VEGETATION ASSESSMENT FIELD PROTOCOL

CONTENTS

CONTENTS (cont)

1.0 SCOPE AND APPLICATION

Ecological assessments of hazardous waste sites are required under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA). Vegetation is an important component of any ecosystem and is generally easily collected and calculated at a hazardous waste site. This Standard Operating Procedure (SOP) provides a protocol for the sequence of steps and selection of methods to evaluate the impact of contaminants on vegetation at hazardous waste sites. The ultimate goal is to provide information that site managers can use in risk assessments and remedial and/or removal decisions.

Specific instructions for some of the methods recommended in this SOP are described below or are available in other U.S. Environmental Protection Agency Environmental Response Team (U.S. EPA/ERT) Scientific, Engineering, Response, and Analytical Services (SERAS) SOPs. Application of other methods may require the use of published literature. A list of pertinent references is presented in Section 12.0. Analytical methods are cited in the Vegetation Assessment Quality Assurance Work Plan template (QAWP)(Appendix A).

This SOP may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure. Any changes in the SOP should be documented and clearly stated in the final deliverable.

The mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

2.0METHOD SUMMARY

Several methods are available to determine the impact to vegetation caused by site contaminants. Initially, steps must be taken to decide which methods are the most appropriate to achieve that goal. The preliminary steps in approaching an assessment are sequenced below, followed by methods that may be applied. These steps and methods are detailed in Section 7.0.

2.1 Sequence of Preliminary Steps

2.1.1 Site Information Acquisition

Prior to conducting a vegetation assessment, information on the type of contaminants, their magnitude and spatial distribution should be reviewed to determine study areas and symptoms of toxicity that might be observed. This information can be gathered, along with topographic maps, wetland inventory maps, soil maps, aerial photographs, and plant species lists, prior to visiting the site.

2.1.2 Initial On-site Survey

The next step is to visit the site, map the vegetation coverage, and identify species in the areas of interest. Areas without contamination (reference areas) should be examined and compared with the community composition in the contaminated areas. Reference areas should have similar physical conditions, such as soil type, hydrology, topography, and

vegetative community as the contaminated areas. Dominant species, or species of importance to area wildlife may be chosen as test species for further study. Visual examination of the soil particle size and organic matter content, and field measurement of soil pH and moisture will provide additional information that should later be confirmed by laboratory analyses.

2.2 Method Selection

2.2.1 Method Selection Considerations

The objectives and scope of the project should be established prior to the initiation of field work. The scientific basis for method selection will depend on the objective and scope as well as specific contaminants and the type of vegetative community present, site accessibility, or conditions that dictate the feasibility of certain methods.

2.2.2 Method Selection for Exposure and Potential Impact Source Determination

An extent of contamination study provides information on the concentration of contaminants that are present. However, the concentration of contaminants at any area may not reflect the amount available for plant uptake. Additional analyses may be conducted to provide this information. These analyses may include mild acid extraction for metals analysis, pore water analysis, and soil moisture content. Plant tissue and transpirational stream analyses may also yield additional information. Laboratory analyses should also include the nutrient content of the soils and plants. At a minimum, nitrogen, phosphorus and potassium should be analyzed. The importance of micronutrient analysis may be dictated by the soil type and the toxicity effects observed on indigenous biota.

2.2.3 Method Selection for Effects Determination

If uptake of contaminants by the plants is confirmed by chemical analyses, or simply suspected from observed evidence, the subsequent step is to quantify the effects of the contaminants on the plants. At the community level, a quantitative plot or transect study to determine species density, dominance and diversity may be conducted. Methods that can be applied at organism and community levels include productivity measurements such as dry matter biomass determinations, carbon/nitrogen determinations, tree ring analysis, and measurements of reproductive capacity (e.g., seed weight determination).

Limited information is available on the use of plant physiology experiments on hazardous waste sites. Most information available has been adapted from laboratory research or physiology studies associated with agricultural field experiments. One technique that is available is a portable field fluorometer. This laboratory instrument has been adapted for field use and measures the photosynthetic capacity of plants (by measuring chlorophyll fluorescence *in vivo*) located on hazardous waste sites. The photosynthetic rate of plants growing on a hazardous waste site may be compared to the same species growing in a reference area. This comparison may indicate that a reduction in photosynthetic rate may be due to a toxic response to chemicals.

Analytical studies are available that measure chlorophyll, protein content, and enzyme activity (such as peroxidase). The results of these studies may be used to determine molecular or organism level effects of chemicals to plants.

Endpoints of interest for future studies that should be considered include leaf area indices and gas exchange (CO_2/O_2) measurements. Data from leaf area measurements can be used with gas exchange, carbon/nitrogen, or biomass data to calculate the net assimilation rate. Net assimilation rate can be compared between plants collected at hazardous waste sites and from reference areas.

2.3 QAWP/SP Preparation

A QAWP or a Sampling Plan (SP) can be prepared once the objectives of the study are determined. The study must be designed so that the results can be analyzed using appropriate statistical techniques. Analysis of the data will be accomplished using computerized statistical software packages.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING AND STORAGE

The amount of sample to be collected and the proper sample container type (e.g., glass or plastic), preservative, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest, and are discussed in ERT/REAC SOP #2003, *Sample Storage, Preservation and Handling*, for the soil and water matrices. Sample preservation, containers, handling and storage for other types of samples are discussed in the specific SOPs for the technique selected. Plant tissue preservation, containers, handling and storage instructions are listed in Appendix A, and may require wet ice (4^oC), dry ice, or liquid nitrogen.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

The effects of contaminants have been demonstrated in controlled laboratory studies, but results from field tests are subject to interferences caused by variables including nonuniform plant age and natural genetic variability, microhabitats, normal environmental stresses, and incidental pollution not related to the site.

For example, temperature can be monitored in the field during assessments but the physiological effects of temperature fluctuation throughout a 24-hour period may be difficult to quantify. Water stress and other microenvironmental effects such as the sun and shade regimes of individual leaves within a plot are difficult to determine rapidly in the field. Air pollutants such as sulfur oxides (SO_x), nitrous oxides (NO_x), and ozone (O_3) may be a concern at many sites, especially under certain weather conditions and near urban areas. The ERT/REAC does not currently have the equipment to monitor these pollutants under ambient conditions. The site may also have been disturbed by mechanical clearing of vegetation or spraying of herbicides.

Conclusive statements about the phytotoxicity of contaminants on a site cannot be made without a knowledge of the site history and field measurements of as many uncontrolled variables as possible. Most types of data must be collected before seasonal degradation of leaves (senescence) and other herbaceous tissues. This usually occurs at the end of the growing season in most species.

5.0 EQUIPMENT

Listed below are common pieces of equipment needed for an initial field assessment:

- Camera and film
- Binoculars
- Compass
- Range finder
- Tape measure (300 feet)
- Survey tape
- Stakes or wire flags
- Munsell soil color charts
- Field guides to plants
- Soil tube augers
- Soil moisture/pH probe
- Small shovel or hand trowel
- Maps/aerial photos
- Logbook
- Knife/pruner
- Appropriate personal protective equipment

6.0 REAGENTS

Reagents are not required for preservation of plant tissue or soil samples. Samples should, however, be cooled to 4^{o}C and protected from sunlight in order to minimize any potential reaction due to the light sensitivity of the sample. Under some circumstances, plant tissue preservation may require storage under dry ice or liquid nitrogen (Appendix A).

Reagents may be utilized for preservation of water samples. The preservatives required are specified by the analyses to be performed and are summarized in ERT/SERAS SOP #2003, *Sample Storage, Preservation and Handling*. Reagents are discussed in the specific SOPs for the techniques selected.

Decontamination solutions are specified in ERT/SERAS SOP #2006, *Sampling Equipment Decontamination*.

7.0 PROCEDURES

7.1 Preliminary Steps

7.1.1 Site Information Acquisition

7.1.1.1 Site-Specific Information

Information on site history and contaminants may be available from state or federal agencies or through the U.S. EPA/ERT Work Assignment Manager. This information may include sampling reports from prior investigations, Remedial

Investigation/Feasibility Studies (RI/FS), extent of contamination investigations, and Resource Conservation and Recovery Act (RCRA) documents. Meteorological data should also be obtained from the National Weather Services or Accu-Weather for the weather station nearest the site.

7.1.1.2 Aerial Photographs

Conventional and infrared photographs are available covering much of the United States (conventional since 1938, infrared since the 1950's) and can be used for historical evaluation of sites. Infrared photographs may be useful in differentiating between areas of healthy and unhealthy plants and in delineating land cover.

Aerial photographs can be acquired from the following resource centers:

Earth Resources Observation Satellite Data Center
U.S. Geological Survey
Mundt Federal Building
Sioux Falls, SD 57198
(605) 594-6511

Agricultural Stabilization and Conservation Service
Aerial Photography Field Office
2222 West 2300 South
P.O. Box 30010
Salt Lake City, UT 84130
(801) 524-5856

Aerial photographs for hazardous waste sites may be obtained from the following sources (available through the Freedom of Information Act, National Cartographic Information Center):

U.S. Environmental Protection Agency (EPA)
Remote Sensing Branch
P.O. Box 93478
Las Vegas, NV 89193-3478
(702) 798-2100
U.S. EPA Photographical Interpretation Center
Building 166
Bisher Road
Vint Hill Farms Station
Warrenton, VA 22186-5129

When aerial photographs are requested, the latitude and longitude and a map of the site will be submitted. Aerial photos with scales of 1:600 to 1:8,000 are practical for detecting plant stress and identifying vegetation types. Scales up to 1:24,000 are acceptable for land cover delineation. The appropriate scale should

be specified when ordering photographs.

7.1.1.3 Remotely-Sensed Data

Data is available from the Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM), System Probatoire d'Observation dela Terre (SPOT), and also Shuttle-Imaging Radar (SIR). This satellite data has been shown to be useful in characterizing vegetation over relatively large areas. The data may be used on sites larger than 100 km^2, and for quantitative data where monospecific vegetation dominates areas several times as large as the pixels (units of resolution: MSS 80 meters [m], TM 30 m, and SPOT 20 m).

Satellite data should be obtained from centers which can provide interpreted materials, as the technology and expertise required to digitize and interpret the complex data sets are substantial.

Data can be acquired from one of the following resource centers:

EOSAT Services
4300 Forbes Blvd.
Lanham, MD 20706
(800) 344-9933

Earth Resources Observation Satellite Data Center
U.S. Geological Survey
Mundt Federal Building
Sioux Falls, SD 57198
(605) 594-6511

Environmental Data & Information Service
Satellite Data Services Division
Room 100
Princeton Executive Center
5627 Allentown Road
Camp Springs, MD 20746
(301) 763-8400

7.1.1.4 Topographic and Wetland Inventory Maps

Standard topographic quadrangle maps, 7.5 minute series (1:24,000 scale), are produced by the U.S. Geological Survey (USGS), and may be obtained from distributors. The quadrangles are usually named after the most prominent feature in the quadrangle. The site area may lie in more than one quadrangle.

National Wetland Inventory maps are produced by the U.S. Fish and Wildlife Service (USFWS) as paper supplements or mylar overlays to the 7.5-minute series maps. Areas are demarcated and described on Wetland Inventory maps

by their vegetation and hydrological characteristics.

Extra copies of all maps should be made or ordered, so that marks and notations may be made on them in the field. These maps may be ordered from distributors, or from Earth Science Information Center Offices:

National Center	Reston, VA	(703) 648-6045
Rocky Mountain	Denver, CO	(303) 236-5829
Mid-Continent	Rolla, MO	(314) 341-0851
Alaska	Anchorage,, AL	(907) 751-6277
Western	Menlo Park, CA	(415) 329-4309
or call:	1-800-USA-MAPS	

7.1.1.5 Soil Surveys

Soil surveys can be obtained from the U.S. Department of Agriculture (USDA) Soil Conservation Service Office in the county in which the site is located. Soil surveys contain a wide range of information on natural resources, soil properties, hydrology, use and management, and types of wildlife and vegetation the soils will support.

7.1.1.6 Endangered Species Lists

Lists of endangered species that may be found in the vicinity of a site can be obtained from State sponsored Natural Heritage Programs and local sources.

7.1.1.7 Regional Plant Species Lists/Field Guides

Species lists for plants that occur in wetlands are published for the various regions of the country by the USFWS. These also contain the names of many plants that occur in upland areas. Universities, and organizations such state Natural Heritage Programs and national and state level Audubon Societies, may also be consulted. Field guides currently available to ERT/SERAS are listed in Section 12.0.

7.1.2 Initial On-Site Survey

7.1.2.1 Ground Truthing

Activities and observations conducted during the initial on-site survey should define the ecosystem type and areas of concern, areas that need further study, and ground-truthing (i.e., verifying the validity of maps and other information). After the initial survey, a QAWP/SP can be written using existing data as well as on-site observations.

Since there may be only one trip allotted for a site visit, the study may have to be planned without the benefit of observing the site. In this case the initial on-

site survey will take place immediately upon arrival at the site, and an assessment must be made to determine whether the SP will be applied in whole or in part, or modified. Any changes to the QAWP or the SP will be agreed upon with the ERT Work Assignment Manager and documented in site or personal logbooks and the final deliverable.

7.1.2.2 Vegetation Cover Mapping

A vegetation cover map should be developed during the survey, identifying dominant cover types, marking zones of transition between communities, and qualitatively describing the habitat. Plants should be identified in the field whenever possible. Plants that cannot be identified should be collected for taxonomic verification in the laboratory. The procedure is discussed in ERT/SERAS SOP #2037, *Terrestrial Plant Community Sampling*. Diagrams with compass bearings and distance estimates from landmarks can be drawn in a personal or site logbook, or features may be marked and noted on a site map or aerial photograph. The diagrams and notations must contain sufficient information to create an accurate finished map.

