When reporting wastewater monitoring data, describe the sampling location and use the monitoring serial numbers designated in the permit.

Municipal permits should generally require monthly reports for hydraulic loading rates, chlorine residual, and total coliform. The need for this should be determined by the regional office. If monthly reports are necessary to maintain adequate system oversight, it can be specified in the permit.

7.5.9 References

AOAC. Association of Official Analytical Chemists, Official Methods of Analysis. 1990 15th Edition.

Bordner, R.H., and J.A. Winter, eds. 1978. "Microbiological Methods for Monitoring the Environment, Water and Waste." Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency. EPA-600/8-78-017.

CLFP. California League of Food Processors. September 20, 2002. Final Report: Manual of Good Practice for Land Application of Food Process/Rinse Water for California League of Food Processors. Brown and Caldwell, Kennedy Jenks, Komex H_2O Science.

EPA. U.S. Environmental Protections Agency. 1973. Handbook for Monitoring Industrial Wastewater. EPA 625-6-73-002.

EPA. U.S. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring Systems Laboratory-Cincinnati (EMSL-Cllll), EPA-600/4-79-020. Revised March 1983 and 1979 where applicable.

EPA. U.S. Environmental Protections Agency. 1982. Handbook for Sampling and Sample Preservation of Water and Wastewater. EPA-600/4-82-029.

EPA. U.S. Environmental Protection Agency. July 2004. NPDES Compliance Inspection Manual. Office of Enforcement and Compliance Assurance, Washington D.C.

Greenberg, A.E. et al. (eds). 1992. Standard Methods for the Examination of Water and Wastewater - 18th Edition.

Metcalf and Eddy (Eds. Tchobanoglous, G., and F. L. Burton). 1991. Wastewater Engineering – Treatment, Disposal, and Reuse. Metcalf and Eddy Inc. 3rd Edition. McGrawHill, Inc. 1334 pages.

Metcalf and Eddy (Revised by Tchobanoglous, G., F. L. Burton, and H.D. Stensel). 2003. Wastewater Engineering – Treatment, Disposal, and Reuse. Metcalf and Eddy Inc. 4th Edition. McGrawHill, Inc. 1819 pages.

7.6 Crop Monitoring and Yield Estimation

7.6.1 Monitoring Objectives

Crop monitoring includes maintaining chronology of cropping activities, plant tissue monitoring, and crop yield estimation. Cropping activity chronology would include dates of planting, harvest, tillage operations, fertilizer application, and dates where crop health was observed (CLFP, 2002 p. 10-18). Crop yield estimation is important to calculate crop uptake of nutrients and salts for regulatory compliance purposes.

Plant tissue monitoring is generally used to ascertain the nutrient status of a growing crop for managing fertilizer applications for maximizing crop yield and quality – i.e. for nutrient sufficiency and deficiency determination. Plant tissue monitoring is also conducted to determine feed value, nutrient toxicity and, in certain instances, the presence and concentration of toxic compounds, of a harvested crop.

The purpose of plant tissue monitoring as it pertains to permitted wastewater land treatment facilities is to determine crop uptake of nutrients and other constituents, and their removal from the treatment acreage. Crop uptake monitoring is discussed primarily in this section. Crop uptake monitoring data are used in nutrient and other constituent balance calculations in order to help characterize constituent losses to the environment. For example, if it is known how much nitrogen is in the soil in early spring, the amount of nitrogen applied in wastewater and fertilizers, how much is in the soil after harvest, and how much is taken up and removed by the crop, the difference represents losses of the constituent to the environment. Such loss estimates can then be partitioned into various pathways of loss, such as leaching and atmospheric losses. Estimates of leaching losses can then be used in conjunction with site-specific environmental data and modeling to help characterize the potential and degree of environmental impacts, such as those to ground water.

7.6.2 Monitoring Instrumentation

See Section 7.6.5.1 for description of sampling equipment used for plant tissue monitoring.

7.6.3 Monitoring Parameters

Parameters of interest for plant tissue monitoring at wastewater land application facilities include nitrogen, phosphorus, and some measure of inorganic salts.

7.6.3.1 Nitrogen

Nitrogen in plant tissue is typically measured from TKN analyses. TKN measures reduced forms of nitrogen in plant tissue including proteins and nitrogen in cellular tissues. The TKN analyses does not measure nitrate in plant tissue, so nitrate should be analyzed as well.