7.1.2.3 Sampling Area Selection

Areas to be sampled will be chosen based on the levels of contaminants and the objectives of the study. For example, if the objective of the study is to determine the levels of soil/sediment contaminant concentration that result in impacts to plants, then sampling quadrates should be selected along a contaminant gradient ranging from the most contaminated areas to the reference area. If the objective is to determine that soil/sediment contamination will be removed to an intermediate level, then sampling quadrattes should be selected in areas with contamination at that level and below, to determine whether further removal is necessary. Additionally, for physiological measurements, it may be necessary to place the quadrattes so that all quadrattes will contain the species identified as the target(s) of the study.

Areas without contamination (reference areas) should be examined and compared with the community composition in the contaminated areas. Reference areas should have the same physical conditions, such as soil type, hydrology and topography, as the contaminated areas.

It may be obvious that upland and wetland areas cannot be compared, however, other differences critical to some studies may be less obvious. A quantum (light) meter and soil moisture probe should be used to determine if habitats are similar. Soil type should be checked using soil survey maps and by using tools such as a tube auger or shovel to reveal the soil profile and hydrology. Soil colors should be compared with the aid of a Munsell Soil Color Chart. Soil pH should be checked in the field. Soil texture should be examined qualitatively and any anomalies (e.g., mottles) should be noted. Estimates should be made of the amount of shade from trees, other plants and permanent structures during an

average day for each quadrate.

7.2 Method Selection

7.2.1 Method Selection Considerations

Methods to be used in the study must be selected after review of acquired information and initial survey observations.

7.2.1.1 Project Scope

The scope of the project (i.e., the level of effort and amount of resources required) will be determined by the objectives of the study. The overriding question in any ecological assessment is whether or at what concentrations the contaminants are impacting the biota at the site. More specific questions may be asked, such as: "Have the contaminants altered the natural community structure?" or "Is the photosynthetic capacity of the community as a whole reduced by the contaminants, and by how much?" If the level of effort and resources required to answer the questions are not available, the questions must be modified or changed.

7.2.1.2 Scientific Basis

The scientific basis for method selection will depend on the specific contaminants and the type of vegetative community present.

(a) Certain methods may be especially suited to one or a specific type of contaminant, as are certain enzyme assays. Other methods may be effective for a wide variety of contaminants. Literature should be consulted when contaminants for a site are known, to identify new or more sensitive methods for a specific application. Literature searches for affects of specific contaminants can be conducted through scientific citation databases. This service is available through the U.S. EPA Environmental Response Center (ERC).

(b) Tree ring analysis can be conducted in plant communities that contain trees of sufficient diameter, however, this method requires a certain amount of interpretive skill. Reproductive capacity can be used in communities that propagate by seed and not vegetatively; and direct biomass measurements can be made in uniform communities without woody plants. Further stipulations are listed in the specific SOP for the method in question.

7.2.1.3 Site Limitations

There may be limits to accessibility or barriers and conditions which might dictate that only certain methods are feasible. Access must be gained for legal entry to all areas to be studied. This may involve seeking permission from land owners. Accessibility may also be limited by steep slopes, fast-moving currents

in rivers and streams, or other physical barriers. Also, season and weather conditions may hinder a method.

7.2.2 Method Selection for Exposure and Potential Impact Source Determination

7.2.2.1 Soil/Sediment

(a) Contaminant Analysis

Analytes, methods, holding times, containers and volumes required are listed in Appendix A. The ERT/SERAS SOPs to be followed for sampling methods include #2012, *Soil Sampling* and #2016, *Sediment Sampling*. When possible, method(s) that determine the concentrations of contaminants available to the plant should be used.

(b) Indirect Measures of Contaminant Availability

Chemical and physical factors important in determining whether contaminants are available for uptake include particle size distribution (grain size), total organic carbon and pH. Methods to determine the available concentrations, holding times, containers, and volumes required are listed in Appendix A.

(c) Nutrient Analysis

For most site sampling, only analyses for nitrogen (N), phosphorus (P) and potassium (K) need be conducted. These analyses should measure the available N, P and K forms used by the plant. Baseline studies conducted prior to remediation or testing of remediated soils should include the complete list of macro- and micronutrients.

If plant tissue is to be sampled, the soil/sediment sample must be taken from the root zones of the specific plants to be sampled. The plant tissue samples should be cross-referenced but not have the same sample number as the soil sample collected from its root zone. The percent solids must be determined for all soil and sediment samples, so that the analyte concentration can be presented on either a wet or dry weight basis.

7.2.2.2 Water

(a) Contaminant Analysis

In aquatic or wetland habitats, surface water should be sampled since contaminants can be absorbed by the stems, leaves, and roots of plants living in and around open water. The samples may be taken at various depths and, depending on the objectives of the study, filtered through a 0.45 micrometer filter. Analytes, methods, holding times, containers, and volumes required are listed in Appendix A. Sampling methods should be conducted in accordance

with ERT/SERAS SOP #2013, *Surface Water Sampling*.

Porewater samples should be taken in addition to soil/sediment bulk chemistry samples as a measure of contaminant availability, especially in shallow-depth or saturated conditions. Several methods are available (see Section 12.0), and the literature should be consulted for the most effective method for a particular application.

Exposure may also be determined by extracting a water sample directly from the transpirational stream of a plant using a Vacutainer™. The plant stem is cut several centimeters above the ground using pruning shears and one end of a double-ended hollow needle is sealed to the cut stem with rubber tubing and grafting paint. The other end of the Vacutainer is inserted into a 20-millimeter (mL) Vacutainer™ tube, and the sap is sucked into the tube. If contaminants are being taken up and transported through the plant, they may be detected in this sample. This may be especially useful for organic compounds, which may not be detectable in tissue analyses due to volatilization or rapid metabolism by the plant. Consult the literature referenced in Section 12.0 for use of this method.

(b) Water Quality Parameters

Parameters measured by the Hydrolab Surveyor II (temperature, dissolved oxygen, pH, conductivity and oxidation reduction potential) are important in assessing standard habitat characteristics. Ambient water quality monitoring is described in ERT/SERAS SOP #2041, *Operation of the Hydrolab Surveyor II Water Quality Measurement System*.

(c) Nutrient Analysis

Porewater and surface water should be sampled in wetland habitats. Nutrient analysis should be conducted for dissolved potassium, nitrogen (as ammonium), nitrate, and phosphorus (as phosphate). Methods, holding times, containers, and volumes required are listed in Appendix A.

7.2.2.3 Plant Tissue

(a) Contaminant Analysis

Analytes, methods, holding times, containers, and amounts of tissue required are listed in Appendix A. Tissues may be separated into leaves, stems, roots and reproductive parts to determine contaminant partitioning, depending upon the goals of the study. For food chain studies, parts consumed by the animals being studied should be analyzed and consideration should be given to analyses with and without washing the tissues. For most plant physiological studies, only the leaves need be sampled. In this case, the leaves should be washed prior to analysis so that only contaminants that have been internalized will be detected. A Plant Tissue Sampling Field data sheet is attached as Appendix B. This data

sheet can be used to record all pertinent information regarding the collection and analysis of plant tissue.

Herbaceous tissues are only sampled during the growing season, prior to senescence and frost. Woody tissues may be sampled at any time. Tree rings from a tree core sample may be analyzed individually to determine the time of onset of contaminant uptake and the annual exposure. Consult ERT/SERAS SOP #2036, *Tree Coring and Interpretation*, and the literature for appropriate methods.

(b) Elemental Composition Analysis

Total carbon, nitrogen, phosphorus and potassium should be determined in the same leaf tissues analyzed for contaminants and physiological parameters. These data will indicate nutrient uptake efficiency and a component of productivity and resource allocation efficiency (carbon to nitrogen ratio). Methods, holding times, containers, and volumes required are listed in Appendix A.

The percent solids must be determined on all plant tissue samples, so that the analyte concentration can be presented on a dry weight basis. This will enable appropriate comparisons between tissue type, species and soil concentrations.

7.2.3 Method Selection for Effects Determination

7.2.3.1 Community/Population/Organism Effects

(a) Community Composition/Quadrat and Transect Sampling

Quantitative techniques, including quadrate and transect sampling are described in ERT/SERAS SOP #2037, *Terrestrial Plant Community Sampling*. Quadrattes and transects are used to collect information that will be evaluated for shifts in community structure as a function of site contamination. The choice of appropriate sampling technique (i.e., quadrattes or transects) depends upon site characteristics, plant characteristics, and study objectives. Values for species density, coverage, and frequency will be computed. The data may also be used for diversity and similarity calculations and cluster analyses.

(b) Biomass

Biomass can be determined as a measure of primary productivity. The method is described in ERT/SERAS SOP #2034, *Plant Biomass Determination*. The data can be used with growth measurements or leaf area measurements to gauge the efficient use of environmental resources by the plant, population or community.

(c) Reproductive Capacity

Reproductive capacity measurements involve the collection of seeds from plants that reproduce sexually and that do not usually propagate vegetatively. Seeds are collected from plants in the study units (e.g., quadrats), counted, and weighed. Seed collection can only be performed at the time of the growing season when the species under study is bearing sufficiently matured reproductive structures. Knowledge of any unusual germination requirements of the species tested should be obtained. The collected seeds may be placed in water or soil and allowed to germinate. The percent of seeds from the contaminated and reference areas that germinate are calculated.

(d) Growth

Growth is usually measured as a rate, over time. Changes in growth over several years can be measured by examining tree rings. This is discussed in ERT/SERAS SOP #2036, *Tree Coring and Interpretation*. Most growth measurements, however, cannot be made over the course of one site sampling event. For some sites, multiple sampling events may be possible. In these cases, measurements of changes in plant height and leaf area for native plants can be made, or *in situ* toxicity tests may be installed and monitored.

7.2.3.2 Organism/Metabolic System Effects

(a) Photosynthetic Capacity Measurement using *In Vivo* Chlorophyll Fluorescence

The procedure involves attaching clips called "dark-adapting cuvettes" to the leaves of the plants. Adapting the leaves to darkness essentially brings the chlorophyll molecules in all the plant tissues to a baseline state so that valid comparisons can be made. After dark adaptation, light from a light source is introduced to the tissue through the cuvette by a fiber optic cable. The chlorophyll molecules in the tissue emit fluorescent light, and the signal recorded is the fluorescence signature for that plant. It is called a fluorescence induction curve. The curves can be compared between the contaminated and reference areas, and with curves published in the literature, if available. Key parameters that are calculated from the curves by the instrument's computer can be downloaded to a personal computer for statistical analysis.

This method is likely to be most useful in cases of herbicide contamination but has also shown differences between controls and plants exposed to heavy metals. There is evidence that polychlorinated biphenyls (PCBs) inhibit photosynthesis. Little work has been done concerning volatile and semivolatile organic contaminants. Gas exchange and radioisotope methods should be considered for future projects.

(b) Chlorophyll Content

Determination of chlorophyll content in leaf tissue is a method used to determine the photosynthetic fitness of a plant. The method is described in ERT/SERAS SOP #2030, *Chlorophyll Determination*. This method may be most useful in certain cases of metal contamination.

(c) Enzyme Activity

The most tested enzyme method is the peroxidase activity test. This method is discussed in ERT/SERAS SOP #2035, *Plant Peroxidase Activity Determination*. Peroxidase is temperature-stable when compared to other enzymes, it is involved in several physiological roles in plants, and it is found throughout the plant kingdom. Peroxidase has shown sensitivity toward several metals (cadmium, chromium, copper, manganese, selenium, lead, zinc, mercury and nickel), a polycyclic aromatic hydrocarbon compound (anthracene) and a sulfometuron methyl herbicide.

Several other enzymes have also shown sensitivity to various heavy metals. These include -aminolevulinic acid dehydratase (lead and mercury), ribulose 1,5 bisphosphate carboxylase/oxygenase (also known as RubisCo; lead, cadmium, copper, zinc, nickel, cobalt and manganese), and superoxide dismutase, glucose-6-phosphate dehydrogenase, glutamate dehydrogenase and isocitrate dehydrogenase (zinc and cadmium). Superoxide dismutase has also shown sensitivity toward potassium cyanide.

(d) Protein Determination

The analysis of plant proteins can be used as a basis for normalizing enzyme or chlorophyll data, as described in ERT/SERAS SOP #2033, *Plant Protein Determination.*

7.3 QAWP/SP Preparation

Once the methods have been selected, a QAWP must be written. A standard Vegetation Assessment QAWP template, which lists the methods and analyses available, is attached as Appendix A. If a vegetation assessment is to be conducted in conjunction with other activities, the Vegetation Assessment QAWP can be combined with the standard site work QAWP or other information as necessary.

The SP will be site-specific and will contain essentially an expanded and detailed description of the Technical Approach section (Section 3.0) of the QAWP. The SP will contain supporting information from SOPs and applicable literature. The study will be designed so that the resulting data can be analyzed using appropriate statistical techniques. Personnel trained in statistics should be consulted during the design phase of the experiment. Analysis of the data will be accomplished using computerized statistical software packages.

8.0 CALCULATIONS

Calculations, where necessary, are presented in the specific SOP for the technique selected.

9.0 QUALITY ASSURANCE/QUALITY CONTROL

There are no specific quality assurance activities which apply to the implementation of these procedures. However, the following general QA procedures apply:

1. All data must be documented on field data sheets or within site or personal logbooks.

2. A QAWP/SP, including numbers and sample size, will be written prior to sampling.

3. All deliverables will receive a peer review prior to release, and 10% of the calculations will be rechecked.

4. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and they must be documented.

10.0 DATA VALIDATION

The project's data quality objectives will be stated in the QAWP. Data validation will be conducted according to those objectives.

11.0 HEALTH AND SAFETY

The preparation of a Health and Safety Plan is required prior to any field activity. When working with potential hazardous materials, follow U.S. EPA, OSHA, and SERAS health and safety procedures.

12.0 REFERENCES

AERIAL PHOTOGRAPHY AND REMOTE SENSING

Applied Infrared Photography. 1981. Publication No. M-28. Rochester, New York: Eastman Kodak Company.

Avery, T.E. 1977. Interpretation of Aerial Photographs. 3rd ed. Minneapolis, Minnesota: Burgess Publishing Company.

Becker, F., F. Nerry, P. Ramananesizehena and J. Fischer. 1988. "Towards a quantitative use of aerial color infrared films." *Photogrammetric Engineering and Remote Sensing*. 54:743-750.

Everitt, J.H., D.E. Escobar, M.A. Alanig and M.A. Hussey. 1987. "Drought stress detection of buffelgrass with color infrared aerial photography and computer-aided image processing." *Photogrammetric Engineering and Remote Sensing*. 53:1255-1258.

Lyon, J.G. 1987. "Use of maps, aerial photographs, and other remote sensor data for practical evaluations

of hazardous waste sites." *Photogrammetric Engineering and Remote Sensing*. 53:515-519.

National Research Council (NRC). 1974. *Remote sensing for resource and environmental surveys: A progress review.* Washington, D.C. National Academy of Sciences. p. 101.

Rock, B.N., J.E. Vogelmann, D.L. Williams, A.F. Vogelmann and T. Hoshizaki. 1986. "Remote detection of forest damage." *Bioscience*. 36:439-445.

Welch, R., M. Madden Remillard and R.B. Slack. 1988. "Remote sensing and Geographic Information System techniques for aquatic resource evaluation." *Photogrammetric Engineering and Remote Sensing*. 54:177-185.

CHLOROPHYLL

Singh, A. 1988. "Heavy metal influences chlorophyll content in Indian pasture legume." *Photosynthetica*. 22(1):125-126.

Singh, K.K. and L.C. Mishra. 1988. "Reduction in chlorophyll and energy contents in plants as indicators of atmospheric pollution." *Photosynthetica*. 22(1):129-132.

Mirecki, R.M. and A.H. Teramura. 1984. "Effects of ultraviolet-B irradiance on soybean." *Plant Physiology*. 74:475-480.

CHLOROPHYLL FLUORESCENCE/PHOTOSYNTHESIS

Arndt, U. 1974. "The Kautsky-Effect: A method for the investigation of the actions of air pollutants in chloroplasts." *Environmental Pollution*. 6:181-195.

Bolhar-Nordenkampf, H.R., S.P. Long, N.R. Baker, G. Oquist, U. Schreiber and E.G. Lechner. 1989. "Chlorophyll fluorescence as a probe of the photosynthetic competence of leaves in the field: a review of current instrumentation." *Functional Ecology*. 3:497-514.

Croxdale J.G. and K. Omasa. 1990. "Chlorophyll a fluorescence and carbon assimilation in developing leaves of light-grown cucumber." *J. Plant Physiology*. 93:1078-1082.

Krause, H.G. and E. Weis. 1988. "The photosynthetic apparatus and chlorophyll fluorescence: An introduction." In: *Applications of Chlorophyll Fluorescence.* Ed. H.K. Lichtenthaler. Dordrecht, Netherlands: Kluwer Academic Publishers. p. 3-11.

Lavorel, J. and A.L. Ettienne. 1977. "*In vivo* chlorophyll fluorescence." In: *Primary Processes of Photosynthesis.* Ed. J. Barber. Amsterdam. Elsevier/North Holland Biomedical Press, .

Lichtenthaler, H.K. 1988. "*In vivo* chlorophyll fluorescence as a tool for stress detection in plants." In: *Applications of Chlorophyll Fluorescence*. Ed. H.K. Lichtenthaler. Dordrecht, Netherlands: Kluwer Academic Publishers. p. 129-142.

Lichtenthaler, H.K. and U. Rinderle. 1988. "The role of chlorophyll fluorescence in the detection of stress

conditions in plants." *CRC Critical Reviews in Analytical Chemistry*. 19(1):529-585.

Miles, D. 1980. "Mutants of higher plants." In: *Methods in Enzymology*. New York, New York: Academic Press. p. 2-23.

Oquist, G. and R. Wass. 1988. "A portable, microprocessor operated instrument for measuring chlorophyll fluorescence kinetics in stress physiology." *Physiologia Plantarum*. 73:211-217.

Papageorgiou, G. 1975. "Chlorophyll fluorescence: An intrinsic probe of photosynthesis." In: *Bioenergetics of Photosynthesis*. Ed. J. Govindjee. New York, New York: Academic Press. p. 320-366.

Samson, G. and R. Popovic. 1988. "Use of algal fluorescence for determination of phytotoxicity of heavy metals and pesticides as environmental pollutants." *Ecotoxicology and Environmental Safety*. 16:272-278.

Schafer, C. and O. Bjorkman. 1989. "Relationship between efficiency of photosynthetic energy conversion and chlorophyll fluorescence quenching in upland cotton (*Gossypium hirsutum* L.)." *Planta*. 178:367-376.

Schreiber, U., W. Vidaver, V.C. Runeckles, and P. Rosen. 1978. "Chlorophyll fluorescence assay for ozone injury in intact plants." *J. Plant Physiology*. 61:80-84.

Sivak, M.N. and D.A. Walker. 1985. "Chlorophyll a fluorescence: can it shed light on fundamental questions in photosynthetic carbon dioxide fixation?" *Plant, Cell, and Environment*. 8:439-448.

Smillie, R.M. and R. Nott. 1982. "Salt tolerance in crop plants monitored by chlorophyll fluorescence *in vivo*." *J. Plant Physiology*. 70:1049-1054.

van Kooten, O. and J.F.H. Snel. 1990. "The use of chlorophyll fluorescence nomenclature in plant stress physiology." *Photosynthesis Research*. 25:147-150.

Walker, D.A. 1988. "Some aspects of the relationship between chlorophyll a fluorescence and photosynthetic carbon assimilation." In: *Applications of Chlorophyll Fluorescence*. Ed. H.K. Lichtenthaler. Dordrecht, Netherlands: Kluwer Academic Publishers. p. 13-20.

Walker, D.A. 1981. "Secondary fluorescence kinetics of spinach leaves in relation to the onset of photosynthetic carbon assimilation." *Plants*. 153:273-278.

Walker, D.A., P. Horton, M.N. Sivak and W.P. Quick. 1983. "Anti-parallel relationship between O_2 evolution and slow fluorescence induction kinetics." *Photobiochemistry and Photobiophysics*. 5:35-39.

COMMUNITY SAMPLING

Simpson, R.L., R.E. Good, M.A. Leck, and D.F. Whigham. 1983. "The Ecology of Freshwater Tidal Wetlands." *BioScience*. 33:255-259.

Odum, W.E., T.J. Smith III, J.K. Hoover and C.C. McIvor. 1984. "The Ecology of Tidal Freshwater Marshes of the United States East Coast: A Community Profile." Washington, D.C. U.S. Fish and

Wildlife Service Report FWS/OBS-83/17.

Brower, J.E. and J.H. Zar. 1984. "Field and Laboratory Methods for General Ecology." 2nd ed. Dubuque, Iowa: Wm. C.Brown.

United States Armey Corps of Engineers. 1989. "Federal Interagency Committee for Wetland Delineation." Washington, D.C: U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S.D.A. Soil Conservation Service.

CONTAMINANTS

CYANIDE

Alstrom, S., and R.G. Burns. 1989. "Cyanide production by rhizobacteria as a possible mechanism of plant growth inhibition." *Biology and Fertility of Soils*. 7:238.

Sesay, A., C.R. Stewart and R. Shibles. 1988. "Cyanide-resistant respiration in light- and dark-grown soybean cotyledons." *Plant Physiology*. 87:655-659.

Wallace, A., J.W. Cha, and R.T. Mueller. 1977. "Cyanide effects on transport of trace metals in plants." *Communications in Soil Science and Plant Analysis*. 8:709-712.

HEAVY METALS

Baker, A.J.M. 1987. "Metal tolerance." *The New Phytologist*. 106:93-111.

Baker, A.J.M., C.J. Grant, M.H. Martin, S.C. Shaw and Whitebrook J. 1986. "Induction and loss of cadmium tolerance in *Holcus lanatus* L. and other grasses." *The New Phytologist*. 102:575-587.

Baker, A.J.M. 1984. "Environmentally-induced cadmium tolerance in the grass *Holcus lanatus* L." *Chemosphere*. 13(4):585-589.
Baker, A.J.M. 1981. "Accumulators and excluders-strategies in the response of plants to heavy metals." *Journal of Plant Nutrition*. 3(1-4):643-654.

Barry S.A.S. and S.C. Clark. 1978. "Problems of interpreting the relationship between the amounts of lead and zinc in plants and soil on metalliferous wastes." *The New Phytologist*. 81:773-783.

Baszynski, T., A. Tukendorf, M. Ruszkowska, E. Skorzynska, and W. Maksymiec. 1988. "Characteristics of the photosynthetic apparatus of copper non-tolerant spinach exposed to excess copper." *J. Plant Physiology*. 132:708-713.

Bradley R., A.J. Burt and D.J. Read. 1981. "The biology of mycorrhiza in the Ericaceae, VIII. The role of mycorhizal infection in heavy metal resistance." *The New Phytologist*. 91:197-209.

Brown M.T. and D.A. Wilkins. 1984. "Zinc tolerance of mycorhizal *Betula*." *The New Phytologist*. 99:101-106.

Buchauer, M.J. 1973. "Contamination of soil and vegetation near a zinc smelter by zinc, cadmium, copper, and lead." *Environmental Science and Technology*. 7(2):131.

Carlson, R.W., and F.A. Bazazz. 1977. "Growth reduction in American Sycamore (*Plantanus occidentalis*) caused by Pb-Cd interaction." *Environmental Pollution*. 12:243-253.

Carlson, R.W., F.A. Bazazz and G.L. Rolfe. 1975. "The effect of heavy metals on plants ll. Net photosynthesis and transpiration of whole corn and sunflower plants treated with Pb,Cd, Ni, and Tl." *Environmental Research*. 10:113-120.

Coughtrey, P.J. and M.H. Martin. 1978. "Tolerance of *Holcus lanatus* to lead, zinc and cadmium in factorial combination." *New Phytologist*. 81:147-154.

Cox R.M. and T.C. Hutchinson. 1980. "Multiple metal tolerances in the grass *Deschampsia cespitosa* (L) Beauv from the Sudbury smelting area." *The New Phytologist*. 84:631-647.

Cox R.M. and T.C. Hutchinson. 1981. "Multiple and co-tolerance to metals in the grass *Deschampsia cespitosa*: Adaptation, preadaptation and cost." *J. Plant Nutrition*. 3(1-4):731-741.

Foy C.D., R.L. Chaney and M.C. White. 1978. "The physiology of metal toxicity in plants." *Annual Reviews in Plant Physiology*. 29:511-66.

Gingas V.M., T.D. Sydnor and T.C. Weidensaul. 1988. "Effects of simulated acid rain on cadmium mobilization in soils and subsequent uptake and accumulation in poplar and sunflower." *J. American Society of Horticultural Science*. 113(2):258-261.

Godbold, D.L. and A. Huttermann. 1988. "Inhibition of photosynthesis and transpiration in relation to mercury-induced root damage in spruce seedlings." *Physiologia Plantarum*. 74:270-275.

Grill, E., E.L. Winnacker and M.L. Zenk. 1985. "Phytochelatins: The principal heavy-metal complexing peptides of higher plants." *Science*. 230:674-676.

Homer, J.R., R. Cotton and H.E. Evans. 1980. "Whole leaf fluorescence as a technique for measurement of tolerance of plants to heavy metals." *Oecologia (Berl.)*. 45:88-89.

John, M.K., C.J. VanLaerhoven and H.H. Chuah. 1972. "Factors affecting plant uptake and phytotoxicity of cadmium added to soils." *Environmental Science and Technology*. 6(12):1005-1008.

Lawrence, G.B., R.D. Fuller and C.T. Driscoll. 1987. "Release of aluminum following whole-tree harvesting at the Hubbard Brook Experimental Forest, New Hampshire." *Journal of Environmental Quality*. 16(4):383-390.

Lolkema, P.C., M.H. Donker, A.J. Schouten and W.H.O. Ernst. 1984. "The possible role of metallothioneins in copper tolerance of *Silene cucubalus*." *Planta*. 162:174-179.

McNaughton, S.J., T.C. Folsom, T. Lee, F. Park, C. Price, D. Roeder, J. Schmitz and C. Stockwell. 1974. "Heavy metal tolerance in *Typha latifolia* without the evolution of tolerant races." *Ecology*. 55:1163-1165.

Mika, J.S., K.A. Frost, W.A. Feder and C.J. Puccia. 1985. "The impact of land-applied incinerator ash residue on a freshwater wetland plant community." *Environmental Pollution Series (Series A)*. 38:339-360.

Moore, T.R. and R.C. Zimmerman. 1977. "Establishment of vegetation on serpentine asbestos mine wastes, southeastern Quebec, Canada." *J. Applied Ecology*. 14:589-599.

Ray, S.N. and W.J. White. 1979. "*Equisetum arvense* - An aquatic vascular plant as a biological monitor for heavy metal pollution." *Chemosphere*. 8(3):125-128.

Reeves, R.D. and A.J.M. Baker. 1984. "Studies on metal uptake by plants from serpentine and non-serpentine populations of *Thlaspi goesingense* Halacsy (Cruciferae)." *The New Phytologist*. 98:191-204.

Shaw, J.A. (ed.). 1989. "Heavy Metal Tolerance in Plants: Evolutionary Aspects." Boca Raton, Florida: CRC Press, Inc.

Simon, E. 1978. "Heavy metals in Soils, vegetation development and heavy metal tolerance in plant populations from metalliferous areas." *New Phytologist*. 81:175-188.

Street, J.J., B.R. Sabey, and W.L. Lindsay. 1978. "Influence of pH, phosphorus, cadmium, sewage sludge, and incubation time on the solubility and plant uptake of cadmium." *J. Environmental Quality*. 7:286-290.

Taylor, G.J. and A.A. Crowder. 1984. "Copper and nickel tolerance in *Typha latifolia* clones from contaminated and uncontaminated environments." *Canadian J. of Botany*. 62:1304-1308.

White, T.A. and G.L. Rolfe. 1980. "Differing effects of cadmium on two varieties of Cottonwood *Populus deltoides* Bartr." *Environmental Pollution Series (Series A)*. 22:29-38.