Nitrate concentrations in plant tissue can be significant in crops which have been grown with an abundance of supplied nitrogen. The presence of elevated nitrate levels in plant tissue can indicate that luxury consumption – crop uptake above the amount of nutrient a crop would normally need to take up to satisfy growth and development demands – has likely occurred.

Alternately, elevated nitrate levels in plant tissue can indicate nutrient stress; moisture stress; or cloudy, cool weather that can cause slow metabolism of nitrate to ammonia in the synthesis of amino acids in the plant.

Nitrate is also important to characterize because it can be toxic to animals. Lethal dose is determined by the nutritional state, size, and type of animal; and consumption of feed other than nitrate-containing material:

- Ruminant animals are most sensitive to nitrate intake, because nitrate is converted to nitrite in the rumen and nitrite binds and inactivates hemoglobin in the bloodstream.
- Concentrations of less than 1,000 mg/kg in the feed ration are acceptable for all cattle.
- Concentrations greater than 2,000 are not suitable for the entire feed ration and should be blended with other feed.
- Potentially lethal level of nitrate-nitrogen in animal feed is over 2,100 mg/Kg (Ensminger et al., 1990).

Nitrate in plant tissue can be chemically reduced to benign forms by green-chopping and ensiling and crop. This is a common practice at many wastewater land treatment facilities, not only for the removal of nitrate, but to achieve rapid removal of the harvested crop so that wastewater land treatment activities can proceed with only minimal delays.

7.6.3.2 Phosphorus

Phosphorus is also important to assess in plant tissue. A significant amount of phosphorus can be taken up by the crop and removed at harvest. Accounting for these amounts is important when determining permit limits for phosphorus loading to land application sites.

7.6.3.3 Salts

Inorganic salts are important to assess in plant tissue. Accounting for inorganic salt uptake in crops can be significant when modeling salt (i.e. TDS) impacts to ground water. The ash content of plant tissue is assumed to represent these salts. A significant amount of inorganics are taken up by the crop and removed at harvest.

7.6.4 Monitoring Frequency

Plant tissue monitoring for obtaining data for nutrient and other constituent balances is done at harvest. For hay crops, each cutting is a harvest, so samples should be obtained from each cutting and each hydraulic management unit. For crops that are harvested once at the end of their respective growing seasons, sampling should take place then.

7.6.5 Sampling and Sample Location Determination

7.6.5.1 Sampling

Only the plant parts that are removed from the site need be sampled. In the case of a hay crop, the entire plant top is cut and removed, so the entire plant should be sampled. In the case of small grains, if the grain and stover (above-ground plant parts excluding the seed) are both harvested and removed, both should be sampled. If the stover is left on site, then only the grain should be sampled.

CES (1997) outlines plant tissue sampling methods, which are summarized here. Plant tissue samples of green, growing crops such as forages should be taken immediately prior to harvest. Sampling forage crops immediately prior to harvest can result in 10 to 20 percent higher nitrogen levels because of plant tissue degradation following harvest. Samples should be collected to be representative of the crop at the time of harvest or just prior to harvest. Sampling of small areas of the field where plants are under severe moisture or temperature stress is not recommended. Plants that are dust covered, mechanically injured, diseased, or dead should not be sampled (Walsh and Beaton, 1973). The exception to this is when mechanical injury, disease or crop death is representative of the material being harvested. Crop tissue should be tested in these cases.

Samples should be collected at random locations in the hydraulic management unit. Specific crop types require particular sampling methods. For harvested grain, bean, silage or green chop, one grab sample from each day of harvest should be collected. They should be placed in paper bag and refrigerate, then mixed and a composite sample (1 liter wet or ½ liter dry) sent to the laboratory. For bailed hay, collect three composite samples from each harvest from each field. Each hay sample should be composited from at least ten cores from the ends of randomly selected bales. Then mix and send to the laboratory.

Potatoes require special sampling methods due to their size and the presence of two harvested plant parts, namely the potato and the vines. Collect on grab sample per day during harvest consisting of at least five potatoes. Quarter each potato and discard three of the quarters. Retain one quarter from each potato for a daily grab sample. Keep subsamples refrigerated and send all quarters to the laboratory for analysis. If the potato vines are to be burned, vine yield and nutrient (nitrogen only) uptake by the vines should be measured. Collect the vines from three four-foot sections of row in four locations in each hydraulic management unit (CES, 1997). Then reduce the sample size by splitting the pile of collected vines prior to shipping to the laboratory. Refrigerate after sampling and send at least 1 liter, but preferably one gallon, of volume of sample to the laboratory.