ORGANICS/PESTICIDES/PCBS/DIOXINS/PENTACHLOROPHENOL

Bacci, E. and C. Gaggi. 1985. "Polychlorinated biphenyls in plant foliage: Translocation or volatilization from contaminated soils?" *Bulletin of Environmental Contamination and Toxicology*. 35:673-681.

Bacci, E. and C. Gaggi. 1987. "Chlorinated hydrocarbon vapors and plant foliage: Kinetics and applications." *Chemosphere*. 16:2515-2522.

Bellin, C.A. and G.A. O'Connor. 1990. "Plant uptake of pentachlorophenol from sludge-amended soils." *Journal of Environmental Quality*. 19:598-602.

Cassidy, K. and J.H. Rodgers, Jr. 1989. "Response of Hydrilla (*Hydrilla verticillata* [L.f.] Royle) to diquat and a model of uptake under nonequilibrium conditions." *Environmental Toxicology and Chemistry*. 8:133-140.

Cessna, A.J., J. Waddington and S. Bittman. 1989. "Residues of 2,4-D and picloram in aspen poplar and soil after application with a roller." *Canadian J. Plant Science*. 69:205-212.

Gobas, F., E.J. McNeil, L. Lovett-Doust and G.D. Haffner. 1991. "Bioconcentration of chlorinated aromatic hydrocarbons in aquatic macrophytes." *Environmental Science and Technology*. 25:924-929.

Harvey, S.D., R.J. Fellows, D.A. Cataldo and R.M. Bean. 1990. "Analysis of 2,4,6-trinitrotoluene and its transformation products in soils and plant tissues by high-performance liquid chromatography." *Journal of Chromatography*. 518:361-374.

Kjeller, L.O., K.C. Jones, A.E. Johnston and C. Rappe. 1991. "Increases in polychlorinated di-benzo-p-dioxin and -furan content of soils and vegetation since the 1840s." *Environmental Science and Technology*. 25:1619-1627.

J.C. McFarlane, T. Pfleeger and J. Fletcher. 1987. "Transpiration effect on the uptake and distribution of bromacil, nitrobenzene and phenol in soybean plants." *J. Environmental Quality*. 16(4):372-376.

O'Connor, G.A., J.R. Lujan and Y. Lin. 1990. "Adsorption, degradation and plant availability of 2,4-dinitrophenol in sludge-amended calcareous soils." *J. Environmental Quality*. 19:587-593.

Paterson, S., D. Mackay, D. Tam and W.Y. Shiu. 1990. "Uptake of organic chemicals by plants: A review of processes, correlations and models." *Chemosphere*. 21(3):297-331.

Safe, S., K.W. Brown, K.C. Donelly, C.S. Anderson, K.V. Markiewicz, M.S. McLachlan, A. Reischl and O. Huttzinger. 1992. "Polychlorinated dibenzo-p-dioxins and dibenzofurans associated with wood-preserving chemical sites: Biomonitoring with pine needles." *Environmental Science and Technology*. 26:394-396.

Schreiber, L. and J. Schonherr. 1992. "Uptake of organic chemicals in conifer needles: Surface adsorption and permeability of cuticles." *Environmental Science and Technology*. 26:153-159.

Shane, L.A. and B. Bush. 1989. "Accumulation of polychlorobiphenyl congeners and p,p'-DDE at environmental concentration by corn and beans." *Ecotoxicology and Environmental Safety*. 17:38-46.

Sinclair, J., S. Garland, T. Arnason, P. Hope and M. Granville. 1977. "Polychlorinated biphenyls and their effects on photosynthesis and respiration." *Canadian J. Botany*. 55:2679-2684.

Sivalingan, P.M., T. Yoshida and Y. Inada. 1973. "The modes of inhibitory effects of PCBs on oxidative phosphorylation of mitochondria." *Bull. Environmental Contamination and Toxicology*. 10(4):242-247.

Trapp, S., M. Mattheis, I. Scheunert and E.M. Topp. 1990. "Modeling the bioconcentration of organic chemicals in plants." *Environmental Science and Technology*. 24:1246-1252.

ENZYMES

Archbold, D.D. and R.L. Houtz. 1988. "Photosynthetic characteristics of strawberry plants treated with paclobutrazol or flurprimidol." *HortScience*. 23(1):200-202.

Byl, T., H.D. Sutton, and S.J. Klaine. 1990. "Peroxidase as a biochemical indicator of sublethal stress on the aquatic plant *Hydrilla verticillata* (Royle)." (Poster presentation #213). Annual Meeting of the Society of Environmental Toxicology and Chemistry. Washington, D.C.

Rabe, R. and K.H. Kreeb. 1979. "Enzyme activities and chlorophyll and protein content in plants as indicators of air pollution." *Environmental Pollution*. 19:119-137.

VanAssche, F. and H. Clijsters. 1990. "Effects of metals on enzyme activity in plants." *Plant, Cell and Environment*. 13:195-206.

Willaert, G. and M. Verloo. 1988. "Biological effects of nickel species and their determination in plant and soil." *Plant and Soil*. 107:285-292.

FIELD GUIDES

Cobb, B. 1963. *A Field Guide to the Ferns*. The Peterson Field Guide Series. Boston, Massachusetts: Houghton Mifflin.

Fassett, N.C. 1957. *A Manual of Aquatic Plants*. Madison, Wisconsin: The University of Wisconsin Press.

Little, E.L. 1988. *The Audubon Society Field Guide to North American Trees, Eastern Region*. New York, New York: Alfred A. Knopf.

Newcomb, L. 1977. *Newcomb's Wildflower Guide*. Boston, Massachusetts: Little, Brown, and Company.

Niering, W.A. and N.C. Olmstead. 1985. *The Audubon Society Field Guide to North American Wildflowers, Eastern Region*. New York, New York: Alfred A. Knopf.

Petrides, G.A. 1986. *A Field Guide to Trees and Shrubs*. The Peterson Field Guide Series. Boston, Massachusetts: Houghton Mifflin.

Spellenberg, R. 1988. *The Audubon Society Field Guide to North American Trees, Western Region*. New York, New York: Alfred A. Knopf.

Symonds, G.W.D. 1962. *Some Grasses of the Northeast*. Newark, Delaware: University of Delaware Agricultural Experiment Station.

Symonds, G.W.D. 1958. *The Tree Identification Book*. New York, New York: Quill.

GROWTH AND REPRODUCTION

Abrahamson, W. G. and B.J. Hershey. 1977. "Resource allocation and growth of *Impatiens capensis* (Balsaminaceae) in two habitats." *Bulletin of the Torrey Botanical Club*. 104(2):160-164.

Doumlele, D.G. 1981. "Primary production and seasonal aspects of emergent plants in a tidal freshwater marsh." *Estuarine Research Federation*. 4(2):139-142.

Grace, J.B. and R.G. Wetzel. 1981. "Phenotypic and genotypic components of growth and reproduction in *Typha latifolia*: Experimental studies in marshes of differing successional maturity." *Ecology* 62(3):789-

801.

Grace, J.B. and R.G. Wetzel. 1981. "Niche differentiation between two rhizomatous plant species: *Typha latifolia* and *Typha angustifolia*." *Canadian J. Botany*. 60:46-57.

Krattinger, K. 1975. "Genetic mobility in *Typha*." *Aquatic Botany*. 1:57-70.

Nozzolillo, C. and I. Thie. 1983. "Aspects of germination of *Impatiens capensis* Meerb., Formae *capensis* and *immaculata*, and *I. pallida* (Nutt.)." *Bulletin of the Torrey Botanical Club*. 110(3):335-344.

Price, S.D. and S.C. Barrett. 1982. "Tristly in *Pontederia cordata* (Pontederiaceae)." *Can J. Botany*. 60:897-905.

Sharma, K.P. and B. Gopal. 1978. "Seed germination and occurrence of seedlings of *Typha* species in nature." *Aquatic Botany*. 4:353-358.

Silvertown, J. and B. Smith. 1989. "Mapping the microenvironment for seed germination in the field." *Annals of Botany*. 63:163-167.

Simpson, R.L., M.A. Leck and T.V. Parker. 1985. "The comparative ecology of *Impatiens capensis* Meerb. (Balsaminaceae) in Central New Jersey." *Bulletin of the Torrey Botanical Club*. 112(3):295-311.

NUTRIENTS

Bernard, J.M. and M.L. Fitz. 1979. "Seasonal changes in aboveground primary production and nutrient contents in a central New York *Typha Glauca* ecosystem." *Bulletin of the Torrey Botanical Club.* 106(1):37-40.

Chambers, R.M. and J.W. Fourqurean. 1991. "Alternative criteria for assessing nutrient limitation of a wetland macrophyte (*Peltandra virginica* (L. Kunth)." *Aquatic Botany*. 40:305-320.

Couillard, D. and Y. Grenier. 1989. "Effect of applications of sewage sludge on N, P, K, Ca, Mg and trace element contents of plant tissues." *The Science of the Total Environment*. 80:113-125.

Craft, C.B., S.W. Broome and E.D. Seneca. 1988. "Nitrogen, phosphorus and organic carbon pools in natural and transplanted marsh soils." *Estuaries*. 11(4):272-280.

Grace, J.B. 1988. "The effects of nutrient additions on mixtures of *Typha latifolia* L. and *Typha domingensis* (Pers.) along a water-depth gradient." *Aquatic Botany*. 31:83-92.

Klopatek, J.M. 1978. "Nutrient dynamics of freshwater riverine marshes and the role of emergent macrophytes." In: *Freshwater Wetlands: Ecological Processes and Management Potential*. Eds. R.E. Good, D.F. Whigham, R.L. Simpson, and C.G. Jackson, Jr. New York, New York: Academic Press. p. 195-216.

Marschner, H. 1986. "Diagnosis of deficiency and toxicity of mineral nutrients." In: *Mineral Nutrition of Higher Plants*. New York, New York: Academic Press. p. 391-416.

Mitsch, W.J. and J.G. Gosselink. 1986. *Wetlands.* New York, New York: Van Nostrand Reinhold.
Reddy, K.R., W.H. Patrick, Jr. and C.W. Lindau. 1989. "Nitrification-dentrification at the plant root-sediment interface in wetlands." *Limnolology and Oceanography*. 34:1004-1013.

Richardson, C.J., D.L. Tilton, J.A. Kadlec, J.P.M. Chamie and W.A. Wentz. 1978. "Nutrient dynamics of northern wetland ecosystems." In: *Freshwater Wetlands, Ecological Processes and Management Potential.* Eds. R.E. Good, D.F. Whigham, and R.L. Simpson. New York, New York: Academic Press. p. 217-241.

Sabey, B.R., R.L. Pendleton and B.L. Webb. 1990. "Effect of municipal sewage sludge application on growth of two reclamation shrub species in copper mine spoils." *Journal of Environmental Quality*. 19:580-586.

Sutcliffe, J.F. and D.A. Baker. 1974. *Plants and Mineral Salts*. Southampton, England: Camelot Press. p. 58.

Tinker, B. and A. Lauchli. 1986. *Advances in Plant Nutrition, Vol. 2*. New York, New York: Praeger.

Troug, E. 1961. *Mineral Nutrition of Plants.* Madison, Wisconsin: University of Wisconsin Press.

POREWATER SAMPLING

Carigan, R., F. Rapin, and A. Tessier. 1985. "Sediment Porewater Sampling for Metal Analysis: A Comparison of Techniques." *Geochimica Cosmochimica Acta*. 149:2493-2497.

Howes, B.L., J.W. Dacey, and S.G. Wakeham. 1985. "Effects of Sampling Technique on Measurements of Porewater Constituents in Salt Marsh Sediments." *Limnology and Oceanography*. 30(1):221-227.

U.S. Fish and Wildlife Service. 1990. *A simplified sediment porewater extractor, Information Bulletin No. 90-43.* U.S. Department of the Interior, Washington, D.C.

SOILS

Brady, N.C.. 1974. *The Nature and Properties of Soils*. 8th ed. New York, New York: Macmillan Press.

DiToro, D.M., J.D. Mahony, D.J. Hansen, K.J. Scott, A.R. Carlson and G.T. Ankley. 1992. "Acid volatile sulfide predicts the acute toxicity of cadmium and nickel in sediments." *Environmental Science and Technology*. 26:96-101.

Kollmorgen Corporation. 1975. *Munsell Soil Color Charts*. Baltimore, Maryland: Macbeth Division of Kollmorgen Corporation.

U.S. Army Corps of Engineers. 1990. "Environmental effects of dredging." In: *Technical Notes: A computerized procedure for predicting uptake of heavy metals from contaminated freshwater dredged material, Publication EEDP-04-12*. Vicksburg, Mississippi: Waterways Experimetal Station.
Soil Conservation Service. 1987. "Hydric soils of the United States." *National Technical Committee for Hydric Soils*. U.S. Department of Agriculture, Washington, D.C.

TREE CORING

DeWitt, E. and M. Ames (eds). 1978. *Tree-Ring Chronologies of Eastern North America. Laboratory of Tree-Ring Research*. University of Arizona, Tucson, Arizona.

Fritts, H.C. and T.W. Swetnam. 1989. "Dendroecology: A tool for evaluating variations in past and present forest environments." *Advances in Ecological Research*. 19:111-188.

Innes, J.L. and E.R. Cook. 1989. "Tree-ring analysis as an aid to evaluating the effects of pollution on tree growth." *Canadian J.Forest Research.* 19:1174-1189.

TRANSPIRATIONAL STREAM SAMPLING

McFarlane, C. and T. Pfleeger. 1990. "Effect, uptake and disposition of nitrobenzene in several terrestrial plants." *Environmental Toxicology and Chemistry*. 9:513-520.

WATER

U.S. Environmental Protection Agency. 1986. *Quality Criteria for Water*. U.S. Environmental Protection Agency, Washington, D.C. EPA 440/5-86-001.

Wetzel, R.G. 1975. *Limnology*. Philadelphia, Pennsylvania: W.B. Saunders.

APPENDIX A
Standard Vegetation Assessment Quality Assurance Work Plan Template
SOP #2038
March 1996

QUALITY ASSURANCE WORK PLAN
FOR
VEGETATION ASSESSMENTS

(SITE NAME)

(SITE LOCATION)

Prepared by
Lockheed Martin, Inc.

(MONTH YEAR)

U.S. EPA Work Assignment No. 0-###
Weston Work Order No. 03347-040-001-0###-01
U.S. EPA Contract No. EP-C-04-032

Approved By:

_____
(Name) Date
SERAS Task Leader

_____
(Name) Date
SERAS Group Leader

_____
(Name) Date
SERAS QA Officer

_____
Dennis Miller Date
Program Manager

_____
(Name) Date
US EPA/ERT Work Assignment Manager

1.0 OBJECTIVE

The objective of this project/sampling event is to determine:
[Select appropriate items; and or delete other(s)]

- the impact of contamination on the vegetation at the site
- the effectiveness of new sampling methods or instrumentation
- other (specify)

for the purpose of providing:
[Select appropriate items; and or delete other(s)]

- baseline monitoring data
- site remediation recommendations
- ecological risk assessment
- other (specify)

The data will be evaluated and interpreted based on information from:
[Select appropriate items; and or delete other(s)]

- an existing database (specify)
- published scientific literature (specify)
- federal/state action levels (specify)
- other (specify)

2.0 PROJECT SCOPE

The following information is known about the site:

The site is located [in/near the city of _____] in the State of _____ (include Figure if available). It is a [type of facility] on [No.] acres which has/had been operating for [No.] year(s) [and is now abandoned since date].

The types of material(s) handled by this facility were/are: [specify]
[Select appropriate items; and or delete other(s)]

- radionuclides
- organics
- petroleum
- acids
- bases
- inorganics
- unknown
- other (specify)

The volume(s) of contaminated materials to be addressed are: [specify in acreage, drum count, volume of liquid (waste, etc.)].

The contaminants of concern are: concentration ranges:

_____ _____ to _____
_____ _____ to _____
_____ _____ to _____

The population, community, or ecosystem of concern is: (delete if not applicable):

_____
_____
_____

The basis of this information/data may be found in: (cite references)

SERAS will arrange for: [Select the appropriate item(s); add or delete the other(s)]

- ☐ protective gear
- ☐ sampling equipment
- ☐ sample containers
- ☐ sampling personnel
- ☐ field analysis
- ☐ analysis
- ☐ subcontract analysis
- ☐ sample collection
- ☐ sample disposal
- ☐ taxonomic identification
- ☐ toxicity tests

3.0 TECHNICAL APPROACH

3.1 Preparation for Field Activities

Satellite images; historical and color infrared aerial photographs; and topographical, soil survey and wetland inventory maps will be obtained to prepare for the site visit, orient the field crew, and reveal possible areas of wetlands or vegetative stress.

3.2 Field Sampling Design

The sampling design is to be detailed in the Sampling Plan, to be completed prior to the field activities. Activities to be undertaken are summarized below.

3.2.1 Ecology

[Select the appropriate item(s); delete the other(s)]

A cover map will be developed during a walk-through survey identifying dominant cover types, marking transition zones between communities, describing habitat, and noting signs of stressed vegetation.

Quantitative plant community sampling will be performed using [plot/transect/point-quarter] sampling techniques.

3.2.2 Chemistry

[Select the appropriate item(s); delete the other(s)]

[Water/soil/sediment] will be sampled for the contaminants listed in Section 2.0 to determine the total contaminant level present. [Soil/sediment] samples will be collected from the root zones of plants and studied. Analyses to be performed on [soil/sediment] to determine the biological availability of these contaminants will include:

[Select the appropriate item(s); delete the other(s)]

- grain size
- total organic carbon
- pH
- Diethylenetriamine Pentaacetic Acid (DTPA) extraction (metals)
- aqueous extraction
- other (specify)

Surface water quality will be monitored using a Hydrolab Water Quality Measurement System.

[Soil/pore water] nutrient levels to be determined will include nitrogen, phosphorus and potassium (NPK), macronutrients, and micronutrients as listed in Tables 9.1 and 9.2.

Exposure will also be assessed by analyzing plant tissue. Whole plants and above-ground plant parts will be collected and analyzed for contaminants. Leaves, stems, roots and reproductive parts will be collected and analyzed separately for contaminants. The transpirational stream will be sampled using a Vacutainer™, and the liquid will be analyzed for contaminants.

Plant tissue will also be analyzed for NPK, macronutrients, and micronutrients, and total carbon.

3.2.3 Physiology

Physiological measurements at the site will include:
[Select the appropriate item(s); delete the other(s)]

- *in vivo* chlorophyll fluorometry
- chlorophyll content determination
- leaf area index determination
- biomass measurement
- reproductive capacity
- enzyme assay (specify)
- toxicity testing
- tree ring analysis

3.3 Field Sampling Equipment

The following equipment will be utilized to obtain samples from the respective media/matrix:

Material of Media/Matrix	Sampling Equipment	Construction	Dedicated (Y/N)

3.3.1 Sampling Equipment Decontamination

The following sampling equipment decontamination procedure will be employed prior and subsequent to sampling each station in the following numerical sequence: (number required steps and delete others)

__ physical removal
__ non-phosphate detergent wash [specify:]
__ potable water rinse
__ distilled/deionized water rinse
__ 10% nitric acid rinse
__ solvent rinse
__ air dry
__ distilled water rinse
__ organic free water rinse

3.4 Standard Operating Procedures

3.4.1 Sample Documentation

All sample documents must be completed legibly and in ink. Any corrections or revisions must be made by drawing a line through the incorrect entry and by initialing the error.

Personal Logbooks

Personal logbooks will be used to record data and observations so that an accurate account of field operations can be reconstructed. All entries will be dated and signed by the individual(s) making the entries and will contain the following information (unless formally recorded elsewhere):

- Site name and location
- Date and location of field work
- Times (military time is preferred, use a.m. or p.m. references)
- Names and addresses of field contacts
- Site sketches and photographic references
- Weather conditions

- Sample descriptions, locations, times taken, identification numbers
- Chain of custody information, shipping paper identification number, recipient address and phone number, etc.
- Field observations and discussion
- Field measurements (e.g., pH, temperature, surface water flow rates, etc.)
- Instructions issued by the Work Assignment Manager

Field Data Sheets and Sample Labels

Field data sheets and corresponding sample labels will be used to identify samples and document field sampling conditions and activities. The appropriate field data sheets and sample labels will be used corresponding to the respective activities.

Field data sheets will be maintained by the Task Leader or designee. At a minimum, originals will be filed in the Central File. As necessary, copies of field data sheets can be attached to Trip or Final Reports.

Chain of Custody

A chain of custody record will be maintained from the time a sample is taken to the final deposition of the sample.

The chain of custody record will contain, at a minimum, the following information: project name, project number, the SERAS contact and their telephone number. For each sample collected, the chain of custody record will include the sample number, sampling location, sample matrix, date collected, container/preservative, analysis requested, and special instructions, if applicable.

Chain of custody records will be completed legibly, with all required information, so that miscommunication with, or misunderstanding by, the receiving laboratory can be prevented.

If samples collected during a sampling event will be forwarded to more than one laboratory, then a separate chain of custody record, indicating which samples are being sent to that particular laboratory, will be completed for each laboratory.

Every transfer of custody will be noted and signed for on the chain of custody record. If a sample or group of samples is not under direct control or observation of the individual responsible for the samples, then the samples will be stored in a locked container that has been sealed with a chain of custody seal. A copy of the chain of custody record should be kept by each individual who has signed it. The final copy will be included with the Analytical Report.

Chain of Custody Seals

Chain of custody seals demonstrate that a sample container has not been opened or tampered with during transport or storage. The seal or seals will be affixed so that the

container cannot be opened without breaking the seal. The person in direct possession of the samples will sign and date the seal. The individual's name, along with a package description, shall be noted in the individual's personal logbook.

3.4.2 Sampling Techniques

Samples will be collected for vegetative assessment at the site in accordance with the following Standard Operating Procedures: [Select appropriate item(s); add or delete others]

ERT/SERAS SOP #2030, *Chlorophyll Determination*
ERT/SERAS SOP #2031, *In Vivo Chlorophyll Fluorescence Measurement*
ERT/SERAS SOP #2033, *Plant Protein Determination*
ERT/SERAS SOP #2034, *Plant Biomass Determination*
ERT/SERAS SOP #2035, *Peroxidase Enzyme Activity Determination*
ERT/SERAS SOP #2036, *Tree Coring and Interpretation*
ERT/SERAS SOP #2037, *Terrestrial Plant Community Sampling*
ERT/SERAS SOP #2038, *Vegetation Assessment Protocol*

ERT/SERAS SOPs to be used for general sampling will include:
[Select appropriate item(s); add or delete others]

ERT/SERAS SOP #2001, *General Field Sampling Guidelines*
ERT/SERAS SOP #2003, *Sample Storage, Preservation, and Handling*
ERT/SERAS SOP #2004, *Sample Packaging and Shipment*
ERT/SERAS SOP #2012, *Soil Sampling*
ERT/SERAS SOP #2013, *Surface Water Sampling*
ERT/SERAS SOP #2016, *Sediment Sampling*

3.5 Waste Residual Disposal

All the treated and untreated samples will be maintained for 60 days after the issuance of the final report. If no additional testing has been requested, at the end of the 60 days, and with the approval and concurrence of the Task Leader, arrangements will be made for disposal.

4.0 PROJECT MANAGEMENT AND REPORTING

The SERAS Task Leader will maintain contact with the U.S. U.S. EPA/ERT Work Assignment Manager to provide information on the technical and financial progress of this project. This communication will commence with the issuance of the work assignment and project scoping meeting. Activities under this project will be reported in status or trip reports and other deliverables (e.g., analytical reports, final reports) identified in Section 8.0. Activities will also be summarized in appropriate format for inclusion in SERAS Monthly and Annual Reports.

In accordance with the terms and conditions of U.S. U.S. EPA Contract Number 68-C4-0022, Roy F. Weston, Inc. (WESTON®) has conducted a conflict of interest search of Corporate records and databases for the (indicate name of site), (indicate location), and to the best of WESTON's knowledge and belief, no

actual or potential organizational conflict of interest exists.

WESTON an C.C. Johnson & Malhotra, P.C. (CCJM) personnel performing work under this work assignment have received the SERAS Conflict of Interest Plan and have been informed of their obligation to report personal conflicts of interest. Each employee has agreed to this policy by signing a statement related to conflict of interest responsibilities. In addition, WESTON and CCJM will conduct searches of corporate conflict of interest databases in reference to this work assignment. Any actual or potential conflict of interest associated with this work assignment will be brought to the attention of the Contract and Project Officers. Lastly, WESTON recognizes the continuing obligation to identify and report any actual or potential conflict of interest arising at anytime during performance of this work assignment.

5.0 PROJECT SCHEDULE

The work assignment for this project was issued on (date). This Quality Assurance Work Plan (QAWP) was initiated at that time, developed, and completed within ten working days of the issuance of the work assignment. A detailed sampling plan will be completed prior to the initiation of field activities on (date). During this period, the equipment needed to conduct the site activities was assembled and shipped.

Samples are expected to be transferred to the lab on (date) and results are expected on (date). The overall project is expected to close out with the issuance of a final report on (date). Refer to Section 8.0 for a list of milestones and deliverable due dates.

6.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

The U.S. U.S. EPA Work Assignment Manager (___Name____) will provide overall direction to SERAS staff concerning project sampling needs, objectives, and schedule.

The SERAS Task Leader is (Name) is the primary SERAS point of contact with the U.S. U.S. EPA Work Assignment Manager. The Task Leader is responsible for the development and completion of the QAWP, project team organization, and supervision of all project tasks, including reporting and deliverables.

The SERAS Site QC Coordinator (____Name_____) is responsible for ensuring field adherence to the QAWP and recording any deviations from the QAWP. The Site QC Coordinator is also the primary project team contact with the SERAS lab. The following SERAS field sampling personnel will work on this project:

Personnel	Responsibility
_____	_____
_____	_____

The SERAS QA Officer is (Name), the Health and Safety Officer is (Name), the Operation Section Leader is (Name), and the Analytical Section Leader is (Name). These individuals are responsible for auditing and guiding the project team, reviewing/auditing the deliverables and proposing corrective action, if necessary, for nonconformity to the QAWP or HASP.

The following identified laboratories are expected to provide the listed analyses:

Lab Name	Location	Parameters

7.0 MANPOWER AND COST PROJECTIONS

The estimated costs (including labor, travel, materials and equipment, subcontractor, and analytical laboratory services) to complete this project are presented in the attached cost summary sheet.

8.0 DELIVERABLES

The following deliverables will be provided under this project:
[choose or add appropriate items; delete others]

ITEM	DATE

__ QAWP
__ Sampling Plan
__ Field Activities
__ Trip Report
__ Status Report
__ Maps/Figures
__ Analysis
__ Data Review
__ Analytical Report
__ Preliminary Report
__ Final Report
__ Technical Report Abstract (Project Summary)
__ Videos
__ Slides

__ Conference/Seminar Presentations

All project deliverable dates are estimates based on the information available at the time of QAWP completion. New information, additional tasks, changes in scope, and events outside the control of SERAS may result in revisions to these dates.

9.0 QUALITY ASSURANCE

(delete QA protocols that are not applicable and modify text where appropriate)

QA objectives and protocols are summarized in Tables 9.1 and 9.2.

The following QA Protocols for QA1 data are applicable to all sample matrices:

1. Sample documentation in the form of field logbooks, the appropriate field data sheets, and chain of custody forms will be provided.
2. All instrument calibration and/or performance check procedures/methods will be summarized and documented in the field/personal or instrument log notebook.
3. Detection limit(s) will be determined and recorded, along with the data, where appropriate.

The following QA Protocols for QA2 data are applicable to all sample matrices:

1. Sample documentation in the form of field logbooks, the appropriate field data sheets, and chain of custody forms will be provided. Chain of custody sheets are optional for field screening locations.
2. All instrument calibration and/or performance check procedures/methods will be summarized and documented in the field/personal or instrument log notebook.
3. Detection limit(s) will be determined and recorded, along with the data, where appropriate.
4. Sample holding times will be documented; this includes documentation of sample collection and analysis dates.
5. Initial and continuing instrument calibration data will be provided.