For forage crops, each sample should consist of the clippings from a minimum ten square feet of area. A square wooden frame or a wire whoop placed on the forage is effective to delineate the area to be sampled. The frame should be randomly dropped along a transect or grid pattern. The plants should be clipped within the frame at the same level that would result from the mechanical harvesting equipment. Hand operated or other clippers may be used.

Place each composite sample in a large paper bag so the sample can ‘breath’ (some sources recommend a perforated plastic bag). Put the sample in a cool place and deliver to the laboratory within two hours (CES, 1997). Ship or store samples in a chilled cooler if delivery in two hours cannot be accomplished. Delivery within 24 to 48 hours is acceptable if samples are kept dry and chilled in ‘breathable bags. Illinois (No Date) recommends a quick washing of plant tissue in a 0.1 – 0.3 percent non-phosphate containing detergent accompanied by three rinses in de-ionized water, in order to remove any dust, fertilizer, pesticide or other residues from the leaf surfaces.

As an alternative to collecting and transporting fresh plant tissue samples to the laboratory within short time-frames, samples may be dried in a clean muslin bag or tray inside a forced draft oven at 65 C for 48 hours. Tissue samples may then be ground after drying and placed in a bottle and allowed to dry for an additional 24 hours at 65 C. After this, samples are ready for analyses (Illinois, No Date). Walsh and Beaton (1973) may be consulted for further information regarding plant tissue sampling and analyses.

7.6.5.2 Sampling Location Determination

As mentioned in 7.6.4, each harvest of every crop on a hydraulic management unit should be sampled. Sampling within the hydraulic management unit is addressed in 7.6.5.1.

7.6.6 Analytical Methods

Table 7-12 presents analytical methods that are recommended for plant tissue sample analysis.

Table 7-12. Plant Tissue Analyses.

Parameter	**Abbreviations**	**Units**	**Recommended Methods(1)**
Crude Protein	--	% by weight	TKN * factor(2)
Total Kjeldahl Nitrogen	TKN	% by weight	978.04
Total Combustible Nitrogen	TCN	% by weight	990.03 Note: This method yields results comparable to TKN above and is becoming more commonly used.
Nitrate + Nitrite	NO3 + NO2	% by weight	968.07
Ash	--	% by weight	930.04
Moisture	--	% by weight	930.05

1. Association of Official Analytical Chemists, Official Methods of Analysis (AOAC). 1990 15th Edition. All methods cited in this appendix are recommended methods. Other comparable methods yielding the same interpretive results are acceptable unless otherwise stated in the Wastewater Reuse Permit.
2. Use 6.25 for mixed feeds and forages; 5.72 for grains.

7.6.7 Quality Assurance and Quality Control

As discussed in Section 7.1.6.1, the facility should have a quality assurance project plan (QAPP). For more information on the development of a QAPP, refer to Section 7.1.6.

7.6.8 Data Processing, Verification, Validation, and Reporting

As with other types of monitoring, the facility's permit will specify what parameters to monitor, when to monitor, and when results must be submitted. When reporting plant tissue monitoring data, describe the sampling location (hydraulic management unit) and use the monitoring serial numbers designated in the permit.

7.6.9 Crop Nutrient Content Reference Values

Wastewater land treatment sites that are loaded at agronomic rates or up to 150% of the agronomic rate are often required to have crop chemical analyses performed and make crop nutrient removal calculations. It may be appropriate for certain sites loaded at or below agronomic rates to use crop nutrient concentration values found in standard tables. Table 7-30 compiles nitrogen contents of a wide variety of crops. Sources of the data are documented in the footnotes. These sources include Follett et al. (1991), Fonnesbeck et al. (1984), NRCS (June 1999), and DEQ (1988). Ducnuigeen et al. (1997), Tables B-1, B-2, and B-3 provide a comprehensive source of non-crop species nitrogen and phosphorus uptake information. These tables are found at the following Web site:

http://www.potomacriver.org/info_center/publicationspdf/ICPRB97-4.pdf.

Table A-2 of Martin et al. (1976) provides typical ash, nitrogen, phosphorus, and moisture content information for cereal crops. Table A-1 of Martin et al. (1976) gives weight per bushel information for cereal crops. The USDA NRCS web site

http://www.nrcs.usda.gov/technical/land/pubs/nlapp1a.html

also provides nitrogen, phosphorus and potassium uptake rates. Bushel weights of common commodities are also found in Table 31 of Midwest Laboratories (No Date).