6a. For **soil, sediment and water samples**, rinsate blanks, field blanks, and trip blanks will be included at the rate specified in Table 9.1, footnotes 2 and 3, respectively.

6b. For **air samples**, lot blanks, field blanks, collocated samples, trip blanks, and breakthrough samples will be included at the rate specified in Table 9.2, footnotes 1-7, respectively.

6c. For **soil gas samples**, duplicate samples, zero air samples, field standards, ambient air samples, and matrix spikes will be included at the rate specified in Table 9.1, footnotes 2-6, respectively.

7. Performance Evaluation (PE) samples are optional, if available.
8. Choose any one or any combination of the following three options (delete if not applicable):

   a. **Definitive Identification** - Analyte identification on 10 percent of the screened (field or lab) or 100 percent of the unscreened samples will be confirmed using a U.S. EPA-approved method; documentation such as chromatograms, mass spectra, etc will be provided.

   b. **Quantitation** - documentation for quantitative results from screening, and U.S. EPA-approved verification methods (for screened samples), or quantitative results (in the case

of unscreened samples) will be provided.

c. **Analytical Error** - the analytical error will be determined by calculating the precision, accuracy, and coefficient of variation on a subset of the screened or all of the unscreened samples using an U.S. EPA-approved method.

The following QA Protocols for QA3 data are applicable for all matrices:

1. Sample documentation in the form of field logbooks, the appropriate field data sheets, and chain of custody forms will be provided. Chain of custody sheets are optional for field screening locations.
2. All instrument calibration and/or performance check procedures and methods will be summarized and documented in the field/personal or instrument log notebook.
3. Detection limit(s) will be determined and recorded, along with the data, where appropriate.
4. Sample holding times will be documented; this includes documentation of sample collection and analysis dates.
5. Initial and continuing instrument calibration data will be provided.

6a. For **soil, sediment and water samples**, rinsate blanks, field blanks, and trip blanks will be included at the rate specified in Table 9.1, footnotes 2 and 3, respectively.

6b. For **air samples**, lot blanks, field blanks, collocated samples, trip blanks, and breakthrough samples will be included at the rate specified in Table 9.2, footnotes 1-7, respectively.

6c. For **soil gas samples**, duplicate samples, zero air samples, field standards, ambient air samples, and matrix spikes will be included at the rate specified in Table 9.1, footnotes 2-6, respectively.

7. PE samples are required.
8. Definitive identification will be confirmed on 100 percent of the "critical samples" by a U.S. EPA-approved method.
9. Quantitation - documentation for quantitative results from screening and U.S. EPA-approved verification method(s) (for screened samples) or quantitative results (in the case of unscreened samples) will be provided.
10. Analytical error will be determined on 100 percent of the "critical samples" by an U.S. EPA-approved method. Precision, accuracy, and coefficient of variation will be determined. False positive and false negative values will be determined.

Numbers of samples to be collected for this project/event are presented in Table 9.1, Field Sampling Summary, and Table 9.2, QA/QC Analysis and Objectives Summary. These tables identify analytical parameters desired; type, volume and number of containers needed; preservation requirements; number of samples to be collected; and associated number and type of QA/QC samples based on the QA level.

All project deliverables will receive an internal peer review prior to release, per guidelines established in the SERAS Administrative Procedure (AP #22, *Peer Review of SERAS Deliverables*).

TABLE 9.1 Field Sampling Summary - Soil/Water/Plant Tissue
(Select appropriate parameters, add/delete others including applicable footers)

							QC Extra's				
Analytical Parameter	Action Level[1]	Matrix*	Container Type and Volume (# Containers rq'd)	Preservative	Holding Times	Subtotal Samples	Rinsate Blanks[2]	Field/Trip Blanks[3]	PE Samples[4]	Total Matrix Spikes[5]	Total Field Samples[6]
AMMONIUM (NH_4^+)		W	400-mL glass or Plastic 1)	H_2SO_4/L, 4°C	28 days						
BNA		S	8-oz glass 1)	4°C	7/4O days			/NA			
BNA		W	32-oz amber glass (2)	4°C	7/4O days			/NA			
CATION EXCHANGE CAPACITY		S	32-oz glass or polyethylene 1)	4°C**	**			/NA			
CHLORINE		S	8-oz glass or plastic 1)	NA	Immediate			/NA			
CHLORINE		W	200-mL glass or plastic (1)	NA	Immediate			/NA			
CHLOROPHYLL		X	Refer to ERT/SERAS SOP #2030, *Chlorophyll Determination*					/NA			
CYANIDE		S	8-oz glass (1)	4°C	14 days			/NA			
CYANIDE		W	1-L polyethylene (1)	NaOH to pH>12 4°C	14 days			/NA			

Notes:

* Matrix: S-Soil, W-Water, X-Plant Tissue.

** To be determined during contracting with the laboratory performing the analysis

NA denotes Not Applicable

1. The concentration level, specific or generic, that is needed in order to make an evaluation. This level will provide a basis for determining the analytical method to be used.
2. Only required if dedicated sampling tools are not used. For QA2 and QA3, one blank required per parameter per 20 samples. For QA1, enter NA.
3. For QA2 and QA3, one trip blank required per cooler used to ship VOA samples. Each trip blank consists of two 40-mL vials filled with distilled/deionized water. For QA1, enter NA.
4. Performance check samples are optional for QA2, and mandatory for QA3 at one per parameter per matrix. For QA1, enter NA.
5. Ensure that sufficient environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a frequency of 10 percent total samples, regardless of QA Objective. For QA2 (optional) and for QA3 (mandatory), determine bias (percent recovery) using a minimum two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory MS/MSD may be utilized to fulfill these additional QA requirements.
6. Add the numbers of rinsate blanks, field, blanks, trip blanks, and PE samples to the subtotal number of samples to determine this.

TABLE 9.1 Field Sampling Summary - Soil/Water/Plant Tissue (Cont'd)
(Select appropriate parameters, add or delete others including appropriate footers)

							QC Extra's				
Analytical Parameter	Action Level[1]	Matrix*	Container Type and Volume (#Containers rq'd)	Preservative	Holding Times	Subtotal Samples	Rinsate Blanks[2]	Field/Trip Blanks[3]	PE Samples[4]	Total Matrix.Spikes[5]	Total Field Samples[6]
DTPA-EXTRACTED METALS (Cd, Cr, Co, Cu, Pb, or Ni)[7]		S	200-g glass or polyethylene(1)	4°C	6 months			/NA			
GRAIN SIZE		S	32-oz glass (1)	NA	NA			/NA			
MACRO-NUTRIENTS[8]		S	8-oz glass (1)	4°C	**			/NA			
MICRO-NUTRIENTS[9]		S	8-oz glass (1)	4°C	**			/NA			
NITRATE (NO_3)[10]		W	100-mL glass or plastic (1)	Varies with Method	Varies With Method						
PEROXIDASE		X	Refer to ERT/SERAS SOP #2035, *Determination of Plant Peroxidase*					/NA			

PEST/PCB		W	32-oz amber glass (2)	4°C***	7/40 days			/NA			
PEST/PCB (Including lipids)		X	50-g minimum	4°C	7/40 days			/NA			
PEST/PCB		S	8-oz glass (1)	4°C	7/40 days			/NA			

NOTES

* Matrix: S-Soil, W-Water, X-Plant Tissue.

** To be determined during contracting with the laboratory performing the analysis

*** If residual chlorine is present, preserve with 0.008 percent $Na_2S_2O_3$

NA denotes Not Applicable

1. The concentration level, specific or generic, that is needed in order to make an evaluation. This level will provide a basis for determining the analytical method to be used.
2. Only required if dedicated sampling tools are not used. For QA2 and QA3, one blank required per parameter per 20 samples. For QA1, enter NA.
3. For QA2 and QA3, one trip blank required per cooler used to ship VOA samples. Each trip blank consists of two 40-mL vials filled with distilled/deionized water. For QA1, enter NA.
4. Performance check samples; optional for QA2, mandatory for QA3 at one per parameter per matrix. For QA1, enter NA.
5. Ensure that sufficient environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a frequency of 10 percent total samples, regardless of QA Objective. For QA2 (optional) and for QA3 (mandatory). Determine bias (percent recovery) using a minimum two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory MS/MSD may be utilized to fulfill these additional QA requirements.
6. Add the numbers of rinsate blanks, field blanks, and PE samples to the subtotal number of samples to determine this.
7. DTPA (diethylene triamine penta acetic acid) extraction, followed by appropriate analyte determination. Determine requirement for either glass or polyethylene container from laboratory performing analysis
8. Analyses of macronutrients in soils include total organic nitrogen, ammonium, nitrate, phosphorus, potassium, calcium, magnesium, and sulphur.
9. Analyses for available micronutrients include copper, zinc, manganese, iron, molybdenum, and boron.
10. Standard agricultural N-P-K analyses may be used.

TABLE 9.1 Field Sampling Summary - Soil/Water/Plant Tissue (Cont'd)
(Select appropriate parameters, and or delete others including appropriate footers)

							QC Extra's				
Analytical Parameter	Action Level[1]	Matrix*	Container Type and Volume (# Containers rq'd)	Preservative	Holding Times	Subtotal Samples	Rinsate Blanks[2]	Field/ Trip Blanks[3]	PE Samples[4]	Total Matrix Spikes[5]	Total Field Samples[6]
pH		S	4-oz glass or plastic (1)	NA	Immediate			/NA			
pH		W	25-mL glass or plastic (1)	NA	Immediate			/NA			
PHENOL		S	8-oz glass (1)	4°C	28 days			/NA			
PHENOL		W	1-liter amber glass (1)	H_2SO_4 to pH <2 4°C	28 days			/NA			
PLANT PROTEIN DETERMINATION		X	Refer to ERT/SERAS SOP # 2033, *Plant Protein Determination*					/NA			
POTASSIUM[7]		W	Varies with method	HNO3 to pH<2 4°C	6 months			/NA			
PRIORITY POLLUTANT METALS		S	8-oz glass (1)	4°C	6 months			/NA			

PRIORITY POLLUTANT METALS		W	1-L glass or polyethylene (1)	HNO_3 to pH<2 4°C	6 months			/NA			
SALINITY (SPECIFIC CONDUCTANCE)		S	100-g glass or polyethylene (1)	4°C	28 days			/NA			

NOTES

* Matrix: S-Soil, W-Water, X-Plant Tissue.

NA denotes Not Applicable

1. The concentration level, specific or generic, that is needed in order to make an evaluation. This level will provide a basis for determining the analytical method to be used.
2. Only required if dedicated sampling tools are not used. For QA2 and QA3, one blank required per parameter per 20 samples. For QA1, enter NA.
3. For QA2 and QA3, one trip blank required per cooler used to ship VOA samples. Each trip blank consists of two 40-mL vials filled with distilled/deionized water. For QA1, enter NA.
4. Performance check samples; optional for QA2, mandatory for QA3 at one per parameter per matrix. For QA1, enter NA.
5. Ensure that sufficient environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a frequency of 10 percent total samples, regardless of QA Objective. For QA2 (optional) and for QA3 (mandatory). Determine bias (percent recovery) using a minimum two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory MS/MSD may be utilized to fulfill these additional QA requirements.
6. Add the numbers of rinsate blanks, field blanks, and PE samples to the subtotal number of samples to determine this.
7. Standard agricultural N-P-K analyses may be used.

TABLE 9.1 Field Sampling Summary - Soil/Water/Plant Tissue (Cont'd)
(Select appropriate parameters, and or delete others including appropriate footers)

							QC Extra's				
Analytical Parameter	Action Level[1]	Matrix*	Container Type and Volume (# Containers rq'd)	Preservative	Holding Times	Subtotal Samples	Rinsate Blanks[2]	Field/ Trip Blanks[3]	PE Samples[4]	Total Matrix Spikes[5]	Total Field Samples[6]
SALINITY (SPECIFIC CONDUCTANCE)		W	100-mL glass or polyethylene (1)	4°C	28 days			/NA			
TAL METALS		W	1-L glass or polyethylene (1)	HNO_3 to pH<2 4°C	6 months			/NA			
TAL METALS		S	8-oz glass (1)	4°C	6 months			/NA			
TAL METALS		X	50-g dry weight **(Do Not Freeze)** (1)	4°C	1 months			/NA			
TOTAL CARBON		X	** (1)	4°C**	**			/NA			
TOTAL ORGANIC CARBON (TOC)		S	8-oz glass or polyethylene (1)	4°C	28 days			/NA			

TOTAL ORGANIC CARBON (TOC)		W	100-mL glass or polyethylene (1)	HCl/H_2SO_4 to pH<2 4^oC	28 days			/NA			
TOTAL ORGANIC NITROGEN[7]		W	500-mL glass or plastic (1)	H_2SO_4/L to pH<2 4^oC	24 hours			/NA			

NOTES

* Matrix: S-Soil, W-Water, X-Plant Tissue.

** To be determined during contracting with the laboratory performing the analysis

NA denotes Not Applicable

1. The concentration level, specific or generic, that is needed in order to make an evaluation. This level will provide a basis for determining the analytical method to be used.
2. Only required if dedicated sampling tools are not used. For QA2 and QA3, one blank required per parameter per 20 samples. For QA1, enter NA.
3. For QA2 and QA3, one trip blank required per cooler used to ship VOA samples. Each trip blank consists of two 40-mL vials filled with distilled/deionized water. For QA1, enter NA.
4. Performance check samples; optional for QA2, mandatory for QA3 at one per parameter per matrix. For QA1, enter NA.
5. Ensure that sufficient environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a frequency of 10 percent total samples, regardless of QA Objective. For QA2 (optional) and for QA3 (mandatory). Determine bias (percent recovery) using a minimum two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory MS/MSD may be utilized to fulfill these additional QA requirements.
6. Add the number of rinsate blanks, field blanks, trip blanks, and PE samples to the subtotal number of samples to determine this.
7. Standard agricultural N-P-K analyses may be used.

TABLE 9.1 Field Sampling Summary - Soil/Water/Plant Tissue (Cont'd)
(Select appropriate parameters, add or delete others including appropriate footers)

							QC Extra's				
Analytical Parameter	Action Level[1]	Matrix*	Container Type and Volume (# Containers rq'd)	Preservative	Holding Times	Subtotal Samples	Rinsate Blanks[2]	Field/ Trip Blanks[3]	PE Samples[4]	Total Matrix Spikes[5]	Total Field Samples[6]
TOTAL ORTHOPHOSPHATE[7]		W	**	4°C	48 hours			/NA			
TOTAL PHOSPHORUS		X	50-g dry weight (1)	4°C	1 month			/NA			
VOA		S	40-mL vial (1)	4°C	7 days						
VOA		W	40-mL vial (3)	4°C***	7 days						

* Matrix: S-Soil, W-Water, X-Plant Tissue.
** To be determined during contracting with the laboratory performing the analysis
*** If residual chlorine is present, preserve with 0.008 percent $Na_2S_2O_3$
NA denotes Not Applicable
1. The concentration level, specific or generic, that is needed in order to make an evaluation. This level will provide a basis for determining the analytical method to be used.
2. Only required if dedicated sampling tools are not used. For QA2 and QA3, one blank required per parameter per 20 samples. For QA1, enter NA.
3. For QA2 and QA3, one trip blank required per cooler used to ship VOA samples. Each trip blank consists of two 40-mL vials filled with distilled/deionized water. For QA1, enter NA.
4. Performance check samples; optional for QA2, mandatory for QA3 at one per parameter per matrix. For QA1, enter NA.
5. Ensure that sufficient environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a

frequency of 10 percent total samples, regardless of QA Objective. For QA2 (optional) and for QA3 (mandatory). Determine bias (percent recovery) using a minimum two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory MS/MSD may be utilized to fulfill these additional QA requirements.

6. Add the number of rinsate blanks, field blanks, trip blanks, and PE samples to the subtotal number of samples to determine this.
7. Standard agricultural N-P-K analyses may be used.

TABLE 9.2 QA/QC Analysis and Objectives Summary - Soil/Water/Plant Tissue
(Select appropriate parameters, add or delete others including appropriate footers)

			Matrix Spikes		QA/QC	
Analytical Parameter	Matrix*	Analytical Method Reference	Lab[1]	Additional[2]	Detection Limits[3]	QA Objective[4]
BNA	S	8250 or 8270/ SW-846				
BNA	W	625/CLP				
CATION EXCHANGE CAPACITY	S	SW-846 9080				
CHLORINE	S	U.S. EPA-600/4-79-020, 325.3				
CHLORINE	W	Std. Methods, 16th ed. 409A: U.S. EPA 330.4, Titrimetric, residual; Std. Methods, 16th ed. 408A: or U.S. EPA 330.0, Titrimetric				
CHLOROPHYLL	X	Refer to ERT/SERAS SOP #2030, *Chlorophyll Determination*				
CYANIDE	S	SW-846				
CYANIDE	W	SW-846				
DTPA-EXTRACTION OF METALS (Cd, Cr, Co, Cu, Pb, or Ni)	S	DTPA-Extraction[5,6]/ICP, AA Flame, or AA Furnace				

GRAIN SIZE	S	ASTM-D422-63				
PERCENT LIPID	X	See below[7]				

NOTES

* Matrix: S-Soil, W-Water, O-Oil, DS-Drum Solid, DL-Drum Liquid, SD-Sediment, PW-Potable Water, GW-Groundwater, SW-Surface Water, SL-Sludge, X-Other

1. Ensure that sufficient volume of environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a frequency of 10 percent total samples, regardless of QA Objective.
2. For QA2 (optional) and for QA3 (mandatory): Determine bias (percent recovery) using a minimum of two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory matrix spikes may be utilized to fulfill these additional QA requirements.
3. To be determined by the person arranging the analysis. Should be equal to or less than the action level.
4. Enter QA Objective desired: QA1, QA2, or QA3.
5. Watanabe, F.S. and S.R. Olsen. 1965. "Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. "Soil Sci. Soc. Am. Proc., Vol. 28, pp. 677-678.
6. U.S. Army Corps of Engineers Waterways Experiment Station. Technical Notes on Environmental Effects of Dredging. "A Computerized procedure for predicting plant uptake of heavy metals from contaminated freshwater dredged material," EEDP-04-12. March, 1990.
7. Method described in Losurdo, A., memo to David Charters, U.S. EPA/ERT, "Methods for Biological Tissues Summary Tables (WA# 3347-21-01-3407)", February 1, 1991.

TABLE 9.2 QA/QC Analysis and Objectives Summary - Soil/Water/Plant Tissue (Cont'd)
(Select appropriate parameters, add or delete others including appropriate footers)

			Matrix Spikes		QA/QC	
Analytical Parameter	Matrix*	Analytical Method Ref.	Lab[1]	Additional[2]	Detection Limits[3]	QA Objective[4]
PEROXIDASE	X	Refer to ERT/SERAS SOP #2035, *Plant Peroxidase Activity Determination*				
PEST/PCB	W	608				
PEST/PCB	S	8080/SW-846				
PEST/PCB	X	Soxhlet or Column Extraction/GC/ECD[5,6]				
pH	S	Methods for Chemical Analysis of Water and Wastewater 150.1, Electrometric				
pH	W	Methods for Chemical Analysis of Water and Wastewater 150.1, Electrometric				
PHENOL	S	8040/SW-846				
PHENOL	W	604/CFR 40				

PLANT PROTEIN DETERMINATION	X	Refer to ERT/SERAS SOP #2033, *Plant Protein Determination*				
PRIORITY POLLUTANT METALS	S	SW-846				
PRIORITY POLLUTANT METALS	W	U.S. EPA-600/CFR 40				

NOTES

* Matrix: S-Soil, W-Water, O-Oil, DS-Drum Solid, DL-Drum Liquid, SD-Sediment, PW-Potable Water, GW-Groundwater, SW-Surface Water, SL-Sludge, X-Other

1. Ensure that sufficient volume of environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a frequency of 10 percent total samples, regardless of QA Objective.
2. For QA2 (optional) and for QA3 (mandatory): Determine bias (percent recovery) using a minimum of two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory matrix spikes may be utilized to fulfill these additional QA requirements.
3. To be determined by the person arranging the analysis. Should be equal to or less than the action level.
4. Enter QA Objective desired: QA1, QA2, or QA3.
5. Hiatt, M.H. 1983. Journal of Analytical Chemistry, Vol. 53, pp. 1541-1543.
6. Hiatt, M.H. 1983. Journal of Analytical Chemistry, Vol. 55, pp. 506-516.

TABLE 9.2 QA/QC Analysis and Objectives Summary - Soil/Water/Plant Tissue (Cont'd)
(Select appropriate parameters, add or delete others including appropriate footers)

			Matrix Spikes		QA/QC	
Analytical Parameter	Matrix*	Analytical Method Ref.	Lab[1]	Additional[2]	Detection Limits[3]	QA Objective[4]
SALINITY (SPECIFIC CONDUCTANCE)	S	U.S. EPA 120.1				
SALINITY (SPECIFIC CONDUCTANCE)	W	U.S. EPA 120.1				
TAL METALS	S	SW-846				
TAL METALS	W	U.S. EPA-600/CFR40				
TAL METALS	X	MICROWAVE DIGESTION (SW-846-3051)				
TOTAL ORGANIC CARBON	X	ASTM D3178				
TOTAL ORGANIC CARBON	S	SW 846-9060				
TOTAL ORGANIC CARBON	W	SW 846-9060				
TOTAL PHOSPHORUS	X	U.S. EPA 365.4				
VOA	S	8240/SW 846				
VOA	W	634/CLP				

NOTES

* Matrix: S-Soil, W-Water, O-Oil, DS-Drum Solid, DL-Drum Liquid, SD-Sediment, PW-Potable Water, GW-Groundwater, SW-Surface Water, SL-Sludge, X-Other

1. Ensure that sufficient volume of environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a frequency of 10 percent total samples, regardless of QA Objective.
2. For QA2 (optional) and for QA3 (mandatory): Determine bias (percent recovery) using a minimum of two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory matrix spikes may be utilized to fulfill these additional QA requirements.
3. To be determined by the person arranging the analysis. Should be equal to or less than the action level.
4. Enter QA Objective desired: QA1, QA2, or QA3.

TABLE 9.3 QA/QC Analysis and Objectives Summary - Soil Macro and Micro Nutrients
(Select appropriate parameters, delete others)

			Matrix Spikes		QA/QC	
Analytical Parameter	Matrix*	Analytical Method Ref.	Lab[1]	Additional[2]	Detection Limits[3]	QA Objective[4]
TOTAL ORGANIC NITROGEN	S	U.S. EPA 600/4, 351.2-4, Potentiometric			30 □g TKN/L	
AMMONIUM (NH_4^+)	S	KCL Extraction[5] Colorimetric			Not Specified	
NITRATE (NO_3^-)	S	KCL Extraction[5] Colorimetric			Varies	
AVAILABLE PHOSPHORUS	S	Ammonium Fluoride[6] Colorimetric			1 □g/L	
AVAILABLE POTASSIUM OR PHOSPHOROUS	S	$NaHCO_3$ Extraction[6] or ICP/AA			Flame varies or 10 □g/L, respectively	
AVAILABLE POTASSIUM	S	Ammonium Acetate Extraction[5] or ICP/AA			Varies or 10 □g/L, respectively	
AVAILABLE CALCIUM	S	U.S. EPA-600/4-79-020, 215.2			10 □g/L	
AVAILABLE CALCIUM	S	Ammonium Acetate Extraction[5], ICP/AA, or titrimetric			10 □g/L, 10 □g/L, or 50 □g/L, respectively	

MAGNESIUM	S	DTPA Extraction[7] or ICP/AA			30 □g/L or 1 □g/L, respectively	
MAGNESIUM	S	Ammonium Acetate Extraction[5] or ICP/AA			30 □g/L or 1 □g/L respectively	
SULPHUR	S	ASTM D12964			Not Specified	

NOTES

* Matrix: S-Soil, W-Water, O-Oil, DS-Drum Solid, DL-Drum Liquid, SD-Sediment, PW-Potable Water, GW-Groundwater, SW-Surface Water, SL-Sludge, X-Other

1. Ensure that sufficient volume of environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a frequency of 10 percent total samples, regardless of QA Objective.
2. For QA2 (optional) and for QA3 (mandatory): Determine bias (percent recovery) using a minimum of two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory matrix spikes may be utilized to fulfill these additional QA requirements.
3. To be determined by the person arranging the analysis. Should be equal to or less than the action level.
4. Enter QA Objective desired: QA1, QA2, or QA3.
5. Couillard, D. and Y. Grenier. 1989. The Science of the Total Environment. Vol 80:113-125.
6. Watanabe, F.S. and S.R. Olsen. 1965. "Test of an Ascorbic Acid Method for Determining Phosphorus in Water and NaHCO3 Extracts from Soil." *Soil Sci. Soc. Am. Proc.* 28:677-678.
7. U.S. Army Corps of Engineers Waterways Experiment Station. 1990. Technical Notes on Environmental Effects of Dredging. A computerized procedure for predicting plant uptake of heavy metals from contaminated freshwater dredged material. EEDP 04-12.

TABLE 9.3 QA/QC Analysis and Objectives Summary - Soil Macro and Micro Nutrients (Cont'd)
(Select appropriate parameters, add or delete others including appropriate footers)

			Matrix Spikes		QA/QC	
Analytical Parameter	Matrix*	Analytical Method Ref.	Lab[1]	Additional[2]	Detection Limits[3]	QA Objective[4]
COPPER	S	DTPA Extraction[5] or ICP/AA Flame or AA Furnace			6 □g/L, 20 □g/L, or 1.0 □g/L	
ZINC	S	DTPA Extraction[5] or ICP/AA or AA Furnace			2 □g/L, 5 □g/L, or 0.05 □g/L, respectively	
MANGANESE	S	DTPA Extraction[5] or ICP/AA Flame			2 □g/L or Not Specified	
IRON	S	DTPA Extraction[5] or ICP/AA or AA Furnace			30 □g/L or 1 □g/L, respectively	
MOLYBDENUM	S	SW-846, 7480, or AA Flame			0.1 mg/L	
BORON	S	U.S. EPA-600/4-79-020, 212.3/Colorimetric			0.1 mg/L	

NOTES
* Matrix: S-Soil, W-Water, O-Oil, DS-Drum Solid, DL-Drum Liquid, SD-Sediment, PW-Potable Water, GW-Groundwater, SW-Surface Water, SL-Sludge,

X-Other

1. Ensure that sufficient volume of environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a frequency of 10 percent total samples, regardless of QA Objective.
2. For QA2 (optional) and for QA3 (mandatory): Determine bias (percent recovery) using a minimum of two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory matrix spikes may be utilized to fulfill these additional QA requirements.
3. To be determined by the person arranging the analysis. Should be equal to or less than the action level.
4. Enter QA Objective desired: QA1, QA2, or QA3.
5. U.S. Army Corps of Engineers Waterways Experiment Station. 1990. Technical Notes on Environmental Effects of Dredging. A computerized procedure for predicting plant uptake of heavy metals from contaminated freshwater dredged material. EEDP 04-12.