Typical yields for common Idaho crops by county and by year can be obtained from the Idaho Department of Agriculture, Agricultural Statistics Division. A useful Web site is the following:

http://www.nass.usda.gov:81/ipedbcnty/c_groupcrops.htm

7.6.10 Crop Yield Estimation

CES (1997) provides guidance on how to estimate crop yields from wastewater land treatment sites. This guidance is summarized here. The date of harvest should be recorded, as should the harvest method (bale, green chop, other) and crop type. The crop yield from each harvest, such as multiple cuttings, should be recorded. For forage crops, either the total measured weight method or average bale weight methods can be used, as discussed below. Both methods require the measurement of moisture content of the harvested material to calculate dry weight.

7.6.10.1 Total Measured Weight Method

The total measured weight method requires each truckload of harvested material to be weighed. This method is best suited to crops that are immediately removed from the field, including corn grain, corn silage small grains, potatoes, and green chopped hay.

The methodology is as follows:

(1) Measure each full truckload weight and empty truckload weight. The difference is the individual truckload weight of harvested material.

(2) Sum all individual truckload weights to obtain total harvested weight.

(3) Calculate the total dry matter weight as follows:

a. Total harvested weight (lbs) * (1 – moisture content expressed as a fraction) = total dry matter content (lbs)

b. Convert total dry matter to average yield as follows:

(4) Total dry matter content (lbs) divided by field size (acres) = average yield (lb/acre)

7.6.10.2 Average Bale Weight Method

The average bale weight method is best suited for forage crops or other crops removed in uniform discrete units. This method involves weighing at least 20 randomly chosen bales or one truck load of at least 20 randomly chosen bales. The average weight per bale of these bales is then calculated from individual bale weights. The total harvest weight consists of counting the number of bales from a field and multiplying by the average weight per bale. The total harvest weight of the field is converted to total dry matter weight and average yield in the manner described in items c. and d. in Section 7.6.10.1 above.

7.6.11 References

AOAC. Association of Official Analytical Chemists, Official Methods of Analysis. 1990 15th Edition.

CES. Cascade Earth Sciences, October 1997. Process Water Irrigation Systems: Design and Management. Soil and Crop Monitoring.

CLFP. California League of Food Processors. September 20, 2002. Final Report: Manual of Good Practice for Land Application of Food Process/Rinse Water for California League of Food Processors. Brown and Caldwell, Kennedy Jenks, Komex H_2O Science.

Ducnuigeen, J., K. Williard, and R.C. Steiner. September 1997. Relative Nutrient Requirements of Plants Suitable for Riparian Vegetated Buffer Strips. Interstate Commission on the Potomac River Basin. ICPRB Report Number 97 – 4.

Ensminger, M.E., J.E. Oldfield, and W.W. Heinemann. 1990. Feeds and Nutrition Digest. Second Edition. The Ensminger Publishing Company, Clovis, California. Page 103.

Fonnesbeck, P.V., H. Lloyd, R. Obray, and S. Romesburg. 1984. International Feed Institute Tables of Feed Composition. Intl. Feedstuffs Inst. Utah State Univ., Logan.

Follett, R.F., Keeney, D.R., and Crose, R.M., 1991. Managing Nitrogen for Ground Water Quality and Farm Profitability.

IDHW-DEQ. Idaho Department of Health and Welfare, Division of Environmental Quality. 1988. Guidelines for Land Application of Municipal and Industrial Wastewater.

Illinois, State of. No Date. Administrative Code, Title 35: Environmental Protection; Chapter II: Environmental Protection Agency; Part 391: Design Criteria for Sludge Application on Land; Section 391.530: Plant Tissue Sampling and Analyses.

Martin, J., W.H. Leonard, and D.L. Stamp. 1976. Principles of Field Crop Production – Third Edition. Macmillan Publishing Company, Inc. 1118 pp.

Midwest Laboratories. No Date. Agronomy Handbook. 132 pp.

USDA-NRCS. National Resource Conservation Service. National Engineering Handbook June 1999. Part 651, Agricultural Waste Management Field Handbook. U.S. Gov. Print. Office, Washington, DC.

Walsh, L.W., and J.D. Beaton (eds), 1973. Soil Testing and Plant Analysis, Revised Edition. Soil Science Society of America, Inc.