TABLE 9.4 QA/QC Analysis and Objectives Summary - Water Macro and Micro Nutrients
(Select appropriate parameters, add or delete others including appropriate footers)

			Matrix Spikes		QA/QC	
Analytical Parameter	Matrix*	Analytical Method Ref.	Lab[1]	Additional[2]	Detection Limits[3]	QA Objective[4]
TOTAL ORGANIC NITROGEN	W	U.S. EPA 351.1, Colorimetric			0.05 - 2.0 mg TKN/L	
AMMONIA (NH^3)	W	U.S. EPA 350.1, Colorimetric, Auto Phenate			Not Specified	
AMMONIA (NH^3)	W	U.S. EPA 350.3, Potentiometric by pH			Not Specified	
NITRATE (NO_3^-)	W	U.S. EPA 353.1, Colorimetric			0.01 mg/L N	
NITRATE (NO_3^-)	W	U.S. EPA 353.3, Spectrophotometric			0.01 mg/L N	
TOTAL ORTHOPHOSPHATE	W	U.S. EPA 365.1			0.001 mg/L	
POTASSIUM	W	SW 846 6010, ICP			Varies	
POTASSIUM	W	SW 846 7610, AA Flame			0.01 mg/L	
POTASSIUM	W	U.S. EPA 258.1, AA Flame			0.01 mg/L	

NOTES

* Matrix: S-Soil, W-Water, O-Oil, DS-Drum Solid, DL-Drum Liquid, SD-Sediment, PW-Potable Water, GW-Groundwater, SW-Surface Water, SL-Sludge, X-Other

1. Ensure that sufficient volume of environmental sample is collected for lab spiking. All analyses conducted at the SERAS laboratories require matrix spike samples at a frequency of 10 percent total samples, regardless of QA Objective.
2. For QA2 (optional) and for QA3 (mandatory): Determine bias (% recovery) using a minimum of two matrix spikes. Determine precision using a minimum of eight matrix spikes. Laboratory matrix spikes may be utilized to fulfill these additional QA requirements.
3. To be determined by the person arranging the analysis. Should be equal to or less than the action level.
4. Enter QA Objective desired: QA1, QA2, or QA3.

TARGET COMPOUND LIST (TCL) AND QUANTITATION LIMITS (QLs)[1]

Volatiles	CAS Number	Quantitation Limits[2] Water µg/L	Low Soil/Sediment[3] µg/L
Chloromethane	74-87-3	10	10
Bromomethane	74-83-9	10	10
Vinyl Chloride	75-01-4	10	10
Chloroethane	75-00-3	10	10
Methylene Chloride	75-09-2	5	5
Acetone	67-64-1	10	10
Carbon Disulfide	75-15-0	5	5
1,1-Dichloroethane	75-35-4	5	5
1,1-Dichloroethene (DCE)	75-34-3	5	5
1,2-Dichloroethane (total)	540-59-0	5	5
Chloroform	67-66-3	5	5
1,2-Dichloroethane	107-06-2	5	5
2-Butanone	78-93-3	10	10
1,1,1-Trichloroethane	71-55-6	5	5
Carbon Tetrachloride	56-23-5	5	5
Bromodichloromethane	75-27-4	5	5
cis-1,3-Dichloropropene	10061-01-5	5	5
Trichloroethene (TCE)	79-01-6	5	5
Dibromochloromethane	124-48-1	5	5
1,1,2-Trichloroethane	79-00-5	5	5
Benzene	71-43-2	5	5
trans-1,3-Dichloropropene	10061-02-6	5	5
Bromoform	75-25-2	5	5
4-Methyl-2-pentanone	108-10-1	10	10
2-Hexanone	591-78-6	10	10
Tetrachloroethene (PCE)	127-18-4	5	5
Toluene	108-88-3	5	5
1,1,2,2-Tetrachloroethane	79-34-5	5	5
Chlorobenzene	108-90-7	5	5
Ethyl Benzene	100-41-4	5	5
Styrene	100-42-5	5	5
Xylenes (total)	1330-20-7	5	5

TARGET COMPOUND LIST (TCL) AND QUANTITATION LIMITS (QLs)[1]

Volatiles (cont'd)	CAS Number	Quantitation Limits[2] Water µg/L	Low Soil/Sediment[3] µg/L
Dichlorofluoromethane	75-43-4	10	10
Trichlorofluoromethane	75-69-4	5	5
trans-1,2-Dichloroethene	156-60-5	5	5
2,2-Dichloropropane	94-20-7	5	5
cis-1,2-Dichloroethene	156-59-2	5	5
1,1-Dichloropropene	563-58-6	5	5
1,2-Dichloropropane	78-87-5	5	5
Dibromomethane	74-95-3	10	10
1,3-Dichloropropane	142-28-9	5	5
1,2-Dibromomethane	106-93-4	5	5
1,1,1,2-Tetrachloroethane	630-20-6	5	5
p-Xylene	106-42-3	5	5
m-Xylene	108-38-3	5	5
o-Xylene	95-47-6	5	5
Isopropylbenzene	98-82-8	5	5
1,2,3-Trichloropropane	96-18-4	5	5
Bromobenzene	108-86-1	5	5
n-Propylbenzene	103-65-1	5	5
2-Chlorotoluene	95-49-8	5	5
4-Chlorotoluene	106-43-4	5	5
1,3,5-Trimethylbenzene	25551-13-7	5	5
tert-Butylbenzene	98-06-6	5	5
1,2,4-Trimethylbenzene	25551-13-7	5	5
sec-Butylbenzene	135-98-8	5	5
1,3-Dichlorobenzene	541-73-1	5	5
p-Isopropyltoluene	99-87-6	5	5
1,4-Dichlorobenzene	106-46-7	5	5
1,2-Dichlorobenzene	95-50-1	5	5
n-Butylbenzene	104-51-8	5	5
1,2-Dibromo-3-Chloropropane	96-12-8	5	5
1,2,4-Trichlorobenzene	120-82-1	5	5
Naphthalene	91-20-3	5	5
Hexachlorobutadiene	87-68-3	10	10
1,2,3-Trichlorobenzene	12002-48-1	10	10

Notes:

(1) Specific quantitation limits are highly matrix dependent. The quantitation limits listed herein are provided for guidance and may not always be achievable.

(2) Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, on a dry weight basis will be higher.

(3) Medium Soil/Sediment QLs for Volatile TCL Compounds are 125 times the individual Low Soil/Sediment QL.

TARGET COMPOUND LIST (TCL) AND QUANTITATION LIMITS (QL)[1]

Semivolatiles	CAS Number	Quantitation Limits[2] Water µg/L	Low Soil/Sediment[3] µg/L
Phenol	108-95-2	10	330
bis (2-Chloroethyl) ether	111-44-4	10	330
2-Chlorophenol	95-57-8	10	330
1,3-Dichlorobenzene	541-73-1	10	330
Benzyl alcohol	100-51-6	10	330
1,2-Dichlorobenzene	95-50-1	10	330
2-Methylphenol	95-48-7	10	330
bis (2-Chloroisopropyl) ether	108-60-1	10	330
4-Methylphenol	106-44-5	10	330
N-Nitroso-di-n-propylamine	621-64-7	10	330
Hexachloroethane	67-72-1	10	330
Nitrobenzene	98-95-3	10	330
Isophorone	78-59-1	10	330
2-Nitrophenol	88-75-5	10	330
2,4-Dimethylphenol	105-67-9	10	330
bis (2-Chloroethoxy) methane	111-91-1	10	330
2,4-Dichlorophenol	120-83-2	10	330
1,2,4-Trichlorobenzene	120-82-1	10	330
Naphthalene	91-20-3	10	330
4-Chloroaniline	106-47-8	10	330
Hexachlorobutadiene	87-68-3	10	330
4-Chloro-3-methylphenol	59-50-7	10	330
2-Methylnaphthalene	91-57-6	10	330
Hexachlorocyclopentadiene	77-47-4	10	330
2,4,6-Trichlorophenol	88-06-2	10	330
2,4,5-Trichlorophenol	95-95-4	50	1700
2-Chloronaphthalene	91-58-7	10	330
2-Nitroaniline	88-74-4	50	1700
Dimethylphthalate	131-11-3	10	330
Acenaphthylene	208-96-8	10	330
2,6-Dinitrotoluene	606-20-2	10	330
3-Nitroaniline	99-09-2	50	1700
Acenaphthene	83-32-9	10	330
2,4-Dinitrophenol	51-28-5	50	1700
4-Nitrophenol	100-02-7	50	1700
Dibenzofuran	132-64-9	10	330

TARGET COMPOUND LIST (TCL) AND QUANTITATION LIMITS (QL)[1] (Cont'd)

Semivolatiles (cont'd)	CAS Number	Quantitation Limits[2] Water µg/L	Low Soil/Sediment[3] µg/L
2,4-Dinitrotoluene	121-14-2	10	330
Diethylphthalate	84-66-2	10	330
4-Chlorophenyl-phenyl ether	7005-72-3	10	330
Fluorene	86-73-7	10	330
4-Nitroaniline	100-01-6	50	1700
4,6-Dinitro-2-methylphenol	534-52-1	50	1700
N-nitrosodiphenylamine	86-30-6	10	330
4-Bromophenyl-phenyl ether	101-55-3	10	330
Hexachlorobenzene	118-74-1	10	330
Pentachlorophenol	87-86-5	50	1700
Phenanthrene	85-01-8	10	330
Anthracene	120-12-7	10	330
Carbazole	86-74-8	10	330
Di-n-butylphthalate	84-74-2	10	330
Fluoranthene	206-44-0	10	330
Pyrene	129-00-0	10	330
Butylbenzylphthalate	85-68-7	10	330
3,3-Dichlorobenzidine	91-94-1	20	6700
Benzo (a) anthracene	56-55-3	10	330
Chrysene	218-01-9	10	330
bis (2-Ethylhexyl) phthalate	117-81-7	10	330
Di-n-octylphthalate	117-84-0	10	330
Benzo (b) fluoranthene	205-99-2	10	330
Benzo (k) fluoranthene	207-08-9	10	330
Benzo (a) pyrene	50-32-8	10	330
Indeno (1,2,3-cd) pyrene	193-39-5	10	330
Dibenz (a,h) anthracene	53-70-3	10	330
Benzo (g,h,i) perylene	191-24-2	10	330

(1) Specific quantitation limits are highly matrix dependent. The quantitation limits listed herein are provided for guidance and may not always be achievable.

(2) Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment on a dry weight basis will be higher.

(3) Medium Soil/Sediment QLs for Semivolatile TCL Compounds are 60 times the individual Low Soil/Sediment QL.

TARGET COMPOUND LIST (TCL) AND QUANTITATION LIMITS (QL)[1]

Pesticides/PCBs	CAS Number	Quantitation Limits[2] Water µg/L	Low Soil/Sediment[3] µg/L
alpha-BHC	319-84-6	0.02	3.3
beta-BHC	319-85-7	0.02	3.3
delta-BHC	319-86-8	0.02	3.3
gamma-BHC (Lindane)	58-89-9	0.02	3.3
Heptaclor	76-44-8	0.02	3.3
Aldrin	309-00-2	0.02	3.3
Heptachlor epoxide	1024-57-3	0.02	3.3
Endosulfan I	959-98-8	0.02	3.3
Dieldrin	60-57-1	0.02	3.3
4,4'-DDE	72-55-9	0.02	3.3
Endrin	72-20-8	0.02	3.3
Endrin aldehyde	7421-93-4	.002	3.3
Endosulfan II	33213-65-9	0.02	3.3
4,4'-DDD	72-54-8	0.02	3.3
Endosulfan sulfate	1031-07-8	0.02	3.3
4,4'-DDT	50-29-3	0.02	3.3
Methoxychlor	72-43-5	0.02	3.3
Endrin ketone	53494-70-5	0.02	3.3
alpha-Chlordane	5103-71-9	0.02	3.3
gamma-Chlordane	5103-74-2	0.02	3.3
Toxaphene	8001-35-2	0.50	83
Aroclor-1016	12674-11-2	0.25	42
Aroclor-1221	11104-28-2	0.50	83
Aroclor-1232	11141-16-5	0.25	42
Aroclor-1242	53469-29-6	0.25	42
Aroclor-1248	12672-29-6	0.25	42
Aroclor-1254	11097-69-1	0.25	42
Aroclor-1260	11096-82-5	0.25	42

(1) Specific quantitation limits are highly matrix dependent. The quantitation limits listed herein are provided for guidance and may not always be achievable.

(2) Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment on a dry weight basis will be higher.

(3) Medium Soil/Sediment QLs for Pesticides/PCB TCL compounds are 15 times the individual Low Soil/Sediment QL.

INORGANIC TARGET ANALYTE LIST (TAL)

Analyte	Range of Detection Limits Water µg/L	Soil mg/kg
Aluminum	100	20
Antimony	10	6
Arsenic	5	1
Barium	5	5
Beryllium	2	0.5
Cadmium	5	1
Calcium	500	50
Chromium	5	1
Cobalt	10	1.5
Copper	10	1
Iron	50	10
Lead	5	5
Magnesium	500	50
Manganese	5	2
Mercury	0.2	0.04
Nickel	10	2
Potassium	2000	200
Selenium	5	1
Silver	5	1
Sodium	500	50
Thallium	5	1
Vanadium	10	2
Zinc	5	2

APPENDIX B
Plant Tissue Sampling Field Data Sheet
SOP #2038
March 1996

DATA SHEET
PLANT TISSUE

SAMPLE NO:

SERAS, Edison, NJ
U.S. U.S. EPA Contract EP-C-04-032

Samplers: _____ Signatures: _____ Chain of Custody No.:_____

SERAS Task Leader:_____

Date: _____ Site Name: _____ U.S. EPA Task Monitor:_____

Time: _____ Sample Location: _____ Project No:_____

SITE

landfill
designation:
wooded
farmland
wetland
lotic
old field
industrial
Residential
commercial
lentic
terrestrial
aquatic
wetland
macrophyte

MATRIX/HABITAT DESCRIPTION

soil type:
Munsell
water: color
odor
depth
flow
sediment type
DO
temp
matrix pl
NOTES:

SAMPLE TYPE:
Species:
leaves
stems
roots
fruits
whole plant

WEATHER PARAMETERS:
Photosynthetically Active Radiation (PAR
ambient temp
relative humidity
weather conditions

ANALYSES
total carbon
total nitrogen
total phosphorus
total potassium
chlorophyll a and b
protein
wet weight
dry weight
identification
fluorescence

SAMPLE PREPARATION
Container:
Preservation: shipping_____

storage_____

enzyme assay

ORGANICS	METALS	LIMITED CHEMISTRY
halogenated & aromatic volatiles List:		total cyanide
volatiles		total phenol
pesticides/PCB		petroleum hydrocarbons
PCB		
BNA		
herbicides		

OTHER ANALYSES (specify):_____
_____

COMMENTS: